



A FORUM ON ECOSYSTEM-BASED MANAGEMENT (EBM) AND ALLIED TOPICS

PROCEEDINGS

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Trenton, New Jersey**

INVITED PARTICIPANTS



***A FORUM ON ECOSYSTEM-BASED MANAGEMENT (EBM) AND ALLIED
TOPICS***

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PREFACE

As part of its Scientific Advisory Board (SAB) responsibilities, the Ecological Processes Subcommittee, Chaired by Dr. Michael P. Weinstein, presented the findings of its report *Critical Habitat for Flora and Fauna in New Jersey: Revisiting the Definition* in a meeting with NJDEP Commissioner Bob Martin. Among its recommendations was that protocols for management of New Jersey's natural resources including critical habitat would benefit from adopting principles of *Ecosystem-Based Management (EBM)* and *Spatial Planning*. Because EBM focuses on multiple activities within specific areas defined by *ecosystem* rather than *political* boundaries, and also places humans in the landscape within the broader context of the biological and physical environment, it ultimately combines ecology and human dimensions into "society-integrated" management guidelines. Commissioner Martin was intrigued by the discussion and asked how we might follow up on these subjects. It was soon agreed that a Forum to introduce the topic to NJDEP personnel was in order, and Drs. Weinstein and Buchanan developed a detailed program that included invitations to leaders in the field of EBM, Spatial Planning and related topics, Landscape Ecology, Sustainability Science and Urban Ecology. The Forum was designed to allow managers and staff to hear directly from leading experts, and vice-versa. This Proceedings from the days' sessions will function as a summary "one-stop" compilation of current knowledge and will be widely disseminated within the Department. The Forum was also timely, as EBM is rapidly gaining traction as a useful tool in the decision-makers toolkit, especially at the Federal level.

Despite several weather delays, the Forum was finally held at NJDEP's Trenton Offices on 26 March 2014, and attracted more than 60 registered staff. During the morning hours, invited speakers addressed the aforementioned topics with power point presentations, and after lunch a two hour Panel Discussion was held that addressed a series of Challenge Questions provided by NJDEP personnel. The combined findings of the day, plus several published articles on these subjects, are summarized in the accompanying Proceedings that has been distributed in-house to all Forum attendees.

We hope that you find this Proceedings useful:



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ACKNOWLEDGEMENTS

The Forum Conveners thank NJDEP Commissioner Bob Martin for his foresight and support in bringing this Forum to fruition. Special thanks also to the NJDEP Office of Science including Terri Tucker and Gwen Haile for their logistical assistance and patience with weather delays to update the schedule and all related arrangements, as well as, Joseph Bilinski and Robert Hazen for assistance and interaction with NJDEP Programs to develop the Challenge Questions. Our invited Panel Members, all leaders in their field, freely gave of their time and expertise to lead a most lively discussion, and audience interface. Drs. Jagadish Torlapati and Firas Saleh compiled and organized this document and provided oversight for the printing and publication process. Funding for this Forum was provided by the NJDEP Office of Science.

With the kind assistance of the Panel Members and NJDEP, several Appendices were made available to this Proceedings:

Appendix I – Forum Program and Abstracts

Appendix II – Biosketches.

Appendix III – Challenge Questions for the Visiting Expert Panel

Appendix IV – NJDEP Programs Represented at the Forum

Appendix V - A reprint copy of Dr. Weinstein's paper entitled *The Global Sustainability Transition: It is more than Changing Light Bulbs*

Appendix VI – A reprint copy of Dr. Fogarty's paper entitled *The Art of Ecosystem-Based Fishery Management*

Appendix VII – A reprint copy of Dr. Hecht's paper entitled *Working toward a Sustainable Future*

Appendix VIII – Speaker Power Point Presentations

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ECOSYSTEM BASED MANAGEMENT (EBM) FORUM: SYNTHESIS OF PRESENTATIONS AND PANEL DISCUSSION

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INTRODUCTION

In response to New Jersey Department of Environmental Protection's (NJDEP) expressed interest to learn more about Ecosystem Based Management (EBM) and related spatial planning principles, and the potential to identify and adopt some or most of those concepts in NJDEP's environmental management "toolkit", the *Center for Natural Resource Development and Protection* (CNRDP) at NJIT conducted a one-day Forum at NJDEP headquarters in Trenton, NJ on 26 March 2014. The overarching theme for the meeting was focused on Commissioner Martin's query "how can we look at these [EBM] concepts more broadly" in managing the state's natural capital? The effort brought scientists and managers from NJDEP together with a group of academic and government scientists in a day-long effort to introduce the subject of EBM and explore its use of EBM in managing New Jersey's vast natural resources. A conceptual outline of the project follows, along with a statement of need, goals and objectives, and a format to conduct the effort. The audience for this Forum consisted of NJDEP personnel from various programs and disciplines.

Need for the Forum

Because growing demands on coastal resources can no longer be met by access to unexploited resources, conflict management and consensus building will become the norm for sustainable natural resource management. An integrated systems approach is required, taking into account conflicting goals and inter-linkages among environmental issues, as well as the geographic scales of both the issues and political jurisdictions. The multidimensional nature of these conflicts – their normative framework, complex knowledge basis, and the amalgam of empirical knowledge – makes the task challenging, but progress is being made with current efforts at *Ecosystem Based Management (EBM)* and *Marine/Watershed Spatial Planning*. For example, the US Commission on Ocean Policy (2004) recognized that "ocean policies cannot manage one activity, or part of the system, without considering its connections with all the other parts ...". Thus, the potential for sacrifice, compromise, and tradeoffs will need to be addressed in a consensus building paradigm.

Scientific understanding of both ecosystem processes and of the underlying role of variability in maintaining ecosystem resiliency (that might otherwise descend irreversibly into degraded states) has advanced in the past several decades. As a result, emerging management approaches can begin to conform more closely to ecological and societal values rather than being driven by

purely political constraints. Scientists speak of the need to better understand “coupled human-environmental systems” (CHE)¹ as the foundation for science informing policy and improved natural resource management.

While the need for more comprehensive EBM is understood, it should be noted that the NJDEP has taken steps to incorporate these concepts in at least some of its programs (e.g., coastal management, water resources, and fisheries. This Forum was developed to expose and inform all programs to contemporary EBM concepts and methods. At this Forum, Deputy Commissioner Michele Siekerka emphasized the need to think comprehensively in using EBM, to work with other agencies and external groups, and to effect iterative improvement in the State’s ecosystems.

FORUM TOPICS

The Forum was organized around the central theme of EBM but included related topics that established a framework for interactive discussion. A brief summary of these topics and the invited speakers follows. The list of topics was finalized after review and input from NJDEP staff:

1. Systems Theory and Complex Adaptive Systems (CAS)

Speaker 1

- **Peter J. Morin**, Department of Ecology, Evolution, and Natural Resources, Rutgers University

Systems theory is concerned with both wholes and wholeness. It emphasizes connectedness, context, and feedback as underlying components and processes. The understanding arising from systems theory comes from integrating knowledge of how parts of the system work together, rather than how they work in isolation. Of particular interest to sustainability scientists is the observation that complex adaptive systems (CAS) also have emergent properties and phase transitions not normally observed in simpler systems: nonlinearity, uncertainty, multi-scale interactions, emergence, hierarchy, and self- organization (Levin 1998; Anderies *et al.* 2010; Solé 2011). CAS structure is often hierarchical or nested. Phenomena at each level tend to have their own emergent properties that are coupled by feedback loops and allow the system to be self-organizing and buffered against external forcing. Most importantly, because of the multiplicity of scales, there is no one “correct” perspective on a complex system. CASs are comprised of agents that interact locally based on information they use to adaptively respond to their environment. Behaviors typically emerge from such interaction that are not imposed or predetermined (Levin 1998; 2010). Unlike their linear counterparts, numerous potential equilibria may co-occur as multiple stable states or stability domains in CASs.

¹ The dynamics of CHEs relate to the ways their behaviors emerge from adaptive actions by their constituent agents, interacting across multiple scales. Unraveling the complexity of CHESs will require the merging of holistic and reductionist perspectives into integrated physical, social, and biological sciences, and scales from the genomic to the biosphere.

The concept of CASs may be extended further to address the interrelationships between humankind and nature in Coupled Human Environmental systems (CHE)(Gunderson and Holling 2002; Berkes *et al.*; Anderies *et al.* 2010) . CHEs can also organize around one of several equilibrium states (or “attractors”). When conditions change, feedback loops act to maintain the current state, but at a certain threshold the system may move to a new stable state. Like any CAS, CHEs are often unpredictable. An important observation of the behaviors in CHEs is that they cannot be understood, let alone managed, through scientific activity organized along traditional disciplinary lines (Jasanoff *et al.* 1997), but require a transdisciplinary approach. While sustainability science focuses on macroscopic interactions between humans and their environment, it must be recognized that control may rest at lower levels of organization. Thus, a more complete, more systemic understanding of emergent behavior in CHEs is critical to unraveling how such systems can promote sustainable development.

2. Landscape Ecology

Speaker 2

- **Brian J. Clough**, Grant F. Walton, Center for Remote Sensing and Spatial Analysis (CRSSA) Rutgers University

There are numerous reasons to adopt a landscape approach to managing natural resources. First, the sustainability of many systems varies on spatio-temporal scales that are linked in both bottom-up and top-down directions. Secondly, the landscape represents the most pivotal scale for place-based ecosystem management because “landscape gives identity to place and landscape is where past and present meet” (Phillips 2007). The term “landscape” connotes both ecological and social elements that address spatial scale and the different aspects of a landscape that are emphasized. Human perceived landscapes, for example, coincide with geographical units such as watersheds or urban centers. These spatial domains of human perception also resonate well with the public and decision-makers “who are conscious of the environmental setting in which they live, work and play” (Wu 2012). Secondly, ecosystems are highly complex and may be viewed as multi-scale hierarchies; i.e., they constitute spatially heterogeneous areas of various sizes and should be managed as such. Different species perceive and respond to spatial heterogeneity at different scales, and patterns and processes in the landscape tend to have these different characteristic scales. Again, the biota respond to ecosystem boundaries, not the artificial political constraints we place on the ecosystem components that we manage (e.g. “transition areas” in wetlands

3. Urban Ecology and Coastal Seascapes

Speaker 3

- **Michael P. Weinstein**, Center for Natural Resource Development and Protection, New Jersey Institute of Technology

By 2050, approximately 60% of the world’s population will live in urban settings; in the United States that percentage is now nearly 80%! This demographic shift has led to some habitat loss

and alteration, regional and local climate effects, changes in water resources, and increases in pollution. Perhaps more than most human-dominated ecosystems, the urban setting presents a plethora of opportunities to link ecological and social science theories using resource economics concepts. There are growing opportunities to integrate knowledge of the flows and cycles of critical resources in urban ecosystems with social and governance institutions into a new paradigm for landscape management (Zonneveld 1989). While urban-rural gradients are complex, multidimensional constructs, the analysis of such systems has become a powerful tool for understanding ecosystems across a wide range of defining variables, stress factors, disturbances, and other drivers. Common themes in urban sustainability science research include questions of hierarchy and scale; how they are related to our ability to understand the dynamics of landscape change, biodiversity, wildlife distribution, and vegetation patterns; and the reciprocal relationships among all of these factors and human activity.

4. Sustainability Science and the United States Environmental Protection Agency (EPA)

Speakers 4 and 5

- **Malin L. Pinsky**, Dept. of Ecology, Evolution, and Natural Resources, Rutgers University
- **Alan D. Hecht**, Office of Research and Development, USEPA

By focusing on the science–policy interface, sustainability science addresses the fundamental character of interactions between nature and society, and society’s capacity to guide those interactions along sustainable trajectories. For the USEPA, this means going beyond an existing regulatory framework and “advancing an environmental policy and research agenda that promotes sustainability science, innovation, and problem solving ...sustainability science must be [a] major driver to advance economic growth while protecting the environment and human health”:

Sustainability is based on a simple and long recognized factual premise: Everything that humans require for their survival and well-being depends, directly or indirectly, on the natural environment. The environment provides the air we breathe, the water we drink, and the food we eat. Recognizing the importance of sustainability to its work, the EPA has been working to create programs and applications in a variety of areas to better incorporate sustainability into decision-making at the agency. To further strengthen the scientific basis for sustainability as it applies to human health and environmental protection, the EPA asked the National Research Council (NRC) to provide a framework for incorporation sustainability into the EPA’s principles and decision-making.

This published framework, *Sustainability and the U.S. EPA* (NRC 2011), provides recommendations for a sustainability approach that both incorporates and goes beyond an approach based on assessing and managing the risks posed by pollutants that has largely shaped environmental policy since the 1980s. Although risk-based methods remain important tools, the report concludes that they are not adequate to address many of the complex problems that put

current and future generations at risk, such as depletion of natural resources, climate change, and loss of biodiversity. The report suggests that sophisticated tools are increasingly available to address cross-cutting, complex, and challenging issues that go beyond risk management. The report recommends, moreover, that EPA formally adopt its sustainability paradigm the widely used “three pillars” approach², which means considering the environmental, social, and economic impacts of an action or decision. Health should be expressly included in the “social” pillar. EPA should also articulate its vision for sustainability and develop a set of sustainability principles that would underlie all agency policies and programs.

5. Ecosystem Based Management

Speaker 6³

- **Vincent S. Saba** and **Michael J. Fogarty**, Ecosystem Assessment Program Northeast Fisheries Science Center, NOAA

Ecosystem-based management (EBM) emerged in the late 1980s as an alternative to the piecemeal, jurisdiction-by-jurisdiction approach to natural resource management that dominated the twentieth century. EBM features three central attributes: (1) planning at a landscape scale, (2) collaboration with stakeholders, and (3) adaptive and flexible implementation. According to its proponents, EBM can generate management that is not only ecologically sensitive and responsive to new scientific information but also widely accepted. Application of EBM has yielded some important environmental benefits, including improvements in scientists’ understanding of large-scale ecosystems.

EBM also focuses on multiple activities within specific areas defined by ecosystem rather than political boundaries. It places humans in the landscape, within the broader context of the biological and physical environment, and ultimately combines ecology and human dimensions into “society-integrated” or transdisciplinary ecosystem management (NRC 2002). Scientific understanding of both ecosystem processes and of the underlying role of variability in maintaining ecosystem resiliency (that might otherwise descend irreversibly into degraded states; Holling 2000; 2001) has improved in the past several decades. As a result, emerging management approaches can begin to conform more closely to ecological and societal values rather than being driven by purely political constraints.

6. Marine/Watershed Spatial Planning

Speaker 7

- **Kris Ohleth**, Mid-Atlantic Regional Council on the Ocean (MARCO)

Marine/Watershed Spatial Planning emphasizes the broader “problem-shed” (the area that encompasses all of the affected stakeholders), and is specifically designed to address competing uses. Its success depends on the ability to create new paradigms that will resolve the growing

² NJDEP has adopted a similar framework in its watershed management and sustainability initiatives (M. Siekerka, pers. commun.)

³ Presented by V. S. Saba

tensions among the involved communities. New policies for knowledge production and dissemination in which multiple stakeholder groups are involved are critical to this approach. Social scientists suggest that “soft factors” such as the values, attitudes, interests, and aspirations of stakeholders should also be incorporated into the development process. If these are neglected in the formal and legal rules systems, escalation of existing conflicts may ensue.

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A FORUM ON ECOSYSTEM-BASED MANAGEMENT (EBM) AND ALLIED TOPICS

FACILITATED DISCUSSION (INVITED PANEL AND ATTENDEES)

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DISCLAIMER

Original panel discussion transcript prepared by Toby Feldman Inc., and edited by Dr. Michael P. Weinstein, NJIT Center for Natural Resources Development and Protection (CNRDP), and Gary A. Buchanan, Office of Science, New Jersey Department of Environmental Protection. Any errors, omissions, or misrepresentations in the edited text are wholly those of the Editors.

EDITED FORUM DISCUSSION

The Panel Discussion began with a summary posting of Challenge Questions (see below) provided by NJDEP personnel (the full list of Challenge Questions appears in Appendix I). The Moderator asked Panel Members, in turn, to briefly address these questions, then opened the discussion to the full list of questions and audience participation. Rather than recognize individuals by name, a general approach was taken to identify speakers only as “Moderator”, “Panel Member” or “Audience”. A very lively and enthusiastic discussion and interactions among attendees ensued. The hope is that this discussion will serve as a springboard for future planning on the topic of Ecosystem Based Management and Spatial Planning.



