

NATURAL RESOURCE NAVIGATOR

Charting a Smart Future for a Changing Climate

Guidebook v1.0

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Welcome to the Natural Resource Navigator Guidebook

The Natural Resource Navigator is an on-line, interactive decision support and mapping tool designed to help natural resource managers make climate smart decisions to sustain natural resources. This Guidebook is the companion document to the Navigator Map Tool found at: maps.naturalresourcenavigator.org.

The Guidebook contains the following sections:

- I. **Wayfinder** helps you get started with using the Map Tool applications and data based on your needs and interests.
- II. **Course Adjustment Worksheets** help you refine conservation objectives to more specific strategies in light of climate change, using data in the Map Tool as well as your own knowledge and judgment.
- III. **More to Explore** provides additional information on planning for climate change, and highlights additional resources to help you plan and implement your project.

I. Wayfinder: Setting a Course

In this section you will find step-by-step instructions for finding and using the right parts of the Navigator, based on what you want to do.

1. In the list below, pick the section that best matches the type of question you want to answer.
2. Follow the instructions, which generally guide you through:
 - a. The Navigator Map Tool applications and data,
 - b. Which worksheets to complete within the Course Adjustments section of the Guidebook

What do you want to do? You can:

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Develop a strategy for a project area.

A project area can be a watershed, a protected area, or anything in between. Use this guidance when you have a particular habitat and/or place that you work on and want to know what conservation or natural resource management work to do, particularly in light of climate change.

1. Navigate to the project area by zooming with your mouse wheel, the zoom on the left side of the screen, or typing your desired location into the search field at the upper left.
2. Use Boundary and Reference layers to help you define your project area. Launch the Map Layers from the application sidebar to view counties, watersheds, or protected lands. You can also adjust the base map using the drop down at the upper right.
3. If it is not already open, click on the Habitat Explorer and select the habitat type you are interested in.
4. The Habitat Explorer shows you the conservation objectives recommended for your area on the Objectives tab.
5. To see why the objective(s) are recommended, click on the other tabs to view the summary scores for Condition, Threat, Exposure and Sensitivity. The indicators used to create the summary scores are listed on each component tab.
6. If you want to create a custom habitat analysis, adjust the sliders under any indicator to change its weighting, or move the slider to 'None' to remove the indicator entirely. You might adjust an indicator's weight to reflect its importance to the ecosystem, or your confidence in the data.
7. Return to the Objectives tab to see the results of your adjustment (not all adjustments will result in a different recommendation). The Explorer will retain your settings unless you click the Reset button or reload the webmap.
8. If you wish to keep a copy of your map, you can print it by clicking the printer icon in the upper right of the Explorer window. Or you can save your session as a permanent hyperlink using the 'Save & Share' button on the lower left of the screen.
9. Open the Course Adjustment worksheet for the objective that best fits your project area for help refining a more specific conservation strategy with potential tactics.

Develop a strategy for a large project area with several recommended objectives

If your project area is large (e.g. a municipality or larger watershed) it may contain sections with different recommended objectives. You have several options for completing the instructions above:

1. Narrow your scope to one section of your project area, and proceed with the worksheet for the corresponding objective.
 - a. The Priority Places worksheet may be helpful in identifying places to focus
2. Select a single objective, and choose a location where that objective is recommended.
 - a. See the instructions below for "Decide where to work..." for help in choosing among multiple places
3. Proceed with different objectives in multiple places. You will need to work through the decision support guides for each of the different objectives independently.

Evaluate an existing project to see if it is “climate smart.”

If you are already committed to a pre-defined project in a particular place, you can still use the Navigator. Use the directions below to evaluate an existing project and incorporate climate adaptation into your work.

1. Navigate to the project area by zooming with your mouse wheel, the zoom on the left side of the screen, or typing your desired location into the search field at the upper left.
2. Use Boundary and Reference layers to help you define your project area. Launch the Map Layers from the application sidebar to view counties, watersheds, or protected lands. You could also adjust the base map using the drop down at the upper right.
3. If it is not already open, click on the Habitat Explorer and select the habitat type you are interested in.
4. The Habitat Explorer shows you the conservation objectives recommended for your area on the Objectives tab. If you want to focus on a particular Objective, open the Map Layers and select the map for the appropriate Objectives Group.
 - a. IF the general recommendation that comes up for your project area matches what you are generally doing: Proceed through the worksheet for that objective (see step 5 below) and then continue to the Preparing for Climate Change section.

OR

- b. IF the general recommendation that comes up for your project area DOES NOT match what you are already doing: Use the Habitat Explorer to view the underlying data and see what is driving the recommended objective, and see if you agree with it.
 - i. To see why the objective(s) are recommended, click on the other tabs to view the summary scores for Condition, Threat, Exposure and Sensitivity. The indicators used to create the summary scores are listed on each component tab.
 - ii. If you want to create a custom habitat analysis, adjust the sliders under any indicator to change its weighting, or move the slider to ‘None’ to remove the indicator entirely. You might adjust an indicator’s weight to reflect its importance to the ecosystem, or your confidence in the source data.
 - iii. If you agree with the recommendation, consider modifying your objective or adding this objective to your project.
5. Open the Course Adjustment worksheet for the objective that best fits your project area for help refining a more specific conservation strategy with potential tactics.

Decide where to work on a particular strategy

Use this guidance when you have a strategy you employ but you want to know where it would be best to work within a large area. Examples: land protection, floodplain restoration, connectivity improvements.

1. View the maps statewide, or if you have a narrower region of interest, navigate to it by zooming with your mouse wheel, the zoom on the left side of the screen, or typing your desired location into the search field at the upper left.
2. Use Boundary and Reference layers to help you define your project area. Launch the Map Layers from the application sidebar to view counties, watersheds, or protected lands. You could also adjust the base map using the drop down at the upper right.
3. If your work focuses on land protection:
 - a. Open the Course Adjustment worksheets and complete the Priority Places and Protection worksheets to identify potential places to employ this strategy.
4. If your work focuses on restoration:
 - a. Launch the Map Layers and navigate to the right HABITAT: Condition Score layer to view areas with low condition that may benefit from restoration. If you work on a particular condition factor that has been mapped, view those data as well.
 - b. Open the Course Adjustment worksheets:
 - i. Complete the 'Improve Condition: What to do' worksheet for your focal condition factor, and others if you choose.
 - ii. Complete the 'Improve Condition: Where to work' worksheet to identify places in your area.
5. If your work focuses on reducing a particular threat:
 - a. Launch the Map Layers and navigate to the right HABITAT: Threat Score layer to view areas with high threat that may benefit from mitigation. If you work on a particular threat that has been mapped, view those data as well.
 - b. Open the Course Adjustment worksheets:
 - i. Complete the 'Reduce Threat: What to do' worksheet for your focal condition factor, and others if you choose.
 - ii. Complete the 'Reduce Threat: Where to work' worksheet to identify places in your area.
6. If you work on habitat connectivity...
 - a. ...for Forests: Launch the Map Layers and expand the Forests: Supporting data folder. View the Linkage layers to view the places most important for regional connectivity.
 - i. View current local connectedness under Forests: Sensitivity to see what areas might benefit from restoration, and threats to connectedness under Forests: Threats to see where protection may be needed.

- b. ...for Streams: Launch the Map Layers and expand the Streams: Sensitivity folder and view the Connected Network Length.
 - i. Currently short networks may be candidates for restoration of connectivity. Dams may be viewed under Streams: Condition.
 - ii. Data on risk of future fragmentation can be found in Streams: Threats: Connectivity Threat from Additional Road Crossings.
7. If you work on flood mitigation:
 - a. Open the Course Adjustment worksheets and complete the Flood Mitigation worksheets to help you use the data in Map Layers: Freshwaterflooding.
8. If you work on ecosystem services:
 - a. Launch the Map Layers and open the Ecosystem Services folder. You will find maps of current and future modeled nutrient retention and carbon storage.
9. Refine any of your selected activities in light of climate change, using the Preparing for Climate Change worksheet.

Decide what species to focus on

Use these instructions when you want to know which species are most important to conserve in a place and/or with a particular strategy, or you want to incorporate species considerations into other work.

1. Navigate to the project area by zooming with your mouse wheel, the zoom on the left side of the screen, or typing your desired location into the search field at the upper left.
2. Use Boundary and Reference layers to help you define your project area. Launch the Map Layers from the application sidebar to view counties, watersheds, or protected lands. You could also adjust the base map using the drop down at the upper right.
3. Open the Species Explorer and click on a hexagon that captures the project area. (If the project area covers more than one hex, each must be selected in turn.)
4. If the species list is very long, consider using the Habitat Availability filter to remove species with low modeled habitat availability in the selected hexagon.
5. If desired, narrow the list to a specific taxonomic group by entering the taxon name in the search box at the top of the species list.
6. If working in a particular habitat, you can use the Habitat Associations filter to select one or more habitat types to narrow the list further.
7. Open the Course Adjustments and complete the Incorporating Species worksheet to identify species that may need special consideration in your planning.
8. View the Assessing Species guidance to identify species that are appropriate for your selected objective.
 - a. You can download the statewide list of modeled species, using the button in the Species Explorer, to view additional information about each species and create custom lists.
9. Click the printer icon in the upper right of the Explorer window to export your species list to PDF format or print a report.

Decide what to do for a particular species

The Navigator contains a variety of detailed spatial datasets on individual species. If you have a particular species of interest, these instructions will help you identify what data are available.

...within a project area

1. Open the Species Explorer, if not already open, and click on a hexagon that includes the project area. (If the project area covers more than one hex, each must be selected in turn.)
2. Find the species of interest in the species list by typing all or part of the species name or taxonomic group in the boxes at the top of the list. Click on the species name to display details.
3. Click on the check box to display a map of modeled suitable habitat for the selected species.
4. The following field in the species details display indicate that there are additional spatial data available for the species:
 - a. If Future connection area is not null, then a migration pathways model is available. These models, which are currently available for a small number of species, indicate areas that may support movement between current and future suitable habitat.
 - b. If Hex Avg Vulnerability Index is not null, then a spatial climate change vulnerability index is available. This index maps the local climate vulnerability of locations within the species' current modeled suitable habitat.
 - c. If Hex Future Habitat Change is not null, then a future suitable habitat model is available.
 - d. For all species, the source habitat model(s) available are indicated by the Habitat Availability records.
5. Open the Map Layers and search or browse the Species folder to find all the spatial data available for any single species.
6. Open the Course Adjustments and use the Assessing Species worksheet to identify appropriate tactics for the selected species.
 - a. Examine the Climate Considerations columns, and the Preparing for Climate Change worksheet, to think about adaptation approaches.
7. Use the Tactics Toolbox to view candidate tactics for the selected outcomes and approaches.

...across its range in NY

1. Open the Map Layers and search or browse the Species folder to find all the spatial data available for any single species.
2. The data available varies by species, but includes:
 - a. multiple models of current modeled suitable habitat
 - b. future modeled suitable habitat
 - c. spatial climate change vulnerability index
 - d. modeled connections between current and future suitable habitat
3. Open the Course Adjustments and use the Assessing Species Module to identify places appropriate for different objectives.
4. Use the Tactics Toolbox to view candidate tactics for the selected outcomes and approaches.

Understand freshwater flooding in a community

1. Navigate to the community of interest by zooming with your mouse wheel, the zoom on the left side of the screen, or typing your desired location into the search field at the upper left.
2. Use Boundary and Reference layers to help you define your project area. Launch the Map Layers from the application sidebar to view counties, watersheds, or protected lands. You could also adjust the base map using the drop down at the upper right.
3. Open the Map Layers and expand the Freshwater Flooding folder to view data on current flood conditions, future land use changes that could affect flooding regimes, flood risk, and future projections of extreme precipitation.
4. Open the Course Adjustments and view the Flood Mitigation section for directions on how to use the data in the Navigator to assess flood risks and mitigation opportunities.

II. Course Adjustment Worksheets

Collectively, this suite of decision support guides and worksheets will help you identify strategies based on the data in the Natural Resource Navigator. Below is a list of the topics covered:

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How to use the worksheets

Each worksheet presents you with questions that you can answer using data within the Navigator web tool, resources outside of the explorer, and/or your own knowledge and judgment. Going through these questions will help you refine your project, and may redirect you to a different objective or lead you to modify your original geographic scope.

Linking to the Tactics Toolbox

Throughout the guidance, we highlight places where you can further develop your plan by looking up possible tactics to implement in the Tactics Toolbox spreadsheet. The spreadsheet is organized with several filters to help you narrow down the suggested tactics. Each filter has a dropdown list from which you can select one or more categories. You can also sort the list by any filter. Climate Considerations are also noted to the right of the tactics, to help you think about how traditional conservation actions might need to be altered in light of climate change.

How does this section help you? If your potential region of interest is larger than a few stream segments or an individual parcel, it may be helpful to identify places to focus on. The table below helps you identify focal areas within that region, based on a regional and statewide adaptation context. Also consider looking for priority places outside your original region or interest that you might incorporate into your work.

Once you have identified potential priority places, consider protection tactics for any places that you list—check out the Protection Worksheet on the next page. Also view the Recommended Objective map (in the Navigator Map Layers) for each place, and check out the worksheet that matches that. You may also want to complete the Preparing for Climate Change and Incorporating Species worksheets.

1. Look at these Navigator layers ...	2. to find places that are...	3. List any places you found:
HABITAT: Recommendations: Objective Maintain Group	...recommended to Maintain.	
HABITAT: Sensitivity Score – low values	...predicted to be resilient to climate change.	
HABITAT: Exposure Score — low values Species: Predicted habitat maps - persisting	...potentially serving as climate refugia.	
Forests: Supporting: Matrix Forest Blocks Streams: Sensitivity: Connected Network Length Streams: Supporting: Floodplain Complexes	...particularly large or intact example/s.	
Forests: Supporting: Underprotected Settings, Rare Settings Streams: Supporting: Stream Geology	...contributing an important element of structural diversity or heterogeneity.	
Forests: Supporting: Current and Future Linkage Zones Forests: Sensitivity: Connectedness Streams: Sensitivity: Connected Network Length Streams: Supporting: Regional Dams and Obstacles	...important for regional connectivity.	
Species: Rare Species Richness	...used by a lot of species.	
Species: Predicted habitat maps	...important to the persistence of a particular species of interest.	
Ecosystem Services: Carbon Storage, Phosphorus Retention Streams: Supporting: Active River Area User knowledge: water supplies	...important to the provision of an ecosystem service.	

Protection

How will this section help you? This worksheet helps you think through whether formal protection, and what level of protection, might be required for some of the areas you identified through your work. It also helps you identify potential tactics for that protection work.

What to do: List the places you have identified as priorities to focus on at the top of the table. Some of the answers to these questions can be found using the Navigator while others will rely on your expert knowledge or other sources. **To view current protection status, open the Map Layers and expand the Protection folder; to view threat of conversion, expand the Land Use/Land Cover folder.** Keep in mind the full spectrum of protection efforts, including fee ownership, agricultural or working forest easements, zoning or other restrictions, and policy changes, to secure the conservation value of the site.

Question	Place 1:	Place 2:	Place 3:	Place 4:	Place 5:
What protection extent and level do you need to maintain condition and functions?					
What protection extent and level do you need to secure the success of restoration or threat reduction strategies?					
Is there threat of conversion?					
Might shifts in climate lead to additional development or more intensive use? ¹					
Is there zoning or other local restrictions on development? Are those sufficient protections, even given future development and people's responses to climate change?					
Is there an opportunity to fill gaps in the existing network of protected lands?					
Is public access to the site desirable?					

Tactics Toolbox Filters:

- ✓ **Target** (if desired).
- ✓ **Issue** = conversion of habitat

¹ Patterns of development might change in response to increasing demand for water, possible shifts in agricultural patterns, changes in climate dependent recreational industries, changing flood risk, etc.

Maintain

How will this section help you? This section helps you identify tactics for maintaining resources that are in good condition and not under significant threat.

Overall, places with this recommended objective are in good condition currently and have low future threats predicted. However, you will also want to:

1. Think about your role in regional adaptation – complete **Priority Places** the worksheet on page 2.
2. Consider protection - complete the **Protection** worksheet on page 3.
3. Monitor for changes in condition.
4. Monitor for new threats.
5. **Reduce Threats**---look at the Threats tab in the Habitat Explorer and the related worksheet on page 6. If any of the individual Threat indicators are high, it may be worth addressing them, regardless of the overall threat score.² Also consider other potential future threats that we did not include in the Navigator because there were not sufficient statewide data.
6. **Improve Condition** – Look at the Condition tab in the Habitat Explorer and the related worksheet on page 8. Individual indicators that are moderate or poor may be worth restoring, regardless of the overall score.
7. Think about climate risk – where are you on the risk gradient in the Recommendation map? If risk is low, this location may serve as refugia from climate changes. Think about maintaining connectivity into and out of you location. If risk is high, secure habitat may provide species the opportunity to adapt as needed. Go through the **Preparing for Climate Change** worksheet on page 11 for more detailed tactics.

