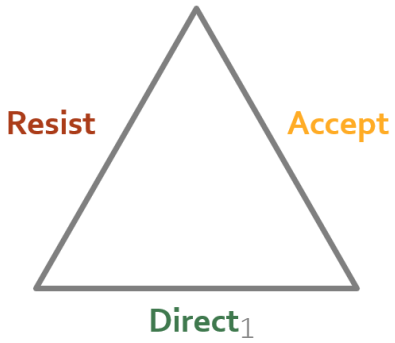
Scenario-based climate change adaptation that strategically resists, accepts, and directs human-caused ecological trajectories in grasslands

USFWS Grasslands & Climate Adaptation Workshop

Gregor Schuurman, PhD

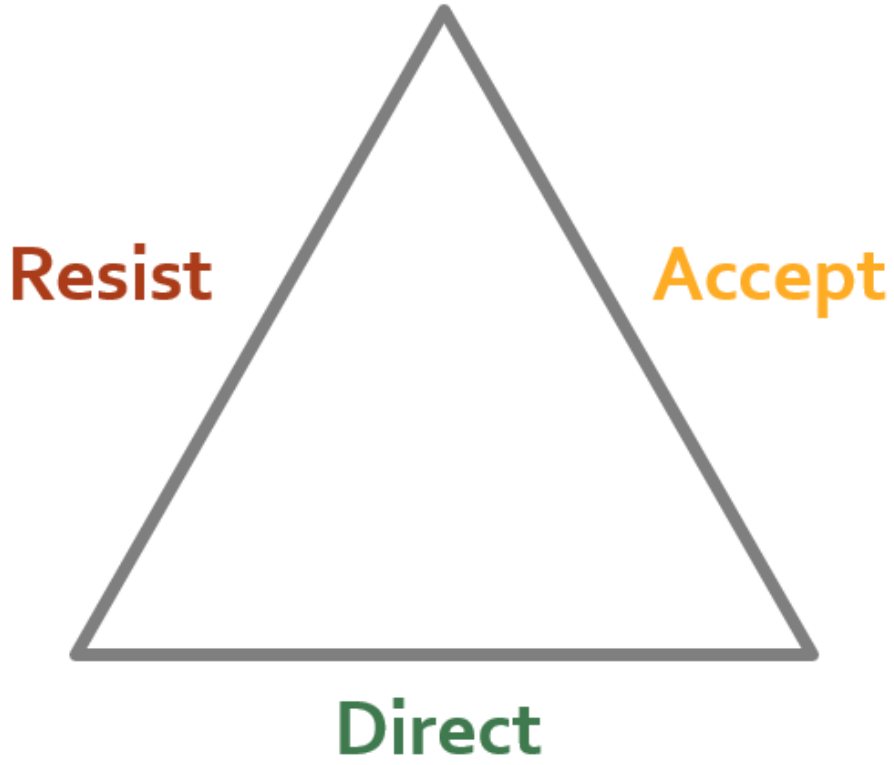
NPS Climate Change Response Program

24 January 2023



Scenario-based CC adaptation

The RAD framework



Scenario-based CC adaptation

The RAD framework

First, a quick poll
to gauge your familiarity

Please indicate your level of experience (if any) with scenario-based natural resource climate change adaptation:

1) I don’t know much, beyond maybe having heard the term,
2) I am somewhat familiar with the approach but haven’t been trained
3) I have some training or experience

Scenario-based adaptation!

Key recent partners in NPS scenario-based adaptation R&D:

Brian Miller – USGS North Central Climate Adaptation Science Center

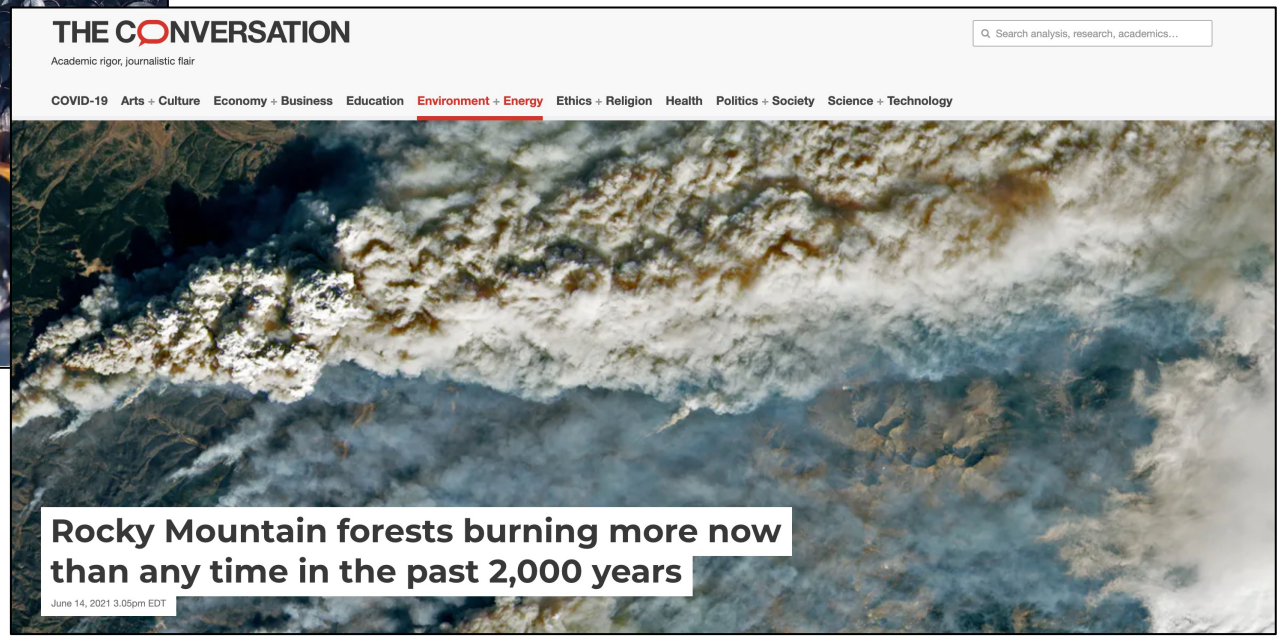
Amy Symstad – USGS Northern Prairie Wildlife Research Center

Amber Runyon – NPS Climate Change Response Program

Brecken Robb – USFWS Science Applications

https://www.theguardian.com/environment/2021/jul/08/heat-dome-canada-pacific-northwest-animal-deaths

https://www.nytimes.com/2022/06/15/us/yellowstone-national-park-floods.html



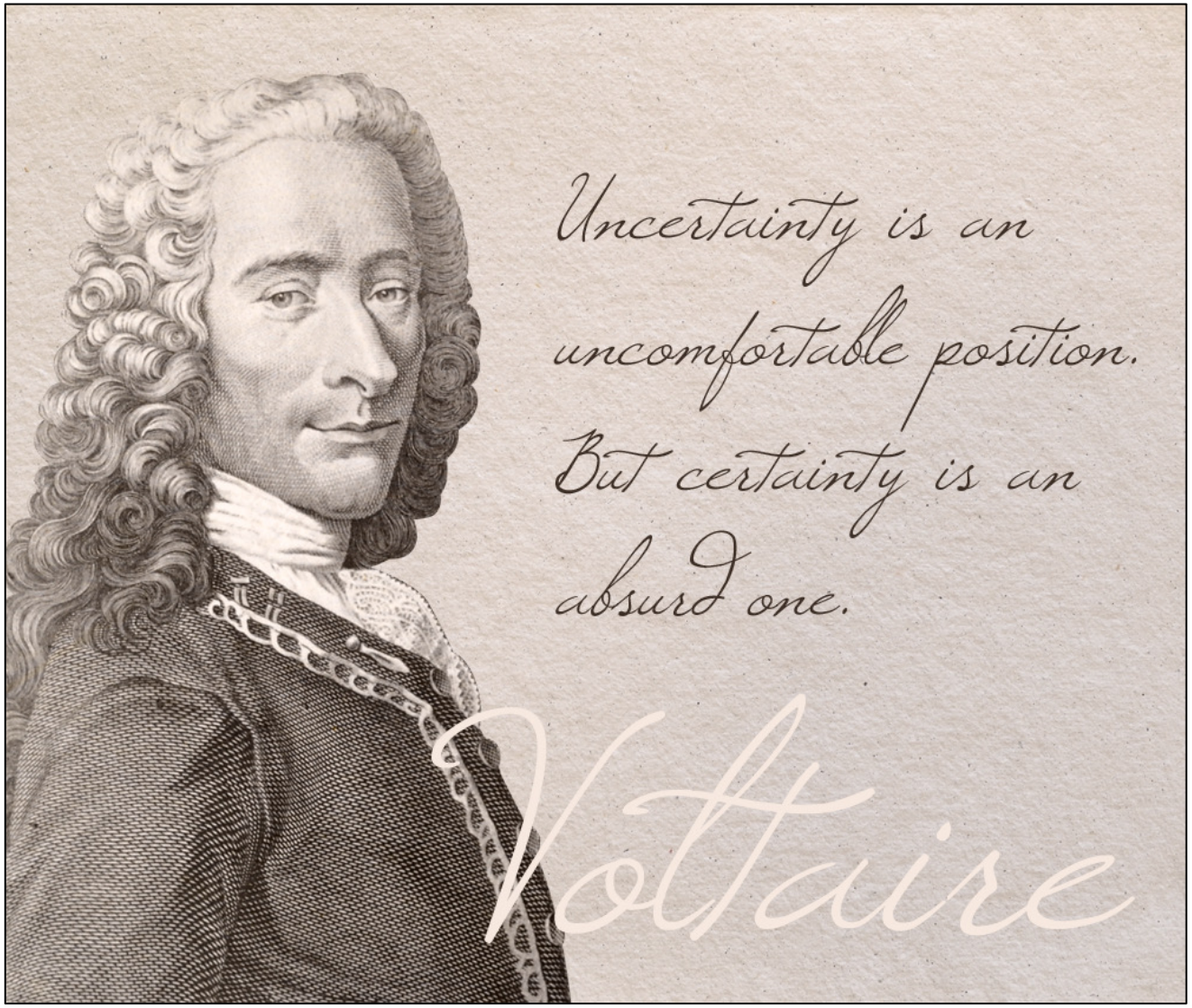
https://theconversation.com/rocky-mountain-forests-burning-more-now-than-any-time-in-the-past-2-000-years-162383

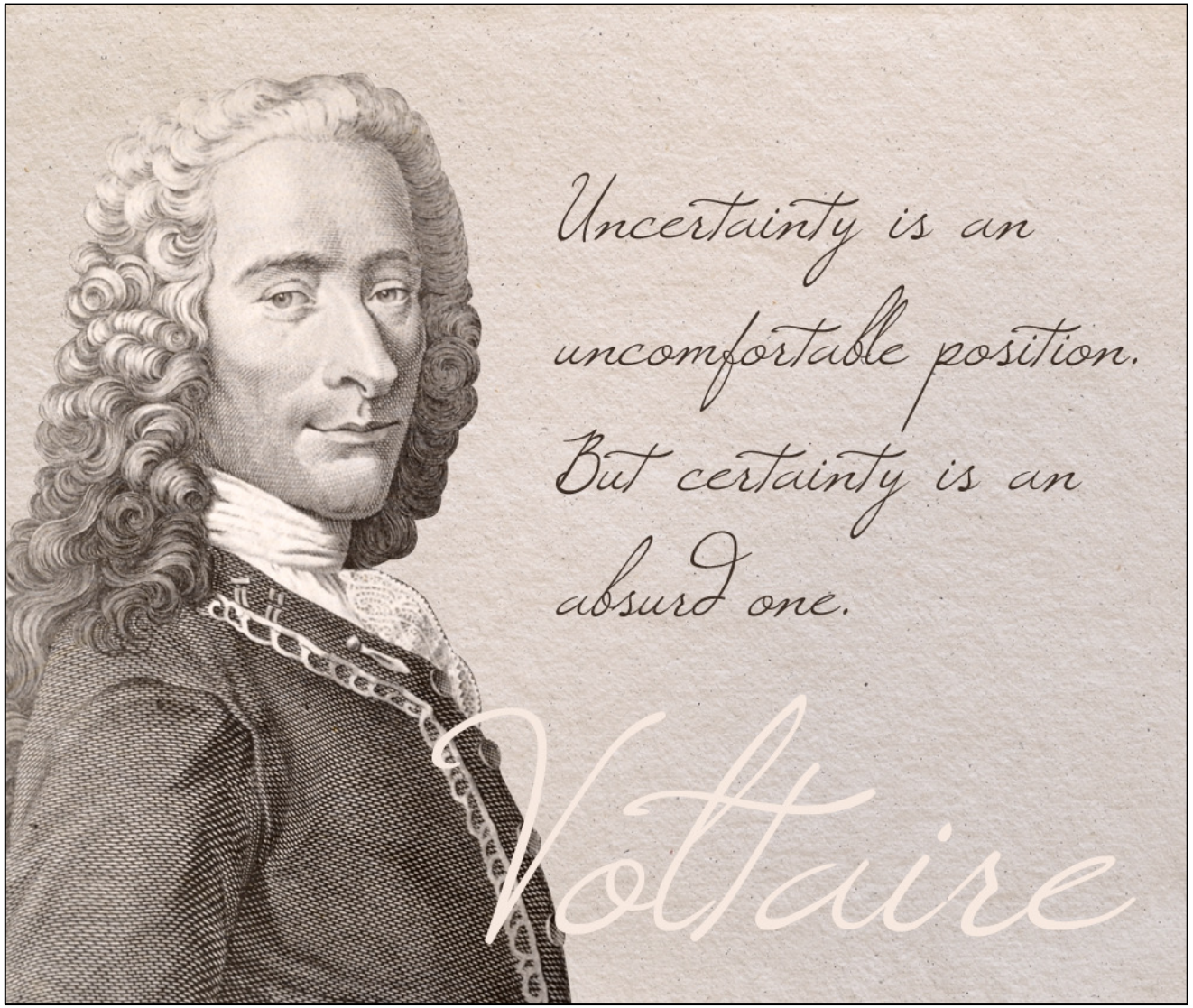
OUTLINE – Scenario-based adaptation

- Introduction to scenario planning
- Participatory scenario-based climate change adaptation
  - Generalized approach
  - Management outcomes
- Q&A

OUTLINE – Scenario-based adaptation

- Introduction to scenario planning


Uncertainty is an
uncomfortable position.
But certainty is an
absurd one.
Voltaire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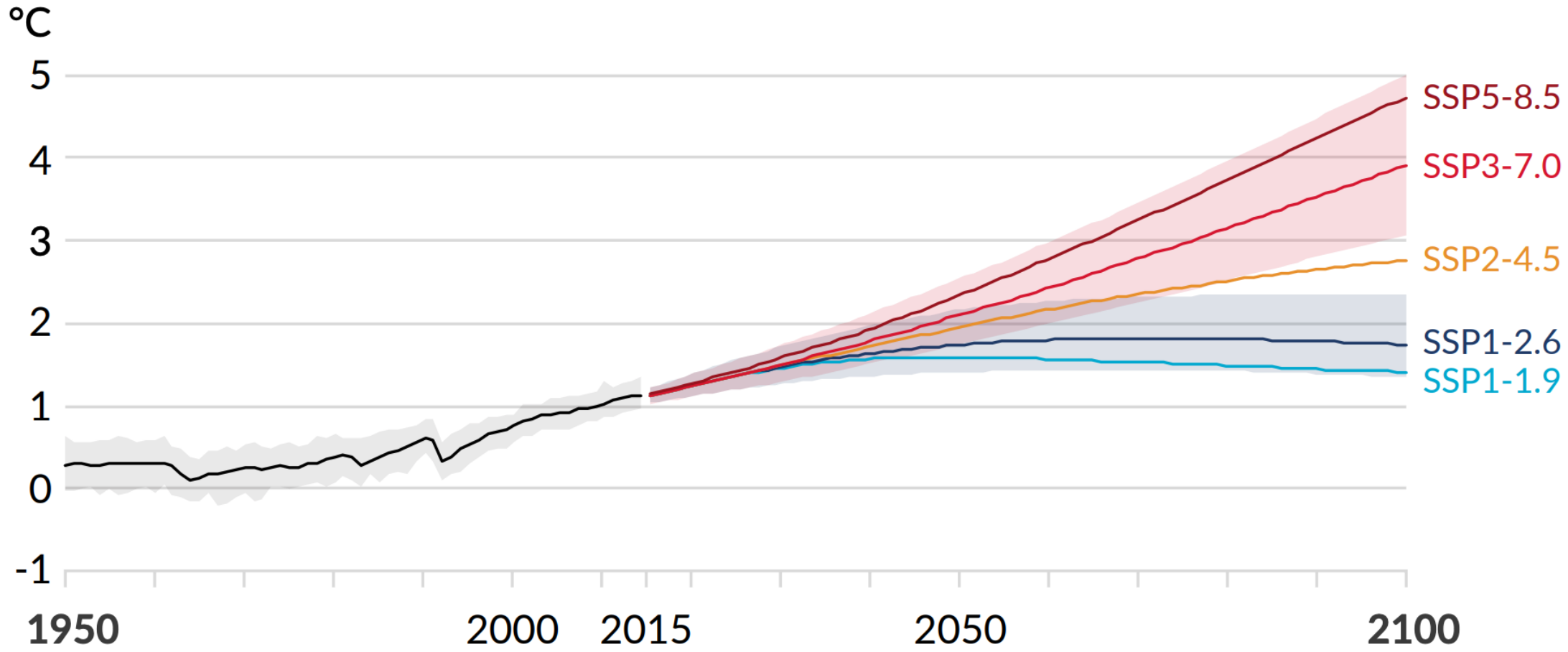
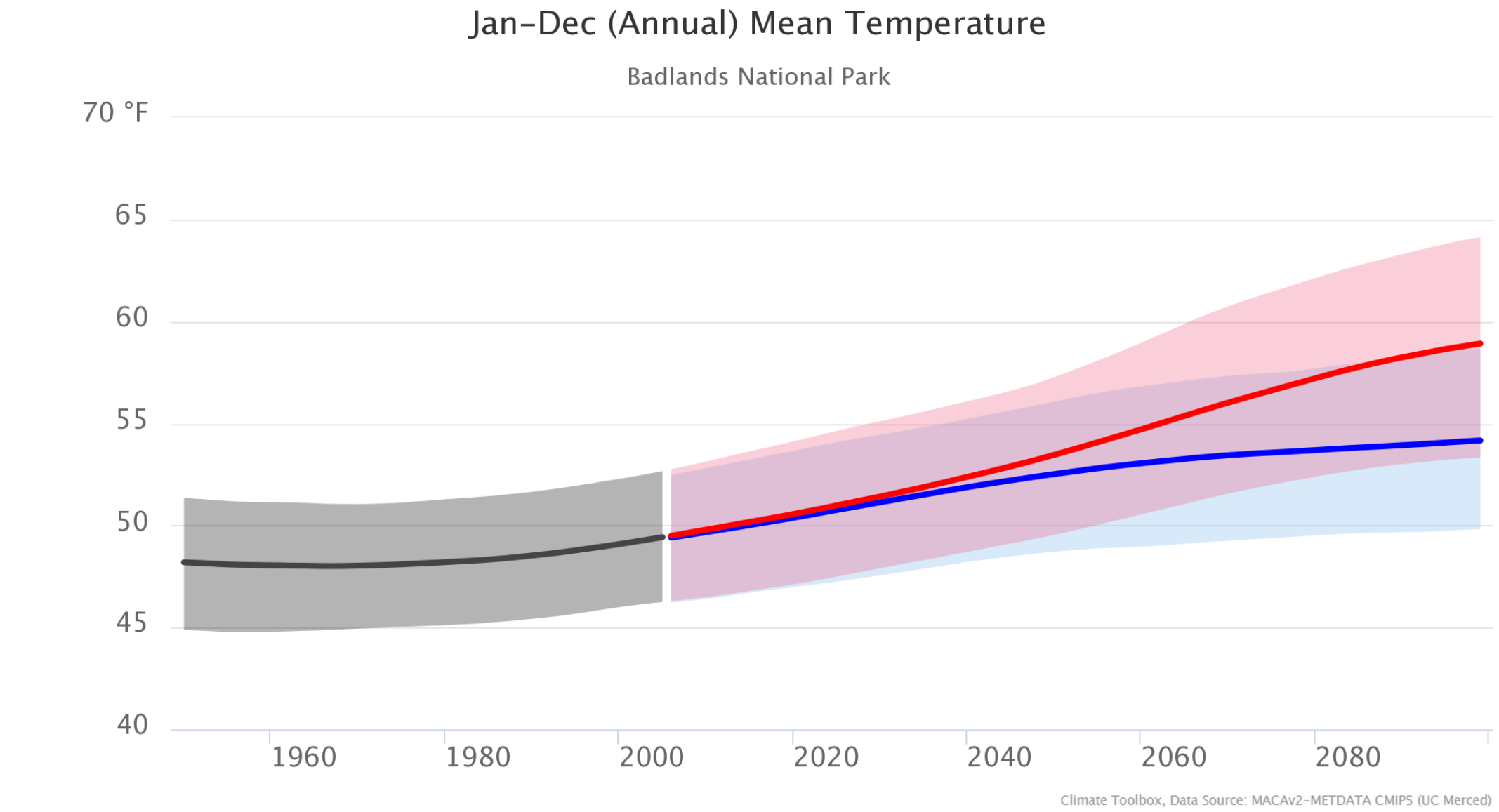
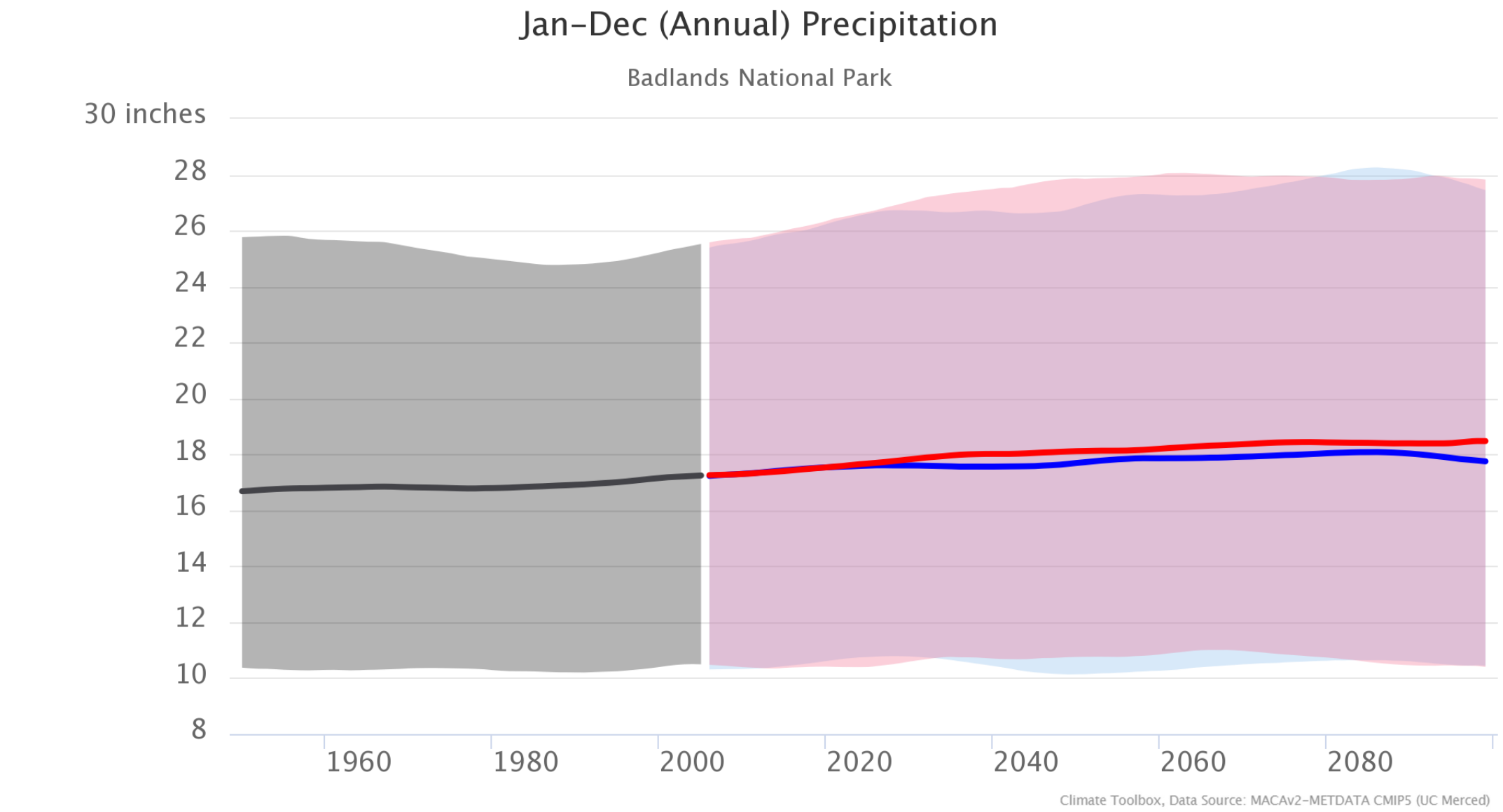
MORE IMPORTANT than the quest for certainty is the quest for CLARITY.
-Francois Gautier

a) Global surface temperature change relative to 1850-1900



IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Pp. 3-32.


Jan–Dec (Annual) Mean Temperature
Badlands National Park
70 °F
65
60
55
50
45
40
1960
1980
2000
2020
2040
2060
2080
Climate Toolbox, Data Source: MACAv2-METDATA CMIP5 (UC Merced)
Historical Average
Historical Range
RCP 4.5 (Lower Emissions) Ave.
RCP 4.5 Range
RCP 8.5 (Higher Emissions) Ave.
RCP 8.5 Range


Jan-Dec (Annual) Precipitation
Badlands National Park
30 inches
28
26
24
22
20
18
16
14
12
10
8
1960
1980
2000
2020
2040
2060
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In a changing world with an uncertain future, how can we know what to do?

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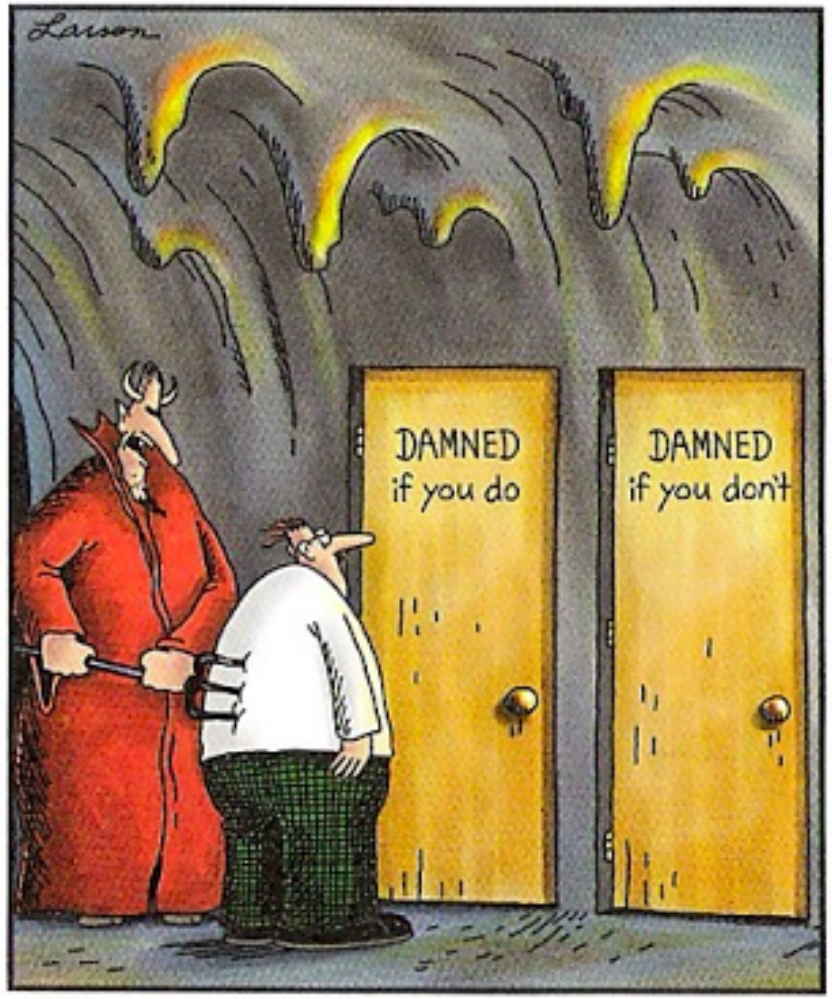
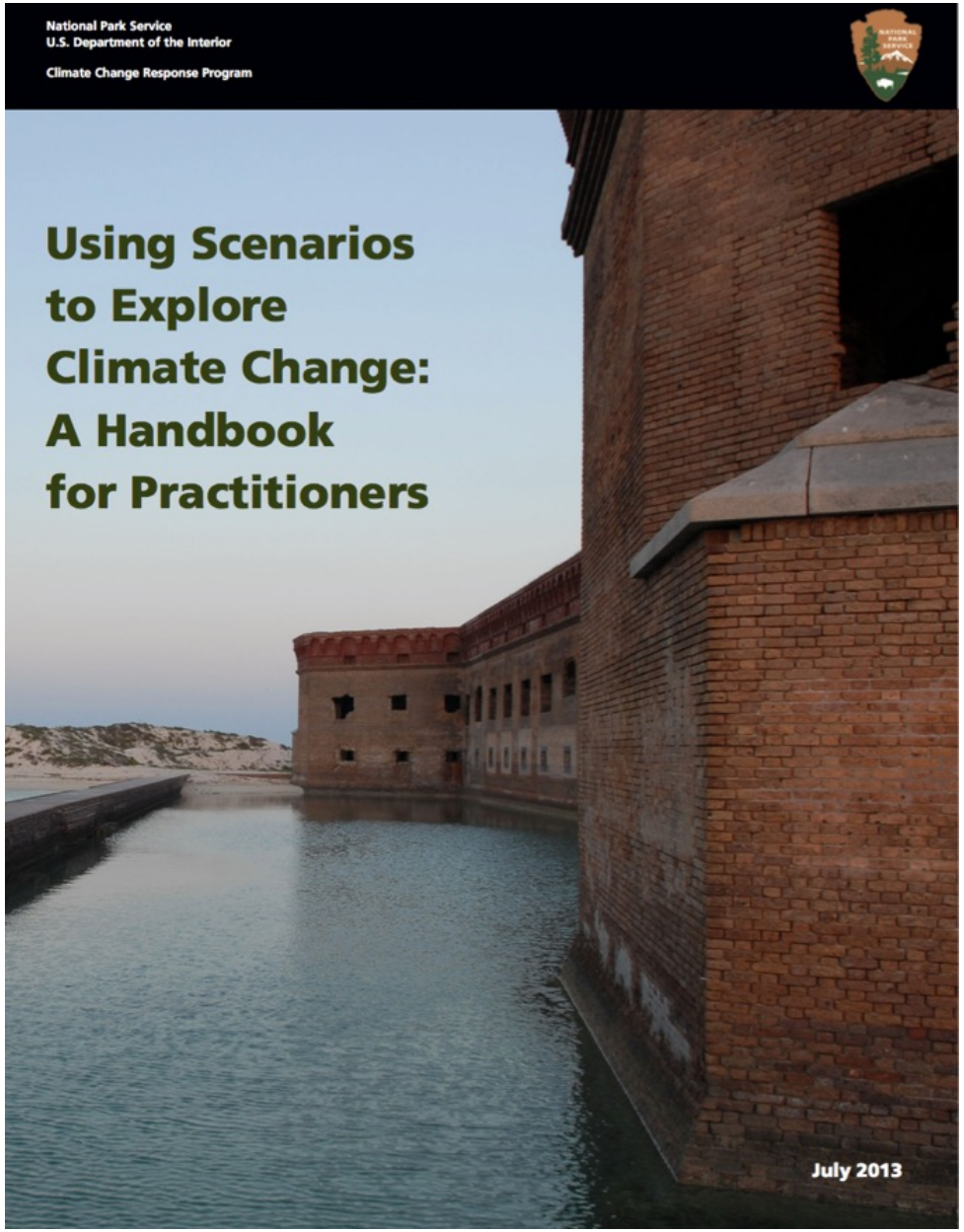
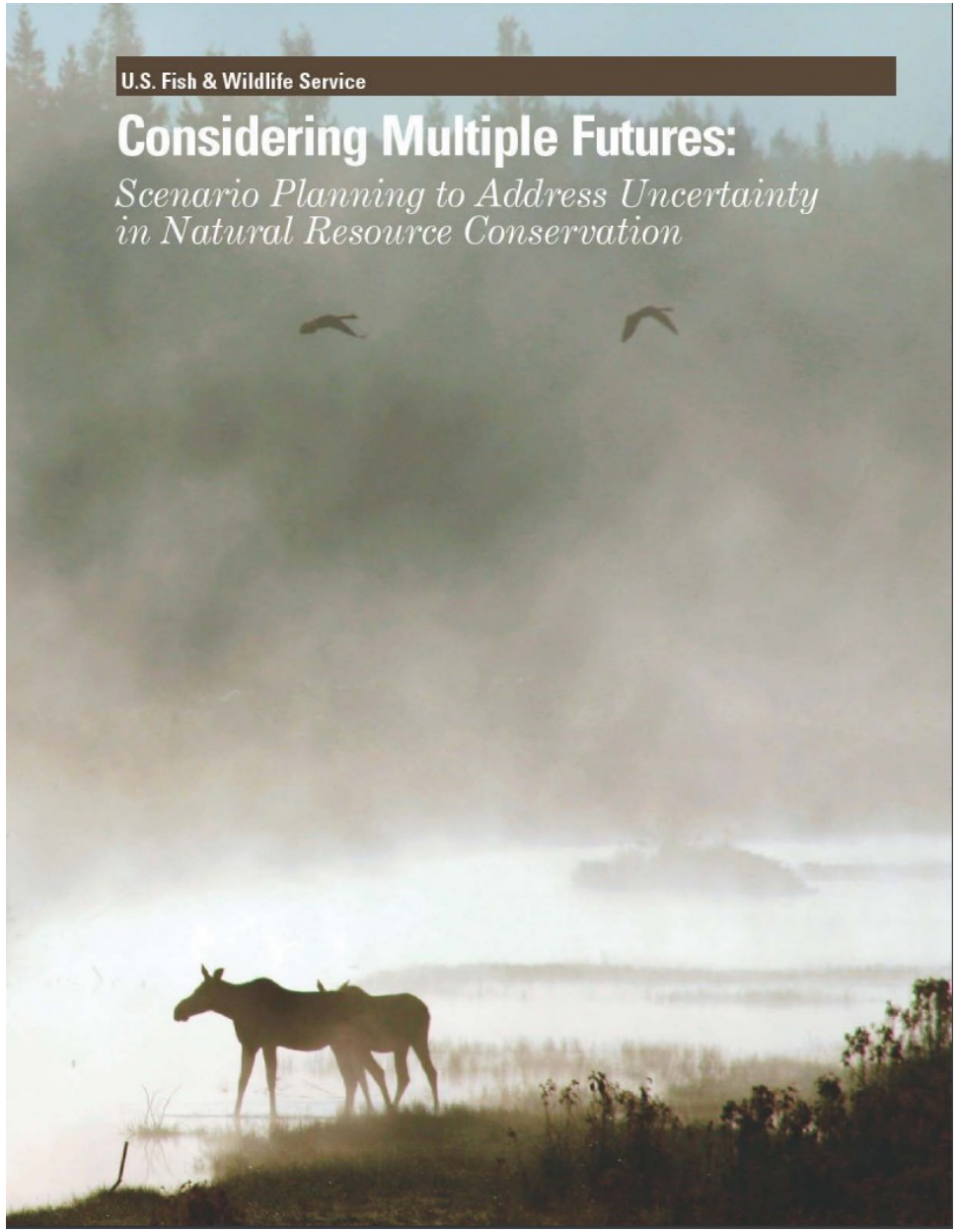


"C'mon, c'mon—it's either one or the other."

Image: Gary Larson
http://allyduncan.blogspot.com/2009/09/daily-lol-far-side-damned-if-you-do.html


National Park Service
U.S. Department of the Interior
Climate Change Response Program
Using Scenarios to Explore Climate Change: A Handbook for Practitioners
July 2013


U.S. Fish & Wildlife Service
Considering Multiple Futures:
Scenario Planning to Address Uncertainty in Natural Resource Conservation

NPS.gov / Home / Adapt to Change / Scenario Planning Showcase

Climate Change Scenario Planning Showcase

New publication! Jump to the publications section to view a new journal article on scenario planning from the NPS.

ON THIS PAGE

What is scenario planning?