EBM FORUM (26 March 2014) Challenge Question Summary

1. How can EBM integrate economic, environmental and social components of sustainability without negating the goal of critical habitat conservation, and future mitigation efforts?
2. With build-out on the horizon, how should the NJDEP prioritize its protection and management of ecosystems to foster resiliency?
3. Ecosystem goods and services are values related to human use. How important is ecological integrity/condition (independent of humans) in implementing EBM?
4. Several ecosystem classification systems already being used by the NJDEP. How do you find a common language to communicate and effectively conduct EBM in NJ?
5. In a policy context, how does EBM address impediments to sustaining important ecosystem processes?
6. Ecological units have values in and of themselves, and therefore EBM cannot always replace single species management designed to restore and/or maintain species populations. What are your thoughts on this?
7. Describe data limitations and future data needs to accurately and fully implement EBM within the marine environment, specifically marine fisheries systems.
8. How can you effectively manage at the ecosystem level when there are multiple regulatory agencies, or states, with various authorities and oversight, and with potentially different goals and objectives involved?

MODERATOR: (to Audience). Every panel member was impressed by your list of Challenge Questions. I took the full list (Appendix I) and excised out the cross-cutting elements to shorten the list to one page (see above), and I suggest we'll start with these, but you should have your full sets of questions in your folders, and feel free to add to anything that needs to be answered and which goes beyond what we have here. The protocol that we'll use to proceed is my asking our Panel members to first to introduce themselves, and then addressing each question in turn. Dr. Hecht, I'm going to ask you to address Question #1; how can EBM integrate the "three-legged stool" and other components of sustainability science without negating critical habitat

conservation and future litigation efforts that NJDEP undertakes?

PANEL MEMBER: I think there are some common themes that have emerged today, and I think it's important that they be shared with federal agencies, with states, and even with stakeholders, so I think when you summarize this, it will important to capture the recommendations or at least the common themes. I deal with things like breaking down silos, collaboration among regulators, and I'm also dealing with the reality of today's world. We're trying to be innovative and designing things for the future, so I look forward to working with you as you move forward.

Now, of course, one of your big themes is ecosystem-based management, and I think one of the challenges is first to make sure there's a common understanding of terms like "green infrastructure" and "ecosystem services" and "natural services," so I think definitions are very important. And it's basically how can we use the natural system in a way that protects it, but also allows for its economic and social benefits to be contributing, in part.

Your question deals with how to do this in light of negating habitat conservation or functionality or whatever. And I'm interpreting that to mean that we may have some existing rules and regulations like conservation rules or so on, that may be a limitation or may be a factor that we have to deal with in terms of using ecosystem services in a whole other sense. And that goes to the general question we've had before about how flexible can we be with existing rules and regulations and how can we adapt them and be innovative in using them.

But I think the approach that sells arguments are good case studies and examples. And the more we can put together a clear example of how this is working, the more people can buy into it in terms of understanding what it is. I think overall, it's an important element, certainly in EPA and elsewhere, an element of sustainability that has to be taken into account as we move forward, and I think your recommendations or this discussion on this panel could go a long way in helping.

MODERATOR: Because these are taken from the longer list of questions, does anyone else want to amplify on this particular one? And, if not, we'll go on to Question 2.

PANEL MEMBER: If the goal is to balance economic, environmental and social components of sustainability and achieving those sustainability goals that rely on habitat conservation, then mitigation of impacts is a critical component of meeting those goals. They're not necessarily in conflict, that's how I see them given the limitations that you were talking about Dr. Hecht.

MODERATOR: I like what we're doing; i.e., let's make the responses to each question interactive, and if you feel you want to embellish the question, do so, but first, please identify yourself.

AUDIENCE: I didn't write this question [#1], but working for the Endangered Species Program; economic issues, political issues, etc. do come into play, and critical habitat issues don't always win out. And I think perhaps that might be where this question was headed.

MODERATOR: Does anyone want to react to that? Dr. Hecht?

PANEL MEMBER: That was one of the examples I was going to raise. If your goal is sustainability and you say, "Okay, we want wind, offshore wind, but if it affects let's say bird

migration or species behavior, the question is how do you resolve it?”

MODERATOR: Anyone else wish to amplify on that? No, I suspect that we'll be coming back to this question. Let me go into the second question, with Dr. Saba as our “volunteer”. New Jersey’s build-out on the horizon, how should NJ DEP prioritize its protection and management of ecosystems to foster the resiliency we're all talking about?

PANEL MEMBER: I'm coming from a biased research perspective in terms of how my answer would be applied, and how it may relate to state government, or the Environmental Protection Agency. In terms of how to move forward and prioritize protection and management, especially in those ecosystems that might be most sensitive to anthropogenic perturbations, both direct and indirect; for example, climate change, is that we try to focus on those areas in our region and individual species or species assemblages that may be most sensitive to future climate change. Please note that I am addressing climate as just one specific example, it could be many effects, like eutrophication, pollution, etc. The more data and good science we have now, the better we might make future projections in terms of climate change and how the ecosystem could respond. And the same could be done with smaller, more local ecosystems within the state in terms of how ecosystems may respond to future development, and which may be more resilient. The ability to make projections is based on how much science has been done, and it might very well be that some of these ecosystems that are most sensitive may be, as Dr. Morin pointed out, less diverse, and may be the least studied. I think the key focus has to be on where all the good science is coming from and what the key uncertainties are as well. Something that we deal with in our region is to address uncertainty, so we think we know what the process is or how it functions in the present, and then we think about future scenarios with changes in the climate, things that we really can't do anything about right now; e.g., keeping emissions as they are now, or lowering them. We know it's presently happening, it's going to continue happening. We try to base our potential management, scenarios on sound science that's being done, but we always need to be aware of the uncertainties involved. And when these decisions could affect people's livelihoods in terms of, for example, changing catch quotas for fishermen, redirecting target species to other species that may do better in a warm ocean, we need to be careful that we not only fully examine all the science involved in making these decisions.

AUDIENCE: I spent some time on the hazard mitigation program, and we talked a lot about risks and risk reduction. I'm wondering if to address some of the things that you just mentioned, maybe there's some kind of risk analysis that needs to occur as part of the equation in terms of the decision-making process.

PANEL MEMBER: I used to work as a risk assessment person when I was in the private sector. I did ecological risk assessments. Maybe that's what you're getting at. I don't know if New Jersey does this, but for the US Army Corps of Engineers, risk assessment was a common science. But I'm not sure if that's done on a state agency basis or not.

MODERATOR: Let me respond to that. We're doing a risk assessment (an Environmental Constraints Analysis) for NJDEP in the aftermath of Hurricane Sandy. New Jersey universities have been engaged by the State’s GORR office. Our task is to look at the preliminary engineering plans, including green infrastructure, and through a qualitative risk analysis, assess

the effects of the infrastructure footprints on natural resources and on ecosystem goods and services. The idea is to protect people and property, while ideally, at the same time, reducing the potential effects on natural resources. The way we stated it at the first of two “town meetings” with stake-holders way was first, protect people and property, but if we can during that process minimize effects on our natural resources but “adjusting” the alternatives and choices through our qualitative risk assessment, why not?

At the first town meeting, we presented the natural resource inventory we planned to use, then at the next town meeting we're going to put the engineering designs onto the maps and say, "here's what we think". If you choose this design, here are the potential effects, but if choose this or that alternative, or modify a current design you might achieve the best of both worlds. So that's a very small step, and if we didn't pose this, it wouldn't have happened. We believe it is a step forward in the decision making process.

So there are lots of things that can be done right now, and it just takes a little bit of imagination and political will. We've got to give our decision-makers the wherewithal to be able to weigh alternatives.

PANEL MEMBER: With respect to prioritization, we need to know whose priorities we're talking about. If we're talking about the NJDEP taking statewide approach to ecosystem assets and priorities, then we're looking at statewide ecosystem assets, and at that level we're managing the state. But, we also have our counties, we have our planning agencies, and municipal governments so I think what's really important in this discussion is whose specific assets are we making decisions about, and how do we agree at some level, with local needs and interests? Just what boundary or ecosystem you're talking about is important. You can't manage resources if you can't agree on what you're managing, right?

MODERATOR: Does anyone want to say something more? We're managing to the people of New Jersey. That's who we're managing for. We need to get the people of New Jersey to the table. We need to give them the tools for understanding the consequences of their decisions and actions and to see how the politicians respond.

PANEL MEMBER: I want to make a distinction between the sorts of societal and even political processes in making those kinds of decisions. And then trying to bring the best science you can bear to the question of how we actually meet those goals. One thing about this question in particular is that it wasn't just protecting ecosystems. It was protecting the resiliency of these ecosystems.

And there's something that Dr. Morin brought up earlier, there's quite a bit of knowledge about how complex adaptive systems are or are not resilient. And I think they're fairly abstract concepts, but I think they can be really valuable in this context as well, so diversity is one key aspect of that, in part because it allows for complementarity among different components of the ecosystem. Maybe one species is declining, but another species is increasing. We saw this earlier about how fish catch has been relatively stable in the northeast U.S. and yet the composition of species within that trend has been quite variable. Fewer species were fished and fewer species were available to be fished.

Other components of complex adaptive systems that make them resilient is the idea of modularity. It's not that everything is really well connected, but actually, there are subcomponents, or modules. It might be functional groups within subcomponents. It might be

units within a landscape. And it's within these modules that you really care about complimentary diversity. And you also need connectivity between these modules, at least at some level, so that there can be, as one example, re-colonization if there happens to be a local extinction. You get colonists from other parts of the system.

There's also this tension between wanting stability from an economic perspective and yet natural ecosystems are highly variable. But I think what we learned from complex adaptive systems is that it largely has to do with what scale you're looking. So natural ecosystems are naturally quite stable at a high level because there's a lot of variability at lower levels. You might have species replacing each other and, therefore, they confer stability at a functional level. So there is actually a way to meet those seemingly disparate goals at the same time.

PANEL MEMBER: Going back to the question of the need to identify stakeholder needs and values at the regional versus the state level. This is actually something that community colleges and political geographers engage in as well. When I was talking about scale earlier, I was talking about it in a purely landscaped context, but this would be another excellent potential academic policy linkage to engage people who are more familiar with scale in terms of social and political relevance.

MODERATOR: One concern I have is the difference between stable versus resilient ecosystems is that you may experience shifts to new stable states may not be very desirable. I would say forecasting gets really difficult in these type of situations.

PANEL MEMBER: That was something I was going to touch on in one of the later questions, but long-term monitoring of these systems becomes critical both in terms of understanding what's going on and potentially in terms of getting early warning indicators that there may be undesirable changes.

MODERATOR: In other words, we're working on it?

PANEL MEMBER: Yes.

MODERATOR: Let's go on to Question #3, and I'll ask Dr. Morin to respond.

PANEL MEMBER: I'm going to begin by saying that there's controversy about both of these sentences. The first is how we value ecosystem good and services, and one would say we've always had these things before there were people and we'll probably have them after there are people, and so the value that we attempt to put on this has become somewhat arbitrary at the moment and, if anything, it's just pragmatic because people may try to make the monetary argument for why these things should be preserved on the basis that money talks and nothing else does. That's essentially my first, I realize cynical, comment.

The other comment, though, is that people have attempted to put value on these things, perhaps the most famous example is by Bob Constanza, who with colleagues back in 1997 published a paper in *Nature* evaluating, by "back-of-the-envelope" calculation, what the monetary value of the planetary ecosystem services were¹. And there was a lot of controversy

¹ Editor's note: NJDEP has funded research on *Valuing New Jersey's Natural Capital*; reports can be found at www.state.nj.us/dep/dsr/publications/pub.htm#economics

about that, but they did the calculation and they commented that if you had to pay for this stuff, it would be approximately equal to the gross national product of the entire planet, and you're getting it for free. That was essentially their argument.

Now, the counter-argument from the traditional economist is that you can't put a value on something that you don't pay for, and so the traditional economist simply says, "No, no, you can't do that. That's not the way economics works."

And ecological economists were trying to flip it the other way around and say, "Well, if you were building a planetary support system from scratch after activating the "Death Star", or something like that you might ask the question what is its cost?" And that argument continues. So there's the second aspect of it.

Now, the last thing is how important is ecological integrity or condition of the system? Again, I think you can play that out. When people going all the way back to Hal Mooney and Paul Ehrlich started talking about these kinds of things, they suggested that the contribution of every species could be important to integrating ecosystem services. And as a result, they thought that this might be an important argument for conserving these things.

But the problem is that an increasing number of experimental studies have been done, by Tillman, Logan, by me, and by everyone in their own niche, what we found was that you can lose many species and still maintain a fairly high level of functioning throughout the various services. So it's not an all-or-none kind of thing. And that argument cuts both ways. That means you don't have to preserve only pristine systems to maintain functionality. And that's important because we don't have many pristine systems left. So basically, almost everything is worth saving and managing, even a Phragmites marsh. That's the good news.

The bad news is that you do lose some level of functioning as you lose some of the species, but it's very non-linear, so the trend goes pretty flat until you lose what's essentially the last species in the functional group, an autotroph, predator or a consumer of some sort, and then bang, we lost that component of functioning. So it's not an all-or-none kind of argument. I think it's very much a matter of perspective. You can make the argument that almost everything is worth saving and managing, and then it becomes more of an issue of once you've got it, can you restore it to a higher level of functioning, and that's the tricky bit. That's putting Humpty Dumpty back together again. Sometimes you can do it and sometimes you can't, and that's a long-winded answer.

AUDIENCE: One thing that I've been challenged with in studying complex systems and resiliency and sustainability, and trying to tie them together, is they're not tied together very well! When we talk about resilience, when we talk about panarchy, we're talking about sociological systems. And in social science, the belief is that a lot of the technology and our built environment supports us just as much as ecosystem services do. Natural functioning isn't accounted for. We've got resistance in the engineering literature, the technological and sociological literature.

So I think in a question like this, you have to think about whose functions you're talking about. Are we talking about the resilience of the ecosystem and its provision of services? Are we talking about human related functions? Or are we actually talking about the interplay between sociotechnical and ecological integrity? And I would argue it's the latter, but again, it's generally not clear what it is that we're trying to focus on in our research and in our policies.

PANEL MEMBER: Yes. The human component is supportive and the technology is supportive.

Realistically, though, what most of the ecologists have done is they've just looked at the natural part of the system and they're saying here's how these things function in the absence of any impact that we have other than changing say diversity or functional composition and things like that. So the whole natural system-human interaction part is not as well supported at all. It's tough to do it experimentally. It's not easy to do theoretically either, but it – once again, silo mentality is a challenge.

I'm an ecologist. I study everything but people, even though I probably should study people, too. So your point is well taken. Beyond that, I think that we can probably generalize just by looking at these things in the abstract sense as complex systems and saying here's how this complex system works and here's how systems with different complexity works. And we start adding the complexity of human-natural system interactions into that. That's a whole other way that we could take it. I don't think there's a pat answer.

MODERATOR: Let me add the consideration of baselines (“shifting” ones aside!). You might consider the baseline for urban wetlands in the New York/New Jersey harbor to be quite different than the baseline for wetlands in the Delaware Bay. And if you accept this, then the target goals for improvement, as was mentioned earlier, are quite different.

For example, the *Phragmites*-dominated marshes in the Hackensack Meadowlands do indeed support a fauna, but the fauna, at least some in the wetlands where I work, don't do as well in the *Phragmites* marsh as they do in the *Spartina*-dominated marsh. But *Phragmites* is great at holding the soil together and resists erosion. So, in the latter context, why not leave the Hackensack Meadowlands alone (present baseline), and rather than declare an all-out “war” on *Phragmites* in Delaware Bay, adopt a more modest approach to simply break up the monoculture, and that forms the site-specific baseline. The idea is to identify the main parameters and criteria for developing the baselines. Obviously there are multiple parameters to address, and I have suggested just one, but we're talking about baselines and that should bring together all of the human elements, social economic and natural, that would result in different baselines for different locations. And that I suggest is one way to approach this subject.

With respect to Question #4, to address the issue of a common language, I suggest that you set up an advisory body to work this issue, and come up with a glossary and dictionary of whatever it is we need to put into common language. Again, when we develop the sustainability science curriculum, you'll have engineers taking economy courses and ecology courses and vice versa. That's going to help because it's going to create a common language so that we can speak to one another, something we don't do very well right now. People will be able to translate what the others are saying into their own language, if nothing else. So that's one step, there are many more.

PANEL MEMBER: I'd like to put in a plug for the Data Portal, I think spatial representation can be a really valuable tool for communicating amongst stakeholders. Having maps and figures can facilitate that communication. I think that's a really powerful tool. We try to homogenize some of the language in the Data Portal by not using, really technical terms, but rather by allowing folks to understand by visualization.

