Managing DoD Natural Resources in Response to Climate Change: Portfolio Approach, Adaptive Management

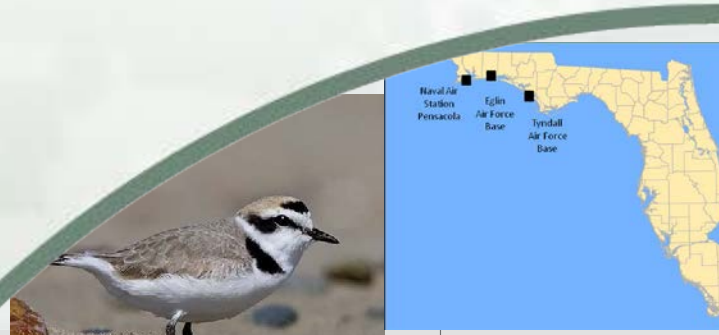
Igor Linkov, Rich Fischer & Christy Foran

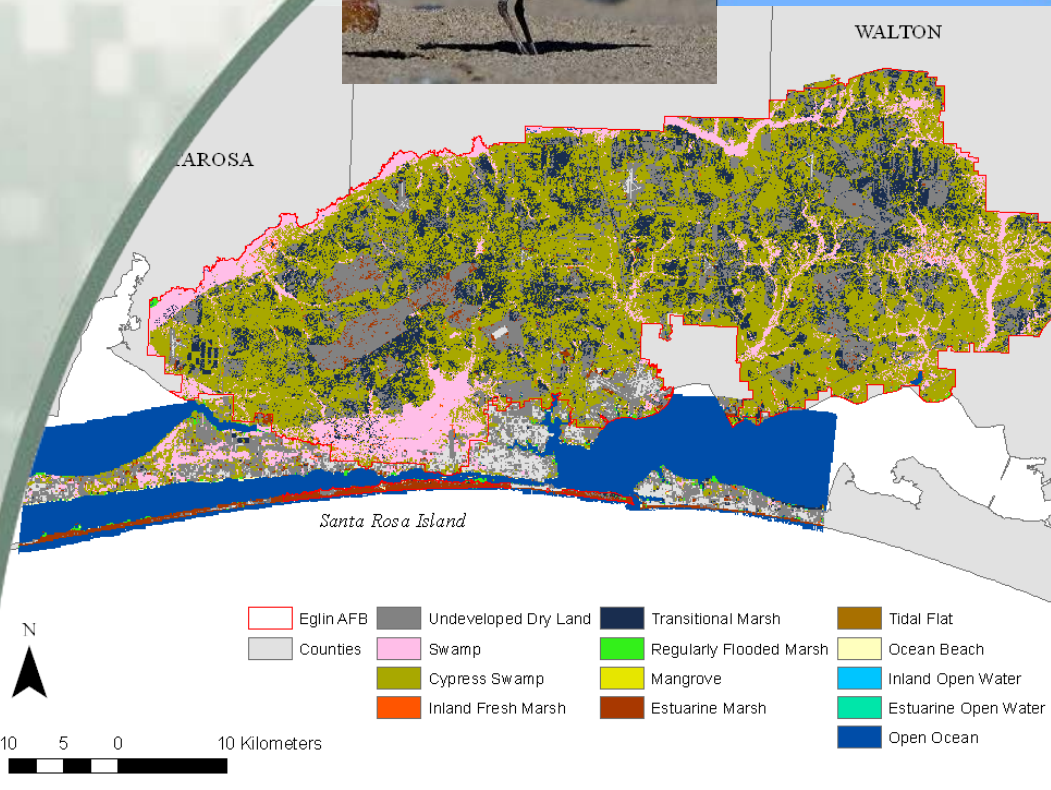
USACE ERDC-EL

Risk & Decision Science Team

igor.linkov@usace.army.mil

30 NOV 2016





U.S. ARMY

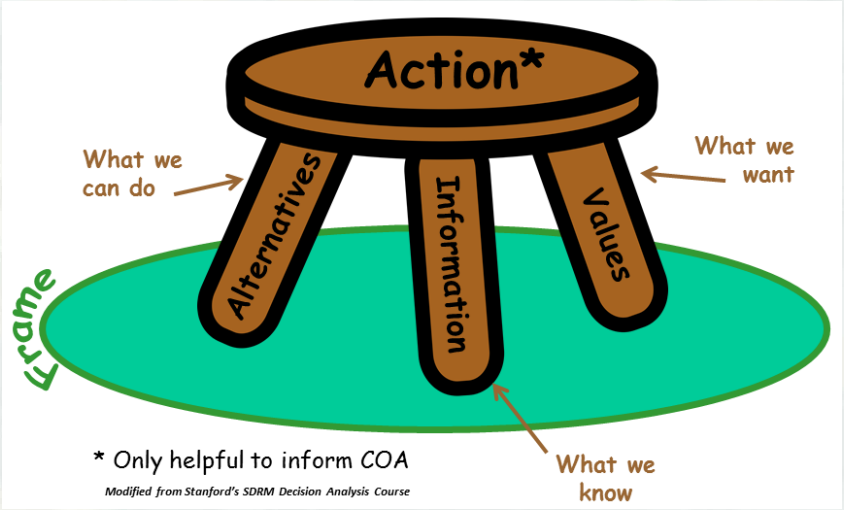
US Army Corps of Engineers

ERDC
Engineer Research and Development Center

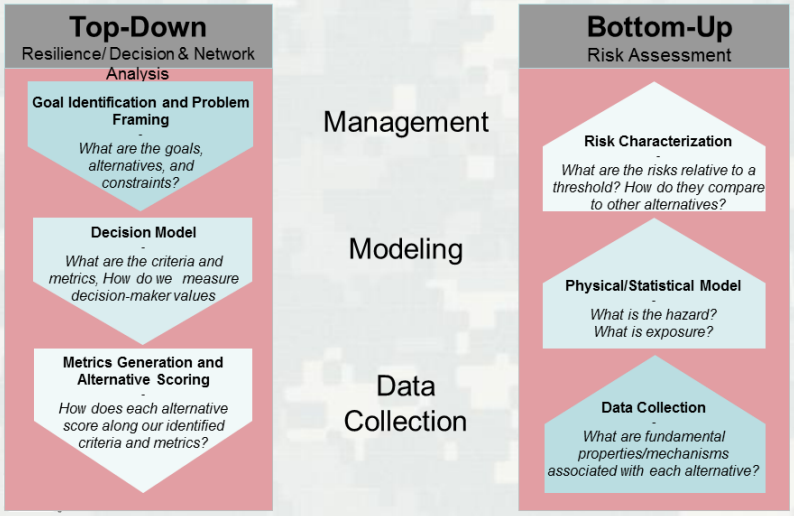
ERDC
Engineer Research and Development Center

