What is an appropriate Adaptive Management formulation in the wind-energy context?

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And, *when* is adaptive management (AM) appropriate?

- Answers to these 2 questions might be different

  – at the Site, County, State, or National levels.

  – where have different opportunities for multiple treatments and replication.

Very popular phrase, now-a-days

- Sprinkled widely through talks and papers
- Can mean
  - trial and error
  - wait and see what happens, then react
    - (learning by doing)
- Can mean squeeze an operator step by step
- Can mean formal AM
  - based on Carl Walters & disciples
- Bit of a linguistic free for all

Adaptive Management has many flavors

- Minimum components (motherhood version):
  - Learn from management decisions
    - So, must be some monitoring
  - Adjust management based on learnings
    - "Close the loop"
- The minimum formulation is not too different from, "wait and react," or, "trial and error."

Styles of management [Parkes 2006]

- Defer action
  - until uncertainties resolved.
  - follow "standard operating procedure," tried and true.
- Biological risk-aversion
  - shut facility down, system is delicately balanced
- Dogmatic approach
  - Do not disturb fixed policy positions
  - Winner take all fight between antagonistic stakeholders
- Trial and error, learn by doing
  - An event prompts a change, but results may be unclear
- Formal adaptive management

Sobering quote

- “[AM] implies thoughtful experimentation, research, testing through implementation, monitoring, and redesign…..

- “This is a time consuming and complex process that few organizations have taken seriously,
  - preferring a more simplistic by-line of ‘learning by doing’.” [Wells, 2004]

Implied components of any AM plan

- Must have an objective
- Some authors claim need sign-off on objective(s)
  - Who are players? County? State? Broad group of stakeholders?
- Some authors claim objective must be quantifiable
- Objectives may change as gain new understanding
  - Potential trouble spot with stakeholders
- Some authors claim need management committee
  - and scientific advisory committee

Basic questions about objectives in developing AM proposals:

- What is being managed?
- Who is doing the management?
- Is the monitoring focused on the objectives?
- What are the politics?
  - Management is a very political business (Walters, 1986)

Challenges to AM

- “..understand at the outset that there are formidable obstacles to practical implementation.” [Walters, 1986]

If objectives are vague

- And, details left to be worked out

- It is unlikely that the management loop will be closed

What are appropriate objectives in wind context?

- Maintain (possibly help)
  - populations of T & E species?
- Reduce turbine kills by some percentage?
- Minimize kills
  - per peak kilowatt-hr generated?
- Identify suitable sites?
- Until objectives worked out, can't expect any consensus on AM in wind/wildlife context

Once have objective, can narrow the AM description (*Skip slide at talk)*

- Adaptive bird/bat collision management

- Adaptive bird/bat population management

There are other implied components in all AM versions

- Management action will be taken in response to learnings
  - Big assumption

Closing the loop

- “Despite the intuitive appeal of the adaptive management concept,

- “there are startlingly few examples in wildlife management in which the adaptive management “loop” has been completed.” [Gibbs et al., 1999]

Who would close the loop in New York State?

- NYSERDA?
- NYDEC?
- USFWS?

- Operator, under an agreement with agencies or stakeholders?

Some other implied components or assumptions in all AM versions:

- Management is treated as a kind of experiment [Scaretta 2005]
- Iteration
- Convergence
  - Raises question of efficiency
  - Leads to more formal versions of AM

Formal Adaptive Management

- Authors assume learning in formal AM will be systematic
- Most authors demand that
  - multiple, competing models or hypotheses be involved
    - to improve efficiency
- Two versions of formal AM in literature

System 1: Hypothesis formulation & testing

- [hypothetico-deductive approach (H-D)]
    - Well understood by all researchers
    - Perhaps, most appropriate when have opportunity for multiple treatments and replication.
    - However, vulnerable to politics
        - because deductions and interpretations are subjective

System 2: Model weighting (model evaluation)

- Perhaps, most appropriate when have only one “ball game” with limited treatments/replications
  - E.g., waterfowl harvest regulations
  - And/or contesting stakeholders
- Model weighting requires both
  - Prediction, and
  - assignment of prediction uncertainty
  - Allows for Bayesian approach, suitable for contested situations