Tactics Toolbox Filters:

- ✓ **Target** (if desired)
- ✓ **Objective** = Maintain, Reduce Threats (opt), Restore (opt)
- ✓ **Approach** = selected approach (if desired)

² Note: Since much of the future threats data in the Navigator is dependent on the 2050 projected land use model we included, which is based on past trends that could change, especially given climate change, it might be more important to reduce future threats than our analysis indicates.

Reduce Threats

How will this section help you? This module helps you determine whether or not it is worthwhile to invest in threat reduction strategies and which strategies to pursue. If you have arrived here from a map recommendation to Reduce Threats, or it is work you are already doing, these questions should help you verify whether that makes sense and will help you refine that objective. If your Recommended Objective from our map is to both Reduce Threats & Restore, these questions will help you determine whether or not threat reduction is worth pursuing.

What to do:

1. To figure out which threats are important in your area, examine the individual threat indicators within the toolkit (found under HABITAT: THREAT in the Map Layer Tree). You can also adjust the sliders on the Threats tab on the Habitat Explorer app to quickly give you a sense of which threats are driving the overall score. Please also use your personal knowledge of the local severity of these threats and additional threats not captured in the spatial data. Finally, consider how these threats may interact with each other, with a changing climate, and with human responses to climate change.
2. Use the column headers below to record your choices.
3. Decide whether you can feasibly and meaningfully reduce the important threats, and which ones to work on. Questions in the table below can help—more yes answers increase the feasibility, urgency or importance of addressing that threat. If there are or will be urgent threats you don't address, that may affect the success of your other strategies.

Reduce Threats: What to do

Question	Threat 1:	Threat 2:	Threat 3:
Can the threat be addressed at the scale at which you work?			
Does your organization have the necessary resources to address this threat?			
Are you suited to tackle this threat given your expertise, your organization's strength, or timely opportunities? OR For any threats you can't feasibly address, are there better-positioned organizations that you can partner with?			
Are the impacts very difficult to reverse once they occur?			
Is there benefit to fixing this threat, even if the others are not addressed?			
If condition is low or moderate, do you need to address these threats to ensure restoration success?			
Is the threat worsened by climate change?			
Will the threat impact the resource too quickly to detect impacts and adjust actions in time?			

4. Once you identify what threat(s) you wish to reduce (based upon your answers above or based on an existing project), there may be more than one location that would benefit from that work. Use the table below to prioritize places on the ground to reduce your selected threat(s). Even if your threat-reduction strategy is not site-specific, such as a policy change or an outreach campaign, identifying places that will benefit most may be useful for monitoring effectiveness. **If you haven't already done so, completing the Priority Places worksheet (see page 2) may help you to identify important places.** Write candidate locations in the column headers below:

Reduce Threats: Where to work

Are there any locations that ...	Look at...	Place 1:	Place 2:	Place 3:	Place 4:
...you noted in the Priority Places worksheet?	Priority Places				
...have lower climate risk?	HABITAT: Recommendations: Reduce Threats Group				
...have higher current condition?	HABITAT: Condition Score				
...have otherwise low threats, with only the threat(s) of interest driving the rating?	HABITAT: Threats Score				
...have high ratings for the selected threat(s), where actions could have the greatest benefit?	Maps for individual threats				
...where there is a higher chance of successfully reducing the threat(s), due to other elements of feasibility?	Your own knowledge				
...could have secondary benefits for the other habitats, or could benefit species or ecosystem services?	Objective Recommendations for other targets Ecosystem Services				

Tactics Toolbox Filters:

- ✓ **Target** (if desired).
- ✓ **Objective** = Reduce Threats
- ✓ **Issues** = Selected threat(s)

How will this section help you? This section helps you determine whether or not it is worthwhile to invest in restoration and/or where the best places are to do so. If your Recommended Objective is to Restore, or that is work you are already doing, these questions should help you verify whether that makes sense, and will help you refine that objective in terms of where to work and/or what to do. If your Recommended Objective is to both Reduce Threats & Restore, these questions will help you determine whether or not restoration is feasible to pursue, given the likelihood of future declines in condition.

What to do:

1. To figure out which aspects of condition to focus on in your area, examine the individual condition indicators within the toolkit (found under HABITAT: Current Condition in the Map Layers). You can also adjust the sliders on the Condition tab in the Habitat Explorer to quickly give you a sense of which indicators are driving the overall score. Please also use your personal knowledge of the local conditions and additional condition indicators not captured in the spatial data to identify those factors most important to restore.
2. Use the column headers below to record your choices.
3. Decide whether you can feasibly and meaningfully improve condition by answering the questions below for each of your impaired conditions. If you accumulate more yes's, you might consider restoration in this area, and consider focusing on conditions with the most yes's. If you accumulate more no's, you may need to reassess work in the area. Use your knowledge of the area and the Navigator data, when possible, to answer the questions.

Improve Condition: What to do

Questions	Condition 1:	Condition 2:	Condition 3:
Is the condition the result of a past event, as opposed to ongoing threats?			
Can restoration be achieved with a single, or limited, treatment?			
Are there well-tested methods that have a high chance of success?			
Can conditions be improved to very good or excellent, even given other threats or condition impairments?			
Are you well-positioned to tackle this condition due to your expertise, your organization's strengths, or timely opportunities?			
Can the condition be addressed in concert with other work (addressing threats or other condition attributes)?			
Will the costs be low or affordable?			
Will there still be significant benefits if you fix this condition but not the others?			
Are there other climate adaptation benefits associated with improving this condition? <i>Ex: restored wetlands may help communities with high flood risk.</i>			
Is the timeframe needed for restoration relatively short, compared to the time horizon for climate change?			

4. Once you know what condition/s you wish to restore, based on answers above or based on an existing project, use this table to help you prioritize places on the ground to do that work. **If you haven't already done so, completing the Priority Places worksheet (page 2) may help you to identify important places.**
Write candidate locations in the column headers below:

Improve Condition: Where to work

Are there any locations that ...	Look at...	Place 1:	Place 2:	Place 3:	Place 4:
...you noted in the Priority Places worksheet?	Priority Places				
...have lower climate risk?	HABITAT: Recommendations: Objective Restore Group				
...have low future threat?	HABITAT: Threats Score				
...have otherwise good condition, with only the condition factor(s) of interest driving the low rating?	HABITAT: Condition Score				
...have a low rating for the selected condition, where actions could have the greatest benefit?	Maps for individual Condition Indicators				
...where there is a higher chance of successful restoration due to other elements of feasibility?	User knowledge				
...could have secondary benefits for the other habitats, or could benefit species or ecosystem service?	Objective Recommendations for other targets Ecosystem Services				

Tactics Toolbox Filters:

- ✓ **Target** (if desired).
- ✓ **Objective** = Improve Condition
- ✓ **Issues** = Selected condition factor(s)

Reduce Threats & Restore

How will this section help you? This section will help you identify whether and what conservation work to focus on in areas hampered by both poor current condition and high future threat, identifying whether the area may still provide important adaptation benefits to nature or people.

What to do:

1. **Complete the Priority Places worksheet (page 2)** to see whether your project area might be regionally or locally important in light of climate change. This might help you prioritize whether to invest in restoration or threat reduction strategies and where to focus.
2. Consider reasons for working here even with substantial challenges to achieving success. For instance:

<input type="checkbox"/> Is the site currently in some form of land protection?	<input type="checkbox"/> Do you have any legal obligations regarding the management of this resource? If so, is it infeasible to modify those obligations?
<input type="checkbox"/> Is there dedicated funding that cannot be redirected?	<input type="checkbox"/> If you let the resource decline, will it have impacts on other areas or resources that cannot be mitigated?
<input type="checkbox"/> Are lots of people/communities/organizations engaged or benefitting?	<input type="checkbox"/> Do you have any other reasons to remain committed to conservation action in this place (e.g. donor intent, programmatic benefits)?
<input type="checkbox"/> Do you have goals outside of conservation, such as research or education and outreach?	
3. **Complete the Improve Condition: What to do worksheet (page 7)** to determine whether restoration, to the level needed for your purposes, is feasible in light of poor current condition and high future threat. Recognize that the site may be dependent on continuous or frequently repeated management if threats are not addressed.
4. **Complete the Reduce Threats: What to do worksheet (page 5)** to determine whether reducing threats meets the needs you identified for the site and is feasible.
5. Think about climate risk. **Complete the Preparing for Climate Change worksheet (page 14)** to consider whether additional actions will be needed to resist or adapt to expected climate impacts, and how that could affect the feasibility of your other strategies.
6. If you decide that conservation actions for this site are likely to be infeasible or too risky, think about ways you might adjust your work:
 - Can you change your geographic scope to include areas where conservation is less challenging or particularly important in light of climate change? (see the **Priority Places** worksheet on pg 2)
 - Can you redirect resources to other places for implementation of a desired strategy? (See the Wayfinder for help finding places)
 - Does the area have the potential to provide ecosystem services? (see maps for Ecosystem Services in the Map Layers)
 - Can this place serve research or education/outreach objectives about the impacts of climate change or other threats?

Tactics Toolbox Filters:

- ✓ **Target** (if desired).
- ✓ **Objective** = Reduce Threats, Restore, Reduce Threats & Restore

Preparing for Climate Change

How will this section help you? To prepare for climate change impacts, managers can improve a system's ability to adapt and recover, proactively facilitate anticipate changes, or choose to resist change. The questions and worksheet on the following pages will help you think through what kinds of changes to anticipate, determine what is currently limiting your ability to respond to the ones of most concern, and what you might do to prepare. Even if this isn't work you have the capacity to do now, we strongly urge you to consider it, as climate impacts are already playing out across New York.

Please note that there are a lot of very useful guidance documents for structuring your approach to climate change preparation listed in the More to Explore section. Please consult these other resources for more in-depth help developing adaptation strategies and making adaptation part of your everyday workflow.

What to do:

- 1) **Determine the overall climate risk for the places you are considering.**³ For habitats, use the shading in the Recommended Objectives maps; for Species use the CCVIS maps if available, or the general climate vulnerability rating in the Species Explorer. The greater the climate risk, the more important it will be to prepare. Note your risk at the top of the worksheet on page 14.
 - a) If climate risk is low, a hands-off approach may be the best choice. You should plan to closely monitor the system for climate impacts and be prepared to adaptively adjust your approach if needed to prevent undesirable changes. Consider expanding the geographic scope of your work to incorporate connectivity and geophysical diversity, to enhance the role of this site in landscape-scale adaptation. Complete the **Priority Places** worksheet if you have not already. Also consider whether there are particular species within the project area that may have climate change vulnerabilities that could be addressed – see the **Incorporating Species** worksheet (pg 15) for more assistance.
- 2) **Determine your sources of climate risk.** We evaluate climate risk based on exposure, or direct change in climate conditions, and sensitivity, or attributes that affect how the system responds to climate change. These sensitivity attributes may be inherent properties of the system, such as geophysical diversity, or conditions that can be modified through management, such as connectivity. Poor condition in general can also create climate sensitivity, since stressed or degraded systems may be less adaptable. All three types of drivers should be considered; write your top choices in the spaces provided in the worksheet.
 - a) **Sources of exposure.** Examine the Exposure tab in the Habitat Explorer, or the Exposure folder for your habitat type in the Map Layers. Additional climate change projections may be found in the Climate folder. In deciding which factors you are most concerned about, consider:
 - Which exposure indicators are highest for your project area?
 - Does the projected future climate exceed the historic range of variability or thresholds of tolerance for the system?
 - Are the projected changes likely to result in any shifts in phenology, or timing of events, that are critical to the system?

³ Given the fairly short time horizon (2050) we selected for this toolkit, we encourage users to consider that even places with comparatively “low” exposure are likely to experience moderate exposure by 2080, and may be at risk of temperature and precipitation extremes or variability beyond what we previously considered the normal range of variation.

- Are disturbance events, such as flooding, scouring, storms, fire, drought, etc., key drivers for this system? Extreme events are, in general, expected to increase in frequency (see Climate: Extreme Precipitation). Some disturbance-dependent species or habitats may benefit from this up to a point, but eventually the change may exceed their ability to adapt.
 - Will any of the changes in climate exacerbate existing problems with condition or other future threats?
 - How will people respond to climate impacts, and will those actions further impair natural resources, or possibly create an opportunity to increase resilience for people and nature?
- b) **Sources of sensitivity to climate change.** Which sensitivity indicators are highest for your project area? Which ones are particularly relevant to the climate change impacts you are most concerned about? Are they ones that can be modified?
- c) **Are there aspects of current condition that are low and likely to reduce the ability to adapt?** Often the surest bet for increasing adaptive capacity is to reduce other stressors by restoring structure and function and mitigating future threats. View the Condition indicators for your area or complete the Improve Condition worksheet (page 7) if you haven't already. If you know of additional condition problems that we have not mapped, consider those as well.
- 3) **Think about what kind of approach to take in response to climate change.**
Look at what you identified as climate impacts you care about and things that might be reducing your system's ability to respond to them. Think about whether you have a compelling need to resist that change and for how long. If you do not need to resist, you can still help the system adapt by decreasing sensitivity/increasing resilience to climate change. This approach also includes 'no regret' actions to improve condition or reduce threats, which are advisable regardless of climate change. You might select multiple approaches to address different issues. To help you, see the suggestions below for when you might consider each approach, and refer to the data in the Navigator to help.

Climate Change Approaches

Resisting Change: Resisting change may not be possible for the long term and can be resource intensive. However, there may be situations when resisting change is necessary in order to protect a resource or service that has high value or is not easily replaced if lost or altered. Keep in mind that resistance strategies may not be effective if climate change is more rapid or extreme than predicted, and should only be used in the short term. Favor actions that are easily adjusted or reversed if needed, and do not restrict options for future adaptation.

Consider reducing or delaying change when:

- ☐ The system is already intensively managed
- ☐ You need or want more control over how and when changes occur
- ☐ Very high exposure and sensitivity create the potential for rapid undesirable change
- ☐ You need to buy time to allow the system or species to recover from past damage
- ☐ You need to help species survive long enough to shift elsewhere
- ☐ Reducing sensitivity or proactively facilitating change will not sufficiently reduce the risk

➔ If you decide to resist change, identify which of the climate factors you are most concerned about resisting, and look up tactics for that issue.

Managing for change: If you do not have a compelling need to resist change, then you should consider strategies to manage for change. You can manage for change by passively monitoring change as it happens, removing barriers to adaptation through restoration or threat reduction, taking actions to reduce sensitivity and increase adaptive capacity, or proactively anticipating change and managing the system toward an anticipated future state. These approaches represent a spectrum of actions which may be applied in combination and which may not be clearly distinct. In general:

You might choose to actively facilitate change when:

- ☐ Sensitivity is high and you have limited options for reducing it
- ☐ Exposure is high, creating a potential for rapid change
- ☐ You are already manipulating or actively managing the system
- ☐ You have a desired future state and need or want to control how and when changes occur
- ☐ You have the ability to manage disturbance regimes or how the system responds to disturbance
- ☐ You have high confidence in the likely impacts of climate change

➔ If you decide to facilitate change, identify which changes you are most interested in facilitating, and look up tactics for that issue.

Support adaptation when:

- ☐ Exposure is lower, so change is more likely to be gradual (although due to high uncertainty, abrupt or extreme change is still possible)
- ☐ Sensitivity is due to factors that can be altered
- ☐ When adaptive capacity is lowered by current conditions, or likely will be in the future due to non-climate threats
- ☐ You have some ability to manage the system, but intensive management is infeasible or undesirable
- ☐ Catastrophic or abrupt change would be undesirable
- ☐ Uncertainty about future conditions is acceptable

➔ If you decide to support adaptation, you may wish to improve condition and/or decrease sensitivity, in general or with regard to specific climate factors. Identify which factors you are most interested in addressing, and look up tactics for those issues.

If neither resistance nor managing for change is feasible within the existing project area, consider whether the likely climate impacts will interfere with your desired outcomes. It may be necessary for you to reassess your goals, or consider working in other places:

- Could you adjust your project area to include places where conservation is less challenging or particularly important in light of climate change? (see the **Priority Places** worksheet on page 2)
- Could you shift resources to other places for implementation of a desired strategy? (See the Wayfinder for help finding places.)
- Does the area have the potential to provide ecosystem services? (See maps for Ecosystem Services in the Map Layers.)
- Could this place serve research or education/outreach objectives about the impacts of climate change or other threats?