Last update (15-NOV-16)

Decision Support Tools



Risk-Resilience Integration



BUILDING STRONG®

Linkov et al., 2014

Purpose:

Support decision making for complex problems through development and deployment of easy-to-use, transparent, and rigorous decision support aids. Provide improved understanding of decision factors to enhance management processes, conceptual design of alternatives, and resource allocation.

Products:

- Decision Support – Prioritization
- Robust Decision Making – Scenario analysis
- Decision analysis module in GRL's GEAR
- Sustainability assessment – energy use data
- Life Cycle Assessment/ LCCA

Payoff:

- More effective decision making
- Enhanced collaboration and communication
- Transparency decision making process to share
- Improved risk management
- Resilience in system design and management

Technically Speaking

Last update (27-OCT-16)

What Is It? (Description/Definition)

- Cognitive psychology and engineering design principles to understand the scope of problem and range of available alternatives
- Applied mathematics to formalize how alternatives achieve decision objectives
- Computational models to estimate in-situ efficacy of an alternative
- Subject-matter expertise across a broad range of domains:
  - Civil & environmental engineering
  - Toxicology & ecology
  - Risk assessment & communication
  - Scientific management & human factors

What Does It Offer?

- Promotes collaboration & introspection among decision owners and stakeholders to clarify objectives
- Enables alternative selection based on common goals
- Supports rapid prototyping of conceptual alternatives

Technical Approach:

- Cognitive Science
  - ▶ Decision conferencing
  - ▶ Task analysis
- Operations Research
  - ▶ Decision trees
  - ▶ Portfolio analysis
  - ▶ Value of information
- Modeling & Simulation
  - ▶ Network science
  - ▶ Monte Carlo
  - ▶ Agent-based models

Outline

- SERDP Project
- Water Management
- New SERDP Proposal

SERDP Project

- Integrated Climate Change and Threatened Bird Population Modeling to Mitigate Operations Risks on Florida Military Installations

Drs. Igor Linkov, Christy Foran
US Army ERDC
Risk Assessment and Multi-Criteria Decision Analysis

Dr. Richard Fischer
US Army ERDC
Avian field ecology, threatened and endangered species

Drs. Gregory Kiker and Matteo Convertino
University of Florida, habitat modeling, decision analysis

Dr. Christopher Martinez
University of Florida, climate change and sea level rise modeling

Drs. Rafael Muñoz-Carpena and Maria Librada-Chu Agor
University of Florida, uncertainty analysis for complex systems

Drs. Resit Akcakaya, Matthew Aiello-Lammens, Lev Ginsberg and Nick Friedenberg
SUNY:Stoneybrook and Applied Biomathematics,
population dynamic, metapopulation modeling

Technical Objective

Goal - integrate multi-scale climate, land use and ecosystem information into a systematic tool set to:

(1) assess current vulnerability scenarios and information on selected Florida installations by documenting and reviewing Florida-specific climate, land use databases and information;

(2) develop a set of habitat- and species-based models for selected coastal TER-S,

(3) assess the current prediction level and assumptions of selected categories of TER-S models for use in benchmarking model performance and uncertainty levels,

(4) integrate scientific data, modeling and uncertainty results into a risk-informed, multi-criteria decision analysis system to allow systematic analysis of management options.

Technical Approach

- Research Overview
- Research Approach
  - Ecological, Physical and Climate Database Development
  - Habitat Modeling with SLAMM
  - Habitat Suitability Modeling / Species Distribution Modeling
  - Global Sensitivity and Uncertainty Analysis
  - Multi-Criteria Decision Analysis

Overview: Integration of Data, Models, Uncertainty and Decision Analysis

Varied Information& Data

Climatic Information:
Sea-level
Hurricane frequency
Heavy rain frequency

Development Information:
Pop/Development Increases
Base Encroachment
Changing expectations

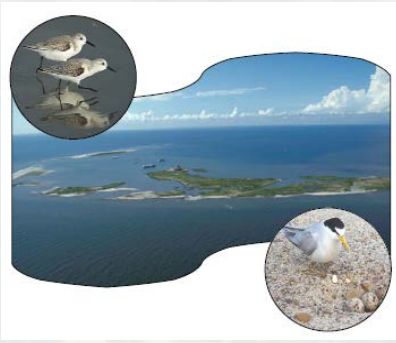
Base Management:
Training Schedules
TER-S policies
Expanding/Adapting training reqs

Landscape Information:
Human land-use
Land-cover
Hydrology
Elevation

Data Uncertainty and Scale Dependence

TER-S Model Tools at both Habitat and Population Scales

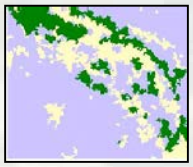
Habitat specific data:
requirements for breeding, wintering, and stopover habitat



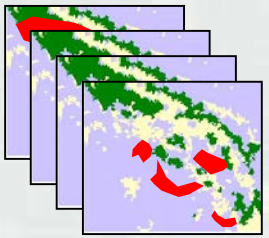
TER-S specific data:
survival, fecundity, variability, dispersal

Modeled Uncertainty

Scientific/Model Results



Static (current) habitat suitability map



Possible Future habitat and population map(s)

?

Management-Useful Results

Comparing Management Alternatives with respect to Performance Metrics:
Habitat/Species Resilience?
Training schedules
Cost?