Climate change is having far-reaching impacts on natural and cultural resources, facilities, operations, and the visitor experience. However, parks face a major challenge in anticipating future impacts: not knowing their exact timing and nature. A single forecast is likely to be inaccurate, so it is risky to rely on any one prediction of the future to make management decisions. Scenario planning—a longstanding military and private-sector tool adapted by the NPS and partners in recent years for NPS purposes—addresses this challenge. **It offers a framework for working with uncertainty and preparing for a wide range of plausible future conditions.** This structured process identifies a small set of scenarios—descriptions of potential future conditions that characterize a broad range of critical uncertainties—and uses them to inform planning.

Scenario planning vs. forecast planning

Forecast-based planning (left) uses predictions of a single future. Scenario planning (right) works with a set of plausible futures that capture a broad range of conditions, providing a framework to support decisions under conditions that are uncertain and uncontrollable. NPS image

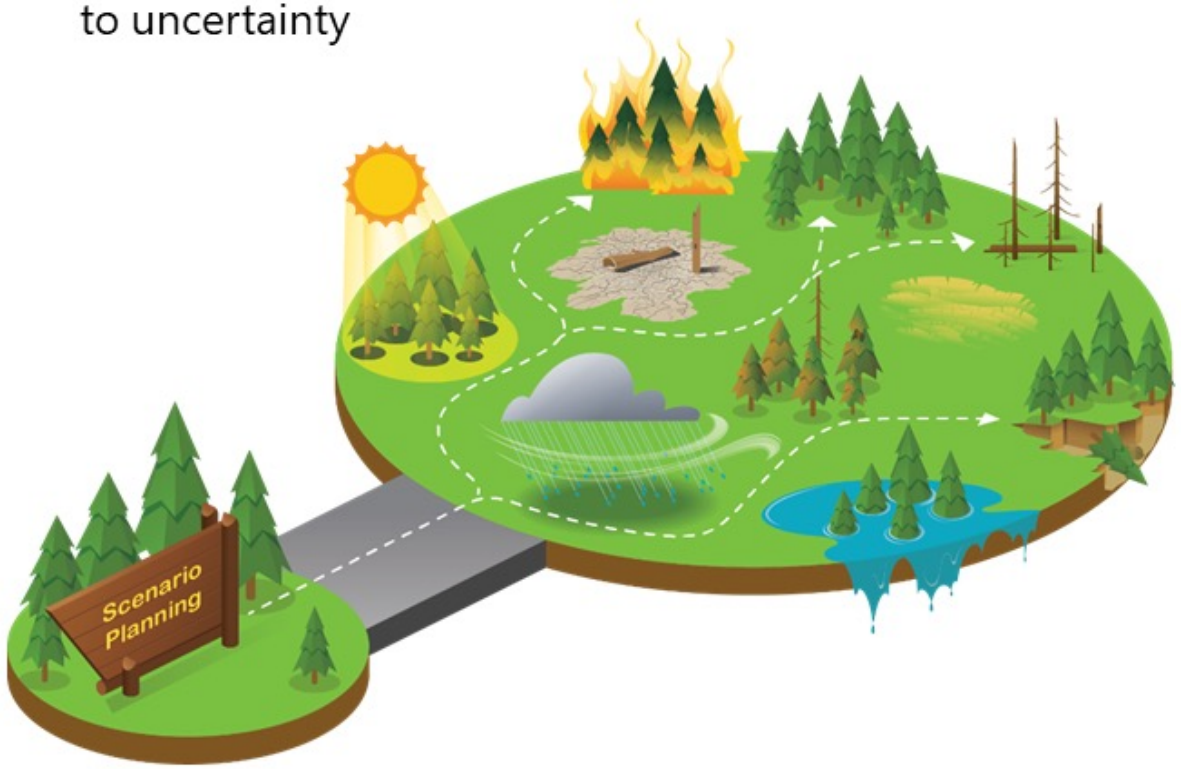
https://www.nps.gov/subjects/climatechange/scenarioplanning.htm

Traditional planning

- Assumes the future will resemble the past
- Assumes high certainty in our ability to accurately predict the future
- Encourages a precise characterization of the future
- Leaves managers vulnerable to surprises in situations of high uncertainty

Scenario planning

- Assumes the future will likely differ from the past
- Recognizes uncertainty and asks "what might happen?" in a rigorous and structured way
- Encourages broad and open-minded exploration of future possibilities and surprises
- Helps managers identify strategies that are robust to uncertainty



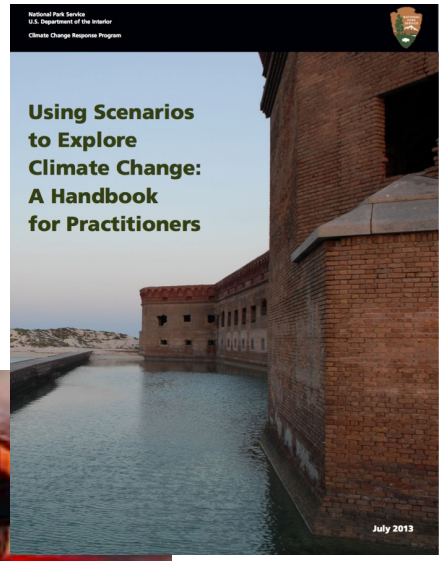
Schuurman et al. 2022 (Park Science)

Scenario Planning

- Has been applied in a variety of contexts, and in many forms

By Konstantin Von Wedelstaedt [GFDL 1.2]


By Sai Saketh [CC-BY-SA-4.0]



Images: Wikimedia Commons

Scenario Planning

Images: Wikimedia Commons

Scenario Planning

Scenario planning asks a simple question: What *might* happen?

We cannot know what *will* happen, but we can prepare for what *might* happen.

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We cannot know what *will* happen, but we can prepare for what *might* happen.

When we ask what might happen, we need to guard against

OPTIMISM BIAS

- A common human tendency to underestimate the probability and consequences of negative outcomes.

Unfortunately, a number of imagined, worst-case scenarios have played out on NPS lands in recent years…

Unprecedented wildfire

Lassen Volcanic NP

Extreme rain+flooding

Acadia NP

Permafrost thaw+landslides

Denali NP

Strategies for tempering OPTIMISM BIAS

- *Think about the unthinkable:* We are better prepared to act when we proactively confront the possibility of worst-case realities.
- *Think bigger:* Don't downplay the severity or magnitude of extreme scenarios. Anticipating extremes boosts our capacity regardless of what happens.
- *Plan for sooner rather than later:* It's better to imagine difficult futures happening sooner than anticipated, and recognize signs of extreme change.
- *Give fair attention to the improbable:* Strive for objectivity in interpreting the best available information for scenarios to help prepare for extreme, complex events.

OUTLINE – Scenario-based adaptation

- Introduction to scenario planning
- Participatory scenario-based climate change adaptation

NPS Climate Change Scenario Planning

Devils Tower National Monument

DETO

Knife River Indian Villages National Historic Site

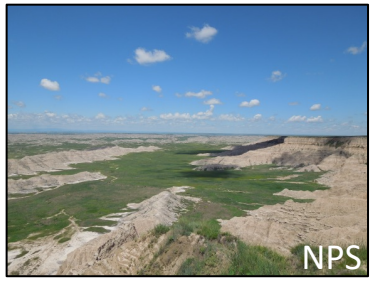
KNRI

AZRU/CHCU
2022
WRST
LAVO
APIS
YELL
DINO
BLCA
DENA
2019
WICA
YELL training
DETO
KNRI
2016
BADL
ACAD
GLAC
HALE & W. HI
PINN
Coastal & Rocky bioregions
ISRO
CATO
2013
Central AK
Interior AK
SE AKR
NW AKR
SW AKR
SEKI
KEFJ
4-wksp training series
CALO, DEPO
Crown of Continent
ASIS
2010
WICA
JOTR
2007

WICA

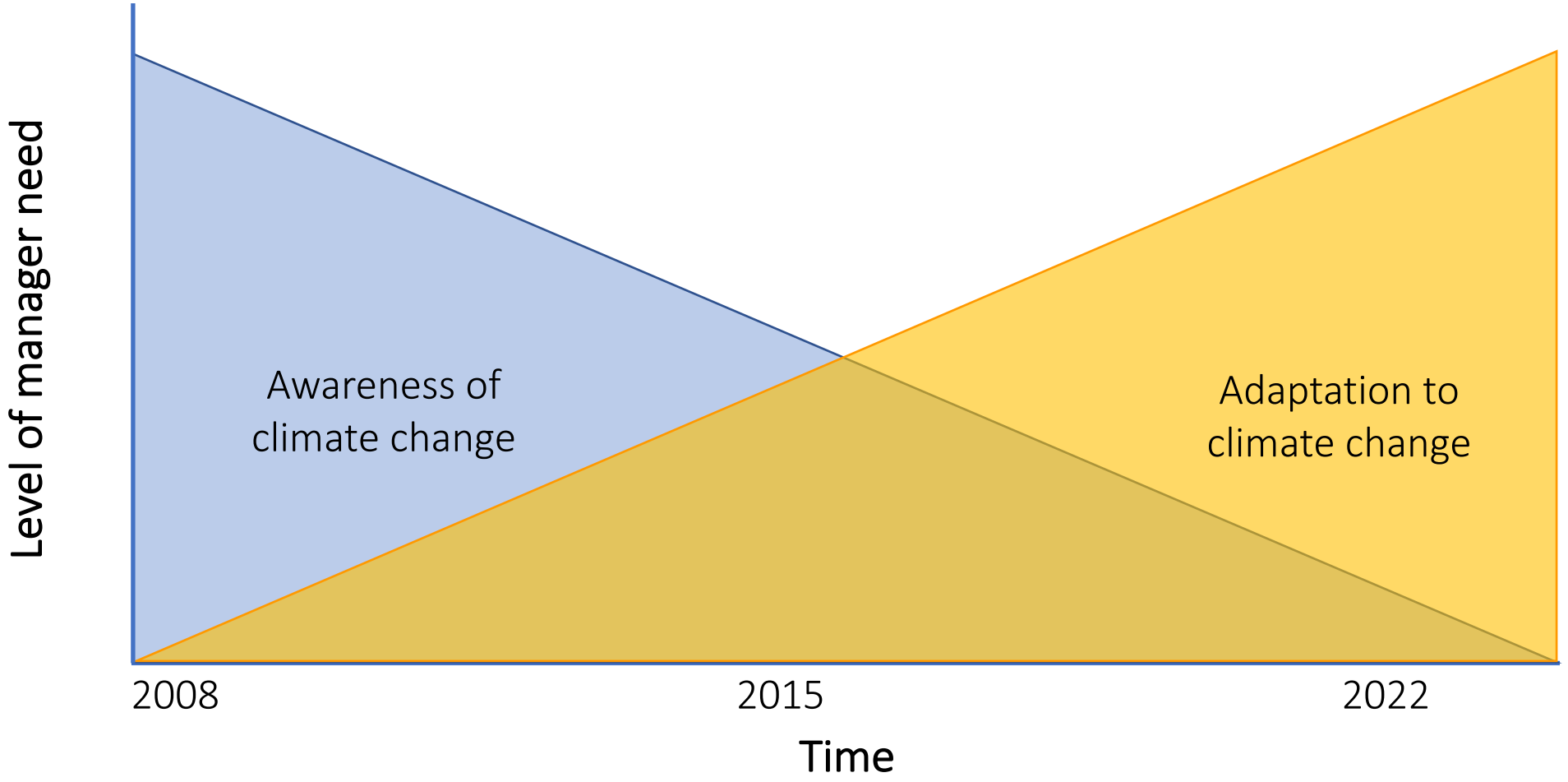
Wind Cave National Park

Badlands National Park



Wind Cave National Park

Changing use of scenario-based approaches to address climate change uncertainty



OUTLINE – Scenario-based adaptation

- Introduction to scenario planning
- Participatory scenario-based climate change adaptation
  - Generalized approach

Generalized scenario-based adaptation approach

Scenario-based climate change adaptation

Climate Future

Summary of relevant climate data from specific climate projections. Multiple climate futures are used to encompass the range of ways climate could change in coming decades. Climate futures establish the fundamental structure of climate-resource scenarios (Gross et al., 2016).

Scenario-based climate change adaptation

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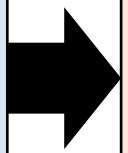

Climate-Resource Scenario

Climate-resource scenarios are created – generally in collaboration with park staff and resource specialists – by adding potential resource implications to climate futures.

Scenario-based climate change adaptation

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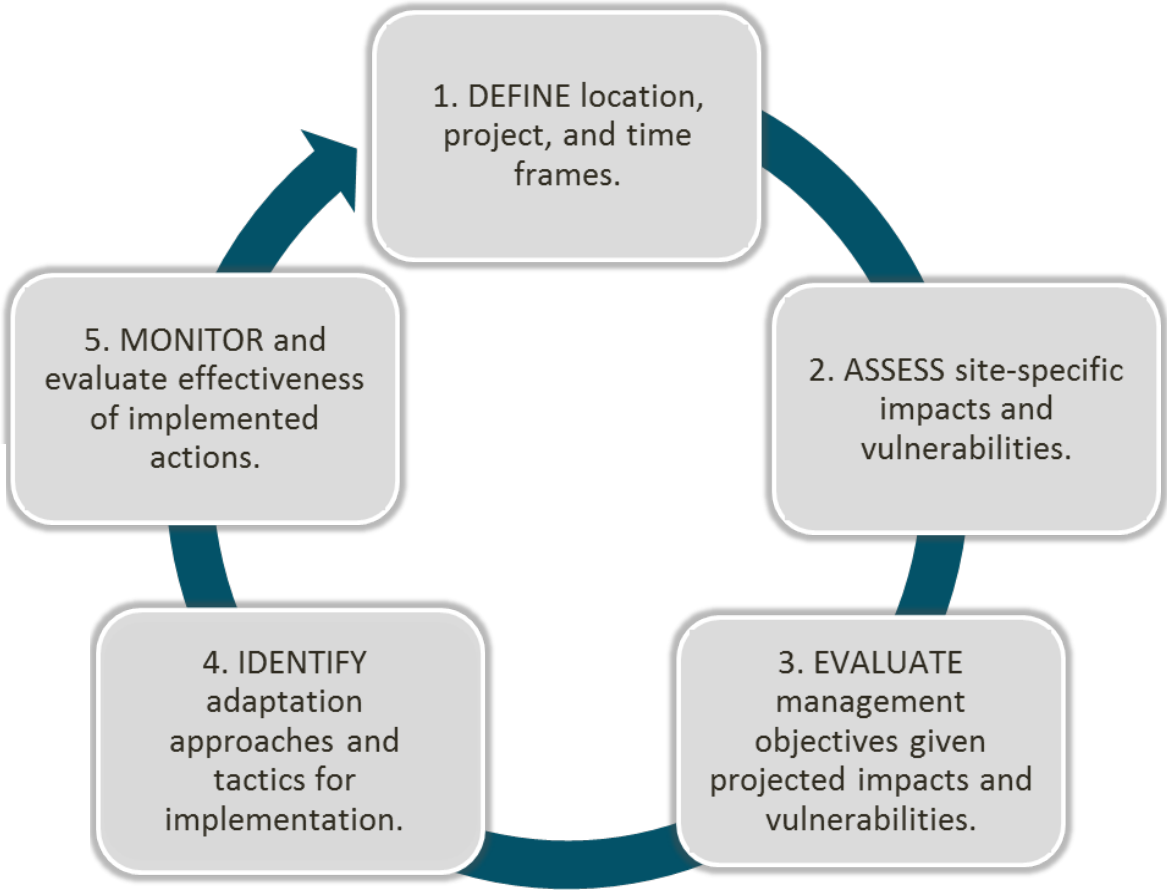
Example from Devils Tower National Monument

A climate future for Devils Tower National Monument projects a 4 °F increase in annual temperature with 14% decreases in spring and summer precipitation–resulting in substantial declines in soil moisture and runoff.

Resulting in a climate-resource scenario with: decreased vegetation production, increased fire risk, and drought-induced declines in ponderosa pine, cottonwoods, and oaks. Visitation increase due to expanded shoulder season, and potential for increase in heat-related illness.

Based on this and additional scenarios, the park realized that their historical goals of improving riparian and maintaining ponderosa forests might be untenable. Therefore, they brainstormed a broad set of new approaches to detect and respond to change, incl revising monitoring.

Generalized scenario-based adaptation approach



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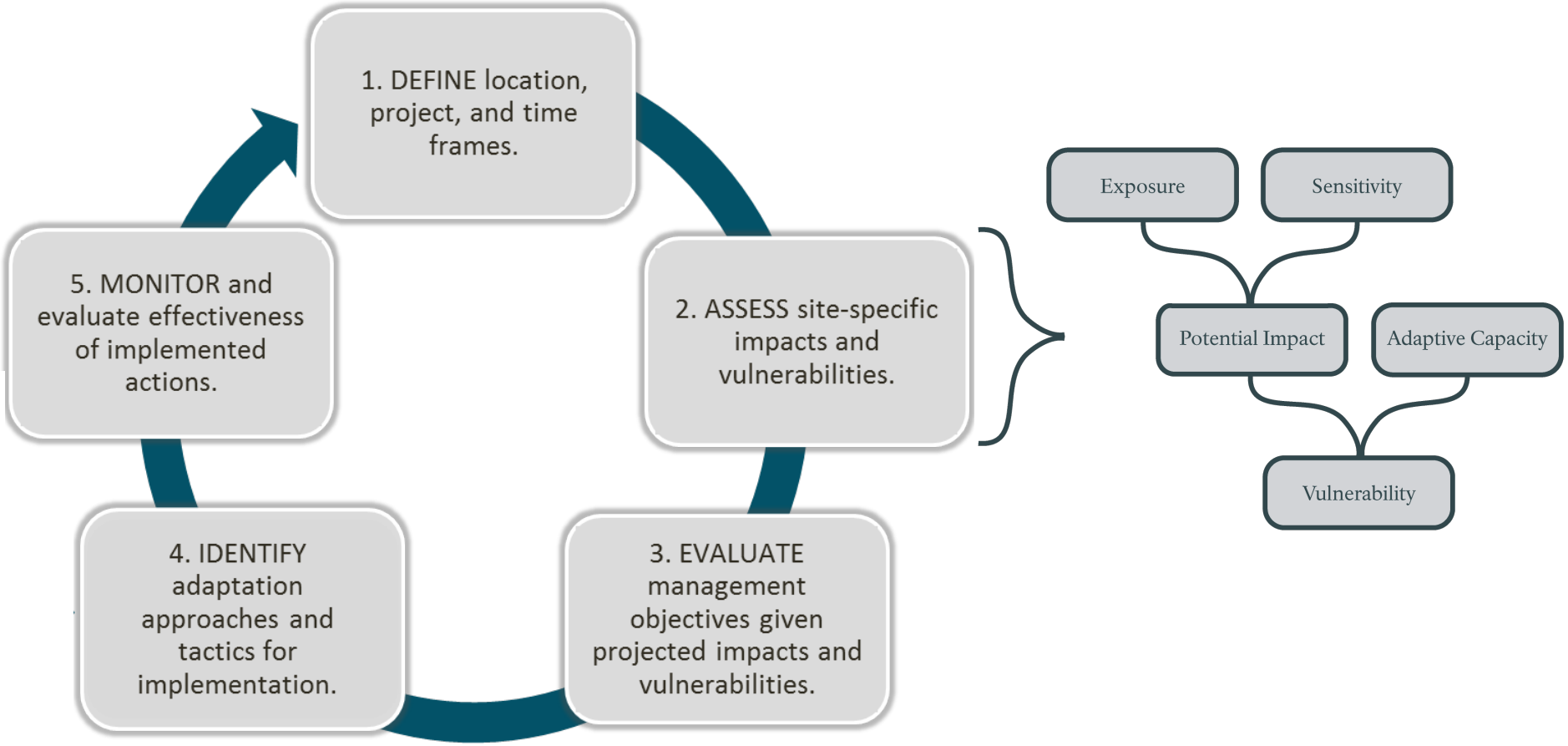

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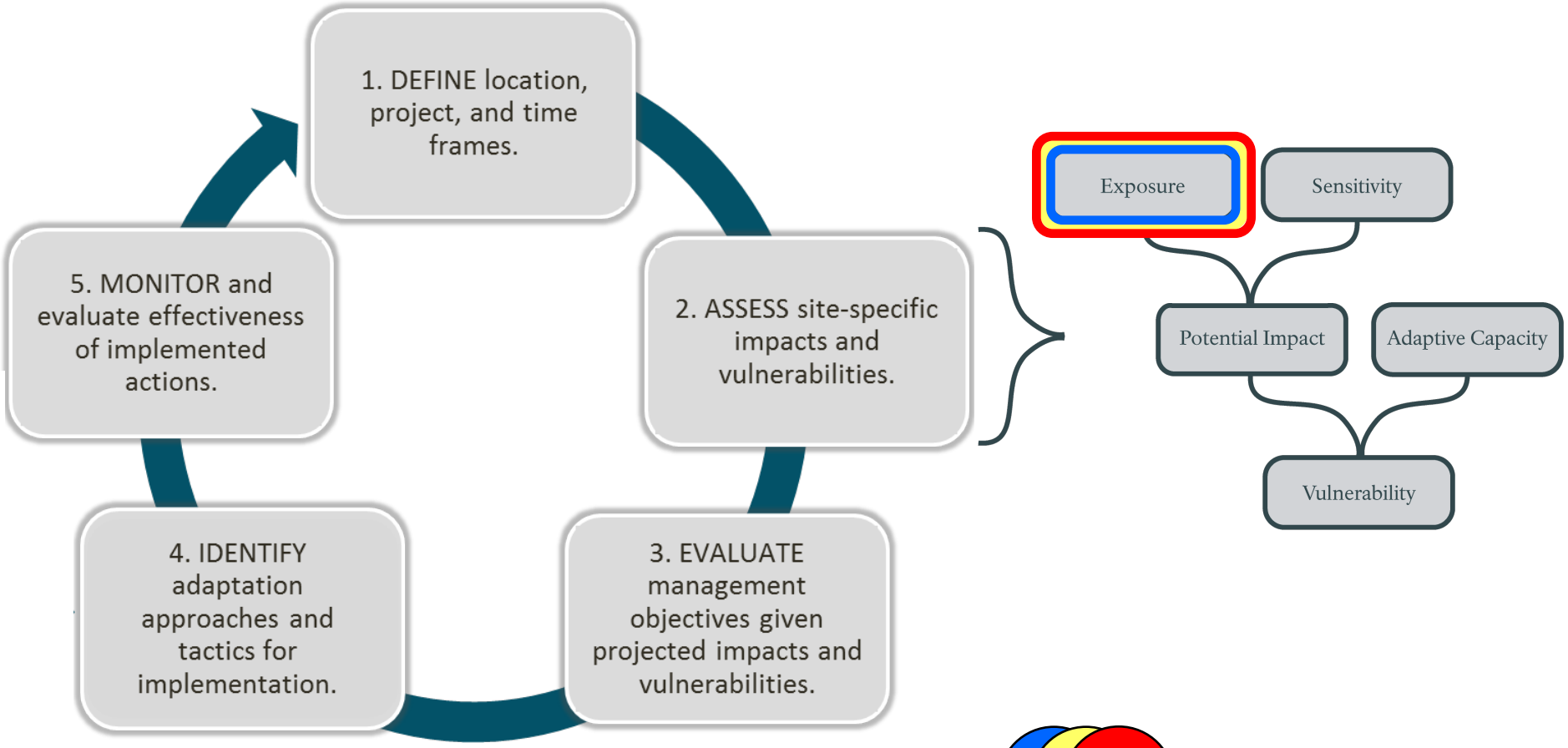

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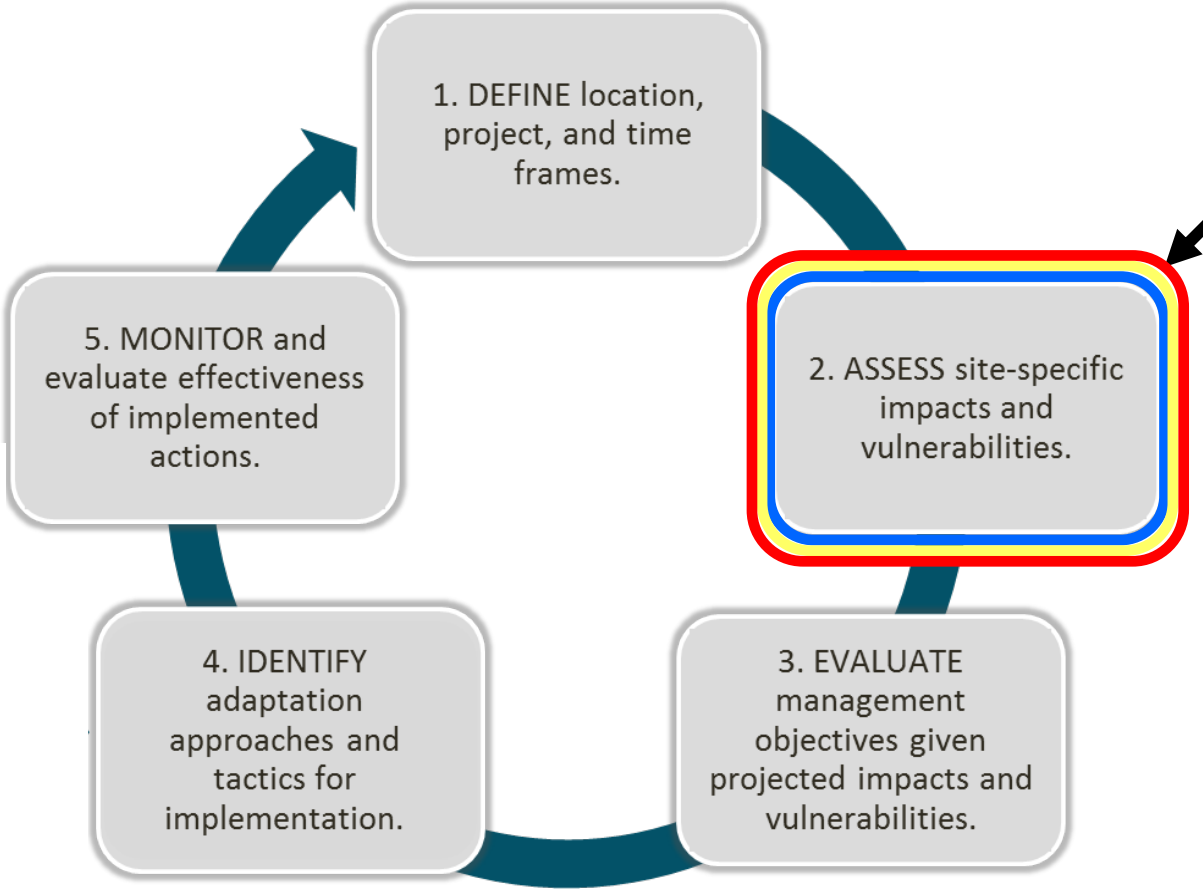

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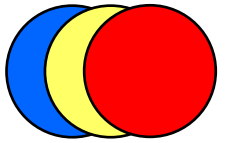
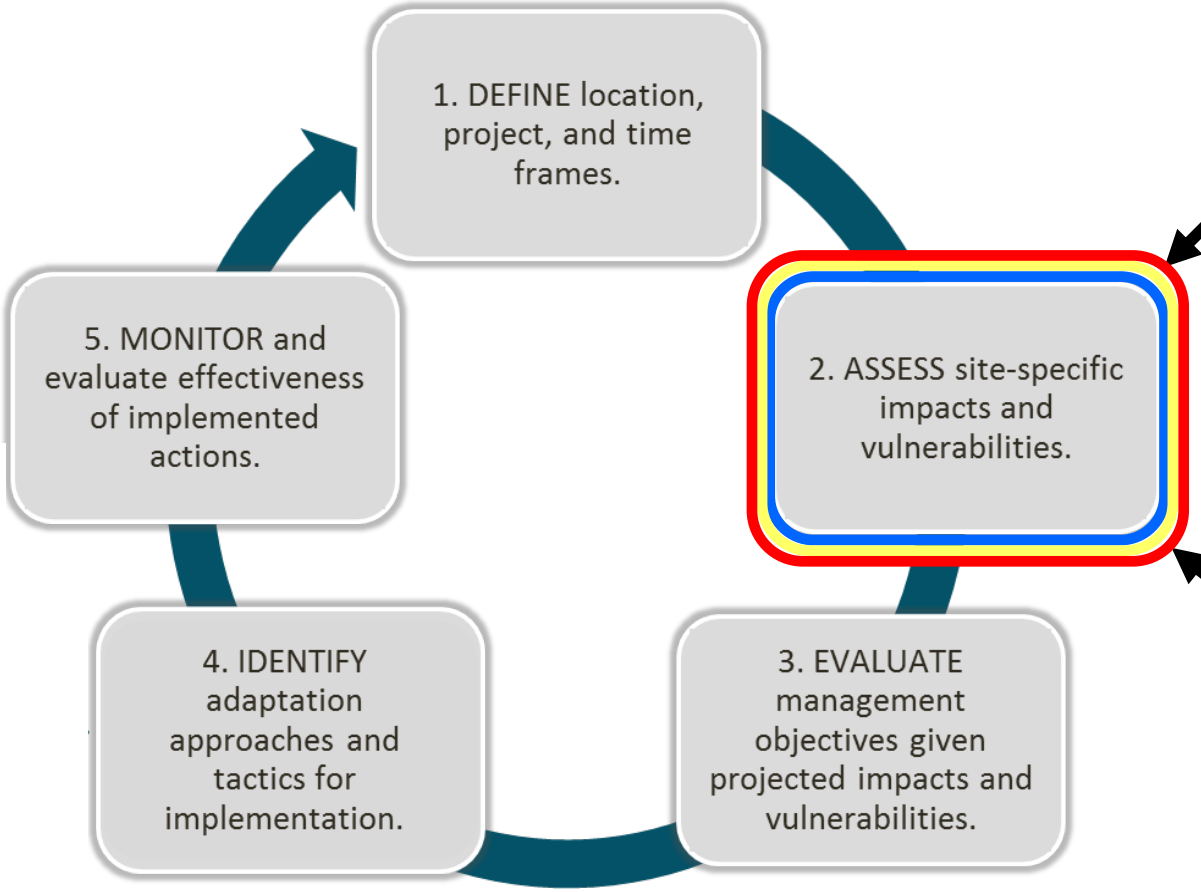


Scenarios

Generalized scenario-based adaptation approach



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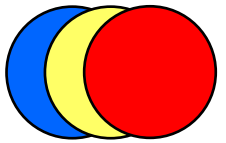

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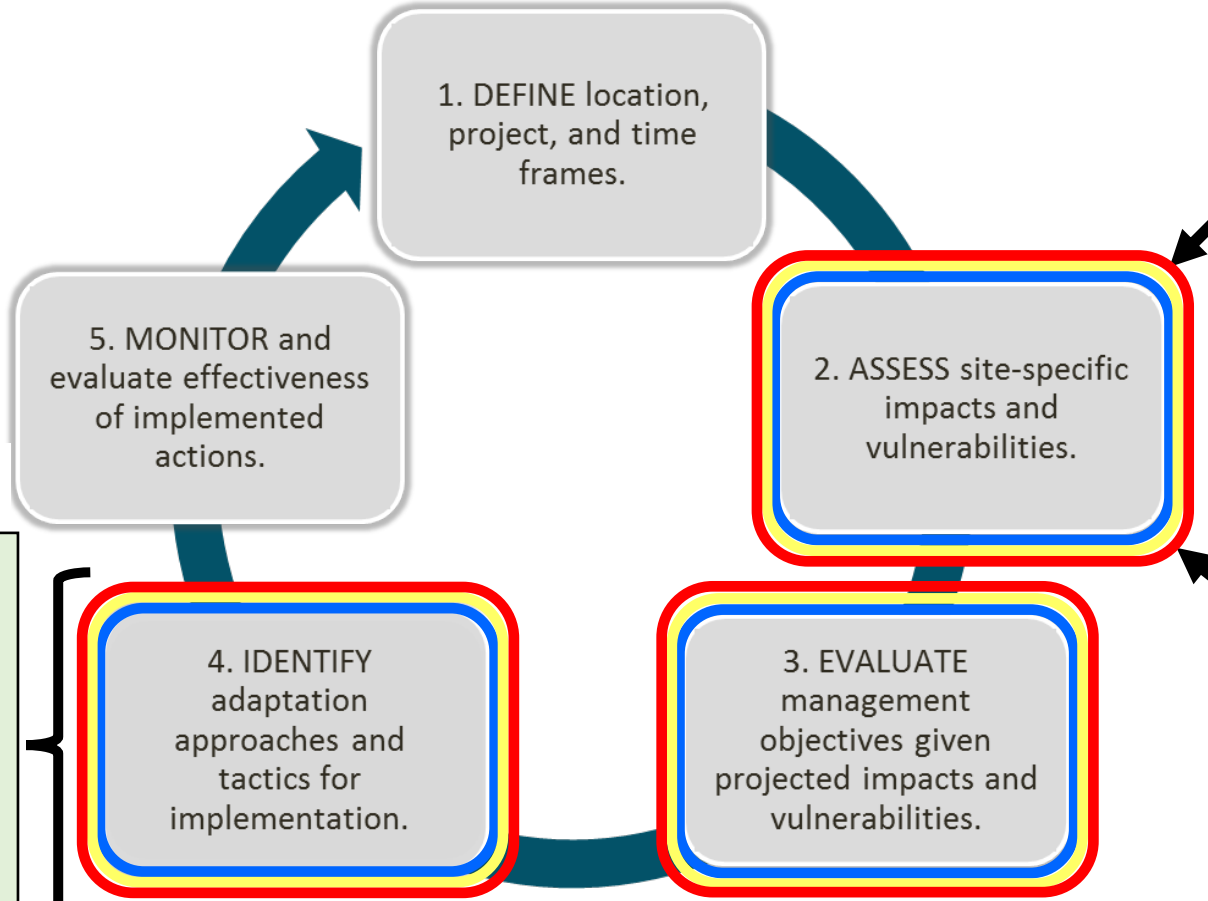

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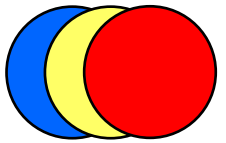

Scenarios

Illustrating scenario-based adaptation

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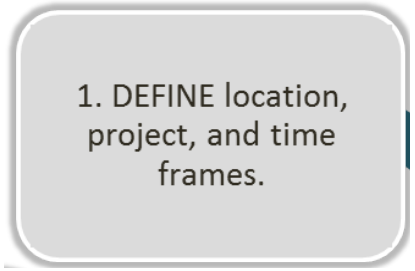
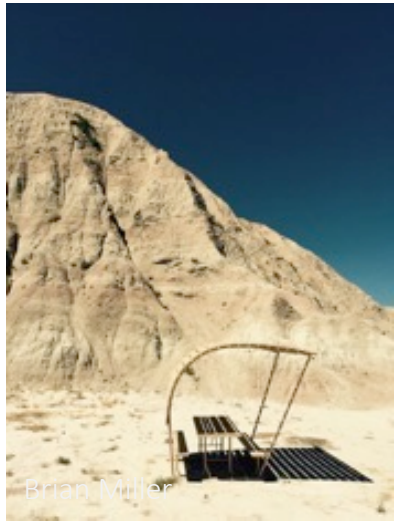


Badlands NP


Brian Miller


Amy Symstad


Brian Miller


NPS


NPS


NPS


Amy Symstad

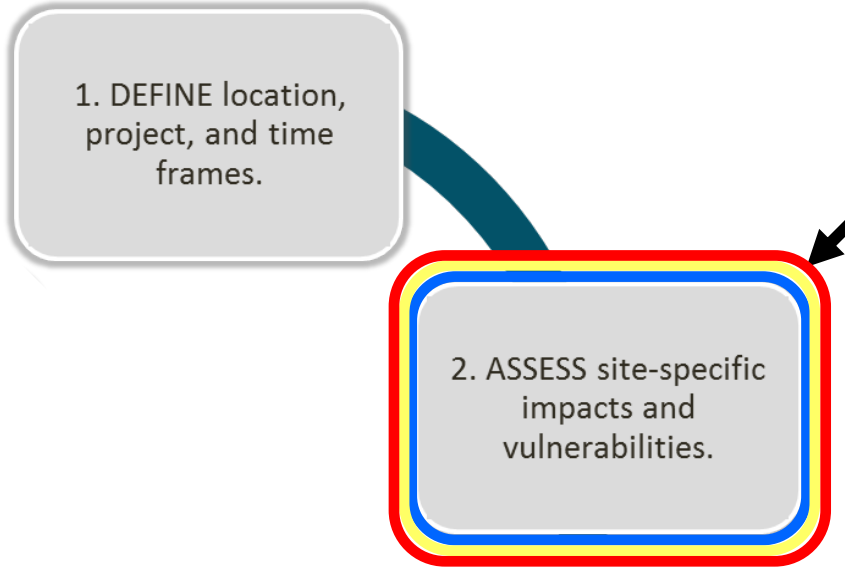

NPS


NPS

Illustrating scenario-based adaptation

Badlands NP focal resources

- Grasslands & grazing
- Infrastructure
- Paleo & archaeological resources
- T&E Species



