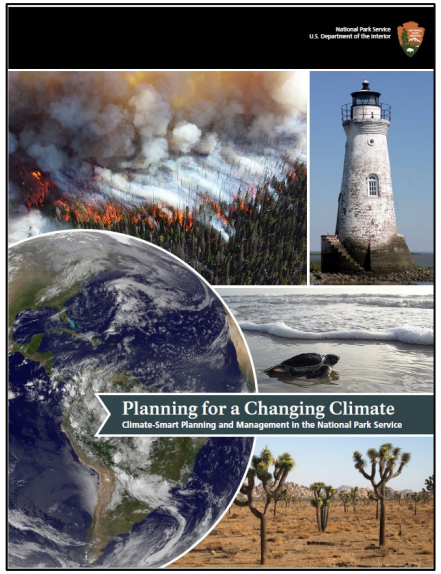
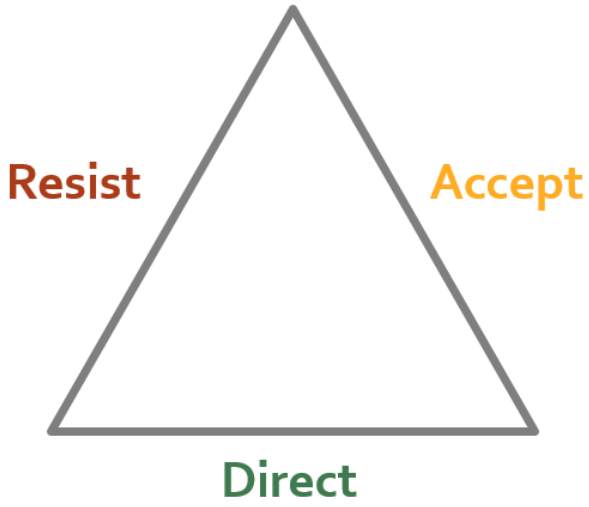
How the Resist-Accept-Direct (RAD) framework clarifies the challenge of modern natural resource management and supports strategic, forward-looking action



NC CASC webinar
8 July 2021

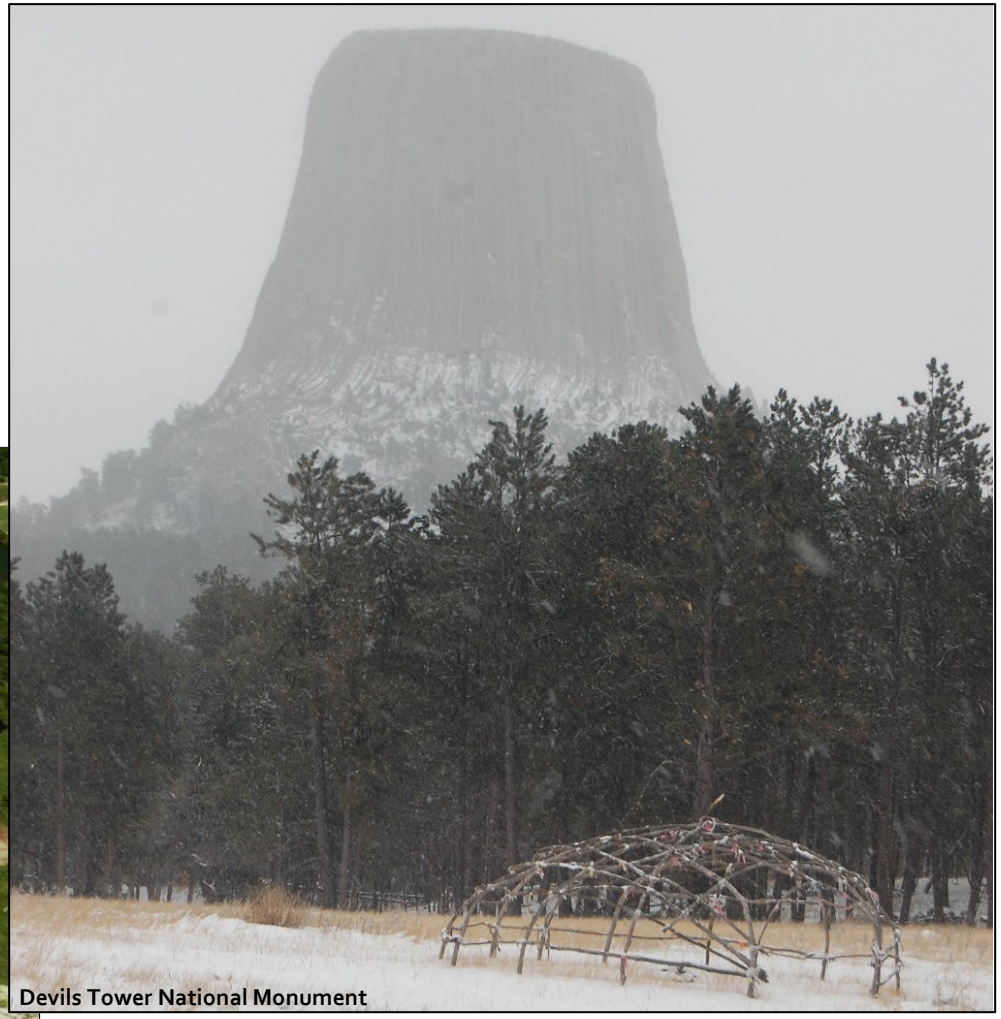
Gregor Schuurman, PhD
NPS Climate Change Response Program



Natural resource focus, but broad relevance

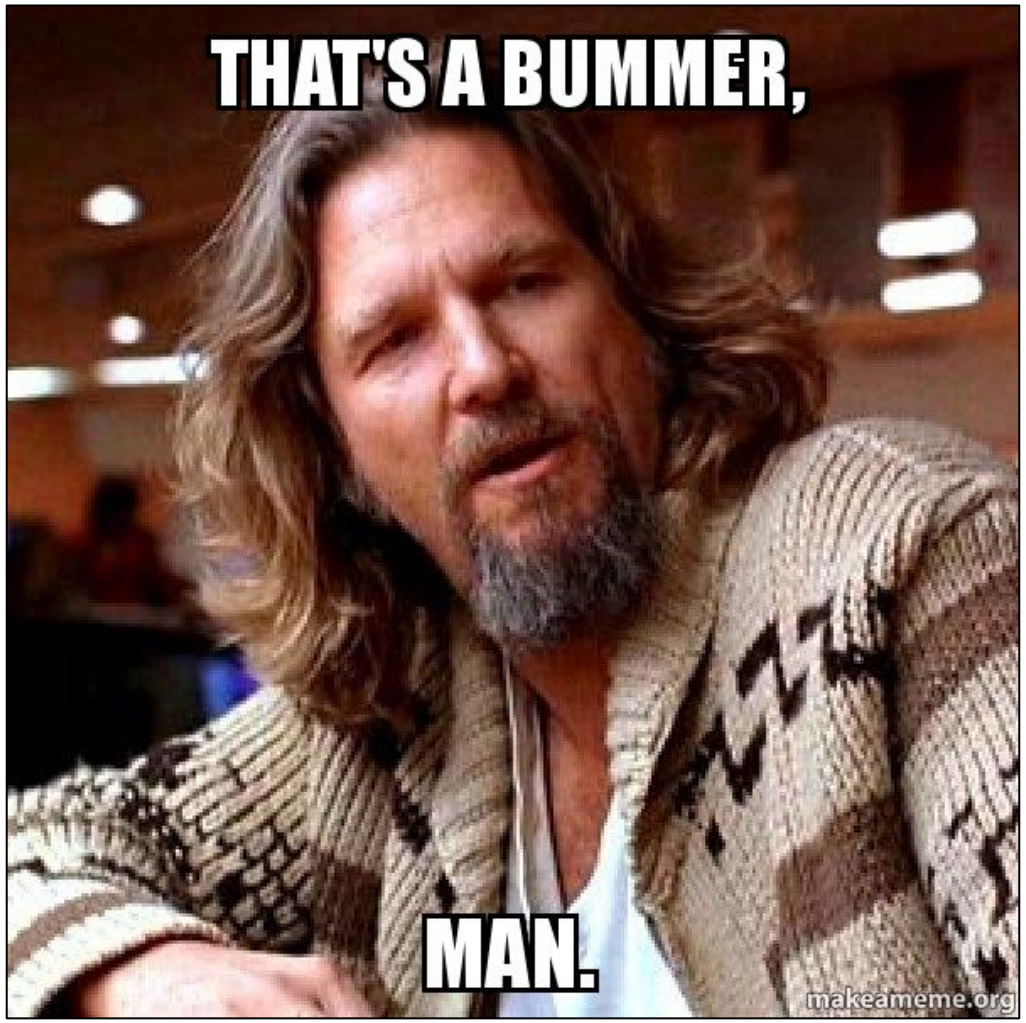
Mount Rainier National Park 2006

Cape Hatteras National Seashore



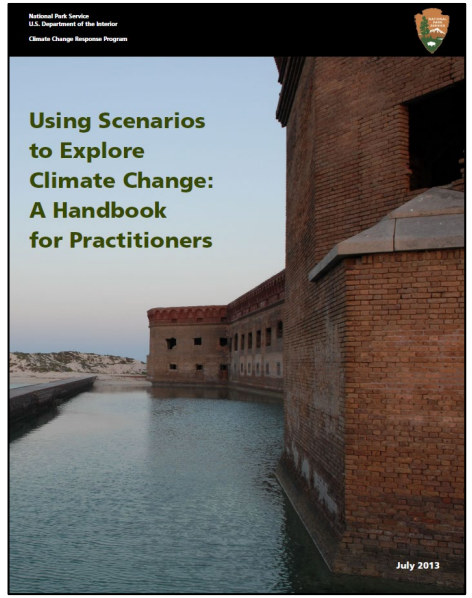
Devils Tower National Monument

This is a heavy topic



An evolution of NPS climate change adaptation tools and approaches

2013



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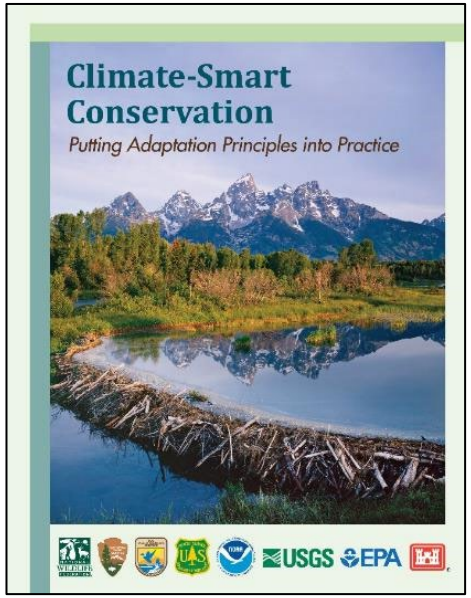
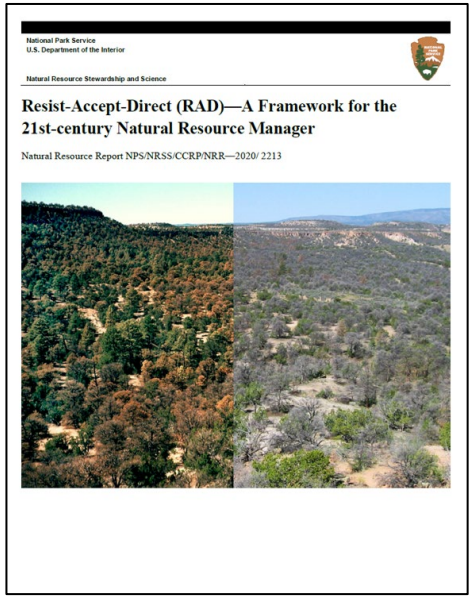
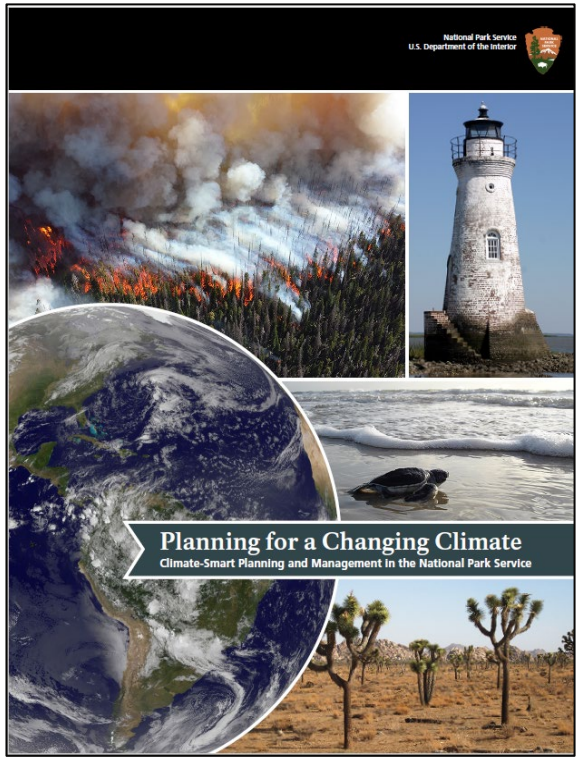


2020



2021



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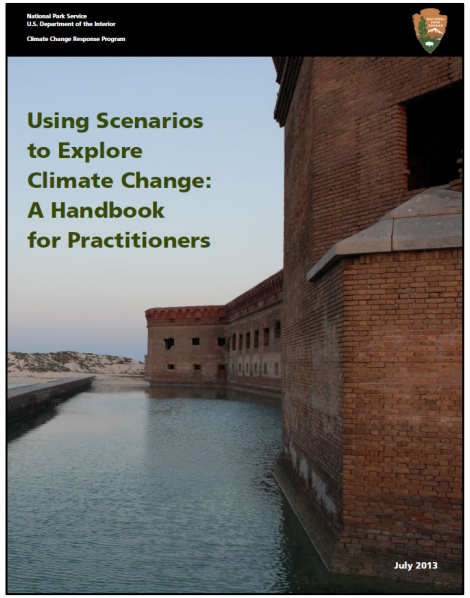
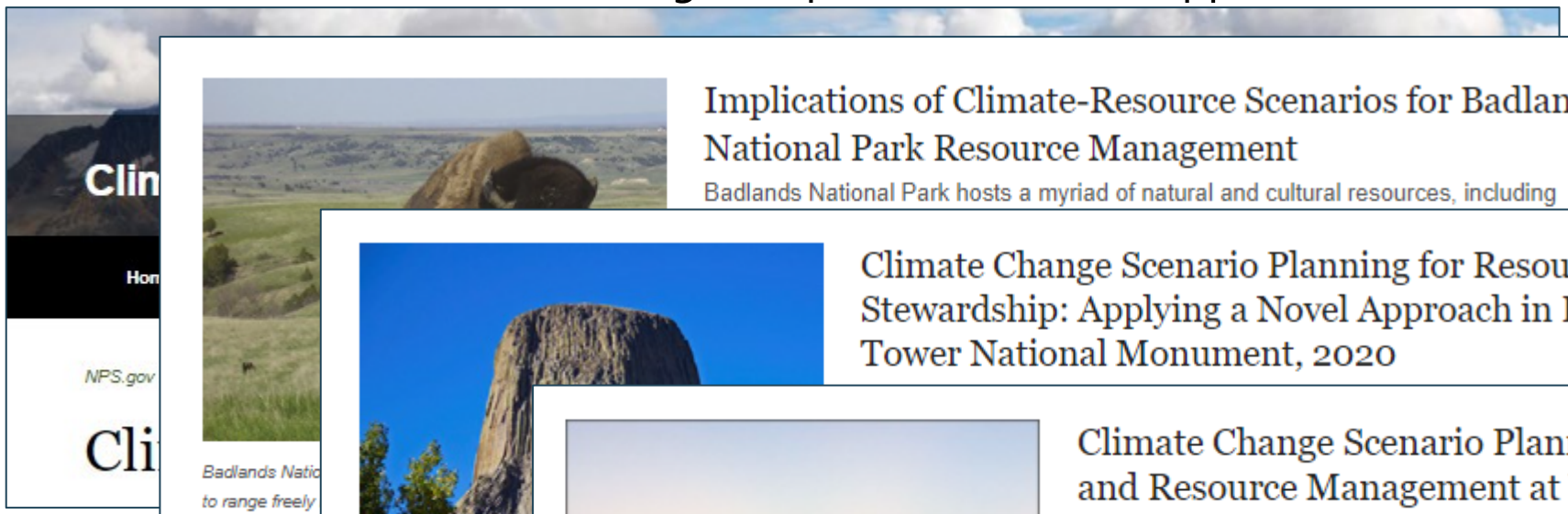


An evolution of NPS climate change adaptation tools and approaches



NPS.gov

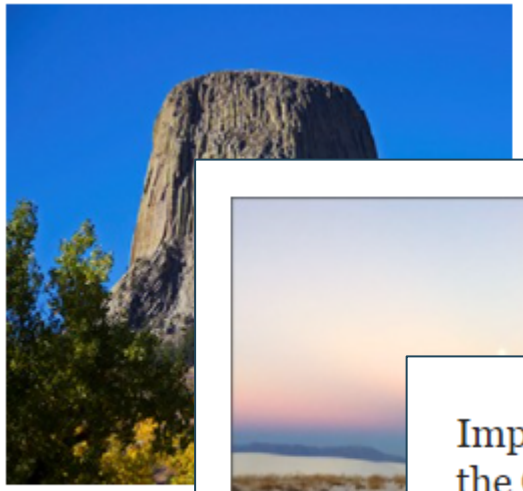
Cli

Badlands Natio
to range freely

NPS Image by

Implications of Climate-Resource Scenarios for Badlands National Park Resource Management

Badlands National Park hosts a myriad of natural and cultural resources, including

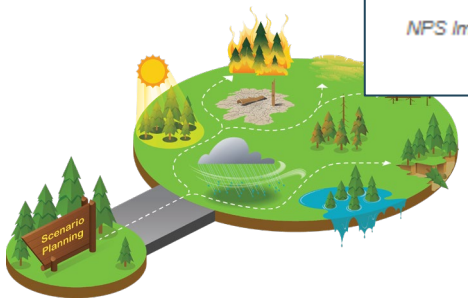


Fall foliage brings brig

NPS Image Courtesy

Climate Change Scenario Planning for Resource Stewardship: Applying a Novel Approach in Devils Tower National Monument, 2020

Climate Change Scenario Planning to Guide Research and Resource Management at White Sands National Park, 2021



Implications of Climate Change for the Water Supply of the Chisos Mountains Developed Area, 2019

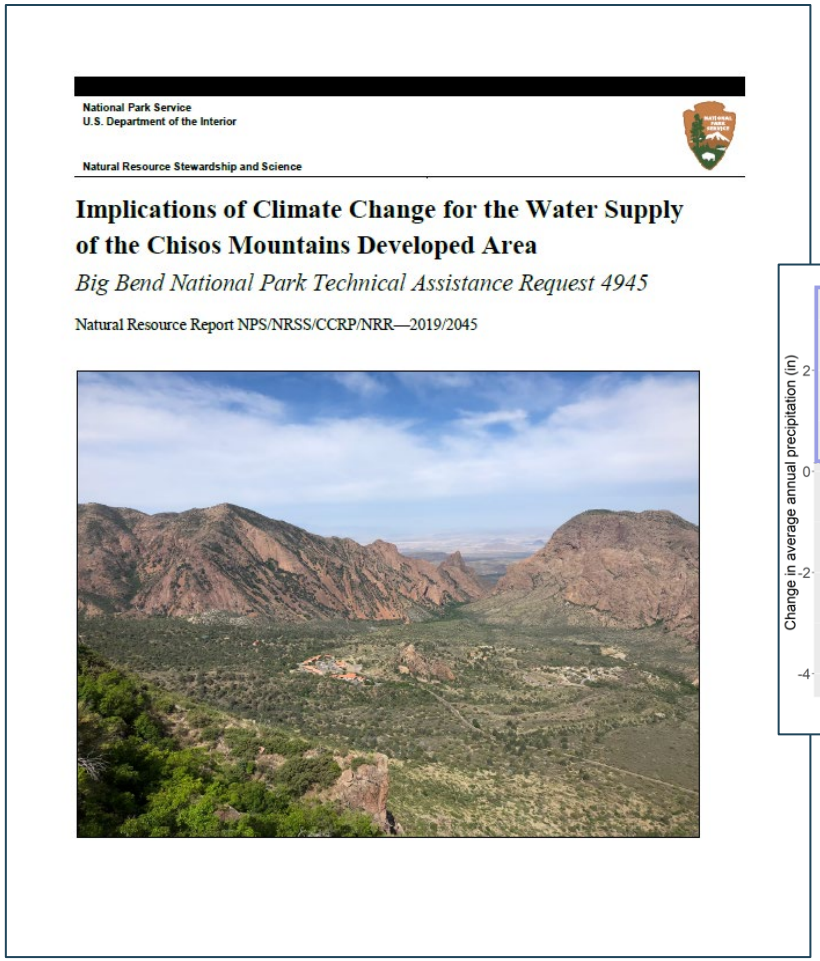
Groundwater discharged from Oak Spring currently serves as the sole water source for the Chisos Basin--a hub of visitor infrastructure and services within Big Bend National Park. Given a known link between precipitation and spring discharge, the NPS undertook an analysis to clarify which strategies and investments might be best at Oak Spring given climate change projections, or whether the park should seek to develop an alternative water source. The **resulting report** [5 MB PDF] helps clarify the relationship between Oak Spring and contemporary climate conditions, and uses projected future climate to assess long-term reliability of discharge from the spring.

Chisos Basin including Ward Mountain and the flow path towards Oak Spring

NPS Image Courtesy Max Woolley

https://www.nps.gov/subjects/climatechange/scenarioplanning.htm

An evolution of NPS climate change adaptation tools and approaches


National Park Service
U.S. Department of the Interior

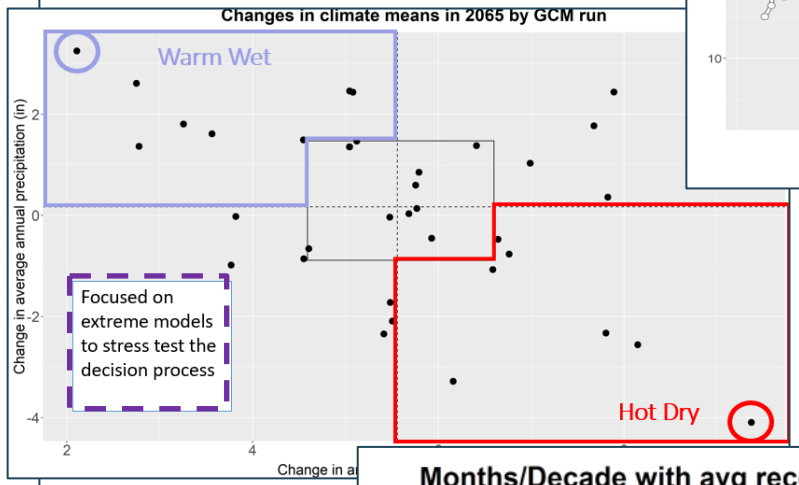
Natural Resource Stewardship and Science

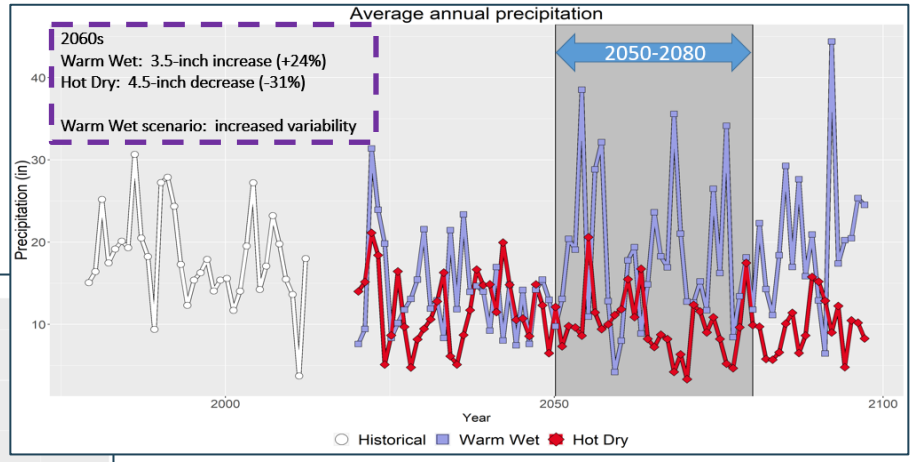
Implications of Climate Change for the Water Supply of the Chisos Mountains Developed Area

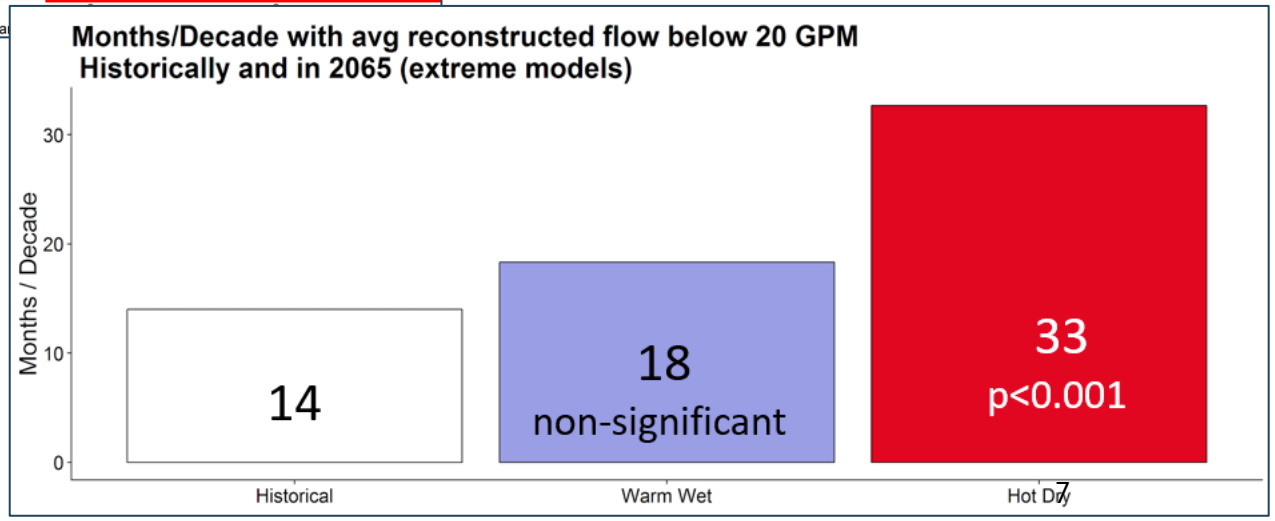
Big Bend National Park Technical Assistance Request 4945

Natural Resource Report NPS/NRSS/CCRP/NRR—2019/2045

Lawrence, D. J., and A. N. Runyon. 2019. Implications of climate change for the water supply of the Chisos Mountains developed area: Big Bend National Park technical assistance request 4945. Natural Resource Report NPS/NRSS/CCRP/NRR—2019/2045. National Park Service, Fort Collins, Colorado.