Big divide in formal AM: Bayesians vs non-Bayesians

- Bayesians (Model evaluators)
  - Search after probabilities
    - to assign to validity of theories or models
- Non-Bayesians (Hypothetico-deducers)
  - Search after truth
    - E.g., which theory is valid
- Under both schools, can have models and fits to parameters
  - New software (WINBUGS) makes dealing with complex models in AM highly feasible [Dorazio 2003]

Advantage of Bayesian approach in contested situation

- Anyone can propose or champion a favorite theory
  - and is encouraged to do so.
  - Doesn’t matter if the theory is deemed biologically wrong by some players
  - But must assign an uncertainty to the predictions
    - Which differentiates this approach from use of multiple hypotheses in hypothetico-deductive approach

Regulatory agencies can stand above the fray

- After picking an initial “best” management option
  - based on initial judgment of “best” science
- Changes to management can be made based on
  - probabilities assigned to different theories by Bayes’ formula
    - in response to how well each theory predicted the field results

Limitations of Bayesian AM approach

- Not as familiar to researchers as H-D approach
  - Lack of familiarity could block agreement of stakeholders to participate
  - Some statisticians abhor Bayesian approaches
- Highly mathematical
  - Few computer programs available yet specifically for Bayesian AM

Limitations of Bayesian AM approach (con’t)

- If there are multiple outcomes, treatments, or objectives
  - Different models may perform better on different parts of field data
    - Leading to potential paralysis in decision making or review bodies

Some stated advantages of AM in the literature

- Can reduce management uncertainty
  - (vague statement)
  - (In fact, AM can actually increase perceived uncertainty initially)
- AM can get rid of bad hypothesis that are out there
  - And can prevent bad hypotheses from arising
- AM can resolve disputes between stakeholders promoting different theories
  - "Put up or shut up" (Contested AM)
- AM can provide research funds
- AM can provide more meaningful research opportunities than academic research

Credibility

- “Indeed, to be credible, the wildlife research and management community will need to be vigilant for cases where management actions are undertaken and justified as adaptive management, when they are not.” [Lancia et al., 1996]

Adaptive Management in avian/wind context (*skip slide at talk*)

- In 1994, Tom Nudds discusses AM at a National Avian-Wind Power Planning Meeting [Nudds 1994]

- Wisconsin DNR highly recommends AM
  - http://dnr.wi.gov/org/es/science/energy/wind/studies.htm

- New Jersey panel on wind also calls for AM
  - citing [Ashcraft, undated]
  - www.nj**wind**panel.org/docs/final**wind**panelreport.pdf

Some management options in wind context

- Modifications to design/ placement on landscape
- Modifications to operations
  - Rodent control (tricky).
  - Time restrictions on turbine operations
- Offsite mitigation

Site-specific proposals

- Proposal at Cape Wind by Mass Audubon
  - [Allison 2005];
  - (For a more stakeholder-oriented proposal, see [Ashcraft, undated])

- Proposals at Altamont
  - [WEST 2005], [Smallwood 2005]

Cape Wind (off shore) (Non-Bayesian)

- Mass Audubon’s Plan to be presented to
  - Operator
  - Corps of Engineers and MMS
    - as a recommended permit condition
  - Massachusetts Government

Key bird species at Cape Wind (and NY offshore sites)

- Roseate terns
- Piping plovers

Cape Wind possible loop actions

- Reduction in avian mortality
- Seasonal shutdown
- Offsite mitigation
- Establishment of an independent fund

Mass Audubon’s Cape Wind AM goals

- Correct any unanticipated and ecologically significant collision mortality; and
- Correct any ecologically significant loss of habitat due to avoidance of the wind farm.

Some comments on Mass Audubon’s Cape Wind proposal

- Strengths:
  - Goals are tied to larger issues
  - Operator’s responsibility largely pre-determined by fund
    - with exception of seasonal shutdowns

Cape Wind comments (con't)

- Limitations:
  - "Ecologically significant" left to a review panel.
    - Inevitably, there will be a dispute.
    - Mass Audubon aware of this difficulty, but says such decisions made all the time by regulators
  - Not yet clear who will trigger which actions
    - and in what sequence
  - Lack of Bayesian component could lead to paralysis within decision-making group
    - on data interpretation

Altamont AM proposals [Non-Bayesian]