Focal Species - Snowy Plover (SNPL)

Charadrius nivosus– A beach-nesting and wintering species found year-round in FL

- **Status**

  State Threatened Species - FL Fish and Wildlife Conservation Commission

  "Extremely High Priority for Conservation" - US Shorebird Conservation Plan

  Potential Federal Candidate Species for Listing - USFWS

- **Importance of DoD Lands**

  Eglin AFB and Tyndall AFB, along with State Park and NPS shorelines accounted for 80% of all estimated nesting Snowy Plover pairs in the Florida Panhandle during recent statewide surveys.

- **Justification for Selection**
  - **Species is easily surveyed; population data and estimates of population parameters are available.**
  - **SNPL is a good sentinel for detecting climate change effects on coastal habitats. Habitat changes are relatively easily detected and birds respond rapidly to these alterations.**

Additional Focal Species

Piping Plover (PIPL) (*Charadrius melodus)*

- The Piping Plover is federally listed as 3 separate sub-populations
- Birds from all populations winter in high numbers on Florida's barrier islands during the non-breeding season
- DoD has high stewardship responsibility for this species

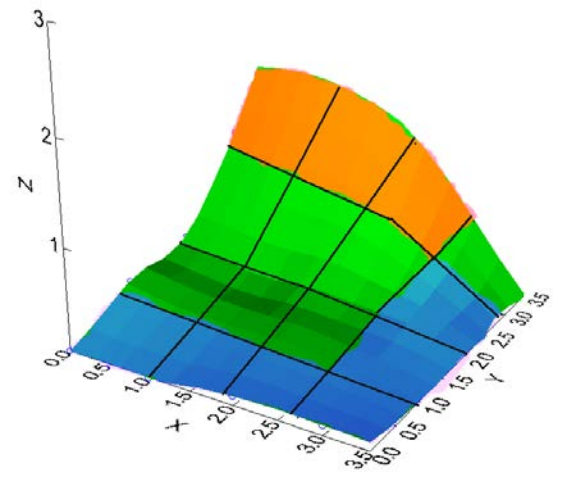
Red Knot (REKN) (*Calidris canutus)*

- Red Knots have declined dramatically during the past decade
- *rufa* Red Knot may be Federally listed in the near future (and subsequently was in 2014)
- Red Knots "stop over" in Florida during spring and fall migration at various locations along the Atlantic and Gulf Coasts

SLAMM Modified for Nourishment

Scenarios:

- Effects of beach re-nourishment with SLR
- Effects of major historic storms at different times with SLR
- Effects of beach re-nourishment and major storms with SLR



Conclusions:

Without re-nourishment:

- *loss in area after storm approximately 97 to 100 %*

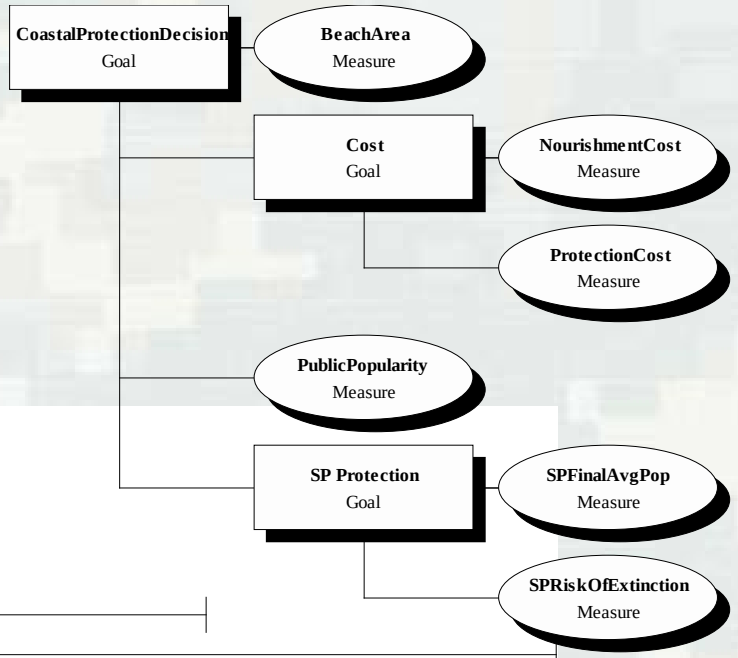
With re-nourishment

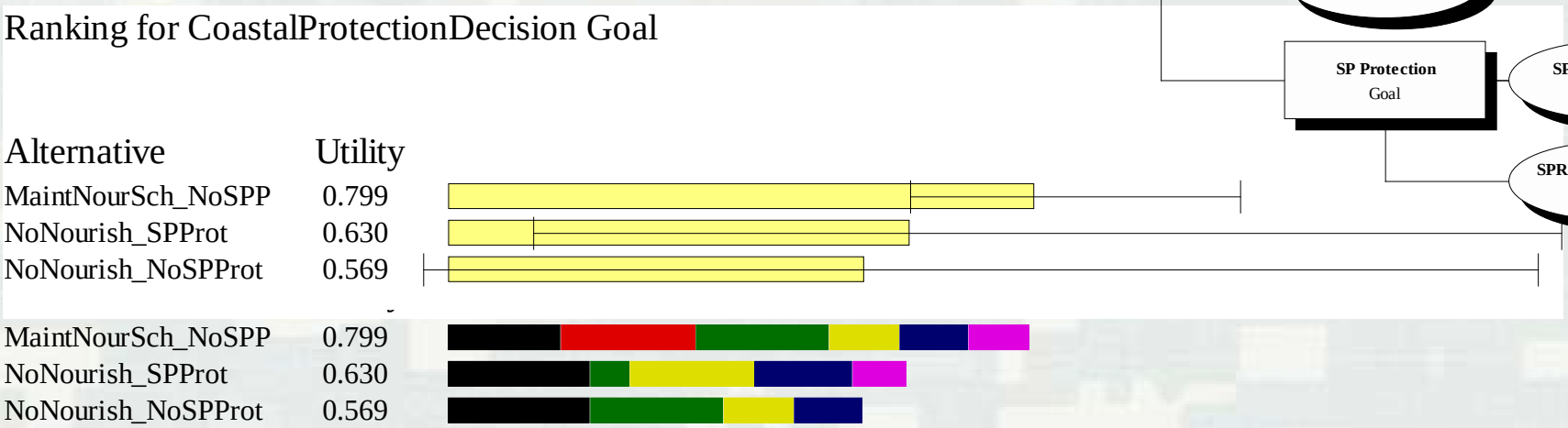
- *Loss in area after 1st storm around 60% storm*
- *Length of time the remaining 40% stays depends on storm category*
- *Effects of 2nd storm vary depending on the 1st storm*