An evolution of NPS climate change adaptation tools and approaches

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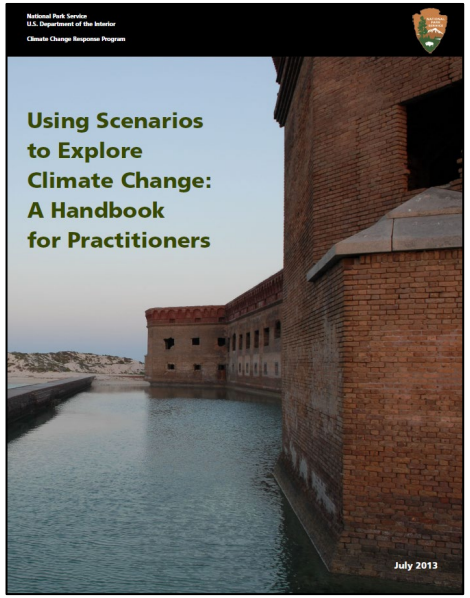

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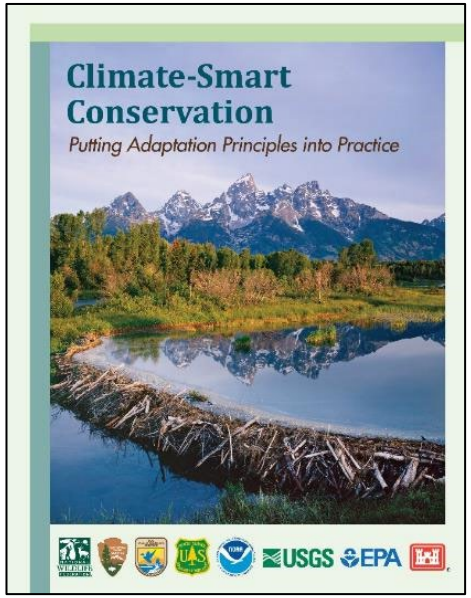

"Manage for change, not just persistence"

"Reconsider goals and actions"

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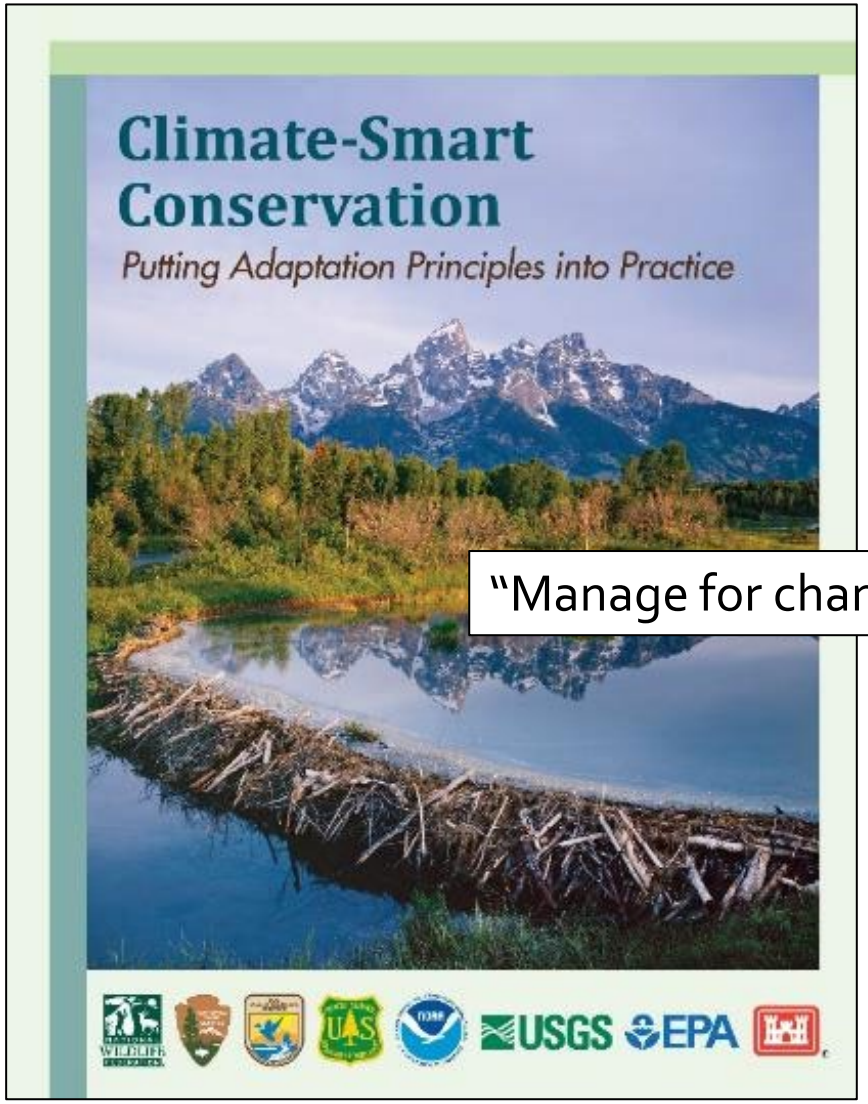

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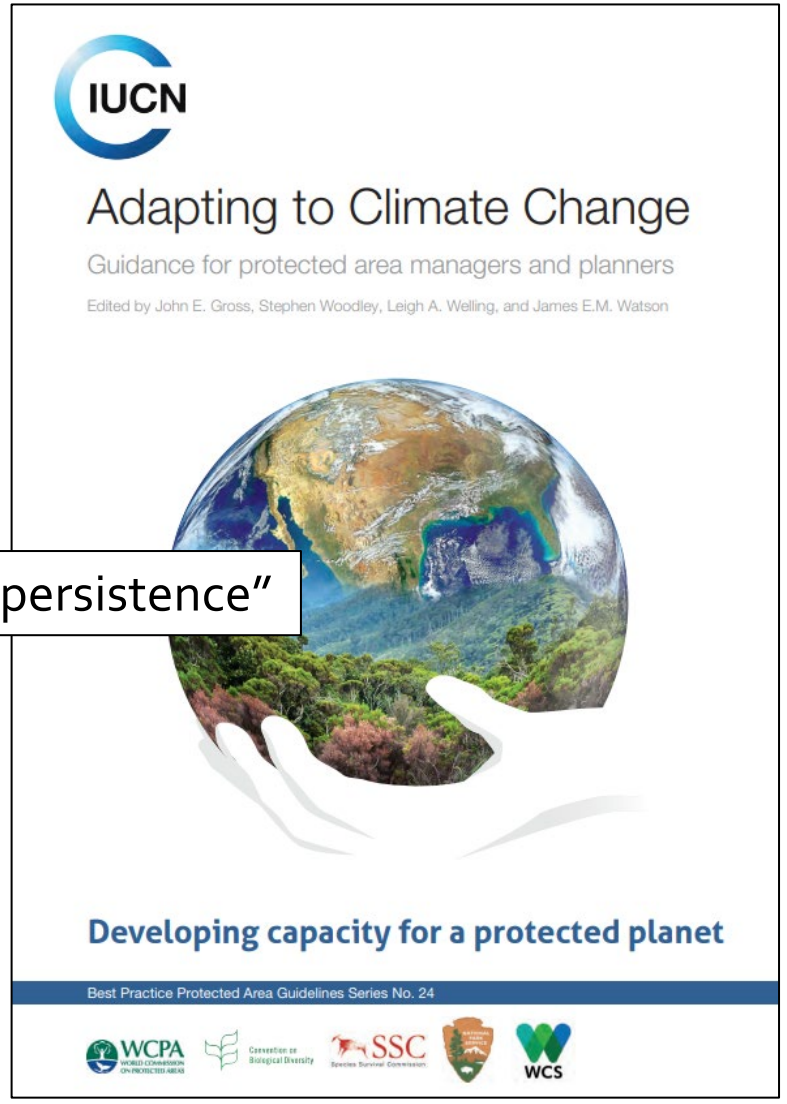

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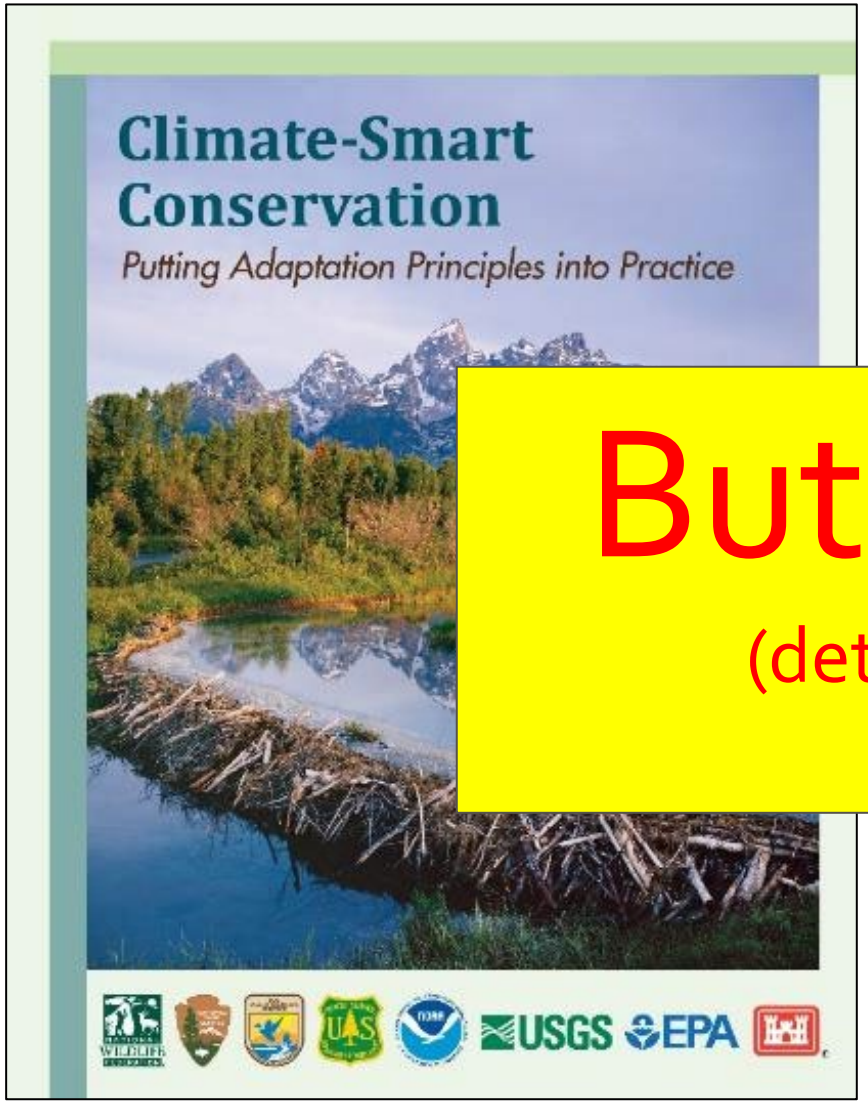
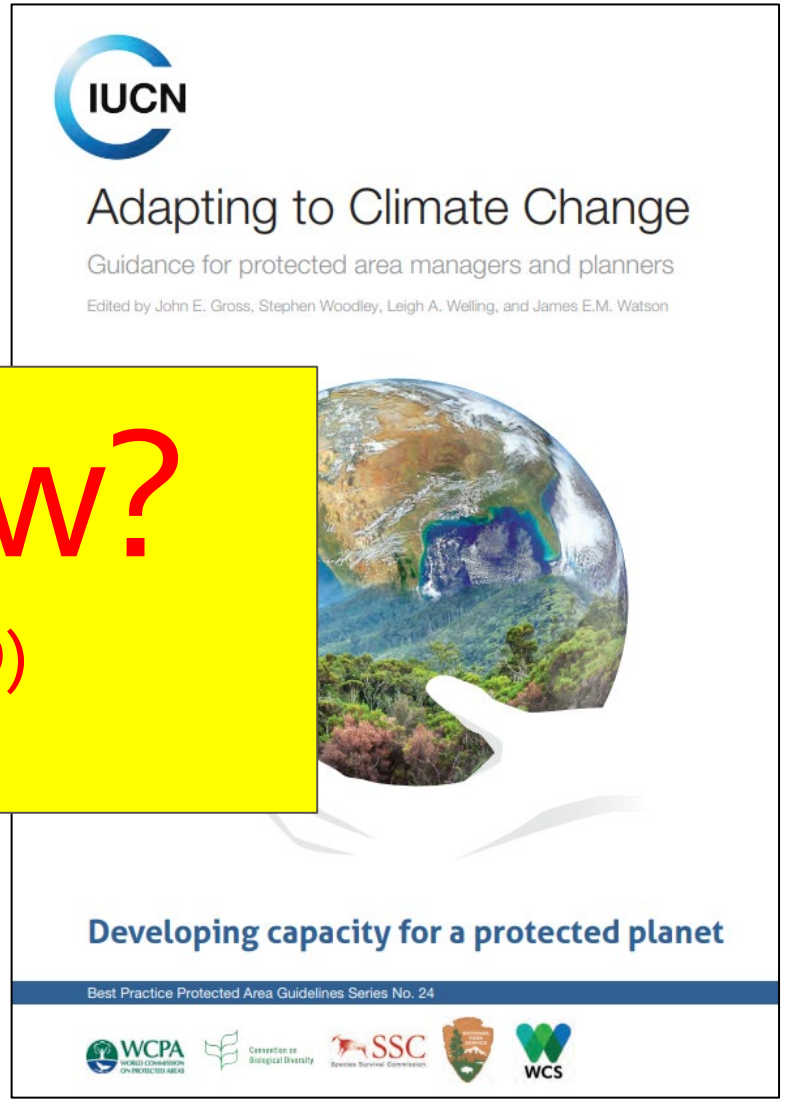


But how?

(details TBD)



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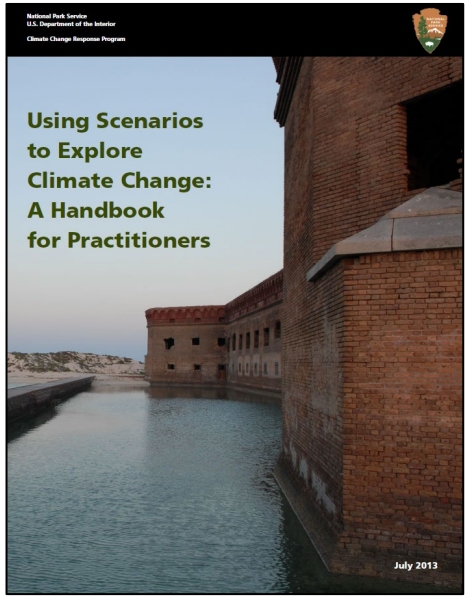

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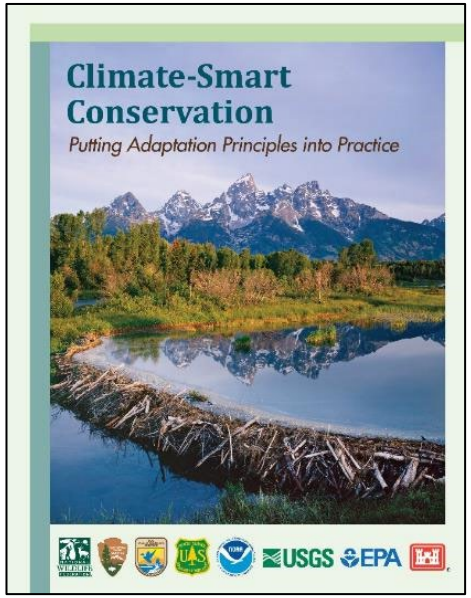

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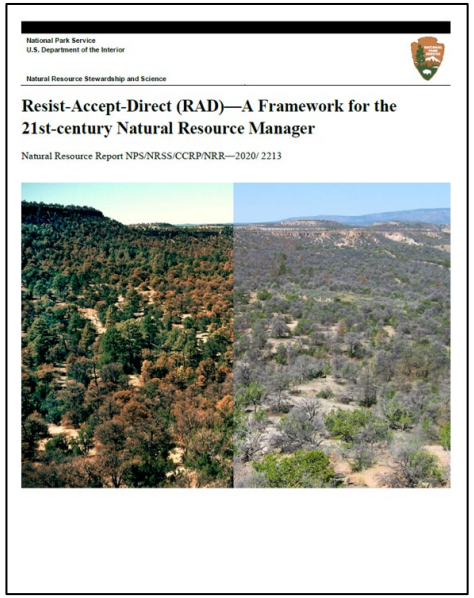

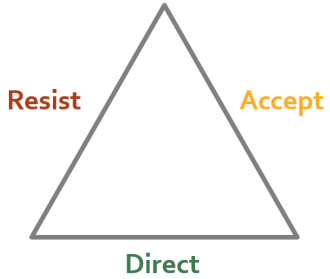

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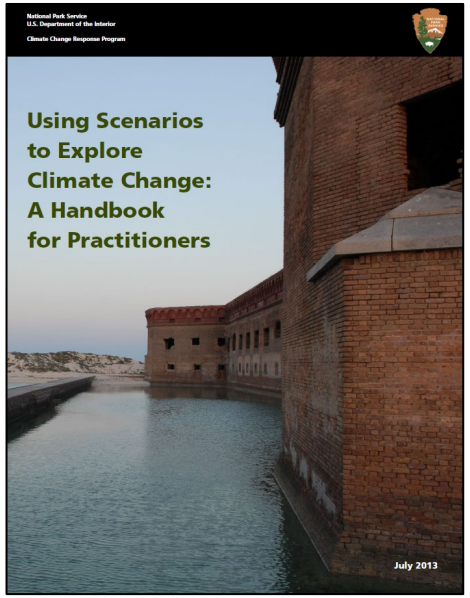

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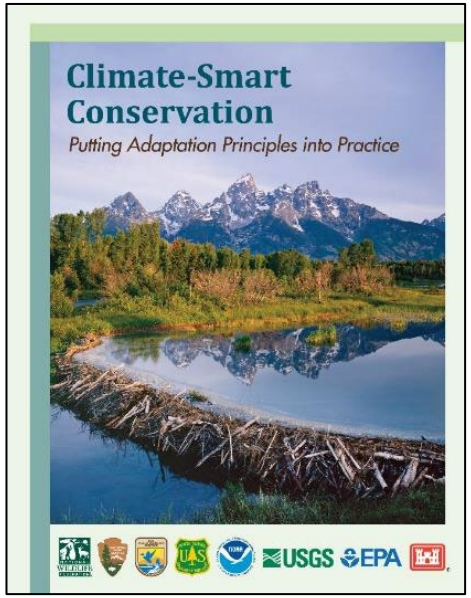

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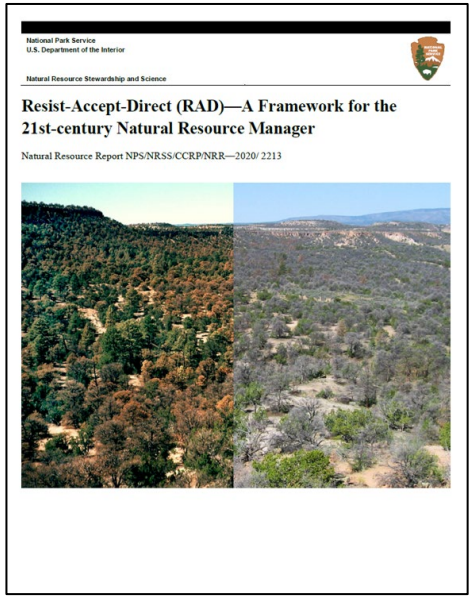
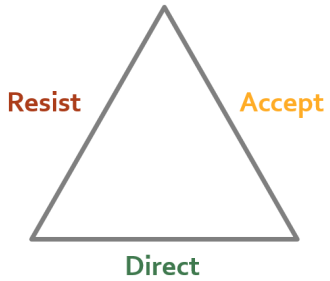
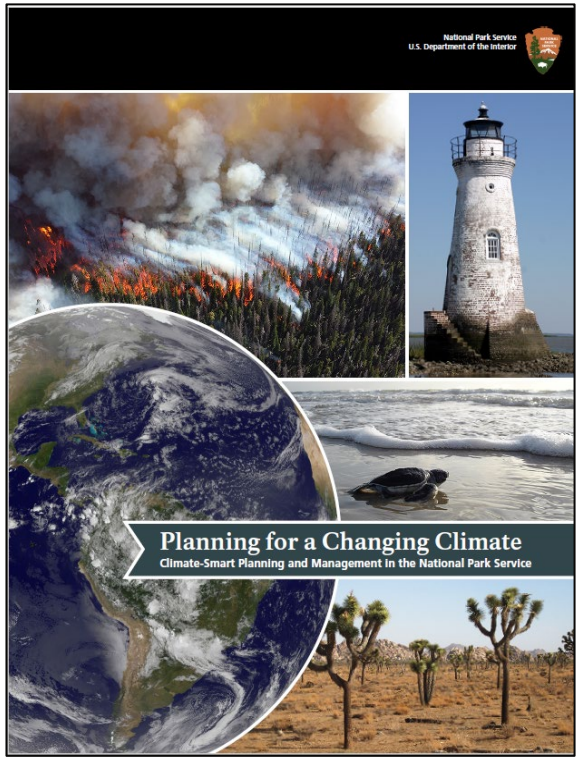




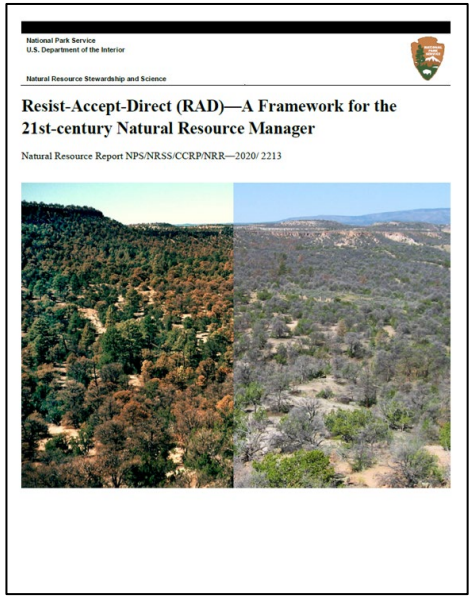
2021



"Develop forward-looking goals that consider climate change"

"Consider more than one scenario of the future"

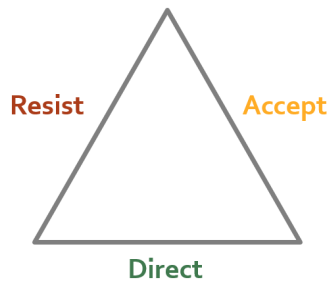
2020


National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager

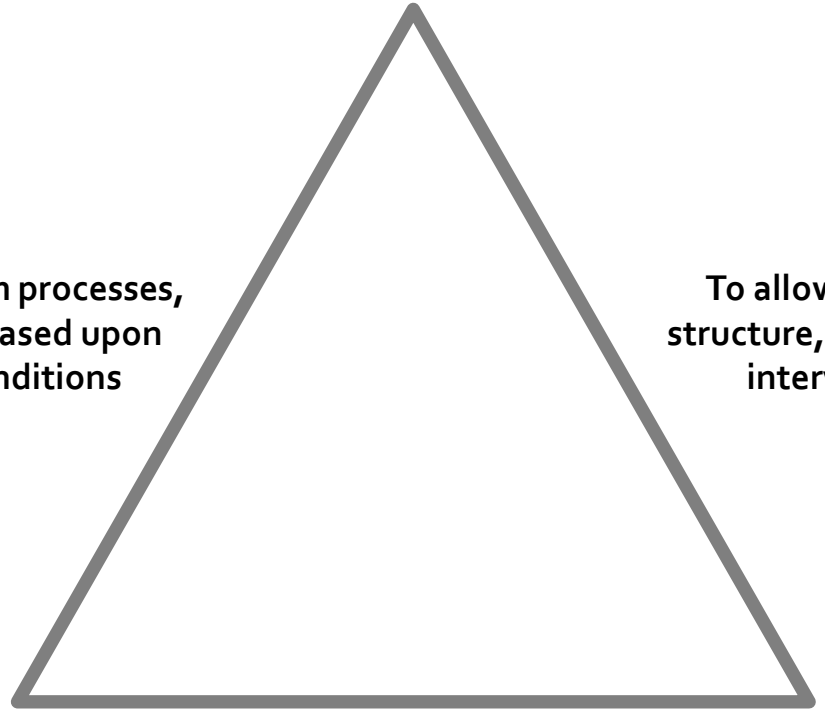
Natural Resource Report NPS/NRSS/CCRP/NRR—2020/ 2213



What is the RAD framework?

