NYSGI-T-06-001

Sea Grant
New York

MANAGING AND COMMUNICATING FISHERIES UNCERTAINTIES
FINAL REPORT

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New York Sea Grant

A Joint Program of the
State University of New York
and Cornell University

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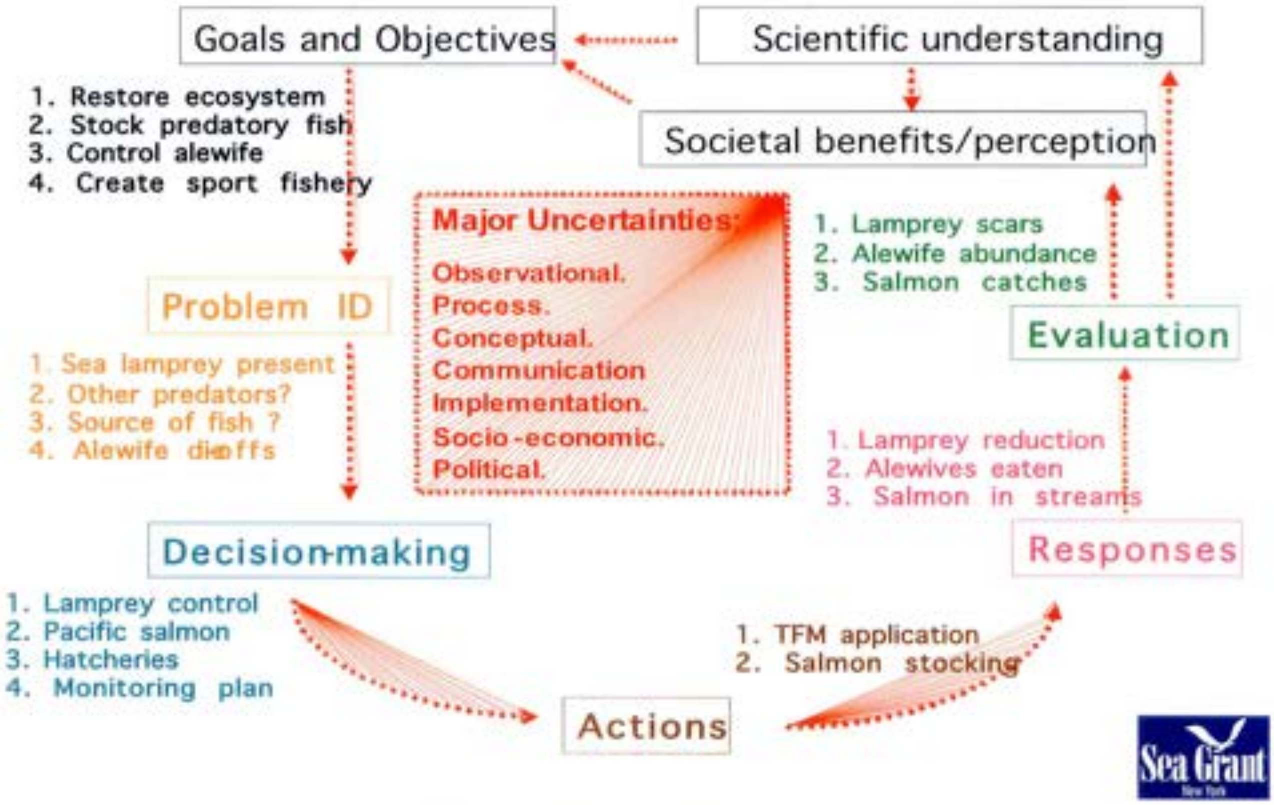


Sea Grant New York

Major Uncertainties

Type	Sources:
Observational uncertainties	– measurement errors.
Process	– (random) variations in biophysical processes.
Conceptual	– inadequate knowledge of natural resource dynamics, using the wrong analysis.
Communication	– oversimplifications of processes, misinterpretation, lack of clarity.
Implementation	– incomplete plan development, monitoring, follow-up or evaluation.
Socio-economic	– unpredictable social and economic issues, ineffective cost/benefit analysis or valuation.
Political	– unexpected changes in institutional support, organization, and governmental influence.

Project Abstract

Uncertainties are ubiquitous in resource management; yet they are extremely difficult to incorporate into the development of management policies. In the Great Lakes, ecological uncertainties are escalating due to dramatic ecosystem changes that impede sustainable fisheries management and ecosystem restoration initiatives. Invariably, these factors are likely the primary source of polarity between fisheries managers and stakeholders, indicating that increased attention should be paid to identifying uncertainties, addressing them and communicating risks to the resource users. Under a grant from the New York Great Lakes Protection Fund, New York Sea Grant (NYSG) developed a workshop designed to familiarize fisheries managers with sources of uncertainty and the basic tools for addressing uncertainty in fisheries management. The workshop also developed a list of research topics to address specific uncertainties with the Lake Ontario ecosystem.

Background Summary

Fisheries are dynamic systems that pose considerable challenges to fisheries managers (Peterman 2004, Caswell 1998, Matsuda 2002). These challenges stem largely from uncertainties associated with unpredictable and poorly understood interactions between fish and the supporting ecosystem as well as the human dimensions aspects (social and economic factors) of fisheries that impede fisheries management. Uncertainties can impair all steps in the fisheries management process, such as defining goals/objectives, identifying barriers to the achievement of goals, making effective decisions to develop management actions, observing system responses to management actions, and evaluating action efficacy through monitoring (Cochrane 1999, Lane et al. 1999). The realities are that fisheries are a component of the complex ecosystem within which they are contained and the complete picture of how they operate will never be completely seen.

Hillborn and Peterman (1996) identified several specific sources of uncertainty in fisheries, namely: fish abundance estimates, widespread use of single-species models to simulate fish populations trends, fish population parameter estimates (i.e., mortality rates, growth rates, reproductive rates, recruitment), future environmental conditions, behavior/attitudes of fisheries resource stakeholders; future fisheries management objectives, and future economic, political, and social conditions.

Uncertainties directly contribute to communication gaps between fisheries managers and stakeholders (Cochrane 1999). Stakeholders often fail to recognize that fisheries systems are highly spatially complex and that complete control of fisheries is simply beyond the management capabilities of fisheries managers. Managers often wrestle with balancing conflicting stakeholder demands for socio-economic sustainability with biological objectives that are developed with little consideration of risk, not the result of inattention to detail, but an unfamiliarity with current technology to better assess uncertainty and factor it into decision-making (Lane et al. 1999, Cochrane 1999).

Fisheries managers are faced with either ignoring uncertainties, or accounting for uncertainties in designing fisheries policies (Caswell 1998). Ignoring uncertainties comes with a great deal of risk since some fisheries problems are not immediately apparent (i.e., depensatory processes – or increased per capita effects as populations decline) and may be only detectable by existing sampling frameworks when the situation has reached a point of no return (Lauck et al. 1998).

Addressing uncertainties often requires sophisticated analytical procedures (Meyers et al. 1998, Cochrane 1999), modeling simulations (Matsuda et al. 2002, Caswell 2002) and development of communication plans for fisheries stakeholders (Lane et al. 1999, Cochrane 1999) that are beyond the scope of agency responsibilities. These tools also have a steep learning curve. Most of these tools are used to estimate important population parameters (population size, mortality rates, growth rates, food intake, recruitment, etc.) and to reduce the variance associated with estimated parameter values. Model simulations combined with probabilistic bracketing of parameter values can be used to forecast fish population dynamics (Omlin 1999, Matsuda et al. 2002). In so doing, these efforts permit an *a priori* evaluation of a series of alternative management strategies with other tools such as decision analysis (Levy et al. 2000, Lane et al. 1999).

These tools can provide unique opportunities for improved decision-making by helping to identify uncertainties and formulating a suite of management actions and likely outcomes, including risks. Such decision-making frameworks include cost/benefit analysis of each management option (Lane et al. 1999, Cochrane 1999, Matsuda et al. 2002). Unfortunately, such tools are often the purview of mathematical modelers and social scientists and are therefore unfamiliar to many fisheries managers.

In an effort to expose fisheries managers to such tools, New York Sea Grant organized a workshop to introduce such tools to representatives of the New York State Department of Environmental Conservation (NYSDEC) and the Ontario Ministry of Natural Resources (OMNR). The objectives of this workshop were to:

1. provide a unique forum for fisheries managers to meet with academic researchers and discuss the concept of uncertainty;

2. familiarize fisheries managers with the concept of uncertainty, the sources and impacts of uncertainties on sustainable fish management and the basic tools for accounting for uncertainties in fisheries management policy;

3. better understand some of the tools being applied to understand uncertainties in managing fisheries;

4. better understand how uncertainties are communicated properly to fisheries stakeholders;

5. identify research topics/methods that will facilitate better understanding of uncertainties in Great Lakes fisheries and ecosystems; and

6. stimulate interest among fisheries managers and researchers for further joint workshops addressing uncertainties.

Project Implementation

Escalating ecosystem changes—a source of many additional uncertainties for fisheries managers—has challenged the sustainability of Great Lakes fisheries. NYSG has recognized that fisheries managers, stakeholders, and extension staff need to be more familiar with the uncertainty concept as it relates to sportfishing sustainability. After funding was secured from the New York Great Lakes Protection Fund, NYSG convened meetings with Steve LaPan, NYSDEC; Bruce Morrison, OMNR; and Pat Sullivan, Cornell University, to identify workshop topics and faculty and to develop the workshop approach. It was decided that the topic of uncertainty be addressed through presentations focusing on a toolbox approach that presented actual case histories of various modeling tools being applied to address uncertainty. It was also decided to include a session on risk/ uncertainty communication tools for stakeholders.

The workshop was convened in Syracuse on October 24, 2005. The agenda is included as Appendix A. Following the workshop at a special session convened at the Cornell University Shackleton Point Field Station, a list of research needs to address uncertainties in the Lake Ontario fisheries was developed as a part of a group discussion.

Facilitated Discussion Results: Research Needs (Topics/Methodology) to Address Uncertainties in Lake Ontario Fisheries

1. Address uncertainties of alewife and zooplankton dynamics by examining relationships between invertebrate diets and alewife recruitment; P levels and zooplankton production; and quantifying interactions between alewife growth and their body condition index.

2. Obtain better estimates of alewife growth, total abundance, spatial distribution and better understand errors associated with these estimates by comparing trawl and (expanded) hydro-acoustic estimates.

3. Collect additional information to understand the long-term determinants of stocked salmonine survival and contributions of naturally produced Chinook salmon by conducting an extensive coded wire tagging program, followed by an assessment program from creel census and hatchery return data that accounts for proportions of different age groups in the fish samples.

4. Define the role of naturally produced salmonines in the lake food web through tagging studies, total tributary contributions and scale microstructure.

5. Assess the feasibility of restoring native forage species (i.e., bloaters) by resolving the disease issues and develop a target or threshold level of restoration by quantifying the potential impact of alewife and smelt on these native fish.

6. Identify or develop strategies for developing a public participation process for DEC and OMNR in response to potential sport fishing crises (i.e., stocking level changes).

7. Address the uncertainties associated with a *Diporeia* collapse and the impact on the benthic community.

8. Determine the role of angler harvests (in terms of fish catchability) and alewife abundance, Chinook growth rates, and lake trout cannibalism.

9. Develop better understanding of the human health affects associated with dreissenid trophic transfer of contaminants.

10. Define the role of new or newly studied contaminants (i.e., thallium) in the food web.

11. Develop better estimates of natural mortality and determine factors affecting early-life-history mortality to predict recruitment of important fish species.

12. Determine the relative contributions of nearshore versus offshore factors that influence fish recruitment in nearshore areas, and the linkage between habitat and fish production and identify fish species impacted by changes in zooplankton prey consumption and seasonal zooplankton dynamics.

13. Using available long time series data possibly from power plants and other sources, identify indicator species to be used as surrogates for production in the nearshore and offshore areas.

14. Develop improved estimates of ecosystem efficiency to address how or if production is being redirected and determine whether a change in current pelagic fish production will lead to increased benthic fish production.

15. Develop research that will increase understanding of the alewife/zooplankton link in changes in pelagic production from benthification by examining changes in nearshore algal production and the microbial food loop, define the mechanisms involved and how these dynamics may affect alewife carrying capacity (biomass).

16. Define the role of the round goby in the benthic food web and its role in avian botulism.

17. Assess goby production to better understand its growth and trophic transfer dynamics.

18. Improve predictions to identify the next invader and its potential food web impacts.

19. Improve our understanding of the population dynamics of walleye in the Eastern basin; define the walleye population origins (Black River, Oswego River, Bay of Quinte/recruitment mechanisms, as well as determine the role of the round goby in these changes in walleye abundance.

20. Develop an improved plan that focuses on the process of science (i.e., how science really works) for science communication to decision-makers, stakeholders, legislators, and the media.

21. Develop improved means of addressing economic and political uncertainties associated with the lake and its fisheries for stakeholder and fisheries managers.

22. Develop a risk communication plan to develop a suite of relative risks associated with management decisions.

23. Revisit a study on angler expectations either by a statewide angler survey or by a new NYSG study.

24. Develop a process of understanding that will assist stakeholders to better understand the rationales of various management decisions.

Project Implications

This workshop presented a unique opportunity for academic researchers and fisheries managers to examine the sources of uncertainty in the Lake Ontario fisheries and ecosystem and to be familiarized with the basic tools for accounting for uncertainty in the fisheries management process. It established the groundwork for additional venues for fisheries managers to learn more about innovative uncertainty tools, their limitations and their utility. Moreover, spin-off projects are now in progress by NYSG.

Results of the workshop evaluation (Appendix N) indicated nearly unanimous support for additional information, particularly from an illustrated case-history approach. This approach uses the step-by-step application of a decision analysis tool to a specific fisheries issue. Decision analysis is a useful process that facilitates decision making by weighing pros and cons of a suite of management decisions, using probabilistic models. There are some noteworthy examples to draw upon. One example developed by Dr. Jim Peterson at the University of Georgia involved a decision analysis for a bass fishery in an empoundment.

The academic participants were impressed with the innovative modeling tools presented by Evan Cooch of Cornell University's Department of Natural Resources. He discussed the use of non-linear dynamic models, originally developed by theoretical physicists, with biological systems in an effort to understand uncertainty from the standpoint of understanding data trends. One particular model template, originally developed by the U.S. Department of Naval Research in Maryland to predict physical stress in ship hull designs, is being applied to model ecosystem structure and has shown some promising results.

As a direct spin-off of the uncertainty workshop, NYSG and Cooch are organizing a workshop on the use of non-linear dynamic models that entail the application of new, innovative modeling simulations incorporating actual Lake Ontario fisheries/ecosystem dataset. Workshop presenters will include Cooch and researchers from the US Geological Survey Patuxent Research Center in Maryland and the Great Lakes Environmental Research Laboratory (GLERL). Collaboration is being sought with Cornell University and GLERL. Researchers affiliated with the comparative ECOPATH modeling study of the Bay of Quinte and Oneida Lake have expressed considerable interest in participating in this forum. The workshop is tentatively scheduled for mid-2006 at Cornell University.

Most fisheries managers in attendance also expressed interest in receiving more training in the use of communication tools for educating the public on understanding the concepts of risk and uncertainty in fisheries. This is not surprising since much polarity between fisheries stakeholders and managers originates from these concepts.

Project Spin-off Publications and Planned Activities

The following publication and activities are a result of the uncertainties workshop project:

- **Managing Coastal Businesses in Times of Resource and Economic Uncertainties and Risks Workshop** – a program for coastal business owners and managers, April 2006.
- **Uncertainties and Risks in Fisheries** – an 8-page extension factsheet for stakeholders, July 2006.
- **Dynamic Ecosystem Modeling Workshop with Evan Cooch**
- **Risk Communication Workshop for Fisheries Managers** – a program taking a case history approach for developing a risk communication plan and fish management decision analysis re: stocking levels.
- **Decision Analysis Workshop for Fisheries Managers** – a program taking a case history approach for addressing fisheries management problems using a step-by-step example. Collaboration will be sought externally with Antoinette Clemetson, NYSG, and fisheries counterparts from Rhode Island, Connecticut and New Hampshire Sea Grant Programs.
- **Invasive Species Research Roundtable** — a program on recent modeling tools used for predicting the next Invader and for developing a risk assessment for invasion of Asian Carp and Northern Snakehead into the Niagara, Hudson and St. Lawrence rivers. Collaboration with academic institutions will be sought.

Summary

In summary, this Great Lakes Protection Fund project is a stepping stone for additional, more focused efforts to address uncertainty; some of which are already in development. This project has generated considerable interest among Lake Ontario fisheries managers, assessment biologists and researchers for learning more about the uncertainty paradigm and how to apply some of the more useful tools for incorporating uncertainty into fisheries management process.

The next steps are to take some of the tools discussed at the workshop and apply them in a real-world, case history approach so that fisheries managers better understand the mechanics of the techniques. A workshop in which Lake Ontario fisheries data are simulated, using these tools, into a predictive, probabilistically-based decision-making framework to address specific fisheries issues is a future step. Finally, once comprehensive economic information, such as the valuation of the Lake Ontario sport fisheries to coastal communities, becomes available from other studies, decision-making (again from probabilistic tools) will achieve its highest level of efficacy.

The end beneficiaries of this process are sport fishing stakeholders. Enhanced awareness among fisheries managers will lead to more careful consideration of uncertainty in fisheries management policy development, mediated by an improved decision-making process. Sport fishing stakeholders will also be able to make better business management decisions because of this process. Stakeholder economic interests could be then more effectively considered with biological information that also better accounts for uncertainty – a situation once thought unachievable.

Appendix A.
Workshop Agenda

NYSG/GLPF Workshop
Uncertainty in Great Lakes Fisheries

Holiday Inn
Carrier Circle
Syracuse NY
October 24th 2005

Agenda

8:30 **Welcome, Purpose of the Workshop:** Dave MacNeill /Lane Smith/ Jack Mattice, NYSG

8:45 **Uncertainties in Fisheries and the Basic Tool Box:** Jim Bence, Michigan State

9:15 **What are the Uncertainties in the Lake Ontario Ecosystem:** Tom Stewart, OMNR

9:45 **State Specific Optimal Decision Theory and its Applications to Age/size Structured Models:** Evan Cooch, Cornell University

10:15 **Ecosystem Models – ECOPATH Project: Oneida Lake and Bay of Quinte:** Marten Koops, CCIW

10:45 **Break**

11:00 **Nonlinear Dynamic Models: a New Approach for Modeling Ecosystems:** Evan Cooch, Cornell University

11:30 **The Lake Ontario Alewife Risk Model Revisited:** Don Stewart, SUNY ESF

12:00 **Lunch**

1:00 **Age Structured Walleye Model in Oneida Lake:** Brian Irwin, Cornell University

1:30 **Ecological Economic Approaches to Understanding Resource Management Under Uncertainty:** Valerie Luzadis, SUNY ESF

2:00 **Decision Analysis for Lake Whitefish Management:** Marten Koops, CCIW

2:30 **Break**

2:45 **Communicating Uncertainties to the Public and Developing the Communication Plan (Facilitated discussion):** Cliff Scherer, Cornell University

3:30 **What are the Research Needs to Address Uncertainties of Fisheries Management in the Great Lakes? Facilitated discussion**

4:15 **Wrap up**

4:30 **Adjourn**

6:00 **Barbeque at Shackelton Point Station, Informal Discussion and Brainstorming**

Appendix B.
Speaker Biographies, 10/24/05

Jim Bence is a researcher in the Department of Fisheries and Wildlife of Michigan State University. He holds an M.A. degree in statistics and a Ph.D. in biology from the University of California, Santa Barbara. He has just finished a five-year stint with NMFS. His current research specializations include fish stock assessment methods and Great Lakes fisheries.

Evan Cooch is an Assistant Professor in the Department of Natural Resources at Cornell University. He conducts research on the application of theoretical and quantitative methods to the management and conservation of natural resources. Particular interests include population modeling, trophic dynamics, statistical and theoretical ecology, and optimal decision theory.

Tom Stewart is a fisheries biologist with the Ontario Ministry of Natural Resources and has more than 20 years of experience working on fisheries research, assessment and management issues on inland lakes across Ontario, Lake Ontario and the St. Lawrence River. He has a Masters in Science degree from York University and is a Ph.D. candidate at the University of Toronto at Mississauga under the supervision of Dr. Gary Sprules. He is currently studying the effects of exotic species on the potential for Lake Ontario to support a re-introduced bloater (*Coregonus hoyi*) population.

Brian Irwin received his Bachelor's degree from the University of Illinois and interned for the Illinois Natural History Survey. He received his M.S. degree from Auburn University's Department of Fisheries and Allied Aquacultures. Currently, he is a Ph.D. candidate in Natural Resources at Cornell University and serves as a teaching assistant for Field Biology. He is a contributor to a large-scale comparative project between Oneida Lake, NY and the Bay of Quinte, Ontario. In addition to this ecosystem-level project, Brian is working on models for walleye and yellow perch in Oneida Lake.

Valerie A. Luzadis holds the position of Associate Professor of Ecological Economics and Natural Resources Policy on the Faculty of Forestry and Natural Resources Management at SUNY College of Environmental Science and Forestry. She brings to the academic world strong practical experience and leadership in the forestry community having worked as both Cooperative Extension Agent and Director of Communications and Education for the Empire State Forest Products Association. Luzadis has taught courses in ecological economics, environmental ethics and values, economics, research methods, forestry in New York, and current policy issues. Her research focuses on the relationships between social, economic, and ecological systems from the very applied context of decision-making in small, rural communities to the global social, economic, and philosophical foundations that influence human interaction with ecosystems. Luzadis is an integrator of ideas and people in an effort to understand interactions between people and natural resources. In addition to teaching and research, she consults regularly with groups such as The Nature Conservancy and The Wildlife Conservation Society to advise and facilitate community-based conservation efforts.

Luzadis served as the coordinator of the team that founded the United States Society for Ecological Economics. She served on the first Board of Directors of that organization and represented the USSEE with the International Society for Ecological Economics during its organizational period. A member of SAF for more than 20 years, Luzadis has held several leadership positions in that organization, including Chair of NYSAF, Chair of the House of Society Delegates and in 1997 she won the National SAF Young Forester Leadership Award.

Clifford W. Scherer is an Associate Professor with the Department of Communication, Social and Behavioral Research Unit at Cornell University. He received a Ph.D. in Mass Communication from the University of Wisconsin, Madison; an M.S. degree in Advertising/ Radio-Television from the University of Illinois, Urbana-Champaign; and a B.S. degree in Agricultural Science and Journalism, University of Illinois, Urbana-Champaign. His primary interest is in the communication of complex scientific and technical information to lay audiences in an environmental and health context. His current work includes a study of how social networks influence risk perceptions, knowledge and behaviors, and a study of the structure of risk messages, and how various audiences react to and understand risk situations.

Appendix C:
Workshop Attendees

Jim Bence, Michigan State University
Dan Bishop, NYS Department of Environmental Conservation
Antoinette Clemetson, New York Sea Grant
Evan Cooch, Cornell University
Bill Culligan, NYS Department of Environmental Conservation
Mike Connerton, SUNY College of Environmental Science & Forestry
John Farrell, SUNY College of Environmental Science & Forestry
Kofi Finn-Aikens, US Fish and Wildlife Service
Tom Goodwin, Monroe County Legislature
Brad Hammers, NYS Department of Environmental Conservation
Tom Hughes, SUNY College of Environmental Science & Forestry
Brian Irwin, Cornell University
Brian Kelder, SUNY College of Environmental Science & Forestry
Marten Koops, Division of Fisheries and Oceans, Canada
Brian Lantry, US Geological Survey
Steve LaPan, NYS Department of Environmental Conservation
Valarie Luzadis, College of Environmental Science & Forestry
Paul McKeown, NYS Department of Environmental Conservation
Ed Mills, Cornell University
Brent Murry, SUNY College of Environmental Science & Forestry
Bob O'Gorman, US Geological Survey
Donna Parish, US Fish and Wildlife Service
Web Pearsall, NYS Department of Environmental Conservation
Lars Rudstam, US Geological Survey
Ed Sander, Great Lakes Fishery Commission
Matt Sanderson, NYS Department of Environmental Conservation
Cliff Scherer, Cornell University
Lane Smith, New York Sea Grant
Don Stewart, College of Environmental Science & Forestry
Rochelle Sturvetant, Great Lakes Environmental Research Laboratory
Pat Sullivan, Cornell University
Molly Thompson, New York Sea Grant
Fran Verdoliva, NYS Department of Environmental Conservation
Mike Waterhouse, Orleans County Tourism
Mike Whittle, Division of Fisheries and Oceans, Canada

Appendix D.
Uncertainties in fisheries and the basic toolbox

Uncertainties in fisheries and the basic toolbox

Jim Bence
NY Sea Grant Workshop
October 24, 2005

"As we know, there are known knowns. There are things we know we know. We also know there are known unknowns. That is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know."

Donald Rumsfeld, Feb. 12, 2002, Department of Defense news briefing

"Prediction is very difficult — especially if it is about the future."
Niels Bohr

"The future ain't what it used to be."
"When you arrive at a fork in the road, take it."
Yogi Berra

$$R = \alpha S e^{-\beta S} e^{\varepsilon}$$

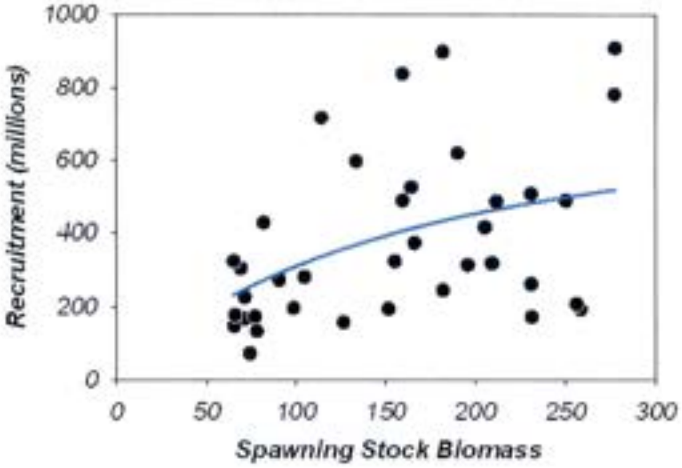
Other examples of structural uncertainty: obs error in stock size?; correlated process errors?; B-H instead of Ricker function?

$$\varepsilon \overset{iid}{\sim} N(0,\sigma^2)$$

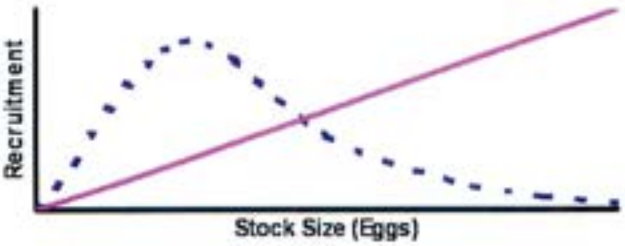
Process error + observation error

Parameter uncertainty

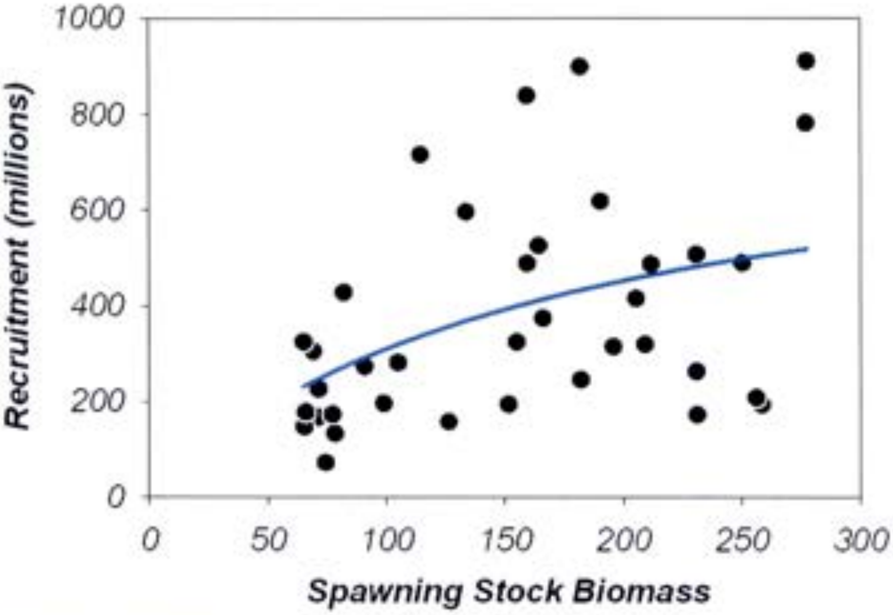
$$\theta = \{\alpha, \beta, \sigma^2\} \longrightarrow \hat{\theta} \neq \theta$$



Through the 1950s theory focused on deterministic models based on the underlying trend in data



North Sea Cod

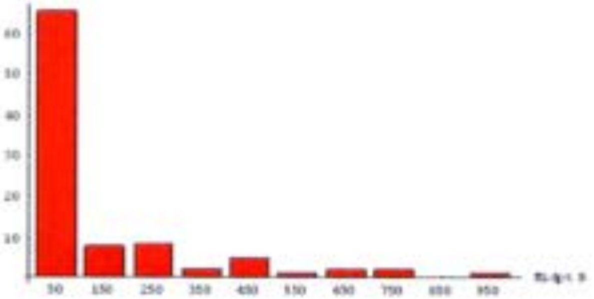


Slide from Steve Murawski

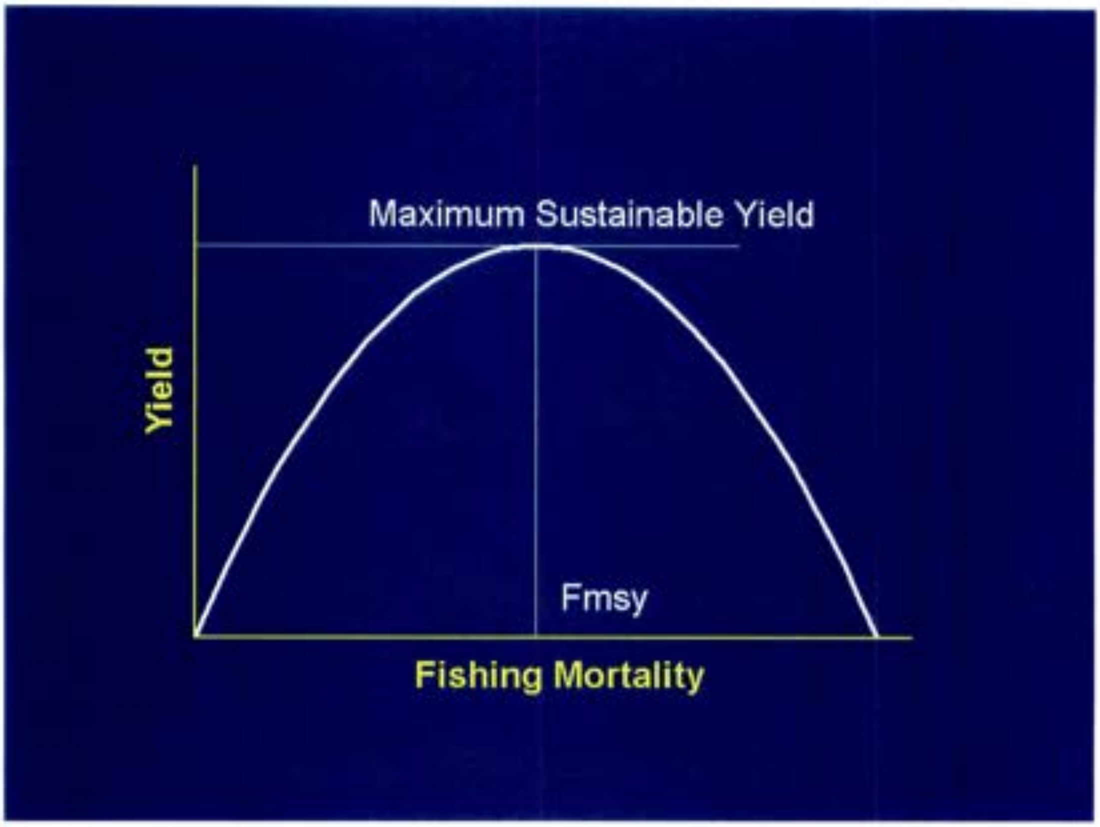
Simple simulation

One million eggs/young fish suffer Z=0.1 (d^{-1} on average) for 100 days. Z varies from year to year about this average, with SD=0.02 (CV=20%)

Resulting distribution of recruitment obtained:



Mean recruitment = 265.3, 3 over 1000 (max>2300)



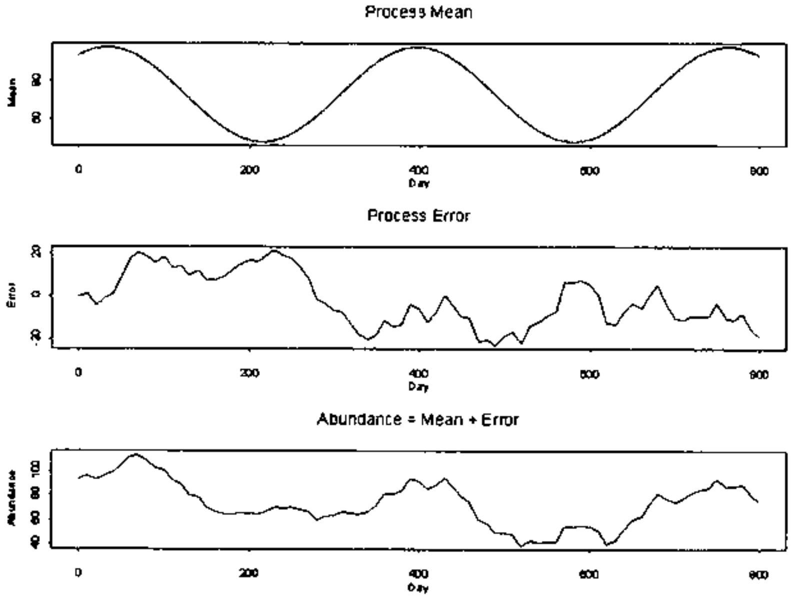
Topics to cover

- Types of uncertainty
- Describing uncertainty
  - Fisherian CI and SEs, Bayesian
  - Stochastic Simulation models
  - Propagating error to predictions
    - Basic methods
    - Stochastic simulation based
- Managing in the face of uncertainty
  - Burdens of proof and the precautionary approach
  - Problems with ad hoc "conservative" approaches
  - Decision analysis

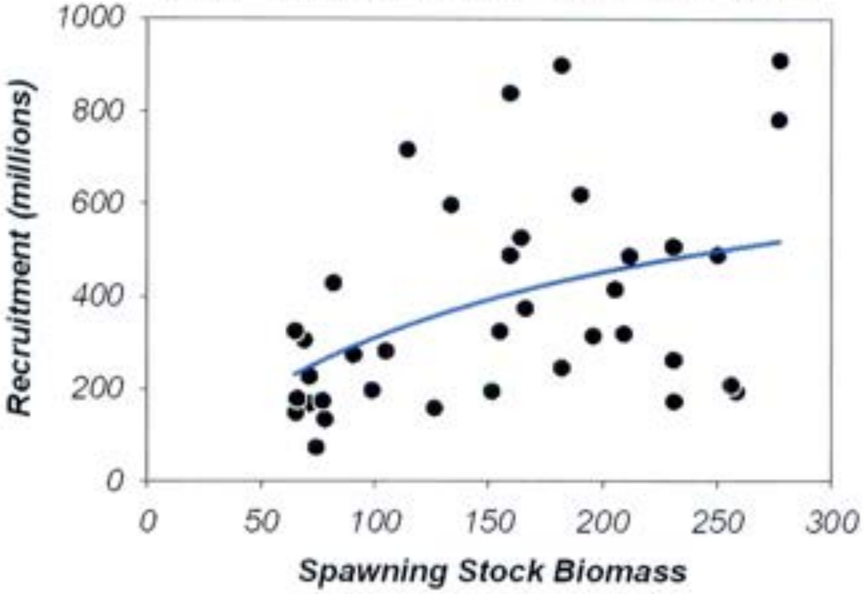
Types of uncertainty

- Natural variation (process error)
- Observation error
- Uncertain states of nature
  - Parameter uncertainty
  - Structural uncertainty (model misspecification)
  - Process errors sometimes put here
- Implementation uncertainty
  - Mistakes (ignoring discards, unaccounted for catch,...)
  - Changing goals

A closer look at natural variation



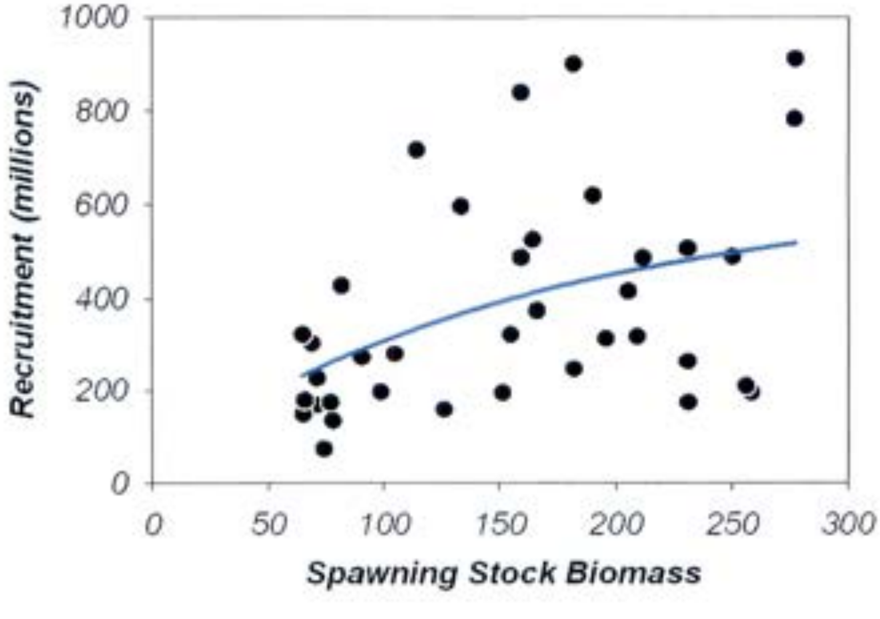
Observed recruitment =F(spawning stock)
+ error
error = process error + observation error



Slide from Steve Murawski

Observed recruitment =F(spawning stock)
+ G(temperature)+error
error = process error + observation error

Temperature = expected value + error



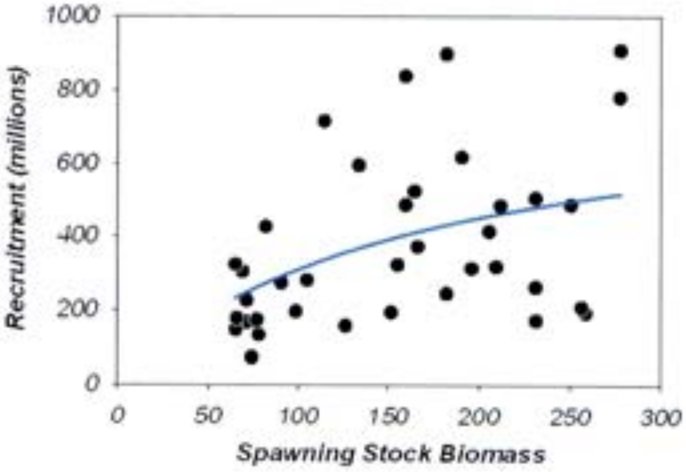
Fisherian (conventional) approach

- **Parameters are fixed quantities**
- **Confidence intervals and standard errors are two common descriptors of the (hypothetical) distribution of our estimate if we were able to repeat our sampling process**
- **Hypothetical because this would require rerunning the world.**

$$R = \alpha S e^{-\beta S} e^{\varepsilon} \xrightarrow{\text{Observation error}} \text{Observed R} \neq \text{R}$$

$$\varepsilon \overset{iid}{\sim} N(0,\sigma^2) \leftarrow \text{Process error}$$

$$\theta = \{\alpha, \beta, \sigma^2\} \xrightarrow{\text{Parameter uncertainty}} \hat{\theta} \neq \theta$$



Why can uncertainty affect the best decision?

1. Because of our attitudes to risk

Are you a gambler? How big risk are you willing to take?

Option A: $10, guaranteed

Option B: 50% chance to lose $200 versus 50% chance to win $400

Expected value of A is $10

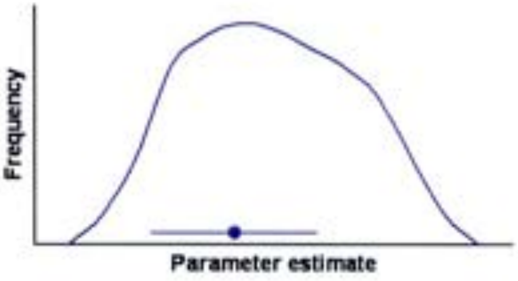
Expected value of B is $100

Confidence interval

- If we were able to repeat our sampling many times, a 95% confidence interval would overlap the true value 95% of the time.
- This is not the same as saying there is a 95% probability the true value is in the interval

Standard error

- This is the standard deviation of the estimated quantity (parameter or something calculated from parameters).
- Often "incorrectly" used as though it describes the distribution of the parameter (e.g., in risk assessment).



Ways of estimating standard errors and confidence intervals

- Distributional theory (usually normal)
- Asymptotic approximations
  - Approximations can be for both distribution and propagation of errors
- Jackknife and bootstrap
  - Replace normal assumptions with calculations
  - Still make assumptions
  - Perform best when sample sizes are large

Standard asymptotic inference in nonlinear regression and max likelihood

- **First obtain an asymptotic variance-covariance matrix**
- **Base inferences on t- or normal distribution and asymptotic variance covariance matrix. E.g., apply same equation to standard errors as for linear regression to obtain CIs for parameter estimates.**
- **For non-linear regression:** $\Sigma = \sigma^2_{\varepsilon}(J^TJ)^{-1}$
- **For general maximum likelihood:** $\Sigma = -H^{-}$
- **For quantities calculated from parameters use delta method (propagates errors)**

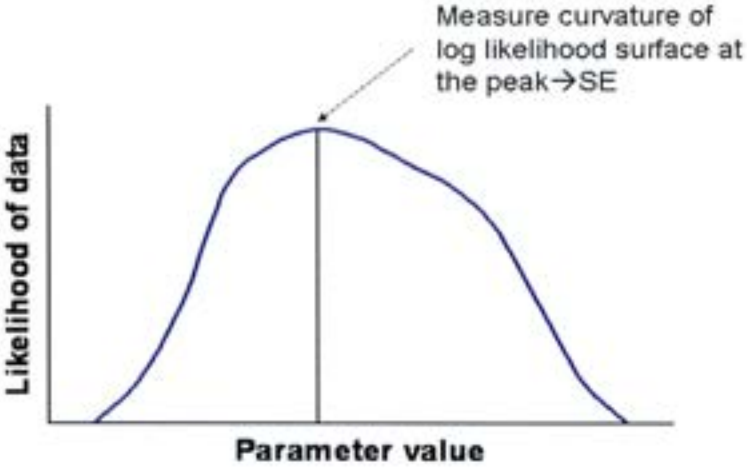
- Inferences depend upon the variance-covariance matrix:

$$\Sigma = \begin{bmatrix} \sigma^2{}_{11} & \sigma^2{}_{12} & \cdots & \sigma^2{}_{1j} & & \sigma^2{}_{1p} \\ \sigma^2{}_{21} & \sigma^2{}_{22} & \cdots & \sigma^2{}_{2j} & \cdots & \sigma^2{}_{2p} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \sigma^2{}_{i1} & \sigma^2{}_{i2} & \cdots & \sigma^2{}_{ij} & \cdots & \sigma^2{}_{ip} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \sigma^2{}_{p1} & \sigma^2{}_{p2} & \cdots & \sigma^2{}_{pj} & & \sigma^2{}_{pp} \end{bmatrix}$$

- Diagonal elements are variances of parameter <u>estimates</u>, off-diagonals are covariances.

$$\hat{\theta}_1 \pm 1.96\sqrt{\hat{\sigma}^2_{11}}$$

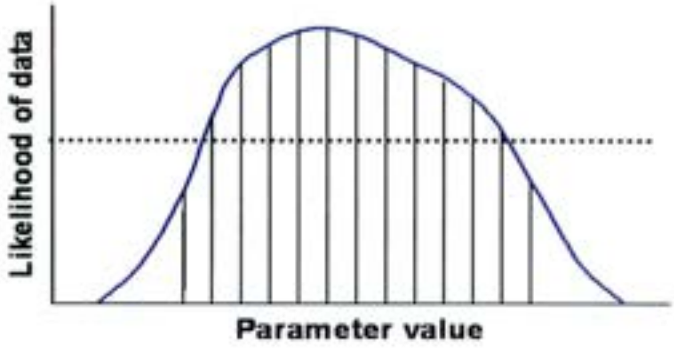
Graphical portrayal of the basis for asymptotic standard errors


Measure curvature of log likelihood surface at the peak→SE

Likelihood profile procedure

- Find the MLE
- Fix the parameter of interest over a range (above and below the best estimate)
- Find the MLE for these "reduced" models (with the target parameter fixed at a range of values).
- Find the range of fixed values that do not degrade the fit (in terms of likelihood) too much. This defines a confidence interval.

Graphical portrayal of likelihood profile method



- Still asymptotic
- Not as sensitive to linearity
- Can produce non-symmetric confidence intervals

Bootstrap methods

- Basic idea is to pretend that frequency of observations in data approximates true probability density function. (observed frequency is called empirical pdf)
- Resample (with replacement) from the observed data to obtain a pseudo-sample
- Calculate statistics of interest for pseudo-samples
- Make inferences based on frequency distribution of statistics calculated from pseudo-samples. This estimates the distribution for the statistic of interest.

Assumptions of bootstrap procedure

- Assumes independent and identically distributed data.
- Performance can depend upon depend sample size.
- Does not assume normality for data or for statistic being evaluated.

Bootstrap advantages and disadvantages

- Is not guaranteed to work for all cases.
- Can allow confidence intervals for complex functions of the parameters that were directly estimated.
- There are more sophisticated bootstrap approaches that sometimes work better but these are more complicated to calculate.

Standard errors are estimates!

- We want data and estimation procedure so that real uncertainty is low.
- Want estimate of uncertainty to be as close to correct as possible.
- Underestimating uncertainty does not make actual uncertainty small.
- Real example: Indices of abundance based on mixed models (GLMMs) have larger estimated standard errors than those based on general linear models (GLMs). This is because the GLMs incorrectly assume all the observations are independent!

What is this Bayesian stuff anyway?

- Bayesian statistics is <u>not</u> just another method for doing things like asymptotic standard errors versus bootstrap standard errors. Different paradigm!
- For Bayesians all the parameters are random.
- Bayesians have to specify a prior probability distribution for the parameters.
  - What is it we believe before we see the data

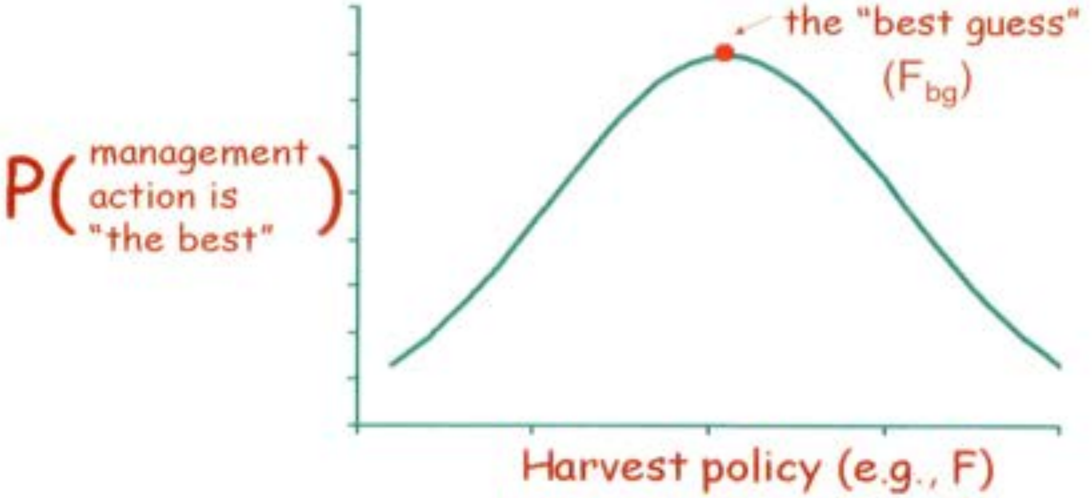
Why use the Bayesian approach

- How probable different parameter values are is really what we want to know (for risk assessment and decision analysis).
- Many uses of bootstrap and asymptotic standard errors treat the distribution of the estimate like it is the distribution of the parameters.
- This is can be reasonable approximation of Bayesian approach when our prior distributions are "flat" and the resulting "posterior distribution is not too asymmetric.
- If you want to act like a Bayesian there is no escape from priors!

Risk Attitudes - Utility

utility is used to re-scale outcomes according to a decision-maker's risk attitude

Example: Asymmetrical Outcomes



Asymmetrical Outcomes

If F_{bg} is applied to the fishery…

Why can uncertainty affect the best decision?

- Asymmetrical outcomes can alter the best decision – called a “loss function”
- Asymmetrical uncertainty distributions can alter the best decision too
- Not easy to determine when uncertainty will matter
- Wise not to assume it won’t matter (i.e., ignore uncertainty)
- See Frederick and Peterman, 1995. CJFAS 52:291-306

2. Account for uncertainty subjectively and qualitatively

Potential abuses

- justify status quo
  e.g., acid rain - "we don't know enough to act"
- justify extreme pessimism
  e.g., zero discharge - "we don't know effects so don't do anything"
- justify optimism
  e.g., cage aquaculture, northern cod fishery – "risks poorly known, and benefits are large"
- justify moderate pessimism
  e.g., 80% of F_{msy} - "build in a margin for error"

Subjective approach and burden of proof – two examples

- During the early 1990s in the southeast Atlantic quotas set for some stocks so that the upper bound for the confidence interval for F was below a target. Burden is to show that F is not too high.
- During late 1980s in California, elevated levels of some water quality parameters were prohibited. Elevated was defined by being significantly higher than background. Burden is to show there is any increase.

The Precautionary Approach

- The precautionary approach versus the precautionary principle.
- "The precautionary approach is about applying judicious and responsible fishery management practices, ..., proactively rather than reactively (once all doubt has been removed)..." (Restrepo et al. 1999)
- "The [FAO] guidelines do not explicitly call for a reversal of the burden of proof,... they conclude that if the precautionary approach is properly applied, then the burden of will be appropriately placed." (Mace and Sissenwine 2002)
- Reality is that in most US Marine cases the precautionary approach has led to subjective justification for moderate pessimism (treat FMSY as maximum rather than target...)

What to do?

- Many fisheries scientists have explored the effect of uncertainty on fishery policies
- There are no general rules of thumb
  - It depends on your fishery and on manager stakeholder attitudes to risk
- Growing consensus is to use simulation and decision-theoretic approaches to evaluating policies

What does that mean?

- Develop tools that allow you to simulate the effects of different policies on management outcomes of importance to managers and stakeholders
- Design the simulations so that they can include critical uncertainties and forecast the distribution (range) of possible consequences of a policy
- Search for policies that appear to perform well under a variety of possible true "states of nature", and that are not sensitive to assumptions included in your models
- In general, this kind of approach can be called "Decision Analysis"

Putting decision analysis in context

Risk Management

Decision Analysis

Risk Assessment

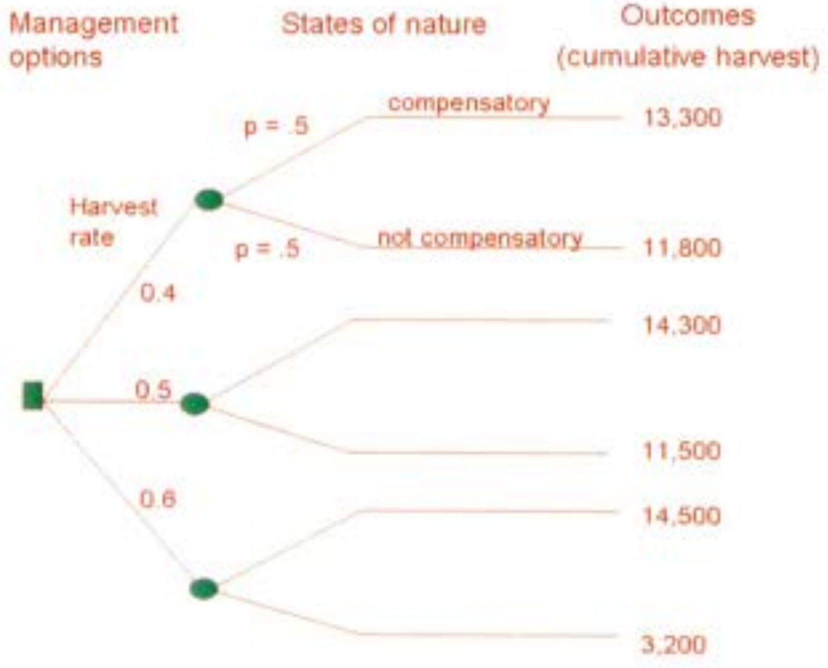
Steps of decision analysis

- Management objectives
- Management options
- Critical uncertainties - alternative states of nature
- Probabilities of alternative states
- Model to forecast outcomes
- Decision tree
- Ranked outcomes
- Sensitivity analysis

A simple example

- Management objective: maximize cumulative harvest
- Management options: alternative harvest rates
- Critical uncertainty: natural mortality hypothesis (M fixed or M decreases when F increases)
- Probabilities: who knows? 50:50
- Model: simple age-structured model, with stock-recruitment relationship
- Decision tree: ...

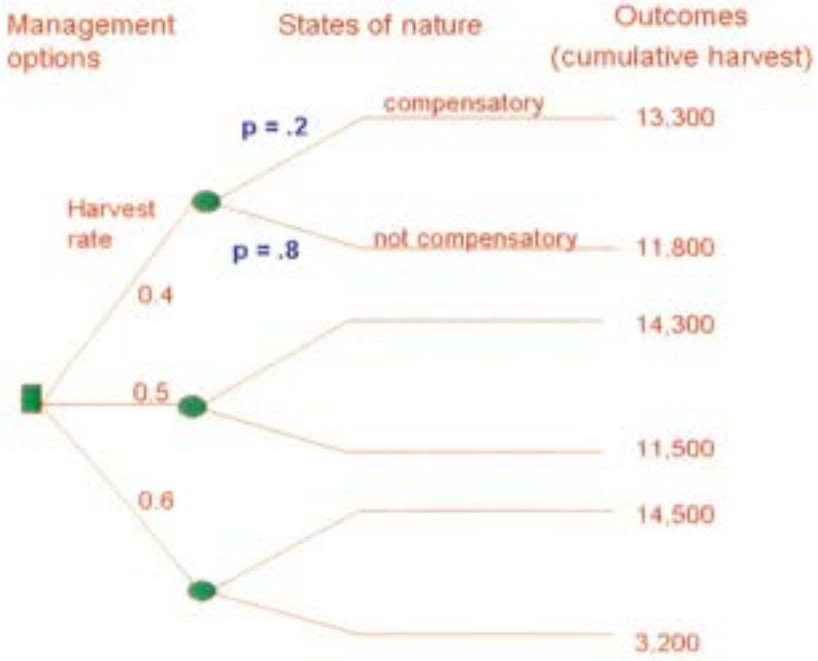
A Simple Decision Tree



Comparing management options
ranking outcomes

Option (Harvest rate)	Calculation	Uncertainty-weighted outcome
.4	.5 * 13,300 + .5 * 11,800	12,550
.5	.5 * 14,300 + .5 * 11,500	**12,900**
.6	.5 * 14,500 + .5 * 3,180	8,840

What if? - sensitivity analysis



Comparing management options
changing degrees of belief

Option (Harvest rate)	Calculation	Uncertainty-weighted outcome
.4	.2 * 13,300 + .8 * 11,800	**12,100**
.5	.2 * 14,300 + .8 * 11,500	12,060
.6	.2 * 14,500 + .8 * 3,180	5,444

Appendix E.
Uncertainties in the Lake Ontario Ecosystem

Uncertainties in the Lake Ontario Ecosystem

T.J. Stewart
University of Toronto and
Ontario Ministry of Natural Resources
NY Sea Grant Workshop
October 24, 2005

Abstract

In this presentation, I present my perspective on the major uncertainties in the Lake Ontario ecosystem. My purpose is to stimulate discussion and provide a framework for the consideration of uncertainty. I examine the idealized management decision process as the context for our interest in uncertainty and classify sources and scales of uncertainty in this process. Using examples from Lake Ontario, I propose Tom's Top Ten Lake Ontario Uncertainties.

Overview of Presentation

- The management decision process as the context for our interest in uncertainty
- Sources and scales of uncertainty
- Examples from Lake Ontario:
  Tom's Top Ten Lake Ontario Uncertainties

The management decision process as the context for our interest in uncertainty

IDEALIZED MANAGEMENT DECISION PROCESS

System State

Societal Benefits & Perceptions

Scientific Understanding

Management Objectives

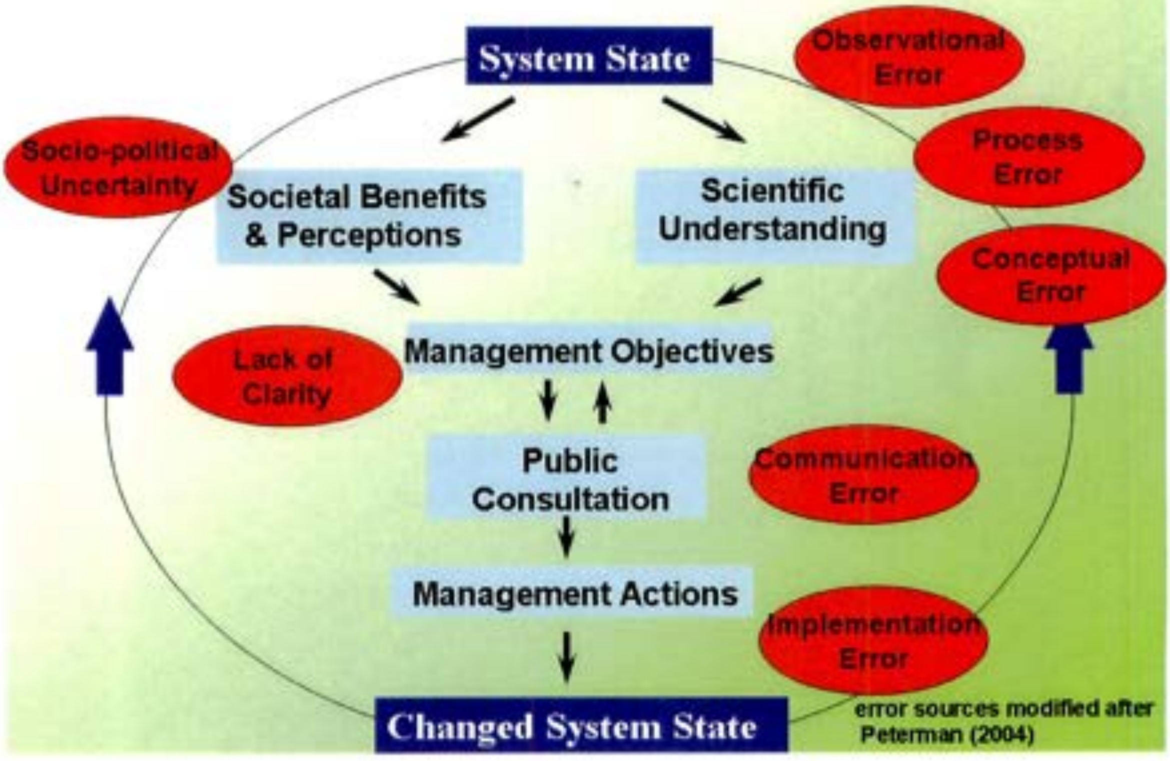
Public Consultation

Management Actions

Changed System State

Sources of Uncertainty

MANAGEMENT DECISION PROCESS- Sources of Uncertainty



System State

Observational Error

Process Error

Socio-political Uncertainty

Societal Benefits & Perceptions

Scientific Understanding

Conceptual Error

Lack of Clarity

Management Objectives

Public Consultation

Communication Error

Management Actions

Implementation Error

Changed System State

error sources modified after Peterman (2004)

Scales of Uncertainty

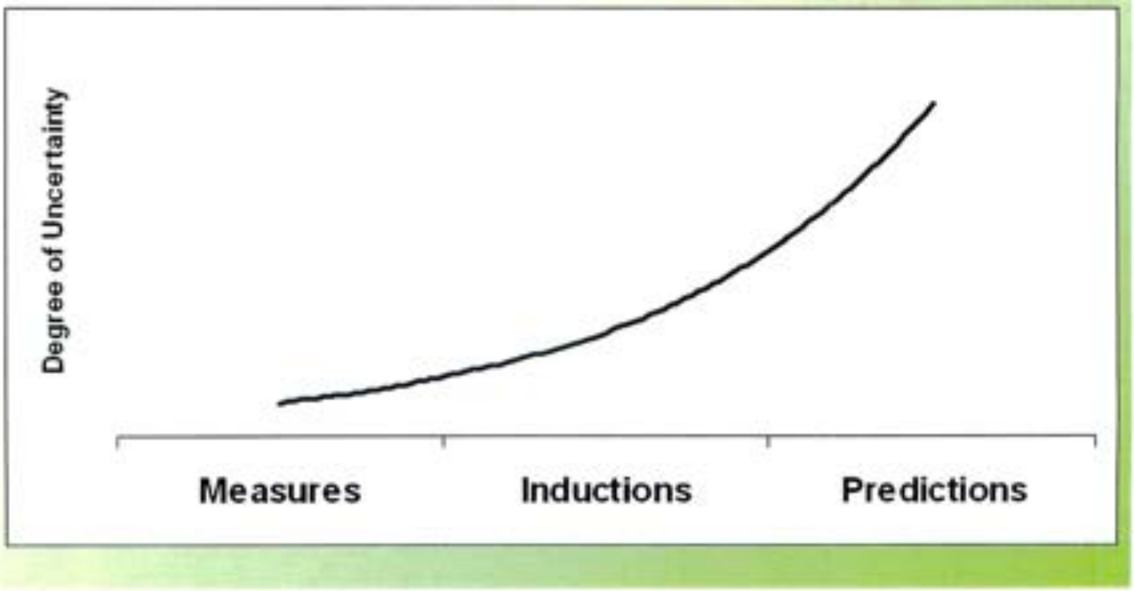
Scale of uncertainties

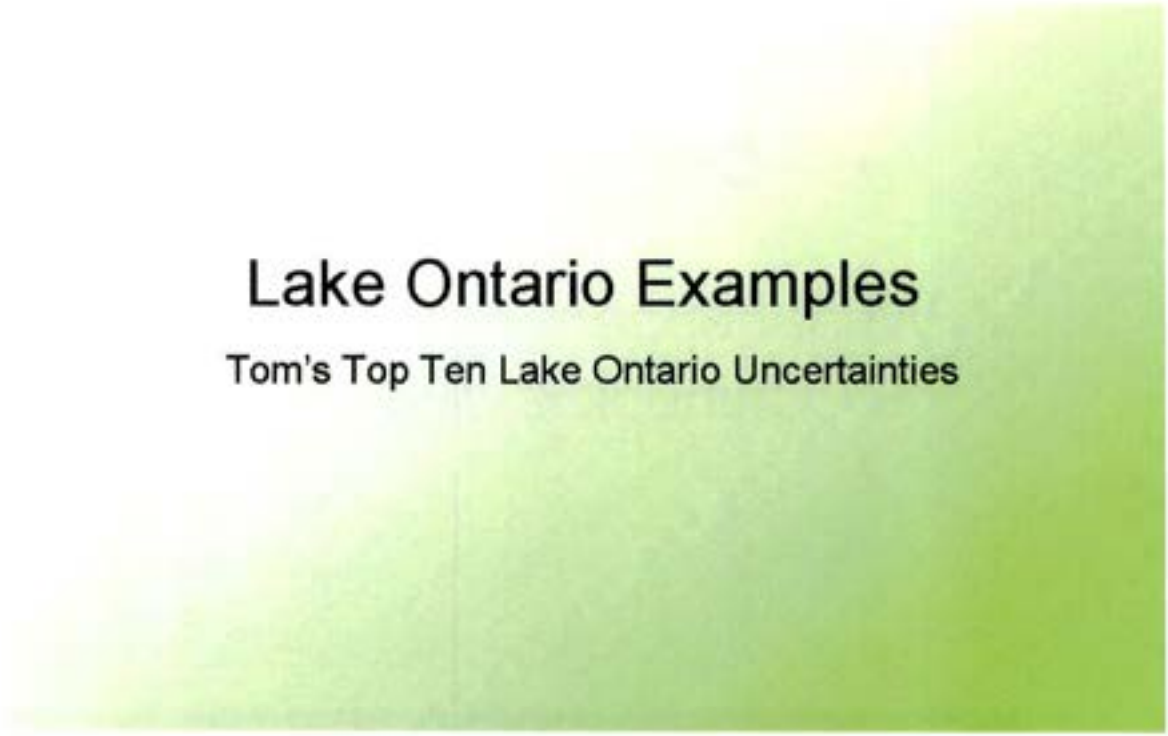
	Small	Large
Observational Error	Determining the age of a fish	Estimating population abundance
Process Error	Variation around size-at-age	Variation in recruitment
Conceptual Error	Overgeneralization	Thinking that invasive species only have negative impacts
	Poor choice of a statistical model	Missing important species interactions in models

Scale of uncertainties

	Small	Large
Socio-political Uncertainty	Reaction to a poor fishing season	Change in government or fiscal priorities
Communication Error	Oversimplification of ecosystem processes	Not communicating key ecosystem drivers
Lack of Clarity	Wishy-washy management policy or objectives	No policy (eg. wild production of Chinook)
Implementation Error	Watered down harvest reduction	Not monitoring compliance

Another scale issue





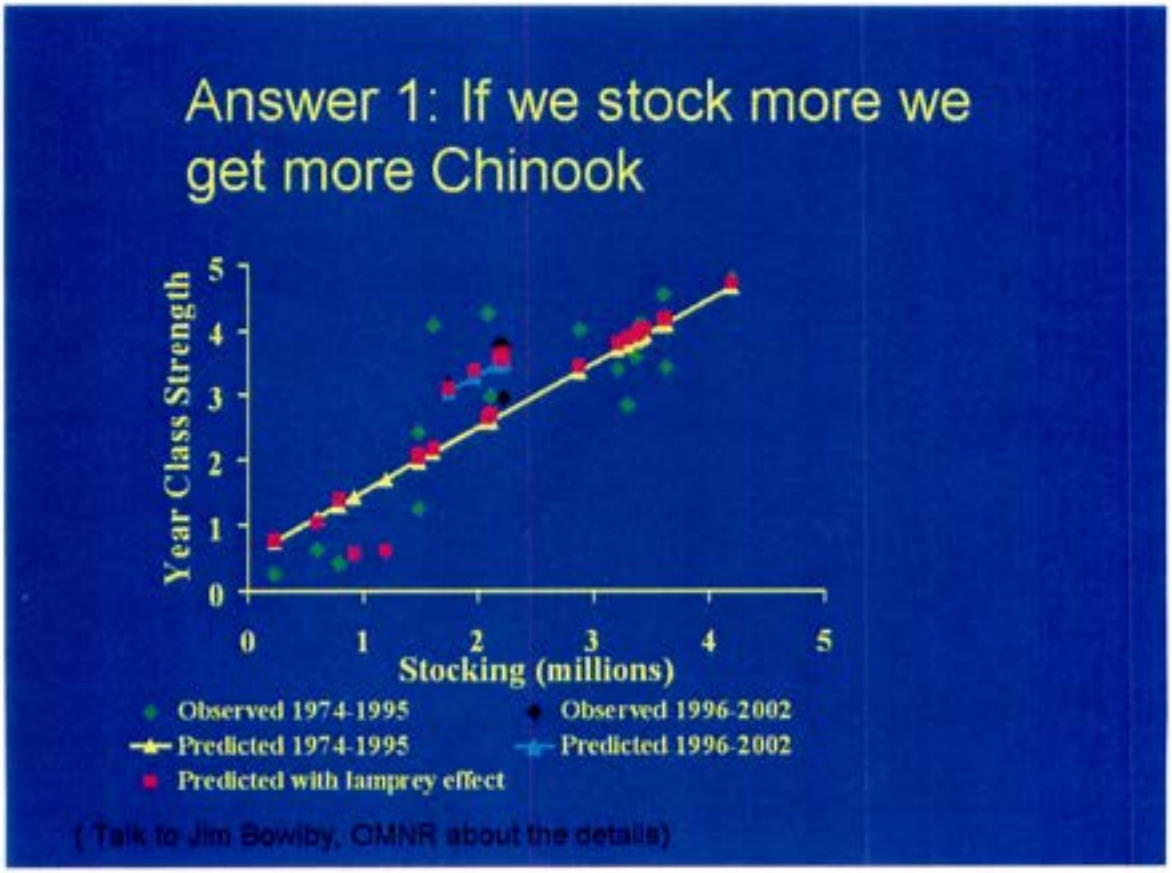
Lake Ontario Examples

Tom's Top Ten Lake Ontario Uncertainties

N?

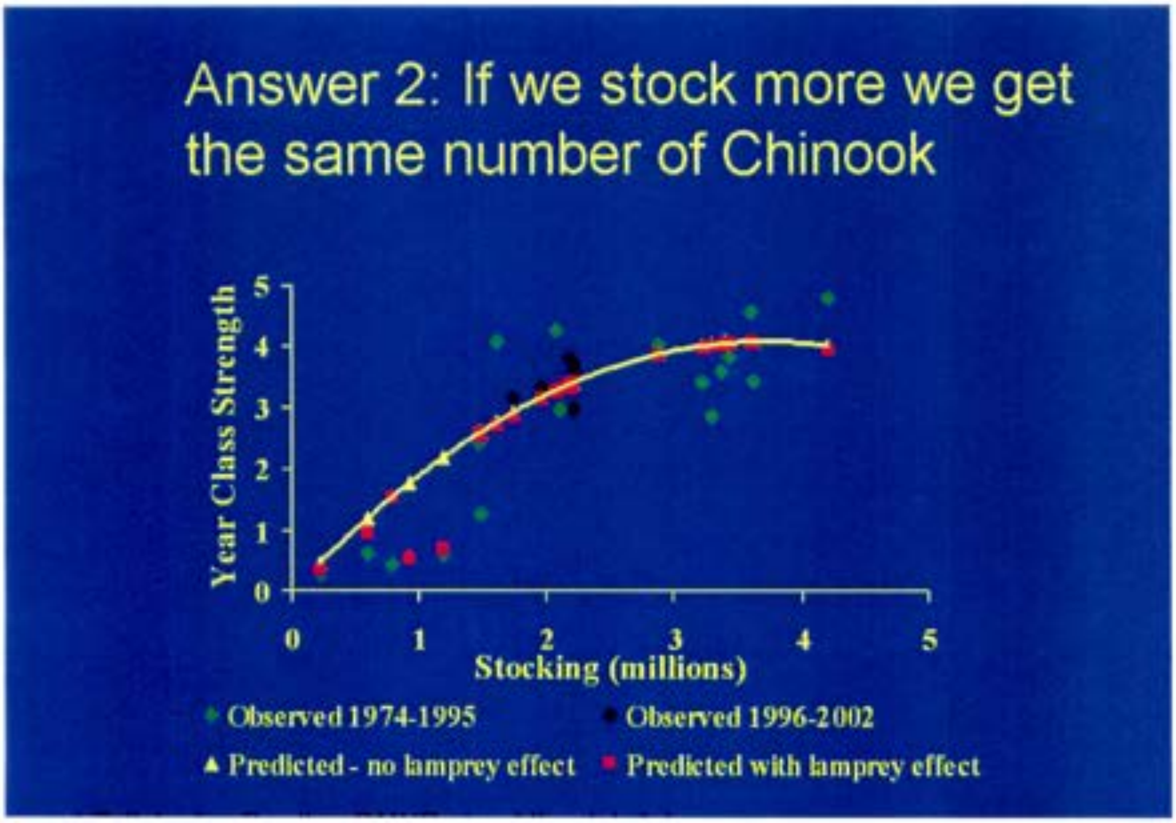
Chinook Recruitment

What happens to the abundance of Chinook if we stock more?

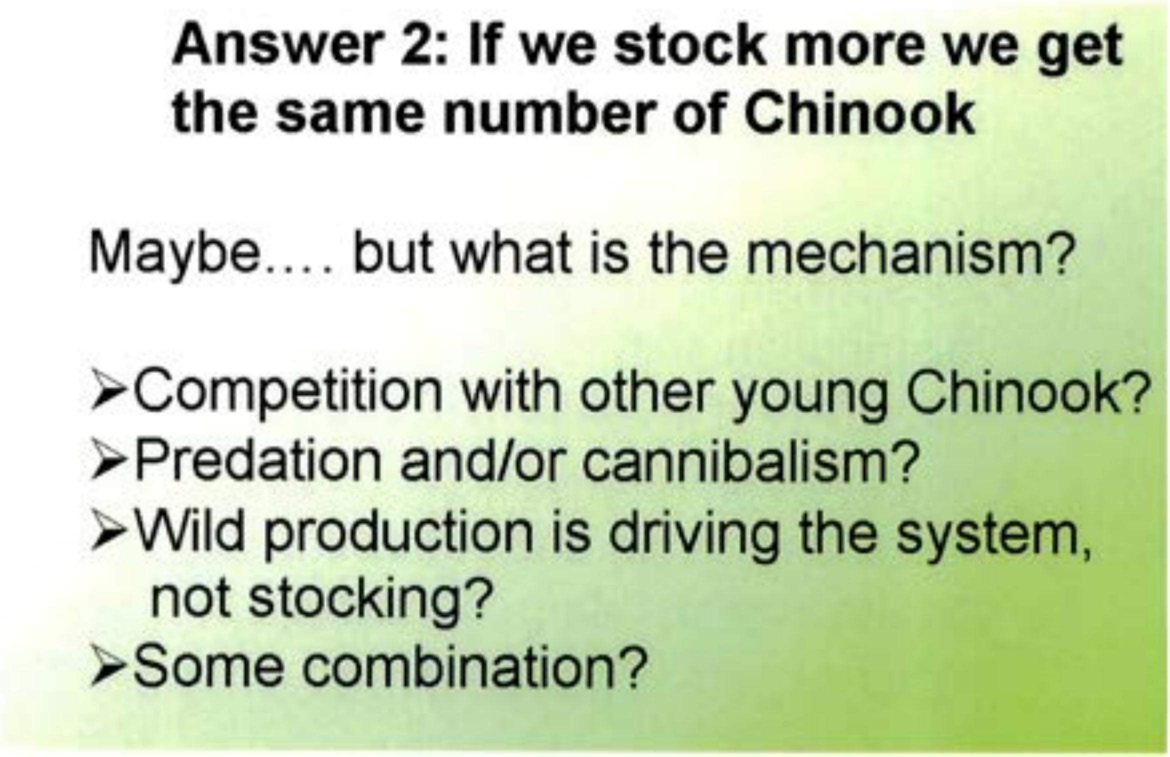


Answer 1: If we stock more we get more Chinook

(Talk to Jim Bowlby, OMNR about the details)



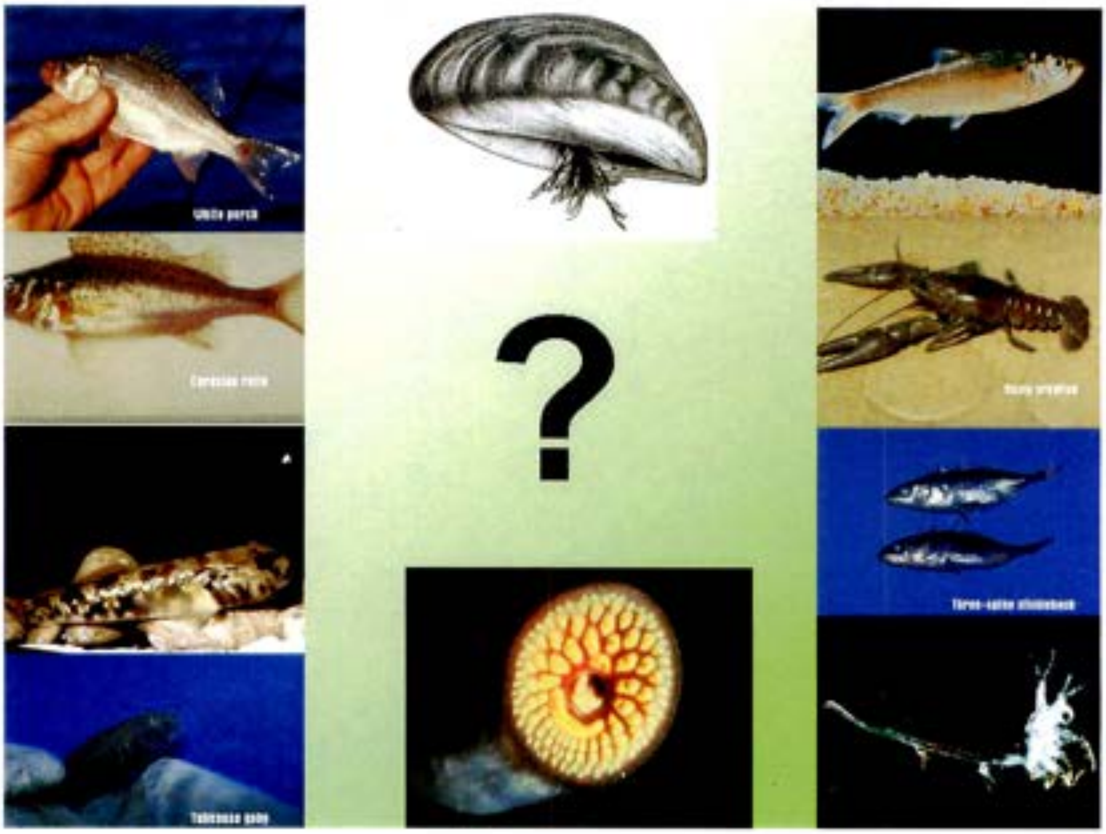
Answer 2: If we stock more we get the same number of Chinook



Answer 2: If we stock more we get the same number of Chinook

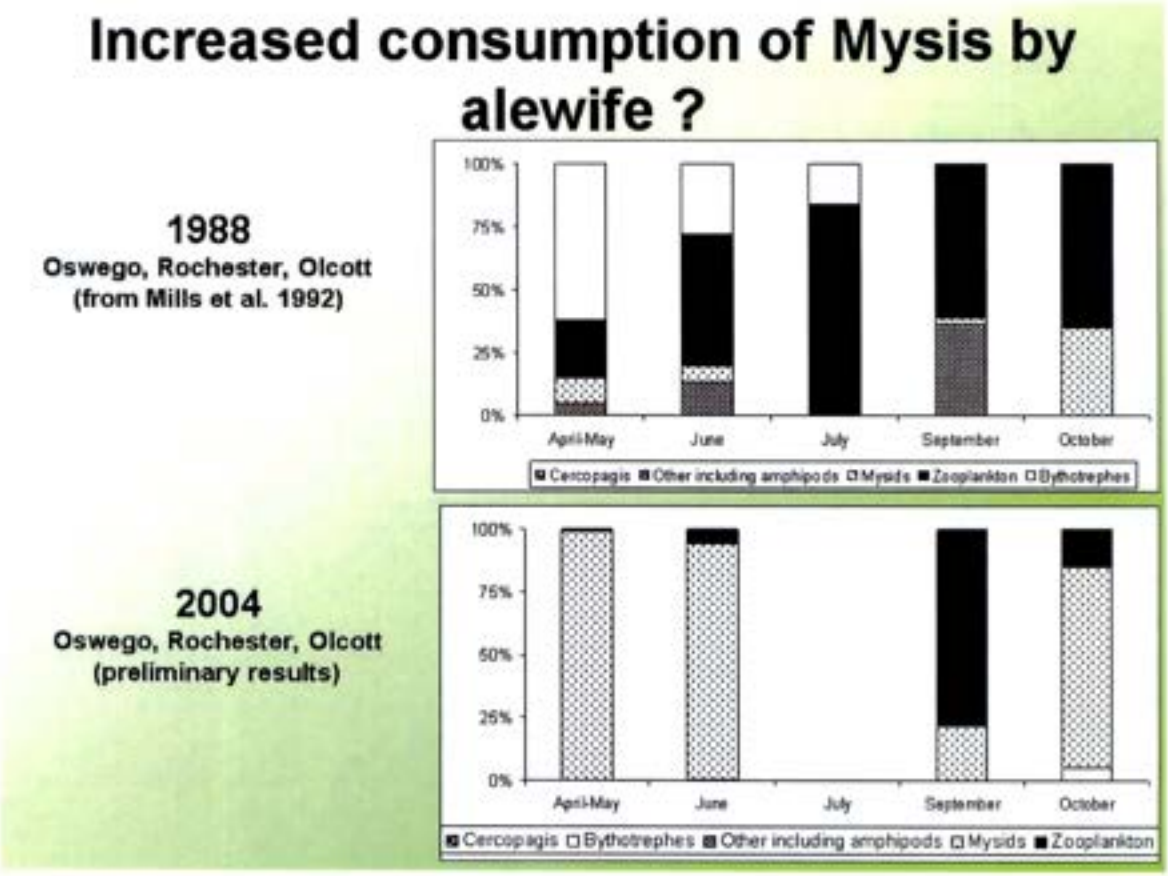
Maybe…. but what is the mechanism?

- Competition with other young Chinook?
- Predation and/or cannibalism?
- Wild production is driving the system, not stocking?
- Some combination?



Diet and distribution shifts of offshore prey fish, including goby

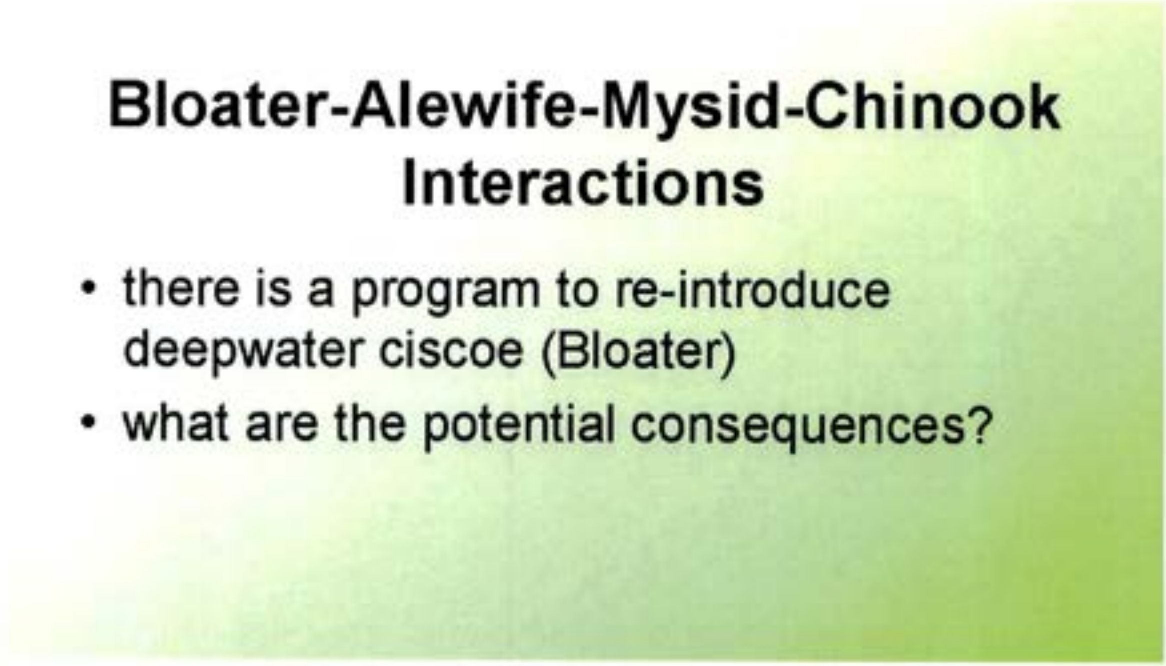
- O'Gorman et al. (2000) documented a distribution shift to deeper depths by alewife and juvenile lake trout
- Walsh et al. (in prep.) documented increased depth distribution of round gobies (up to 150 m. of water)
- What are the consequences?



Increased consumption of Mysis by alewife ?

