Sebastes aleutianus (rougheye rockfish), possibly born the same year as Darwin (maximum age of S. aleutianus ~205 yrs)

Marc Mangel

Toyota-ANU Lecture, Australian National University
March 2009
Question: How to we bring first class basic science to bear on important applied questions?
Question: How to we bring first class basic science to bear on important applied questions?

One Answer: “Why bother?”
Question: How to we bring first class basic science to bear on important applied questions?

One Answer: “Why bother? Let’s just do good science.”
Another Answer:

“Silent Spring (1962) is the most important book written by an American”

The path is not at all clear, but some parts of it are becoming clear.
The path is not at all clear, but some parts of it are becoming clear

The path is the focus of this talk, with applications to conservation and resource management but the ideas are general
Answering a question with a series of questions

• How does the nature of environmental problems differ from other kinds of problems?

• How do we deal with uncertainty, data and models?

• How can science support policy making?

• How do we and what should we learn from other disciplines?

-- No definitive formulation

-- No stopping rule

-- No final resolution

-- Solutions are “good or bad” not “right or wrong”

-- Plurality of legitimate perspectives

“The best environmental policy depends on how you frame the question”

---John Maddox
Wicked problems are not dealt with by

-- Optimizing
Wicked problems are not dealt with by

-- Optimizing

-- Managing

Nobody “manages” climate change, El Nino, or the economy for that matter (although we might be able to do something about them)

Banish ‘ecosystem management’ from the lexicon
Wicked problems are not dealt with by

-- Optimizing

-- Managing

Nobody “manages” climate change, El Nino, or the economy for that matter (although we might be able to do something about them)

Banish ‘ecosystem management’ from the lexicon

And often lack clear stopping rules

--There is no easy scientific answer to the question “when is a recovery complete”
Who manages climate change…

Ecological Applications, 18(8), 2008, pp. 1932–1955
© 2008 by the Ecological Society of America

MULTIPLE HYPOTHESIS TESTING AND THE DECLINING-POPULATION PARADIGM IN STELLER SEA LIONS

Nicholas Wolf\textsuperscript{1,2,4} and Marc Mangel\textsuperscript{1,2,3}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{population.png}
\caption{Population trend of Steller sea lions over the years.}
\end{figure}
A result that neither Environmentalists nor the National Marine Fishery Service likes
Wicked problems are swathed in uncertainty

- Principle of irreducible uncertainty: No matter how much science we do, there will always be remaining a level of uncertainty.

We need to think about data and their interpretation
The classical/frequentist approach to dealing with data: The Earth is Round (p< 0.05)

“I argue herein that NHST (null hypothesis significance testing has not only failed to support the advance of psychology as a science but also has seriously impeded it” (J. Cohen. 1994. American Psychologist. 49:997-1003)

What is a null hypothesis?

Null hypotheses entertain the possibility that nothing has happened, that a process has not occurred, or that change has not been produced by a cause of interest. They are reference points against which alternatives should be contrasted.

However, since it is often impossible to prove that something has occurred, we construct a null hypothesis that is the complement of the hypothesis of interest and use the accumulated data to assess the probability that the null hypothesis is true.
Examples of Environmental Null Hypotheses That Were Rejected

• The occurrence of sheep remains in coyote scats does not vary across season (p=0.03)

• Duckling body mass does not vary across years (p<0.0001)

• The density of large trees is not greater in unlogged than logged forests (p=0.02)


• Driving cessation [in the elderly] leads to a decline in out-of-home activity (p<0.001)

What’s wrong with NHST?

“Well, among many other things, it does not tell us what we want to know, and we so much want to know what we want to know that, out of desperation, we nevertheless believe that it does.

