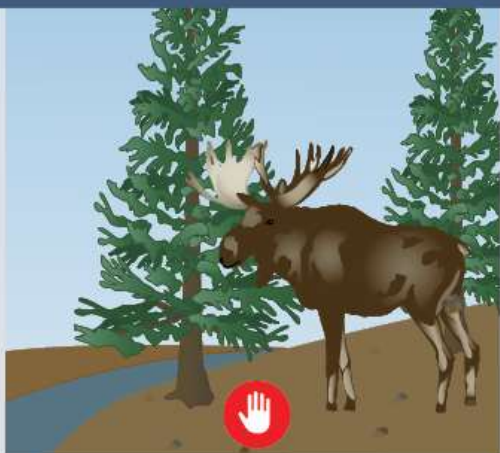
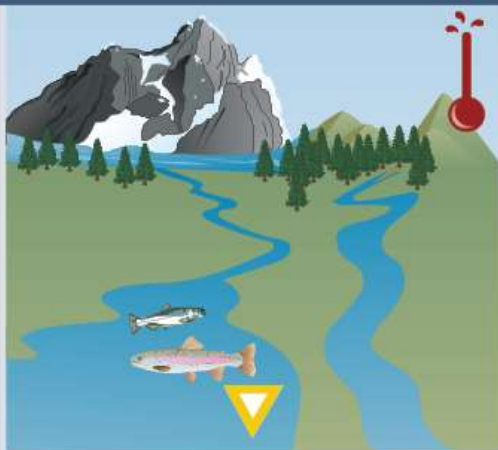


# Resisting, Accepting or Directing Change: A new way to think about climate adaptation

## Kenai Peninsula, Alaska: A Case Study



Stream banks are restored, some invasive species are eradicated, fire is managed progressively, and landscape connectivity is maintained through fish and wildlife passages under or over highways. Many invasives are not managed either due to infeasibility or lack of perceived threat.



Glaciers are melting, non-glacial streams are warming, tree line is rising, and wetlands are drying. Yet, the effects have not been severe enough to prompt a management response. Society has accepted the changes in fish and wildlife communities, even with higher costs to ecosystem services.



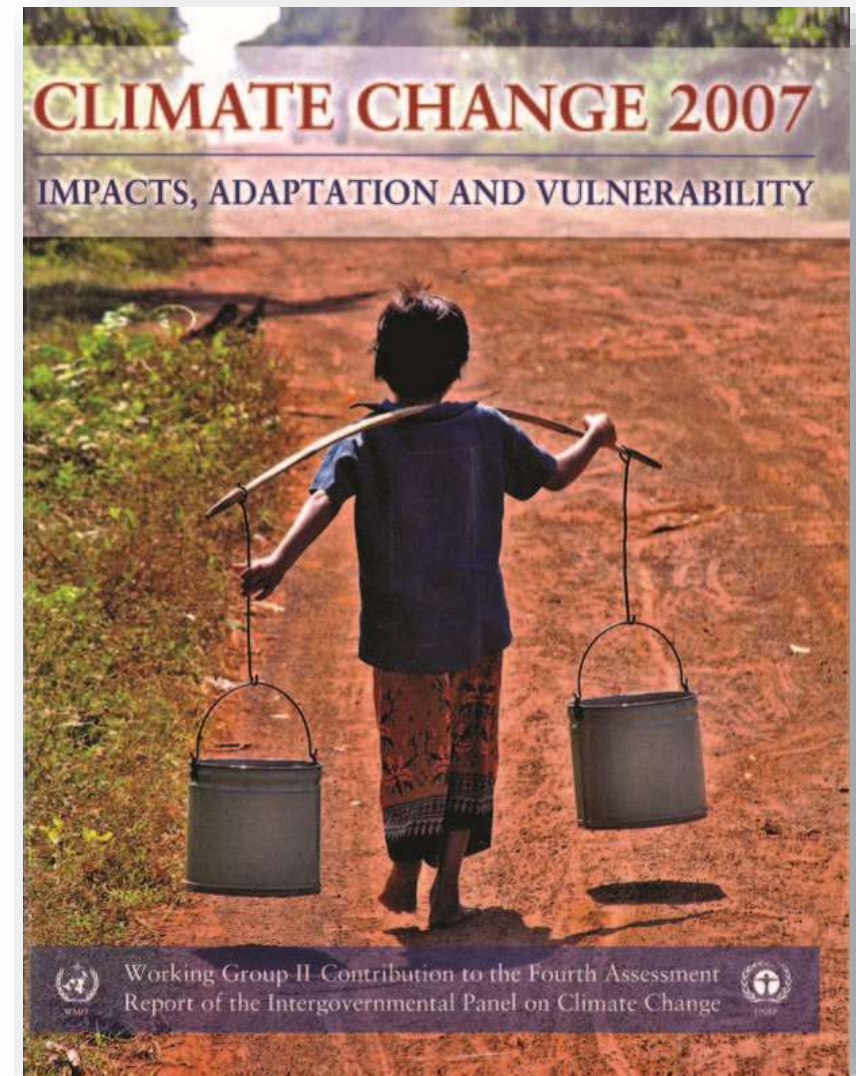
A spruce bark beetle epidemic and human-caused fire have shifted white spruce forests into a novel grassland ecosystem. Non-native trees are being planted, and the introduction of large grazers is being considered to stabilize the new grasslands and related communities.