Resist

Work to maintain or restore ecosystem processes, function, structure, or composition based upon historical or acceptable current conditions



Accept

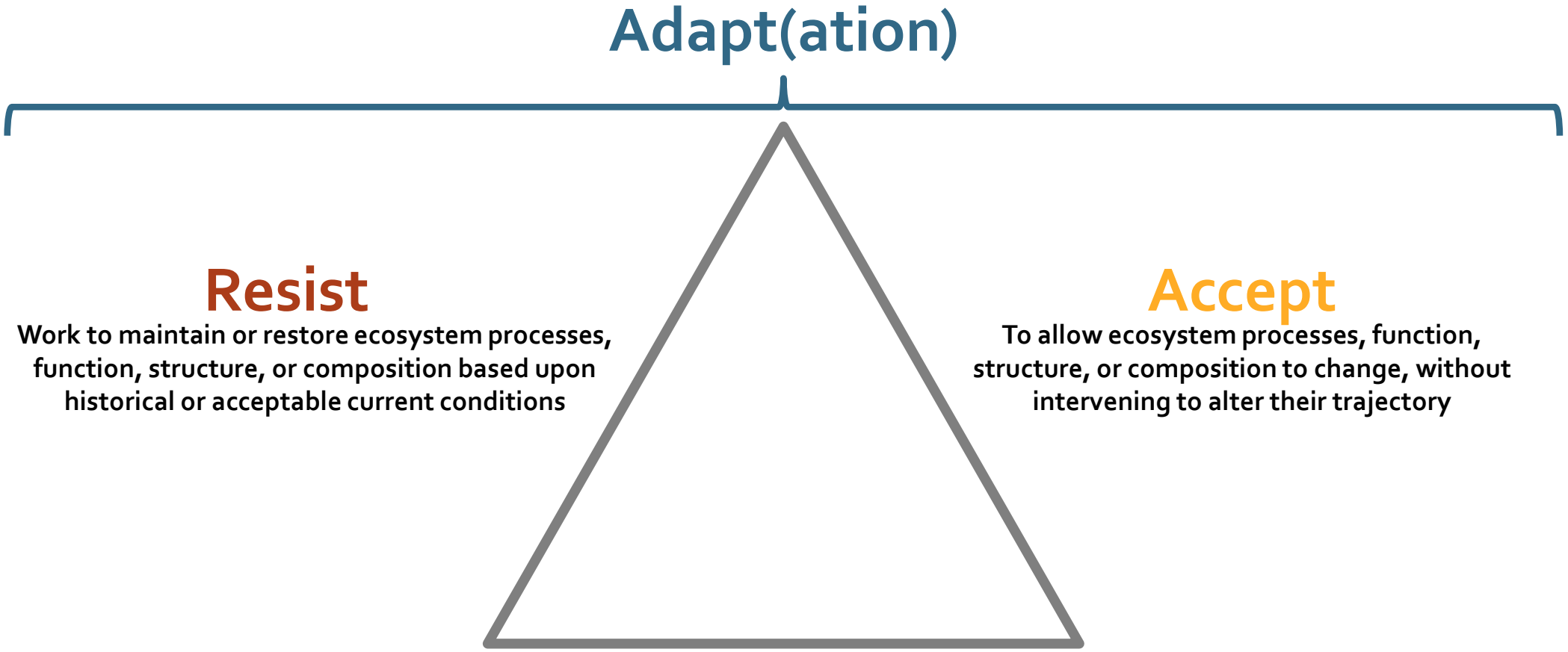
To allow ecosystem processes, function, structure, or composition to change, without intervening to alter their trajectory

Direct

Actively shape ecosystem processes, function, structure, or composition towards preferred new conditions

Definitions from Schuurman et al. (in press); design adapted from Thompson et al. 2020

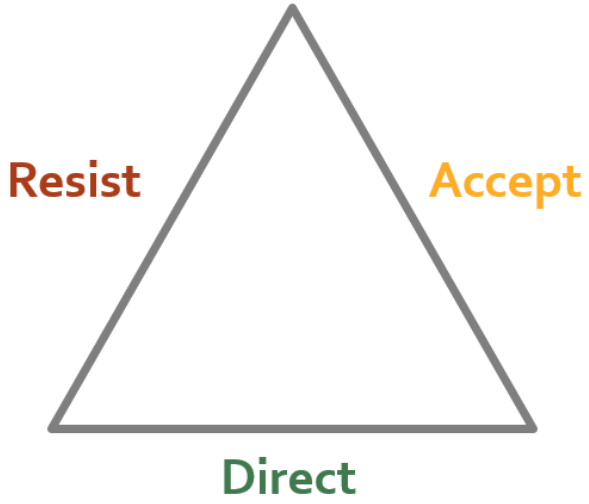
What is the RAD framework?



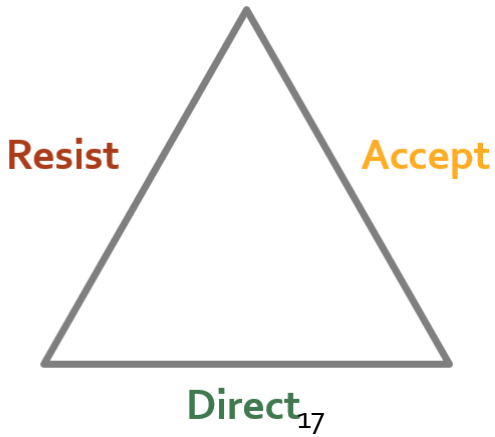
Definitions from Schuurman et al. (in press); design adapted from Thompson et al. 2020

How does the RAD framework support natural resource management decision making?

- Focuses on manager intent
- Identifies manager actions
- Encompasses all possible options
- Simple
- Neutral (toolkit)
- Works across time and space
- Complements other approaches



Where does the RAD framework come from?



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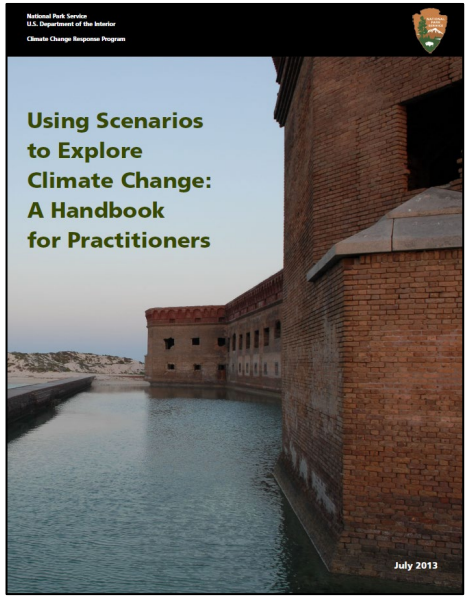

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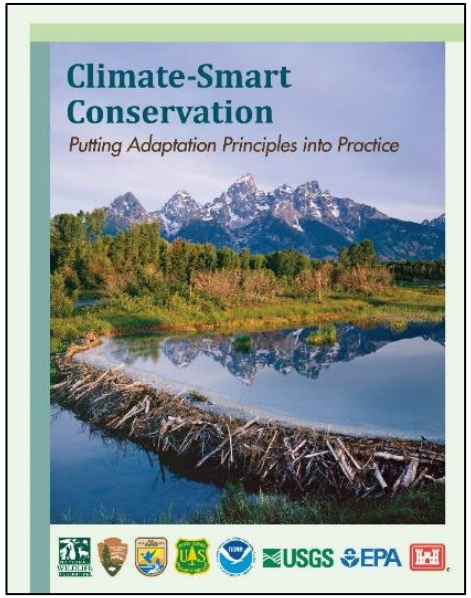

"Manage for change, not just persistence"

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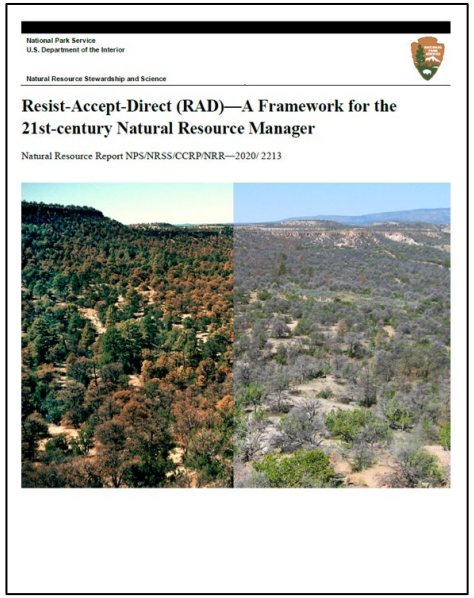
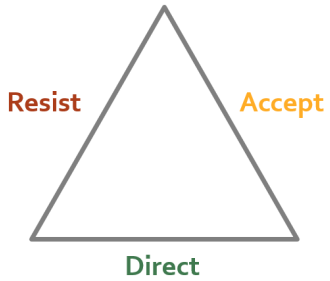
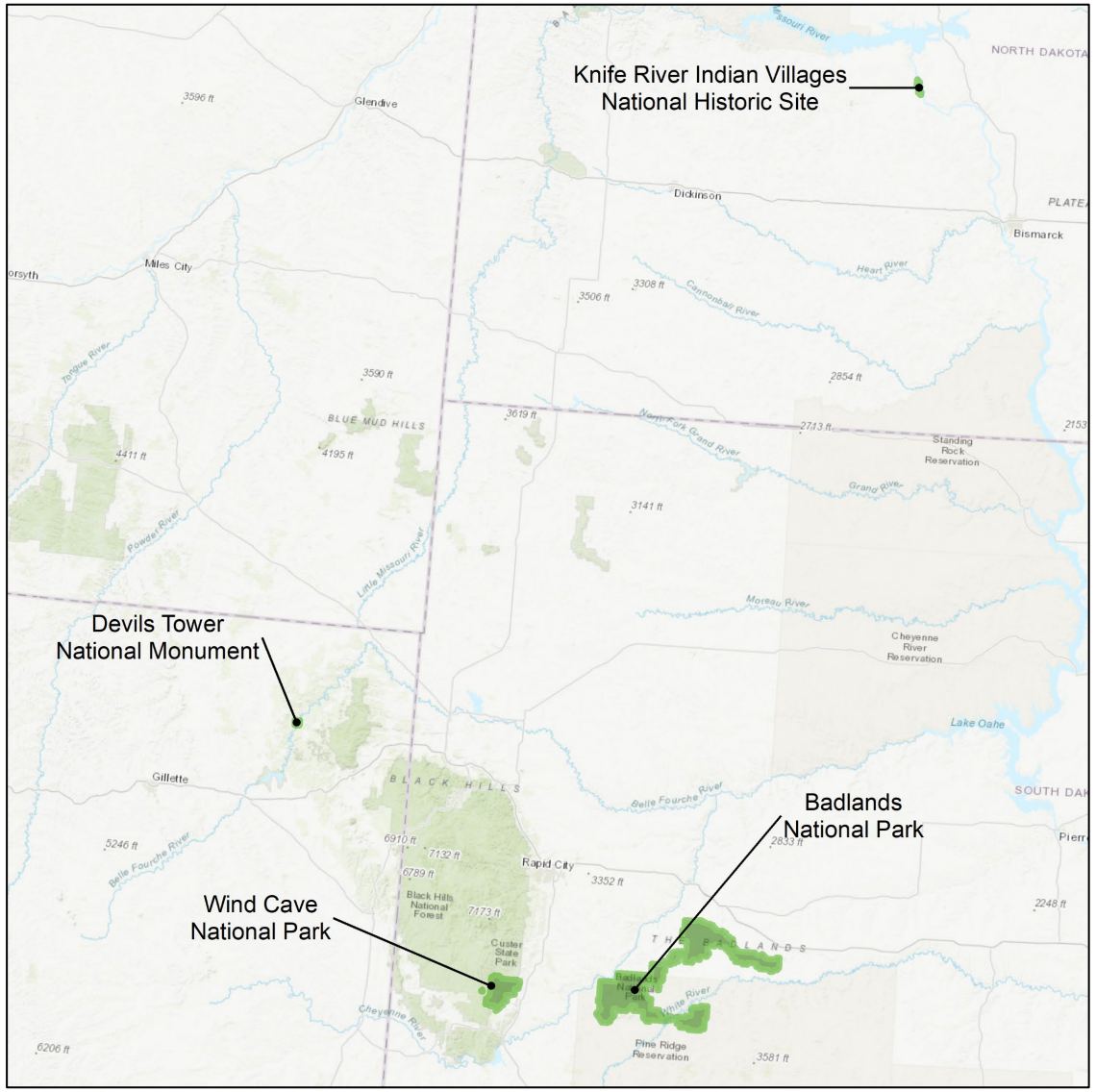




NC CASC-funded project to advance adaptation in the northern Great Plains (2015-2019)



National Park Service
U.S. Department of the Interior

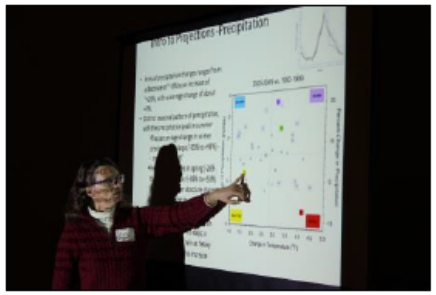
Natural Resource Stewardship and Science

Resource Management and Operations in Central North Dakota

Climate Change Scenario Planning Workshop Summary

November 12-13, 2015, Bismarck, ND

Natural Resource Report NPS/NRSS/NRR—2016/1262



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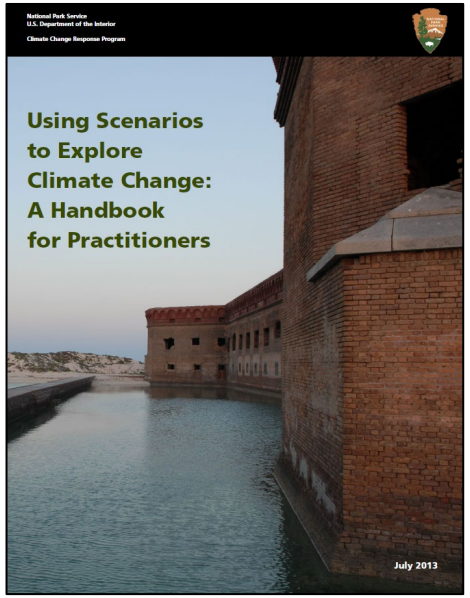

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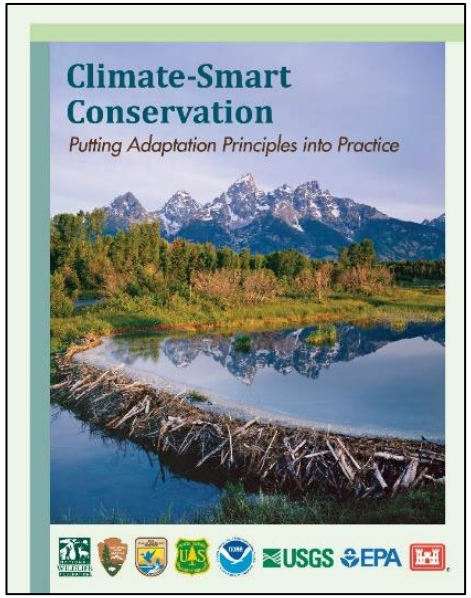

"Manage for change, not just persistence"

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NC CASC-funded project to advance adaptation in the northern Great Plains (2015-2019)

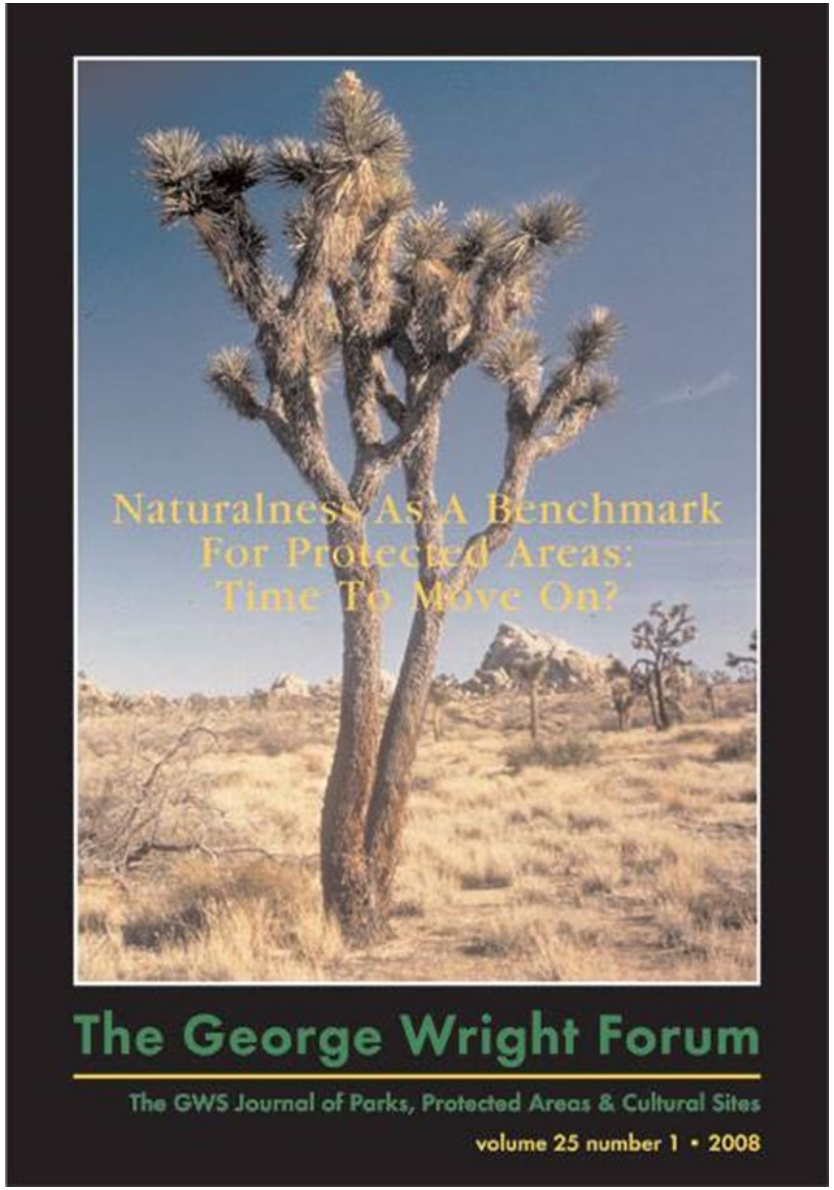
Environmental Management (2016) 57:753–758
DOI 10.1007/s00267-015-0650-6

FORUM

Is 'Resilience' Maladaptive? Towards an Accurate Lexicon for Climate Change Adaptation

Nicholas A. Fisichelli[1] · Gregor W. Schuurman[1] · Cat Hawkins Hoffman[1]

NC CASC-funded project to advance adaptation in the northern Great Plains (2015-2019)

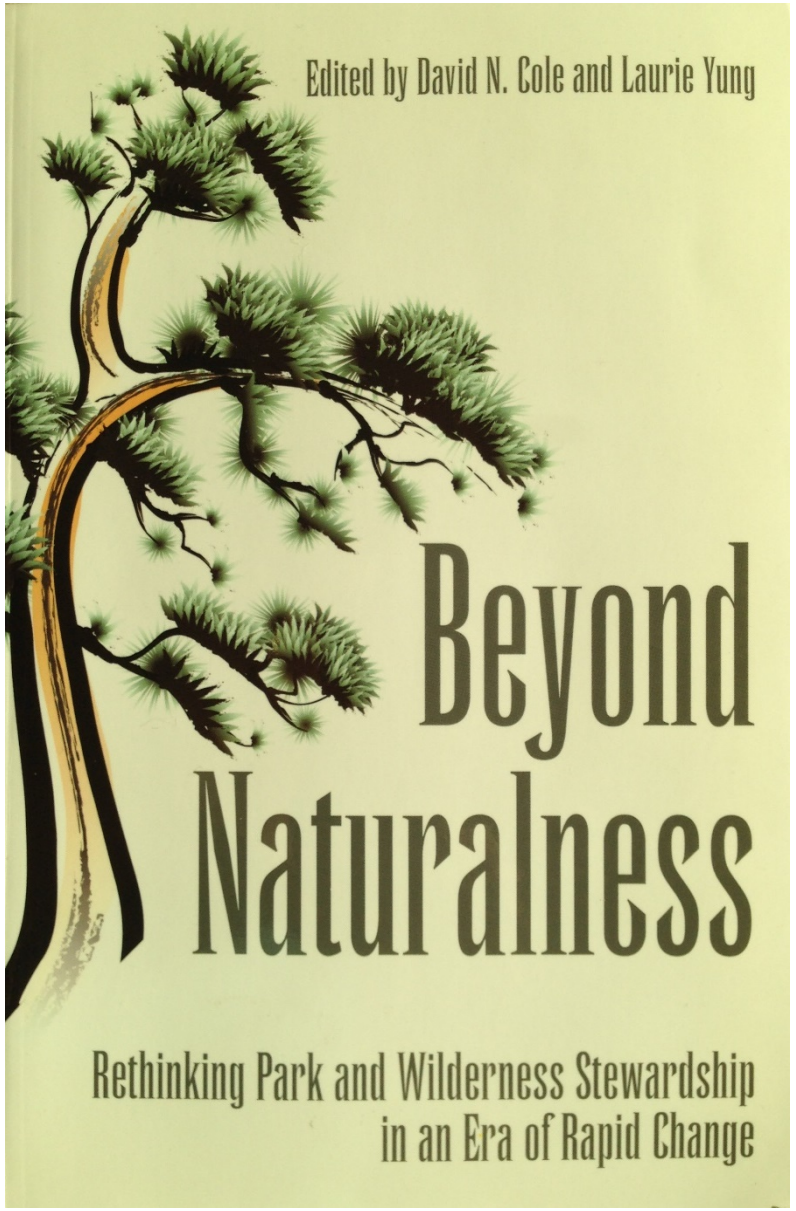


"In short, it is increasingly clear that naturalness is no longer the umbrella under which all protected area values comfortably sit.

D. Cole, et. al. 2008

"…new concepts are needed to guide management… concepts that account for human impacts, global change, and evolving public

G. Aplet, D. Cole, 2010



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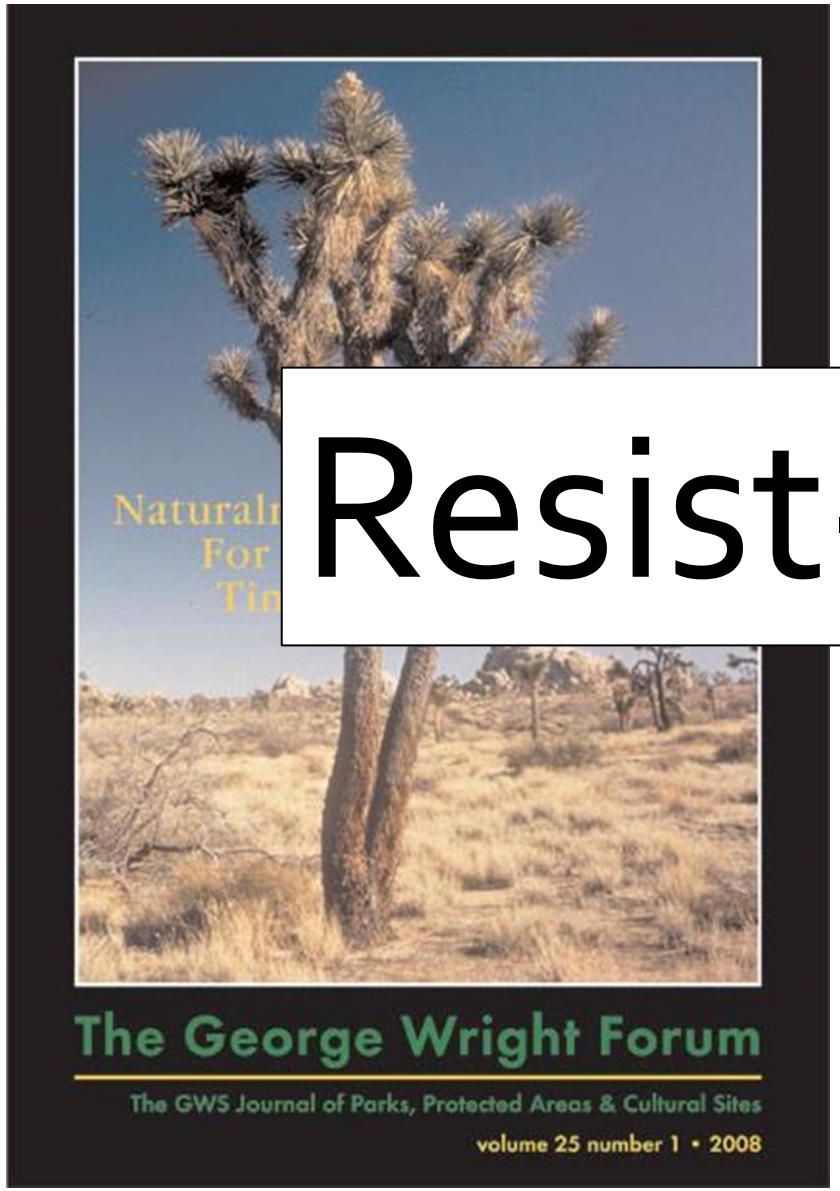

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Resist-Accept-Guide

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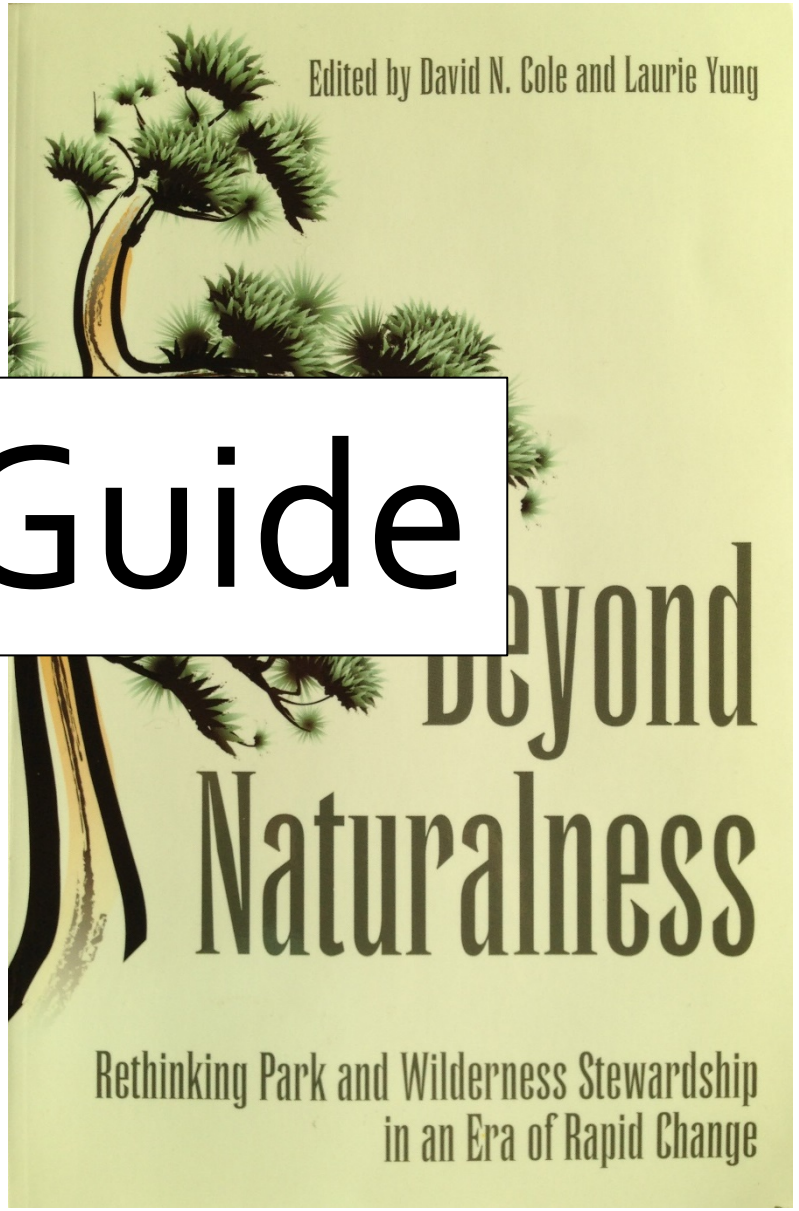