MODERATOR: That's exactly what we're doing in the ECA related town meetings I mentioned earlier. We posted many relevant maps of the areas affected by Hurricane Sandy, and asked attendees to place an “X” on the map where your house was washed away, or where you know

extensive damage has been done, and so far, that has been a good way to go.

AUDIENCE: So you're talking about common language for definitions, communications, that kind of thing, but there's also common value to consider. We are doing work in Barnegat Bay an important regional asset. People come from Washington D.C. to the Barnegat Bay, but are we going to be able to do the same thing in other areas that have as much, more or less value on a statewide level?

We don't go with a common language within the Department in terms of whose values and whose boundaries we want, so if we can't find a common language amongst one agency, let alone amongst all the state agencies, let alone the state and the federal government, and the regional planning, you know, that's the problem. It's like a new challenge question trying to agree on the meaning of value.

MODERATOR: After this next question we'll go to the rest of the audience, but sustainability science is, in a sense, grounded in place-based issues, so for the community living on say one of the more polluted water bodies in the United States, they will likely have a very different set of values than the folks that live in some densely populated places, like along the shoreline of Barnegat Bay. So what comes to mind when I hear these kinds of discussions, is what Bonnie McKay and others do, the human ecology discipline or curriculum. The social scientist is the key here and we haven't engaged a social scientists very well in terms of managing natural resources. And to get into the appropriate landscape, social scientists need to play a larger role.

Okay, so we addressed common language and now we go back to Dr. Saba. How do we sustain important ecosystem processes? I think we've already begun to answer this question with EBM addressing the impediments to sustaining ecosystem processes.

PANEL MEMBER: Thanks. I can pull examples from our experience with fisheries management and our use of closed areas. One issue with this question (Question #6) is that it assumes EBM is already in place in the context of policy for our region, which it is not. We're still in the prototype stages of adopting EBM, however, our use of closed areas is probably the best example that I can think of. When we close an area to all fishing, for example on Georges Bank, do we see these ecosystems bounce back? The answer is yes we do, so some of the inherent processes that are important for scallops, say getting a three-dimensional structure back to the habitat, changing the composition of the predators that will be involved, and getting all these things back in place, closed areas seem to work for the most part in our region. But I guess it's really a question of which ecosystem process you're talking about. If you're talking about say the bottom-up process, you might be trying to address community structure at the base of the food web. But there's only so much we can do at the moment to affect this or any other process.

You've probably heard about people trying to fertilize the ocean with iron to try to get more carbon dioxide drawn out of the atmosphere. This doesn't go over well both scientifically or politically, largely because of level of uncertainty, and we really don't know a lot about how that stuff even works or even if it could work, so it's really a question of which process you're talking about. But typically from our federal level, management perspective, it's a top-down process that we can invoke in terms of closing fishing, and by just closing off the ecosystem altogether we let those processes get the system back to where it once was, or at least get close to it.

PANEL MEMBER: So the question that was posed in the program is a little bit more pointed. Ecosystem processes that are referenced are disturbance processes, such as fire in the Pine Barrens, storms like Sandy, and disease outbreak and what they do to ecosystems and some of the species and habitats in that ecosystem that are dependent on those disturbances.

How does ecosystem-based management address those processes (like fire) because of the potential conflicts with societal values invoked that we're trying to protect, like health and human safety. There are impediments to replacing those natural disturbances with human-made substitutes, so how do we get around that? That's the question.

AUDIENCE: Say we're managing the Pine Barrens by starting fires, for example, how do we make up for the loss of this management tool? Is that what you're suggesting?

PANEL MEMBER: Yes. Where you can't do that, what else can you do? How does ecosystem-based management inform that question?

PANEL MEMBER: Unfortunately, I can't pull specific examples from our region because ecosystem-based management isn't part of our policy, our official legislation yet. It's still all single species-based. I can only do hypothetical examples, but in our case, the disturbances, at least in the marine environment, typically from fishing, at least in the offshore regions, away from eutrophication, pollution and things like that, we're talking about fishing mortality. And so ultimately, it still comes down to closing down areas or cutting back on how much you can take from the ecosystem. I can't really pull from such examples, but maybe some folks here on the panel can.

PANEL MEMBER: In reference to the specific question of fire regimes in the Pine Barrens, I think that's a classic example of where there's this inherent conflict in the way people are using the landscape and the patterns of those natural disturbances. Implementing predictive models does have a lot to add towards that, at least pointing out areas we feel that we can manage more effectively versus those we feel we can't. And also in terms of identifying those regions across space, and in terms of informing safe practices in ecologically logical ways. So the primary goal may be to simply reduce the fuel load. We can take action without some of the species that are dependent on these kinds of disturbances as well.

One example is where you pull in a landscape predictive model to address this management problem and then say, "let's consider a few different scenarios in reference to the distribution of this particular species or maybe a certain ecotype in general," and that may be a good way forward.

AUDIENCE: I hear what you're saying, but I think ultimately, that's just sort of chipping away at the problem because what you're doing is simply drawing a box over here and saying, "we're going to be creative here and make it this lovely ecosystem," but then we still have development inching in. And so eventually, this can no longer be managed by fire, and now we're trying to do another spot, so we're just sort of chipping away.

I think what you were getting at was in those scenarios where we have habitat adjacent to residential communities, how do we meet the criteria-- how do we balance that? How do we make it so we maintain that ecosystem by fire and provide public safety. What would be the best format? I know you probably can't answer that question.

AUDIENCE: I think we're talking about the problem on multiple levels. There's an immediate need to conserve rare and endangered species, to maintain populations of these species at viable levels, etc. In that case, I think about what you can do that now makes sense, but then the larger question is, how is this going to interact with regional government policies going forward for the next decade, several decades or maybe even several centuries.

That's where thinking about the temporal scale as well as the spatial scale that you are managing at is relevant and may become really beneficial. If we could wind back time and more critically examine the conflict of the natural fire regime with development in managing the Pine Barrens, maybe then there'd be an opportunity to do something a little bit different. So at the very least, we can think about ways forward from here that can prevent future kinds of conflicts from cropping up down the line. For the particular case of fire regimes at that suburban-wild interface in the Pine Barrens, that's a whole new "can of worms" in and of itself.

AUDIENCE: Just to echo that point, from a planning perspective, there are some things that have been done that we can't undo, and perhaps if we had the data, the planning tools and the coordination 50 years ago, a 100 years ago, we wouldn't have done a lot of the things we've done over this past century. And I was struck by a figure I saw of two overlaid slides that were dealing with these kinds of post-Sandy issues, and first one showed the traditional flood boundaries and all of the places where water used to flow and inundate. And then they showed the second slide of the major destruction from a storm and they were pretty much 100% correlated. The point that the speaker made at the time was, well at least we now have the information that can better inform our decisions going forward.

PANEL MEMBER: One of the things my doctoral advisor used to say was the best way that you can preserve intact ecosystems was to give them to the Army, but don't give the Army any money to do anything. And we've got some really good examples of that in here in New Jersey, basically, you don't have neighbors! That's one way that we can do this and it's an unintended consequence of having that kind of patchy land use in the Pine Barrens and other kinds of forests. And it doesn't just happen here.

A couple years ago, I was in Germany doing some panel work and we went on a field trip to a beautiful swamp of European beech forest. It was one of the most extensive chunks of beech forest left in what used to be East Germany. And the reason why it's there is that that's where the Warsaw Pact used to do their tank maneuvers. And now it's the best-looking piece of real estate around, and they're doing fabulous ecological research there on nutrient cycling. And that place would not have been there if it hadn't been for that particular situation. It would have been turned into farms, villages, et cetera, but instead it was a buffer zone between East and West Germany, and now it has tremendous ecological value.

So there are ways around some of the most challenging stuff. If you can create what are essentially buffers, you can separate people and the core areas that you want to preserve.

PANEL MEMBER: That's actually what I was going to bring up as well. Often it's not a matter of protecting against land development. We often need certain other kinds of zones that are managed in various ways, e.g., buffer zones being used in more ways than core protective areas can be, by trying to place some distance between more natural fire regimes and man-made structures you're trying to protect.

In some ways you can think of it as a variation all the way from complete wilderness to a cornfield. It all depends on how carefully we manage it. At one end you've got a more natural fire regime. Towards the other end maybe you may be trying to mimic a fire regime with other kinds of human disturbance, e.g., mowing or some other kind of disturbance that doesn't fully recreate the fire regime, but maybe meets a couple of goals that are still feasible to reach, in close proximity to the goal.

AUDIENCE: Ecosystem-based management sounds wonderful. At the end of the day I'll probably go home thinking it may possibly solve all of those problems. My 23 years as a regulator, in those silos, have left me proud of what I do and think I have accomplished things, but I could leave regulating in a heartbeat; it's not a fun way to make a living. If there were a better way to protect ecosystems, I would have switched and started doing that a long time ago. My problem is I still at least partially find it to be the most realistic and effective way to achieve that goal.

I know planners. They're great people. We have lunch occasionally. I know people that buy land and preserve it and it's hard not to argue with those philosophies and those senses, but I think the reality that I'm more familiar with is that there's not enough money in the entire country to solve New Jersey's problems alone.

Planning, in my experience, is great, but you know, one election cycle later and you're planning in another direction. I can't tell you how many individuals in the state of New Jersey were proscribed masters or whatever you want to call them. So despite all of its downsides, and they are numerous, and I can probably list more than you're even familiar with, regulations can be, have been, the best of all possible scenarios, and it may not be the best scenario, but it's the only one that we have.

So I guess my question is everything I've heard so far where ecosystem-based management has been implemented and the examples you've expressed have been marine examples, I was wondering if that's where the money and the fisheries are, and my current theory is it's because there's no alternative that it may work. Nobody's fighting for that little right to do something out there or, or if they are, those efforts are much less. How realistic is it that this type of a planning approach could either by itself or maybe just through an informing of regulations process actually work in the protection of land development? Certainly in a state like New Jersey where everything is based on property rights, nobody's got to do things just because someone else thinks it's the right thing to do. First of all, they themselves don't think it's the right thing to do. It's someone else's thought.

We still live in a country where one whole political party doesn't really even acknowledge climate change, so I just don't understand how this planning approach is going to solve a lot of the actual development problems and loss of habitat problems and sustainability problems that New Jersey faces.

MODERATOR: Response any one? No one?

AUDIENCE: I'm going to elaborate on his statement, comment, question, and speech. That was excellent, by the way.

What we deal with on a daily basis is the fragmentation of the forest through all the properties that are around or within, and I'm going to say adjoining. We're talking about adjoining by bodies of water, streams and so forth, so they may not touch exactly, but they are

touching.

Where do we go, how do we manage the situation where the statute of place where these people have been raised for the last hundred years, generations have not moved, and they're used to one way and one way only, and try to tell somebody and their family, "look, we can't do this anymore." That's just not going to work. So we need either guidance, leadership, or a workable plan to save what we have for everybody's sake.

PANEL MEMBER: I sense your frustration and I'm completely in agreement with it, and all I can do is say, first of all, to the previous question, it could be that the kinds of things that you can do in marine systems just are not going to be feasible in terrestrial systems in New Jersey just because of property right issues and the historical patterns of land use. You might not be able to do it, in fact, I'll just say you probably can't do it. We can't do it at the same scale and at the same level of system integrity, so scratch that. However, you might be able to get partway, you can apply some of the principles, but it's always going to be tough. How do you get people to change?

Now, one of the great things that I get to do by being a professor is that I get to travel all over the place, and I go to Europe a lot. And one of the things that happens every time I'm there, especially when I go to Scandinavia, is I'm incredibly impressed by the sense of appreciation that people have for their surroundings. There's this "green" mentality that permeates the whole place even among the conservatives. And partly it's a different cultural structure.

If you go to Sweden, there's this rule that allows anyone to go anywhere on public land and collect berries and mushrooms. It's a commons, and people don't abuse it because everyone knows that if you do abuse it, you'll lose it. And this has been inculcated in the culture there for centuries.

The other thing that you find is that instead of doing what we do with our kids in kindergarten, you see the equivalent happening when they take their kids out with a bunch of butterfly nets or insect nets at the age of five and they're teaching them about nature and what lives in their backyards, and instead of having fear of the natural world, they have an appreciation for it. They know the names of the flowers. They know the names of the birds. They even know the calls, for birds, frogs and everything. And we do a pathetic job of that in this country partly because – I don't really know why – but I'll wager this, we were a colony and we're an extractive culture. We have built our economy based on living off the ecosystem.

Those other places I've already alluded to, they're ecosystems and they appreciate what's gone, and now when you go there, they really appreciate what's left.

Just another quick anecdote. I've got a lot of friends in the Netherlands, and I gave a course there, and when I told people I was going there to teach this course, they said, "Oh, yeah, that place, there are trees there." Because if you go to any place else in the Netherlands, it's all an agriculture-based ecosystem. It's sheep or tulips or crops and canals, and there are only two places in the country where you can walk through the forest, and they appreciate what they've got. So we're sort of - New Jersey - is heading in that direction, but we're so much better because the remaining forest is a big deal. It could be worse.

PANEL MEMBER: I think EBM has grown out of this desire to go farther than we can with regulations and part of that is the realization that that's going to require new partnerships and new approaches due to the traditional ways we've been doing things. It may be a little bit easier on the ocean because there aren't the same private land issues, but I think even in this case the

recognition that you've got to find some way to engage owners of private lands. Not that's easy, but it becomes a critical part of management that goes beyond simple regulations.

AUDIENCE: Not to interrupt, but when you've got issues of scale, you may ask "how many conflicts are there in square miles?" In the north woods of Maine where you have a number of land owners, you might have one forestry company that owns those square miles and the 9 million trees, whereas New Jersey you've got 9 million people that need land instead. I'm just trying to make sure that as wonderful as this all this, and I'm trying not to be down on it because really, I'm really encouraged by this discussion, but I just want to make sure that some of the people I work with don't get idea that in New Jersey that we might do all of the wonderful things just for a few rare or endangered species in New Jersey. I love what I'm hearing, and I'm trying not to sound like a pessimist. I just need to make sure I can buy into all this.

PANEL MEMBER: I think the point about the appropriate scale, and there are differences in actual ecological scales between marine and other systems, and marine systems tend to operate in an ecosystem perspective at much larger spatial scales than terrestrial systems do. So conducting something like EBM at a smaller spatial scale may make a lot of sense, obviously, the key is to identify what kinds of ecosystem processes you're trying to maintain.

AUDIENCE: While we're talking about EBM and how to execute it and figuring out how we're going to simultaneously break down silos; in the '90s Montreal process, the National Association of State Foresters came up with a series of criteria and indicators that were measures of sustainability, and the forestry community uses them quite a bit, and some of the criteria are reducing and accounting for parcelization, fragmentation, sequestration of carbon, et cetera. And if we're going to break down silos and we're talking about ecosystem based management, are you guys also thinking about measurements when we start doing it, and are you familiar with the criteria and indicators from the Montreal process?

We're hearing a lot about the marine ecosystem, which is wonderful. I learned a lot today and I had no idea all those transcontinental and intercontinental cables were out there. And also to answer, or to help answer this gentleman's questions, one of our jobs for our private lands program is to keep forests as forests, and working forests working. And one way we do that is try to encourage the public to get into our program at five acres or greater. We had landowners that have up to 10,500 acres, so what we try to do then is manage a forest for a variety of ecological services that follow everybody's rules and that will encourage them to keep their property, but sometimes people have constraints, transgenerational issues where they have to sell a parcel to pay for Jimmy's college or whatever, and what we're finding now is a lot of the kids, they don't want to stay in the forest. They don't want to do that, and those are big challenges, but I was just wondering, from the conversation that you're familiar with, what are the criteria and indicators for that kind of situation?

PANEL MEMBER: I'm not familiar with that particular set of criteria, but to answer the question more broadly, I think the way forward in terms of identifying the criteria you were going to use and maybe implement comes back to making sure that we can start to baseline those things, whether it's through data that exists already or through establishing new monitoring programs as we go forward. I mean, this is certainly something that the forestry community has been ahead of the curve on compared to some other disciplines, especially the recognition that

not only do we need data, to do things like run models or to provide a baseline for carbon accounting efforts in general, but that we need it to be spatially explicit. We need it to be distributed across the landscape.