Linkage of Integrated Modeling Results with MCDA

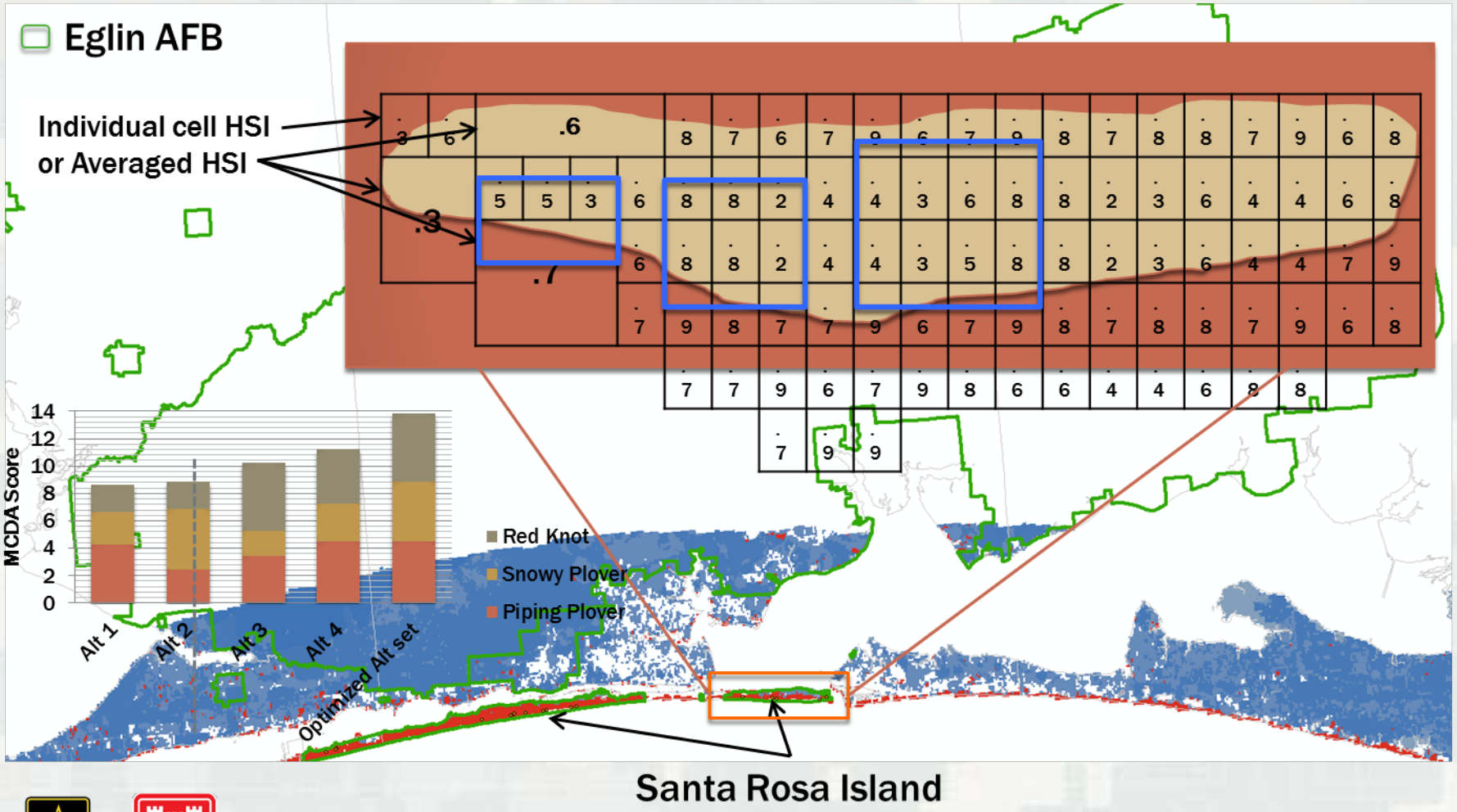
MCDA framework with example ranking

- Objectives under development with Elgin AFB
- Rankings with uncertainty + Future SLR
- Criteria contribution to decision