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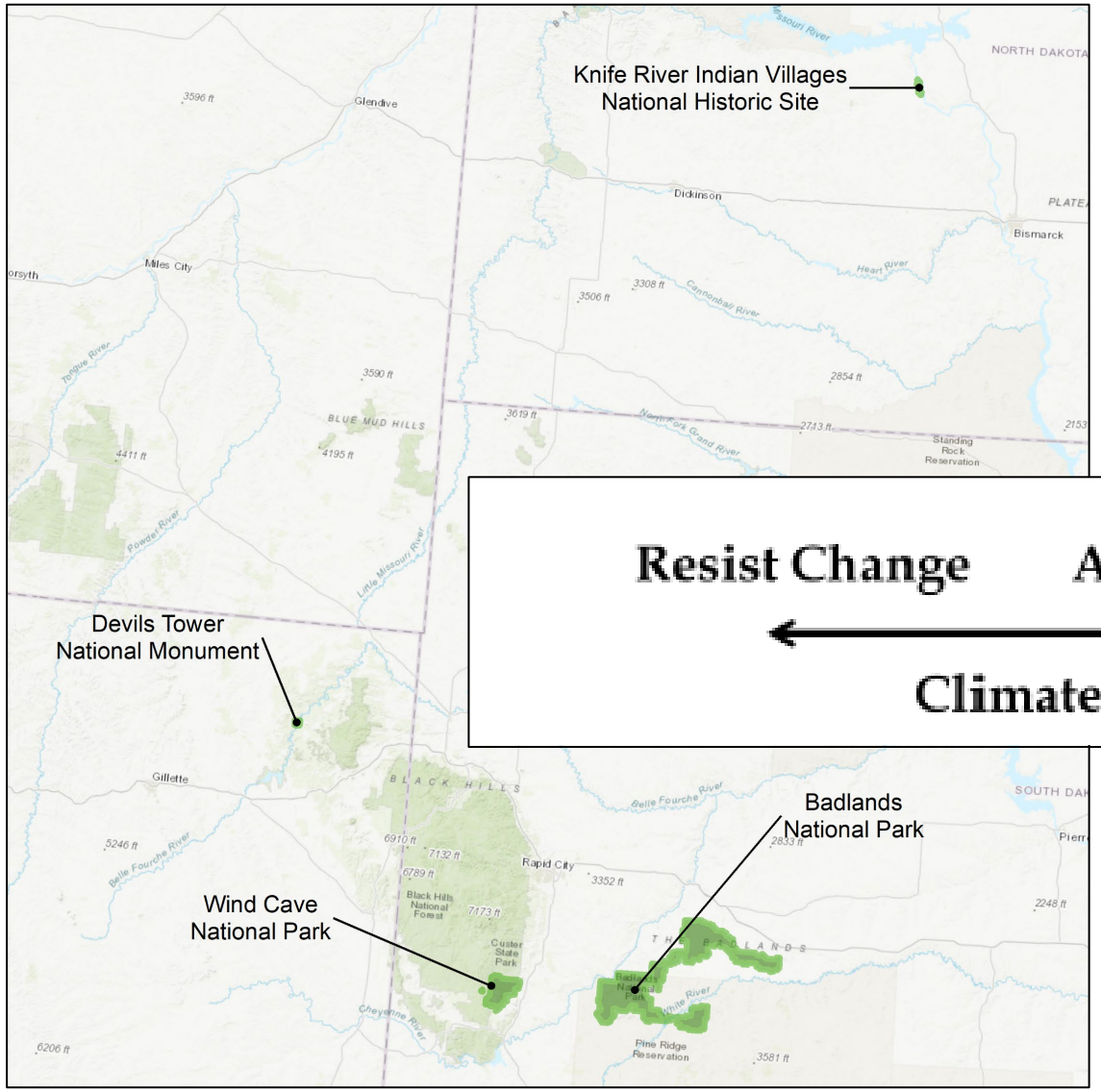
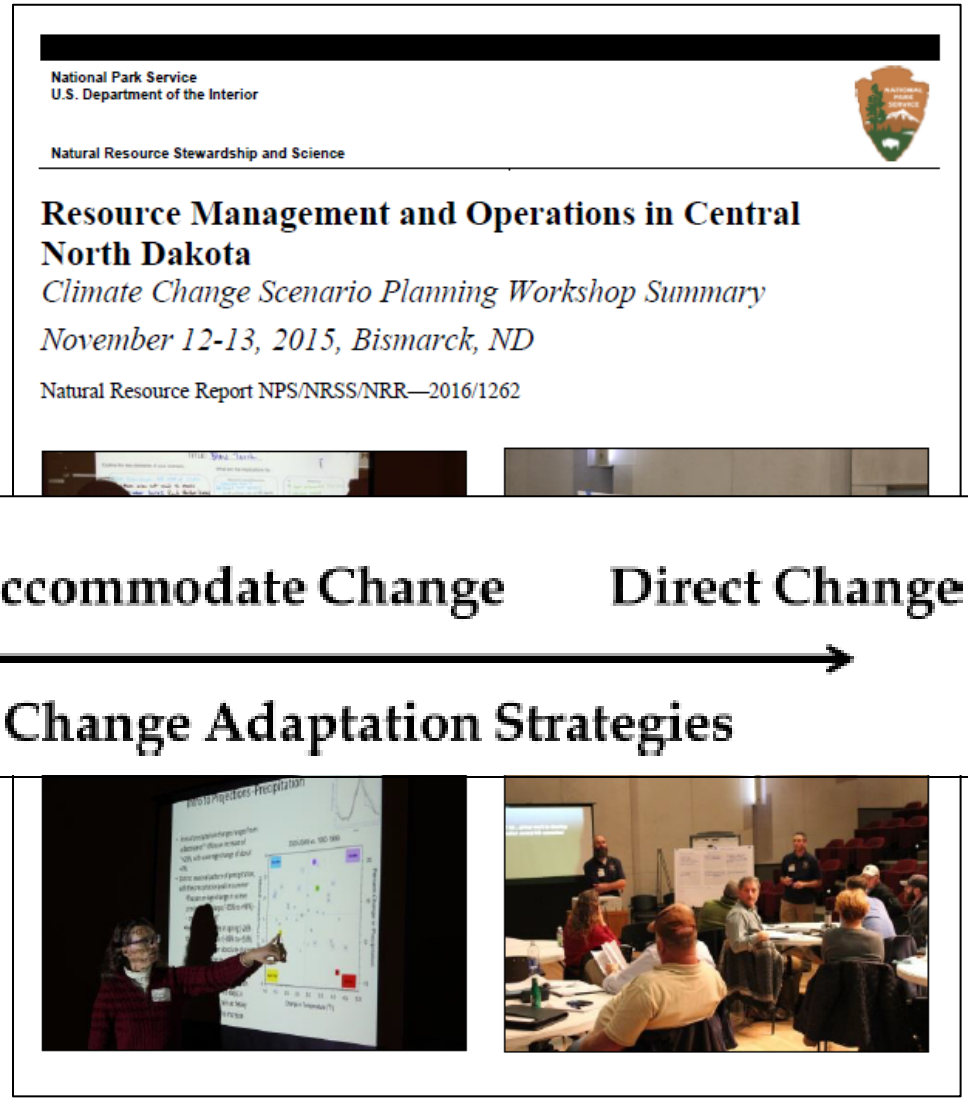
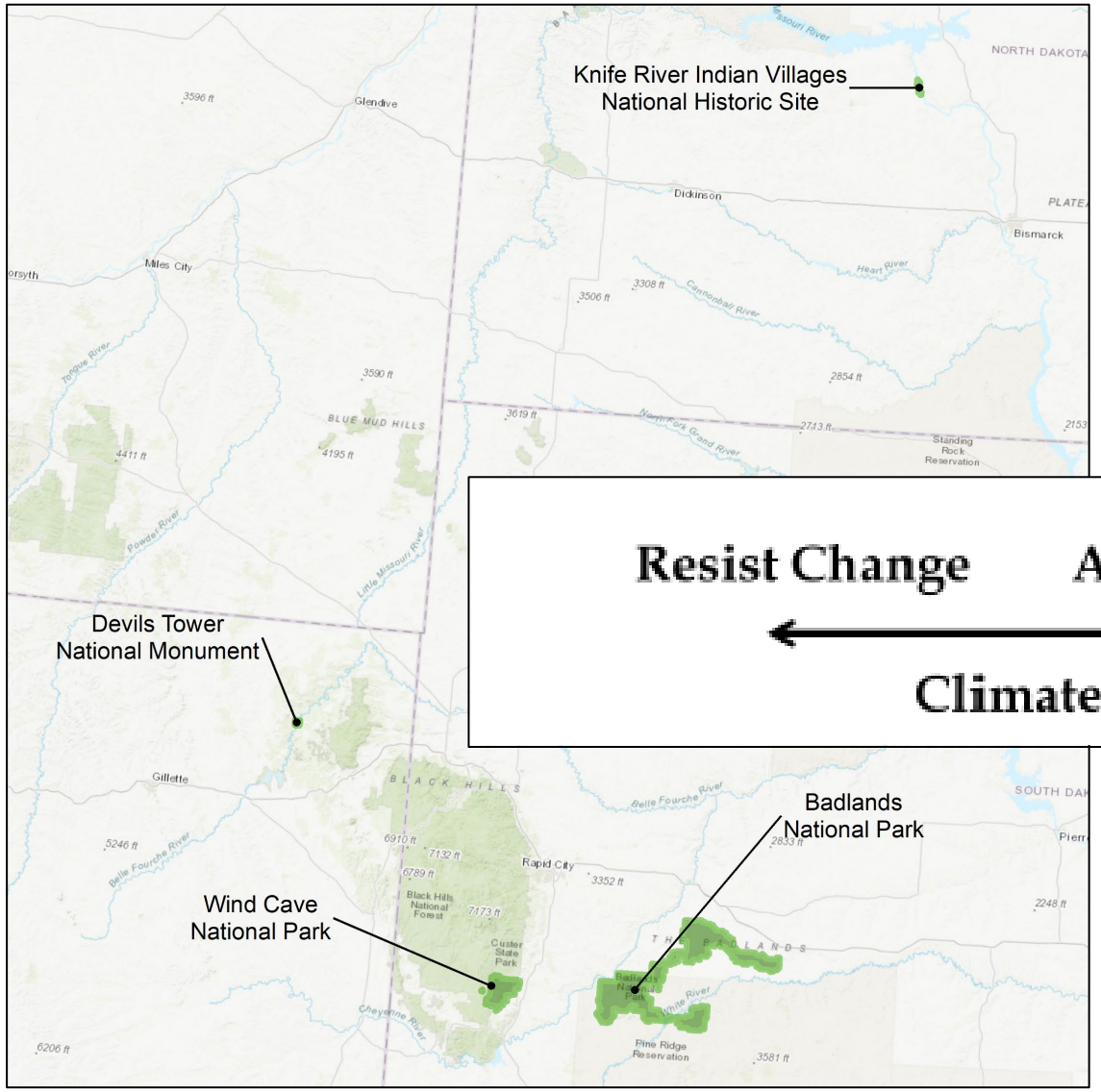




Resist Change **Accommodate Change** **Direct Change**

Climate Change Adaptation Strategies

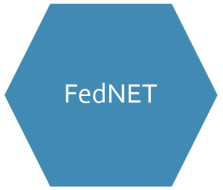
NC CASC-funded project to advance adaptation in the northern Great Plains (2015-2019)



Resist Change **Accommodate Change** **Direct Change**

Climate Change Adaptation Strategies

Federal Navigating Ecological Transformation (FedNET) working group (2017-present)



Federal Navigating Ecological Transformation (FedNET) working group (2017-present)

"existing agency guidance does not anticipate rapid, directional, transformative ecological changes that are currently underway."

"develop a shared science-based framework from which land management entities may derive guidance for managing changing conditions, including wide-ranging changes that may result in ecological transformation of ecosystems - while considering how each entity's parcels fit into the overall system."

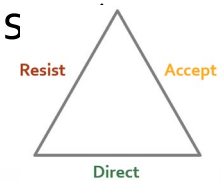
Federal Navigating Ecological Transformation (FedNET) working group (2017-present)

WHEN RESISTANCE IS FUTILE: ADAPTATION IN THE FACE OF SYSTEM TRANSFORMATION (Meeting Room 5)

Symposium Organizer: Bruce Stein, National Wildlife Federation

Accelerating climate change is already beginning to transform the structure, composition and function of ecosystems, with attendant consequences for the services and benefits these systems provide to people. Unfortunately, much of the climate adaptation currently underway still focuses on efforts to resist change as a means of retaining the persistence of current conditions. Natural resource managers increasingly will be confronted by situations where such persistence-oriented approaches are untenable: in other words, when resistance is futile. This symposium will focus on adaptation in the context of change management, and specifically the challenges of preparing for and adapting to system realignments and transformations. The session will address the conceptual basis for transformation-oriented adaptation, including the challenges of identifying ecological thresholds and tipping points, and the cyclical nature of managing for persistence and change. Symposia talks will also review the historical context for ecosystem transformation, drawing lessons from the paleo record and major ecological transitions in the past. Finally, the symposium will focus on a system undergoing major ecological transformations, and explore various management options for responding to, or even facilitating, such transitions, along with policy issues that may constrain or promote such change-oriented responses.

Federal Navigating Ecological Transformation (FedNET) working group (2017-pres



INCREASINGLY DIFFICULT AND PERHAPS SOMETIMES FUTILE

WHEN RESISTANCE IS ~~FUTILE~~: ADAPTATION IN THE FACE OF SYSTEM TRANSFORMATION (Meeting Room 5)

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Federal Navigating Ecological Transformation (FedNET) working group (2017-present)

FedNET

Last Name	First Name	Organization
Bamzai	Aparna	USGS
Carr	Wylie	NPS Climate Change Response Program
Clifford	Katie	USGS
Cole	David	retired, Leopold Wilderness Ctr
Covington	Scott	USFWS
Crausbay	Shelley	NC Climate Adaptation Science Ctr
Cravens	Amanda	USGS
Hawkins Hoffman	Cat	NPS Climate Change Response Program
Hoang	Linh	USFS
Hudson	Mike	USFWS
Jackson	Steve	USGS
Lawrence	Dave	NPS Climate Change Response Program
Magness	Dawn	USFWS
Morrison	Wendy	NOAA/NMFS
Morton	John	retired; USFWS
O'Malley	Robin	retired; USGS
Peterson	Dave	retired, USFS
Peterson	Jay	NOAA
Prentice	Karen	BLM
Reynolds	Joel	NPS Climate Change Response Program
Rittenhouse	Bruce	BLM
Ross-Winslow	Danielle	USFWS Social Science
Schuurman	Gregor	NPS Climate Change Response Program
Stephenson	Nate	retired; USGS

Federal Navigating Ecological Transformation (FedNET) working group (2017-present)

FedNET

NEWS RELEASE

Resist-Accept-Direct (RAD)

A Framework for the 21st-century Natural Resource Manager

Cole et al. (2011) foresee "the future elimination of Joshua tree throughout most of the southern portions of its current range," thus invalidating a past premise of stability of the Joshua tree as a climax species.

NPS / Emily Hassell

News Release Date: January 19, 2021

Contact: Jeff Olson

The National Park Service and several federal land management agency partners recently published a report titled ***Resist-Accept-Direct (RAD)—A Decision Framework for the 21st-century Natural Resource Manager***. The report presents and explores a simple set of distinct management options that decision makers can consider when responding to ecosystems facing the potential for rapid, irreversible ecological change. In so doing, the report provides a framework that encourages natural resource managers to consider strategic, forward-looking actions, rather than structure management goals based on past conditions.

National Park Service
U.S. Department of the Interior

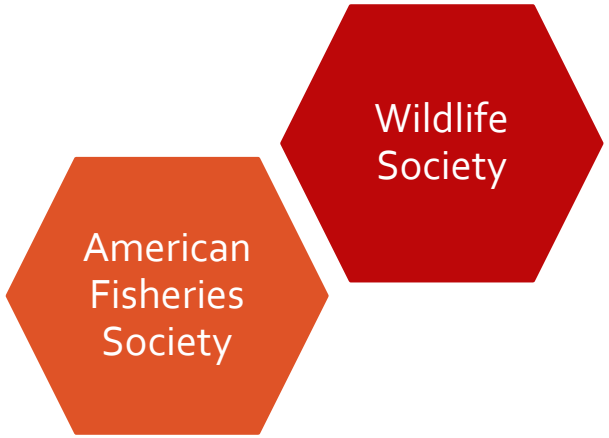
Natural Resource Stewardship and Science

Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager

Natural Resource Report NPS/NRSS/CCRP/NRR—2020/ 2213

https://irma.nps.gov/DataStore/DownloadFile/654543

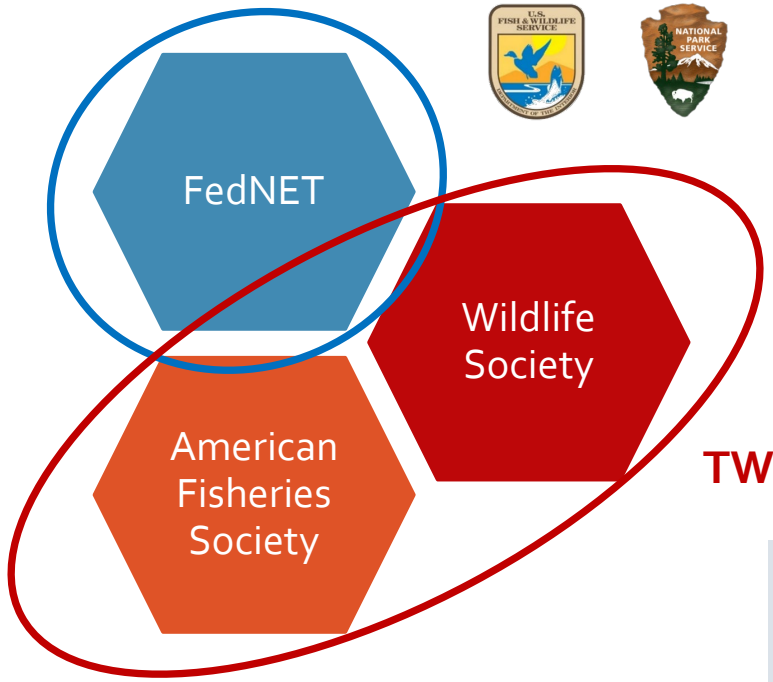
TWS-AFS Ecosystem Transformation working group (2018 onward)



TWS-AFS Ecosystem Transformation Working Group

FedNET-TWS/AFS collaboration

Federal Navigating Ecological Transformation Working Group



TWS-AFS Ecosystem Transformation Working Group

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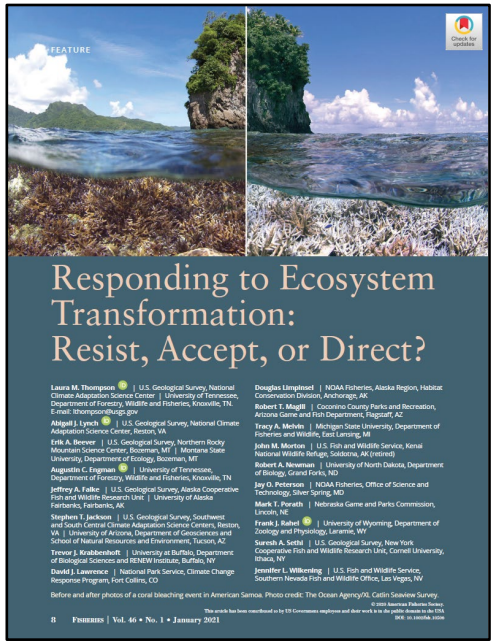
Schuurman	Gregor	NPS Climate Change Response Program
Stephenson	Nate	retired; USGS

Wildlife Society

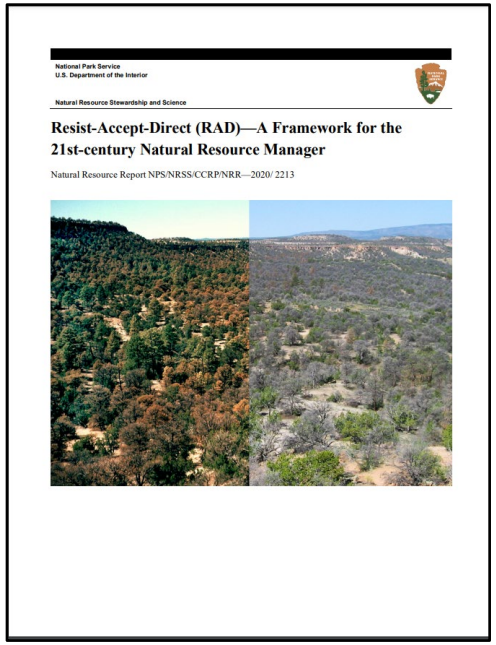
American Fisheries Society

Last name	First name	Organization
Beever	Erik	USGS
Clifford	Michael	The Nature Conservancy
Engman	Gus	University of Tennessee
Falke	Jeff	USGS; University of Alaska - Fairbanks
Jackson	Steve	USGS
Krabbenhoft	Trevor	University of Buffalo
Lawrence	David	NPS Climate Change Response Program
Limpinsel	Doug	NOAA
Lynch	Abby	USGS
Magill	Rob	Independent consultant
Melvin	Tracy	Michigan State University
Morton	John	retired, USFWS
Newman	Robert	University of North Dakota
Peterson	Jay	NOAA
Porath	Mark	Nebraska Game and Parks Commission
Rahel	Frank	University of Wyoming
Sethi	Suresh	USGS; Cornell University
Thompson	Laura	USGS
Wilkening	Jennifer	USFWS

Rapidly expanding body of **RAD** literature…



Thompson et al. 2020

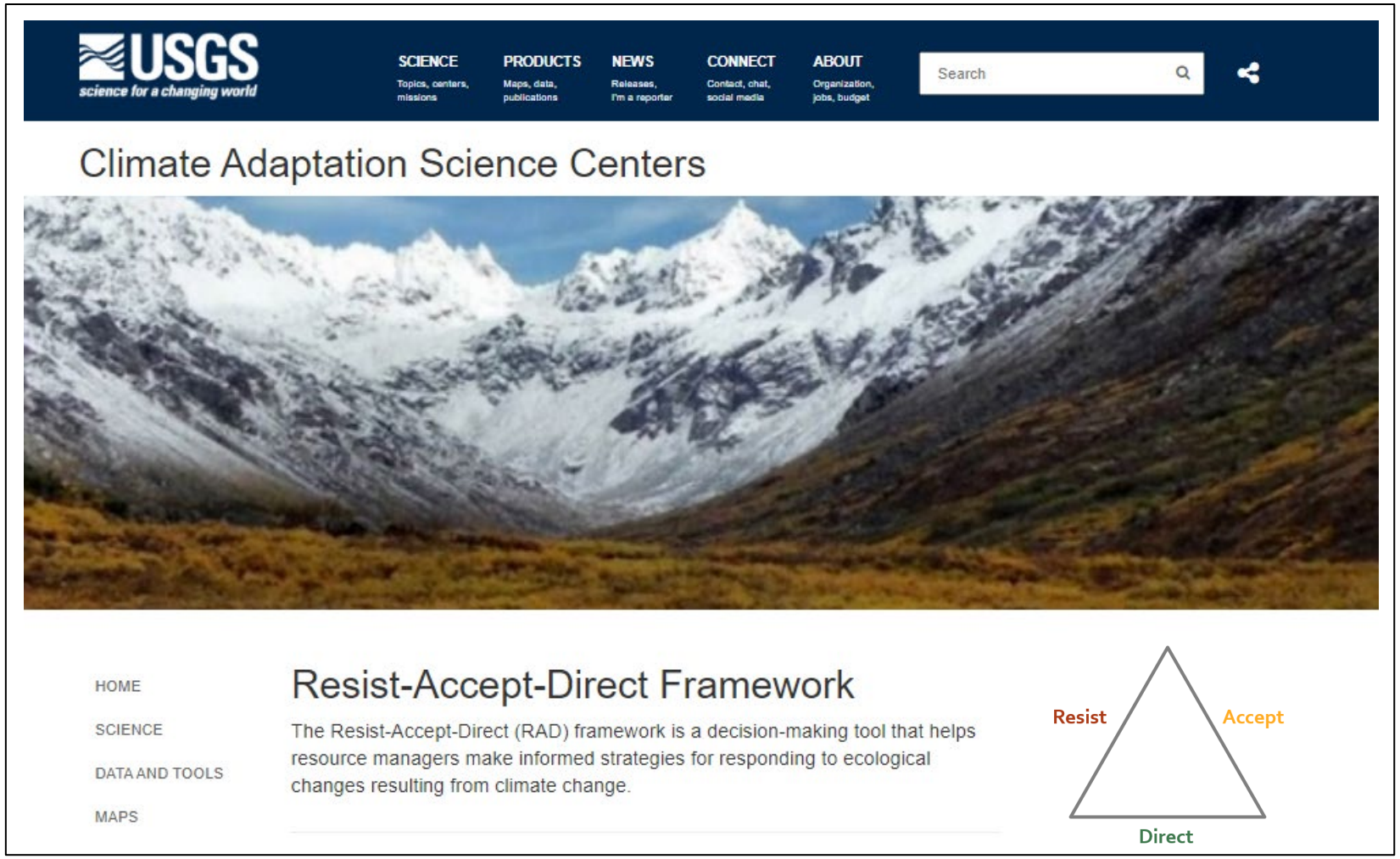


Schuurman et al. 2020

Lynch et al. 2021

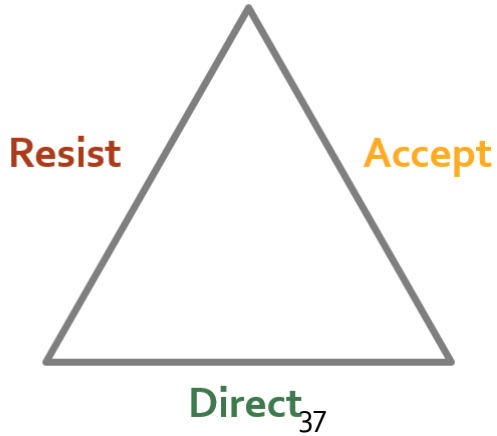
Published online today

Rapidly expanding body of **RAD** literature…



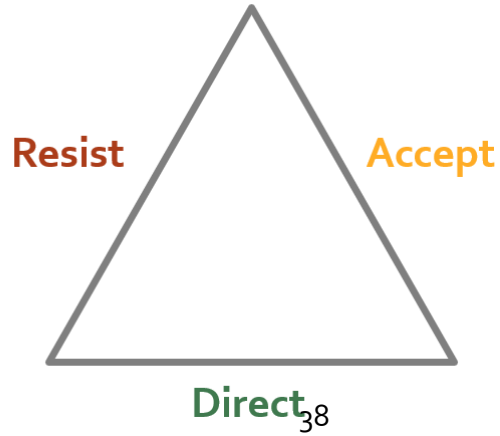
usgs.gov/casc/rad

Why is the RAD framework needed?



