Challenges in Framing the Problem: Just what are we trying to optimize anyway?

Michael C. Runge
USGS Patuxent Wildlife Research Center
Laurel, MD

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USGS Patuxent (and others…)

- Mission: Bring quantitative tools to bear on real management problems
  - Decision analysis
  - Estimation, modeling
  - Monitoring design
  - Optimization
- Intense focus on
  - Understanding the real decision context
  - Helping frame the decision problem
  - Developing quantitative tools that are appropriate to the specific decision context

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PrOACT*

- Defining the Problem
- Objectives
- Actions
- Consequences (models)
- Trade-offs and optimization
- …in recurrent decisions, also Monitoring and Feedback

*Hammond et al. 1999. Smart Choices: a practical guide to making better life decisions. Broadway Books, NY. 242 pp.

Two Framing Challenges

- Identify an appropriate abstraction of the real world
  - What aspects of the real problem are critical to include in the analysis?
  - How might this be biased by our viewpoint?
- Identify an abstraction of the real world *that we can solve*
  - Our abstraction is also guided by the methods we anticipate using
  - Does this sometimes lead us astray?

Natural Resource Management

- In reality, almost all of our natural resource management problems are
  - multiple-objective,
  - spatially-explicit,
  - recurrent (hence dynamic and potentially adaptive) decisions,
  - made under considerable uncertainty (both aleatory and epistemic),
  - with partial observability of the system
- We never treat them as such
  - How much of this complexity can we ignore in framing the problem?

This talk

- Focus on the OAC in PrOACT
  - Objectives
  - Alternative actions
  - Consequences (models)
- I'll leave the rest to others
  - Tradeoffs/Optimization: Conroy
  - Monitoring: Nichols
- We often find the framing solves much of the problem…

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Case Studies

White-nose Syndrome in Bats

Goose Harvest Management

Little Brown Bats, New York. Photo credit: Nancy Heaslip, NYSDEC

White-nose Syndrome

- Emergent disease in cave-dwelling bats
  - First reported in 4 sites in NY in 2006-7
  - Spread to 38 sites by May 2008, 65 sites by April 2009
- Cumulative mortality rates have exceeded 90% in affected caves
- Mechanisms:
  - Causal agent suspected, new species of fungus in the genus *Geomyces*
  - Mechanisms of spread not known with certainty
  - Mechanisms of mortality may be increased energetic demands during hibernation, leading to starvation