1988
Oswego, Rochester, Olcott
(from Mills et al. 1992)

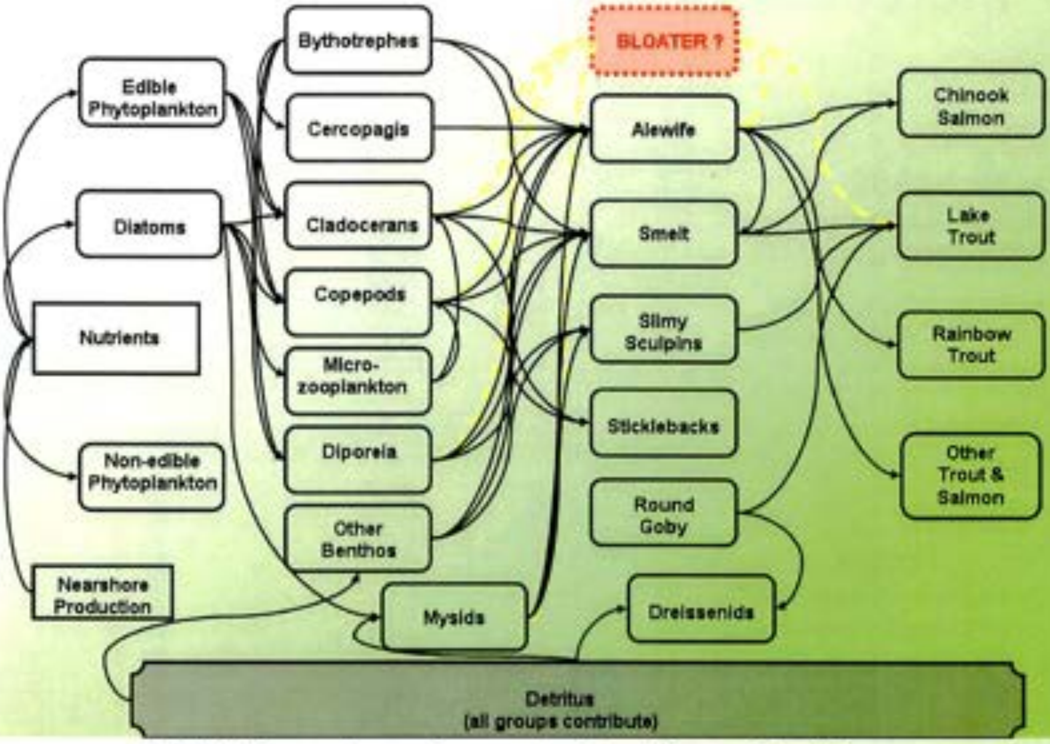
2004
Oswego, Rochester, Olcott
(preliminary results)



Bloater-Alewife-Mysid-Chinook Interactions

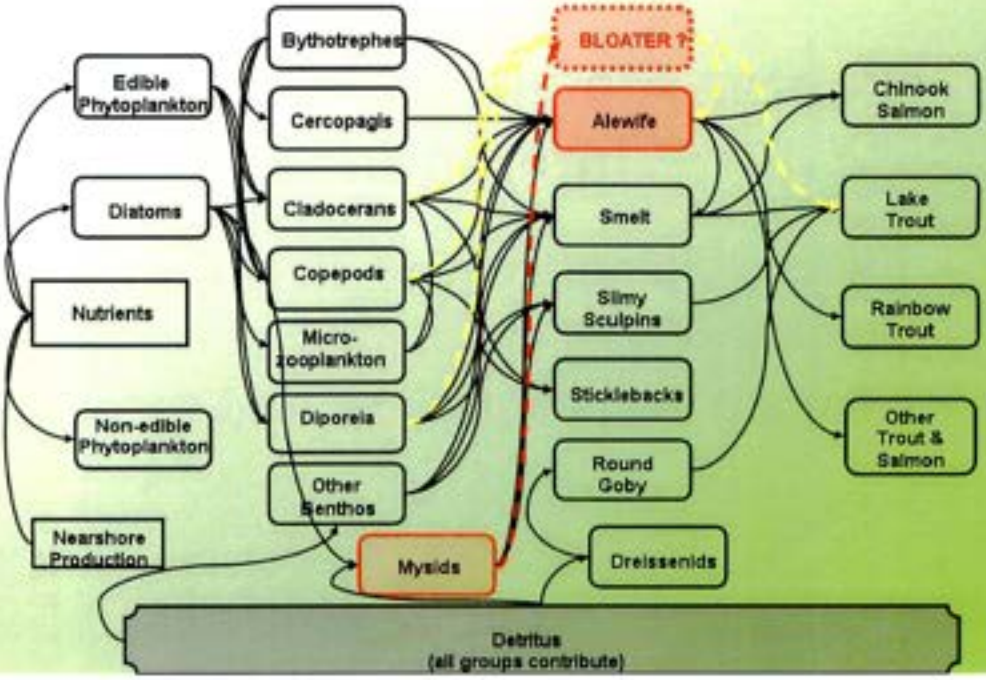
- there is a program to re-introduce deepwater ciscoe (Bloater)
- what are the potential consequences?

Simplified Lake Ontario Offshore Food Web



Bythotrephes
BLOATER ?
Edible Phytoplankton
Cercopagis
Alewife
Chinook Salmon
Diatoms
Cladocerans
Smelt
Lake Trout
Copepods
Nutrients
Slimy Sculpins
Rainbow Trout
Micro-zooplankton
Sticklebacks
Non-edible Phytoplankton
Diporeia
Other Trout & Salmon
Round Goby
Other Benthos
Nearshore Production
Mysids
Dreissenids
Detritus
(all groups contribute)

Will there be adequate Mysid production to support alewife and bloater?



Bythotrephes
BLOATER ?
Edible Phytoplankton
Cercopagis
Alewife
Chinook Salmon
Diatoms
Cladocerans
Smelt
Lake Trout
Copepods
Nutrients
Slimy Sculpins
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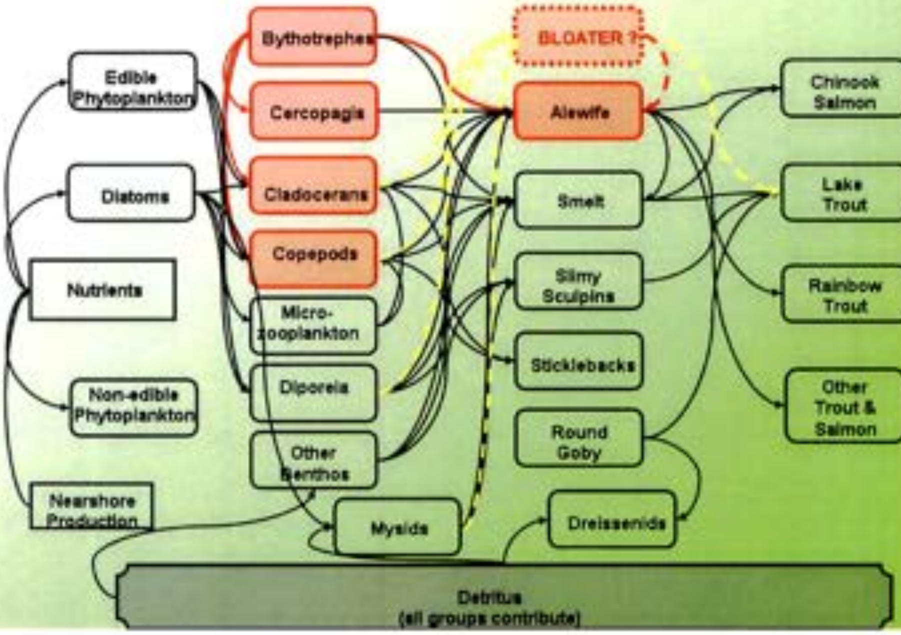
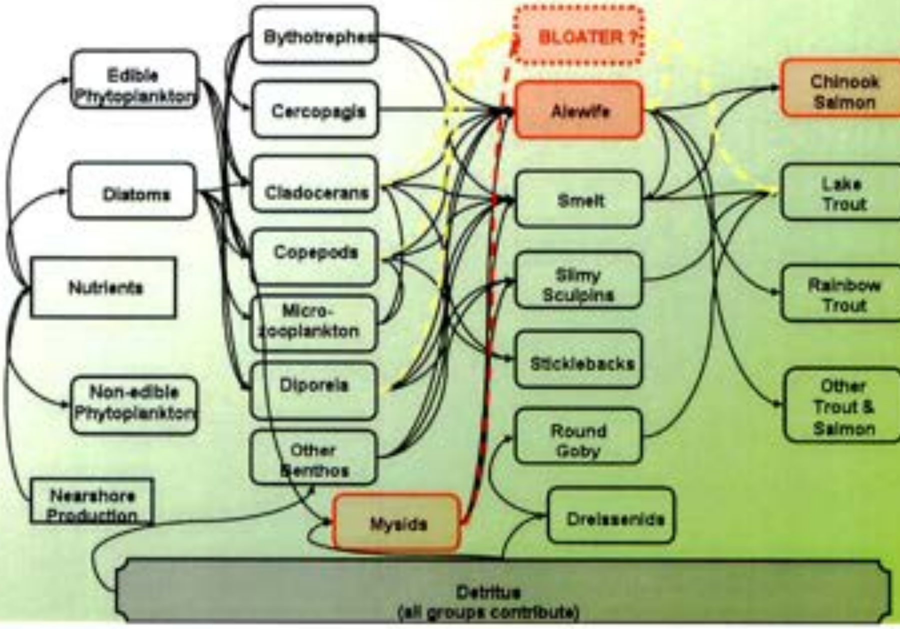
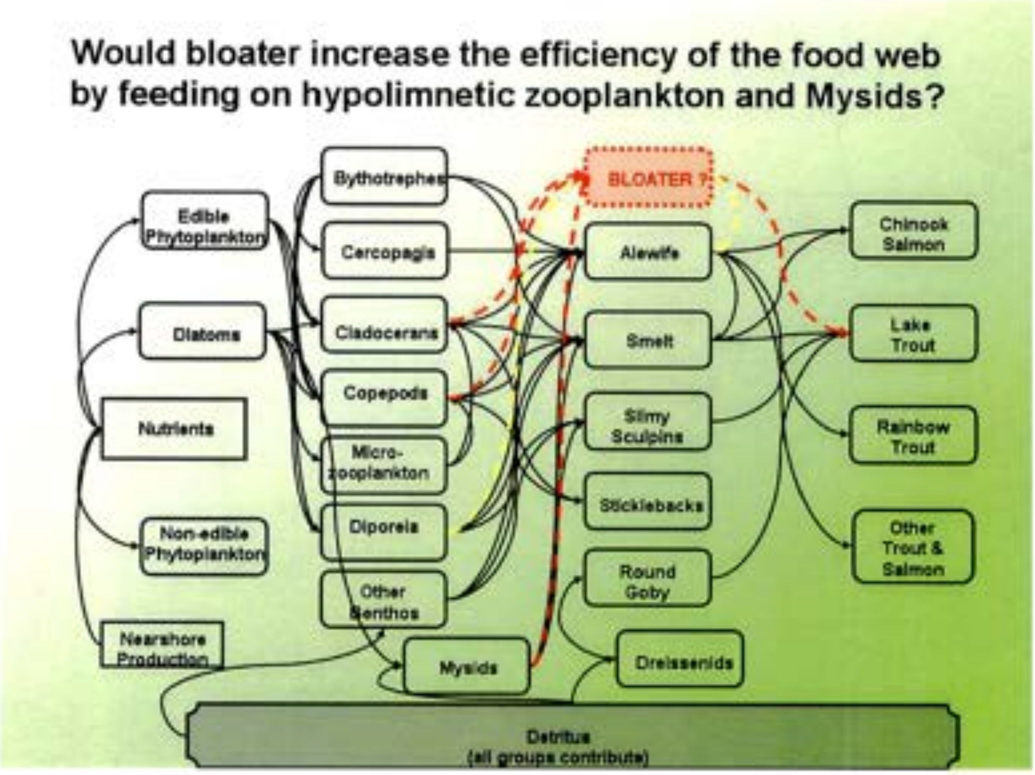
Micro-zooplankton
Sticklebacks
Diporeia
Non-edible Phytoplankton
Other Trout & Salmon
Round Goby
Other Benthos
Nearshore Production
Mysids
Dreissenids
Detritus
(all groups contribute)

Could bloater reduce alewife abundance thus releasing *Bythotrephes* and *Cercopagis* from predation and increasing pressure on zooplankton prey?



Are there states of the food web supporting recreational salmonid fisheries and sustainable biomasses of alewife, bloater and Mysids?





Would bloater increase the efficiency of the food web by feeding on hypolimnetic zooplankton and Mysids?

The nearshore phosphorus shunt

(Hecky et al. 2004, CJFAS, 61 1285-1293)

- a conceptual model describing a change in nearshore to offshore nutrient and energy fluxes as a result of mussels
- increased deposition of nutrients in the nearshore
  - higher downstream discharge
  - poorer water quality in the nearshore
  - increased Cladophora growth
  - **<u>loss of production potential to the offshore</u>**

Anticipating thresholds and irreversible states of the system

- Bay of Quinte walleye (we can't go back to the 1980s)
- Lake whitefish (changed growth, recruitment, and distribution patterns?)
- A new alewife depth distribution?
- Phosphorus shunt- is phosphorus cycling different now because of mussels?
- Is wild production going to dominate chinook recruitment?
- Can we anticipate other thresholds and irreversible states?

Determining the consequences of being wrong

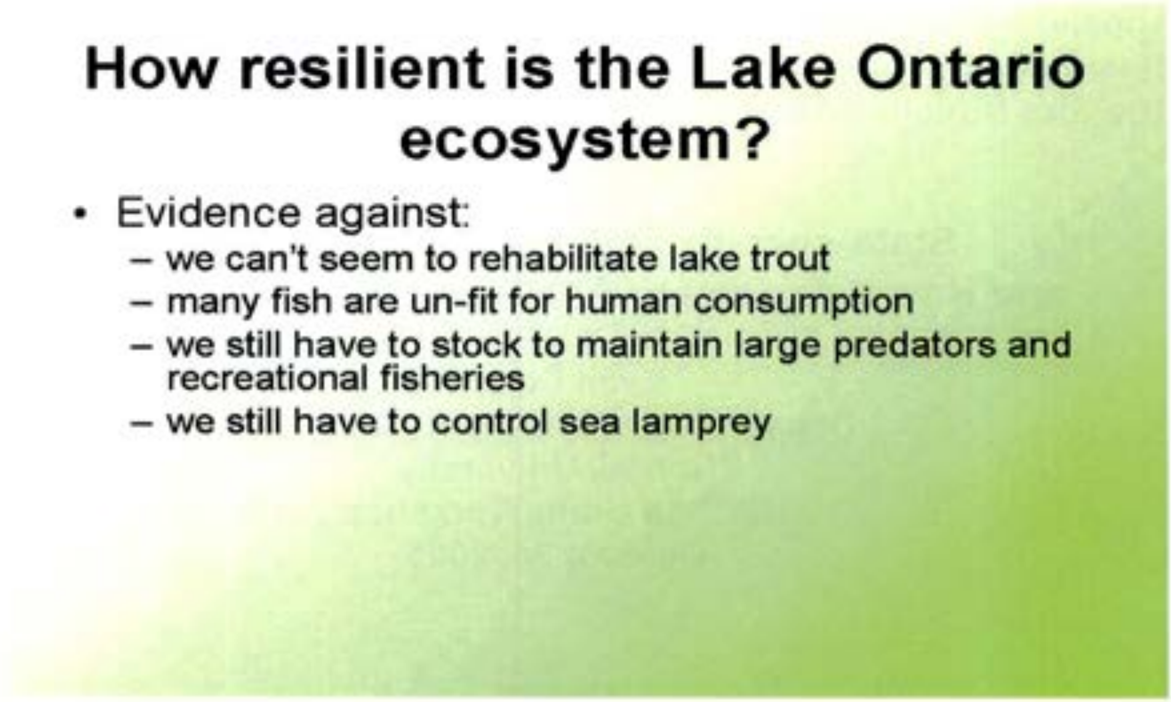
- Stocking
  - What are the consequences of over-stocking?
  - What are the consequences of under-stocking?
  - Are the costs comparable in both cases, how do we decide?
- Bloater Re-introduction
  - What are the consequences of not trying to rehabilitate bloater?
  - What are the consequences of trying, but failing?
  - What are the consequences of succeeding, but having to give up some alewife and salmon production?

No conceptual paradigm for the current mixture of mostly non-native species

- Our mixture of species has no evolutionary history
- We are missing knowledge concerning these novel situations and interactions
- We are missing knowledge about the consequences of actions and events like re-introductions, or appearance of new exotics
- no way of getting that knowledge

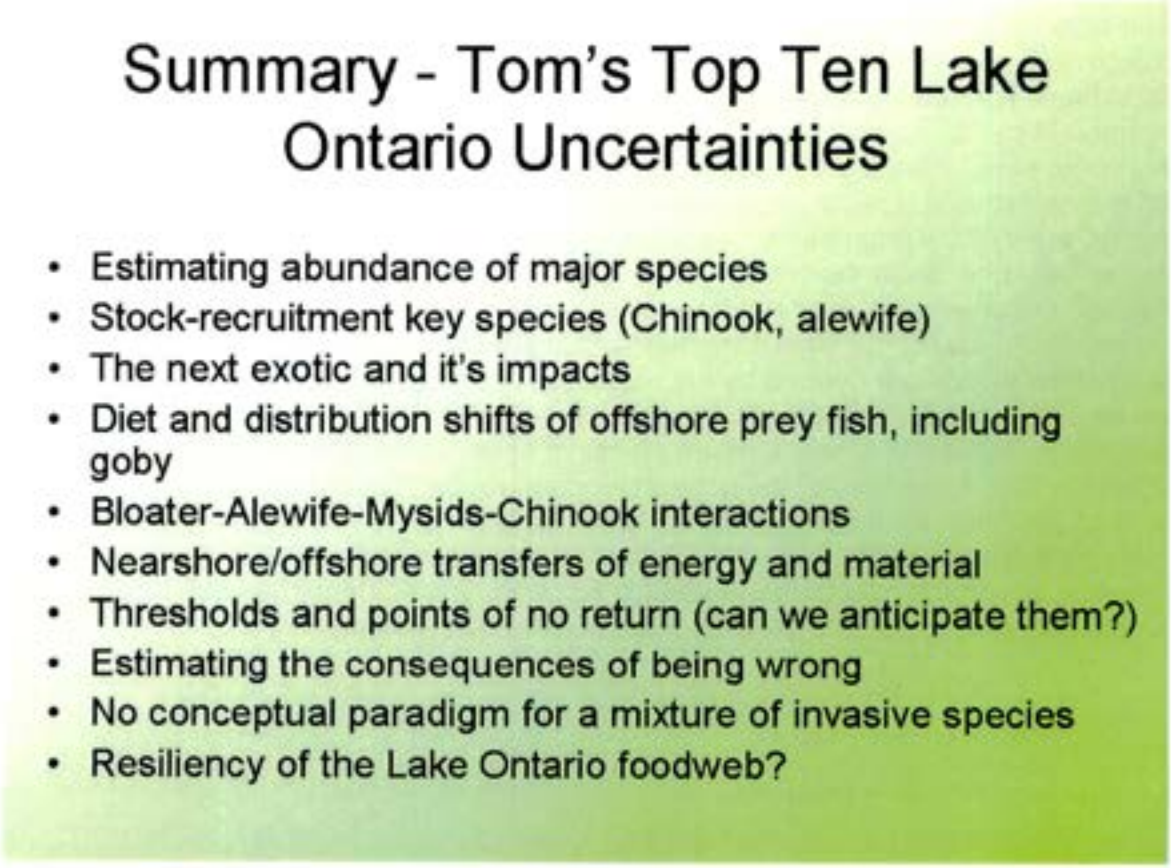
How resilient is the Lake Ontario ecosystem?

- Evidence for:
  - we have yet to see a catastrophic change in salmon production and the recreational fishery economy despite phenomenal changes in the foodweb
  - we did see dramatic changes in the whitefish population and associated commercial fishery but it may have stabilized?
  - there has been no new species extirpations since the GLWQA
  - biodiversity has increased (albeit through exotic invasion and introductions)



How resilient is the Lake Ontario ecosystem?

- Evidence against:
  - we can't seem to rehabilitate lake trout
  - many fish are un-fit for human consumption
  - we still have to stock to maintain large predators and recreational fisheries
  - we still have to control sea lamprey



Summary - Tom's Top Ten Lake Ontario Uncertainties

- Estimating abundance of major species
- Stock-recruitment key species (Chinook, alewife)
- The next exotic and it's impacts
- Diet and distribution shifts of offshore prey fish, including goby
- Bloater-Alewife-Mysids-Chinook interactions
- Nearshore/offshore transfers of energy and material
- Thresholds and points of no return (can we anticipate them?)
- Estimating the consequences of being wrong
- No conceptual paradigm for a mixture of invasive species
- Resiliency of the Lake Ontario foodweb?

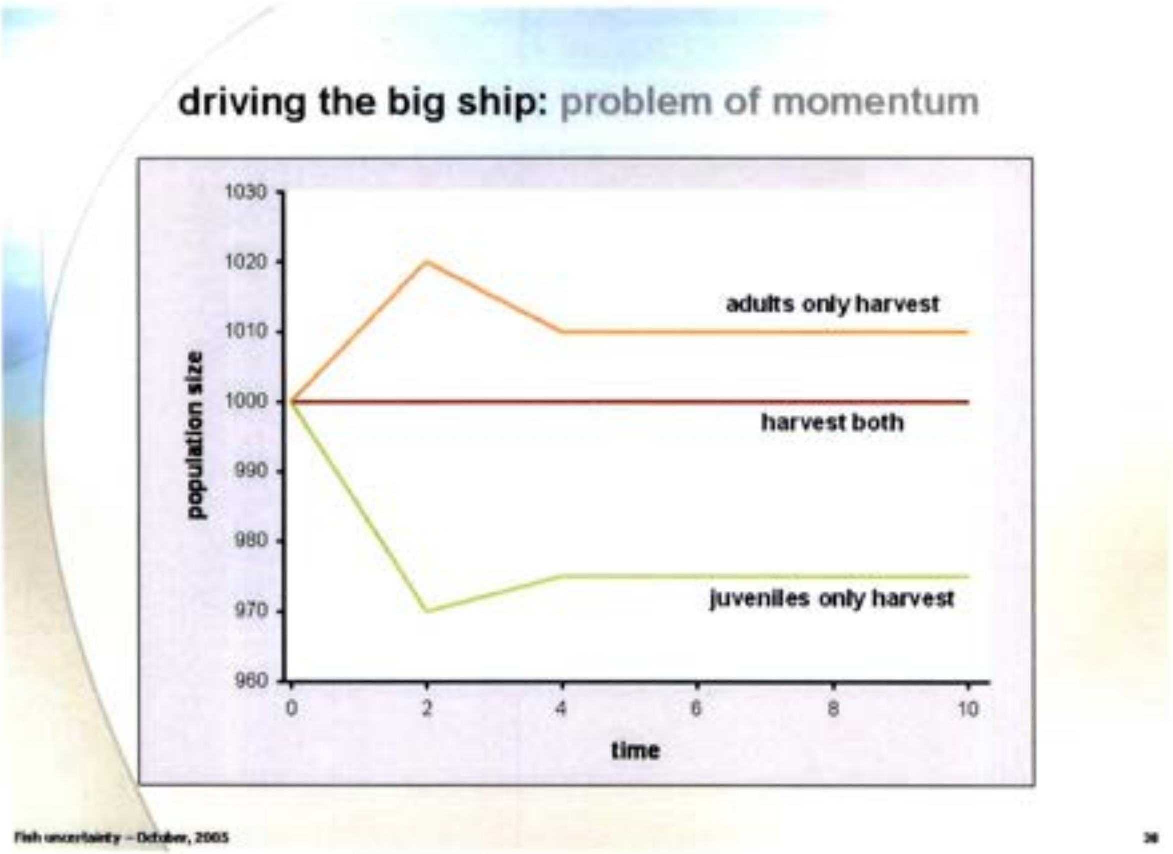
Appendix F.
State-specific Optimal Decision Theory and How it Applies to Age/Size Structured Models

State-specific Optimal Decision Theory and How it Applies to Age/Size Structured Models

Evan Cooch
Department of Natural Resources
Cornell University
NY Sea Grant Workshop
October 24, 2005

Abstract

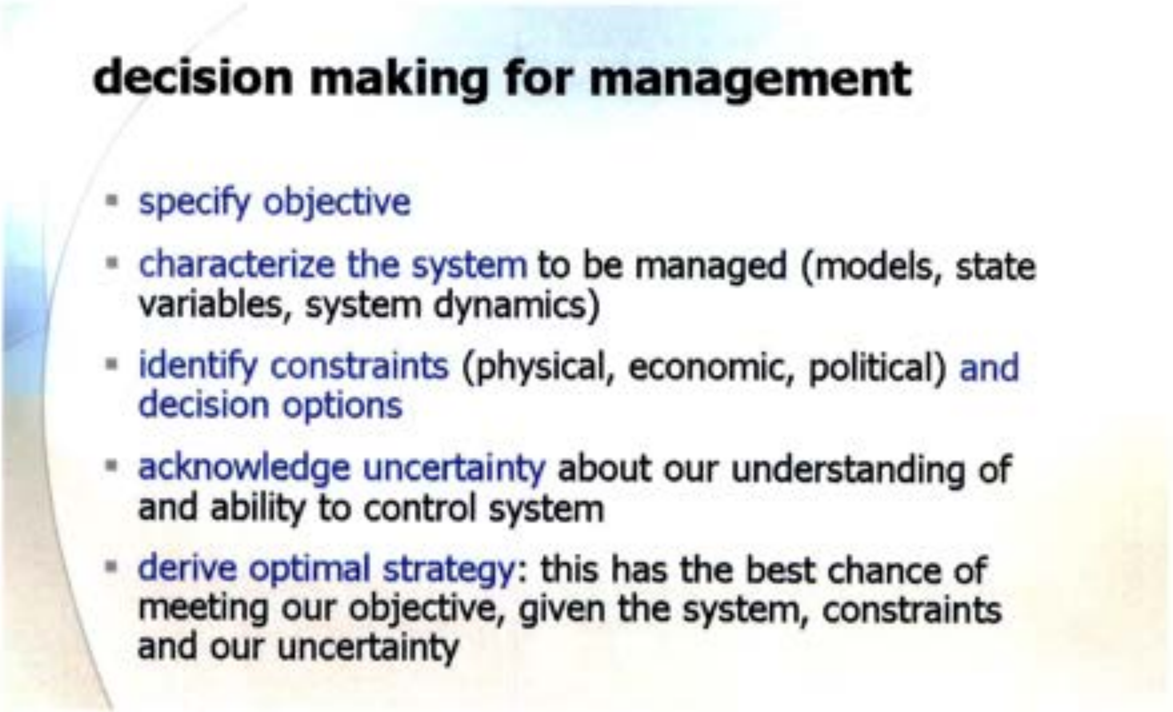
Most harvest literature has focused on the question of maximizing yield over an infinite time horizon. However, increasingly, there is interest in cases where the management objective to control the target population at a steady-state where the equilibrium abundance is often significantly below the carrying capacity. Achieving such an objective by harvest can be complicated by the presence of significant structure (age or stage) in the target population. In such cases, optimal harvest strategies must account for differences among age- or stage-classes of individuals in their relative contribution to the demography of the population. In addition, structured populations are also characterized by transient non-linear dynamics following perturbation, such that even under an equilibrium harvest, the population may exhibit significant momentum, increasing or decreasing before cessation of growth. For simple models with linear dynamics, we show that the equilibrium harvest conditions are defined by the reproductive values of each age- or stage-class at the time of harvest. Furthermore, the state-space of the optimal harvest vector may be extremely narrow if the management objective seeks to achieve an equilibrium value while simultaneously constraining the desired momentum and structure of the population at equilibrium. Although stochastic optimization techniques can be shown to provide an optimal policy to achieving control under a particular momentum constraint, it can be shown that if there is uncertainty about the state of the system at the time of harvest, that the ability to optimally control the population becomes extremely unlikely.



driving the big ship: problem of momentum

Fish uncertainty – October, 2003

38



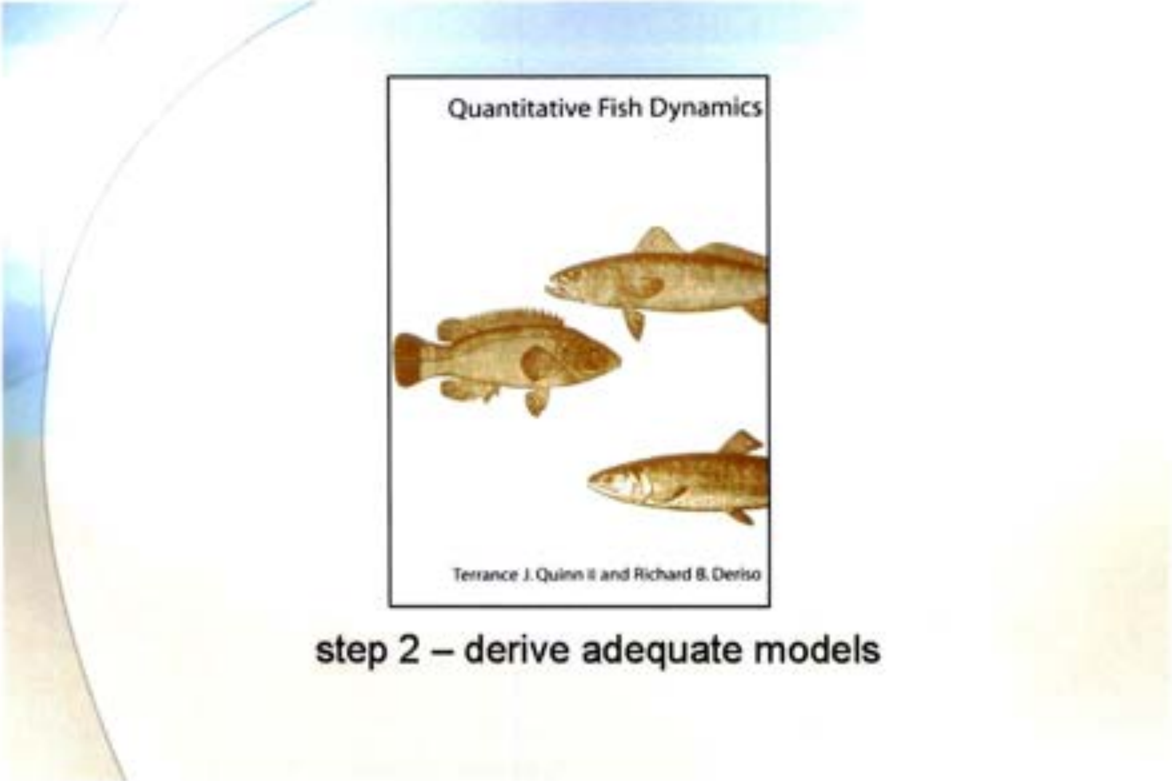
decision making for management

- specify objective
- characterize the system to be managed (models, state variables, system dynamics)
- identify constraints (physical, economic, political) and decision options
- acknowledge uncertainty about our understanding of and ability to control system
- derive optimal strategy: this has the best chance of meeting our objective, given the system, constraints and our uncertainty

step 1 - specify objective

Exploitation of wild resources

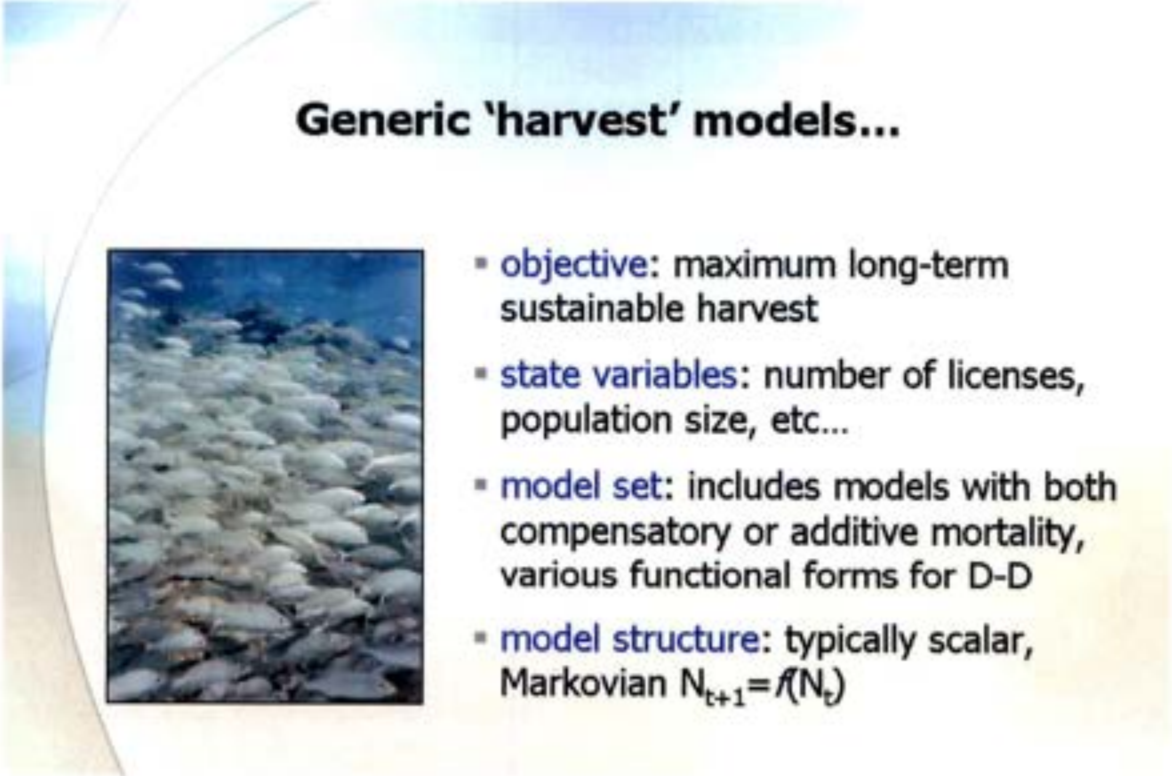
- traditionally 'harvest' (consumptive) based
- the traditional value of the harvest is economic
- more recently, non-consumptive use



Quantitative Fish Dynamics

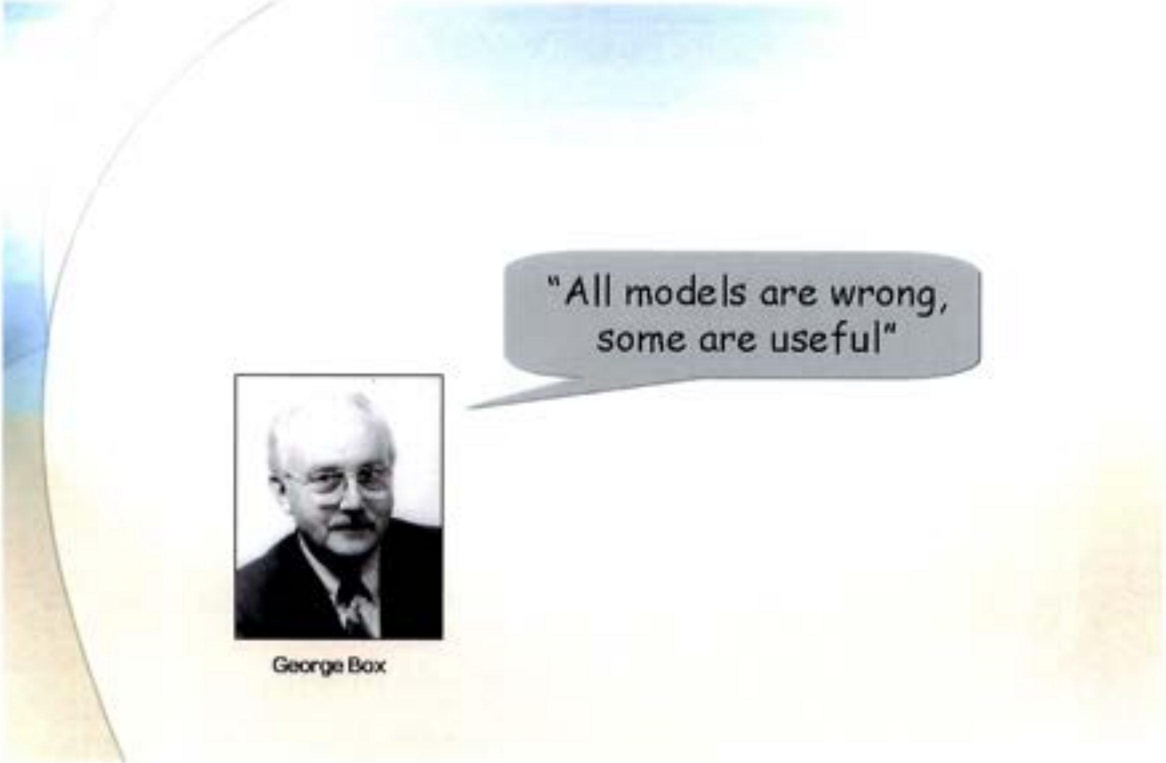
Terrance J. Quinn II and Richard B. Deriso

step 2 – derive adequate models



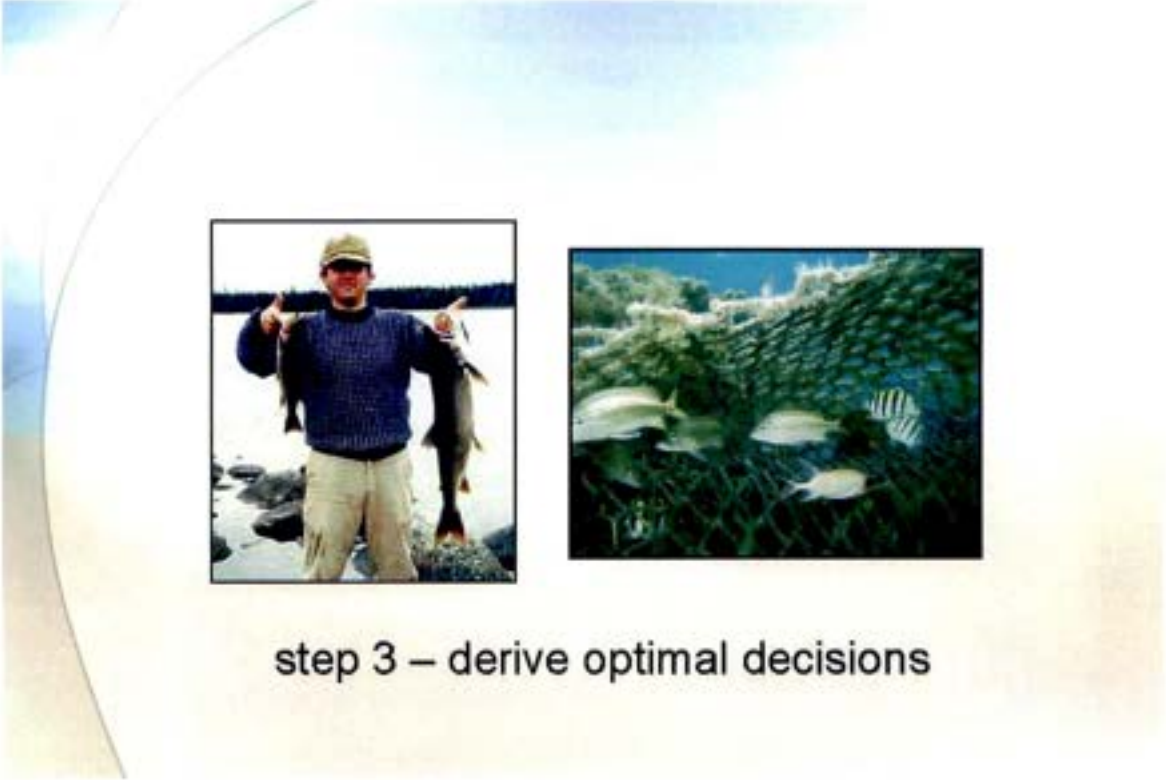
Generic 'harvest' models...

- objective: maximum long-term sustainable harvest
- state variables: number of licenses, population size, etc...
- model set: includes models with both compensatory or additive mortality, various functional forms for D-D
- model structure: typically scalar, Markovian $N_{t+1}=f(N_t)$

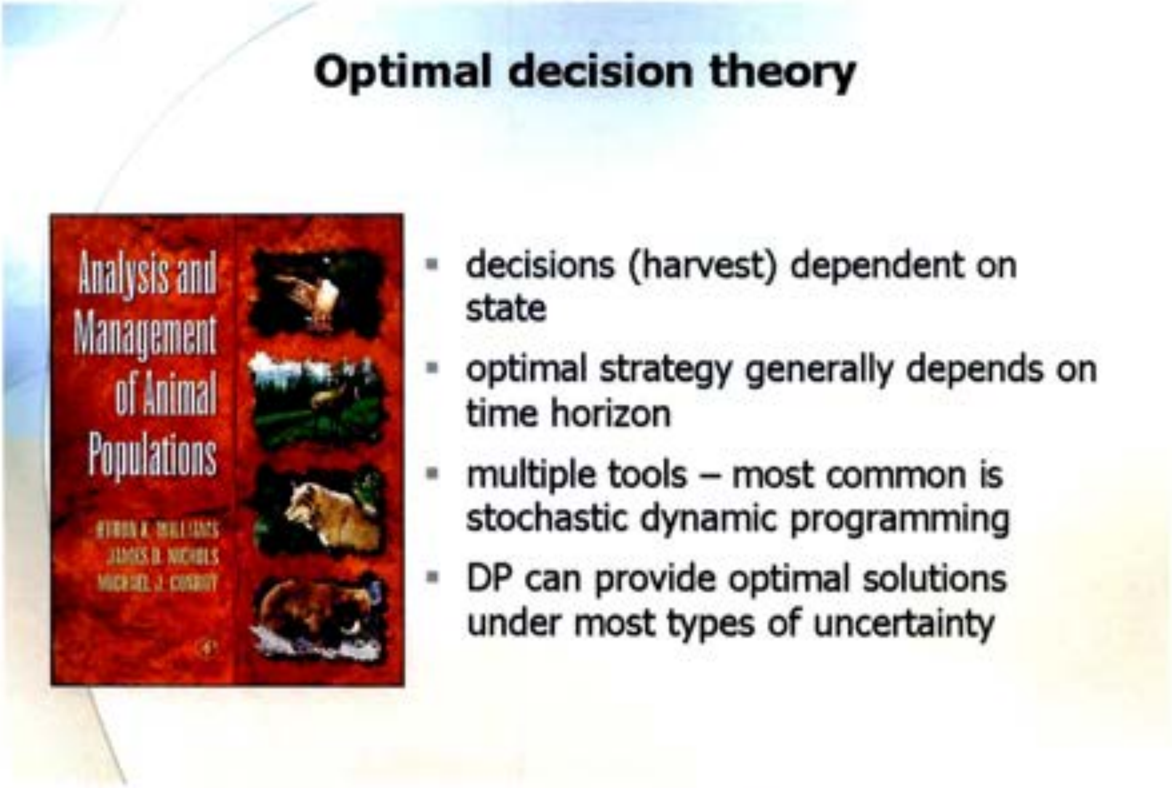


"All models are wrong, some are useful"

George Box

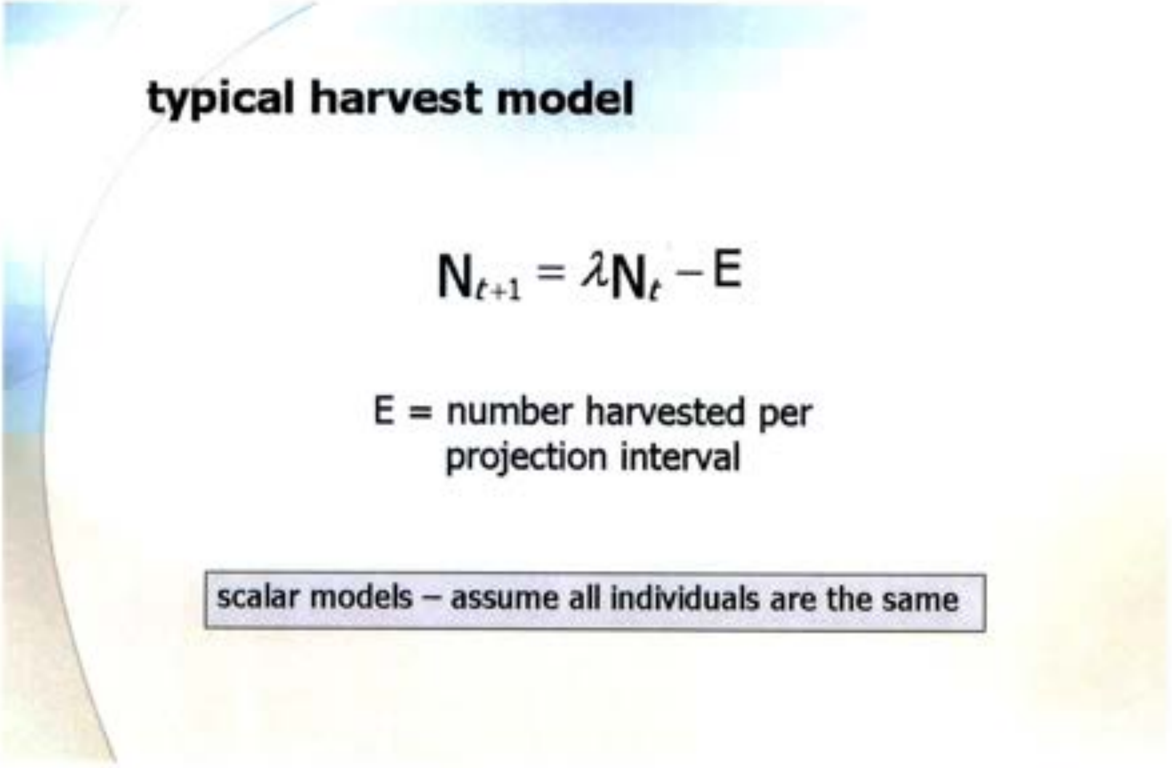


step 3 – derive optimal decisions



Optimal decision theory

- decisions (harvest) dependent on state
- optimal strategy generally depends on time horizon
- multiple tools – most common is stochastic dynamic programming
- DP can provide optimal solutions under most types of uncertainty



typical harvest model

$$N_{t+1} = \lambda N_t - E$$

E = number harvested per projection interval

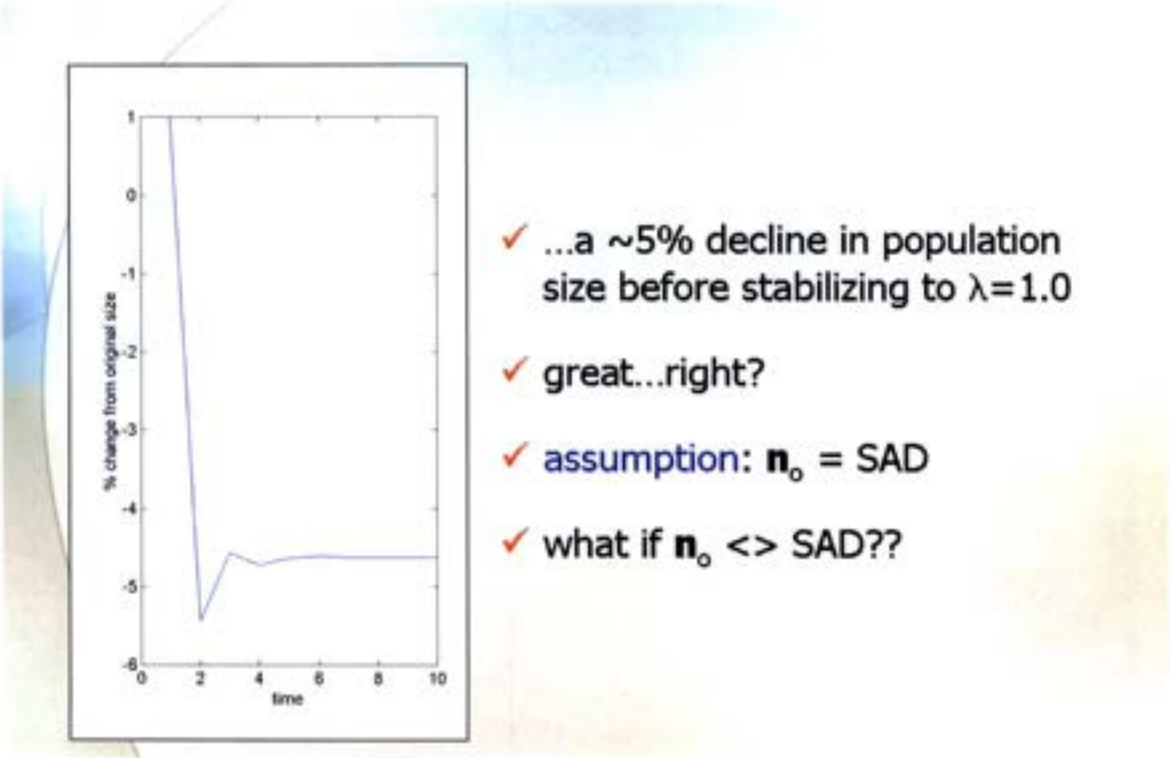
scalar models – assume all individuals are the same

however...

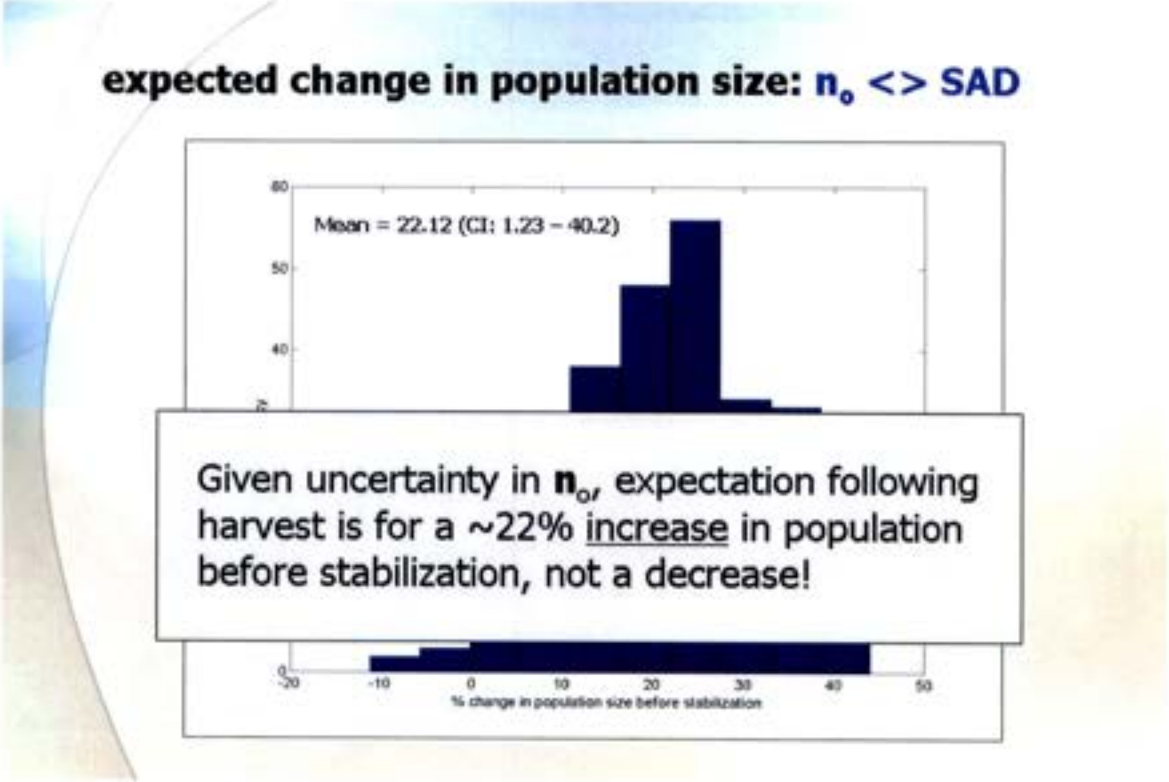
- **the real world isn't scalar!!**
- many populations have significant 'stage' **structure**
- individuals in different stages contribute differently to population growth
- since our purpose is to control population growth, harvest and harvest models must account for these differences! (harvesting a big fish is not *demographically* equivalent to a harvesting a small fish)

dual problem

1. how can we measure the relative value of an individual?
2. can we find the optimal harvest that accounts for these differences in relative value?

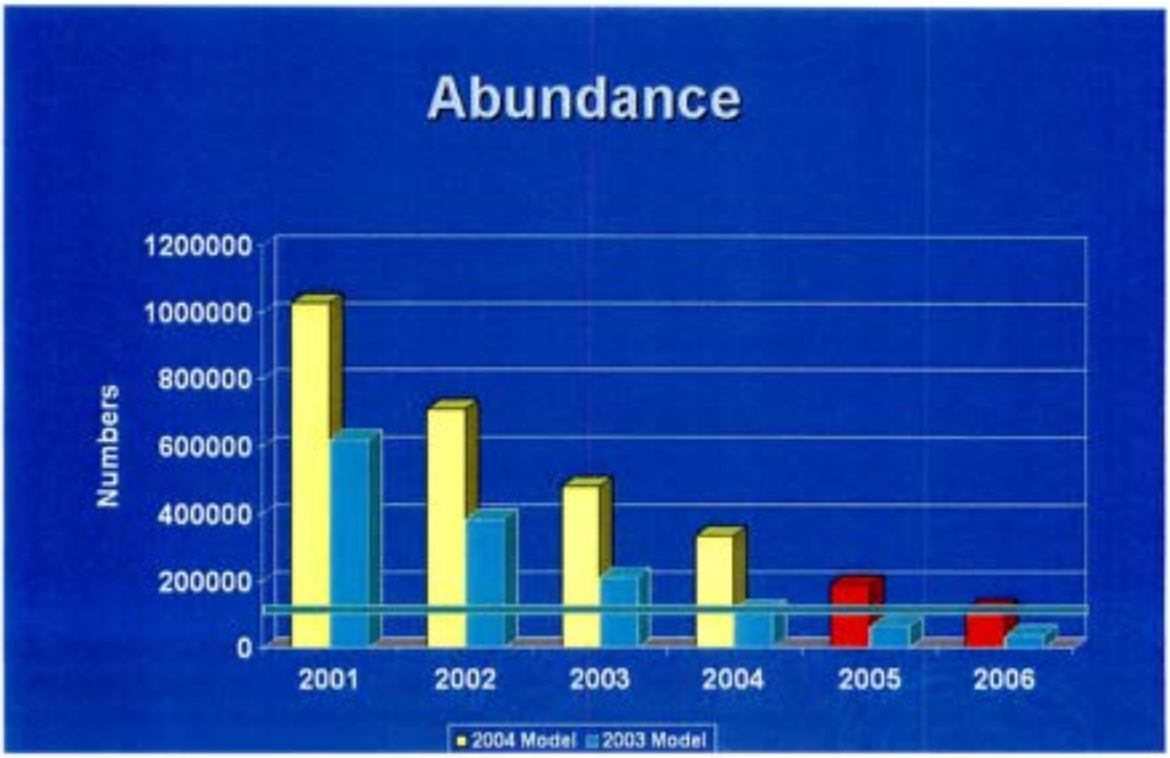


- ✓ …a ~5% decline in population size before stabilizing to λ=1.0
- ✓ great…right?
- ✓ assumption: $\mathbf{n}_o$ = SAD
- ✓ what if $\mathbf{n}_o$ <> SAD??



expected change in population size: n_o <> SAD

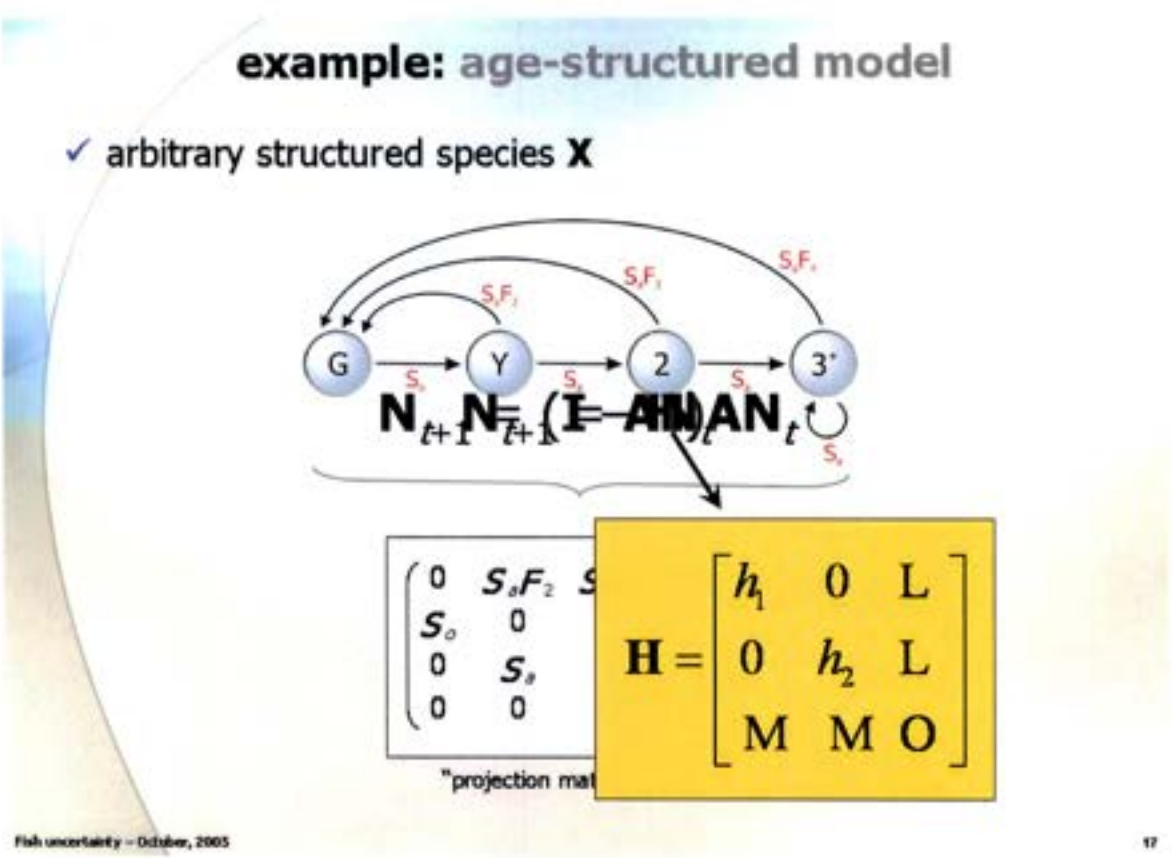
Given uncertainty in $\mathbf{n}_o$, expectation following harvest is for a ~22% <u>increase</u> in population before stabilization, not a decrease!



Abundance

Some MNR Objectives

- Ensure long term sustainability of the ecosystem so that we:
  - Protect biodiversity,
  - Enhance and maintain socio-economic benefits,
- Use sound science,
- Be transparent and encourage democracy in decision making



example: age-structured model

- ✓ arbitrary structured species **X**

$$\mathbf{N}_{t+1} = \mathbf{A}\mathbf{N}_t$$

$$\mathbf{N}_{t+1} = (\mathbf{I}-\mathbf{H})\mathbf{A}\mathbf{N}_t$$

$$\begin{pmatrix} 0 & S_aF_2 \\ S_o & 0 \\ 0 & S_a \\ 0 & 0 \end{pmatrix}$$

"projection mat

$$\mathbf{H} = \begin{bmatrix} h_1 & 0 & \mathrm{L} \\ 0 & h_2 & \mathrm{L} \\ \mathrm{M} & \mathrm{M} & \mathrm{O} \end{bmatrix}$$

Fish uncertainty – October, 2005

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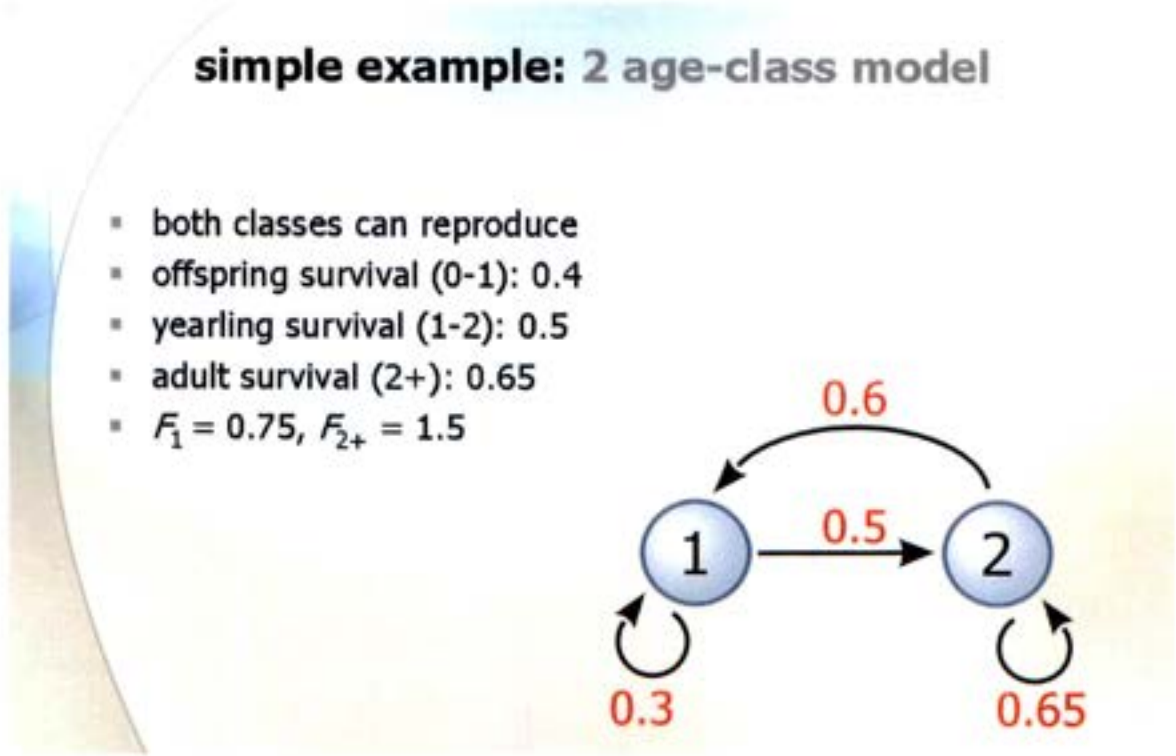
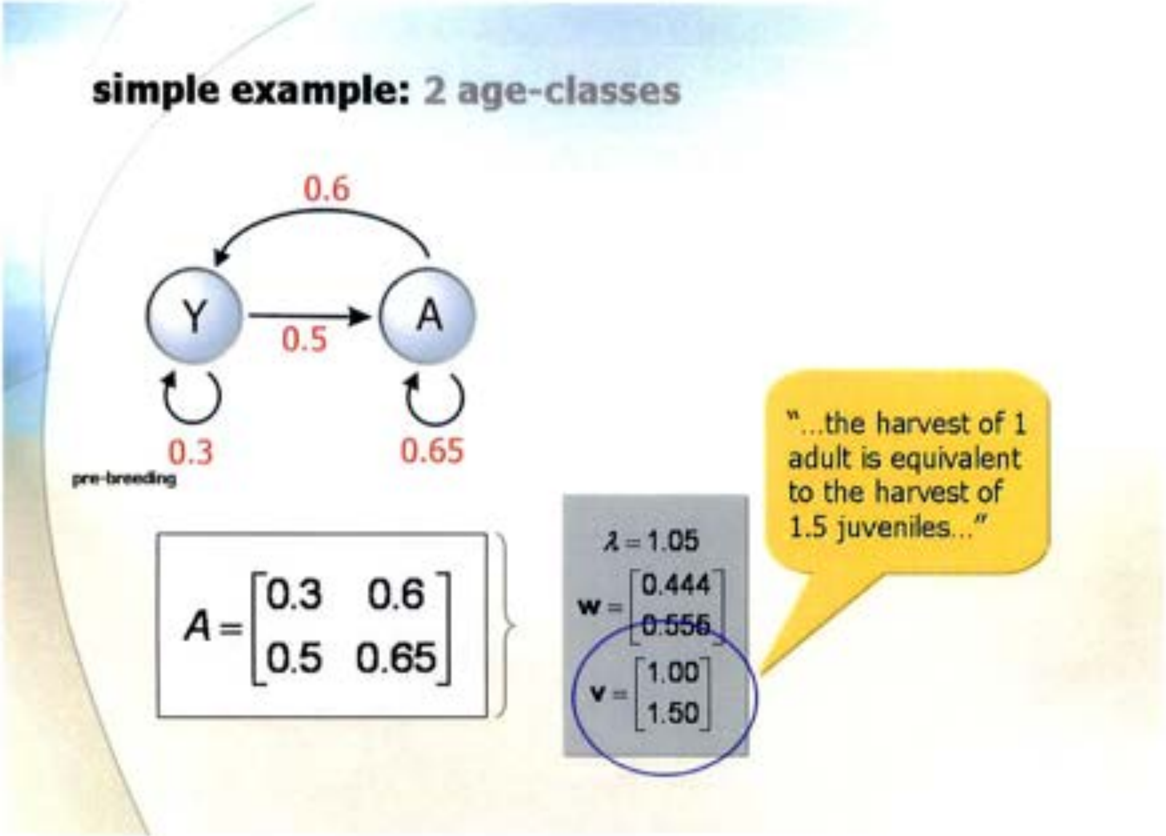


simple example: 2 age-class model

- both classes can reproduce
- offspring survival (0-1): 0.4
- yearling survival (1-2): 0.5
- adult survival (2+): 0.65
- $F_1 = 0.75$, $F_{2+} = 1.5$



simple example: 2 age-classes

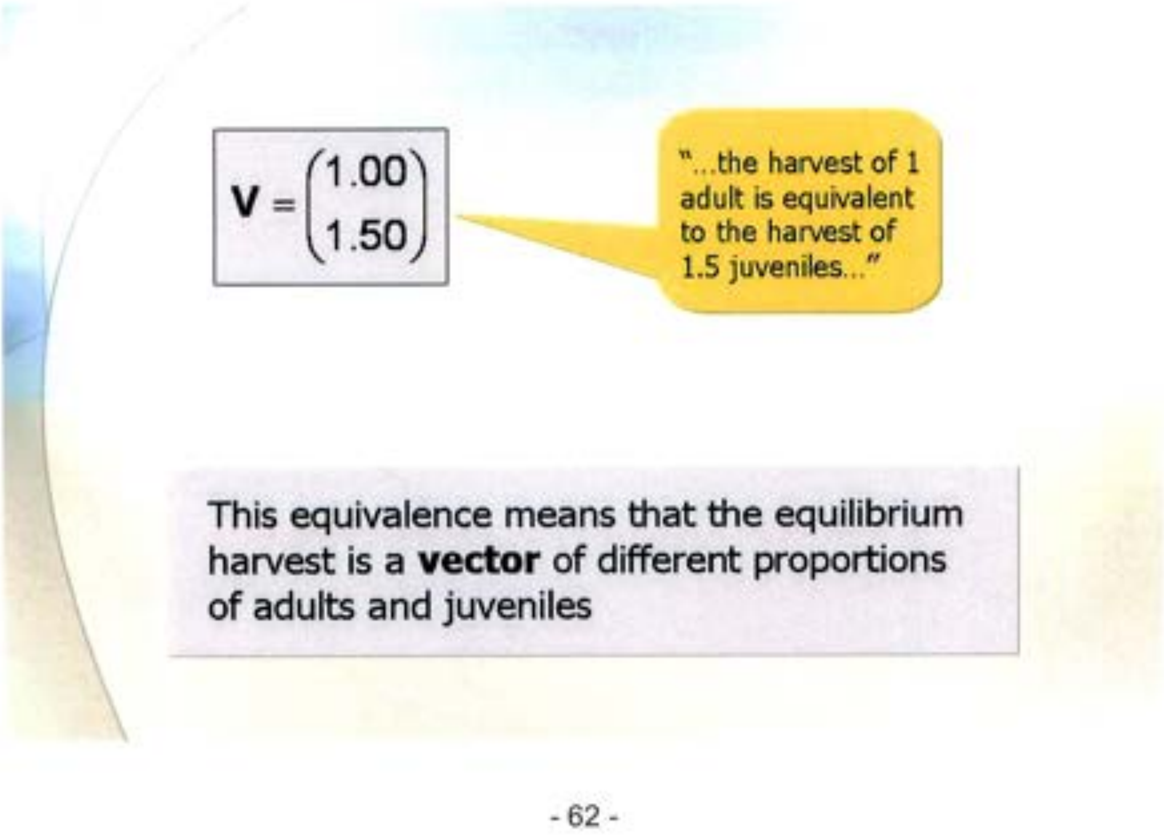
$$A = \begin{bmatrix} 0.3 & 0.6 \\ 0.5 & 0.65 \end{bmatrix}$$

$$\lambda = 1.05$$

$$\mathbf{w} = \begin{bmatrix} 0.444 \\ 0.556 \end{bmatrix}$$

$$\mathbf{v} = \begin{bmatrix} 1.00 \\ 1.50 \end{bmatrix}$$

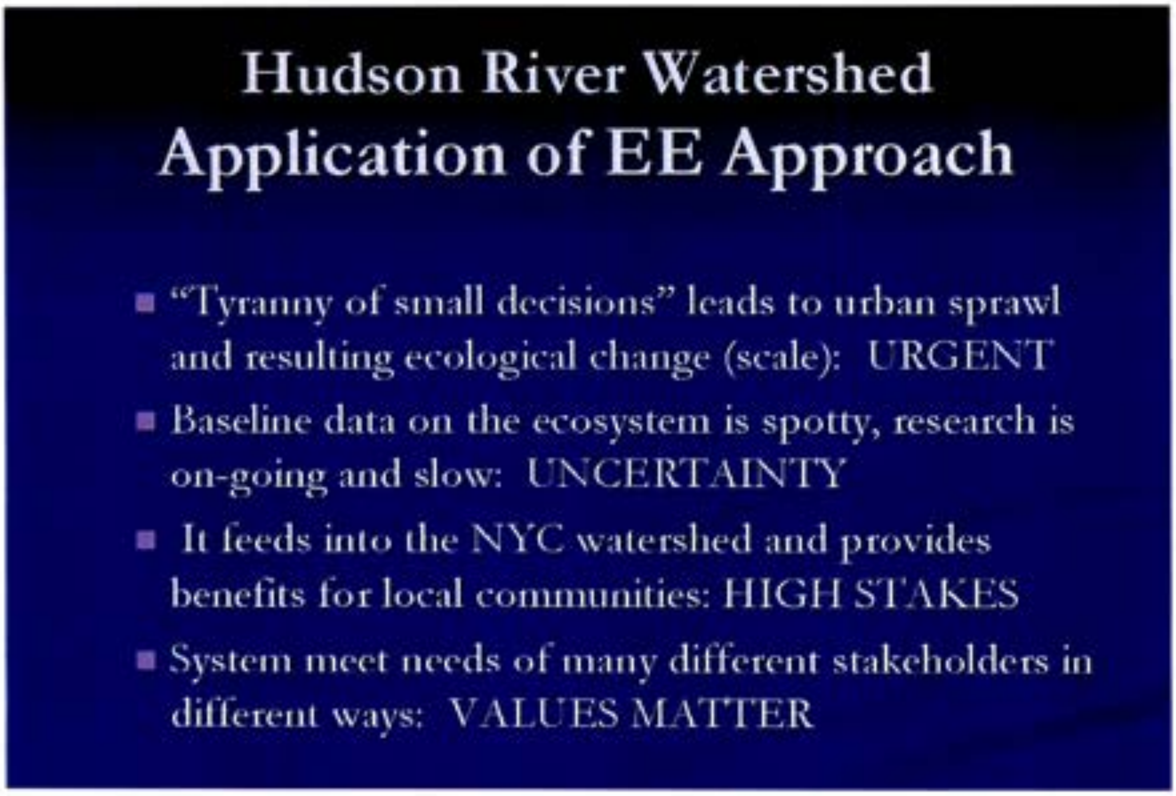
"...the harvest of 1 adult is equivalent to the harvest of 1.5 juveniles..."



$$\mathbf{V} = \begin{pmatrix} 1.00 \\ 1.50 \end{pmatrix}$$

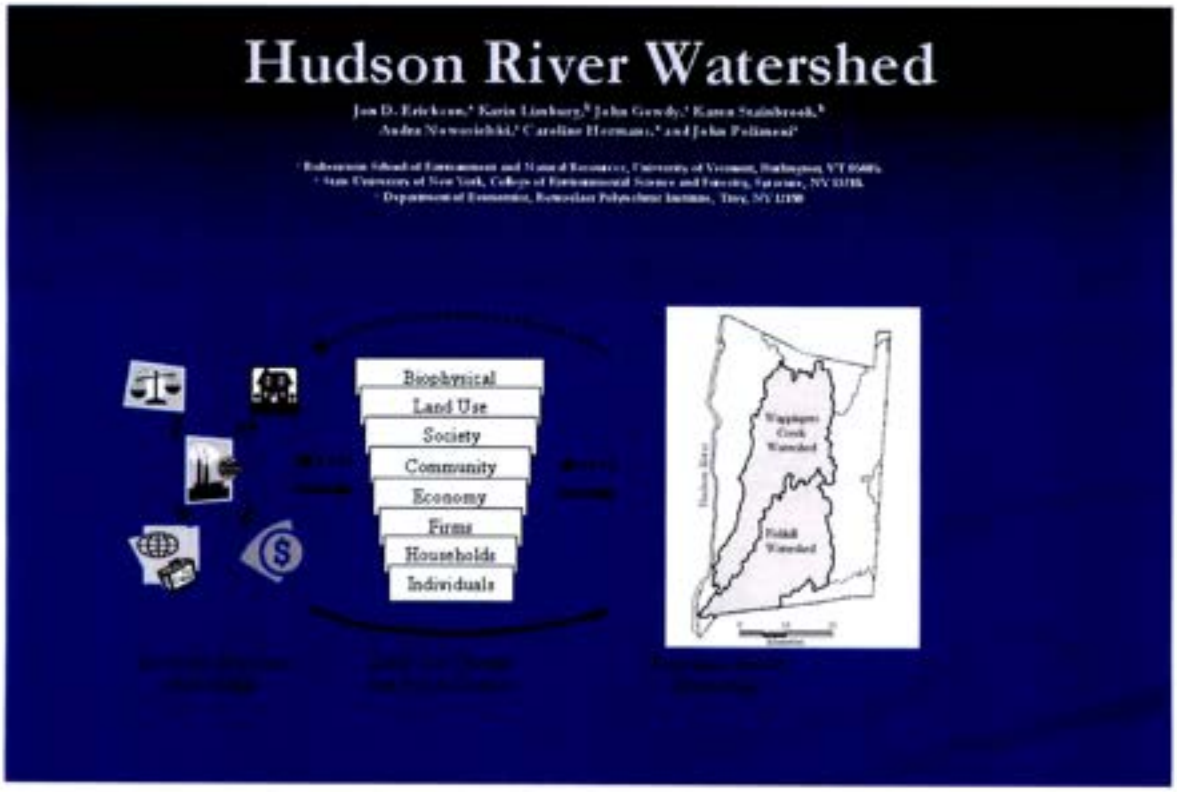
"...the harvest of 1 adult is equivalent to the harvest of 1.5 juveniles..."