Why is the RAD framework needed?

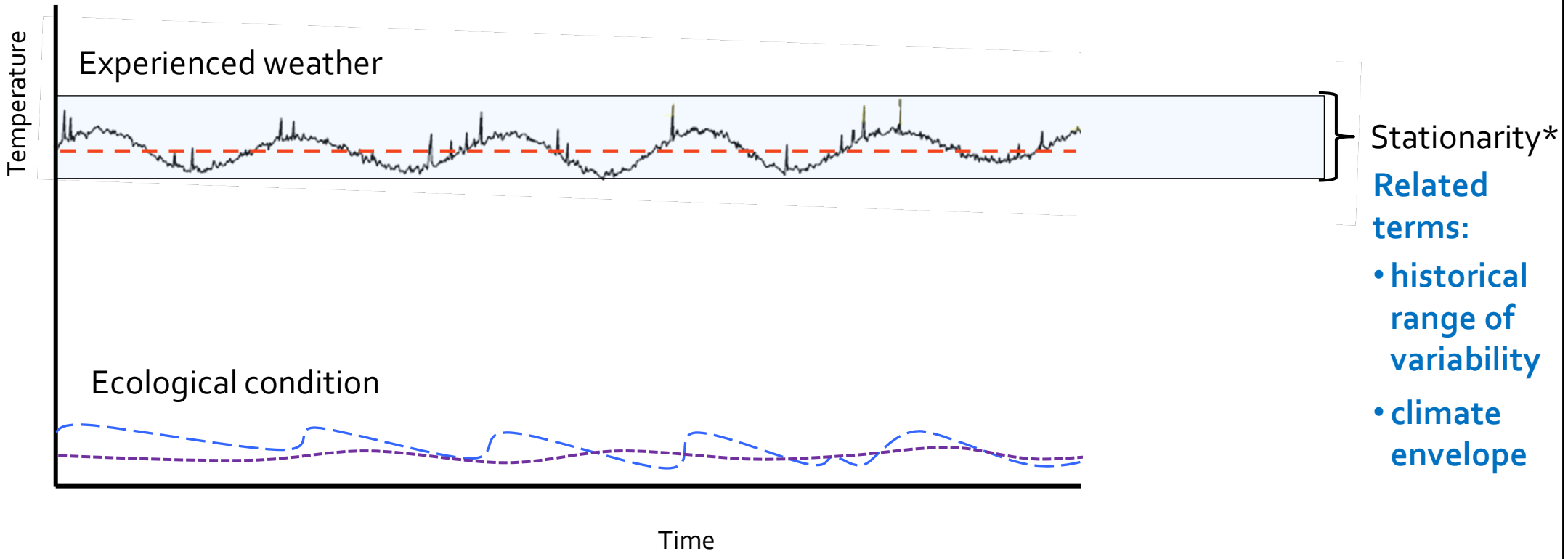
Answer: to help managers make unavoidable choices strategically



Modern human-driven ecological trajectories bring new choices and questions

Modern human-driven ecological trajectories bring new choices and questions

How climate change drives ecological change and transformations



* "the idea that natural systems fluctuate within an unchanging envelope of variability" (Milly et al. 2008. Stationarity is dead: Whither water management? Science 319: 573–574)

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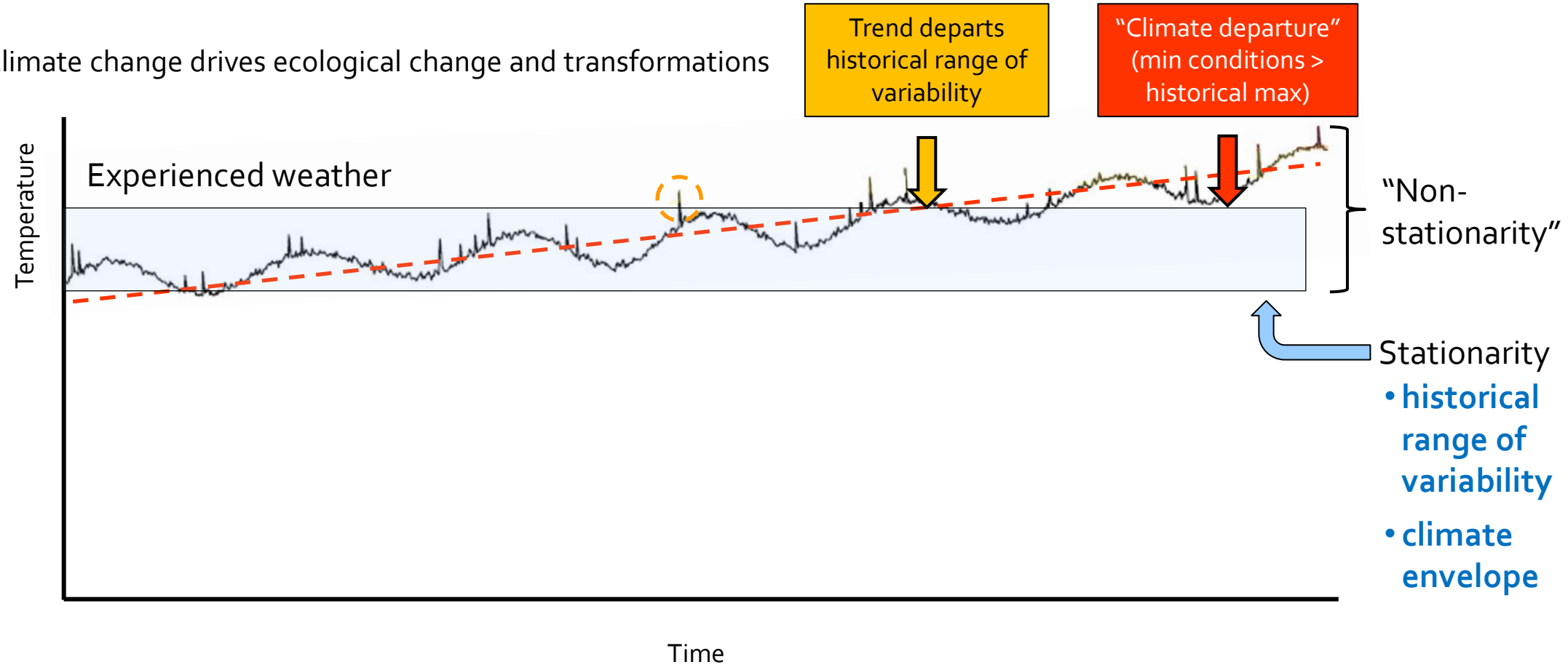

Modern human-driven ecological trajectories bring new choices and questions

How climate change drives ecological change and transformations

The Guardian

Seascape: the state of our oceans
Canada

Seascape: the state of our oceans is supported by

About this content

Leyland Cecco *in Toronto*

Thu 8 Jul 2021 05.00 EDT

'Heat dome' probably killed 1bn marine animals on Canada coast, experts say

▲ Dead mussels at the waterline in British Columbia. Photograph: Christopher Harley

British Columbia scientist says heat essentially cooked mussels: 'The shore doesn't usually crunch when you walk'

Modern human-driven ecological trajectories bring new choices and questions

How climate change drives ecological change and transformations

Drought is here to stay in the Western U.S. How will states adapt?

Drought "is not a temporary condition we can expect to go away, but rather something we have to deal with," one expert said.

Modern human-driven ecological trajectories bring new choices and questions

How climate change drives ecological change and transformations

https://theconversation.com/rocky-mountain-forests-burning-more-now-than-any-time-in-the-past-2-000-years-162383

Modern human-driven ecological trajectories bring new choices and questions

How climate change drives ecological change and transformations

Rocky Mountain subalpine forests now burning more than any time in recent millennia

Philip E. Higuera[a,1], Bryan N. Shuman[b], and Kyra D. Wolf[a]

[a]Department of Ecosystem and Conservation Sciences, University of Montana, Missoula, MT 59812; and [b]Department of Geology and Geophysics, University of Wyoming, Laramie, WY 82071

Higuera, P.E., Shuman, B.N. and Wolf, K.D., 2021. Rocky Mountain subalpine forests now burning more than any time in recent millennia. Proceedings of the National Academy of Sciences, 118(25).

Modern human-driven ecological trajectories bring new choices and questions

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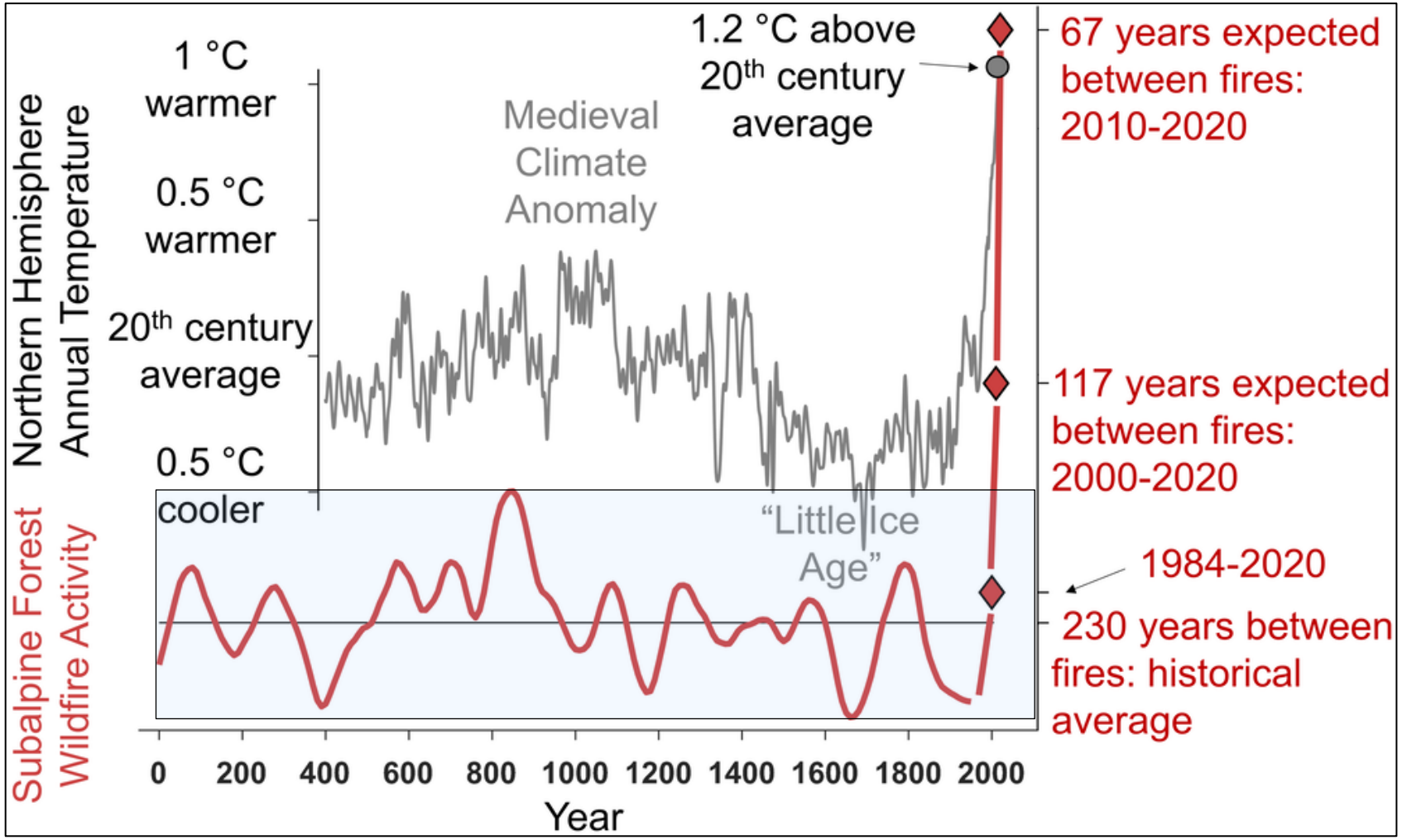

Historically, fires burned in the subalpine central Rockies every 230 years, on average. That has increased significantly in the 21st century. Philip Higuera

https://theconversation.com/rocky-mountain-forests-burning-more-now-than-any-time-in-the-past-2-000-years-162383

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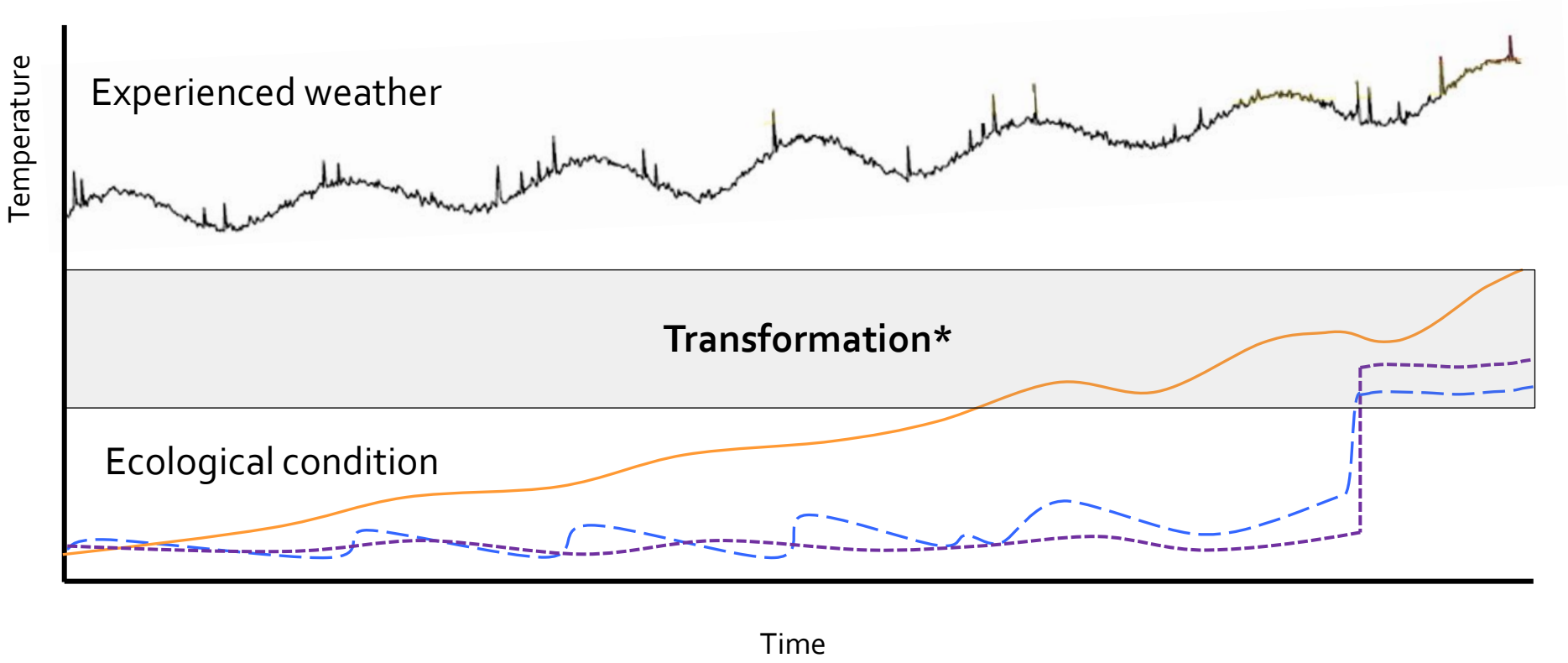


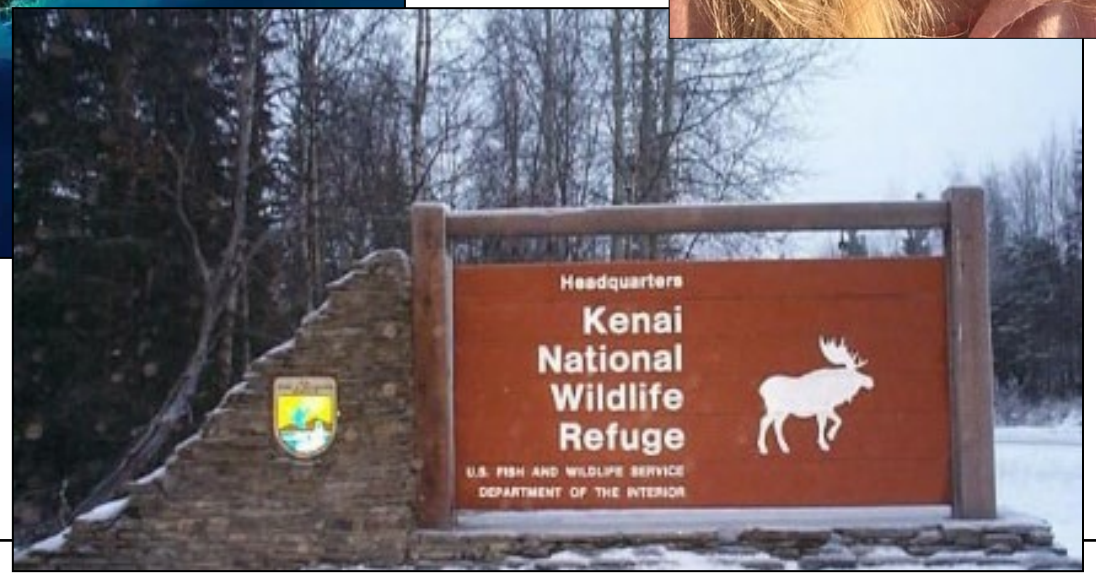
* Ecological transformation: "the dramatic and effectively irreversible shift in multiple ecological characteristics of an ecosystem, the basis of which is a high degree of turnover in ecological communities" (Schuurman et al. *in press*)

Modern human-driven ecological trajectories bring new choices and questions

Modern human-driven ecological trajectories bring new choices and questions

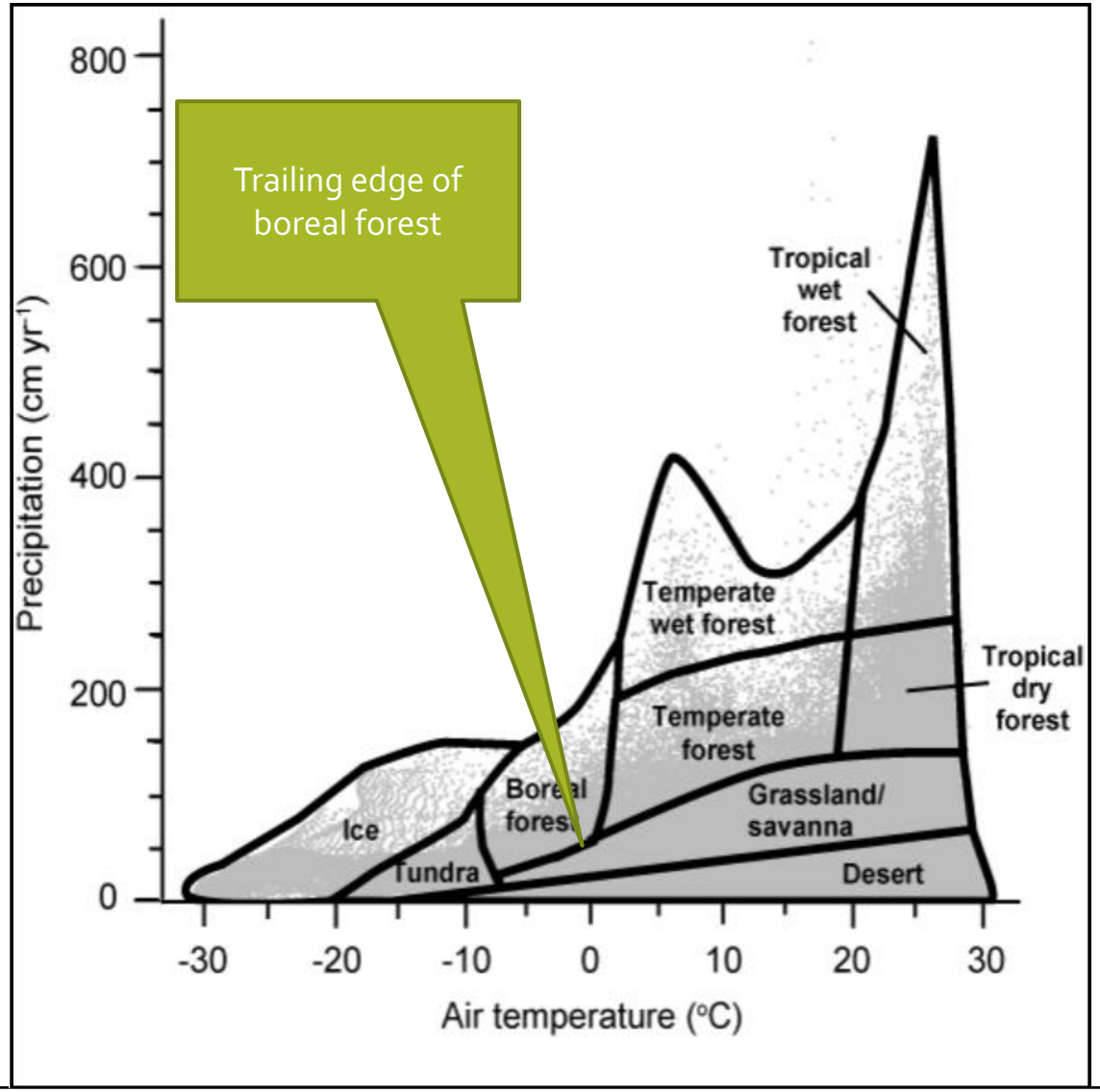
John Morton

Dawn Magness



Kenai case study slides courtesy of J. Morton and D. Magness

Modern human-driven ecological trajectories bring new choices and questions



Staudinger et al. 2012. Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment. Cooperative Report to the 2013 National Climate Assessment.

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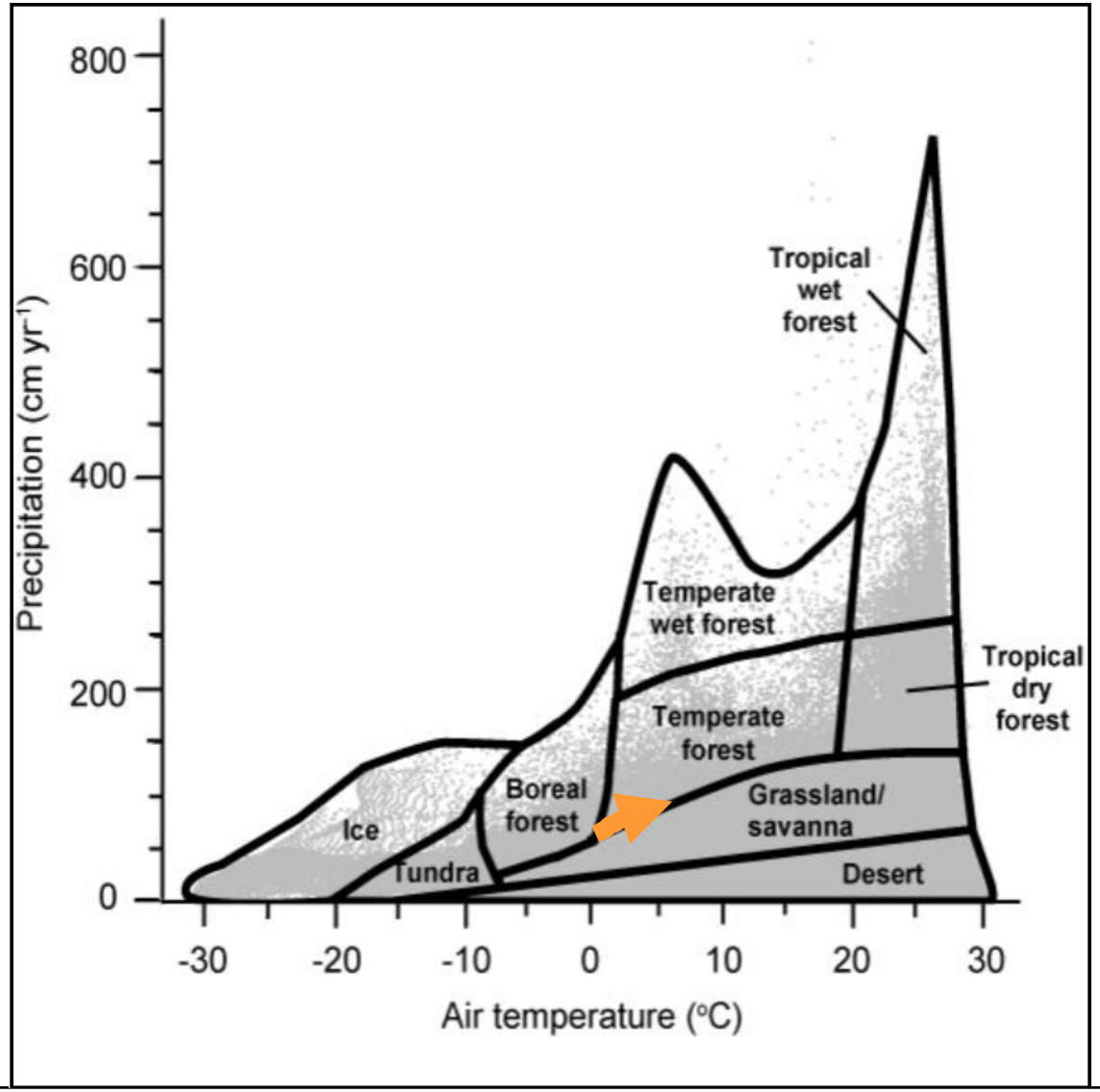

1900 - 68 cm, 2.3° C

1980 - 73 cm, 3.3 ° C

2090 - 84 cm, 6.8 ° C

Staudinger et al. 2012. Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment. Cooperative Report to the 2013 National Climate Assessment.