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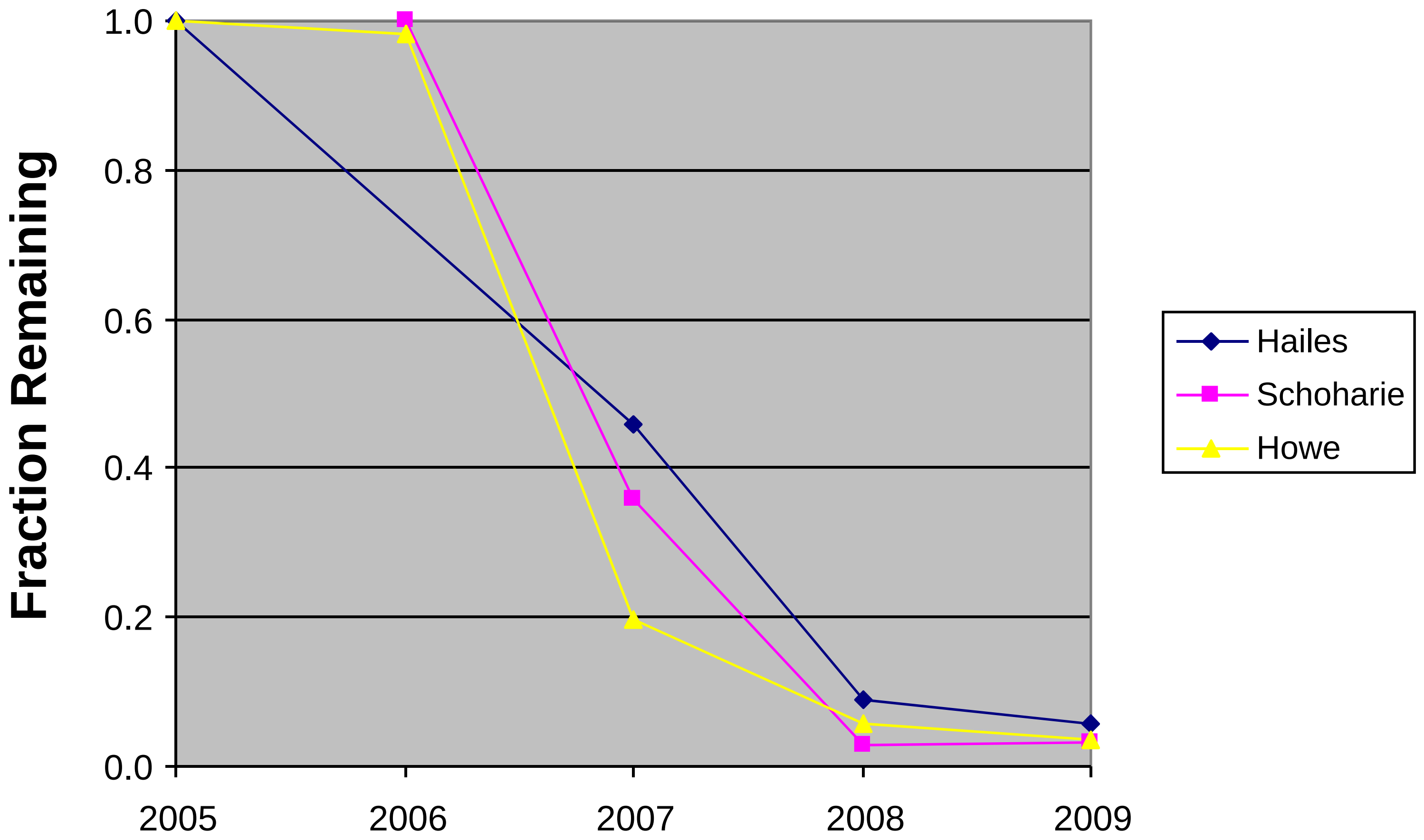