4) Use the Tactics Toolbox to identify possible tactics to deal with each issue, and list the ones you choose in the worksheet:

Tactics Toolbox Filters:

- ✓ **Target** (if desired)
- ✓ **Issues** = sources of risk (step #2 in worksheet)
- ✓ **Approach** = selected response to change

Preparing for Climate Change Worksheet

1: Overall climate risk:		
2: Enter your sources of risk in the rows below:	3: Decide on an adaptation approach _____	
	4: List draft strategies to...	
Exposure indicators	... resist change	... facilitate change
Sensitivity indicators	...decrease sensitivity	
Condition factors impacting sensitivity	...improve or maintain condition	

5) **Prioritize your tactics! Consider:**

- Can you incorporate the action into existing or planned activities at low cost?
- Does the action address a key driver of the ecology of the habitat?
- Will there be co-benefits for condition, or other targets, or people?
- Will there be benefits to this action even if climate change impacts are slower or less than predicted?
- Will the costs be low or affordable?
- Is there high confidence in the effectiveness of the intervention, even if climate change is faster/more extreme than expected?
- Is the result expected to persist over time without further intervention even if climate change is faster/more extreme than expected?
- Does the intervention allow for other adaptation actions to be taken in the future if needed?

Incorporating Species

How will this section help you? This section helps you use the Species Explorer to identify species present in your project area now OR in the future (based on models of suitable habitat under climate change) that might benefit from conservation attention. Please keep in mind that the Navigator does not contain data on all species that may be present, and that our coverage of each species' condition, threats, and climate vulnerability varies. It may be helpful to seek supplemental information, particularly for species-specific protection, threat reduction, and restoration techniques.

Question	Look at...	✓ Tactics Toolbox Filters: Target = Species
What rare or conservation priority species are associated with the project area? ⁴ List them at right.	Species Explorer: Special Designations filter: Rare only	Note species:
Does this location support a particularly large or stable population of any rare species? ⁵ Circle them at right.	Species Predicted Habitat maps Local biodiversity data	
Are there known threats or poor conditions associated with a particular species that are not captured by the habitat assessment?	Use Species Explorer & your own knowledge	✓ Issues = threat or condition factor
Do any of the above species have high climate vulnerability or are predicted to decline in this location? Do any of those species have lower vulnerability, or future suitable habitat, in other nearby areas?	Species Explorer: Habitat Change filter/Species Details Species Map Tree: CCVIS, Future Suitable Habitat (only available for some species)	If yes, Approach = Facilitate Change If no, Approach = Resist OR Adaptive Capacity
For species needing to access new habitat, is there sufficient connectivity between current and future habitat (if modeled), or to more northerly/upslope/cooler habitat areas?	Species: Migration Paths Reference: Topography Forest: Connectedness Stream: Connected Networks	✓ Issues = connectivity
Are there new species expected to have suitable habitat in this location in the future? Think about positive or negative interactions with species currently present. Are new species undesirable?	Species Explorer: Habitat Change filter Species: Future Species Distributions Your own knowledge	✓ Issues = shifts in species composition ✓ If yes, Approach = Resist ✓ If no, Approach = Facilitate Change/Adaptive Capacity

⁴ Consult NYSDEC and NYNHP for any regulatory requirements, especially if planning any habitat restoration work.

⁵ Consult the New York Natural History Program for more information about specific occurrences of rare species.

How will this section help you? This section helps you use the species data in the Navigator to identify species or habitat locations appropriate for different strategies, or for identifying actions to implement for conservation of a particular species.

Which Species? Use the Species Explorer to view the species predicted to occur in your area. View Species Details or download the Statewide Data to view the available status, threat, and vulnerability information for each species.

In Which Locations? To find where to work on a particular species, search for it in the Species Map Layers to find all the spatial data available for that species.

Objective	Which Species?	In Which Locations?	Tactics Toolbox Filters: Target = Species
Maintain when ...	Current status is high and threats are low. These species are likely to persist without significant conservation intervention, unless climate vulnerability is high.	Places with suitable habitat in both current and future conditions. Areas within the current or future range where the associated habitats have good condition and low threat Habitat areas with low climate vulnerability	<ul style="list-style-type: none"> ✓ Objective = Maintain ✓ Approach = selected response to change (if desired) ✓ Issues = range shifts; connectivity
Reduce threats when ...	Current status is high but threats are also high. Threat abatement actions may be needed to retain the species statewide or in particular habitat areas. Some threats may be exacerbated by climate change.	For species that face a particular future threat, target actions in those current habitat areas where the threat is known or expected to occur, and where habitat is otherwise in good condition.	<ul style="list-style-type: none"> ✓ Objective = Reduce Threats ✓ Approach = Adaptive Capacity OR Resist
Improve conditions when...	Current status is low but threats are low. Habitat quality for these species may be worth restoring in your project area, particularly if the project area might contribute to overall species viability.	Current habitat areas that have low future threat and low climate vulnerability are good candidates for restoration. Improving populations and habitat conditions may also help to reduce climate vulnerability.	<ul style="list-style-type: none"> ✓ Objective = Restore ✓ Approach = Adaptive Capacity
Monitor when...	Species status and/or threats are unassessed. Local populations may have restoration needs or threats. Monitor for signs of decline, particularly if they have commercial, recreational, or other value. Common species may have climate vulnerabilities that have not been identified.	Collect more information in locations where information about condition or threats is lacking, particularly where associated habitats have high climate risk, or near the edge of a species' range.	<ul style="list-style-type: none"> ✓ Objective = Maintain ✓ Approach = Monitor
Evaluate risk when...	Current species status is low and threats are high. These species are likely to require significant and ongoing conservation investment to sustain viable populations.	Locations modeled to lose suitable habitat may not support long-term investment. Consider whether restoration is feasible in the face of ongoing threats. If a species is expected to decline in much of its range, prioritize those places with the lowest vulnerability.	<ul style="list-style-type: none"> ✓ Objective = Reduce Threats & Restore ✓ Approach = Resist and/or Transform

How will this section help you? According to the 2014 New York State Hazard Mitigation Plan, 34 of 56 local hazard mitigation plans identified flooding as a high or moderately high hazard. The following worksheets help you use the data layers in the Navigator to think about strategies you might use to mitigate flooding impacts, based on:

1. Your current flood condition
2. How projected land use and climate might impact the community in the future
3. How sensitive or vulnerable the community might be to flooding

Data along with local knowledge can help you visualize:

- whether your area is flood prone
- the degree to which hydrology has been altered by floodplain development and impervious surfaces
- if developed areas are at risk
- whether current building regulations/standards will accommodate estimated changes in precipitation magnitudes and frequency
- whether property owners have insurance resources to help them recover from flooding
- where natural land is available to mitigate flooding

Four general strategies are recommended. More specific information can be found in the **Tactics Toolbox**.

1. Manage water on the landscape	2. Improve floodplain function	3. Restrict/mitigate development	4. Outreach and education
Allow water to spread out, slow down and sink into the ground in areas outside of floodplains.	Allow floodplains to provide for movement of water and sediment, storage of flood waters, recharge of groundwater, treatment of pollutants, and habitat diversity.	Keep structures, infrastructure and people out of harm's way.	Provide information to residents and business owners on resources that can help them prepare for, respond to and recover from flooding.
Tactics Toolbox Filters: Issues = habitat conversion; impervious surfaces; alterations to flows; high flows and flooding Further refinement of filters follows each section.	Tactics Toolbox Filters: Issues = floodplain condition; floodplain connectivity; high flows and flooding Further refinement of filters follows each section.	Tactics Toolbox Filters: Issues = high flows and flooding; alterations to flow; road-stream crossings Further refinement of filters follows each section.	This could include notifying floodplain property owners that they are in a floodplain and providing information on the National Flood Insurance Program, distribution of written materials on flood preparation resources, or educating contractors and highway departments on stream intervention techniques.

Flood Mitigation Worksheets

Questions should be answered by either referring to the data layer referenced or with local knowledge. Due to inherent data limitations, components of the worksheet should be used collectively to think about big themes and priorities.

1.	Current Flooding Condition				
	Question to Answer	Data Layer to Look At	This Info Indicates...	Opportunities	Strategies
	Idea of Flood Risk (probability and consequence)				
	For your focus municipality or county as well as those downstream:				
C1.	How many flood disasters have been federally declared?	CONDITION Number of Flood Disaster Declarations	How flood prone the county is particularly to large, damaging floods.	Federal assistance is available for recovery from declared disasters.	<ul style="list-style-type: none"> Education/outreach
C2.	How many flood events have been recorded?	CONDITION Number of Flood Events	How flood prone the county is.	Public education can inform decision makers and residents of the need to prepare for flooding.	<ul style="list-style-type: none"> Education/outreach
C3.	How many residential properties are estimated to be in the Special Flood Hazard Area ⁶ (SFHA)?	CONDITION Number of Residential Parcels in the 100-yr Floodplain	How many structures and people in the municipality might be exposed to flooding and thus how impactful a large flood event might be.	Emergency preparedness enhances public safety and enables property protection.	<ul style="list-style-type: none"> Restrict/mitigate development Education/outreach
Answers/Notes:					

⁶ Special Flood Hazard Areas (SFHA) are areas mapped by FEMA as having a 1% or greater annual probability of flooding.

1.	Current Flooding Condition				
	Question to Answer	Data Layer to Look At	This Info Indicates...	Opportunities	Strategies
	For your focus reach as well as up and downstream reaches:				
C4.	Has a high proportion of the Active River Area ⁷ (ARA) been developed?	SUPPORTING DATA Active River Area <i>with</i> SUPPORTING DATA Current Impervious Cover	How much development might be exposed to flooding and how much area is no longer available to mitigate flooding.	Education and assistance can facilitate mitigation of existing development in floodplain areas.	<ul style="list-style-type: none"> • Manage water on landscape • Improve floodplain function • Restrict/mitigate development • Education/outreach
C5.	Is there a high proportion of impervious cover in the reach's catchment ⁸ ?	CONDITION Percent Impervious Cover	The degree to which hydrology might be altered due to more runoff in a shorter period of time.	Runoff management practices can mitigate the impacts of development on stream flow.	<ul style="list-style-type: none"> • Manage water on landscape
C6.	Are there a high number of road stream crossings?	CONDITION Fragmentation Road-Stream Crossing	The degree to which stream flow and/or debris/sediment transport might be impeded by culverts and thus the susceptibility of roads to flood damage.	Properly sized and maintained culverts pass water, debris and sediment more efficiently.	<ul style="list-style-type: none"> • Improve floodplain function
ANSWERS/NOTES:					

⁷ Active River Area (ARA) is a visual and spatial representation of rivers and streams that includes the channels and riparian lands necessary to accommodate the physical and ecological processes associated with river systems. The ARA is *not* the regulatory floodplain; for this project, they are lands with the potential for “localized flooding problems” (ie. smaller scale flooding which includes shallow flooding in low-lying areas after a heavy rain, flooding in small watersheds, ponding, and localized stormwater and drainage problems).

⁸ The reach's “catchment” is the land surface area that contributes flow to each stream reach.

1.	Current Flooding Condition				
	Question to Answer	Data Layer to Look At	This Info Indicates...	Opportunities	Strategies
	<u>Mitigating Factors</u>				
	For your focus reach as well as up and downstream reaches:				
C7.	Do stream reaches tend to have high, moderate, or low amounts of natural adjacent lands?	CONDITION Floodplain Connectivity	Lands that are able to slow flows, allow water to sink into the ground and possibly provide space for overbank flows (if connected to overbank flows).	Protect existing natural areas so they continue to provide flood mitigation services and/or restore natural lands to areas adjacent to streams so they can provide these services.	<ul style="list-style-type: none"> • Manage water on landscape • Improve floodplain function
C8.	Are upstream watersheds largely forested?	FORESTS SUPPORTING DATA Forest Habitat	Forest canopies intercept precipitation and forest soils absorb and slow surface water thereby decreasing runoff.	Protect forests to slow and decrease the flow of surface runoff to stream channels.	<ul style="list-style-type: none"> • Manage water of the landscape
C9.	Are stream reaches part of a Floodplain Complex ⁹ (FPC)?	SUPPORTING DATA Floodplain Complexes	Whether the area of interest is providing flood mitigation or is influenced by an upstream area that provides flood mitigation.	Protect lands within FPCs so they retain floodplain functions and mitigate flooding for adjacent and downstream areas.	<ul style="list-style-type: none"> • Manage water on landscape • Improve floodplain function
C10.	What portion of the ARA lies in a FPC in the watershed and upstream watersheds?	CONDITION Functioning Floodplains	How much of the sub-watershed and upstream area is providing flood mitigation.	Protect lands within FPCs so they continue to provide flood mitigation services for areas downstream.	<ul style="list-style-type: none"> • Manage water on landscape • Improve floodplain function
ANSWERS/NOTES:					
<p>To view tactics for improving current condition (reducing risk or improving mitigating factors) apply Tactics Toolbox Filters: Objective = Improve Condition, AND Issues = see suggested filters by selected strategy on first page of flood worksheet</p>					

⁹ Floodplain Complexes (FPC) represent undeveloped areas that are large enough to allow for natural floodplain processes like movement of water and sediment, storage of flood waters, recharge of groundwater, treatment of pollutants, and habitat diversity. They are identified as areas within the ARA that consist of a core which is at least 150 acres of natural land cover, and corridors which are lands adjacent to cores that have undeveloped land cover.

2. Future Projections					
	Question to Answer	Data Layer to Look At	This Info Indicates...	Opportunities	Strategies
	<u>Changes Due to Projected Future Land Use (2050)</u> ¹⁰				
	For your focus reach as well as up and downstream reaches:				
F1.	Is the percent of developed ARA expected to increase?	SUPPORTING DATA Active River Area <i>with</i> SUPPORTING DATA Future Impervious Cover	More development could be exposed to flooding and less natural land would be available for flood mitigation.	Land use tools can be used to restrict future development in floodplain areas.	<ul style="list-style-type: none"> • Manage water on landscape • Improve floodplain function • Restrict/mitigate development • Education/outreach
F2.	Is the amount of impervious surfaces expected to increase?	THREATS Change in Percent Impervious Cover	Whether future drainage alterations might increase flood flows.	Runoff management practices and land use tools can reduce impacts of impervious surfaces.	<ul style="list-style-type: none"> • Manage water on landscape
F3.	Is the amount of natural adjacent land expected to decrease?	THREATS Change in Floodplain Connectivity	Whether more or less land will be available to slow flows, allow water to sink into the ground or mitigate floods (if connected to overbank flows).	Natural lands adjacent to streams could be protected or restored to keep development out of harm's way and mitigate flooding impacts.	<ul style="list-style-type: none"> • Manage water on landscape • Improve floodplain function
ANSWERS/NOTES:					

¹⁰ Future land use to 2050 was predicted by SUNY ESF Environmental Studies, using a spatial model that identified the top drivers of past conversion from among a variety of input variables, including soils, distance to highways, and census data. Separate models were developed by region for new development, new agriculture, and conversion back to natural cover. The model assumes past patterns and amounts of land conversion will continue. It does not include any economic or population forecasting. We have also incorporated sea level rise and forest succession to create a 2050 land cover map.

1.	Current Flooding Condition				
	Question to Answer	Data Layer to Look At	This Info Indicates...	Opportunities	Strategies
	<u>Changes Due to Projected Climate¹¹</u>				
	For your regional watershed (HUC8):				
F4.	How much is the magnitude ¹² of both the 100-year and 10-year precipitation event projected to increase?	EXPOSURE Percent Increase in 10-yr (& 100-yr) Magnitude	More precipitation can end up as stream flow and contribute to local drainage problems.	Building standards and drainage systems can be modified to accommodate increased precipitation.	<ul style="list-style-type: none"> Restrict/mitigate development
F5.	Compare this to current magnitudes for both size events.	SUPPORTING DATA Magnitude of 10-yr (& 100-yr) Precipitation Event			
F6.	Will the 100-yr or 10-yr precipitation event occur more frequently ¹³ ?	EXPOSURE Future 10-yr (& 100-yr) Equivalent Recurrence Interval	How much more often your community might experience precipitation events that could produce flood flows.	If extreme precipitation events produce more flood events, restrictions on land use in floodplains could reduce damage and allow land to continue to provide flood mitigation.	<ul style="list-style-type: none"> Restrict/mitigate development
ANSWERS/NOTES:					
<p>To view tactics for reducing threats from future land use, apply Tactics Toolbox Filters: Objective = Reduce Threats OR Action Classification = land/water management and law and policy AND Issues = see suggested filters by strategy on first page of flood worksheet</p>					

¹¹ The Northeast Regional Climate Center has modeled the average predicted percent increase in future precipitation amount for extreme precipitation events (1 day duration) and how the recurrence interval for extreme events is predicted to change. Averages presented are across techniques for the A2 scenario for 2040-2069. This footnote will be updated with an article citation once it is available.