John Morton  
Kenai National Wildlife Refuge



Adaptation is...

“an adjustment in **natural** or **human** systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”



—Intergovernmental Panel on Climate Change (2007)

# Resistance vs Resilience vs Transformation

**NFWPCAS developed to promote unified agency responses to climate change impacts**

— National Fish, Wildlife, and Plants  
Climate Adaptation Strategy 2012



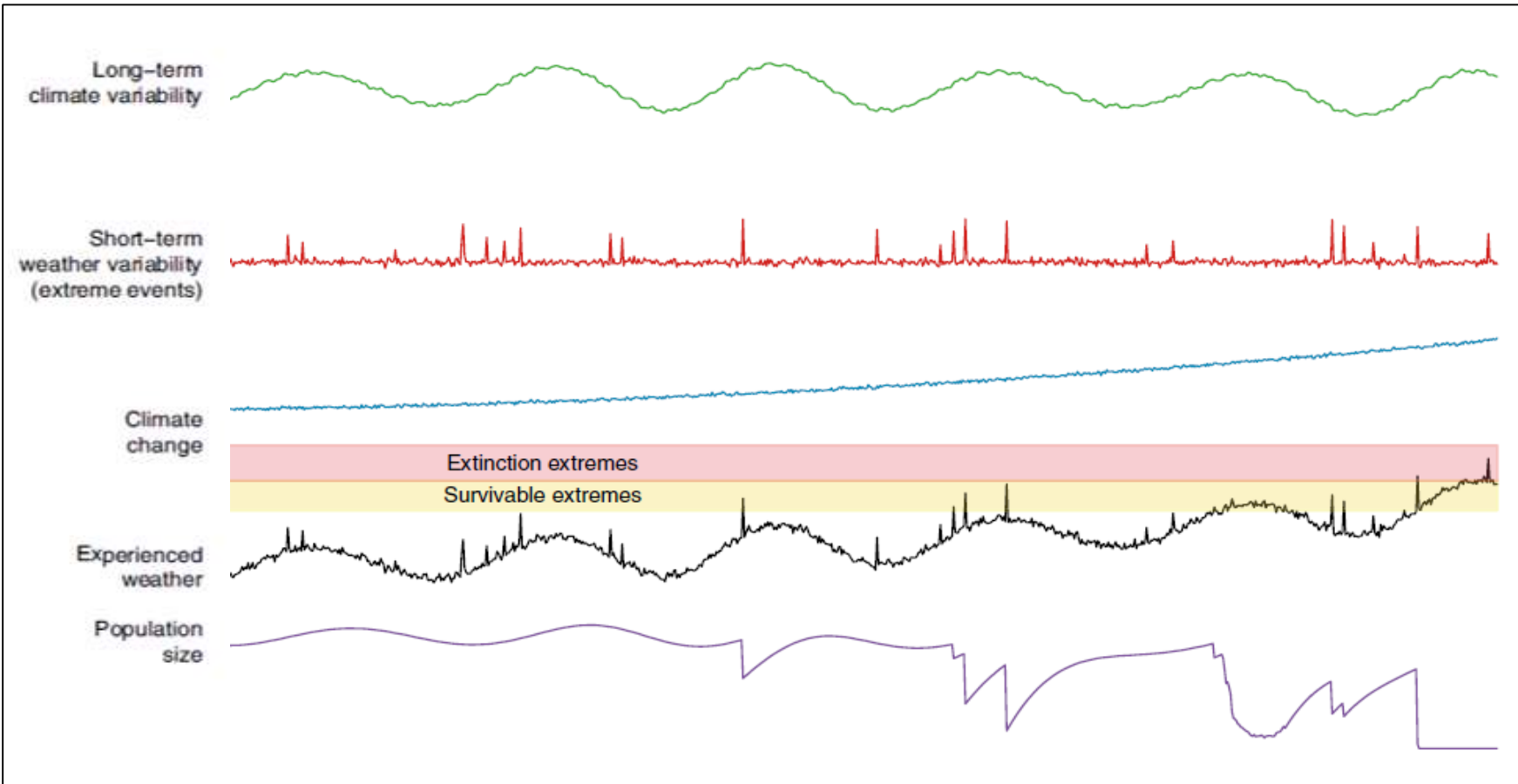
# RAD framework squarely assigns the adaptation response to a managerial decision