What we want to know is

\[ \text{Given these data, what is the probability that the null hypothesis is true?} \]

But, as most of us know, what it tells us is

\[ \text{Given that the null hypothesis is true, what is the probability of these (or more extreme) data} \]

(Cohen pg 997)

What we want
What we get from
NHST
for scientific understanding

\[ \Pr\{H|D\} \neq \Pr\{D|H\} \]

NHST has “caused scientific research workers to pay undue attention to the results of the tests of significance they perform on their data..and too little to the estimates of the magnitude of the effects they are estimating”

But Sometimes You Might (Jagger and Richards, op. cit.)

Likelihood and Bayesian Methods Show the Way to Get What You Want

“...the discipline of statistics has neglected a key question for which it is responsible: when does a given set of observations support one statistical hypothesis over another?”

The principle fundamental to providing this answer is the law of likelihood, which “provides the explicit objective quantitative concept of evidence that is missing”

**Law of Likelihood**: If hypothesis A implies that the probability that a random variable X takes the value x is \( p_A(x) \), while hypothesis B implies that the probability is \( p_B(x) \), then the observation \( X=x \) is evidence supporting A over B only if \( p_A(x) > p_B(x) \), and the likelihood ratio, \( p_A(x)/p_B(x) \), measures the strength of that evidence.

Ecological Detection in Environmental Problem Solving

"Method of multiple working hypotheses"

--T.C. Chamberlain (1890)

The three questions we need to ask

Given two (or more) hypotheses/models and an observation (data) we can ask

• What do I believe, now that I have this observation?

• What should I do, now that I have this observation?

• How should I interpret this observation as evidence regarding the different models/hypotheses?
Simple example

H is the hypothesis of interest, with prior probability p; H₀ is the alternative hypothesis, with prior probability 1-p.

We collect data. Then

\[
\Pr\{H|\text{data}\} = \frac{p \Pr\{\text{data}|H\}}{p \Pr\{\text{data}|H\} + (1-p) \Pr\{\text{data}|H_0\}}
\]

*Bayesian and likelihood methods allow us to deal with uncertainty and information in a consistent framework*
Science in support of policy making: Conservation biology provides the context for understanding policy decisions

We have had some successes

[Graph showing sardine biomass trajectory over years, with arrows indicating trends and changes.]
Some other successes in fishery management

### The Best at a Glance

<table>
<thead>
<tr>
<th>Fishery</th>
<th>No. of participants</th>
<th>Season</th>
<th>Gear</th>
<th>Management body</th>
<th>Record revenue</th>
<th>Record harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALASKA SALMON</td>
<td>17,000 permit holders</td>
<td>Late May to late September</td>
<td>Gillnets (set and drift), seines and fishwheels</td>
<td>Alaska Department of Fish and Game</td>
<td>$781.4 million (1988)</td>
<td>994.1 million pounds (1995)</td>
</tr>
<tr>
<td>CALIFORNIA HERRING</td>
<td>416 in San Francisco Bay</td>
<td>November to March</td>
<td>Gillnet</td>
<td>California Fish and Game Commission</td>
<td>$18.5 million ('95-'96)</td>
<td>13,543 tons ('96-'97)</td>
</tr>
<tr>
<td>MAINE LOBSTER</td>
<td>6,600 permits</td>
<td>Year round, with some daily closures</td>
<td>Traps</td>
<td>Maine Division of Marine Resources</td>
<td>$138 million (1997)</td>
<td>47 million pounds (1998)</td>
</tr>
<tr>
<td>NEW ENGLAND SHRIMP</td>
<td>Open access; 260 vessels in 1998</td>
<td>December to May</td>
<td>Trawl equipped with Nordmore grate to reduce bycatch</td>
<td>The Atlantic States Marine Fisheries Commission</td>
<td>$15.1 million (1996)</td>
<td>9,166 metric tons (1996)</td>
</tr>
</tbody>
</table>
Science is not always needed to understand consequences
Before bottom trawling

From PK Dayton. Reversal of the burden of proof in fisheries management. Science 279:821
After bottom trawling
To remain credible, we must separate environmental science and environmentalism

Science by Assertion

• Marine stock enhancement

• Marine reserves
To remain credible, we must separate environmental science and environmentalism

Science by Assertion

- Marine stock enhancement
- Marine reserves
The Myth of Diver Damage

Coral reefs are usually portrayed as sensitive ecosystems vulnerable to sedimentation, excess nutrients, disturbances from fishing, groundings, and excessive contact. Not only are corals very resilient to moderate physical damage, some corals actually require physical damage to propagate.