This equivalence means that the equilibrium harvest is a **vector** of different proportions of adults and juveniles



Hudson River Watershed Application of EE Approach

- "Tyranny of small decisions" leads to urban sprawl and resulting ecological change (scale): URGENT
- Baseline data on the ecosystem is spotty, research is on-going and slow: UNCERTAINTY
- It feeds into the NYC watershed and provides benefits for local communities: HIGH STAKES
- System meet needs of many different stakeholders in different ways: VALUES MATTER



Hudson River Watershed

Jon D. Erickson,[a] Karin Limburg,[b] John Gowdy,[c] Karen Stainbrook,[b]
Audra Nowosielski,[a] Caroline Hermans,[a] and John Polimeni[c]

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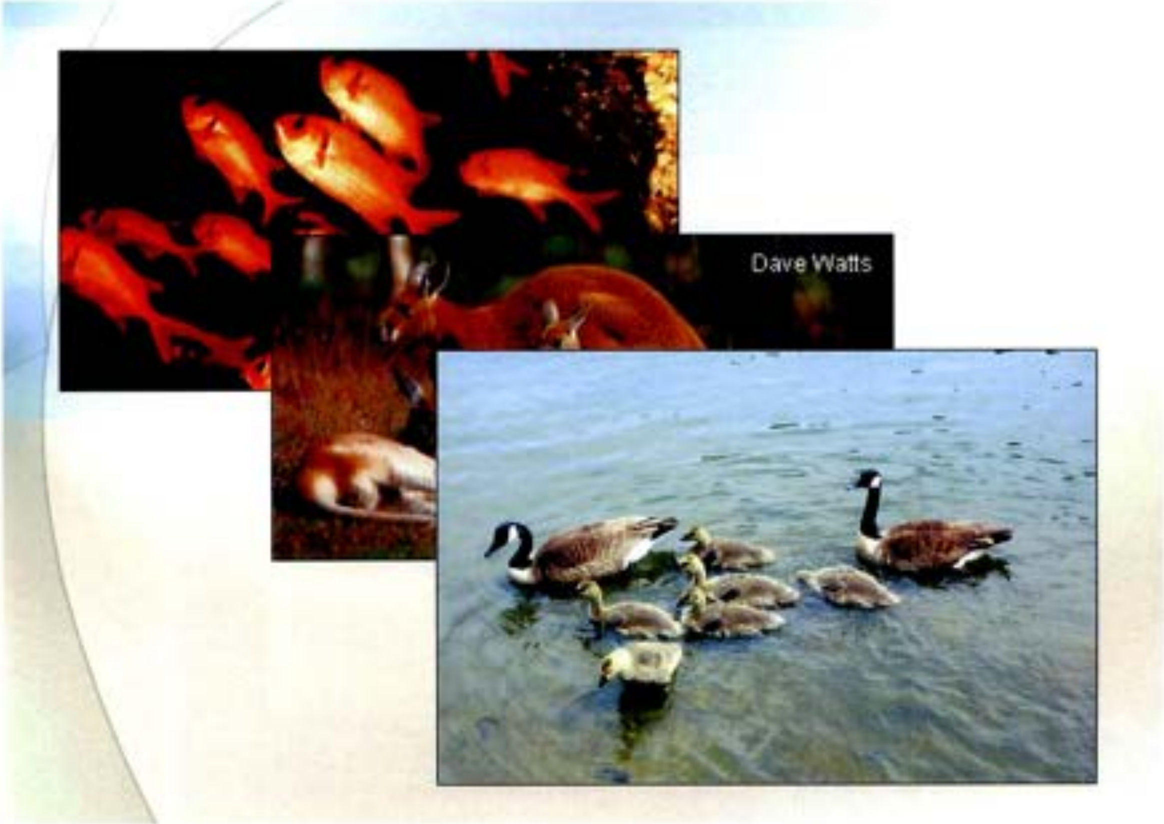
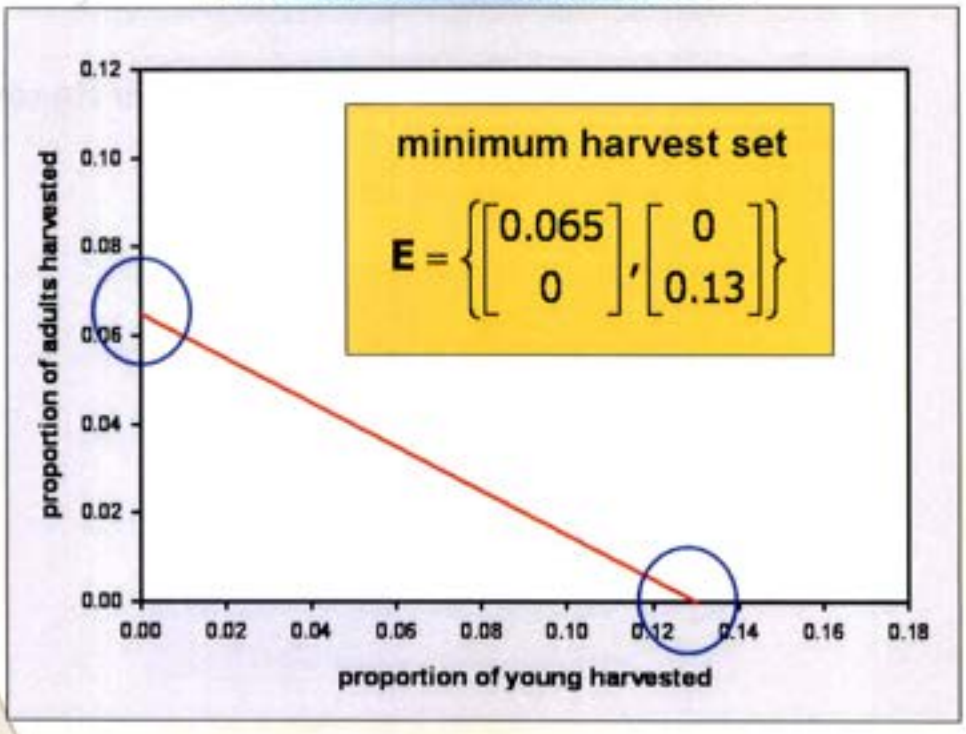
2. Value-specific harvest

- optimal harvest will be structured
- more uncertainty:
  - ✓ we don't know population structure
  - ✓ for some taxa, we can't choose who to harvest
  - ✓ human dimensions



suboptimal 'rule-of-thumb' approach



minimum harvest set

$$\mathbf{E} = \left\{ \begin{bmatrix} 0.065 \\ 0 \end{bmatrix}, \begin{bmatrix} 0 \\ 0.13 \end{bmatrix} \right\}$$

minimizing uncertainty: nonoptimal 'rule of thumb'

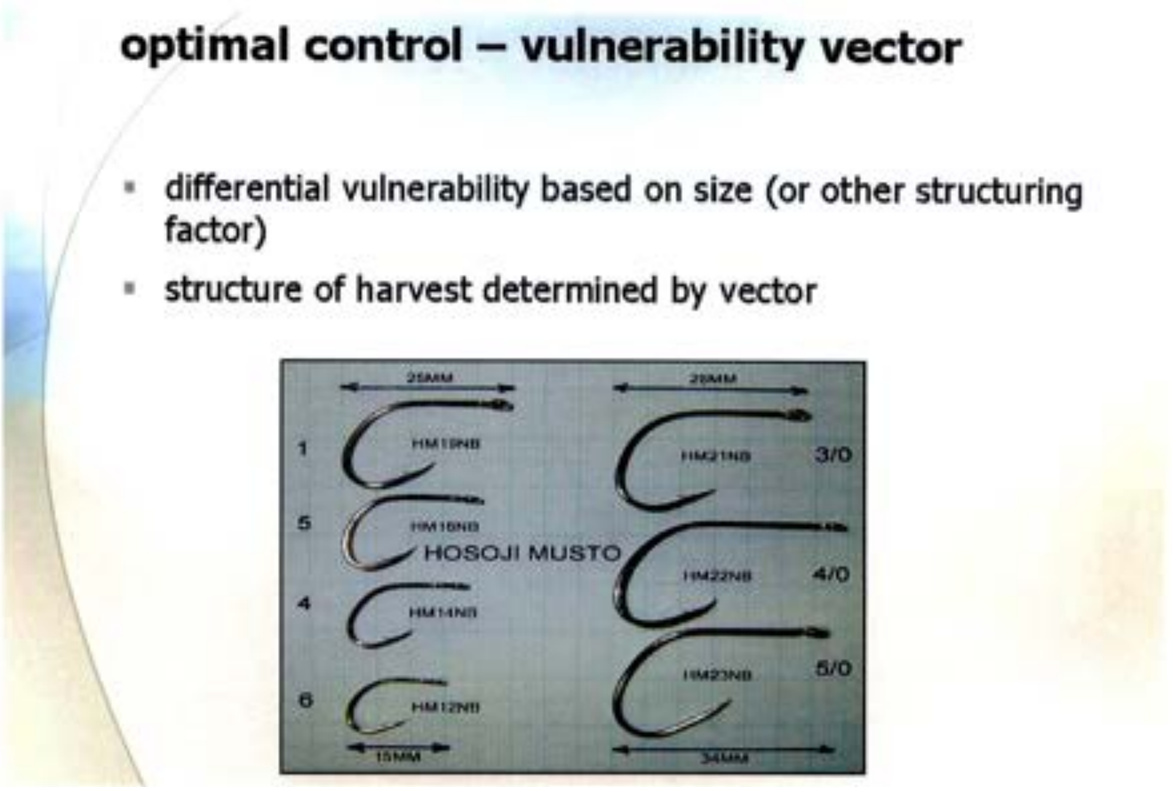
minimum harvest set

$$\mathbf{E} = \left\{ \begin{bmatrix} 0.065 \\ 0 \end{bmatrix}, \begin{bmatrix} 0 \\ 0.13 \end{bmatrix} \right\}$$

conservative strategy set

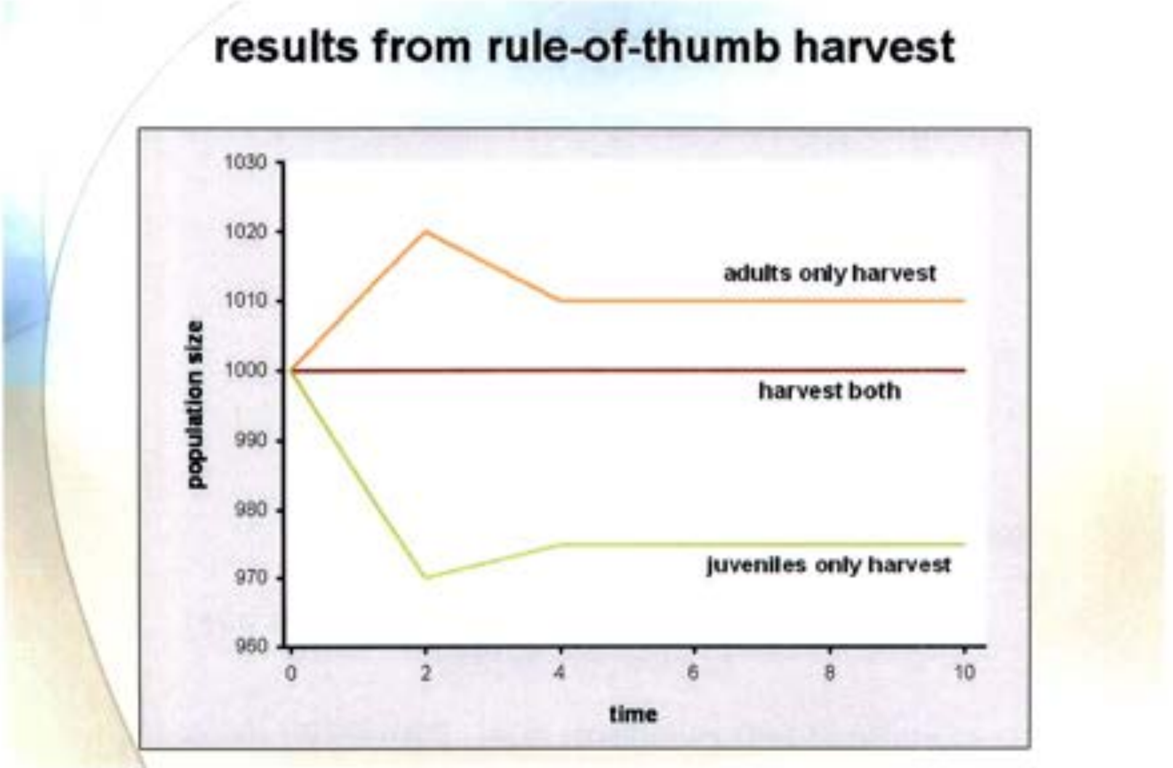
">0.13 proportional harvest rate (unknown age), population decline"

"<0.065 in bag (unknown age), population increase"

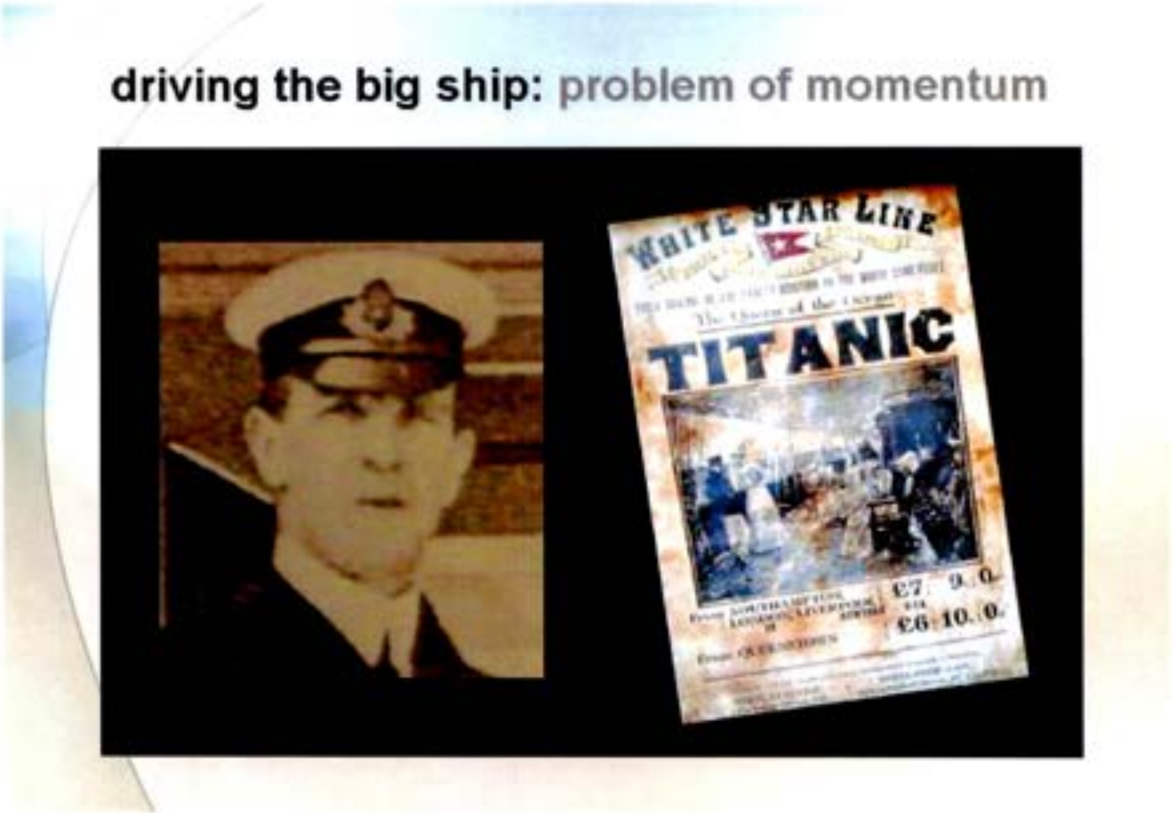


optimal control – vulnerability vector

- differential vulnerability based on size (or other structuring factor)
- structure of harvest determined by vector



results from rule-of-thumb harvest

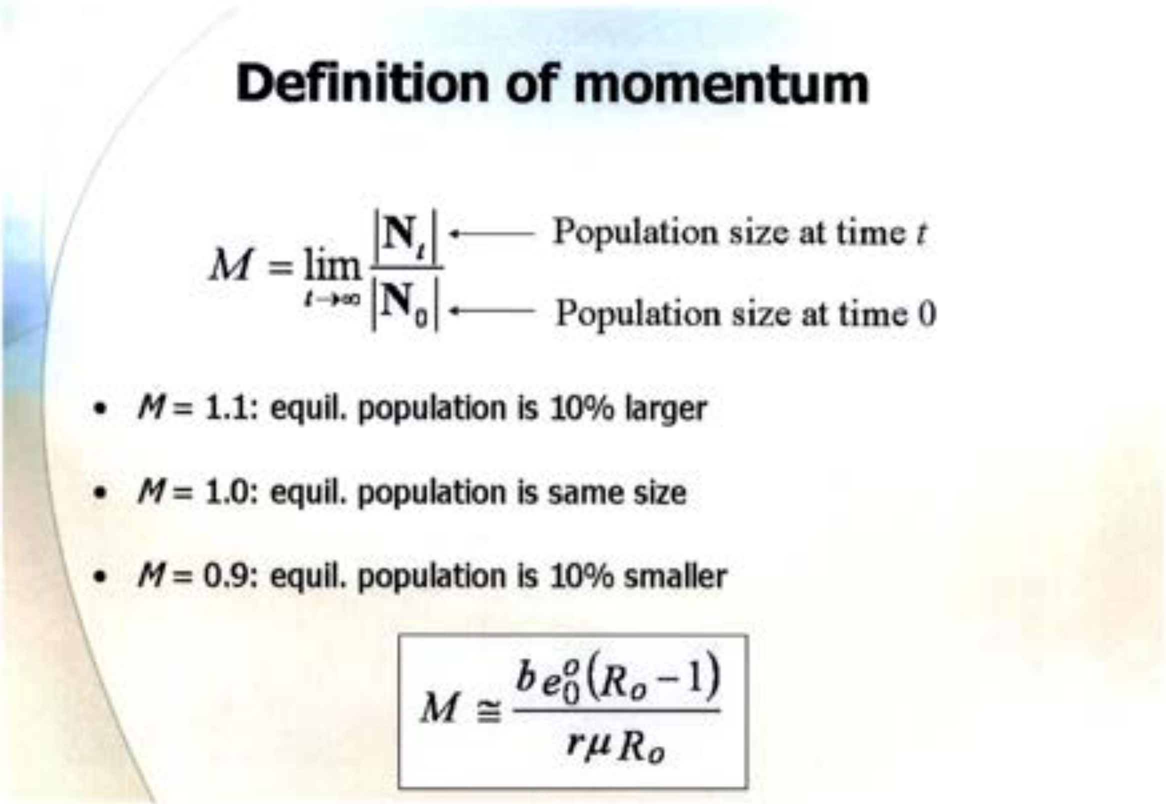


driving the big ship: problem of momentum

Significant empirical needs

- derivation of functional form for density-dependence
- derivation of state-dependent models for geese — What are environmental drivers
- human dimensions issues — derivation of minimum acceptable, maximum tolerable — what constitutes upper limit

✓ vulnerability vector

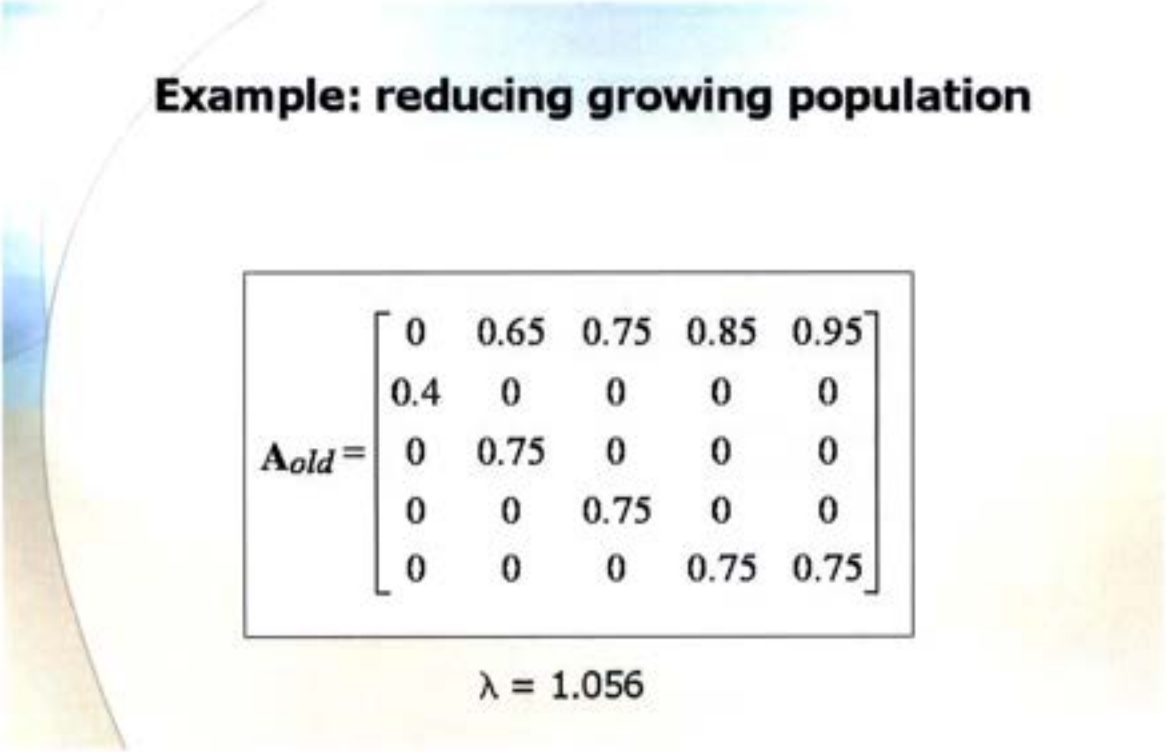


Definition of momentum

$$M = \lim_{t\to\infty}\frac{|\mathbf{N}_t|}{|\mathbf{N}_0|}\begin{array}{l}\longleftarrow \text{Population size at time } t\\ \longleftarrow \text{Population size at time } 0\end{array}$$

- $M = 1.1$: equil. population is 10% larger
- $M = 1.0$: equil. population is same size
- $M = 0.9$: equil. population is 10% smaller

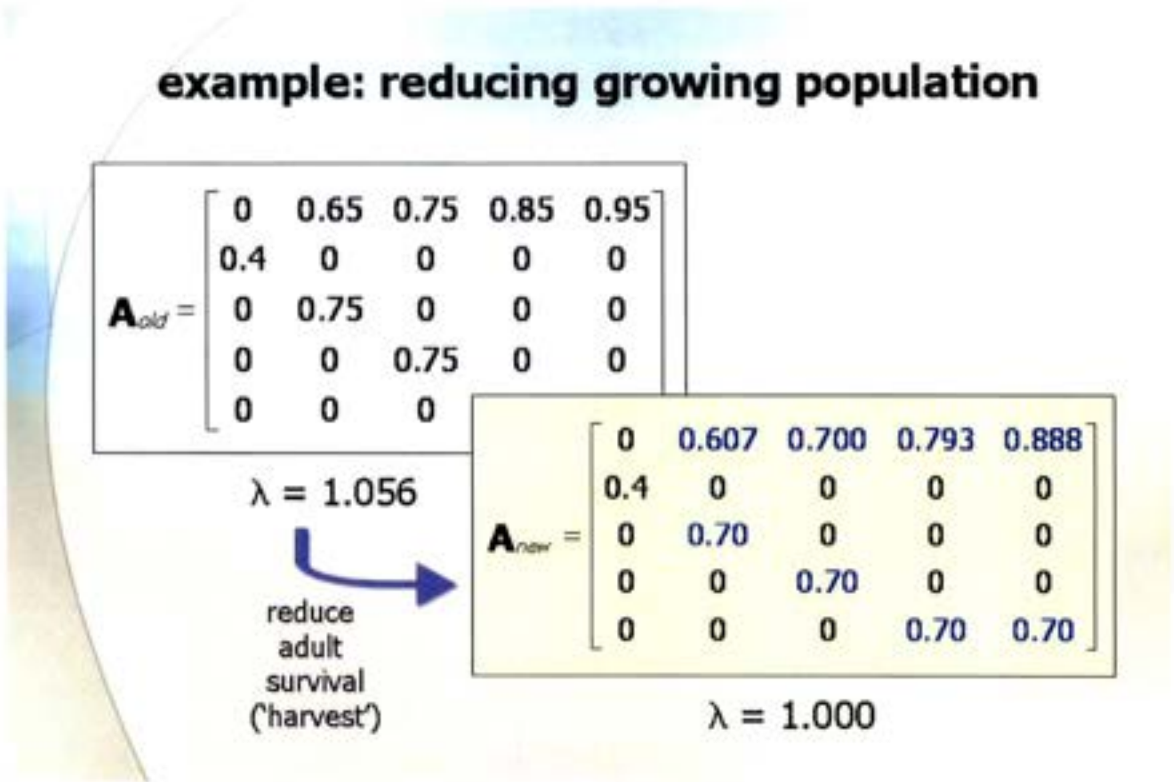
$$\boxed{M \cong \frac{b\,e_0^o(R_o-1)}{r\mu R_o}}$$



Example: reducing growing population

$$\boxed{\mathbf{A}_{old} = \begin{bmatrix} 0 & 0.65 & 0.75 & 0.85 & 0.95 \\ 0.4 & 0 & 0 & 0 & 0 \\ 0 & 0.75 & 0 & 0 & 0 \\ 0 & 0 & 0.75 & 0 & 0 \\ 0 & 0 & 0 & 0.75 & 0.75 \end{bmatrix}}$$

$\lambda = 1.056$



example: reducing growing population

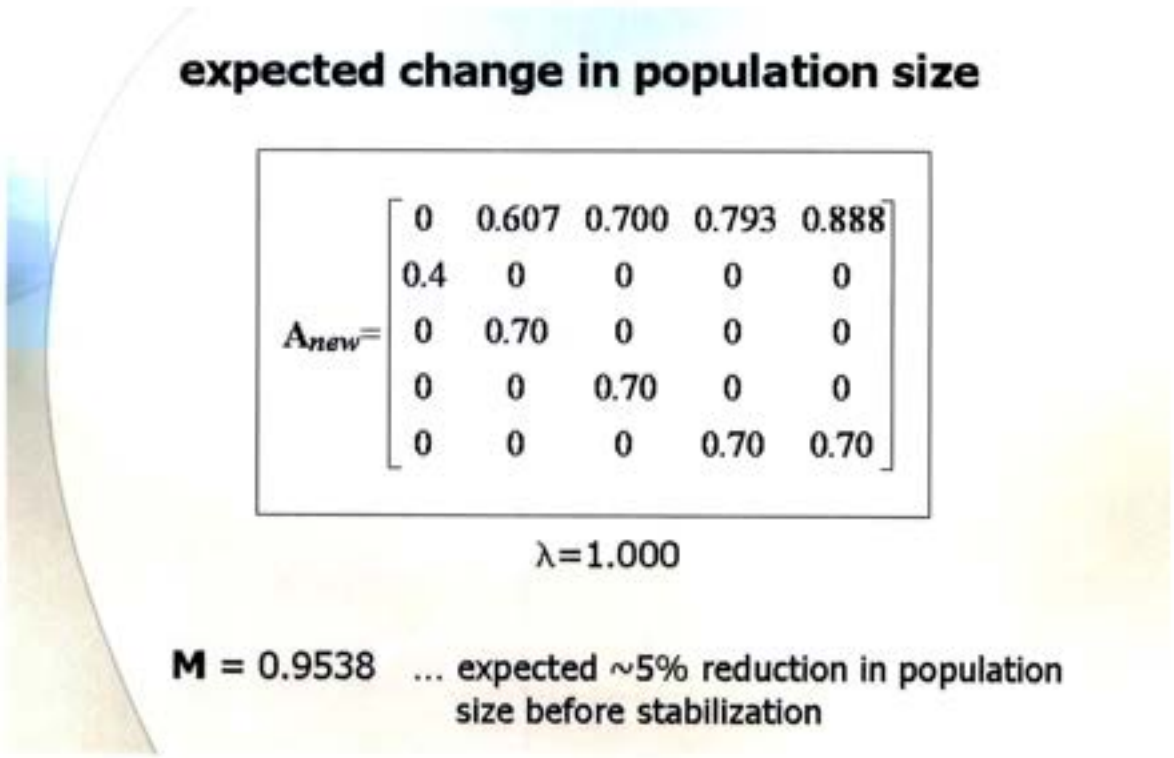
$$\mathbf{A}_{old} = \begin{bmatrix} 0 & 0.65 & 0.75 & 0.85 & 0.95 \\ 0.4 & 0 & 0 & 0 & 0 \\ 0 & 0.75 & 0 & 0 & 0 \\ 0 & 0 & 0.75 & 0 & 0 \\ 0 & 0 & 0 & & \end{bmatrix}$$

$\lambda = 1.056$

reduce adult survival ('harvest')

$$\mathbf{A}_{new} = \begin{bmatrix} 0 & 0.607 & 0.700 & 0.793 & 0.888 \\ 0.4 & 0 & 0 & 0 & 0 \\ 0 & 0.70 & 0 & 0 & 0 \\ 0 & 0 & 0.70 & 0 & 0 \\ 0 & 0 & 0 & 0.70 & 0.70 \end{bmatrix}$$

$\lambda = 1.000$

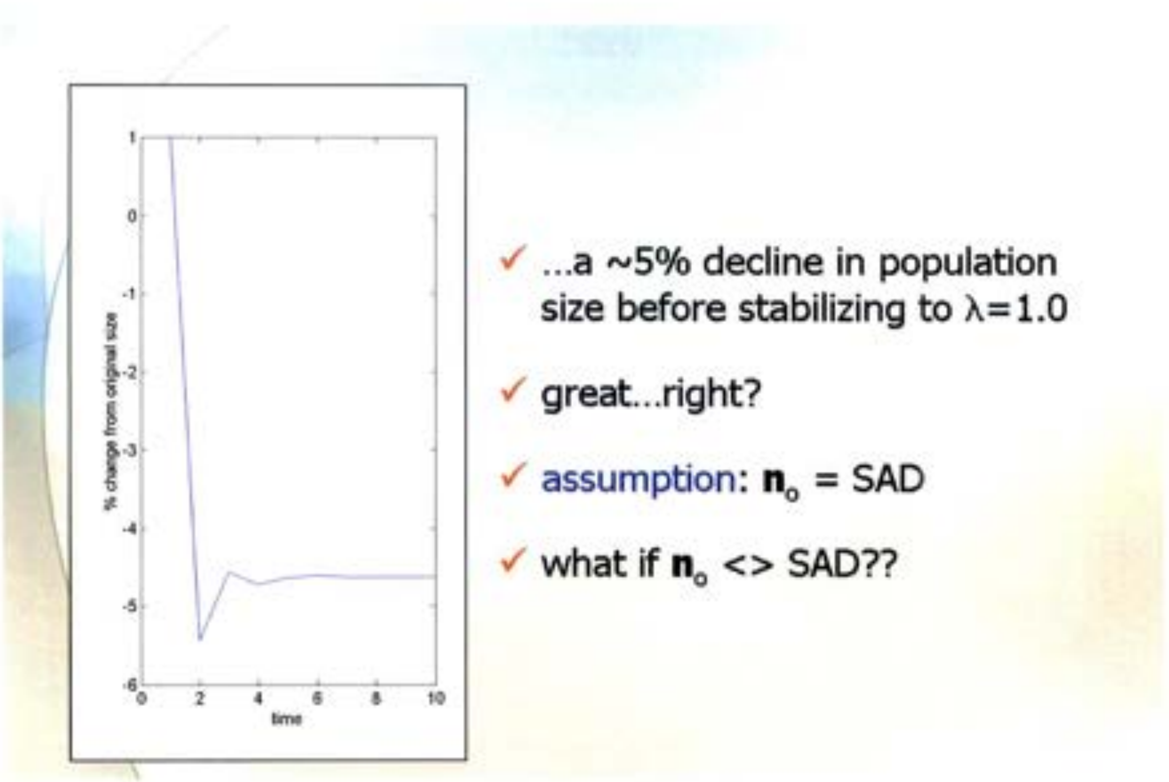


expected change in population size

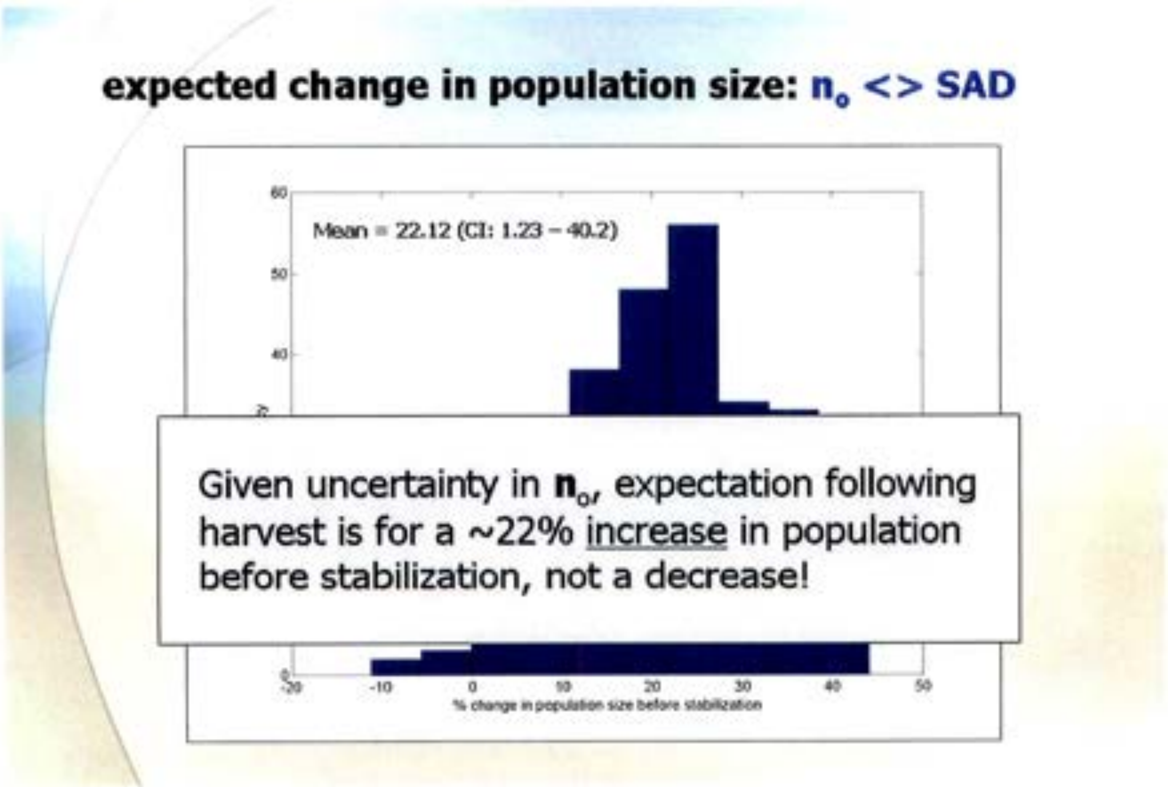
$$\mathbf{A}_{new} = \begin{bmatrix} 0 & 0.607 & 0.700 & 0.793 & 0.888 \\ 0.4 & 0 & 0 & 0 & 0 \\ 0 & 0.70 & 0 & 0 & 0 \\ 0 & 0 & 0.70 & 0 & 0 \\ 0 & 0 & 0 & 0.70 & 0.70 \end{bmatrix}$$

$\lambda=1.000$

M = 0.9538 ... expected ~5% reduction in population size before stabilization



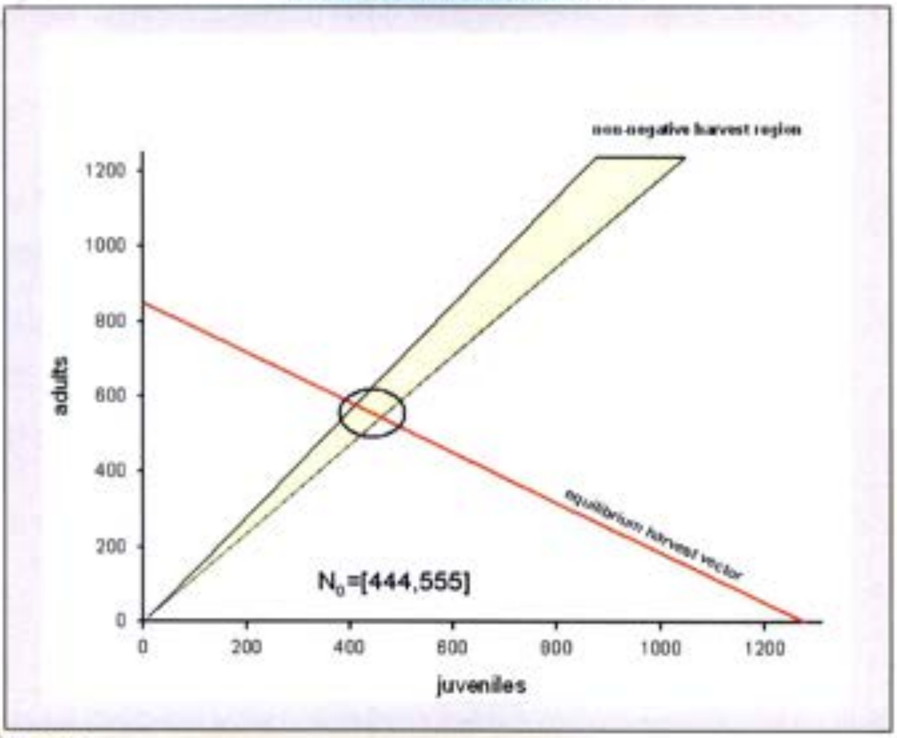
- ✓ …a ~5% decline in population size before stabilizing to λ=1.0
- ✓ great…right?
- ✓ assumption: $\mathbf{n}_o$ = SAD
- ✓ what if $\mathbf{n}_o$ <> SAD??



expected change in population size: $\mathbf{n}_o$ <> SAD

Given uncertainty in $\mathbf{n}_o$, expectation following harvest is for a ~22% increase in population before stabilization, not a decrease!

target momentum



Fish uncertainty – October, 2005

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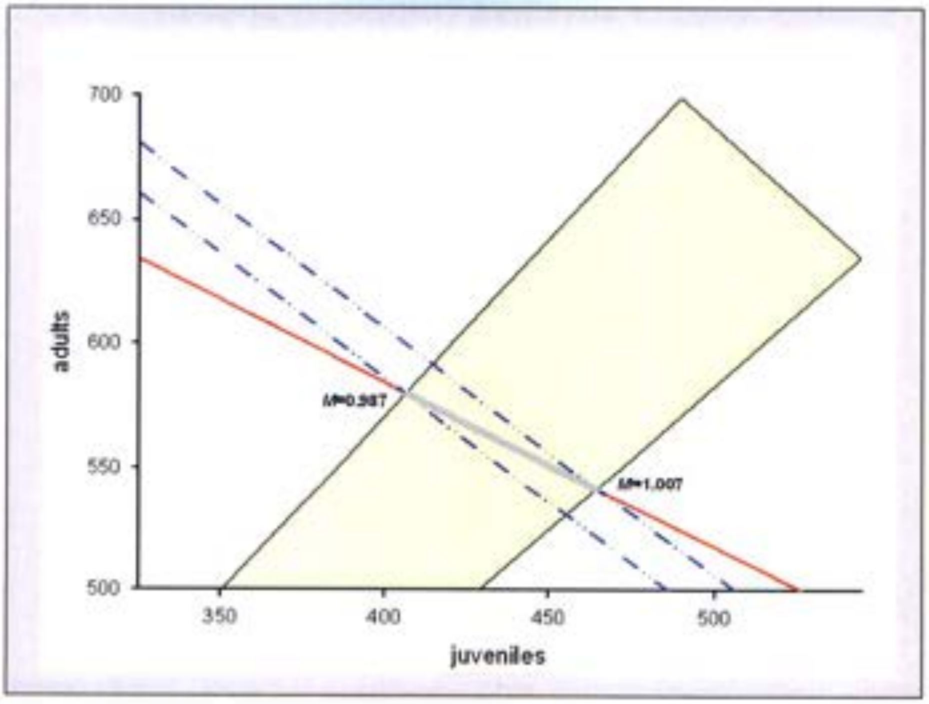
target momentum: plausible bounds



Theoretical results to date...

- ✓ If system completely identified (observed), SDP will provide an optimal solution to achieve point objective
- ✓ The optimal decision space if objective is to achieve point objective with momentum constraint very small
- ✓ If system only partially observable, achieving optimal control, especially given momentum constraint, probably not possible

future theoretical work...

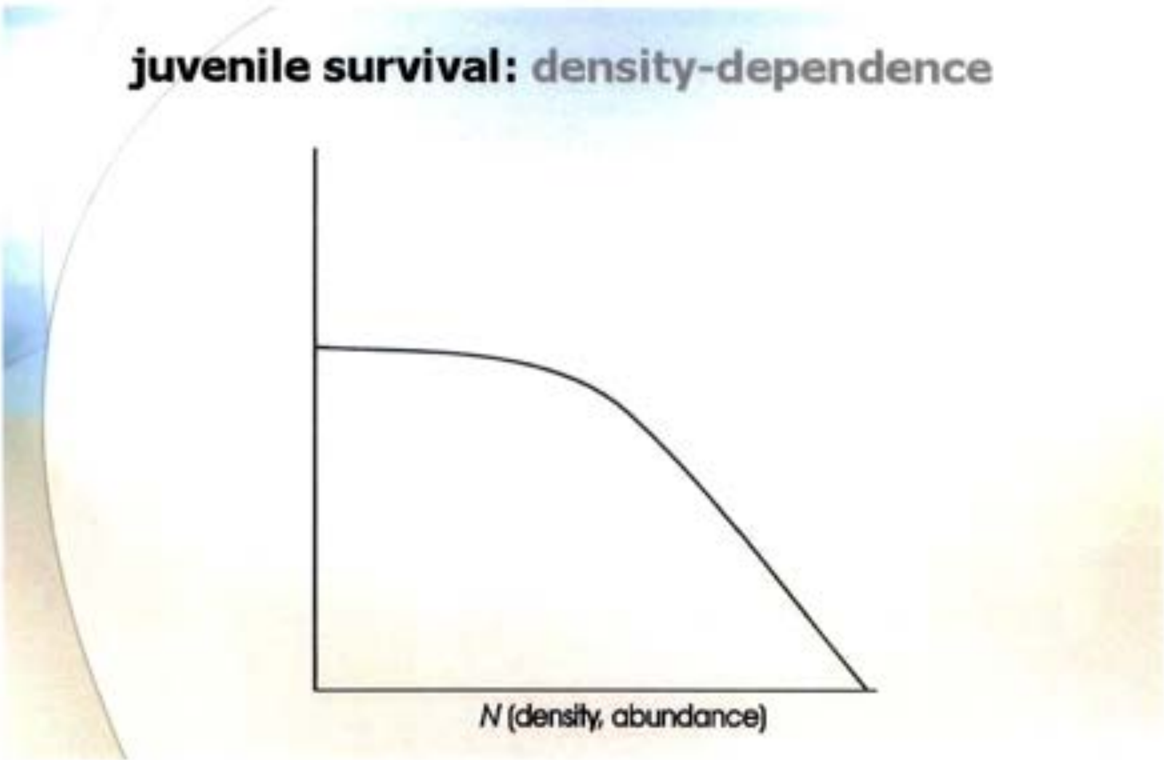
- other kinds of structure (especially spatial)
- addition of time constraint, and different objectives (e.g., mean/variance)
- 'model' complexity – how much is needed
  - ✓ population models, vunerability vectors
  - ✓ the graphs are difficult to visualize
  - ✓ the math gets harder
  - ✓ observation gets more difficult/costly
- frequency-dependence of stage-structure
- timing of decisions

Timing of management decisions

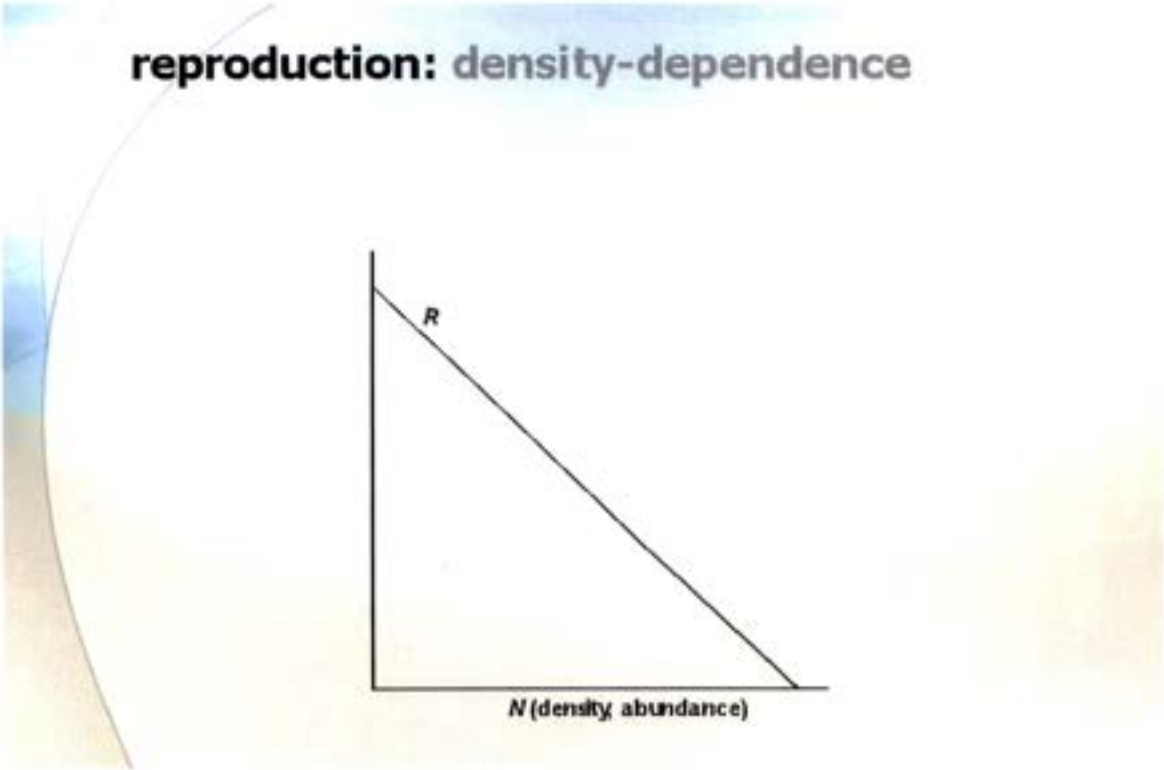
- most management based on annual decisions (annual harvest regulations)
- is this optimal for structured (non-Markovian) populations?
- non-linear response – 'oversteering'

Significant empirical needs

- ✓ derivation of functional form for density-dependence
- derivation of state-dependent models — what are environmental drivers
- human dimensions issues
- vulnerability vector



juvenile survival: density-dependence



reproduction: density-dependence

Significant empirical needs

- derivation of functional form for density-dependence
- ✓ derivation of of state-dependent models — what are environmental drivers
- human dimensions issues – derivation of minimum acceptable, maximum tolerable — what constitutes upper limit
- vulnerability vector

Significant empirical needs

- derivation of functional form for density-dependence
- derivation of of state-dependent models for geese — what are environmental drivers
- ✓ human dimensions issues
- vulnerability vector

Appendix G.
Comparative Ecosystem Modelling in the Bay of Quinte and Oneida Lake

Comparative Ecosystem Modelling in the Bay of Quinte and Oneida Lake

Marten A. Koops
Great Lakes Laboratory for Fisheries and Aquatic Sciences
Fisheries and Oceans Canada

NY Sea Grant Workshop
October 24, 2005

The Quinte-Oneida Comparative Ecosystem Modelling Project Team

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- Ora Johannsson
- Bob Randall
- Mohi Munawar
- Ron Dermott
- Kelly Bowen
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- Christine Brousseau
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- Dean Fitzgerald

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- Jim Hoyle
- John Casselman
- Tom Stewart
- Jason Dietrich

University of Toledo:

- Christine Mayer
- Bin Zhu

University of Waterloo:

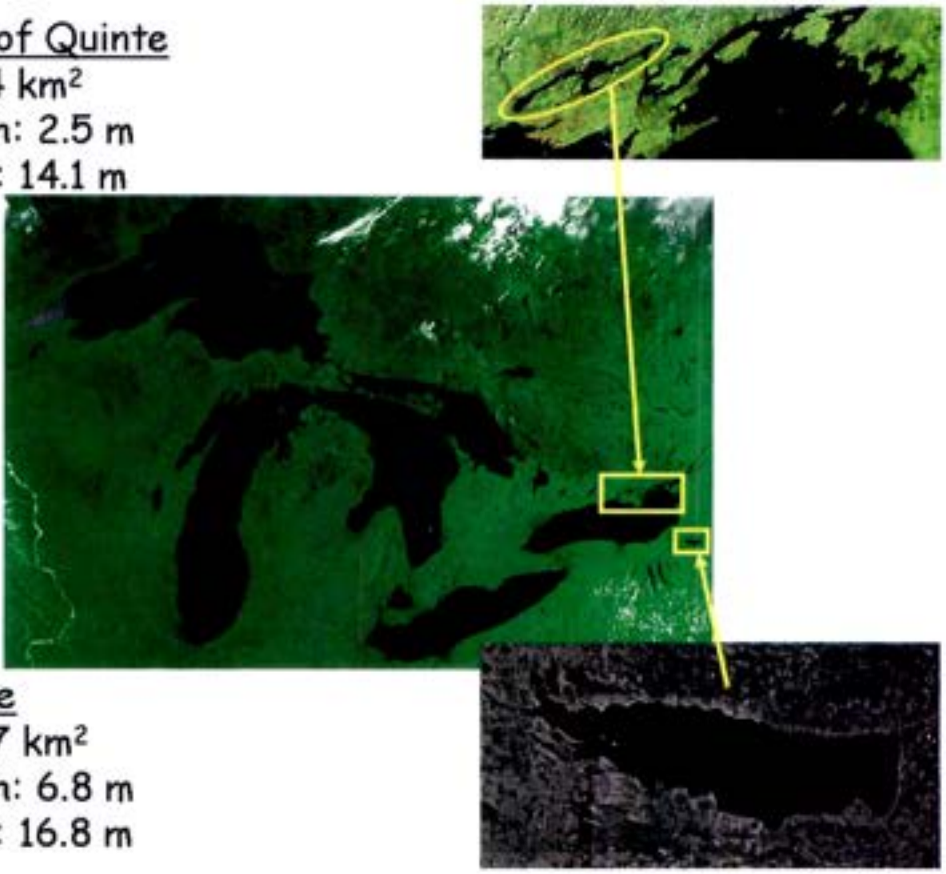
- Jennifer Bowman
- Michael Power

- What are the ecosystem impacts of recent invasions?
- Why did walleye decline through the 1990s in both the Bay of Quinte and Oneida Lake?

Hypotheses:

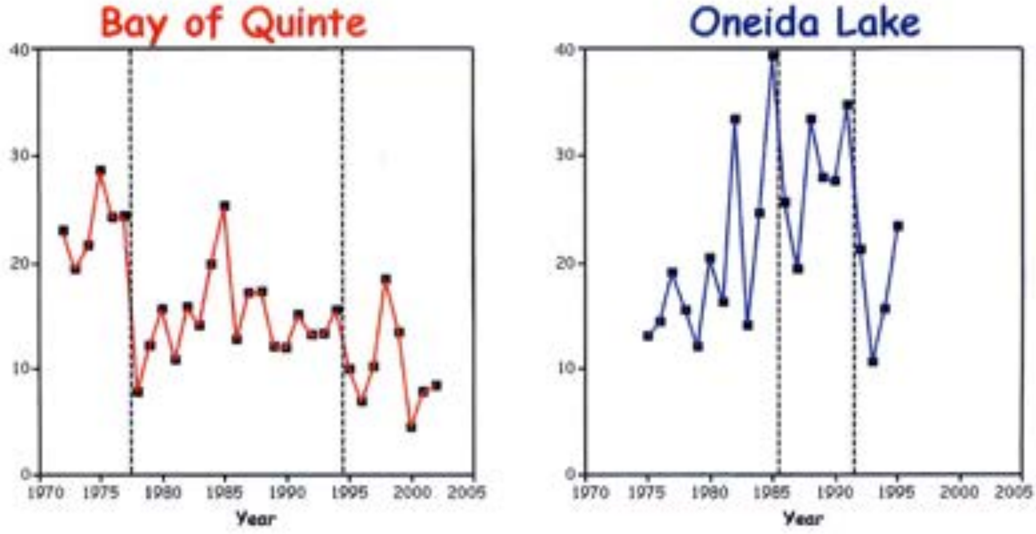
- Decreased walleye habitat due to increased water clarity and increased macrophyte coverage
- Increased mortality on walleye from cormorant consumption
- Increased mortality on walleye from increased exploitation

Upper Bay of Quinte
Area: 133.4 km^2
Mean Depth: 2.5 m
Max Depth: 14.1 m

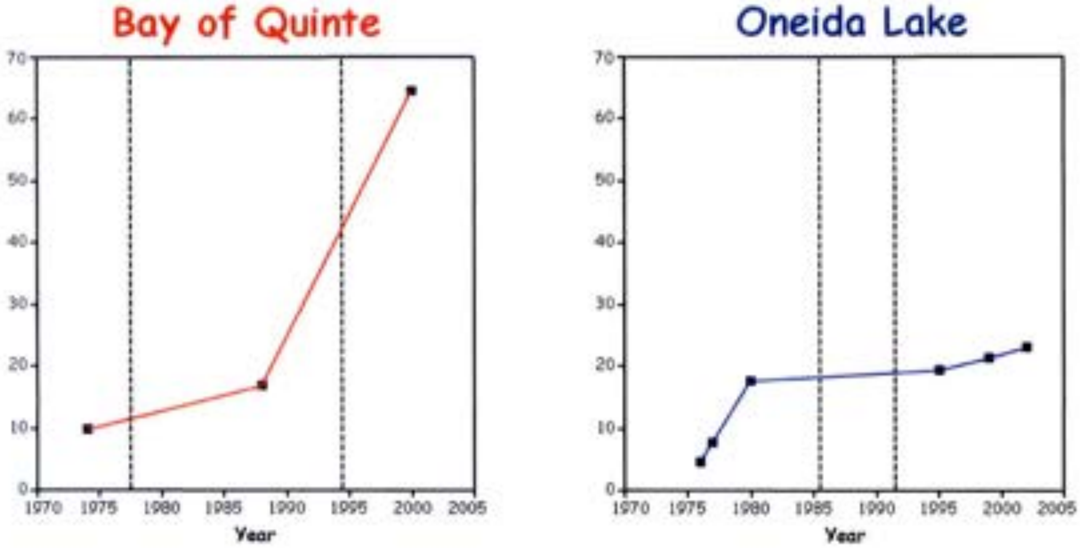


Oneida Lake
Area: 206.7 km^2
Mean Depth: 6.8 m
Max Depth: 16.8 m

Phytoplankton Biomass (t/km^2)



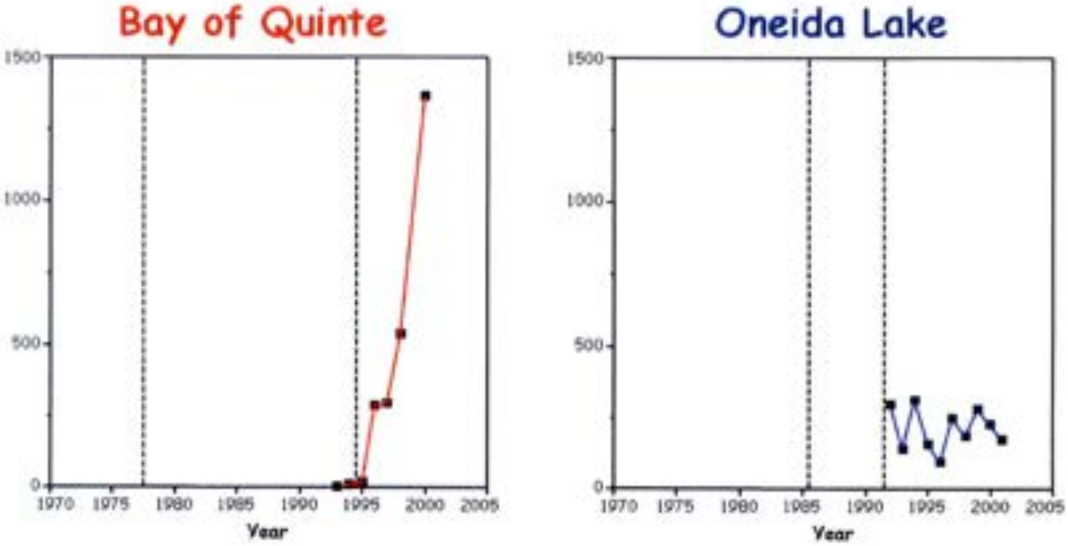
Macrophyte Biomass (t/km²)



Bay of Quinte

Oneida Lake

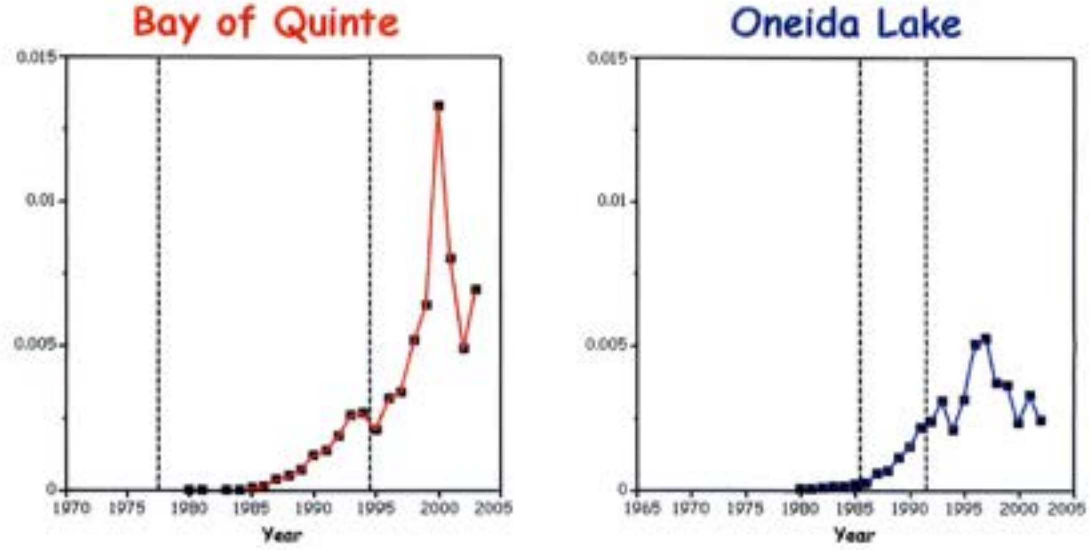
Dreissenid Biomass (t/km²)



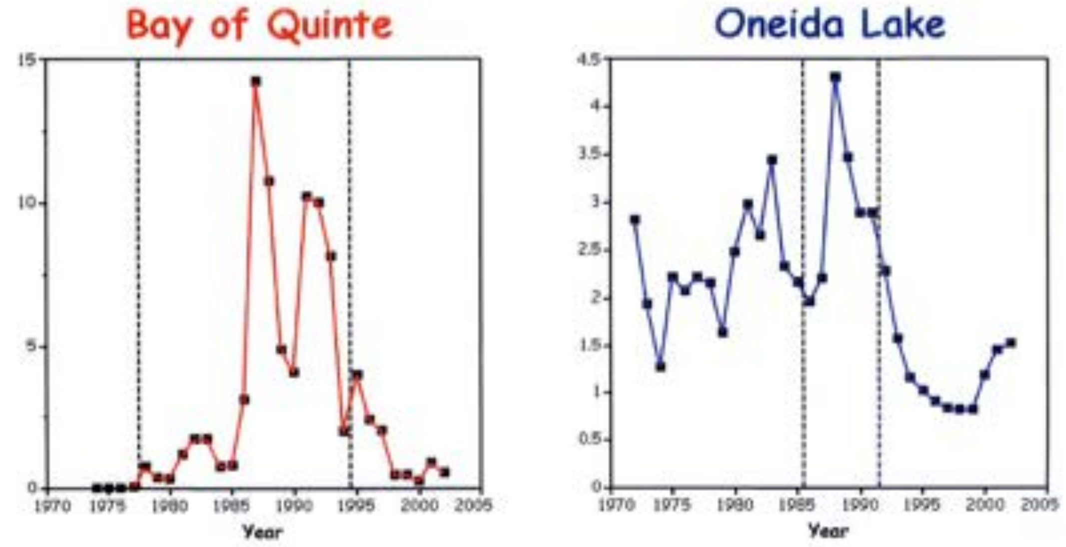
Bay of Quinte

Oneida Lake

Cormorant Biomass (t/km^2)



Walleye Biomass (t/km^2)



Bay of Quinte and Oneida Lake Milestones:

1950s-1970s	Phosphorus loadings Eutrophication
mid-late 1970s	Phosphorus control
1980s	Reduced phosphorus More macrophytes
early 1990s	Zebra mussel invasion Increased water clarity Benthification
thru 1990s	Increased cormorants Decreased walleye
late 1990s	Quinte invaded by: - *Cercopagis* - round goby

Approach

Build Ecopath models as snapshots of each ecosystem in each time period:

2 ecosystems X 3 time periods = 6 Ecopath models

Use Ecosim to explore the effects of

dreissenids, cormorants, and fishing

on the decline of walleye

ECOPATH
Mass Balance Model

Routines for entry of key data on the biology and exploitation of ecosystem groups and for establishing mass balance.

www.ecopath.org

Ecopath mass balance is achieved by solving:

Production =

Predation Mortality

+ Fisheries Catches

+ Biomass Accumulation

+ Net Migration

+ Other Mortality

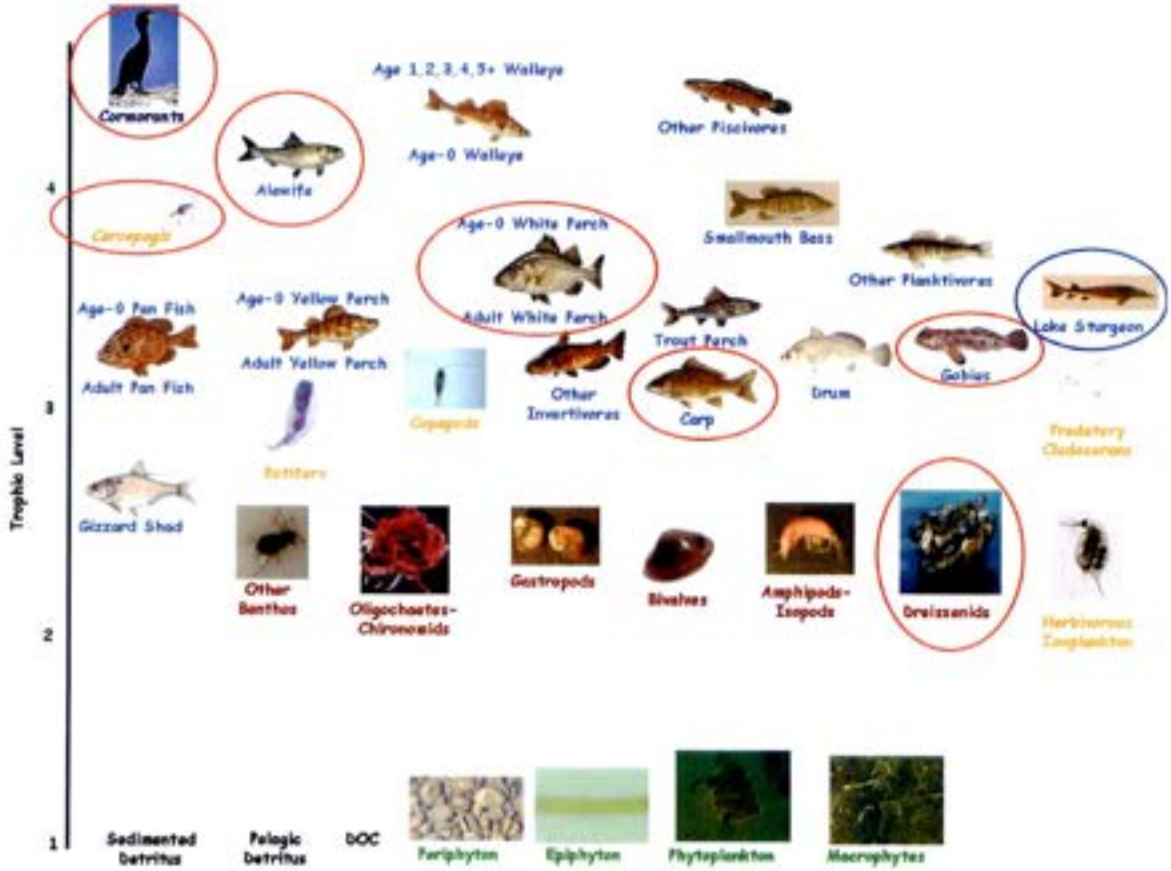
Ecopath Inputs

Mandatory User Inputs:

- DC = **Diet Composition (proportions)**
- BA = **Biomass Accumulation ($t \cdot km^{-2}$)**
- Y = **Fishery Catches ($t \cdot km^{-2}$)**
- **E = Net Migration ($t \cdot km^{-2}$) = emigration - immigration**

User Inputs 3 of 4:

- **P/B = Production/Biomass (yr^{-1})**
- **Q/B = Consumption/Biomass (yr^{-1})**
- **B = Biomass ($t \cdot km^{-2}$)**
- **EE = Ecotrophic Efficiency (proportion)**



ECOSIM
Time Dynamic Model

Dynamic simulation of the effect that changes may have on fisheries catches and the abundance of various groups in the ecosystem.

Uncertainties

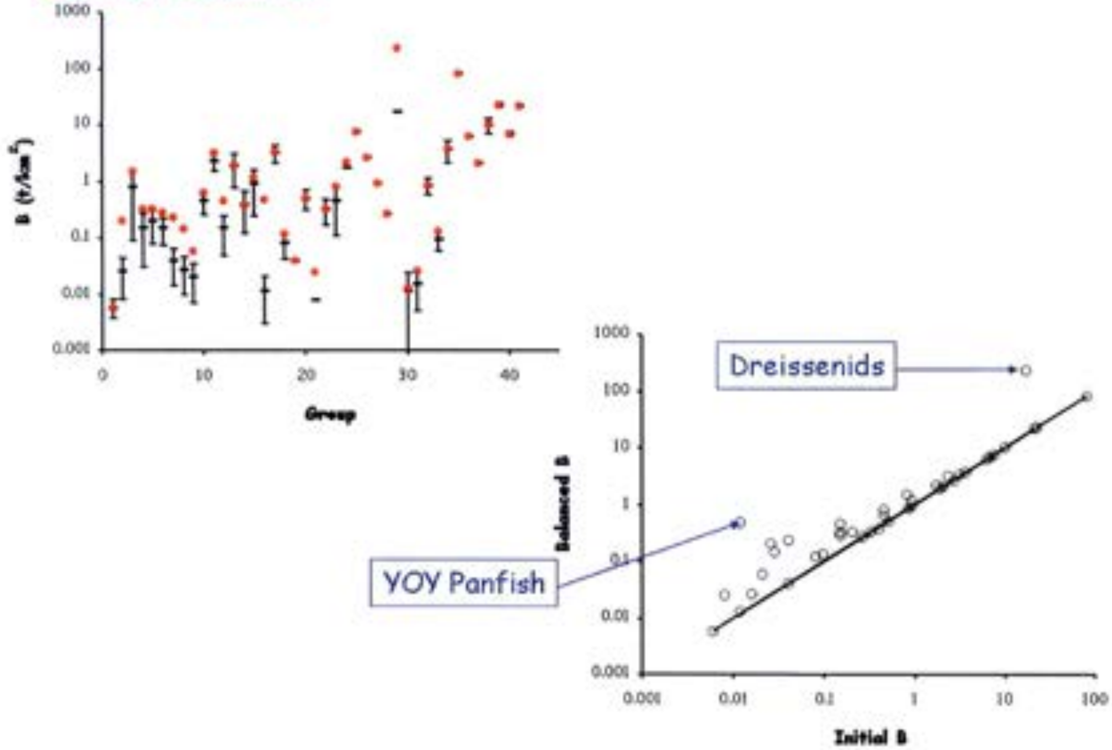
1. Input values
    - Sensitivity analyses (B, P/B, Q/B)
    - Diet validation

2. Model output
    - Time series replication
    - Monte Carlo simulations

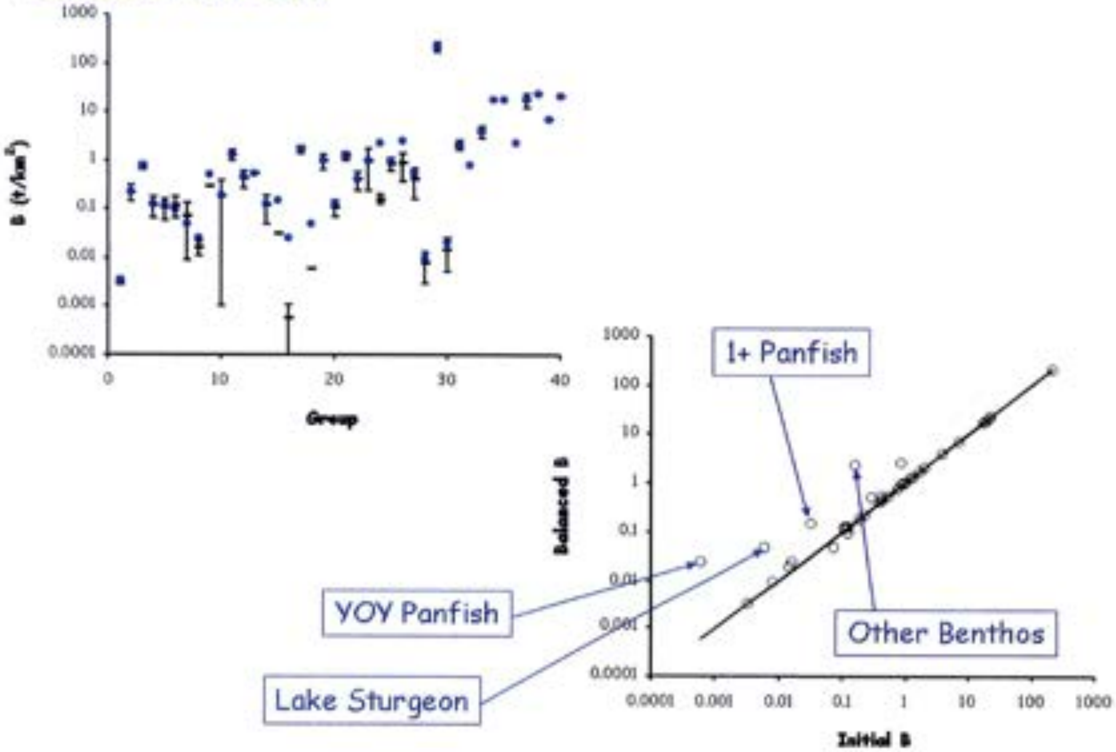
Uncertainty about input values (B, P/B, Q/B):

- B estimated from data
- P/B estimated from data or allometry
- Q/B estimated from literature

Quinte: Post-ZM



Oneida: Post-ZM



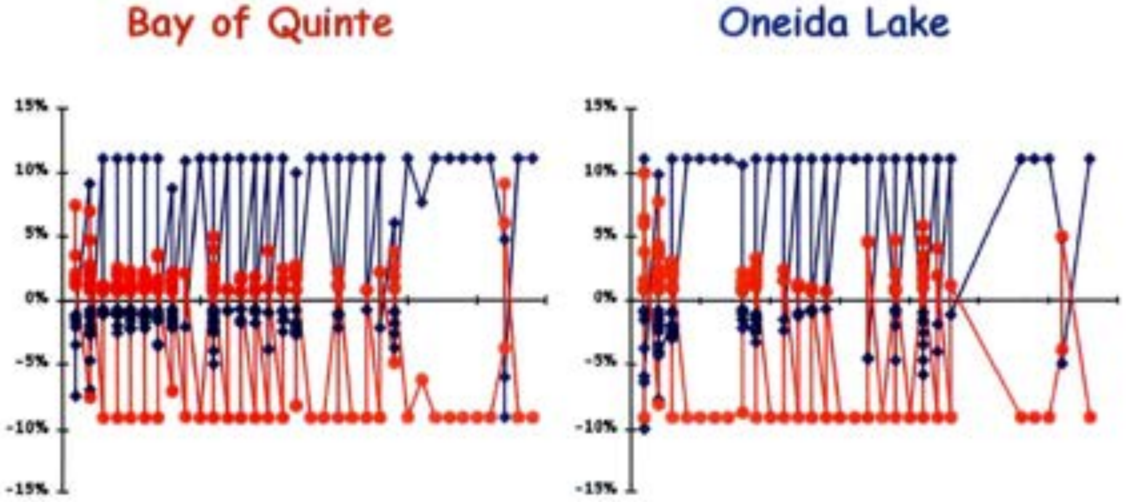
Uncertainty about input values (B, P/B, Q/B):

- B estimated from data
- P/B estimated from data or allometry
- Q/B estimated from literature

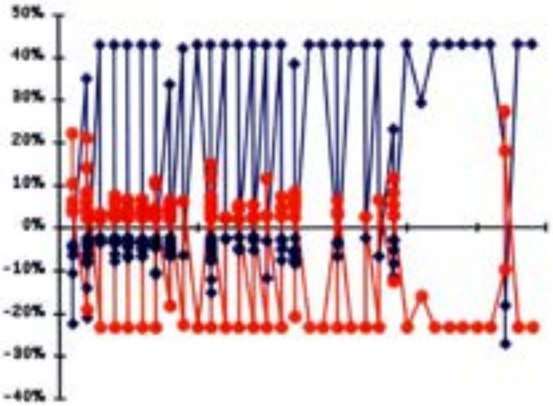
Sensitivity analyses:

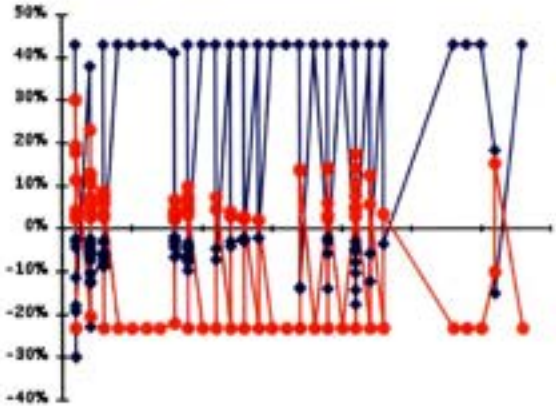
- vary inputs by a set amount (e.g. 10% or 50%)
- examine response of Ecopath estimates

+10% or -10% Biomass (t/km^2)

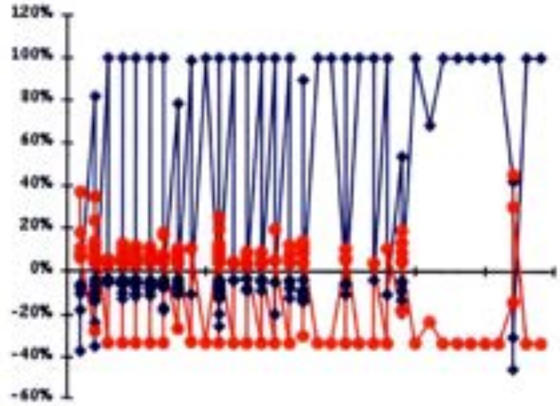


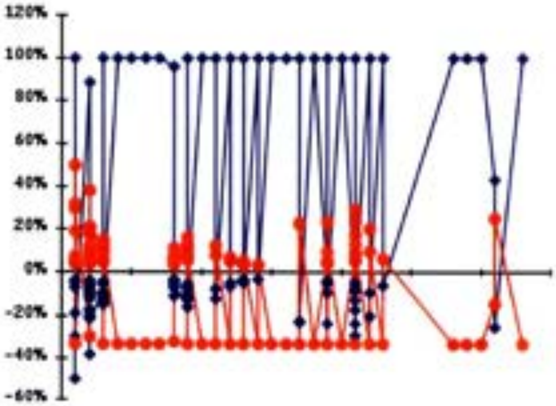
+30% or -30% Biomass (t/km^2)


Bay of Quinte

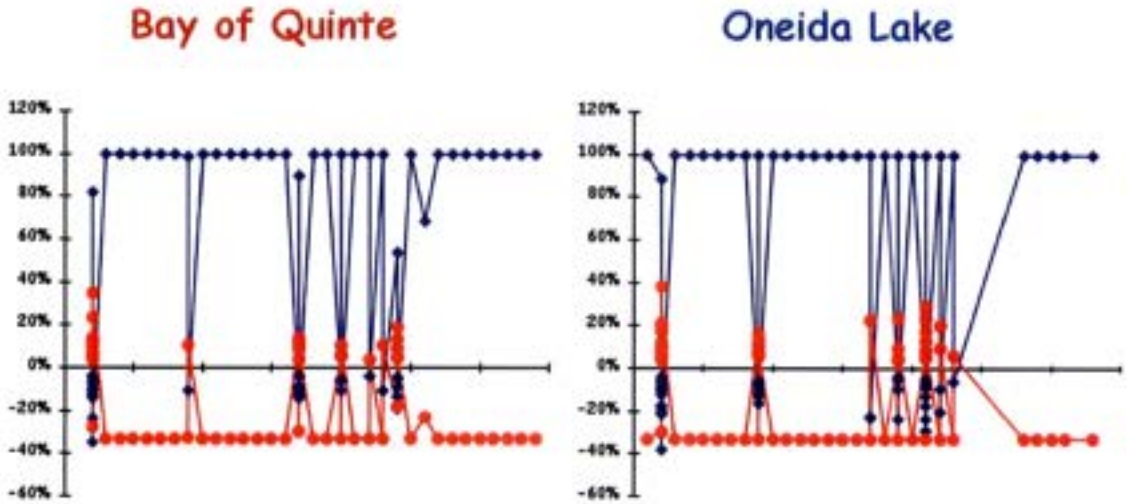

Oneida Lake

+50% or -50% Biomass (t/km^2)

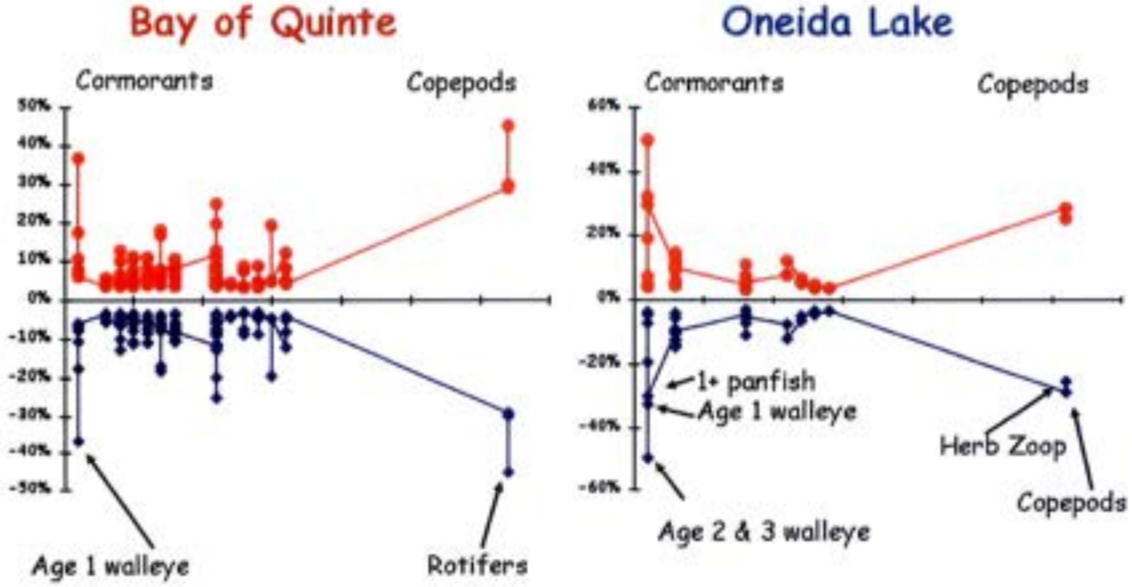

Bay of Quinte


Oneida Lake

+50% or -50% P/B



+50% or -50% Q/B



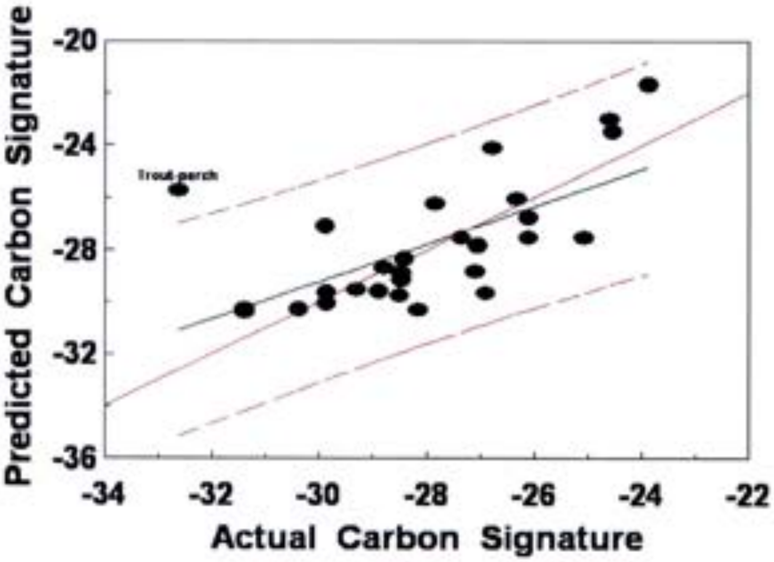
Uncertainty about the diet matrix:

- some general literature diets (e.g. Scott & Crossman)
- some presence/absence diet data
- little system-specific quantification of diets
- initial diets modified to achieve mass balance

Diet validation:

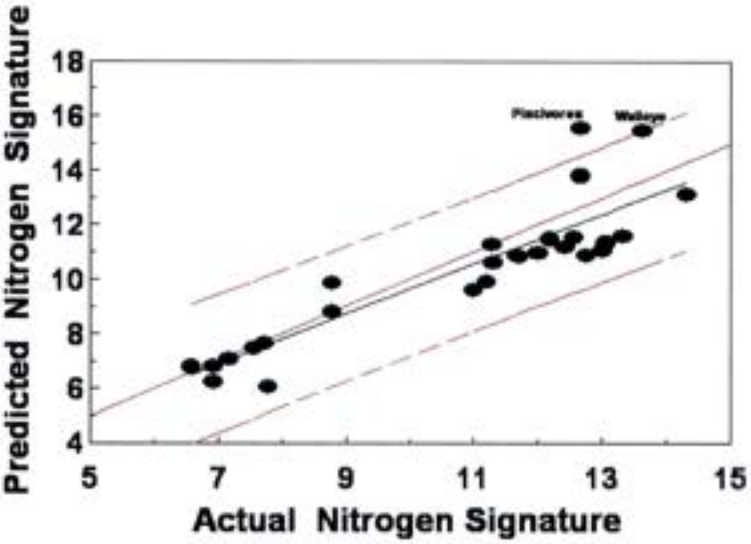
- stable isotope analysis of fishes in both systems
- use diet matrix to predict predator isotope signatures
- compare and test actual and predicted signatures

Quinte: δ^{13}C Results



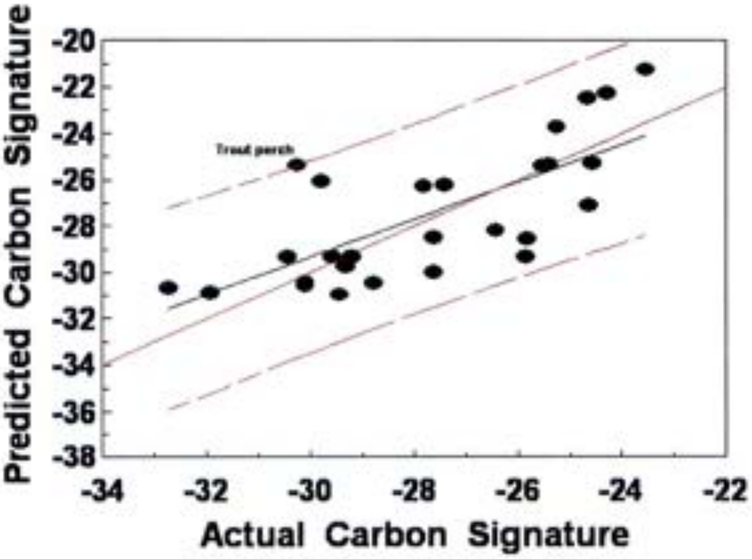
Slope not significantly different than 1

Quinte: δ^{15}N Results



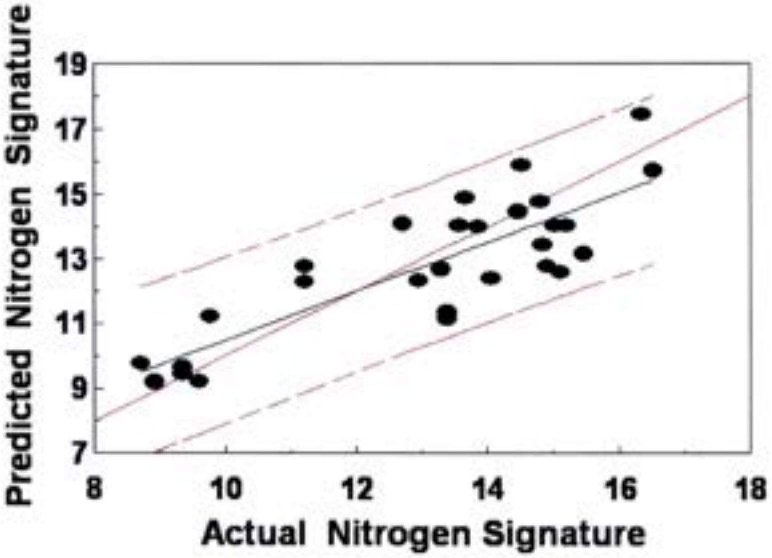
Slope not significantly different than 1

Oneida: δ^{13}C Results



Slope not significantly different than 1

Oneida: $\delta^{15}N$ Results



Slope significantly different than 1 (*P*=0.019)

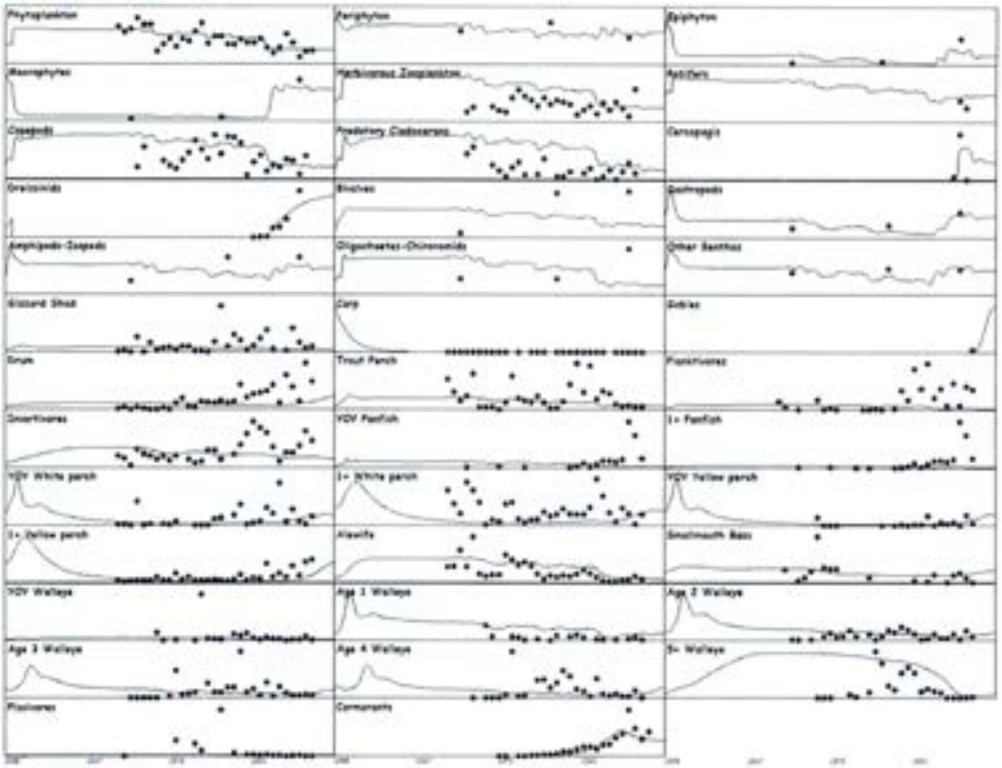
Uncertainty about model performance:

- is the model output "reasonable"?

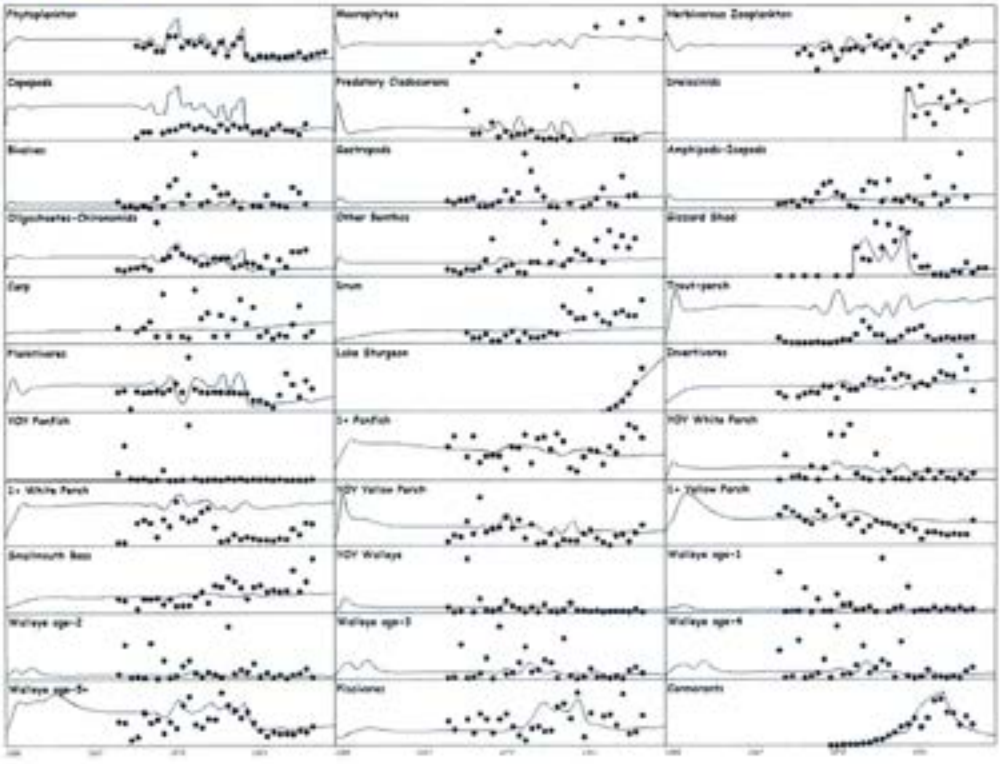
Historical replication:

- run the model through known historical perturbations
- does the model replicate historical time series

Bay of Quinte



Oneida Lake

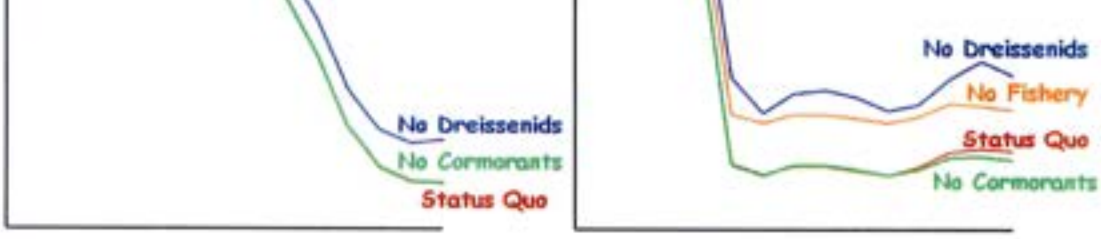


- What are the ecosystem impacts of recent invasions?
- Why did walleye decline through the 1990s in both the Bay of Quinte and Oneida Lake?