RESIST	ACCEPT	DIRECT
<p>Many changes will be <b>RESISTED</b> by managers, to maintain ecosystem processes, function, and composition toward a <u>historical</u> baseline</p>	<p>Many changes will be <b>ACCEPTED</b> by managers, perhaps because...</p> <ul style="list-style-type: none"><li>• Infeasible to be managed</li><li>• insufficiently impactful to warrant response</li><li>• acceptable to (even desirable by) stakeholders</li><li>• unknowingly occurring</li><li>• lack of will or impetus despite sufficient knowledge or resources</li></ul>	<p>Some changes will be <b>DIRECTED</b> by managers toward a specific <u>future</u> state because...</p> <p>so dramatic that resisting is untenable and there is a feasible opportunity to steward change towards a more desirable outcome than what would be achieved with acceptance</p>



**...with the goal of a self-sustaining, self-organizing system**

# RAD addresses Directional Change and Ecological Transformation



## Directional Change

unrelenting and unprecedented change in key drivers of ecological conditions

## Ecological Transformation

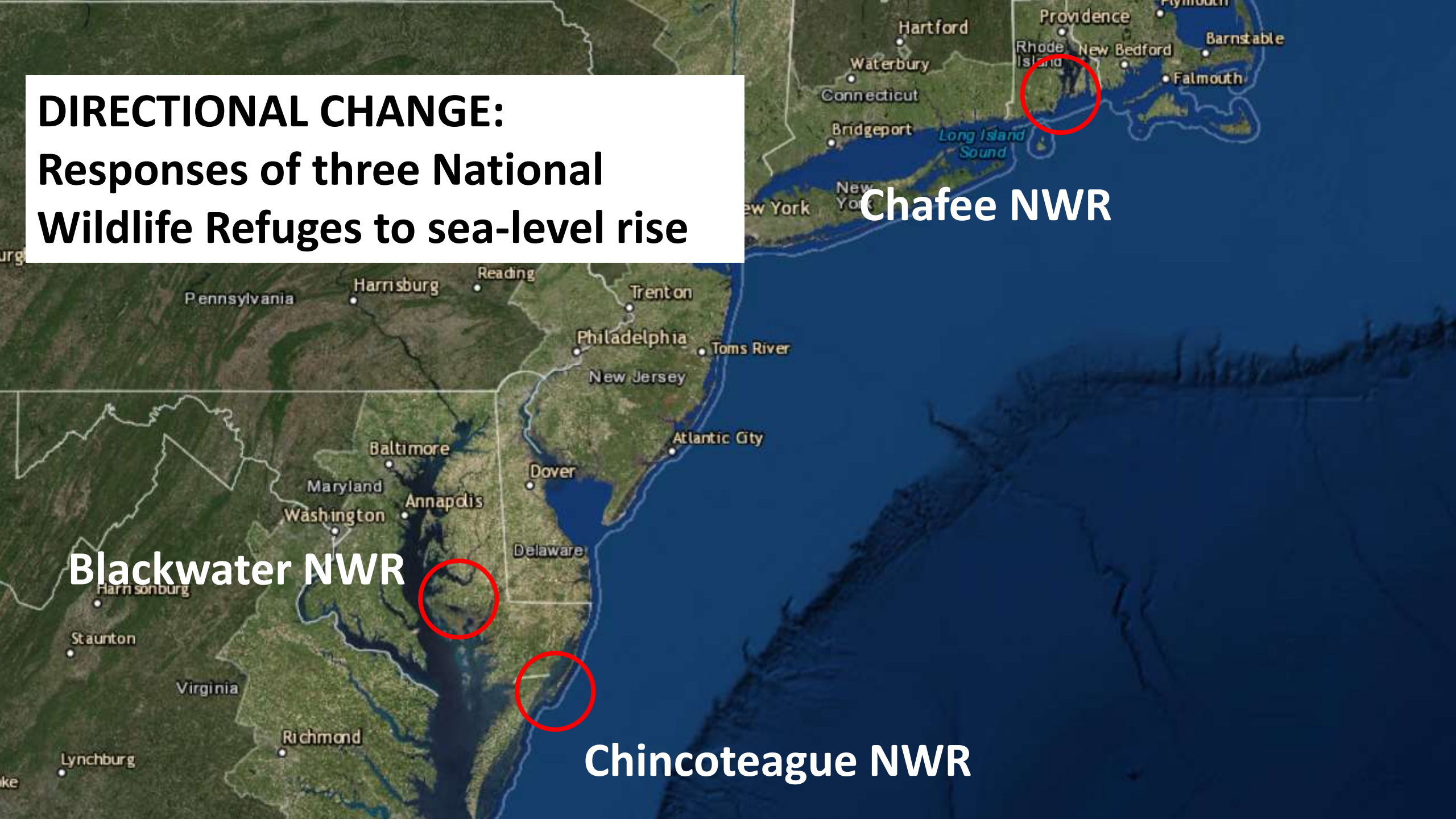
“a dramatic, persistent, and statistically ‘extreme’ shift in multiple ecological characteristics, the basis of which is dramatic changes in species composition”