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Potential responses to ecological transformation on the Kenai National Wildlife Refuge

Modern human-driven ecological trajectories bring new choices and questions

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Q: Can the change be reversed or resisted?

Modern human-driven ecological trajectories bring new choices and questions

Potential responses to ecological transformation on the Kenai National Wildlife Refuge

Q: Can the change be reversed or resisted?
A: Think about scale, directional climate change, and ecological uncertainty.

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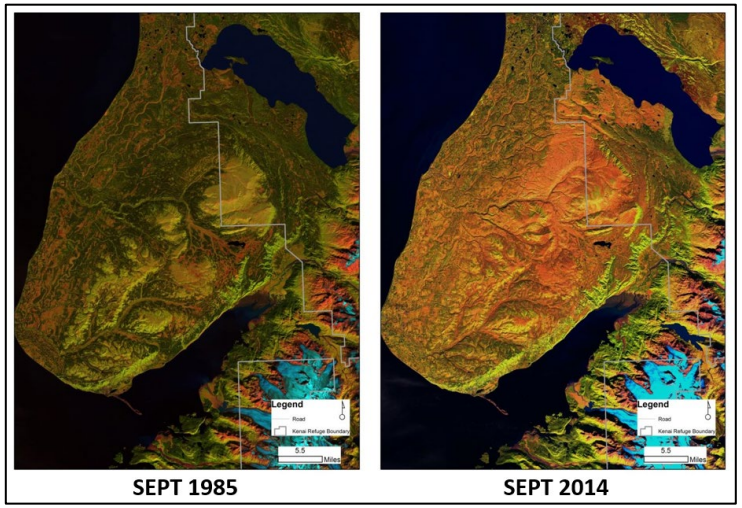

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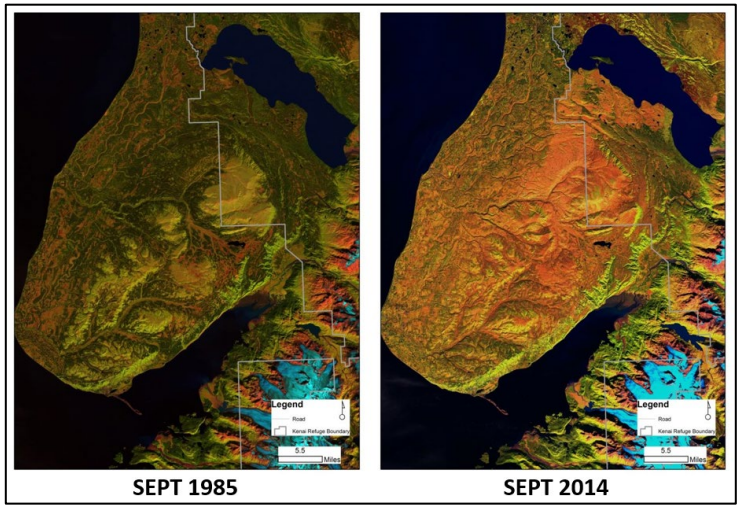

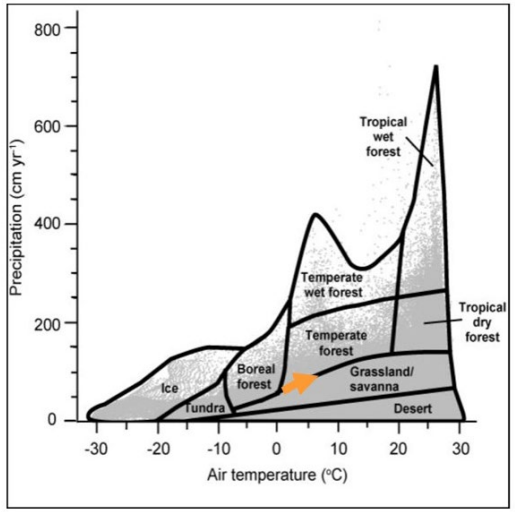

Modern human-driven ecological trajectories bring new choices and questions

Potential responses to ecological transformation on the Kenai National Wildlife Refuge

Q: What happens if we accept the trajectory? Where is it going?

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Potential responses to ecological transformation on the Kenai National Wildlife Refuge

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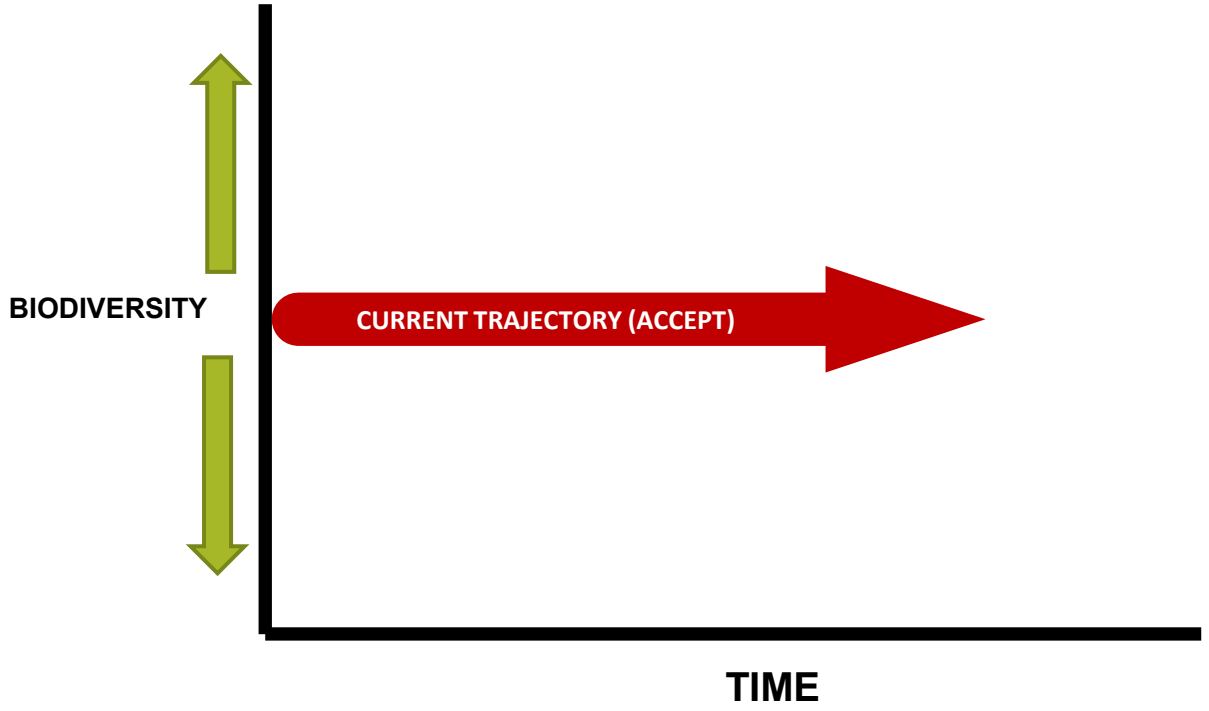
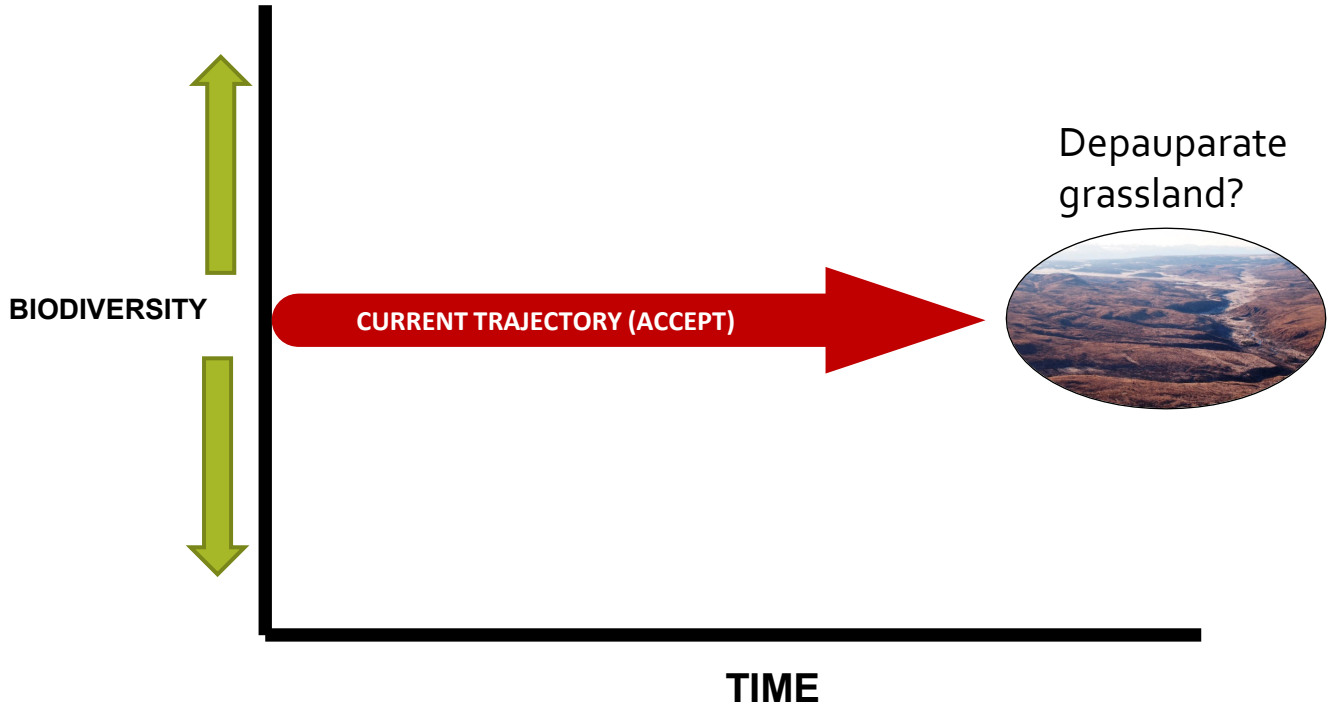


Modern human-driven ecological trajectories bring new choices and questions

Potential responses to ecological transformation on the Kenai National Wildlife Refuge

Q: What happens if we accept the trajectory? Where is it going?
A: We don't really know (this is a novel circumstance).



Modern human-driven ecological trajectories bring new choices and questions

Potential responses to ecological transformation on the Kenai National Wildlife Refuge

Q: Can we try to direct this ecological trajectory?

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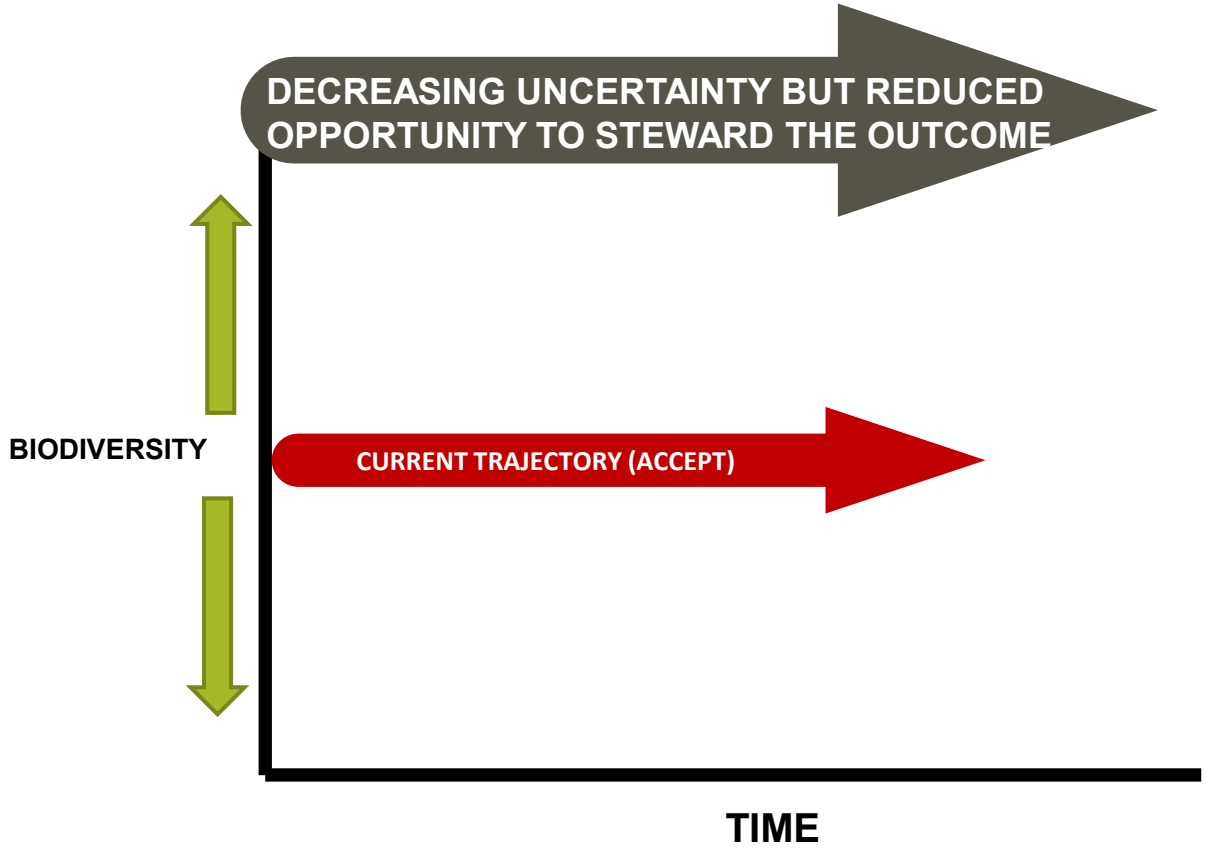

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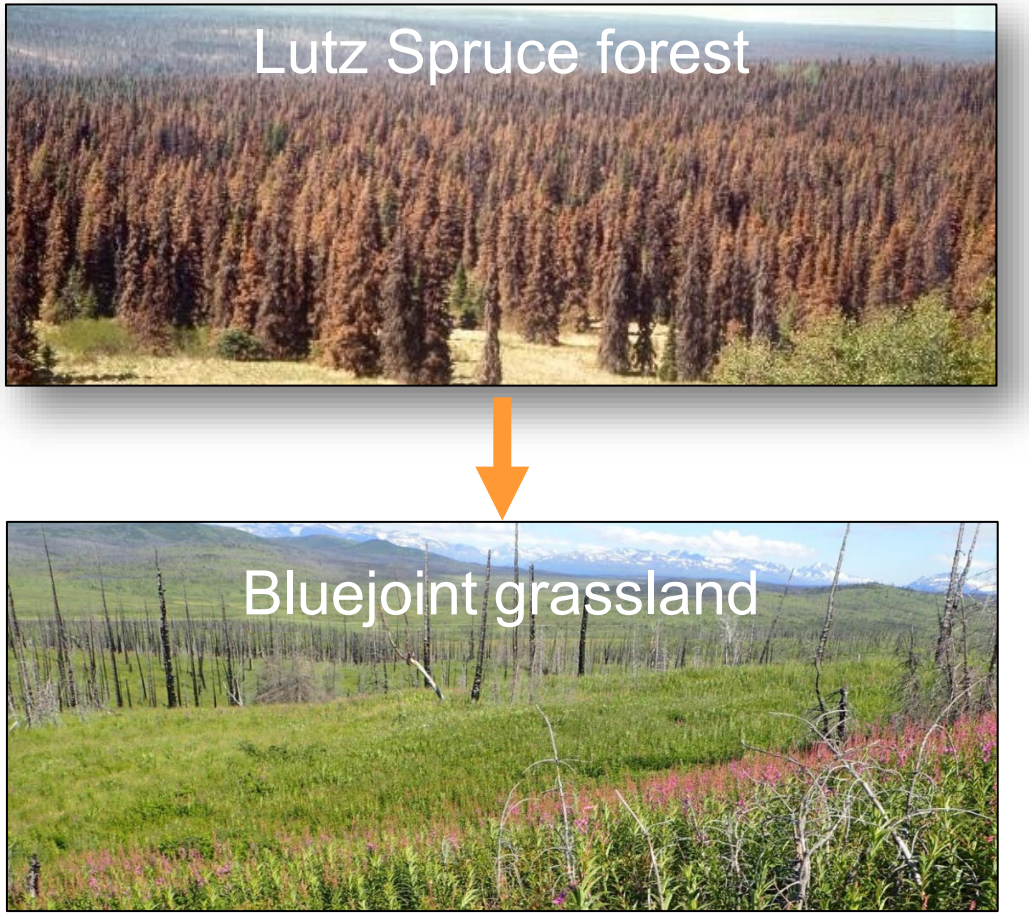
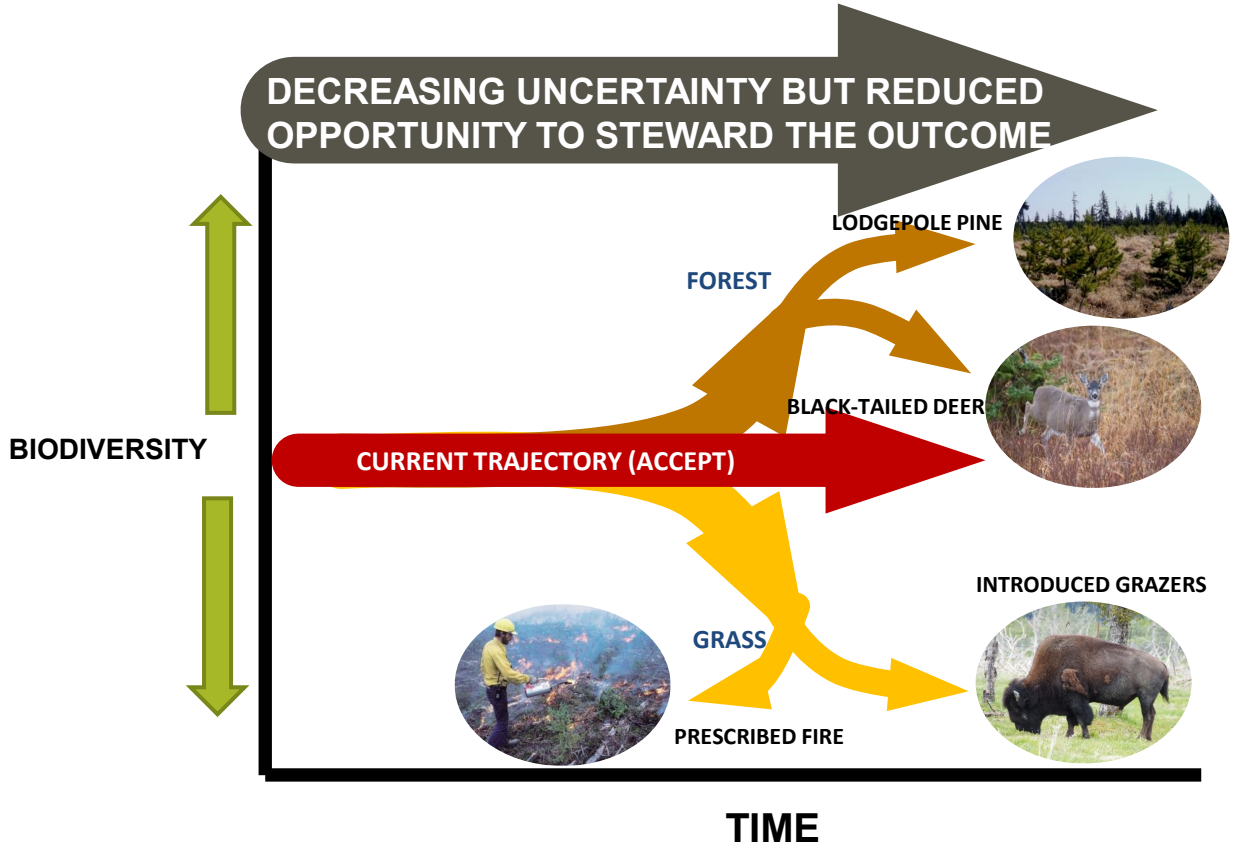


Potential responses to ecological transformation on the Kenai National Wildlife Refuge

Q: Can we try to direct this ecological trajectory?

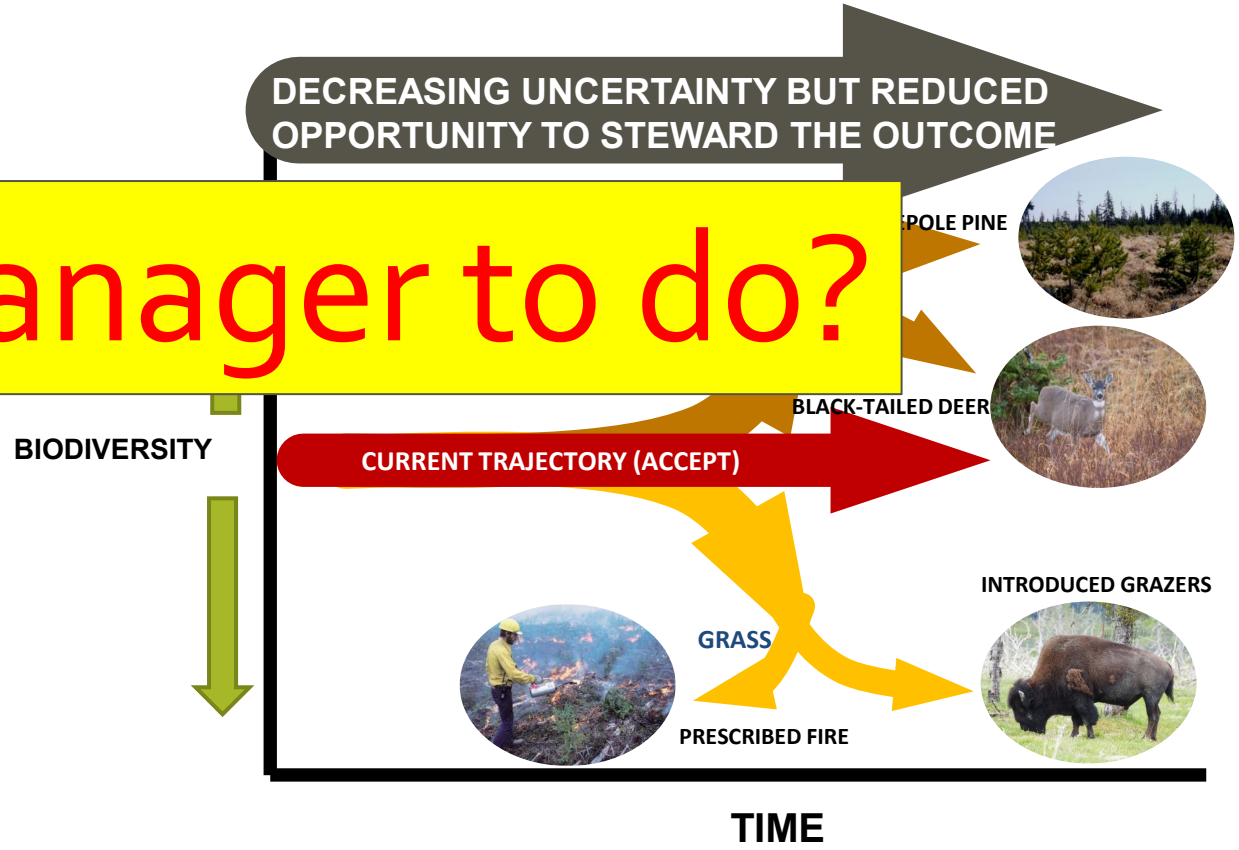
A: Yes, in fact, neighbors are already doing some of this.



Modern human-driven ecological trajectories bring new choices and questions

Potential responses to ecological transformation on the Kenai National Wildlife Refuge

What's a manager to do?



What does RAD framework application look like?

RAD natural resource management in action

U.S Fish and Wildlife Service

National Conservation Training Center

Training Announcement

Thinking About Adaptation: Exploring the Resist-Accept-Direct Framework

Case Studies and Panel Discussion

Date
June 22, 2021 2:00-3:30 PM EST

Who Should Attend
The course is highly recommended to managers, biologists, other natural resource professionals who are interested in responding to climate change.

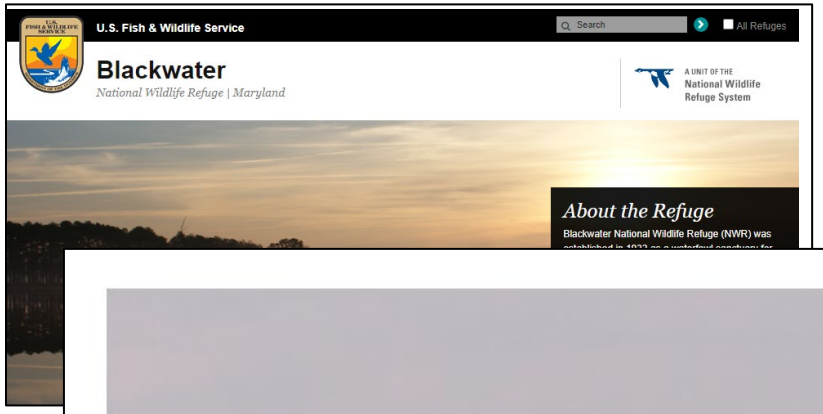
Tuition
There is no cost to attend.