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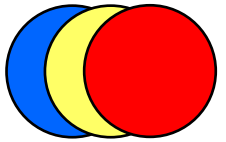

Scenarios

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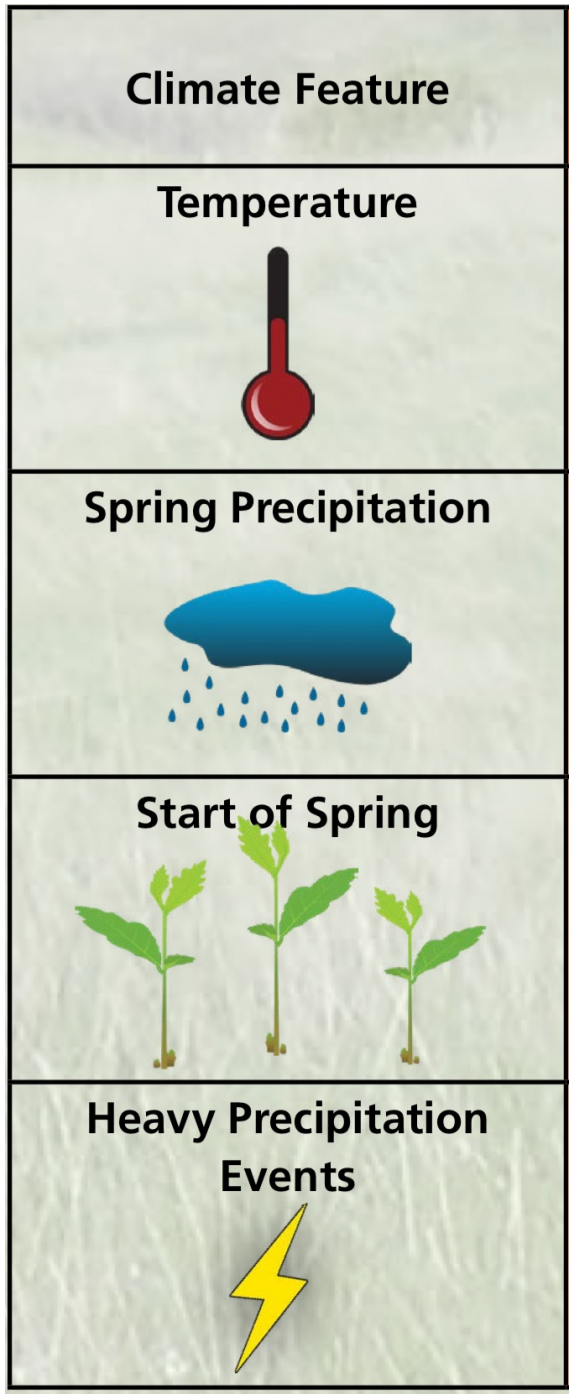
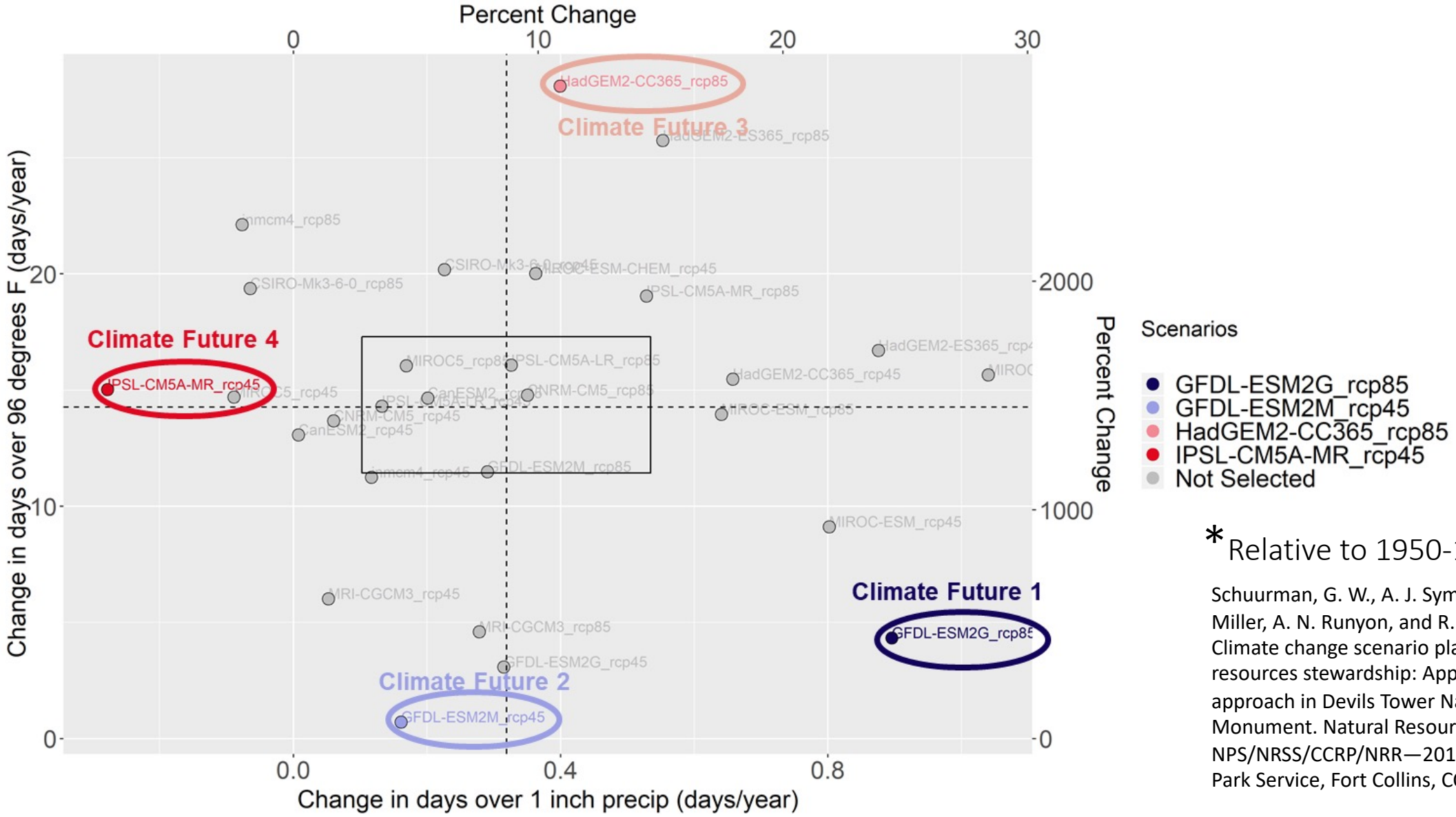


Miller BW, Symstad AJ, Schuurman GW. 2019. Implications of Climate Change Scenarios for Badlands National Park Resource Management. Resource Brief, National Park Service Resource Brief. Fort Collins, CO.

Illustrating scenario-based adaptation

Devils Tower NM - changes in extreme precip. events & hot days in 2040*



*Relative to 1950-1999

Schuurman, G. W., A. J. Symstad, B. W. Miller, A. N. Runyon, and R. Ohms. 2019. Climate change scenario planning for resources stewardship: Applying a novel approach in Devils Tower National Monument. Natural Resource Report NPS/NRSS/CCRP/NRR—2019/2052, National Park Service, Fort Collins, CO.

Climatic Change (2021) 167:38
https://doi.org/10.1007/s10584-021-03169-y

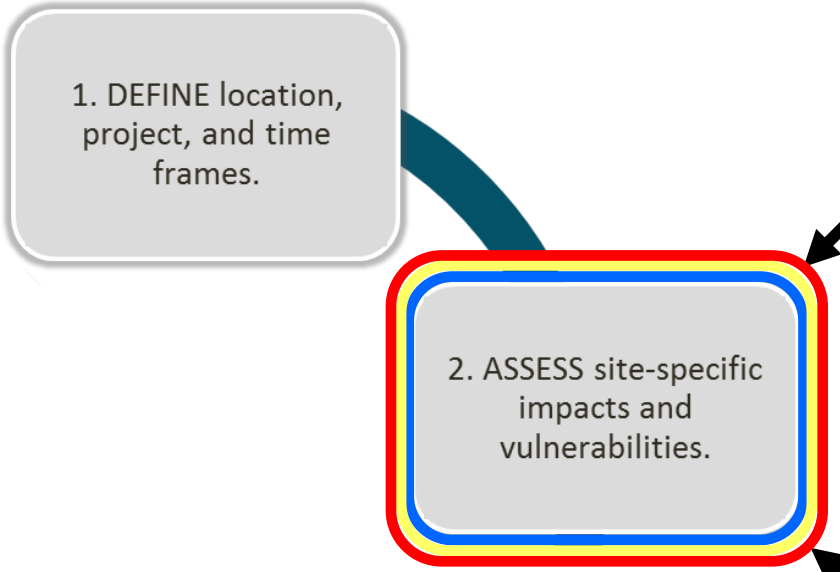
Divergent, plausible, and relevant climate futures for near- and long-term resource planning

David J. Lawrence[1] · Amber N. Runyon[1] · John E. Gross[1] · Gregor W. Schuurman[1] · Brian W. Miller[2]

Table 1. Changes in key aspects of BADL climate through 2050 for four climate futures. Arrow size and direction denote trends compared to conditions of the recent past (1950-1999). Down arrows denote decreasing values or earlier dates, up arrows increasing values, and sideways arrows no change. Larger arrows indicate greater change.

Climate Feature	Rather Hot	Awfully Dry	Wet in Bursts	The Jungle
Temperature 	↑	↑	↑	↑
Spring Precipitation 	↔	↓	↑	↑
Start of Spring 	↔	↓	↔	↓
Heavy Precipitation Events 	↑	↔	↑	↑

Miller BW, Symstad AJ, Schuurman GW,. 2019. Implications of Climate Change Scenarios for Badlands National Park Resource Management. Resource Brief, National Park Service Resource Brief. Fort Collins, CO.



Climate Futures

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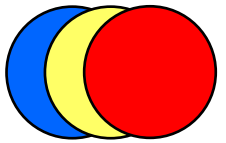


Scenarios

What are scenarios?

"Scenarios are stories about the ways that the world might turn out tomorrow…

…that can help us recognize and adapt to changing aspects of our current environment"

-Peter Schwartz

Photo: Tomáš Malík (Unsplash)

Illustrating scenario-based adaptation

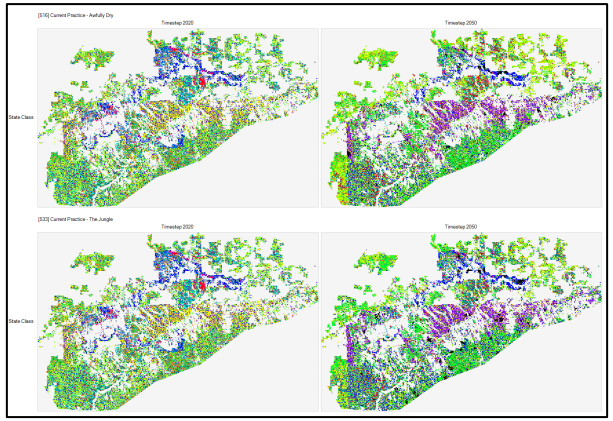
Badlands NP participatory scenario-building

Photos: B.W. Miller, G. Schuurman

Illustrating scenario-based adaptation

Badlands NP quantitative scenario-building

- Modeled veg. biomass & composition & mgmt. costs:
  - 4 climate futures
  - 4 management alternatives
    - Grazing rates/seasons
    - Rx fire
    - Invasive inventory & treatment
    - Vary by jurisdiction



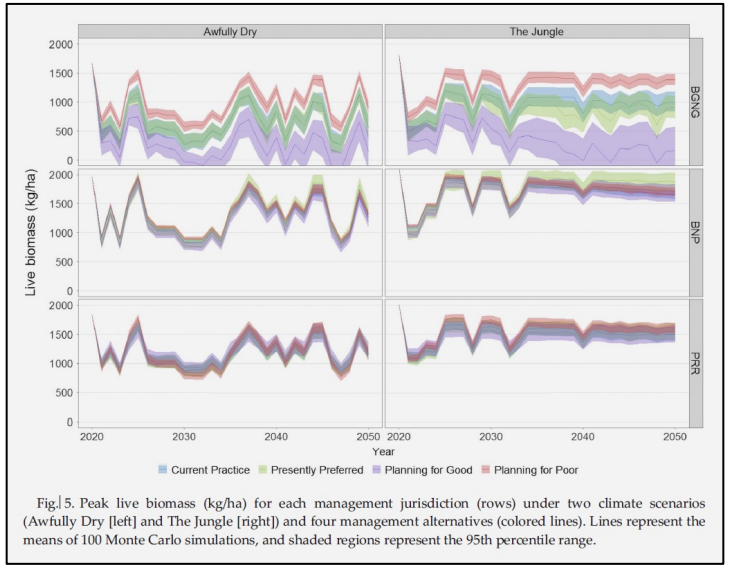


Fig. 5. Peak live biomass (kg/ha) for each management jurisdiction (rows) under two climate scenarios (Awfully Dry [left] and The Jungle [right]) and four management alternatives (colored lines). Lines represent the means of 100 Monte Carlo simulations, and shaded regions represent the 95th percentile range.

Miller, BW, AJ Symstad, L Frid, NA Fisichelli, GW Schuurman. 2017. Co-producing simulation models to inform resource management: a case study from southwest South Dakota. *Ecosphere* 8(12).

Table 2. Resource implications, achievability of current goals, and potential management responses for four climate futures by mid-century, for five re
they are based on qualitative scenario planning assessments, with some modifications or notes based on simulation modeling.

Resource or Concern	Current Goals	Rather Hot Impacts	Awfully Dry Impacts	Wet in Bursts Impacts	The Jungle Impacts
Native Vegetation 	• 30-60% of BADL vegetation in "historical climax plant community" (grassland with large component of grazing-sensitive species), 10-20% in each of late-intermediate and early-intermediate stages of succession, and 10% in early successional stage (composed largely of species highly tolerant of multiple disturbances)* • Exotic species comprise a small component	• Lowest vegetation production of all scenarios	• Lower vegetation production • Strongest expansion of shortgrass species of all scenarios	• Higher vegetation production • Tends toward greatest increase in Canada thistle of all scenarios	• Higher vegetation production • Tends toward greatest woody encroachment into grasslands of all scenarios under current management**
Bison 	• Maintain herd health, promote genetic diversity, protect vegetation, and work with Tribes and the Intertribal Buffalo Council to establish and maintain tribal herds for sustenance and cultural use	• Reduced forage and water	• Similar to Rather Hot, but also increase in wildlife disease with concentration around water sources	• Larger bison populations may be supportable • Increase in ticks and mosquitos and associated pathogens and diseases	• Similar to Wet in Bursts
Black-Footed Ferret 	• Expand the area occupied by prairie dog (the ferret's primary prey)	• Dry conditions favor expansion of prairie dog towns because shorter vegetation reduces predation risk	• Similar implications as Rather Hot	• Increase in unsuitable habitat (taller vegetation and potentially greater woody encroachment)	• Similar implications as the Wet in Bursts scenario, but impacts may be more severe due to persistently wetter conditions
Archeological & Paleontological 	• Preservation and protection	• Exposure of resources to weather and looting due to greater erosion from extreme precipitation events and reduced vegetation cover	• Exposure of resources to weather and looting due to reduced vegetation cover	• Loss of some sites due to vegetation growth • Exposure of resources in other sites to weather and looting due to greater erosion from extreme precipitation events and flooding	• Similar implications as Wet in Bursts
Infrastructure & Geohazards 	• Maintain infrastructure safety and usability and minimize geohazards	• More erosion, flooding, mass wasting • Damage to road infrastructure	• Increased soil instability due to decreased vegetation	• Similar implications as Rather Hot, plus increased flood- and erosion-related geohazards	• Similar implications as Wet in Bursts

*Badlands National Park does not have an established goal for vegetation composition. The goal listed here is an approximation of the current goal for the adjoining Buffalo Gap National Grassland, and it was used as the BADL vegetation goal in the qualitative scenario planning discussions.

Miller BW, Symstad AJ, Schuurman GW,. 2019. Implications of Climate Change Scenarios for Badlands National Park Resource Management. Resource Brief, National Park Service Resource Brief. Fort Collins, CO.

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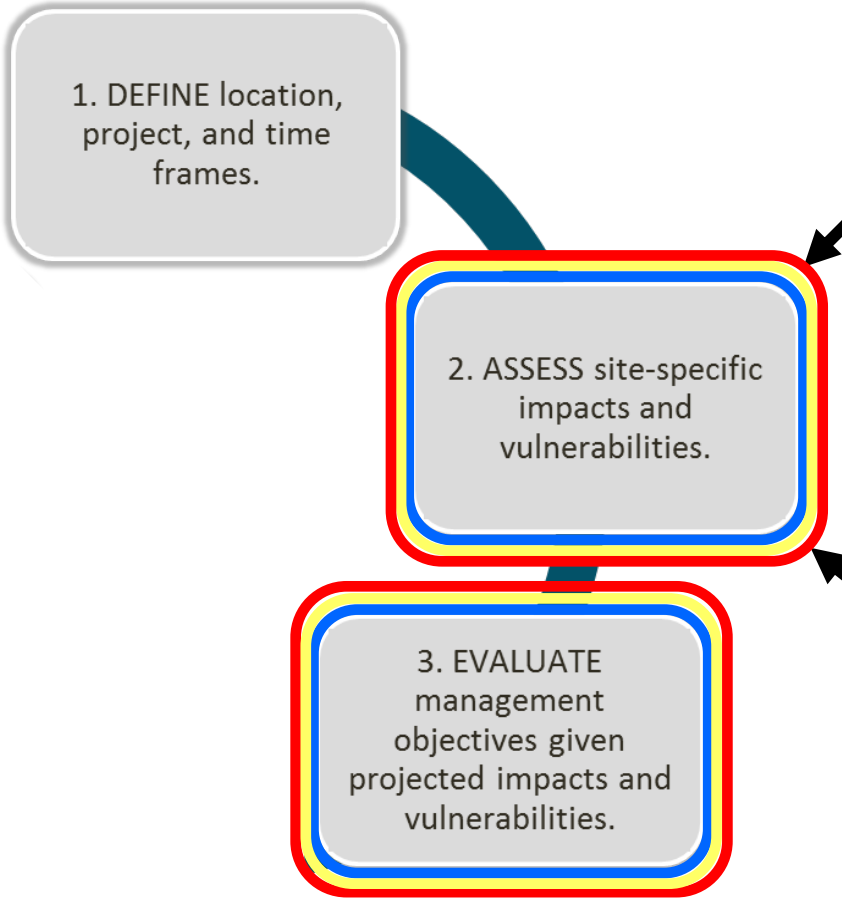
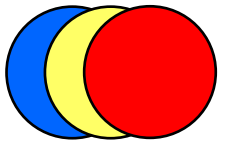
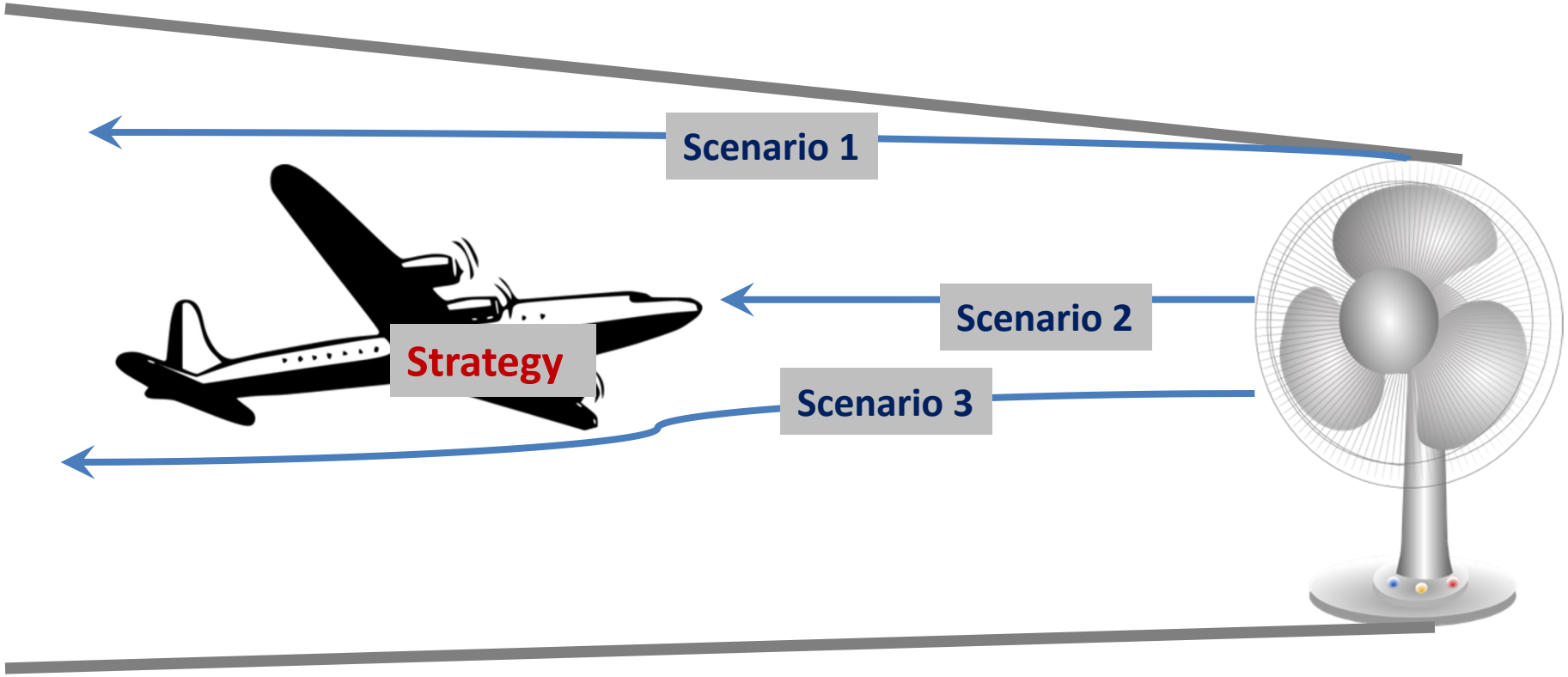




Scenarios

Illustrating scenario-based adaptation

‘Wind-tunneling’



Graphic: modified from NPS Climate Change Response Program

National Park Service
U.S. Department of the Interior

Sequoia and Kings Canyon National Parks

A Climate-Smart Resource Stewardship Strategy for Sequoia and Kings Canyon National Parks

October 2017

Current Management Goals	Scenario	Goal feasible in the future?			
		20 years		80 years	
	1				
	2				
	3				

National Park Service
U.S. Department of the Interior

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		2				
		3				

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		2				
		3				Not feasible due to path-ogens, especially for fir

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		2	🟢		🔴	
		3	🟢		🔴	Not feasible due to path-ogens, especially for fir
				Structure		
2	RESTORATION: Reduce total dead and down fuel load (target: by 60-95% immediately following initial treatment with prescribed fire)(FFMP).	1	🟢	Feasible where management tool is applied	🟢	Feasible where management tool is applied
		2	🟢		🟢	
		3	🟢		🟢	
3	RESTORATION: Use prescribed fire to restore giant sequoia mixed-conifer forest mean stand density (FFMP).	1	🟢	Feasible where management tool is applied	🔴	Not feasible due to death of many big trees
		2	🟢		🟢	Likely to be feasible where management tool applied
		3	🟢		🟡	Maybe feasible in some places
4	MAINTENANCE: Use fire to maintain fuel load mosaic across the landscape (FFMP).	1	🔴	Productivity may decrease (more area in 5-30 tons/acre), not feasible	🔴	Productivity may decrease (more area in 5-30 tons/acre), not feasible.
		2	🟢	Productivity could remain similar, somewhat feasible	🟢	Productivity could remain similar, somewhat feasible
		3	🟡	Productivity may increase (more area in >60 tons/acre), maybe somewhat feasible	🟡	Productivity may increase (more area in >60 tons/acre), maybe somewhat feasible
5	MAINTENANCE: Use fire to maintain gap/patch size distribution (FFMP).	1	🔴	Probably not feasible	🔴	Probably not feasible
		2	🟢	Maybe feasible	🟢	Maybe feasible
		3	🔴	Probably not feasible	🔴	Probably not feasible

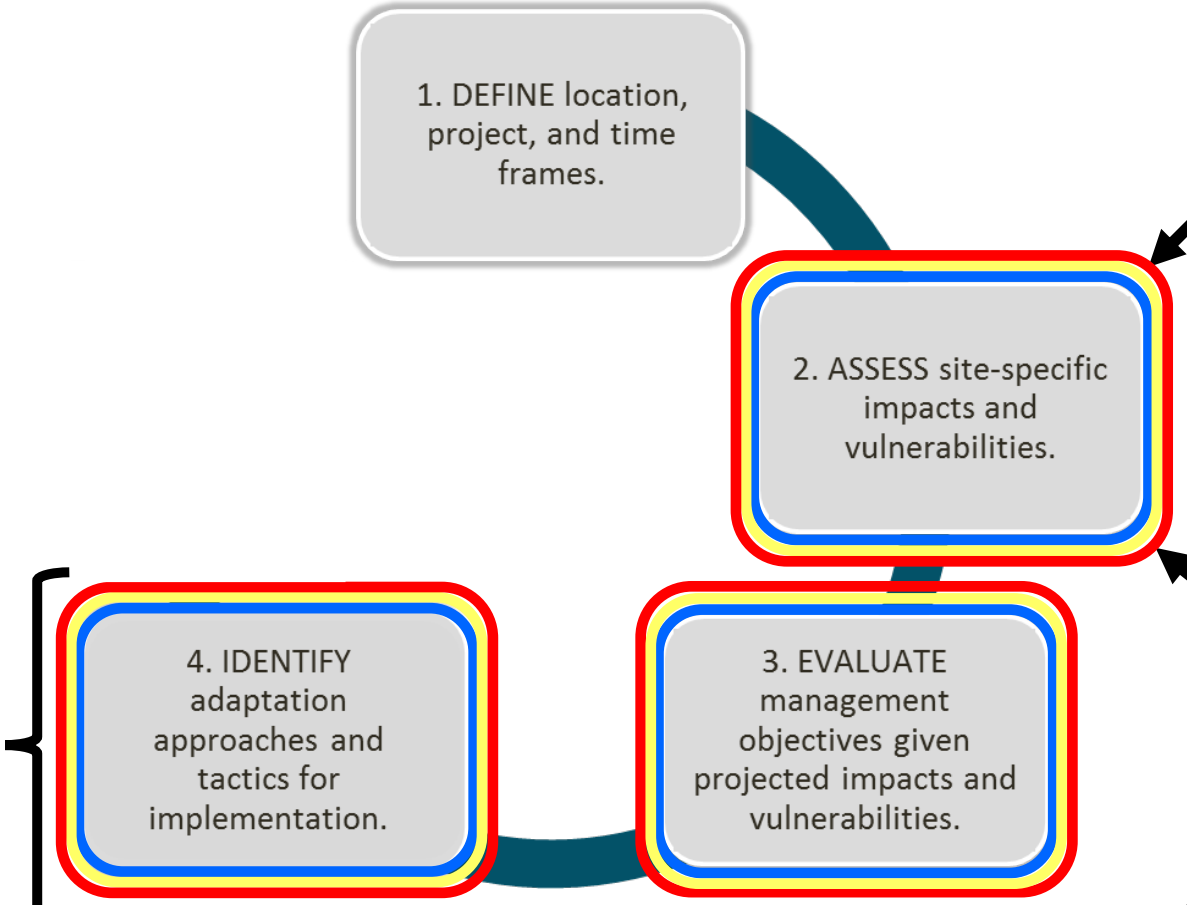
Illustrating scenario-based adaptation

Categorizing wind-tunneling outcomes

Illustrating scenario-based adaptation

Categorizing wind-tunneling outcomes

Resource	Rather Hot	Awfully Dry	Wet in Bursts	The Jungle
Archeological and Paleontological	Retrofit/ Rebuild	Business as Usual	Retrofit/ Rebuild	Retrofit/ Rebuild
Native Vegetation	Business as Usual/ Retrofit	Business as Usual/ Retrofit	Retrofit/ Rebuild	Retrofit/ Rebuild
Bison	Retrofit	Retrofit	Retrofit	Retrofit
Black-footed Ferret	Business as Usual	Business as Usual	Retrofit	Retrofit
Infrastructure, Roads, and Geohazards	Retrofit/ Rebuild	Business as Usual	Retrofit/ Rebuild	Retrofit/ Rebuild



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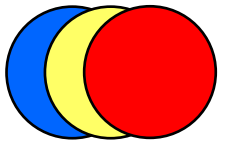
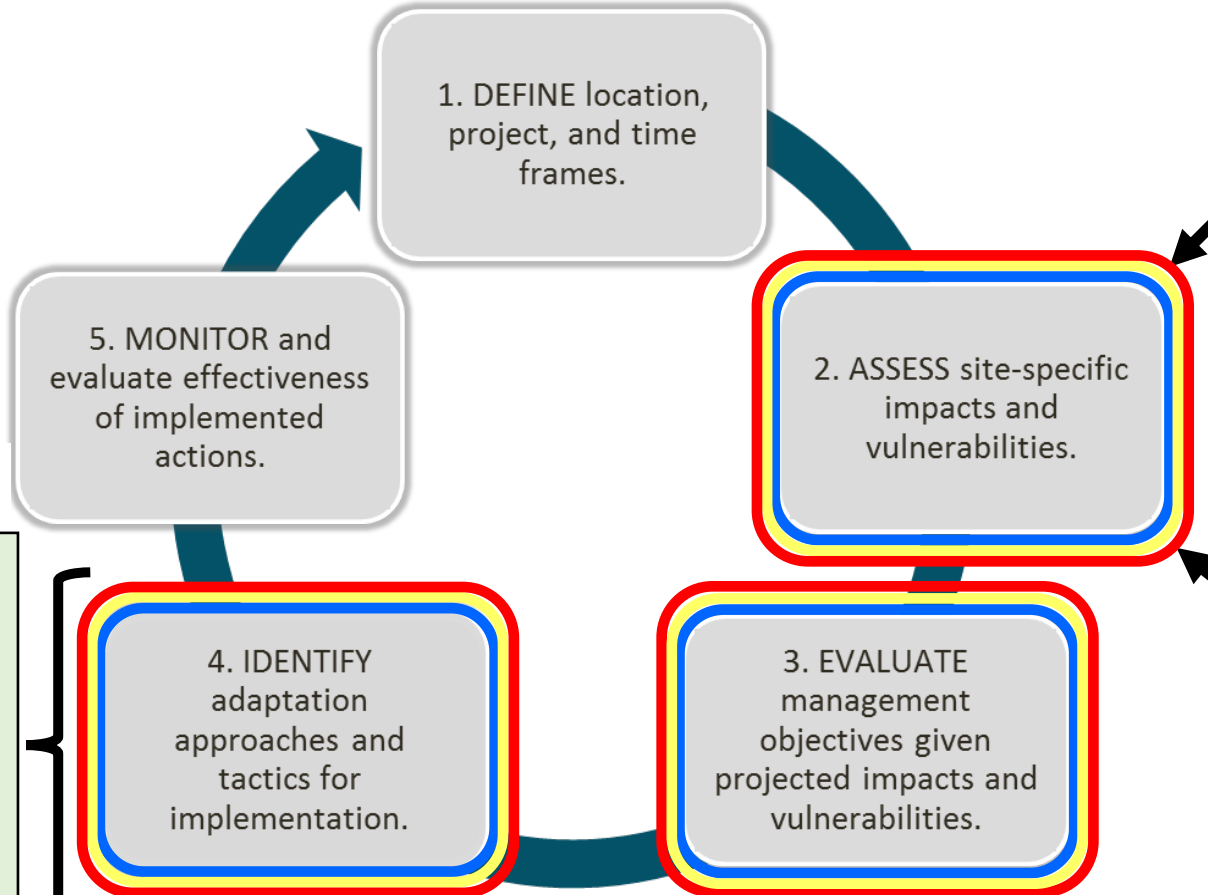


Scenarios



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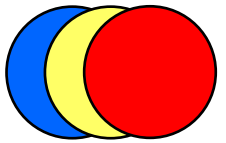

Scenarios

OUTLINE – Scenario-based adaptation

- Introduction to scenario planning
- Participatory scenario-based climate change adaptation
  - Generalized approach
  - Management outcomes

Scenario-based climate change adaptation

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Example from Devils Tower National Monument

A climate future for Devils Tower National Monument projects a 4 °F increase in annual temperature with 14% decreases in spring and summer precipitation–resulting in substantial declines in soil moisture and runoff.

Resulting in a climate-resource scenario with: decreased vegetation production, increased fire risk, and drought-induced declines in ponderosa pine, cottonwoods, and oaks. Visitation increase due to expanded shoulder season, and potential for increase in heat-related illness.

Based on this and additional scenarios, the park realized that their historical goals of improving riparian and maintaining ponderosa forests might be untenable. Therefore, they brainstormed a broad set of new approaches to detect and respond to change, incl revising monitoring.


Photo: Russ Cash (NPS)


NPS

Photo: NPS

Photo: NPS

OUTLINE – Scenario-based adaptation

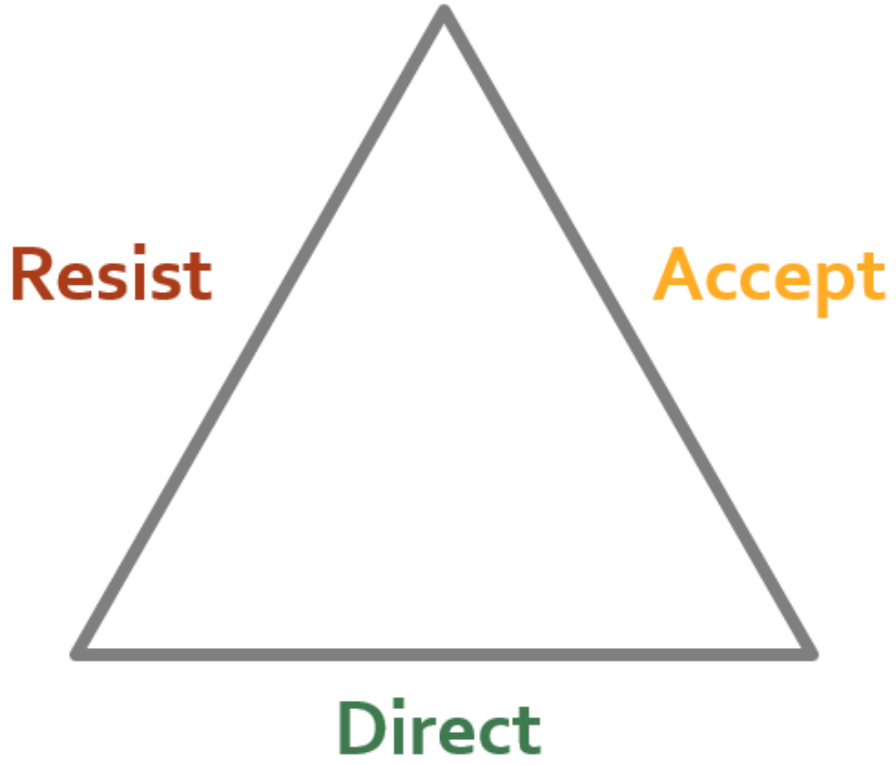
- Introduction to scenario planning
- Participatory scenario-based climate change adaptation
  - Generalized approach
  - Management outcomes
- Q&A

Questions or comments about scenario-based climate change adaptation?

Intermission

Scenario-based CC adaptation

The RAD framework



Another quick poll
to gauge your familiarity

Please indicate your level of experience (if any) with the resist-accept-direct (RAD) framework:

1) I don’t know much (“isn’t this surfer slang from the 80s?”)
2) I am somewhat familiar with the framework
3) I am familiar with the framework (e.g., have seen webinars or read key papers)

OUTLINE – the RAD framework

- Brief RAD framework introduction
- Background – the challenge of climatic & ecological non-stationarity
- Addressing non-stationarity
- Exploring the framework
- Applying the framework
- RAD vs other frameworks

OUTLINE – the RAD framework

- Brief RAD framework introduction

What is the RAD framework?