**DIRECTIONAL CHANGE:  
Responses of three National  
Wildlife Refuges to sea-level rise**

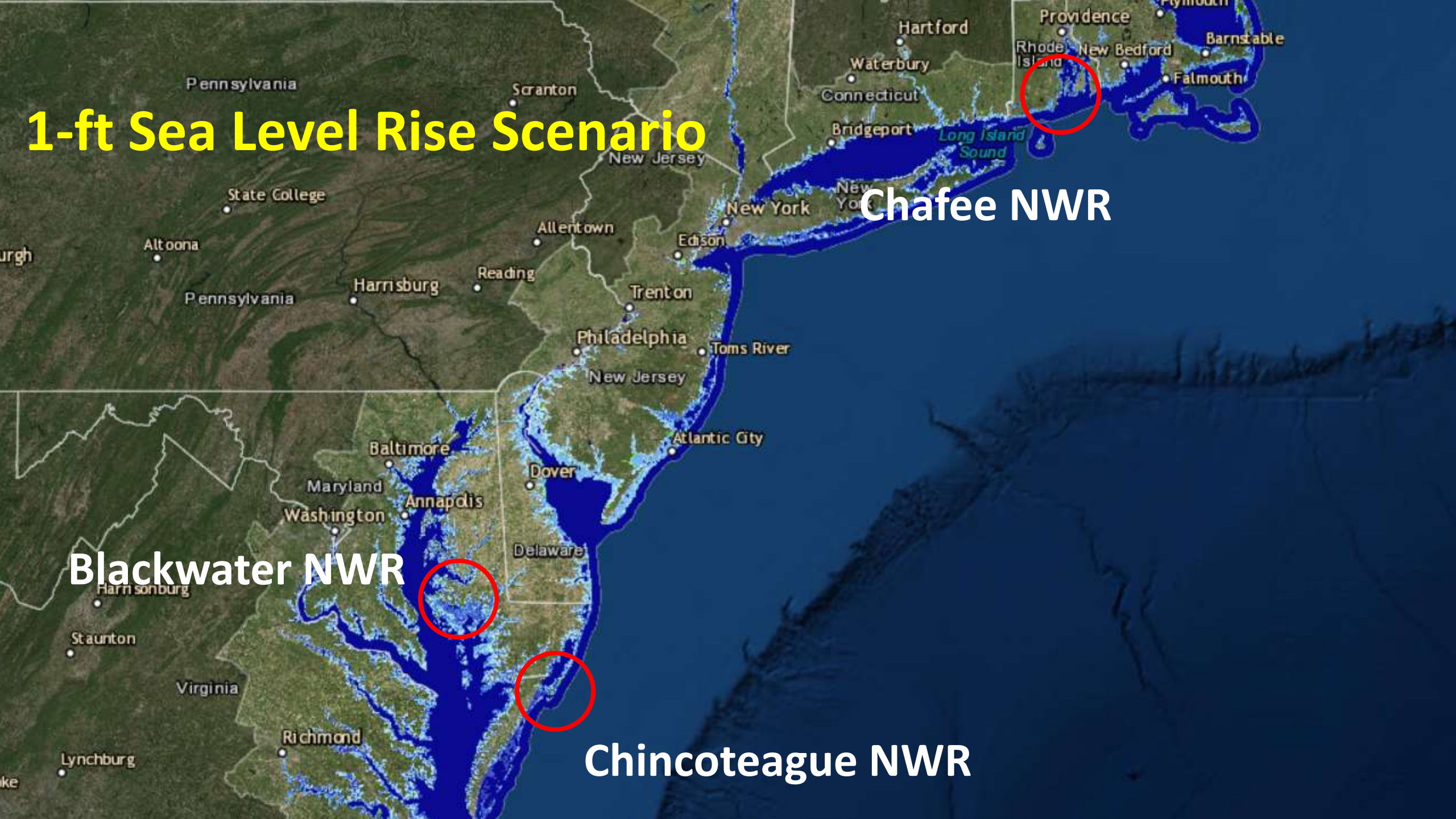
**Chafee NWR**

**Blackwater NWR**

**Chincoteague NWR**



# 1-ft Sea Level Rise Scenario



Chafee NWR

Blackwater NWR

Chincoteague NWR

# RESISTING CHANGE: Chafee National Wildlife Refuge

- ✓ \$1.4 million project to use thin-layer deposition to keep *Spartina patens* saltmarsh in situ
- ✓ 3,000 bags of clam and oyster shells to sediment and water on the marsh platform
- ✓ Amphibious excavator to disperse sediment





# ACCEPTING CHANGE: Chincoteague National Wildlife Refuge and Assateague Island National Seashore

- ✓ After 6 decades of maintaining artificial dunes, the island will be allowed to overwash during storm events and migrate in response to long-shore current
- ✓ Since 2003, increasing storm damage to infrastructure (visitor center, roads, parking lots) has cost \$3.5 million
- ✓ NPS beach facilities have been moved inland and two refuge waterfowl impoundments will be allowed to deteriorate