¹² Magnitude is the amount of precipitation expected to fall within a 24-hour period. There is not a direct correlation between magnitude of precipitation and stream flow.

¹³ The frequency of a precipitation event, or recurrence interval, is an estimate of how often a certain size precipitation event might occur. There is not a direct correlation between frequency or recurrence of precipitation and the resulting stream flow.

3.	Sensitivity/Vulnerability to Flooding				
	Question to Answer	Refer to Data Layer	This Info Indicates...	Opportunities	Strategies
	For your municipality (town, village, or city):				
S1.	How many National Flood Insurance Program (NFIP) policies are there?	SENSITIVITY Number of NFIP Policies	Because flooding is not included in standard homeowner policies, this indicates the number of buildings for which flood loss are insured.	Increased flood insurance coverage can improve a community's ability to recover from a flood.	• Education/outreach
S2.	Is the ratio of NFIP policies to SFHA properties greater than 0.76?	SENSITIVITY # NFIP Policies per 100-Yr Residential Property	A higher ratio indicates that more flood-prone buildings have flood insurance and thus might recover from a flood better. A ratio of 0.10 would indicate that only 10% of SFHA properties are covered by flood insurance.	SFHA properties and other flood-prone locations could be targeted for NFIP education and outreach to improve the owners' ability to recover from flood damage.	• Education/outreach
S3.	What is the amount of NFIP claims that have been paid?	SENSITIVITY Paid NFIP Claims	The amount of flood insurance claims is a function of the number of flood-prone buildings that are covered, the frequency of damaging floods, and the severity of damage. It is typically much lower than the actual damages sustained.	Mitigation of flood-prone properties can reduce future damage and may also enable lower flood insurance premiums.	• Restrict/mitigate development
ANSWERS/NOTES:					

3. Sensitivity/Vulnerability to Flooding					
	Question to Answer	Refer to Data Layer	This Info Indicates...	Opportunities	Strategies
S4.	How many Repetitive Loss Properties ¹⁴ (RLPs) are there?	SENSITIVITY Number of Repetitive Loss Properties	That there are NFIP-insured buildings that have been repeatedly damaged from flooding, indicating that damaging floods are not rare events.	Areas with RLPs should be targeted for mitigation programs that remove occupants from harm's way and reduce/eliminate the amount of damage sustained during flood events.	<ul style="list-style-type: none"> Restrict/mitigate development
S5.	How much has been paid in claims to RLPs?	SENSITIVITY Paid Repetitive Loss Property Claims	How extensive flood damage has been to buildings with multiple NFIP insurance claims. Actual historic damage to these buildings may be greater due to deductibles, uninsured losses, and periods without NFIP coverage.	Buyouts and other mitigation projects are more likely to be cost-effective in areas with high RLP claims payments (meaning that long-term benefits exceed project costs).	<ul style="list-style-type: none"> Restrict/mitigate development
S6.	What is the ratio of the number of RLP claims to the number of RLPs?	SENSITIVITY # Repetitive Losses per Repetitive Loss Property	The higher the number the more frequently RLPs experience flood damage.	Areas with frequent RLP damage should be targeted for mitigation to promote safety and reduce future property damage.	<ul style="list-style-type: none"> Restrict/mitigate development
ANSWERS/NOTES:					
<p>To view tactics for reducing sensitivity, apply Tactics Toolbox Filters: Issues = High flows and flooding AND Action Classification = land/water management, and law and policy</p>					

¹⁴ A Repetitive Loss Property (RLP) is any insurable building for which two or more claims of more than \$1,000 were paid by the National Flood Insurance Program (NFIP) within any rolling ten-year period, since 1978. A RLP may or may not be currently insured by the NFIP. There may be properties that experience regular flooding damage but would not be included in this number because they do not or did not hold flood insurance through the NFIP.

III. More to Explore: Additional Resources for Climate Change Planning

If you want to know more about approaches for preparing for climate change, in this section you will find FAQs intended to provide additional information about some of the terms and concepts associated with climate change adaptation. Each question and answer is accompanied by a bibliography that highlights additional resources on that particular topic. Many of these resources, where publicly available, can be found in the [Resource Library](#) on our website.

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What are refugia?

As regional temperatures continue to increase, areas that are consistently cooler than other locations due to persistent factors (altitude, geographic position, aspect, proximity to water) can act as climatic “refugia,” in that they may have the greatest potential for retaining species that otherwise would be lost from an area. In the conservation realm, the concept of refugia is also applied in a more relative sense, with areas expected to slower rates of change (regardless of their starting condition), and places where species are potentially less sensitive to a specific amount of change due to long term exposure to high climate variability also sometimes described as refugia (Ashcroft et al. 2010, Groves et al. 2012, Schmitz et al. 2015). As these ideas suggest, the concept of refugia has been applied to work at many different scales, and the mechanisms that underlie the extent to which these cooler areas vary from neighboring locations, and how they are identified and described, varies (Ashcroft et al. 2010). For example, Saxon et al. (2005) used a relative scale (based on the difference between current temperature and precipitation patterns at a site in Florida and a site in Alaska) to map the amount of change in the factors expected across the continental US. Sites at the lowest end of this range (least change between current and future conditions) are described as potentially being at lowest climate risk (Saxon et al. 2005). In contrast to these “macrorefugia,” work exploring the interaction between topography and climate can be used to highlight “microrefugia” (Ashcroft 2010). Examples in this area, which build upon well-documented relationships between climate exposure and elevation, aspect, slope, and the flow of moisture, include work by Ashcroft et al. (2009) and Dobrowski (2011). Topo-climate relationships are also being incorporated into metrics for assessing climate change “resilience” at the site scale for the purpose of informing conservation investments (Anderson et al. 2014).

In addition to scale, the use of the term refugia varies with context, and is often invoked as part of planning for shifts in the distributions of species and habitats. Comparisons of current and projected future ranges for species often lead to the identification of two different types of areas that may be called refugia: (1) places within a species’ current range that appear to remain suitable over some time period into future, or places that will be suitable for that species in the future, but may be outside of the current range (Ashcroft 2010). In some conservation applications the term refugia has been expanded to encompass the concept of multiple options with respect to future local-scale climatic conditions (Ashcroft 2009, Groves et al. 2012). This expansion shifts the focus away from particular species with particular requirements toward “biodiversity” more broadly, suggesting the more micro-climatic options available with a relatively local area, the greater potential there is for some location to be a good fit. This usage of refugia is analogous to high “site resilience” as described in Anderson et al. (2014), though this metric incorporates both topographic diversity and degree of local permeability (proportion of natural land cover). These approaches highlight areas with diverse topography and a range of water availability. As with many other terms, the most important aspect of the definition is making sure that everyone engaged in the conversation is on the same page, so groups tackling this issue will likely find time spent reviewing their own definition, potentially with reference to categories described in Ashcroft et al. (2010), to be well spent.

While protection of refugia in the context of climate change typically focuses on the identification of cooler areas, in the eastern US, large-scale influences on regional climate include the “lake effect” in areas around the Great Lakes, which acts to modify both high and low temperatures in coastal areas and on Great Lakes islands (Scott and Huff 1996). Other large waterbodies such as lakes and rivers can also act as moderators of local climate as well, and again can act to buffer both high and low temperature

extremes. Buffering against low temperature extremes can also be important in the context of reducing risks to species and systems under climate change, especially in the context of shifts in spring phenology as temperatures warm. For example, Gu et al. (2011) documented reduced frost damage for trees near water bodies when during the pervasive “spring freeze” of 2007 when a strong cold front moved across much of the eastern US following an earlier period of unusually warm temperatures. In this context, the benefit to plants of being located in a refugia/buffer zone are two-fold, in that trees in the cooler near-lake zone tend to leaf out more slowly and thus may have a lower proportion of damage, and may also be protected from the most extreme low temperatures due to the micro-climatic influence of open water.

Key resources:

- Ashcroft, M. B. 2010. Identifying refugia from climate change. *Journal of Biogeography* **37**:1407-1413.
<http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2699.2010.02300.x/epdf>
- Anderson, M. G., M. Clark, and A. O. Sheldon. 2014. Estimating climate resilience for conservation across geophysical settings. *Conservation Biology* **28**:959-970 <http://dx.doi.org/910.1111/cobi.12272>

Why is connectivity important?

Enhancing ecological connectivity is a critical element of protecting species and maintaining ecological processes, and strategies for increasing connectivity have been a focal element of conservation planning for decades (Groves et al. 2003, Aune et al. 2011, Groves et al. 2012, Schmitz et al. 2015). Within the state of New York and across the eastern US, the ability of organisms to move through landscapes and watersheds varies widely, both as a result of differences in mobility and other life history traits, and as a function of the condition of the landscape or freshwater system. This variation is an important aspect of developing management or protection strategies to increase movement of animals, the flow of genes, or the transfer of materials through a system: The degree of connectivity between sites, or across a region, depends on what species or process you choose as your focus. As concerns about the impacts of climate change on biodiversity have increased, we have seen an increasing emphasis on improving connectivity to facilitate species “tracking” their preferred climatic conditions. In a widely-cited review of recommendations for promoting adaptation by Heller and Zavaleta (2009), increasing connectivity was mentioned more than any other approach. While connectivity is clearly an important goal, the fact that enhancing connectivity seems to represent the default solution suggests that we may at times need a reminder to systematically compare the costs and benefits of these investments to other adaptation strategies, and to ask “connectivity for what”, and “what are the potential side effects” as we prioritize our work (Hodgson et al. 2009, Stein et al. 2014).

Much of the work to enhance connectivity in terrestrial systems has focused on landscapes where conversion to human-dominated land uses has created fragmented patches of habitat, surrounded by other lands uses that are inhospitable to some conservation target, often wide-ranging mammals (reviewed in Groves 2003, Chapter 8, and Aune et al. 2011). There are many potential barriers to movement across land, including both natural features like rivers, and conversion of natural areas to managed forests, urban centers, suburbs, and farms. Similarly, aquatic systems become disconnected

either through natural processes like seasonal drying or longer-term changes in flow patterns, or through the placement of barriers such as dams, or water infrastructure that in some way impedes the movement of organisms and/or resources. While early work on enhancing connectivity focused on creating linear corridors and linkages between patches of habitat for one or several terrestrial species, the suite of options for evaluating and addressing connectivity has expanded rapidly, enhanced by rapid advances in GIS methods, computing power, and access to spatial datasets (Aune et al. 2011). As these methods have advanced, and our thinking on connectivity has broadened, assessment of connectivity have increased in spatial scale to look at flow across landscapes and regions (e.g. Beier et al. 2011), and have evaluated multiple species to find areas of highest benefit. Although not a new idea (see Hunter et al. 1988), connectivity assessments that incorporate connectivity across or in response to climatic gradients are rapidly emerging (e.g., Nuñez et al. 2013, Lawler et al. 2013).

Similarly, the suite of strategies used to address connectivity has expanded from corridors and linkages between a few sites to approaches for building regional networks, and has broadened to consider relative values of different forms of “non-natural” habitats for allowing movement. A key goal for helping species and systems adapt in our region is improving connectivity by restoring natural habitats in areas where key connections have been lost and by working to “soften” management in lands managed for multiple purposes, such that the ability of wild species to inhabit and move through those areas is increased.

By increasing connectivity in both terrestrial and aquatic systems, we have the potential to increase the capacity of biodiversity to adapt to climate change through at least three mechanisms. First, restoring connectivity at local scales (i.e., connecting neighboring forest patches or stream reaches) increases the chances that genetic diversity in an area will be maintained by allowing increased mixing of populations. Higher rates of mixing, or “gene flow,” should promote future populations with a wider range of variation in key traits (e.g., heat tolerance, growth rate under drought), which in turn should increase the odds that some individuals will be able to persist and thrive under new climatic conditions. Second, restoring connectivity can improve adaptive capacity by allowing mobile species access to cooler or moister microclimates (north facing hillsides, streams with high forest cover) within the same local area so that individuals can shift into these habitats when conditions are severe. Third, again for mobile species, increasing the connectivity of habitats provides a pathway for long-term shifts in range, as species shift north in our region to “track” their most favorable temperature regime. In addition to these three species-focused mechanisms, increasing the connectivity of ecological systems promotes resilience by allowing large scale ecological processes like flooding to occur, which provides an essential mixing of energy and materials between aquatic and terrestrial systems. By restoring the connectivity and extent of natural systems like floodplains and allowing this natural process to occur in natural areas, we can also help prevent people and property from being harmed as flood frequencies increase due to increases in peak storm intensities.

While connectivity is key to many ecological processes, from gene flow to nutrient and sediment transfer, to continental scale migrations, maintaining or increasing the isolation of systems may also be an important conservation objective. Some systems, such as mountain tops, and fens, are naturally isolated, and isolation is a key driver and speciation and facilitates persistence for some species. It’s also important to remember that even for species that would potentially benefit from range shifts facilitated by improved connectivity, suitable climatic conditions are necessary but not sufficient for survival. Persistence in new habitats also depends on how well new areas meet an organism’s needs for food and

shelter, and habitat for movement needs to be available between current and future ranges. Further, even mobile species that depend on food sources or habitat components that shift at slower rates will be vulnerable if the species that they depend on decline in abundance.

Finally, range and abundance changes can lead to conservation concerns, especially for rare species in the newly occupied locations. First, species that are not able to disperse will be stressed by climatic conditions that are becoming less and less favorable, and this stress can be exacerbated by species moving in from warmer areas that are less challenged by the same climatic conditions. The species moving in may directly compete for key resources and also may contribute to the decline of resident species by spreading diseases and parasites.

Key resources:

- The Wildlife Conservation Society's Assessment & Planning for Ecological Connectivity: A Practical Guide. (Aune et al. 2011) <http://www.wcsnorthamerica.org/ConservationInitiatives/Connectivity/tabid/3243/Categoryid/166/Default.aspx>
- The Wildlife Conservation Society's "Make Room for Wildlife: A Resource for Local Planners and Communities in the Tug Hill region" and "Protecting Wildlife Connectivity Through Land Use Planning – Best Management Practices and the Role of Conservation Development." Available at: <http://www.wcsnorthamerica.org/ConservationInitiatives/Connectivity/tabid/3243/Categoryid/166/Default.aspx>
- National Wildlife Federation's Climate Smart Conservation: Putting Adaptation Principles into Practice (Stein et al. 2014), Chapter 8. The Art of the Possible: Identifying Adaptation Options. www.nwf.org/ClimateSmartGuide.
- Map of projected dispersal corridors for climate-change-driven range shifts from Lawler et al. (2013), with link to downloadable data. <http://databasin.org/articles/504854c10165475bbf60064b14748508>

Why is geological diversity important?

Historically, work to identify what areas should be protected in order to provide the most benefit to biodiversity has focused on mapping patterns of where species are found, and targeting "diversity hot spots. However, many species are likely to shift distributions in response to changing conditions, and individual species' responses to climate change will be complex and individualistic, leading to changes in habitats, ecosystems, and related ecosystem processes and services. So, while species distribution maps are still essential resources for informing conservation, it's helpful to think of them as a snapshot in time, not a long term picture. To help ensure that our conservation efforts help sustain species and systems over longer time periods, it makes sense to think about protecting variation in features that will change less over time, and that correlate with or "drive" patterns of diversity at the scale of a region or landscape (Anderson and Feree 2010, Beier and Brost 2010, Beier et al. 2015). The idea of "protecting the stage" focuses on variation in geophysical settings, which can include geology, soils, and aspects of

landform such as altitude, slope, and aspect. These consistent differences across sites are expected to persist, even as climatic conditions change the species that can inhabit them.

These consistent landscape-scale units of variation have been referred to as “geophysical settings” (Anderson and Ferree 2010) or “land facets” (Beier and Brost 2010). If we can map these stages, we can focus land protection or conservation efforts on capturing the widest possible variety of these land or aquatic units. Although using geophysical settings as an input to conservation decisions was first suggested in the context of climate change responses by Hunter et al. (1988), work in the past several decades has incorporated this approach for many reasons, including a lack of species distribution data (Beier et al. 2015). Adapting our conservation work to include the goal of capturing the range of factors that underlie variation in species should help protect a wider range of species within taxa that are typically not represented as conservation areas are designated, such as mollusks and other aquatic invertebrates (Lydeard et al. 2004; Strayer 2006).