Hypotheses:

- Decreased walleye habitat due to increased water clarity and increased macrophyte coverage
- Increased mortality on walleye from cormorant consumption
- Increased mortality on walleye from increased exploitation

Walleye Biomass – Ecosim Scenarios

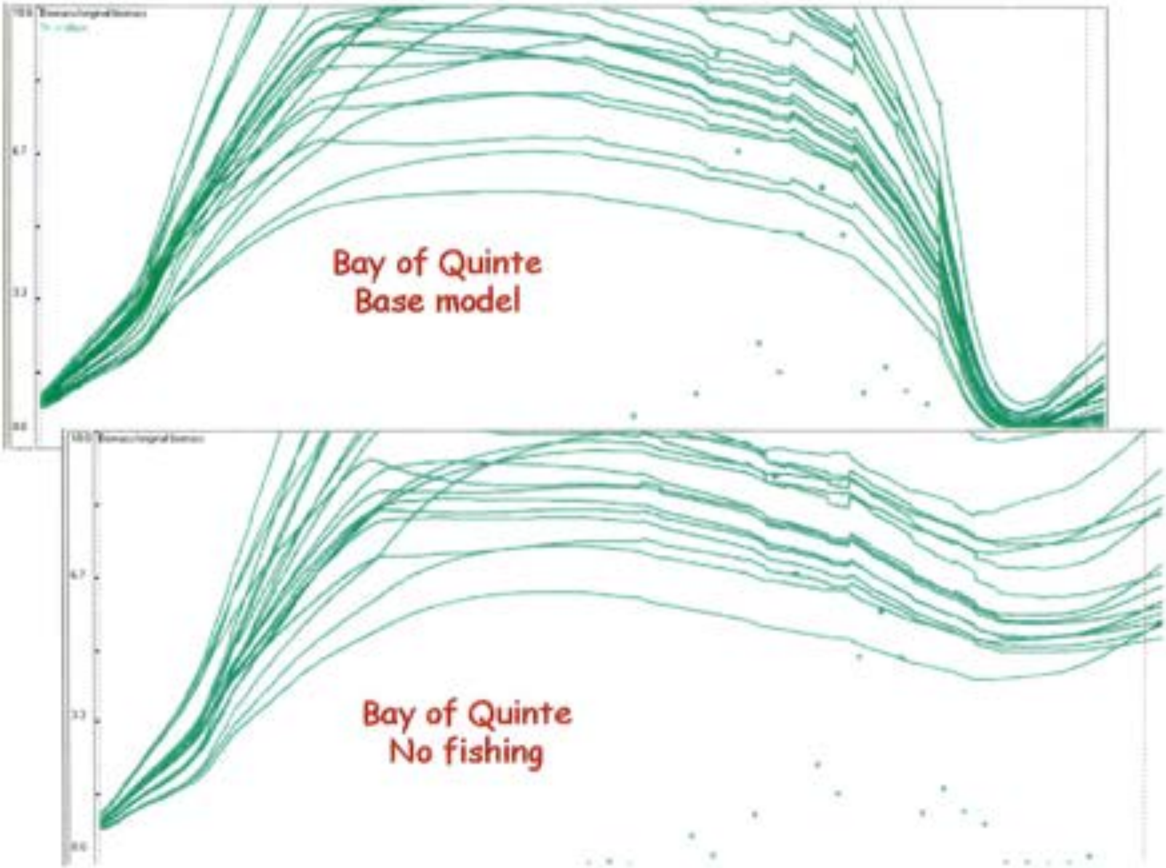


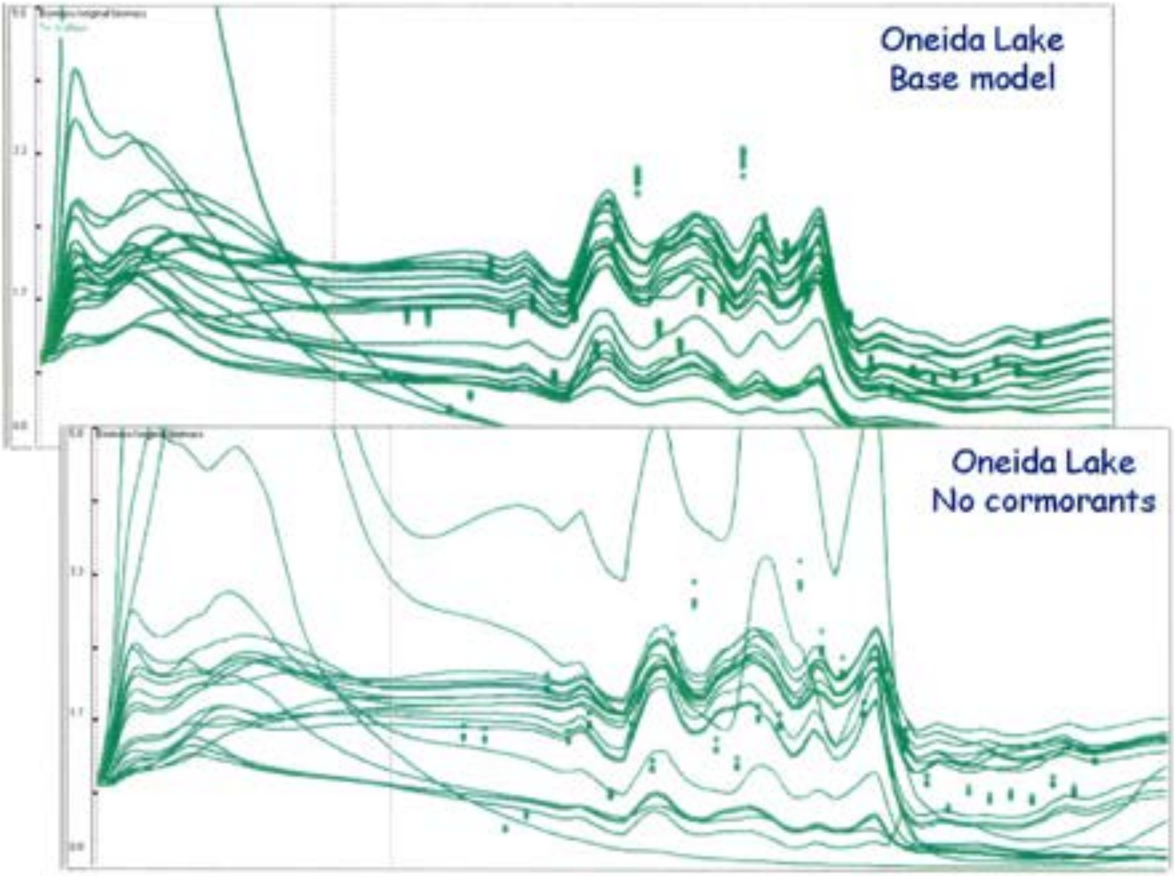
Uncertainty about Ecosim output:

- Ecosim is based on the Ecopath snapshot
- If Ecopath model changes does Ecosim output?

Monte Carlo simulations:

- specify uncertainty in Ecopath inputs (B, P/B, Q/B)
- randomly draw input values
- test for mass balance
- if balanced then run Ecosim simulation
- if unbalanced, discard Ecopath inputs and re-draw




Oneida Lake
Base model
Oneida Lake
No cormorants

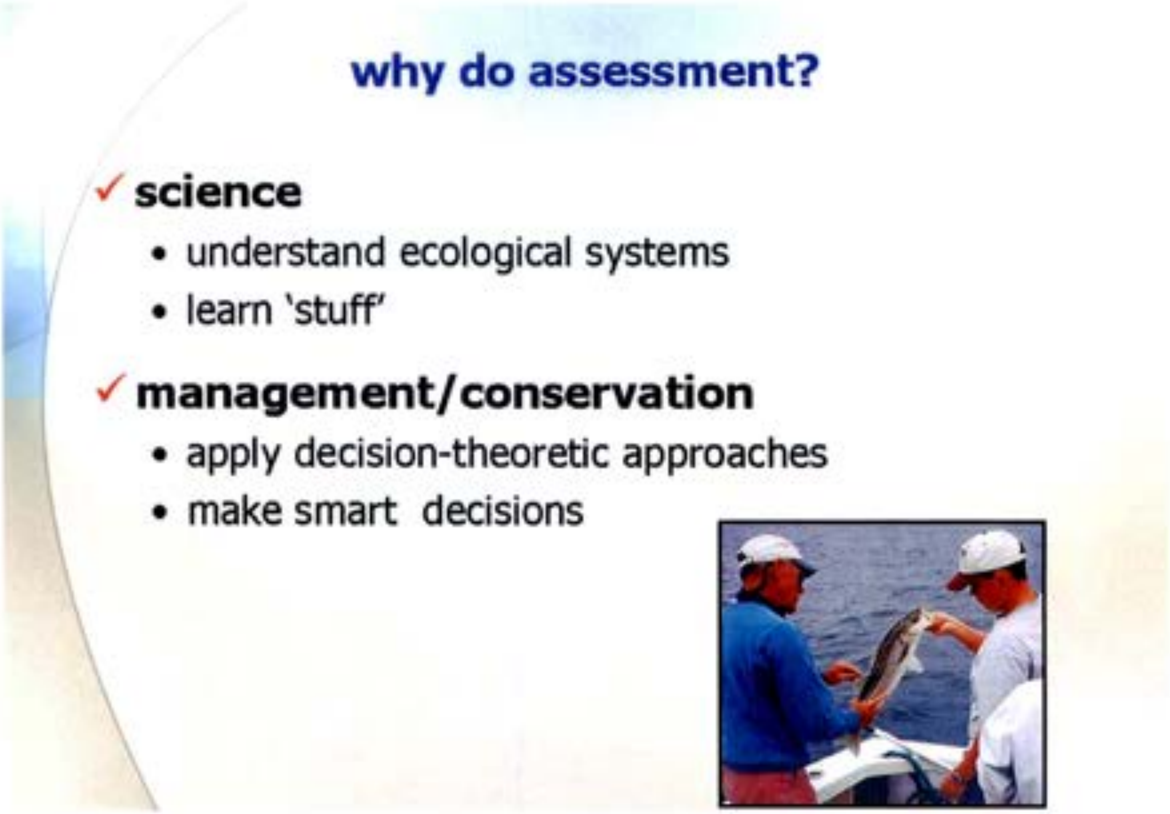
Appendix H.
Assessing Change and Impact in Complex Ecosystems: Approaches Based on Nonlinear Dynamics and Information Theory

Assessing Change and Impact in Complex Ecosystems: Approaches Based on Nonlinear Dynamics and Information Theory

Evan Cooch
Department of Natural Resources
Cornell University
NY Sea Grant Workshop
October 24, 2005

Abstract

Most ecological systems exhibit nonlinear dynamics and can exhibit dramatic responses even to smooth and gradual environmental changes. In order to better describe and understand such systems, especially for the purpose of forecasting, it is necessary to move beyond the ecologists standard set of methods based on linear systems to methods designed specifically for nonlinear systems. I will describe some recent work in this area to responses of coupled systems to environmental change. This work involves development of formal statistical and modeling approaches, which focus on the geometry of dynamical systems and on the information content of dynamical system components, for the (i) selection of indicator species and (ii) the detection of change in system processes, based on time series of a limited number of system components from a surveillance monitoring program. Preliminary research suggests that these methods will provide a basic theory and set of associated methods for information extraction from surveillance monitoring and assessment of important environmental systems. Such monitoring is fundamental to characterizing the state of such systems. The work will move well beyond the traditional ad hoc approach to use of data from traditional environmental monitoring and provide a theoretical basis for such tasks as the selection of indicator species, and the assessment of changes and damage to system processes and functions. This work should have far-ranging applicability to fisheries, and ecosystems in general, both for the analysis of data from extant monitoring programs and for the design of future monitoring programs. Specifically, the methods will permit objective decisions about selection of indicator species in terms of information content about system processes, in addition to permitting assessment of changes in overall system processes (e.g., those resulting from human interventions) using time series from a small subset of system components.



why do assessment?

✓ **science**

- understand ecological systems
- learn 'stuff'

✓ **management/conservation**

- apply decision-theoretic approaches
- make smart decisions

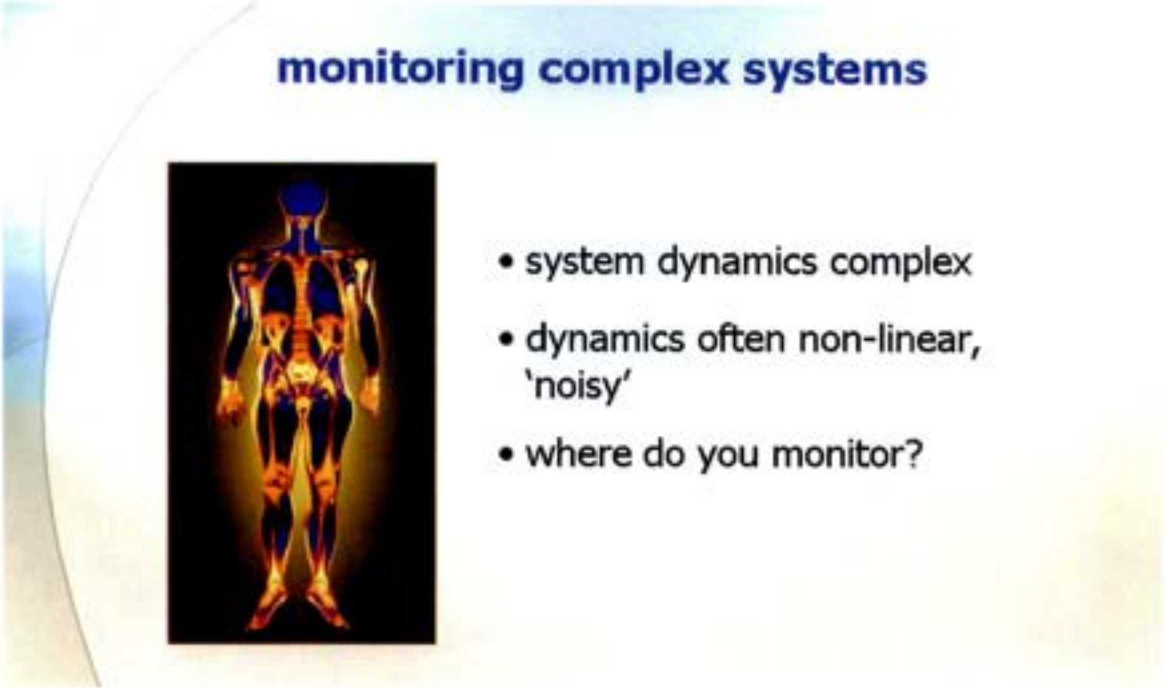
how do we assess system dynamics?
study designs

✓ use design that imposes, or takes advantage of, a manipulation of some sort

- manipulative experimentation (randomization, replication, controls) – Press/Pulse experiments
- impact study (lacks randomization and perhaps replication, but includes time-space controls)

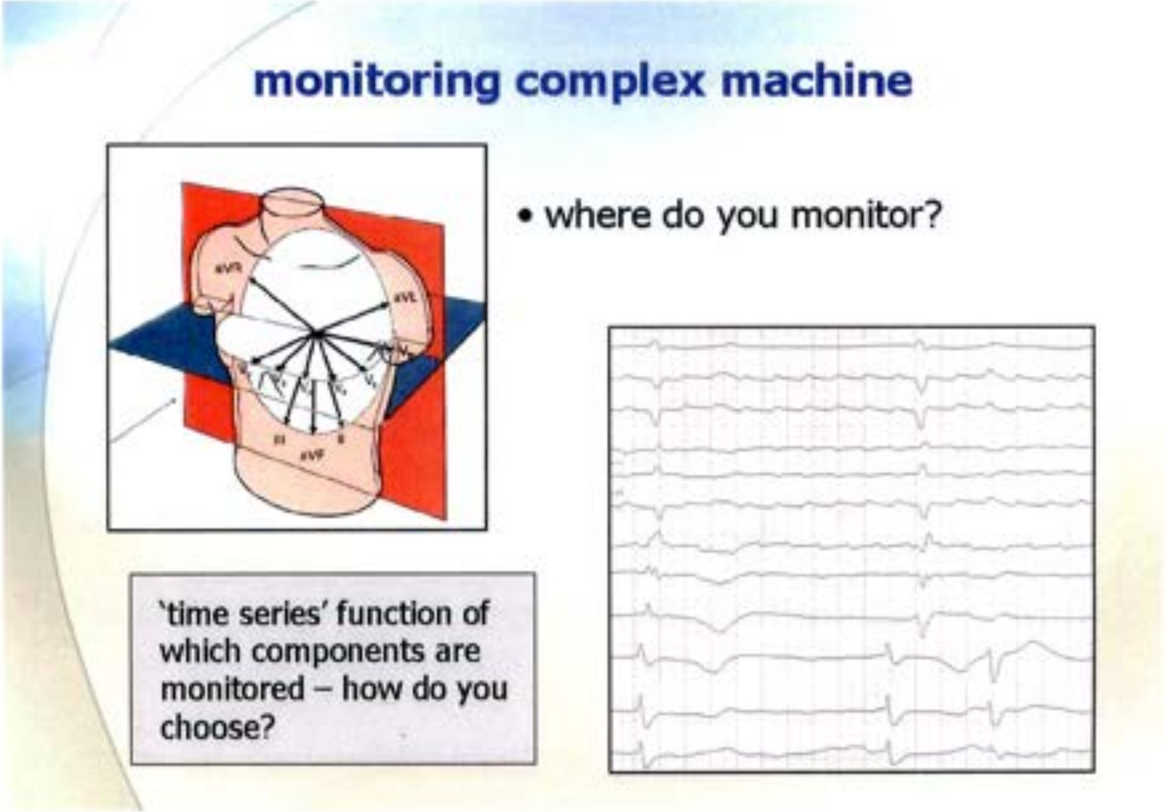
✓ no manipulation - observational study ('surveillance')

- prospective (confrontation with predictions from *a priori* hypotheses)
- retrospective (*a posteriori* story-telling)



monitoring complex systems

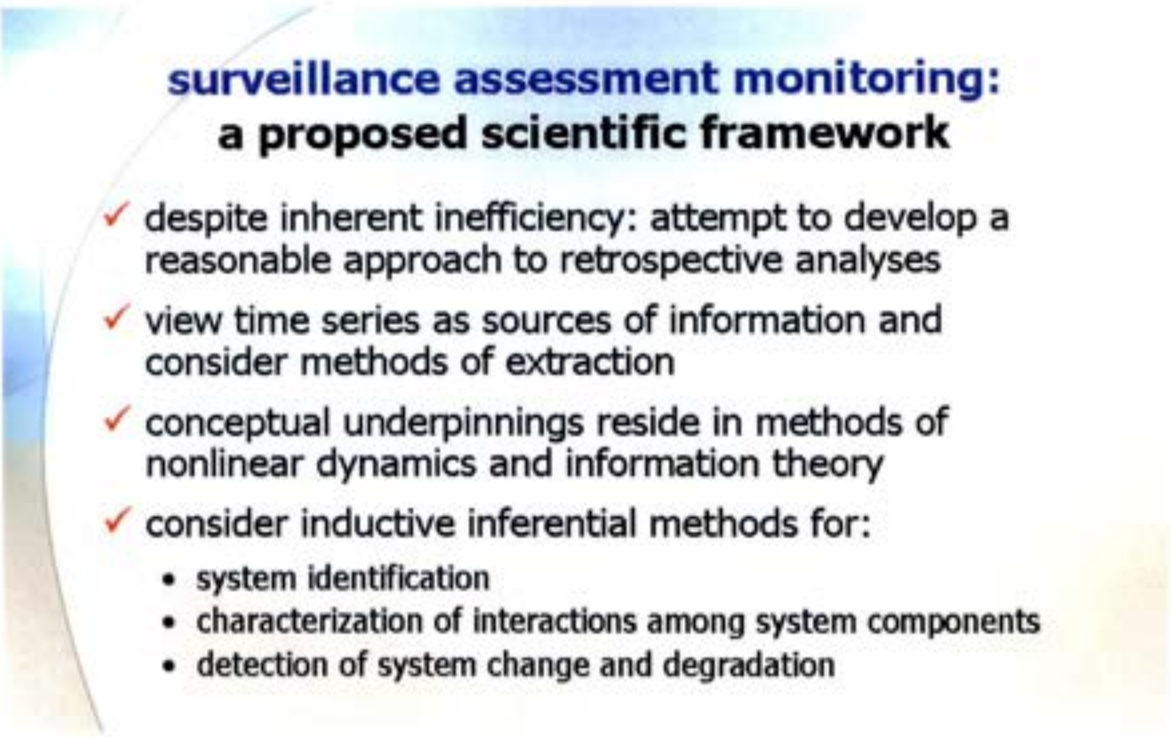
- system dynamics complex
- dynamics often non-linear, 'noisy'
- where do you monitor?



monitoring complex machine

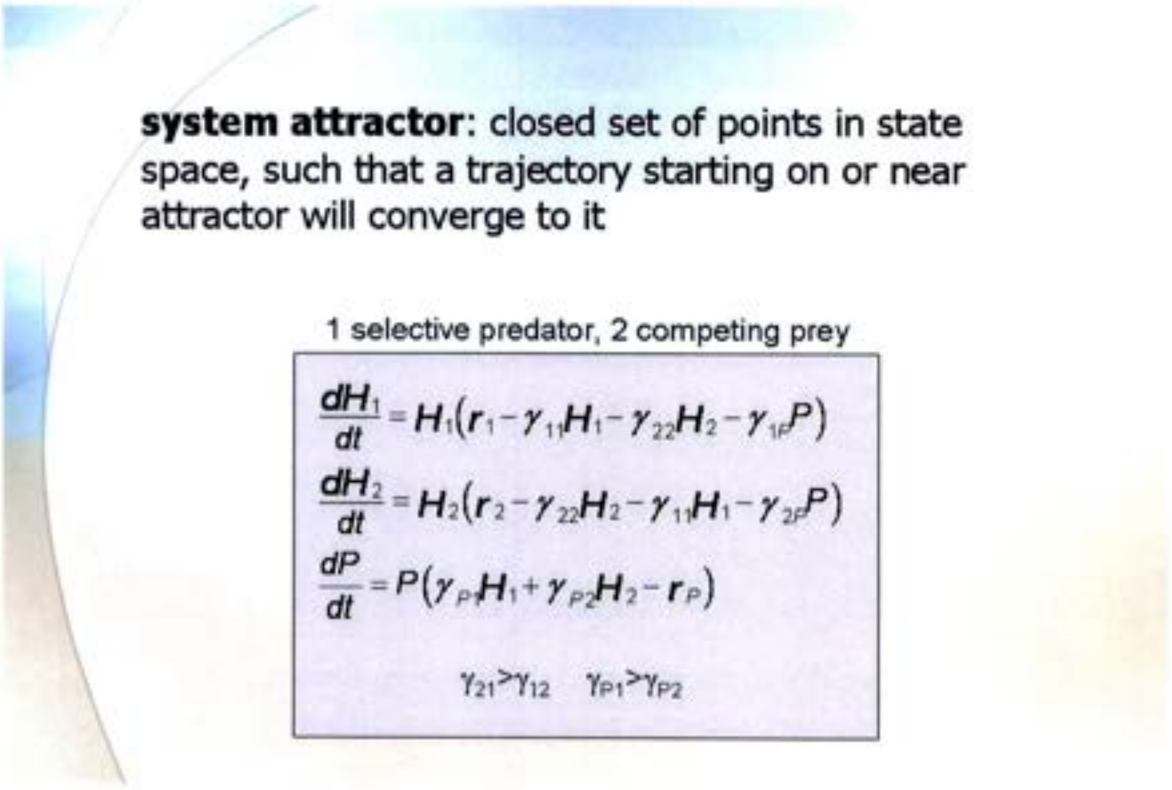
- where do you monitor?

'time series' function of which components are monitored – how do you choose?



surveillance assessment monitoring: a proposed scientific framework

- ✓ despite inherent inefficiency: attempt to develop a reasonable approach to retrospective analyses
- ✓ view time series as sources of information and consider methods of extraction
- ✓ conceptual underpinnings reside in methods of nonlinear dynamics and information theory
- ✓ consider inductive inferential methods for:
  - system identification
  - characterization of interactions among system components
  - detection of system change and degradation



system attractor: closed set of points in state space, such that a trajectory starting on or near attractor will converge to it

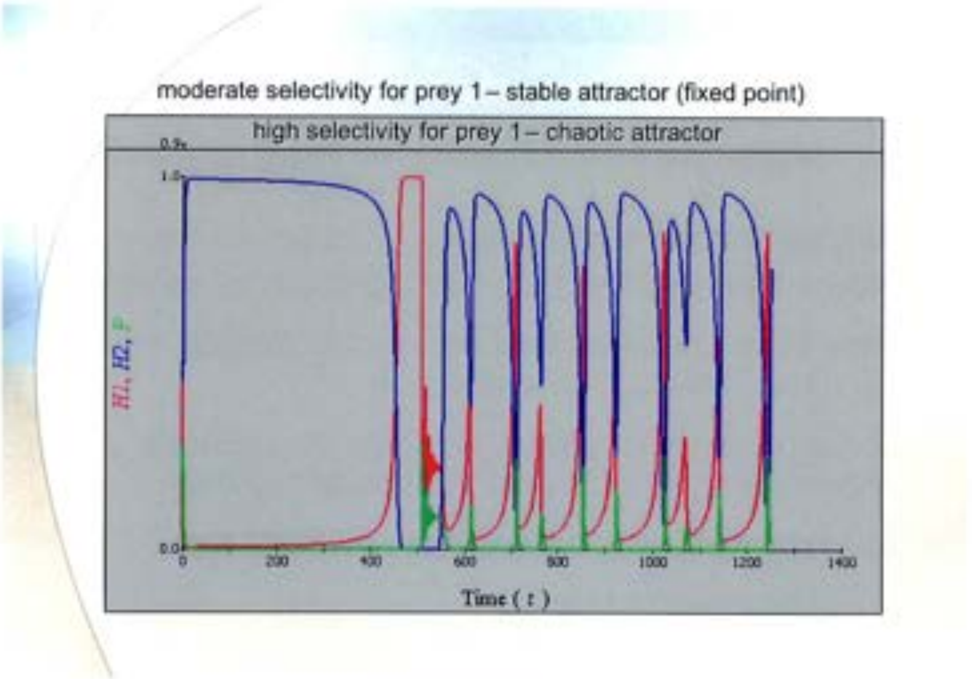
1 selective predator, 2 competing prey

$$\frac{dH_1}{dt} = H_1(r_1 - \gamma_{11}H_1 - \gamma_{22}H_2 - \gamma_{1P}P)$$

$$\frac{dH_2}{dt} = H_2(r_2 - \gamma_{22}H_2 - \gamma_{11}H_1 - \gamma_{2P}P)$$

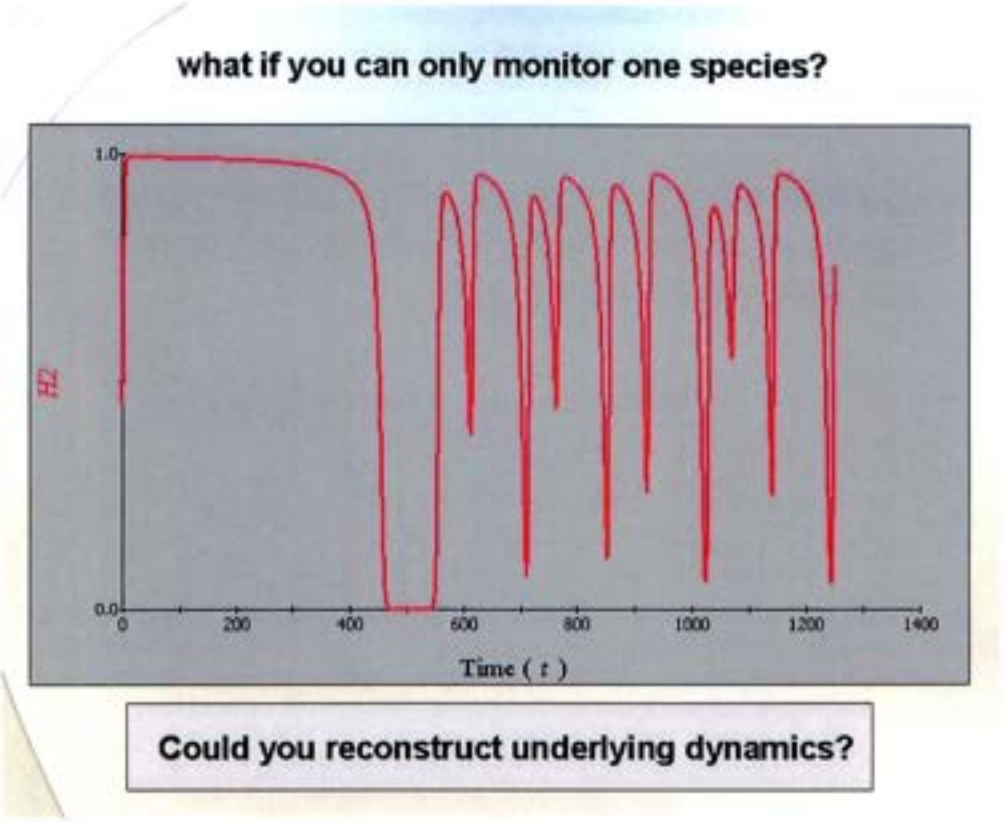
$$\frac{dP}{dt} = P(\gamma_{P1}H_1 + \gamma_{P2}H_2 - r_P)$$

$$\gamma_{21} > \gamma_{12} \quad \gamma_{P1} > \gamma_{P2}$$



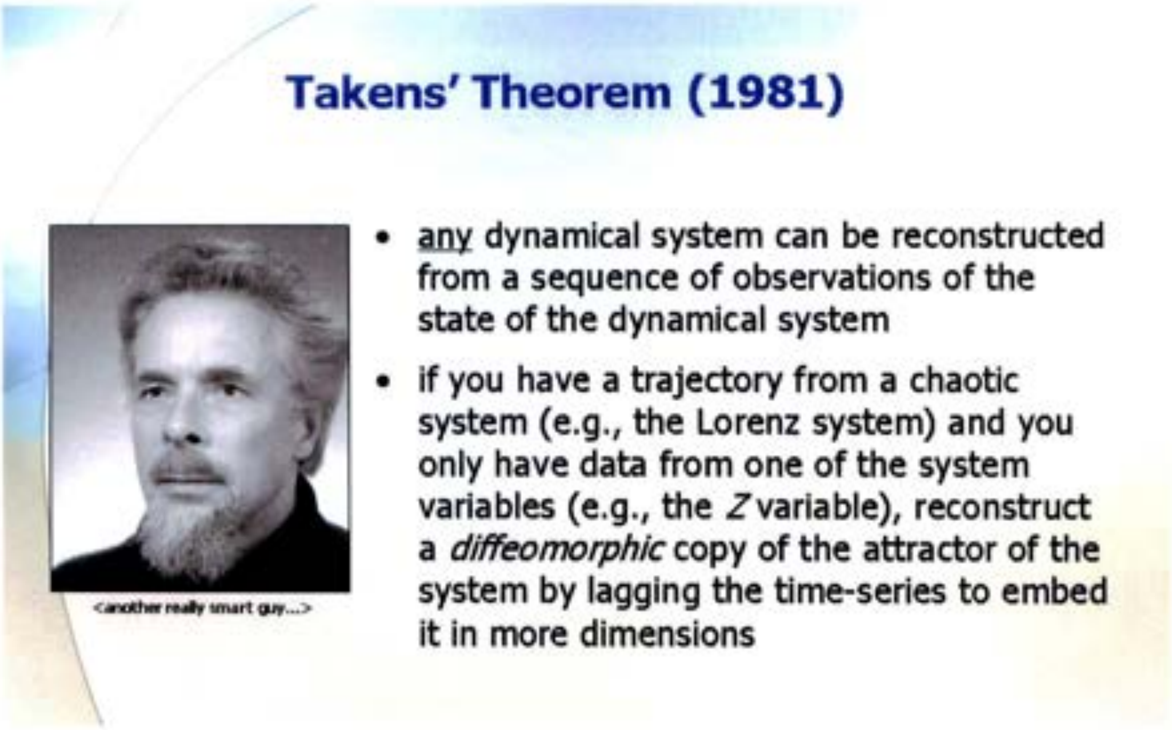
moderate selectivity for prey 1 – stable attractor (fixed point)

high selectivity for prey 1 – chaotic attractor



what if you can only monitor one species?

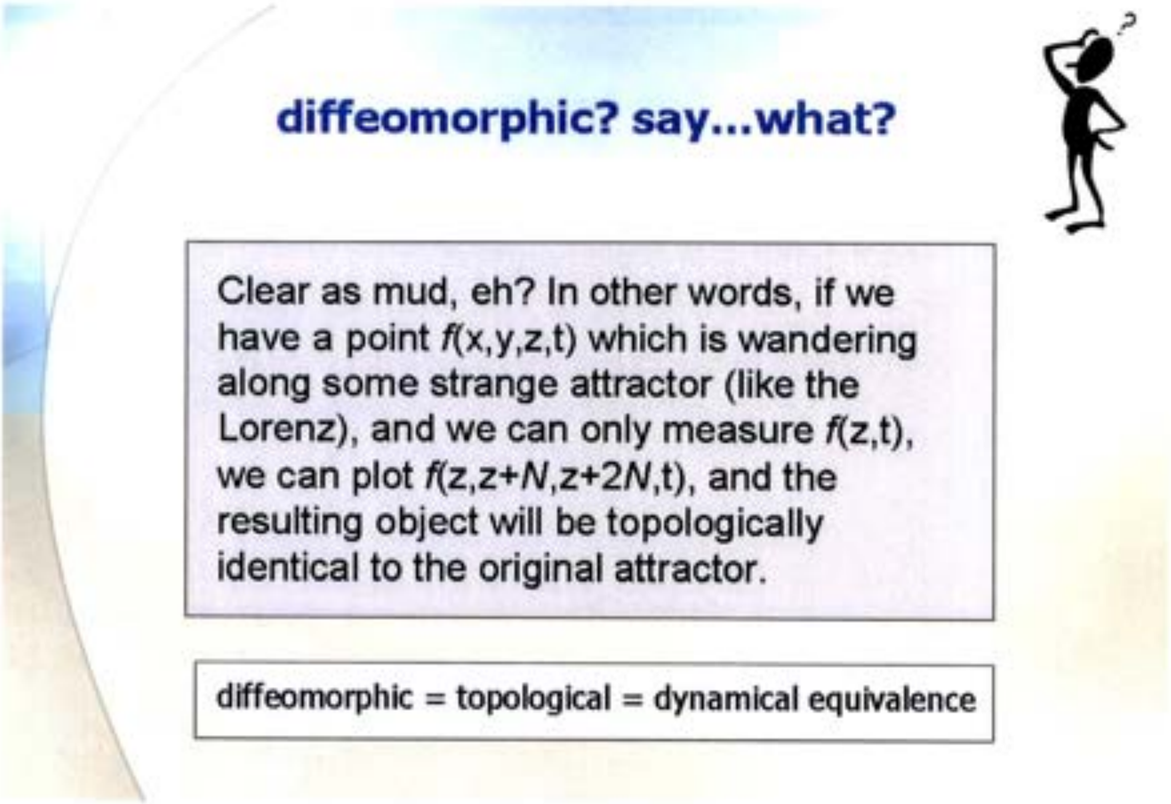
Could you reconstruct underlying dynamics?



Takens' Theorem (1981)

<another really smart guy...>

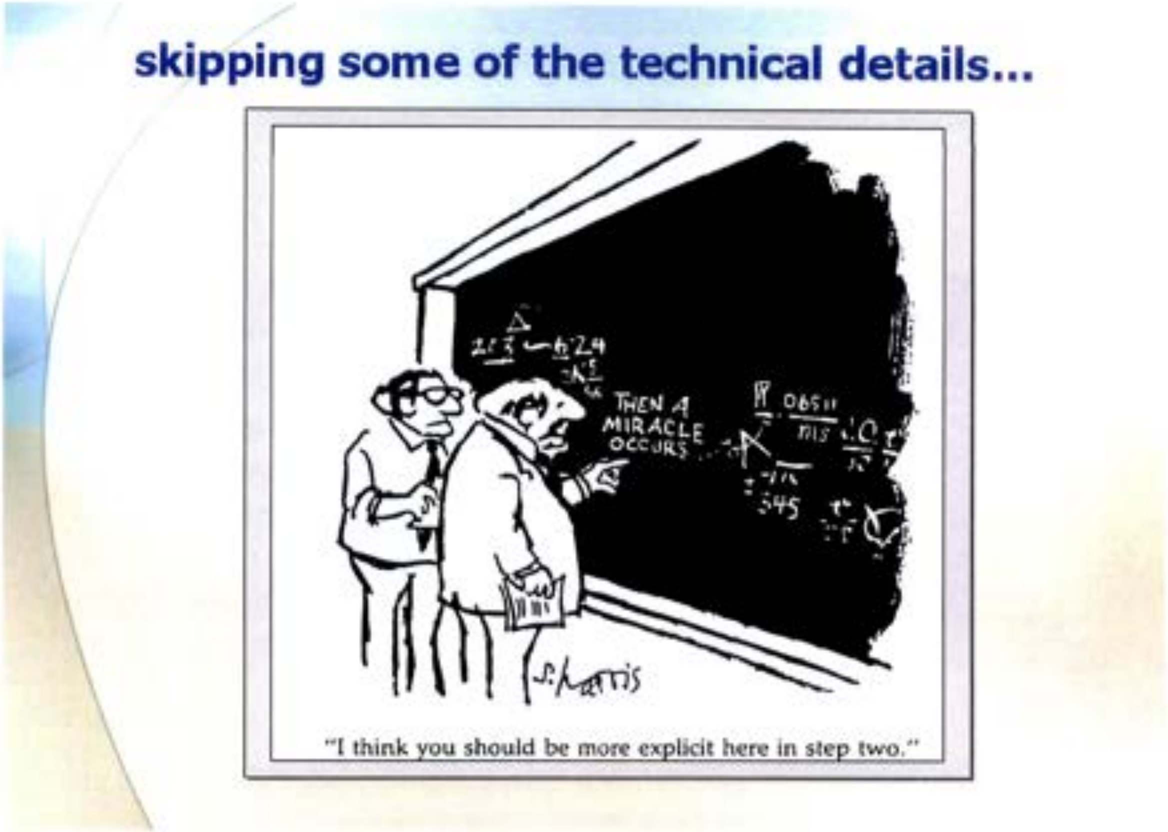
- any dynamical system can be reconstructed from a sequence of observations of the state of the dynamical system
- if you have a trajectory from a chaotic system (e.g., the Lorenz system) and you only have data from one of the system variables (e.g., the Z variable), reconstruct a *diffeomorphic* copy of the attractor of the system by lagging the time-series to embed it in more dimensions



diffeomorphic? say...what?

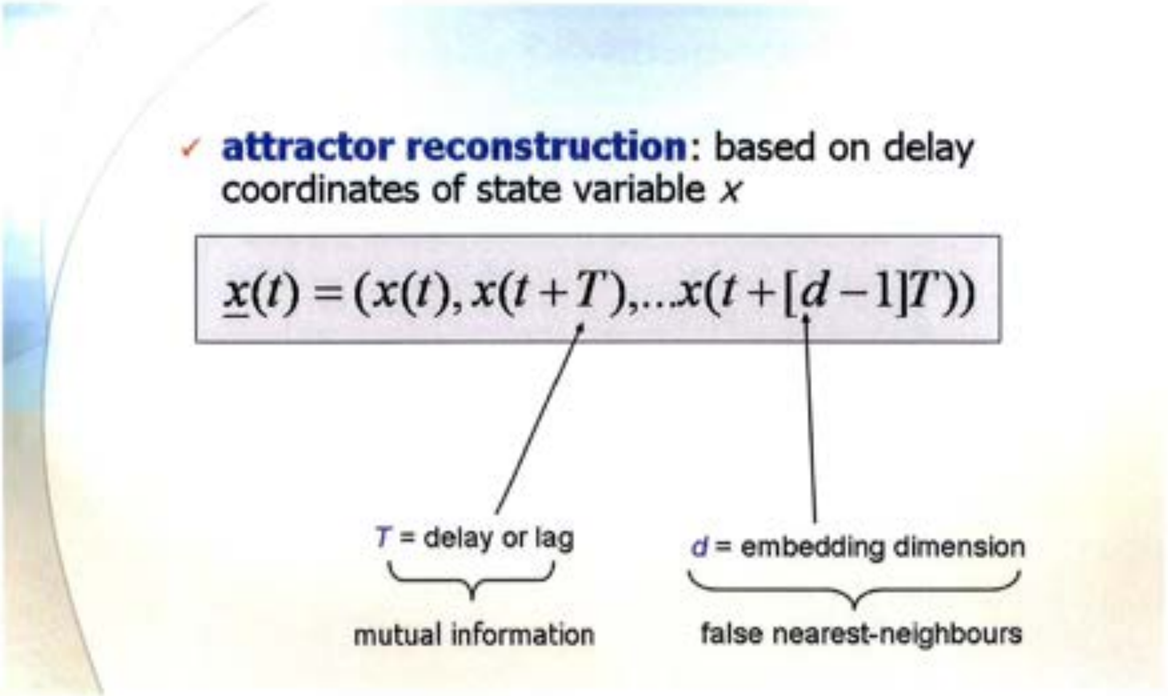
Clear as mud, eh? In other words, if we have a point $f(x,y,z,t)$ which is wandering along some strange attractor (like the Lorenz), and we can only measure $f(z,t)$, we can plot $f(z,z+N,z+2N,t)$, and the resulting object will be topologically identical to the original attractor.

diffeomorphic = topological = dynamical equivalence



skipping some of the technical details...

"I think you should be more explicit here in step two."



- ✓ **attractor reconstruction**: based on delay coordinates of state variable *x*

$$\underline{x}(t) = (x(t), x(t+T), \ldots x(t+[d-1]T))$$

$\underbrace{T = \text{delay or lag}}_{\text{mutual information}}$

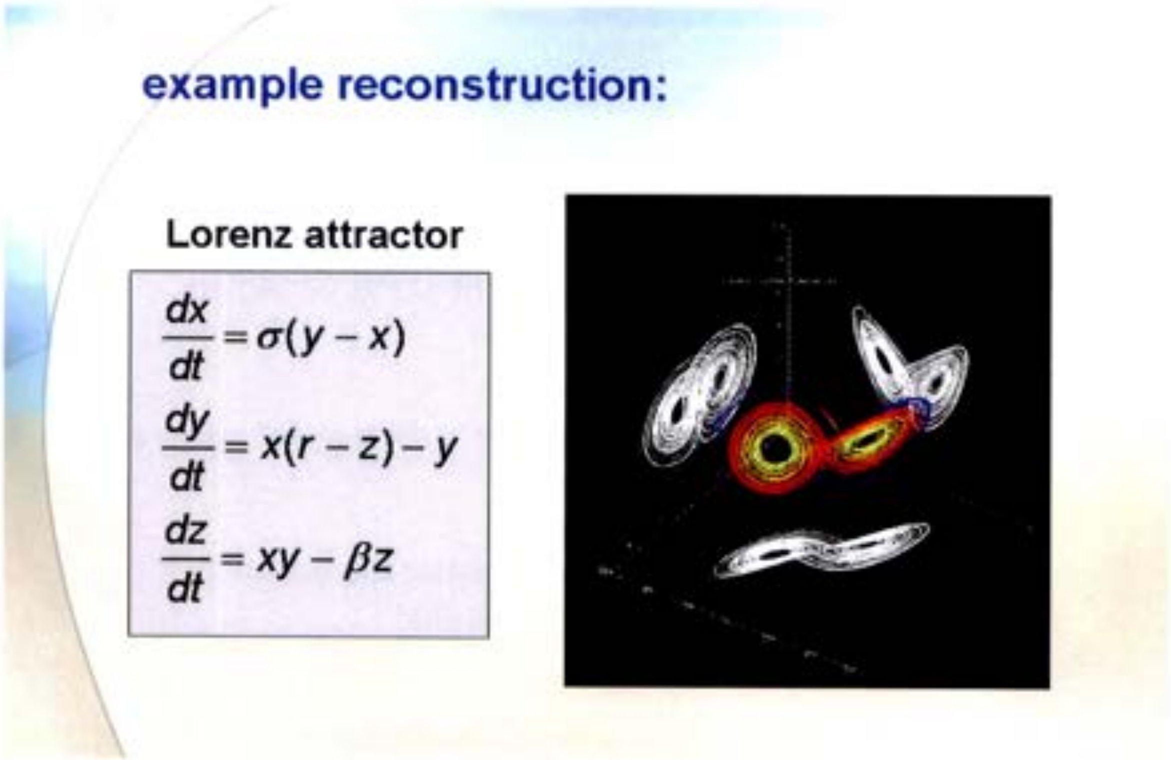
$\underbrace{d = \text{embedding dimension}}_{\text{false nearest-neighbours}}$

- ✓ **embedding dimension**: interesting on its own...

$$\underline{x}(t) = (x(t), x(t+T),\ldots x(t+[d-1]T))$$

dimension conveys information about the number of state variables or groups of state variables (e.g., guilds, trophic levels) that are active determinants of system dynamics...

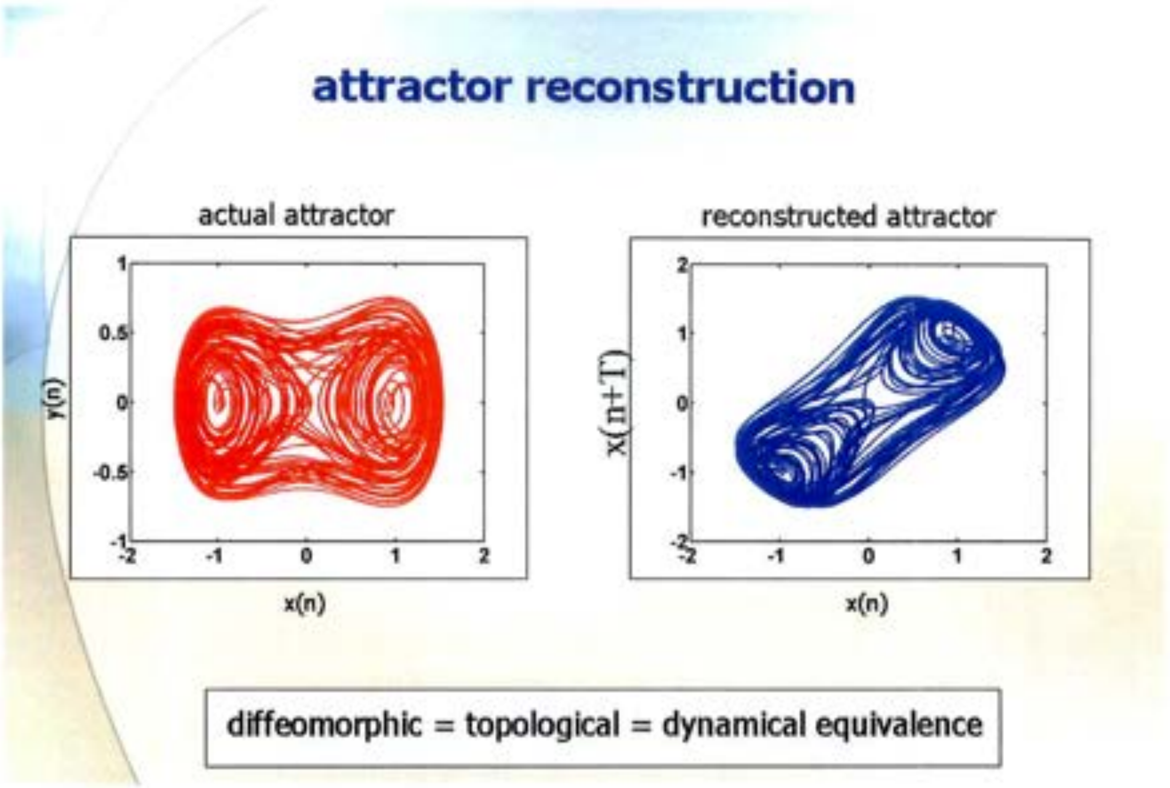
d = embedding dimension



example reconstruction:

Lorenz attractor

$$\frac{dx}{dt} = \sigma(y-x)$$
$$\frac{dy}{dt} = x(r-z)-y$$
$$\frac{dz}{dt} = xy-\beta z$$

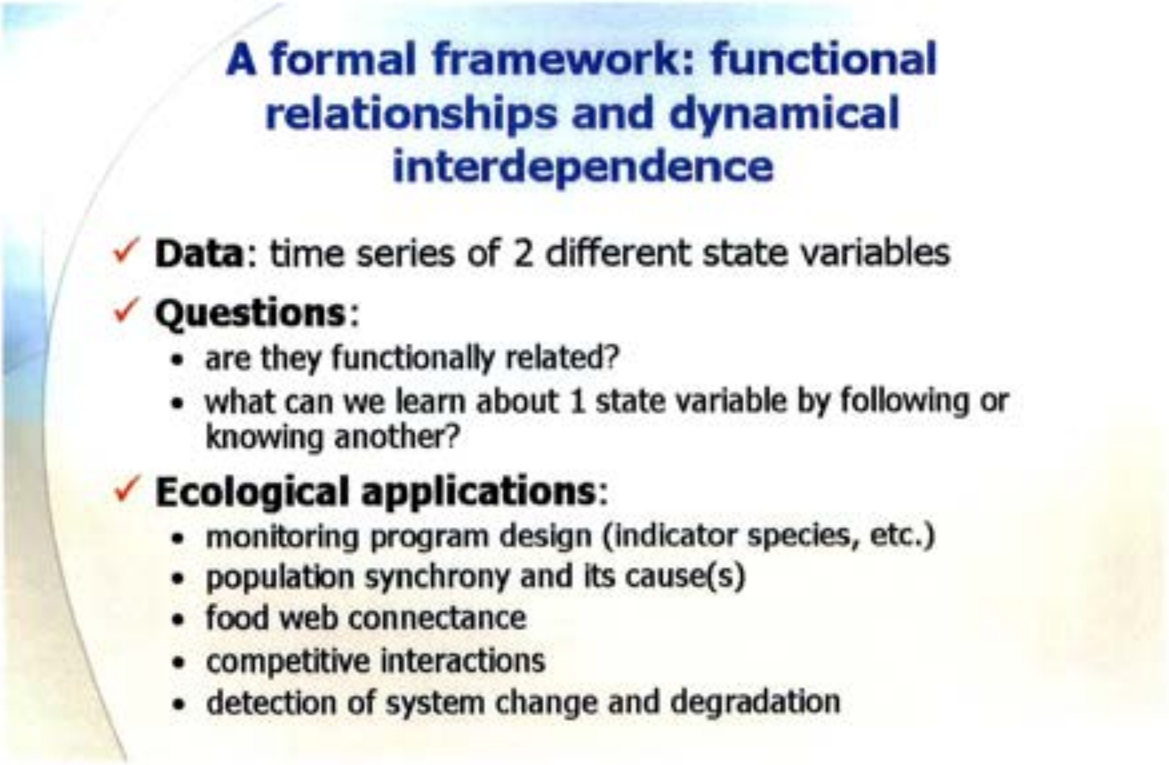


attractor reconstruction

actual attractor

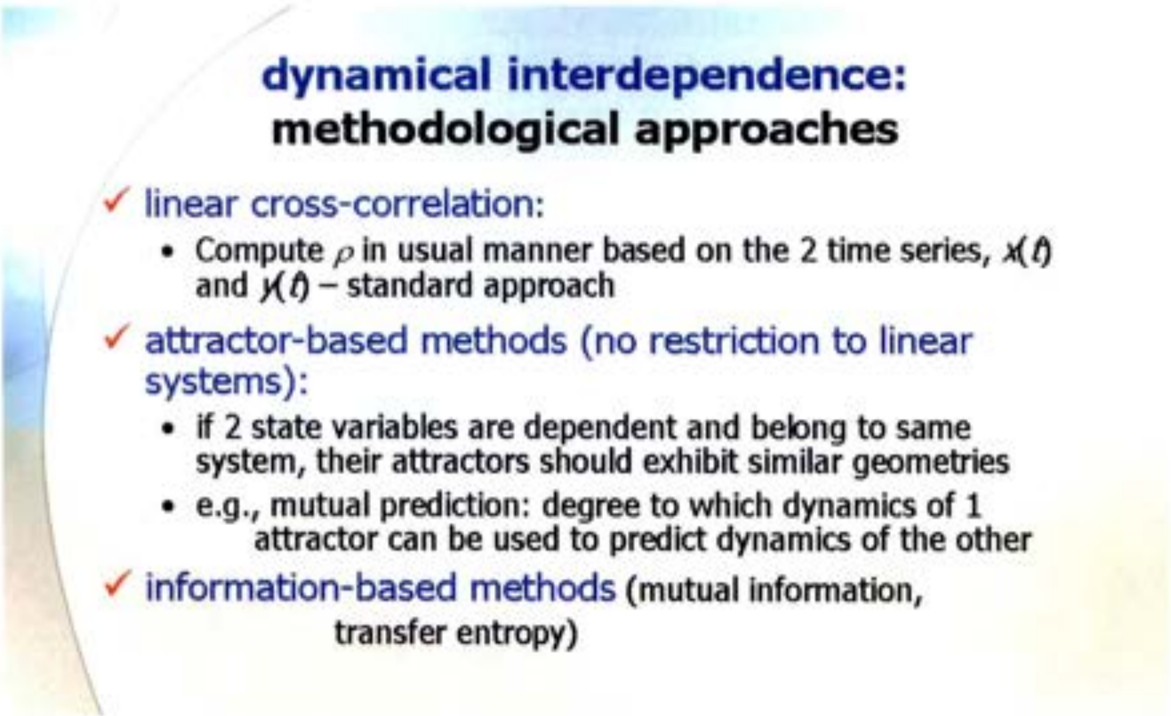
reconstructed attractor

diffeomorphic = topological = dynamical equivalence



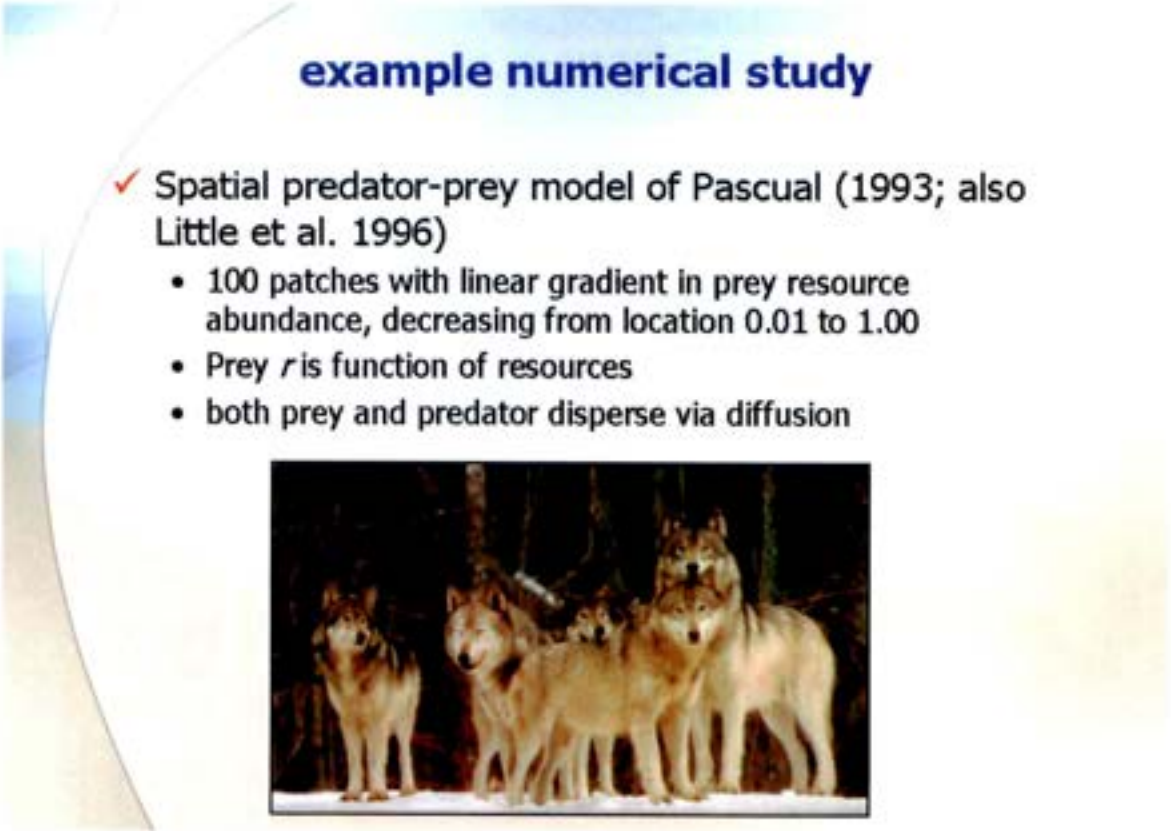
A formal framework: functional relationships and dynamical interdependence

- ✓ **Data**: time series of 2 different state variables
- ✓ **Questions**:
  - are they functionally related?
  - what can we learn about 1 state variable by following or knowing another?
- ✓ **Ecological applications**:
  - monitoring program design (indicator species, etc.)
  - population synchrony and its cause(s)
  - food web connectance
  - competitive interactions
  - detection of system change and degradation



dynamical interdependence: methodological approaches

- ✓ linear cross-correlation:
  - Compute ρ in usual manner based on the 2 time series, $x(t)$ and $y(t)$ – standard approach
- ✓ attractor-based methods (no restriction to linear systems):
  - if 2 state variables are dependent and belong to same system, their attractors should exhibit similar geometries
  - e.g., mutual prediction: degree to which dynamics of 1 attractor can be used to predict dynamics of the other
- ✓ information-based methods (mutual information, transfer entropy)



example numerical study

- ✓ Spatial predator-prey model of Pascual (1993; also Little et al. 1996)
  - 100 patches with linear gradient in prey resource abundance, decreasing from location 0.01 to 1.00
  - Prey r is function of resources
  - both prey and predator disperse via diffusion

Pascual (1993) model

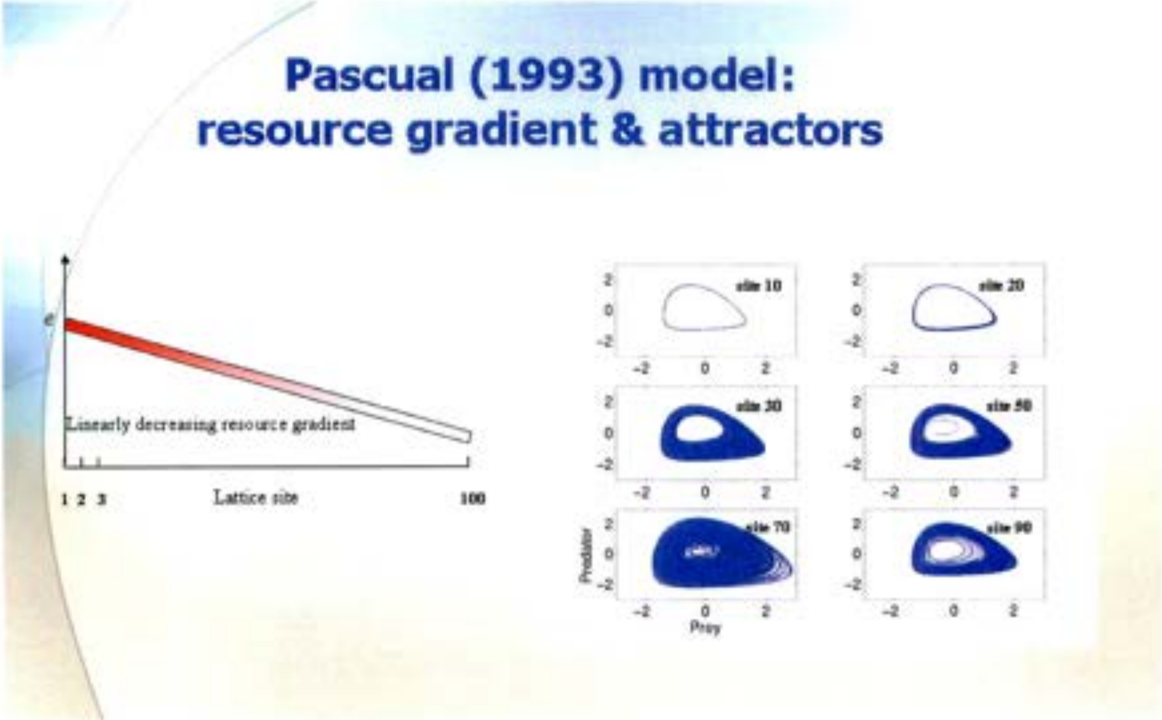
$$\frac{\partial p}{\partial t} = r(x)p(1-p) - \frac{ap}{1+bp}h + D\frac{\partial^2 p}{\partial x^2}$$

$$\frac{\partial h}{\partial t} = \frac{ap}{1+bp}h - mh + D\frac{\partial^2 h}{\partial x^2}$$

$$r(x) = e - fx$$

Prey: p = abundance
$r(x)$ = instantaneous growth rate at location x
b = prey carrying capacity
a = coupling parameter (predation rate)
Predator: h = abundance
m = death rate
Prey & Pred: D = diffusive coupling coefficient

Pascual (1993) model: resource gradient & attractors



Compare Mutual Prediction to Standard Cross-correlation

- **Cross-correlation:** standard technique in Ecology

$$c_{xy}(k)=\frac{1}{N-k}\sum_{i=1}^{N-k}(x(i)-\bar{x})(y(i+k)-\bar{y})$$

Normalize so that value of 0 implies strong coupling, 1 implies weak coupling

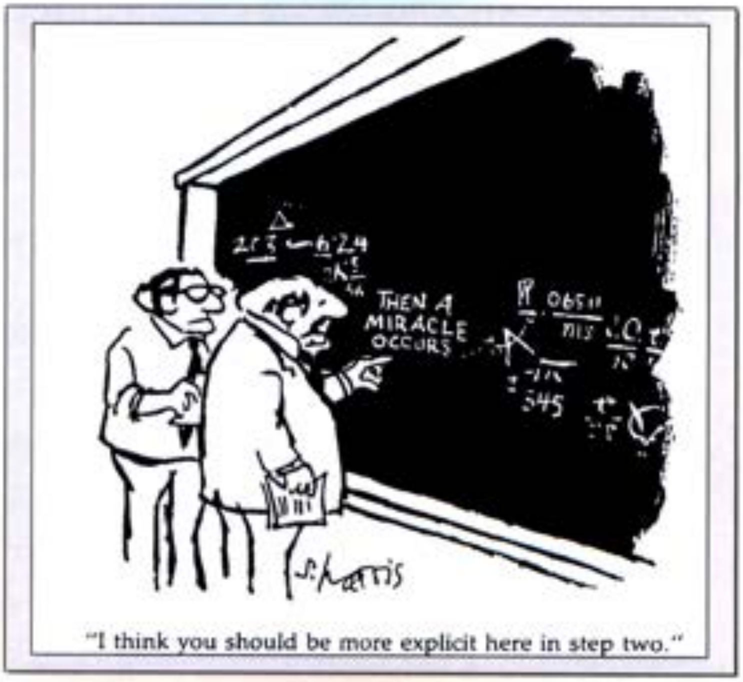
- **Mutual Prediction:** Let one lattice site predict the dynamics of the others. Good predictions imply strong coupling

"Model" cell forecast

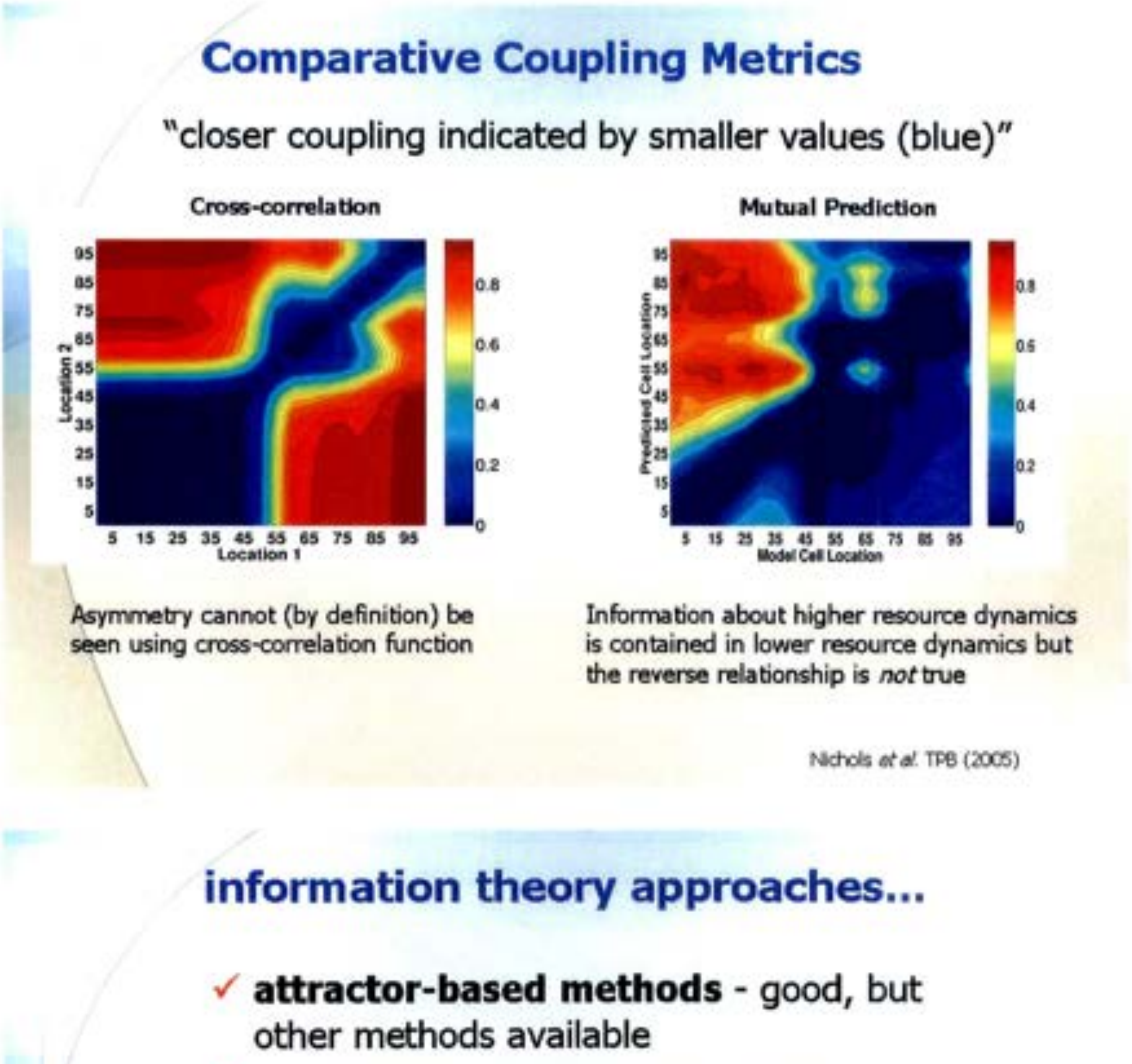
"Predicted" cell

$$\gamma=\frac{1}{\sigma^2}\sum_{f=1}^{N}\left|\hat{y}(f+s)-y(f+s)\right|$$

skipping some of the technical details...



"I think you should be more explicit here in step two."



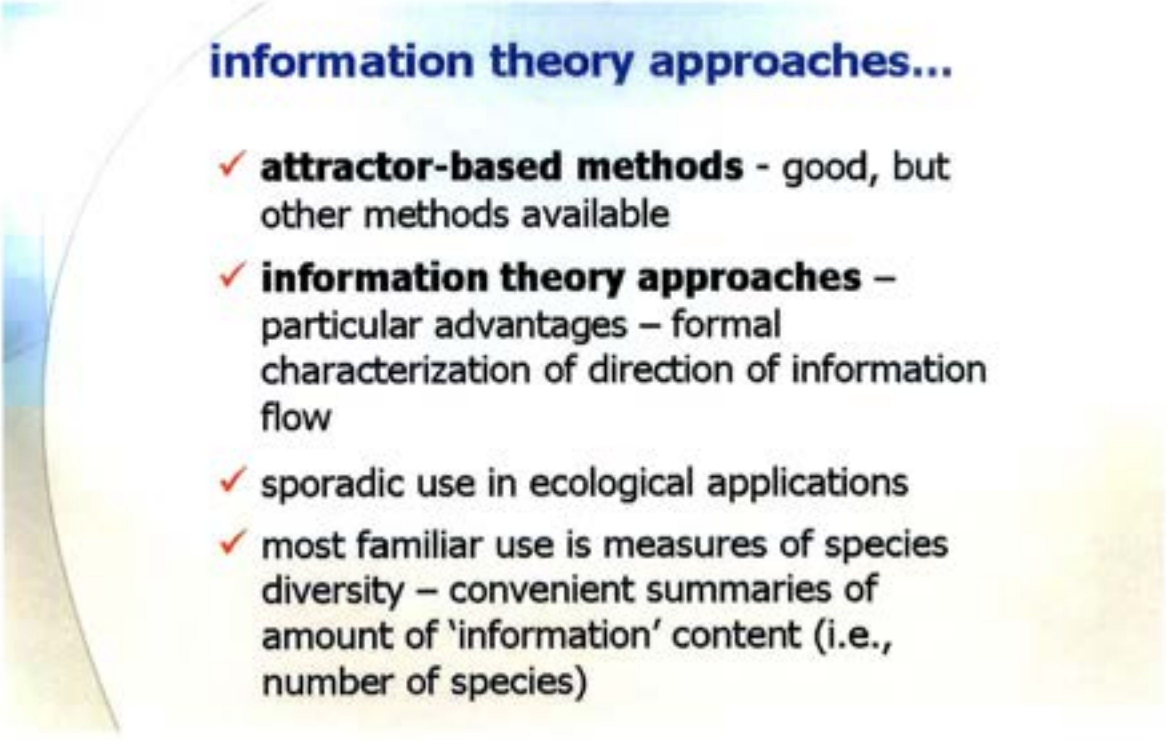
Comparative Coupling Metrics

"closer coupling indicated by smaller values (blue)"

Asymmetry cannot (by definition) be seen using cross-correlation function

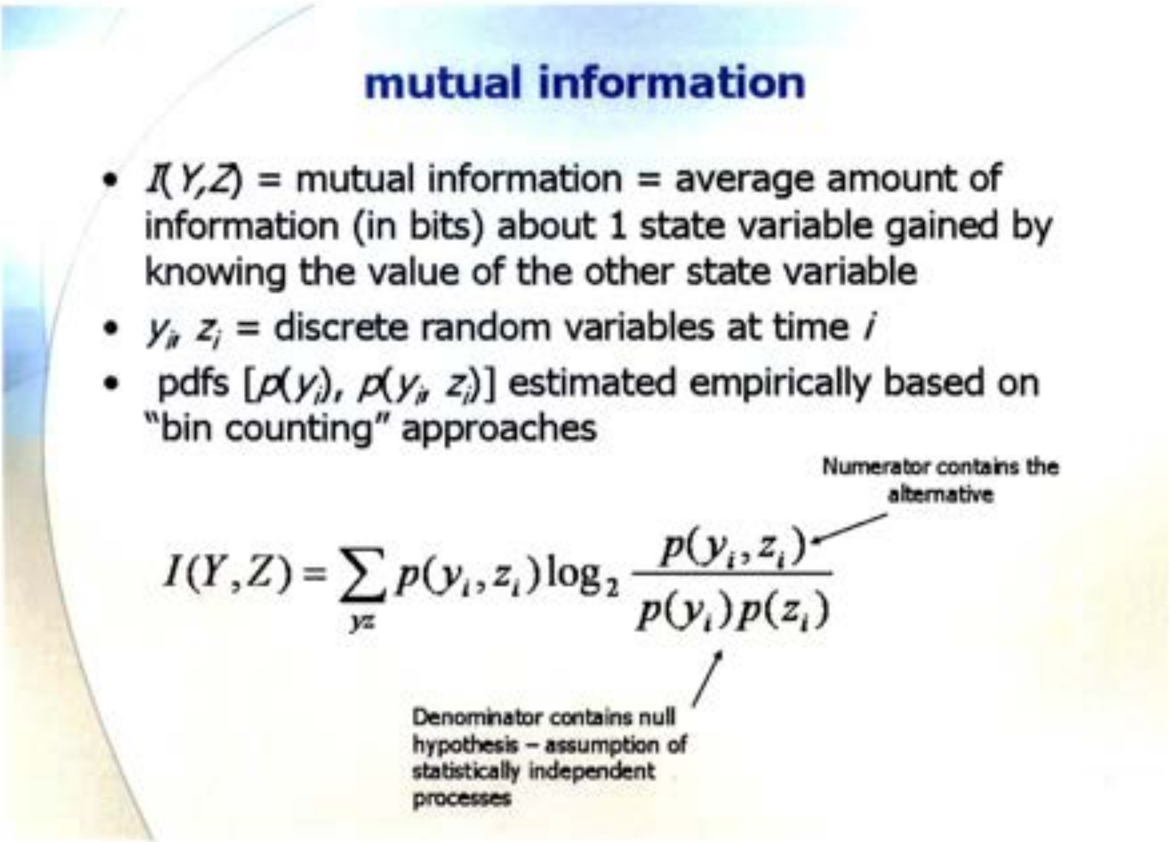
Information about higher resource dynamics is contained in lower resource dynamics but the reverse relationship is *not* true

Nichols *et al.* TPB (2005)



information theory approaches...

- ✓ **attractor-based methods** - good, but other methods available
- ✓ **information theory approaches** – particular advantages – formal characterization of direction of information flow
- ✓ sporadic use in ecological applications
- ✓ most familiar use is measures of species diversity – convenient summaries of amount of 'information' content (i.e., number of species)



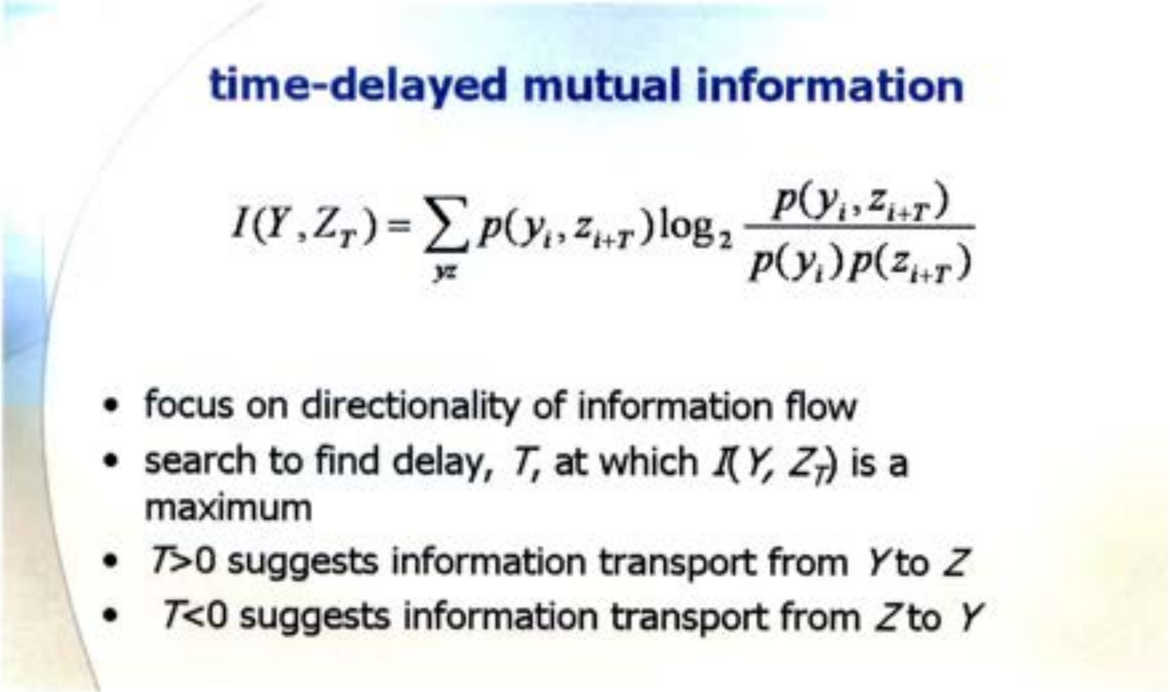
mutual information

- $I(Y,Z)$ = mutual information = average amount of information (in bits) about 1 state variable gained by knowing the value of the other state variable
- y_i, z_i = discrete random variables at time i
- pdfs [$p(y_i)$, $p(y_i, z_i)$] estimated empirically based on "bin counting" approaches

Numerator contains the alternative

$$I(Y,Z) = \sum_{yz} p(y_i, z_i) \log_2 \frac{p(y_i, z_i)}{p(y_i)p(z_i)}$$

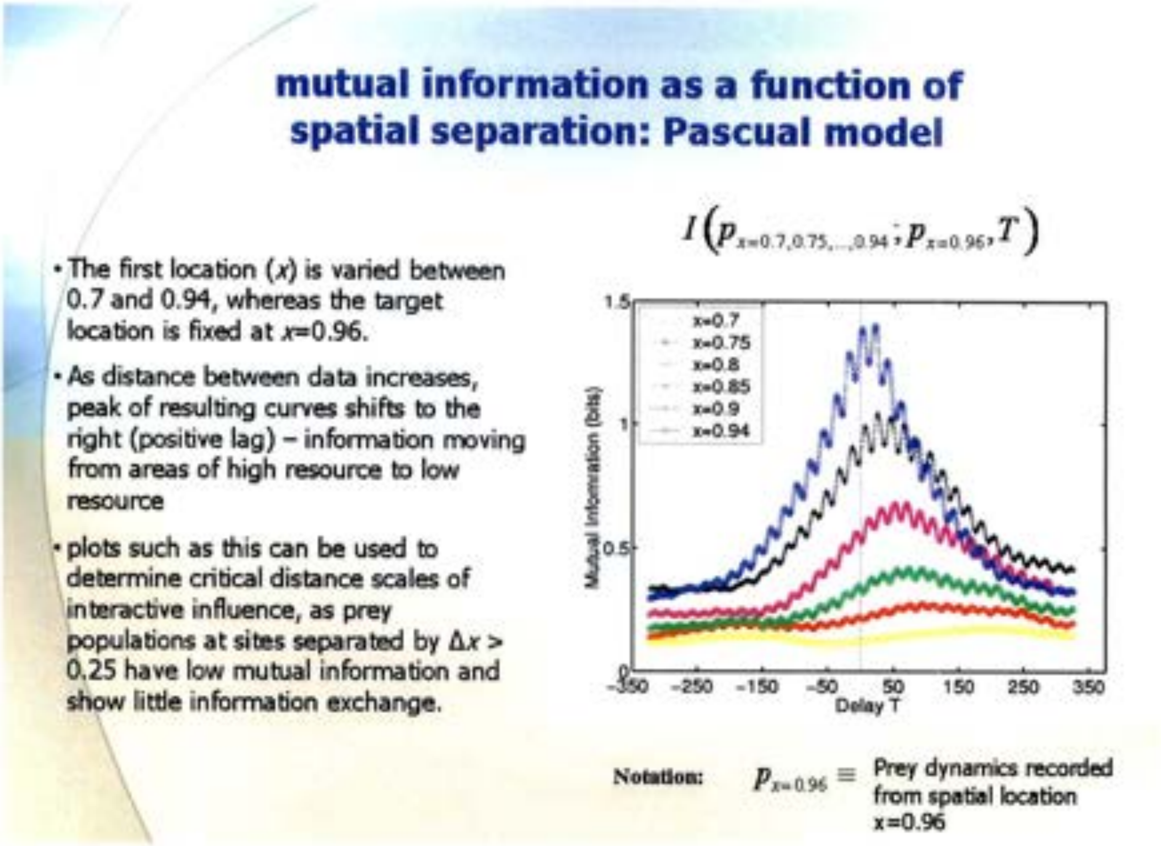
Denominator contains null hypothesis – assumption of statistically independent processes



time-delayed mutual information

$$I(Y, Z_T) = \sum_{yz} p(y_i, z_{i+T}) \log_2 \frac{p(y_i, z_{i+T})}{p(y_i)p(z_{i+T})}$$

- focus on directionality of information flow
- search to find delay, T, at which $I(Y, Z_T)$ is a maximum
- $T>0$ suggests information transport from Y to Z
- $T<0$ suggests information transport from Z to Y

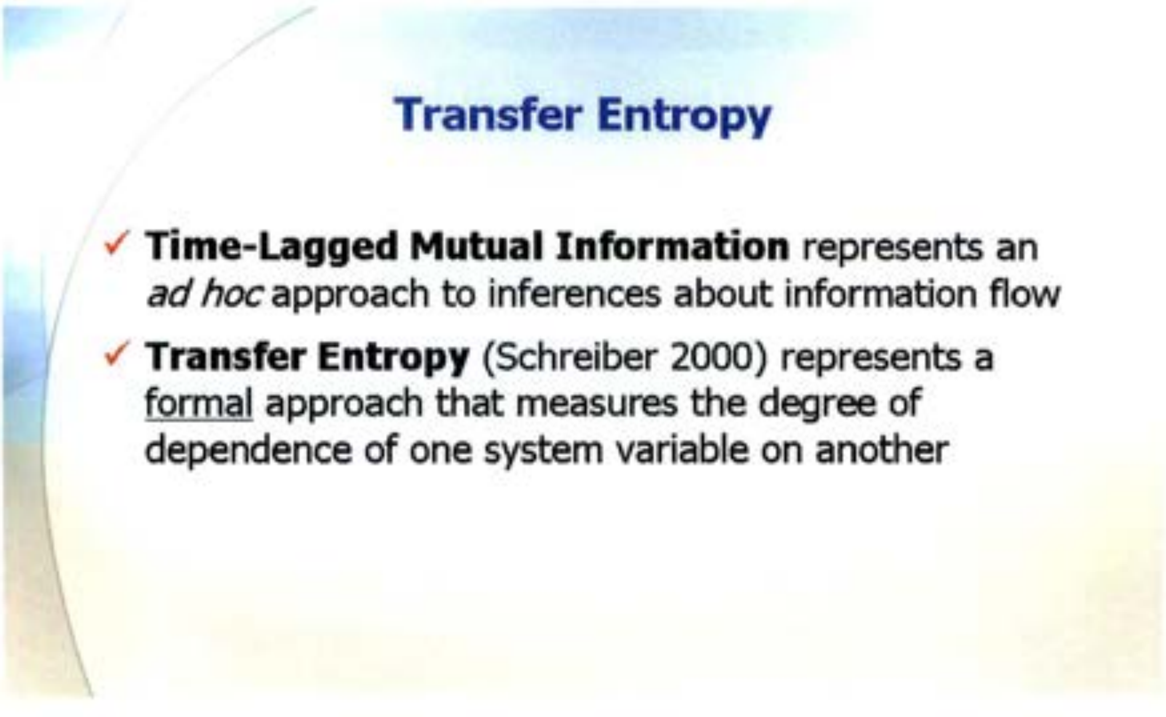


mutual information as a function of spatial separation: Pascual model

- The first location (*x*) is varied between 0.7 and 0.94, whereas the target location is fixed at *x*=0.96.
- As distance between data increases, peak of resulting curves shifts to the right (positive lag) – information moving from areas of high resource to low resource
- plots such as this can be used to determine critical distance scales of interactive influence, as prey populations at sites separated by $\Delta x > 0.25$ have low mutual information and show little information exchange.

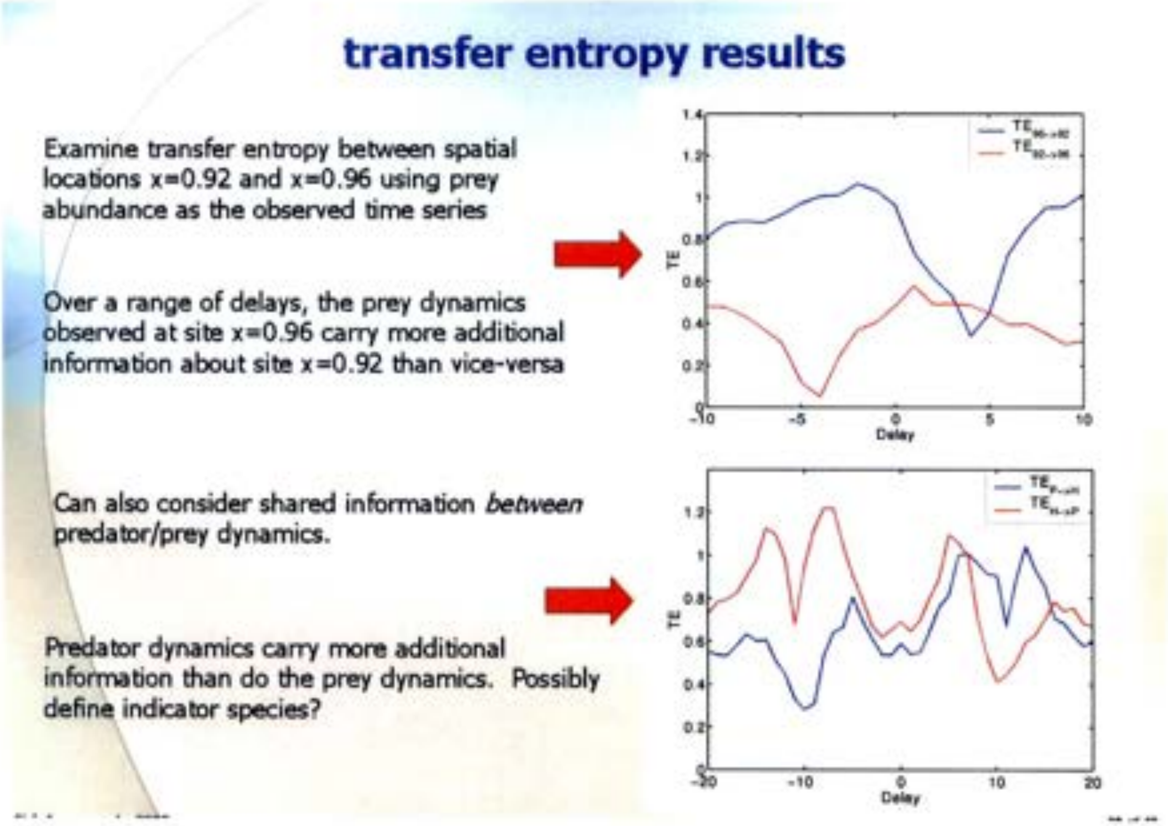
$$I\left(p_{x=0.7,0.75,\ldots,0.94};p_{x=0.96},T\right)$$

Notation: $p_{x=0.96} \equiv$ Prey dynamics recorded from spatial location x=0.96



Transfer Entropy

- ✓ **Time-Lagged Mutual Information** represents an *ad hoc* approach to inferences about information flow
- ✓ **Transfer Entropy** (Schreiber 2000) represents a formal approach that measures the degree of dependence of one system variable on another



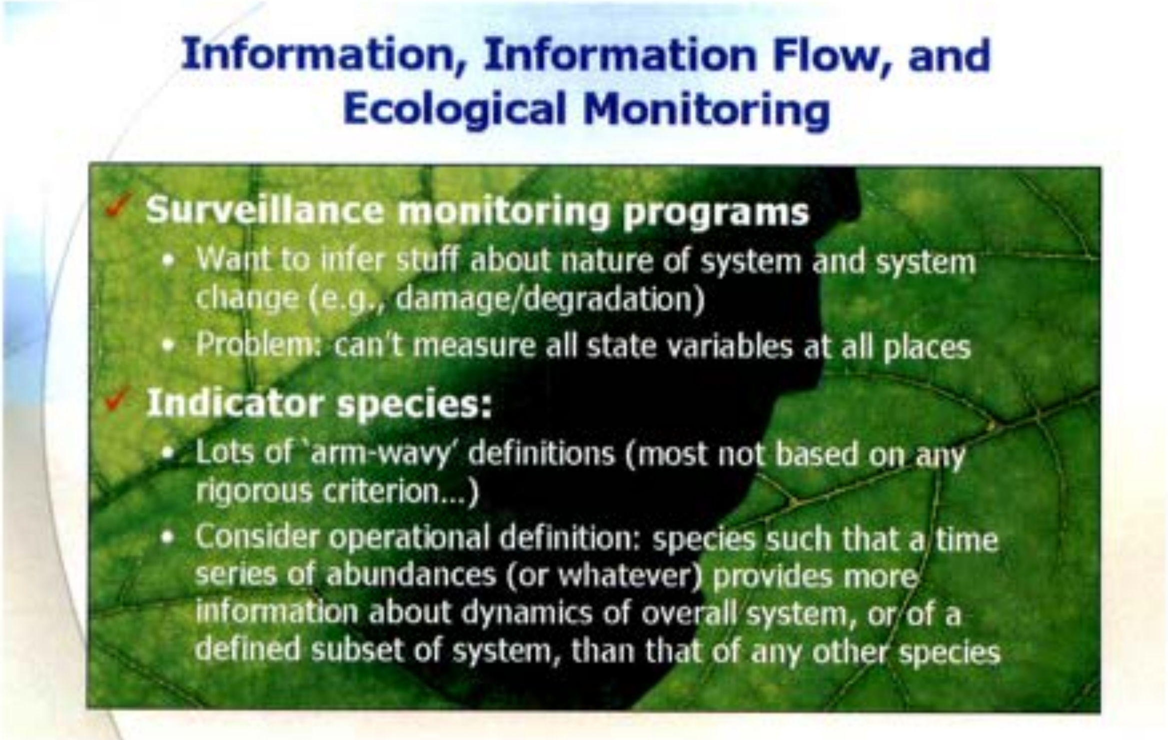
transfer entropy results

Examine transfer entropy between spatial locations x=0.92 and x=0.96 using prey abundance as the observed time series

Over a range of delays, the prey dynamics observed at site x=0.96 carry more additional information about site x=0.92 than vice-versa

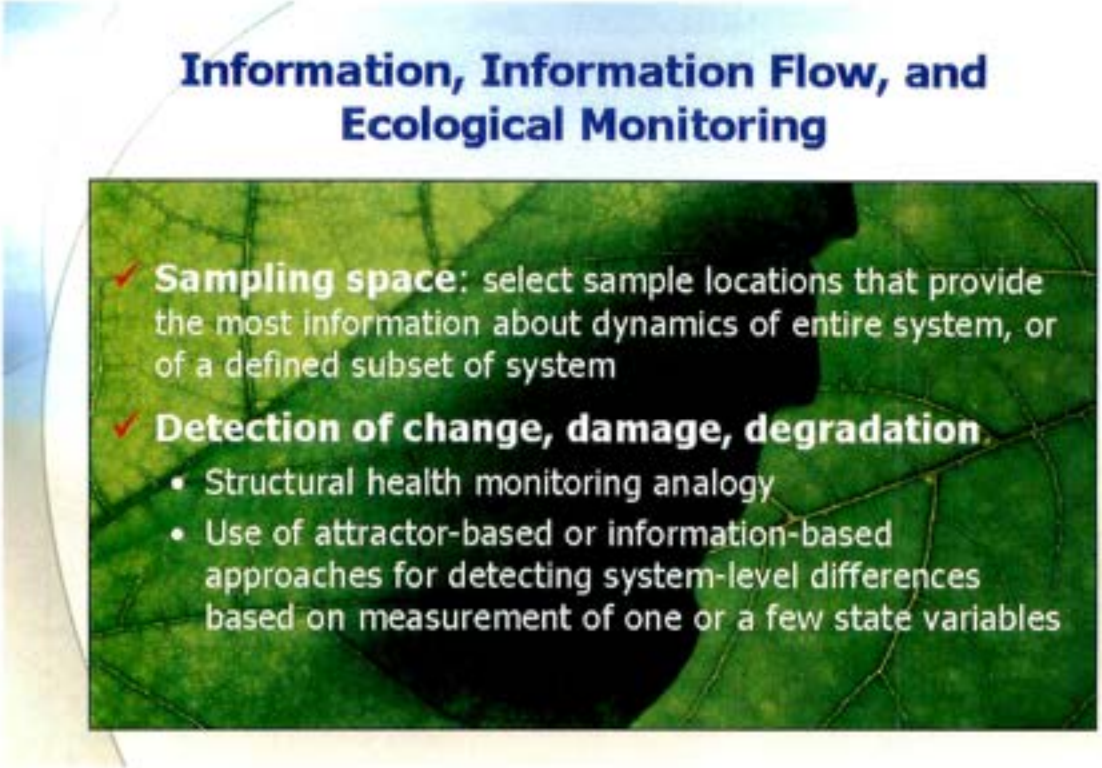
Can also consider shared information *between* predator/prey dynamics.