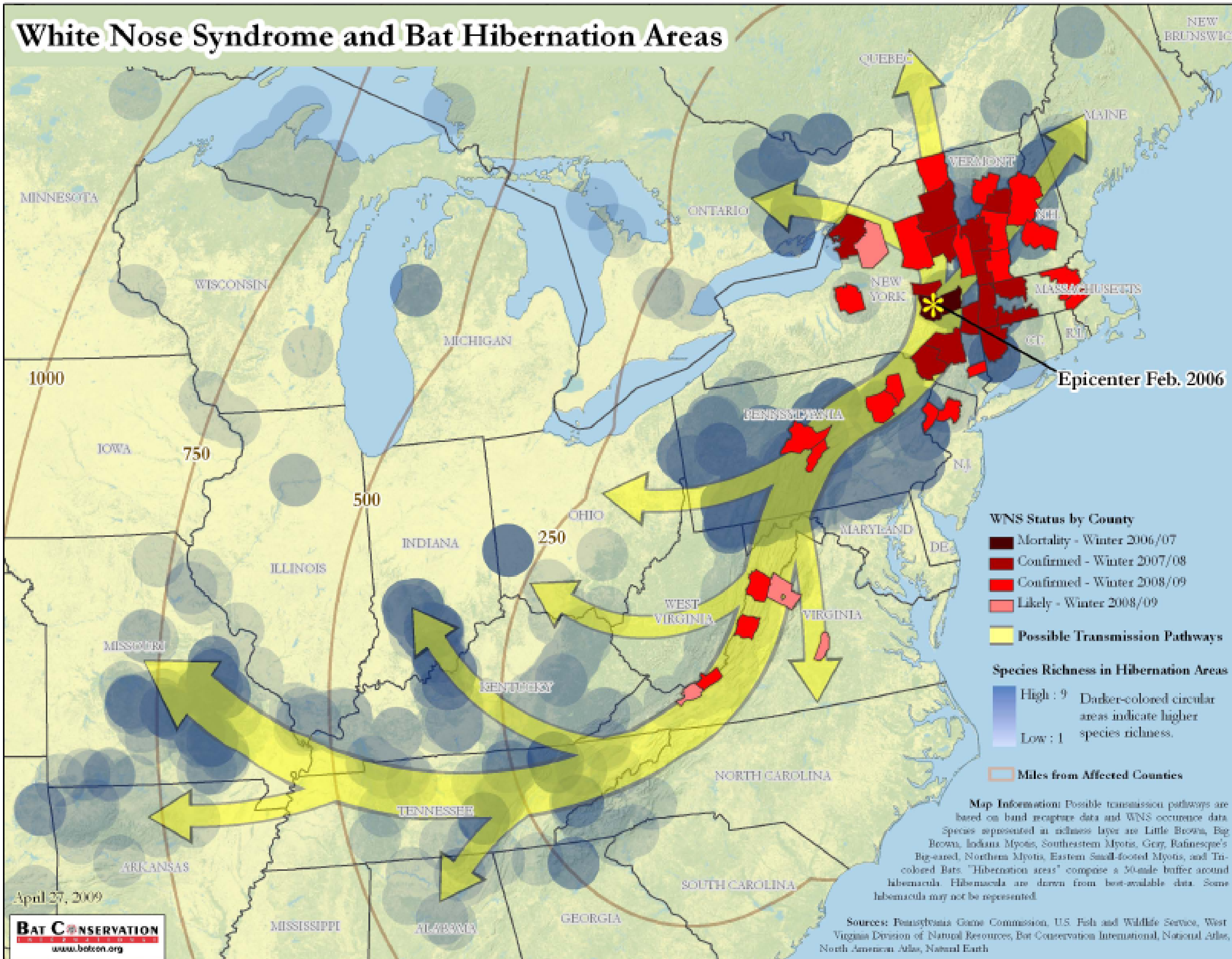
Mortality in Affected Caves