The goal of protecting a diversity of conditions on the landscape and in aquatic systems can be pursued with more certainty in terms of defining the actions to take than one focused on protecting a particular list of species (or “actors” on the stages), as each species may respond to changes in surprising ways. In effect, by adding consideration of geophysical diversity into our collection of tools, we can hedge our bets in favor of biodiversity. If we can protect and connect a network of lands and waters that encompass the widest possible range of abiotic factors, this range of available habitats should continue to promote a high diversity of species, and provide a complement and safety-net to traditional species- and habitat-focused approaches.

Key resources:

- The “Terrestrial Resilience” site on The Nature Conservancy’s Conservation Gateway contains an overview work led by Mark Anderson that focuses on protecting geophysical settings, as well as links to reports, research papers, a fact sheet, and downloadable data for the Eastern US: <http://www.nature.ly/TNCResilience>.
- The June 2015 Issue of the journal *Conservation Biology* contains a special section on using geophysical settings to inform conservation priorities. The section is introduced in: Beier, P., M. L. Hunter, and M. Anderson. 2015. Special Section: Conserving Nature's Stage. *Conservation Biology*: (online early) <http://dx.doi.org/10.1111/cobi.12511>
- Anderson, M. G. and C. E. Ferree. 2010. Conserving the stage: climate change and the geophysical underpinnings of species diversity. *PLoS ONE* 5:e11554. <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0011554>
- Beier, P. and B. Brost. 2010. Use of land facets to plan for climate change: Conserving the arenas, not the actors. *Conservation Biology* 24:701-710.

Why is the size of a natural area important?

The size of a natural area influences conservation value through several different mechanisms. First, more natural habitat is likely to provide a wider range of habitat resources, and thus is likely to support a wider range of species. Increased variety of conditions can result from differences in ecosystem types, variations in underlying topography and slope/aspect, variation in successional stages, and differences in management history. Areas large enough to contain multiple ecosystem types, such as forests and wetlands or ponds are important for many amphibians that breed in aquatic habitats but spend most of their adult lives in terrestrial systems. Even when the ecosystems are similar, sites that are large enough to encompass differences in topography and slope/aspect, and thus include some variation in local microclimates, can provide more climate niche options for species that may be under stress as climate conditions change. For systems that naturally progress through multiple successional stages, such as forests, larger areas are more likely to contain more stages, as they are more likely to have experienced the effects of natural disturbances such as windthrow, pest outbreaks, or fire. Similarly, managed forest stands that are part of larger units can be managed in ways that maintain larger blocks of intact habitat, with harvest actions designed to be similar to natural patterns of disturbance. Keeping variety within larger forest management units can help reduce the susceptibility of systems like forests to pests and pathogens, as the “vulnerable” age classes or species are intermixed with other less vulnerable trees.

Second, from a wildlife perspective, larger areas are more likely to support populations over longer time periods. For birds and mammals that are territorial (i.e., songbirds), the size of an area can correlate well with the maximum number of individuals present. Similarly, even if they do not defend territories, some species require large areas for foraging and other activities, and encompassing full home ranges for multiple individuals can require very large areas. All else being equal, a site that supports larger population sizes should have a higher likelihood of sustaining species over longer periods of time, in part through reduced risks from genetic challenges such as inbreeding, and through reduced odds of a disease, pest, or extreme event killing off all individuals of a species. For species that show highly variable population dynamics across different years, such as some butterflies, larger areas can support multiple populations, which can increase the odds of long-term persistence because different populations can “rescue” declining ones through dispersal between groups.

Larger, more intact areas also have a greater likelihood of supporting a more natural disturbance regime (fire, wind, flooding), which benefits species diversity by continually changing or maintaining (depending on the habitat) key systems. For some systems, such as floodplains, the shape of the area can be especially important in addition to the size, since flooding has strong directional components. In contrast to larger, intact systems, fragmented systems often experience different levels of key climate drivers and/or disturbance factors, and habitats along “edges” will attract different species, and may be much less suitable for species that typically occupy the “interior” of the system type. Maintaining larger protected areas, and reducing roads and other fragmenting features, should increase habitat values for many species. Having enough area that natural disturbance patterns can produce “edges” will also keep edge specialists in the system.

Key Resources

- Groves, C. R., E. T. Game, M. G. Anderson, M. Cross, C. Enquist, Z. Ferdana, E. H. Girvetz, A. Gondor, K. R. Hall, J. Higgins, R. Marshall, K. Popper, S. Schill, and S. L. Shafer. 2012.

Incorporating climate change into systematic conservation planning. *Biodiversity and Conservation* **21**:1651-1671. <http://link.springer.com/article/10.1007/s10531-012-0269-3>

- Schmitz, O. J., J. J. Lawler, P. Beier, C. Groves, G. Knight, D. A. Boyce, Jr., J. Bulluck, K. M. Johnston, M. L. Klein, K. Muller, D. J. Pierce, W. R. Singleton, J. R. Strittholt, D. M. Theobald, S. C. Trombulak, and A. Trainor. 2015. Conserving biodiversity: practical guidance about climate change adaptation approaches in support of land-use planning. *Natural Areas Journal* **35**:190-203.
- For forested systems - Janowiak, M. K. C.W. Swanston, L. Nagel, L.A. Brandt, P.R. Butler, S. D. Handler, P.D. Shannon, L.R. Iverson, S.N. Matthews, A. Prasad, M.P. Peters, Matthew P. 2014. A practical approach for translating climate change adaptation principles into forest management actions. *Journal of Forestry*. 112: 424-433. <http://www.treeseearch.fs.fed.us/pubs/46417>

How does climate exacerbate existing threats?

Many non-climate threats, which we define as any natural or anthropogenic factor that acts in a way that reduces the viability of species or systems, or interferes with natural processes, are described as being exacerbated by the effects of climate change. This statement implies that the mechanism by which climate change is predicted to pose a risk to conservation goals is through an increase in the strength of the threat, or a reduction in the ability of the species or system to tolerate the stressor due to changing climate drivers. As described in more detail in other sections, vulnerability to climate change is often described as being a function of exposure (what climate factor is changing, and by how much), sensitivity (how does climate change influence the focal species or system), and adaptive capacity (the potential for that species, system, or process to respond in a way that allows persistence or maintenance of key functions as conditions change; Schneider et al. 2007, Foden et al. 2008, Klausmeyer et al. 2011, Stein et al. 2015). This same framing can be used to think through the effects of stressors, and can help illustrate interactions between multiple climate and non-climate stressors.

In some cases, changes in climate can increase the likelihood of exposure to a stressor, or increase the magnitude of that exposure. For example, if the threat is low water levels for fish due to water withdrawals for agricultural use, warming conditions are likely to increase the potential for drought stress, increasing the demand for water, while also increasing evapotranspiration rates, increasing the rate at which water is lost from the stream. In other cases, climate change may increase the sensitivity of a species or system to a natural or anthropogenic stressors. A prominent example that is being seen now with increasing frequency in forests in the western US occurs when low soil moisture (ecological drought conditions) increases the susceptibility of trees to forest pests. In some cases, both changes in sensitivity and exposure are happening in the same system – for example, some forest insect pests are now able to fit in additional generations within the same growing season due to warming temperature's effects on increasing the length of the frost-free season, and/or increasing insect growth rates. More generations leads to higher pest abundance, and thus higher exposure.

The same suite of interactions between climate change and non-climate threats can often be described in terms of both sensitivity and adaptive capacity. For example, for cold water fish, an increase in water temperature, which reduces oxygen availability, can make a make a fish more sensitive to the impacts of pollution, particularly if that pollution also contributes to oxygen reduction (i.e., eutrophication). Similarly, you could say that high nutrient concentrations in a lake that lead to anoxia reduce the ability of fish to adapt to changes in water temperature.

Additional examples:

- In watersheds where run-off from agricultural or urban/suburban land uses threatens freshwater biodiversity through effects on water quality (contaminants, nutrients, sediments) increases in peak storm intensities associated with climate change can exacerbate those threats by promoting higher rates of surface runoff that carry these materials into streams.
- Water control structures such as dams, and “hardening” of river edges are major threat to the natural hydrologic processes that define and shape floodplain systems. As peak storm intensities continue to increase, pressure to protect people from flooding is likely to make it even more challenging to maintain and restore natural flow regimes.
- Invasive exotic species are a major challenge in most system types. New York’s relatively cold climate is likely to have provided a barrier to establishment for many species that have arrived in the past, but is likely to be less of a barrier in the future. In addition, increasing growing season lengths increase the likelihood of multiple generations for some exotic insects, again exacerbating potential risks.

Key Resources

- Many of the adaptation strategies in this chapter focus on non-climate stressors: National Wildlife Federation’s Climate Smart Conservation. The Art of the Possible: Identifying Adaptation Actions. Chapter 8. www.nwf.org/ClimateSmartGuide.

How can expected climate impacts be factored into habitat restoration?

As pressures on natural systems continue to increase, it is important that we consider ways to update the strategies that we use to reduce a wide range of threats, such as invasive species, pollution, and land conversion. Climate change is an important consideration with respect to prioritizing areas for restoration, and for identifying restoration goals and strategies. Factoring in climate change is best thought of from multiple perspectives – first, it is important to consider how climate change might stress the system you are hoping to restore, and incorporate those risks into the approaches used to carry out the restoration. This process of assessing climate risks could follow the basic steps of a vulnerability assessment – so, trying to understand the likely exposure to climate change (what climate factors are changing, and by how much), sensitivity (how does climate change influence the focal system), and adaptive capacity (the potential for system to respond in a way that allows persistence or maintenance of key functions as conditions change; Schneider et al. 2007, Foden et al. 2008, Stein et al. 2015). It may be that climate change, or some combination of climate change and the stressors that led to the need for restoration, are strong enough to suggest that restoration to the same system type that has been degraded is not feasible. For example, if a wetland system has been impacted by altered

hydrology from land use change, and is now expected to experience increasing temperatures and increases in drought stress, the goal for restoration may not be the same wetland type as was found there before.

Similarly, if the goal is to restore a particular suite of plant species to provide habitat for specific wildlife species, it makes sense to review how likely it is that those plants and the wildlife that depend on them will still experience the future climate as suitable. In most cases, this is a “for how long” kind of question

for which specific answers are not available. In spite of this uncertainty, it is helpful to go through a process of considering whether a shift in plans related to the restoration goal is likely to lead to a more resilient restoration project. In the wildlife habitat example above, shifting from a goal of specific species toward “diversity” may make more sense, with many aspects of the restoration staying the same, but the goal focusing on producing functional habitats that are likely to be robust and self-sustaining, even as both climate change and other stressors continue. Shifting over to aquatic system restoration, especially those activities that involve structural changes, it will be important to consider changes in hydrology, and the potential to “build in” features that help provide cooler microclimates, such as deeper pools, and shaded areas. It is also important to remember to consider not just the goals of the restoration, but the methods – for example in some locations, increases in peak storm intensities, or changes in the phenology (seasonal timing – i.e., last frost, length of growing season) are already promoting changes in how restoration work is implemented.

In addition to site scale considerations, especially when there are several possible options in terms of what sites should be restored, “factoring in climate change” involves evaluating those opportunities in light of roles those sites might play in terms of helping promote adaptation of species that may be shifting locations in response to changing conditions. Is the site situated in a cooler location (north slope, river valley)? Or would restoration potentially re-connect important pathways for movement? Would restoring this floodplain or wetland significantly reduce risks of flooding for people in the watershed? These types of considerations can help the same investment in restoration have broader impacts with respect to increasing the ability of systems, wild species, and people to thrive in spite of climate change.

- Many of the chapters in the National Wildlife Federation’s Climate Smart Conservation (Stein et al. 2014) will be helpful in the context of restoration, but see in particular Chapter 7, Reconsidering Conservation Goals in Light of Climate Change, and Chapter 8, The Art of the Possible: Identifying Adaptation Actions. www.nwf.org/ClimateSmartGuide

How is climate vulnerability assessed?

The climate change risks to (or vulnerability of) a species, habitat, ecosystem, or ecological service can be described as a function of three factors: 1) exposure to some form of change in climate, such as a trend of temperature increases, or changes in the timing or magnitude of flooding; 2) the **sensitivity** of that species or system to the change in climate, and 3) adaptive capacity, or the potential for that species, system, or process to respond, move, or even transform in a way that allows persistence or maintenance of key functions as conditions rapidly change (Schneider et al. 2007, Foden et al. 2008, Klausmeyer et al. 2011, Stein et al. 2015).

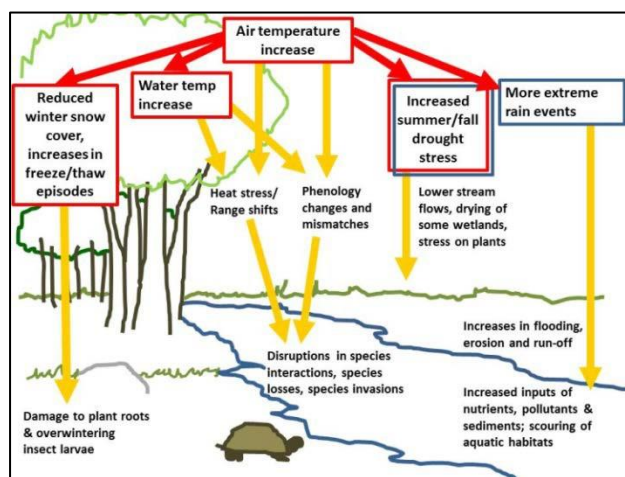
Exposure

The climate change risks to (or vulnerability of) a species, habitat, ecosystem, or ecological service can be described as a function of three factors: 1) **exposure** to some form of change in climate, such as a trend of temperature increases, sea level rise, or changes in the timing or magnitude of precipitation or flooding; 2) the sensitivity of that species or system to the change in climate, and 3) adaptive capacity, or the potential for that species, system, or process to respond, move, or even transform in a way that allows persistence or maintenance of key functions as conditions rapidly change (Schneider et al. 2007, Foden et al. 2008, Klausmeyer et al. 2011, Stein et al. 2015). To understand exposure, it is helpful to think about the climate variability that species and systems have been exposed to over long

(evolutionary) time periods, and are exposed to every year, season, and day. Some systems show remarkably little change in key factors like temperature – for example, caves and streams with a strong linkage to ground water would be expected to show lower variability. These are examples of systems that are strongly buffered from change, but if they were to experience the same magnitude of change (i.e. a 2 °F change in water temperature or cave air temperature) would be likely to have stronger impacts due to lack of similar magnitude changes over time (leading to higher species and system sensitivity).

Time is a key factor to keep in mind – what amount of change in what amount of time? Long term climate data sources (fossil record, ice cores, etc.) remind us that the US has experienced major changes in temperature and precipitation in the past, and in some major periods of change, this exposure has led to high rates of species extinctions. The key concern with anthropogenic climate is the projected rate of change – which of course relates to the magnitude of change, but through the emphasis on time, connects changes in exposure to the slow evolutionary processes that have shaped species life histories. The changes in temperature and other climate factors are occurring in the eastern US, and are projected to change in the future, suggest that many, if not most, wild species and natural systems will experience exposure to climate change as a major stressor in the next century. For highly sensitive systems (see *sensitivity* section), these stresses are likely to become apparent much sooner.

The figure to the right illustrates a suite of potential climate-driven changes in a natural area. The boxes across the top describe potential climate exposure changes, with temperature-driven factors shown in red, and precipitation exposure factors shown in blue. Changes in air temperature are leading to many different kinds of exposure to change, such as changes in water temperature, and changes in the proportion of precipitation that falls as rain instead of as snow. Increased temperatures are also associated with increases in peak storm intensities, as warmer air can hold more water, leading to higher precipitation volumes. Increases in the variability of precipitation are also expected to lead to longer periods between storm events, and this, in addition to higher temperatures (and associated increases in evapotranspiration rates) is expected to increase the risk of drought stress.