# DIRECTING CHANGE: Blackwater National Wildlife Refuge

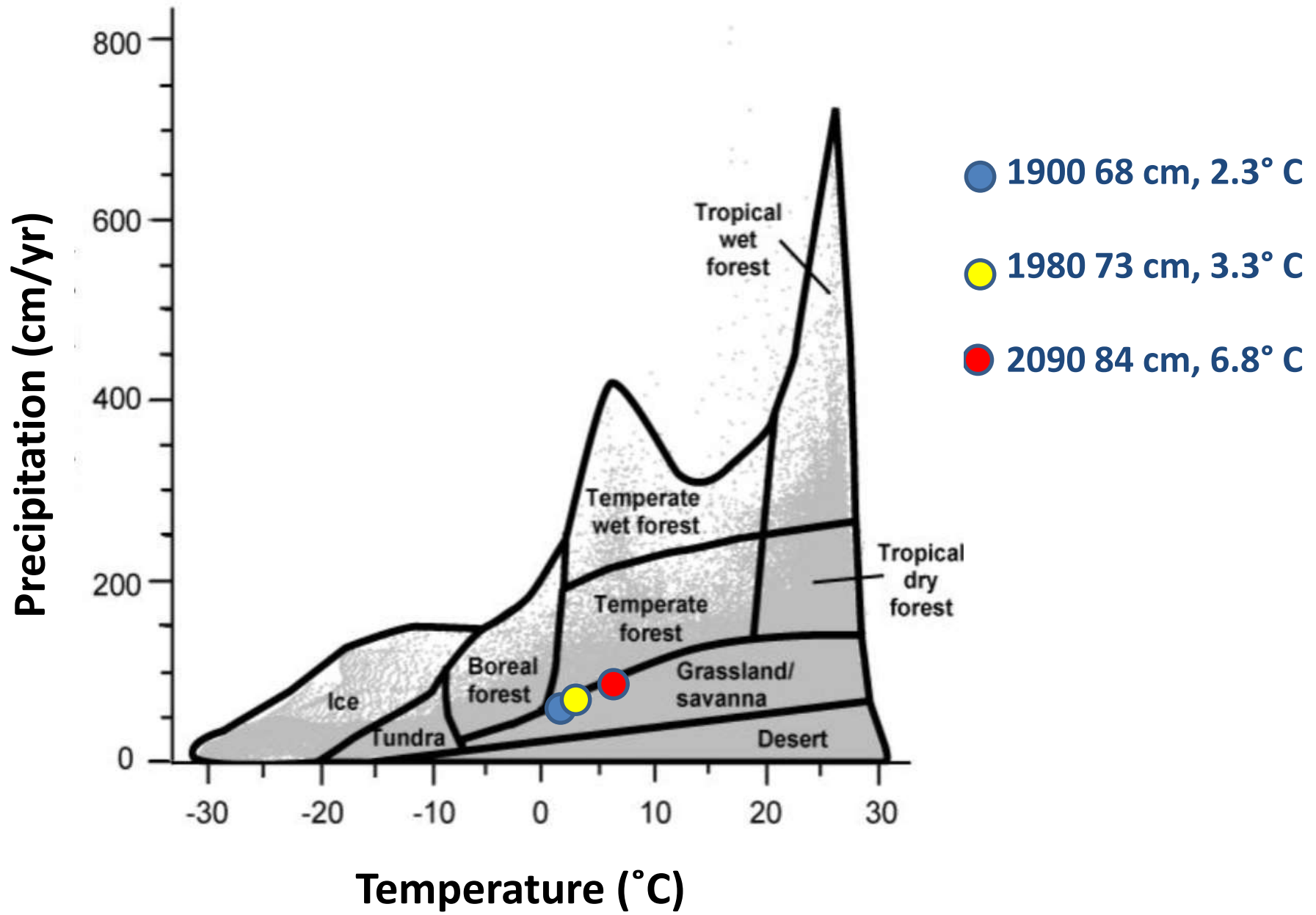
- ✓ Since 1938, 5,000 acres of tidal wetlands converted to open water, but 2,700 acres of new marsh created by upslope migration
- ✓ A partnered \$475K demonstration project to facilitate marsh migration by extending the head of a tidal creek with a low-ground-pressure excavator (DIRECT)
- ✓ Thin-layer deposition to hold some marsh in situ (RESIST)



# TRANSFORMATIONAL CHANGE:

Could this novel system be stewarded towards one that is more diverse?