- Both include commitment to management as hypothesis-based experiment
- Both have lots of ideas to test
- There exists a large research base on which to choose response actions
- Both have well-defined (mortality reduction) goals

Goals in [WEST 2005]

- A 35% reduction in golden eagle, red-tailed hawk, and burrowing owl combined mortality
  - within 3 years of implementation
  - if not prohibitively expensive
    - (This goal does not set a lower bound on the financial responsibility of the owners)
- (The connection to population viability is not made)
  - But note that many California stakeholders are concerned with absolute kill rates
    - regardless of population impacts

Goals in [Smallwood 2005]

- 50-80% reduction in mortality in 3 to 6 years
- Offsite mitigation to bring net reduction to zero

- (This goal does not set an upper bound on the financial responsibility of the owners)

More comments on Altamont AM proposals

- Neither proposal has a Bayesian component
  - that assigns likelihood numbers to contesting theories or models
- As a result, both are vulnerable to political paralysis within decision-making group
  - due to subjective nature of data interpretation in deductive method.

"Adaptive harvest management," an example of a successful AM program in the U.S.

- In 1995, the U.S. Fish and Wildlife Service embraced adaptive management
  - for regulating the harvest of midcontinental mallards
  - Bayesian based

Objective

- Maximize current and future harvest
- As predicted by a weighted sum of models

Methodology: Step 1

- Compare the predictive abilities of (4) candidate models
  - that express different hypotheses about
  - survival (compensatory vs. additive mortality)
  - reproduction (strongly vs. weakly density dependent).

Step 2. Update the management “weight”

- assigned to each model every spring
  - according to how well its predictions match observed population size
  - through use of a Bayesian probability distribution

Step 3. Make predictions of present and future value of harvests

- for each model for a range of regulatory options

- Compute a weighted sum of harvest predictions, using model weights, for each option.

- Pred = w_1*$pred_1$ + w_2*$pred_2$+ w_3*$pred_3$+w_4*$pred_4$

- Choose the management option that maximizes the weighted sum [Williams 1995]

(*Skip slide at talk*) Learning occurs

- as model weights for one of the models converges toward 1
  - i.e., the model has best explained population dynamics over time relative to the other models evaluated.
  -
  - And is therefore assumed to be the best future predictor of the impacts of hunting regulations
  - Such a model then becomes the primary basis for determining annual harvest regulations. [Conn, 2004]

Some other planned and proposed uses of AM

- Florida Everglades Reconstruction
  - Water District has data-driven, conceptual models of the system [Ogden 2005]
  - Therefore can make predictions and test them
  - For some painful prehistory, see [Gunderson 1999]
    - Took decades of head-butting to get to AM.

Some other planned and proposed uses of AM (con’t)

- PA deer-management AM proposal [Latham, 2005]
  - Is it deer browse or acid rain causing loss of understory vegetation diversity?
  - What level of deer density reduction needed to restore system structure and function?

Advice from literature

- Define terms, e.g. flavor of AM that you are selling
- Start simple [Morghan 2006]
- Encourage informal networks [Gundeson 1999]
  - because they produce creative ideas
- Go for stakeholder involvement in other aspects [Schreiber 20004], including Bayesian AM [Failing 2004]
- Have explicit objectives – quantifiable

Advice on objectives

- Develop list of key management questions for the site [Morghan 2006]
- Look at successes and failures at the site [Morghan 2006] or other sites
- Try to get agreement among stakeholders on goals
  - To gain support, use open/inclusive public process [Shindler 1999]
- Main objective of siting studies is problem avoidance [Nudds 1994]

What if parties do not agree initially

- on objectives, metrics, or long-term goals?
- Search for objectives that disputants want to pursue
  – even though they do not agree on long-term goals. [Lee 1999]
- hammer out agreements
  – on the questions about causality that all parties want answered.