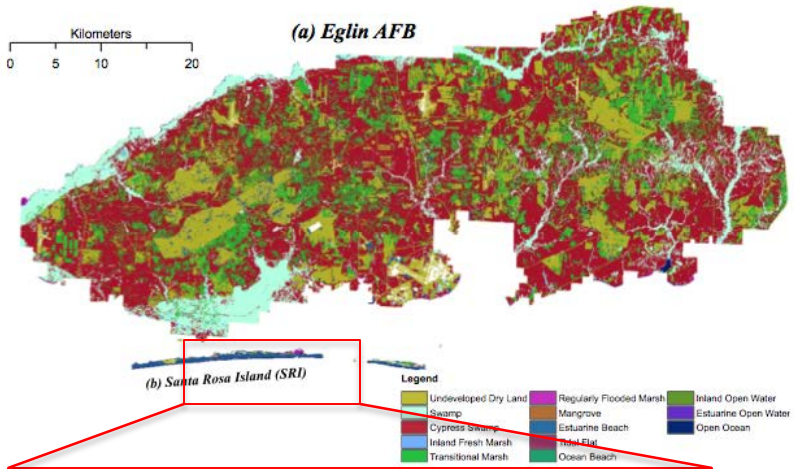




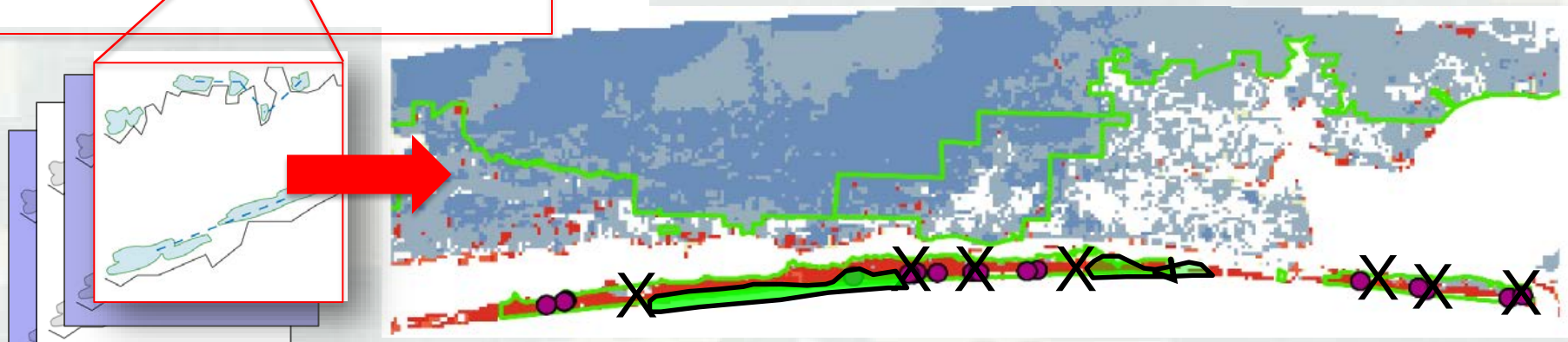
Management Problem



Tools for Integrating Training and Natural Resources



Training Operations and Planning Scales



Spatial areas available for training in Jan, 2030

Climate Models (Temperature + Precipitation, Probability of Extreme Events)
Habitat/Infrastructure Models (SLAMM / SLOSH)
Species Distribution Models
Training Footprints/Mission Objectives

Higher confidence
Lower confidence
Unavailable
X

Water Management – USACE District

- Everglades Challenges

Large Area:

many different interdependent areas to manage

Conflicting objectives:

water supply, flood control, restoration objectives, endangered species objectives, water quality

Complex and Huge Volume of Data:

modeling and monitoring – can be overwhelming

Uncertain future:

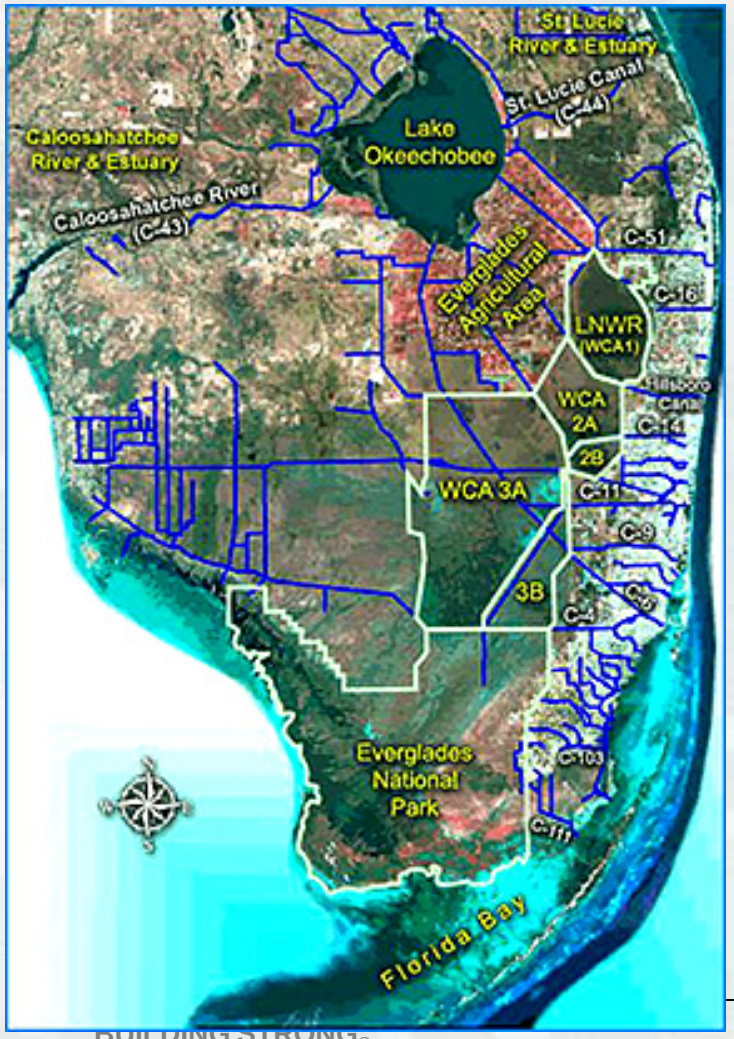
Restoration response and in terms of budget, policy, climate

Adaptive Management: History, Perspective

- **Current and previous effort:**
  - 2000-2005 – Development of an AM plan
  - 2005-2010 – Pilot projects and individual project planning
  - 2010-2012 – Technical guidance and efforts to link science to management decisions (restoration implementation)

- **Concerns:**
  - This decision tool will not integrate current data/efforts
  - The results inform decisions, but will not make them
  - Need a tool that asks: “what is the best action if” we change
    - Restoration priorities
    - Climate or budgetary conditions
    - Monitoring and modeling results