Predator dynamics carry more additional information than do the prey dynamics. Possibly define indicator species?



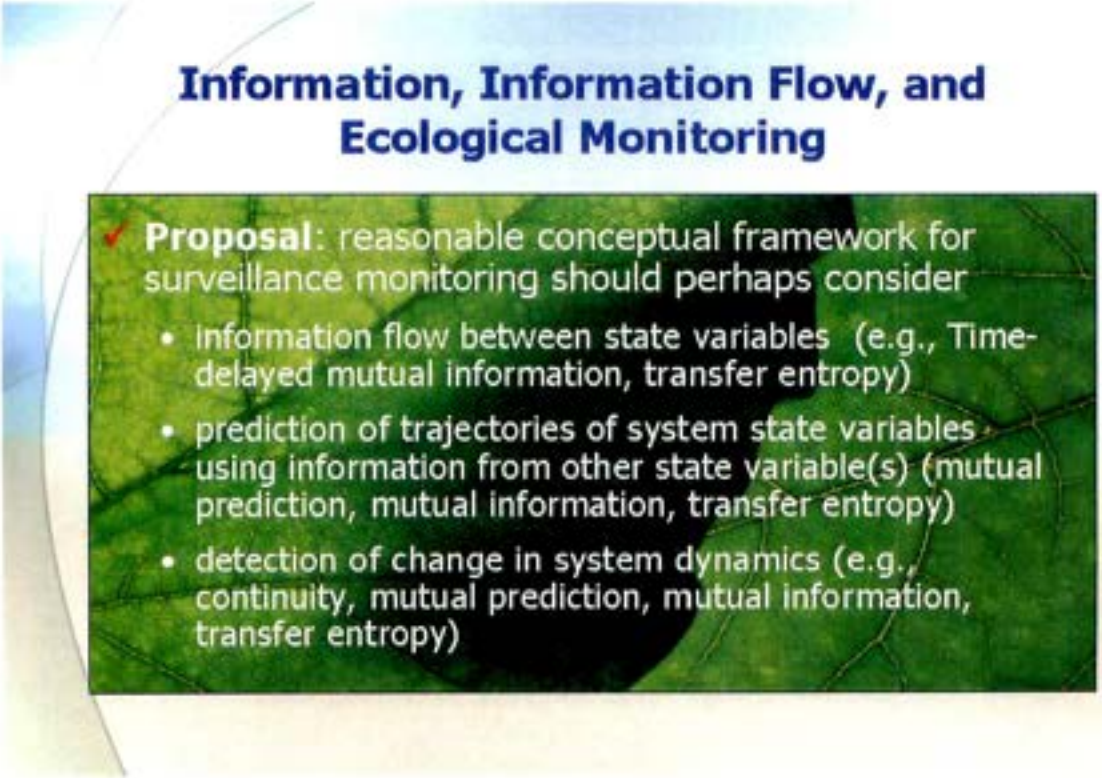
Information, Information Flow, and Ecological Monitoring

- ✓ **Surveillance monitoring programs**
  - Want to infer stuff about nature of system and system change (e.g., damage/degradation)
  - Problem: can't measure all state variables at all places
- ✓ **Indicator species:**
  - Lots of 'arm-wavy' definitions (most not based on any rigorous criterion...)
  - Consider operational definition: species such that a time series of abundances (or whatever) provides more information about dynamics of overall system, or of a defined subset of system, than that of any other species



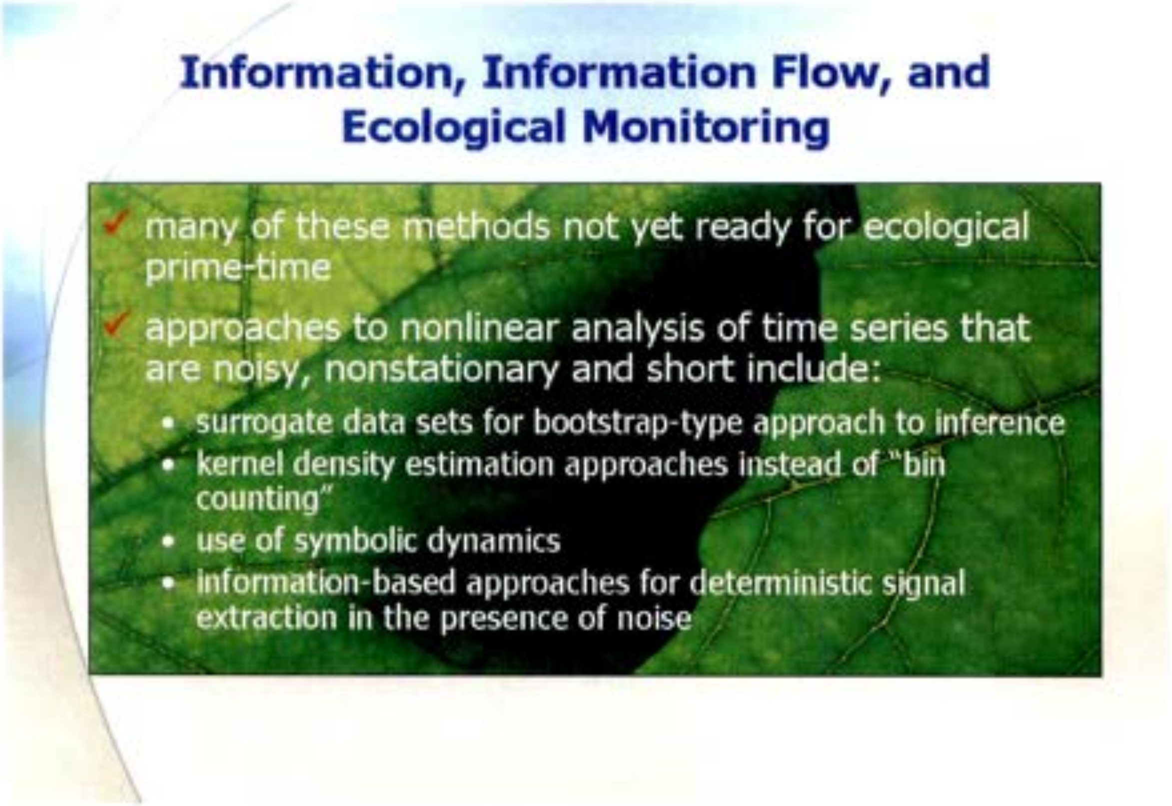
Information, Information Flow, and Ecological Monitoring

- ✓ **Sampling space**: select sample locations that provide the most information about dynamics of entire system, or of a defined subset of system
- ✓ **Detection of change, damage, degradation**
  - Structural health monitoring analogy
  - Use of attractor-based or information-based approaches for detecting system-level differences based on measurement of one or a few state variables



Information, Information Flow, and Ecological Monitoring

- ✓ **Proposal**: reasonable conceptual framework for surveillance monitoring should perhaps consider
  - information flow between state variables (e.g., Time-delayed mutual information, transfer entropy)
  - prediction of trajectories of system state variables using information from other state variable(s) (mutual prediction, mutual information, transfer entropy)
  - detection of change in system dynamics (e.g., continuity, mutual prediction, mutual information, transfer entropy)



Information, Information Flow, and Ecological Monitoring

- ✓ many of these methods not yet ready for ecological prime-time
- ✓ approaches to nonlinear analysis of time series that are noisy, nonstationary and short include:
  - surrogate data sets for bootstrap-type approach to inference
  - kernel density estimation approaches instead of "bin counting"
  - use of symbolic dynamics
  - information-based approaches for deterministic signal extraction in the presence of noise

Appendix I.
Assessing Risk of Predator-Prey Imbalance in the Upper Pelagic Food Web of Lake Ontario

Assessing Risk of Predator-Prey Imbalance in the Upper Pelagic Food Web of Lake Ontario

Don Stewart speaking
Team members:
Peter Rand, Robert O'Gorman, Jana Chrisman
NY Sea Grant Workshop
October 24, 2005

New Research Directions
NY Sea Grant Project 2006-07

- Reevaluate bottom-up effects in model (e.g., Diporeia, zebras, Cercopagis).

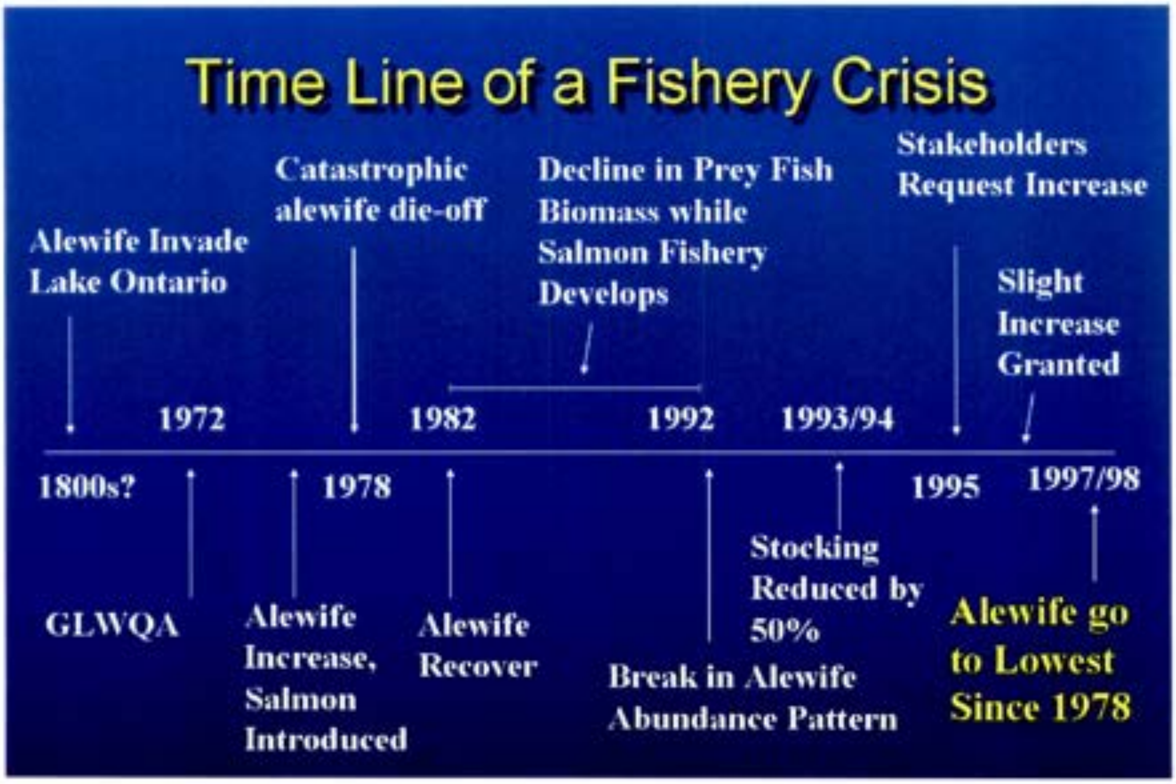
- Update salmonine predation effects to include results of Wurster et al. (2005).

- Further investigate causes of periodic alewife die-offs and explosions (i.e., add warm weather effects) and integrate results from O'Gorman et al. (2004).

- Need updated estimates of growth, diet and survival of both natural and stocked predators (i.e., synthesis of information on natural reproduction).

Workshop Talk Outline

- Brief history of fish and fisheries in Lake Ontario
- Development of an ecological food web model for Lake Ontario
- Management application – risk analysis
- Future directions for research



Time Line of a Fishery Crisis

1800s? Alewife Invade Lake Ontario

1972 GLWQA

1978 Catastrophic alewife die-off

1978 Alewife Increase, Salmon Introduced

1982 Alewife Recover

1982–1992 Decline in Prey Fish Biomass while Salmon Fishery Develops

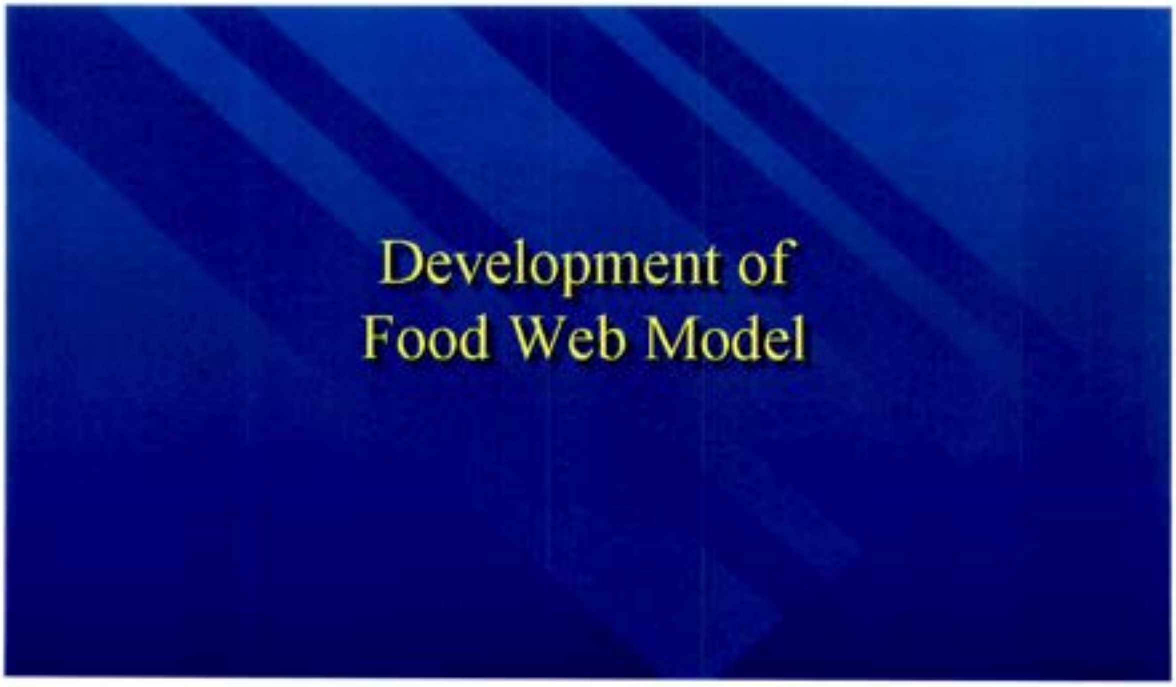
1992 Break in Alewife Abundance Pattern

1993/94 Stocking Reduced by 50%

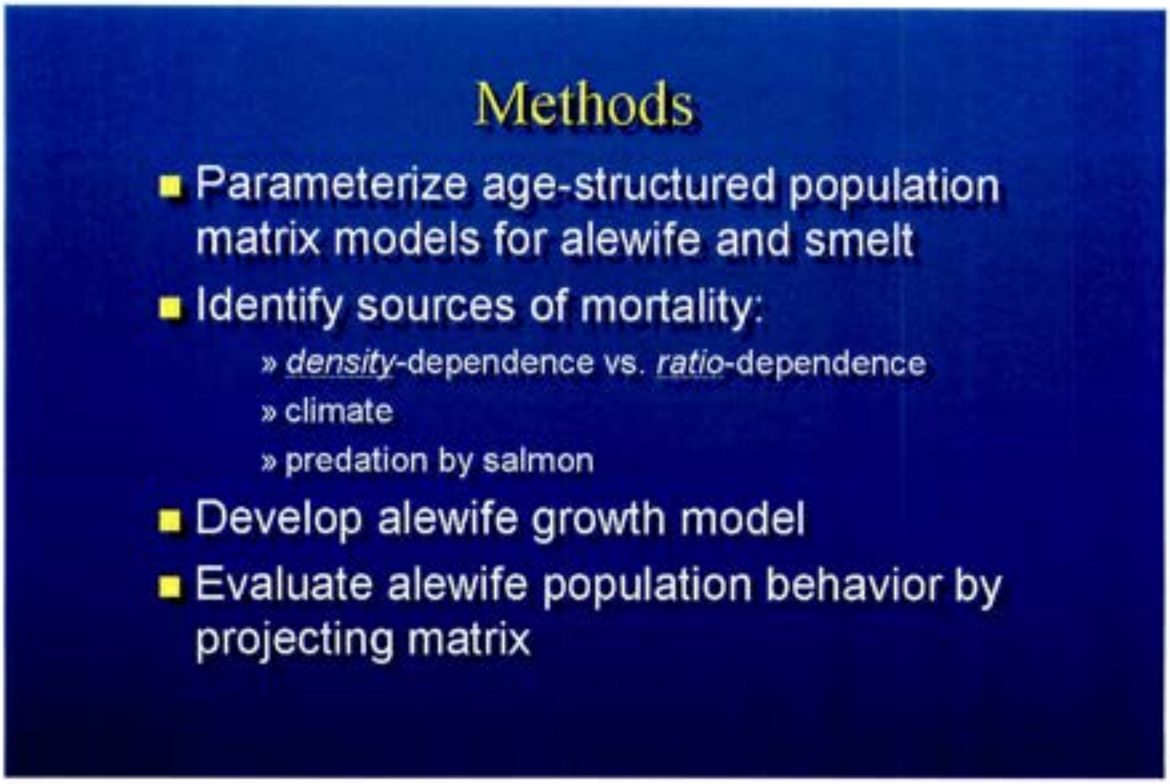
1995 Stakeholders Request Increase

1997/98 Slight Increase Granted

1997/98 Alewife go to Lowest Since 1978

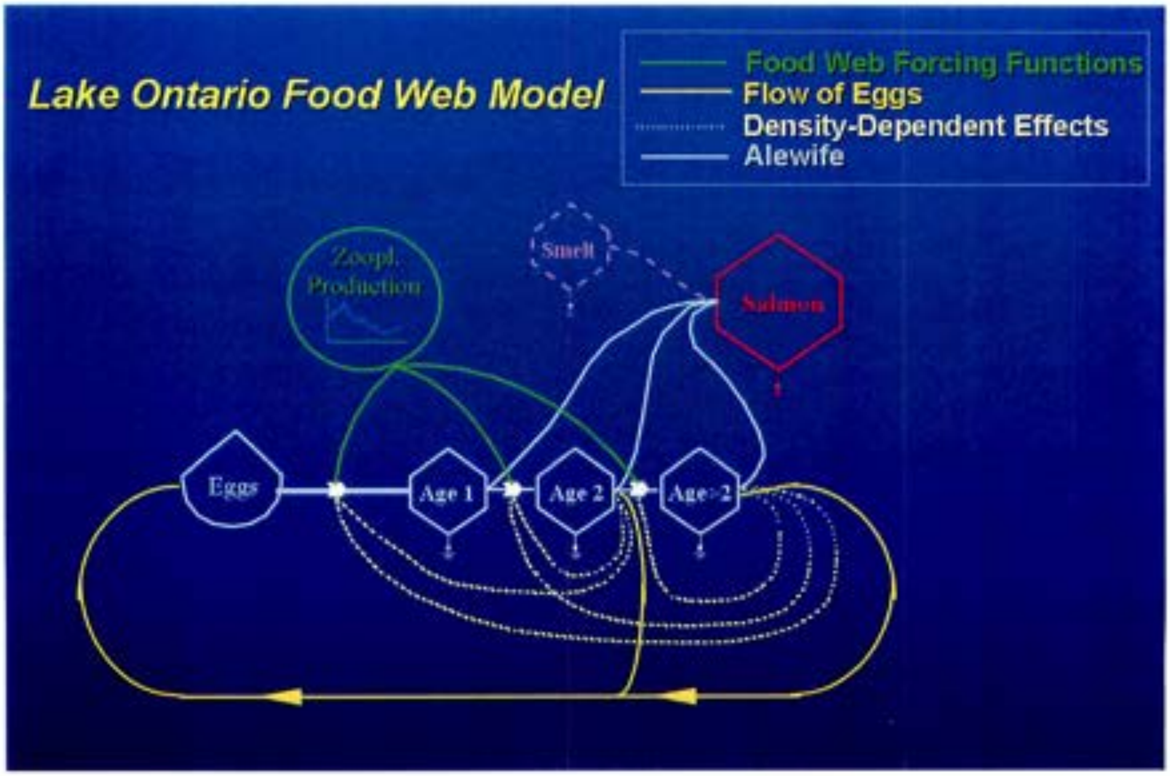


Development of Food Web Model

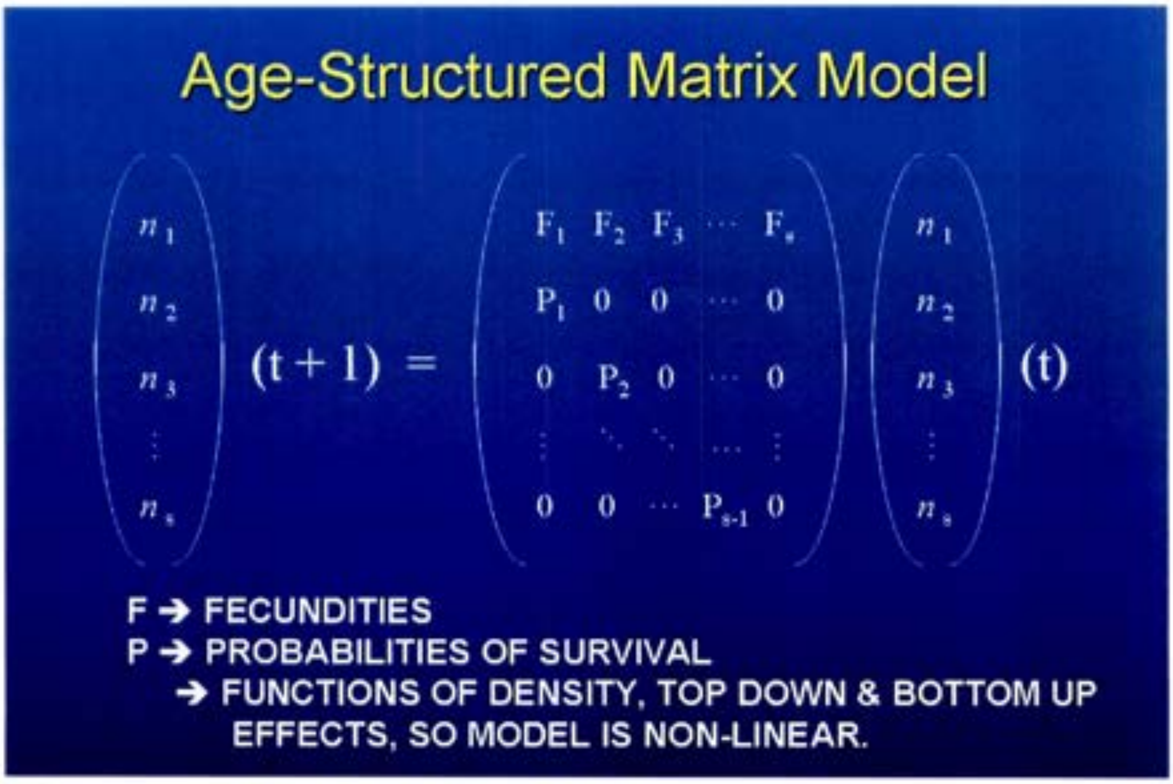


Methods

- Parameterize age-structured population matrix models for alewife and smelt
- Identify sources of mortality:
  - » *density*-dependence vs. *ratio*-dependence
  - » climate
  - » predation by salmon
- Develop alewife growth model
- Evaluate alewife population behavior by projecting matrix



Lake Ontario Food Web Model



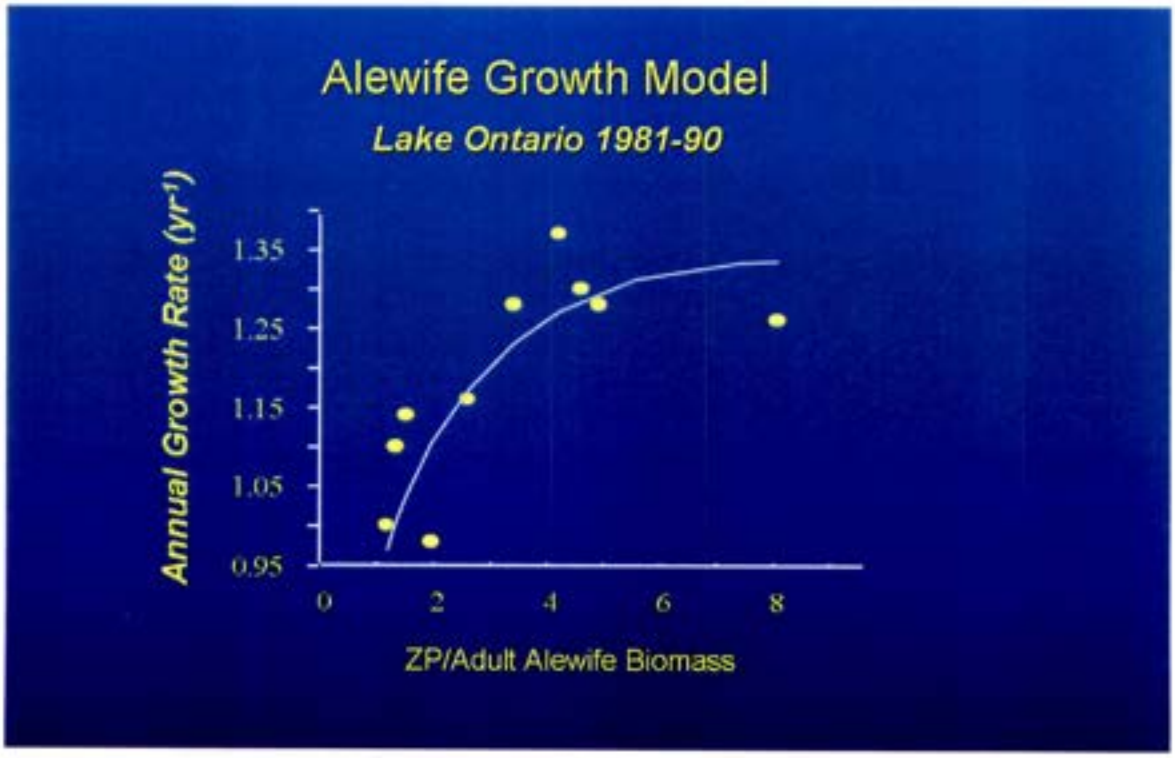
Age-Structured Matrix Model

$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ \vdots \\ n_s \end{pmatrix}(t+1) = \begin{pmatrix} F_1 & F_2 & F_3 & \cdots & F_s \\ P_1 & 0 & 0 & \cdots & 0 \\ 0 & P_2 & 0 & \cdots & 0 \\ \vdots & \ddots & \ddots & \cdots & \vdots \\ 0 & 0 & \cdots & P_{s-1} & 0 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ \vdots \\ n_s \end{pmatrix}(t)$$

F → FECUNDITIES

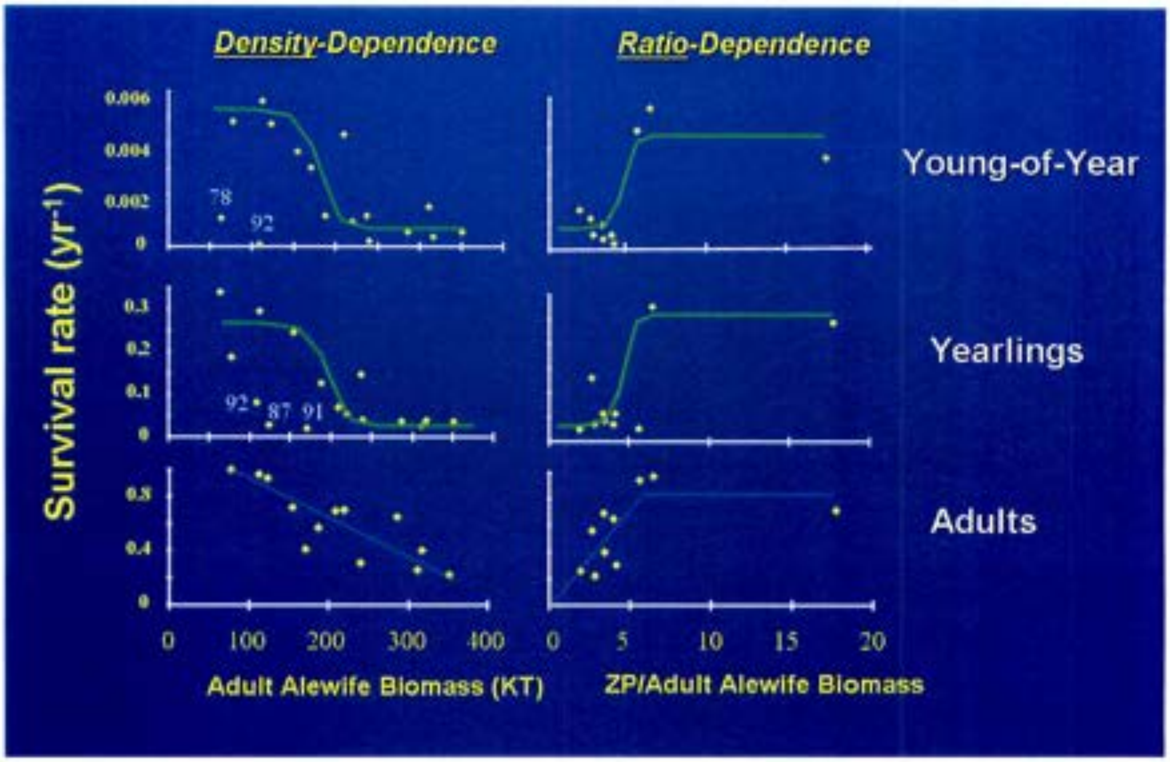
P → PROBABILITIES OF SURVIVAL

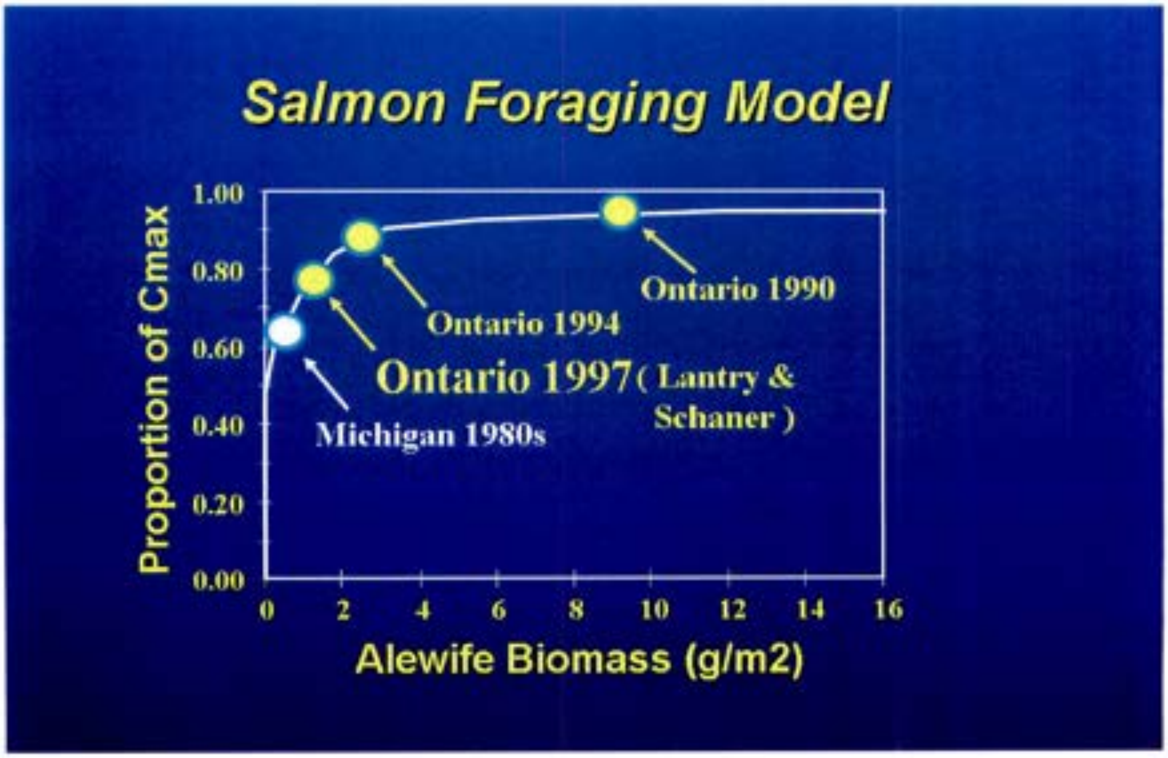
→ FUNCTIONS OF DENSITY, TOP DOWN & BOTTOM UP EFFECTS, SO MODEL IS NON-LINEAR.

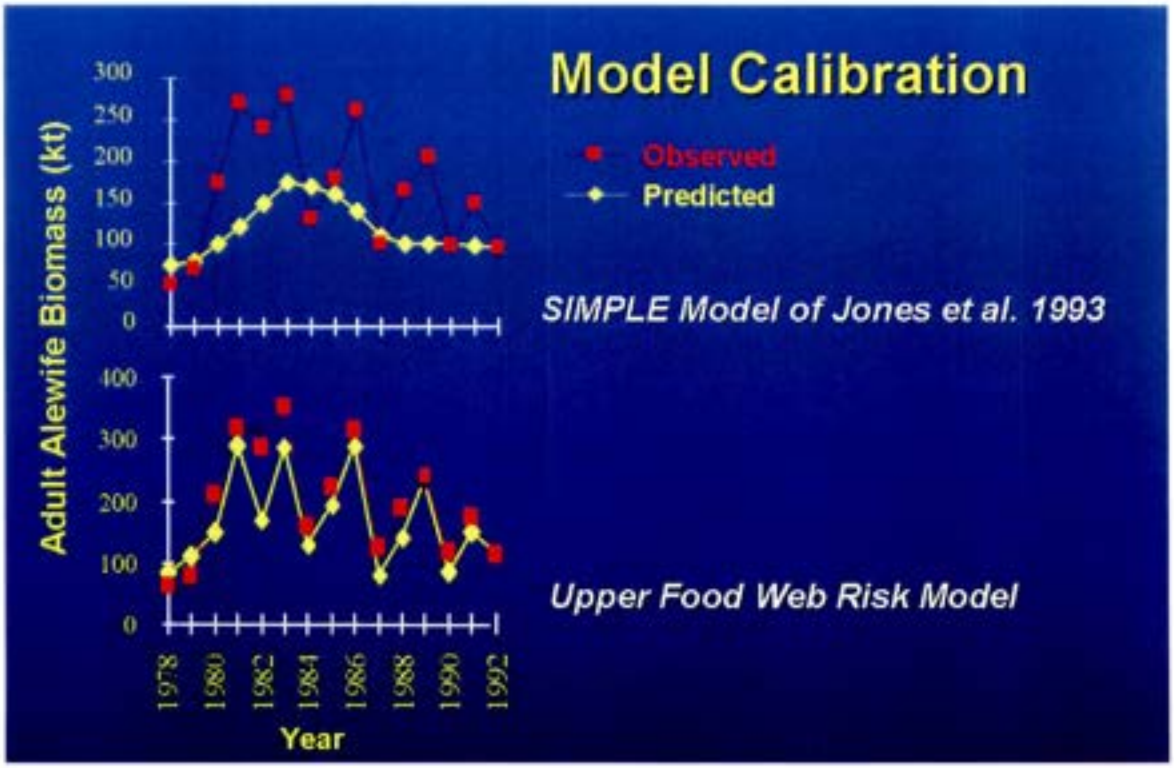


Alewife Growth Model

Lake Ontario 1981-90



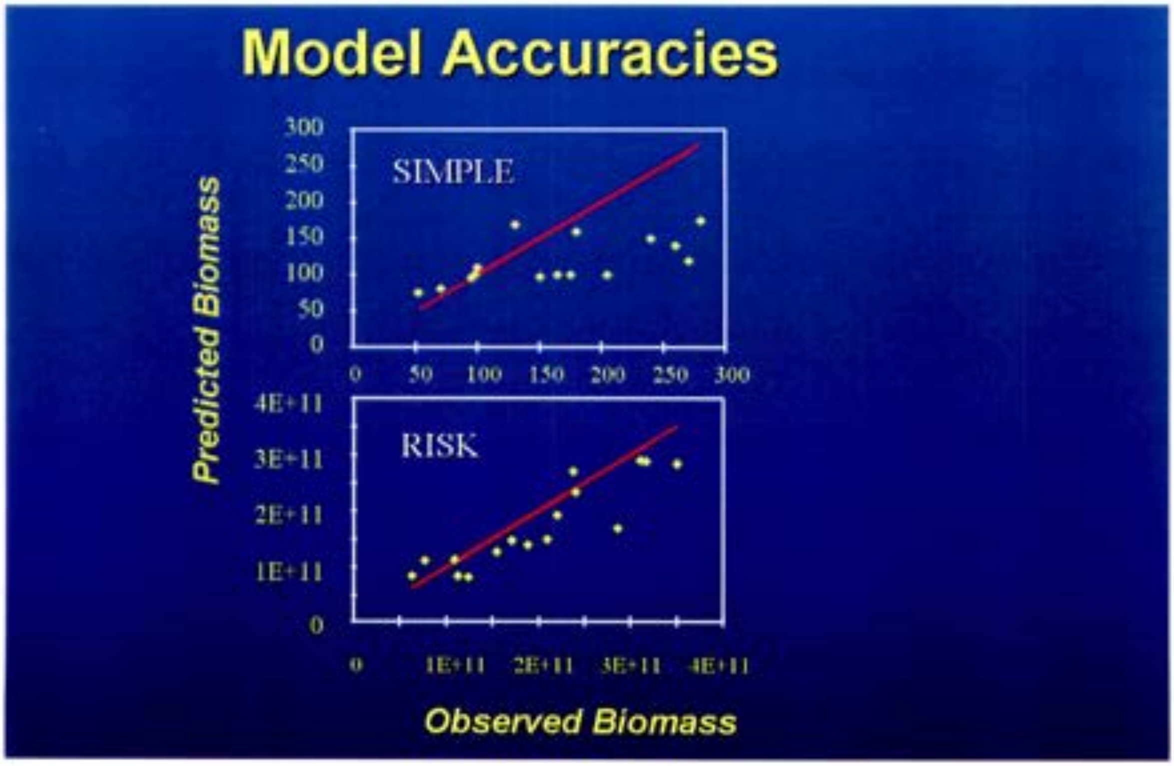

Salmon Foraging Model



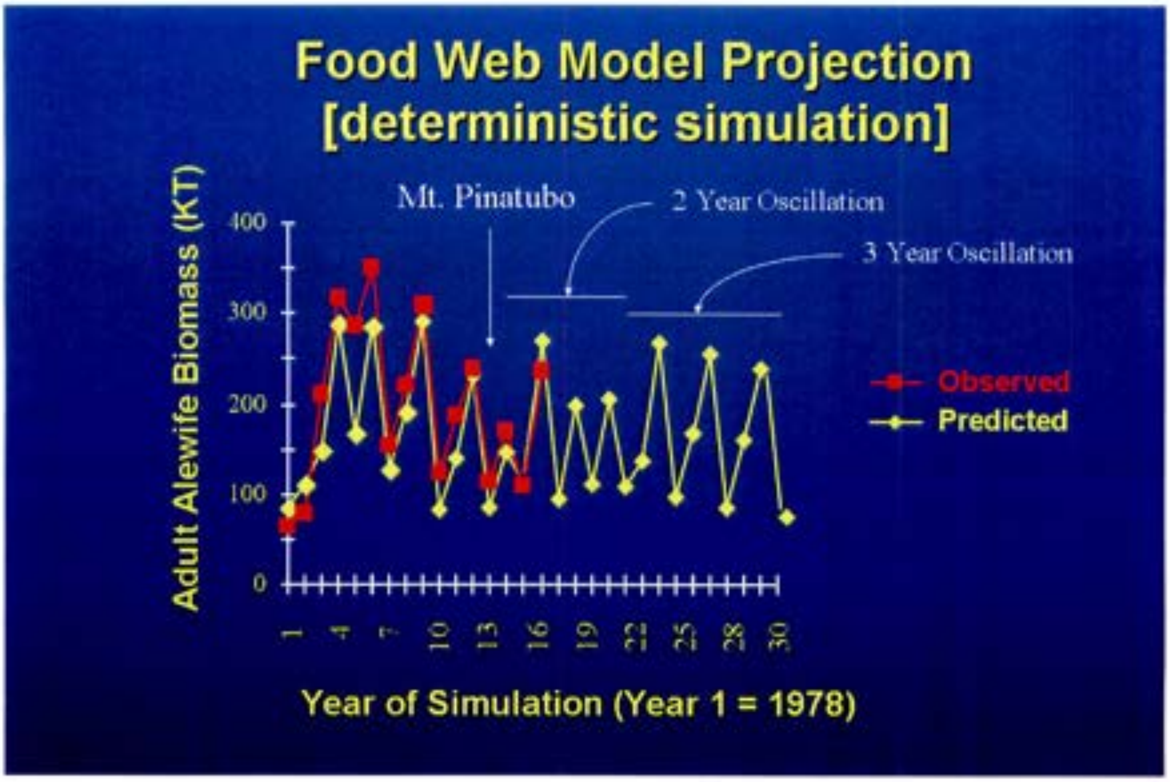
Model Calibration

SIMPLE Model of Jones et al. 1993

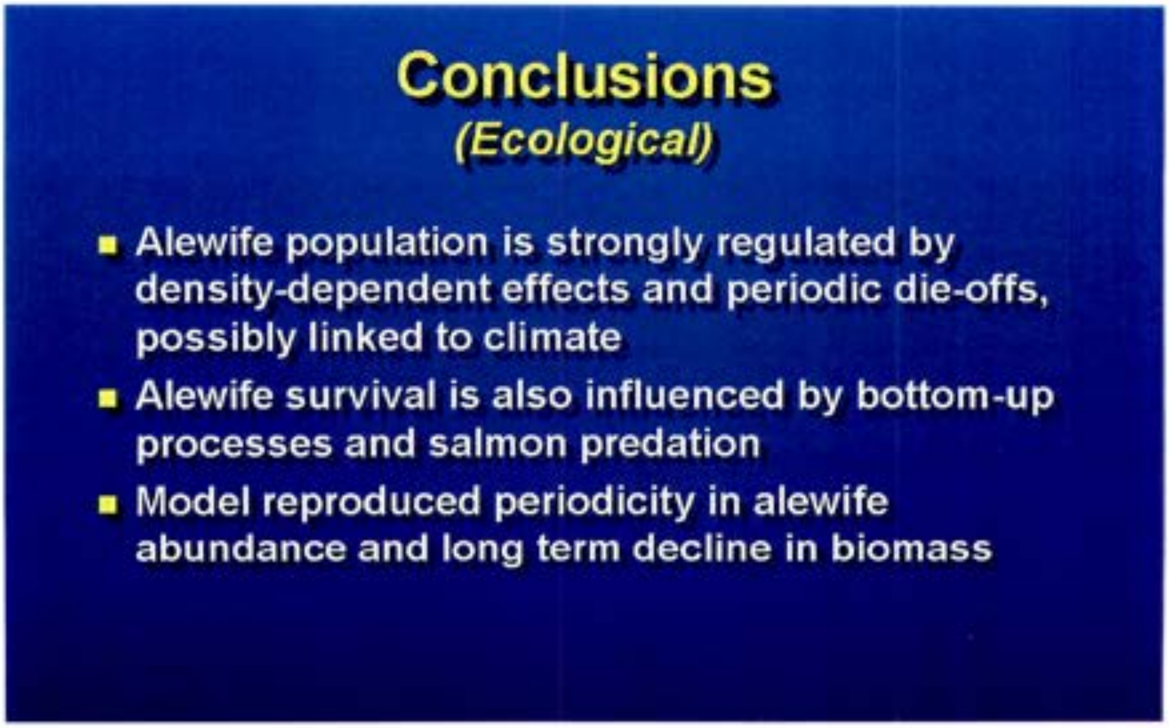
Upper Food Web Risk Model



Model Accuracies



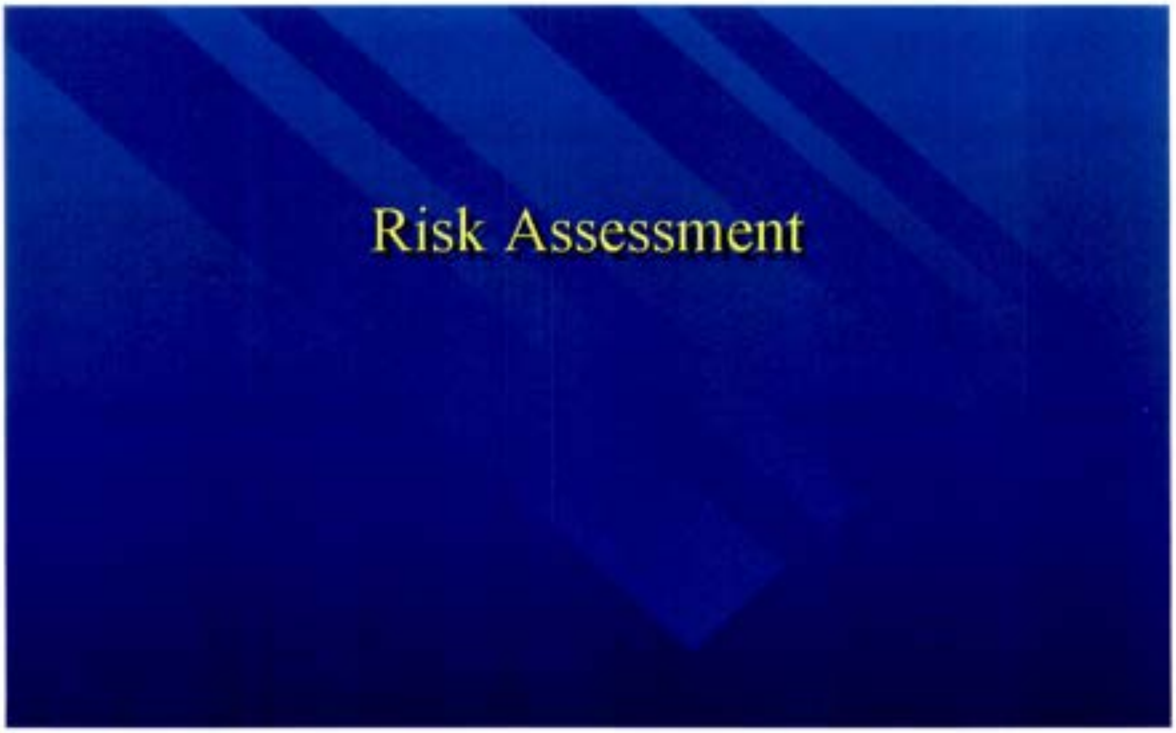
Food Web Model Projection [deterministic simulation]



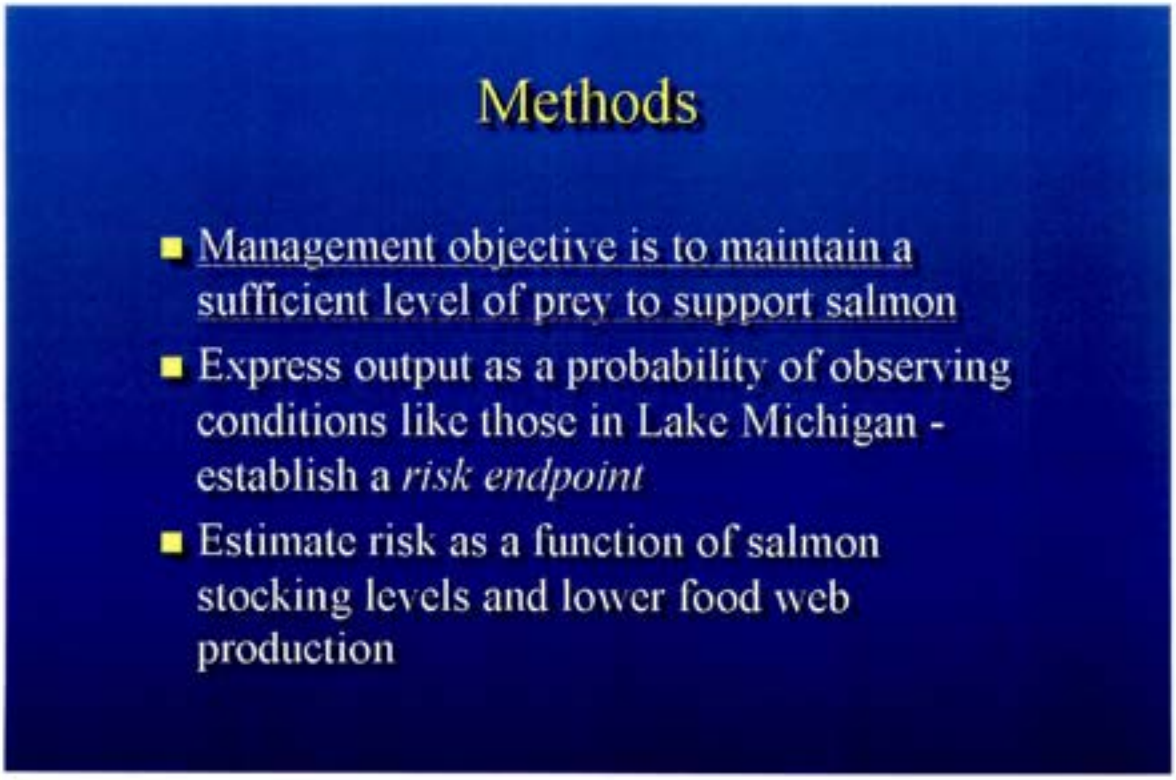
Conclusions

(Ecological)

- Alewife population is strongly regulated by density-dependent effects and periodic die-offs, possibly linked to climate
- Alewife survival is also influenced by bottom-up processes and salmon predation
- Model reproduced periodicity in alewife abundance and long term decline in biomass

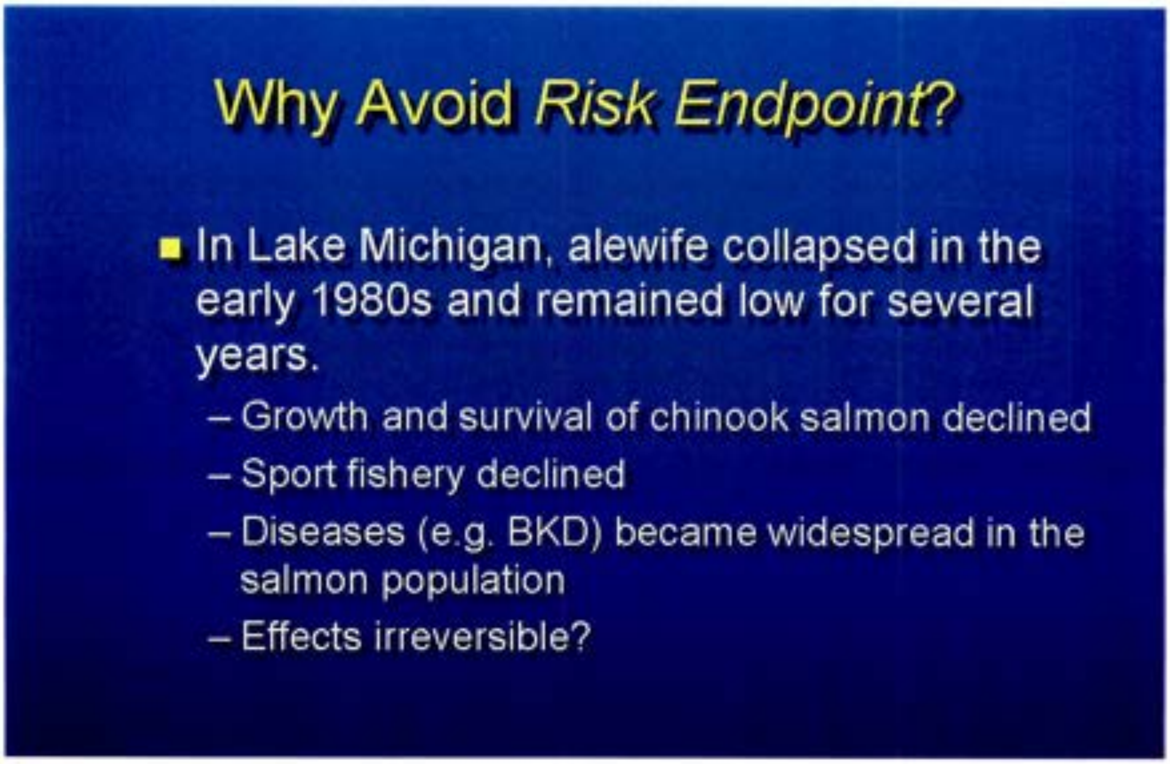


Risk Assessment



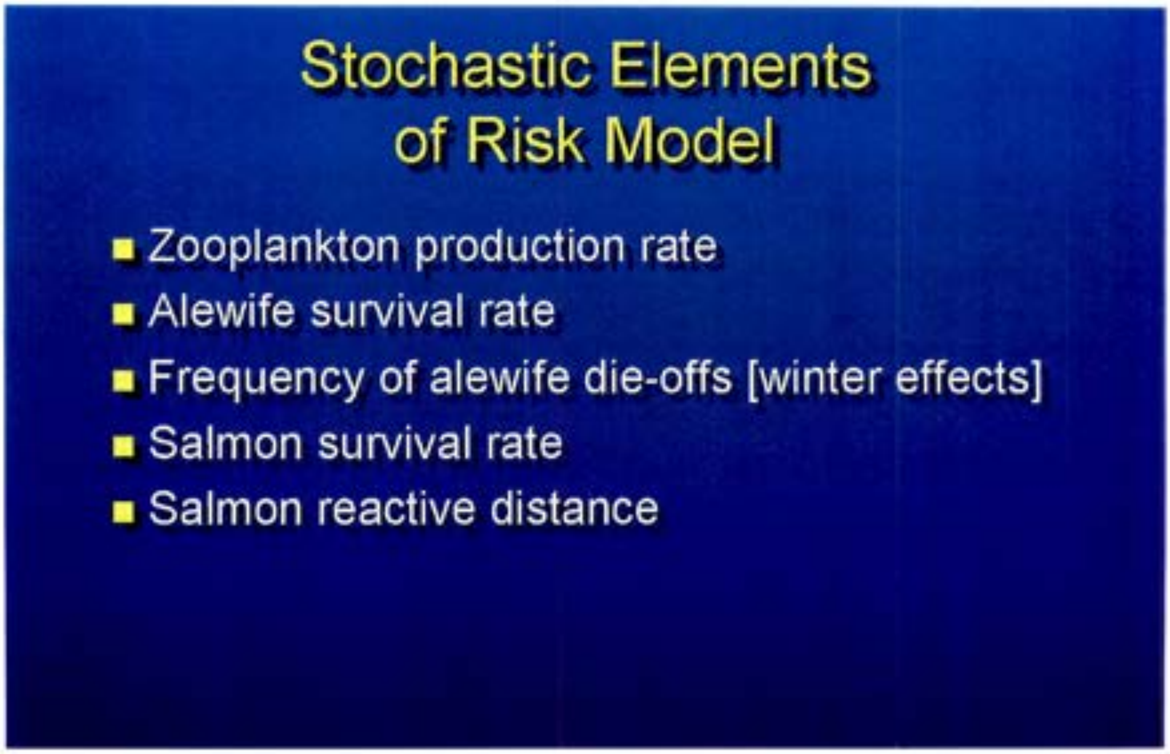
Methods

- Management objective is to maintain a sufficient level of prey to support salmon
- Express output as a probability of observing conditions like those in Lake Michigan - establish a *risk endpoint*
- Estimate risk as a function of salmon stocking levels and lower food web production



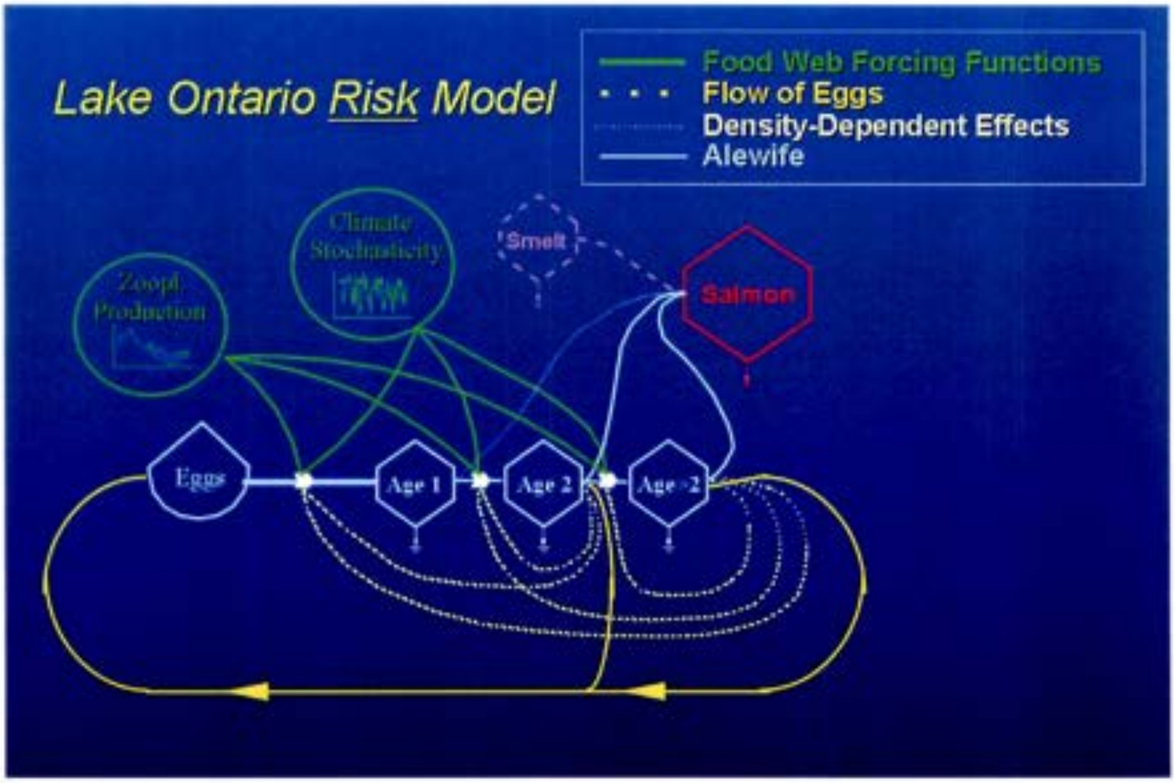
Why Avoid *Risk Endpoint*?

- In Lake Michigan, alewife collapsed in the early 1980s and remained low for several years.
  - Growth and survival of chinook salmon declined
  - Sport fishery declined
  - Diseases (e.g. BKD) became widespread in the salmon population
  - Effects irreversible?



Stochastic Elements of Risk Model

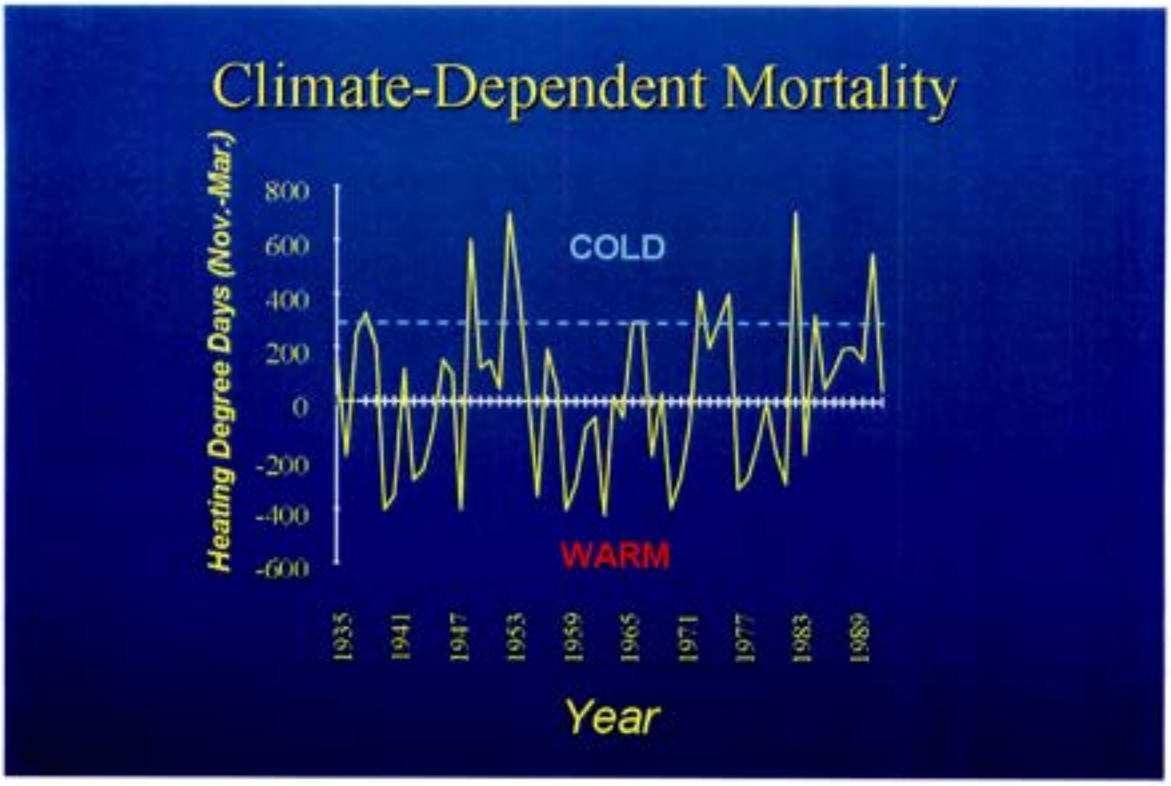
- Zooplankton production rate
- Alewife survival rate
- Frequency of alewife die-offs [winter effects]
- Salmon survival rate
- Salmon reactive distance



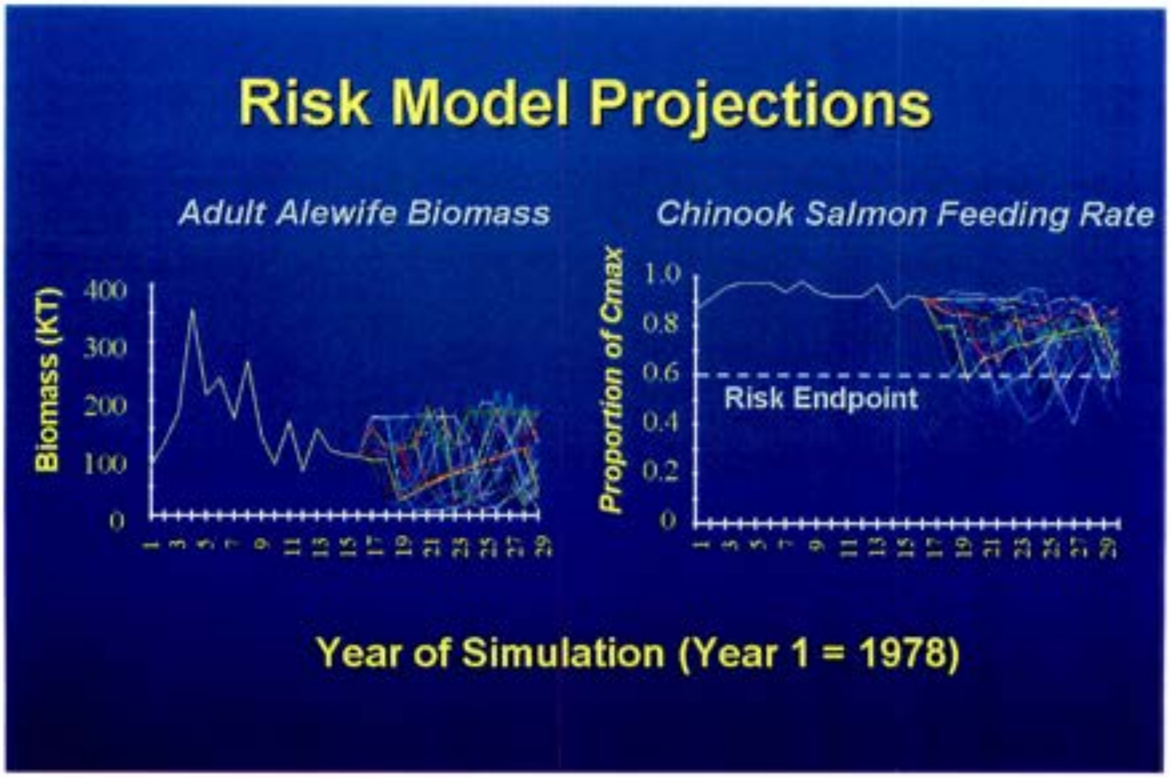
Lake Ontario *Risk* Model

Risk Model Scenarios

- Stocking Rate
  - "Status Quo" stocking (1992)
  - Implemented stocking cuts (0.5*1992)
  - 2X, 3X & 4X 1992 stocking regime
- Zooplankton Production Rate
  - Mean (1985-90)
  - 0.25X, 0.5X & 2X (late 1970s) mean

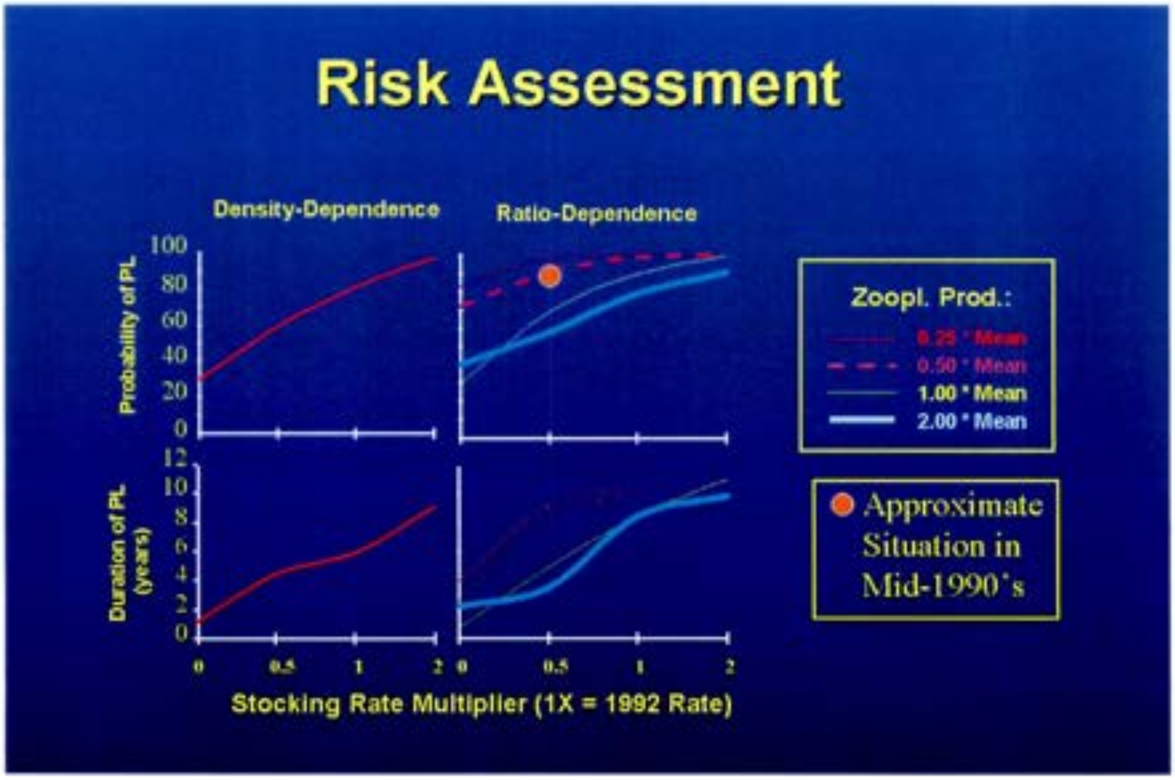


Climate-Dependent Mortality

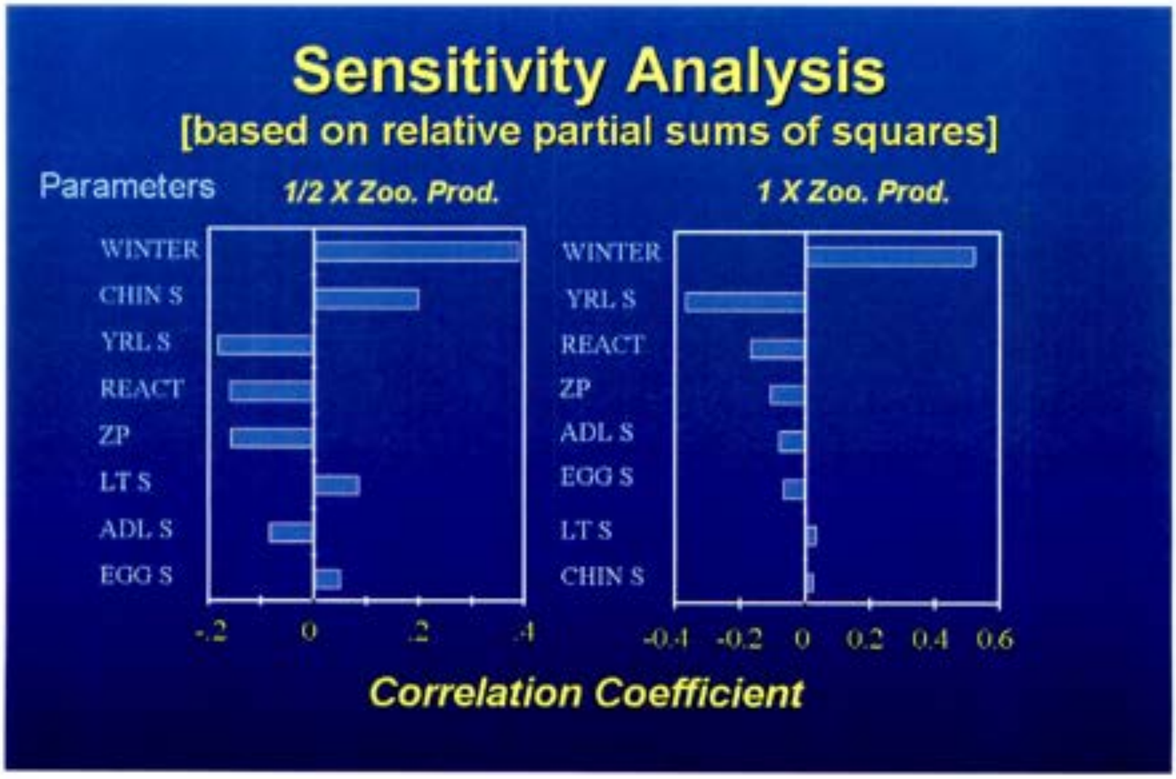


Risk Model Projections

Year of Simulation (Year 1 = 1978)

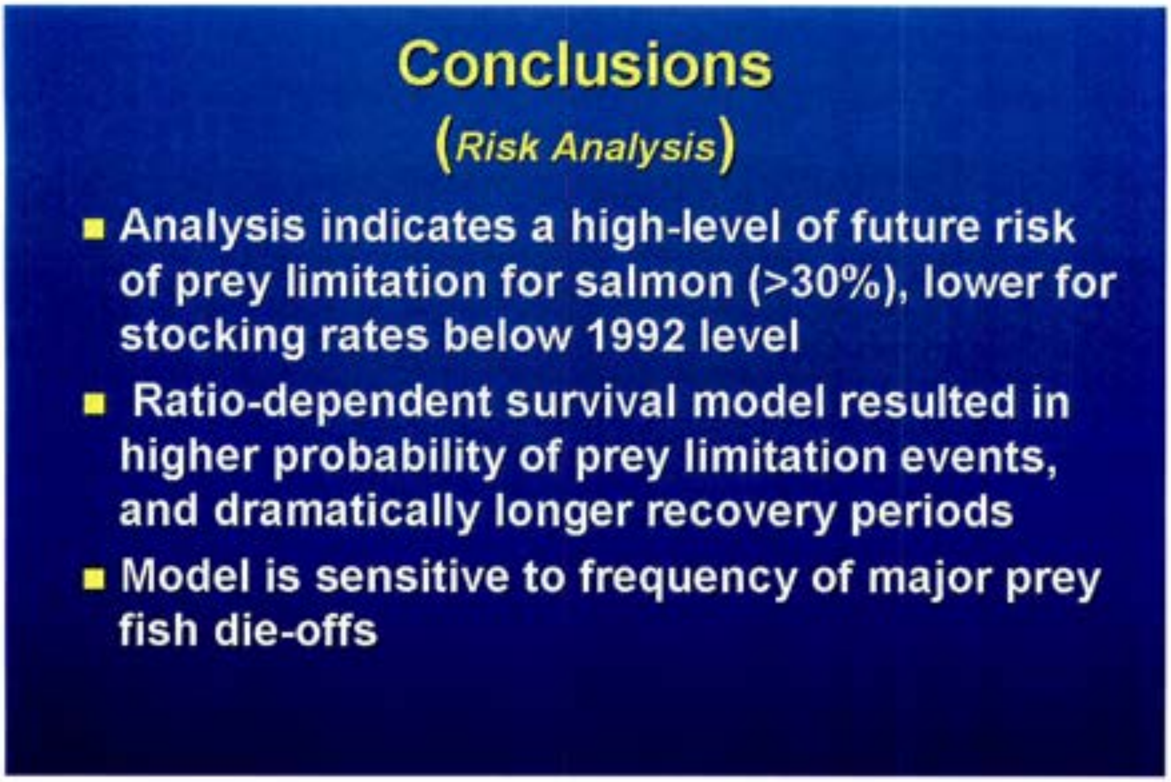


Risk Assessment



Sensitivity Analysis

[based on relative partial sums of squares]



Conclusions

(*Risk Analysis*)

- **Analysis indicates a high-level of future risk of prey limitation for salmon (>30%), lower for stocking rates below 1992 level**
- **Ratio-dependent survival model resulted in higher probability of prey limitation events, and dramatically longer recovery periods**
- **Model is sensitive to frequency of major prey fish die-offs**

Appendix J.
Aged-structured Model for Walleye in Oneida Lake, NY

Aged-structured Model for Walleye in Oneida Lake, NY

Brian Irwin speaking
Team members: T.J. Treska, L.G. Rudstam, P.J.Sullivan,
J.R. Jackson, A.J. VanDeValk, J.L. Forney
NY Sea Grant Workshop
October 24, 2005

Abstract

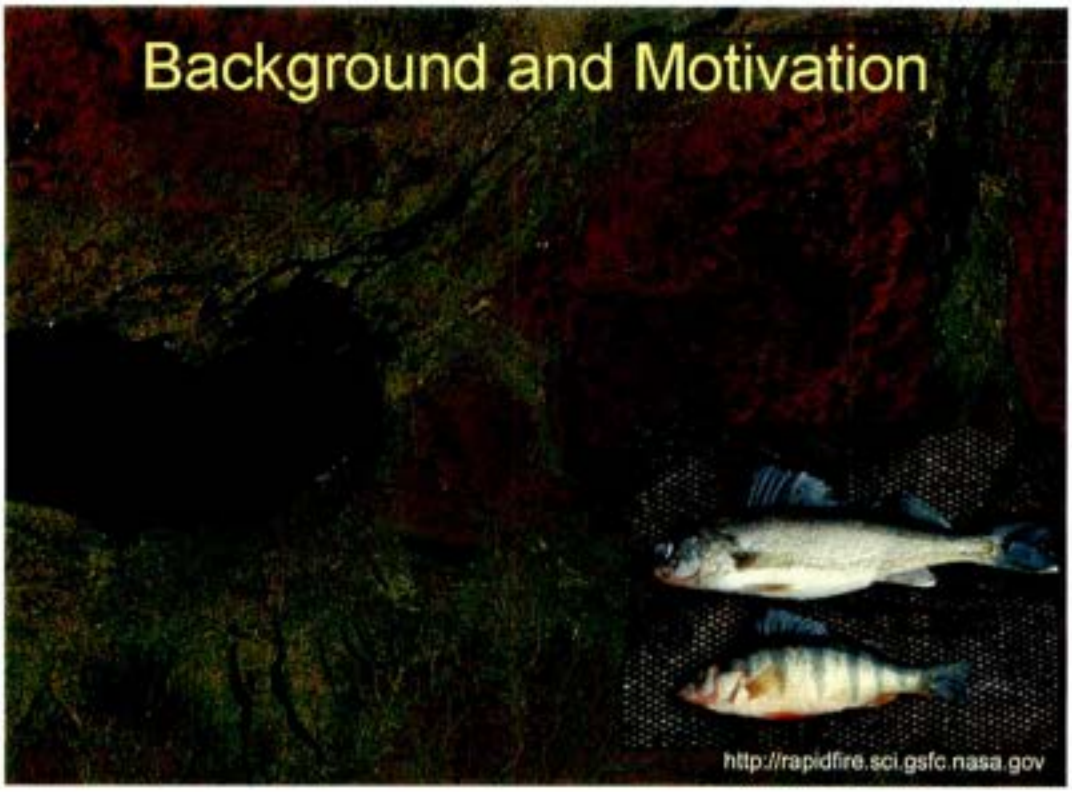
Since the late 1950s, standardized sampling in Oneida Lake has produced three long-term data sets (trawl catch-per-unit-effort, gillnet catch-at-age, and adult mark-recapture population estimates) for walleye. The mark-recapture estimates provide a measure of absolute abundance over a number of non-consecutive years for adult walleye (age-4+) only. However, walleye collected in trawls and gillnets have been aged, providing independent, age-specific estimates of their relative abundance over time. Due to the lack of direct estimates of population abundance for sub-adult fish, the age-specific catchabilities of the sampling gears are largely unknown. We evaluated long-term trends suggested by the individual sampling approaches as well as the effects of various weighting assumptions on sampling components in models utilizing all available data. We used AD Model Builder with the three long-term data sets to simultaneously estimate mortality, age-specific gear catchabilities, and the abundance of sub-adult walleye. We also developed a more complex model to test our hypothesis that sub-adult walleye mortality has increased in Oneida Lake during a period of increased presence of double-crested cormorants.