So I think the way that we start getting at this, you know, first is to identify what criteria are going to be reasonable, which are going to vary immensely from situation to situation, and then go and see what is already out there because as I alluded to earlier, there's a ton, you know. I think the data resources that are out there especially in terms of management and even in terms of sustainability science are probably still being underutilized today. And then where those gaps exist, figure out how to fill them in order to proceed.

PANEL MEMBER: Just a comment on this discussion. We've been zoning the land for a long time and ocean planning is -- folks don't like to use the Z word in the ocean -- is essentially a similar effort. And I would just like to respond about the forest, we try to tell a fisherman who's been fishing somewhere for a hundred years that he can't fish there, that's a big deal. So we still have similar resistances for this, in what's considered almost a wild frontier to a lot of people, a very special space, the ocean, which seems like it should be open to all, but has really fallen tragically in the sense of today's discussion.

I just want to also comment on this idea about regulations versus EBM. At least the way I think about it in marine space, it's not an either or thing; it's thinking about the regulations in a more holistic and broader perspective, it's not that we're addressing a separate thing. And I think the national ocean policy was very clear to say, "We're not setting out any new regulations. There are no new authorities associated with this. We are going to make the most of the existing authorities so that they can be implemented in a coordinated fashion." So I would say with respect to terrestrial EBM, how can folks out there who engage in that best coordinate and collaborate and make the most of what they're doing.

AUDIENCE: I have a question about the applicability, or even the appropriateness, of using EBM in transitional ecosystems, specifically coastal habitats? And it was touched upon today. We all, well the climate change denier folks aside, believe that sea level rises is particularly a problem along the coast and within, let's say, 50 to hundred years we may actually lose a lot of these wetland marsh systems. And what will happen in, let's say, the upland ecotone where these marsh lines actually move landward or we actually completely lose the wetland unless we use an EBM approach where one protective marshland is now, how will we be able to apply that, where we're actually losing these habitats?

MODERATOR: I made the point earlier that there are things we can do now to help wetlands. Other kinds of things that we can do, and now I answer in a broader context, common language is coming up clearly as an issue. We're speaking slightly different languages among the foresters and other disciplines.

Making space for the movement of wetlands landward integrates all of the challenges we're talking about because the landowner is going to be around for generations. We face the all of the negative ramifications, like losing the tax base that will occur by moving these landowners out.

I'll be very upfront, there will have to be tradeoffs, compromises and sacrifices made all along the way. We as a community have to set the guidelines for these. I'm speaking in a sense to all stakeholders.

Let me give you one tiny example based on a slide that we saw earlier related to miscommunication, or not enough communication. Say you have two fairly large patches of forest and you have several open spaces in between, so that there are breaks in the continuity of forest, and you try to do something to get those additional lands in between. But here's rub, New Jersey has a sustainable New Jersey program for municipalities.

I asked a friend involved in the program, why doesn't Sustainable New Jersey applicants get substantial points for not just the community going out there and picking up trash category, or whatever the categories are, but for communities around the state building forest corridors through their adjacent political boundaries so that we end up with, a more ecosystem-based approach? That's not in sustainable New Jersey criteria, but should be! So far, I've been ignored, but it doesn't stop me because I'll keep doing that. So the answer for all of us is to be willing to continue to break down the barriers, wherever they are. We're not, as a community in this generation, or any other going to solve it all. But like the solution to problems, it begins with a single step. You guardians of natural New Jersey, the forestry folks and the habitat folks, connect those damn patches across all county lines. Let's just do it. You guys know what needs to be done, but I will be hammering away until I get a response from the municipalities and program organizers.

So the bottom line is I think we can address all of these issues with an ongoing concerted effort. So keep pecking away.

One other thought relates to the hard lessons learned. How many times have you heard this, we always seem only to react after the fact. We must start doing things more proactively. And look at the hard lessons with the wild fires out West and the homes that were burned and the lives that were lost. It's a terrible thing to say, but hopefully, those hard lessons will take root in some way, and there will be policies formulated to keep people out of harm's way and also recognizing that, the ecosystem priorities are for those same wild lands.

I'm not saying that we have to have all our homes burned down outside the Pinelands, but those post-disaster lessons need to be adopted and brought to the forefront. Somehow with social learning - it has to be an education process for the long-term - thinking of the public, and there are people like Bonnie McKay out there and others that do that kind of work. Robin Lubchenko is another person that comes to mind. So we've got to get these teams of people together as the next steps.

AUDIENCE: I have a thought, and I don't know if it's been discussed in the literature. The community of practitioners has tried, starting with Constanza to place the value of ecosystem goods and service in the politician's ear. And we've managed and we've designed policy and planned around land uses. What are your thoughts on maybe changing that rhetoric from land use to ecosystem use so that we can tie together social functioning and social use, human use, with ecosystem functioning and services and then we can take a landscape-based approach to doing exactly what you do [Panel Member] and layering up human functioning, ecological functioning, provision of services, provision of self-sustaining features that ecosystems provide us with, including resilience going forward and potentially our adaptability, and maybe that's a way to tie that together.

PANEL MEMBER: Yes. I absolutely agree with that. It's certainly a direction that it needs to go, and it's a direction that it's now moving in. Increasingly over the last five to ten years our group has started to engage with social scientists, community colleges, as well as people in

public planning and policy to figure out how we can make this sort of landscape perspective be more than simply just the environmental management aspect.

And yes, I think that's really an interesting point just in terms of even moving away from being narrowly constrained by land use, land classification scenarios, into some sort of landscape ecology-oriented perspective to broaden it, make it a little more inclusive to most people.

PANEL MEMBER: I would just echo Dr. Hecht's earlier point that I think it's the example and case studies that will be most useful. If we come to a point where we have a successful offshore wind industry in the United States, it will be largely due in part to regional ocean policy. And that will be a very lucrative industry for our nation and it will be, the start of a new technology for us. I think there are other examples, but again, it is the ones that are tied to the money that generally get the attention of the general public and the policymakers and the politicians. If we can provide those examples where there's kind of a win/win in that economic balance or success story, I think to be pragmatic, those are the ones that usually are the ones that are hurt.

AUDIENCE: We've been talking a lot about different types of ecosystems, different scales, talked a lot about marine ecosystems, baseline planning and terrestrial systems. We haven't really talked about the applications of EBM to actions of freshwater aquatic systems and relationship between the landscape and freshwater aquatic systems. We talked about scales in terms of watersheds, comprehensive watershed management. Are there examples of EBM applications to freshwater aquatic systems that you can cite and help us think in terms of applying this very well, in my opinion systems thinking, to protection of freshwater aquatic ecosystems?

PANEL MEMBER: Did you ever see the movie Snakehead Terror on the sci-fi channel? I highly recommend it. I'm not entirely familiar with a lot of freshwater examples. I mostly deal with marine stuff, but there's the one example of the Japanese invasive fish, snakeheads, which are not endemic to this area. They were, I guess pets.

MODERATOR: Probably.

PANEL MEMBER: Yes. And now they're -- they basically eat everything, and they can survive in very low oxygen waters, brackish freshwater systems, and the program that they have now, in Virginia and Maryland is to pay people, pay fishermen who catch these invasive species and, kill them and bring them in. They collect reward money because they're affecting other species in the system, so that's one example I could cite. I'm not sure if that's an entirely ecosystem-based perspective, but it is one example that they know from the top down that this invasive snakehead fish is destroying a lot of the lower tropic-level fishes, which the ecosystem depends on. And so that's one way, they give an incentive, monetary incentive, to rid of these invasive species, but, Mike, you might be able to comment further.

MODERATOR: Let me expand on that, despite fear that some of my colleagues may not agree with me, I suggest that among systems -- from my earlier training, invoking the river continuum concept and the recognition that what goes on upstream, affects downstream reaches and vice versa, e.g., we all know what dams do. We know that we need a canopy over the headwaters of the streams to keep the temperatures down. We know we need riparian buffers. Perhaps more

so, I think we've been practicing EBM on watersheds, perhaps longer than we have most systems because of the recognition of that dependency and continuity.

Look at how it's grown. Now we know that the salmon that spend five, six years at sea are critical to the well-being of the forest 500 miles upstream because of the nutrients in their bodies that bears distribute all over the forest are important. And I don't know how well the data integrated. You may know that it's been done or not, but those are the things that we're learning more and more how this entity called a watershed really works.

Look at the progress made despite the ensuing conflict to allow enough water to be released downstream for endangered species; e.g., the rivers in the Southwest. The actual removal of dams despite the economic losses are associated with at least some of that. So this notion of managing our watershed or riverine systems holistically are resulting more in ecosystem and less in political boundaries, and been in practice for quite some time. It's perhaps a reasonable success story of what progress you can make if you adopt the EBM approach, but let me try this on you quickly because we are running out of time.

As regards your basic training, whether undergraduate, graduate, terminal degree, Ph.D., or whatever, how many of you are trained as engineers? One [hand raised]. How many of you have been trained as social scientists? Zero [hands raised]. How many of you have been trained as life scientists in any form? [a majority of hands raised]. And what am I missing? I apologize, I should have said how many of you are trained as economists? One [hand]. So we have one engineer and one economist, and no social scientists in the room. I hope that's a lesson learned. Got to get the silos broken down. This room has to have the weight of all the disciplines if we're ever going to have a transdisciplinary not interdisciplinary, not multidisciplinary, but rather cross-disciplinary discussions, ultimate training for our students like they're doing out at Arizona state.

I hope that's a reasonable point I just made, that common language would hopefully come out of that, also the tools are being improved to better predict the outcomes of our decisions. We need to do a better job with environmental management. We need to do a better job with social learning, et cetera, et cetera. Those are the things that should be propped to move forward with, and I hope we can all take it seriously.

MODERATOR: Let's move on to Question #8, the issue of multiple regulatory agencies, and then open the discussion to all topics.

PANEL MEMBER: Number 8, multiple regulatory agencies. As an example, when we were doing an analysis to understand the different rules and regulations, using case studies, once a wind farm is built, there's operation and maintenance that needs to be done. And for the person on land to get on a boat, take the boat out to a wind farm and step onto the wind-farm foundation, there were nearly a hundred different regulations and overarching rules that that person needed to comply with before they could get out there. And we realized then, this is a problem! Every time someone goes out there, we can't have them check a hundred boxes and get a hundred permits. Everyone from OSHA to NOAA, to EPA wanted a piece of paper, and this was the reason behind the genesis of regional planning for ocean bodies.

And I think the way you get the different regulatory bodies engaged is by showing them what's in it for them, making them care about it; e.g., "what's in it for the Army Corps to be involved in a regional planning body?"

When we were planning wind farms that crossed jurisdictions - because transmission

lines were going through one jurisdiction and the wind farm was built in another jurisdiction – it cause a huge headaches for the Army Corps. So having a single delegate or representative who could coordinate across jurisdictions, and then communicate back to the Army Corps was really powerful for them. They saw some efficiencies.

So that's just one example of bringing the regulators in, showing them the efficiency, the cost savings, etc. that could be realized, and that the process was actually going to make their job easier. I think that is particularly motivating for them.

Having something visual like the Data Portal² for people to participate in, feel ownership of, and have that inner linkage is an important part of getting the multiple agencies committed to the process. By getting them in on the ground level, surveying and understanding -- I don't know how much of this is done on a land-based perspective; i.e., how many of the counties interface with DEP who interface with the municipalities, and then with the federal agencies. Is there a vehicle for that? I know there were joint-permit process meetings where we would go and talk to federal and state bodies at the same time, and that seemed like a really powerful tool here at NJDEP.

AUDIENCE: With respect to the multiple regulatory agencies problem, freshwater is actually a great system to look at and talk about land rights and long-term change and lasting change. NRCS, the National Resources Conservation Service multi-disciplinary staff spends a lot of time in the field working with landowners to develop strong constituencies, in part, targeted for ecosystem services. And, granted, I don't really think NRCS is an ecosystem management agency, but the model they developed to implement change is one that benefits lots of other agencies. And there are examples within New Jersey and different agencies that then pair, partner with NRCS to get the changes that they will use. And so it's sort of an agency that does work on the ground and is not regulating everybody else. In fact, they don't actually regulate at all. They're more of a technical consultant, but take the subject of New Jersey water supply, we worked closely with the relevant group to get grant money to help landowners implement changes that then become lasting changes that people can buy into over time. So there's potentially some really good examples that are very positive that we can look to.

AUDIENCE: Another good example of a partnership that some in the room were involved in, was the cost-effectiveness and efficiencies working on Sandy recovery. There was a recovery support structure that came down from the federal level, and at that level it was natural resources, conservation, and historic values. And then there was infrastructure - they kind of siloed it - but they sent their federal counterparts, those agencies that were overseeing those infrastructure or support functions to our joint field office here in Lincroft, and then New Jersey developed its own structure under that kind of format. But then the governor's office broke us down from infrastructure as a whole to gray infrastructure and communications and transportation infrastructure, effectively putting us in silos a little bit more. But we in DEP, on a regular basis, coordinated amongst ourselves in our support function role. We're always talking.

This was an example that in a very short time based on some federal leadership and then implementation at the state level that resulted in us talking together. We were on weekly calls talking with our federal counterparts, but also with our counterparts at DOT and our counterparts at Community Affairs, starting the process of interconnections. So that's a good example of crisis management and how we can learn from a disaster.

² <http://midatlanticocean.org/data-portal/>

A second example, which I think Dr. Hecht may have touched upon, is the federal partnership among agencies - DEP, DOT, HUD and EPA - where monies are provided to have those management entities work together at the local level. New Jersey has grant support through this mechanism. The partnership also includes New Jersey's state universities. The North Jersey Transportation Authority is also heavily involved. We're all involved in this. But I would challenge my colleagues and, always question the people on the other side of the table, just what is it that is being communicated? So when you're working with Army Corps, you're also working with the federal forest service, and just how is that you are interacting with your counterparts at the federal level.

AUDIENCE: Ms. Ohleth I have a follow-up question. You had mentioned that when you were developing the wind farm, the proposed wind farm, there were hundreds of sets of regulations and permits that were required. And as my colleague had eloquently pointed out, our department is very regulation-driven. In fact, the State in general is, and other states I think are also very regulation-heavy. How did you like getting all the people, all the effective regulators in the same room, but at the end of the day still had like 80 permits, or a hundred sets of regulations that needed to be complied with? Is there a precedent where environmental organizations have sued the regulatory organizations for not enforcing or implementing their rules and regulations? How did you navigate through all of those sets of regulations and get the project to go through?

PANEL MEMBER: Just to be clear, there are no wind farms in the United States, nor have the one that I was working on come to fruition. There were 27 permits that we needed from the State of New Jersey, and I worked with the leadership and the permit coordination folks. We could call, our project coordinator at the agency any time. For example, if we wanted to run a transmission cable through this particular area, could you look at the map, and tell us what species you might be worried about. For these and other examples, I would argue that it was the beginning of the type of coordination and principles of EBM that runs throughout.

Again, this is not, in my mind, a process to supersede or replace regulations, but rather to create an environment where, coordination is paramount so that if I submit one set of plans or one set of figures that could satisfy 20 of the 27 permits, I shouldn't have to submit them 20 times. It's the common-sense part that when brought to the table appeals to so many of us.

AUDIENCE: To the question of having multi-disciplinary agencies that work together. I want to move backwards in time.

I've been with the Department since ocean dumping was allowed, and at that time I was in charge of what was called the PCB project where you collected fish in the waters of New Jersey and analyzed them for PCBs and pesticides. And we found PCBs in bluefish and striped bass in the Hudson River, and we immediately went to the federal agencies and expressed concern over the levels and their ramifications. They told us that the protocols at that time to determine safety of dredge spoils involved taking fish and putting them in a tank of water with some contaminant and letting them sit there for a little while. This was their standard method, and was the basis for determining the safety of dredge spoils and the fate and transport of contaminants therein. From a scientist's perspective, that's nonsense. Other people started asking questions, "Well, what about the water in New York's side of the river? What about the fish on the New York side of the river? What about the fish that are out in the ocean?" As a result, the Army Corps of Engineers, the EPA and the Fish & Wildlife Service who were responsible for

the existing method, asked us to make a presentation to a committee they assembled. We did. All the participating scientists on the committee looked at each other and suggested that the existing method needs to change.

The only way to make a change was because of something specific. It wasn't because of a plan. It was almost an emergency. It was something that showed that something in place needed to be replaced with something new.

With respect to plans and the planning process, DEP had plans in place in the 1970s, then plans were redone in the 1980s and 1990s. A lot of things that we talked about doing didn't get done, and I'm just saying all this as background.