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

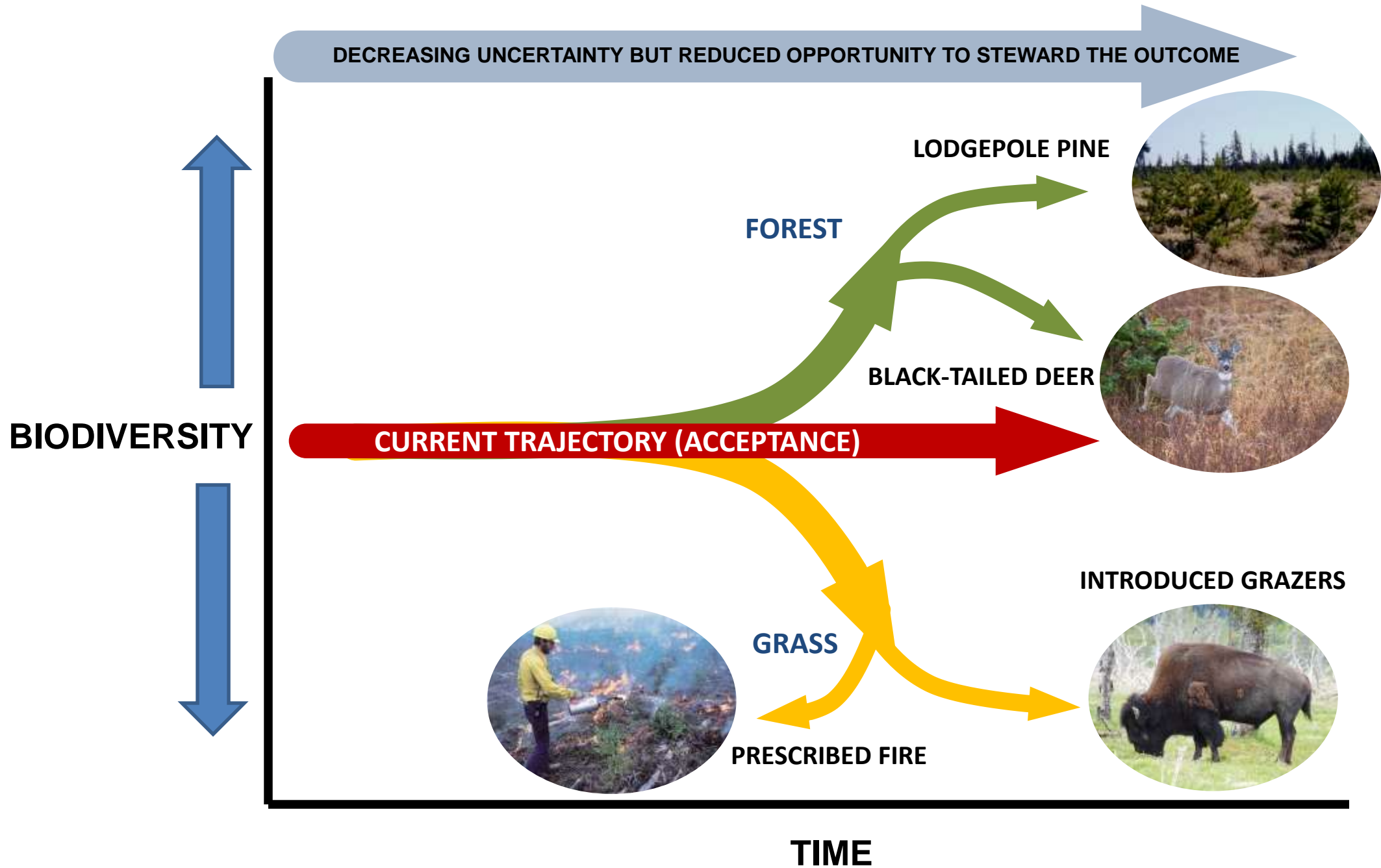
**Could this novel system be stewarded towards one that is more diverse?**

**BIODIVERSITY**

**CURRENT TRAJECTORY (ACCEPTANCE)**



**TIME**



	Human-influenced stressors	Change	Management Responses	
			Kenai NWR	Other entities
Ecological Processes	fire regime	increased ignition rates, spring grassland fires, fires in hemlock	<b>RESIST/ACCEPT</b>	RESIST
	spruce bark beetle	15-yr outbreak on ~ 1 million acres	<b>ACCEPT</b>	ACCEPT/RESIST (KPB, NNAI)
	subalpine tree/shrub line	1 m per yr (trees), 2.8 m per yr (shrub)	<b>ACCEPT</b>	ACCEPT
	glaciers	Harding Icefield lost 5% surface area, 21m elevation; glacial thinning increased 55%	<b>ACCEPT</b>	ACCEPT
	wetlands	6–11% loss per decade in surface area	<b>ACCEPT</b>	ACCEPT
	nonglacial anadromous streams	17 of 48 streams reach sublethal temperatures in July	<b>ACCEPT</b>	ACCEPT/RESIST (Cook InletKeeper, KHLT)
Species	American marten	recent colonization of Kenai Lowlands	<b>ACCEPT</b>	ACCEPT
	Elodea spp.	accidentally introduced by aquarium dumps and floatplane	<b>RESIST</b>	RESIST
	northern pike	transplanted from interior Alaska	<b>RESIST</b>	DIRECT/RESIST (private landowners)
	Sitka black-tailed deer	translocated from SE Alaska	<b>ACCEPT</b>	DIRECT (Cordova Chamber of Commerce)
	earthworms	accidentally/deliberately introduced	<b>ACCEPT</b>	DIRECT (gardeners, anglers)
	Mycoplasma ovipneumoniae	introduced disease in mountain goats	<b>ACCEPT</b>	ACCEPT

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# Could engineering by beavers and humans recharge drying peatlands?