Closing the loop
(*Skip slide at talk*)

- If there are no explicit or implicit thresholds or triggers in the objectives
  - it may be difficult to close the loop

More advice from the literature

- Work with multiple, competing, predictive models
  - with quantified uncertainties
  - so can quantitatively test the models (or obtain parameters) [Conroy 2006], [Schreiber 2004]
- Lay out a wide range of management options
- Lay out management responsibilities at the start
- Consider the politics of management from the beginning

AM should fit into a larger framework [Failing 2004]

- Namely, a structured decision processes involving stakeholders
  - (AM as joint fact finding)

Structured decision framework (*Skip slide at talk*)

- Set objectives; define measures of performance
- Identify policy alternatives and estimate impact on objectives
  - AM is one possible tool
- Evaluate and choose a preferred policy alternative
  - AM is one possible tool

Monitoring is key

- If monitoring is
  - largely irrelevant to the objectives
  - scientifically inadequate
  - Can’t test models
  - Can’t deduce anything useful
  - So, both the policy and research communities need be involved.

Still more advice

- See if can include multiple treatment and replication
  - E.g. install different risk-avoiding turbine designs [Nudds 2005]

- Involve review committees with a wide range of experts

- Develop and work with conceptual models [Schreiber 2004]

Importance of conceptual models

- They link species to ecological parameters
- Form basis for identifying adaptive management actions [Barrows 2005], [Ogden 2005]
- Some illustrative examples follow

Conceptual model 1

- Collision rate= [Pre-construction bird flux] * [Number of turbines] * [Rotor swept area per turbine]*[turbine-specific hit probability]

- Effective death rate = f * [Collision rate]
  - (Accounts for any compensatory mortality and unanticipated side effects of operations)

Conceptual model 2

- Bird impacts (high, medium, low) can be predicted
  - based on a simple score function determined from
  - a pre-siting inspection and knowledge of migratory flight patterns

Conceptual model 3 (*Skip slide at talk*)

- Collision rate= [Pre-construction bird flux] * [Number of turbine strings] * [Rotor swept area per turbine string] * [Turbine-specific hit probability]

- Effective death rate = f * [Collision rate]

Conceptual model 4 (*Skip slide at talk*)

- Raptor collision rate=(1+ A* [rodent density per turbine]) * [Pre-construction raptor flux] * [Number of turbines] * [Rotor swept area per turbine] * [Turbine specific hit probability]
- Note that rodent control can backfire

Conceptual model 5 (*Skip slide at talk*)

- Population viability depends on surrounding land use, food supply, nesting opportunities, non-wind-energy threats, combined with turbine collisions.
  - Avian collisions only one piece of the model.

- For some species, the model might account for global warming risks
  - and account for benefits of wind energy in NY State

Other conceptual models (*Skip slide at talk*)

- might include variables like
  - Percentage increase in perches provided by turbines
  - Number of foggy days
- might assume collisions are non-linear with turbine number
- might assume that collisions will decline over time as birds get acclimated
- might assume that net-annual-mortality does not change
- Might assume that collisions only take place when blades are moving

What might NYDEC do in AM?

- Define the populations of concern
  - E.g., breeding population?, geo-boundary of population

NY endangered bird list

- Golden Eagle (extirpated)
- Peregrine Falcon
- Spruce Grouse
- Black Rail
- Piping Plover
- Eskimo Curlew (extirpated)
- Roseate Tern
- Black Tern
- Short-eared Owl
- Loggerhead Shrike

NY threatened bird list

- Pied-billed Grebe
- Least Bittern
- Bald Eagle (federally threatened in lower 48)
- Northern Harrier
- King Rail
- Upland Sandpiper
- Common Tern
- Least Tern
- Sedge Wren
- Henslow's Sparrow

NY birds of special concern

- Common Loon
- American Bittern
- Osprey
- Sharp-shinned Hawk
- Cooper's Hawk
- Northern Goshawk
- Red-shouldered Hawk
- Black Skimmer
- Common Nighthawk

NY birds of special concern (Con’t)

- Whip-poor-will
- Red-headed Woodpecker
- Horned lark
- Bicknell's Thrush
- Golden-winged Warbler
- Cerulean Warbler
- Yellow-breasted Chat
- Vesper Sparrow
- Grasshopper Sparrow
- Seaside Sparrow

What might NYDEC do in AM? (con't)

- Play a role in development of conceptual impact models on key NY State species
  - Offshore wind issues most challenging
- Play a role in deciding on management changes derived from AM program
- Commission development of predictive models that come complete with uncertainty ranges

- (For advice to agencies on AM, see [Johnson 1999])

NYSERDA role

(possibly in collaboration with NREL)

- Support monitoring that has value
  - beyond individual site
- e.g., compensate operators for experiments
  - Example: pay operators to turn off blades for experimental purposes, say, at end of turbine strings
- Commission development of predictive models
  - that come complete with uncertainty ranges

NYSERDA (Con't)

- Increase tool set for data analysis:
  - kinetic model of collisions
  - case/control methodology
    - for better statistical handling of rare events
  - Infrared cameras on blades

What might AWEA do?