Key Resources

- National Wildlife Federation's Climate Smart Conservation: Putting Adaptation Principles into Practice, Chapter 6. Understanding Climate Change Impacts and Vulnerability. www.nwf.org/ClimateSmartGuide.
- NatureServe's Climate Change Vulnerability Index & associated guidance: <http://www.natureserve.org/biodiversity-science/publications/guidelines-using-natureserve-climate-change-vulnerability-index>

Sensitivity

Sensitivity in this case is defined in terms of the degree of response, and the same species, system, or ecological process may respond strongly to some factors, and be much less affected by other types of changes. Similarly, responses to the same degree of change in a climatic factor often vary with life history stage, or time of year. At a species level, most aspects of sensitivity are intrinsic factors that are not likely represent intervention points for applying adaptation strategies designed to reduce climate risks. However, as the scale of targets increase (i.e., forests instead of individual tree species), actions to reduce sensitivity through actions targeted toward increasing diversity (of species, rather than within a species) arise. Similarly, the success of management actions, such as prescribed burns for reducing invasive species populations, may be “sensitive” to changes in climate. Thus, one adaptation strategy might be to evaluate variations in success, and shift the timing of burns. Most of the following text focuses on the sensitivity of ecological, rather than management, systems, but management systems are often much more tractable targets for changes in strategy.

Some of the most well-studied aspects of sensitivity are responses to and tolerances for water temperature changes in aquatic species, especially cold-water fish, and changes in the timing of seasonal events (phenology) in response to variations in spring temperatures. In animal species, shifts in temperature tend to have the strongest effect on ectothermic (“cold-blooded”) species such as insects, fish, amphibians, and reptiles. However, even for mammals and birds (endotherms that can maintain body temperatures that are different from the environmental temperature) changes in vital rates like survival can be linked back to the physiological constraints of balancing energy reserves under specific climatic conditions. Individuals in highly suitable climatic conditions will often have higher reproduction, survival, or both, than individuals in habitats that are more “costly” (e.g., higher cost of foraging due to heat or cold stress, higher metabolic rate due to higher water temperature for aquatic species). In addition to temperature, physiological aspects of climate change sensitivity includes responses to change in water availability and timing, changes in the concentration of carbon dioxide in the air (which influences photosynthetic rate and drought tolerance in plants), and changes in pH for some marine species. Similarly, ecological processes such as decomposition, uptake and cycling of nutrients, and primary production typically vary with changes in temperature, and may also be affected by availability of water (too much or not enough little).

The wide range of ways that individual species respond to changes in climate drivers leads to many different types of responses (impacts) as one considers interactions between species, impacts on habitats, and the composition of and function of ecosystems. As specific information on how these interactions will play out is typically lacking, when potential sensitivities are tallied up as part of a vulnerability assessment, we often make an assumption that the most specific interactions, and least diverse systems, are most sensitive to change. For example, if you have two species of plants, one of which is pollinated by a wide range of pollinators (or is wind pollinated), and one which has co-evolved with one or just a few bee pollinators, you might anticipate higher climate change risk for the one with just a single pollinator. A specific rationale for this assumption would be that this species with just one pollinator might be at risk due to the potential for changes in in temperature to changes in phenology, and potential mismatches in the timing of when the pollinator is seeking resources. Similarly, if that one pollinator were to shift range in response to warming temperatures such that ranges were no longer overlapping, this would suggest a high sensitivity of a vital process (pollination) to changes in temperature. Logic like this forms the basis for several widely used tools for conducting rapid assessments of species vulnerability, including NatureServe’s Climate Change Vulnerability Index, which has been applied to species in New York by Schlesinger et al. (2011) and is a component of the Toolkit’s Spatial CCVI datasets. It’s important to note that multiple sensitivity factors can interact – for example

freshwater mussels are temperature sensitive, often have high habitat specificity, and have a strong dependence on the presence of one or a few host species (often fish) during their larval stage when they are obligate parasites, and these fish are also likely to be vulnerable (Strayer 2006; Pandolfo et al. 2010).

Characteristics often identified as indicating high sensitivity include (Parmesan et al. 2006, Foden et al. 2008, Young et al. 2011, Stein et al. 2015):

- Species that are near the limits of physiological tolerance (i.e., cold water fish in warming streams).
- Species with very specific habitat requirements, such as a dependence on rare or declining resources (i.e., caves, snow cover), and ties to a particular timing or magnitude of water availability.
- Species that are dependent on interactions with one or a few other species (susceptible to phenology mismatches, and mismatches in rate or location of range shifts).
- Species, habitats, or ecosystems that are dependent on, or highly susceptible to, the timing and/or occurrence of a climate-related event or disturbance factor (flooding, fire, cold-hardening in trees, ice storms).
- Habitats/ecosystems that are close to a critical threshold that strongly influences composition and processes, such as water availability & rate of drying for wetlands.
- Habitats/ecosystems that arise through the influence of a keystone species or ecosystem engineer, and may not occur if that species is lost (e.g., coral reef fishes and coral; wet meadows and beavers).
- Habitats/ecosystems that have lower species diversity, and less replication/diversity of key ecological functions, structures, or processes (e.g., hardwood forests that have been managed toward single-species dominance).

While delineating sensitivity and adaptive capacity can often be helpful for framing discussions, in practice we find they are strongly intertwined, and that the same characteristic of a species or system can often be defined in the context of both sensitivity and adaptive capacity. Teasing the concepts apart can be especially challenging in environments with a strong human influence. For example, a species may be much more sensitive to changes in water temperature if it already stressed by invasive species or changes in hydrology because these challenges act to reduce adaptive capacity (ability to respond). It is not necessary to draw lines between these two concepts, but it is important to consider both of these components of vulnerability when you are considering how to direct actions. Making a clear connection between specific aspects of climate change (i.e., a change in water temperature), cause and effect relationships (sensitivity), and the potential for a response or coping strategy (adaptive capacity) is an important foundation for building adaptation strategies. Making this logic clear is referred to in the

guidance by Stein et al (2014) as “showing your work,” and helps ensure that strategies actually reduce climate-related risks.

Adaptive Capacity

The adaptive capacity of a population or a system can vary widely as a function of intrinsic characteristics, and as a function of other stressors and variations in geographic settings (extrinsic factors; Klausmeyer et al. 2011, Stein et al. 2014, Nicotra et al 2015). The term adaptive capacity can also be helpful for thinking about our ability as resource managers and conservation practitioners to help support species, systems, or ecological processes through management responses. In some cases “management” adaptive capacity may be high (we can shift toward a single-species plantation toward a more diverse system through well-understood practices in silviculture), and in others, we may have little ability to respond, either due to lack of a feasible strategy, lack of sufficient funds, or political/social constraints. While the text below focuses on intrinsic and extrinsic aspects of adaptive capacity, efforts

to increase the effectiveness and agility of management systems also represent essential steps forward to protecting biodiversity from the impacts of climate change.

At the species level, intrinsic components of adaptive capacity include dispersal ability, plasticity of responses, and evolutionary potential (Parmesan 2006, Foden et al. 2008, Young et al. 2011, Stein et al. 2014:95, Nicotra et al. 2015). Plasticity refers to the idea that not all changes in observed characteristics (phenotypes) that allow a species to persist as condition change require a change at the genetic level. Many species are able to show flexible or “plastic” in response to climatic factors like spring temperature or water availability – well known examples include timing of budburst for plants and other phenological traits. When conditions change in a given location over decades to centuries, we can expect to see both flexible changes in some species (phenotypic plasticity), and, if there is evolutionary potential, which is most likely if you have both high genetic diversity, and shorter generation times, natural selection can lead to heritable changes (i.e., evolution). While plasticity is important, in general, it is also likely to be a “short-term” solution, as the limits to these responses will eventually be exceeded as a population experiences a long-term increase or decrease in an environmental factor (Gienapp et al. 2008). That, many species that appear to be tracking changes in climate, or thriving even as factors change, may show sudden declines in viability once the temperature shift exceeds some critical threshold beyond which their “flexible” response is not enough. In general, we know very little about the intrinsic adaptive capacity of species and the systems they comprise (Nicotra et al. 2015).

For species, extrinsic elements of adaptive capacity include the geographic context in which the exposure to climate change takes place – for example, fish in deeper rivers or lakes are more likely to be able to persist as temperatures warm, because they can move into deeper water. Similarly, species that are likely to respond to changes in climate by shifting their range have higher intrinsic capacity to do so if they can swim, fly, or run, and higher extrinsic adaptive capacity to do so if they are currently found in a landscape or aquatic system that is connected to cooler habitats. If you think of maintaining species diversity as one indicator of “coping with change” at the habitat or ecosystem level, it makes sense that similar concepts are used to describe adaptive capacity at this scale. Landscape permeability, diversity of and redundancy of functional groups, and extent to which ecological processes continue to shape composition and function are among the examples cited in Chapter 6 of Stein et al. (2014:95) as factors for assessing adaptive capacity at this scale. From a management and conservation standpoint, we are typically trying to identify intervention points where actions can be taken that increase adaptive capacity – extrinsic for species, and extrinsic (reduction in natural processes due to fire suppression or sea wall) or intrinsic (diversity, replication) for habitats and systems.

While delineating sensitivity and adaptive capacity can often be helpful for framing discussions, in practice we find they are strongly intertwined, and that the same characteristic of a species or system can often be defined in the context of both sensitivity and adaptive capacity. Teasing the concepts apart can be especially challenging in environments with a strong human influence. For example, a species may be much more sensitive to changes in water temperature if it is already stressed by invasive species or changes in hydrology because these challenges act to reduce adaptive capacity (ability to respond). It is not necessary to draw lines between these two concepts, but it is important to consider both of these components of vulnerability when you are considering how to direct actions. Making a clear connection between specific aspects of climate change (i.e., a change in water temperature), cause and effect relationships (sensitivity), and the potential for a response or coping strategy (adaptive capacity) is an important foundation for building adaptation strategies. Making this logic clear is referred to in the

guidance by Stein et al (2014) as “showing your work,” and helps ensure that strategies actually reduce climate-related risks.

Key resources:

- Nicotra, A. B., E. A. Beever, A. L. Robertson, G. E. Hofmann, and J. O'Leary. 2015. Assessing the components of adaptive capacity to improve conservation and management efforts under global change. *Conservation Biology*: (online early) <http://dx.doi.org/10.1111/cobi.12522>.
- [National Wildlife Federation's Climate Smart Conservation: Putting Adaptation Principles into Practice](#), Chapter 6. Understanding Climate Change Impacts and Vulnerability. www.nwf.org/ClimateSmartGuide.
- NatureServe's Climate Change Vulnerability Index & associated guidance: <http://www.natureserve.org/biodiversity-science/publications/guidelines-using-natureserve-climate-change-vulnerability-index>

When and how might you increase adaptive capacity, or resilience, in light of climate change?

The terms resistance, resilience, and realignment (or transformation) are often used to describe the range of options that one might choose as goals for adaptation actions (Millar et al. 2007, Janowiak et al. 2014, Stein et al. 2014). “Resilience” strategies are geared toward enhancing a system’s ability to accommodate and bounce back from climate-related disturbances, or, when applied to species, efforts to increase resilience can refer to increasing the potential for movements toward preferred conditions. In contrast, “resistance” implies that the goal of adaptation actions is to reduce impacts and forestall change. In Millar et al.’s (2007) original framing of these terms for forest managers, resilience was strongly tied to responses to climate-related disturbance such as fires and insect outbreaks. Over time

this definition has broadened (and some would argue has lost meaning), with resilience options often described as facilitating some shifts in species distribution among suites of species with similar traits and ecological functions (Stein et al. 2014, box 2.1). Following this idea, increasing resilience through management strategies can be thought of as increasing the adaptive capacity of species and systems – i.e., reducing obstacles (like pollution, invasive species or lack of connectivity) that might prevent systems from reorganizing in a way that retains functionality and the potential for continued viability (Stein et al. 2014). At the other end of the spectrum, strategies intended to promote realignment or transformation recognize systems at some important climate-related threshold, and a high likelihood of pervasive changes in structure, composition, and/or function as climatic conditions continue to change.

The recent comprehensive climate change adaptation guidance led by the National Wildlife Federation (Stein et al. 2015) reviews all three terms in an introductory chapter (Chapter 2), but in the chapter focused on adaption options (Chapter 8), emphasizes just two concepts, managing for persistence (analogous to resistance) and managing for change, which encompasses both resilience and realignment/transformation. This guide also points out that to date most conservation-oriented

adaptation effort have been closer to the resistance end of the spectrum, with practitioners focusing on tactics for maintaining current dominant systems and species, while also potentially adding a dash of preparing for change through action such as increasing connectivity for the purpose of increasing species immigration, or deploying management techniques that favor species that are expected to continue to be well-suited for a particular site. Given the challenges associated with the range of meanings associated with the term “resilience”, “managing for change” may often be a more useful term, and also has the added benefit of really emphasizing that need to plan for and facilitate change, whether that change is gradual or abrupt.

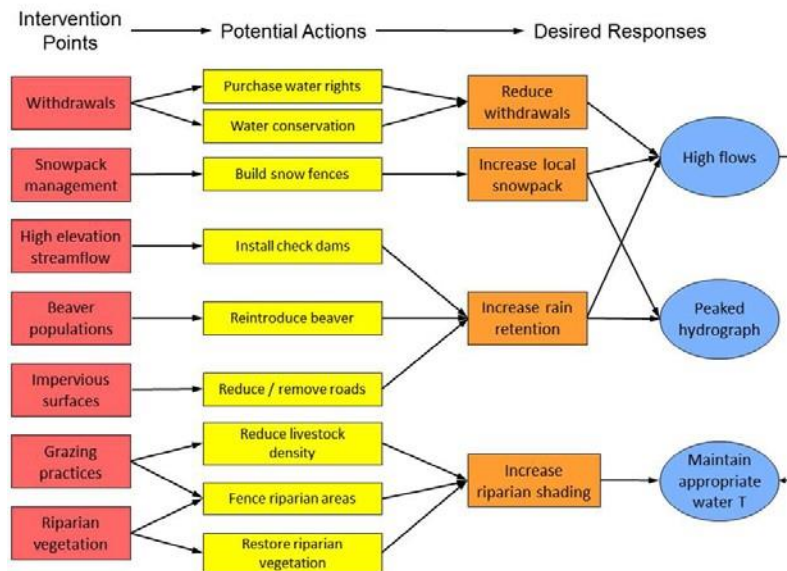


Figure 4 from the ACT Framework demonstrates the essential process of linking a set of potential adaptation options (center boxes) to the desired responses. Used with permission from M. Cross, see also Cross et al. 2012).

Many, if not most, of the strategies and tactics identified as “adaptation options” can be deployed to meet goals at multiple points along the resistance-transformation spectrum. For example, in the list of adaptation options below, from the Northern Institute of Applied Climate Science’s forest adaptation work, the options under “Strategy 9: Facilitate community change through species adjustments” most clearly focus on planning for change, but many of the others can help support change as well, depending on how, where, and when they are used. Often too, the extent to which actions are perceived as addressing (or even embracing) change varies depending on the spatial and organizational scale we are considering. In a nutshell, when thinking about the role of adaptation strategies in your work, it is most important to make a clear connection with your management goals, and discuss with colleagues and stakeholders what achieving this goal looks like under future conditions (and checking to see that this goal remains feasible and desirable – Stein et al. 2014, Chapter 7). Following the terminology described in Cross et al. 2012 (and see Figure X. in the Resistance section), once you have identified these goals and the responses you would need to see in the systems you manage to meet those goals, the next

steps are to identify opportunities for influence (management intervention points), find options to help move (or maintain) the system.

When and how might you want to resist climate change?

The terms resistance, resilience, and realignment (or transformation) are often used to describe the range of options that one might choose as goals for adaptation actions (Millar et al. 2007, Janowiak et al. 2014, Stein et al. 2014). “Resistance” implies that the goal of adaptation actions is to reduce impacts and forestall change, while actions to promote “resilience” are geared toward enhancing a system’s ability to accommodate and bounce back from climate-related disturbances. In Millar et al.’s (2007) original framing of these terms for forest managers, resilience was strongly tied to responses to climate-related disturbance such as fires and insect outbreaks. Over time this definition has broadened (and some would argue has lost meaning), with resilience options often described as facilitating some shifts in species distribution among suites of species with similar traits and ecological functions (Stein et al. 2014, box 2.1). Options on the “realignment” end of the adaptation spectrum are meant to move a system toward a new system that is better suited for future climatic conditions, or potentially could be applied to moving a systems where management has acted in a way that is incompatible with current conditions (i.e. a legacy of fire suppression in a fire-dependent system) toward a system that is better suited for both current conditions and the future.