Future Directions

1) Evaluate uncertainty around parameter estimates
2) Establish a prior distribution rather than a fixed natural mortality rate
3) Forecast population given target mortality rates

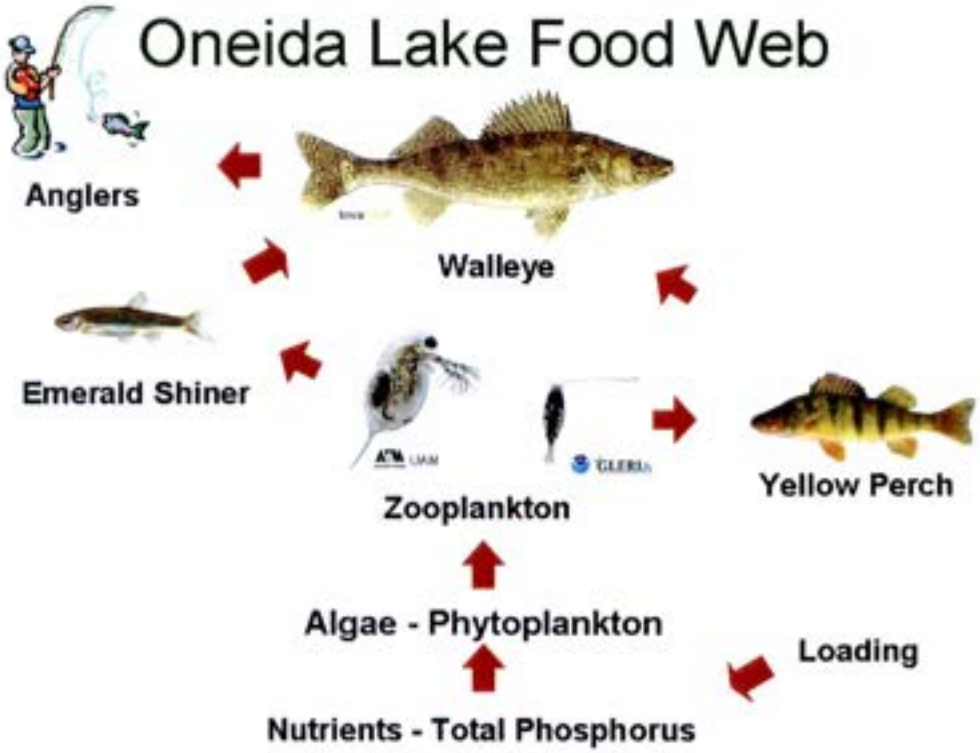
Objectives

1) Synthesize long-term data from three distinct sampling approaches
2) Estimate density of sub-adult walleye and the age-specific catchability of two collection gears, and
3) Evaluate hypothesis that sub-adult walleye mortality has increased over time in Oneida Lake



Background and Motivation

http://rapidfire.sci.gsfc.nasa.gov



Oneida Lake Food Web

Anglers

Walleye

Emerald Shiner

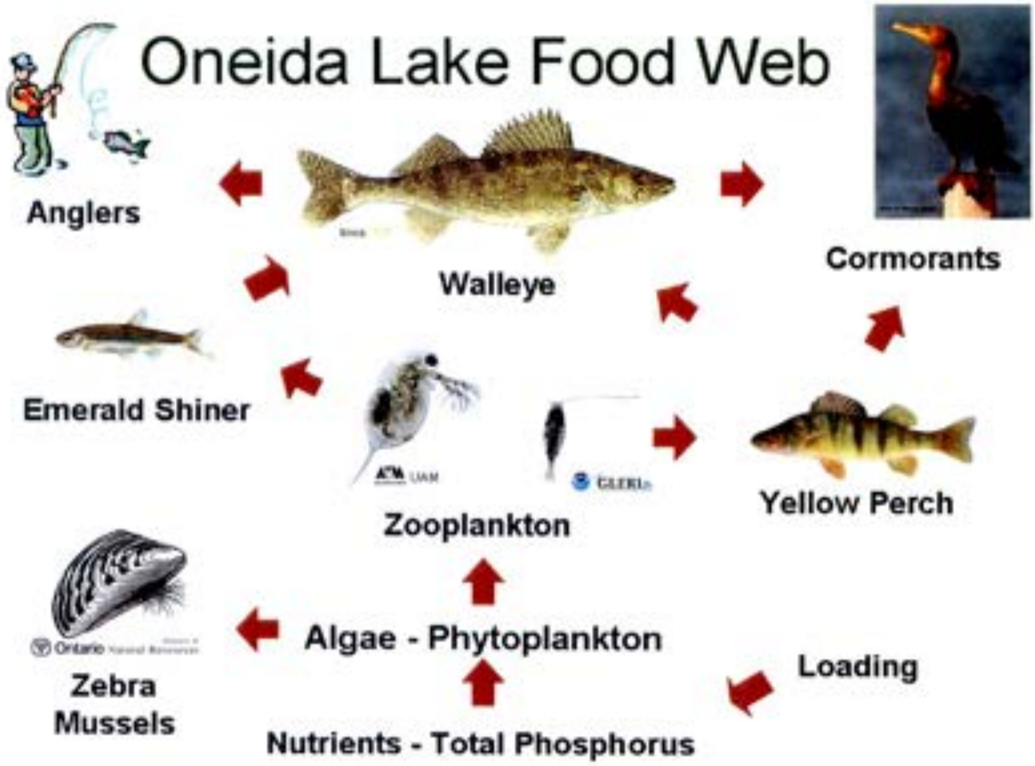
Yellow Perch

Zooplankton

Algae - Phytoplankton

Loading

Nutrients - Total Phosphorus



Oneida Lake Food Web

Anglers

Walleye

Cormorants

Emerald Shiner

Yellow Perch

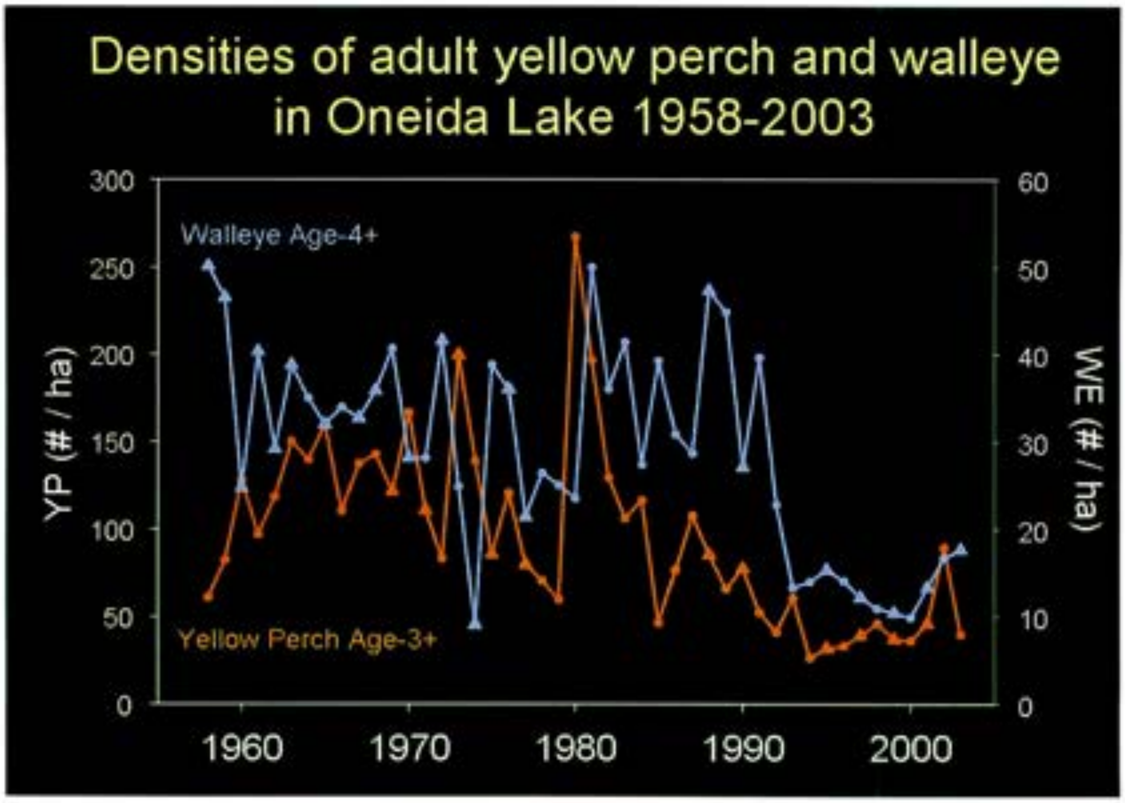
Zooplankton

Zebra Mussels

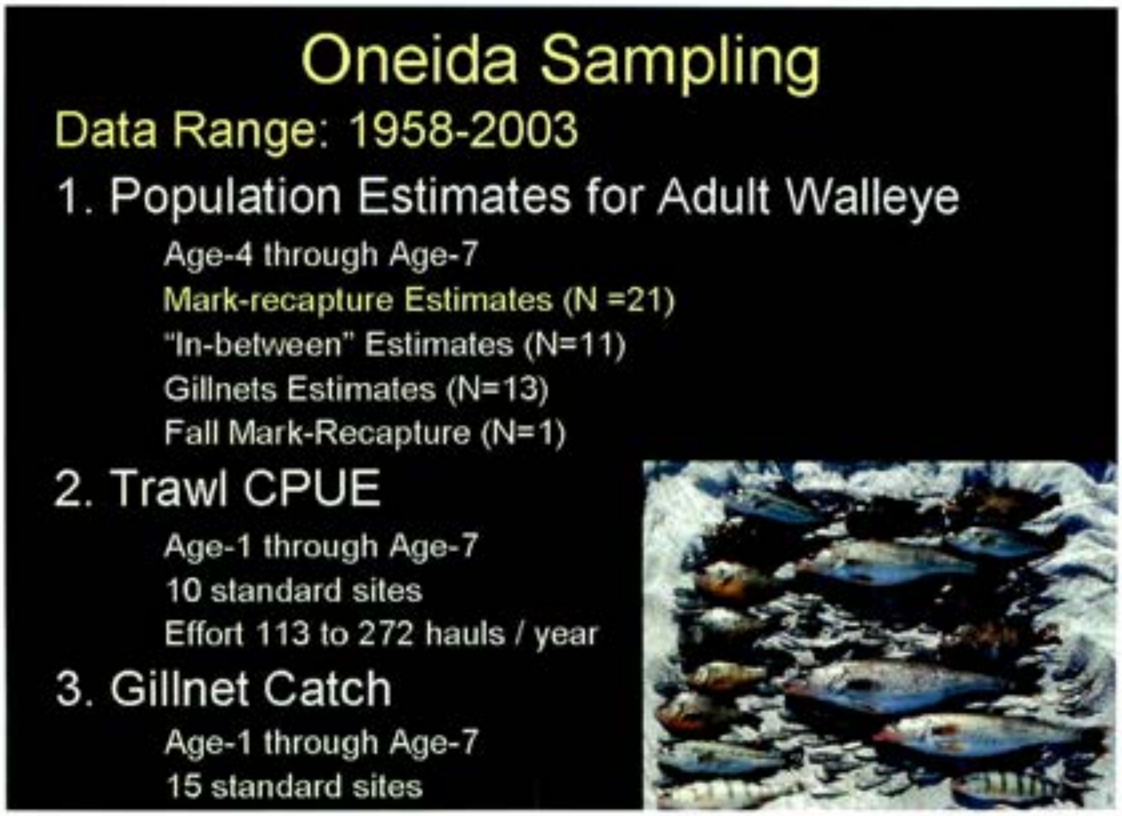
Algae - Phytoplankton

Loading

Nutrients - Total Phosphorus



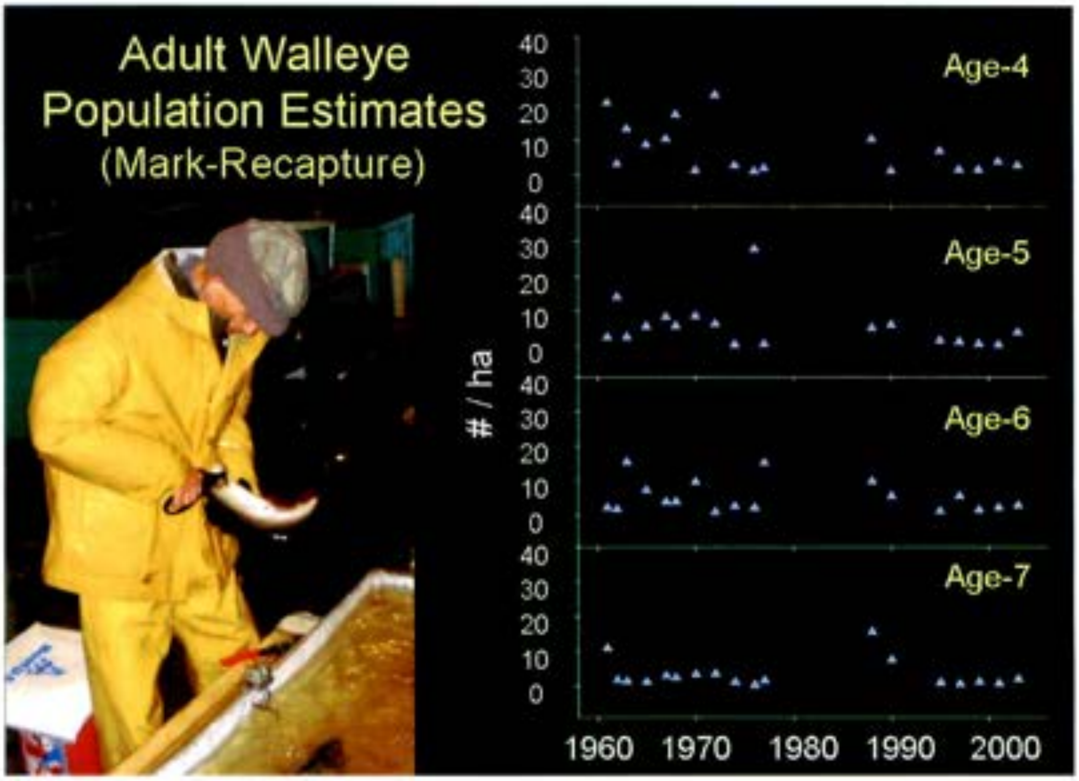
Densities of adult yellow perch and walleye in Oneida Lake 1958-2003



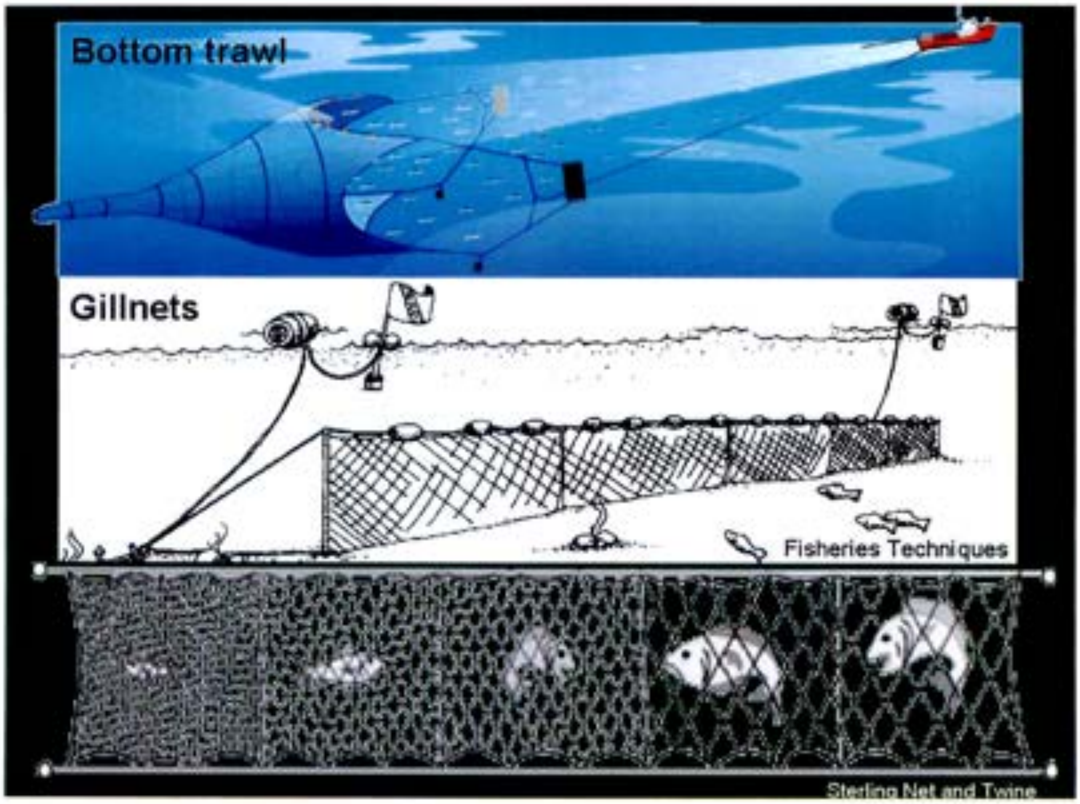
Oneida Sampling

Data Range: 1958-2003

1. Population Estimates for Adult Walleye
   - Age-4 through Age-7
   - Mark-recapture Estimates (N =21)
   - "In-between" Estimates (N=11)
   - Gillnets Estimates (N=13)
   - Fall Mark-Recapture (N=1)
2. Trawl CPUE
   - Age-1 through Age-7
   - 10 standard sites
   - Effort 113 to 272 hauls / year
3. Gillnet Catch
   - Age-1 through Age-7
   - 15 standard sites

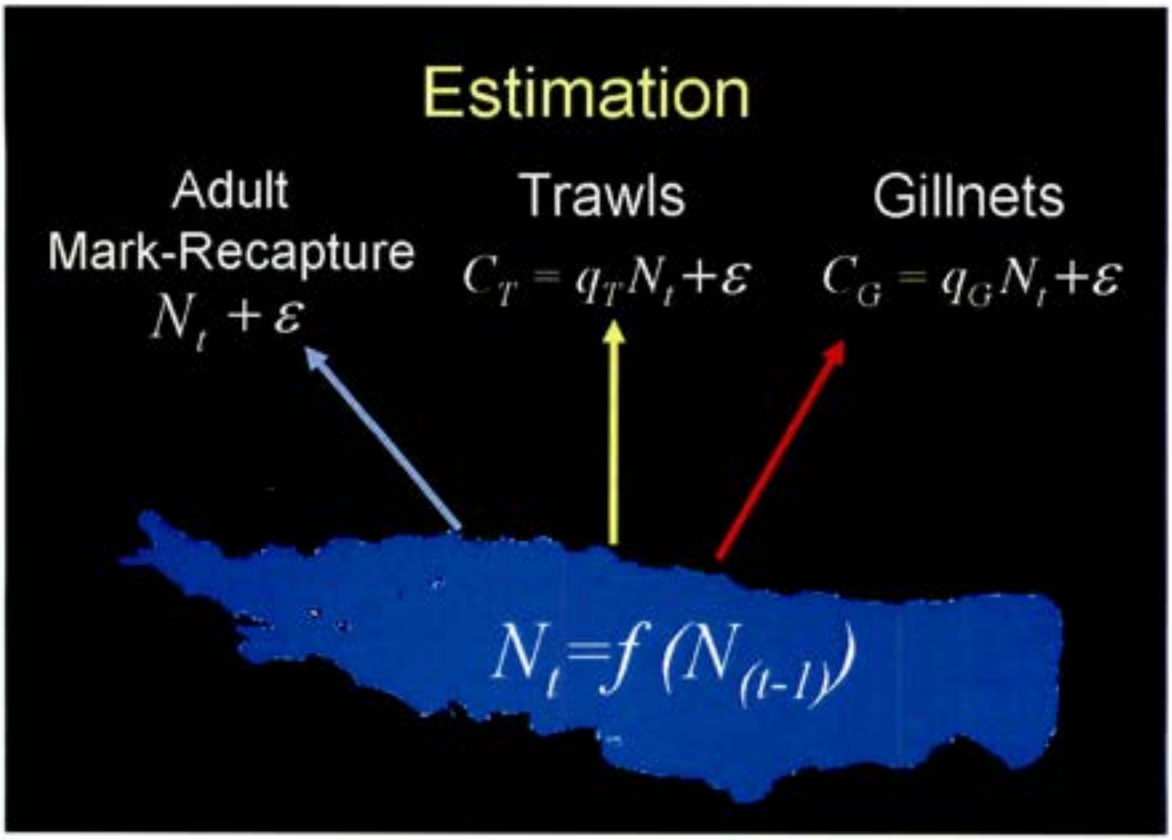


Adult Walleye Population Estimates (Mark-Recapture)



Fisheries Techniques

Sterling Net and Twine



Estimation

Adult Mark-Recapture

$N_t + \varepsilon$

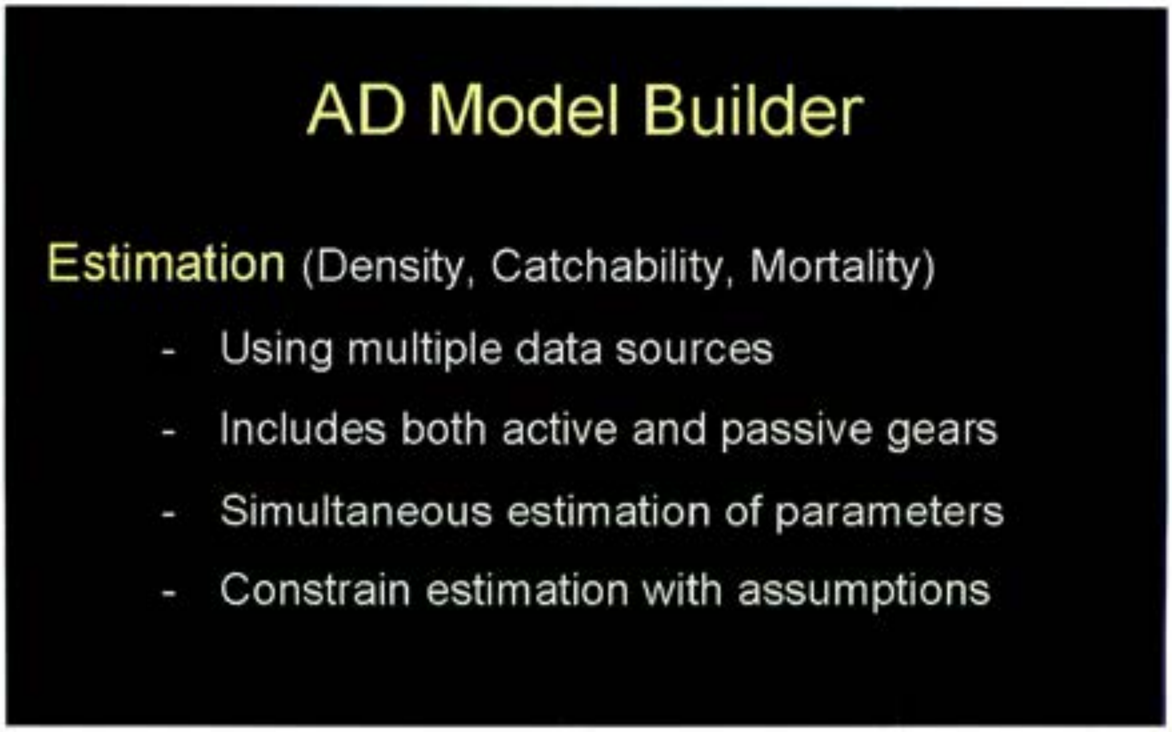
Trawls

$C_T = q_T N_t + \varepsilon$

Gillnets

$C_G = q_G N_t + \varepsilon$

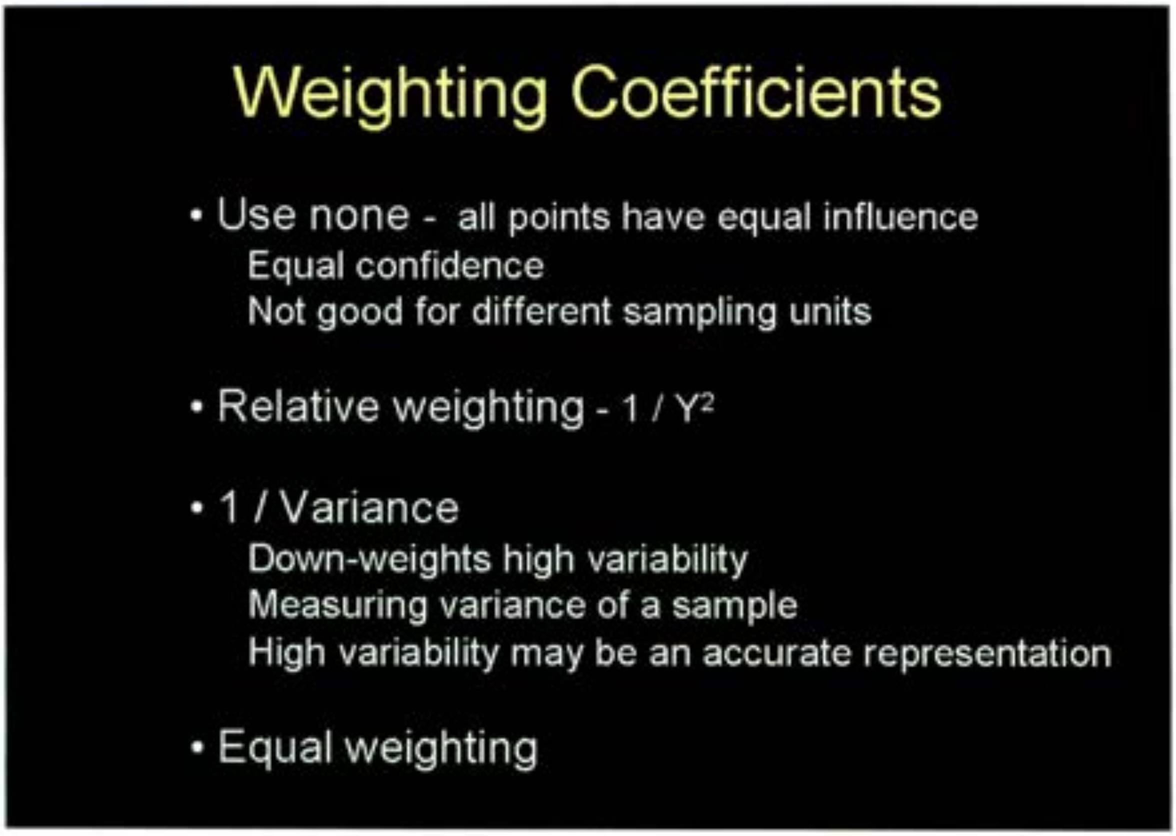
$N_t = f(N_{(t-1)})$



AD Model Builder

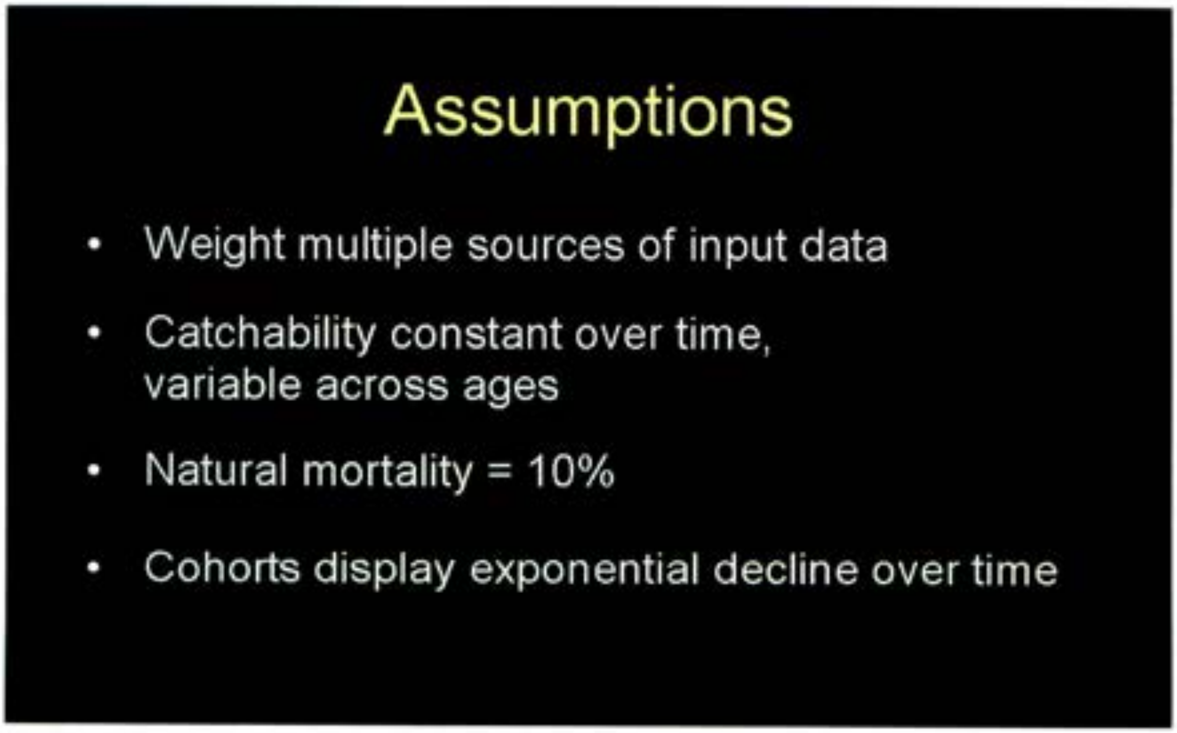
Estimation (Density, Catchability, Mortality)

- Using multiple data sources
- Includes both active and passive gears
- Simultaneous estimation of parameters
- Constrain estimation with assumptions



Weighting Coefficients

- Use none - all points have equal influence
  Equal confidence
  Not good for different sampling units
- Relative weighting - $1 / Y^2$
- 1 / Variance
  Down-weights high variability
  Measuring variance of a sample
  High variability may be an accurate representation
- Equal weighting



Assumptions

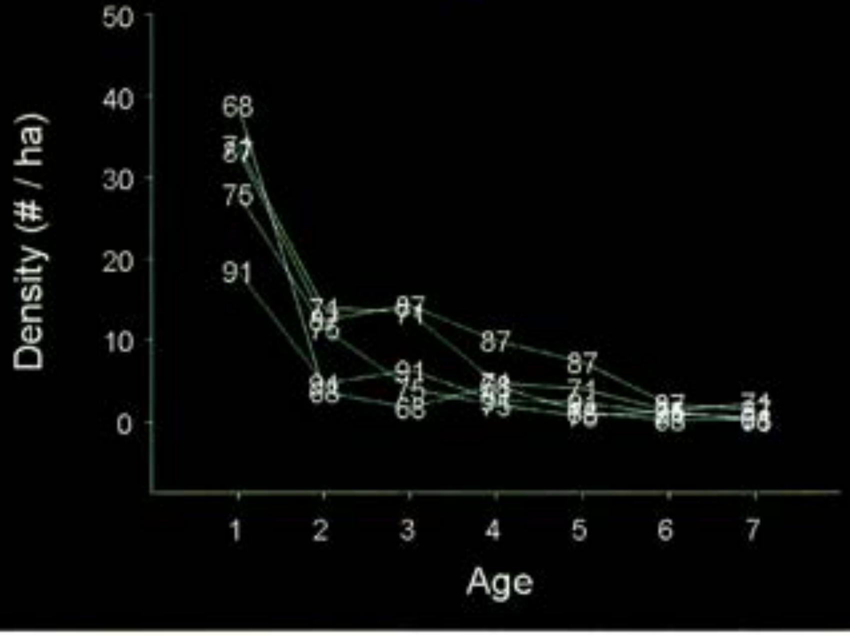
- Weight multiple sources of input data
- Catchability constant over time, variable across ages
- Natural mortality = 10%
- Cohorts display exponential decline over time

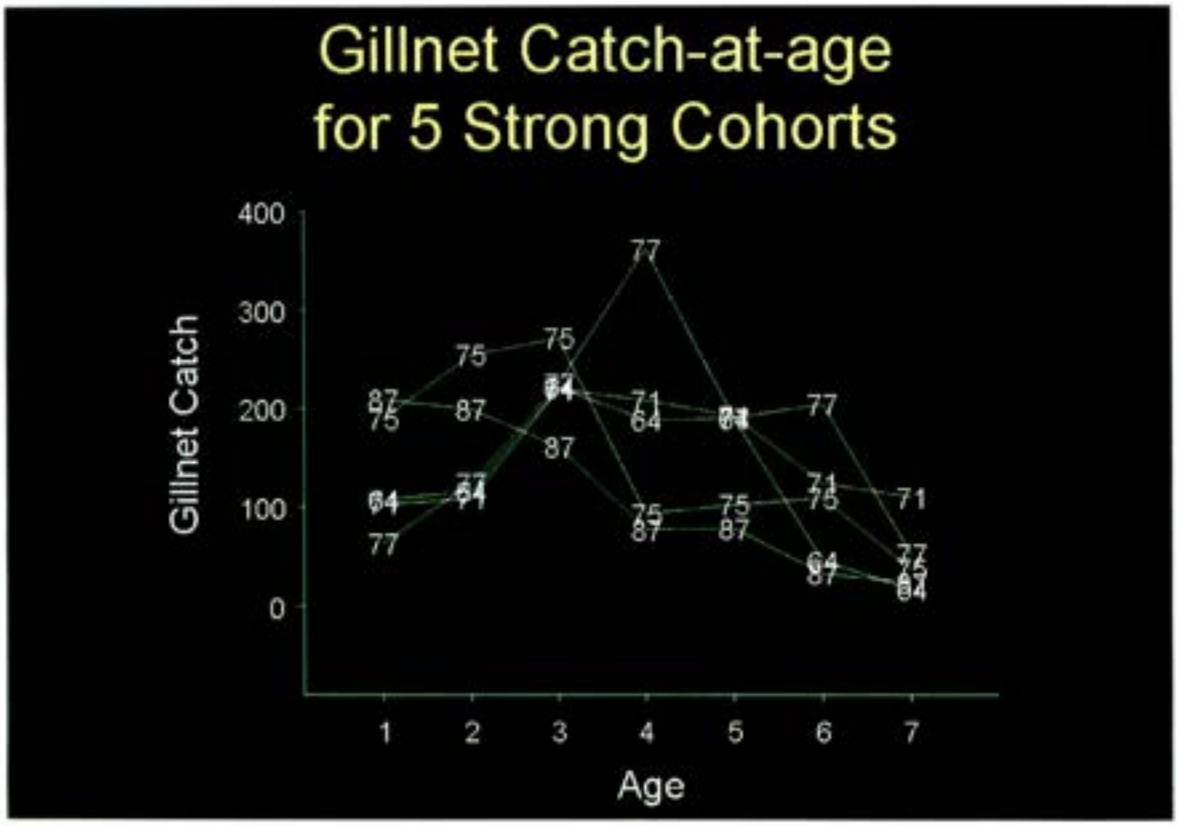
Assumptions

- Two periods of mortality
  1) 1958-1989
     - No size limits for 1958-1974
     - 12" or 15" limit for 1975-1989

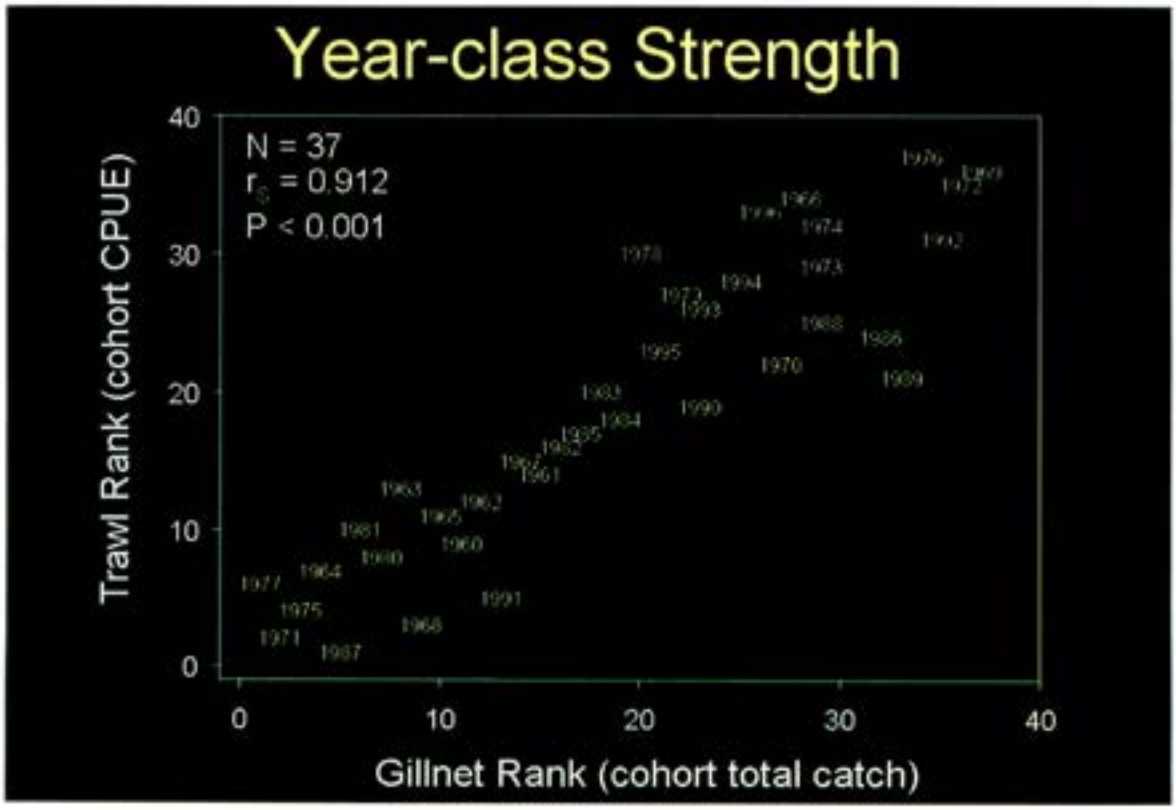
  2) 1990-2003
     - 15" or 18" size limit for 1990-2003
     - Cormorants present 1990-2003
     - Zebra Mussel establishment 1992

Trawl CPUE-at-age for 5 Strong Cohorts



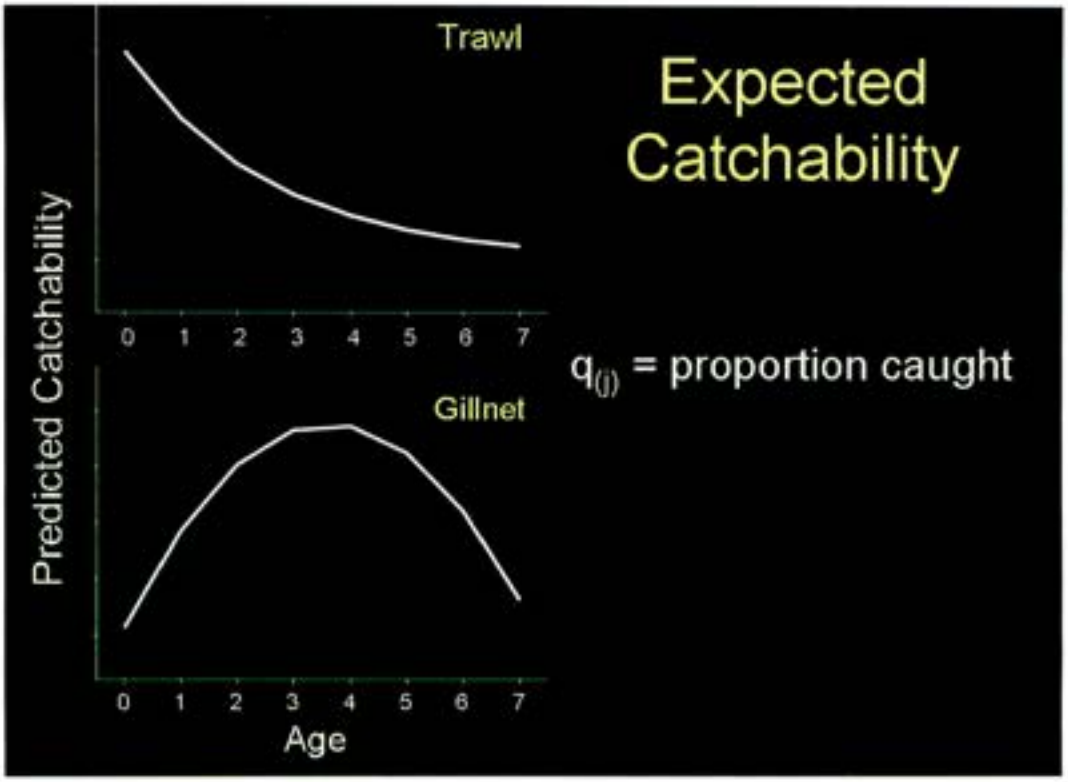


Gillnet Catch-at-age for 5 Strong Cohorts



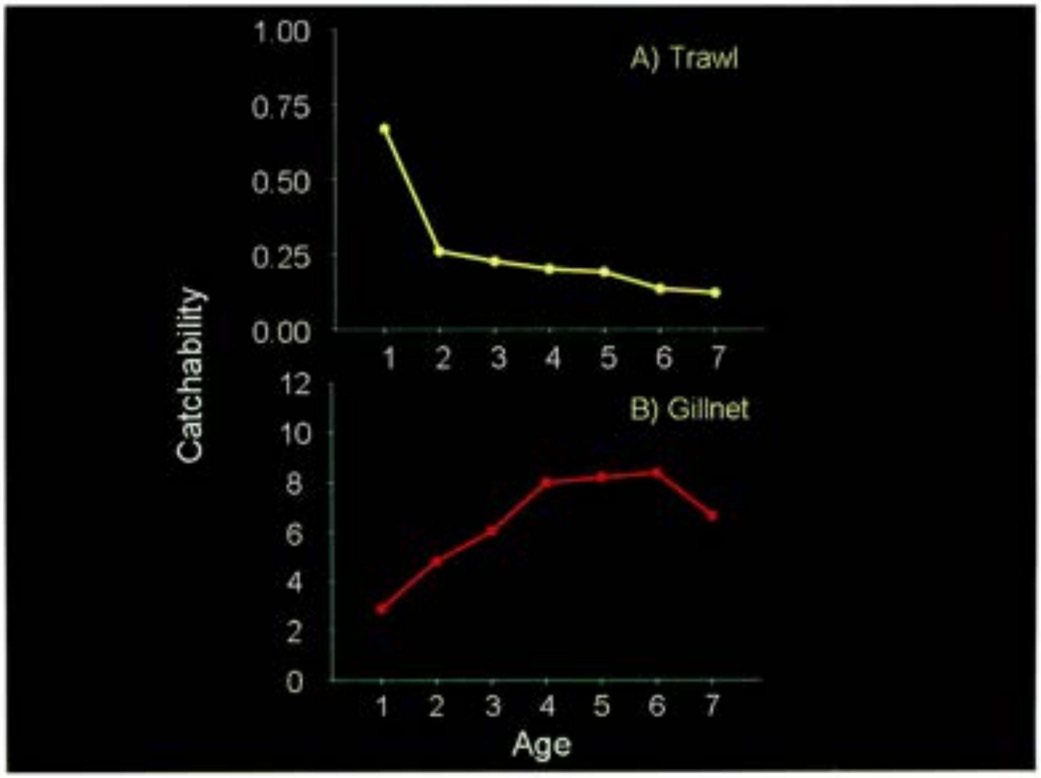
Year-class Strength

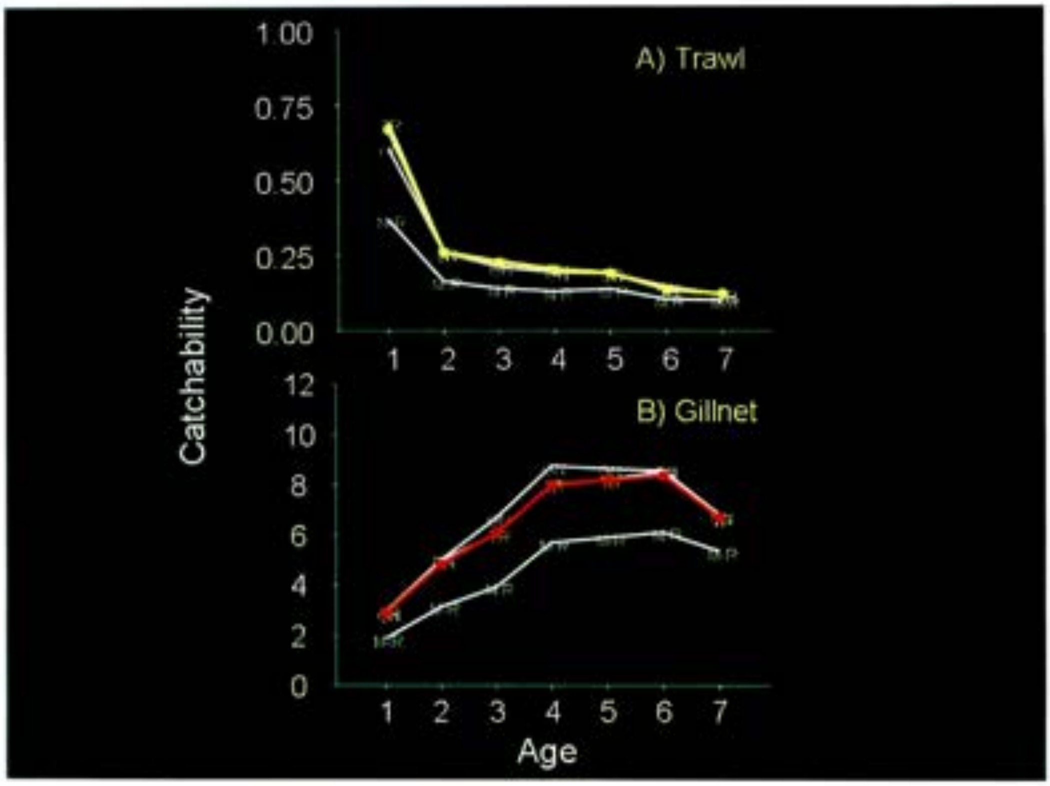
N = 37
$r_S = 0.912$
$P < 0.001$

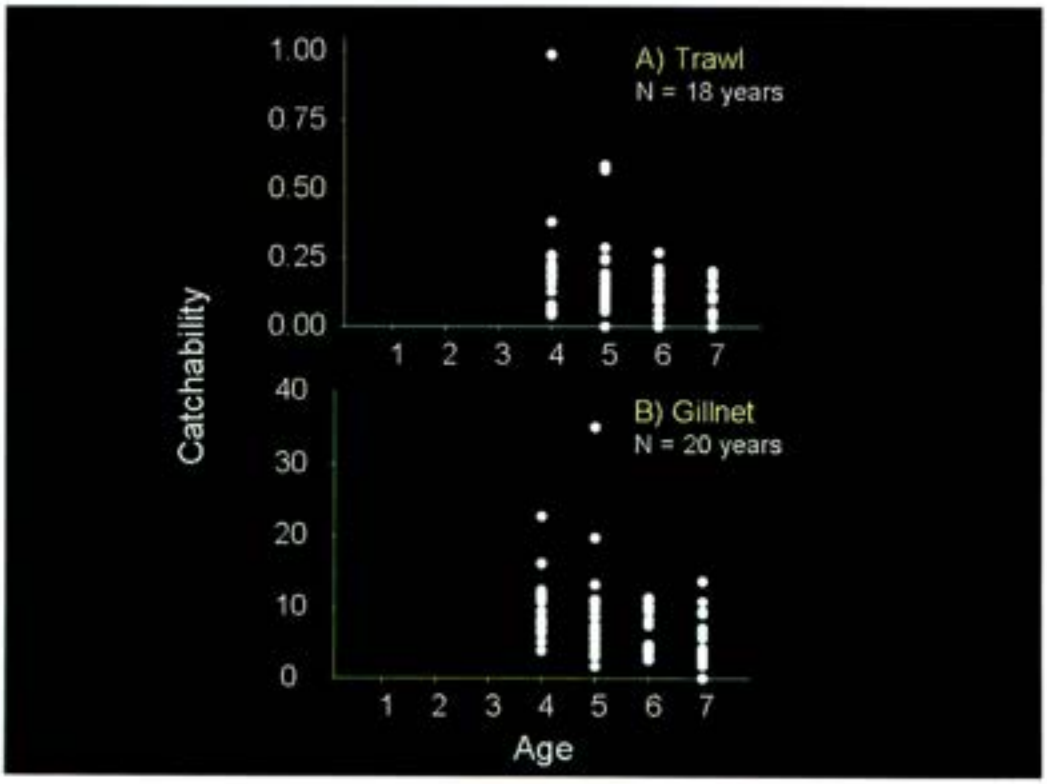


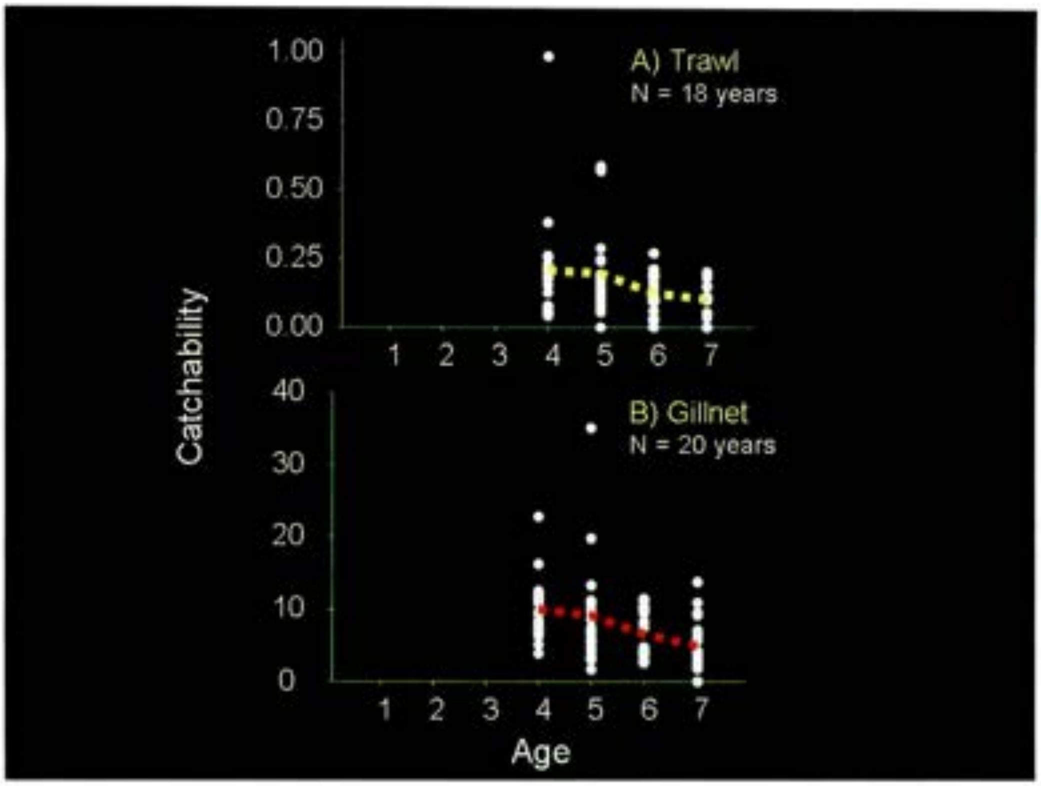
Expected Catchability

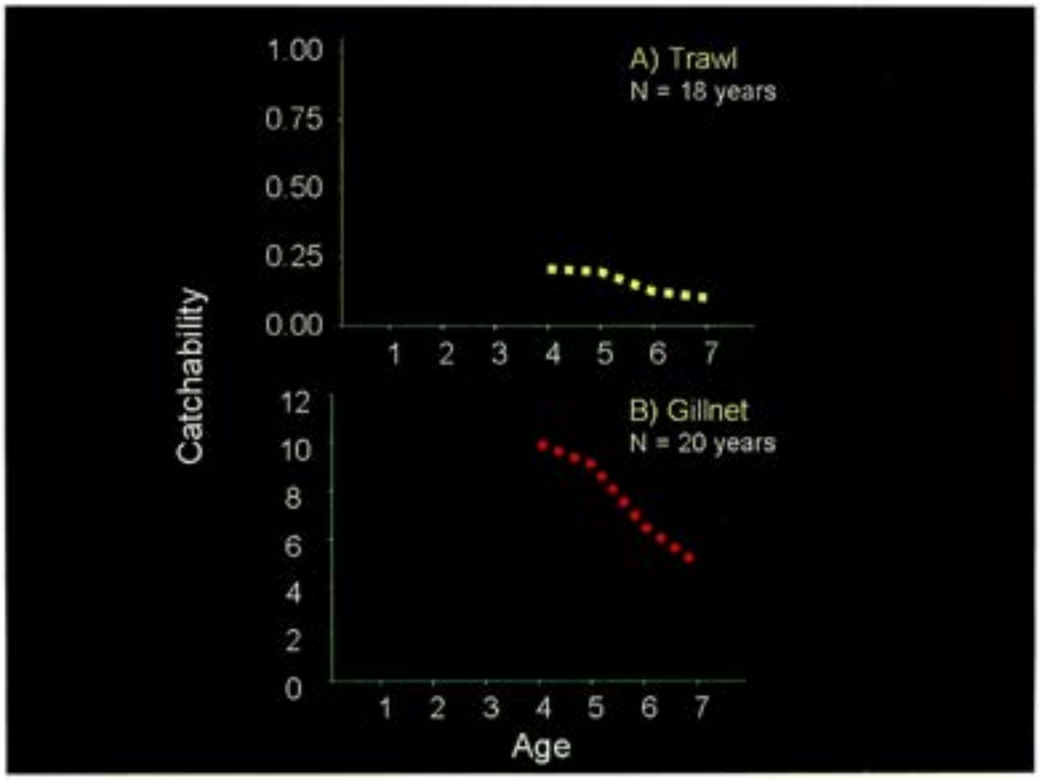
$q_{(j)}$ = proportion caught

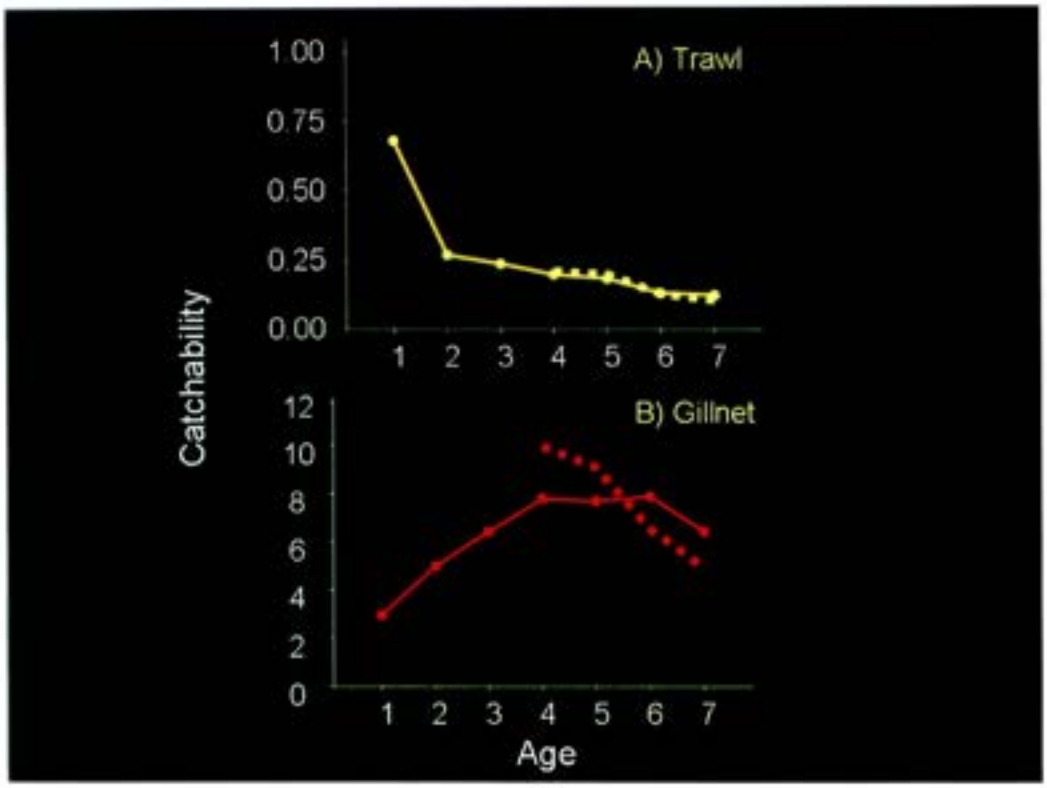


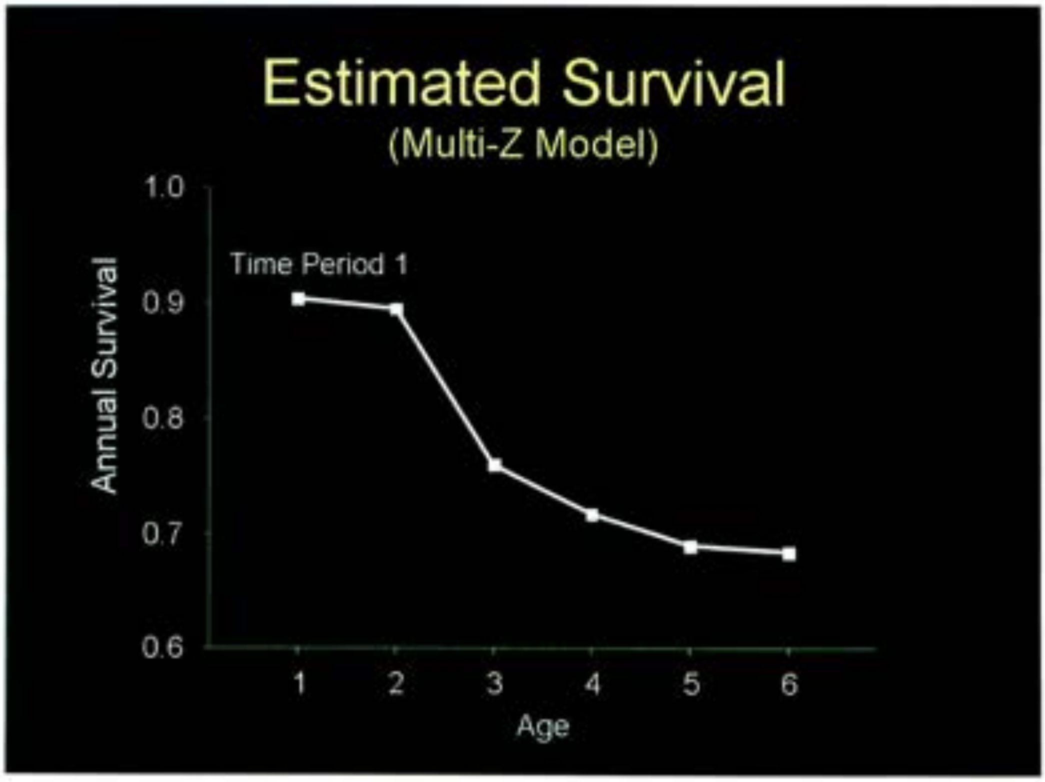

A) Trawl
B) Gillnet
Catchability
Age
1.00
0.75
0.50
0.25
0.00
12
10
8
6
4
2
0
1 2 3 4 5 6 7


A) Trawl
N = 18 years
B) Gillnet
N = 20 years
Catchability
Age
1.00
0.75
0.50
0.25
0.00
40
30
20
10
0
1 2 3 4 5 6 7


Catchability
1.00
0.75
0.50
0.25
0.00
A) Trawl
N = 18 years
1 2 3 4 5 6 7
40
30
20
10
0
B) Gillnet
N = 20 years
1 2 3 4 5 6 7
Age

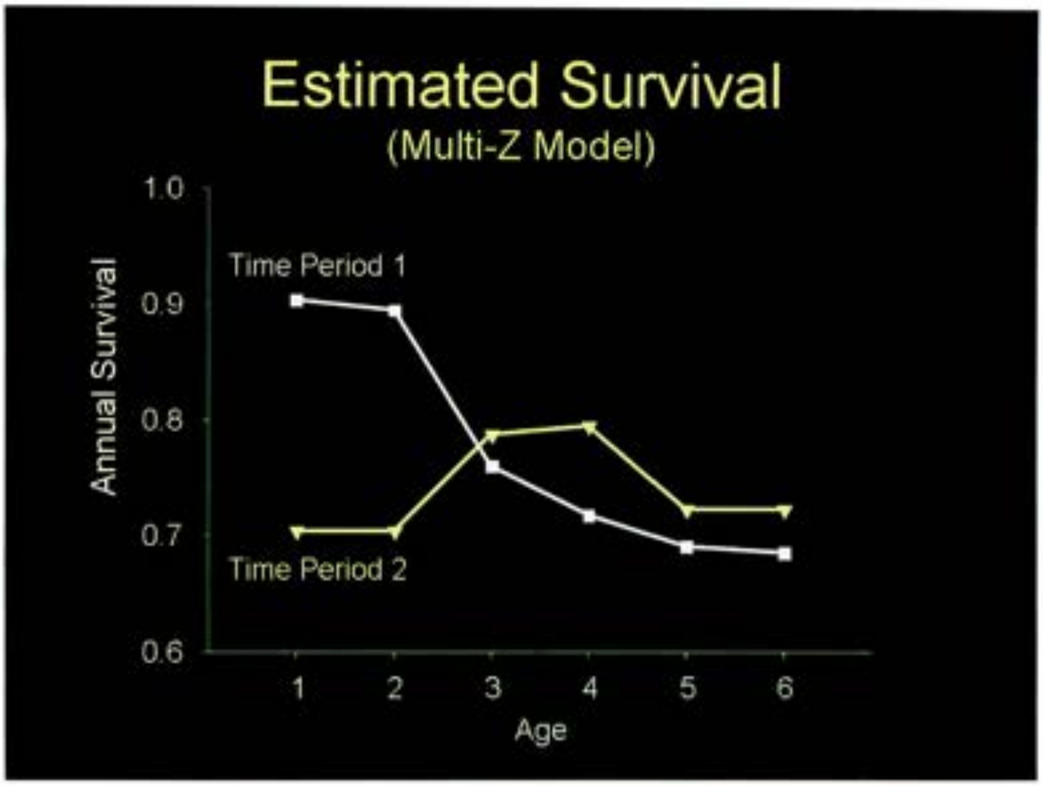

Catchability
1.00
0.75
0.50
0.25
0.00
A) Trawl
N = 18 years
1 2 3 4 5 6 7
12
10
8
6
4
2
0
B) Gillnet
N = 20 years
1 2 3 4 5 6 7
Age





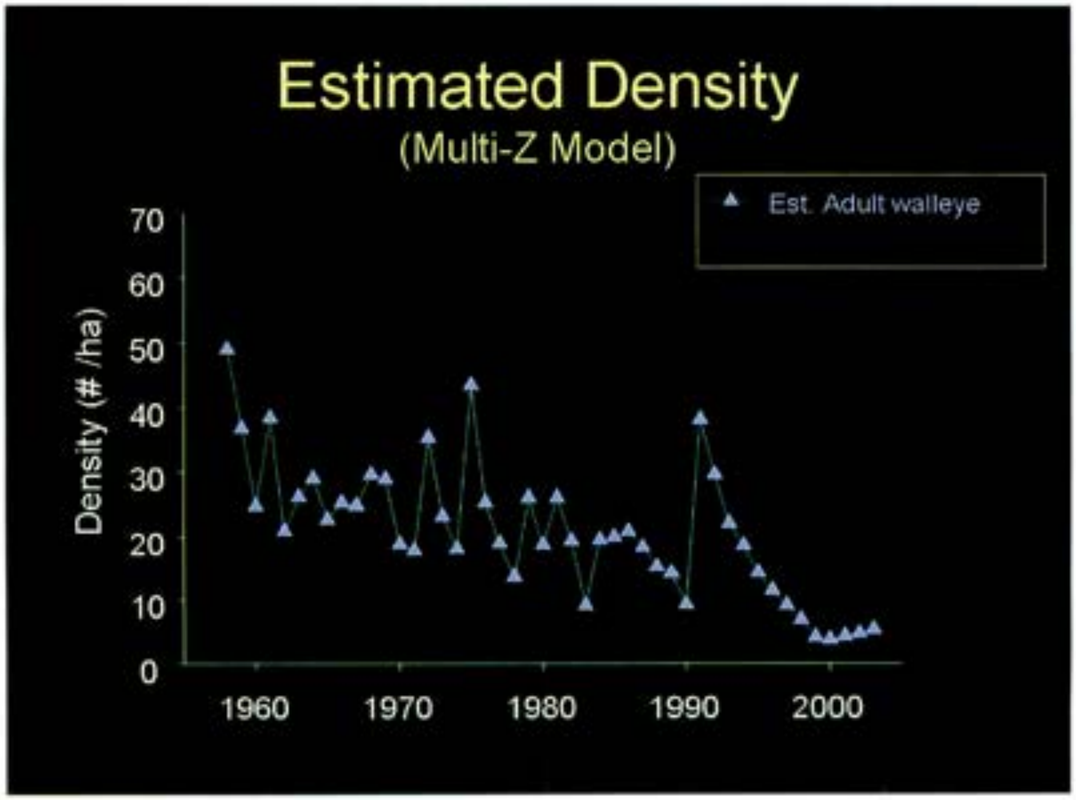
Estimated Survival

(Multi-Z Model)



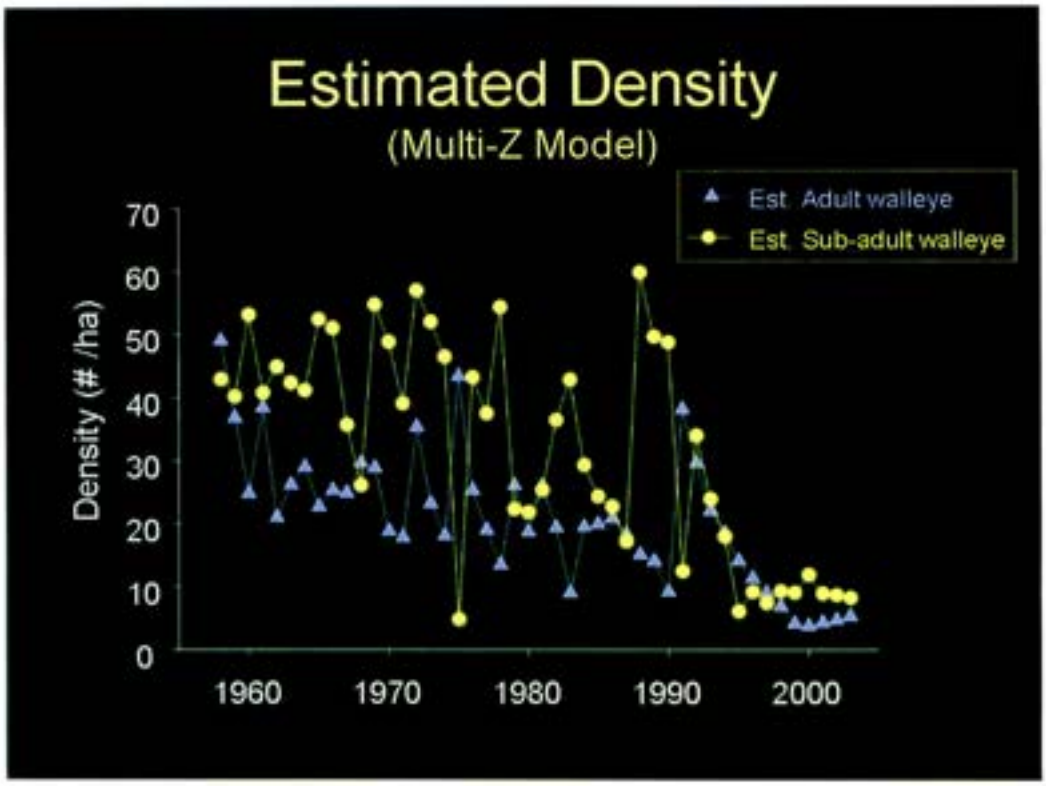
Estimated Survival

(Multi-Z Model)



Estimated Density

(Multi-Z Model)



Estimated Density

(Multi-Z Model)

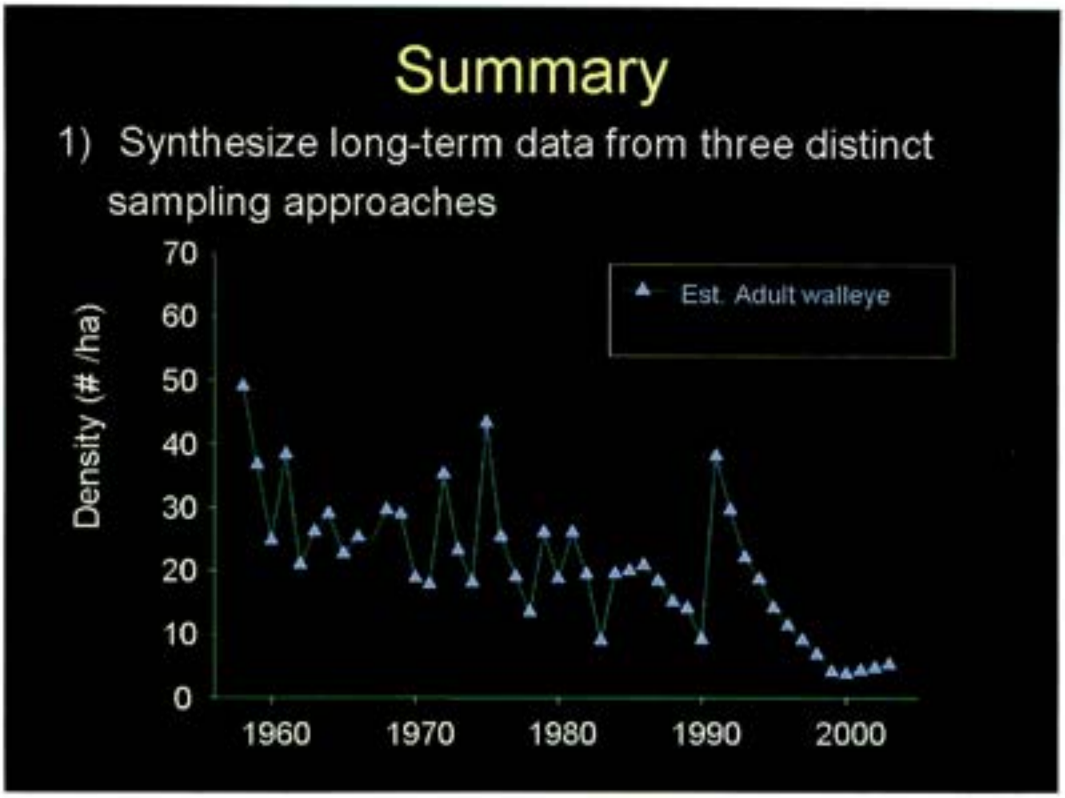
Summary

1) Synthesize long-term data from three distinct sampling approaches

21 Years of Mark-Recapture Data for Age-4+

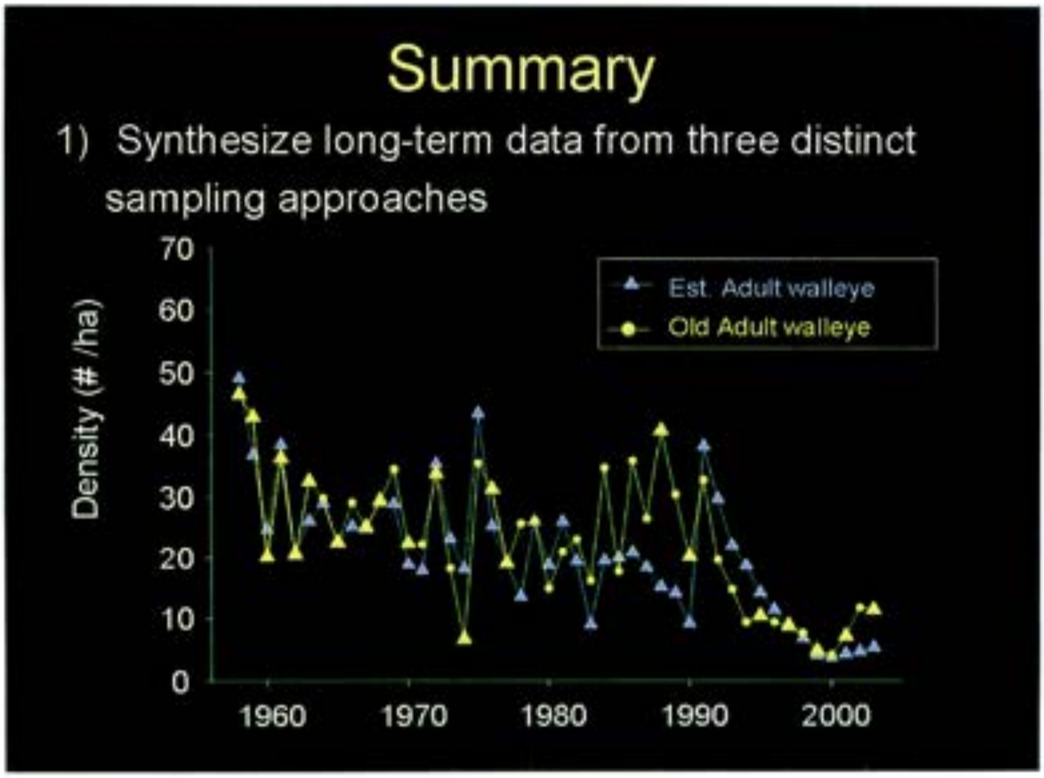
43 Years of Trawls

45 Years of Gillnets



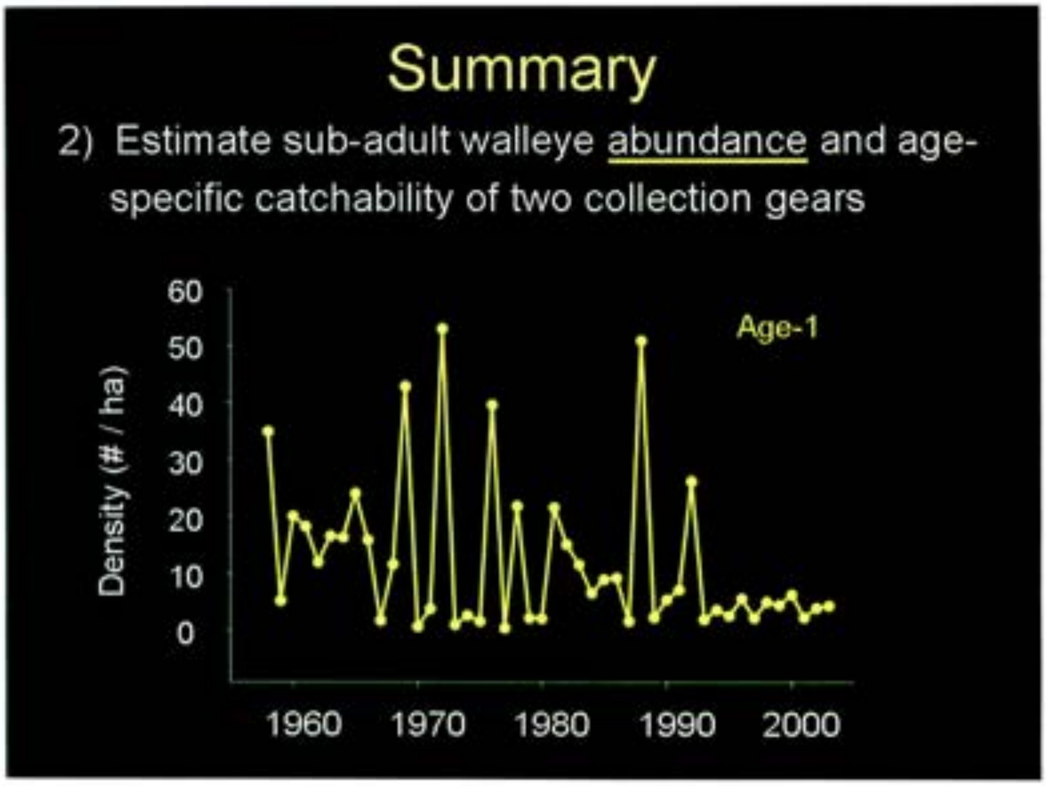
Summary

1) Synthesize long-term data from three distinct sampling approaches



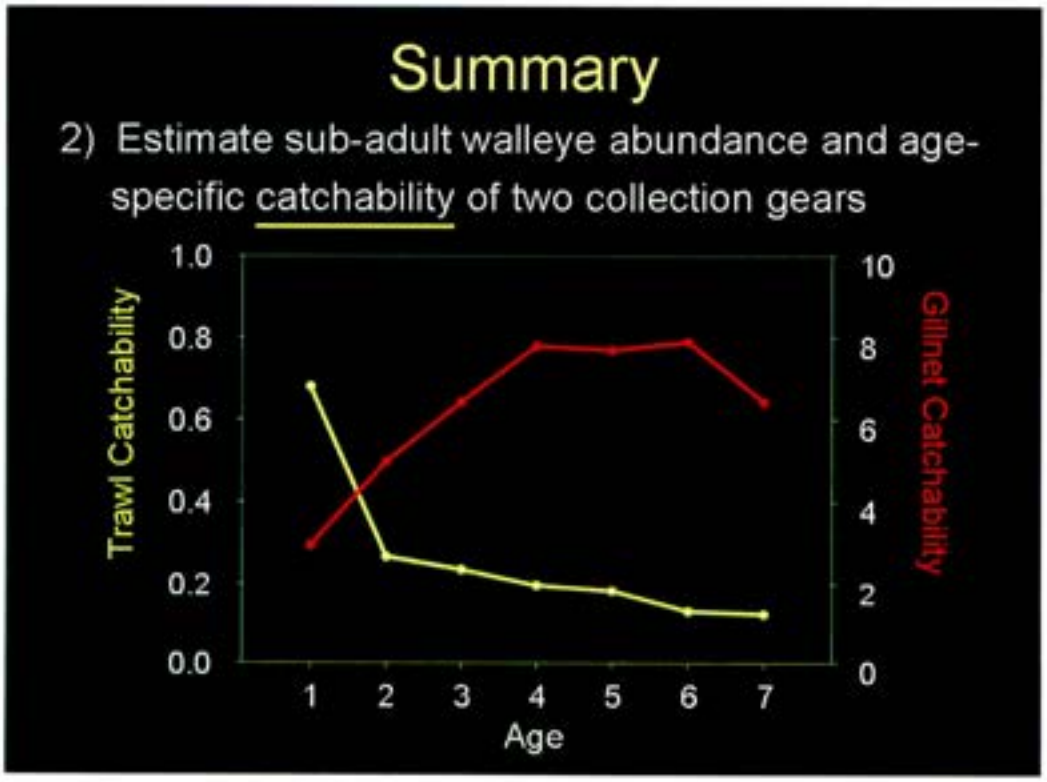
Summary

1) Synthesize long-term data from three distinct sampling approaches



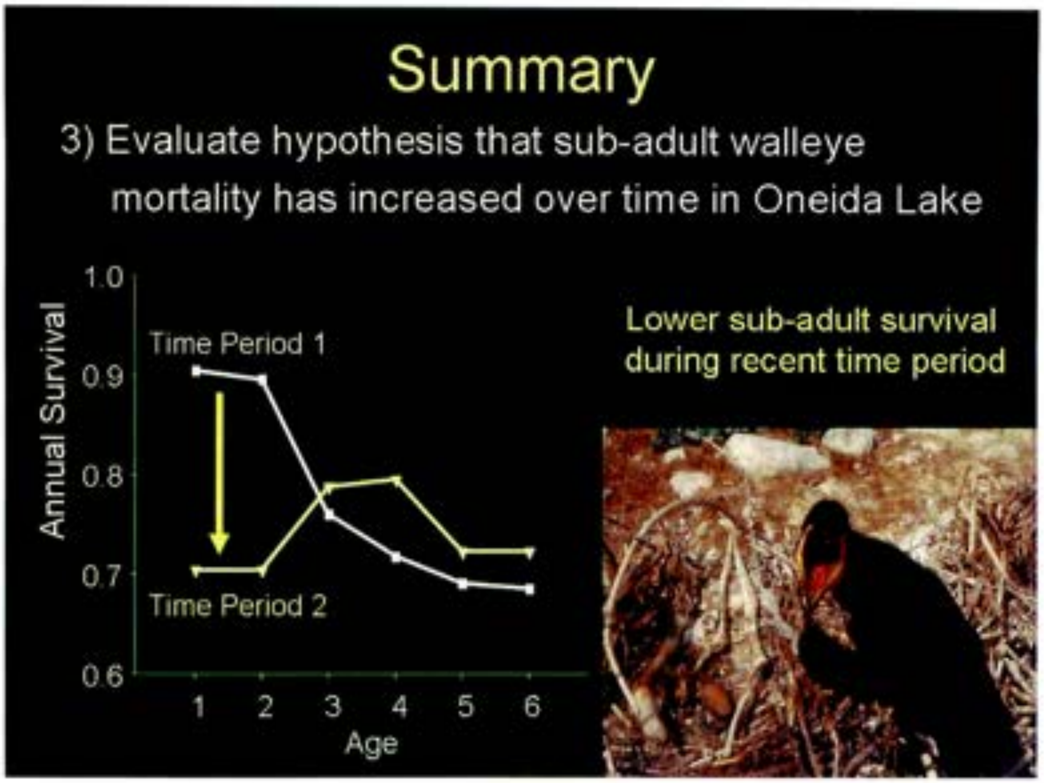
Summary

2) Estimate sub-adult walleye abundance and age-specific catchability of two collection gears



Summary

2) Estimate sub-adult walleye abundance and age-specific catchability of two collection gears



Summary

3) Evaluate hypothesis that sub-adult walleye mortality has increased over time in Oneida Lake

Lower sub-adult survival during recent time period

Appendix K.
Assessing Risk of Whitefish Decline When Recruitment is Known

Assessing Risk of Whitefish Decline When Recruitment is Known

Bruce J. Morrison
Ontario Ministry of Natural Resources
NY Sea Grant Workshop
October 24, 2005

Abstract

Lake Ontario lake whitefish have been commercially fished on Lake Ontario for well over 100 years. The commercial fishery closely followed the fish population's recovery in the 1980s, increasing in yield to around 1 million pounds and then declining precipitously in the late 1990s. In recent years, more sophisticated modeling was done to estimate abundance but the uncertainty around the short time series presented predictive problems. Also, for 6 of the last 7 years, survival of young fish has been poor resulting in virtually no recruitment. As recruitment is one of the more uncertain aspects of stock assessment, the loss of recruitment presented a unique opportunity to assess risk of different harvest policies albeit using rather uncertain abundance estimates. A very simple accounting approach was used to show potential outcomes of fisheries yields with respect to future adult biomasses. These polices were presented to the fishers so that they could accept some of the responsibility of the future of the fish population and their fishery. In the end, the fishers chose a more conservative approach among the options presented to them.

