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The Art of the Possible: Adaptation Options and Decision Support

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Overview

- Adaptation requires thinking along two pathways: for persistence and change
    - Managing for persistence = preventing systems from crossing thresholds of major change
    - Managing for change = anticipating unavoidable thresholds and preparing for/guiding the transition to a different state
- Methods exist to enable adaptation decisions to be made, even under large uncertainties

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Adaptation Approaches

Reduce Non-Climate Stresses	Minimize localized human stressors that hinder the ability of species or ecosystems to withstand or adjust to climatic events
Protect Key Ecosystem Features	Focus management on structural characteristics, organisms, or areas that represent important “underpinnings” or “keystones” of the current or future system of interest
Ensure Connectivity	Protect, restore, and create landscape features that facilitate movement of organisms (and gene flow) among resource patches
Restore Structure and Function	Rebuild, modify or transform ecosystems that have been lost or compromised, in order to restore desired structures and functions

Source: Stein, Glick, Edelson et al. (In Prep.) Climate-Smart Conservation: Sustaining Nature in a Changing Climate.

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Adaptation Approaches Cont'd

Support Evolutionary Potential	Protect a variety of species, populations and ecosystems in multiple places to bet-hedge against losses from climate disturbances, and where possible manage these systems to assist positive evolutionary change
Protect Refugia	Protect areas less affected by climate change as sources of "seed" for recovery or as destinations for climate-sensitive migrants
Relocate Organisms	Engage in human-facilitated transplanting of organisms from one location to another in order to bypass a barrier

Source: Stein, Glick, Edelson et al. (In Prep.) Climate-Smart Conservation: Sustaining Nature in a Changing Climate.

Managing For Persistence

- Initial work on adaptation has focused on managing for persistence of existing species and ecosystems under current goals

- Managing for persistence remains a viable goal where there is (1) potential for long term success or (2) a high priority placed on "buying time"

- Managing smartly requires understanding system specifics and identifying actions designed to address climate change impacts in combination with other stressors

Example: U.S. East Coast Salt Marsh

Conservation target level: Ecosystem	Adaptation approach	Example of specific management options	Key climate-smart questions
Example: Salt marshes 	Reduce non-climate stressors	Work with watershed coalitions to reduce non-point sources of pollution that favor invasive *Phragmites*	How will climate change affect inputs of non-point source pollution (e.g., through effects on timing and flashiness of precipitation)? Given the nature of these effects, what are the best options (e.g., permeable pavements, rain catchers, sewer system upgrades) for reducing runoff of pollutants onto the marsh?
	Protect key ecosystem	Modify ditches to re-establish natural hydrology and maintain	How will climate change affect salinities and sediment transport through effects on hydrology? How many, what type, and what locations of ditch
Conservation goal: Maintain healthy, functioning, East coast salt marsh ecosystems	Restore Structure and Function	Plan timing of restoration projects (i.e., incorporate known climatic oscillations) to maximize likelihood of success	How will climate change have implications for the success of restoration projects, in terms of the need to take into account inter-annual (e.g., El Nino/La Nina) or seasonal (e.g., wet/dry season) oscillations? What is the optimal timing for restoration projects in order to maximize successful establishment of restored salt marsh?
	Support	Ensure high clonal diversity of	How will climate change affect or change the top stressors of salt
		as sea level rise continues	
	Relocate Organisms	NA	NA

Ensure Connectivity	Reinstate tidal connections to support appropriate inundation regimes	How will climate change affect tidal inundation regimes through sea level rise and changes in hydrology? What number and locations of restored tidal connections will be sufficient to support appropriate inundation regimes?

Protect Refugia	Model, identify, and acquire (or set up easements for) areas in the upper estuary that will serve as refugia, i.e., locations where favorable conditions such as tidal inundation are anticipated as sea level rise continues	How will climate change shift the future locations of appropriate salt marsh habitats in the upper estuary based on sea level rise projections? Where do these locations correspond with areas that are available or can be acquired/set aside as refugia? What preparations (e.g., installation of larger culverts) can be made to ready these locations for unimpeded tidal inundation?

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Managing For Change

- Managing for change will become increasingly necessary as ecosystems experience regime shifts due to climate change
- To date we have mostly reacted to regime shifts after they have occurred or while they are occurring
- More recently researchers have been working on ways to affect trajectories toward more favorable future states as climate changes
- The same adaptation approaches are used, but under different management contexts and objectives

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Example: Alligator River NWR

Target: Multi-Ecosystem Mosaic	Adaptation approach	Example of specific management options	Key climate-smart questions
Bogs, fresh/ brackish marshes, hardwood/ white cedar swamps 	Reduce non-climate stressors	(Persistence) Mitigate runoff of sediments and pollutants from surrounding croplands by preventing further losses (and/or replacing) bottomland hardwood forests	How will climate change related shifts in precipitation patterns and hydrology affect overland runoff of sediments and pollutants? In what locations should priority management of forests be focused to minimize runoff?
	Protect key	(Persistence) Mimic natural hydrology by	How will sea level rise and changes in the intensity and
Protect and preserve wetland	Restore Structure	(Change) Restore structures for coastal soil stabilization by planting flood-tolerant	What cleared areas along the coastal edge are most impacted by erosion from sea level rise and storm surge? Which tree
- Erosion - Saltwater intrusion - Inundation - Increased sediment runoff	refugia	potential sites within the path of connected Refuges (see above) that provide future refugia for endangered species	changes in vegetation and predator-prey relationships shift endangered species habitat along the refuge corridor? What number, location and size of sites is needed for continued provision of habitat?
• Altered hydrology - Rising water table	Relocate Organisms	(Change) If corridors between refuges do not yet exist/are not possible, manually transport species with limited dispersal capabilities to destination habitats	See climate-smart questions for refugia. Relocate species to appropriate locations identified/ protected.