Source: Al Hicks, NYSDEC


White Nose Syndrome and Bat Hibernation Areas
QUEBEC
NEW BRUNSWICK
MAINE
VERMONT
NH
ONTARIO
MINNESOTA
WISCONSIN
MICHIGAN
NEW YORK
MASSACHUSETTS
CT
RI
Epicenter Feb. 2006
1000
750
500
250
IOWA
PENNSYLVANIA
N.J.
OHIO
INDIANA
ILLINOIS
MARYLAND
DE
WEST VIRGINIA
VIRGINIA
MISSOURI
KENTUCKY
NORTH CAROLINA
TENNESSEE
ARKANSAS
SOUTH CAROLINA
MISSISSIPPI
ALABAMA
GEORGIA
April 27, 2009
BAT CONSERVATION INTERNATIONAL
www.batcon.org
WNS Status by County
Mortality - Winter 2006/07
Confirmed - Winter 2007/08
Confirmed - Winter 2008/09
Likely - Winter 2008/09
Possible Transmission Pathways
Species Richness in Hibernation Areas
High : 9
Low : 1
Darker-colored circular areas indicate higher species richness.
Miles from Affected Counties
Map Information: Possible transmission pathways are based on band recapture data and WNS occurrence data. Species represented in richness layer are Little Brown, Big Brown, Indiana Myotis, Southeastern Myotis, Gray, Rafinesque's Big-eared, Northern Myotis, Eastern Small-footed Myotis, and Tri-colored Bats. "Hibernation areas" comprise a 50-mile buffer around hibernacula. Hibernacula are drawn from best-available data. Some hibernacula may not be represented.
Sources: Pennsylvania Game Commission, U.S. Fish and Wildlife Service, West Virginia Division of Natural Resources, Bat Conservation International, National Atlas, North American Atlas, Natural Earth

WNS Decision Problem

- USFWS and State wildlife management agencies feel some urgency to take action
- What actions should be taken at which sites under what conditions, now and in the future?
  - Can they wait until more is known, or are there some actions that are better taken sooner?
- Characteristics
  - Multiple-objectives
  - Dynamic
  - Substantial uncertainty
  - Spatially-explicit

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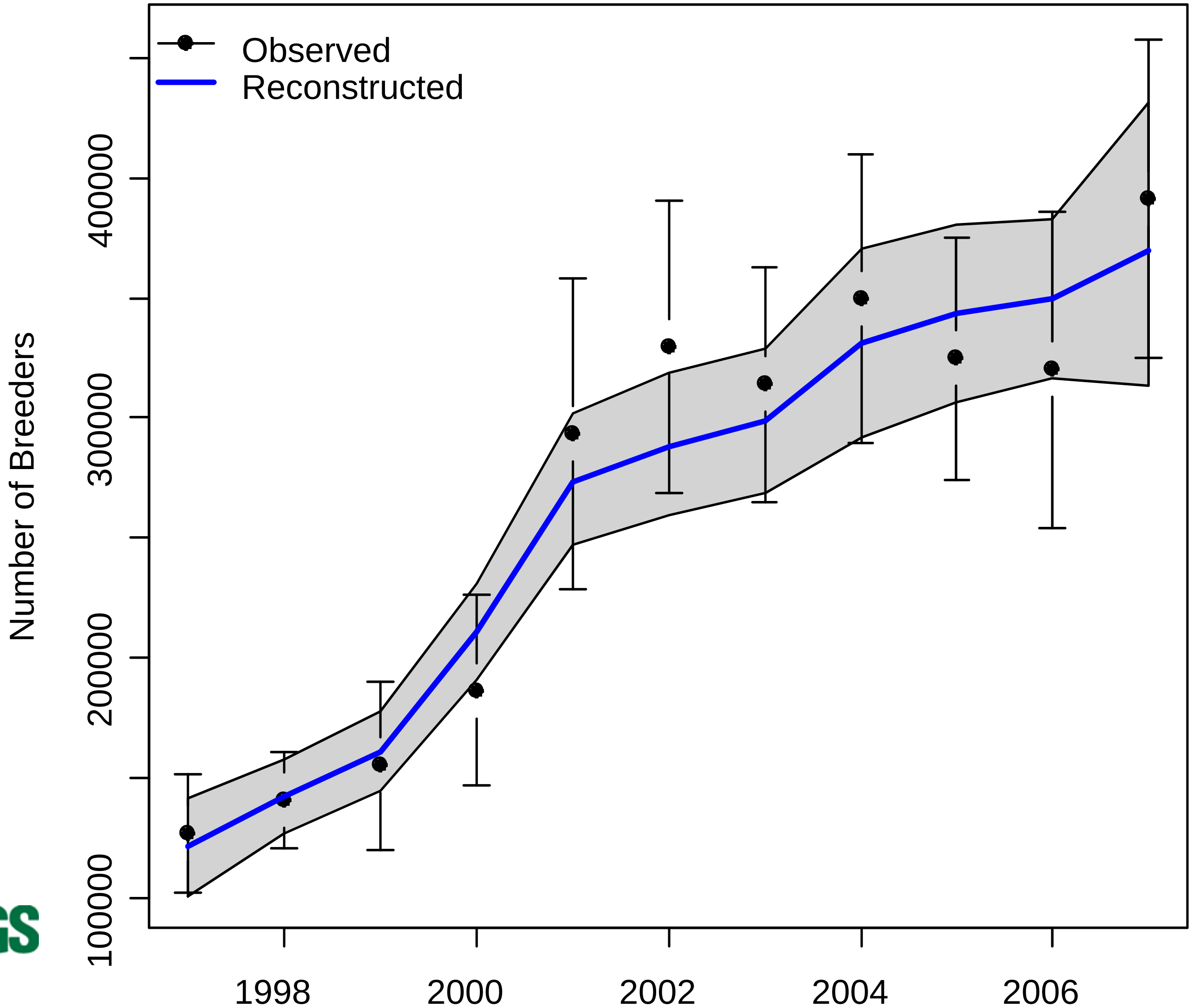
Atlantic Population Canada Geese