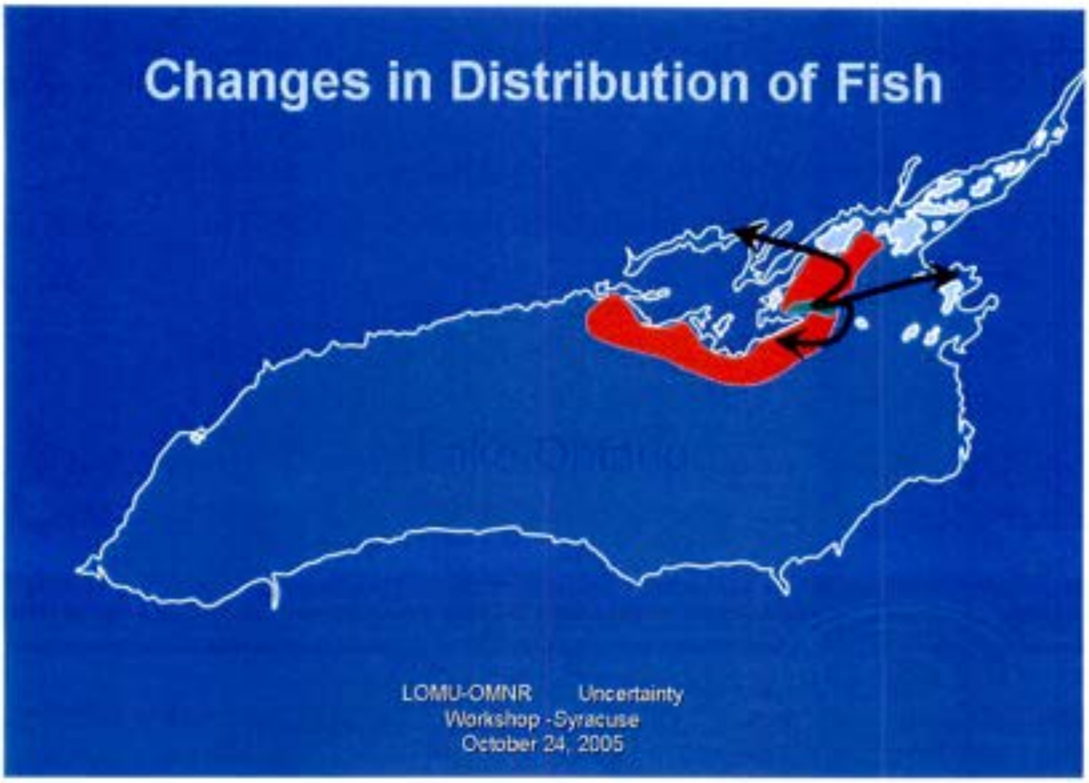
Introduction:

Background about whitefish fishing on Lake Ontario

Population dynamics of LO lake whitefish

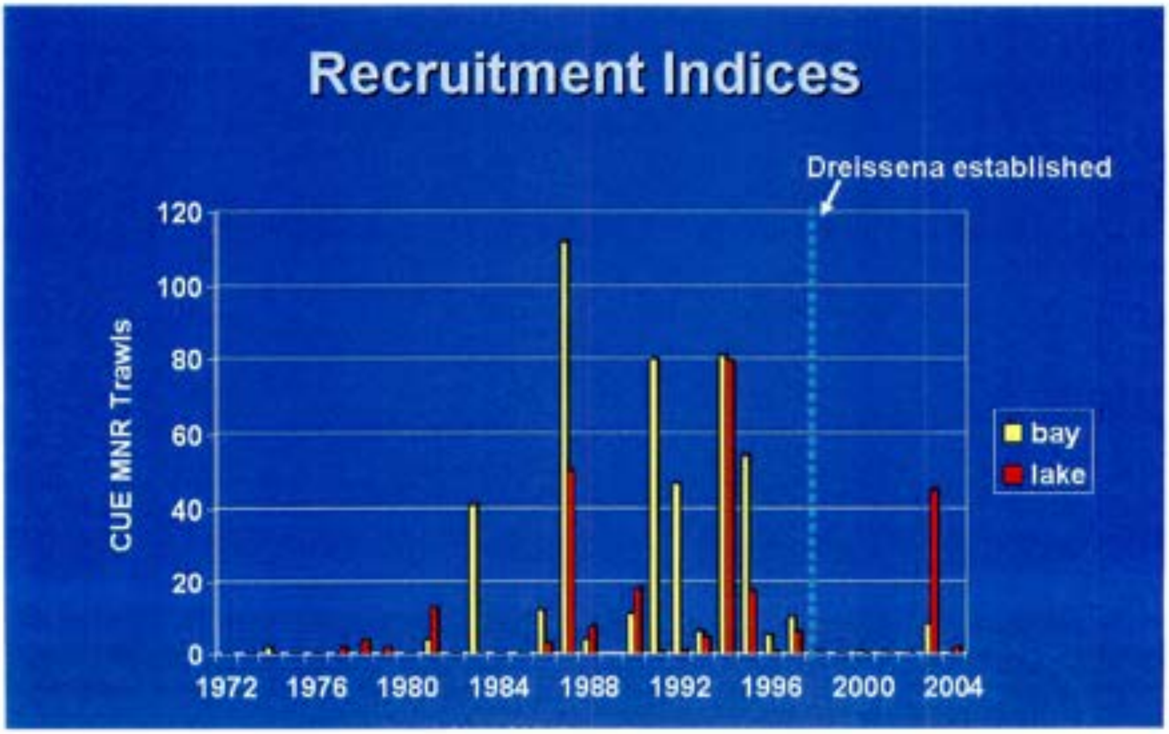
Communicating the risk using simple graphs

Conclusions

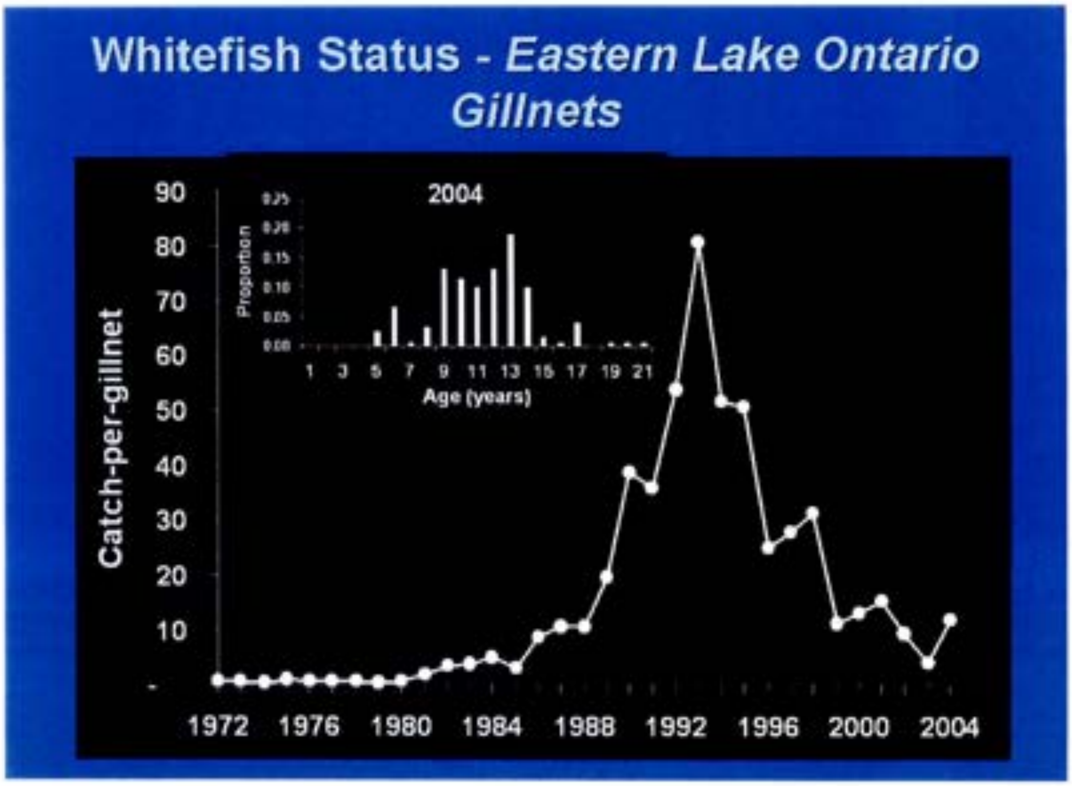


Changes in Distribution of Fish

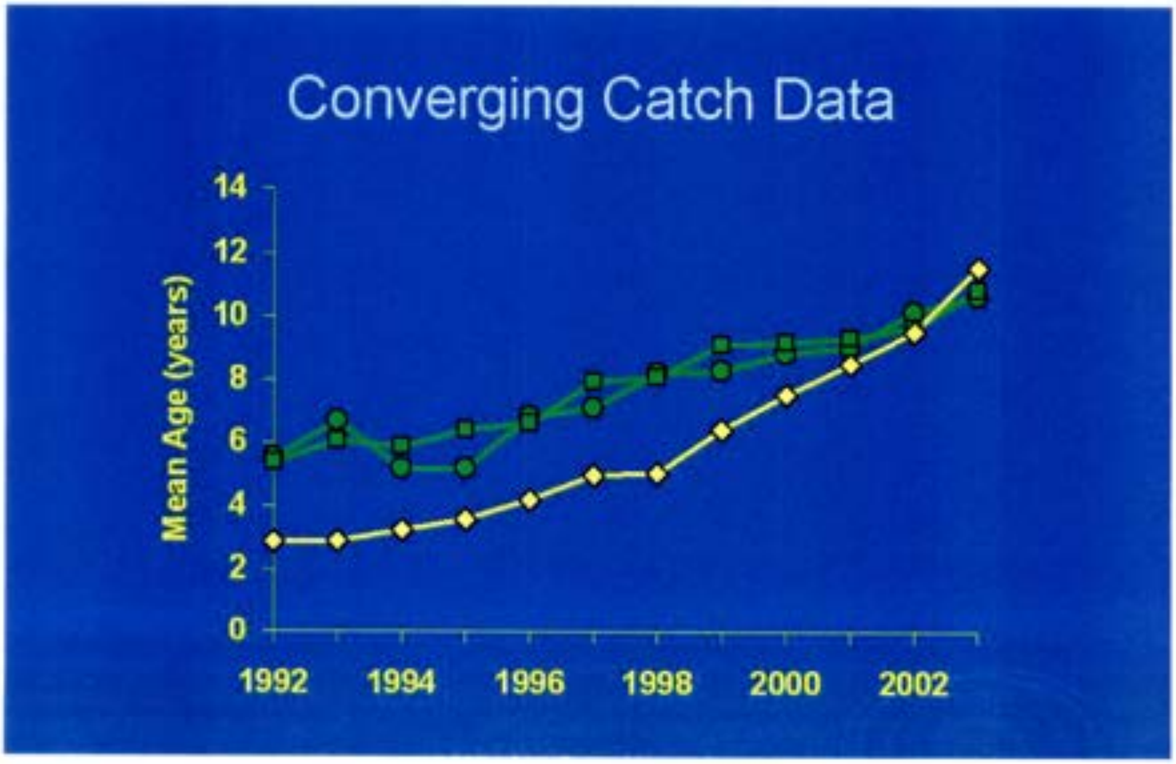
LOMU-OMNR Uncertainty
Workshop -Syracuse
October 24, 2005



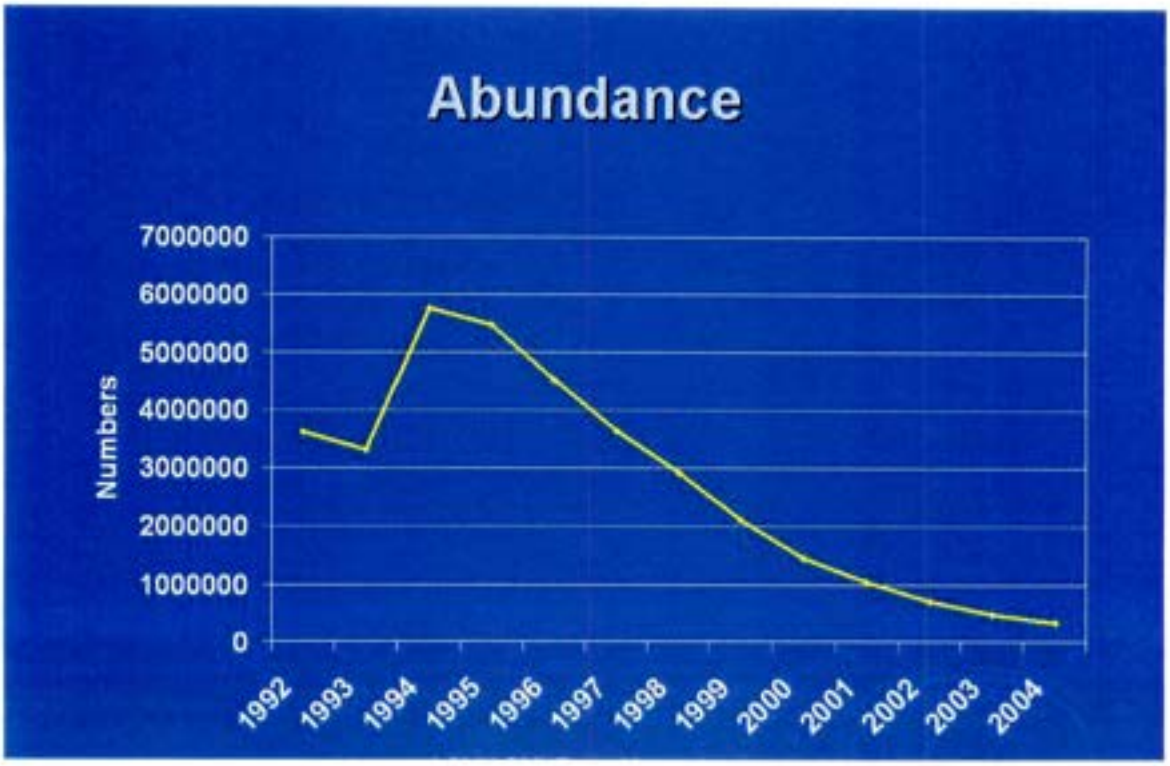
Recruitment Indices



Whitefish Status - *Eastern Lake Ontario Gillnets*



Converging Catch Data


Abundance
Numbers
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
1992
1993
1994
1995
1996
1997
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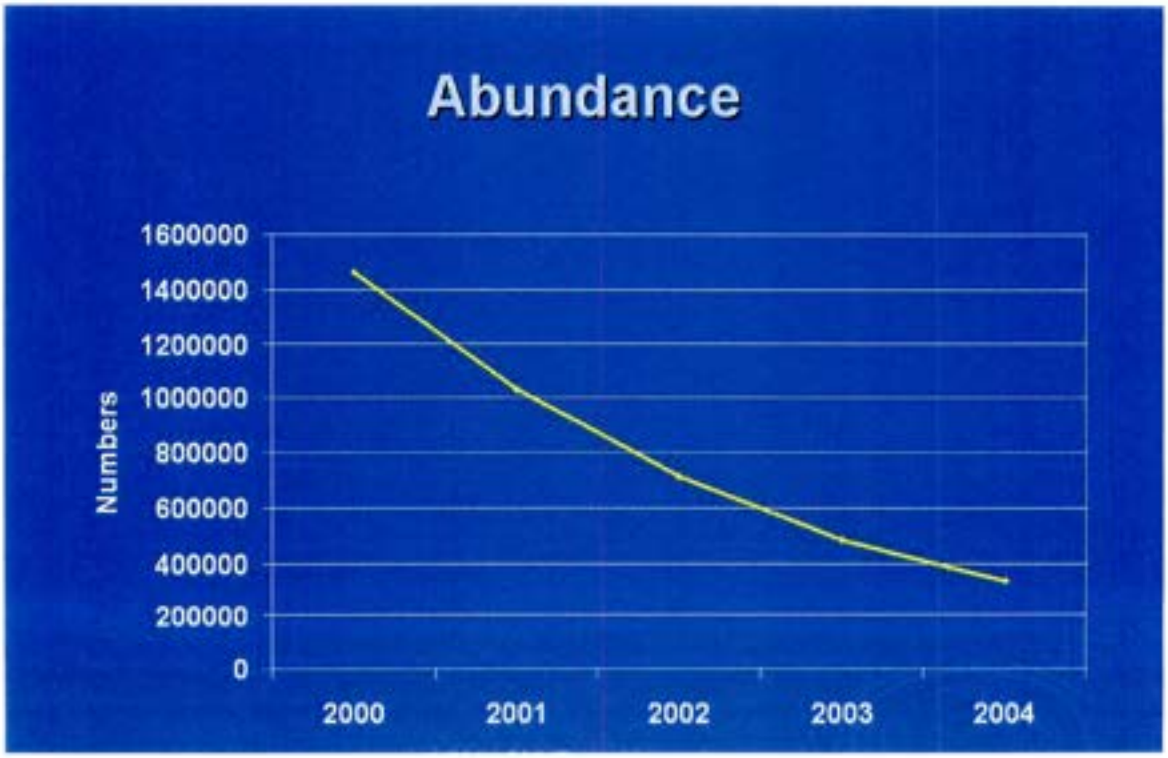
1999
2000
2001
2002
2003
2004


Abundance
Numbers
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
2000
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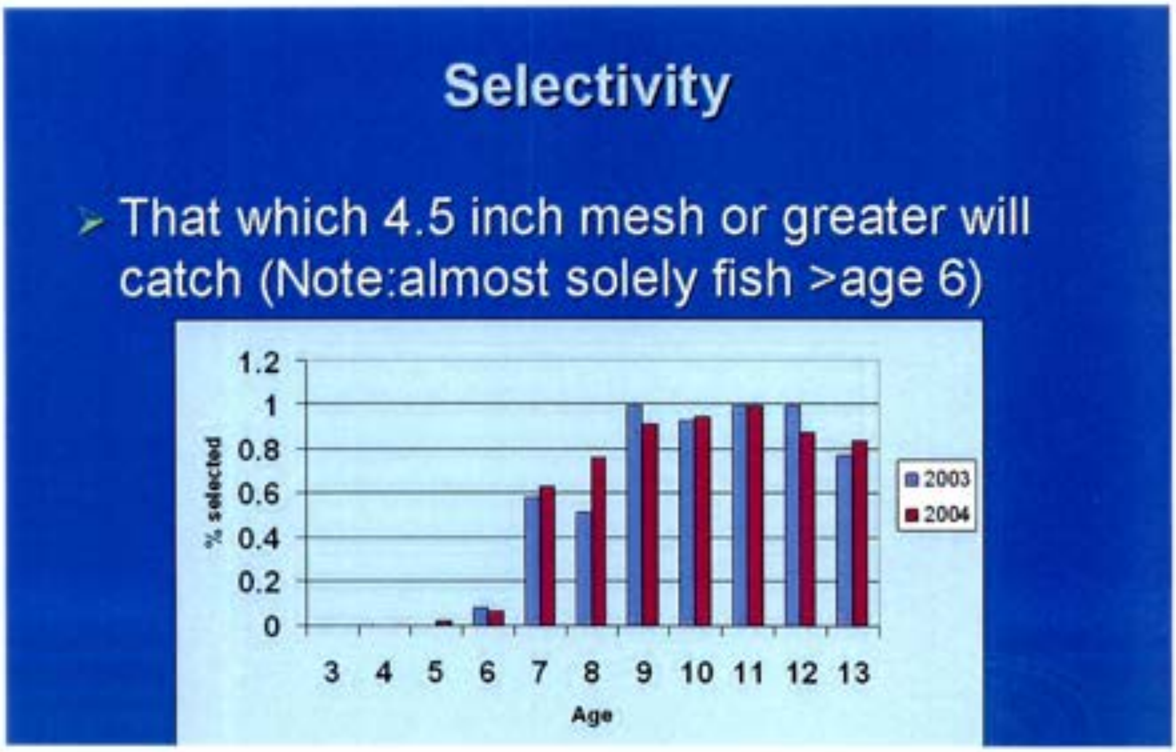
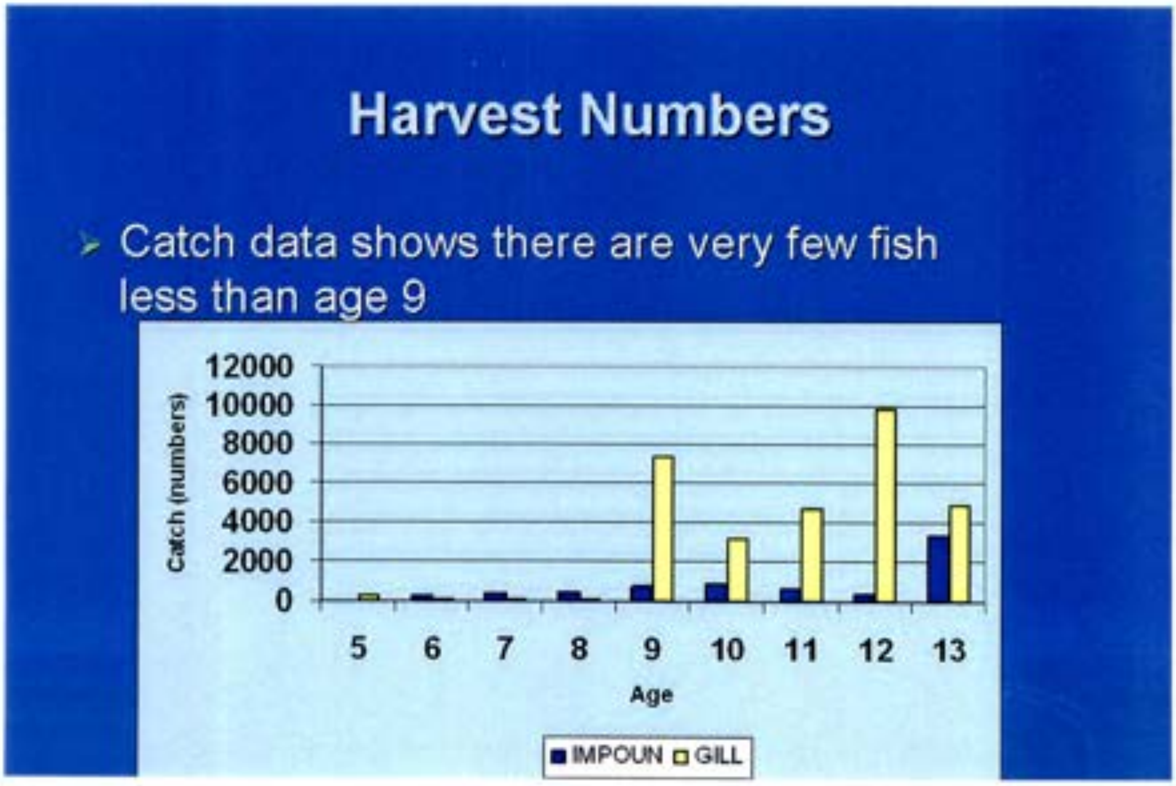
2002
2003
2004



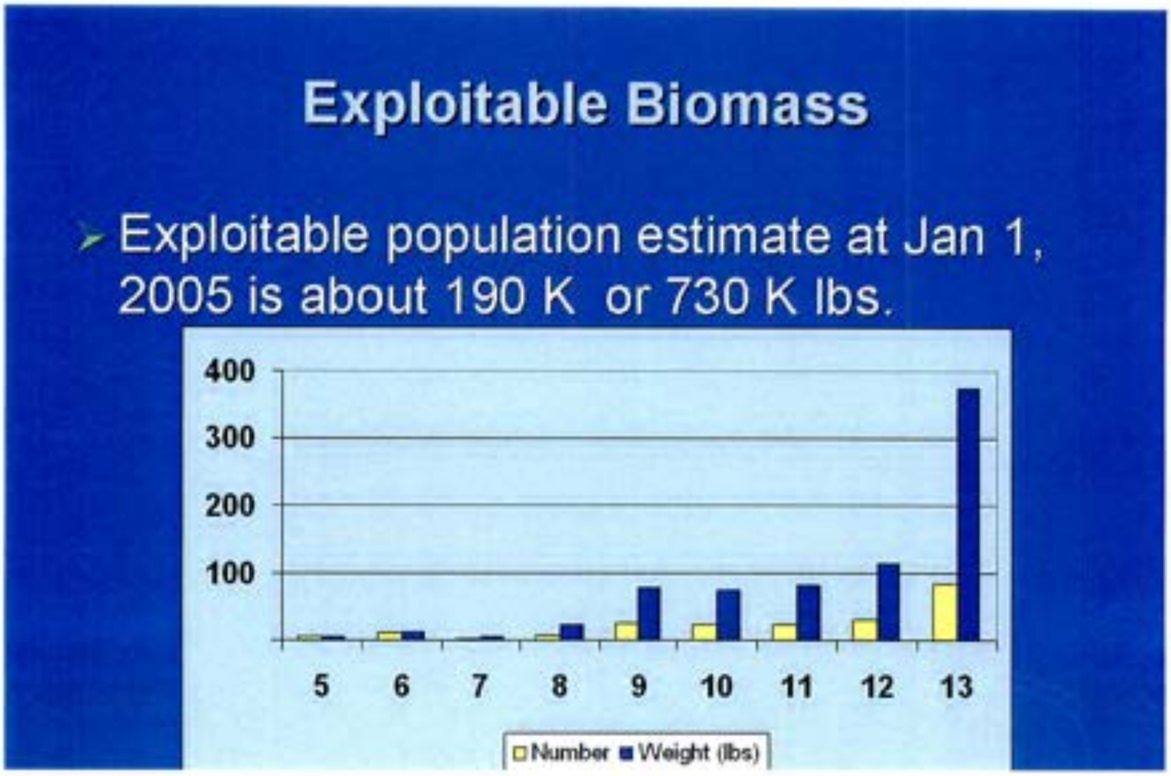
Selectivity

- That which 4.5 inch mesh or greater will catch (Note:almost solely fish >age 6)



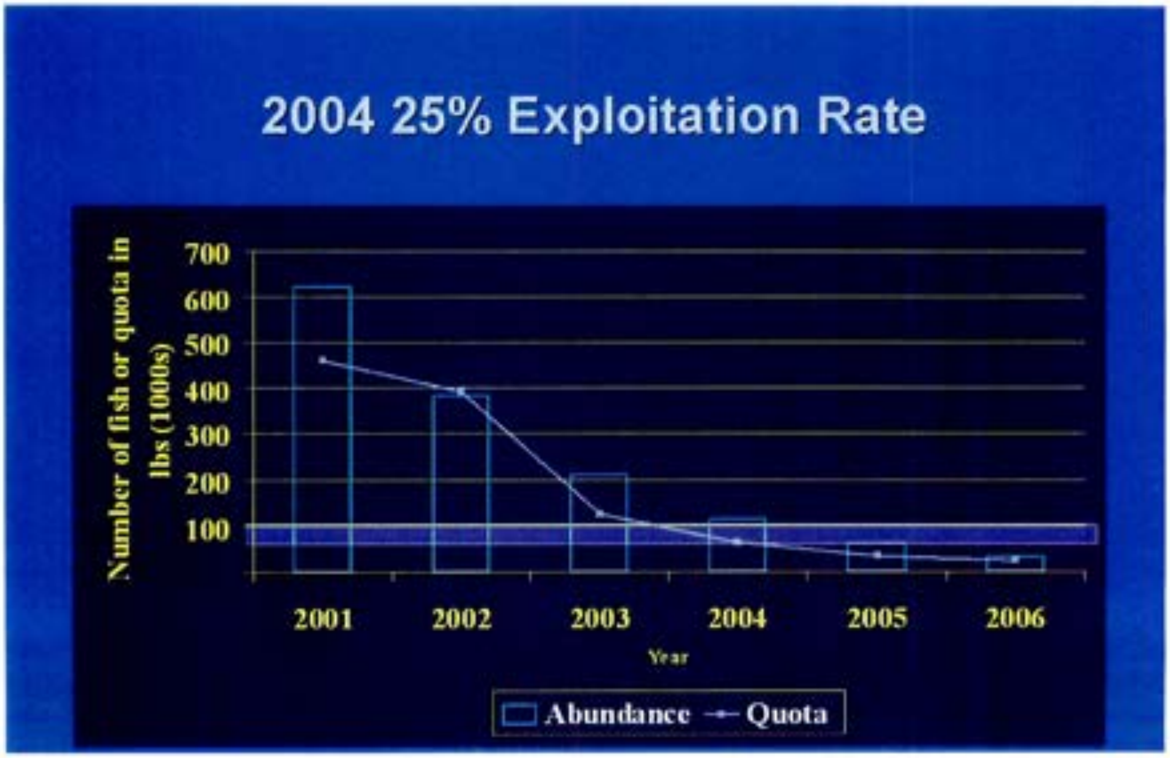
Harvest Numbers

- Catch data shows there are very few fish less than age 9

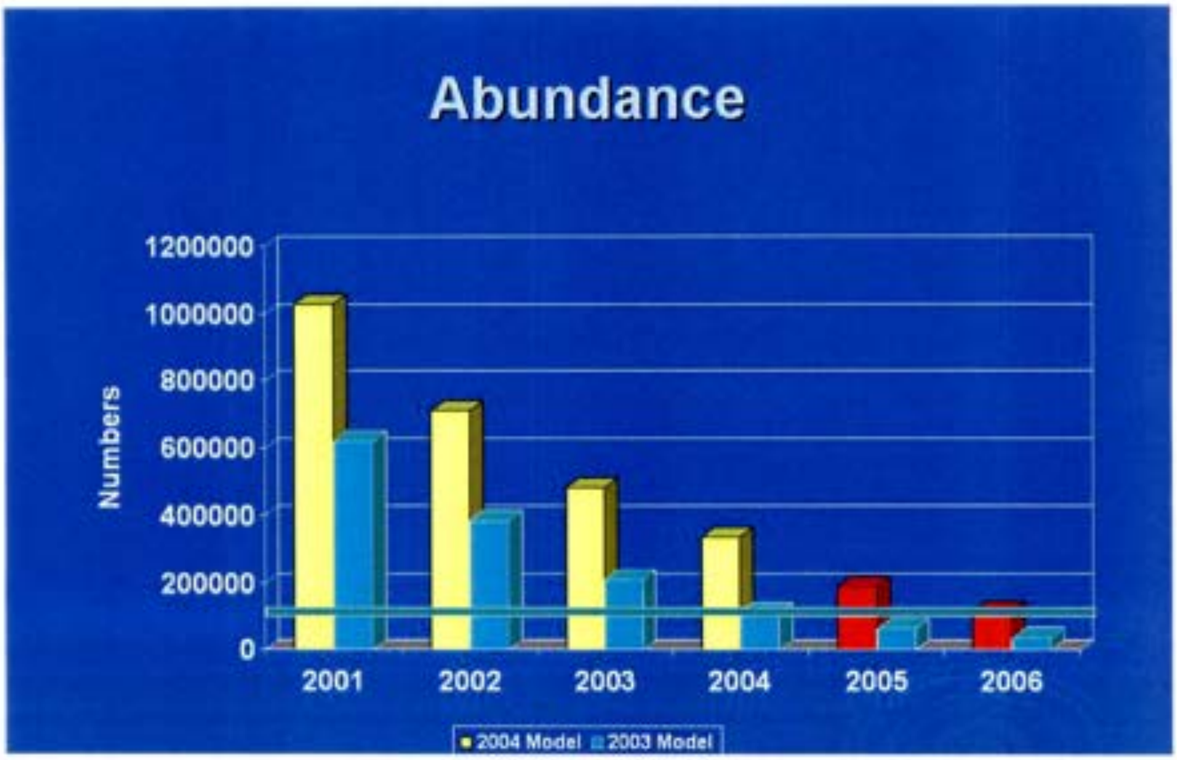


Exploitable Biomass

- Exploitable population estimate at Jan 1, 2005 is about 190 K or 730 K lbs.



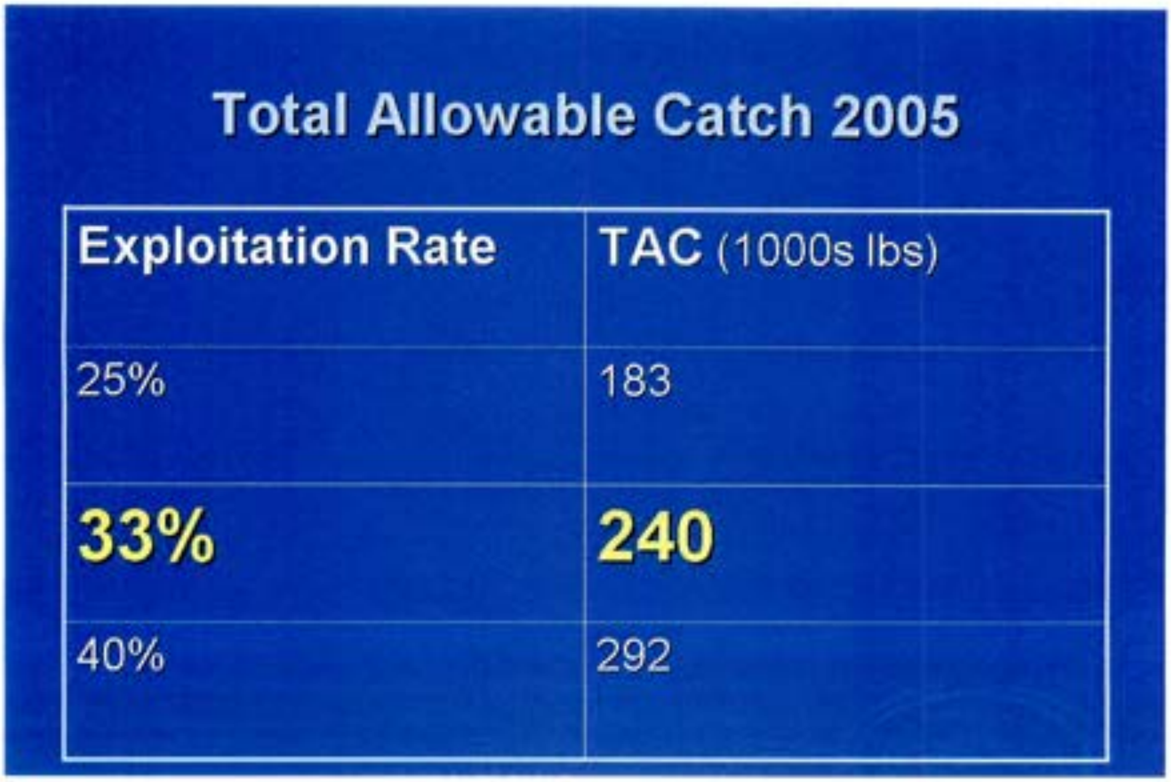
2004 25% Exploitation Rate



Abundance

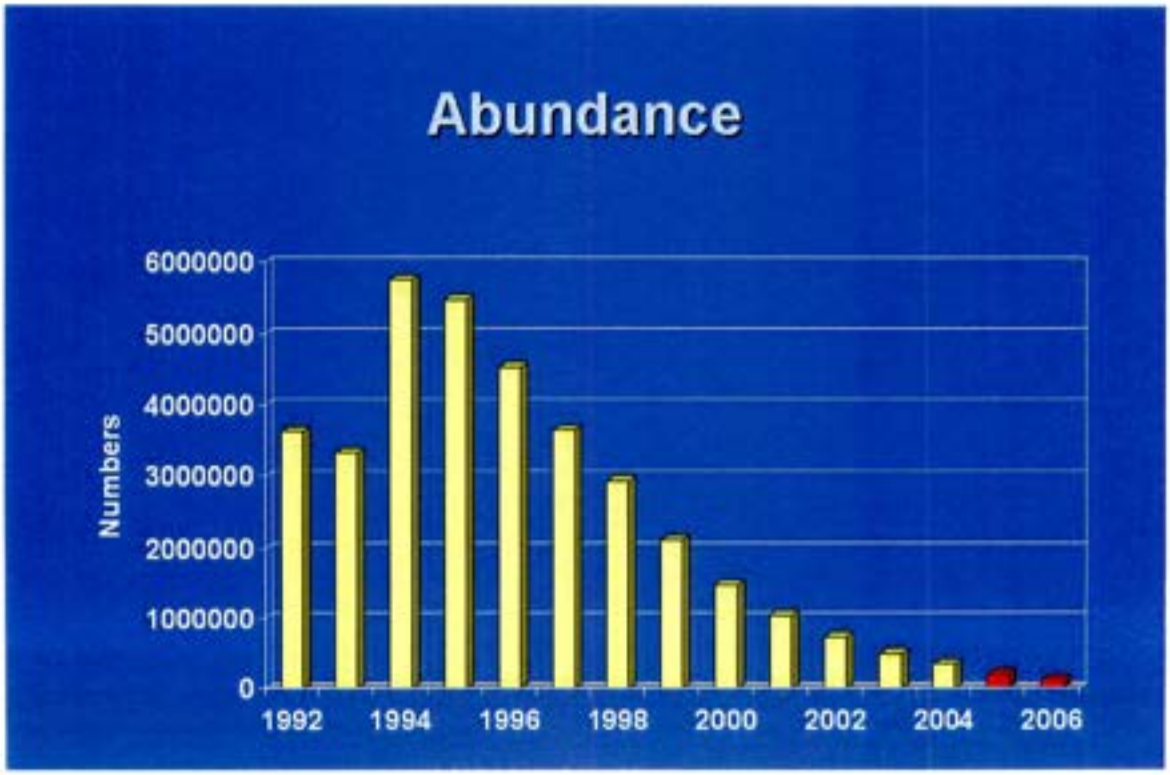
Some MNR Objectives

- Ensure long term sustainability of the ecosystem so that we:
  - Protect biodiversity,
  - Enhance and maintain socio-economic benefits,
- Use sound science,
- Be transparent and encourage democracy in decision making

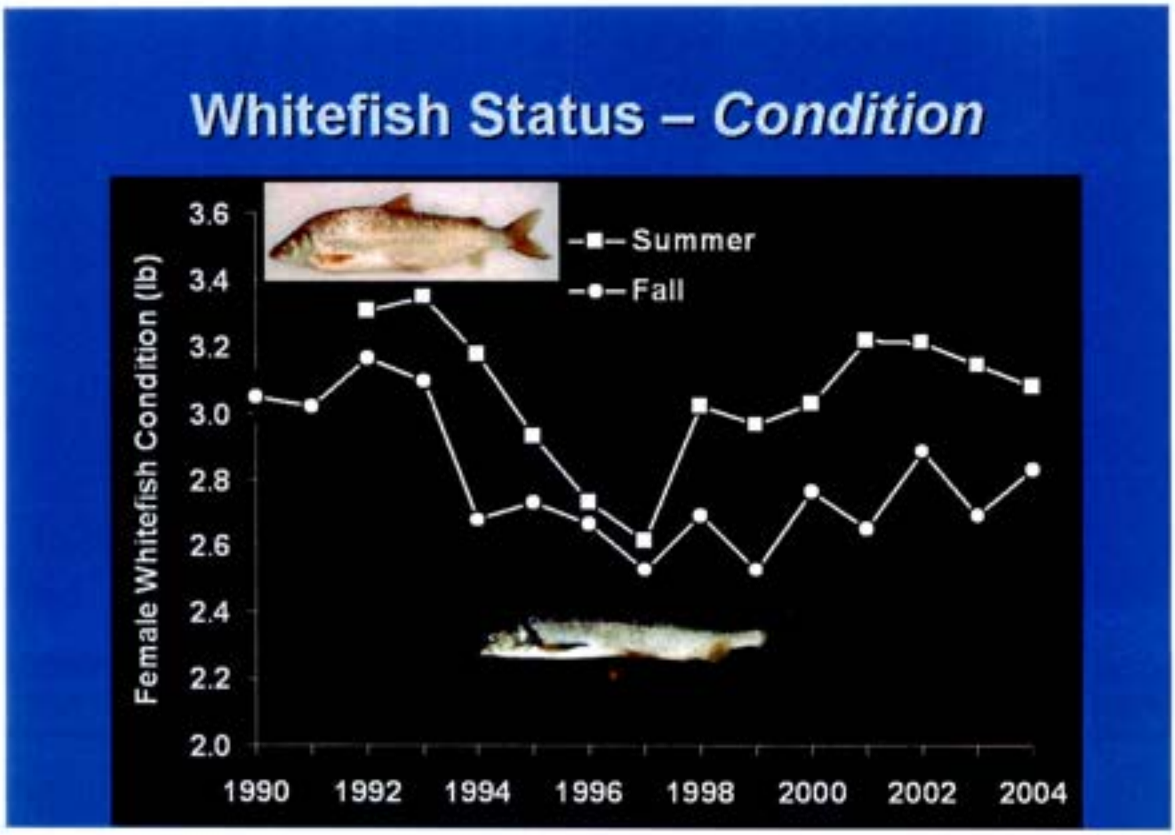


Total Allowable Catch 2005

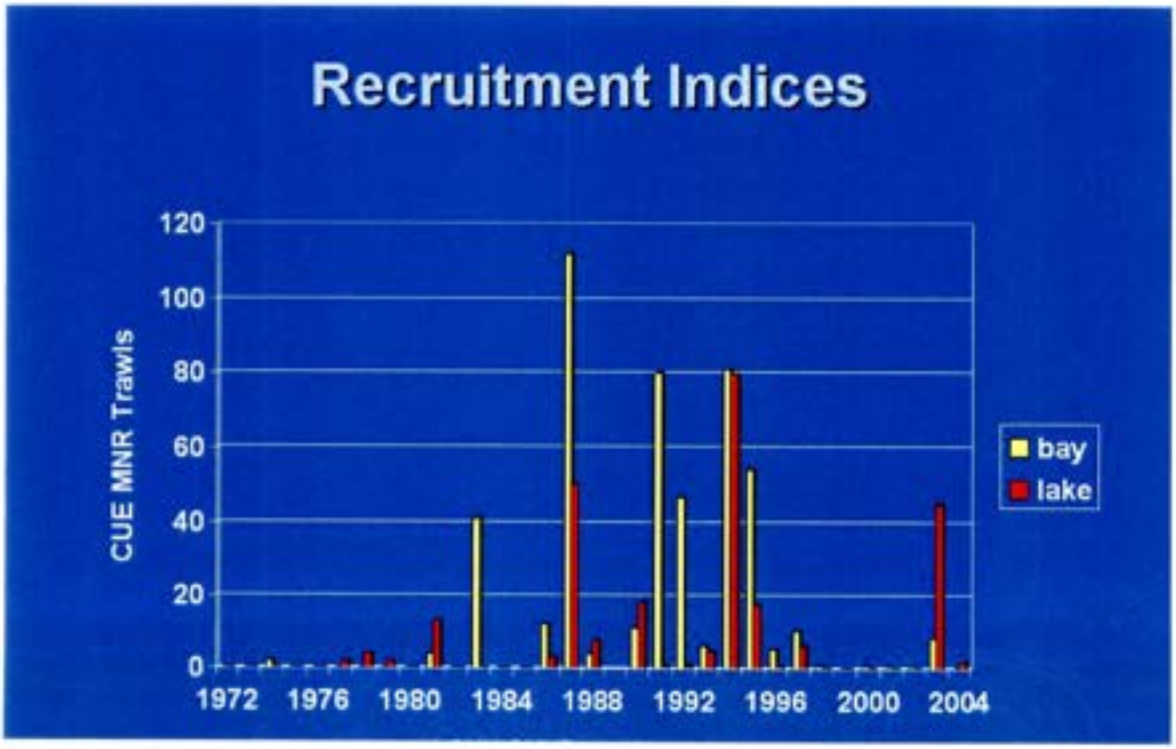
Exploitation Rate	**TAC** (1000s lbs)
25%	183
33%	**240**
40%	292



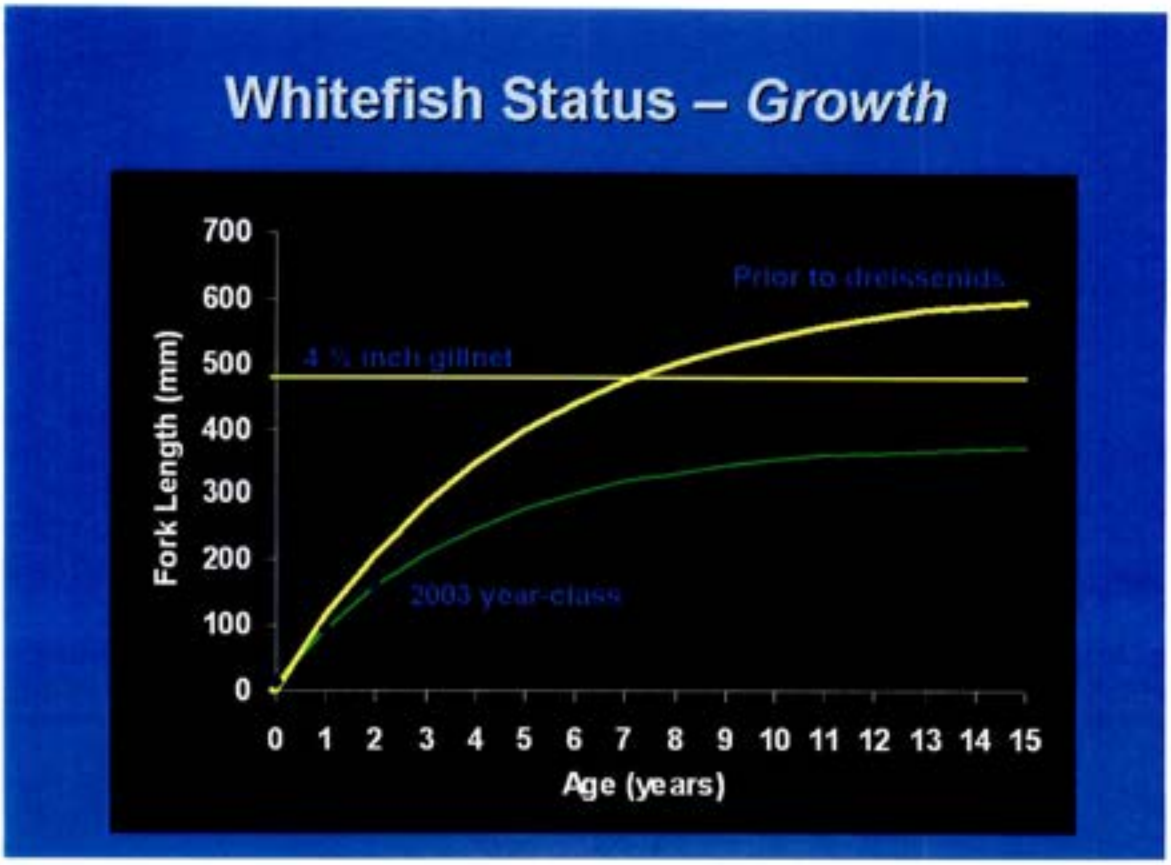
Abundance



Whitefish Status – *Condition*



Recruitment Indices



Whitefish Status – *Growth*

Conclusions

- Without recruitment to fishery, risk of fishery collapsing is fairly certain
- Time when that occurs is not
- Whitefish being produced now may never recruit to fishery
- Fishers accept shared responsibility and know the consequences

Appendix L.
Ecological Economic Approaches to Resource Management Under Uncertainty

Ecological Economic Approaches to Resource Management Under Uncertainty

Valerie A. Luzadis
State University of New York College of
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NY Sea Grant Workshop
October 24, 2005

Abstract

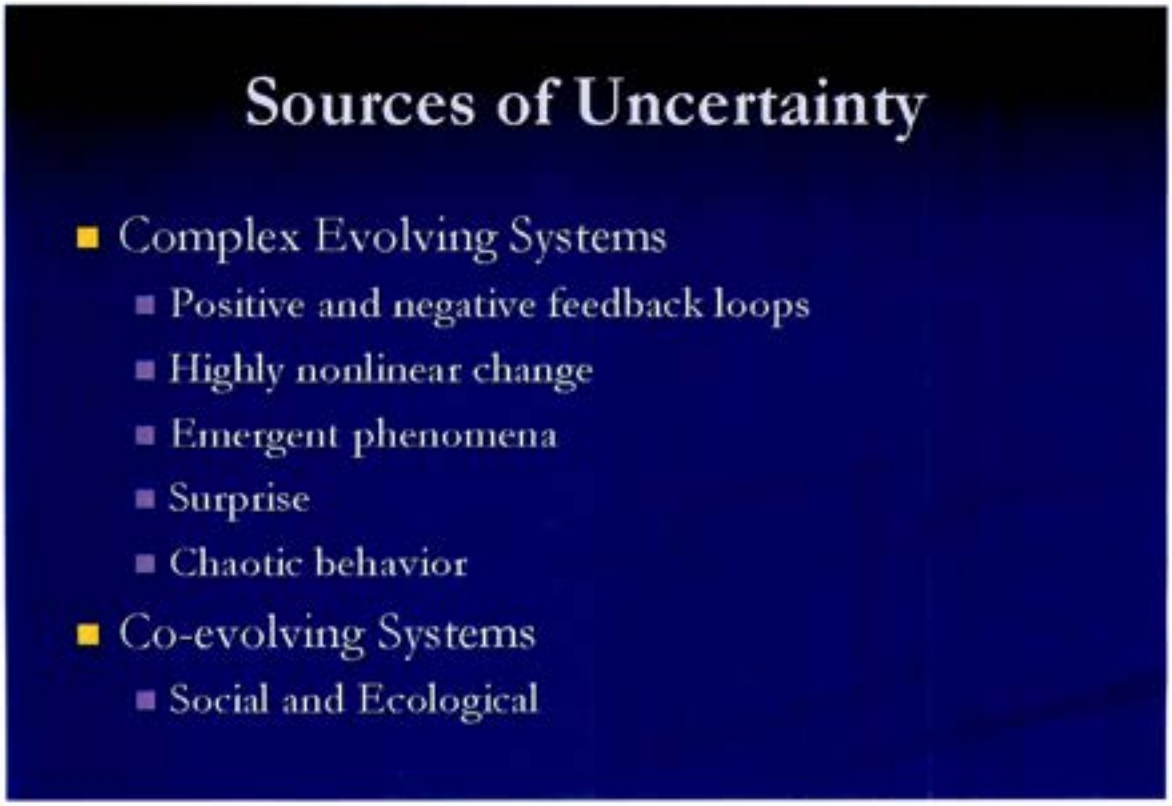
Ecological economics approaches issues of sustainability in a way that is particularly relevant to managing natural resources under conditions of uncertainty. Most resource management decisions are made under the condition of uncertainty since we have relatively limited understanding of the complex, evolving systems of humans and nature that we are attempting to manage. Often the management context is one of urgency and high stakes. The ecological economics transdisciplinary approach offers alternatives to traditional methods by making use of participatory approaches and systems level thinking to inform science and management. The background of this approach and several specific synthesizing tools are introduced.

Literature Cited:

- Daiy, Herman D. and Joshua Farley. 2004. Ecological Economic Principles and Applications. Island Press, Washington, D.C.
- Costanza, R. et al. 1997. An Introduction to Ecological Economics. St. Lucie Press, Boca Raton, FL.
- Erickson, J.D., Karin Limburg, John Gowdy, Karen Stainbrook, Audra Nowolsielski, Caroline Hermans, and John Polimeni. 2004. Anticipating Change in the Hudson River Watershed: An Ecological Economic Model for Integrated Scenario Analysis, Ch. 13, pp. 341-370 in R. Bruins and M. Heberling (Eds), Economics and Ecological Risk Assessment Applications to Watershed Management. CRC Press, Boca Raton, FL.
- Farley, J., J.D. Erickson, and H.E. Daly. 2005. Ecological Economics: A workbook for problem-based learning. Island Press, Washington, D.C.
- Funtowicz, S.O. and J.R. Ravetz. 1991. A new scientific methodology for global environmental problems. In R. Costanza, ed. Ecological Economics: the science and management of sustainability. Columbia University Press, New York.

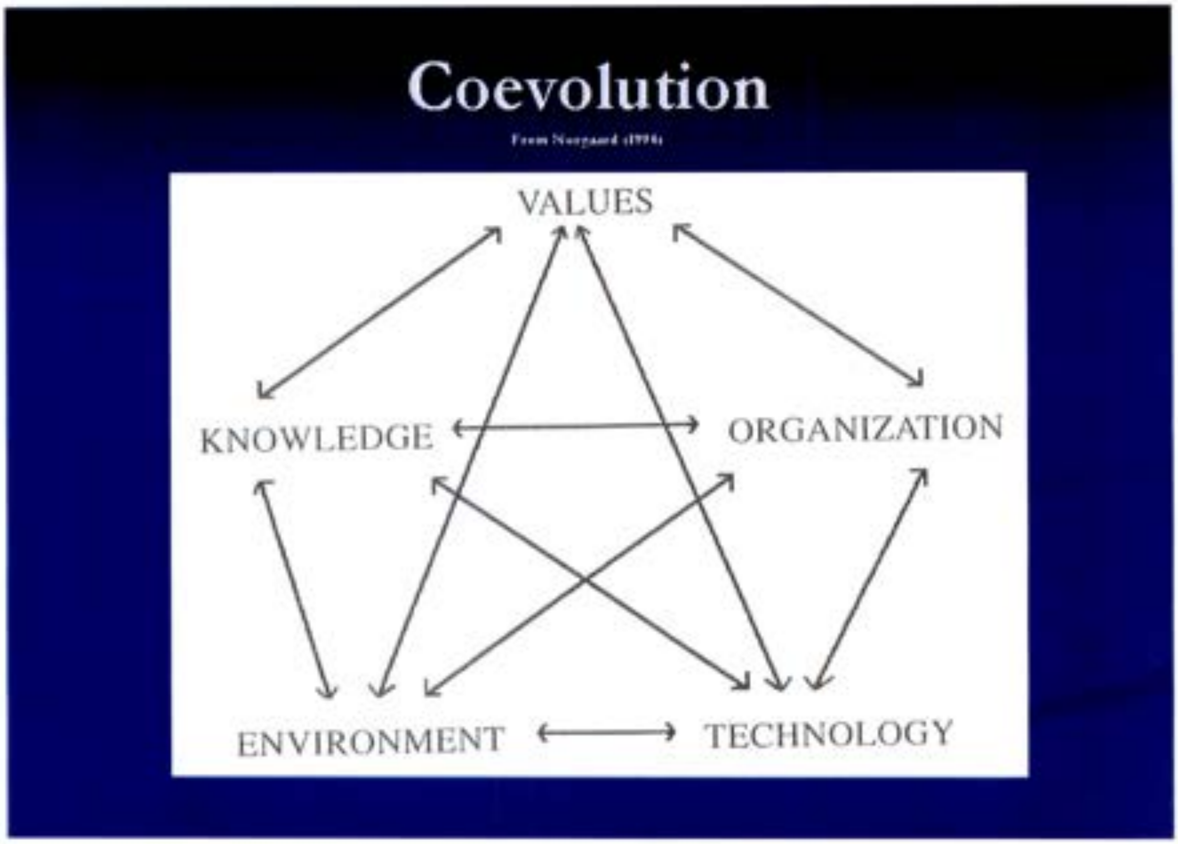
Management Under Uncertainty: Nature of the Problem

- Complex
  - Part of interconnected social and ecological systems that continually interact with one another
- High stakes
  - Potential loss of species, habitat destruction
- Urgent
  - Many resource issues need immediate attention



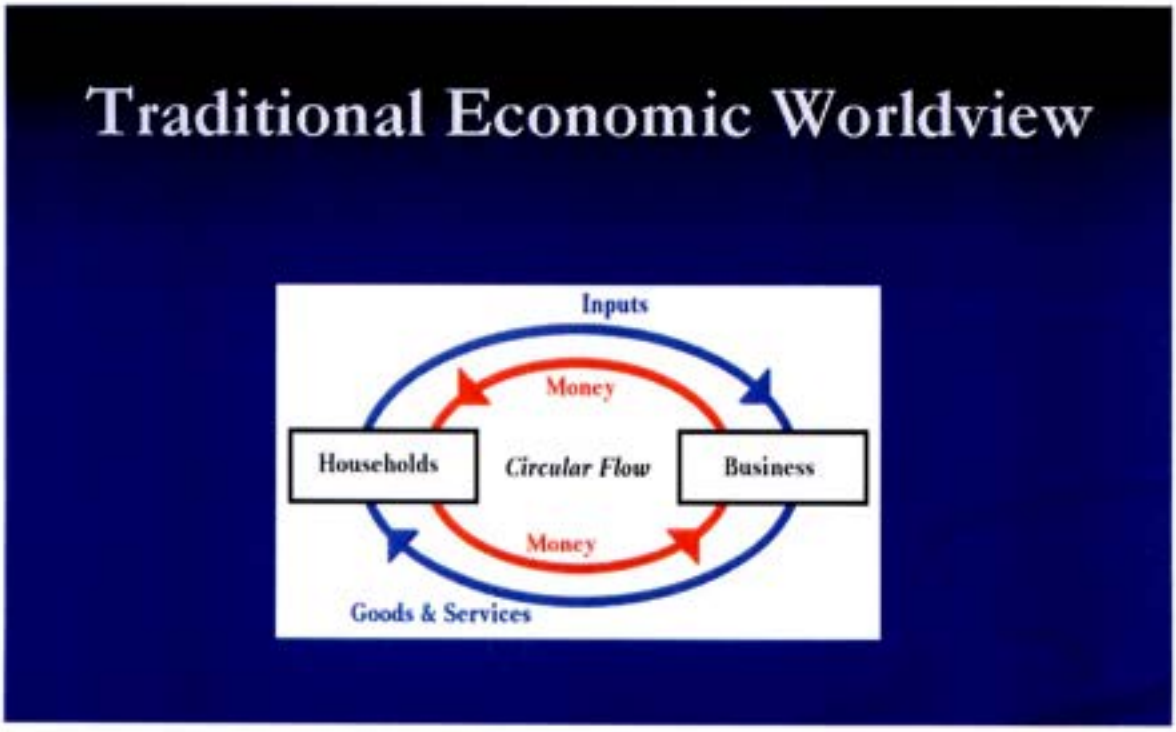
Sources of Uncertainty

- Complex Evolving Systems
  - Positive and negative feedback loops
  - Highly nonlinear change
  - Emergent phenomena
  - Surprise
  - Chaotic behavior
- Co-evolving Systems
  - Social and Ecological



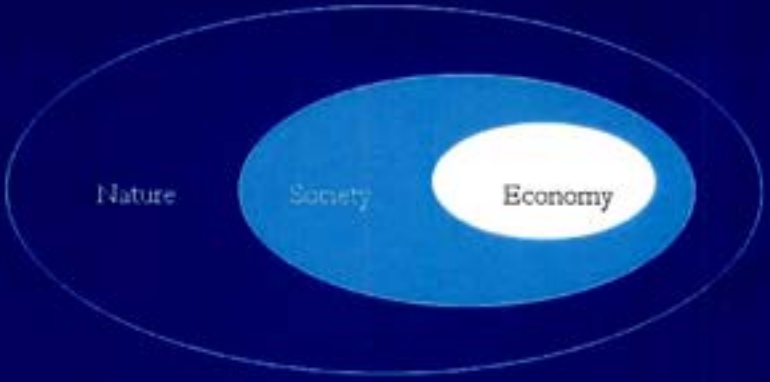
Coevolution

From Norgaard (1994)



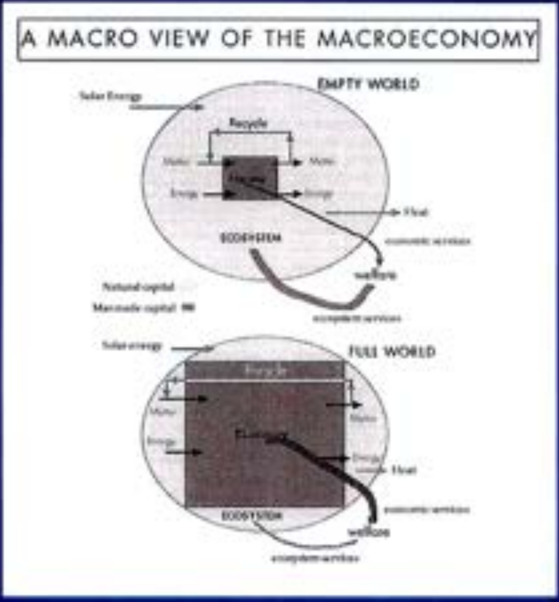
Traditional Economic Worldview

Ecological Economics Worldview



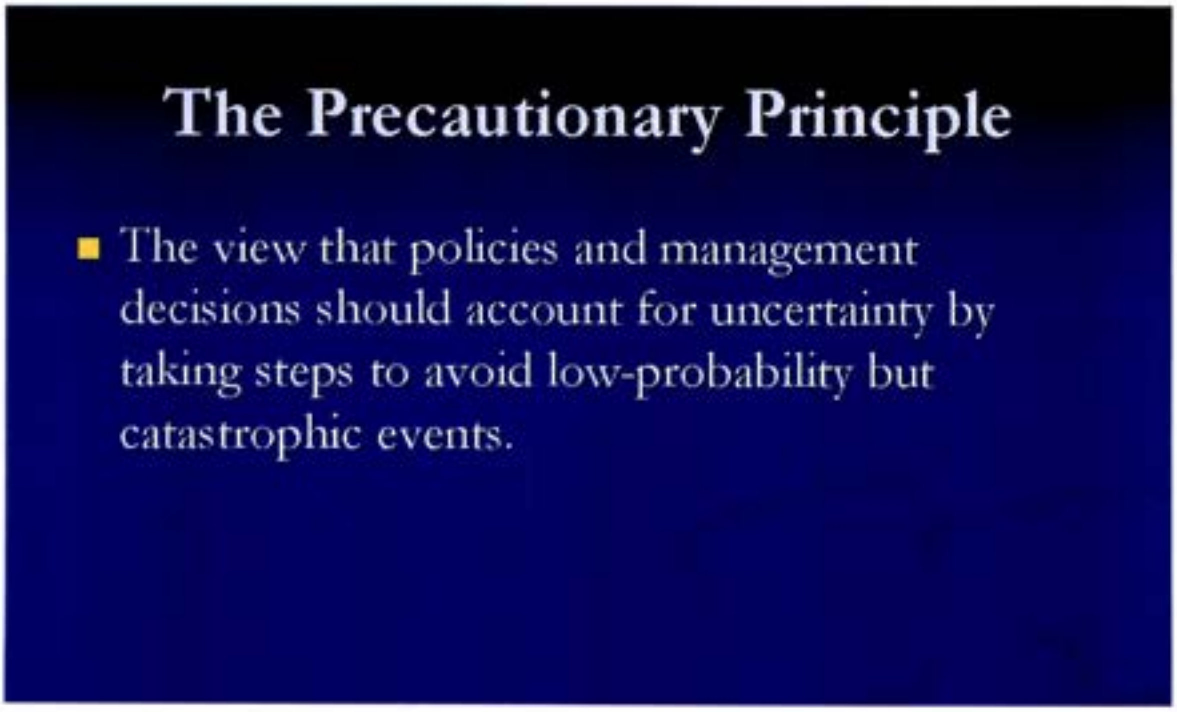
Empty World-Full World

From: Daly and Farley 2004, p.18



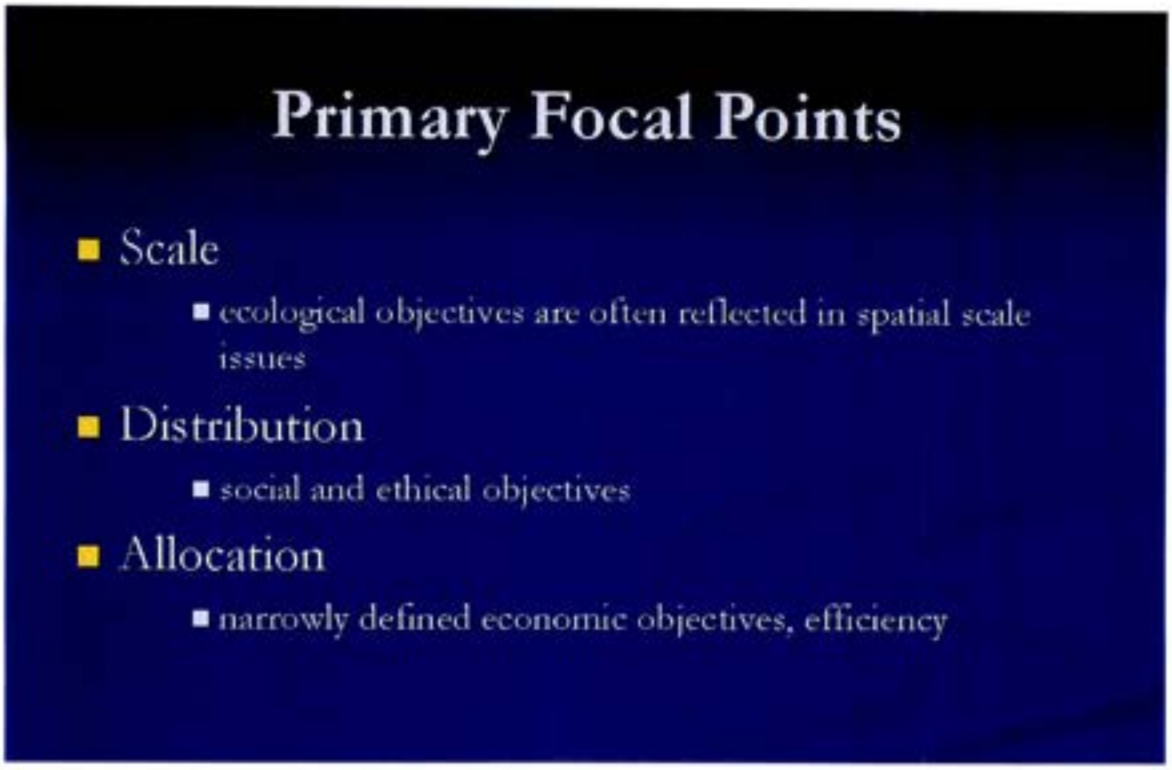
Ecological Economic Principles

- Pluralism
  - Draw on knowledge across disciplines
  - Methodological and conceptual
  - Accepts local, indigenous, folk knowledge
- Openness
  - To new ideas, new approaches
  - Differing types and sources of knowledge
- Flexibility
  - Prepared to adjust as change occurs
  - Proactive management



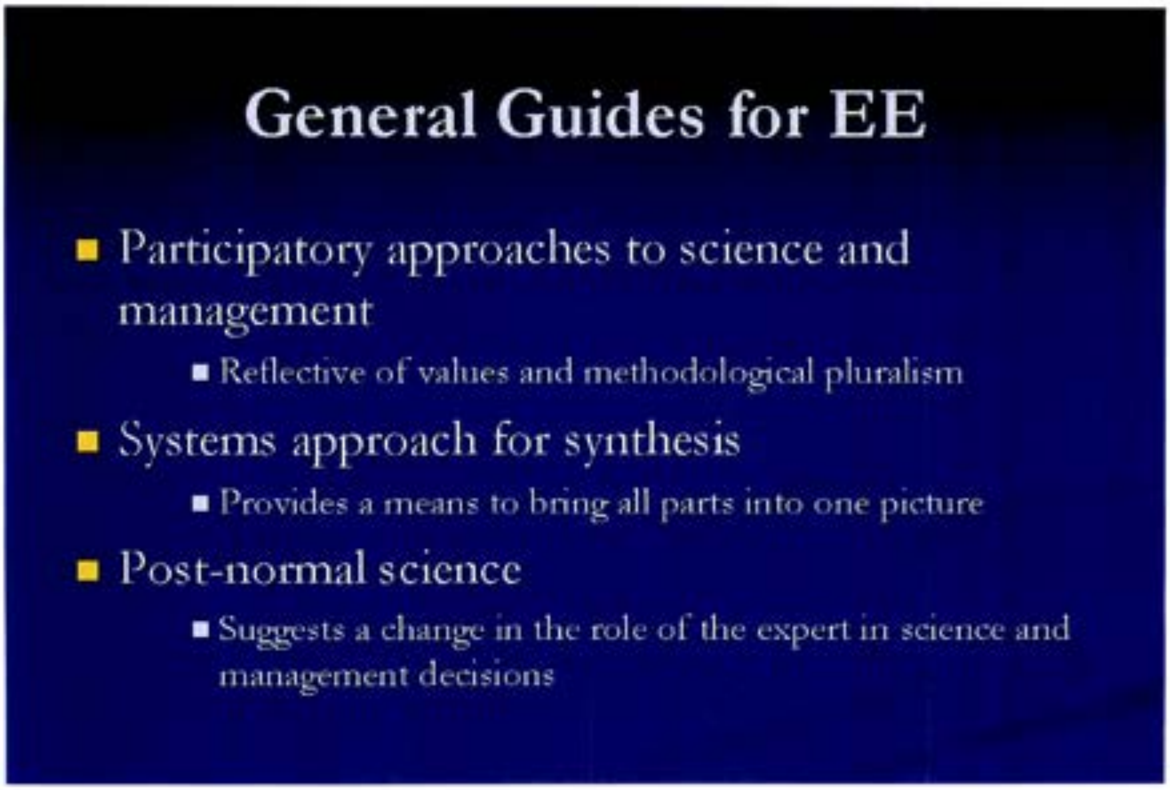
The Precautionary Principle

- The view that policies and management decisions should account for uncertainty by taking steps to avoid low-probability but catastrophic events.



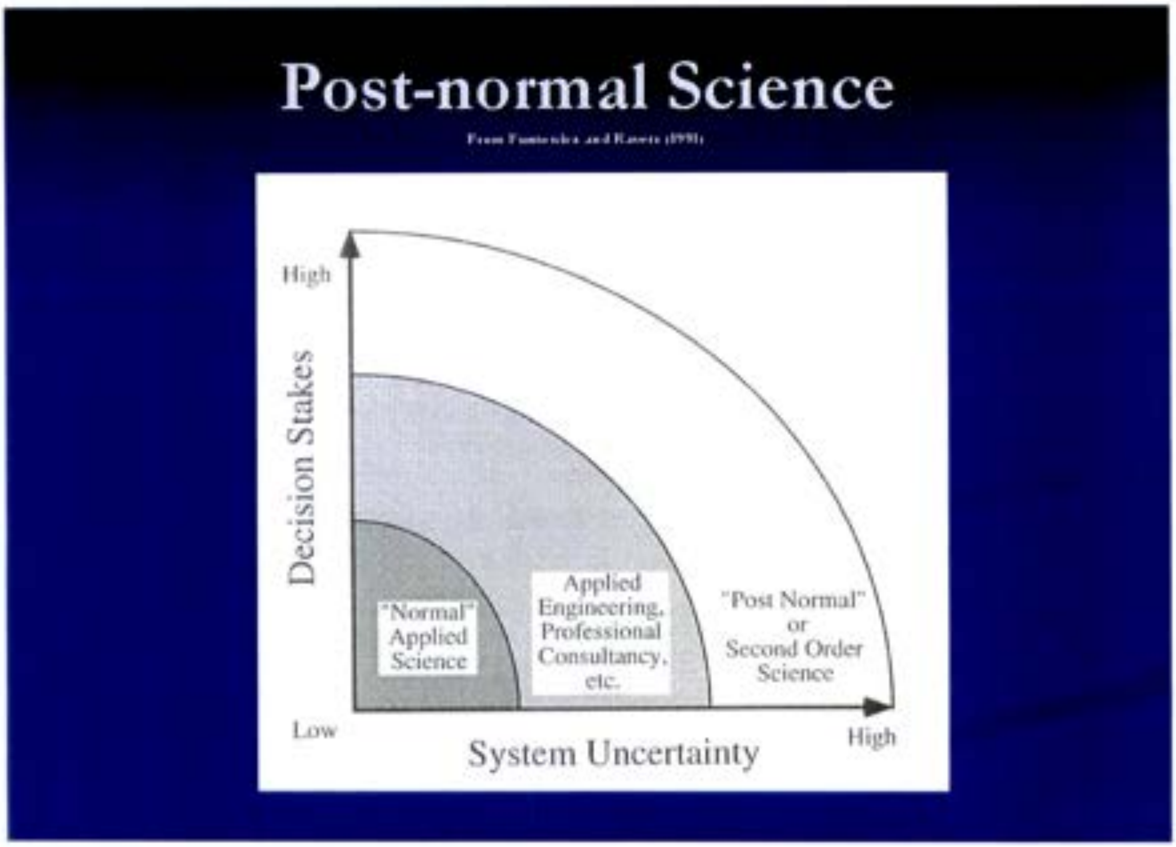
Primary Focal Points

- Scale
    - ecological objectives are often reflected in spatial scale issues
- Distribution
    - social and ethical objectives
- Allocation
    - narrowly defined economic objectives, efficiency



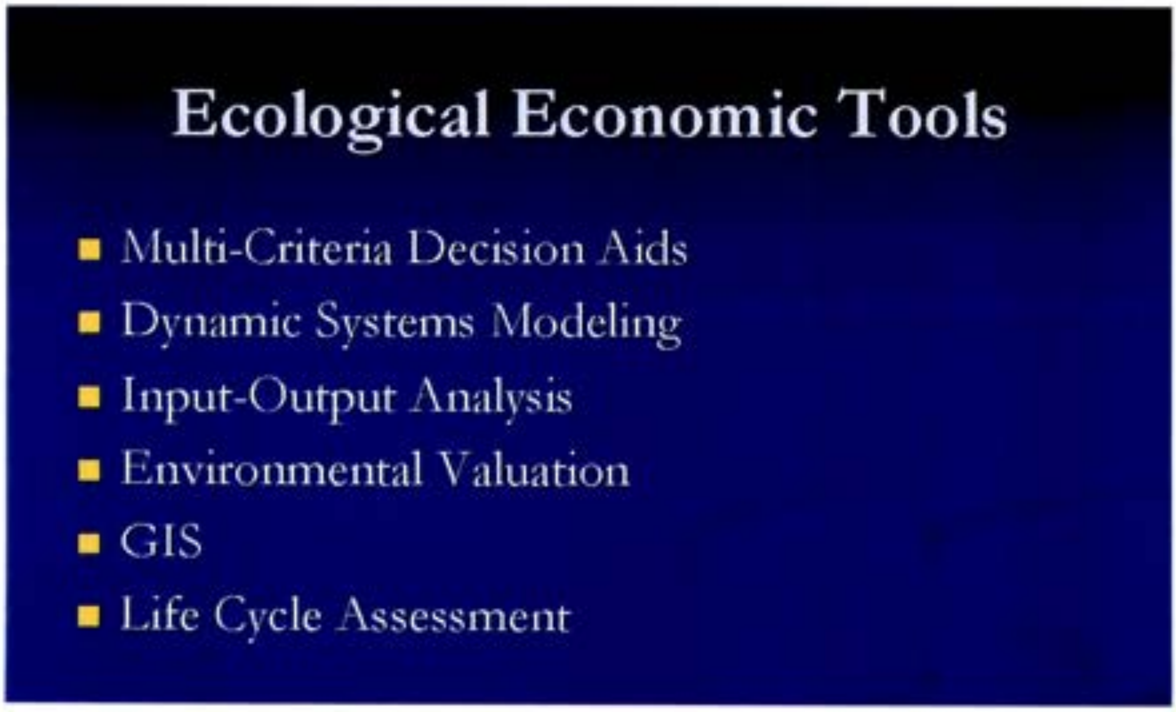
General Guides for EE

- Participatory approaches to science and management
    - Reflective of values and methodological pluralism
- Systems approach for synthesis
    - Provides a means to bring all parts into one picture
- Post-normal science
    - Suggests a change in the role of the expert in science and management decisions



Post-normal Science

From Funtowicz and Ravetz (1991)



Ecological Economic Tools

- Multi-Criteria Decision Aids
- Dynamic Systems Modeling
- Input-Output Analysis
- Environmental Valuation
- GIS
- Life Cycle Assessment

Ecol Econ Tools:

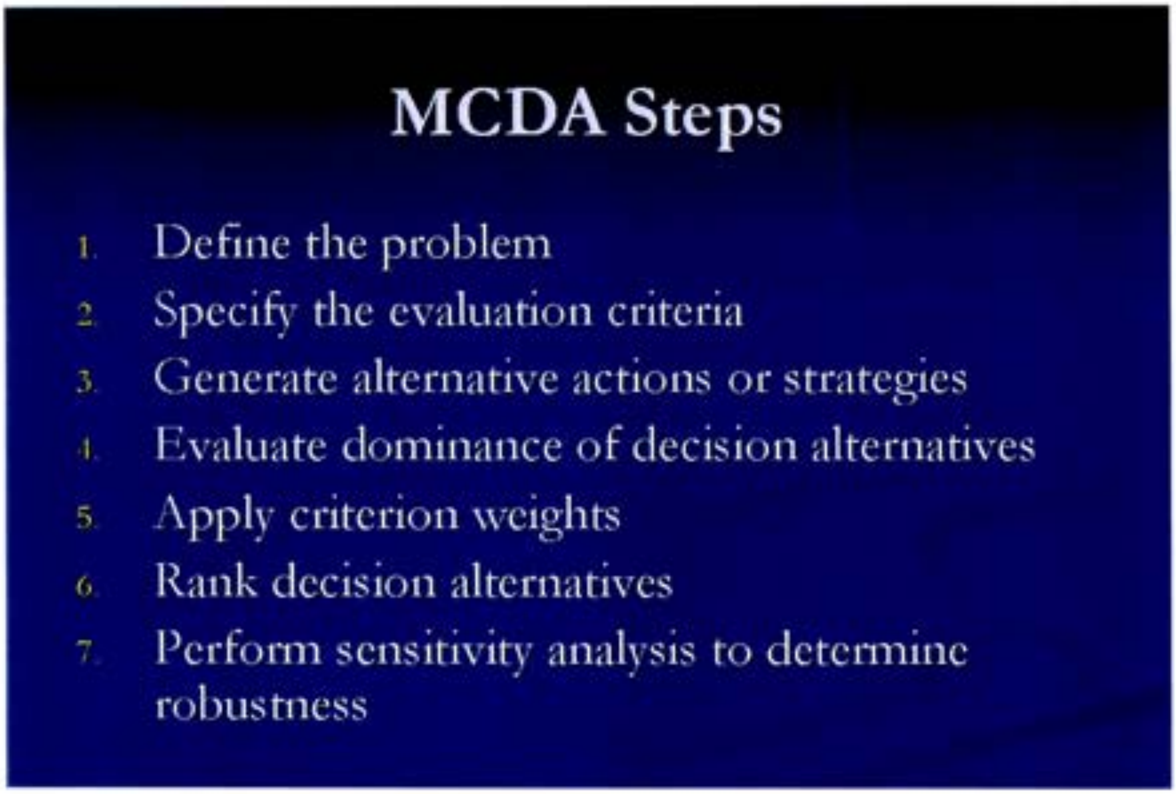
Multi-Criteria Decision Aid

- A general approach to decision making in the presence of multiple objectives
- Useful for multidimensional problems
  - ecological issues (scale)
  - social and ethical objectives (distribution)
  - narrowly defined economic objectives (efficient allocation)
- Useful in conditions of pervasive uncertainty

MCDA

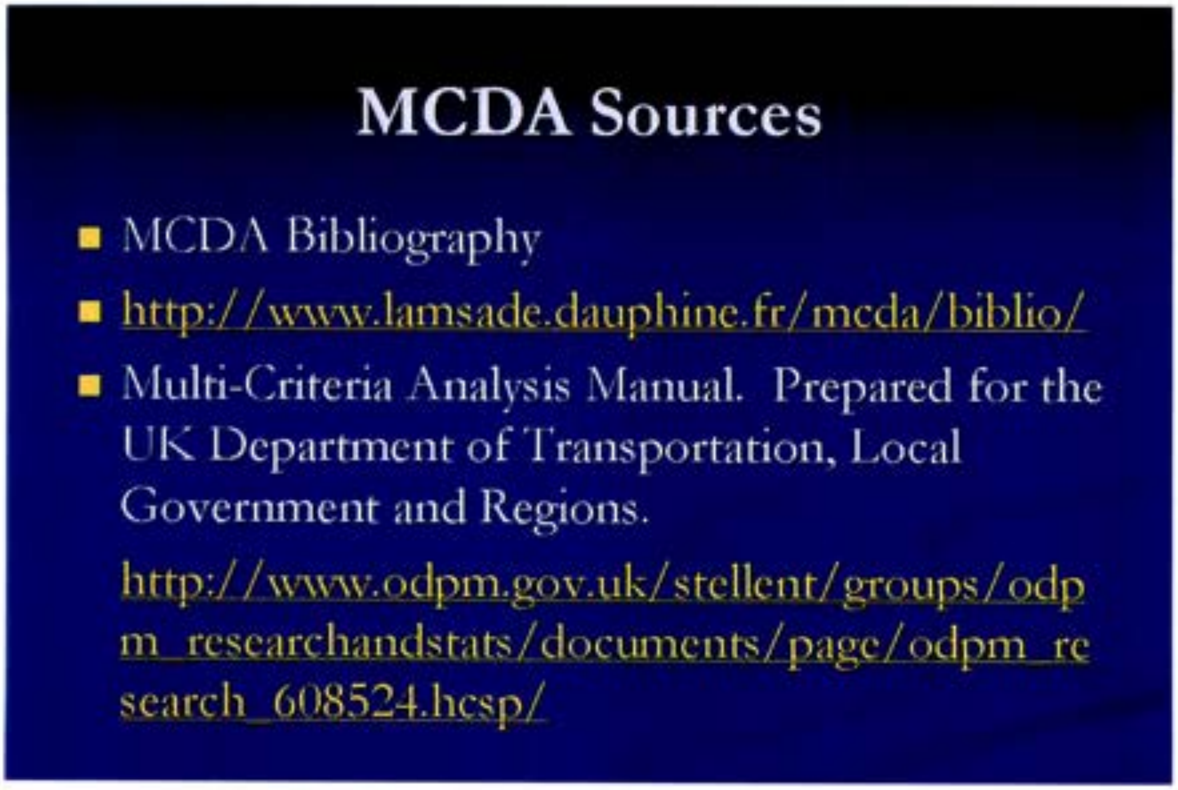
From Farley et al 2005

General Hierarchy of MCDA



MCDA Steps

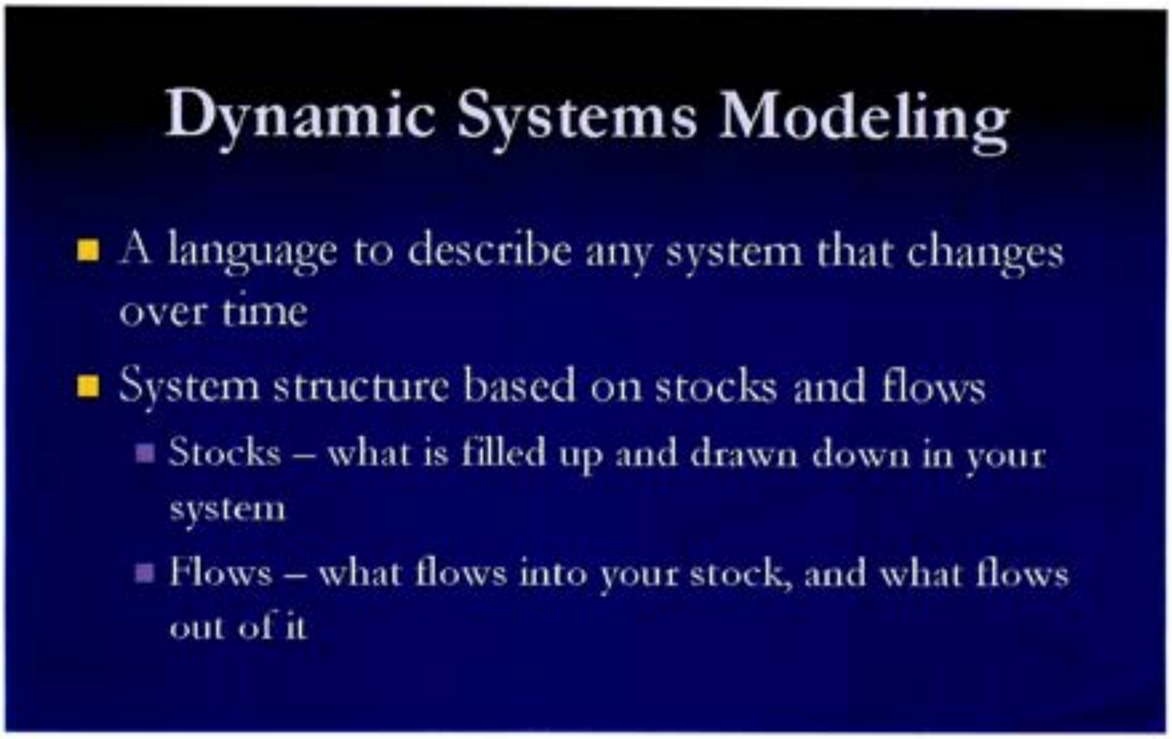
1. Define the problem
2. Specify the evaluation criteria
3. Generate alternative actions or strategies
4. Evaluate dominance of decision alternatives
5. Apply criterion weights
6. Rank decision alternatives
7. Perform sensitivity analysis to determine robustness



MCDA Sources

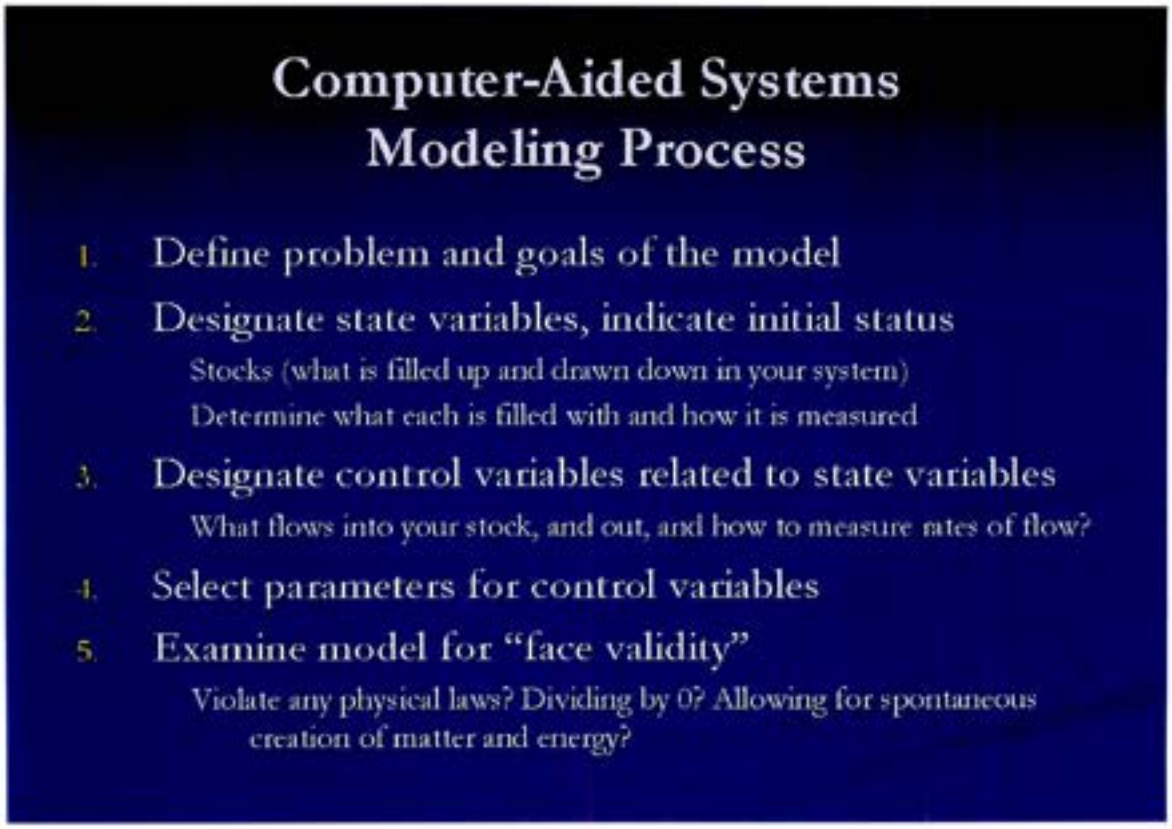
- MCDA Bibliography
- http://www.lamsade.dauphine.fr/mcda/biblio/
- Multi-Criteria Analysis Manual. Prepared for the UK Department of Transportation, Local Government and Regions.

  http://www.odpm.gov.uk/stellent/groups/odpm_researchandstats/documents/page/odpm_research_608524.hcsp/



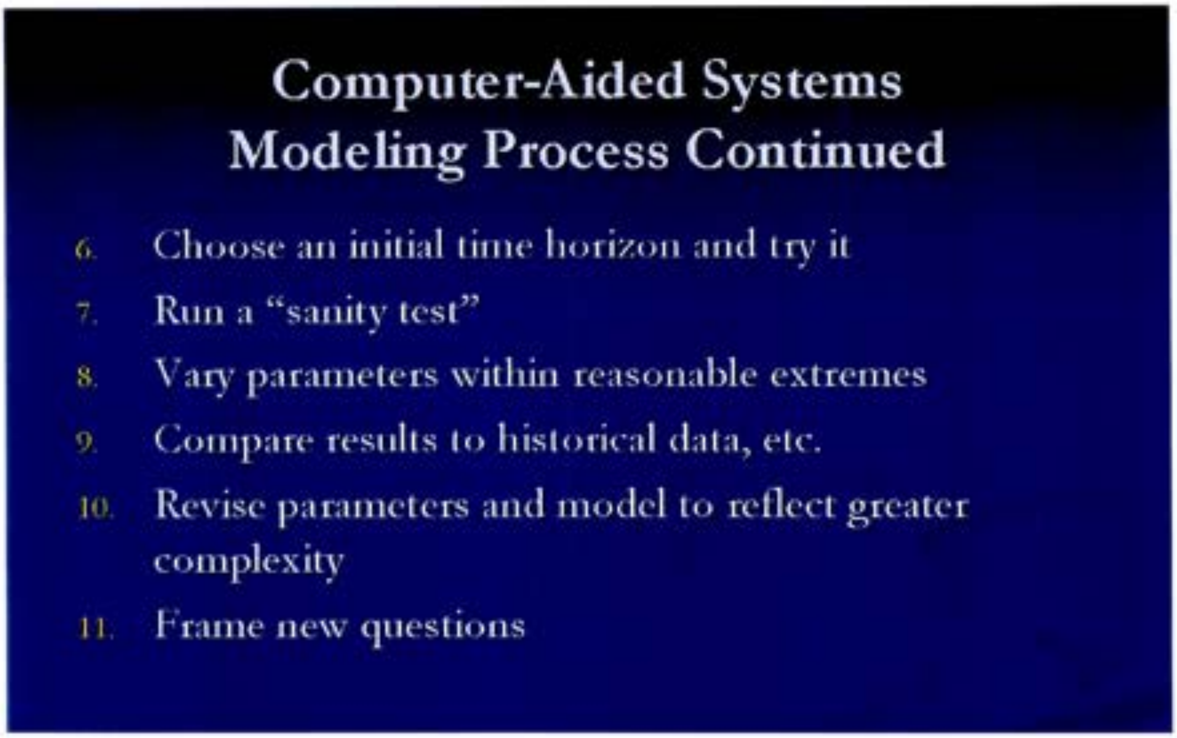
Dynamic Systems Modeling

- A language to describe any system that changes over time
- System structure based on stocks and flows
    - Stocks – what is filled up and drawn down in your system
    - Flows – what flows into your stock, and what flows out of it



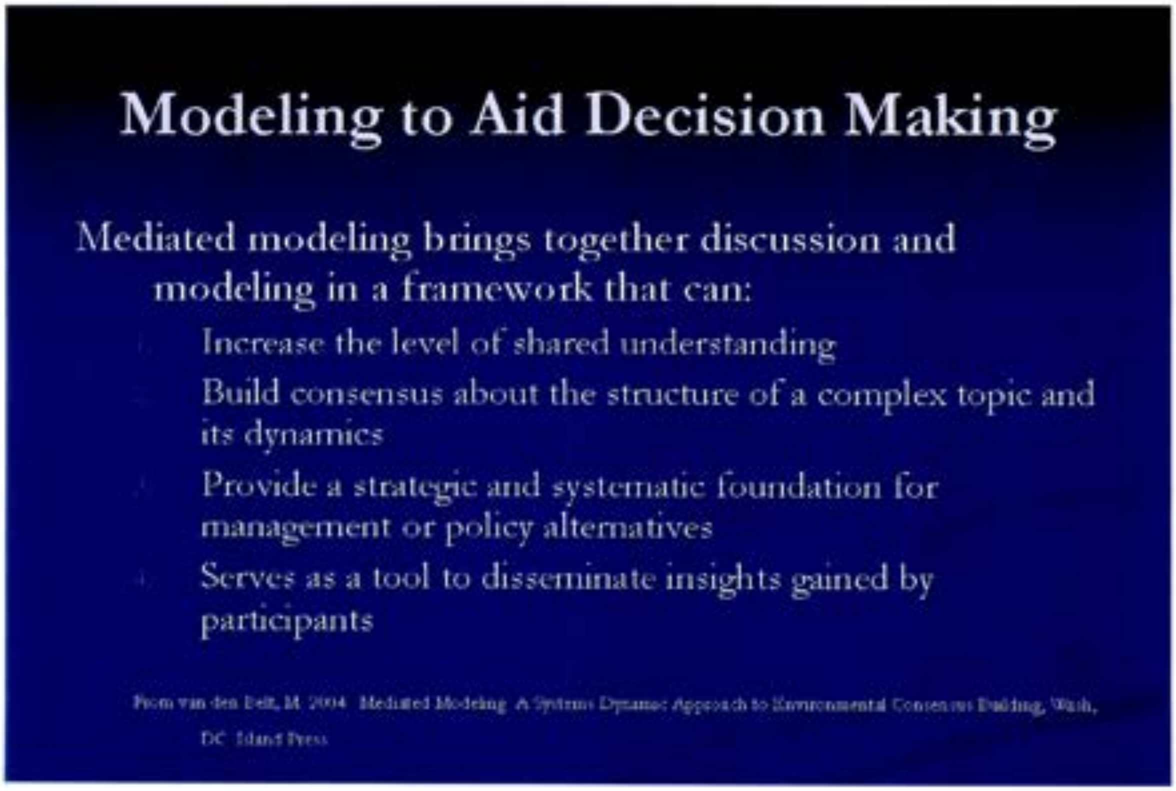
Computer-Aided Systems Modeling Process

1. Define problem and goals of the model
2. Designate state variables, indicate initial status
    Stocks (what is filled up and drawn down in your system)
    Determine what each is filled with and how it is measured
3. Designate control variables related to state variables
    What flows into your stock, and out, and how to measure rates of flow?
4. Select parameters for control variables
5. Examine model for "face validity"
    Violate any physical laws? Dividing by 0? Allowing for spontaneous creation of matter and energy?