Journal of Hydrology

Content lists available at ScienceDirect

Journal of Hydrology

Analysing peatland discharge to streams in an Alaskan watershed: An integration of end-member mixing analysis and a water balance approach

Michael B. Coates<sup>a,b,c</sup>, Mary F. Meffert<sup>d</sup>, Donald I. Siegel<sup>e</sup>, Paul H. Glenn<sup>a,b</sup>

<sup>a</sup>Department of Biological Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA; <sup>b</sup>Department of Earth Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA; <sup>c</sup>Department of Earth Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA; <sup>d</sup>Department of Earth Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA; <sup>e</sup>Department of Earth Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA

ARTICLE INFO

ABSTRACT

Peatlands are the largest carbon storage reservoir on land, and their discharge to streams is a significant source of organic carbon to aquatic ecosystems. However, the hydrology of peatlands is poorly understood, and the impact of climate change on peatland discharge is uncertain. We use a water balance approach to estimate the discharge of peatlands to streams in an Alaskan watershed. We use a water balance approach to estimate the discharge of peatlands to streams in an Alaskan watershed. We use a water balance approach to estimate the discharge of peatlands to streams in an Alaskan watershed.

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Journal of Hydrology: Regional Studies

Content lists available at ScienceDirect

Journal of Hydrology: Regional Studies

Simulating the effects of a beaver dam on regional groundwater flow through a wetland

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<sup>a</sup>Department of Earth Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA; <sup>b</sup>Department of Earth Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA

ARTICLE INFO

ABSTRACT

Beaver dams are a natural form of infrastructure that can be used to manage water resources in a watershed. They can increase groundwater recharge and reduce stream discharge. We use a numerical model to simulate the effects of a beaver dam on regional groundwater flow through a wetland. We use a numerical model to simulate the effects of a beaver dam on regional groundwater flow through a wetland.

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Peatlands represent 55% of streamflow during low flow

Beaver dams increase groundwater discharge 70% (no clay) to 90% (clay pan)

	Human-influenced stressors	Change	Management Responses	
			Kenai NWR	Other entities
Ecological Processes	fire regime	increased ignition rates, spring grassland fires, fires in hemlock	RESIST/ACCEPT	RESIST
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# Ice911 is a “Silicon Valley moonshot aiming to stabilize climate by restoring ice in the Arctic”



RESEARCH ARTICLE

10.1029/2018EF001201

Special Section:  
The Arctic in AGU 100  
Special Collections

Key Points

- Arctic sea ice extent is a critical lever in global climate
- Albedo modification of sea ice is an efficient method of ice preservation
- Albedo enhancement increases the sea ice area and volume and decreases the surface temperature

Supporting Information:

- Supporting Information S1

Correspondence to:  
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Citation

Field, L., Ivanova, D., Bhattacharyya, S., Mlakar, V., Sholtz, A., Decca, R., et al. (2018), Increasing Arctic sea ice albedo using localized reversible ice albedo modification technology, *Earth's Future*, 6, e2018ef001201. doi:10.1029/2018EF001201

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FIELD ET AL.

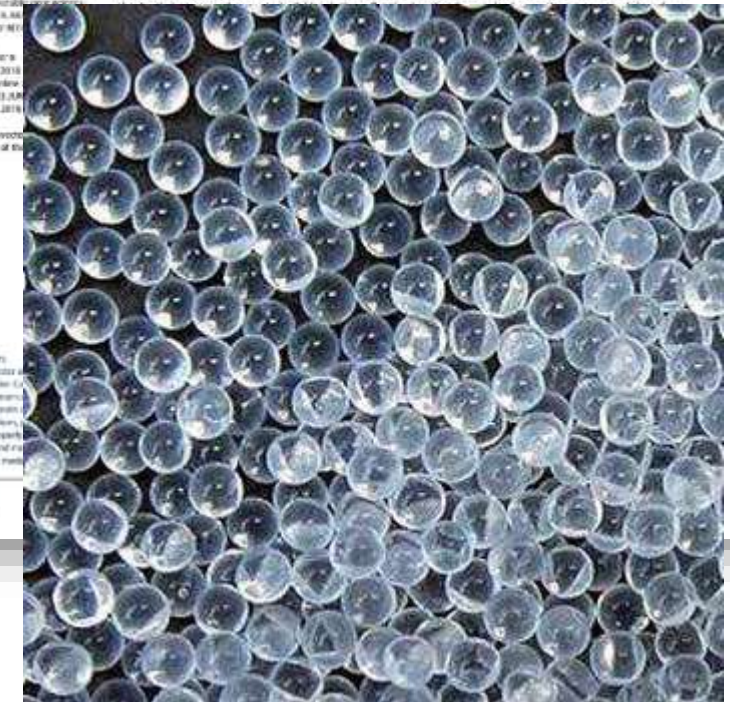
## Increasing Arctic Sea Ice Albedo Using Localized Reversible Geoengineering