Protect key ecosystem features	(Persistence) Mimic natural hydrology by installing water control structures to reduce the impact of saltwater intrusion	How will sea level rise and changes in the intensity and frequency of large storms affect coastal hydrology? What are the implications for the number, placement and viability of water control structures to mimic natural hydrology?

Restore Structure and Function	(Change) Restore structures for coastal soil stabilization by planting flood-tolerant tree species on cleared land	What cleared areas along the coastal edge are most impacted by erosion from sea level rise and storm surge? Which tree species (e.g., black gum, bald cypress) would be most effective as well as least sensitive to climate change?

Moving from Options to Decisions

Paradigm 1: "Predict Then Act"

- "What's most likely to happen?"
- Use best-guess future; design best policy
- Maximize expected utility

Paradigm 2: "Robust Decision Making"

- "How does my system work?"
- "When might my policies fail?"
- Identify vulnerabilities across full range of futures; identify suite of actions that perform well across this range
- Minimize regret

Source: Adapted from Weaver, et al. 2013. Improving the contribution of climate model information to decision making: the value and demands of robust decision frameworks. *WIREs Clim Change,* 4:39-60.

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Moving from Options to Decisions (cont.)

- How do we harness climate science and model data to support effective decision making?
- Turn the problem around -- start with decisions, not climate data
- Collectively develop an understanding of the sensitivity of the system and the decision to climate variability and change

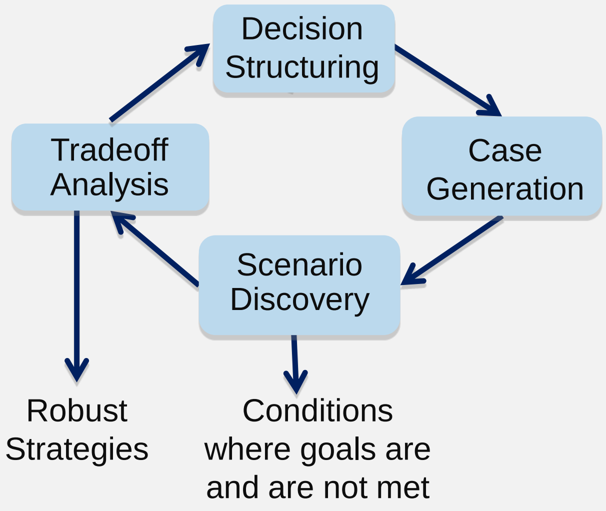
    This process provides insight into the uncertainties that actually matter to the problem

- Use insights to tailor selection of climate model information and other data; sample widely over only those uncertainties important to the problem, and only to the level of detail needed

RDM Example

- RDM Is a Quantitative Decision Framework Useful for Conditions of Deep Uncertainty

- Basic steps include:
  - Define key objectives, uncertainties, strategies, and relationships
  - Model each of many sets of assumptions to explore performance of strategies
  - Identify conditions under which goals are / are not met
  - Analyze tradeoffs among strategies and make potential modifications



Source: Lempert, et al. 2004. Characterizing climate-change uncertainties for decision-makers. *Clim Change*, 65:1-9.

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Structure the Problem

Uncertain Factors (X)	Policy Levers (L)
Land use • Population trends • Infill/development patterns ***Climate change effects*** ***Atmospheric deposition/air quality (?)*** ***Reservoir management (?)*** ***Performance standard uncertainty*** • BMP effectiveness (flashy storms) • Effectiveness at meeting performance standards • Time to meet performance standards • Performance standard cost uncertainty	***Maryland Department of Environment (MDE) Stormwater Performance Standards***; BMPs may include • Stormwater management-filtering practices • Stormwater management-infiltration practices • Urban stream restoration • Riparian forest buffers-urban
System Model Relationships (R)	**Performance Metrics (M)**
Phase 5.3 Chesapeake Bay Watershed Model ***Chesapeake Bay Water Quality and Sediment Transport Model*** ***Scenario Builder***	***Nitrogen loads*** ***Phosphorous loads*** ***Sediment loads*** ***Implementation costs***

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Next Steps and End Results

- Run simulations and explore data to understand which strategies are most robust across the greatest variety of climate scenarios
- Characterize future climate conditions under which most robust perform poorly
- Examine trade-offs with respect to key vulnerabilities and if necessary, revise strategies to address those vulnerabilities and run simulations again
- For situations in which analyses reveal that no strategies are robust, existing conservation goals may not be attainable and may need to be revised
- This process illuminates:
  - Combinations of uncertainties that are most influential in a decision
  - Risk preferences consistent with choosing one option over another
  - Signposts to monitor to determine whether current path of management decisions may not achieve desired goals