- Migratory population of CG, breeds on the Ungava Peninsula
- Large sport-hunting interest and industry
  - Especially in the Chesapeake Bay
- Large declines in 1980s, early 1990s
- Sport hunting closed 1995-1999
- Population recovered
- How to manage hunting seasons now?

APCG Breeding Survey



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APCG Decision Problem

- How to set hunting regulations on an annual basis
  - To allow harvest opportunity
  - To avoid a significant decline like in the past
- Characteristics
  - Age-structured population dynamics (temporal lags in the system response)
  - Incomplete observation of system
  - Uncertainty about regulatory mechanisms, interaction with other species (resident geese)
  - Multiple objectives?

Objectives

Single-species objectives

Multiple objective problems

Single-species Objectives

- For recurrent decisions, the objectives may need to reflect the accrual of returns over time
  - This can be explicit, e.g., $\max \sum_{t=0}^{\infty} H_t$
  - Or implicit, e.g., $\min p(E_{100})$
- The first one captures the bulk of our experience
  - Note, the infinite time horizon captures the desire for sustainability

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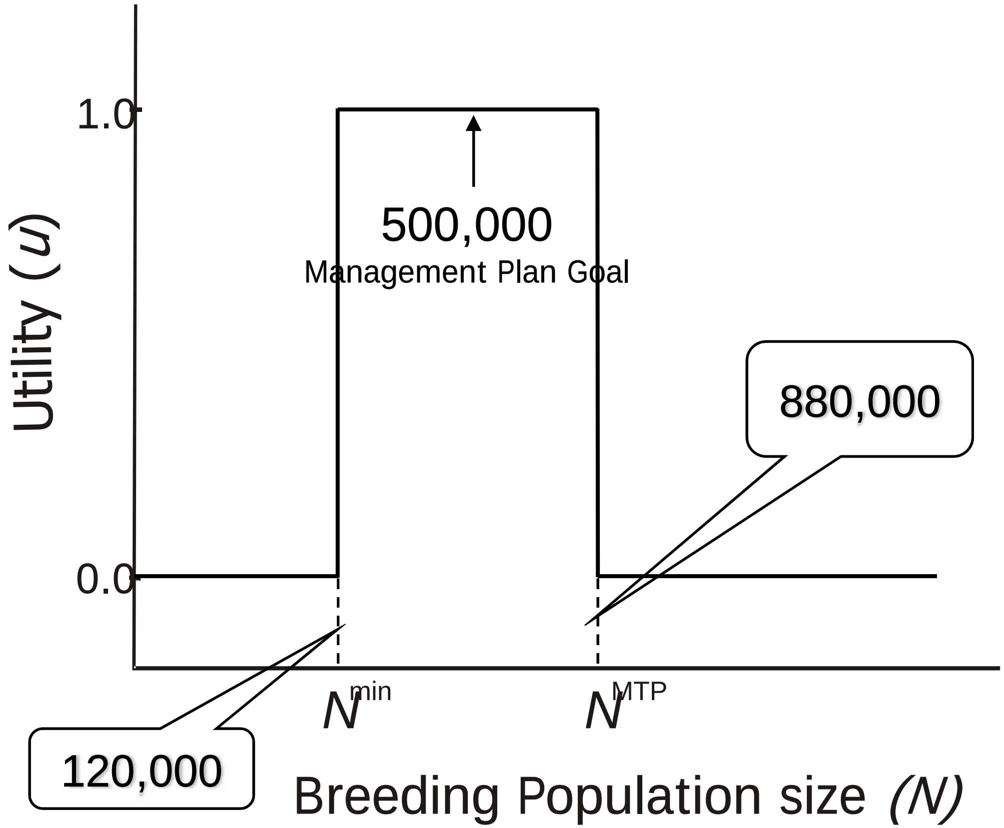
APCG Objective