L. Field<sup>1,2</sup>, D. Ivanova<sup>3</sup>, S. Bhattacharyya<sup>4</sup>, V. Mlakar<sup>5</sup>, A. Sholtz<sup>1</sup>, R. Decca<sup>1,2</sup>, A. Manasa<sup>6</sup>, D. Johnson<sup>7</sup>, E. Christodoulou<sup>1</sup>, P. Walker<sup>8,9</sup>, and K. Katari<sup>10</sup>

<sup>1</sup>Ice911 Research, Menlo Park, CA, USA, <sup>2</sup>Electrical Engineering, Stanford University, Stanford, CA, USA, <sup>3</sup>Scripta Institution of Oceanography, 4444, CA, USA, <sup>4</sup>ThalesAlenia Air, Houston, TX, USA

**Abstract** The rising costs of climate change merit serious evaluation of potential climate restoration solutions. The highest rate of change in climate is observed in the Arctic where the summer ice is diminishing at an accelerated rate. The loss of Arctic sea ice increases radiative forcing and contributes to global warming. Restoring reflectivity of Arctic ice could be a powerful lever to help in the effort to limit global warming to 1.5°C. Polar ice restoration should be considered in planning of 1.5°C pathways. In this paper, a novel localized surface albedo modification technique is presented that shows promise as a method to increase multiyear ice using reflective floating materials, chosen so as to have low subsidiary environmental impact. Detailed climate modeling studying the climate impact of such a method reveals more than 1.5°C cooler temperatures over a large part of the Arctic when simulating global sea ice albedo modification. In a region north of Baffin and Kara Seas temperatures have been reduced by 3°C and in North Canada by almost 1°C. Additionally, there are notable increases in sea ice thickness (20–50 cm Arctic wide) and ice concentration (15–20% across large parts of central Arctic). These results suggest that the geoengineering technology proposed in this study may be a viable instrument for restoring Arctic ice.

**Plain Language Summary** This paper describes a method to preserve and restore ice in the Arctic in order to reduce the effects of climate change. This method is design by design, developed to restore ice in



# Could Ice911 stabilize ice in the Harding Icefield?



RESEARCH ARTICLE

10.1029/2018EF001201

Special Section:

The Arctic Air AGU 100

Special Collection

Key Points

- Arctic sea ice extent is an effective lever to global climate
- Albedo modification of sea ice is an efficient method of ice preservation
- Albedo enhancement can increase the sea ice area and volume and decrease the surface temperature

Supporting Information:

- Supporting Information S1

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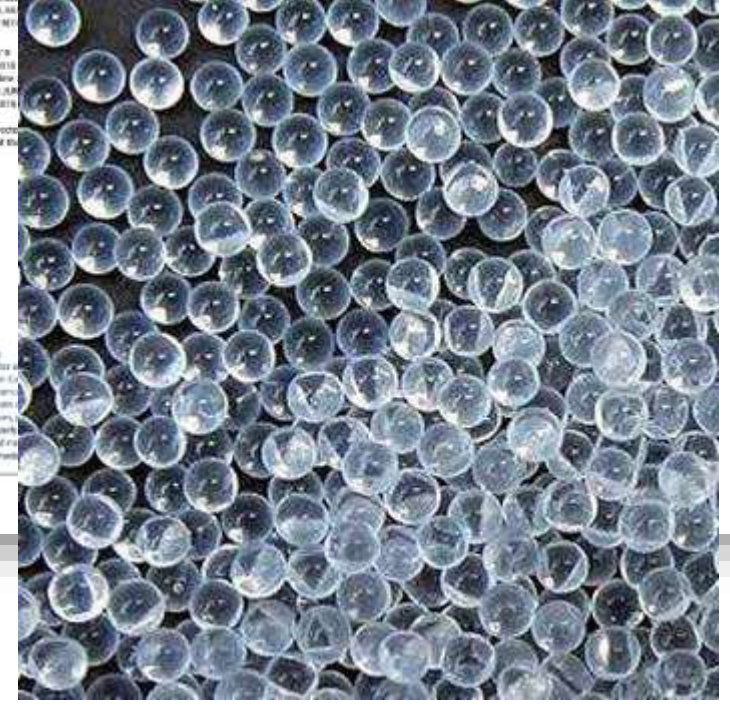
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**It's not rocket science...**



**...it's harder**