You talk about knocking down silos. The dilemma with silos is that there always needs to be a place where people who are regulators have to interpret what's in front of them, so people make decisions because they have to work within a confined universe, so that you could speak to people at a certain level. That's a bad idea, ecosystem based management is a great idea. And that's specifically one of the things that I've been involved in recently. We are trying to use an ecosystem-based model to put a lot of data together, but it has a very specific component to it. In Barnegat Bay, for example, people complain about jellyfish. There are two hypotheses on why stinging sea nettles are increasing in abundance in Barnegat Bay. One states that nutrient pollution and eutrophication cause an ecological shift in their favor, whereas others argue that overfishing (e.g., hard clam filter feeders) or entrainment of zooplankton in power plants may play a major role. The point is that any "plan" that deals with this issue needs to consider all of these factors simultaneously, and an EBM approach is ideal. Also, until jellyfish became a nuisance issue to recreational users, most people were indifferent to water pollution just as they were to ocean dumping until garbage and medical waste washed ashore in the 1980s.

We don't have the answers to really address those questions. The traditional way to do this is to gather enough information, put it into some model and you tweak the model. It may not answer your question, but right now when we finish this process, they'll be multiple solutions available that are worth investigation. But again, and I stated this as an example, if the research and data support several alternative, you'll need multiple pathways to get where you're going, and when you get there, you could affect change and regulations. And you could then convince the legislature that maybe, the legislation needs to be changed.

So again, I think this is great. I think it's really super, but I'm just trying to explain that a lot of us in the room foresters, the parks people and others have been trying for a long time to knock down silos. Instead, they'll build bridges between them. We've often found that something very specific and not just big plans, make things happen.

PANEL MEMBER: I would respond that your comments are excellent fodder for the question "should the regional planning body have a regional ocean plan or should it just have a process by which it hears the issues that are coming to the table." Ocean energy is a big deal and you might be aware that the proposed LNG [liquid natural gas] facility in New York Harbor has moved from New York across the boundary to New Jersey. So in the future, there may be this body that says "we have this plan in which all the states and federal regulators have bought into". But this will not be a shared priority. This is not a go-to-plan for this type of activity. I think what you are saying is just great -- the idea that instead of an ocean plan, maybe it's a quarterly hearing, and these bodies are all present and you make your proposal and you say, "these are the reasons we feel it should be," and the body reviews it and comes back at the next meeting and says, "You are accepted or declined." But you have this idea that we just write up some plan with ten points

that's not going to change much with each situation. I don't think what we have is a plan, it's more flexible than that and more able to be reactive.

AUDIENCE: You need an implementation strategy. You need to figure out what's going to happen before you start the plan.

AUDIENCE: One of the questions we touched upon indirectly, but I don't think that it was answered directly, was the question about ecological units that have values in and of themselves, and the example and the question related to it are species. And you touched upon this in your talks, and when I say "values," I'm not talking necessarily about economic values, but other values that come into play with certain species as well.

And I think I heard this from the panelists and I've heard it certainly from the folks here, but I just sort of want to make sure that it gets heard beyond this room, that ecosystem-based management isn't always going to address those values, and those values are values that the citizens hold that our laws protect and that ecosystem-based management isn't going to be a way to get out of protecting these values especially where laws are in place to protect them, things like the Endangered Species Act. Ecosystem-based management is a way to help ensure that we don't have more species on the list, but it isn't always going to be a way of getting species off the list or avoiding the protections that those laws require.

MODERATOR: I'd like to react to that, re single species, etc. The value of ecosystem-based management, whether it's consideration of a single species that has an inherent value that society assigns to it, in some way, or say it's a whole habitat like forests. What's attractive to me is we're going to manage every level using the ecosystem boundaries we define as the management area as opposed to just some folk's forested land. We're going to manage all the forests in the state while trying to get the other states to cooperate with us where necessary.

The singular difference is wherever we're making management decisions, single species or otherwise, we're doing it on the basis of an encompassing ecosystem rather than species x, Essex County or the state of New Jersey or the mid-Atlantic or whatever. That's, hopefully, the direction we're moving in.

The species can't speak for themselves. I said that a hundred times already today. And species don't recognize political boundaries, and we have to accept that and understand that and get our decision-makers to understand that. I think there's real hope on the horizon, and the form that EBM is now taking is going to change. It's going to evolve over time and it should and it will be a continuous process. I hope that that's a point that's reasonably well taken.

We're not looking to throw anything away. We're looking to evolve the way in which we manage everything from individual species to entire ecosystems.

PANEL MEMBER: Yes. I was going to say something very similar. I feel that there was a common thread that appeared in several of the questions that were posed to us. The impression that there's a direct conflict between EBM and valuing species or ecological integrity or habitat conservation for the sake of itself.

Actually, I think those areas aren't at all opposed to the concept of EBM. The first step is to define what the values are we are trying to get EBM to address. Some of those may have to do with providing ecosystem services, fisheries, biomass, or pollination services or agricultural landscapes. But some of the values also just have to do with existence, existence value, or habitat

values and species values, and we've, as a society, have stated those values very forcefully and with the legislative process. We care a lot about the existence of individual species and we don't want them to disappear.

So EBM is an attempt to coordinate among each of these values and how we meet them within the law, we are not trying to replace those values in any sense. It's just an approach to try to meet them more efficiently.

AUDIENCE: Yes. I think what you're hearing from the audience in some degree, and I'm going to be frank here, is that there's a fear that the leadership who are not necessarily biologists are looking for opportunities, and when they talk about flexibility, that flexibility means that they're looking for opportunities to skirt having to protect those values.

For example, there's an "ecosystem" in Hackensack Meadowlands that is on top of an old landfill, and that landfill needs to be remediated, but the way we set up in this state is the only way that landfill can be remediated is by private investment because we don't have the money to remediate these sites on our own. So that "ecosystem" is in the way, but the people in that community have really rallied around that single mass, that single mass is not critical to recovery of the state's eco population, which is doing very well. And we can lose that ecosystem, but those people, that's the only "ecosystem" that they get to see on a daily basis and they put a high value on protecting that.

I'm just trying to point out that there is a fear that this can be exploited in a way that I don't think any of us intend to see exploited.

PANEL MEMBER: I know exactly you're saying. And there are obviously aesthetic and ethical reasons to preserve species, but it's tough to sell that sometimes. And the EBM approach gives you something potentially more powerful, you're protecting the "ark" that all those things are floating on. If the Pine Barrens suddenly becomes "expendable" in the eyes of some, all the people of New Jersey will decide if that's the case, but they're probably not going to decide that they can do it at the level of the whole Pine Barrens. And if you manage it at that level (whole ecosystems), then the approach becomes tractable.

And that's not to ignore the fact that the preservation of the Pine Barrens and having it on the state list was a very important process that was started a long time ago, and helped preserve the ecosystem, but these kinds of considerations have their utility only up to a point.

AUDIENCE: From a purely practical perspective, you're always going to have these individual species management plans in place, but then adding regional ecosystem-based management plans gives you a lot of flexibility and opportunity to then identify other critical aspects of the system. In the process of identifying what your management goals are going to be for Golden Wing Warblers, et cetera, some of those might be accomplished in the process of managing the Highlands in an ecosystem concept. But, of course, where there might be conflict or where we need to do a little bit more, individual species plans do need to remain a separate and independent entity.

AUDIENCE: We touched on the Pinelands a number of times. I think we've got the best ecosystem-based management plan in the country as an example in our state with the Pinelands, especially what it's done over the past 35, 40 years in protecting the Pinelands. If we didn't have the EBM management plan, the Pinelands would not look like what it currently does. I think we

can all accept that, that the Pinelands would, be more fully developed. We have other great examples in the state, not just the Pinelands, but including the Highlands, where ecosystem-based management works. So there's great examples, and not just for natural settings, but for cultural resources as well. The Pinelands were set up to protect blueberry and cranberry agriculture, so it did look at more than just individual species. It looked at more than just cultural resources. It blended the two really well and it's a good example for the rest of the country, for the rest of the world. So I think it's worth re-emphasizing that we have a great example of EBM right in our own backyard.

MODERATOR: One thing that comes in mind is the question, "how does the Highlands, as a place, interact with surrounding lands? If the Pinelands is an important recharge area for groundwater, for example, I suspect that the system doesn't operate in isolation, so that, on a scale basis, is it just the Highlands that we're trying to manage? How does the Highlands figure into the rest of the region?

AUDIENCE: That's an excellent question. It's a great point. It's a great way of thinking about what the Pinelands was set up to do, and I think it is regional, not just limited to the boundaries of the Pinelands itself. It was centered on regional water resources, and water-shed-based management - the Wading River, and other riverine portions of the watershed would not likely be as they are today, still relatively "pristine"; so well intact, and representative of typical upland communities because of the plan, so "everything flows downhill". Even when we talk about the marine systems, if we're protecting the upland systems, the upland systems flow downhill into the estuary, you're going to, in effect, protect much of the estuary and parts of the marine fisheries and so on if you can protect the upland areas, keep us away from our own misdeeds you have a workable management plan.

AUDIENCE: Just to reflect on that thought, so that the record is complete. Ken Able, the Director at Tuckerton likes to say that the estuary where the Rutgers Marine Field Station sits is one of the cleanest on the East Coast, largely because of the Pinelands.

AUDIENCE: I want to take this opportunity to ask on how to proceed with ecosystem-based management, for example, the forests of the Highlands ecosystem. We're trying to do a lot of things to get private landowners on board. They have their own set of values on how to manage their lands. And we try to get the ecologists and the environmentalists on our side. But the latter have the fear of the logging communities coming in and just wiping out the entire forest. And we also have to keep in mind other species, you know, instead of just ecosystems. So how would you suggest engaging all of these people to get them on the same page, so any suggestions would be appreciated?

PANEL MEMBER: It's really tough because you have private landowner rights and all those sorts of things. It's very difficult to get people to do things they don't want to do.

As nice as those little birds are (Golden Winged Warblers), and they are, we're at a particular point in the transition of the landscape in New Jersey where the kind of habitat that was once very favorable for them is effectively gone. And that habitat was a consequence of changes that happened when the Europeans came over here and basically deforested most of the state. And those gradually progressed to wood lots. There was inherent patchiness, but now

with the loss of agriculture, the forests that were keeping those things open are pretty much gone. And there might not be much that you can do. And, in fact, the abundance of the Golden Winged Warbler, as much as we like them, may rest in the 200-year history of that species in New Jersey.

PANEL MEMBER: I know, but I feel the same way about lots of other transitional species. If you look at all the effort the State has put into keeping grassland preserves open for grassland birds, and New Jersey was never a prairie state, never. And in my township, in Somerset, we've got two big grassland preserves, and they're being planted with basically Midwestern plants, like Bluestem, so that we can get grasshopper sparrows and meadowlarks, bob-o-links, three species that I love. And they were very important in the state when it was mostly agricultural land and you had lots of open space. That's the local habitat for those species. So you're going to have to talk some people into making the kinds of woodlots that your birds need. That's not an easy task.

PANEL MEMBER: Value judgment aside on any one species, and assuming that we're looking at individual species management and that there's at least the recognition among our community members that this is something we're going to proceed with; I think that it comes back to identifying your ecosystem management priorities and getting both stakeholders as well as experts involved in the process from the beginning. I think that with achieving buy-in people at the early stages of the planning process could be important to making stakeholders feel more investment and ownership of the ultimate outcome. I know that's not a full answer because much more is involved. It's easier for me to say than for you guys to go do, but I think this kind of general management approach, getting stakeholders involved early, thinking about how predictive our models are going to help us make management decisions and then updating those models and subsequent management decisions based on what people have to say at the beginning, in the middle and at the end.

AUDIENCE: When you talk about boundaries and scale, I question whose ecosystems we're talking about? There's all different kinds of functions. Like in water, we're trying to take a regional approach, the watershed because that's the medium we manage. But if we want to adopt integrative management approaches to addressing regional issues, our boundary is watershed. That's going to be a different boundary than our forest folks might use, a different boundary than our land-use folks might use, than our flood managers might use. So even within this Department, with the priorities that we have in water, we're not going to get a lot of things done without having land use also considered at that boundary that we set. If you then take it outside of the Department and you're talking about the Pinelands boundary and who decided it; in either case that was set as a hydrological boundary based on that ecosystem function.

But then if you're looking at the habitat, that's a different boundary. So whose boundary wins, and so that's a question that I would also ask you to think about in terms of your promotion of ecosystem-based management?

To switch it back to how do you get things done? Earlier in my time here, I was in the sustainability and alternative energy office, and our challenge was directed at sustainability of the state. And when thinking about that, you're thinking about how you get everybody on the same page and value the same things. We always bring it back to economics and that's why the whole ecosystem services kind of thing came up, and trying to put a price on it. The consensus seemed to be "no, it's not going to work." So how do you explain to someone that the bald eagle

nest isn't important, but what is important is returning this region back to something like a visioning of a place for your kids to play, with clean water and clean air, and with all different types of awesome creatures? So you try to make it meaningful to whomever your constituents are.

PANEL MEMBER: I think that the whole point of stakeholder engagement isn't to impose your own values and meanings on them, so if that bald eagle is really important, and it really is, and if, fishing grounds are really important, they really are, to be honest, but if I live in the Highlands, and it's never going to be important to me, we somehow have to value that too. And so I think the EBM stakeholder context is truly that. It's a context of knowing that sometimes your priorities will lose. Offshore wind has lost for many years, so I know how you feel!

AUDIENCE: Coming back to criteria and indicators, one of the criteria and some of the metrics used to measure the success of implementing management on that criterion, is something we really pay attention to, and when you look at New Jersey's age-class distribution of trees, it's almost a perfect bell-shaped curve with the majority data points falling in say the 70- to 90-year age class.

And when we talk about resiliency, how resiliency is vested in our entire state forest and state resources, then we nearly have all of our eggs in one basket. If we don't have that early successional stage like we need, in another ten years we're going to phase down from that even more, which isn't good. So one of the things while we're talking about EBM, private lands management of people's forests and even state lands is when we start moving forward with our prescriptions, for whatever they may be, habitat management or for the trees themselves as organisms, should we, should we not, and the discussion is part of that age class, to start understanding that age class so we can start having earlier succession forests and areas throughout the state, not necessarily trying to quickly flat-line our age class distribution, but as a measure of sustainability having a variety of age class distributions across the state and a lot of variability.

PANEL MEMBER: It makes eminently good sense to have as much habitat diversity as you can pack into New Jersey because we know that when you've habitat diversity, that's the best way to ensure broader species diversity.

I'm also, an amateur forester because I was the Director of a program, which is amusing when you think about having a microbiologist managing a forest. And the problem we had relates to a special situation. We had restrictions in the deed about what we could and couldn't do. We can't cut trees. We can't use fire management. We can't do anything invasive for most of the property that we have, we can't even hunt deer on the property, and that's led to big problems.

Ideally, what we'd like to do in that situation is to have a mosaic, and we kind of have acquired that over time because we have lots of property that's in different stages of succession. And some of the restrictions on those properties are less intense and we can get some things done. On the other hand, we've got 65 acres of climax forest that's basically senescent and falling dead, and there is essentially nothing that can be done, that's just the way it is.

And we've got other forests that's in between and ideally, what we'd like to be able to do is just to manage that. Brian is one of my managers, he still is, but I don't do that job anymore because the other problem that I had doing that job is that I ended up spending all of my time

talking with the lawyers involved and not doing anything useful for the forest. So I relate your managerial issues to all of these things. And that's just 565 acres of woods. You've got a much bigger problem than I have.

AUDIENCE: I would like to comment more broadly. The age-class distribution is a great criterion for addressing multiple sets of problems for resources in New Jersey. That's precisely the sort of process we want to use here; i.e., identify what the goals are, identify which criteria they're going to be indicators of, and from there the question becomes, "do we have the spatial coverage we need, do we have the data we need to quantify the variation or differences that we're seeing in different parts or regions of New Jersey".

MODERATOR: We're now supposed to be in the wrap-up phase of this discussion, so let me begin by thanking the panel for their time and their expertise.

(APPLAUSE)

And then we thank our DEP partners for their input and their efforts at keeping us honest in our thoughts.

(APPLAUSE)

There will hopefully be additional steps. I just wrote this list down quickly and maybe, we can expand it by email and so on. I think what I heard overall today is that EBM and Spatial Planning are basically sound concepts and they have real potential for letting us do a better job at managing natural resources and ourselves in many ways. But among the impediments that we talked about, those that struck me most, are the things that certainly, we need to go back to the drawing board on, and right at the top I put common language. And the latter will only come about if we do indeed break down silos and institute a systems, transdisciplinary form, of thinking in the process.