Computer-Aided Systems Modeling Process Continued

6. Choose an initial time horizon and try it
7. Run a "sanity test"
8. Vary parameters within reasonable extremes
9. Compare results to historical data, etc.
10. Revise parameters and model to reflect greater complexity
11. Frame new questions

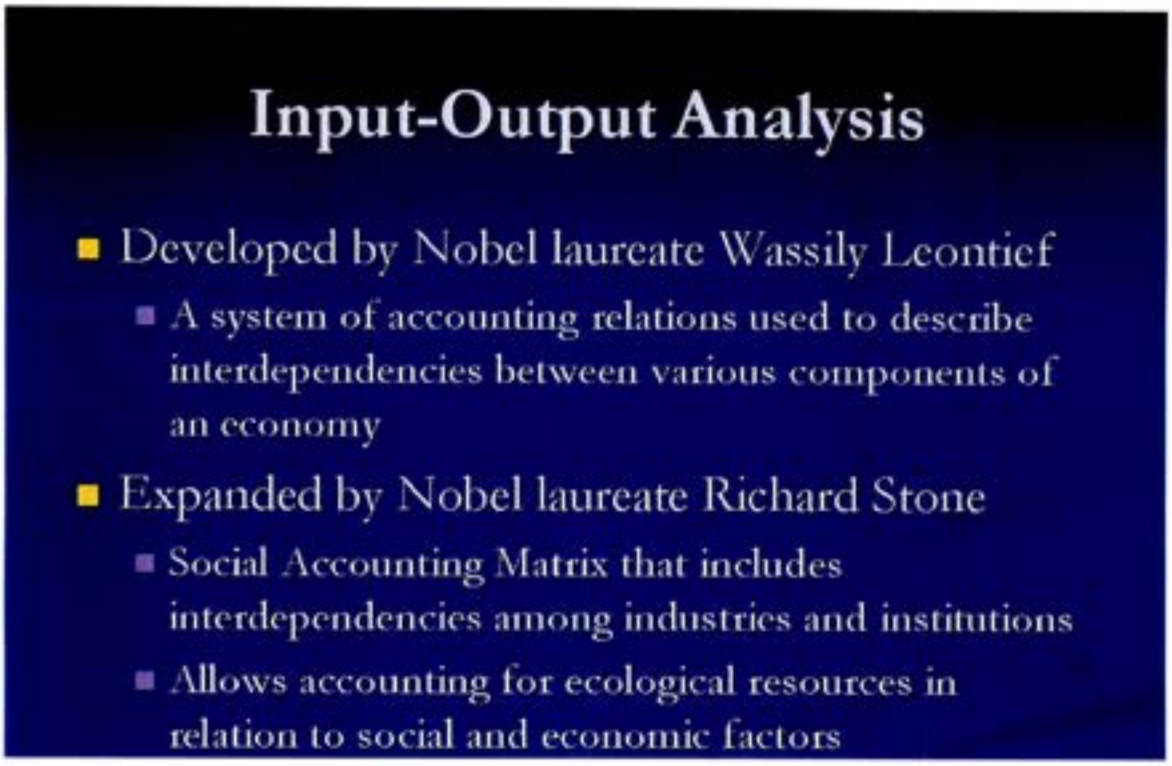


Modeling to Aid Decision Making

Mediated modeling brings together discussion and modeling in a framework that can:

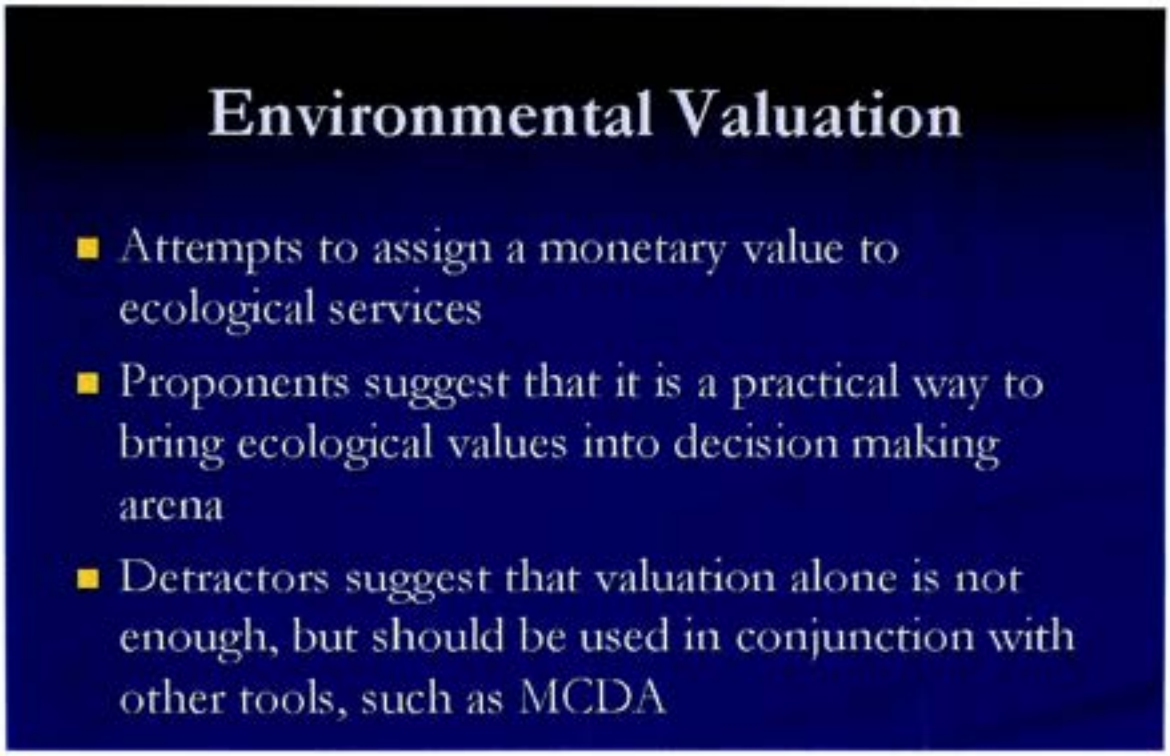
- Increase the level of shared understanding
- Build consensus about the structure of a complex topic and its dynamics
- Provide a strategic and systematic foundation for management or policy alternatives
- Serves as a tool to disseminate insights gained by participants

From van den Belt, M. 2004. Mediated Modeling: A Systems Dynamic Approach to Environmental Consensus Building. Wash., DC: Island Press



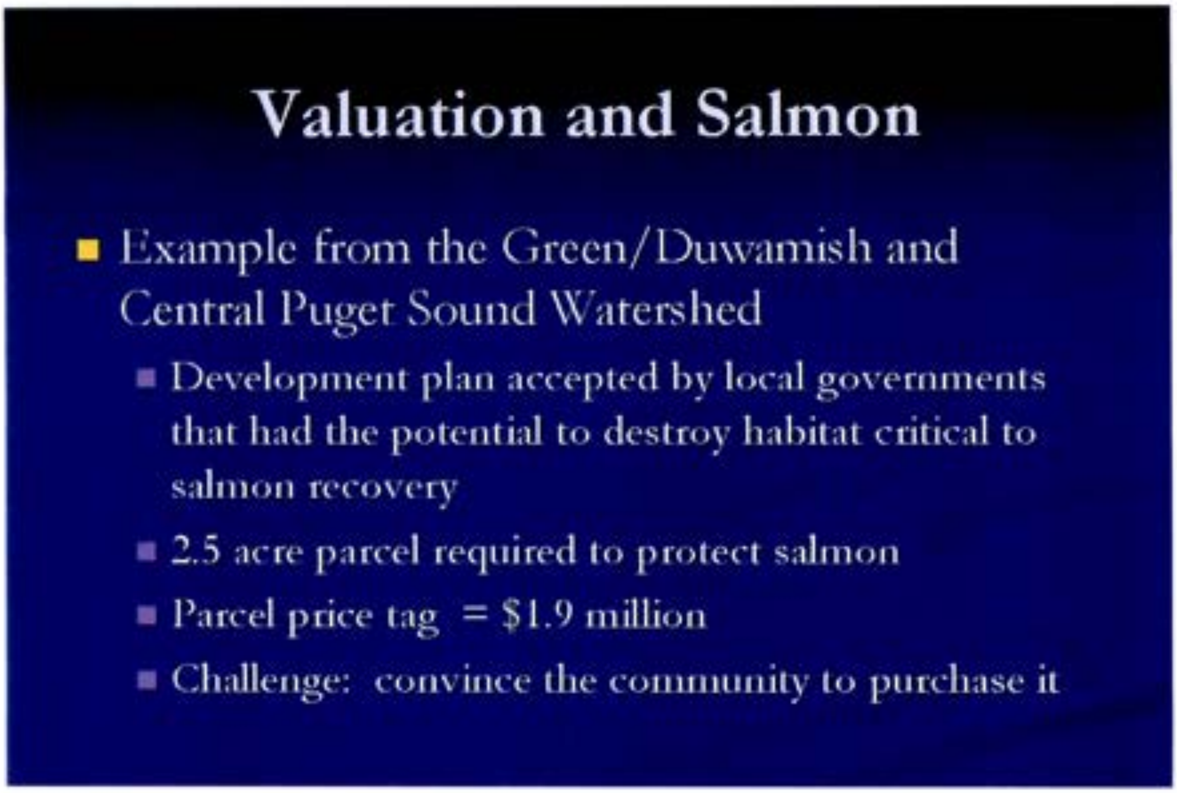
Input-Output Analysis

- Developed by Nobel laureate Wassily Leontief
  - A system of accounting relations used to describe interdependencies between various components of an economy
- Expanded by Nobel laureate Richard Stone
  - Social Accounting Matrix that includes interdependencies among industries and institutions
  - Allows accounting for ecological resources in relation to social and economic factors



Environmental Valuation

- Attempts to assign a monetary value to ecological services
- Proponents suggest that it is a practical way to bring ecological values into decision making arena
- Detractors suggest that valuation alone is not enough, but should be used in conjunction with other tools, such as MCDA



Valuation and Salmon

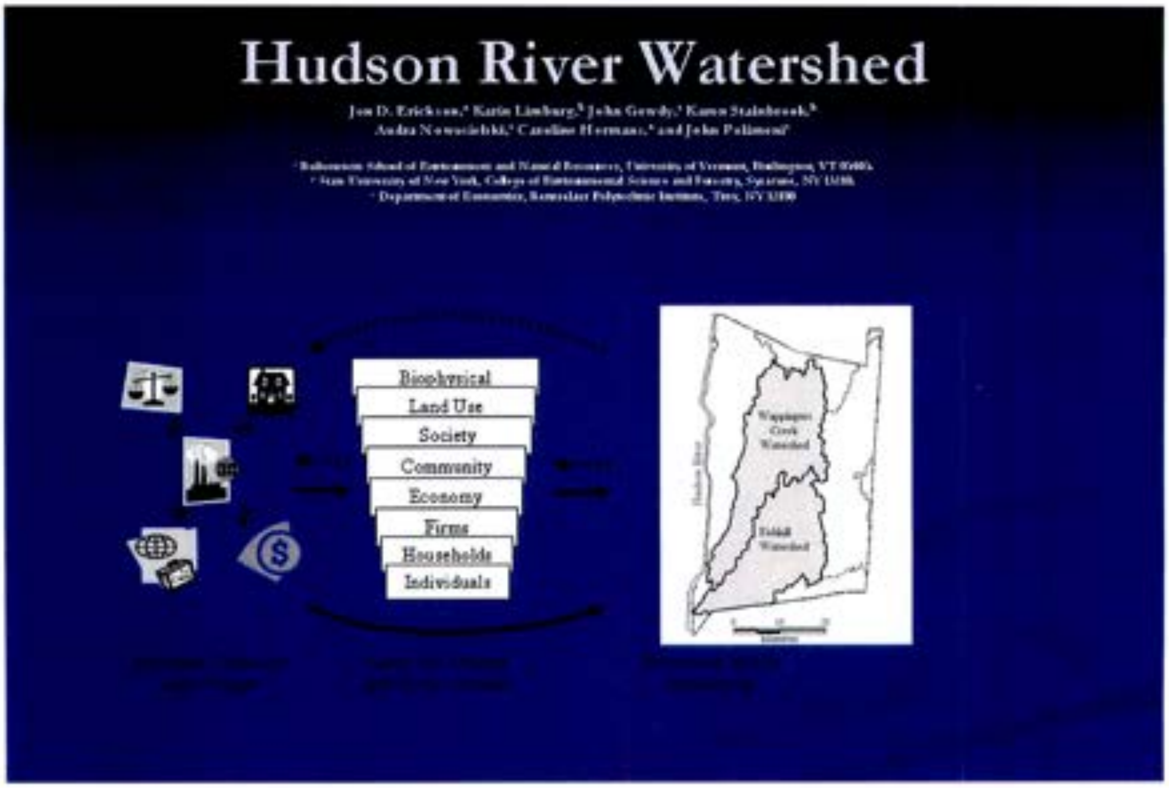
- Example from the Green/Duwamish and Central Puget Sound Watershed
  - Development plan accepted by local governments that had the potential to destroy habitat critical to salmon recovery
  - 2.5 acre parcel required to protect salmon
  - Parcel price tag = $1.9 million
  - Challenge: convince the community to purchase it

Other Tools

- Geographic Information Systems
  - Layering of information in spatial context
  - Allows visual analysis and deeper understanding of relationships in complex systems
- Life Cycle Assessment
  - Cradle-to-grave – formal method to evaluate all environmental impacts that a product creates over its entire lifespan
  - Industrial ecology tool

Hudson River Watershed
Application of EE Approach

- "Tyranny of small decisions" leads to urban sprawl and resulting ecological change (scale): URGENT
- Baseline data on the ecosystem is spotty, research is on-going and slow: UNCERTAINTY
- It feeds into the NYC watershed and provides benefits for local communities: HIGH STAKES
- System meet needs of many different stakeholders in different ways: VALUES MATTER



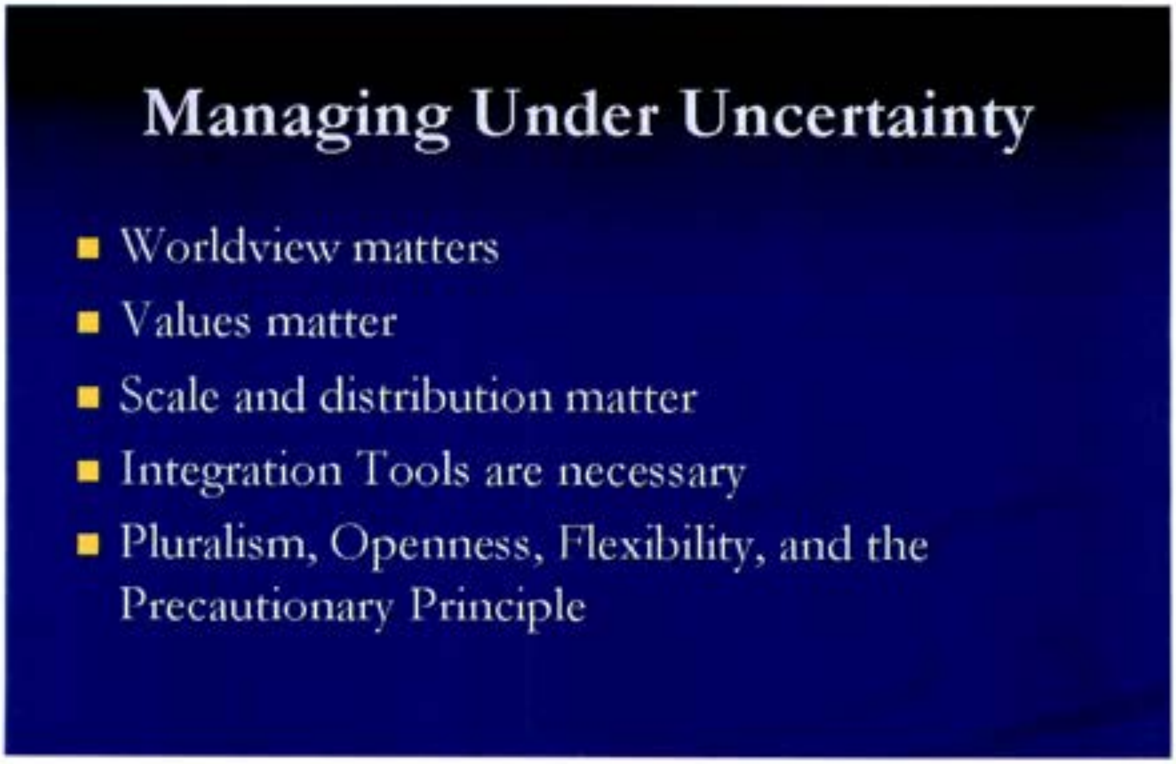
Hudson River Watershed

Jon D. Erickson,[1] Karin Limburg,[2] John Gowdy,[3] Karen Stainbrook,[2]
Audra Nowosielski,[1] Caroline Hermans,[1] and John Polimeni[3]

[1] Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT 05405
[2] State University of New York, College of Environmental Science and Forestry, Syracuse, NY 13210
[3] Department of Economics, Rensselaer Polytechnic Institute, Troy, NY 12180

Tools Used

- Input-Output Analysis using Social Accounting Matrices
- GIS map layers to determine land-use, socio-economic, and biophysical attributes, including an assessment of aquatic ecosystem health based on indices of biotic integrity (IBI).
- Multi-criteria decision analysis



Managing Under Uncertainty

- Worldview matters
- Values matter
- Scale and distribution matter
- Integration Tools are necessary
- Pluralism, Openness, Flexibility, and the Precautionary Principle

Appendix M.
Communicating Risk

Communicating Risk

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Department of Communication
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NY Sea Grant Workshop
October 24, 2005

Abstract

This presentation will focus on methods for improving communication with various publics, the nature of communication, and why communicating complex scientific information is so difficult. It will end with some practical guidelines for addressing public issues and dealing with the media.

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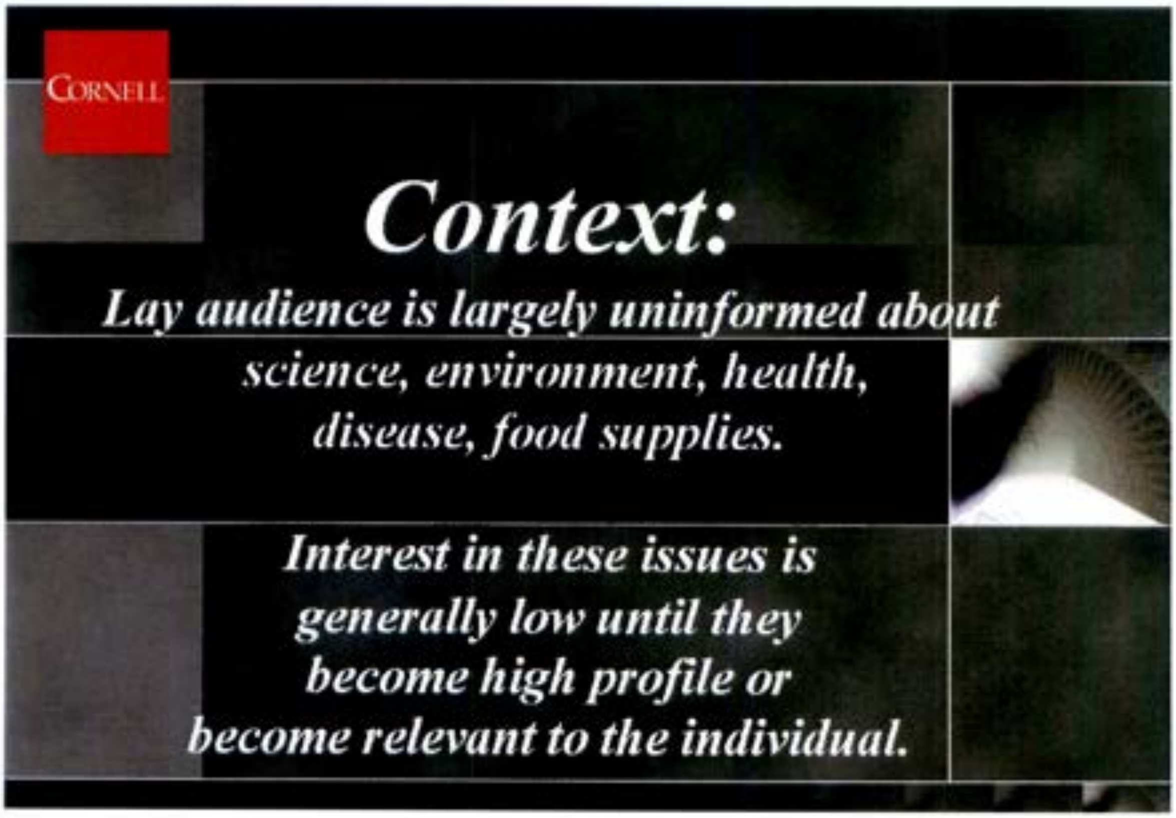
Communicating Complex Science to Lay audiences

- Greatest Communication Challenges?
- Target Audiences?
- What do you want them to know/do?
- What is the greatest barrier?



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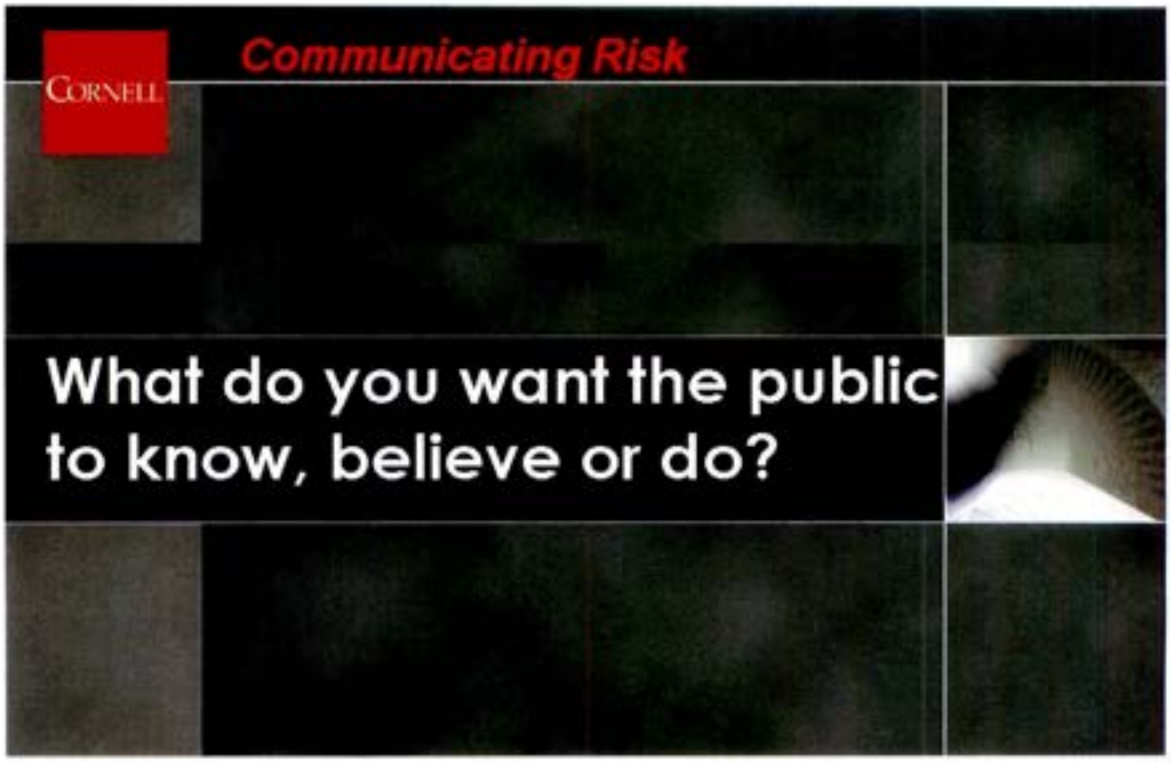
Context:

***Lay audience is largely uninformed about** science, environment, health, disease, food supplies.*

Interest in these issues is generally low until they become high profile or become relevant to the individual.

Communicating Risk

- **Why communicate with the public?**
  - Support programs
  - Support policy changes
  - Change behaviors



Communicating Risk

What do you want the public to know, believe or do?

Communicating Risk

Why is successful Communication so difficult?

Communicating Risk

1 Communication is not a simple one-way process.

- Persuasive models
- One-way information models
- Interactive 2-way models

Communicating Risk

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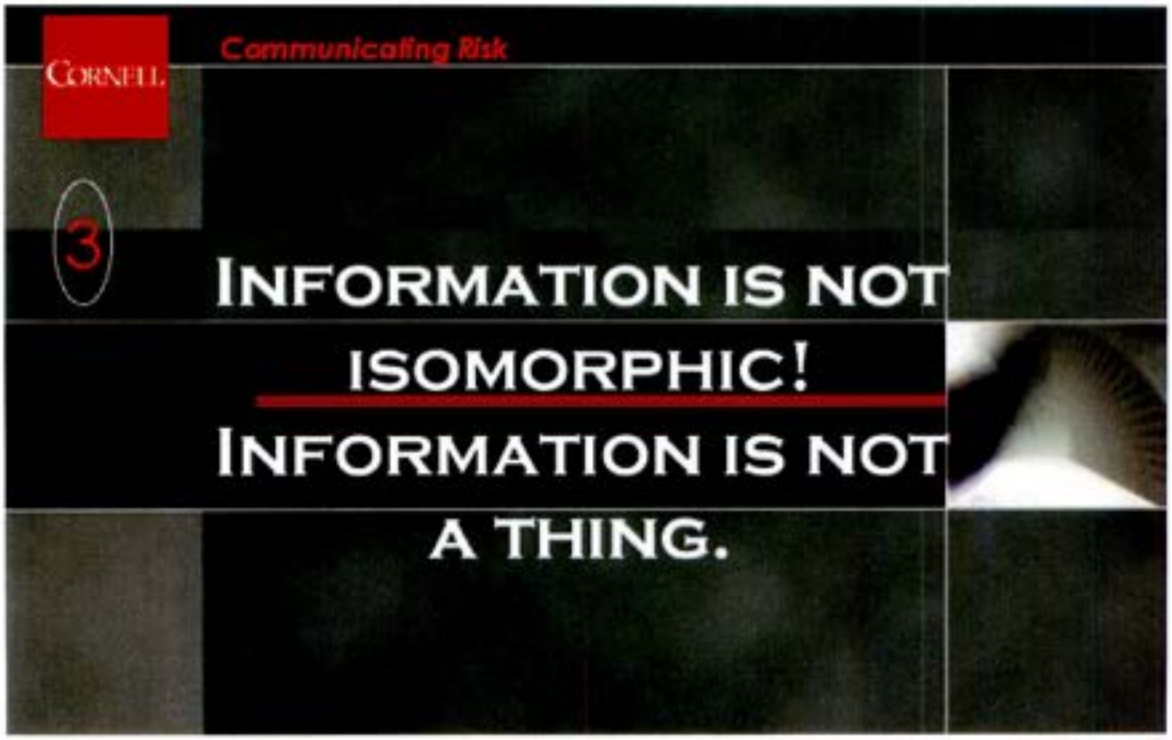
People do not change beliefs, knowledge, or behaviors easily.



Communicating Risk

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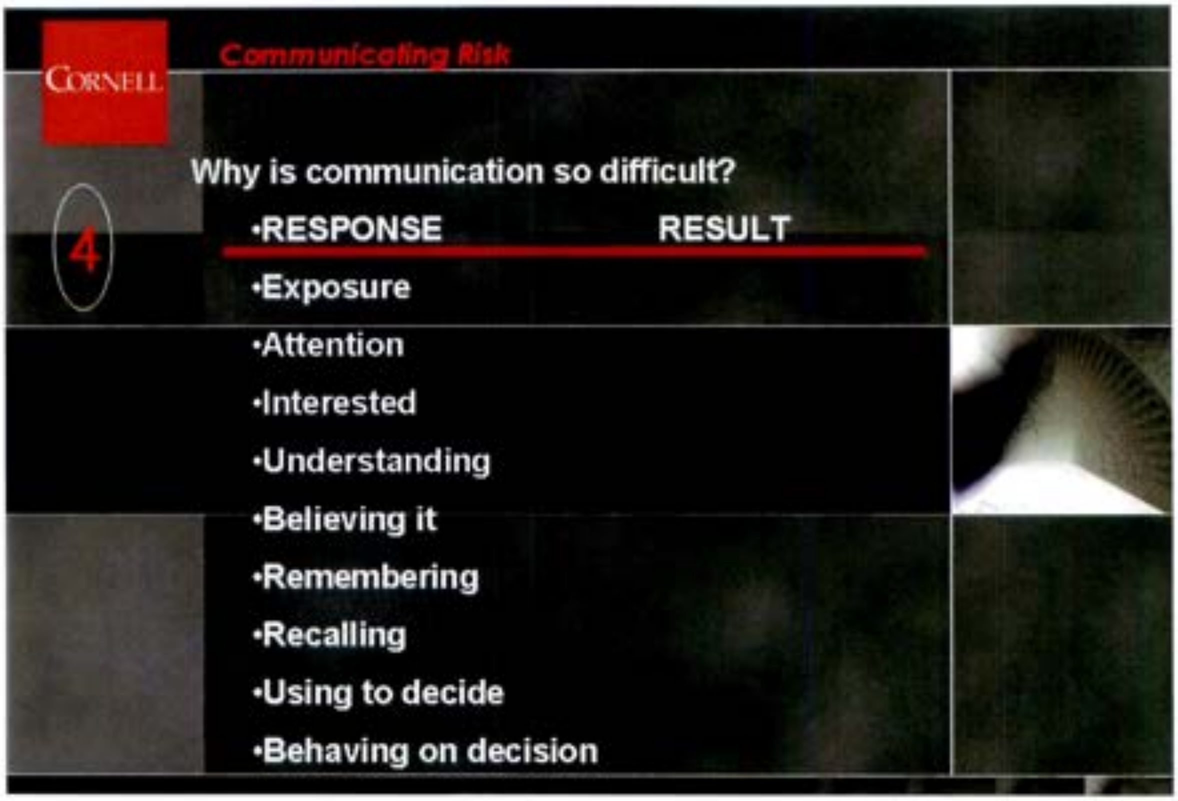
INFORMATION IS NOT ISOMORPHIC!

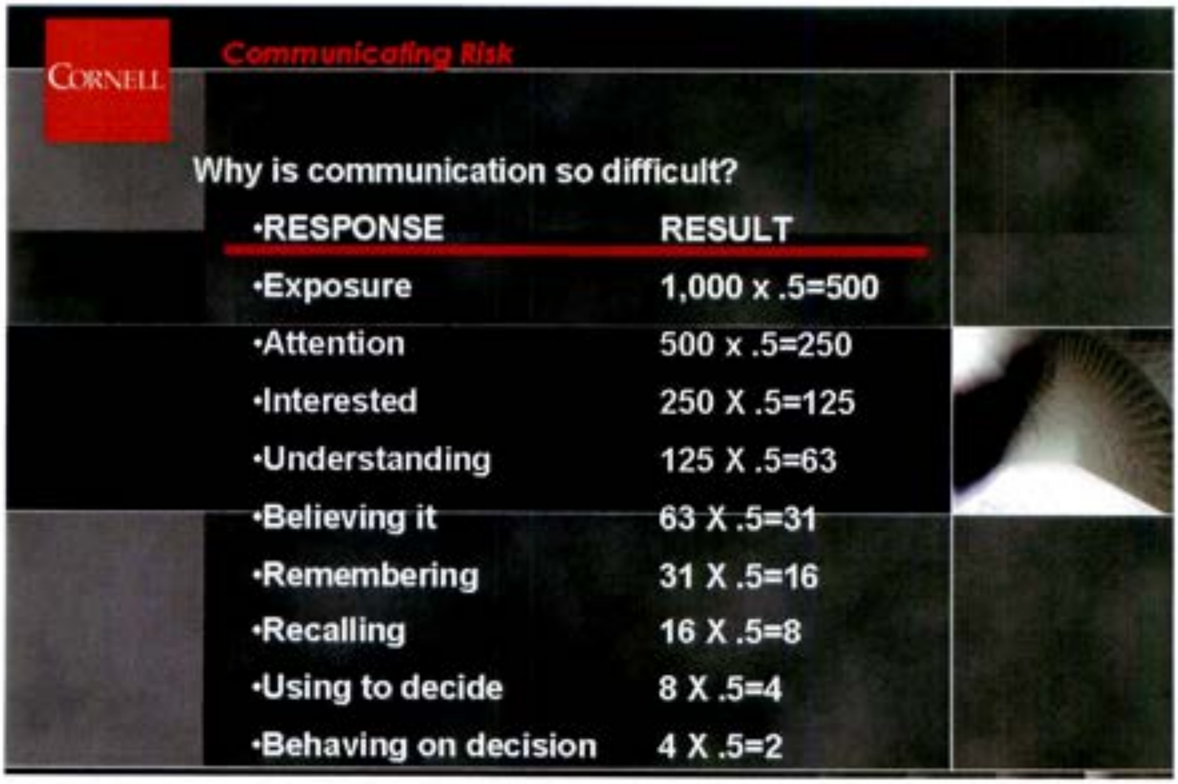
INFORMATION IS NOT A THING.



Communicating Risk

Why is communication so difficult?

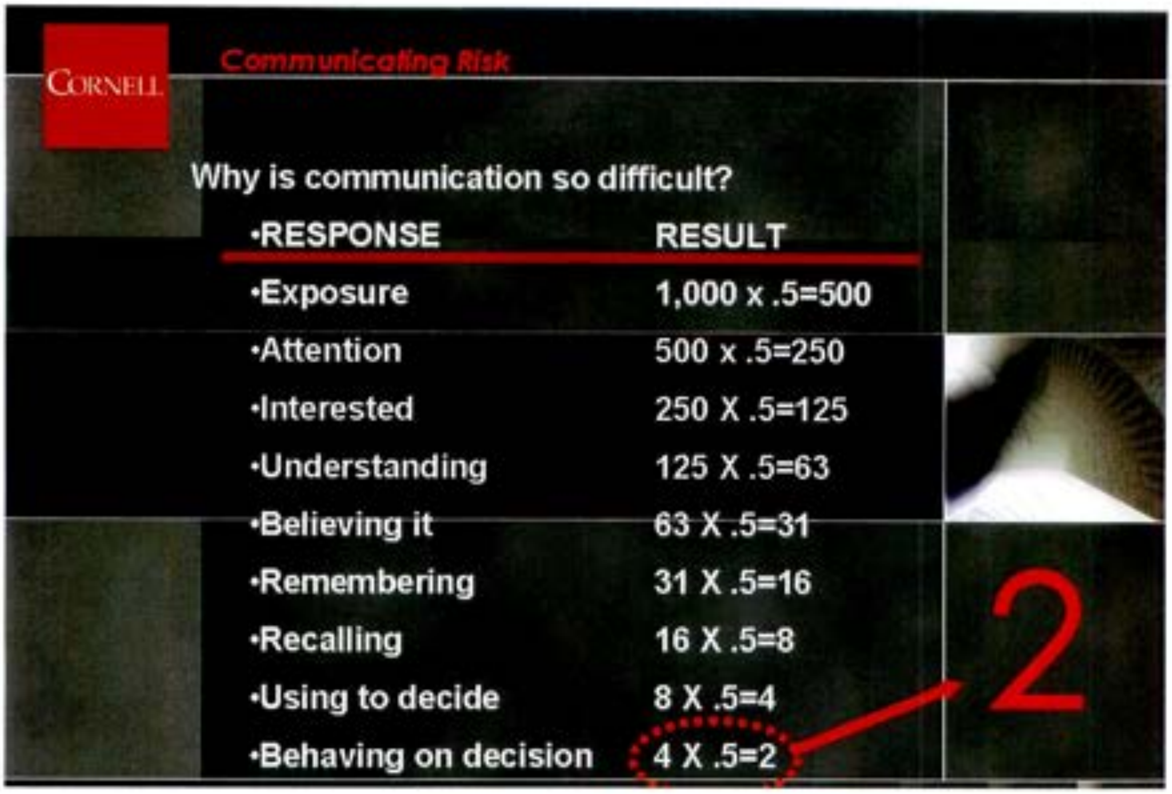
•RESPONSE	RESULT
•Exposure	
•Attention	
•Interested	
•Understanding	
•Believing it	
•Remembering	
•Recalling	
•Using to decide	
•Behaving on decision	



Communicating Risk

Why is communication so difficult?

•RESPONSE	RESULT
•Exposure	1,000 x .5=500
•Attention	500 x .5=250
•Interested	250 X .5=125
•Understanding	125 X .5=63
•Believing it	63 X .5=31
•Remembering	31 X .5=16
•Recalling	16 X .5=8
•Using to decide	8 X .5=4
•Behaving on decision	4 X .5=2



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Communicating Risk

Why is communication so difficult?

•RESPONSE	RESULT
•Exposure	1,000 x .5=500
•Attention	500 x .5=250
•Interested	250 X .5=125
•Understanding	125 X .5=63
•Believing it	63 X .5=31
•Remembering	31 X .5=16
•Recalling	16 X .5=8
•Using to decide	8 X .5=4
•Behaving on decision	4 X .5=2

2

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Communicating Risk

What can we do to improve our chances of success?

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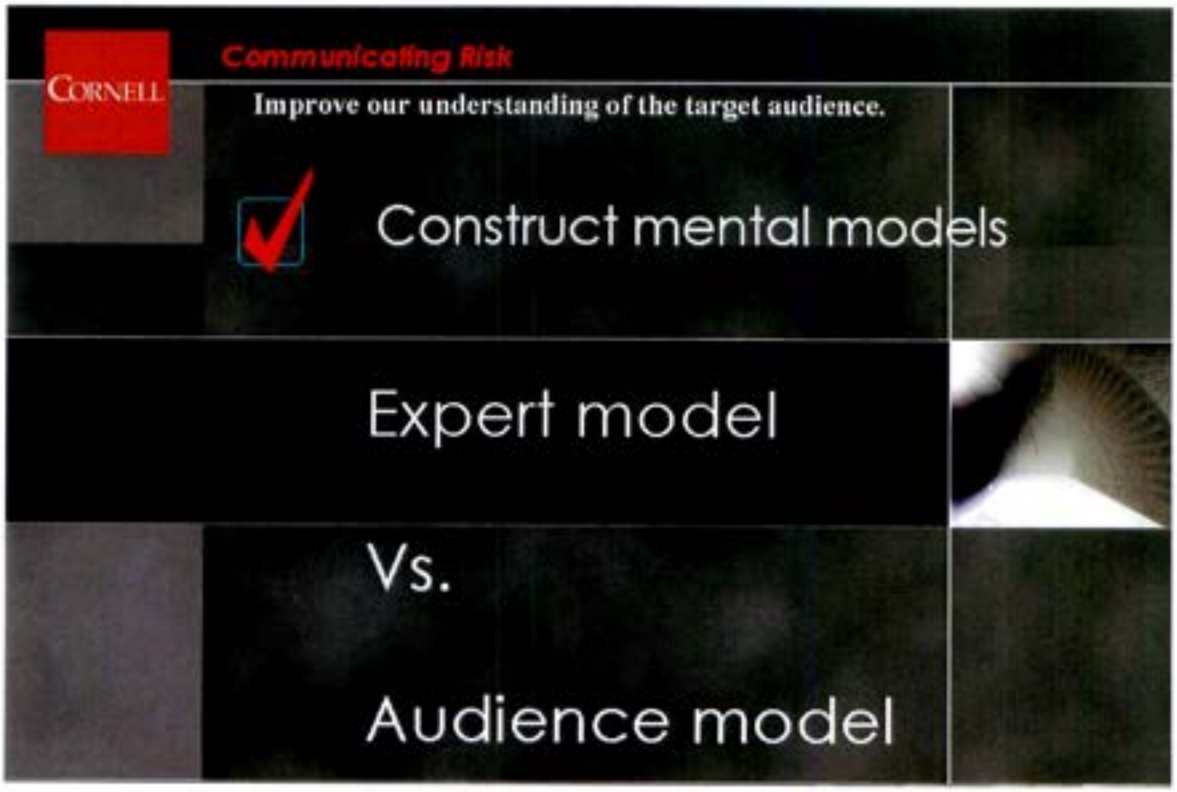
☑ Improve our understanding of the target audience.



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Improve our understanding of the target audience.

☑ Construct mental models

Expert model

Vs.

Audience model

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Improve our understanding of the target audience.

☑ Expert model

How does the audience model differ from Expert?

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Communication in a Risk Context

The Role of Media in Communication

Communicating Risk

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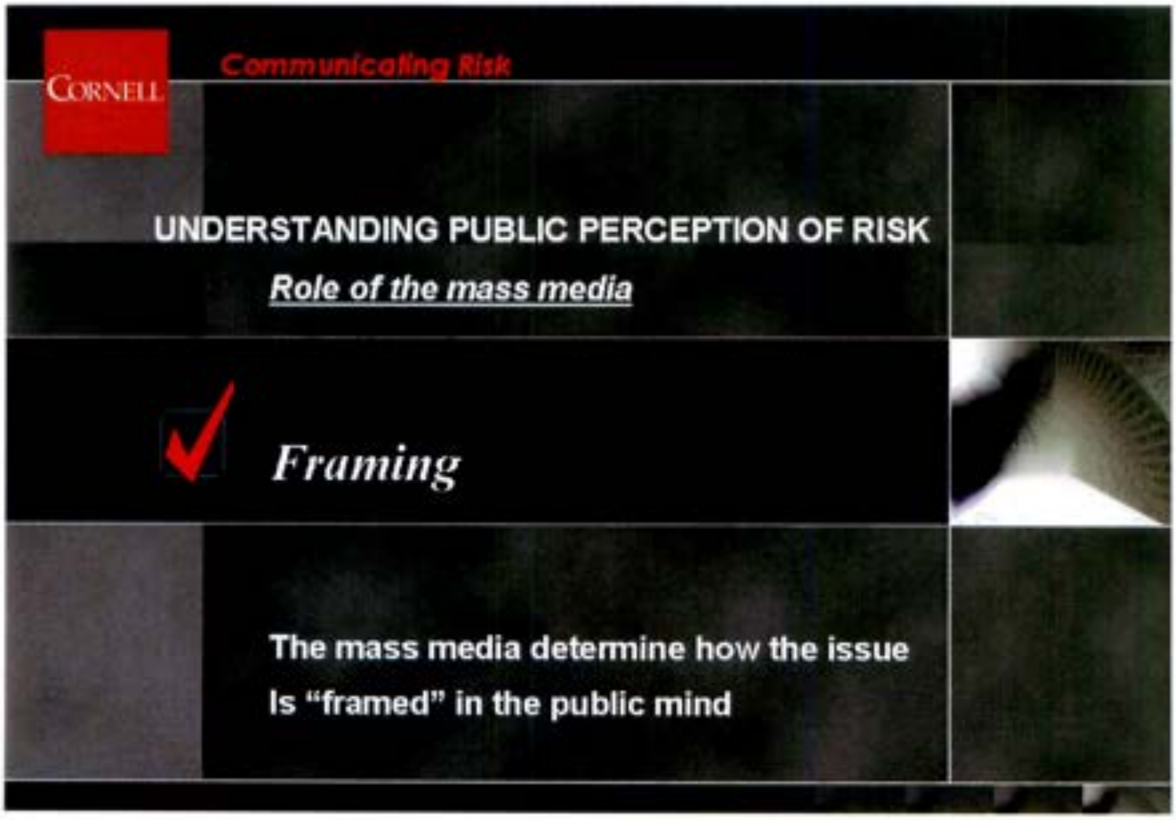
UNDERSTANDING PUBLIC PERCEPTION OF RISK

Role of the mass media

✓ *Agenda Setting*

The mass media set the agenda for interpersonal conversations



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Role of the mass media

✓ *Framing*

The mass media determine how the issue Is "framed" in the public mind

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UNDERSTANDING PUBLIC PERCEPTION OF RISK

Role of the mass media

☑ *Attitude & Value formation*

Much hazard is not within our daily experience, thus the media call attention to topics & events & help us focus our attitudes & values

Communicating Risk

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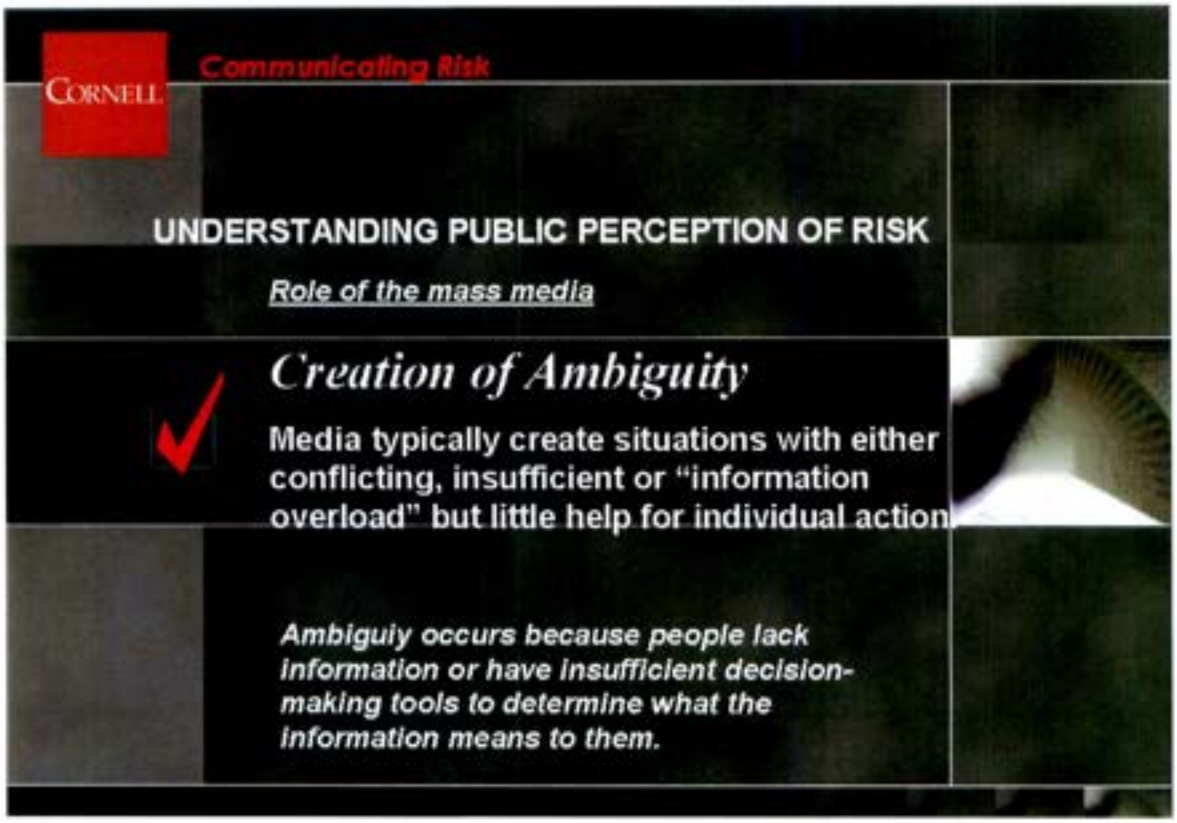
UNDERSTANDING PUBLIC PERCEPTION OF RISK

Role of the mass media

☑ *Manipulation of naïve views*

When we lack strongly held opinions or are not knowledgeable about an issue, we are easily influenced by the way information is presented.



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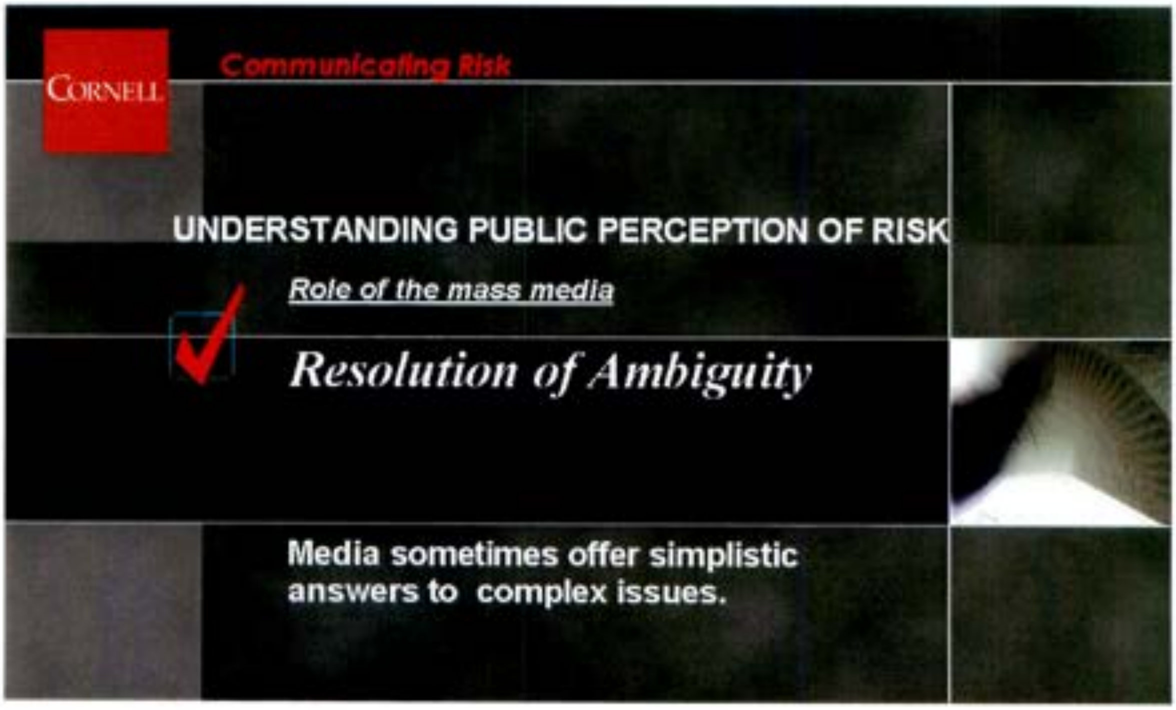
UNDERSTANDING PUBLIC PERCEPTION OF RISK

Role of the mass media

✓ *Creation of Ambiguity*

Media typically create situations with either conflicting, insufficient or "information overload" but little help for individual action

Ambiguiy occurs because people lack information or have insufficient decision-making tools to determine what the information means to them.



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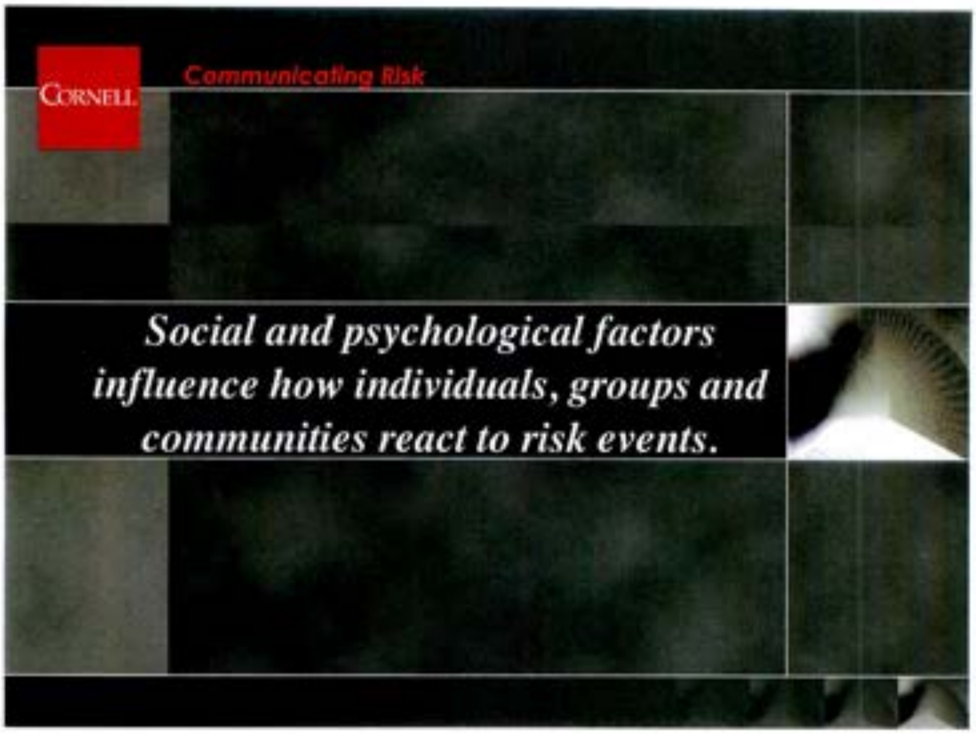
UNDERSTANDING PUBLIC PERCEPTION OF RISK

Role of the mass media

✓ *Resolution of Ambiguity*

Media sometimes offer simplistic answers to complex issues.



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Social and psychological factors influence how individuals, groups and communities react to risk events.

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UNDERSTANDING PUBLIC PERCEPTION OF RISK

Social & Psychological

☑ *“affective vibe”*

We often/may/frequently form opinions based on affective reactions.

Analytic vs. experiential

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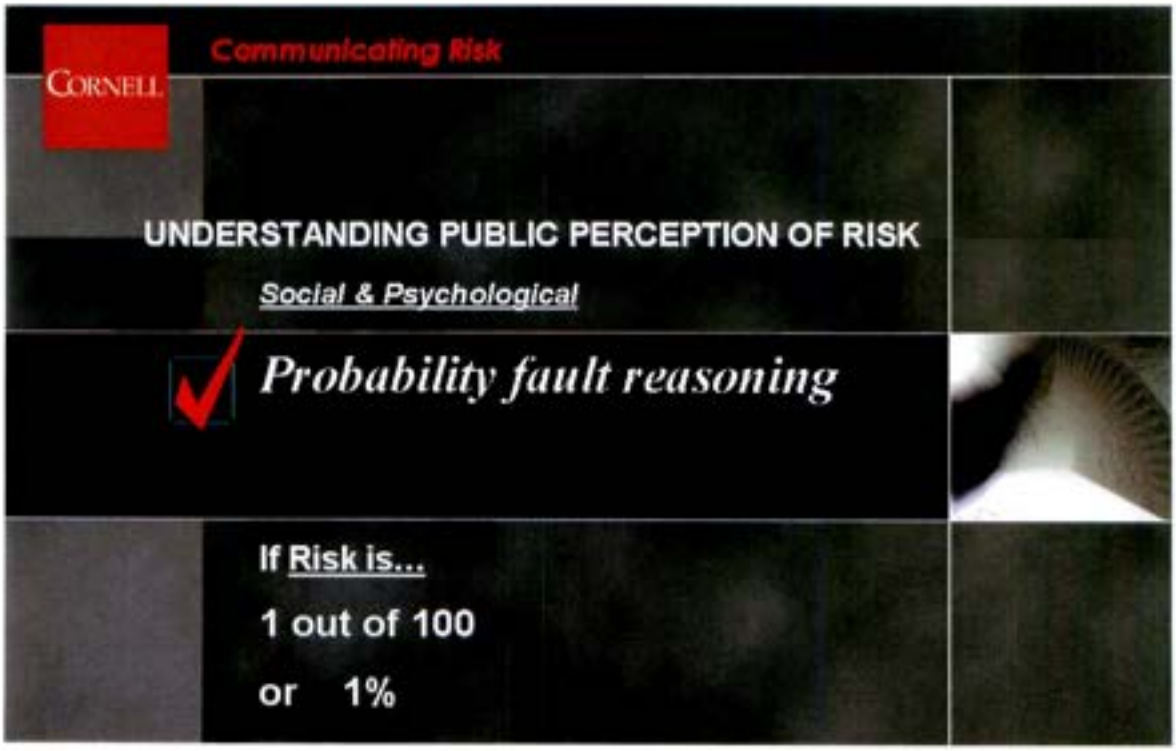
Social & Psychological

✓ *“affective vibe”*

- **Analytic is slow, logical.**
- ***“Affective vibe” is quick, emotional-- Words, images, looks, expressions have emotional meaning.***



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UNDERSTANDING PUBLIC PERCEPTION OF RISK

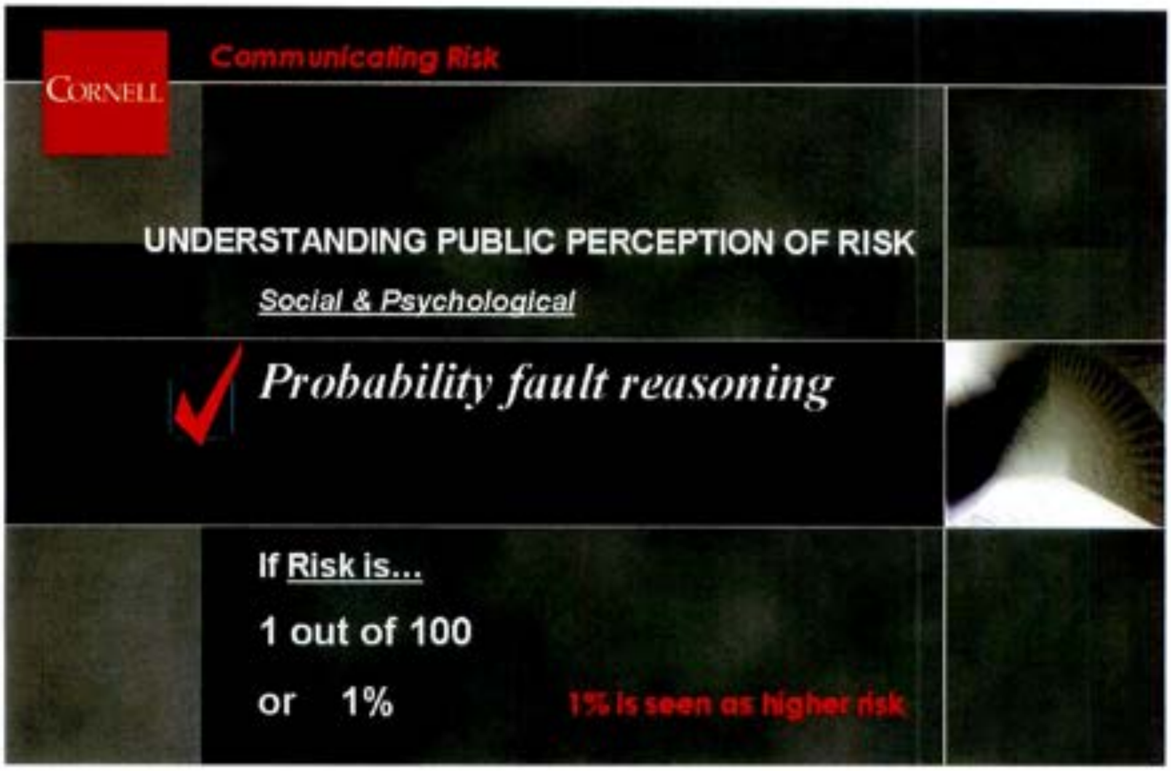
Social & Psychological

✓ *Probability fault reasoning*

If Risk is...

1 out of 100

or 1%



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Social & Psychological

✓ *Probability fault reasoning*

If Risk is…

1 out of 100

or 1%

1% is seen as higher risk

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Social & Psychological

✓ *Resistance to Change*

Attitudes and beliefs change slowly even in the face of contrary evidence.

Once formed, attitudes tend to focus the way information is interpreted.

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UNDERSTANDING PUBLIC PERCEPTION OF RISK

Social & Psychological

✓ *Tendency of Association*

People tend to assume that roughly similar activities or items have the same risks.

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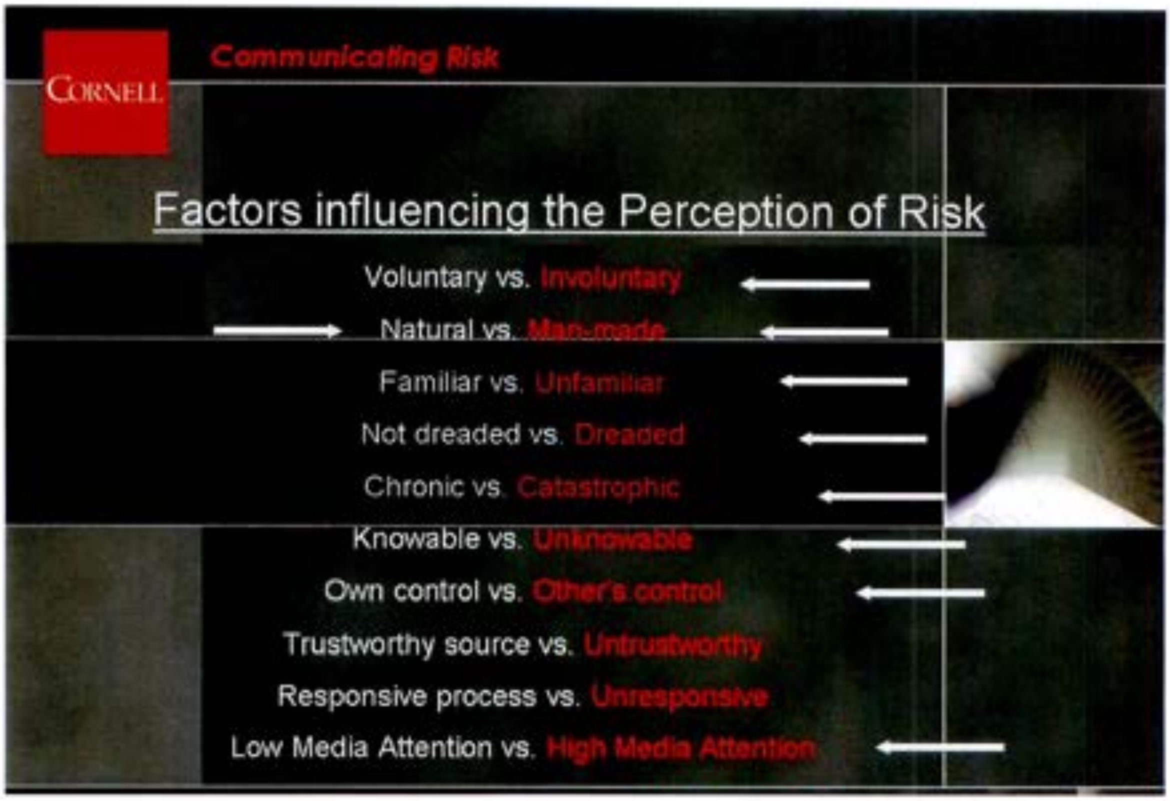
UNDERSTANDING PUBLIC PERCEPTION OF RISK

Social & Psychological

✓ *Simplification Tendency*

People tend to reduce complex risk issues to simple conclusions: “It is Safe” or “It is not safe” .



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Factors influencing the Perception of Risk

- Voluntary vs. Involuntary ←
- → Natural vs. Man-made ←
- Familiar vs. Unfamiliar ←
- Not dreaded vs. Dreaded ←
- Chronic vs. Catastrophic ←
- Knowable vs. Unknowable ←
- Own control vs. Other's control ←
- Trustworthy source vs. Untrustworthy
- Responsive process vs. Unresponsive
- Low Media Attention vs. High Media Attention ←

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Planning communication

Audience segment	Goal	What do they need	Delivery opportunities	Evaluation

Communicating Risk

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Defining Important Audiences

☑

☑

☑

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Perception Is Reality

"Oxymoron of the day"

Communicating Risk

The Nature of Risk…

☑ ***Risk 1 vs. No Risk***

Smoking Vs. not smoking

☑

☑

Communicating Risk

The Nature of Risk…

☑ ***Risk 1 vs. No Risk***

Smoking Vs. not smoking

☑ **Risk 1 vs. Risk 2**

Flying Vs. Driving
SmallPox Vs. Immunization

☑

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Communicating Risk

The Nature of Risk…

☑ *Risk 1 vs. No Risk*

Smoking Vs. not smoking

☑ Risk 1 vs. Risk 2

Flying Vs. Driving

SmallPox Vs. Immunization

☑ **Risk 1 vs. Benefit**

We tend to believe that high risk is related to low benefit. Often, however, high risk is related to high benefit.

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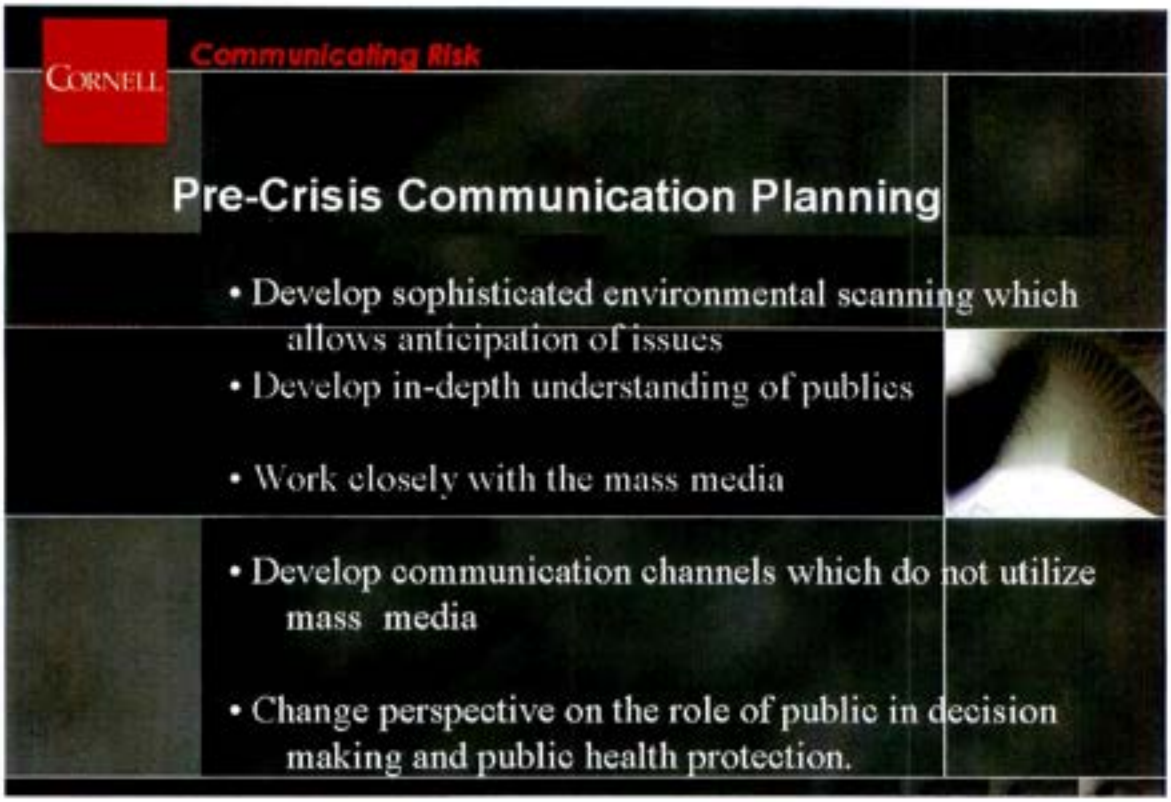
The Nature of Risk…

		Official- View	
		High Hazard	Low Hazard
Public Perception	High Hazard	Agreement (Focus public on correct behaviors)	Disagreement (Reassure or focus on real risk)
	Low Hazard	Disagreement (Call attention, focus efforts)	Agreement (no action needed)



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Pre-Crisis Communication Planning

- Develop sophisticated environmental scanning which allows anticipation of issues
- Develop in-depth understanding of publics
- Work closely with the mass media
- Develop communication channels which do not utilize mass media
- Change perspective on the role of public in decision making and public health protection.

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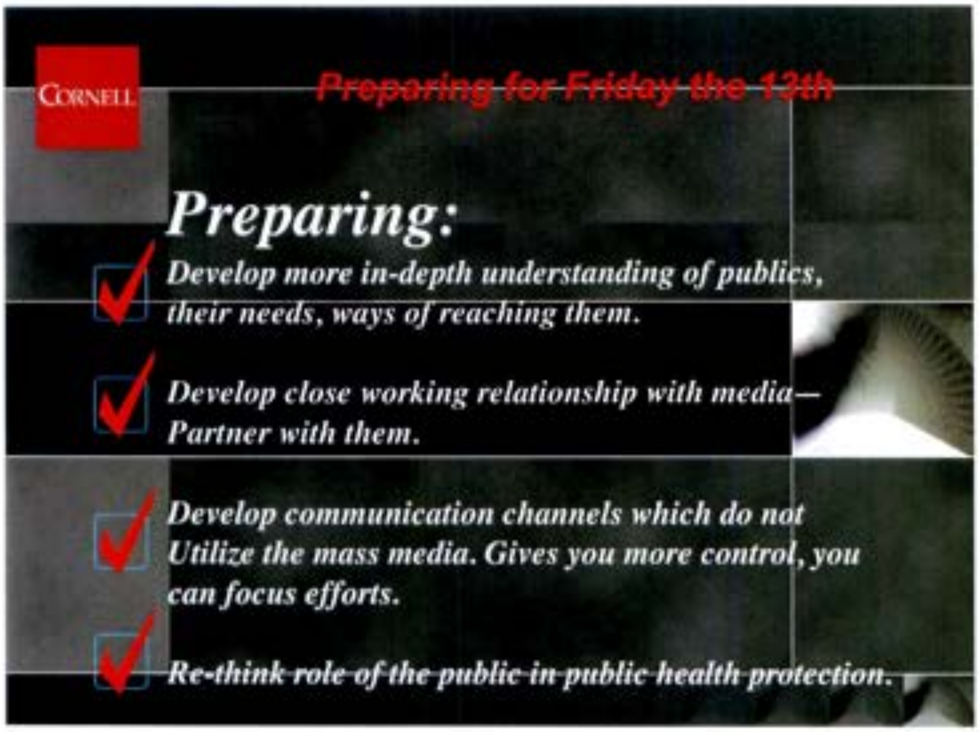
Effective Risk Communication

- **Accept and involve the public as a legitimate partner**
- **Listen to public's concerns**
- **Be honest, frank and open**
- **Coordinate and collaborate with other credible sources**
- **Speak clearly and with compassion**
- **Plan carefully and evaluate your efforts**



Cornell

Preparing for Friday the 13th

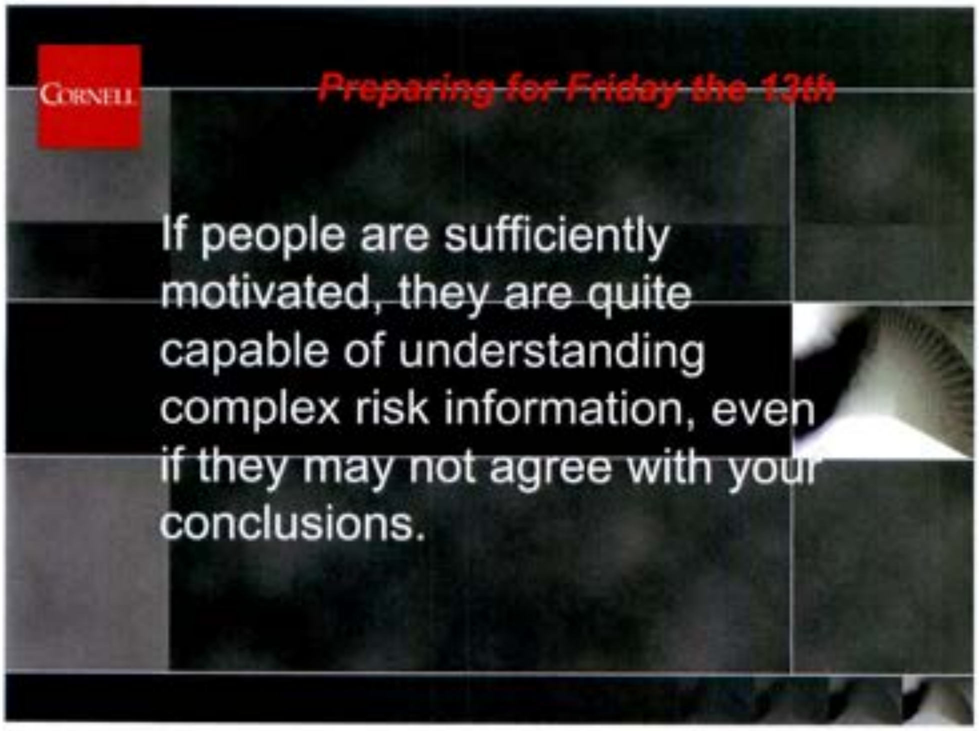
Preparing:

☑ *Develop more in-depth understanding of publics, their needs, ways of reaching them.*

☑ *Develop close working relationship with media—Partner with them.*

☑ *Develop communication channels which do not Utilize the mass media. Gives you more control, you can focus efforts.*

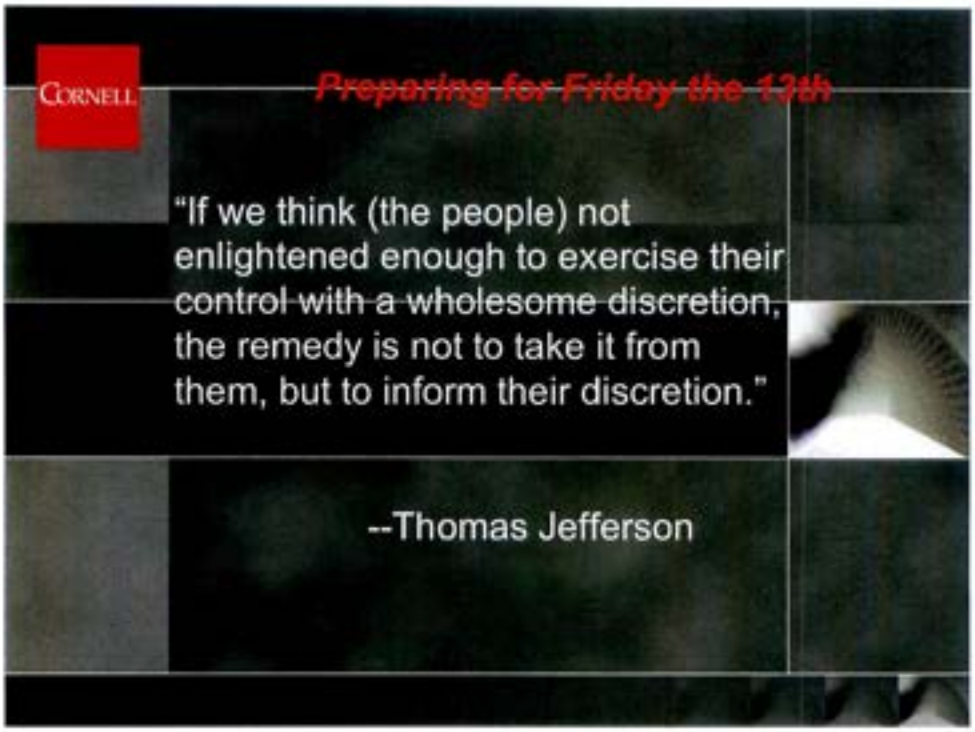
☑ *Re-think role of the public in public health protection.*



Cornell

Preparing for Friday the 13th

If people are sufficiently motivated, they are quite capable of understanding complex risk information, even if they may not agree with your conclusions.



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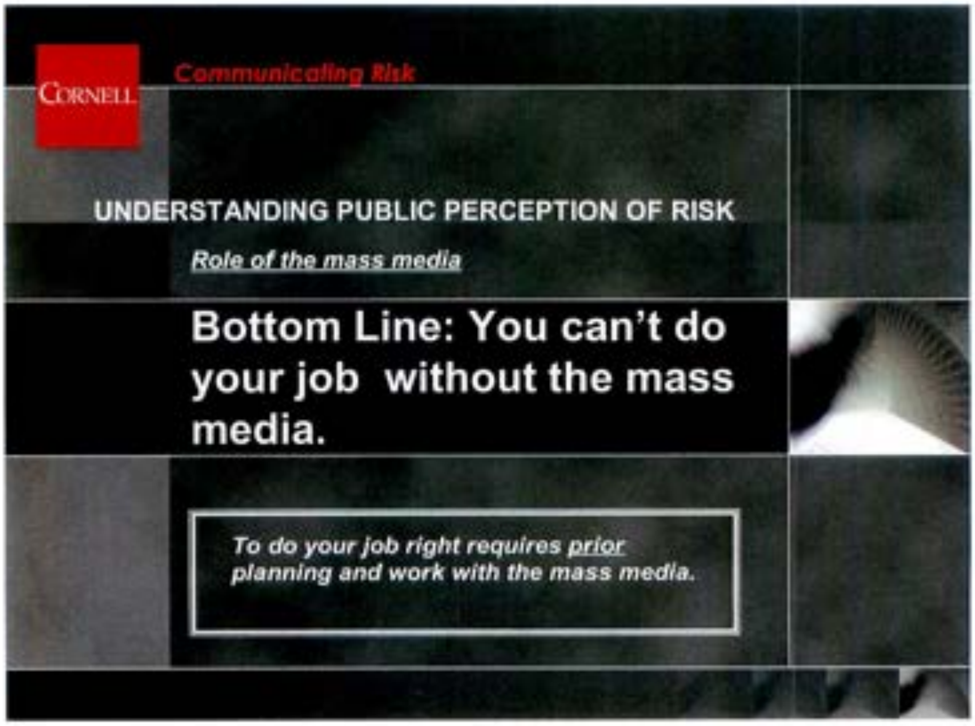
Preparing for Friday the 13th

"If we think (the people) not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion."

--Thomas Jefferson



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Communicating Risk

UNDERSTANDING PUBLIC PERCEPTION OF RISK

Role of the mass media

Bottom Line: You can't do your job without the mass media.

To do your job right requires prior planning and work with the mass media.

Appendix N.
Workshop Evaluation and Results

Sea Grant
New York

Fisheries Uncertainty Workshop Evaluation

In order to evaluate the effectiveness of this workshop and plan for future efforts, please answer the following questions. Please feel free to use the reverse for additional space. Thank you!

1.) **Do you think the workshop achieved its overall goal of sharing information and developing a research agenda?**

Yes 85% No Uncertain 15%

Comments:

"some speakers exceeded time allocations that eliminated research agenda development in main session of workshop"

"we shared info but did not get as far as the research agenda"

"very nicely done"

"more focus on the vast ocean of what we don't know about Lake Ontario, and how that affects error in decision making"

"I feel that the information sharing was excellent, however, time was not reserved for discussion for the research agenda at the actual workshop (behind schedule)"

2.) **Were the presentations and summary session effective/worthwhile?**

Yes 90% No Uncertain 10%

Comments:

"A bit heavy on academics, but still good"

"... had a hard time following discussion summary, a little too technical, although content was interesting"

"the entire range"

"at this point the research agenda was not developed but the goal of sharing information was met"

"some were right on target – more complete coverage on statistical properties"

"I would like to have heard more human dimensions integrated"

3.) **Which portion(s) of the workshop did you find the most informative and interesting?**

"Evan Cooch('s) first talk, but I also found the communication and ecological economic discussions very interesting"

"presentations by V. Luzadis and C. Scherer"

"presentation by Scherer provide the most useful information for fisheries managers"

Assumptions of bootstrap procedure

- Assumes independent and identically distributed data.
- Performance can depend upon depend sample size.
- Does not assume normality for data or for statistic being evaluated.

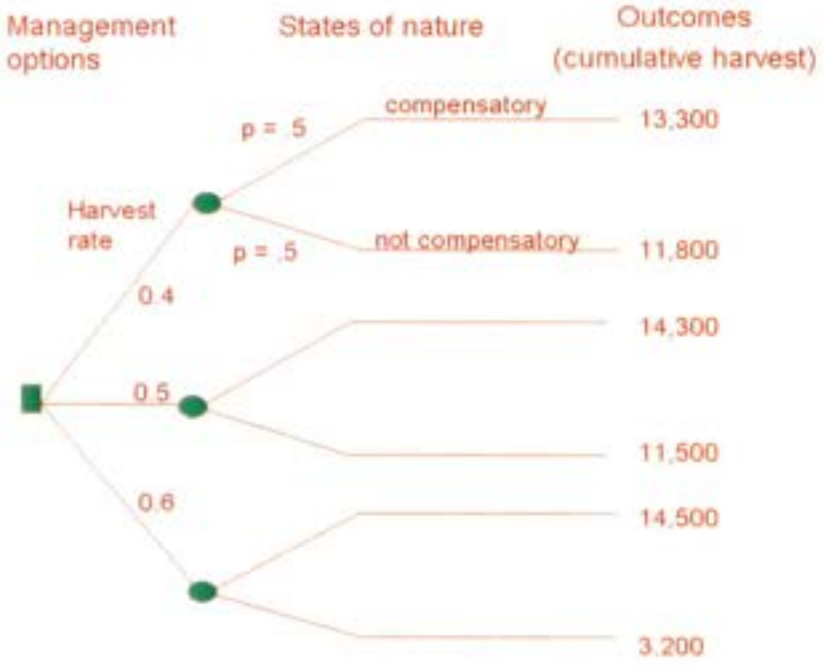
Bootstrap advantages and disadvantages

- Is not guaranteed to work for all cases.
- Can allow confidence intervals for complex functions of the parameters that were directly estimated.
- There are more sophisticated bootstrap approaches that sometimes work better but these are more complicated to calculate.

A simple example

- Management objective: maximize cumulative harvest
- Management options: alternative harvest rates
- Critical uncertainty: natural mortality hypothesis (M fixed or M decreases when F increases)
- Probabilities: who knows? 50:50
- Model: simple age-structured model, with stock-recruitment relationship
- Decision tree: ...

A Simple Decision Tree



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