Management Alternatives



Alt 0 – no change
Alt 1 – minor canal fill, minor levee degradation
Alt 2 – major canal fill, minor levee degradation
Alt 3 – major levee degradation, minor canal fill
Alt 4 – major levee degradation, major canal fill

http://rst.gsfc.nasa.gov/Sect3/

Decision Context

Evaluating and Selecting a Robust Plan –

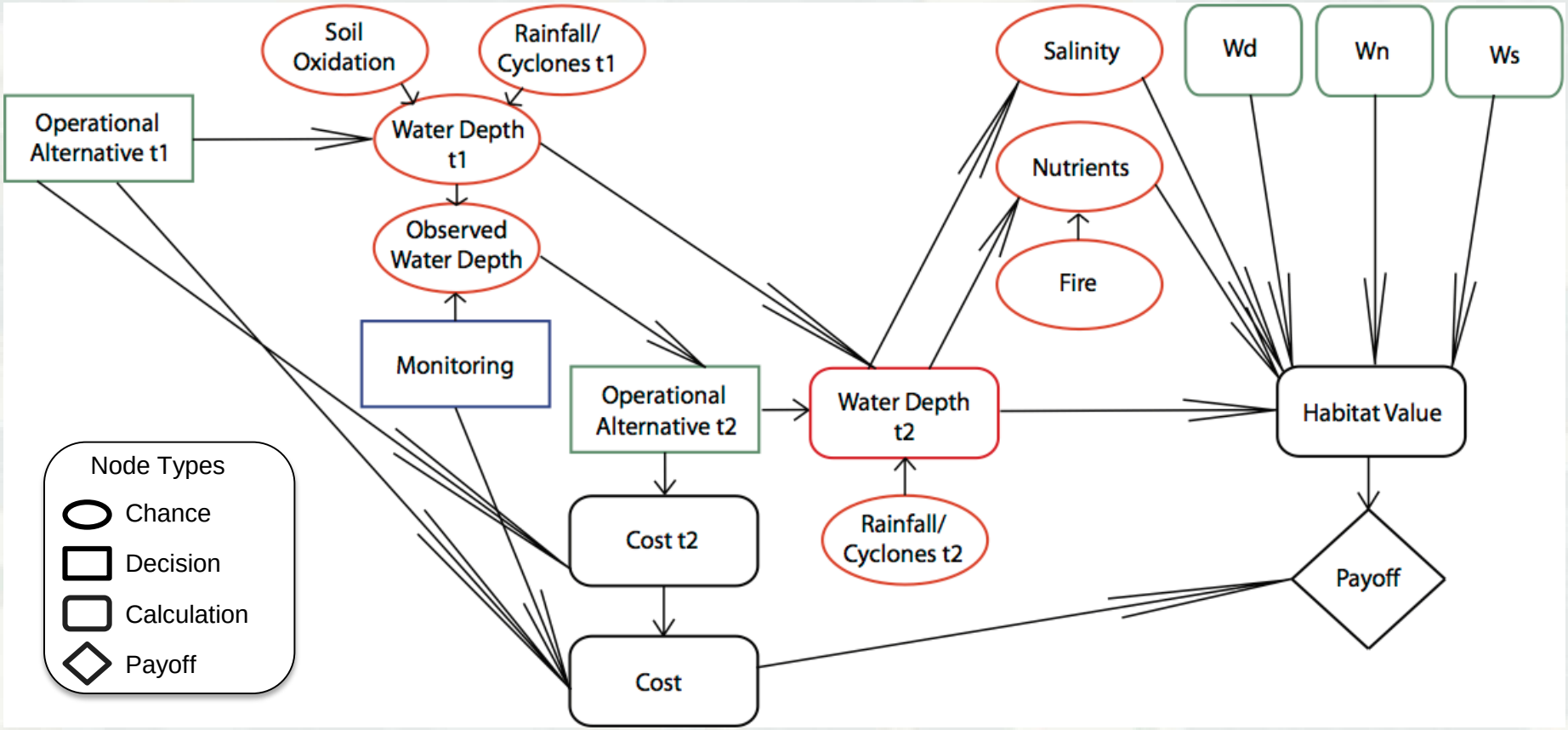
a. Climate – Perform well under different rainfall scenarios
b. Ecosystem Uncertainty – Perform well even if have to switch project implementation, i.e., different options of canal backfill and levee removal in Period 1 (current implementation period) with AM plan to switch to different option in Period 2 (period after observing results from implementing first decision in Period 1)
c. Value of Monitoring – Different monitoring plan intensities/costs: High, med, low