Were it not for physical damage, fast growing branching corals like elkhorn and staghorn would overgrow and kill boulder corals. Periodic storms are the major force that break limbs of branching corals. Broken branches that live start new colonies; branches that die provide substrate for new reef. Indeed, most reef structure is based on dead branching coral, as shown in work by Eugene Shinn in Key Largo from the 1960's.

Moreover, incidental damage to branching corals by diver contact is undetectable compared to other natural stresses. In fact, one storm can produce far more damage than hordes of divers, even at our most heavily used sites. Studies by Jim Tilmant in Biscayne National Park found that diver damage could not be detected because of the extent of natural storm damage.

Boulder corals are essentially impervious to inciden-
It can happen to anyone

20% by 2020!

“A professor bitten by the political bug ceases to be an effective scholar

--Stephen Carter (2002)
Understanding the policy process

Policies expressed by

- Goals articulated by political leaders
- Points of view expressed by staff of government agencies
- Formal statutes, rules, or regulations
- Practices of administrative agencies or courts charged with implementing or overseeing programs

Policy can occur anywhere in the executive, judicial or legislative branches
When science and policy interact, they both may become distorted

- The closer an issue is to human interests, goals or aspirations, the more difficult it is to separate scientific conclusions from other influences
Mediterranean Fruit Fly in California: 1970s and 1980s

“Just do something!”
Mediterranean Fruit Fly in California: 1970s and 1980s

Just doing something to do something in the absence of thinking is usually useless
Mediterranean Fruit Fly in California: 1970s and 1980s

Just doing something to do something in the absence of thinking is usually useless.
1990s and Beyond: Spatial distribution of trap catch
Two models of medfly infestation

Model 1 Reintroduction
- Colonization
- Eradication

Model 2 Established population
- Colonization or suppression

Detection level
Advice for the Next Generation of Ecologists

• The highest function of ecology is understanding consequences
  (Frank Herbert, *Dune*)
Advice for the Next Generation of Ecologists

• The highest function of ecology is understanding consequences (Frank Herbert, Dune)

• Variation is not noise. It is the core of biology.
Advice for the Next Generation of Ecologists

• The highest function of ecology is understanding consequences (Frank Herbert, *Dune*)

• Variation is not noise. It is the core of biology.

• The simpler the mathematical tool, the more likely it is to deliver the goods (John Hammersley)
Advice for the Next Generation of Ecologists

• The highest function of ecology is understanding consequences (Frank Herbert, *Dune*)

• Variation is not noise. It is the core of biology.

• The simpler the mathematical tool, the more likely it is to deliver the goods (John Hammersley)

• I would not give a fig for simplicity this side of complexity, but I would give my life for simplicity on the other side of complexity (Oliver Wendell Holmes)
To be more specific….

- Avoid dealing with uncertainty by averaging positions  -- do the risk analysis
• Avoid goal displacement
• Recognize the diversity of stakeholders and their different values
• Recognize that scientists have values

*The conservation paradigm*: the purpose of management is to conserve fish stocks.

*The economic rationalization paradigm*: the purpose of management is to maximize economic return to society.

*The social/community paradigm*: the purpose of management is to maintain communities, social structure, and ways of life.
Recognize that scientists have values

The conservation paradigm: the purpose of management is to conserve fish stocks.

The economic rationalization paradigm: the purpose of management is to maximize economic return to society.

The social/community paradigm: the purpose of management is to maintain communities, social structure, and ways of life.