To Join
https://livestream.com/nctc

Contact
Danielle Bruce,
danielle_bruce@fws.gov

https://fws.rev.vbrick.com/#/videos/3d468dcb-47bf-4f43-8cc8-efeceoda832a

RAD natural resource management in action



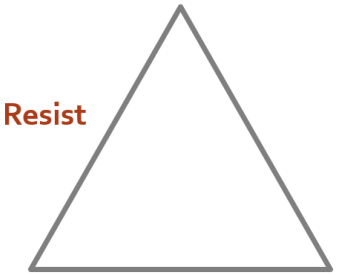
Building up a portion of marsh at Blackwater National Wildlife Refuge with sediment from the Blackwater River. (Photo: Middleton Evans)

Marsh Management

The overarching purpose of marsh management is to develop and promote strategies for tidal marsh adaptation to sea level rise. Blackwater NWR is a Refuge at risk. Since the 1930s, over 8,000 acres of marsh have been lost at Blackwater. That's a rate of 150 acres lost per year. Causes of marsh loss include sea level rise, erosion, subsidence, salt water intrusion and invasive species. The marsh's natural ability to build elevation cannot keep up with sea level rise.

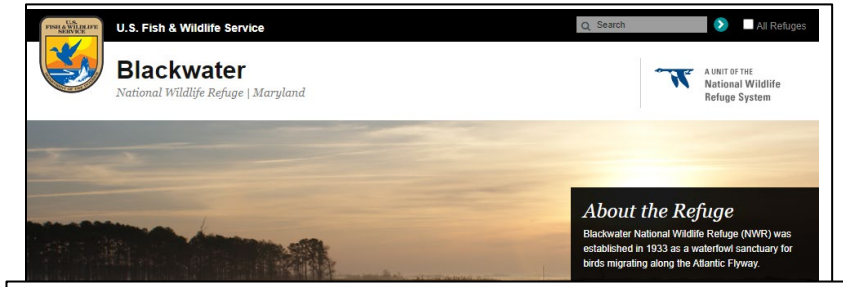
Ongoing efforts to save the marsh include:

- Reducing the population of resident Canada geese, which devour newly-planted crops and marsh plants
- Restoration and protection of brackish marsh Habitat
- Blackwater River thin layer spraying project
- Shoreline stabilization and marsh enhancement
- Use of on-site material for marsh restoration
- Acquisition/protection of priority marsh areas and adjacent upland buffers
- Nutria Eradication Program
- Phragmites control
- Facilitate migration of marsh habitats
- Reducing saltwater intrusion



https://www.fws.gov/refuges/wildlife-conservation/climate-change.html

RAD natural resource management in action



Removing trees to promote marsh growth, Blackwater National Wildlife Refuge. (Photo: Erik J. Meyers/The Conservation Fund)

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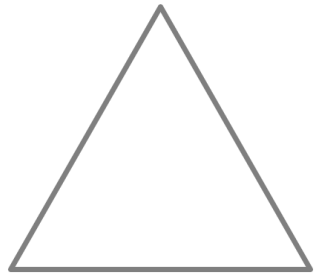
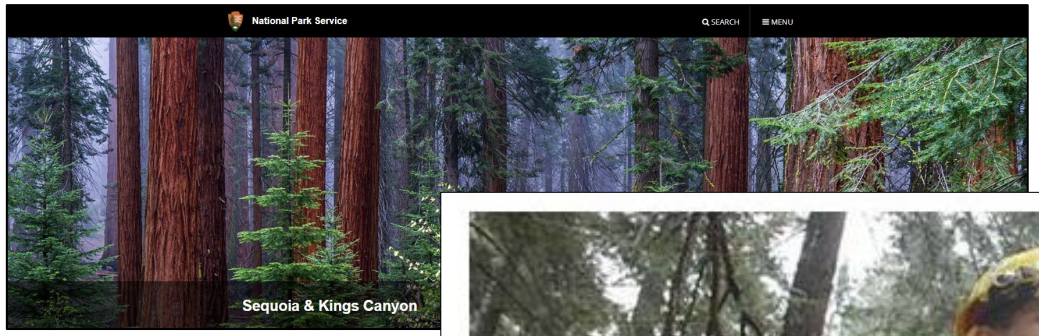
- Facilitate migration of marsh habitats
- Reducing saltwater intrusion



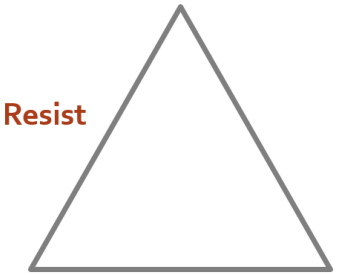
Direct

https://www.fws.gov/refuges/wildlife-conservation/climate-change.html

RAD natural resource management in action



Fire fighter Luis Magana stands guard at General Grant tree at Grant Grove in Kings Canyon National Park, California. Photograph: Gary Kazanjian/AP



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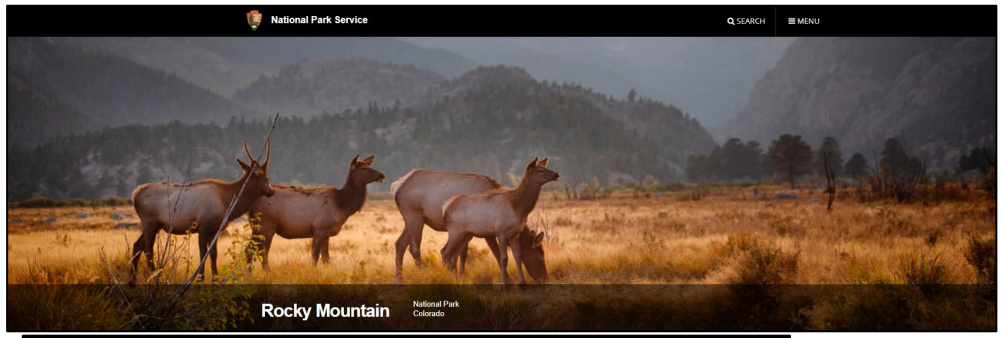
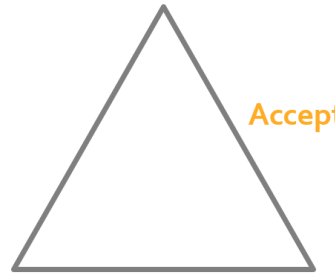
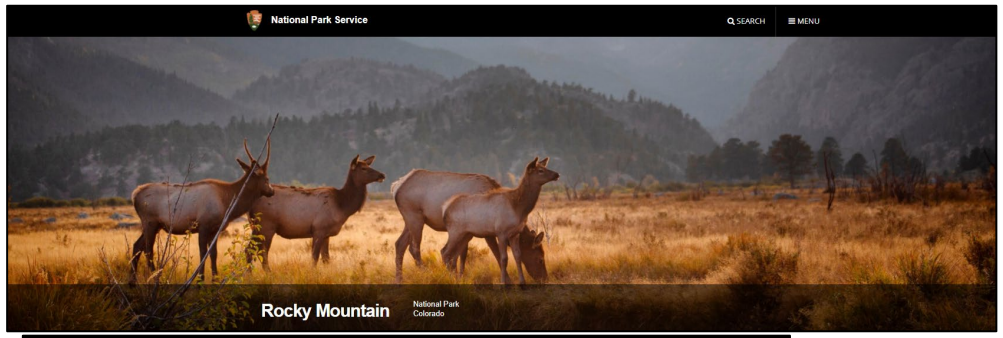
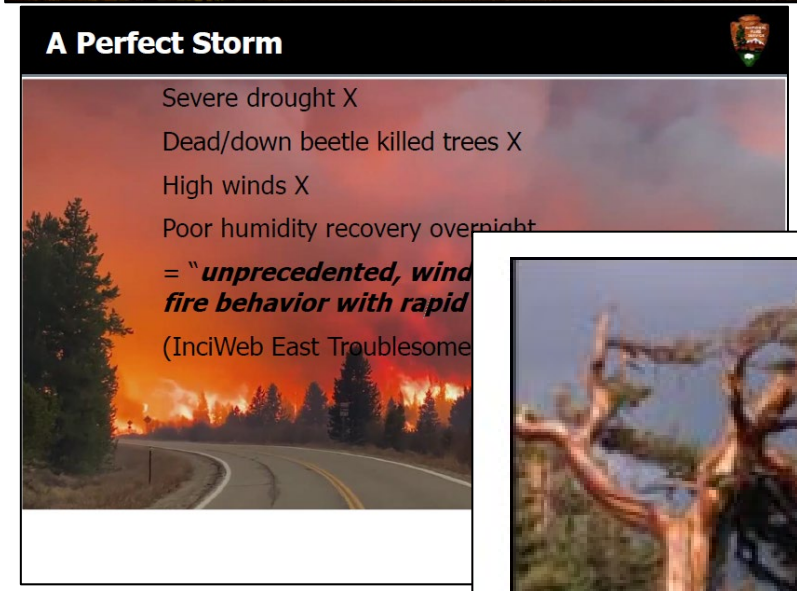
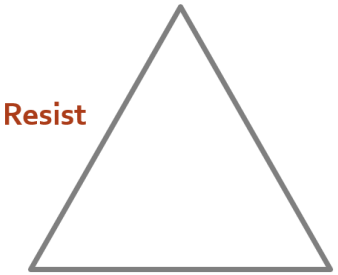




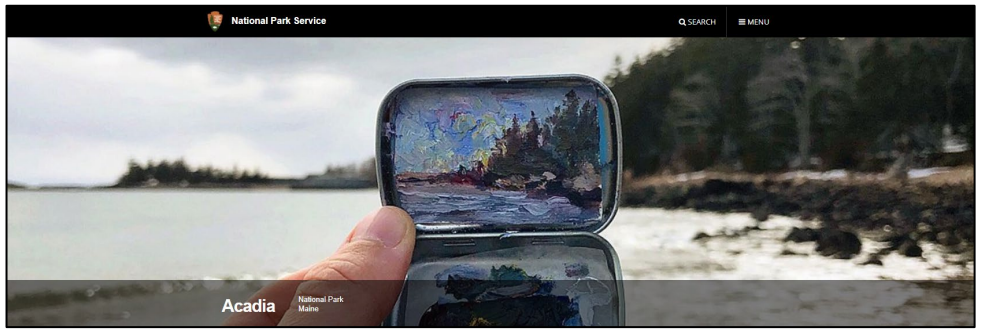
RAD natural resource management in action





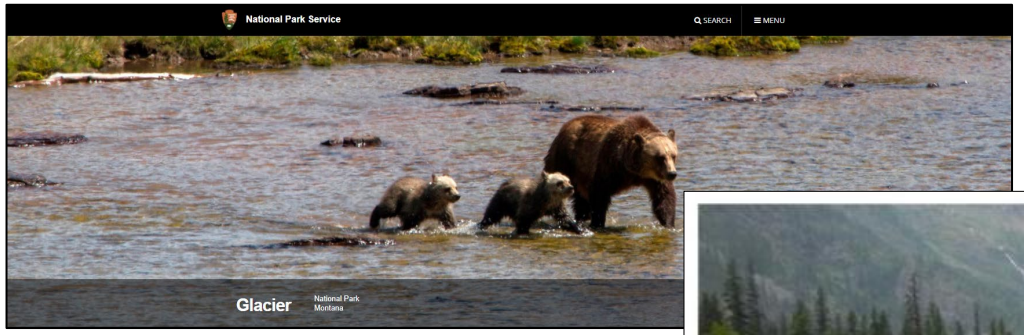


RAD natural resource management in action



Direct

RAD natural resource management in action

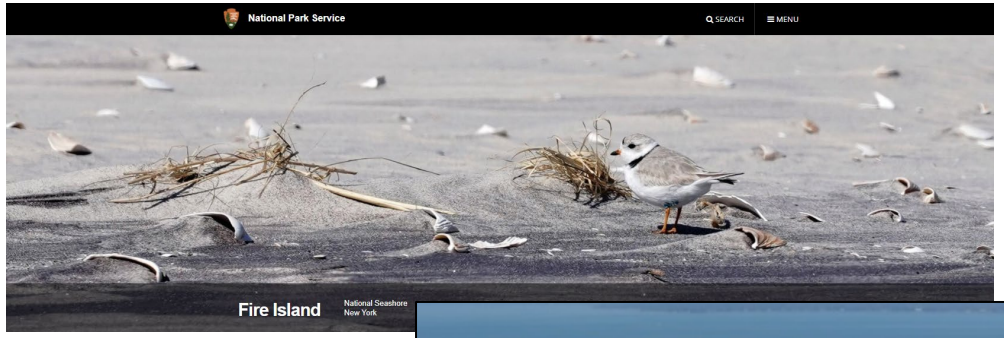


Fisheries biologist Jon McCubbins releases the first juvenile bull trout from 2014 into Logging Creek upstream of Grace Lake — the new bull trout Shangri-La.

Courtesy of Chris Downs/National Park Service

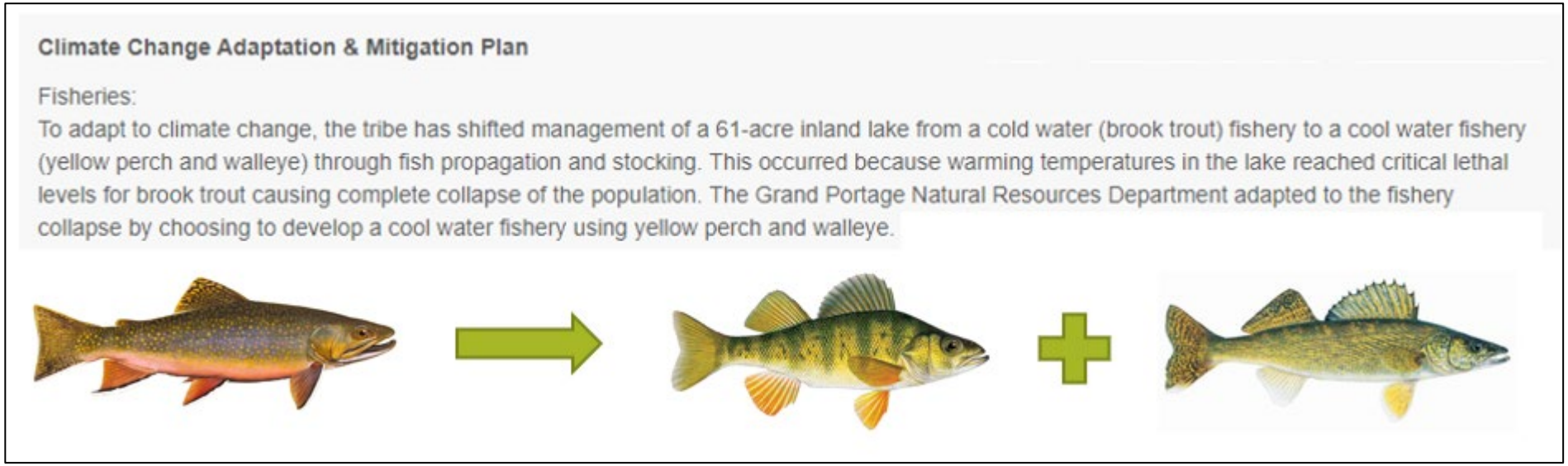
Direct

RAD natural resource management in action

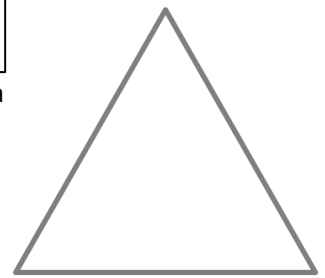


Accept

RAD natural resource management in action



https://www7.nau.edu/itep/main/tcc/Tribes/gl_gpchippewa



Direct

What next?

What next?

Scaling up

U.S. Fish and Wildlife Service

Search...

Climate Change

National Wildlife Refuge System

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A Response Framework

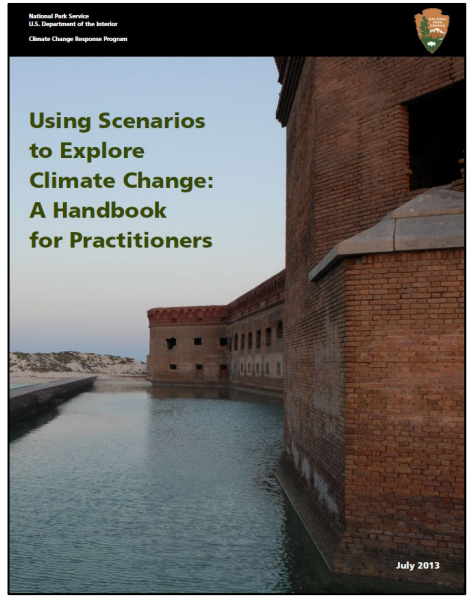
The Resist-Accept-Direct framework allows managers to choose from three management responses:

- **Resist** the direction of change, by working to maintain or restore function, structure or composition, based on historical or acceptable current conditions. To **resist** means to return a system to its historical condition.
- **Accept** the direction of change, by allowing the change to occur without intervening. To **accept** is to allow nature to change conditions without any management response.
- **Direct** the change, by actively shaping managing processes, function, structure or composition toward a new desired condition. To **direct** is to take management actions to forcefully move a system toward some condition that humans find desirable.

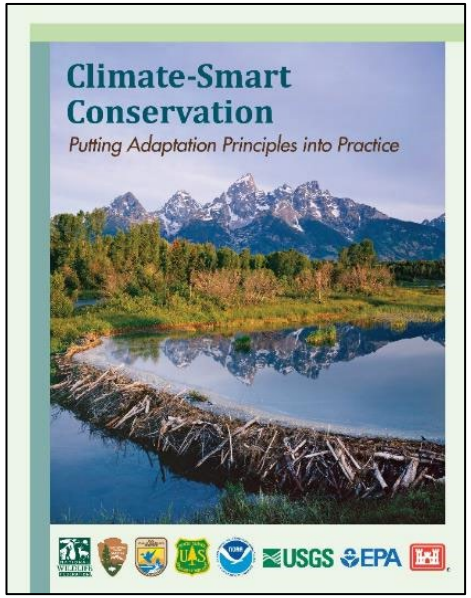
Landscapes in Flux | Managing for Change | A Response Framework |
Case Study: Blackwater National Wildlife Refuge |
Resist-Accept-Direct Resources | Other Agencies Addressing Climate Change

https://www.fws.gov/refuges/wildlife-conservation/climate-change.html

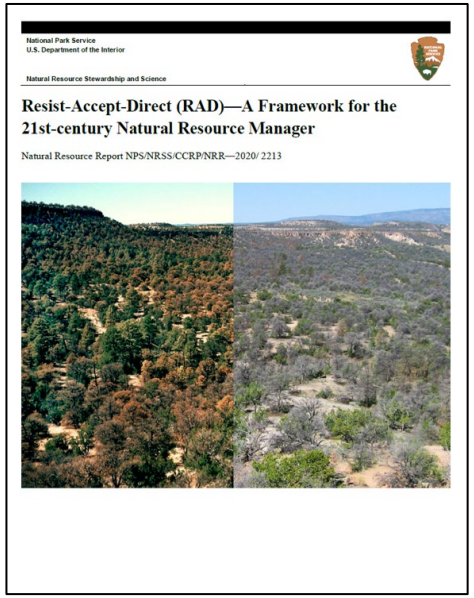
2013



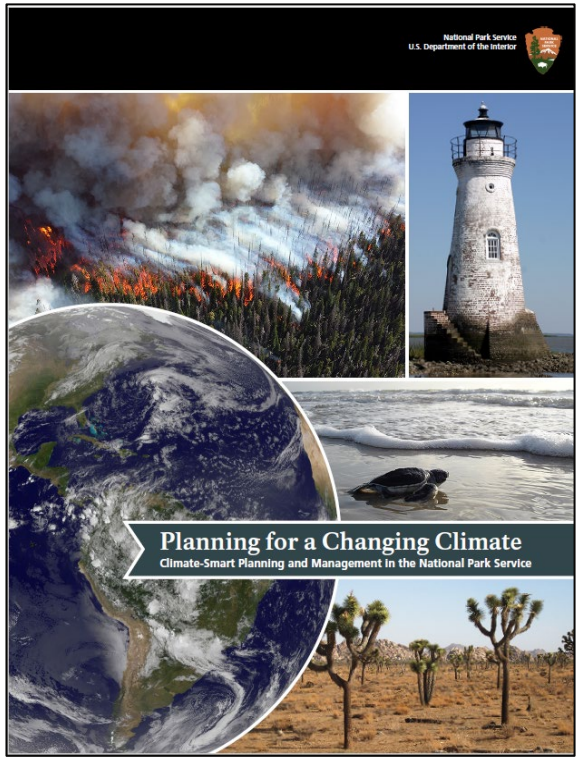
2014

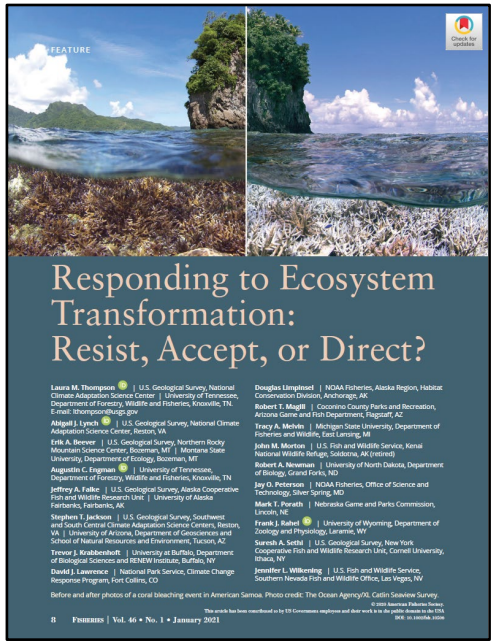


2020

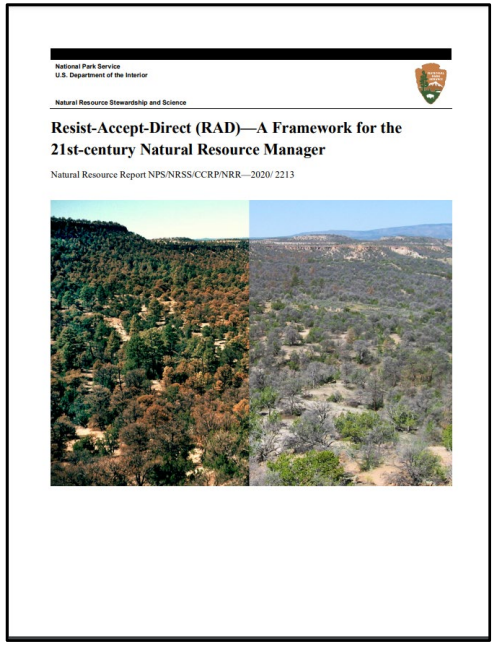


2021





Thompson et al. 2020



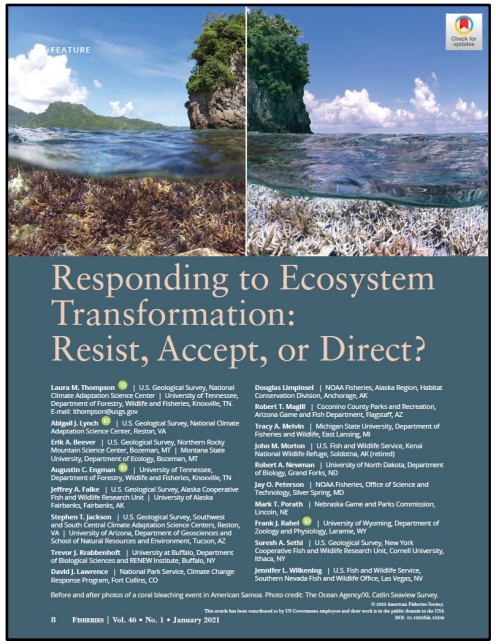
Schuurman et al. 2020

Lynch et al. 2021
Coming 6 July 2021

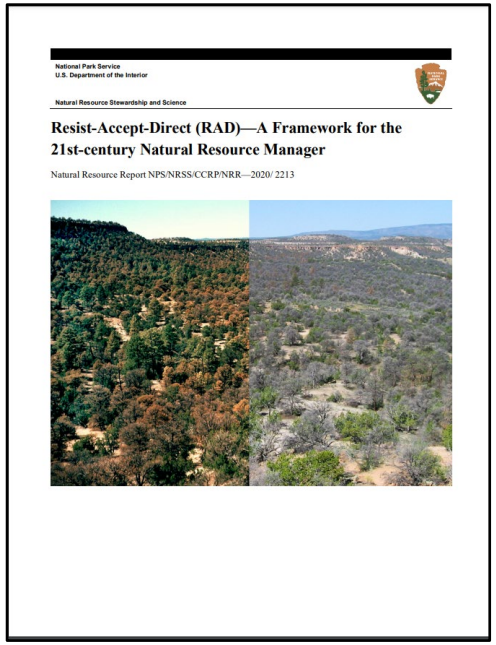
RAD special issue

In review

The body of RAD literature is rapidly expanding



Thompson et al. 2020



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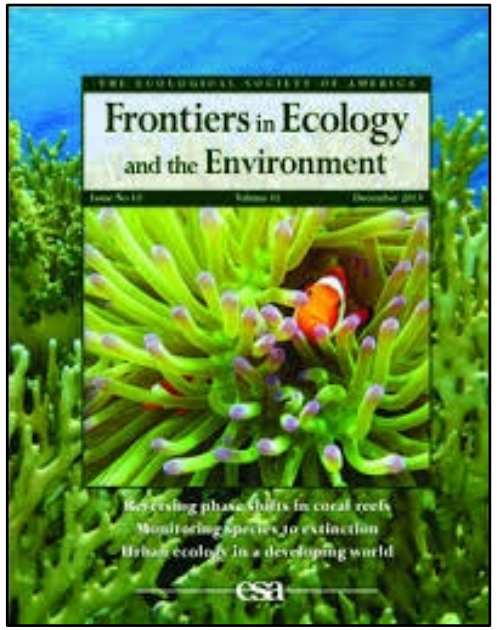

Lynch et al. 2021

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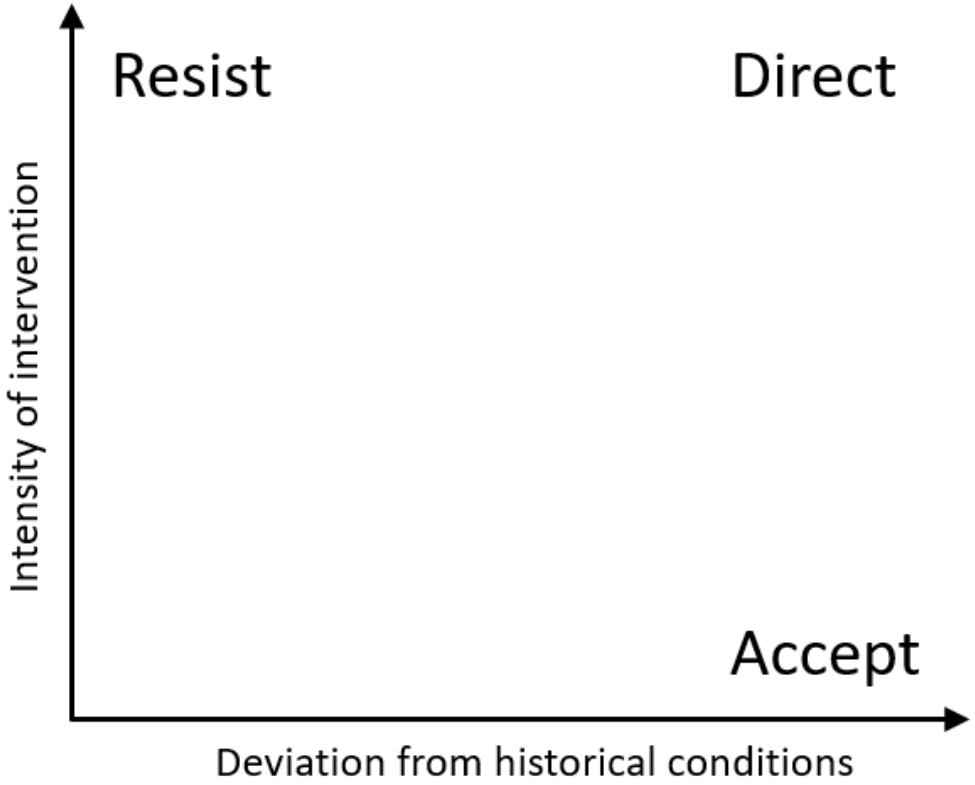
Special issue, in review

1. Schuurman, G., Cole, D., Cravens, A.E., Covington, S., Crausbay, S., Hawkins Hoffman, C., Lawrence, D., Magness, D., Morton, J., Nelson, L., O'Malley, R. **Navigating ecological transformation: Resist-Accept-Direct (RAD) as a path to a new resource management paradigm**.