Maximize harvest

$$\max_{\{h_t | N_t, z_t\}} \sum_{t=0}^{\infty} u\left(N_t\right) H_t$$



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Mean-variance Tradeoffs

- Sometimes we care about temporal aspects of the states and returns
- min Var(N_t)
  - Variance around a target
  - Variance around the mean
- More generally, how to we balance a desire to:

$$\min \sum_{t=0}^{\infty} \left(N_t - N_0\right)^2$$

$$\min \sum_{t=0}^{\infty} \left(N_t - \overline{N}\right)^2$$

$$\max \sum R_t \text{ and } \min Var\left(N_t\right)$$

$$\max \sum R_t \text{ and } \min Var\left(R_t\right)$$

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Multiple-objective Problems

- Most natural resource management problems are, at their heart, multiple-objective trade-off problems
  - The objectives are often very different in nature, and are not readily combined into a single objective function
- Challenges
  - We need to know what these objectives are (human dimensions work is critical here)
  - We need to know how to manage the trade-offs (multi-criteria decision analysis, MCDA, is critical here)

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WNS Objectives

- Maintain persistence of all bat species across their historical range
  - Means: reduce spread, reduce mortality, increase development of resistance
- Avoid unacceptable impacts to non-bat species (e.g., endemic cave fauna)
  - Due to loss of bats (ecosystem function)
  - Due to treatment effects
- Avoid unacceptable human health risks
  - Due to treatment effects
  - Due to secondary disease impacts
- Maintain credibility of wildlife agencies
- Minimize regulatory impact on human activities?

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Dynamic MCDA?

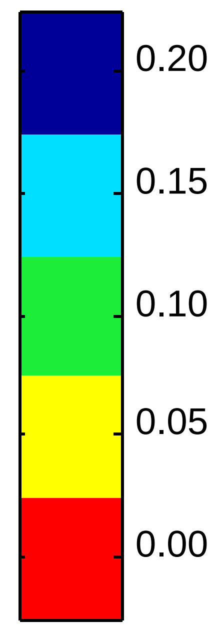
- Has anyone done dynamic optimization with embedded multiple-objective trade-offs?
- Several approaches possible:
  - Know weighting in advance, create a weighted return, and accumulate that
  - Create a proxy single-objective function for optimization, compare performance on multiple objectives, do trade-offs after optimization
  - Integrated dynamic optimization and multiple-objective trade-offs? (*Is this even possible to conceive?)*

Alternative Actions

APCG Alternatives

- Consider 5 discrete possibilities
- Intended adult male harvest rate
  - Measured by reward bands
- 0-20% in steps of 5%
- Harvest rates of other classes in proportion to this

AM harvest rate



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Portfolios

- One type of discrete set involves combinations of like elements arranged in portfolios
- Example
  - Spatial allocation problems, like reserve design. The set of alternatives is all possible combinations of individual spatial units
  - Can specify this set, in theory, but computational burden is huge
  - See McDonald-Madden, later today.

Strategy Tables

- Another type of discrete set involves combinations of unlike elements arranged in strategies
- Example
  - For responding to white-nose syndrome
  - There are a number of things you can do, including cave closures, cave treatment, development of alternative habitats, in-situ or ex-situ bat treatment, and food supplementation
  - What combined strategies might you consider?

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WNS MANAGEMENT: STRATEGY TABLE									
Bat-related Cave/Mine Closures	Decontamination Procedures in Place for Access?	Human-related Cave/Mine Closures	Human-related Closure Duration	Cave/Mine Treatment	Alternative Habitats	In-situ Bat Treatment	Ex-situ Bat Treatment	Duration of ex-situ treatment	Provide Food in Cave/Mine
restrict bat access to cave/mine	yes	close for all uses	year-round	fungicides	Create new roosting space in new place	fungicides (e.g., chemical, vinegar wash)	capture all bats & treat w/ fungicides	indefinite	yes
seasonally restrict bat access to cave/mine	no	recreational access only	winter only	biocontrol agents	Create new roosting space within the cave/mine	biocontrol agents	capture all bats & treat w/ biocontrol agents	multiple seasons	no
do not restrict bat access to cave/mine		research access only	summer only	infrared treatments	No alternative habitat	inoculation/vaccination	capture all bats & treat w/ inoculation	one season	
		commercial access only	No closure	modifications of cave/mine environment (thermal, humidity, airflow), can be at cave or microsite scale		restrict movement of affected bats	capture all & do not treat	short (one-week)	
		recreational and research access only		ultraviolet treatments		place unaffected bats in alternate space	no treatment	no ex-situ treatment	
		recreational and commercial access only		no treatment		no treatment			
		research and commercial access only							
		allow all uses							

This might also have a spatial component…

Dynamic Sets of Actions

- For recurrent decisions, some consideration needs to be given to how the set of alternative actions may change over time

- Several scenarios
  - Fixed set of alternatives
  - Time-dependent set of alternatives (linked decisions)
  - Dynamic set of alternatives (known dynamics)
    - i.e., decision today affects options tomorrow, in known way
  - Developing an adaptive set of alternatives

Models

Model Development

- The model needs to predict the outcomes associated with the different actions in terms that are relevant to the objectives
- What level of complexity is needed in the predictive model?
- What level of complexity can we handle on the computational side?