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A tool to foster clear, strategic responses to strong human-driven ecological trajectories or abrupt changes

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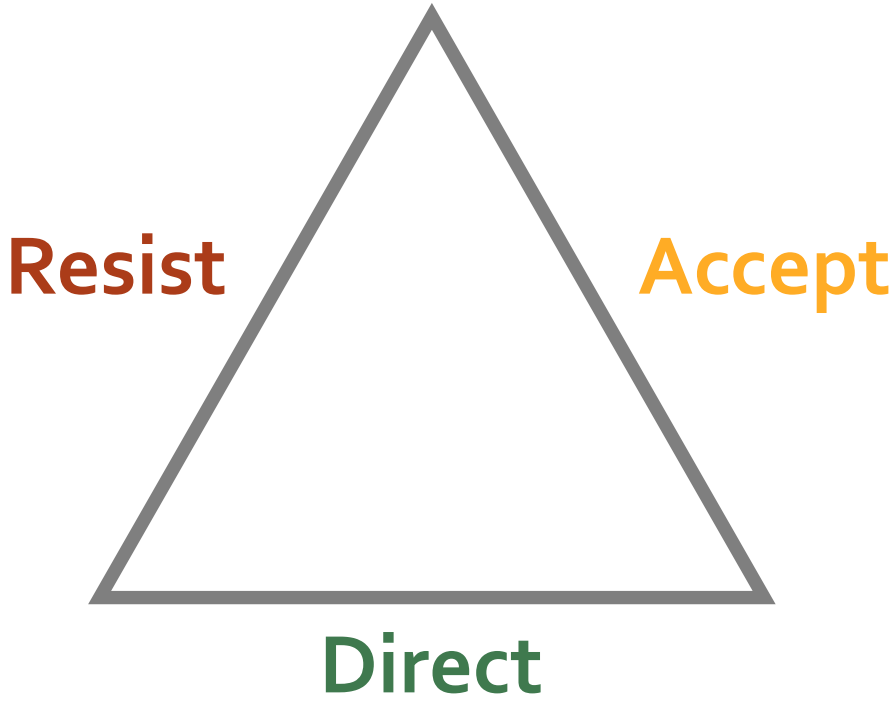

Design adapted from Thompson et al. 2020

U.S. Fish and Wildlife Service

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Climate Change

National Wildlife Refuge System

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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

DEPARTMENT OF THE INTERIOR
CLIMATE ACTION PLAN

2021

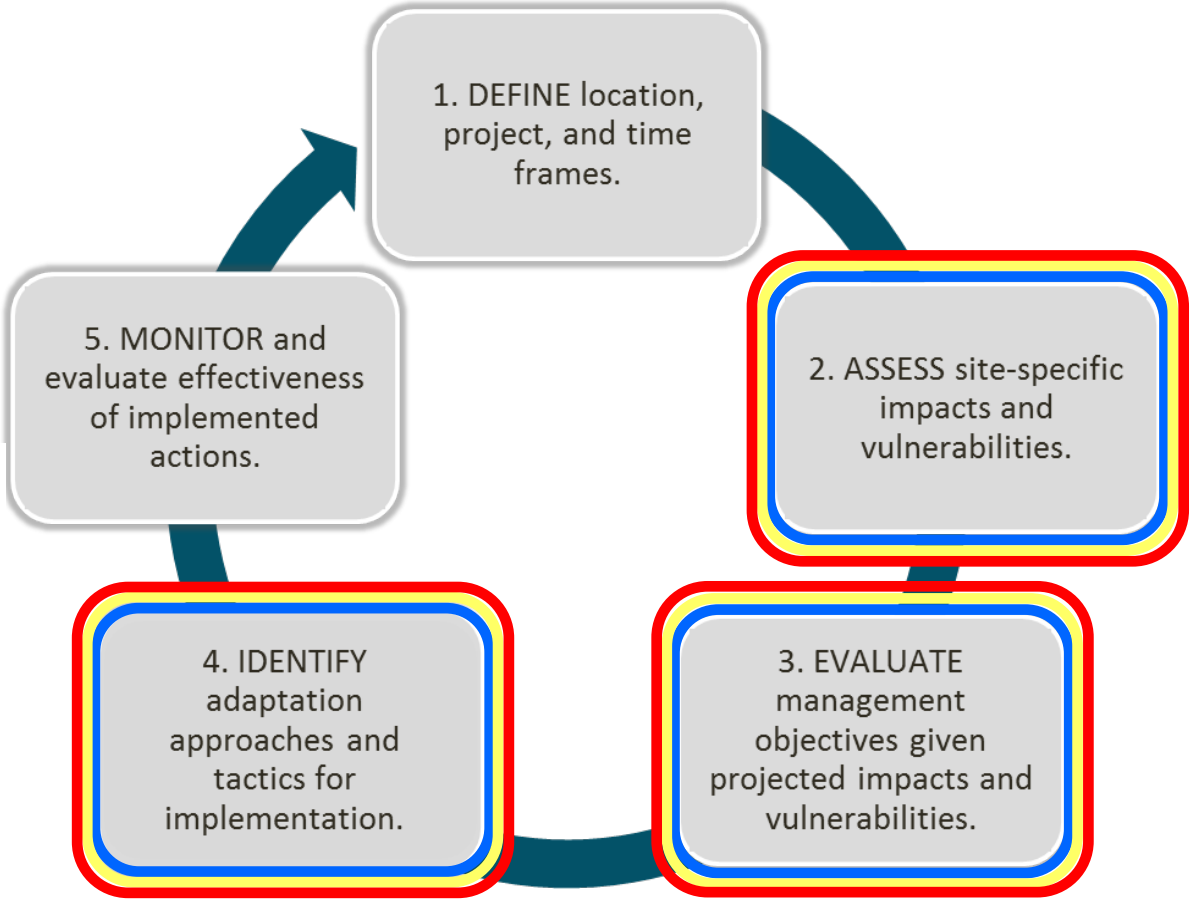
- Preparing and Managing for Ecological Transformation – A consortium of Federal agencies including the NPS, USFWS, USGS, BLM, USFS, and NOAA, as well as States,non-governmental organizations and academia, developed a decision framework to help resource managers prepare for and manage ecosystems undergoing ecological transformation. The Resist-Accept-Direct (RAD) decision framework promotes analysis of the range of options to respond to ecological changes driven by climate change and other factors. The framework acknowledges that resisting ecological change driven by climate change may be infeasible in many instances. In such cases, managers may accept ongoing changes or direct ecologicaltrajectories toward a desired future state, but with a different ecological community (e.g., transition of a boreal forest to a temperate forest).

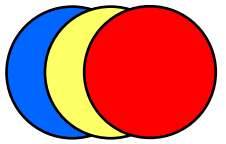
COASTAL CHANGE HAZARDS AND RESILIENCE

USGS scientists integrate coastal maps and models with NOAA forecasts to deliver predictions of coastal erosion and shoreline

Generalized scenario-based adaptation approach

Where is the framework applied in adaptation?





Scenarios

Generalized scenario-based adaptation approach

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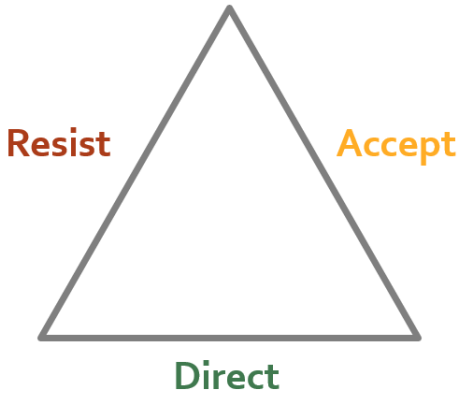


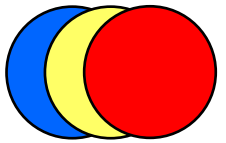
1. DEFINE location, project, and time frames.

2. ASSESS site-specific impacts and vulnerabilities.

3. EVALUATE management objectives given projected impacts and vulnerabilities.

4. IDENTIFY adaptation approaches and tactics for implementation.

5. MONITOR and evaluate effectiveness of implemented actions.



Scenarios

BioScience Special Section, published Jan 2022

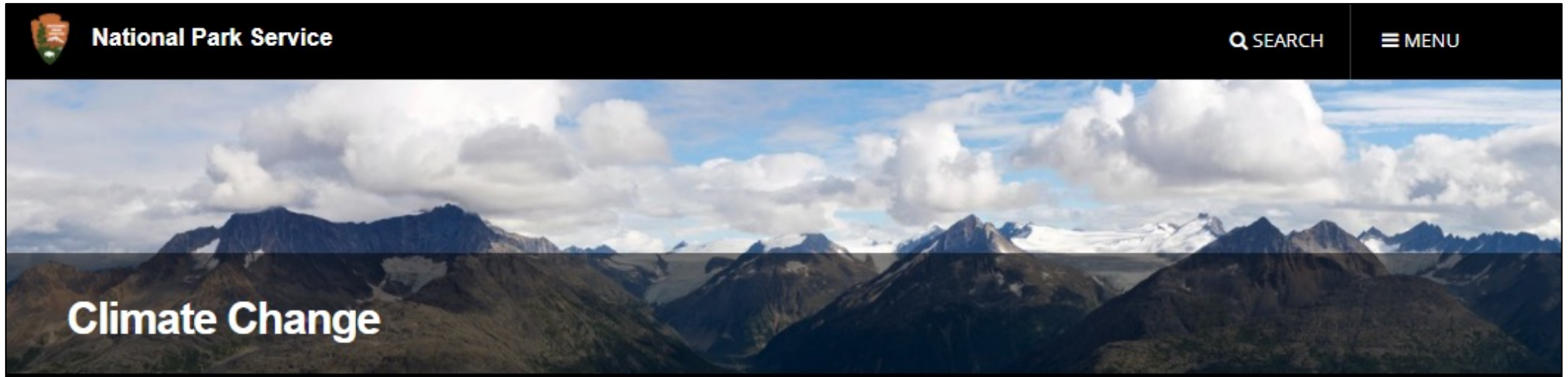
1. Schuurman, G.W., Cole, D., Cravens, A.E., Covington, S., Crausbay, S., Hawkins Hoffman, C., Lawrence, D., Magness, D., Morton, J., Nelson, L., O'Malley, R. Navigating ecological transformation: Resist-Accept-Direct (RAD) as a path to a new resource management paradigm.

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.

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.

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

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.



Resist-Accept-Direct Framework

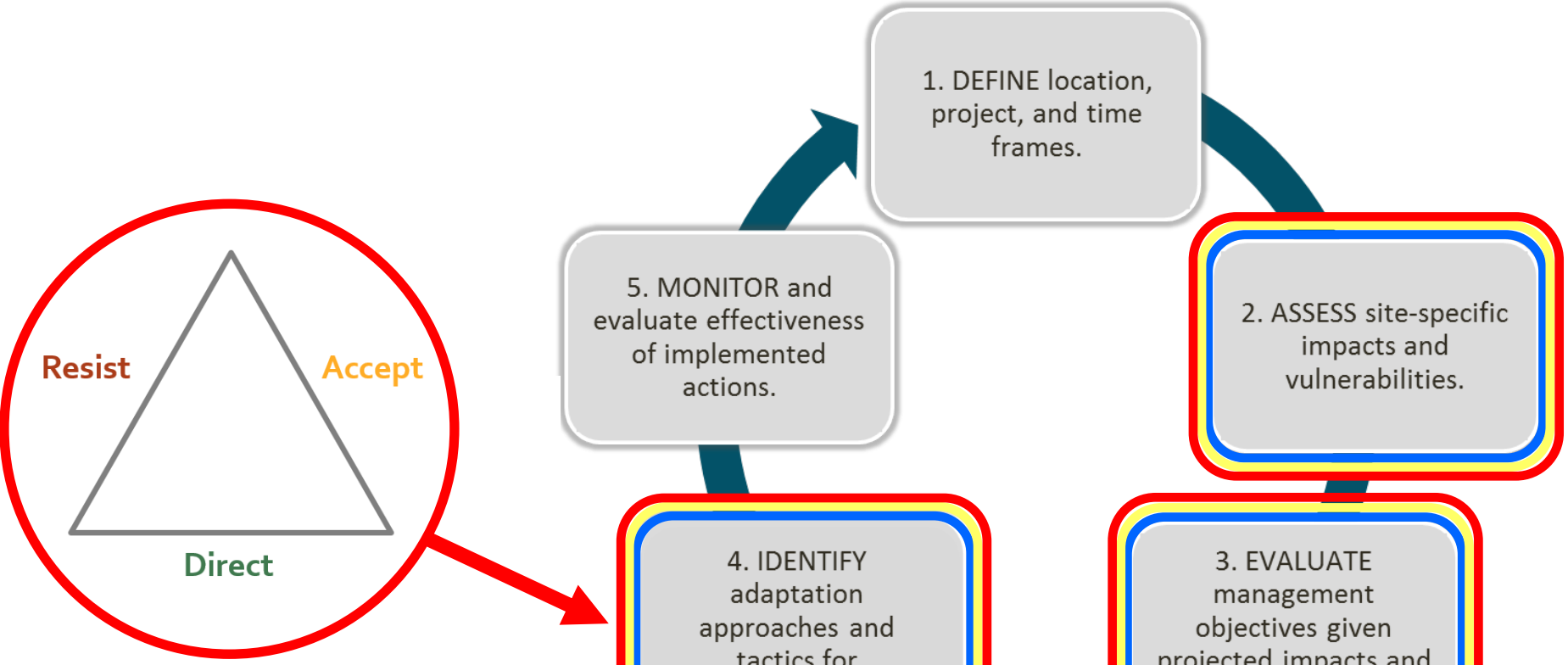
What is RAD?

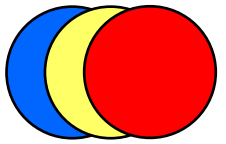
Park managers today face growing challenges. As climate change interacts with other stressors such as land use change, pollution, and nonnative species, ecosystems are changing beyond the bounds of historical variability. These changes are increasingly difficult to resist. Thus, managers are thinking more broadly about how to effectively conserve resources in this rapidly changing world. In this context, the **resist–accept–direct (RAD) framework** helps decision makers make informed, purposeful, and strategic choices. This tool is simple and flexible, complements other important climate change adaptation approaches, and applies to a wide range of decisions that managers must make as they steward transforming ecosystems.

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

Generalized scenario-based adaptation approach

Where is the framework applied in adaptation?





Scenarios

BioScience Special Section, published Jan 2022

1. Schuurman, G.W., 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.

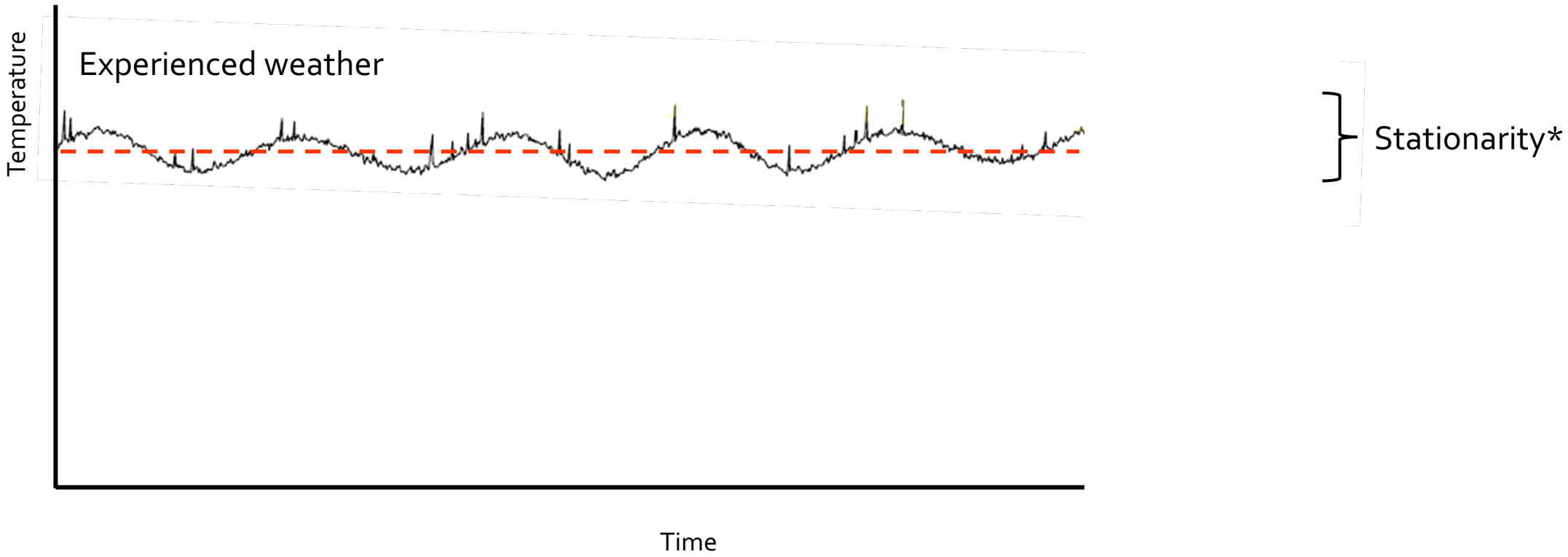
BioScience Special Section, published Jan 2022

1. *Special Section on the Resist–Accept–Direct Framework*

Navigating Ecological Transformation: Resist–Accept–Direct as a Path to a New Resource Management Paradigm

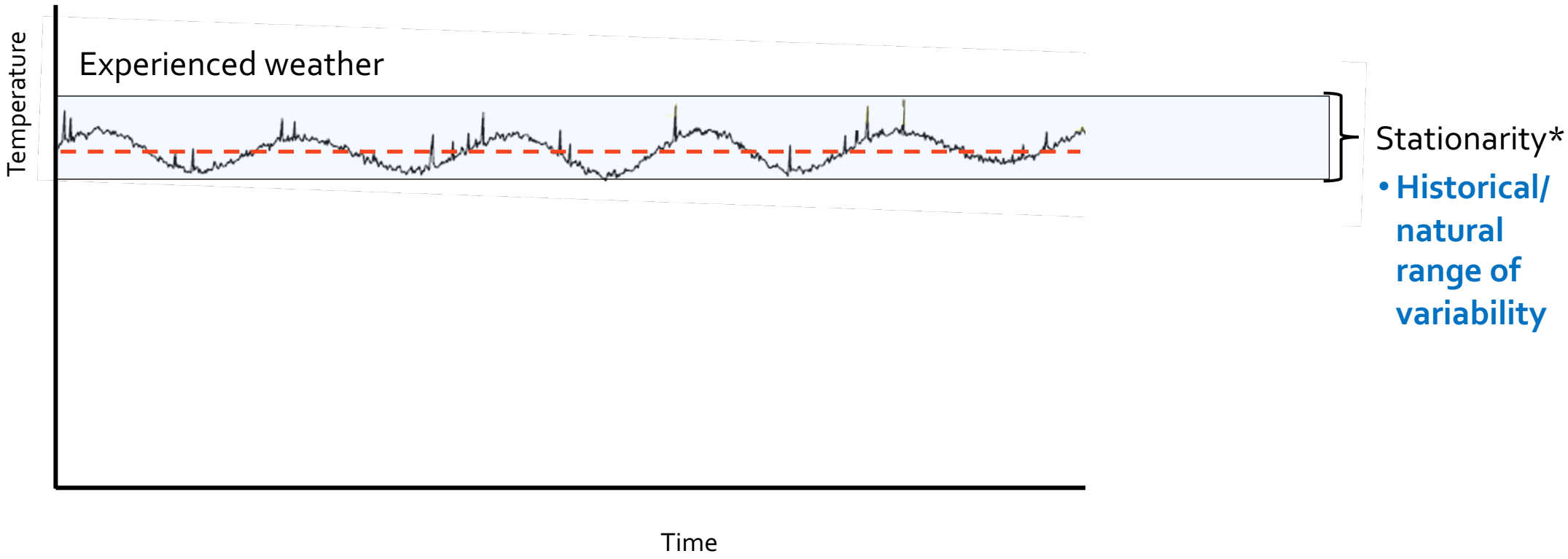
OUTLINE – the RAD framework

- Brief RAD framework introduction
- Background – the challenge of climatic & ecological non-stationarity



*"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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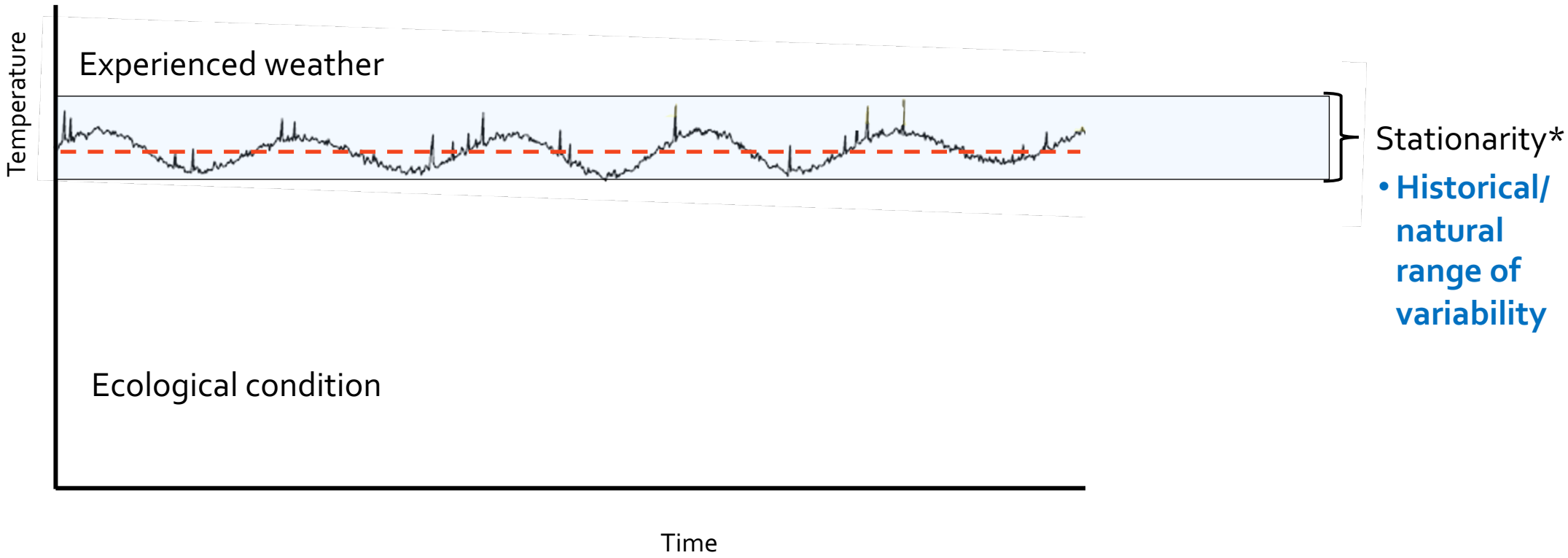

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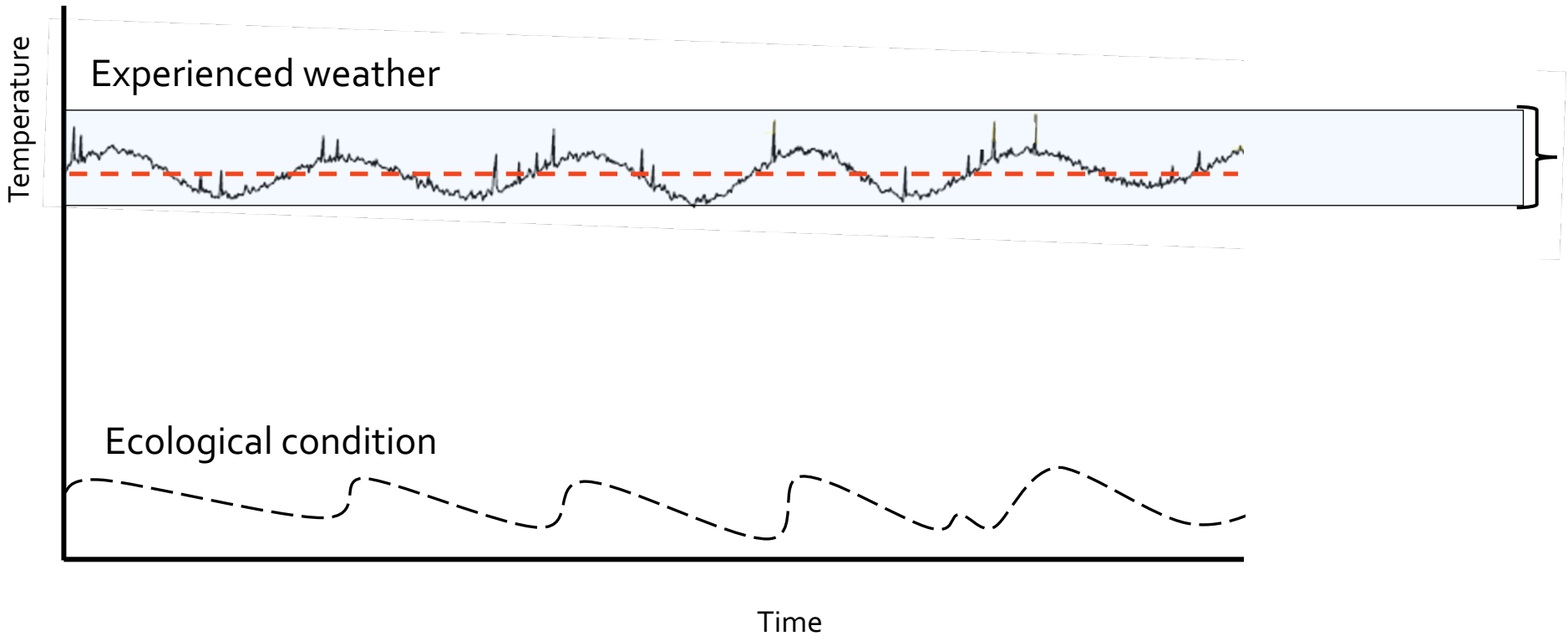

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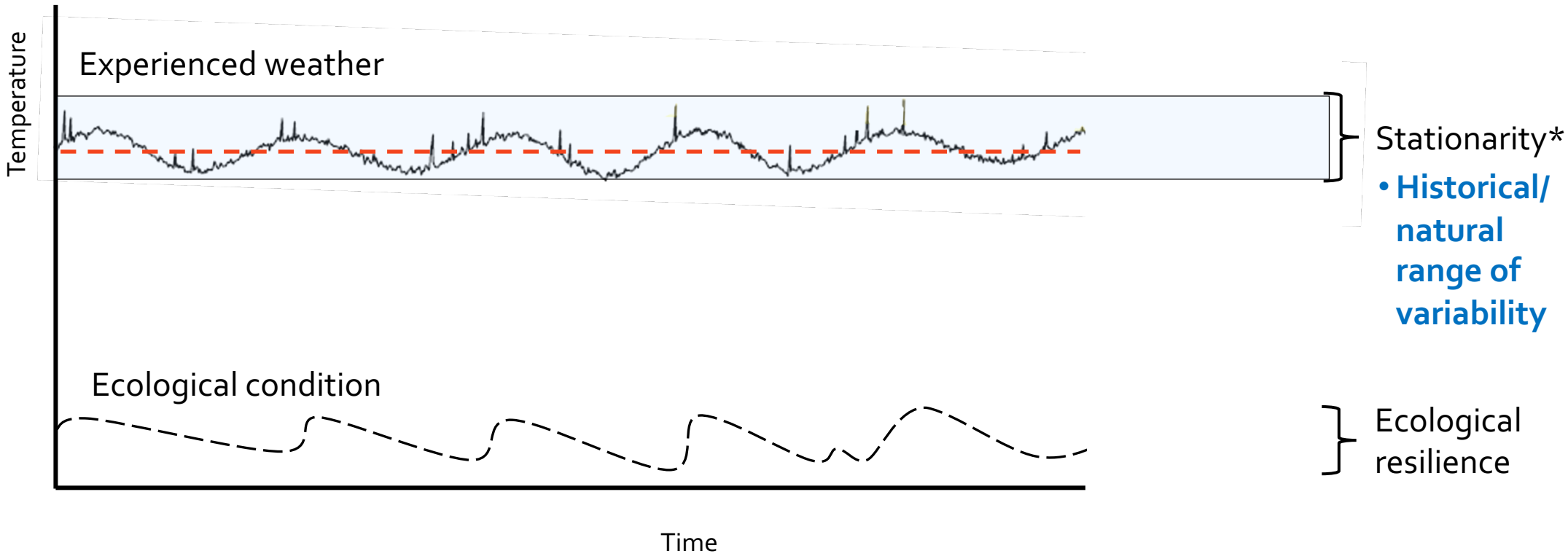

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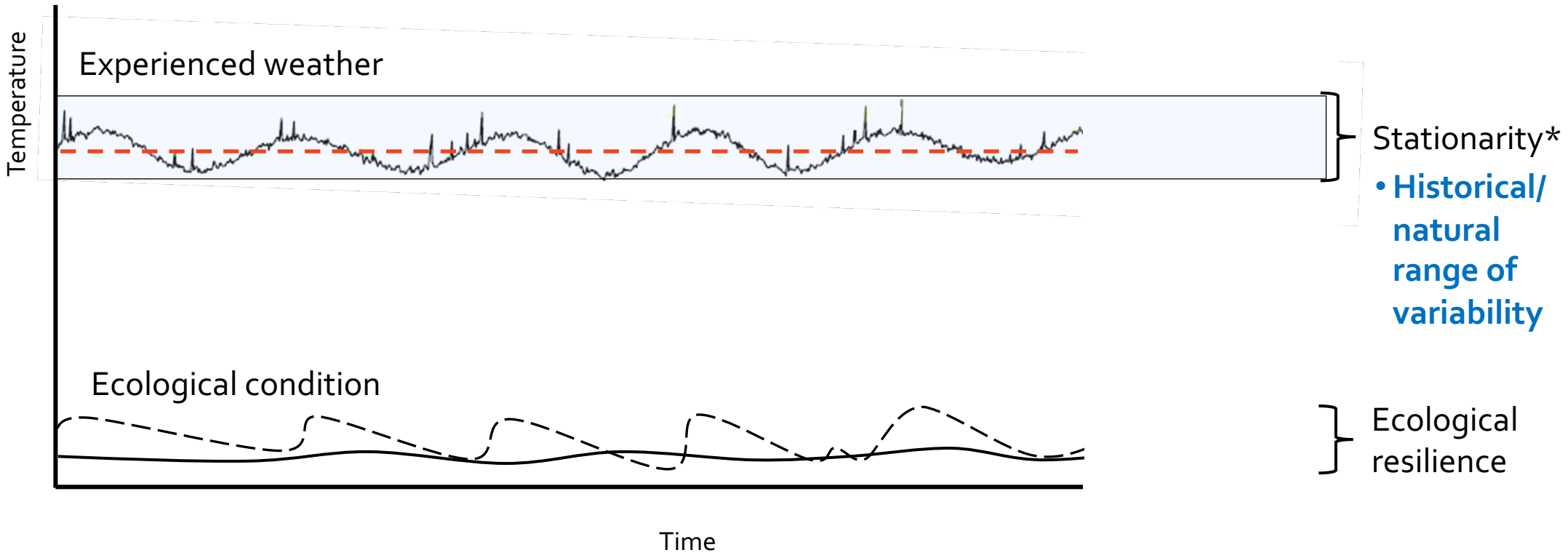

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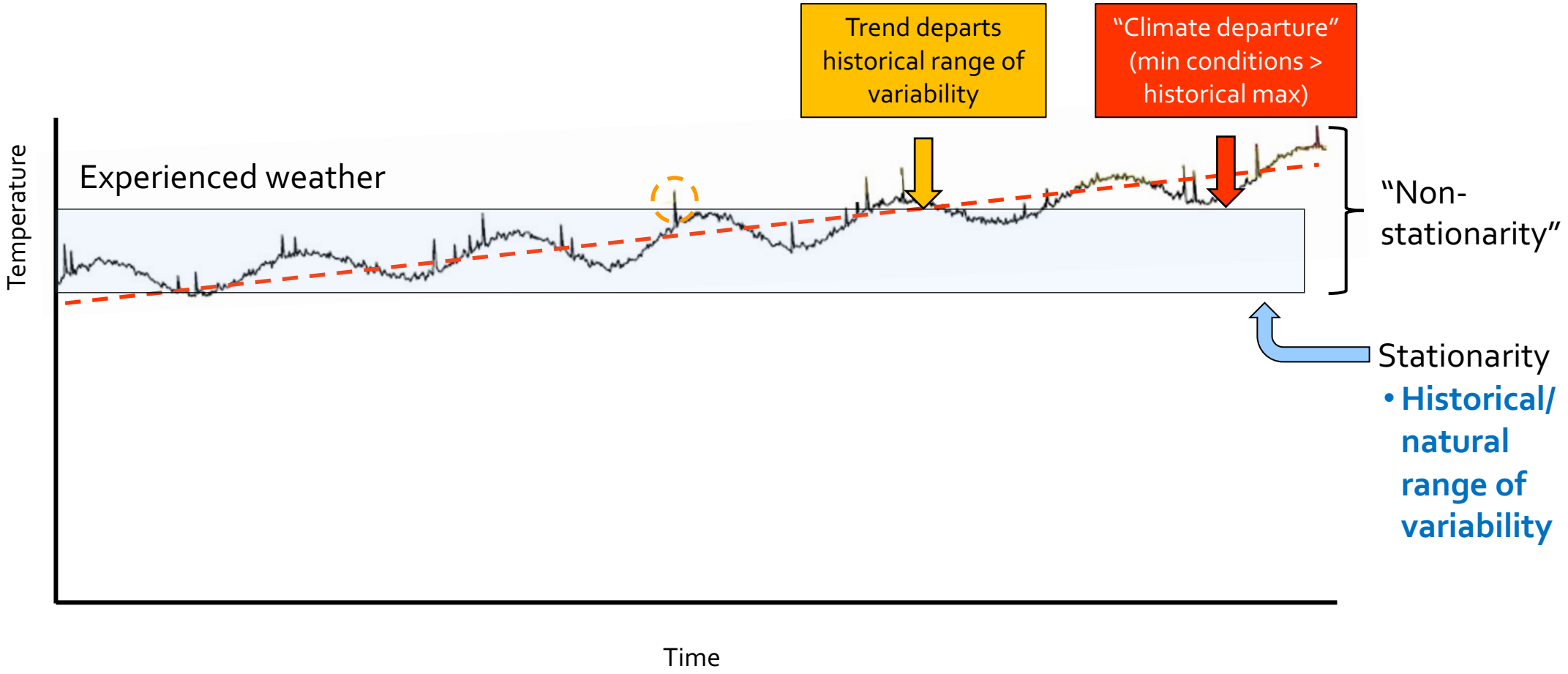

Trend departs historical range of variability
"Climate departure" (min conditions > historical max)
Temperature
Experienced weather
"Non-stationarity"
Stationarity
• Historical/ natural range of variability
Time

https://www.klcc.org/health-medicine/2021-06-29/here-to-stay-extreme-heat-will-be-ongoing-public-health-issue-in-lane-co

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.

CLIMATE CHANGE | JULY 9, 2021

Buckle Up, New York: Subway Flooding Is Here to Stay

By Willy Blackmore

Photo: Timothy A. Clary/AFP via Getty Images

https://www.curbed.com/2021/07/tropical-storm-elsa-subway-flooding.html

Are warmer winters here to stay?