- Establish a joint insurance policy for operators
  - that would pay for offsite mitigation at sites where problems develop and persist.

- Use AM to test theory that pre-siting guidelines make a difference

My answer to initial question, “What is an appropriate AM program for wind?”

- Competing models within a structured decision framework
  - involving multi-stakeholders [Failing 2004]
  - provided it involves an iterative approach
- Bayesian assignment of likelihoods to models
  - if contested situation, or
  - only a few treatments possible

My answer to question, “When?”

- If chosen by stakeholders and there is a political or legal “hammer” available to close the loop

- AM is very appropriate at contested sites.

- Also, appropriate at the state and national levels
  - to test conceptual models that can support generic planning and siting policies

Can we speed up the process?

- It took decades of fighting to come to AM at Altamont and the Everglades
- How about starting earlier from now on?

Hypothetical use of AM in NY State

- At wind sites
- By state agencies

What follows is purely hypothetical

- no doubt different in the real world
  - e.g., I am ignoring issues raised by the migratory bird treaty

- Purpose of example: highlight a process

Hypothetical initial objective:

– To limit impact on birds/bats to “acceptable” levels

– (Very different scale problem with off-shore sites)
  - because of reduced knowledge about impacts

Possible step 1: Bring together stakeholders

- To clarify species of greatest concern
- To identify other objectives
- To identify conflicting views of species impact
  – Including different conceptual models
- To understand developer constraints
- To get views on “acceptable” levels

Step 2: Assume agencies adopt "acceptable level" definition:

- Kill rate of T & E species at wind sites projected by 2050
  - shall be small enough to allay concerns
    - that wind is a significant factor in population survival

Quantification of objective

– where assume, in the absence of other evidence,

- that a combined annual mortality rate of <= 2% of a NY bird/bat species population is insignificant

- (2% is an unsupported guess)

Step 3: Assign initial target kill rate for T&E species

- With help of bird/bat experts
- If inadequate data available on an individual species population
  - Use "Delphi" method to get initial numbers
- With help of projections of number of future wind sites in NY State
  - assign a trigger collision rate per site

Assume agencies adopt for initial management purposes

- a scalable version of conceptual model 1

- Collision rate=s* [Pre-construction bird flux] * [Number of turbines] * [Rotor swept area per turbine]*[average turbine-specific hit probability at US sites]
  - Where, s, is set initially to 1
  - Error rate set by errors in components

- Effective death rate = f * [Collision rate]
  - Where, f, is set initially to 1.

Agencies use this conceptual model for initial siting of facilities

- changing the model over time
  - as collect field data
- Convene experts to get initial numbers for conceptual model
  - And to assign error rates to conceptual model
- If no developer can meet the initial target
  - Require offsite mitigation from the beginning or go back to policy formulation stage

Step 4: Decide on financial liability of developer

- Assume developer must put a fixed fraction of income into an escrow account
- Look for an industry-wide insurance fund
- Identify possible State contribution

Step 5: establish monitoring requirements

- Convene a broad expert review committee
- Identify
  - Funding
  - Methods to insure independence
- Decide on additional questions that stakeholders want answered

Steps 6 and 7

- Put out call for alternate conceptual models
- Convene a management committee

Step 8: Compare field data to conceptual models

- Do they do a better job than the null hypothesis?
- Can data fix the parameters, “s” and “f”?
  - If so, adopt best values to compute next year’s kill rates
  - and to estimate kill rates at new sites
- Are any conceptual models better than any others?
- If so, use Bayesian weighting to estimate projected kill rates

Step 9: Close the loop:

- If any kill rates exceed target levels
  – call for response proposals

- Agencies, with advice of management committee, accept a response
  – which might include offsite mitigation acceptable to agency

Step 10: collect next year's data and iterate

Good luck, NY.

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