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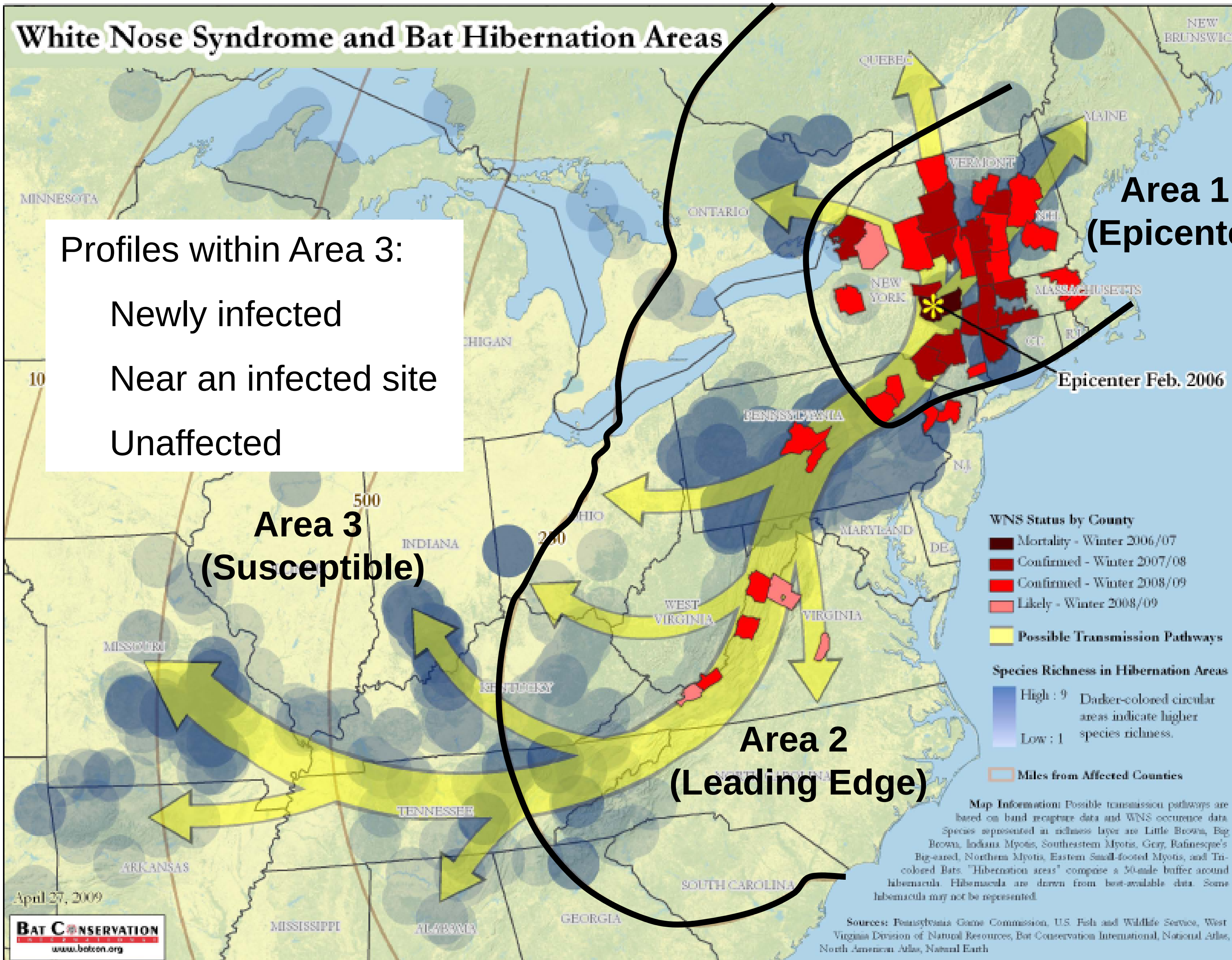
White Nose Syndrome and Bat Hibernation Areas
Profiles within Area 3:
Newly infected
Near an infected site
Unaffected
Area 1
(Epicenter)
Area 2
(Leading Edge)
Area 3
(Susceptible)
Epicenter Feb. 2006
QUEBEC
NEW BRUNSWICK
MAINE
VERMONT
NH
MASSACHUSETTS
CT
RI
NEW YORK
ONTARIO
MINNESOTA
MICHIGAN
PENNSYLVANIA
N.J.
MARYLAND
DE
OHIO
INDIANA
WEST VIRGINIA
VIRGINIA
KENTUCKY
MISSOURI
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
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250
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Bat Conservation International
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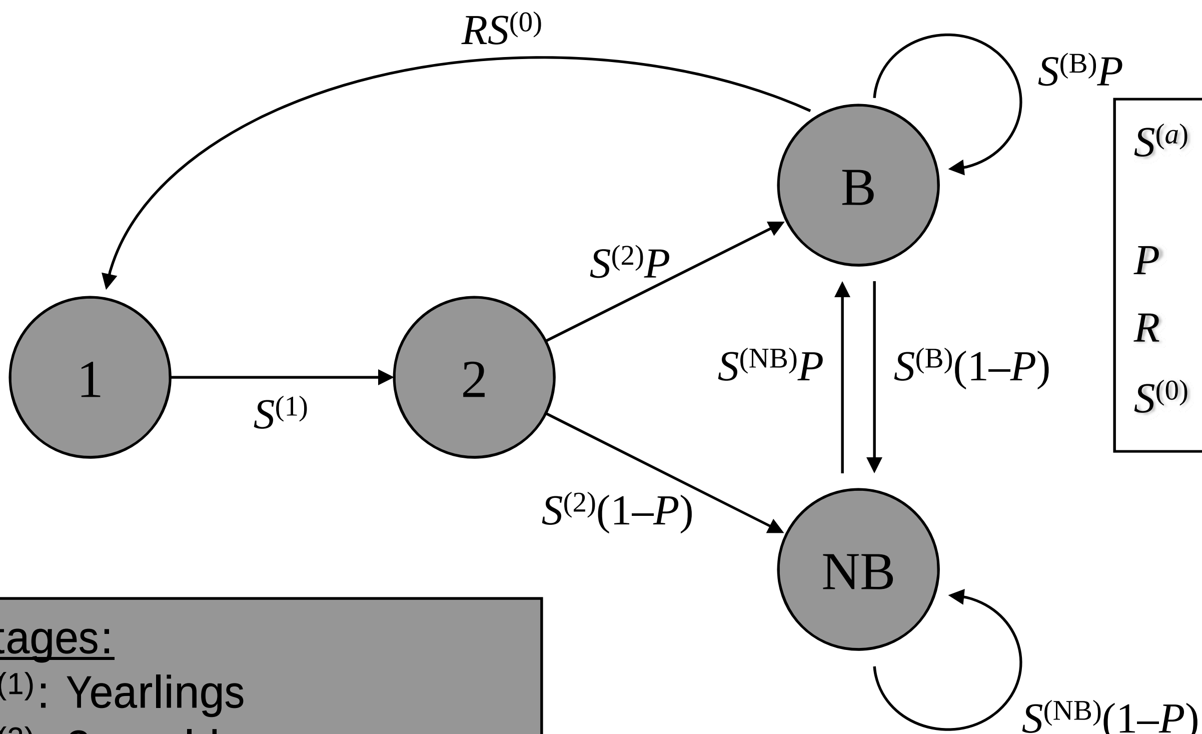
APCG Population Model