The recent comprehensive climate change adaptation guidance led by the National Wildlife Federation (Stein et al. 2015) reviews all three terms in an introductory chapter (Chapter 2), but in the chapter focused on adaption options (Chapter 8), emphasizes just two concepts, managing for persistence (analogous to resistance) and managing for change. This guide also points out that to date most conservation-oriented adaptation effort have been closer to the resistance end of the spectrum, with practitioners focusing on tactics for maintaining current dominant systems and species, while also potentially adding a dash of resilience through action such as increasing connectivity for the purpose of increasing species immigration, or deploying management techniques that favor species that are expected to continue to be well-suited for a particular site.

Several adaptation guides suggest that there may be instances where it makes sense to intentionally cycle between managing for persistence and managing for change as systems transformations become unavoidable (West et al. 2009, Hansen and Hoffman 2011, Stein et al. 2014). Given the many uncertainties associated with understanding climate impacts and the effectiveness of management options, it will also likely be very useful to work together to apply strategies from across the spectrum to similar systems, and monitor the results to inform the next round of strategies. It’s also important to note that strategies related to increasing connectivity, which are broadly recommended for maintaining diversity even without considering climate change, may undermine efforts to resist change in a particular system by facilitating the movement of species into a location. At times there are other good reasons to reduce connectivity (i.e., invasive species concerns, or risks related to spread of pests or pathogens), and as in these cases, it will be important to carefully consider the costs and benefits associated with increasing or reducing connectivity, or maintaining current conditions.

Over time, resisting change will become less and less feasible in most places, and in most situations it is appropriate to think of resistance strategies as a way to “buy time” to help slow the rate of change at a site so that the pace is a better fit for natural processes like migration and biological adaptation (evolutionary change). However, at any given point in time, the choice of a place on the resistance to resilience spectrum (managing for persistence vs. managing for change) should incorporate the condition of the system, current stressors, expected climate changes, and stakeholder values and/or regulatory constraints. If the presence of an endangered species or irreplaceable resource, or strong stakeholder opinion, dictates that change is not tolerable, then resistance strategies are going to be the best option, at least in the near term. Climate refugia, or places where rates of change tend to be slower than in other locations due to some form of buffering, are another example where persistence strategies may make sense for longer periods of time (Ashcroft 2010, Groves et al. 2012, Janowiak et al. 2014, Stein et al. 2014, Schmitz et al. 2015,). Even in these cases, it will likely be important to think ahead about how to proceed when costs outweigh the benefits, with the goal of moving toward a transition strategy before reaching a point where resistance strategies have a high likelihood of failure. Clear communication with stakeholders and policy-makers, potentially aided by tools like structured decision-making or scenario planning that lay out likely consequences of various options, is an important component of facilitating long-term shifts toward managing for change.

Key resources and references:

General guidance

- Adaptation for Conservation Targets (ACT) Framework (Cross et al. 2012). <http://dx.doi.org/10.1007/s00267-012-9893-7>
- National Wildlife Federation’s Climate Smart Conservation: Putting Adaptation Principles into Practice (Stein et al. 2014), Chapter 2. Exploring Climate-smart Conservation. www.nwf.org/ClimateSmartGuide.
- National Wildlife Federation’s Climate Smart Conservation: Putting Adaptation Principles into Practice (Stein et al. 2014), Chapter 8. The Art of the Possible: Identifying Adaptation Options www.nwf.org/ClimateSmartGuide
- EcoAdapt’s Climate Adaptation Knowledge Exchange (CAKE), a source of case studies and other resources describing climate change adaptation. <http://www.cakex.org/>

Forest-focused resources:

- Janowiak, M. K. C.W. Swanston, L. Nagel, L.A. Brandt, P.R. Butler, S. D. Handler, P.D. Shannon, L.R. Iverson, S.N. Matthews, A. Prasad, M.P. Peters, Matthew P. 2014. A practical approach for translating climate change adaptation principles into forest management actions. *Journal of Forestry*. 112: 424-433. <http://www.treesearch.fs.fed.us/pubs/46417>
- Swanston, C. and M. Janowiak, eds. 2012. *Forest Adaptation Resources: Climate change tools and approaches for land managers*. Gen. Tech. Rep. NRS-87. Newtown Square, PA: U.S.

Department of Agriculture, Forest Service, Northern Research Station. 121
p. <http://www.treeseearch.fs.fed.us/pubs/40543>

- Online version of the Adaptation Workbook, previously published in *Forest Adaptation Resources: Climate change tools and approaches for land managers*. This step-by-step process was designed to help people consider climate change at the scale of their own management decisions and design their own customized adaptation actions. <http://www.adaptationworkbook.org/>

How does climate change affect the places we prioritize for protection?

The process of designing reserves, or areas that are managed for their natural values, involves identifying a suite of locations to include within a network or “portfolio” of conservation areas. Given the many pressing demands for terrestrial, freshwater, and marine systems, and limited funds for conservation, reserve design is inherently a process for maximizing the amount of biodiversity protected as a function of dollars invested and land/water managed over the long term. This is a broad topic, and encompasses decades of research and practical experience that have generated a wide range of datasets and modeling tools, processes for engaging diverse stakeholders in collaborative processes, and guidance comprehensive guidance documents (Groves et al. 2003).

In a nutshell, the basic tenets of reserve design include (1) representation, the idea of capturing the full variety of biodiversity within a plan, (2) functionality/viability/ replication of occurrences to hedge bets and promote long term viability, and (3) metrics that consider the efficiency of the design (cost, ability to capture multiple values within the same sites (Groves et al. 2003:229). As the availability of spatial data and computational power have increased, it has become more and more common for conservation planners to use some form of site selection algorithm to explore potential options for reserve design, and these tools can help make the selection process more efficient and transparent (Groves et al. 2003).

Representation and replication are key concepts within the process of developing a plan (i.e., reserve design, conservation blueprint) to protect biodiversity across a focal region. **Representation** refers to the goal of capturing the full variety of biodiversity within that plan. Often applied at the ecosystem or habitat scale, evaluating representation can also incorporate patterns of species diversity, ecological gradients, and diversity of enduring features such as geophysical settings (combinations of geology, elevation, and slope). In this context, **replication** indicates the goal of having various conservation targets (species, ecosystems, processes, and/or geophysical settings) represented by multiple occurrences across the suite of locations identified in the reserve design. Replication of sites with similar conditions helps assure that occurrences of species or systems remain viable over the long term within the conservation region and plays a key role in determining the number and extent of locations identified in the design (Groves et al. 2003, Chapter 8).

While climate variability and other drivers of that lead to change and uncertainty with respect to species distributions, ecological processes, and other key values associated with conservation reserves, the rapid pace of anthropogenic climate change represents a major challenge to any location-focused conservation effort. As these climate-related risks have increased, many researchers and conservation practitioners have explored how to increase the value of investments in conservation reserves over the long term by improving consideration of climate change impacts, and implementing adaptation

strategies (e.g. Hannah et al. 2007, Magness et al. 2011, Groves et al. 2012, Hilty and Chester 2012, Schmitz et al. 2015). Asynthesis by Groves et al (2012) presents five main types of updates, which are the basis for the points below:

- Evaluate the likely vulnerabilities associated with different protected areas, and identify those that can act as refugia, and those that are most likely to undergo major transitions in dominant systems (see section on Refugia).
- Strengthen our focus on increasing connectivity across sites, regions, and landscapes. For on the ground work, this includes many different strategies, including restoration and management of corridors and linkages, as well as “softening” of management in human-dominated systems to increase the permeability of these areas to species movement and other ecological processes (see Connectivity section).
- Increase our consideration of representation and replication of enduring features, such as geophysical settings (geology, topography) that will remain constant as species shift on the landscape (see Protecting the Stage section).
- Pay more attention to maintenance of key ecological processes, as these are important for maintaining diversity and system function, and can facilitate responses to changes by organisms and systems.
- Anticipate human responses to climate change impacts, and incorporate values that ecosystems can provide to people as conditions change (i.e., increasing importance of wetlands and floodplains as “sponges” during storm events, values that forests provide in terms of protecting freshwater water quality) as criteria within the site selection process.

Key resources:

- Groves, C. R., E. T. Game, M. G. Anderson, M. Cross, C. Enquist, Z. Ferdana, E. H. Girvetz, A. Gondor, K. R. Hall, J. Higgins, R. Marshall, K. Popper, S. Schill, and S. L. Shafer. 2012. Incorporating climate change into systematic conservation planning. *Biodiversity and Conservation* **21**:1651-1671. <http://link.springer.com/article/10.1007/s10531-012-0269-3>
- Magness, D. R., J. M. Morton, F. Huettmann, F. S. Chapin III, and A. D. McGuire. 2011. A climate-change adaptation framework to reduce continental-scale vulnerability across conservation reserves. *Ecosphere* **2**: Article 112. <http://www.esajournals.org/doi/pdf/10.1890/ES11-00200.1>

How can easements be modified to incorporate climate change?

A conservation easement is a restriction placed on a piece of property with the goal of securing long-term protection for resources at that specific location. When agreeing to a conservation easement, a landowner voluntarily agrees to sell or donate certain rights associated with his or her property – often the right to subdivide or develop – and a private organization or public agency agrees to hold the right to enforce the landowner's promise not to exercise those rights (The Nature Conservancy 2015). As a result of these legally binding agreements, these rights are forfeited, while owners retain other private property rights and can continue to live on and use their land. The private organization or public agency that holds the easement is responsible for monitoring the condition of the site, and enforcing the agreement defined within the agreement. The **easement language** defines the specific constraints

on the property, targeting rights that are necessary to protect specific conservation values, such as important habitats, aspects of forest management (i.e., goals for compositional or structural diversity), or water quality. These agreements are typically developed individually between a landowner and the easement holder.

Climate change poses a challenge to the development of easement language, in that climate drivers that are external to the property covered by the legally-binding agreement can influence factors such as species composition, disturbance regime, and water availability at the site. Further, climate change can favor increases in invasive species, promote pests or diseases, and in other ways increase stressors on a focal property in ways that may exceed our current expectations for “natural” change overtime. Incorporating research by Rissman et al. (2013, 2015) and others, The Land Trust Alliance (2015) has developed a set of practical tips for updating how these important conservation tools are crafted, a subset of which are shown in the box below, and all of which are available, with additional resources, through the link below under “key resources.” These tips are intended to help facilitate the development of agreements that account for climate-related uncertainties, and help assure the long term value of easements. Key elements include a comprehensive evaluation of the site conditions and likely climate-related changes, and an emphasis on clear communication, a focus on enduring features, and the need for flexibility and updates over time.

- Identify Conservation Values that Will Endure. Be clear about the purposes of the easement. Identify the conservation values that warrant protection, link easement restrictions to the protection of these values, determine which values might be impacted by climate change, and develop a management plan that will help conserve those values over time. Scenario planning may be useful here.
- Provide Sufficient Flexibility. Conditions and needs may change with time, especially as a result of climate change. Do not assume that environmental conditions, social pressure, or resource needs will remain constant. Discuss the need for flexibility with the easement grantor, and determine how much flexibility successor landowners will need in order to adequately respond to climate change. Distinguish between restrictions that will be strictly applied and those that allow for flexibility in interpretation. Then, negotiate and draft the easement so that it incorporates the necessary flexibility, while continuing to protect the land’s conservation values in perpetuity. Scenario planning may be useful here.
- Consider Performance Standards. Performance standards may be appropriate in some circumstances, because they offer a flexible goal. In these cases, combine prescriptive and performance standards so that easement goals are more likely to be met as conditions change due to climate change and/or emerging scientific knowledge or technological capabilities. Determine whether some reserved rights should float based on changing best practices in agriculture, forestry or land management. If so, define the criteria for this in the easement, identify a recognized source of rules which will guide this change, and specify the path for land trust approval of all changes. Include a copy of the rules with the management plan.
- Consider Including Discretionary Approval or Consent Provisions. Specify Amendment Criteria and Procedures. Conditions will change with time. Prevent easement obsolescence and allow for the adaptation to changing conditions by defining the criteria and procedures for amending or modifying the easement.

- **Recognize That Land May Change.** Landscape features, such as shorelines and river channels, as well as ecological conditions, may change over time with temperature, water and other influences. Flexible management plans and zone boundaries may help. Scenario planning may be useful here.

Key resources:

- The Land Trust Alliance website contains a comprehensive curriculum and library that includes guidance on identifying sites for potential easements, drafting easement language, and monitoring & stewarding easement properties over time. <http://www.landtrustalliance.org/training/publications/curriculum>
- The Nature Conservancy: What are Conservation Easements? <http://www.nature.org/about-us/private-lands-conservation/conservation-easements/what-are-conservation-easements.xml>
- The Land Trust Alliance: Develop Conservation Easements that Adapt to Climate Change. <https://www.landtrustalliance.org/climate-change-toolkit/plan/easements/develop-conservation-easements-that-adapt-to-climate-change>
- Rissman, A. R., J. Owley, M. R. Shaw, and B. Thompson. 2015. Adapting conservation easements to climate change. *Conservation Letters* 8:68-76 <http://onlinelibrary.wiley.com.proxy62.cl.msu.edu/doi/10.1111/conl.12099/full>

How can connectivity for climate change be enhanced and maintained?

For terrestrial animals, ways to increase connectivity include taking actions that enhance the likelihood that animals can move through our landscapes, such as restoring key habitats that have been lost, and working with landowners to enhance habitat values (“soften” management) on highly managed or modified lands. These types of actions should also benefit plants, which may be moved either by animals or by wind. To help fish and other aquatic species respond to increasing temperatures by shifting ranges, we need to identify barriers in streams and rivers, and, balancing the risk of allowing access by invasive species (e.g., sea lamprey), take action to remove key barriers to movement. Understanding and developing responses to potential shifts in freshwater species are a particular challenge, because there is typically less information available on the distribution of aquatic species, and conservation areas are often more strongly tied to terrestrial, rather than aquatic, species diversity (Strayer 2006; Herbert et al. 2010). Further, for aquatic invertebrates with limited dispersal abilities, different natural habitats within streams can act as barriers, potentially preventing shifts in range in response to climate change (Strayer 2006).

Climate Adaptation Resources

Climate data portals and synthesis documents

USGS Derived Downscaled Climate Projection Portal (USGS). Downscaled CMIP5 data, with many different derived variables that can be viewed or downloaded. <http://cida.usgs.gov/climate/derivative/>

Climate data mapper for the Central/Eastern Landscape Conservation Cooperatives (LCCs) (University of Wisconsin's Nelson Institute). Dynamical downscaling of CMIP3 data for the region, including important regional variables (e.g., snow). http://ccr.aos.wisc.edu/resources/data_scripts/

Climate Data Center on Data Basin. (Conservation Biology Institute). Access to a wide variety of spatial datasets and maps related to climate change that has been posted by collaborators on DataBasin. Search datasets by key words and/or by selecting an area on a map and looking for overlap. <http://climate.databasin.org/>

ClimateWizard (The Nature Conservancy, University of Washington, and University of Southern Mississippi). Data from the 4th IPCC Assessment/CMIP 3. <http://climatewizard.org/>

Climate Knowledge Portal -Climate Analysis Tool (World Bank, The Nature Conservancy). Data from the 4th IPCC Assessment/CMIP 3. <http://climateknowledgeportal.climatewizard.org/>

Adaptation case study archive, reports – global & national

EcoAdapt's Climate Adaptation Knowledge Exchange (CAKE) website, a source of case studies and other resources describing climate change adaptation. <http://www.cakex.org/>

Adaptation Clearinghouse, Georgetown Climate Center (Georgetown Law School). Tools and resources for state policymakers, resource managers, academics, and others who are working to help communities adapt to climate change. <http://www.georgetownclimate.org/adaptation/clearinghouse>

Updating approaches to conservation planning -general

Groves, C. R., E. T. Game, M. G. Anderson, M. Cross, C. Enquist, Z. Ferdana, E. H. Girvetz, A. Gondor, K. R. Hall, J. Higgins, R. Marshall, K. Popper, S. Schill, and S. L. Shafer. 2012. Incorporating climate change into systematic conservation planning. *Biodiversity and Conservation* **21**:1651-1671. <http://link.springer.com/article/10.1007/s10531-012-0269-3>

Rowland, E. L., J. E. Davison, and L. J. Graumlich. 2011. Approaches to evaluating climate change impacts on species: A guide to initiating the adaptation planning process. *Environmental Management* 47:322-337. http://www.fs.fed.us/rm/pubs_other/rmrs_2011_rowland_e001.pdf

Magness, D. R., J. M. Morton, F. Huettmann, F. S. Chapin III, and A. D. McGuire. 2011. A climate-change adaptation framework to reduce continental-scale vulnerability across conservation reserves. *Ecosphere* **2**: Article 112. <http://www.esajournals.org/doi/pdf/10.1890/ES11-00200.1>