But science is not ‘just another stakeholder position’
• Recognize that disciplines are essential but disciplinary boundaries are an impediment since they tell us what are the “right” questions and the “right” way to approach them.

\[ \frac{\partial N}{\partial t} = \sigma^2 \frac{\partial^2 N}{\partial x^2} + rN \left(1 - \frac{N}{K}\right) \]
• Read widely and think deeply

-- Seek insights from geography, history and anthropology

• Many regional problems require a geographic perspective

• Doing a Population Viability Analysis may be less meaningful than understanding the rate and direction of spread of a city
• Seek insights from economics

Understand the four horsemen of conservation

Density-dependence (what is excess production in a community context)

Common property (belonging to everyone ≠ belonging to no one)

Open access (driving towards the bionomic equilibrium)

Discounting (the future is less valuable than the present)
Seek insights from political science

Recognize the gulf between environmentalism and liberalism (indeed, all moderate politics)

“…[environmentalism] is a political movement that seeks to impose upon the natural sciences and engineering restraints based upon the findings and judgments of the social sciences”

Paehlke (1989)
• Seek insights from philosophy, ethics, and religion

-- Read *A Sand County Almanac*

-- Don’t be sophomoric when dealing with religion

10 March 1967, Volume 155, Number 3767

The Historical Roots of Our Ecologic Crisis

Lynn White, Jr.
Religion is an answer to man’s ultimate questions. The moment we become oblivious to ultimate questions, religion becomes irrelevant, and its crisis sets in. [italics in the original] -- AJ Heschel. 1955. God in Search of Man.

“Nothing that the Lord created in the world was superfluous or in vain; hence, all must be sustained” (Lamm 1986, pg 168).

The human being is the jewel of creation, but every single thing in our physical world -- animal, mineral, and vegetable -- has also been charged with divine energy and purpose, and must be treated according. The environment is sacred and no man has a right to destroy it -- Lubavitcher Rebbe
... we possess the things which God has committed to our hands, on the condition, that being content with a frugal and moderate use of them, we should take care of what shall remain. Let him who possesses a field, so partake of its yearly fruits, that he may not suffer the ground to be injured by his negligence; but let him endeavour to hand it down to posterity as he received it, or even better cultivated.

Let him so feed on its fruits, that he neither dissipates it by luxury, nor permits to be marred or ruined by neglect...let every one regard himself as the steward of God in all things which he possesses. Then he will neither conduct himself dissolutely, nor corrupt by abuse those things which God requires to be preserved.

John Calvin. ~1545-50. Commentaries on Genesis 2:15
• Pick your study species carefully: the problem is paramount
• Recognize that the world is real and be careful of words about words

“He [Comte] understood the role of natural science and the true reasons for its prestige better than most contemporary thinkers. He saw no depth in mere darkness; he demanded evidence; he exposed shams; he denounced intellectual impressionism ... he provided weapons in the war against the enemies of reason, many of which are far from obsolete today. Above all he grasped the central issue of all philosophy — the distinction between words (or thoughts) that are about words, and words (or thoughts) that are about things, and thereby helped to lay the foundation of what is best and most illuminating in modern empiricism” (pg 42).

- Help resolve the science wars in ways that facilitate discussion across disciplinary divides

\begin{figure}
\centering
\includegraphics[width=\textwidth]{chart.png}
\caption{Number of prey present vs. Number of prey consumed}
\end{figure}

Is predation a social construction?
And at the end, get involved:

It is not the critic who counts, not the man who points out how the strong man stumbled or where the doer of deeds could have done better.

The credit belongs to the man who is actually in the arena; whose face is marred by dust and sweat and blood; who strives valiantly; who errs and comes short again and again...who knows the great enthusiasms, the great devotions, and spends himself in a worthy cause; who at least knows in the end the triumph of high achievement; and who, at the worst, if he fails, at least he fails while doing greatly so that his place shall never be with those cold and timid souls who know neither victory nor defeat.

Theodore Roosevelt, quoted by John Kennedy in Profiles in Courage (1956)