News Top Stories February 5, 2020

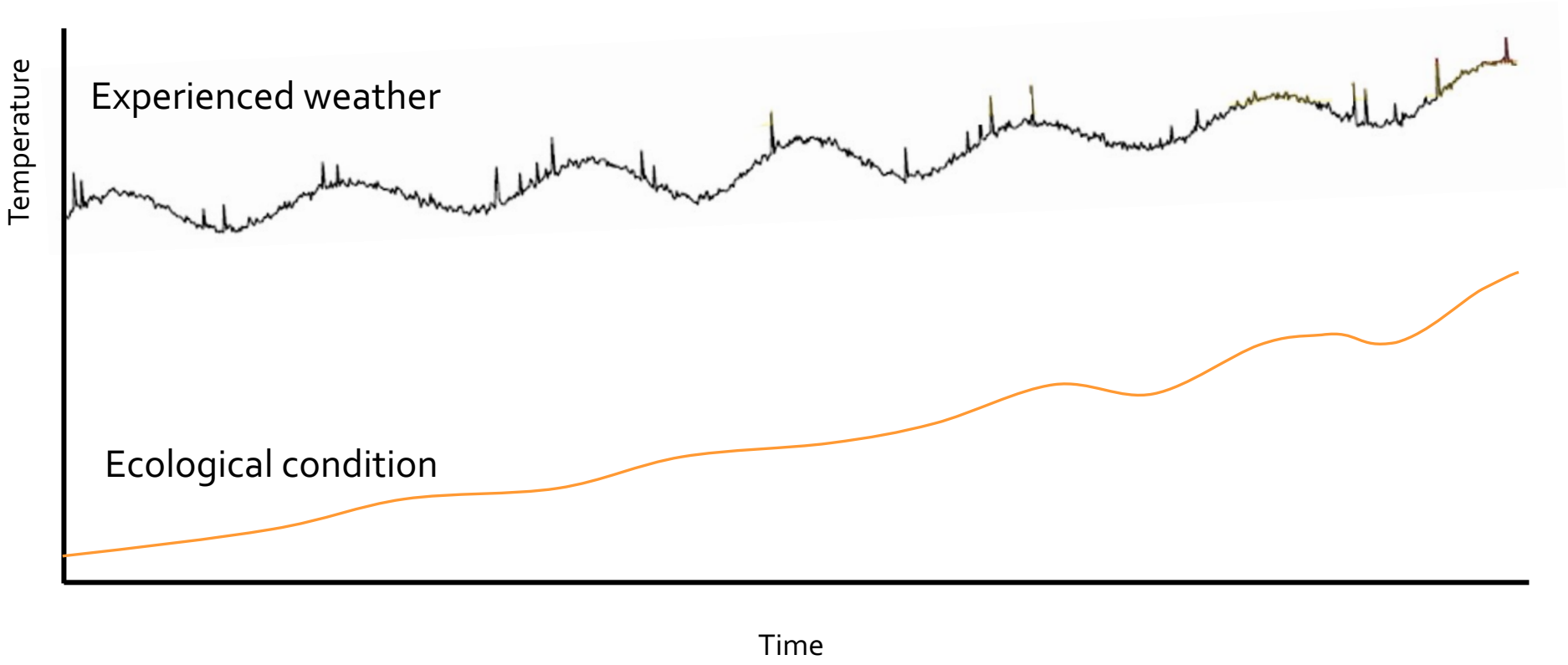
https://glueottawa.com/2020/02/05/are-warmer-winters-here-to-stay/

NOAA: Record-setting high-tide floods here to stay

By Hannah Northey | 07/14/2021 03:50 PM EST

NOAA found that record-breaking high-tide flooding is expected to continue into next year. Minor flooding at high tide during a winter storm in Scituate, Mass., is shown here. Scott Eisen/Getty

https://www.eenews.net/articles/noaa-record-setting-high-tide-floods-here-to-stay/


Temperature
Experienced weather
Ecological condition
Time

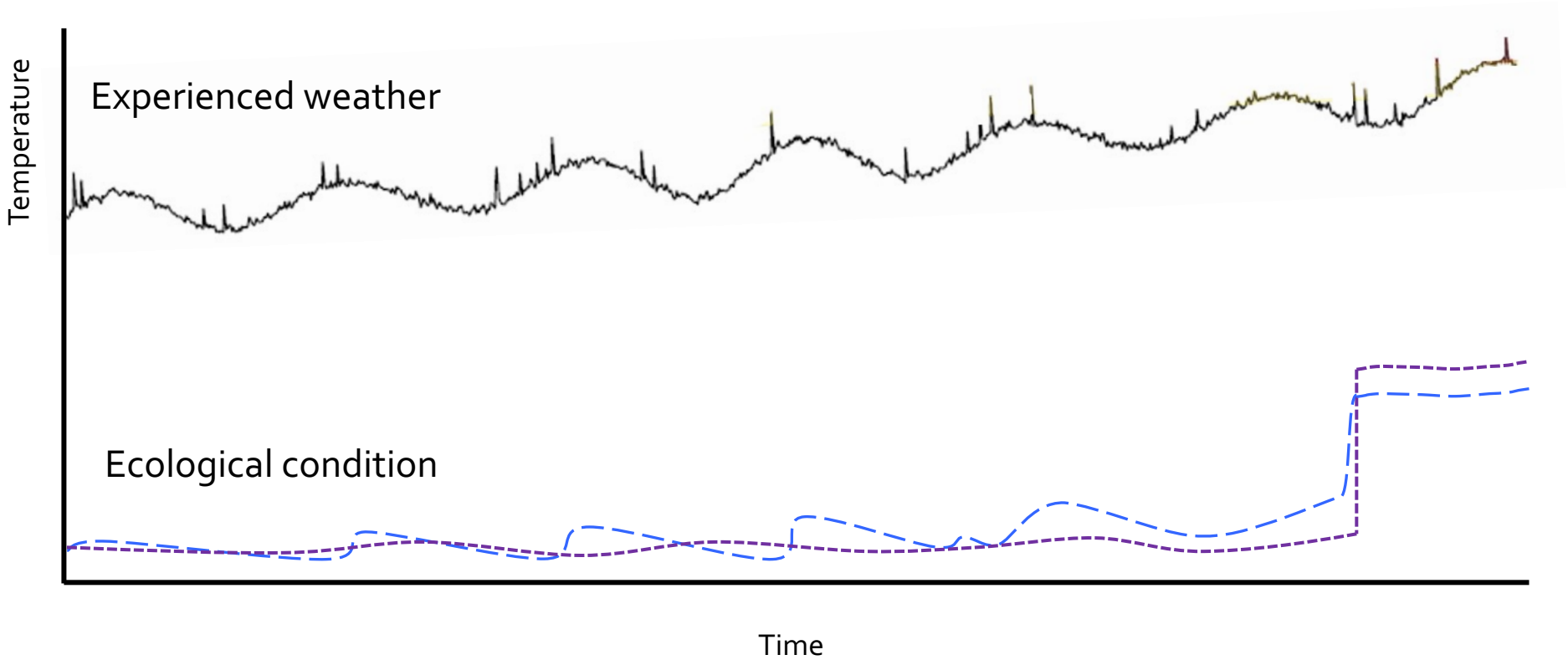
As nature shifts, climate change forces rewrite of U.S. conservation strategy

by Carey L. Biron | @clbtea | Thomson Reuters Foundation

Wednesday, 1 September 2021 01:00 GMT

THOMSON REUTERS FOUNDATION NEWS

Blackwater National Wildlife Refuge; https://news.trust.org/item/20210901005958-qq10g/; image by Carey Biron


Temperature
Experienced weather
Ecological condition
Time

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*

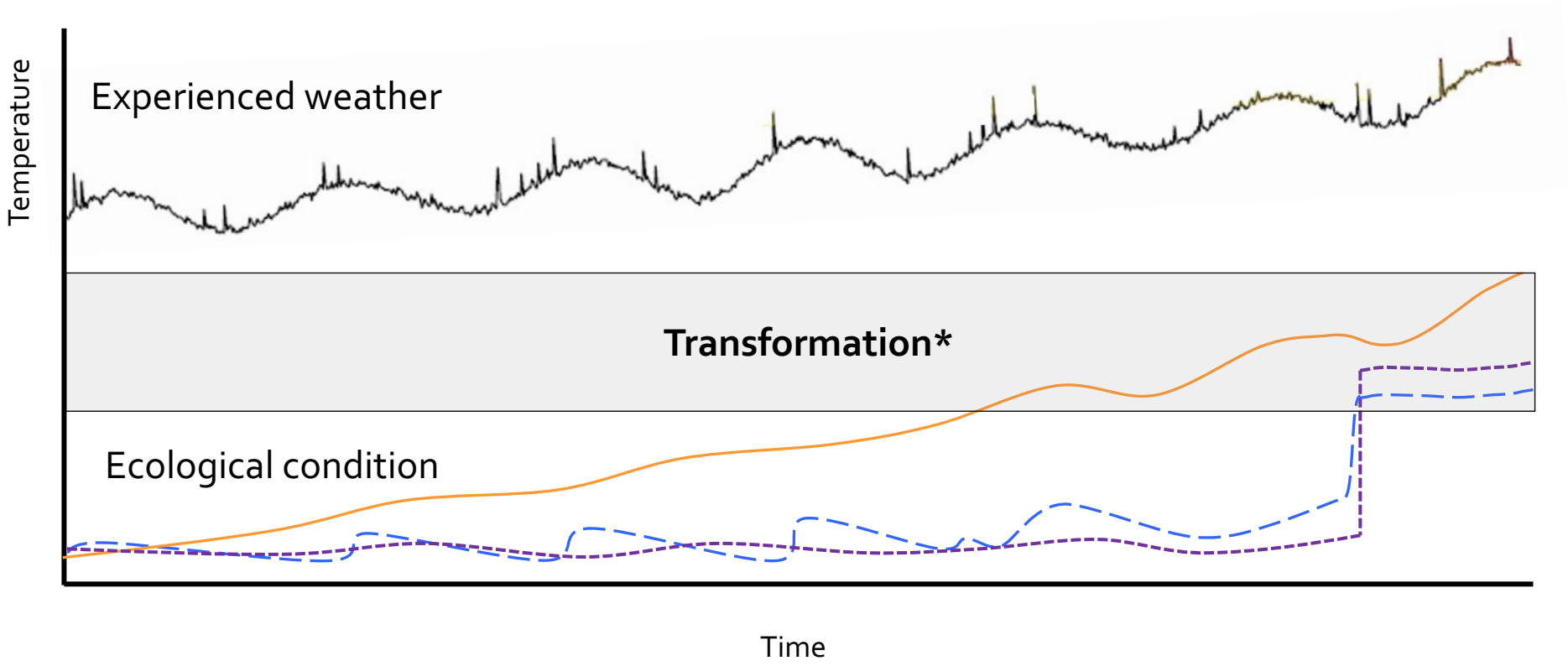
Thu 8 Jul 2021 05.00 EDT

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

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

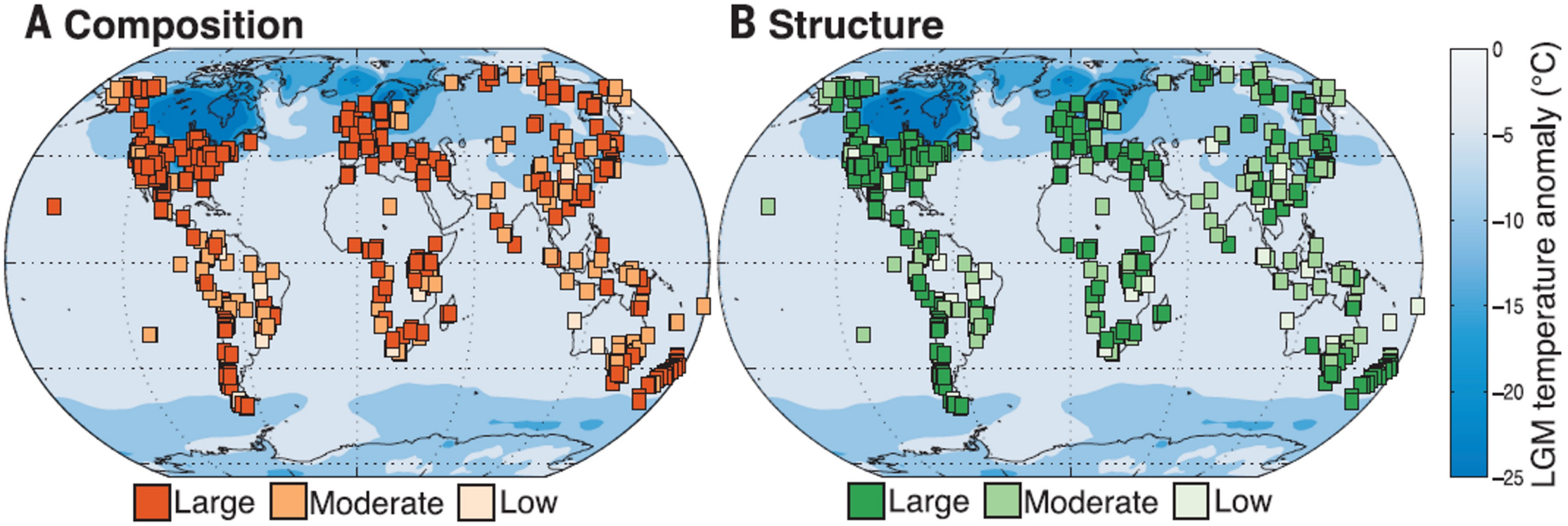
British Columbia scientist says heat essentially cooked mussels: ‘The shore doesn’t usually crunch when you walk’

https://www.theguardian.com/environment/2021/jul/08/heat-dome-canada-pacific-northwest-animal-deaths



* 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" (Crausbay et al. 2022. BioScience)

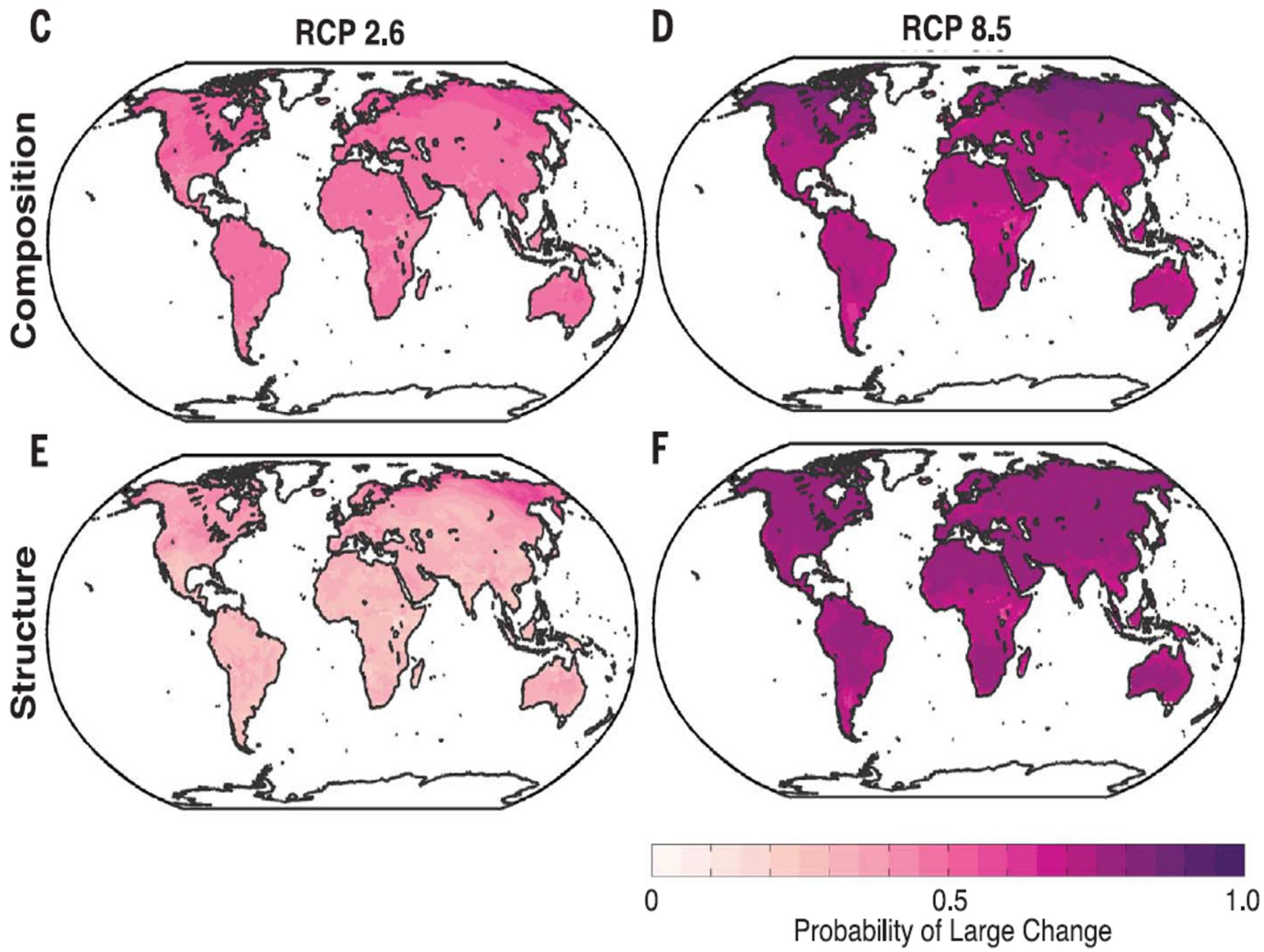
Ecological transformation in the paleorecord



Paleo-transformations were pervasive
when climate change was rapid

Nolan et al. 2018 Science

Ecological transformation in the future

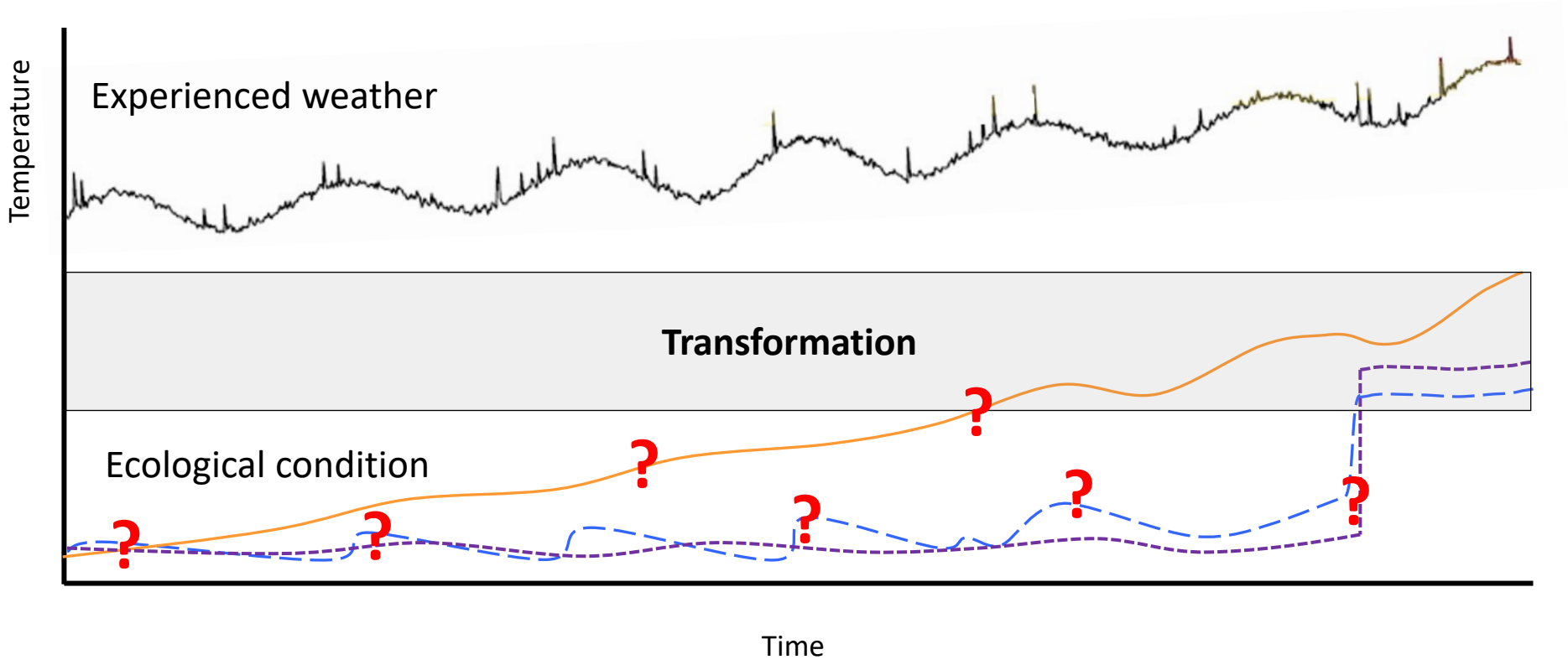


The threat of future transformations is pervasive

Nolan et al. 2018 Science

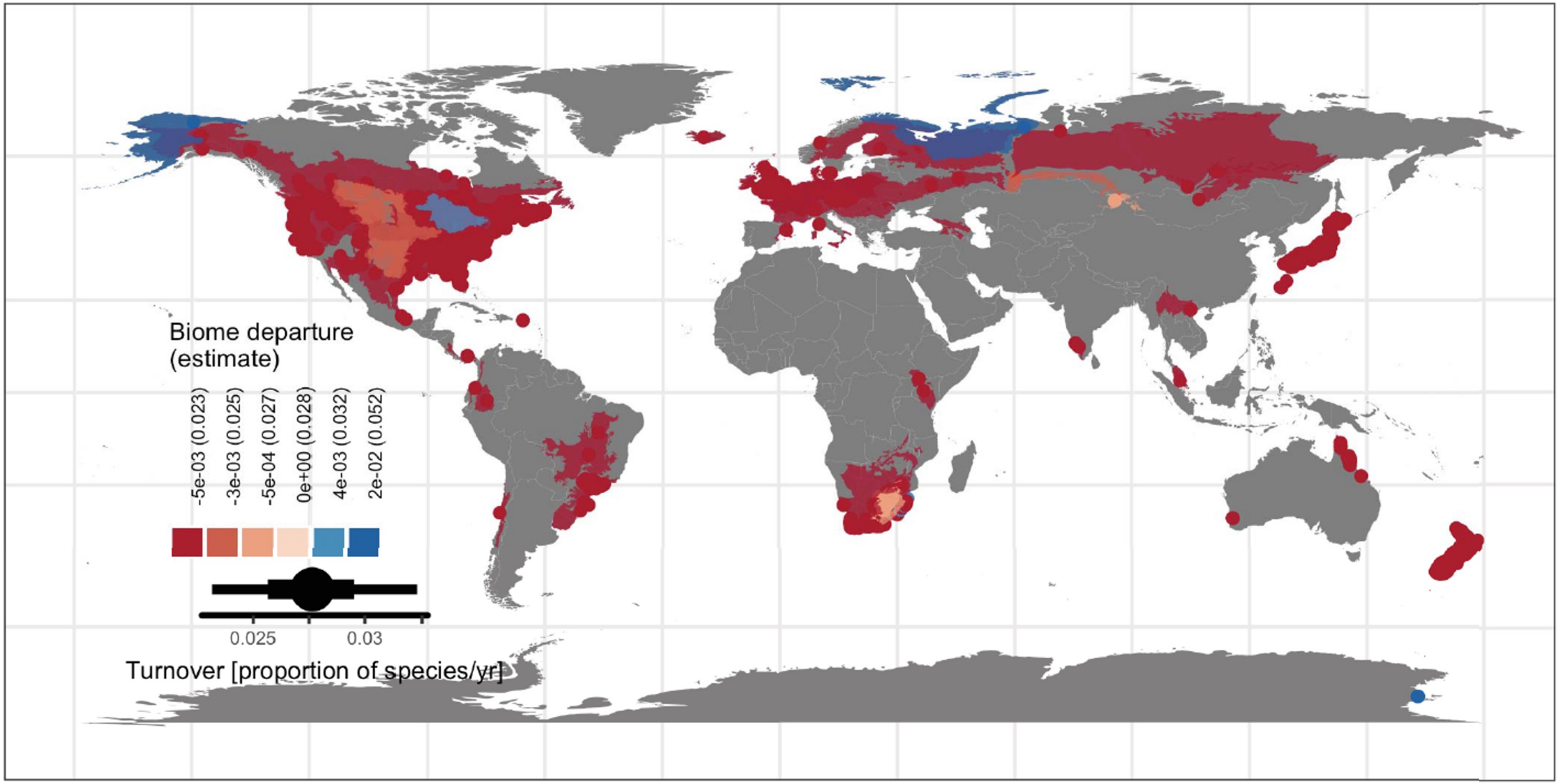
Key points:

1. Systems vary in proximity to transformation
2. But many are on a strong human-driven ecological trajectory or face increasing prospects of large, abrupt ecological change



Recent turnover in ecological communities

median 28% of species replaced / decade



Blowes et al. 2019 Science

Projected Effects of Climate Change on Birds in U.S. National Parks

Birds in U.S. national parks find strong protection from many longstanding and pervasive threats, but remain highly exposed to effects of ongoing climate change. As climate in a particular place changes, suitability may worsen for some species and improve for others. These changes in climate may alter distributions of historically occurring species, creating the potential for local extirpation or new colonization (Figure 1).

This page summarizes model-based projections of changes in climate suitability by mid-century for birds across 274 natural resource national parks under two climate change scenarios (for more information regarding how climate suitability is characterized, see Langham et al. 2015). Results throughout this page focus primarily on the high-emissions pathway (RCP8.5) because it is the scenario most consistent with current greenhouse gas emissions rates; however, comparisons are made to results for the low-emissions pathway (RCP2.6) as a contrasting, best-case scenario for emissions reductions (see Methods).

This study focuses exclusively on changing climatic conditions for birds over time. But projected changes in climate suitability are not definitive predictions of future species ranges or abundances. Numerous other factors affect where species occur, including habitat quality, food abundance, species adaptability, and the availability of microclimates (see Caveats). Therefore, managers should consider changes in climate suitability alongside these other important influences.

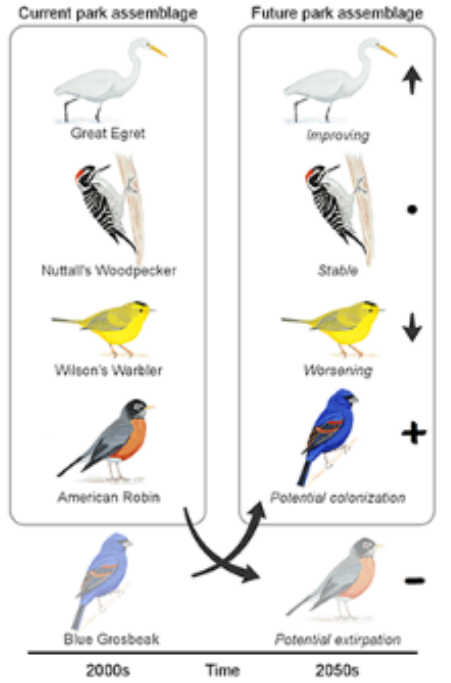


Figure 1. Example of potential changes in the bird assemblage at Golden Gate National Recreation Area by mid-century under the high-emissions trajectory. Bird illustrations by Kenn Kaufman.

The cumulative impact of potential colonizations and extirpations, if realized, would be a 23% change, on average, in a park's bird assemblage between today and mid-century. This finding is based on an index of potential species turnover (i.e., the proportions of potential extirpations and potential colonizations by 2050, relative to today) calculated for each park.

https://www.nps.gov/subjects/climatechange/birdsinparks.htm & https://www.audubon.org/climate/national-parks

CBS NEWS

CALIFORNIA WILDFIRES THREATEN GIANT SEQUOIA TREES

CBS EVENING NEWS with NORAH O'DONNELL

The Windy Fire burns in the Sequoia National Forest in California on September 16, 2021.

NOAH BERGER / AP

https://www.cbsnews.com/news/california-wildfires-sqeuoias-general-sherman-tree-blanket-sierra-nevada/?fbclid=IwAR0pWxhM7W4SEHzNBWQpzI6b6cWrB2dXKx0KQgWbp8LafNQfZJPpeb8nNmQ

Inciweb, Sept 2021

IOP Publishing

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https://doi.org/10.1088/1748-9326/ac6436

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LETTERS

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5 April 2022

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25 April 2022

LETTER

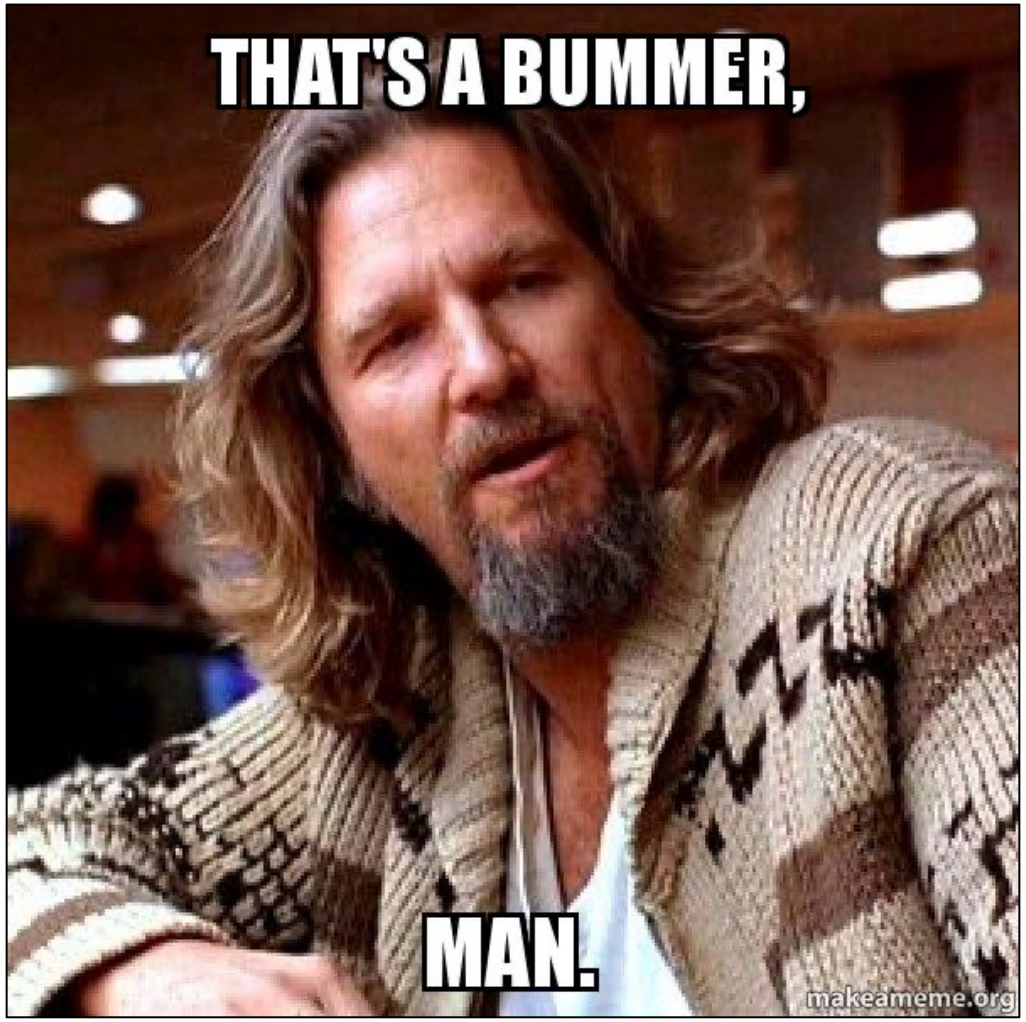
Efficacy of the global protected area network is threatened by disappearing climates and potential transboundary range shifts

Sean A Parks[1,*], Lisa M Holsinger[1], Caitlin E Littlefield[2], Solomon Z Dobrowski[3], Katherine A Zeller[1], John T Abatzoglou[4], Charles Besancon[5], Bryce L Nordgren[6] and Joshua J Lawler[7]

Interactive feature – fill out top box in your worksheet

- What climate change-driven ecological trajectory or abrupt ecological change are you are experiencing or worried is headed your way?

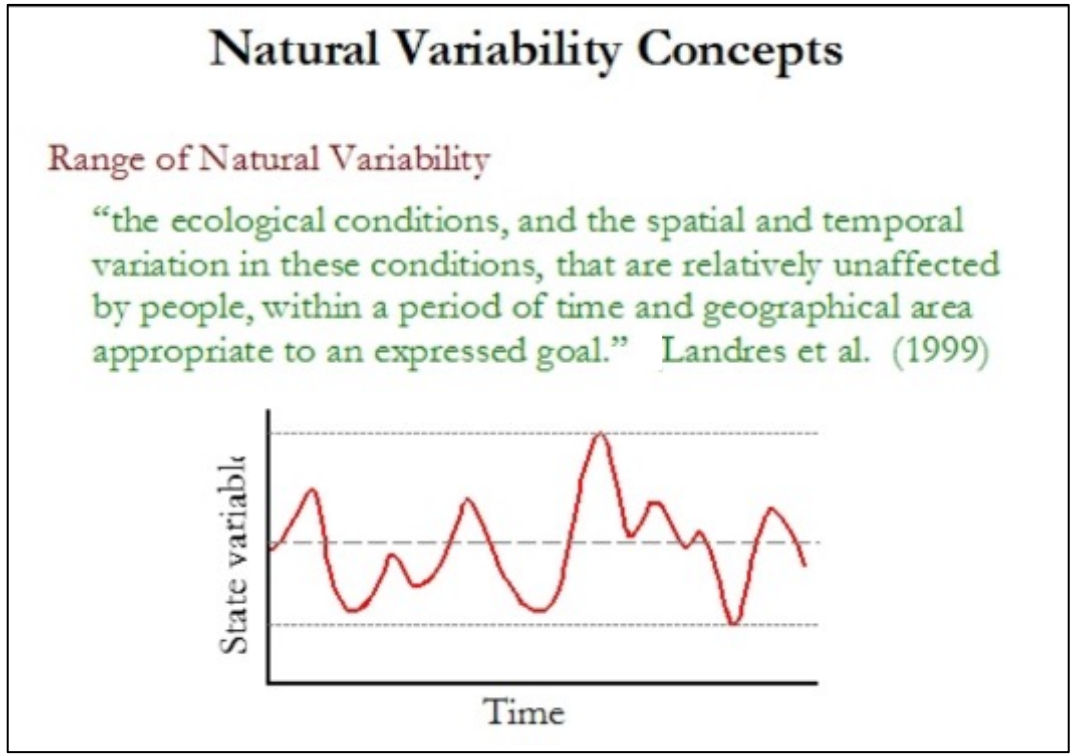
This is a heavy topic



This reality challenges the historical natural resource management paradigm

Slide courtesy of C. Hawkins Hoffman

This reality challenges the historical natural resource management paradigm



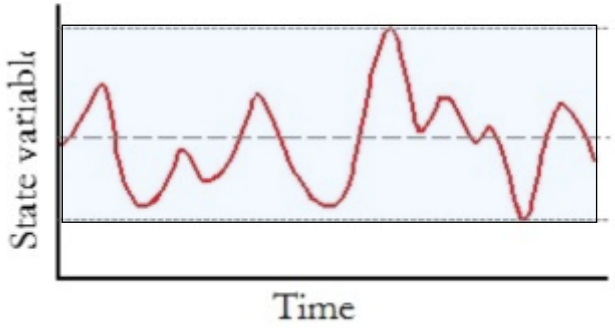
Slide courtesy of C. Hawkins Hoffman

This reality challenges the historical natural resource management paradigm

Natural Variability Concepts

Range of Natural Variability

"the ecological conditions, and the spatial and temporal variation in these conditions, that are relatively unaffected by people, within a period of time and geographical area appropriate to an expressed goal." Landres et al. (1999)



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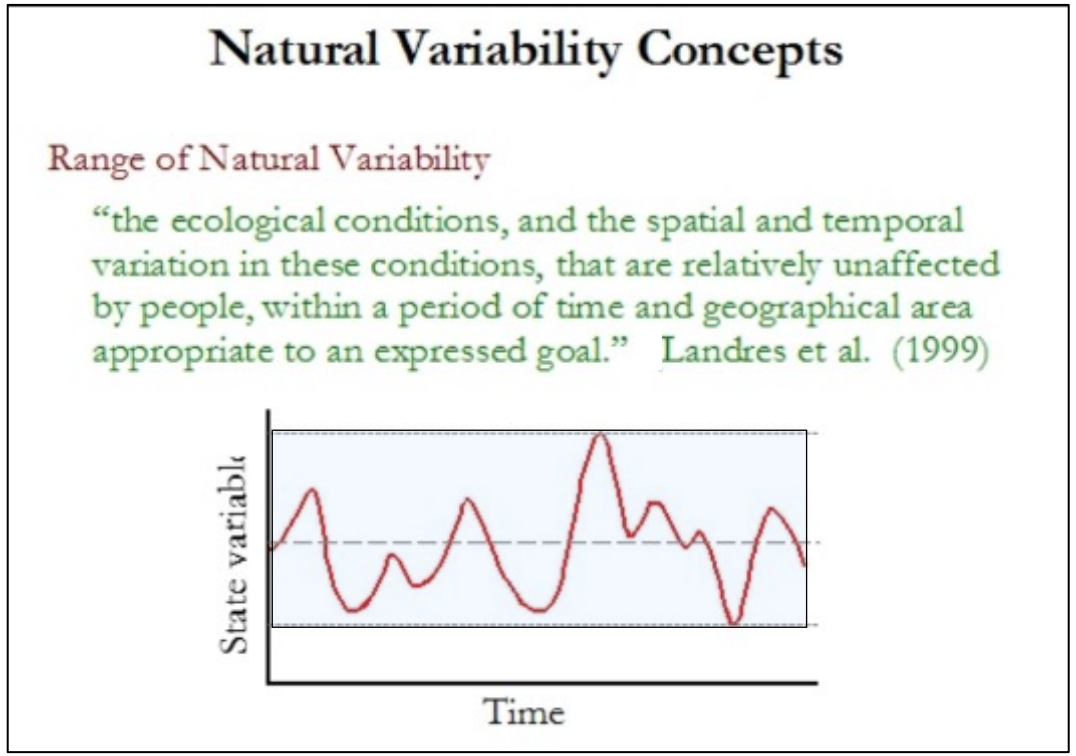


"…managing an ecosystem within its range of natural variability is an appropriate path to maintaining diverse, resilient, productive, and healthy systems." Landres et al. 1999

Slide courtesy of C. Hawkins Hoffman

This reality challenges the historical natural resource management paradigm

National Wildlife Refuge System policy

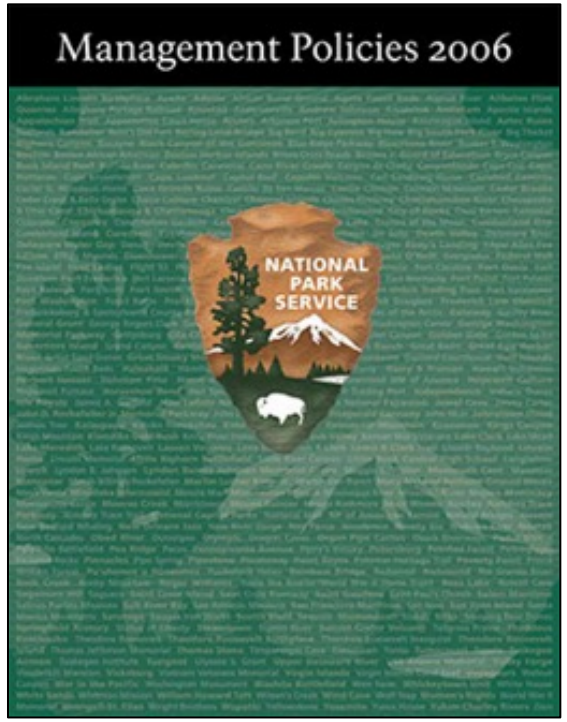
"In administering the System, the Secretary shall…ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans…

Historic Conditions Composition, structure, and functioning of ecosystems resulting from natural processes that we believe, based on sound professional judgment, were present ***prior to substantial human-related changes to the landscape***.