The Conservation Measures Partnership. 2013. Open Standards for the Practice of Conservation, Version 3.0 April 2013. <http://cmp-openstandards.org/download-os/>

Conservation/land use planning & climate change resources that emphasize case studies

Schmitz, O. J., J. J. Lawler, P. Beier, C. Groves, G. Knight, D. A. Boyce, Jr., J. Bulluck, K. M. Johnston, M. L. Klein, K. Muller, D. J. Pierce, W. R. Singleton, J. R. Strittholt, D. M. Theobald, S. C. Trombulak, and A. Trainor. 2015. Conserving biodiversity: practical guidance about climate change adaptation approaches in support of land-use planning. *Natural Areas Journal* **35**:190-203. <http://www.bioone.org/doi/pdf/10.3375/043.035.0120>

Poiani, K. A., R. L. Goldman, J. Hobson, J. M. Hoekstra, and K. S. Nelson. 2011. Redesigning biodiversity conservation projects for climate change: examples from the field. *Biodiversity Conservation* **20**:185-201. <http://link.springer.com/article/10.1007%2Fs10531-010-9954-2>

Updating approaches to resource management - general

Stein, B.A., P. Glick, N. Edelson, A. Staudt (eds.). 2014. Climate-Smart Conservation: Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, DC. http://www.nwf.org/pdf/Climate-Smart-Conservation/NWF-Climate-Smart-Conservation_5-08-14.pdf

Cross, M. S., E. S. Zavaleta, D. Bachelet, M. L. Brooks, C. A. F. Enquist, E. Fleishman, L. J. Graumlich, C. R. Groves, L. Hannah, L. Hansen, G. Hayward, M. Koopman, J. J. Lawler, J. Malcolm, J. Nordgren, B. Petersen, E. L. Rowland, D. Scott, S. L. Shafer, M. R. Shaw, and G. M. Tabor. 2012. The adaptation for conservation targets (ACT) framework: A tool for incorporating climate change into natural resource management. *Environmental Management* **50**:341-351. <http://dx.doi.org/10.1007/s00267-012-9893-7>

National Park Service. 2013. Using Scenarios to Explore Climate Change: A Handbook for Practitioners. National Park Service Climate Change Response Program, Fort Collins, Colorado. <http://www.nps.gov/subjects/climatechange/resources.htm>

Assessing species sensitivity & adaptive capacity – general methods

National Wildlife Federation's Climate Smart Conservation (Stein et al. 2014): Putting Adaptation Principles into Practice, Chapter 6. Understanding Climate Change Impacts and Vulnerability. www.nwf.org/ClimateSmartGuide.

Glick, P., B. A. Stein, and N. A. Edelson, editors. 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington, D.C. <http://www.nwf.org/~media/pdfs/global-warming/climate-smart-conservation/nwfscreeningtheconservationhorizonfinal92311.ashx>

NatureServe's Climate Change Vulnerability Index (CCVI) & associated guidance. This site includes links to several reports that have been created using the CCVI tool, including the report by Schlesinger et al (2011) for New York. <http://www.natureserve.org/biodiversity-science/publications/guidelines-using-natureserve-climate-change-vulnerability-index>

Nicotra, A. B., E. A. Beever, A. L. Robertson, G. E. Hofmann, and J. O'Leary. 2015. Assessing the components of adaptive capacity to improve conservation and management efforts under global change. Conservation Biology: (online early) <http://dx.doi.org/10.1111/cobi.12522>.

Assessing species vulnerability – web tools

Bird and Tree Climate Change Atlas (Landscape Change Research Group, Northern Research Station, U.S. Forest Service). Range change projections for 134 eastern tree species and 147 bird species. These projections are incorporated into most of the forest vulnerability assessments listed below. <http://www.nrs.fs.fed.us/atlas>

FishVis Mapper. (USGS, Michigan State University, Michigan Institute of Fisheries Research, and the Wisconsin Department of Natural Resources). A tool that displays modeling results for the future distribution of a suite of important fish species in the streams of much of the US portion of Great Lakes region. You can view results either by water temperature class (i.e., cold water fish), or can see results for 13 individual species, and can choose among three spatial scales for stream data. Other datasets include projected changes in stream temperature and in stream flow exceedance. <http://wimcloud.usgs.gov/apps/FishVisDev/FishVis.html#>

Assessing species vulnerability - regional guidance and assessments

Staudinger, M., L. Hilberg, M. Janowiak, C. Swanston. 2015. Northeast and Midwest Regional Species and habitats at greatest risk and most vulnerable to climate impacts. Chapter 2 *In*: M.D. Staudinger, T. L. Morelli, and A. M. Bryan. 2015. Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Massachusetts. <https://necsc.umass.edu/sites/default/files/Chapter%202%20Vulnerability%20Assessments.pdf>

Hall, K.R. 2012. Climate Change in the Midwest: Impacts on Biodiversity and Ecosystems. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. Great Lakes RISA. http://www.cakex.org/sites/default/files/documents/NCA_Midwest_Report_0.pdf

Updating planning for wildlife

Staudinger, M. D., T. L. Morelli, and A. M. Bryan. 2015. Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Massachusetts. <http://necsc.umass.edu/projects/integrating-climate-change-state-wildlife-action-plans>

Massachusetts Climate Adaptation Partnership. 2015. Massachusetts Wildlife Climate Action Tool. Information on climate change impacts and vulnerability of species and habitats, and options to explore adaptation strategies and actions to based on location and interests. Initial development of the tool is focused on fish and wildlife species, forests and forestry practices, landscape connectivity (with a focus on climate related impacts on roads and culverts), land protection, and conservation planning. <http://climateactiontool.org/>

Kahl, K.J., K.R. Hall, P.J. Doran, J.Walk, S.L. Hagan, A. Lange. 2011. Updating the Illinois Wildlife Action Plan: Using a vulnerability assessment to inform conservation priorities. Climate Change Adaptation Case Study Series, The Nature Conservancy. Lansing MI. <http://www.nature.org/ourinitiatives/regions/northamerica/areas/greatlakes/explore/climate-change-il-case-study.pdf>

Forest-focused adaptation resources

Swanston, C.W., M.K., Janowiak, L.A. Brandt, P.R. Butler, S.D. Handler, P.D. Shannon, A. Derby Lewis, K.R. Hall, R.T. Fahey, L. Scott, A. Kerber, J.W. Miesbauer, L. Darling. *In press*. Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers, 2nd Edition. General Technical Report NRS-XXX. U.S. Department of Agriculture, Forest Service, Northern Research Station. Newtown Square, PA. 181p. web link coming soon!

Janowiak, M. K., C.W. Swanston, L. Nagel, L.A. Brandt, P.R. Butler, S. D. Handler, P.D. Shannon, L.R. Iverson, S.N. Matthews, A. Prasad, M.P. Peters, Matthew P. 2014. A practical approach for translating climate change adaptation principles into forest management actions. *Journal of Forestry*. 112: 424-433. <http://www.treearch.fs.fed.us/pubs/46417>

Swanston, C. and M. Janowiak, eds. 2012. Forest Adaptation Resources: Climate change tools and approaches for land managers. Gen. Tech. Rep. NRS-87. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 121 p. <http://www.treearch.fs.fed.us/pubs/40543>

Online version of the Adaptation Workbook, previously published in *Forest Adaptation Resources: Climate change tools and approaches for land managers*. This step-by-step process was designed to help people consider climate change at the scale of their own management decisions and design their own customized adaptation actions. <http://www.adaptationworkbook.org/>

Forest adaptation case studies

Climate Change Response Framework (led by Northern Institute of Applied Climate Science) Demonstration Project website. Currently (December 2015) contains information about the status, focal resources, partners, and strategies being designed/implemented by roughly 70 project teams in the upper Midwest – New England that have engaged in workshops using the Climate Change Response Framework tools (see under forest adaptation resources, below). Key word searchable. <http://forestadaptation.org/demonstration-projects>

Swanston, C.W., M.K., Janowiak, L.A. Brandt, P.R. Butler, S.D. Handler, P.D. Shannon, A. Derby Lewis, K.R. Hall, R.T. Fahey, L. Scott, A. Kerber, J.W. Miesbauer, L. Darling. *In press*. Chapter 6: Adaptation Demonstrations. *In Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers*, 2nd Edition. General Technical Report NRS-XXX. U.S. Department of Agriculture, Forest Service, Northern Research Station. Newtown Square, PA. 181p.

Kahl, K.J., K.R. Hall, P.J. Doran, M. White, M. Cornett. 2011. Planning for the Forests of the Future: Updating Northeast Minnesota's Forest Management Strategies. Climate Change Adaptation Case Study Series, The Nature Conservancy. Lansing

MI. <http://www.nature.org/ourinitiatives/regions/northamerica/areas/greatlakes/explore/climate-change-mn-case-study.pdf>

Incorporating climate change into conservation easements

The Land Trust Alliance website contains a comprehensive curriculum and library that includes guidance on identifying sites for potential easements, drafting easement language, and monitoring & stewarding easement properties over time. <http://www.landtrustalliance.org/training/publications/curriculum>

The Nature Conservancy: What are Conservation Easements? <http://www.nature.org/about-us/private-lands-conservation/conservation-easements/what-are-conservation-easements.xml>

The Land Trust Alliance: Develop Conservation Easements that Adapt to Climate Change. <https://www.landtrustalliance.org/climate-change-toolkit/plan/easements/develop-conservation-easements-that-adapt-to-climate-change>

Rissman, A. R., J. Owley, M. R. Shaw, and B. Thompson. 2015. Adapting conservation easements to climate change. *Conservation Letters* 8:68-76 <http://onlinelibrary.wiley.com.proxy62.cl.msu.edu/doi/10.1111/conl.12099/full>

U.S. EPA. An Assessment of Decision-Making Processes: Evaluation of Where Land Protection Planning Can Incorporate Climate Change Information (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/142F, 2011.

Climatic refugia and “Conserving Nature’s Stage”

Ashcroft, M. B. 2010. Identifying refugia from climate change. *Journal of Biogeography* 37:1407-1413. <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2699.2010.02300.x/epdf>

The “Terrestrial Resilience” site on The Nature Conservancy’s Conservation Gateway contains an overview work led by Mark Anderson that focuses on protecting geophysical settings, as well as links to reports, research papers, a fact sheet, and downloadable data for the Eastern US: <http://www.nature.ly/TNCResilience>.

The June 2015 Issue of the journal Conservation Biology contains a special section on using geophysical settings to inform conservation priorities. The section is introduced in: Beier, P., M. L. Hunter, and M. Anderson. 2015. Special Section: Conserving Nature's Stage. Conservation Biology: (online early) <http://dx.doi.org/10.1111/cobi.12511>

Anderson, M. G., M. Clark, and A. O. Sheldon. 2014. Estimating climate resilience for conservation across geophysical settings. Conservation Biology **28**:959-970 <http://dx.doi.org/10.1111/cobi.12272>

Anderson, M. G. and C. E. Ferree. 2010. Conserving the stage: climate change and the geophysical underpinnings of species diversity. PLoS ONE **5**:e11554. <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0011554>

Beier, P. and B. Brost. 2010. Use of land facets to plan for climate change: Conserving the arenas, not the actors. Conservation Biology **24**:701-710. <http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2009.01422.x/abstract>

Connectivity & corridors

Aune, K., P. Beier, J. Hilty, and F. Shilling. 2011. Assessment & Planning for Ecological Connectivity: A Practical Guide. Wildlife Conservation Society, Bozeman. <http://www.wcsnorthamerica.org/ConservationInitiatives/Connectivity/tabid/3243/Categoryid/166/Default.aspx>

The Wildlife Conservation Society’s “Make Room for Wildlife: A Resource for Local Planners and Communities in the Tug Hill region” and “Protecting Wildlife Connectivity Through Land Use Planning – Best Management Practices and the Role of Conservation Development.” At: <http://www.wcsnorthamerica.org/ConservationInitiatives/Connectivity/tabid/3243/Categoryid/166/Default.aspx>

Beier, P., W. Spencer, R. F. Baldwin, and B. H. McRae. 2011. Toward best practices for developing regional connectivity maps. Conservation Biology **25**:879-892. <http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2011.01716.x/abstract>

Brost, B.M., and P. Beier. 2012. Use of land facets to design linkages for climate change. Ecological Applications **22**:87–103. <http://oak.ucc.nau.edu/pb1/vitae/brost-beier.2012.landfacetcorridors.pdf>

Lawler, J. J., A. S. Ruesch, J. D. Olden, and B. H. McRae. 2013. Projected climate-driven faunal movement routes. Ecology Letters **16**:1014-1022. <http://onlinelibrary.wiley.com/doi/10.1111/ele.12132/abstract>

Carrol, Carlos. 2013. Projecting dispersal corridors for climate-change-driven range shifts – article on Databasin that links to data from Lawler et al.

(2013). <http://databasin.org/articles/504854c10165475bbf60064b14748508>

Updating management in urban/suburban natural areas

Derby Lewis, A. K.R. Hall, and J.J. Hellmann. 2012. Advancing Adaptation in the City of Chicago: Climate Considerations for the Management of Natural Areas. The Field Museum, Chicago.

Available on the Collaboratory for Adaptation to Climate

Change: <https://adapt.nd.edu/resources/1019>.

Adaptation policy & engaging resource managers

Georgetown Climate Center (Georgetown University Law School). Portal intended to help advance effective climate, energy, and transportation policies in the US - policies that reduce greenhouse gas emissions and help communities adapt to climate change. Goals of the portal include sharing of best practices and success stories with state and federal policymakers; the Center also analyzes legislative and regulatory developments, and assists with program design. <http://www.georgetownclimate.org/>

The "State and Local Adaptation Plans" section of the Georgetown Climate Center site links to state and local adaptation plans, and for NY resources include links to state laws & policies, plans, assessments, etc., There is also a goal tracker, which evaluates status toward 11 biodiversity goals from the NYS Climate Action Plan Interim Report

(2010). <http://www.georgetownclimate.org/adaptation/state-and-local-plans>

Bierbaum, R., J. B. Smith, A. Lee, M. Blair, L. Carter, F. S. Chapin III, P. Fleming, S. Ruffo, M. Stults, S. McNeeley, E. Wasley, and L. Verduzco. 2013. A comprehensive review of climate adaptation in the United States: more than before, but less than needed. *Mitigation and Adaptation Strategies for Global Change* 18:361-406. <http://link.springer.com/article/10.1007%2Fs11027-012-9423-1>

Brown, C., W. Werick, W. Leger, and D. Fay. 2011. A decision-analytic approach to managing climate risks: Application to the Upper Great Lakes. *Journal of the American Water Resources Association* 47:524-534. <http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2011.00552.x/abstract>

Kahl, K.J., K.R.Hall, P.J. Doran, M.Cornett, and K. France. 2012. Jump-Starting Climate Adaptation: Catalyzing conservation strategy updates through climate clinics in New York, Minnesota and the Dakotas. Climate Change Adaptation Case Study Series, The Nature Conservancy, Lansing MI. <http://www.nature.org/ourinitiatives/regions/northamerica/areas/greatlakes/explore/climatecasestudy-nymn-climateclinics-final.pdf>

Petersen, B.C., K.R. Hall, K.J. Kahl, and P.J. Doran. 2013. In their own words: Perceptions of climate change adaptation from the Great Lakes region's resource management community. *Environmental Practice* 15: 377-392. <http://nature.ly/GLclimateperceptions>

Nature-based climate change adaptation for people

Nelson, E. J., P. Kareiva, M. Ruckelshaus, K. Arkema, G. Geller, E. Girvetz, D. Goodrich, V. Matzek, M. Pinsky, W. Reid, M. Saunders, D. Semmens, and H. Tallis. 2013. Climate change's impact on key ecosystem services and the human well-being they support in the US. *Frontiers in Ecology and the Environment* 11:483-493. <http://www.esajournals.org/doi/pdf/10.1890/120312>

Coastal resilience Partnership website (The Nature Conservancy). Portal describing and linking to map-based resources for a four-pronged approach: (1) Assess risk and vulnerability to coastal hazards including current and future storms and sea level rise scenarios. (2) Identify where nature-based and other solutions can be used for reducing risk. (3) Take Action to help communities develop and implement nature-based solutions to increase coastal resilience. (4) Measure Effectiveness to ensure that our efforts to reduce risk through restoration and adaptation are successful. <http://coastalresilience.org/>

Downing, J., L. Blumberg, and E. Hallstein. 2013. *Reducing Climate Risks With Natural Infrastructure*. The Nature Conservancy, San Francisco, CA.

<http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/ca-green-vs-gray-report-2.pdf>