There was considerable discussion on dealing with scale. One size truly doesn't fit all and how are we going to have to accommodate the various scales in making sound decisions. The inherent value of single species and their role, how do we speak for those individual species or habitats, rare habitats, critical habitats and so on? This notion of getting not only the stakeholders to the table, overcoming the pressures of certain stakeholders like me, and Jamie hogging the microphone, overcoming things like that, the "quiet" people have to speak up and we should always be sensitive to that.

Bringing social scientists to the table are especially important in implementation of social learning, and giving us all (including us as the public and us as practitioners and us as scientists) better understanding of the consequences of our decisions and actions. And I hate to say it, but we are going to face -- and we heard one or two comments about this already -- what many agencies and/or blue-ribbon panels have commented, that compromises, sacrifices and tradeoffs are all going necessary along the way to address the question of balance, and how can we do a much better job to achieve that balance, better than we've done with special interests and the like, to give our decision-makers the political will, the backbone, to make better decisions perhaps than they do these days.

So we'll translate the tapes. Gary and I will write a preface with input, hopefully, from

you all. We'll prepare a brief introduction. We'll have the abstracts and biosketches and challenge questions in there. We'll have the interactive panel discussion as the heart of this effort, and then we'll have a series of next steps and addenda that we could add. I'd like to put the paper that Alan mentioned, the paper that Mike mentioned – assuming publisher's permission, as appendices to the document.

Thank you all. I think it was a productive day, and I look forward to this being a first step in an ongoing process.

FORUM SYNTHESIS

The Human Dimensions of Natural Resource Management

There is a growing awareness that the intractability of environmental problems can be explained in part by the social context in which they occur. When perceptions of a problem vary broadly, and when there is uncertainty in the scientific assumptions and outcomes that underlie the process under review, consensus is difficult to achieve. Under such circumstances, tensions may arise among stakeholders, even when all are committed to a sustainable future. This understanding of the social character of environmental problems has focused the attention of researchers, stakeholders, and policy makers on the important role of governance, participation, and collaborative decision making in better managing, if not solving, environmental problems. The *human dimensions* of natural resource management incorporate the ways people affect, value, utilize, and benefit from their surrounding ecosystems. *While ecological considerations are essential, the successful implementation of sustainable resource management depends on, and is driven by, societal values.* We need a better understanding of the human-induced causes and social drivers of environmental change and how human behavior can be made to coincide with environmental and social priorities. Although political, economic, and social systems make up the human dimensions of natural resource management, natural resource values originate only in the social system. These values are manifested as environmental laws, congressional budgets, volunteerism, voting behavior, and management decisions, and largely determine the fate of the natural systems that sustain our societies.

Implicit in the human dimensions approach is not whether ecosystems will persist – they will – but rather what tradeoffs will be struck and what kinds of ecosystems will be desired by individual social groups, based on their demographics, cultural identity, and existing and expected resource requirements. The present scenario is one in which issues tend to be treated in isolation, instead of being considered as part of a coupled human-environmental system, and broad-scale decisions are generally avoided. Ecosystem management will continue to suffer if managerial and political measures do not incorporate appropriate spatial and temporal scales of essential ecological processes. Accordingly, policy makers may too easily avoid the tradeoffs and there are therefore many conflicts and few solutions.

Conflict mitigation, consensus building, trade-offs, sacrifice, and compromise will become the norm for sustainable ecosystem management, because growing demands on natural resources can no longer be met by access to unexploited resources. An integrated systems approach is required, taking into account conflicting goals and inter-linkages among environmental issues, as well as the geographic scales of both the issues and political jurisdictions.

Spatial Planning and Ecosystem Based Management (EBM)

Spatial Planning

Spatial Planning addresses these issues by considering the broader “problem-shed” (the area that encompasses all of the affected stakeholders), and is designed to manage competing uses. Its success depends on the ability to create new paradigms that will resolve the growing tensions among the involved communities. More effort at the interface between science and society is needed in order to make the transition from the centralized, top-down approach of government institutions to more decentralized, regional, and local approaches to resource management. New policies for knowledge production and dissemination in which multiple stakeholder groups are involved are critical to this approach. “Soft factors” such as the values, attitudes, interests, and aspirations of stakeholders should be incorporated into the development process. If these are neglected in the formal and legal rules systems, escalation of existing conflicts may ensue. Because of the multidimensional nature of these conflicts – their normative framework, complex knowledge basis, and the amalgam of empirical knowledge – the task will not be easy, but progress is being made with current efforts at developing the paradigm of ecosystem-based management (EBM). Managing competing uses also requires a transdisciplinary and systems approach, including the integration of biology, anthropology, engineering, economics, agriculture, government, and law.

Ecosystem Based Management (EBM)

The National Research Council (NRC) has called for a balance between ecological, environmental, and social influences through an *Ecosystem-Based Management (EBM)* approach. They recognize that natural resource management policies cannot manage one activity, or part of the system, without considering its connections with all the other parts. *EBM* thus focuses on multiple interacting stresses within specific areas defined by ecosystem rather than political boundaries. It also places humans in the landscape, within the broader context of the biological and physical environment, and ultimately combines ecology and human dimensions into “society-integrated” or cross disciplinary ecosystem management. Scientific understanding of both ecosystem processes and of the underlying role of variability in maintaining ecosystem resiliency has improved in the past several decades. As a result, emerging management approaches can begin to conform more closely to integrated ecological and societal values rather than being driven by purely political constraints.

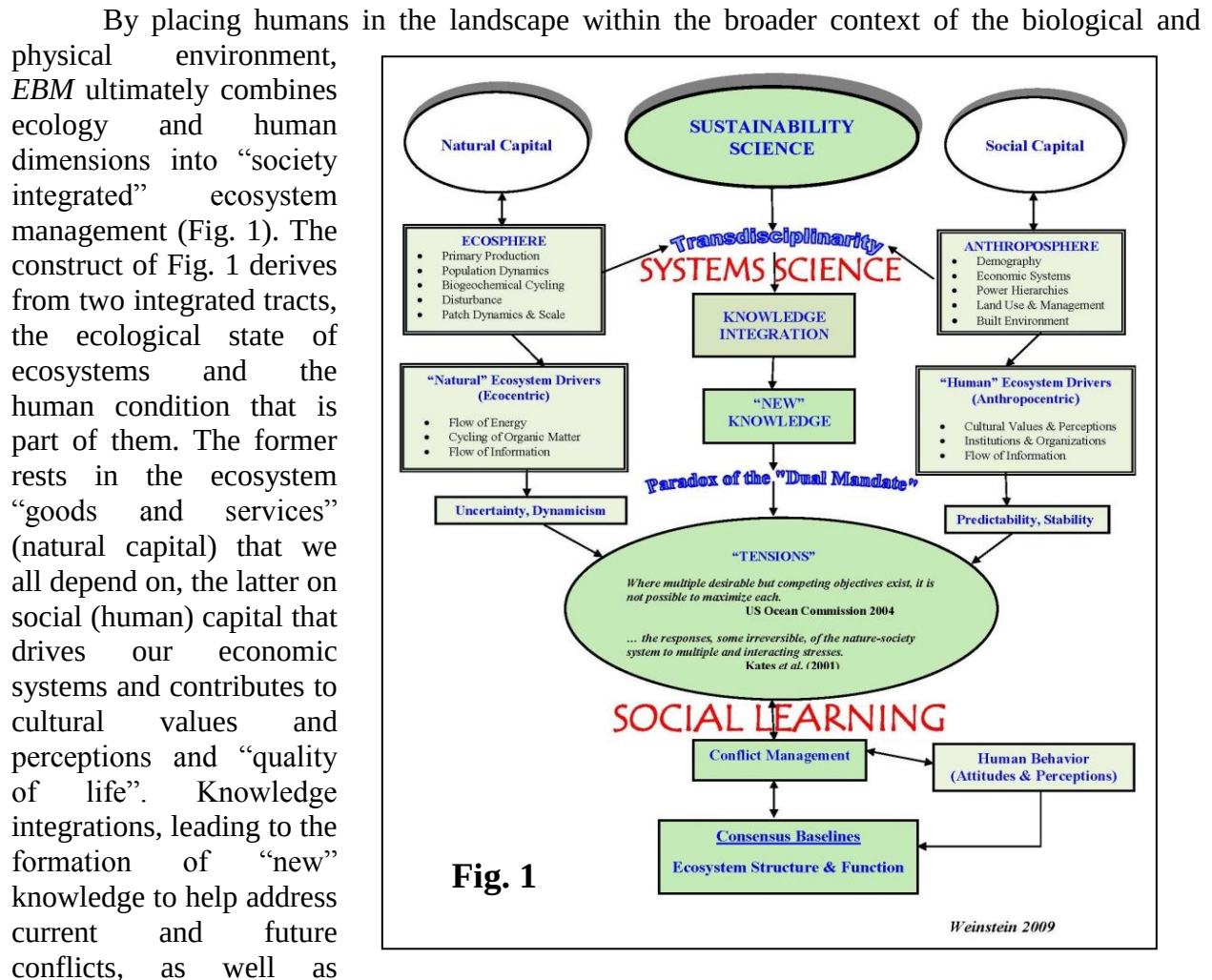


Fig. 1

³ ... an overarching scientific and practical approach, *transcending and crossing disciplines* and professions, aiming together towards a common system goal ... achieved by closely interwoven cooperation between many fields

mandate and the tensions associated with competing uses. Two other ingredients are essential: (1) social learning manifested as the slow, interactive accumulation of scientific knowledge, technical capacity, management institutions, and public concern over extended periods (generations) and (2) new methodologies that generate semi-quantitative models of qualitative data, building upon the lessons of case studies, and extracting “inverse” approaches that work backwards for undesirable consequences to identify pathways that avoid such outcomes. Thus, while ecological considerations and natural capital are essential, the ultimate success of environmental management will rest on societal values (social capital) and is therefore a fundamental human trait.

CONCLUSIONS AND RECOMMENDATIONS

As noted in the concluding comments by the Moderator, the Editors note the following salient conclusions and outcomes from the discussion, as well as recommendations:

- EBM and Spatial Planning are basically sound concepts and they have real potential for letting us do a better job at managing natural resources.
- Among the key impediments identified to invoking EBM as a management tool was the need to establish a “common language” among various scientific disciplines, managers and decision makers, and the stakeholder community. The attendees suggested that the latter can only come about if we continue to break down “silos” and institute a transdisciplinary systems form of thinking in the process.
- Scale was a major discussion point. How do we deal with scale? One size truly doesn't fit all, so how are we going to accommodate the various scales in making sound decisions?
- How do we address the inherent value of single species and their ecological roles, how do we “speak” for individual species or habitats, rare habitats, critical habitats and so on?
- How do we not only get all stakeholders to the table, while at the same time overcoming the pressures of individual stakeholder groups, and simultaneously get the “quiet” people to speak up?
- Social scientists are especially important in implementation of social learning, and giving us all (the public, practitioners and scientists) better understanding of the consequences of our decisions and actions.
- How are we going to manage the compromises, sacrifices and tradeoffs that will be necessary to address questions of balance, and how can we do a better job of achieving balance to give our decision-makers the political will, and the backbone, to make better decisions?
- An NJDEP team should be developed to examine ways to implement EBM methods and conduct outreach. The team should make recommendations to management on implementation and policy issues.

We hope that the principles and concepts presented at this Forum will be embraced by New Jersey's legislators to manage our future. In the end, the successful transition to a sustainable New Jersey rests on a complex infrastructure that translates science-based information into

of knowledge...(Naveh 2002)

public policy. This, in turn, will elicit effective responses from society at large. It is the performance and long-term capacity of a diverse array of entities (including scientific and educational institutions) from global to local scales that will ultimately determine the tempo and mode of any transition to sustainability. Our success will rest in societal action involving all stakeholders, consensus building, and accepting the compromises and sacrifices that will ensure environmental and social justice for all.

APPENDIX I

FORUM PROGRAM AND ABSTRACTS

FORUM PROGRAM AND ABSTRACTS

PROGRAM

8:30-9:15 Introduction, **Gary A. Buchanan**, NJDEP; Welcoming Remarks , **Michele Siekerka**, NJDEP, **Michael P. Weinstein**, NJIT, CNRDP; Moderator and “Ground Rules” for the Day

Introduction and Background – Framing Today's Discussion

9:15-9:45 *A Field Guide to the Properties of Human-Linked Complex Adaptive Systems*; **Peter J. Morin**, Rutgers University

9:45-10:15 *Spatial Dimensions of Ecosystem-Based Management: A Landscape Ecology Perspective*; **Brian J. Clough**, Rutgers University

10:15-10:30 **Break**

10:30-11:00 *Urban Seascapes: A Complex Management Challenge*; **Michael P. Weinstein**, NJIT

11:00-11:30 *Sustainability Science*; **Malin J. Pinsky**, Rutgers University

11:30-12:00 *Sustainability Science and the EPA*; **Alan D. Hecht**, USEPA

12:00- 12:45 **Lunch** (on your own)

Ecosystem Based Management and Marine/Watershed Spatial Planning

12:45-1:25 *Ecosystem Based Management (EBM): Strengths and Weaknesses*; **Michael J. Fogarty and Vincent S. Saba** (Presenter), NOAA

1:25-2:05 *Integrated Management: Linking Ecosystem Services to Comprehensive Planning*; **Whitley Saumweber and Sally Yozell**, NOAA [Paper presented by **Kris Ohleth**, Mid-Atlantic Regional Council on the Ocean (MARCO)]

2:05 – 2:20 **Break**

2:20-4:20 **Interactive Panel Discussion (Moderator) with Attendees based on pre-arranged “Challenge Questions”**

4:20-4:40 **Wrap-up**

4:40 **Adjourn**

ABSTRACTS

A FIELD GUIDE TO THE PROPERTIES OF HUMAN-LINKED COMPLEX ADAPTIVE SYSTEMS

Peter J. Morin

Rutgers University

Ecosystems, the focus of ecosystem based management strategies, are examples of complex adaptive systems. Effective strategies of ecosystem based management rely on an understanding of how complex systems respond to perturbations, or provide signals of impending regime shifts. Ecosystem complexity is obvious to even the casual observer. The fact that all ecosystems are to some extent linked to human activity is a simple consequence of the closed nature of the biosphere. The extent to which ecosystems respond to natural or anthropogenic perturbations determines their adaptive nature. Note that adaptation here does not imply any sort of evolutionary change, but rather refers to the ability of the system to continue functioning in the face of various changes. One classical aspect of adaptive behavior is resilience, the tendency to withstand or recover from various perturbations. This differs from stability in the strict sense, but is often colloquially considered as the same thing. It isn't. Important properties of complex adaptive systems include self-organization, links between diversity and variability, system reliability, system predictability, hysteresis and regime shifts, resilience, and others. The extent to which these properties can be used to inform management scenarios remains controversial, but is considered here in this review of key concepts.

SPATIAL DIMENSIONS OF ECOSYSTEM-BASED MANAGEMENT: A LANDSCAPE ECOLOGY PERSPECTIVE

Brian J. Clough

Rutgers University

Ecosystems are embedded within heterogeneous landscapes where environmental, biological, and anthropogenic factors act on their structure and function at large spatial extents. Landscape ecology provides a theoretical and methodological framework for linking these "regional" effects to "local" dynamics across space and through time, and for characterizing the complex patterns that arise when ecological processes interact across multiple spatial scales. Given that ecosystem based management plans are often implemented across whole landscapes, understanding spatial pattern may be important for analyzing baseline data prior to management activities, improving model-based forecasts, and quantifying uncertainty around projected effects of management decisions. This talk will review key concepts and approaches for understanding spatial ecological processes, and will demonstrate the importance of integrating this perspective into regional management planning through case studies from terrestrial ecosystem science.

URBAN SEASCAPES: A COMPLEX MANAGEMENT CHALLENGE

Michael P. Weinstein

New Jersey Institute of Technology

Pitting the dynamicism and uncertainty inherent in undisturbed coastal ecosystems against the stability and predictability required of human-dominated coastal ecosystems creates the paradox of the dual mandate. Some coastal seascapes, specifically estuaries experience little human intrusion, others are dominated by people and extractive uses. I will classify these estuarine types on the basis of human presence, and will discuss future approaches to managing them. The latter includes conditions where humans are not only a core feature of the landscape but also where extractive uses drive a large part of the local, regional, and even national economy. System reliability and predictability of ecosystem services are integral components of any management scheme in urbanized estuaries. By recognizing this driver, managers can construct appropriate baselines that encompass the biodiversity and ecological integrity inherent in less disturbed systems. The proposed approach does not mean that ecosystem quality is sacrificed in an urbanized seascape; to the contrary, contaminant source control, suitable sediment and water quality, and the human endeavors to address them are just as important to sustaining commercial activity as they are to the well-being of extant biota. So too, are the conservation and preservation of existing critical habitat (proximate reservoirs of biodiversity) in urbanized settings, and rehabilitation of habitats that support species co-adapted to the presence of humans.