Paper 1: RAD for navigating ecological transformation



Schuurman et al. *in press.*

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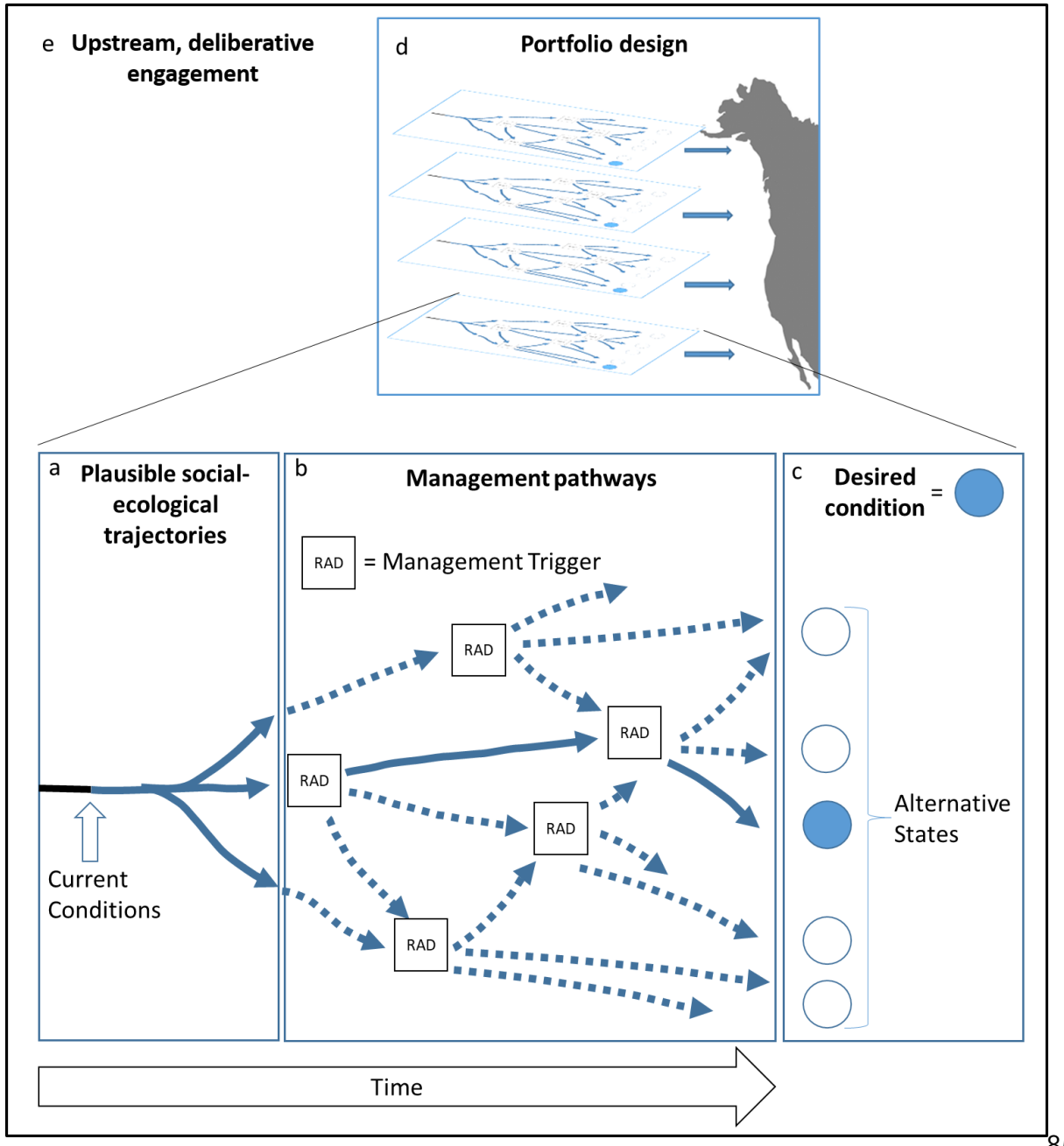
2. Magness, D.R., Hoang, L., Belote, R. T., Brennan, J., Carr, W., Chapin III, F. S., Clifford, K. R., Morrison, W., Morton, J. M., Sofaer, H. R. **Management foundations for navigating ecological transformation by resisting, accepting, or directing social-ecological change**.

Paper 2: Applying the RAD framework

Four Foundations *that enable a transition to future-oriented management*

- identify **plausible social-ecological trajectories**
- apply upstream and deliberative **engagement** and decision-making with stakeholders
- formulate **management pathways** to desired futures
- consider a **portfolio** approach across space and time



Magness et al. *in review.* Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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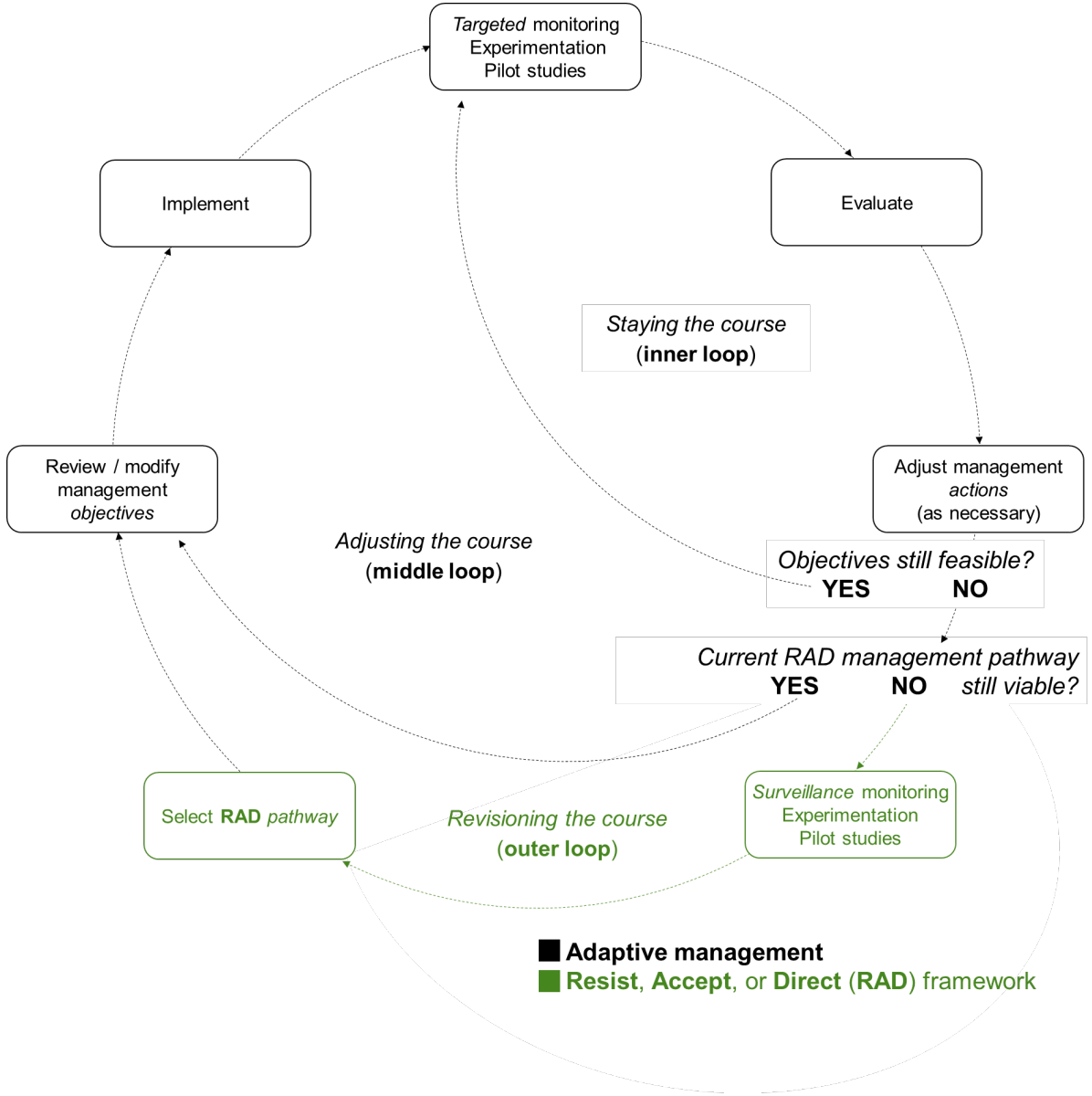
3. Lynch, A. J., Thompson, L. M., Morton, J. M., Beever, E. A., Clifford, M., Limpinsel, D., Magill, R. T., Magness, D. R., Melvin, T. A., Newman, R. A., Porath, M. T., Rahel, F. J., Reynolds, J. H., Schuurman, G. W., Sethi, S. A., Wilkening, J. L. **RAD adaptive management for transforming ecosystems**.

Paper 3: RAD adaptive management

- *When the system state is **stable**:*
  - Traditional **adaptive management** double loop.
- *When the **system** state is **changing**:*
  - **RAD** decisions come into play.



USGS science for a changing world

Lynch et al. *in review.* Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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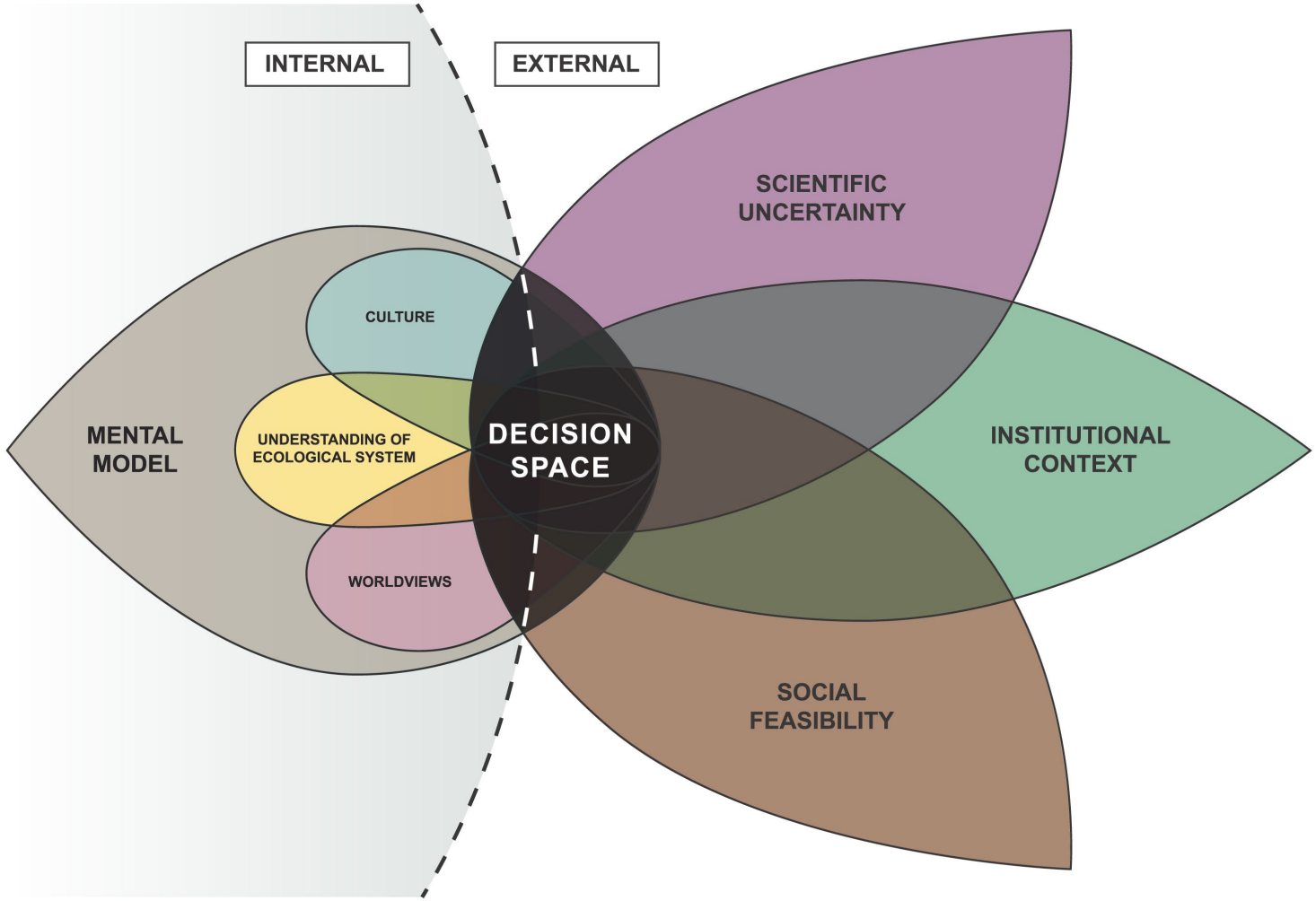
4. Clifford, K.R., Cravens, A.E., Knapp, C. **Responding to ecological transformation: Mental models, external constraints, and manager decision-making**.

Paper 4: Mental models, constraints, & RAD decision making

- Managers make different RAD decisions <u>even</u> when presented with the same information in the same place (Clifford et al. 2020, *Environ. Management*)

- RAD decisions result from intersection of:
  - Internal factors i.e., managers' mental models
  - External factors i.e., understanding of the science, institutional context, and social feasibility



Clifford et. al., in revision. Responding to ecological transformation: Mental models, external constraints and manager decision-making. Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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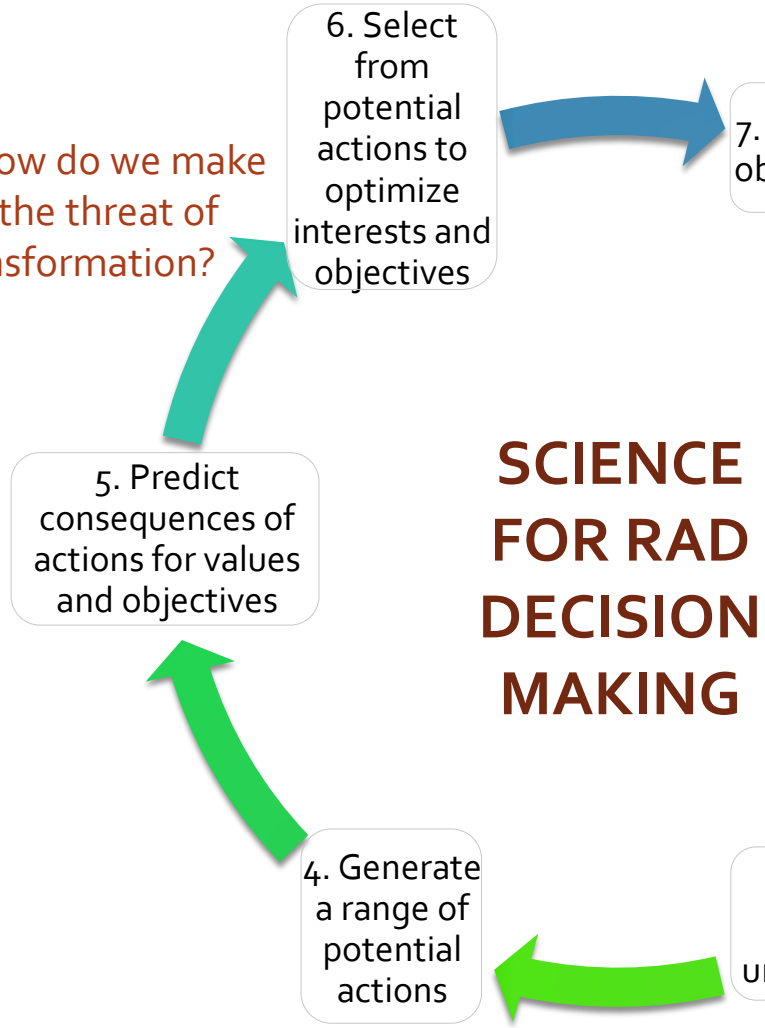
5. Crausbay, S., Sofaer, H.R., Cravens, A.E., Chaffin, B., Clifford, K., Gross, J.E., Lawrence, D.J., Knapp, C., Magness, D.R., Miller-Rushing, A., Schuurman, G.W., Stevens-Rumann, C. **A science agenda to support natural resource management decisions in an era of ecological transformation**.

Paper 5: Ecological transformation science agenda



Question 1. Is transformation a threat?

Question 2. How effective and durable are resistance strategies?

Question 3. What are the plausible ecological futures?

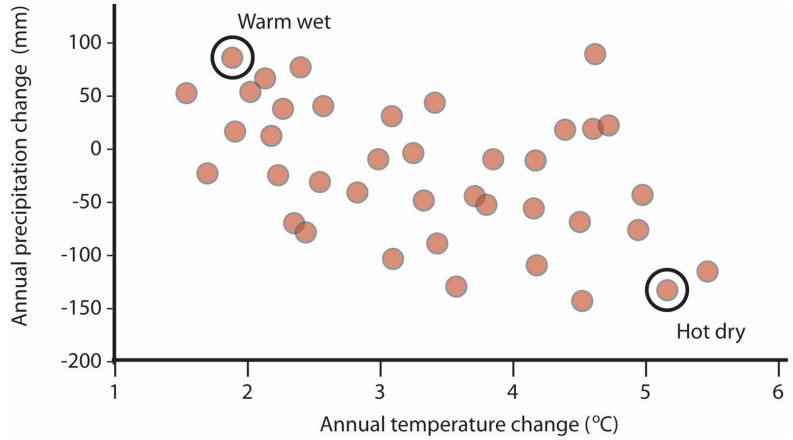
Question 4. What are the consequences of the choice to resist, accept, or direct transformation?

Question 5. How do we make choices about the threat of ecological transformation?

Crausbay et al. *in review.* Preliminary Information-Subject to Revision.

Paper 5: Ecological transformation science agenda

Crausbay et al. *in review.* Preliminary Information-Subject to Revision.



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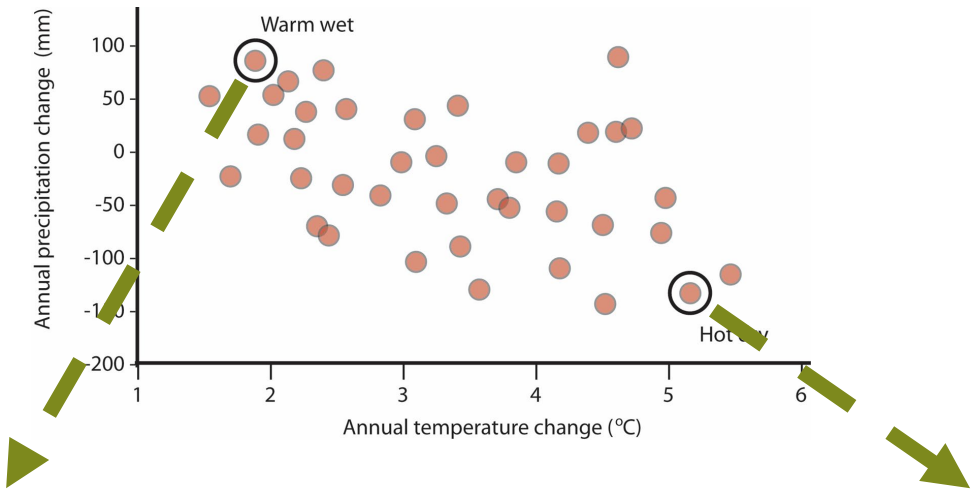

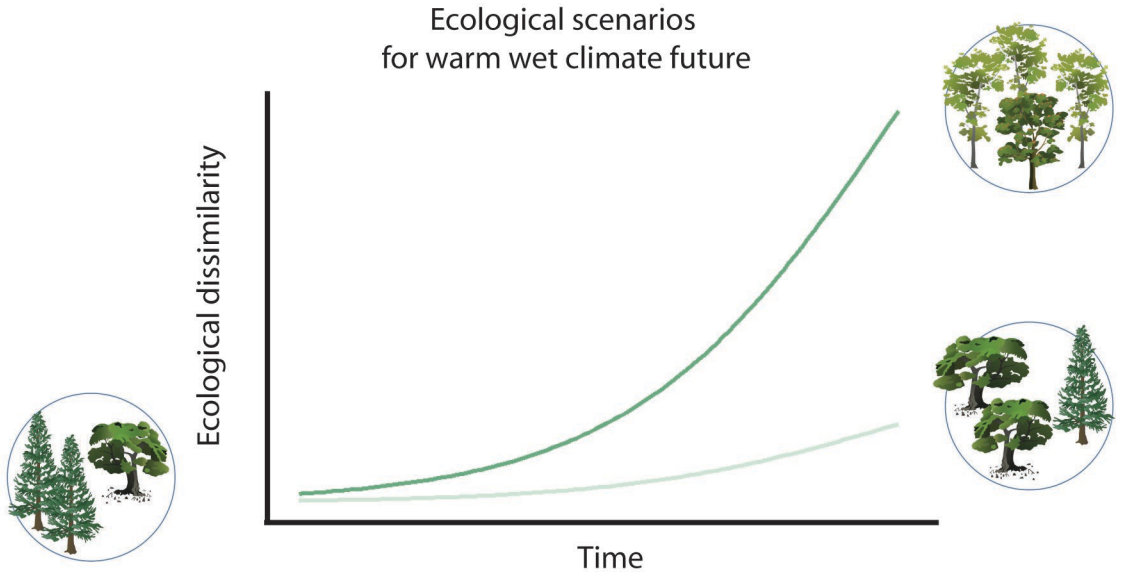

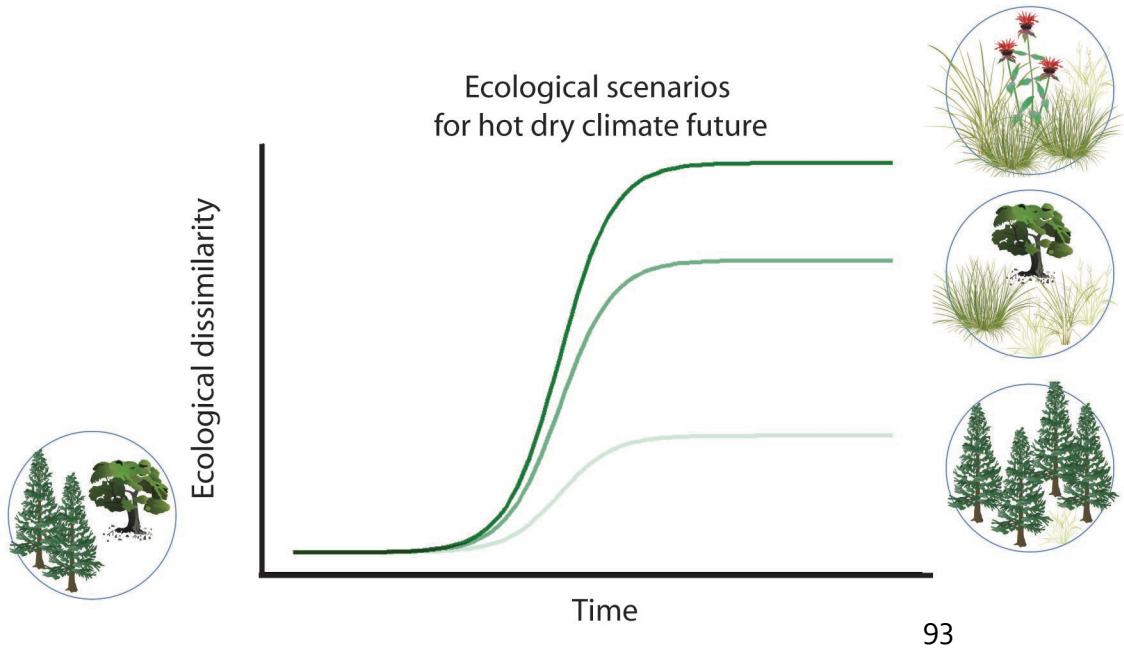

What next?

Scaling up

- Compiling/sharing case studies
- Social dimensions
- Science needs
- Sustaining federal collaboration

Thank you!

For more:

usgs.gov/casc/rad