601 FW 3 *Biological Integrity, Diversity, and Environmental Health*

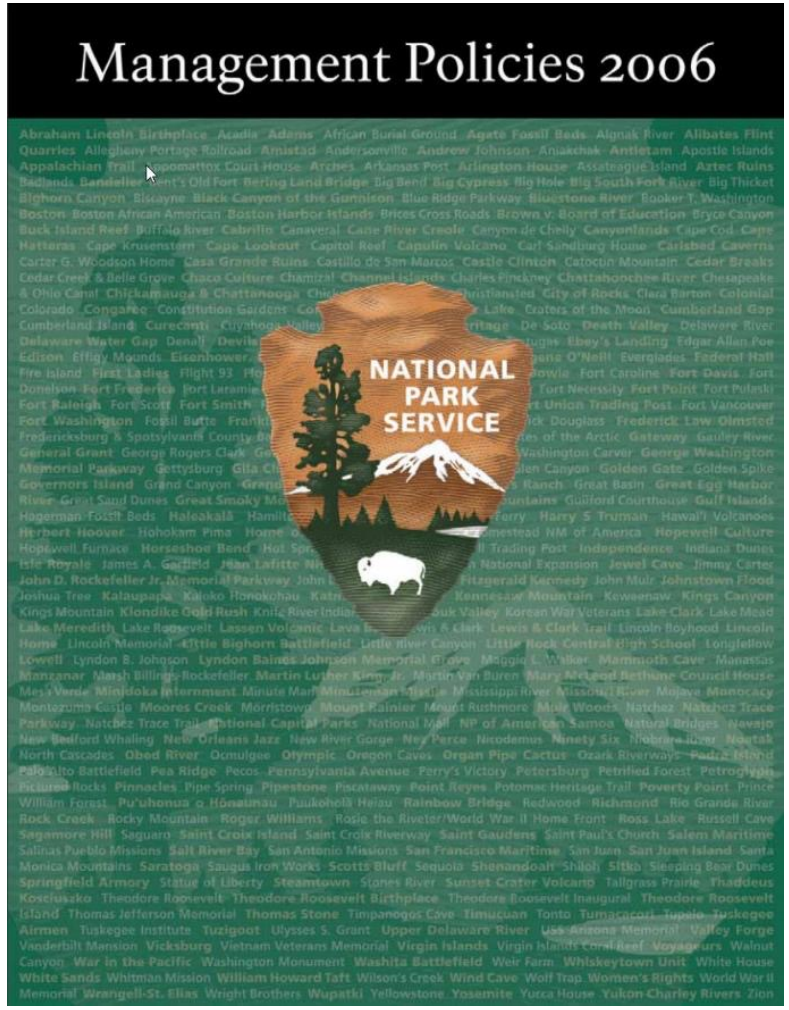
This reality challenges the historical natural resource management paradigm

The Service will…try to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, genetic / ecological integrity of plant and animal species native to those ecosystems. Just as all components of a natural system will be recognized as important, natural change will also be recognized as an integral part of the functioning of natural systems. By preserving these components and processes in their natural condition, the Service will prevent resource degradation and therefore avoid any subsequent need for resource restoration.



NPS Management Policies 2006, 4.1

This reality challenges the historical natural resource management paradigm



Natural condition:

"the condition of resources that would occur **in the absence of human dominance over the landscape**"

This reality challenges the historical natural resource management paradigm

"For managers of ecosystems on trajectories toward transformation, resisting ecological change, even where feasible, may require sustained and intensifying efforts (Millar et al. 2007), as well as trade-offs regarding other management objectives."

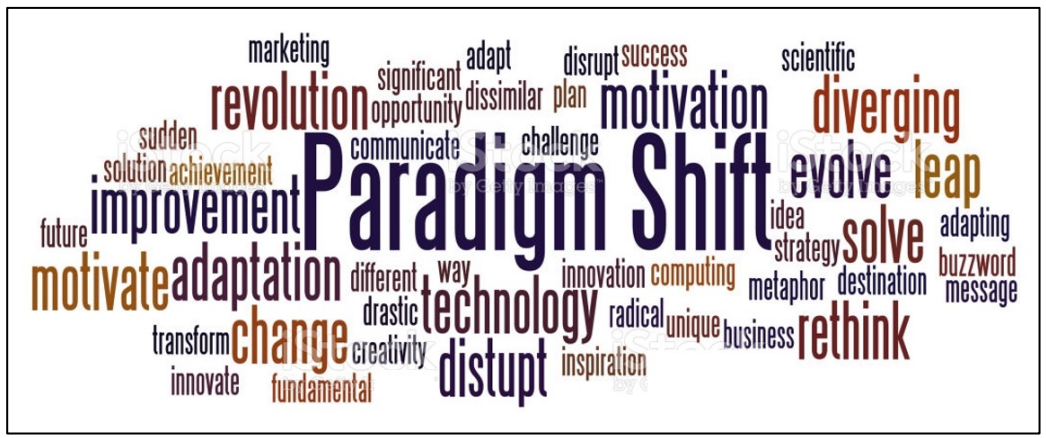
This reality challenges the historical natural resource management paradigm

"For managers of ecosystems on trajectories toward transformation, resisting ecological change, even where feasible, may require sustained and intensifying efforts (Millar et al. 2007), as well as trade-offs regarding other management objectives.

Stream diversions and snow fencing, for example, may delay climate change-induced transformation of a wet meadow into shrubland or forest (via desiccation), but fencing would likely affect other important ecological features and processes (e.g., the stream from which water is diverted or wildlife movement patterns), as well as the human experience of that place."

Special Section on the Resist–Accept–Direct Framework

Navigating Ecological Transformation: Resist–Accept–Direct as a Path to a New Resource Management Paradigm



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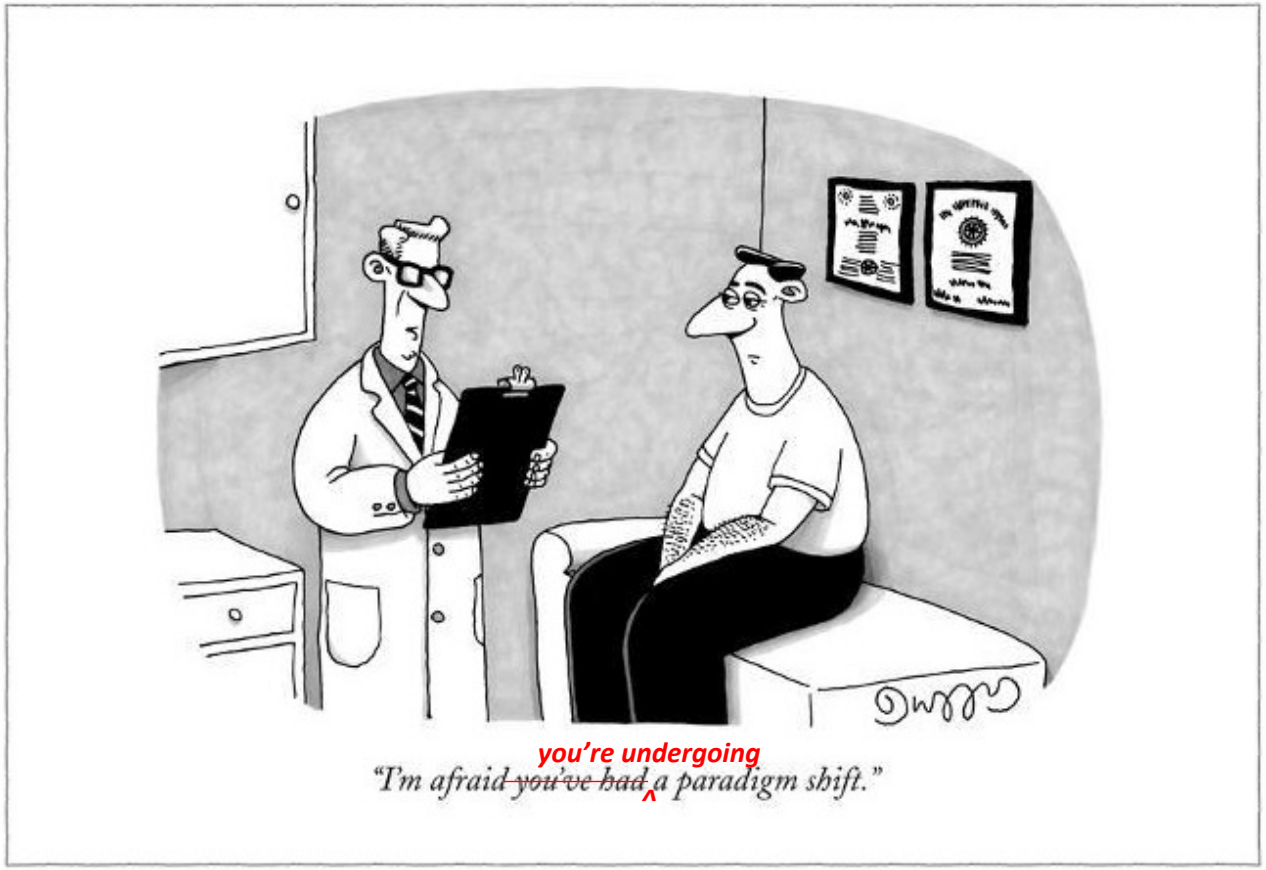


"I'm afraid ~~you've had~~ you're undergoing a paradigm shift."

Special Section on the Resist–Accept–Direct Framework

Navigating Ecological Transformation: Resist–Accept–Direct as a Path to a New Resource Management Paradigm

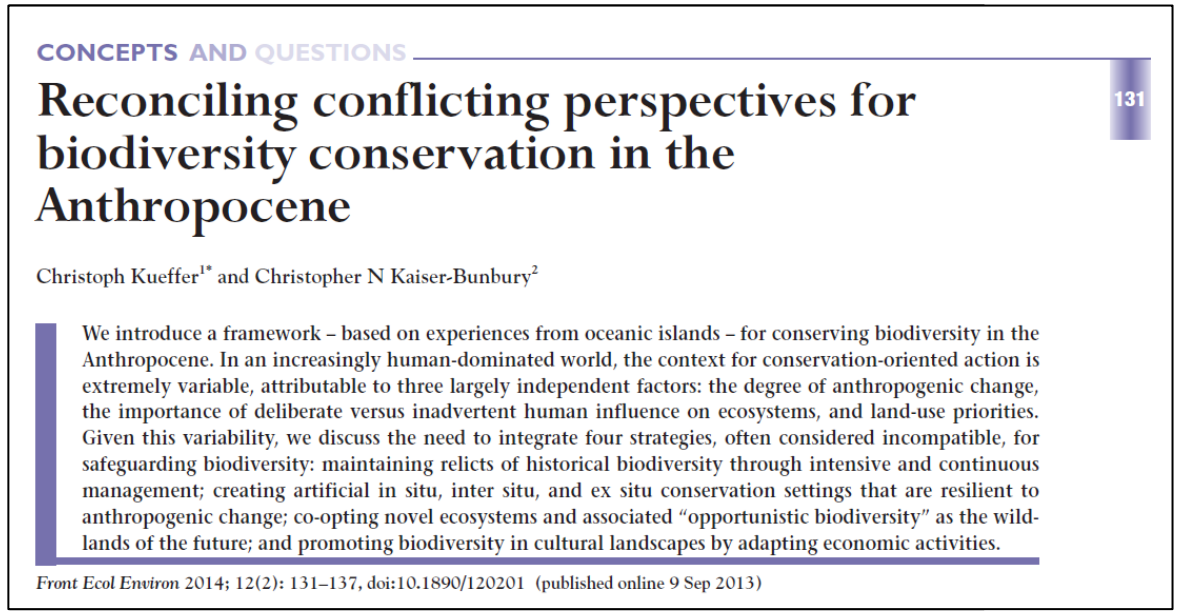
"I'm afraid ~~you've had~~ you're undergoing a paradigm shift."

"That's a bummer, man."

"Natural resource managers and conservation practitioners are working in a world very different from that in which most agencies and management traditions formed..."

"Natural resource managers and conservation practitioners are working in a world very different from that in which most agencies and management traditions formed, and non-stationarity places a manager in a *terra incognita* in which tools and assumptions from the past are increasingly unhelpful and new approaches to address novel climatic and ecological circumstances are urgently needed..."

"Paradigm shifts happen when community members… search for new ways of thinking about or approaching a problem."



CONCEPTS AND QUESTIONS

Reconciling conflicting perspectives for biodiversity conservation in the Anthropocene

131

Christoph Kueffer[1*] and Christopher N Kaiser-Bunbury[2]

We introduce a framework – based on experiences from oceanic islands – for conserving biodiversity in the Anthropocene. In an increasingly human-dominated world, the context for conservation-oriented action is extremely variable, attributable to three largely independent factors: the degree of anthropogenic change, the importance of deliberate versus inadvertent human influence on ecosystems, and land-use priorities. Given this variability, we discuss the need to integrate four strategies, often considered incompatible, for safeguarding biodiversity: maintaining relicts of historical biodiversity through intensive and continuous management; creating artificial in situ, inter situ, and ex situ conservation settings that are resilient to anthropogenic change; co-opting novel ecosystems and associated "opportunistic biodiversity" as the wild-lands of the future; and promoting biodiversity in cultural landscapes by adapting economic activities.

Front Ecol Environ 2014; 12(2): 131–137, doi:10.1890/120201 (published online 9 Sep 2013)

"Driven by the need to find solutions to these emerging challenges, biodiversity conservation is entering a phase of prolific innovation."

Kueffer and Kaiser-Bunbury 2014, p. 131

OUTLINE – the RAD framework

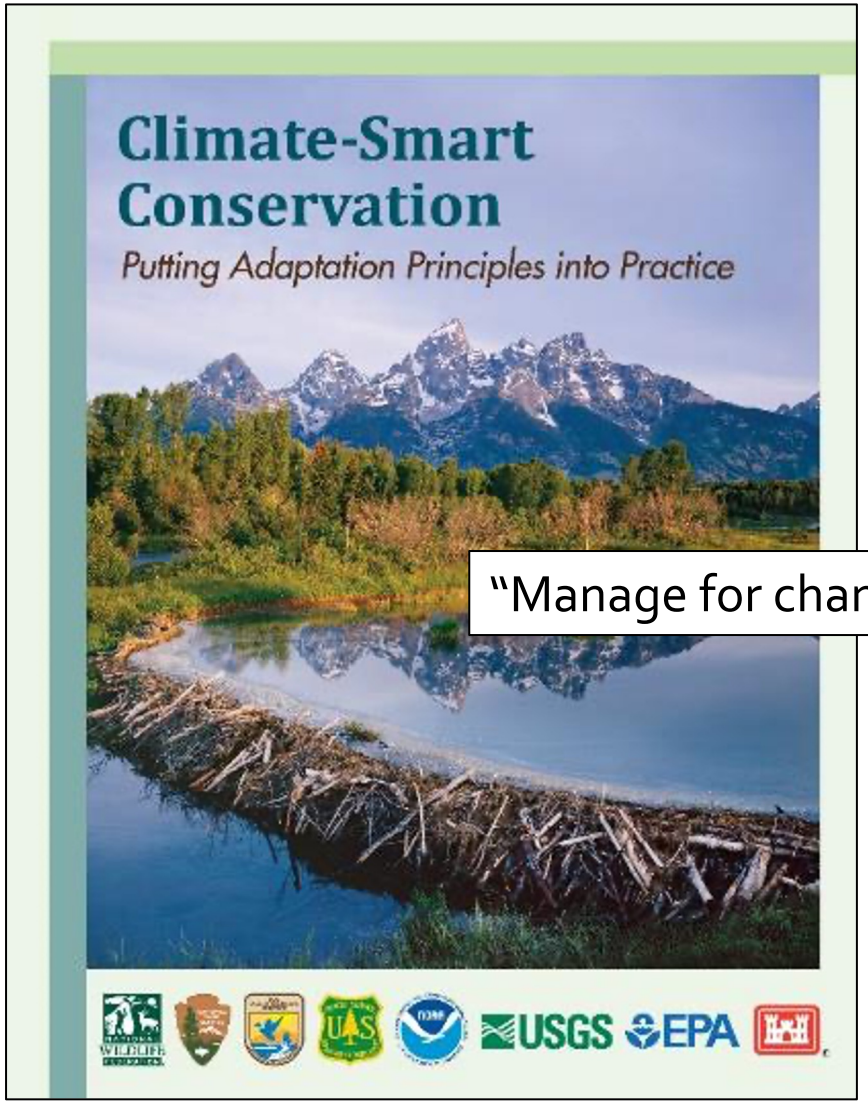
- Brief RAD framework introduction
- Background – the challenge of climatic & ecological non-stationarity
- Addressing non-stationarity

How to make unavoidable choices strategically?

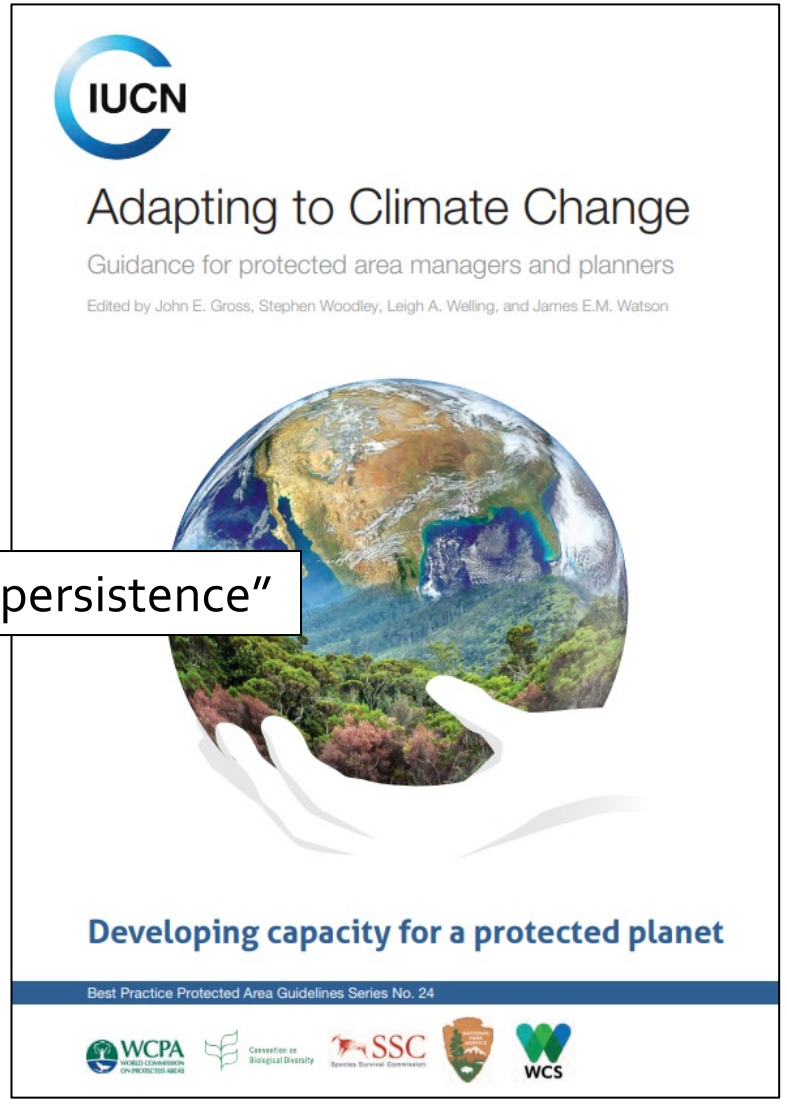
How to make unavoidable choices strategically?

Managers see:

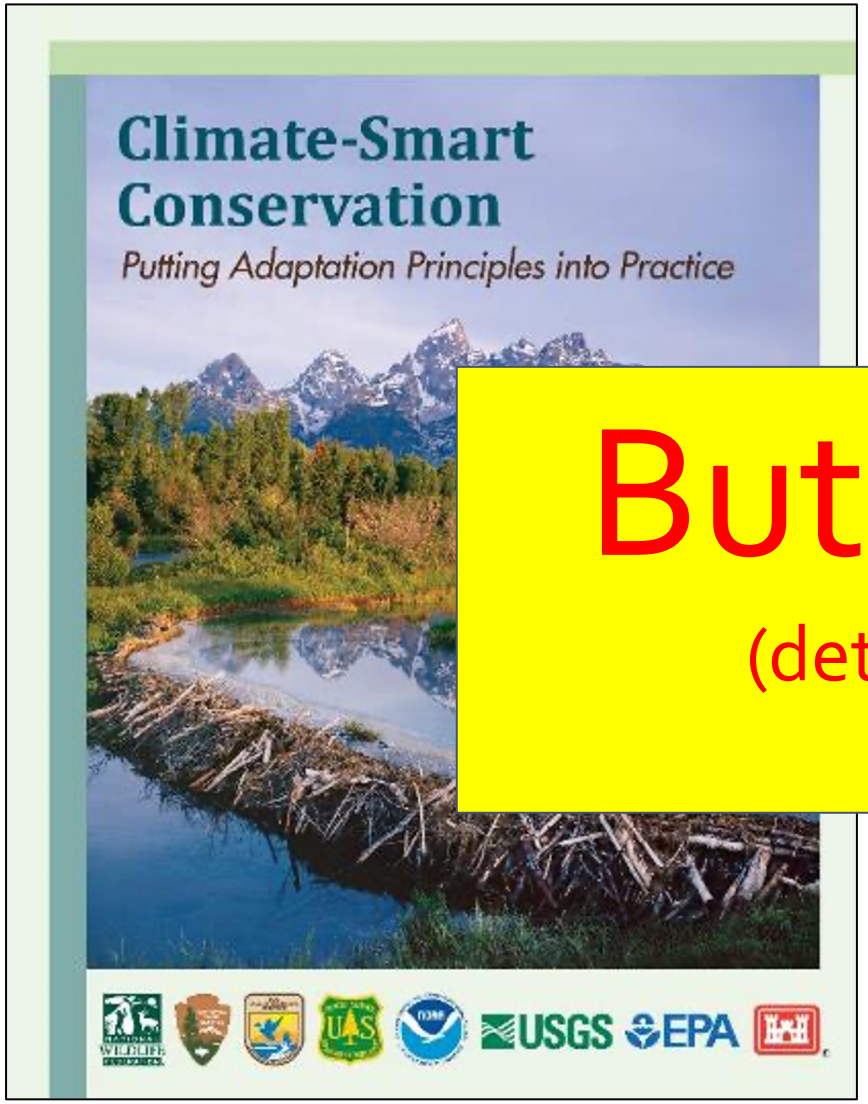
- Unprecedented management challenge(s)
- Broad encouragement to think differently



"Manage for change, not just persistence"



https://portals.iucn.org/library/sites/library/files/documents/PAG-024.pdf



But how?

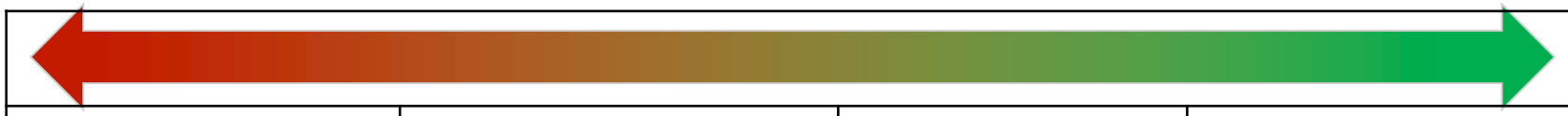
(details TBD)

How to make unavoidable choices strategically?

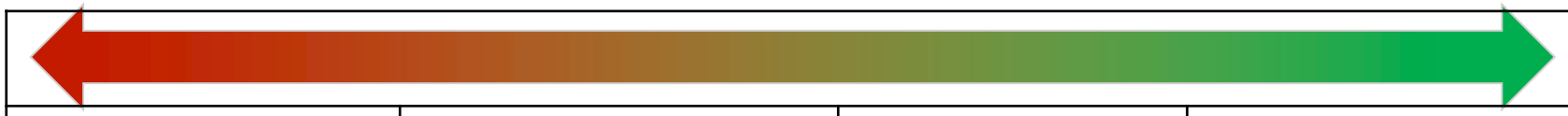
Managers see:

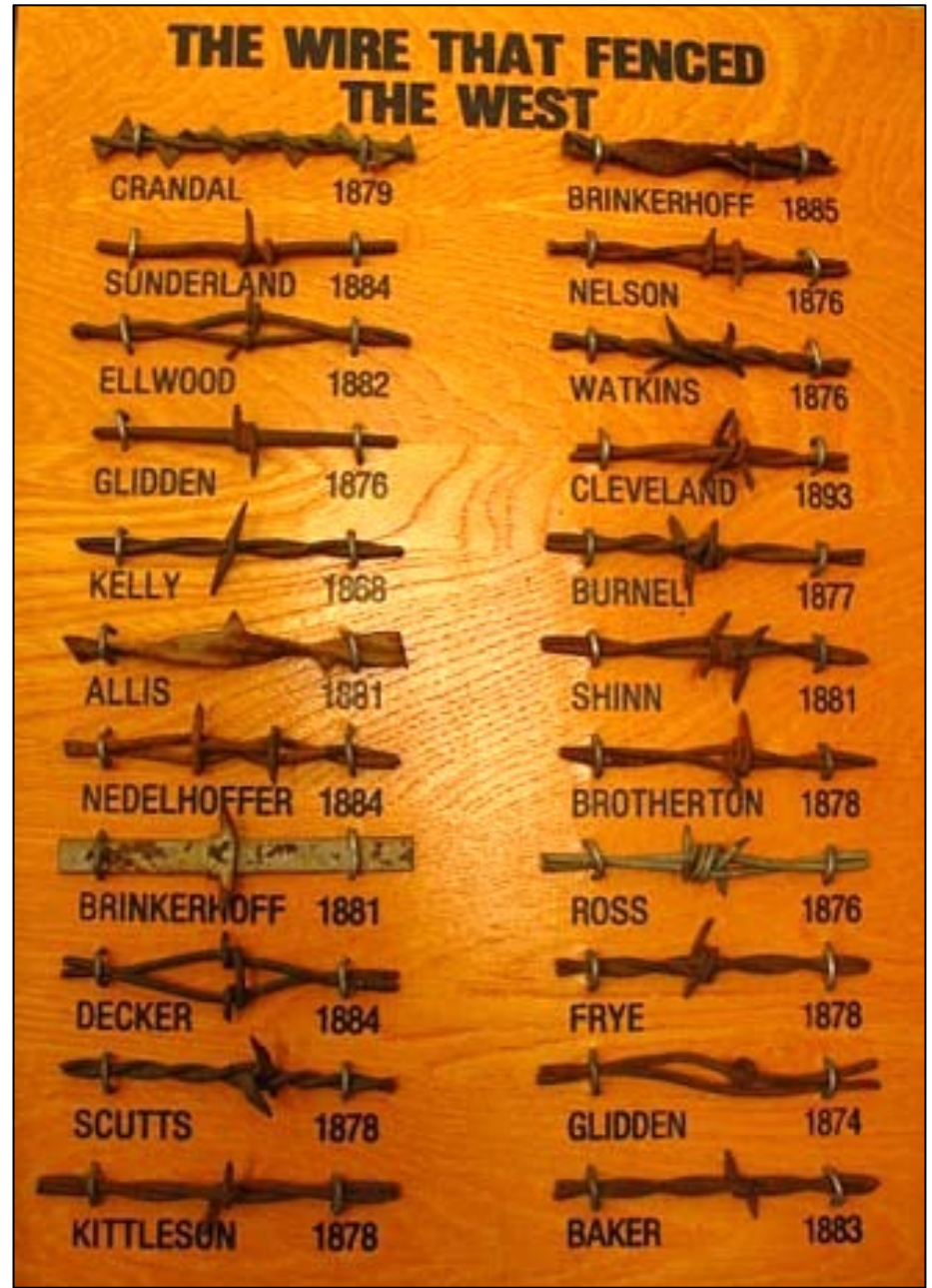
- Unprecedented management challenge(s)
- Broad encouragement to think differently
- But an overwhelming set of options, frameworks, and concepts (paradigm shift)

Adaptation typologies

				Source
Persistence	Change			Stein et al. 2014

Adaptation typologies

				Source
Persistence	Change			Stein et al. 2014
Resist	Resilience	Response		Millar et al. 2007
Resist	Accept	Guide		Aplet & Cole 2010 (from 2007 workshop)
Restraint	Resilience	Resistance	Realignment	Stephenson & Millar 2011
Refugia	Ecosystem maintenance	Natural adaptation	Facilitate transitions	Magness et al. 2011
Anticipatory	Reactive			Stein et al. 2014


THE WIRE THAT FENCED THE WEST
CRANDAL 1879
BRINKERHOFF 1885
SUNDERLAND 1884
NELSON 1876
ELLWOOD 1882
WATKINS 1876
GLIDDEN 1876
CLEVELAND 1893
KELLY 1868
BURNELL 1877
ALLIS 1881
SHINN 1881
NEDELHOFFER 1884
BROTHERTON 1878
BRINKERHOFF 1881
ROSS 1876
DECKER 1884
FRYE 1878
SCUTTS 1878
GLIDDEN 1874
KITTLESON 1878
BAKER 1883

How to make unavoidable choices strategically?

Managers see:

- Unprecedented management challenge(s)
- Broad encouragement to think differently
- But an overwhelming set of options, frameworks, and concepts (paradigm shift)

Managers need tools to help make navigating this challenge tractable:

How to make unavoidable choices strategically?

Managers see:

- Unprecedented management challenge(s)
- Broad encouragement to think differently
- But an overwhelming set of options, frameworks, and concepts (paradigm shift)

Managers need tools to help make navigating this challenge tractable:

- Manager-centered
- Simple and intuitive

How to make unavoidable choices strategically?

"In this place at this time, I am _____ ing the climate change-driven ecological trajectory."

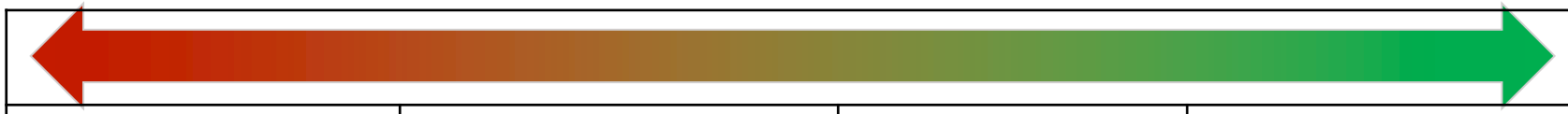
How to make unavoidable choices strategically?

"In this place at this time, I am _____ ing the climate change-driven ecological trajectory."

Adaptation typologies

				Source
Persistence	Change			Stein et al. 2014
Resist	Resilience	Response		Millar et al. 2007
Resist	Accept	Guide		Aplet & Cole 2010 (from 2007 workshop)
Restraint	Resilience	Resistance	Realignment	Stephenson & Millar 2011
Refugia	Ecosystem maintenance	Natural adaptation	Facilitate transitions	Magness et al. 2011
Anticipatory	Reactive			Stein et al. 2014

Adaptation typologies

				Source
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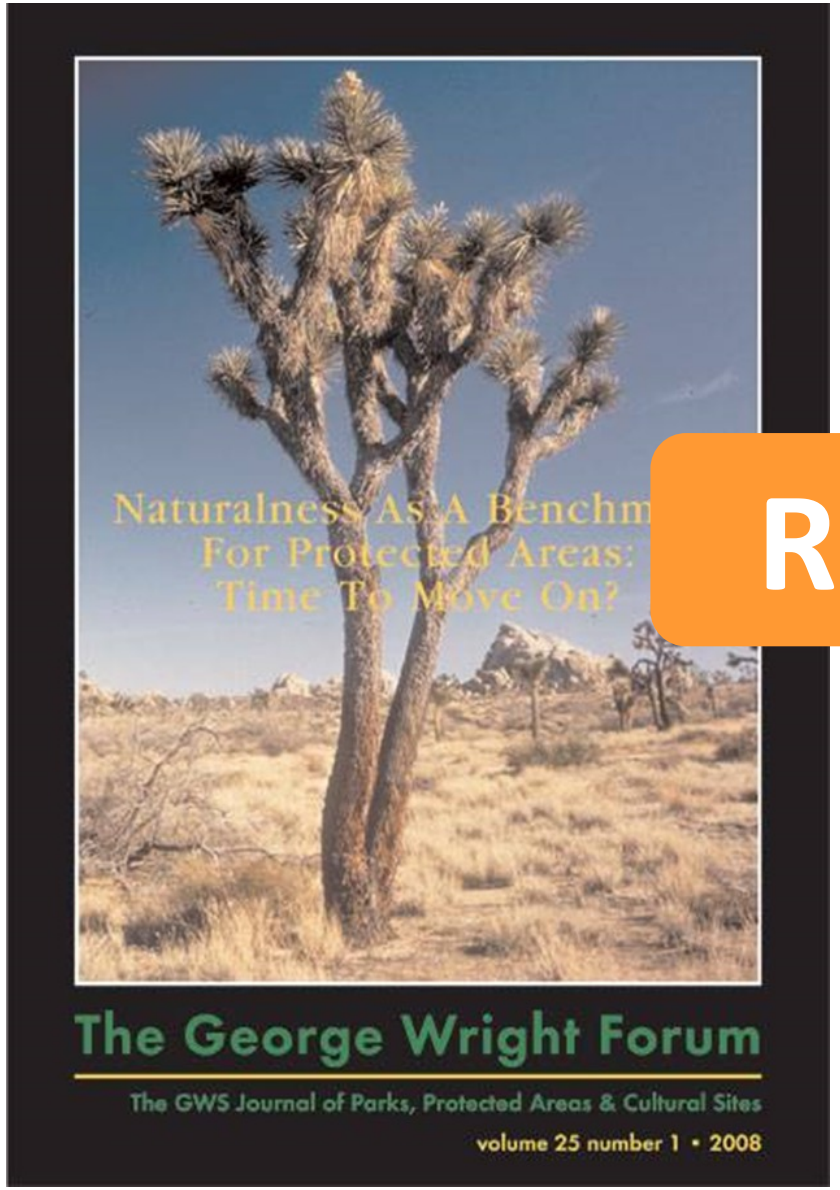
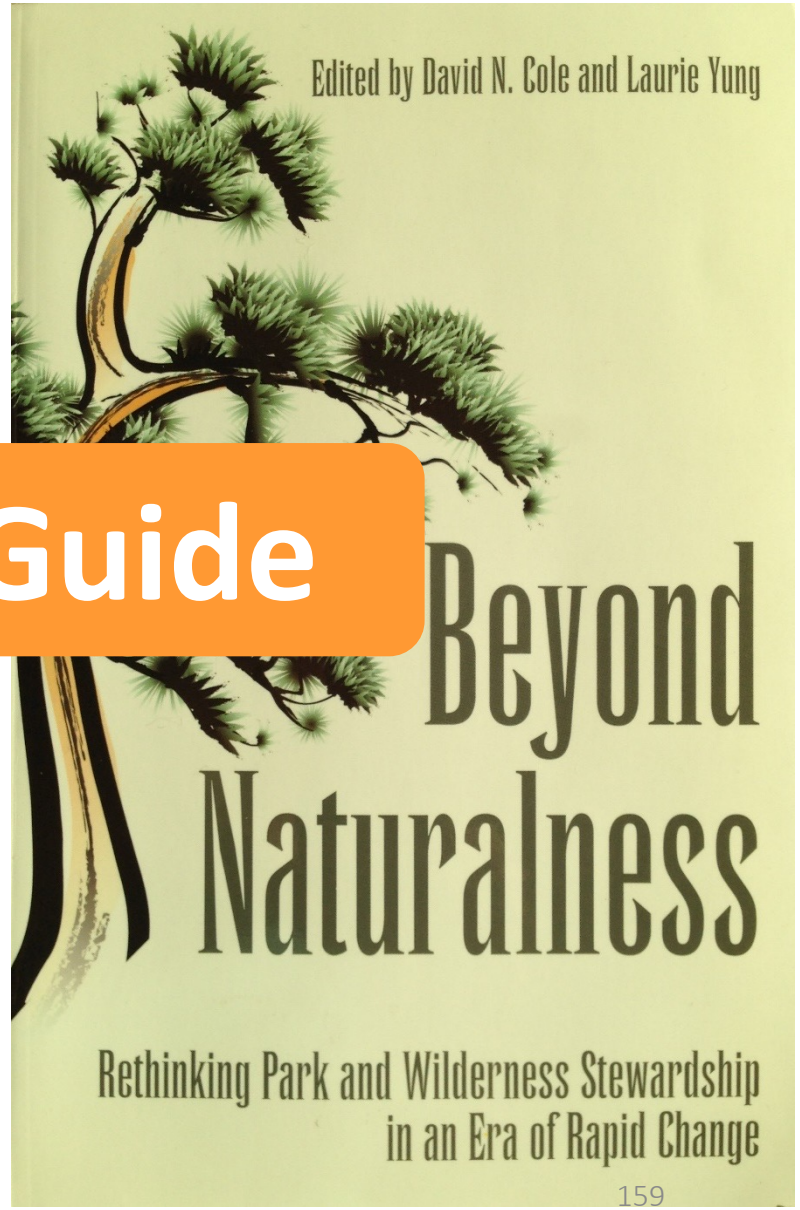


"In short, it is increasingly clear that naturalness is no longer the umbrella under which all protected area values comfortably sit.