SUSTAINABILITY SCIENCE

Malin J. Pinsky

Rutgers University

The field of sustainability science has emerged out of a growing recognition that we still understand little about how to meet the needs of the present without compromising the ability of future generations to meet their needs. The research in this field is problem-driven (much like health or agricultural science) and is therefore inherently multi- and interdisciplinary. How do we address global hunger? Can we reverse the degradation of our natural life support systems? How do we balance economic growth and global climate? The interactions between humans and their environment sit squarely in the center of the field, addressing both how the environment affects human well-being (ecosystem services) and how humans impact the environment. These feedbacks within coupled human-environment systems create complex adaptive systems whose behavior cannot be predicted from simple rules. A common phenomenon is the disconnect between local, individual decisions (e.g., to drive a car to work) and the emergent patterns and trends that can result (e.g., rising sea levels, extreme weather, etc.). A key question is what policy or technology mechanisms can alter the incentives or constraints on behavior and foster more sustainable outcomes. This talk will introduce the field of sustainability science and illustrate its key concepts and initial results with examples from fisheries, coastal ecosystem services, and elsewhere.

SUSTAINABILITY SCIENCE AND THE EPA

Alan D. Hecht

Office of Research and Development, USEPA

Addressing the problems of the 21st century will require a combination of strategies, including creative use of existing environmental policies and regulations, innovative application of science and technology, and collaboration among stakeholders. These are not easy challenges given the rigid nature of government operations and tensions between business, government, and non-government organizations (NGOs.) The United States Environmental Protection Agency (USEPA) is moving in this direction through new actions defined in the agency's Strategic Plan for 2014–2018. In describing the goal of “working toward a sustainable future,” EPA Administrator McCarthy notes that “our traditional approaches to risk reduction and pollution control can only go so far to deliver the long term and broad environmental quality we seek.” New operational model for sustainability in the 21st century requires a convergence of 1) advances in systems science, technology, and innovation; 2) business practices that promote sustainable solutions; 3) greater coordination across federal agencies; 4) effective business and government collaboration; and 5) public support, understanding, and behavior change. All sectors of society will need to work together to pursue this model and assure continued American prosperity and competitiveness. The public must come to understand that sustainability provides both the vision and approach to achieve outcomes that enhance the economy and protect health and the environment. The expanded growth of urban environments and application of ecosystem services is one of the clearest and most pressing areas for achieving sustainable outcomes. All elements of society must work together to effectively plan for the future and disprove Benjamin Franklin's adage, “It is not until the well runs dry that we know the worth of water.”

ECOSYSTEM BASED MANAGEMENT (EBM): STRENGTHS AND WEAKNESSES

Michael J. Fogarty and Vincent S. Saba

NOAA

Ecosystem-Based Management (EBM) fundamentally concerns the sustainable delivery of ecosystem services. Although many definitions of EBM have been proposed, most hold certain elements in common. EBM is place-based and recognizes humans as an integral part of the ecosystem. It accounts for the dynamic interplay among the different parts of the system and with the environment. Further, EBM specifically addresses the cumulative impact of anthropogenic stressors and highlights the critical importance of preserving the basic structure and integrity of the ecosystem as a whole. Finally, an EBM strategy stresses the need to address potentially competing goals and objectives. Through EBM, we seek to develop integrated management strategies for defined ecological regions. By recognizing humans as part of a coupled Social-Ecological System (SES), we see that we both affect other parts of the ecosystem by our activities and are affected by natural changes in these systems. Effective stakeholder engagement in identifying problem areas and overall goals and objectives is essential to the success of any EBM initiative. While ecosystems exhibit varying levels of resilience to different threats and impacts, it is clear that through our actions, we have the capacity to fundamentally alter ecosystem structure and function. These alterations can, in turn, adversely affect the sustainable delivery of the ecosystem services so vital to human well-being. When different

human-use sectors invoke pre-emptive use of space or place other competing demands on the system, tradeoffs among them must be directly confronted.

The strength of EBM lies in its holistic approach to management and its focus on the interplay of the full spectrum of human activities affecting ecosystems and the benefits humans derive from our connection to these systems. A potential stumbling lies in the daunting complexity of ecosystems. We must recognize limits to our understanding, precision, and control in ecosystem assessment and management. Illustrations of these main points are drawn from our experience in developing approaches to marine Ecosystem-Based Management for the Northeast U.S. Continental Shelf. Although clear differences are apparent in the demands for management in terrestrial and aquatic ecosystems, many of the challenges that emerge are common to both and lessons in many cases are transferable.

INTEGRATED MANAGEMENT: LINKING ECOSYSTEM SERVICES TO COMPREHENSIVE PLANNING

[Paper presented by **Kris Ohleth**, Mid-Atlantic Regional Council on the Ocean (MARCO)]

Whitley Saumweber and Sally Yozell
NOAA

The U.S. coasts support approximately 40% of our population and \$6.6 trillion in economic activity, including \$51 billion jobs and \$2.8 trillion in wages. Unfortunately, this economic output and the communities it supports are at increasing risk from a range of factors from extreme weather and the effects of climate change to resource exploitation and man-made disasters. In order to mitigate this risk, we must work to support resilient coastal communities and marine ecosystems through a comprehensive approach to management that relies on an informed understanding of economic, ecological, social and cultural values. The application of such an integrated, or whole systems, approach to management is a paradigm shift in how we think about managing use on our coasts and oceans. It is also a corner stone of the U.S. National Ocean Policy which identifies both ecosystem based management and comprehensive spatial planning as priority objectives. Integrating these objectives with an accurate valuation of coastal resources, ecosystem services, and cultural interest should yield more effective management approaches. National progress in developing regional approaches to marine planning will be discussed along with nascent examples of integrating ecosystem service valuation and ecosystem based management into planning processes.

APPENDIX II

BIOSKETCHES

BIOSKETCHES

BRIAN CLOUGH

Brian Clough is a PhD candidate in the Department of Ecology, Evolution, and Natural Resources at Rutgers University. His research interests are in forest landscape ecology and spatial analysis, and his dissertation work focuses on improving methods for predicting forest carbon stocks at the landscape scale.

MICHAEL J. FOGARTY

Dr. Michael J. Fogarty is the Chief of the Ecosystem Assessment Program at the Northeast Fisheries Science Center, Woods Hole, MA where he has been employed since 1980. He received his doctorate from the University of Rhode Island. He currently holds adjunct professorships at the Woods Hole Oceanographic Institution, the University of Rhode Island, the School of Marine Science and Technology, University of Massachusetts. He has served on numerous national and international panels and committees including the Science Committee of the Global Ocean Observing System Program, the Scientific Steering Committee of the U.S. Global Ocean Ecosystem Dynamics (GLOBEC) Program (Chair 1997-2002), the Science Board of the Comparative Analysis of Marine Ecosystem Organization Program. His research interests center on the ecosystem effects of fishing, the role of climate change in marine ecosystem dynamics and strategies for implementing marine Ecosystem-Based Management.

ALAN D. HECHT

Dr. Hecht a recipient of the Presidential Rank Award for Meritorious Service is Director for Sustainable Development in the Office of Research and Development (ORD) at the U.S. Environmental Protection Agency (EPA). Since 2003 he has actively advanced the concept of sustainability within ORD and EPA. On detail to the White House, from 2001 to 2003 he was Associate Director for Sustainable Development at the Council on Environmental Quality (2002–2003) and Director of International Environmental Affairs for the National Security Council (2001–2002) where he served as White House coordinator for preparations for the World Summit on Sustainable Development. At EPA From 1989 to 2001, he served as the Deputy Assistant Administrator for International Activities and Acting Assistant Administrator for International Activities from 1992 to 1994 and was a key U.S. negotiator at the 1992 Rio Earth Summit. Dr. Hecht has a PhD in geology and geochemistry from Case Western Reserve University. He has written extensively on climate change and sustainability and is credited with being one of the key players in helping to create the Intergovernmental Panel on Climate (IPCC.) His most recent publication (2012) prepared for the Rio +20 Conference (“Creating the Future We Want”) laid the foundation for EPA’s new efforts at creating a new era for business-government collaboration.

PETER J. MORIN

Dr. Morin has been intrigued by the ecology of aquatic systems ever since he received his first microscope at the age of 5. He graduated Phi Beta Kappa from Trinity College with Honors (B.S. Biology) in 1976. He received his Ph.D. in Zoology from Duke University in 1982. He is currently a Distinguished Professor of Ecology, Evolution, and Natural Resources at Rutgers University, where he has been on the faculty since 1983. Much of his recent research has focused on relationships between biodiversity and ecosystem functioning in natural and model communities. His laboratory uses organisms, ranging from aquatic microbes to terrestrial plants and invertebrates, to test basic ideas about the role of different species in driving community and ecosystem processes. These studies include explorations of links between diversity and ecosystem predictability, and studies of effects of biodiversity on responses of ecosystems to gradual environmental change. Other research has explored the consequences of food web structure for population dynamics, relations between productivity and food chain length, and effects of different top predators on food web composition. Additional topics of interest include the interactive effects of competition, predation, and the history of community assembly on patterns of species abundance in organisms including protists, insects, fish, amphibians, and terrestrial plants and invertebrates. He is the author of a textbook, *Community Ecology 2e* published by Wiley Blackwell, that summarizes current views about the many interacting factors that structure ecological communities.

Morin has served on the editorial boards of several prominent journals, including *Ecology*, *Ecological Monographs*, *Ecology Letters*, and *The American Naturalist*, as well as on numerous advisory panels in the US and in Europe. He received the Mercer Award in 1985 from the Ecological Society of America for the best paper published by a young ecologist, and he was elected as a Fellow of the American Association for the Advancement of Science in 1999. He has published numerous scientific papers in a variety of leading journals, including *Nature* and *Science*. Further details of his work can be found on his website at <http://www.rci.rutgers.edu/~pjmorin/index.html> and in his public profile on Google Scholar (<http://scholar.google.com>).

KRIS OHLETH

Kris Ohleth is the Executive Director of a regional policy organization, the Mid-Atlantic Regional Council on the Ocean, also known as MARCO. Before joining MARCO, Kris was immersed in the world of offshore wind energy as the Director of Permitting for the Atlantic Wind Connection offshore backbone transmission project, and the Director of Environmental Affairs for two leading offshore wind energy developers. Other previous positions include Policy Manager for Coastal and Marine Spatial Planning issues for Ocean Conservancy, researcher and editor for the National Marine Fisheries Service in Woods Hole, MA and Narragansett, RI, and communication coordinator for The Nature Conservancy. She earned an undergraduate degree from Rutgers University and a master's degree from the University of Rhode Island in Coastal and Ocean Policy. She serves on the Board of the New Jersey Environmental Lobby. Kris was born, raised, and still lives in New Jersey with her husband and their two rescued greyhounds.

MALIN PINSKY

Dr. Malin Pinsky is an Assistant Professor in the Department of Ecology, Evolution, and Natural Resources at Rutgers University. Broadly, his research aims to understand the interactions between human activities and coastal marine species, including the ecosystem services we derive from the coastal ocean. Much of his current work focuses on the impacts of climate change on fish and fisheries, as well as the strategies we might use to foster successful climate adaptation at local and regional levels. He was previously a David H. Smith Conservation Research Fellow at Princeton University, and received a Ph.D. in Biology from Stanford University. He grew up in Maine and holds an A.B. in Biology and Environmental Studies from Williams College.

VINCENT S. SABA

Dr. Vincent S. Saba is a Research Fishery Biologist within the Ecosystem Assessment Program at the NOAA Northeast Fisheries Science Center. He is based at the NOAA Geophysical Fluid Dynamics Laboratory at Princeton University. He received his doctorate from the College of William and Mary's Virginia Institute of Marine Science. He currently holds a collaborative research status at Princeton University's Atmospheric and Oceanic Sciences Program. He also serves as an editor of two journals: "Endangered Species Research" and "Scientific Reports." His interdisciplinary research interests are in the fields of marine ecosystems and climate variability, fisheries oceanography, climate change impacts on living marine resources, sea turtle biology, ecosystem modeling, and ocean color derived phytoplankton variability.

WHITLEY SAUMWEBER

Dr. Whitley Saumweber currently serves as a Senior Policy Advisor to the Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration (NOAA). He has previously worked in Congress as a NOAA Congressional Detailee and ocean policy advisor to the late Senator Daniel K. Inouye (D-HI) and as a Fellow with the Senate Committee on Commerce, Science, and Transportation. Prior to his detail with Senator Inouye, he served as a policy advisor in NOAA's Office of Ocean and Coastal Resource Management and jointly oversaw the National Estuarine Research Reserve System's (NERRS) Research and Monitoring programs. In addition to working at the interface of science and policy, he has worked in science outreach and education as a Chief Scientist with the Sea Education Association. Dr. Saumweber received his Ph.D. in Biological Oceanography from the University of Rhode Island Graduate School of Oceanography.

MICHAEL P. WEINSTEIN

Dr. Michael P. Weinstein, a Senior Scientist in the Center for Natural Resource Development and Protection (CNRDP) at NJIT, is former Director, PSEG Institute for Sustainability Studies (ISS) at Montclair State University. He was also former President & CEO, New Jersey Marine Sciences Consortium where he served as the New Jersey Sea Grant College Program Director. Dr. Weinstein conducts extensive research in the areas of coastal ecology, sustainability science, fisheries science, wetland ecology, and restoration ecology, primarily in salt marshes, sea grass meadows, and mangrove habitats. The recipient of many awards, he has served on numerous US

National Research Council Committees, an International Working Group on Sustainability, an NCEAS Working Group, the US-Japan CEST Panel, SDWA Audit Panel, and the US-China Initiative in Sustainable Development. He was also a member of the National Working Group for preparing the Nationwide Strategy for Coastal Habitat Restoration. He has authored more than 250 journal articles, abstracts, books, chapters and monographs. His most recent text *Sustainability Science: The Emerging Paradigm and the Urban Environment* will have international impact on the direction and focus of sustainability science.

APPENDIX III

**CHALLENGE QUESTIONS FOR THE
VISITING EXPERT PANEL**



EBM FORUM (26 March 2014)

Challenge Questions for the Visiting Expert Panel

Formulated by NJDEP Staff

1. How can EBM satisfy the economic, environmental and social components of sustainability (e.g., evaluating the entire life-cycle of an activity for a better perspective on the true costs) without negating the overall goal of critical habitat conservation, functionality, and future mitigation efforts?
2. Second, third, and in some cases, fourth, generation forests of NJ's forested ecosystems are in large part a tribute to resilience. Yet there is reluctance within the general populace, as well as within the scientific community, to embrace the concepts of scientific management and actively manage and steward our forest resources. Why do you think this perception persists, and what suggestions do you have for changing it?
3. The largest state forest covers approximately 120,000 acres and may well present resource managers opportunity to implement landscape ecology concepts and EBM. But the average size of a privately-owned forest in NJ is less than 25 acres; the average size of a privately-owned farm is less than 75 acres; and the combined forest and farm acreage in the state is owned by approximately 100,000 different landowners. Given this scenario, how viable are landscape ecology concepts for the average landowner? How realistically and to what extent can they be implemented? What would incentivize a landowner to engage in EBM? In terms of landscape ecology and land management strategies, how would you advise a resource manager with several different clients owning parcels ranging in size from seven acres to 100 acres, all located within Ocean and Burlington Counties, but none of which are contiguous?
4. Is EBM the most expedient and efficient strategy for an entity to develop and implement on-the-ground, scientifically-based, sustainable resource management strategies for delivery of ecosystem services?
5. New Jersey is going to be the first state to reach build-out. In the face of this race against time, how should the NJDEP prioritize its protection and management of ecosystems to foster resiliency?
6. How can the NJDEP come up with a consistent, meaningful map/system of Ecoregions that reflect socio-ecological systems (SES) as well as our environmental regulatory framework for long-term EBM?
7. Ecosystem services and ecological function are values related to human use. How important is the assessment of, or management for, ecological integrity/condition (independent of humans), in implementing EcoSystem Based Management?