$$P(t) = HV(t) - C(t)$$

Hydro-ecological value Socio-economical value

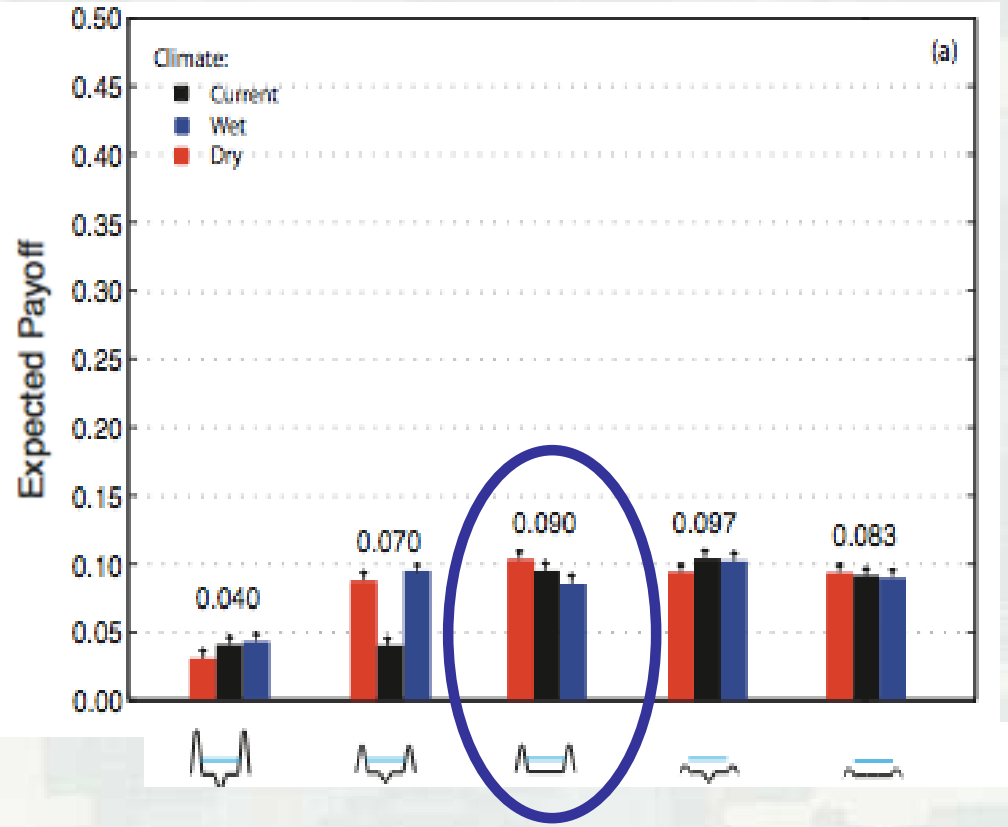
Conceptual Approach

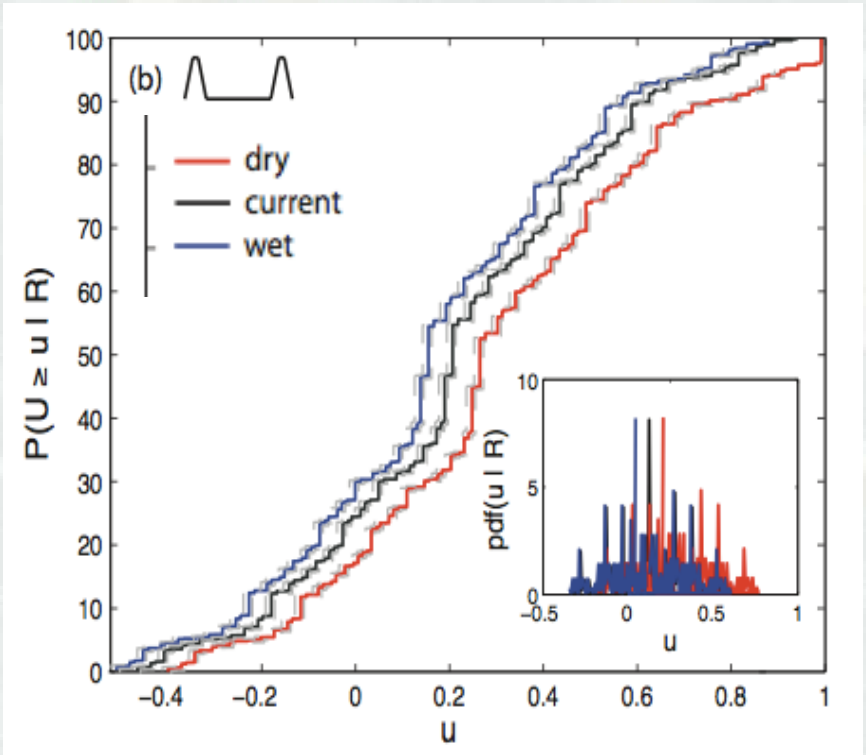
Approach developed, written up, and submitted for peer-review.