Resist-Accept-Guide

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



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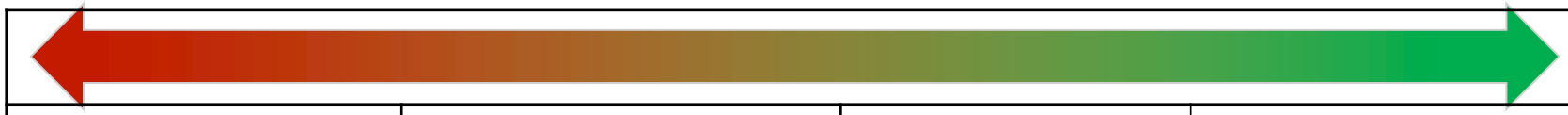
Resist	Accommodate	Direct		Fisichelli et al. 2016b

Fisichelli, N, G Schuurman, A Symstad, A Ray, J Friedman, B Miller, and E Rowland. 2016. 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. National Park Service, Fort Collins, Colorado. <https://irma.nps.gov/DataStore/Reference/Profile/2230834>

Adaptation typologies

				Source
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Anticipatory	Reactive			Stein et al. 2014
Persistence (of current conditions)	Autonomous change	Directed change		Fisichelli et al. 2016a
Resist	Accommodate	Direct		Fisichelli et al. 2016b
Resist	Accept	Guide		Aplet & McKinley 2017
Resist	Accept	Direct		TWS/AFS ET Group – 2018 onward
Resist	Accept	Direct		FedNET – 2017 onward

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 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."

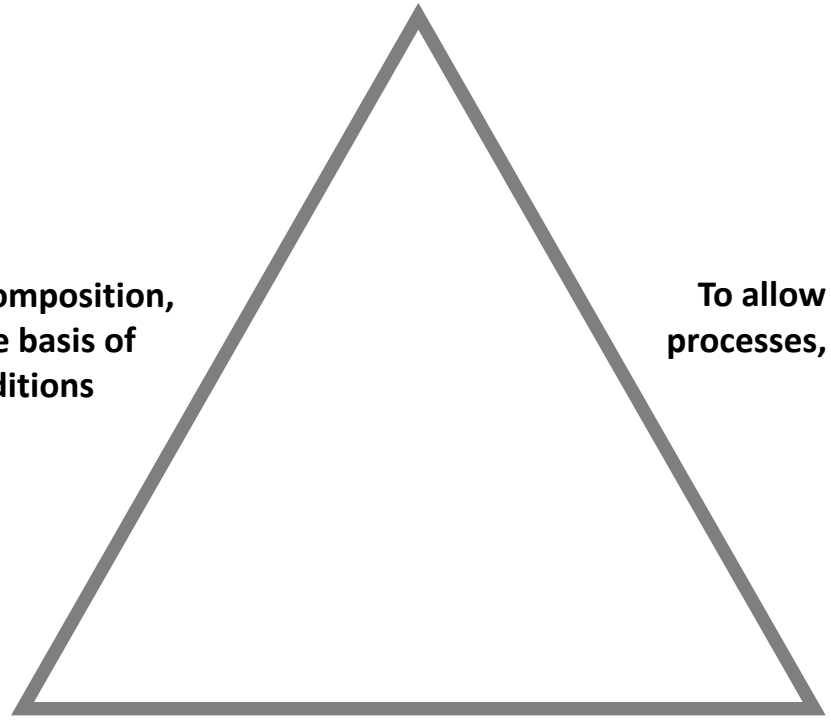
OUTLINE – the RAD framework

- Brief RAD framework introduction
- Background – the challenge of climatic & ecological non-stationarity
- Addressing non-stationarity
- Exploring the framework

What is the RAD framework?

Resist

Work to maintain or restore ecosystem composition, structure, processes, or function on the basis of historical or acceptable current conditions



Accept

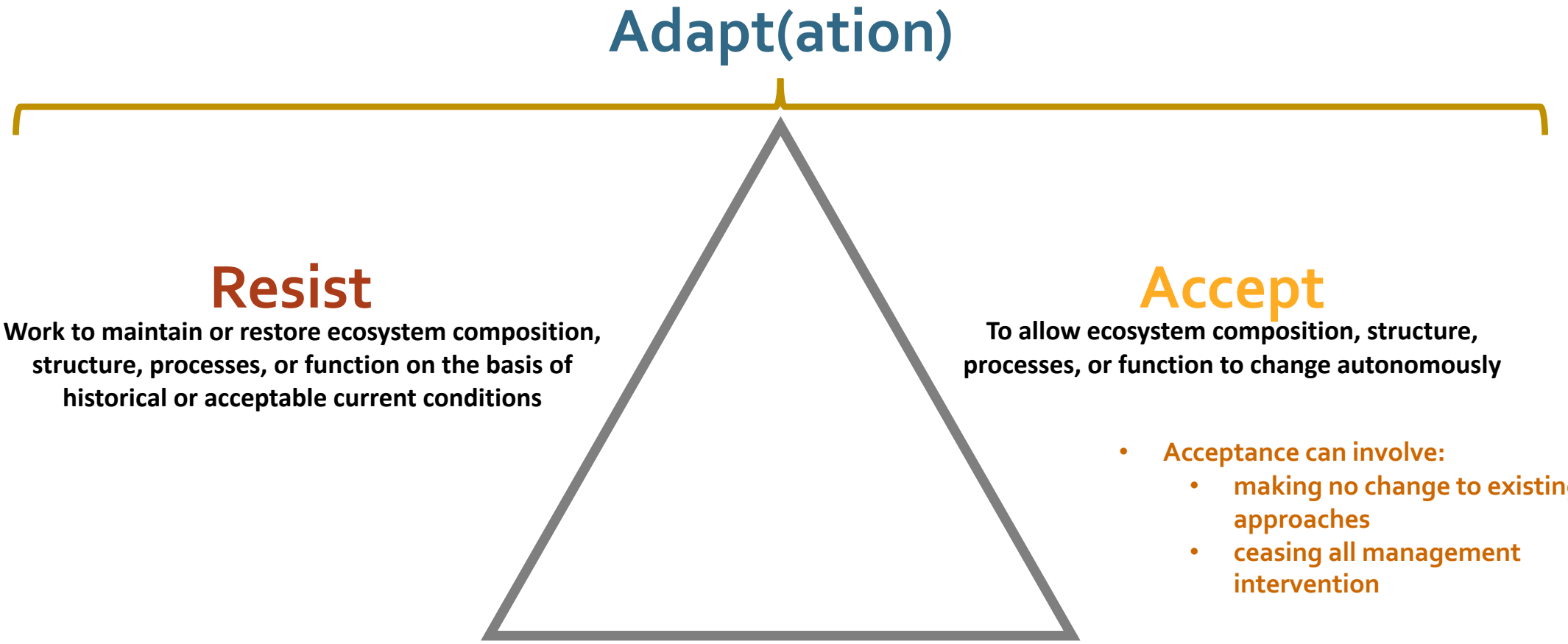
To allow ecosystem composition, structure, processes, or function to change autonomously

Direct

Actively shape change in ecosystem composition, structure, processes, or function toward preferred new conditions

Definitions from Schuurman et al. 2022; design adapted from Thompson et al. 2020

What is the RAD framework?

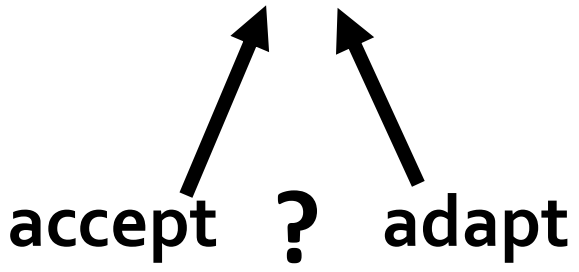


- Acceptance can involve:
  - making no change to existing approaches
  - ceasing all management intervention

Definitions from Schuurman et al. 2022; design adapted from Thompson et al. 2020

How to make unavoidable choices strategically?

"In this place at this time, I am _____ ing the climate change-driven ecological trajectory."



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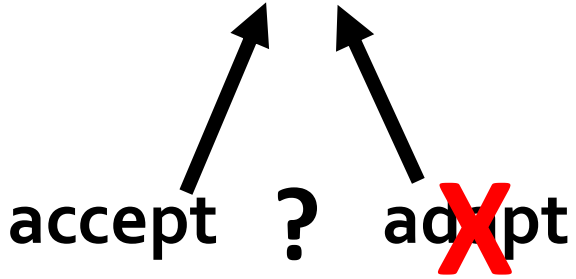


R·A·D FRAMEWORK

ARE YOU SHAPING THE ECOLOGICAL TRAJECTORY?

YES

FOR WHAT CONDITIONS ARE YOU MANAGING?

NO

HISTORICAL CONDITIONS

NEW DESIRED CONDITION

ACCEPT

RESIST

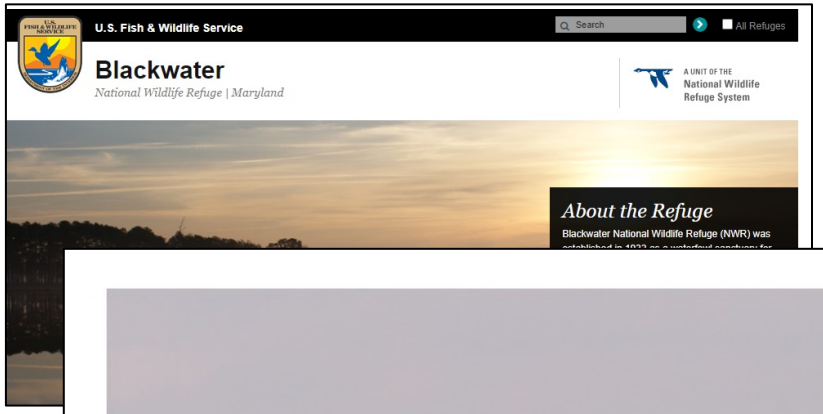
DIRECT

Image by Moline Creative
www.MolineCreative.com

OUTLINE – the RAD framework

- Brief RAD framework introduction
- Background – the challenge of climatic & ecological non-stationarity
- Addressing non-stationarity
- Exploring the framework
- Applying the framework

RAD natural resource management in action



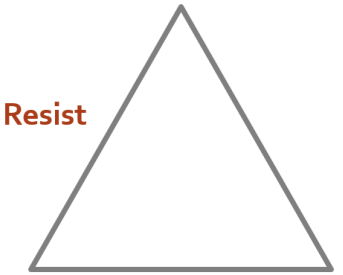
Building up a portion of marsh at Blackwater National Wildlife Refuge with sediment from the Blackwater River. (Photo: Middleton Evans)

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.

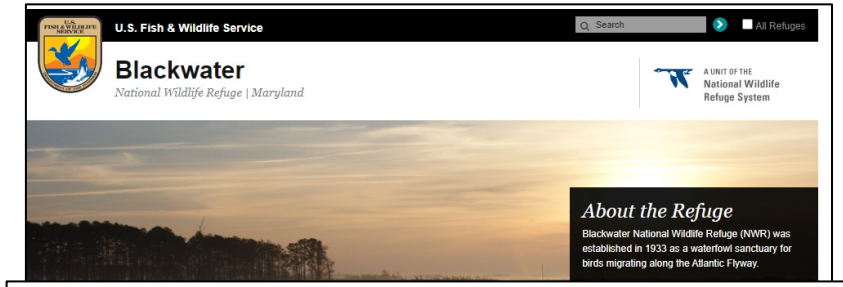
Ongoing efforts to save the marsh include:

- 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



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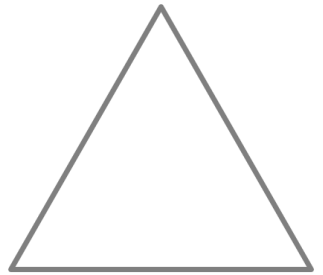
Removing trees to promote marsh growth, Blackwater National Wildlife Refuge. (Photo: Erik J. Meyers/The Conservation Fund)

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



Direct

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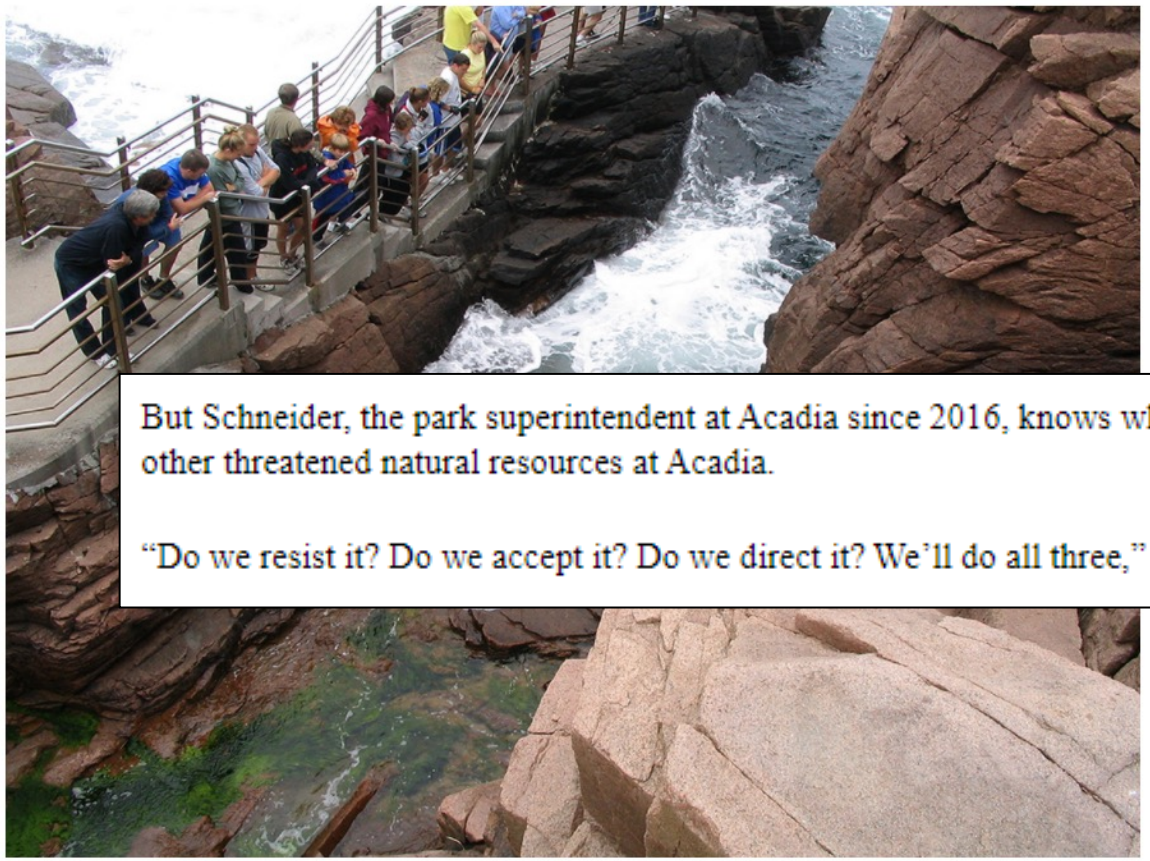
National parks face tough calls battling climate change

By Rob Hotakainen | 11/05/2021 12:12 PM EST

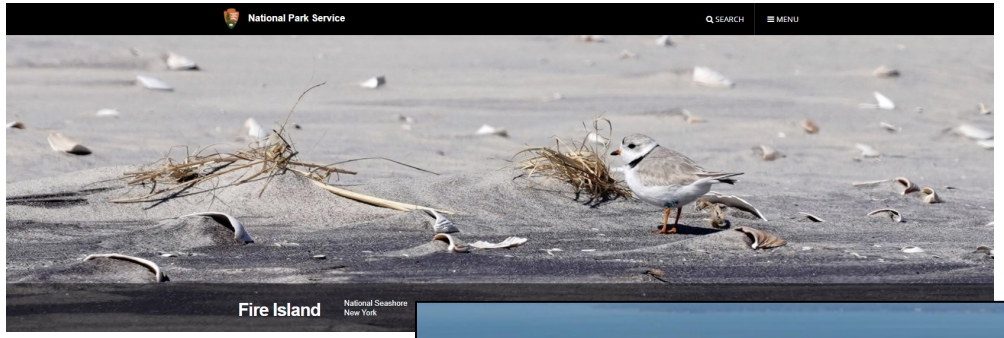


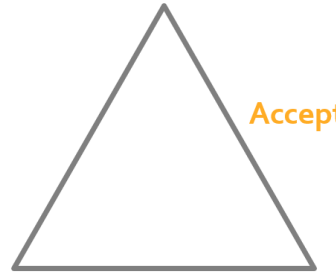
People waiting for the crash of waves at Thunder Hole at Acadia National Park. Ken Lund/Flickr

But Schneider, the park superintendent at Acadia since 2016, knows what principles will guide his thinking in deciding the fate of Thunder Hole and other threatened natural resources at Acadia.

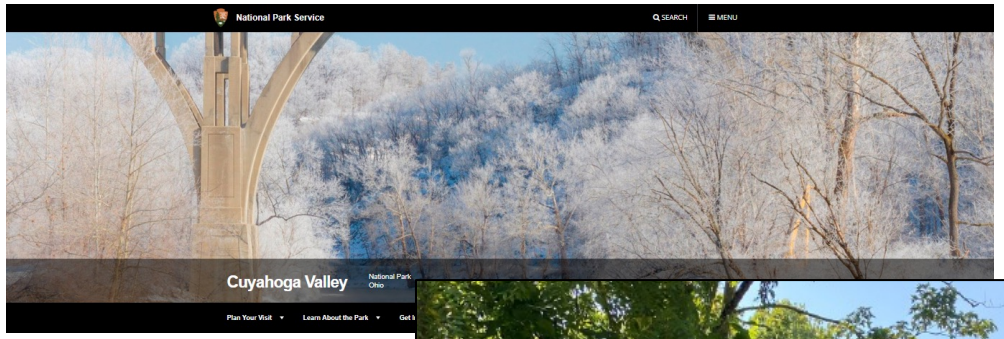
"Do we resist it? Do we accept it? Do we direct it? We'll do all three," he said. "It just depends on the situation."

RAD natural resource management in action



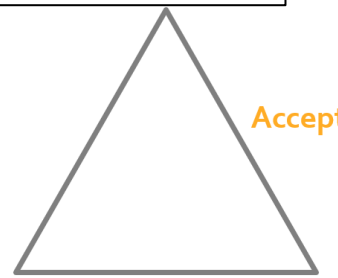


RAD natural resource management in action



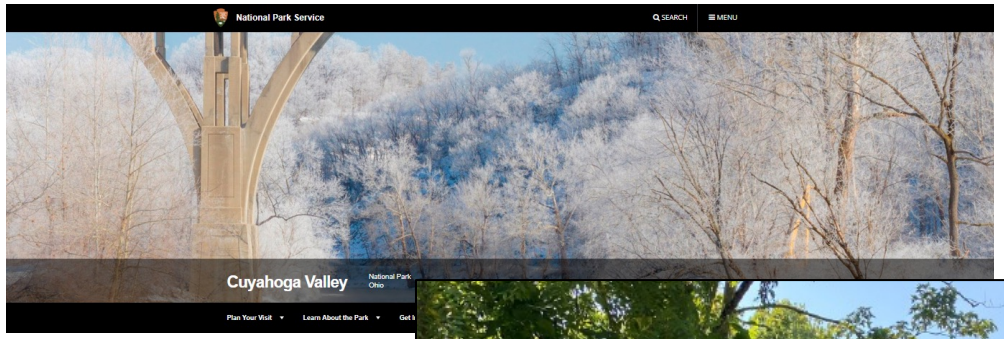
"So, black locust here, historically, we've considered it invasive. It comes in and it will take over a whole field," said Davis. "But it is naturally present just south of here, like in southern Ohio and Kentucky. So, in the past we've been fighting that tree in some sites. And now we're trying to, like, not so much, because it's probably on its way."

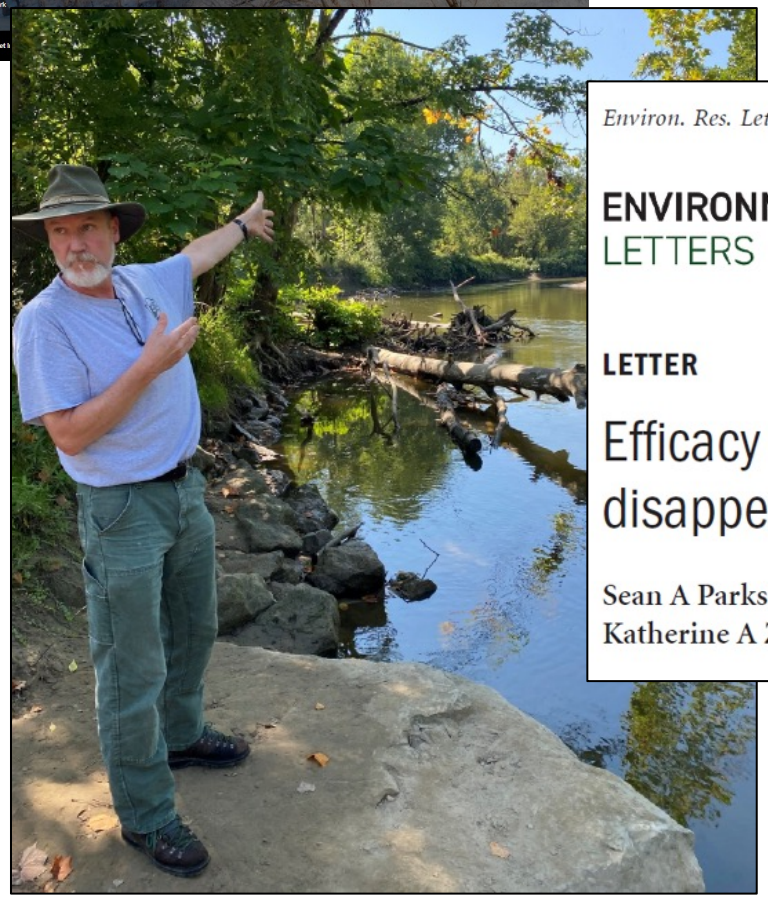
Cuyahoga Valley NP ecologist Chris Davis



https://www.ideastream.org/news/cuyahoga-valley-national-park-struggles-with-the-effects-of-climate-change; image by Cami Miller

RAD natural resource management in action





Environ. Res. Lett. **17** (2022) 054016 https://doi.org/10.1088/1748-9326/ac6436

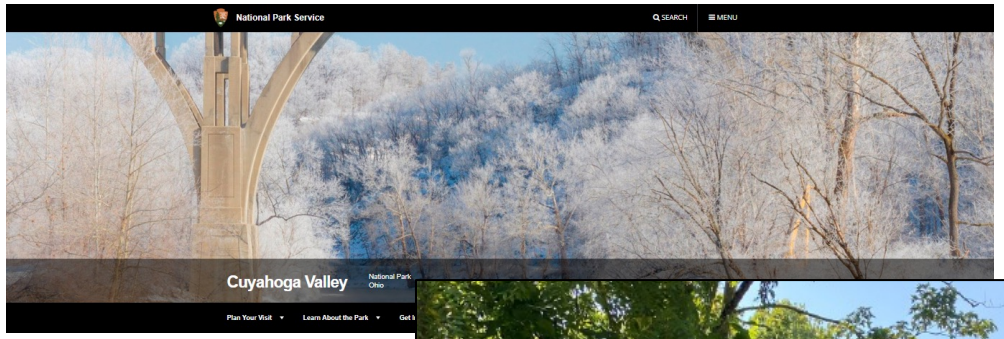
ENVIRONMENTAL RESEARCH
LETTERS

LETTER

Efficacy of the global protected area network is threatened by disappearing climates and potential transboundary range shifts

Sean A Parks[1,*], Lisa M Holsinger[1], Caitlin E Littlefield[2], Solomon Z Dobrowski[3], Katherine A Zeller[1], John T Abatzoglou[4], Charles Besancon[5], Bryce L Nordgren[6] and Joshua J Lawler[7]

RAD natural resource management in action

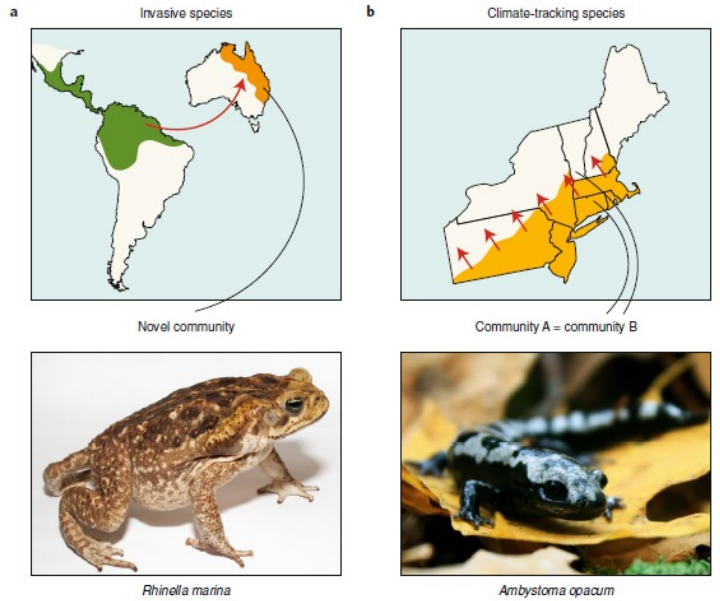


Climate-tracking species are not invasive

Applying an invasive framework to native species that are shifting their ranges in response to climate change adopts an adversarial, local and static paradigm that is often at odds with protecting global biodiversity.

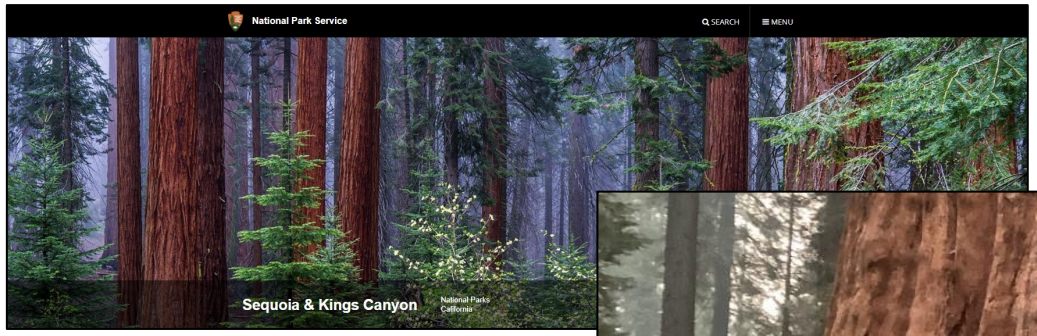
Mark C. Urban

Climate change is already altering local species abundances, affecting ecosystems, inducing extinctions and shifting species ranges along elevational and latitudinal gradients[1,2]. Biologists and managers increasingly must decide how to protect biodiversity and ecosystems from climate change, including when and how to preserve local populations and what



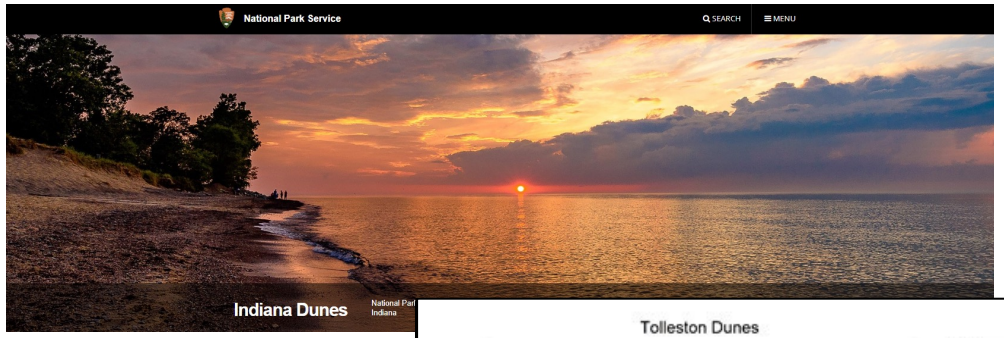
Urban. 2020. Nature Climate Change

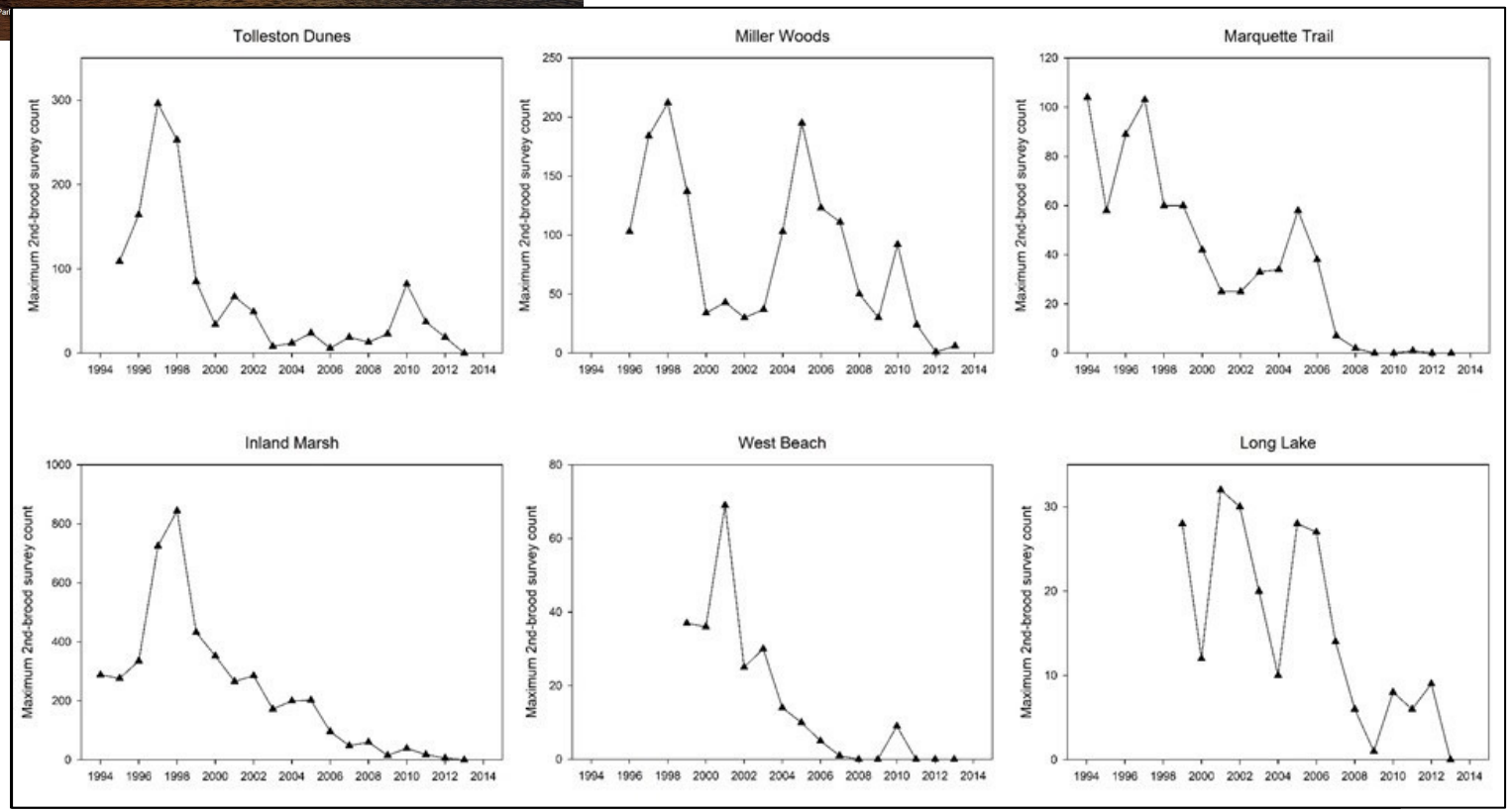
RAD natural resource management in action

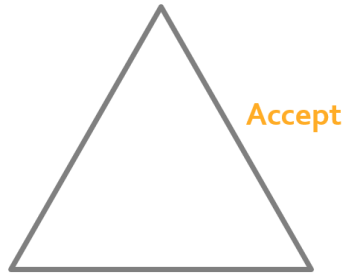


Resist

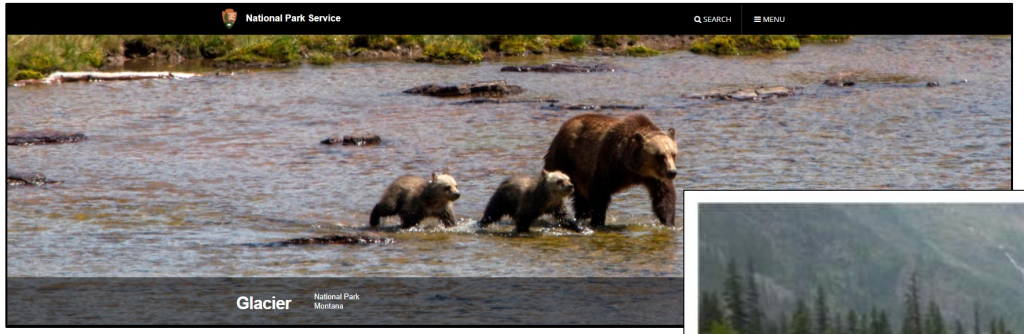
RAD natural resource management in action





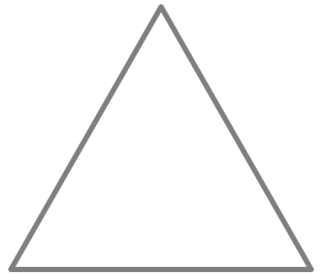


RAD natural resource management in action



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

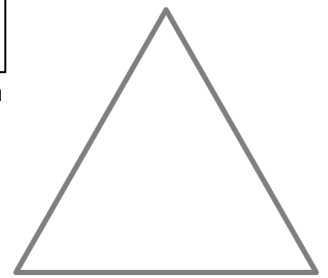
RAD natural resource management in action

Climate Change Adaptation & Mitigation Plan

Fisheries:

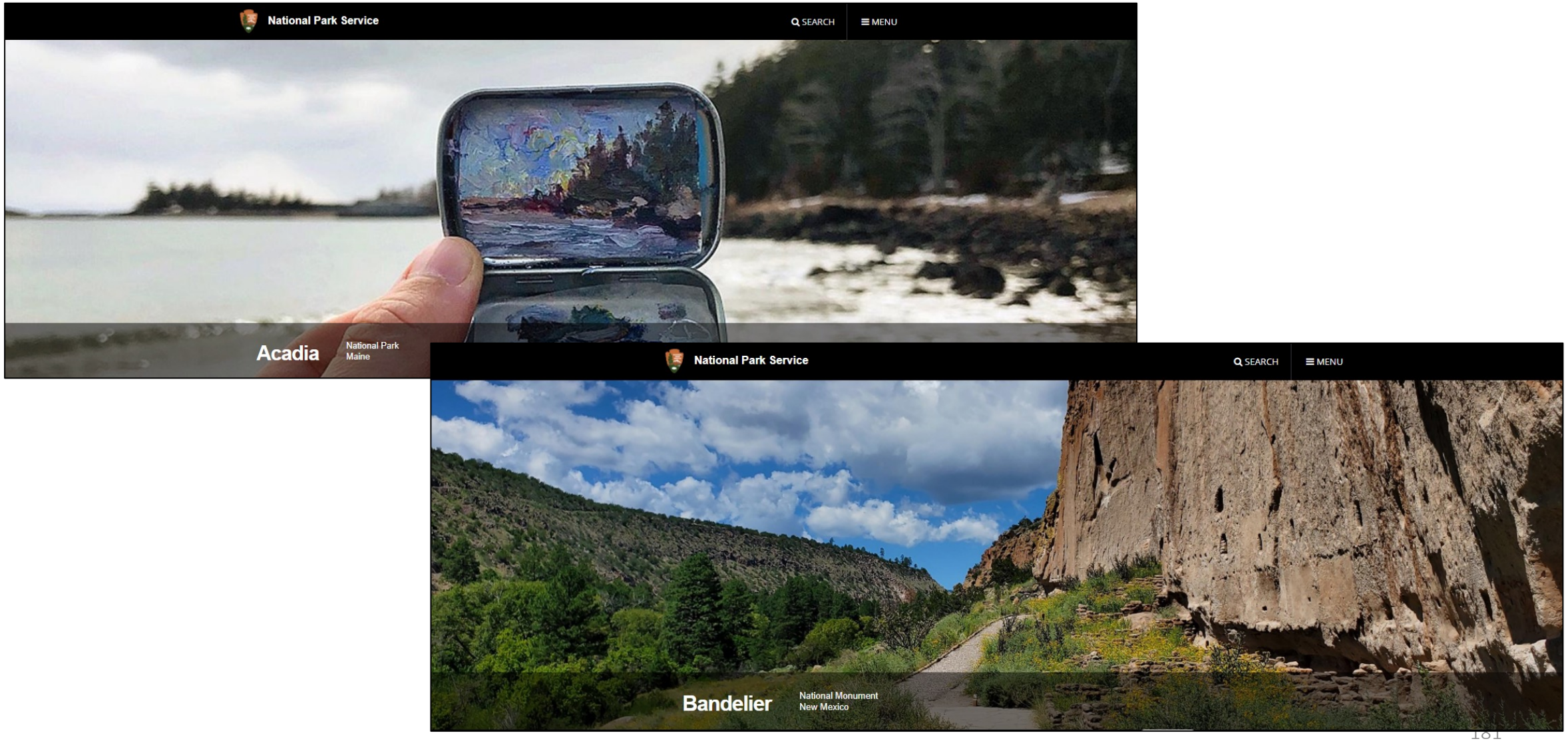
To adapt to climate change, the tribe has shifted management of a 61-acre inland lake from a cold water (brook trout) fishery to a cool water fishery (yellow perch and walleye) through fish propagation and stocking. This occurred because warming temperatures in the lake reached critical lethal levels for brook trout causing complete collapse of the population. The Grand Portage Natural Resources Department adapted to the fishery collapse by choosing to develop a cool water fishery using yellow perch and walleye.