$S^{(a)}$	Annual Survival for age *a*
P	Breeding proportion
R	Basic productivity
$S^{(0)}$	First-year survival

<u>Stages:</u>
$N^{(1)}$: Yearlings
$N^{(2)}$: 2-yr olds
$N^{(B)}$: breeding adults
$N^{(NB)}$: non-breeding adults

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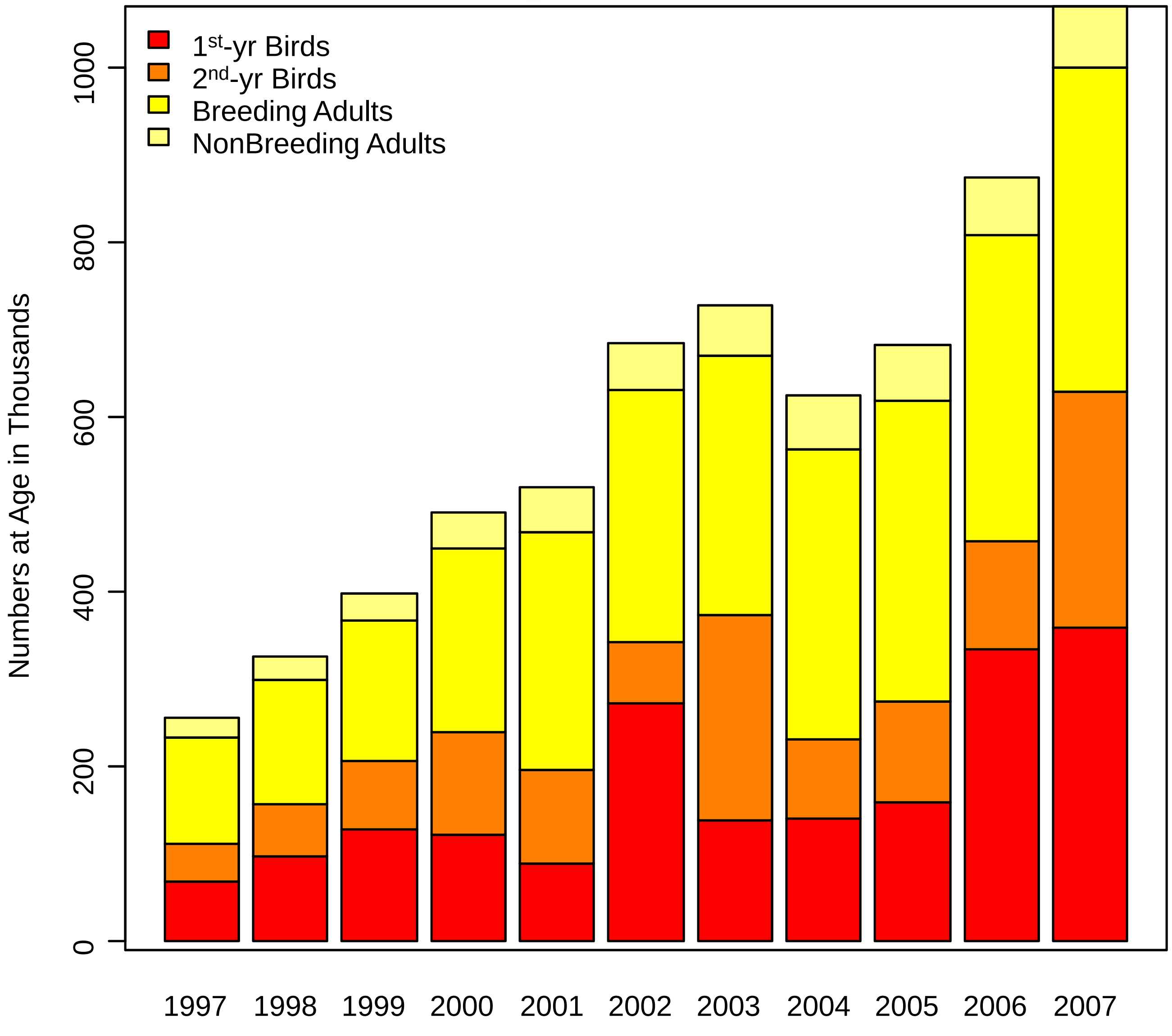
Partially Observed Systems

- When we need a certain level of complexity in the model, but cannot observe all the system states, what do we do?
  - Latent state variables: sometimes we can use time series data to reconstruct latent state variables, but then how do we handle uncertainty about those states?
  - POMDP (see later talks and discussions)

AHM and AP Canada geese: reconstruction



Uncertainty

- We know we've got it, but does it matter?
- What is the relevant uncertainty to include in a model set?
- Can we use techniques akin to EVPI to help guide us?

Learning

- In recurrent decisions, when we hope to take an adaptive approach, we also need models for information dynamics
- How do different actions affect the rate of learning (the resolution of uncertainty)?

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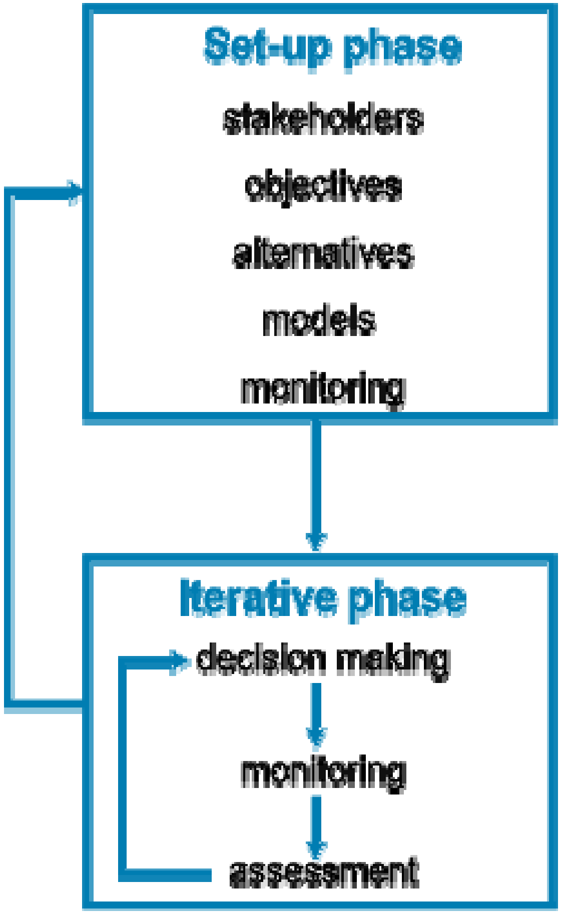
Summary

Double-loop Learning



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