Estimates of Payoff and Robustness

Varying: Climate



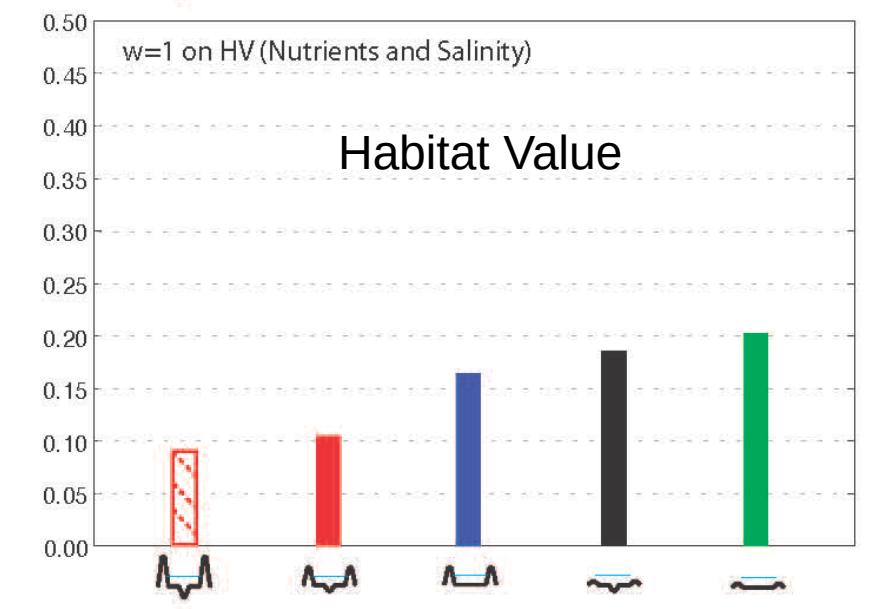


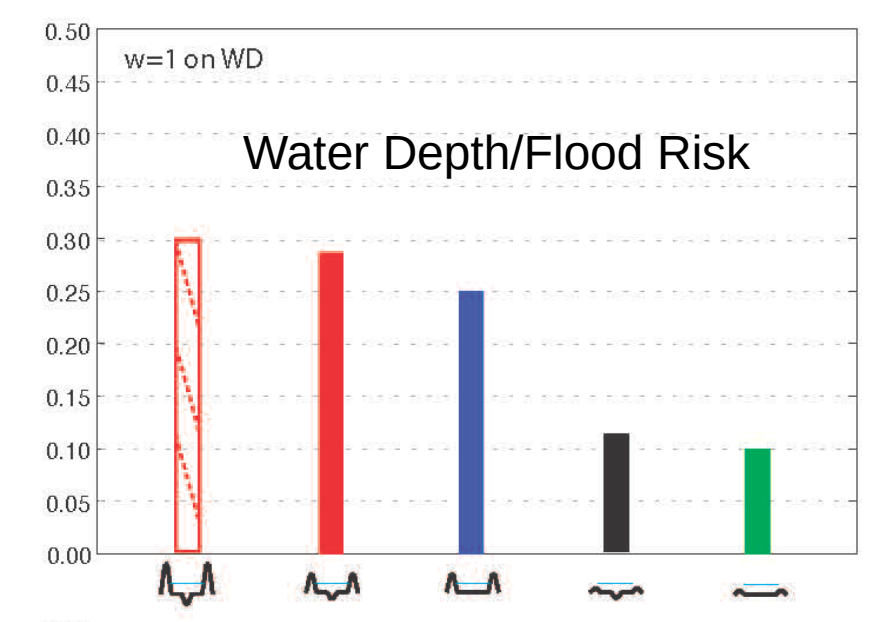
Objective Weights

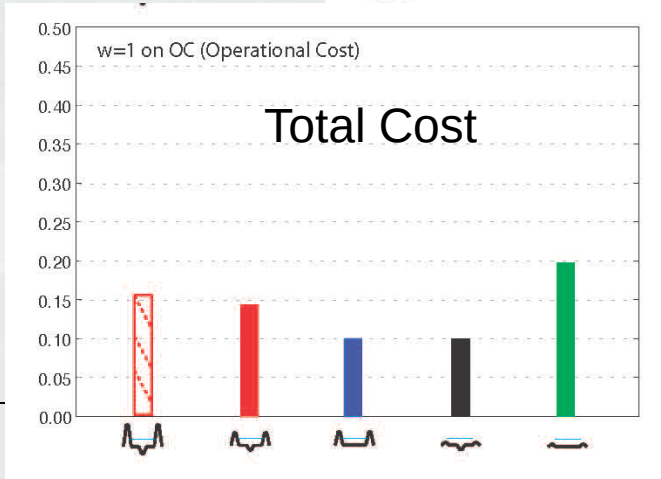
When you have conflicting objectives, what is the "best" action when one is favored over the other?

Contribution of Objectives to Payoff

Utility for different Management Alternatives if you value only:







Added benefit: Value of Information

- How much is more information on a plan's performance worth?
- Compute this: the amount that a payoff increases as a result of improved quality in the monitoring plan
  - ► Payoff with perfect information occurs when there is no uncertainty associated with monitoring

EAM Synthesis

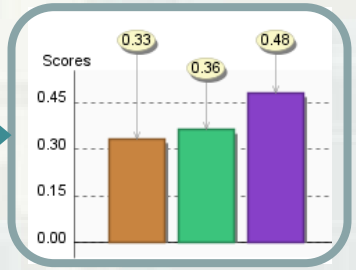
- Decision analysis component directly connects payoffs with objectives
  - ► Everglades: alleviates issues with current AM plan
- Allows for learning of the system based on monitoring and stakeholder inputs
  - ► South River: incremental changes downstream
- Incorporates uncertainty into ranking of alternatives
- Considers costs of readjusting plan

Climate Change Vulnerability Assessment of Major Habitats on/and around DoD Lands

- **Objectives:**
  - Assess habitat vulnerability to climate change and identify the factors that drive vulnerability.
  - Develop an improved understanding of the spatial variability in drivers of vulnerability across a species' range.
  - Develop an improved understanding of the relationship between changing climate and key ecological processes such as fire regime, hydrological regime or food webs.
  - Develop methodologies, tools or guidance that translates research on these issues into practical information that will improve adaptive management of these sensitive habitats to meet conservation objectives.

Scenario Analysis – Stability of Performance

Responses:
Risk of habitat loss
Invasive species risk
Relative resilience
Mission support



Emergent Conditions

Identification of adaptive and future conditions that alone, and in combination, change the performance of management actions as evaluated by the decision model.

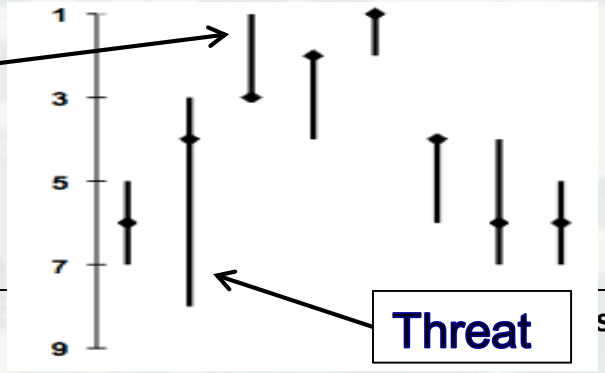
Results of Ft. Belvoir Asset Prioritization with Emergent and Future Conditions

Scenarios w/ Potential Influential Conditions

	Ft. Belvoir Phase I	Ft. Belvoir Expanded Phase I	Ft. Belvoir Phase II	Ft. Belvoir Phase III	Ft. Belvoir Phase III ESPC Route	Ft. Belvoir Phase I + PV	Ft. Belvoir Phase I + Fuel Cells	Ft. Belvoir Phase I + Other Options
Baseline	6th	4th	3rd	2nd	1st	4th	6th	6th
CC1. Cyber and Emission	6th	8th	3rd	2nd	1st	4th	5th	6th
CC2. Increase in Winter Storms	7th	5th	3rd	2nd	1st	6th	4th	7th
CC3. Time-of-Day Pricing	5th	8th	3rd	2nd	1st	4th	7th	5th
CC4. Change of Area 300 Tenants	6th	3rd	1st	4th	2nd	5th	6th	6th
CC5. --	6th	4th	3rd	2nd	1st	4th	6th	6th
Median Ranking	6th	4th	3rd	2nd	1st	4th	6th	6th

Ranks of Alternative Plans

Opportunity



Climate Change Vulnerability Assessment of Major Habitats on/and around DoD Lands

- **Approaches:**
  - Assess habitat vulnerability to climate change and identify the factors that drive vulnerability – **scenario characterization**.
  - Develop an improved understanding of the spatial variability in drivers of vulnerability across a species' range – **decision model (ID) grid**.
  - Develop an improved understanding of the relationship between changing climate and key ecological processes such as fire regime, hydrological regime or food webs - **scenario responses across the grid**.
  - Develop methodologies, tools or guidance that translates research on these issues into practical information that will improve adaptive management of these sensitive habitats to meet conservation objectives – **simulation of management action effects across scenario responses** .

Questions?

- ***Cases are a selection of RaDS team work.***
- ***If you have specific interests or would like to discuss something further, please contact us.***