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

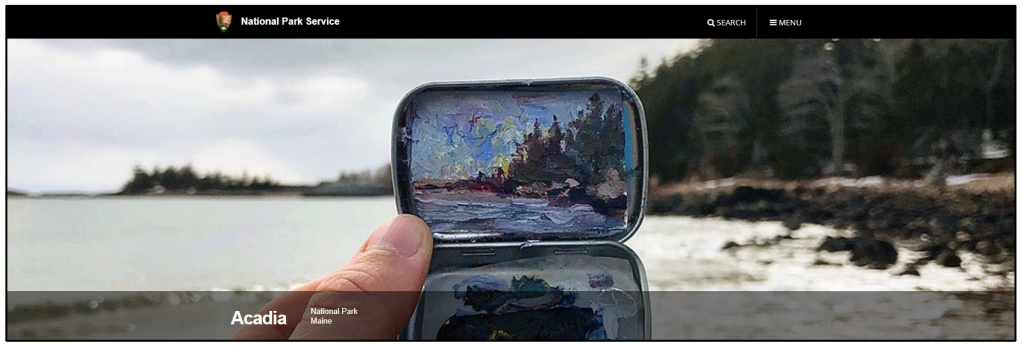


Direct

RAD natural resource management in action – our "RADdest" parks



RAD natural resource management in action



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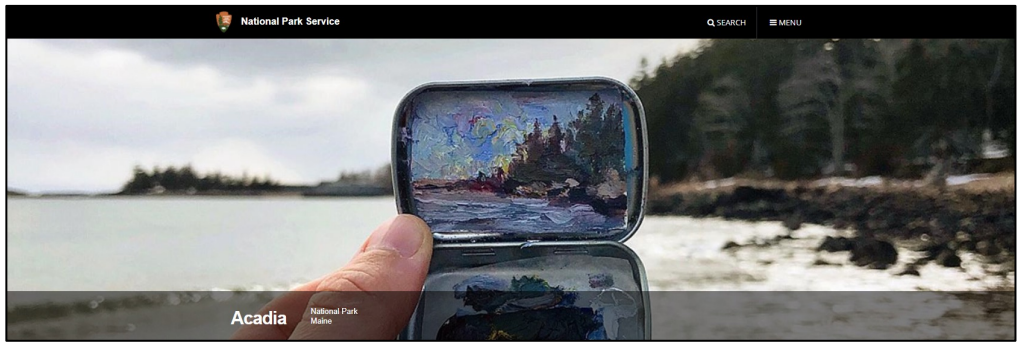


Current conditions

Near future

Resist

Accept

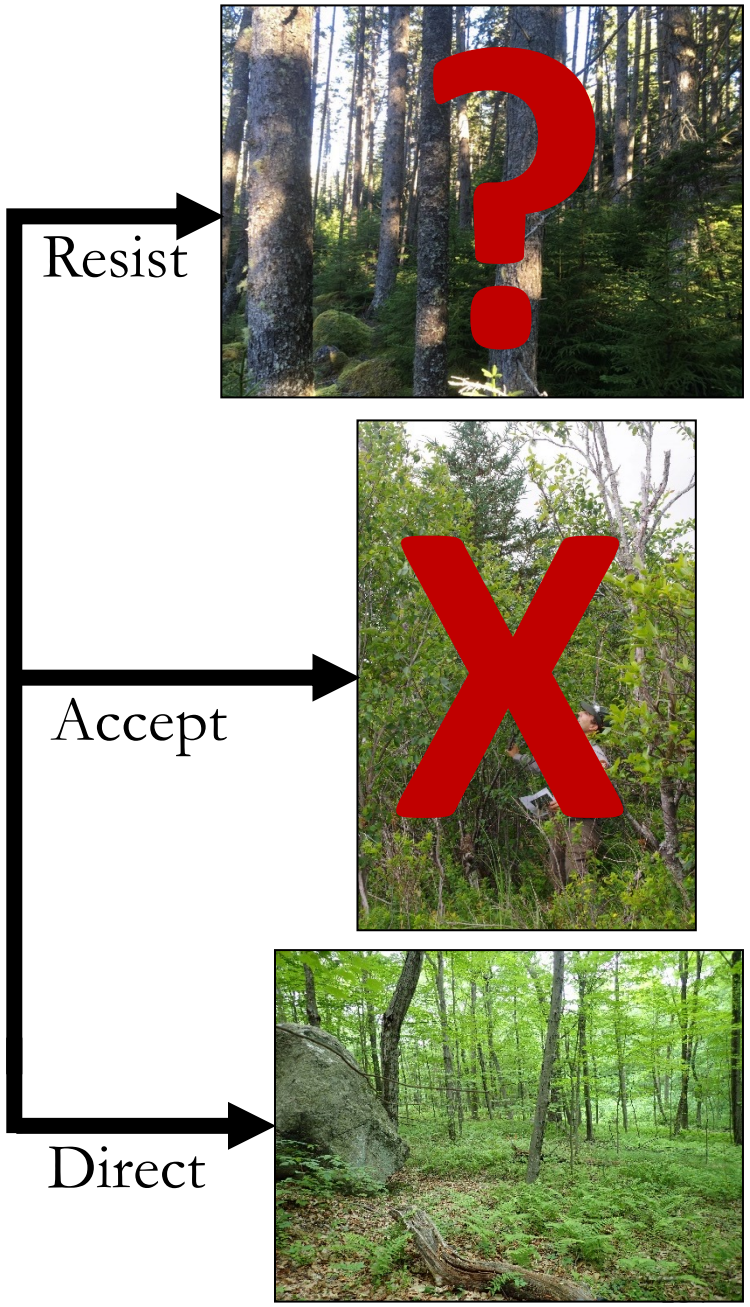
Direct

Slide courtesy of Abe Miller-Rushing

RAD natural resource management in action

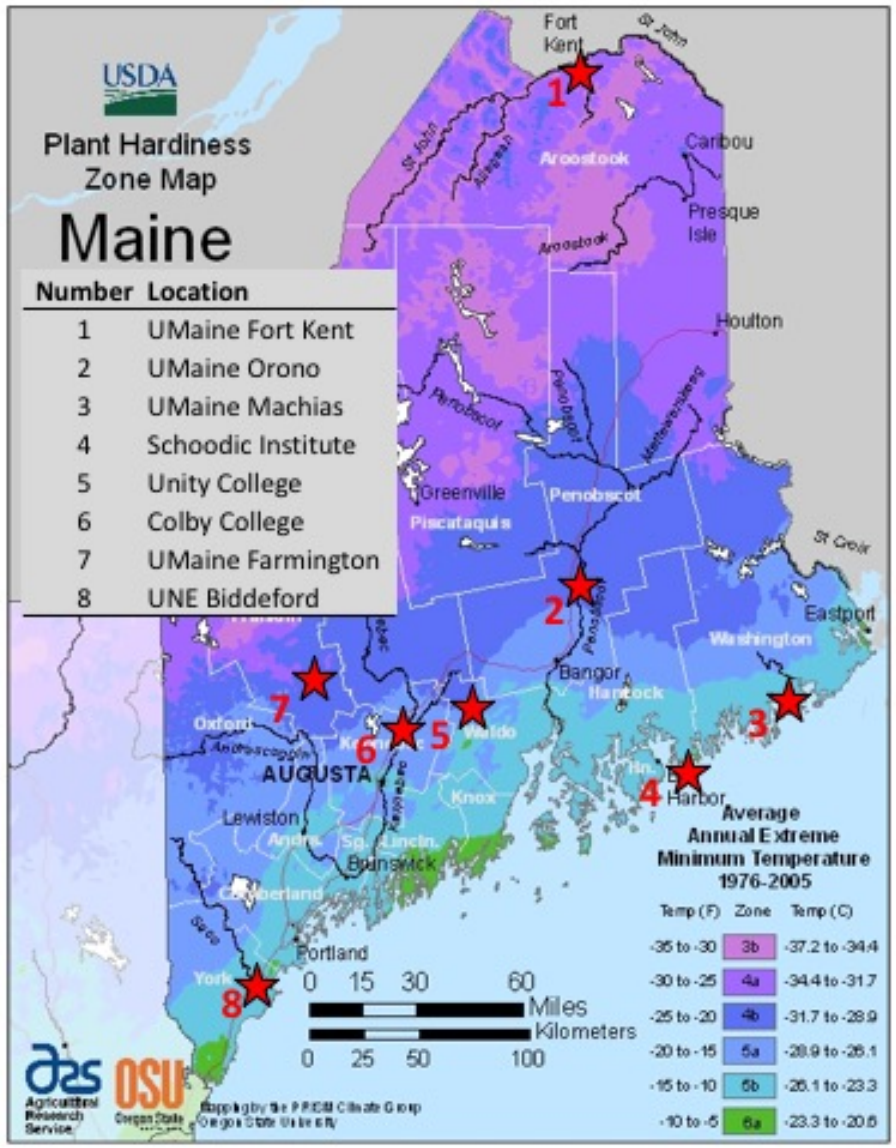
Management is urgent

- Restoration projects offer opportunities to test questions and approaches, but opportunities to resist are limited
- Accepting invasive shrubland is not tenable
- Directing change is an important option



Slide courtesy of Abe Miller-Rushing

RAD natural resource management in action



Slide courtesy of Abe Miller-Rushing

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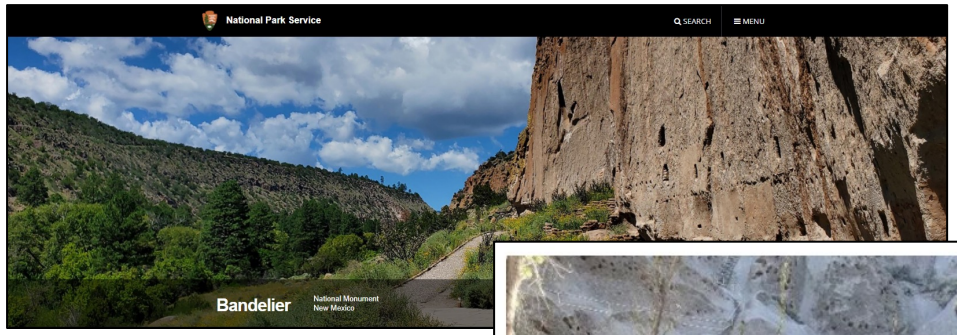


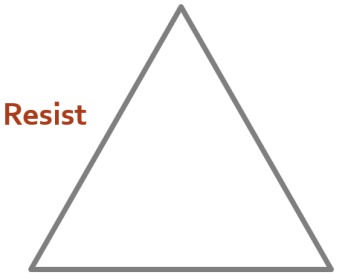
Bianca Gonzalez prepares to carry a load of Douglas fir seedlings for planting in Frijoles Canyon

Photo credit: Carolina May

Bianca Gonzalez plants a Douglas fir seedling on the north side of a "nurse log," Frijoles Canyon

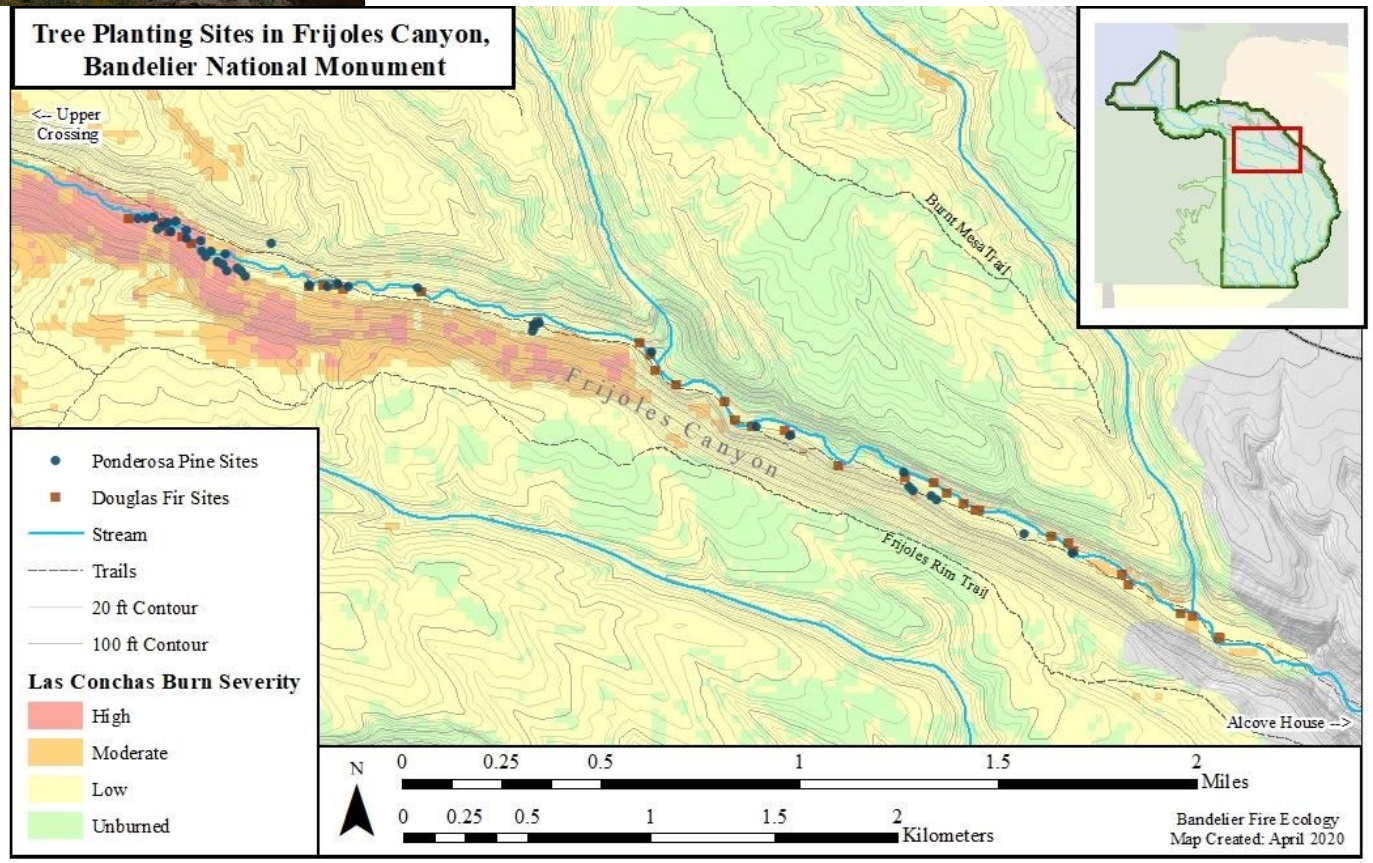
Photo credit: Carolina May

Resist



RAD natural resource management in action

"Planting at the (upper) margins"



Direct

Interactive feature – fill out rest of your worksheet

- Important to be clear and specific re: the focus (species/population, natural community, ecological process, etc.)
- Useful to first characterize what successful resistance looks like, including clarifying time horizon
- Remember that acceptance (of the ecological trajectory/change) can require substantial associated management action

Describe a concerning ecological trajectory or abrupt change (ongoing or anticipated):

Name the species/population, natural community, etc. undergoing change in your answer above and for which you'd like to explore potential resist, accept, or direct approaches: _____.

Term (choice)	**Define each term**	**For resist and direct, list an example action that influences the ecological trajectory.** **For accept, list an example action that may be necessary as a consequence of allowing ecological change to proceed autonomously.**	**Describe the outcome, for your focal species/population, natural community, etc., of each decision**
RESIST	Work to maintain or restore ecosystem composition, structure, processes, or function	An action to **resist** the trajectory/change: *In response to increasing drought impacts on nectar plants relied upon by a Karner blue butterfly population, intervene by increasing canopy cover in the population's pine barrens habitat and favoring drought-tolerant nectar plant species in habitat management and restoration.*	Outcome: *The population experiences less pronounced declines during subsequent droughts and persists as it was, where it was for the expected time period.*
ACCEPT	Allow ecosystem composition, structure, processes, or function to change autonomously	An action necessitated by **accepting** the ecological trajectory/change: *In response to accepting increasing beaver abundances in an Arctic wildlife refuge, alter salmon harvest regulations to address beaver-induced alteration of salmon habitat and relocate a roadway.*	Outcome: *Salmon populations persist at acceptable levels and refuge access remains uninterrupted despite substantial beaver-induced hydrological changes.*
DIRECT	Actively shape change in ecosystem composition, structure, processes, or function toward preferred new conditions	An action to **direct** the trajectory/change: *In response to steady or abrupt declines in boreal forest species in a northeastern national park, intervene by planting northern hardwood forest species from states to the south, guided by ecological and social risk assessments, while continuing traditional invasive species control approaches.*	Outcome: *Declining boreal forest at the park is replaced by native North American hardwood forest, rather than by Eurasian invasive shrubs and vines.*

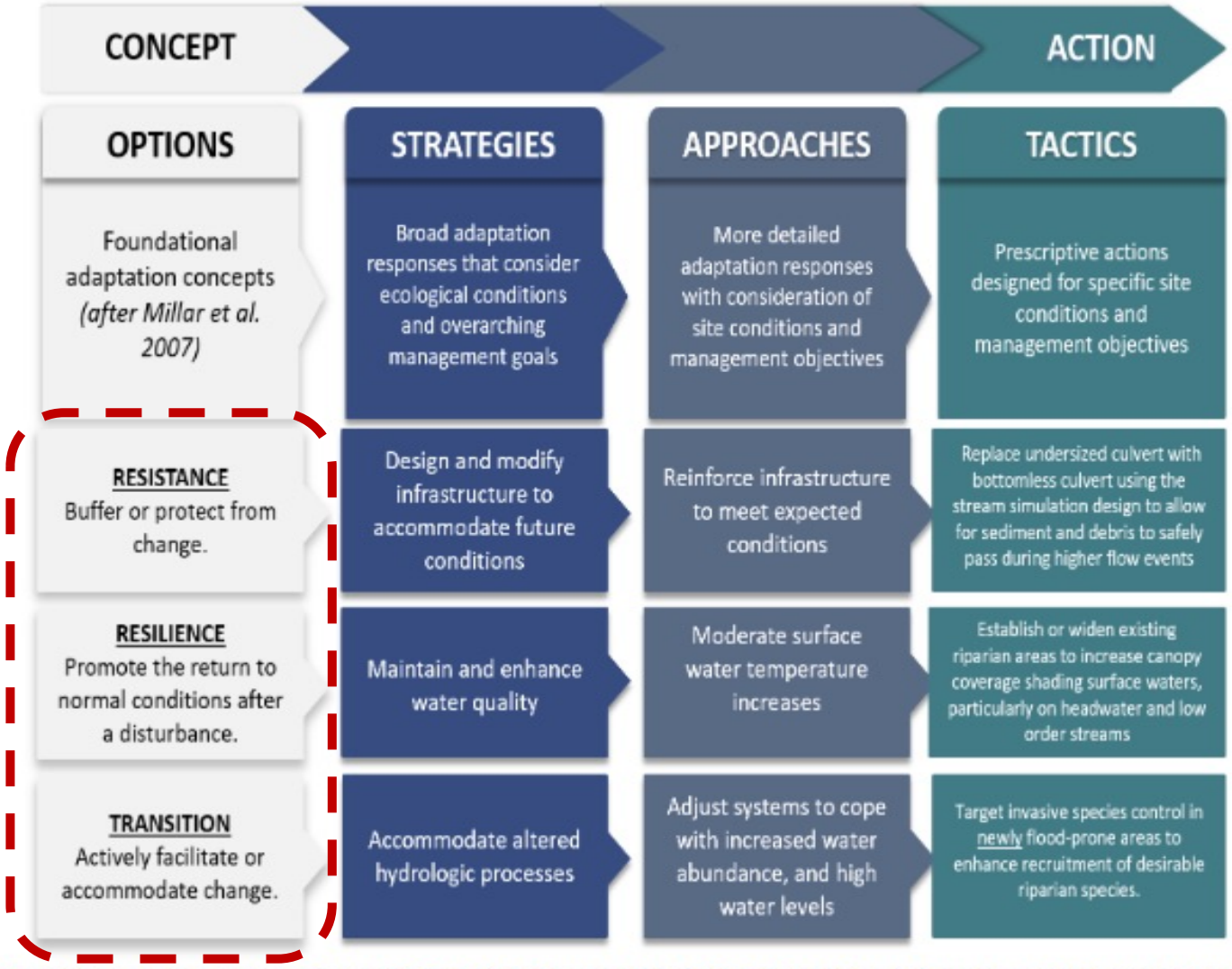
OUTLINE – the RAD framework

- Brief RAD framework introduction
- Background – the challenge of climatic & ecological non-stationarity
- Addressing non-stationarity
- Exploring the framework
- Applying the framework
- RAD vs other frameworks

Comparing and contrasting two popular cc adaptation decision typologies

Comparing and contrasting two popular cc adaptation decision typologies

- Introducing RRT



- **Citation:** Shannon, P. Danielle, Christopher W. Swanston, Maria K. Janowiak, Stephen D. Handler, Kristen M. Schmitt, Leslie A. Brandt, Patricia R. Butler-Leopold, and Todd Ontl. 2019. "Adaptation strategies and approaches for forested watersheds." *Climate Services* https://doi.org/10.1016/j.cliser.2019.01.005

Comparing and contrasting two popular cc adaptation decision typologies

- RAD and RRT

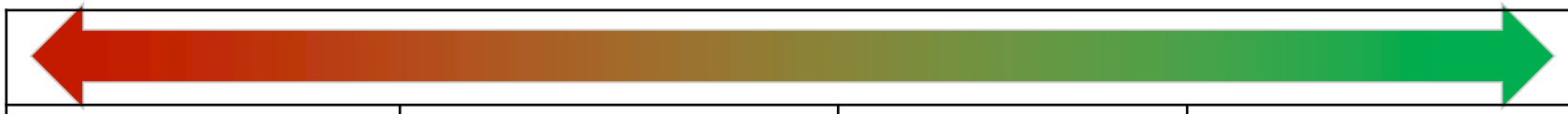
Adaptation typologies

				Source
Persistence	Change			Stein et al. 2014
Resist	Resilience	Response		Millar et al. 2007
Resist	Accept	Guide		Aplet & Cole 2010 (from 2007 workshop)
Restraint	Resilience	Resistance	Realignment	Stephenson & Millar 2011
Refugia	Ecosystem maintenance	Natural adaptation	Facilitate transitions	Magness et al. 2011
Anticipatory	Reactive			Stein et al. 2014

Comparing and contrasting two popular cc adaptation decision typologies

- Where RAD came from

Adaptation typologies

				Source
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Resist	Accommodate	Direct		Fisichelli et al. 2016b

Fisichelli, N, G Schuurman, A Symstad, A Ray, J Friedman, B Miller, and E Rowland. 2016. 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. National Park Service, Fort Collins, Colorado. <https://irma.nps.gov/DataStore/Reference/Profile/2230834>

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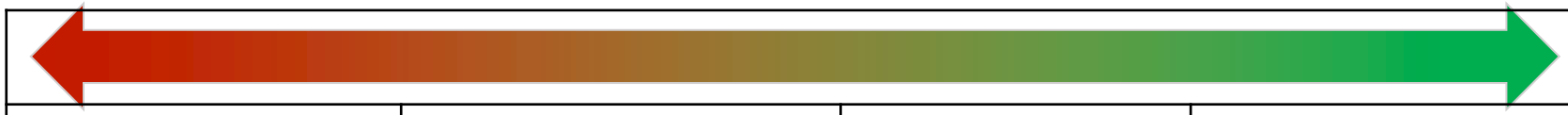				Source
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Persistence (of current conditions)	Autonomous change	Directed change		Fisichelli et al. 2016a
Resist	Accommodate	Direct		Fisichelli et al. 2016b
Resist	Accept	Guide		Aplet & McKinley 2017
Resist	Accept	Direct		TWS/AFS ET Group – 2018 onward
Resist	Accept	Direct		FedNET – 2017 onward

Comparing and contrasting two popular cc adaptation decision typologies

- Where RRT came from

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Anticipatory	Reactive			Stein et al. 2014
Resistance	Resilience	Transition		NIACS, WCS, etc.

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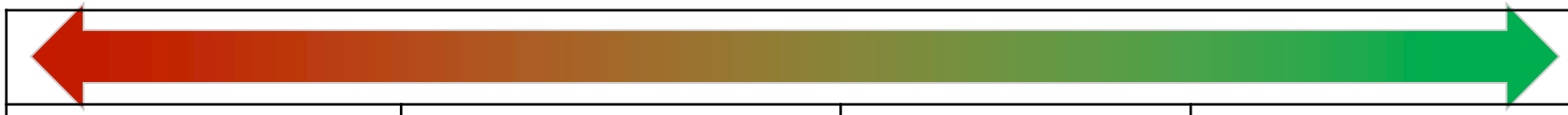
Adaptation typologies

				**Ultimate source**
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Adaptation typologies

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Adaptation typologies

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In common:

- Deeply rooted frameworks
- Recognize resisting/resistance to change and the need (sometimes) to do/foster it
- Recognize ecological change and the need (sometimes) to work with it
- Can be applied in diverse environmental stewardship settings – from urban watersheds to wilderness areas
- Support a lot of strategic, forward-looking adaptation

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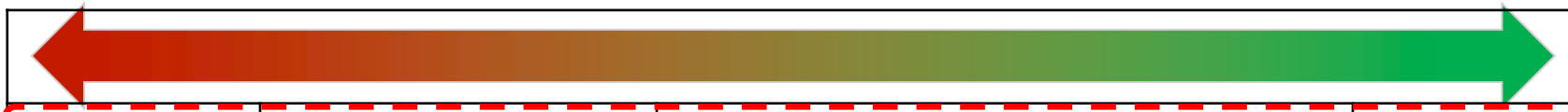
Adaptation typologies



					Ultimate source
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Unique RRT attributes:

- Clarity regarding desired ecosystem state/trajectory
- Resilience in (part of) the picture

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Resistance	**Resilience**		**Transition**	**RRT**	**Millar et al. 2007**
Resist		**Accept**	**Direct**	**RAD**	**Aplet & Cole 2010**

Unique RAD attributes:

- Centered on manager action and intent
- Explicitly recognizes intentional acceptance of ecological change
- Does not rely on resilience

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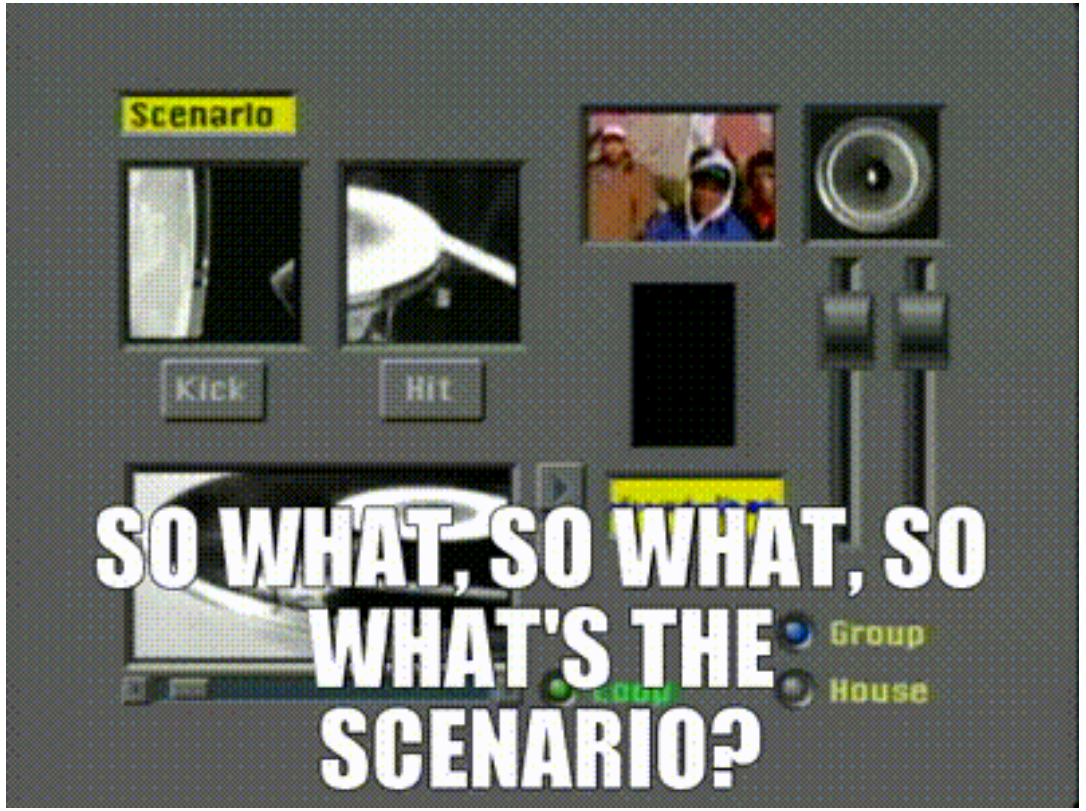
Thank you!



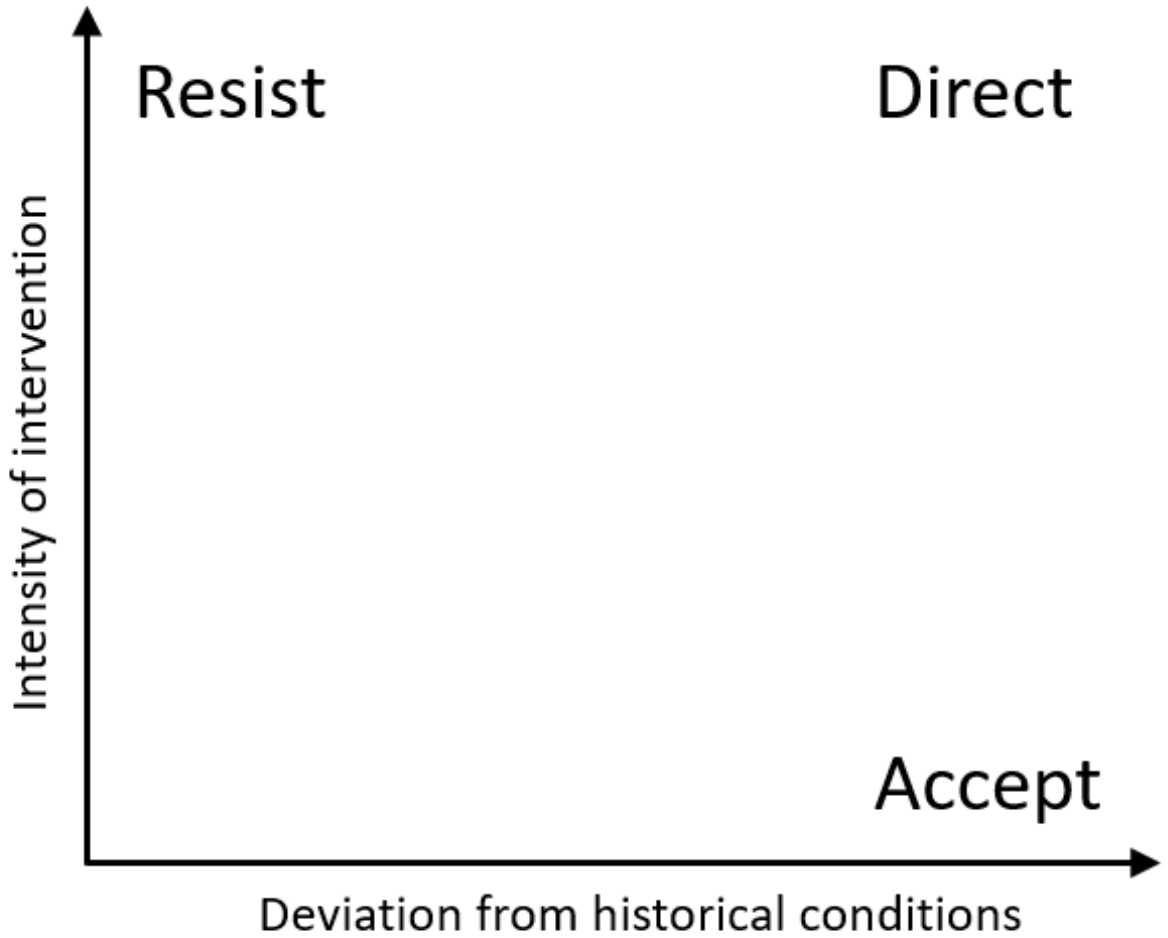
Extra slides

The RAD framework

Consider the analogy of a sailboat being pushed away from its home port by strong winds (right). Each option differs in terms of costs and outcome:

- To **accept** is to lower the sails and allow the boat to move with the winds, arriving wherever they lead.
- To **direct** is to use the winds, via sails and rudder, to steer the boat to a specific new, preferred destination, both far from home port and from where the winds alone would take it.
- To **resist** is to lower the sail and fight the prevailing winds, using a motor to attempt to return to home port.

Schuurman et al. 2022



Schuurman et al. 2022