8. There are a number of ecosystem classification systems already being used by the NJDEP. How important would it be to find a common language in which to communicate and effectively conduct Ecosystem Based Management in NJ?
9. The Pinelands Protection Act makes reference to management of the Pinelands ecosystem as part of the purpose of the Act. The Pinelands Comprehensive Management Plan is the body of regulations that implement the Pinelands Protection Act. Is the Pinelands Comprehensive Management Plan a good example of Ecosystem-Based Management in the state?
10. Ecosystem-based management implies a strong recognition of the importance of ecosystem processes. Disturbance, including storms (e.g., Sandy), floods, fire, etc. are some of the processes that maintain ecosystem function. How does Ecosystem-Based Management in a policy context address (necessary) impediments to maintaining or mimicking important ecosystem processes?
11. The U.S. Fish and Wildlife Service has developed and implemented Landscape Conservation Cooperatives (LCCs) as a more holistic, integrative and collaborative approach to conservation of biological and cultural resources. Are you familiar with LCCs, especially the two LCCs that cover New Jersey (Appalachian Landscape Conservation Cooperative and North Atlantic Conservation Cooperative) and do you believe these approaches adequately embrace the tenants of ecosystem-based management?
12. Some would argue that species as an ecological unit have values in and of themselves that cannot be replaced by other species or processes, and that therefore ecosystem-based management cannot always replace single species management designed to restore and/or maintain species populations. Do you agree/disagree? Why?
13. Please describe the current data limitations and future data needs to accurately and fully implement EBM approaches within the marine environment, specifically marine fisheries systems.
 - a. We have difficulty now managing single populations and collecting data enough data on that population with increasing skepticism by the regulated community – what would be the data needs, the costs associated with that collection and the general timeframe you would anticipate being needed to effectively manage at the ecosystem level with “buy-in” from the regulated community that this approach is a better way to go?
 - b. In theory EBM based tools and management approaches are the most holistic and ideal approach to natural resource management, but in practice how does one begin to effectively manage at the ecosystem level when there are multiple regulatory agencies, or states, with various authorities and oversight with potentially different goals and objectives involved?

APPENDIX IV

**NJDEP PROGRAMS REPRESENTED AT
THE FORUM**



New Jersey Department of Environmental Protection Programs Represented at the Forum

Commissioner's Office

- Economic Analysis

Deputy Commissioner's Office

- Office of Science

Land Use Management:

- Office of Coastal and Land Use Planning
- Office of Policy Implementation and Watershed Restoration

Natural and Historic Resources:

- Division of Fish and Wildlife
 - Endangered and Nongame Species Program
 - Marine Fisheries
- Division of Parks and Forestry
 - Natural Lands Management
 - State Forestry Service
- Green Acres and Ecological Restoration
- Office of Historic Preservation

Sustainability and Green Energy

Water Resource Management:

- Division of Water Monitoring and Standards
- Division of Water Quality

Environmental Research Library (NJ State Library)

APPENDIX V

**A REPRINT COPY OF DR. WEINSTEIN
ET AL. PAPER ENTITLED *THE GLOBAL
SUSTAINABILITY TRANSITION: IT IS
MORE THAN CHANGING LIGHT BULBS***



ARTICLE

The global sustainability transition: it is more than changing light bulbs

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Current policies and norms to reconcile human demands for resources with the Earth's ability to supply them have resulted in practices that mainly treat the symptoms of unsustainability rather than their underlying causes. Moreover, the increase in our knowledge about humankind's role in ecosystems is not keeping pace with our understanding of the consequences of our actions, resulting in a deepening inability to address sustainability issues. The extreme complexity and intricate workings of the world require the expansion of our mental models in a systems-thinking framework if we are to realize a sustainable place for humans in it. The challenge of the emerging transdiscipline of sustainability science lies in developing specific tools and processes, including curriculum development and a new generation of systems models, to help us better understand complexity—uncertainty and surprise, scale, hierarchy, and feedback loops—and to educate a new generation of sustainability scientists to design better policies, to facilitate social learning, and to catalyze the technical, economic, social, political, and personal changes needed to create a sustainable world.

KEYWORDS: sustainable development, rights of future generations, interdisciplinary research, technology, education, public policy

Introduction

Un-sustainability is an inevitable emergent property of the systemic interaction between contemporary global society and the ecosphere.

William Rees (2012)

Humankind has become a dominant force of nature, shaping the global landscape, exerting unprecedented pressures on the planet's resources, and pushing the Earth's biophysical system far outside of its historic operating range (Steffen et al. 2005). It is not just the patterns and functions of many ecosystems that have changed during the Anthropocene era (Crutzen, 2006), it is that they are also increasingly framed within the context of climate change, habitat degradation, globalization of species distribution, and loss of biodiversity, all caused by the evolving suite of intense human activities. Peterson-Meyers & Reichert (1997) ask, "[H]ow much of the Earth's ecological integrity can we disrupt before we pass a threshold in the loss of life support services?" In fact, "threshold behavior" may already be a pervasive characteristic of key global social-ecological systems, including trade (e.g., market "bubbles"), finance (stock-market collapses), food (famine), and resource

extraction (supply-demand cycles) (Westley et al. 2011).

Defying our best intentions, the future consequences of these changes will likely be to dehumanize and stratify society and to create catastrophic instabilities, but unfortunately, not to effect a transition toward qualitatively desirable sustainability. Although important, the "sustainable practices" that society increasingly engages in are insufficient to create sustainable systems because, as Sterman (2012) notes,

[M]ost efforts by firms, individuals, and governments in the name of sustainability are directed at symptoms of unsustainability rather than causes...policies to reduce waste, cut energy and material use, reduce greenhouse gas emissions, promote green products and local consumption...fail to address the underlying source of the unsustainable world we have created...[a] focus on symptoms and low-leverage policies reflects a widespread failure of systems thinking.

In other words, we seem to be moving along a path where innovation is primarily leading to optimi-

zation of the status quo rather than to system innovation. As van der Leeuw (2010) comments, there are warning signs that technological innovation, “far from serving human needs, is driving development in directions potentially opposed to sustainability.” Clearly, the transition to sustainability will require more than changing light bulbs!

The issues of sustainability are, therefore, broad, interrelated, and all-encompassing. This situation is problematic because opinions about how to transition to a sustainable world are about as diverse as their proponents! We adopt here a systemic approach to building capacity for the necessary transition by: 1) providing a general overview summarizing six major challenges; 2) addressing these challenges within the context of the nascent field of sustainability science; and 3) providing suggestions for key areas of attention. We do not claim that these are the only ways forward, but rather that they are essential, fertile components in bringing an obvious set of conclusions within the sustainability community to the general population and to various governance institutions and functions.

Knowing the Challenges

Challenge 1: Naiveté and the Bretton Woods Conference

World leaders assembled in Bretton Woods, New Hampshire in the waning days of World War II to plan the aftermath of the most devastating conflict in human history. In his concluding remarks at the conference, Henry Morgenthau, then Secretary of the Treasury of the United States, commented that the goal was to rebuild Europe and Asia by recreating:

A dynamic world economy in which the peoples of every nation will be able to realize their potentialities in peace...and enjoy increasingly the fruits of material progress on an earth *infinitely blessed with natural riches* [emphasis added] (quoted in Daly & Farley, 2004).

During the intervening years, the world’s population has roughly tripled, per-capita resource throughput has increased more than nine-fold, and billions of people have been unable to overcome poverty. Morgenthau’s first goal, realizing our human potential, was directly linked to economic prosperity perceived as having no fixed limits. The coupling of human potential (above a minimum need) with economic development was an acceptable premise in the 1940s, and today remains the dominant development paradigm. We treat the world’s material resources and ecological systems as infinitely regenerative.

However, as William Rees (2012) notes, “the growth-oriented values and assumptions underpinning contemporary economic models and consequent ‘environmental’ behavior are fundamentally at odds with the biophysical laws and dynamics governing vital ecosystem and geophysical processes.” It is difficult to envision any politically acceptable reform of the prevailing paradigm that would produce a sustainable relationship between the modern human enterprise and “nature” if we are to have shared governance. Rees and many others have also suggested that the global human enterprise is currently in a state of overshoot. Our aggregate energy and material consumption and waste production have begun to exceed the ecosphere’s regenerative and -assimilative capacities. Thus, the magnanimity of Morgenthau’s goal for humanity is compromised by the naiveté of the linked economic paradigm.

Moreover, decision makers throughout society increasingly recognize that the policies we implement have not only failed to solve our persistent sustainability problems but are, in fact, causing them (Sterman, 2012). Well-intentioned programs, for example, may create unanticipated “side effects.” The pesticide DDT and polychlorinated biphenyls (PCBs), for instance, have wondrous industrial properties that dramatically improved human health, safety, and quality of life in the short term, but the result has been “policy resistance,” the tendency for interventions to be defeated by the system’s response to the intervention itself (Sterman, 2012). The challenge, therefore, is to embrace a new narrative about human well-being without the slavish attachment to illusory economic compromises.

Challenge 2: Earth Demands in the Anthropocene

How do we reconcile human use of the Earth’s natural resources with the planet’s ability to provide them at sustainable levels? The challenge is to learn how to make the transition from the threatening set of present circumstances to a sustainable Earth system that encourages, not just allows, realization of Morgenthau’s human potential. One way is to examine the assumptions and outcomes of our own decisions. Even though human society cannot be manipulated as if in a laboratory experiment, the interactions between humans and their environment are, as many have suggested, suitable subjects of rigorous scientific analysis and advancement to improve our understanding of the threats to, and opportunities for, sustainable development (NRC, 2002). Tradeoffs, sacrifices, and compromises will be needed to make use of this improved understanding, and so learning about the consequences of *how* we manage the global commons is essential. Successful conflict manage-

ment and consensus building is also important. Both require innovative approaches and the rediscovery of proven ones. A successful transition to sustainability will involve critical advances both in new knowledge and in humankind's social and technological capacity to turn that knowledge into action (NRC, 2002). This is the essence of the emerging field of sustainability science (Kates et al. 2001; Clark & Dickson, 2003), and is the core fabric of the modern institution that seeks the knowledge, experiential base, and wisdom necessary to maintain human-environment interactions on sustainable trajectories.

The sustainability transition must, therefore, consider the dynamics of evolution and the complex interplay of social, economic, and natural systems. The required integration of disciplines goes beyond individual areas of study—population, economy, water, food, energy, and climate—to identify the common threads and drivers of systemic change.

Challenge 3: Economies and Energy Use

An example of these integrative biophysical-social dynamics is the dependence of the world's economy on energy and other resources to manufacture goods, to provide services, and to create capital. The direct relationship between energy use and Gross Domestic Product (GDP) reveals the central role of energy in the economies of nations and underscores the limits imposed on any global economic growth model.

Several emergent properties of the relationship are shown in Figure 1. First, the ecological footprint of humans on Earth, or the aggregate influence of per capita resource consumption and waste production, increases with energy use and GDP. It has not been possible to increase socially desirable goods and services without raising the use of resources or increasing environmental degradation, i.e., climate change, habitat loss, pollution, and reduced biodiversity. Second, to support the projected global population of 9.5 billion by mid-century with a standard of living approaching that of the United States would require about 268 terawatts (1 terawatt = 10^{12} watts) of energy, or about sixteen times current global energy use (Brown et al. 2011). Third, of the eleven recessions in the United States since World War II, ten, including the most recent, were preceded by a spike in oil prices (Murray & King, 2012). Finally, although some economists have dismissed warnings that energy shortages might ultimately limit economic growth because of the belief that technological innovations will always meet demand, there is little or no scientific support for the latter proposition (Brown et al. 2011).

Ominously, there is evidence of threshold changes appearing. Since 2005, for example, the oil

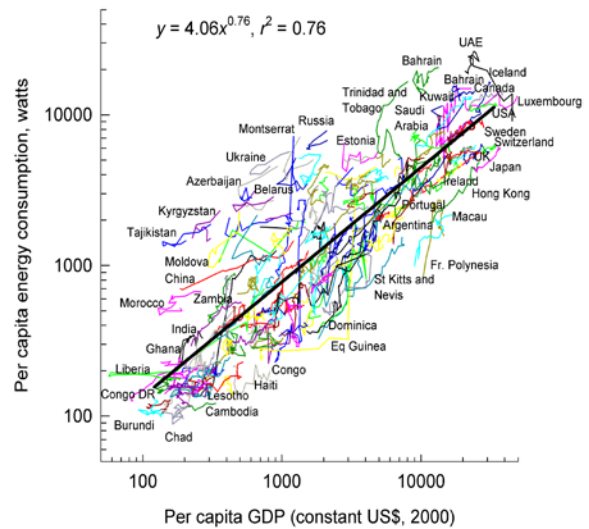


Figure 1 The relationship between per capita energy use and per capita GDP (in US dollars) of countries from 1980 to 2003. The thin colored lines show trends for individual countries. The thick black line is a regression model fit to the mean values for each nation during this period (Brown et al. 2011).

market has tipped into a new “system state” that is similar to a phase transition in physics: oil production is now “inelastic” and unable to respond to rising demand (Murray & King, 2012). Among the challenges we have to recognize and address are the subtleties and compromises of our relationships with nonrenewable energy, to optimize what we use, and to prepare for pending scarcities.

Challenge 4: Urbanization

The climate crisis won't be solved by changing light bulbs and inflating your tires more, planting a tree and driving a little less. It's going to require a truly fundamental shift in how we build our cities and live in them.

Richard Register (2009)

A second example of these complexities is a worldwide process of urbanization that increasingly defines the human ecological niche and its planetary “footprint” (Rees, 1992). Cities comprise the major habitat of the dominant species on the planet and make unmatched biophysical demands on the ecosphere. The future organization and functions of cities will demonstrate how well we are creating sustainable systems. Urbanization is the greatest mass migration of people in history, and its pace is accelerating. The United Nations projects that the world's cities will add 2.9 billion people over the next 40 years, which is more than had accumulated on Earth in the entire history of *H. sapiens* up until 1957, and

more than the anticipated increase in total human numbers of 2.3 billion (Rees, 2012). Like the ecosphere, cities are self-organizing dissipative structures existing far from thermodynamic equilibrium. They are open, growing, dependent subsystems of the materially closed, non-growing finite ecosphere. Yet, while the ecosphere evolves and maintains itself by “feeding” on an extraterrestrial source of energy and by continuously recycling matter, cities grow and maintain themselves by “feeding” on the rest of the ecosphere and ejecting their wastes back into it (Rees, 1992; 2012). Cities are heterotrophic nodes of intense energy/material consumption and waste generation that are entirely dependent on the productive and assimilative capacities of complementary producer ecosystems often located at great distances from the cities themselves. They are urban parasites of the rural landscapes. In other words, cities can grow and increase their internal order only by “disordering” the ecosphere and increasing global entropy (disorder) elsewhere.

Importantly, this process of urbanization creates a dramatic shift in city-dwellers’ spatial/psychological relationships to the land, but there is no corresponding change in eco-functional relationships. Despite this psychological shift, decoupling people from nature, in a material sense, urbanization generally increases human per capita “load” on the cities’ surrounding ecosystems. Failure to understand the basic facts of urban *human* ecology may doom our quest for sustainability and increase the vulnerability of cities to global ecological change. Understanding the ecology and management of cities and their dependent relationships with the countryside is a fundamental challenge of sustainability science.

Challenge 5: Controlling Nature

Humans have a duty to restructure nature for their survival.

Freeman Dyson (quoted in Dawdoff, 2009)

This anthropocentrism expresses humankind’s faith in its technology and knowledge to manage nature, with the supposition that “survival” is sufficient. We are a product of evolution and have been “trained” to do whatever it takes to survive, which is perhaps the “duty” that Dyson refers to. The polar opposite to this knowledge-based worldview is an ignorance-based one that holds we know very little about many things, and not much about most (e.g., Vitek & Jackson, 2008; Turner, 2009). The problem is not whether natural systems are going to change because of human influences—but *how* this happens and *to what end*. There was more than just survival in mind when Morgenthau spoke of the human “potentialities in peace.” Because fluctuations in nature im-

pose problems in meeting production goals, the strategies for controlling environmental variability and natural disturbance become essential for managing nature. Unfortunately, such practices create a model in which humans attempt to dominate nature in the sense that nature is to be conquered, controlled, and ruled (*sensu* Holling & Meffe, 1996; Folke et al. 1998).

This “command and control” approach to environmental management is still today’s *modus operandi* and has not been effective in keeping global growth tracking along sustainable trajectories. In fact, a case can be made that reducing uncertainties in natural systems themselves damages the values that we aim to preserve. The “paradox of the dual mandate” remains at the very heart of the matter (Roe & van Eeten, 2001): whereas complexity, interdependence, high levels of uncertainty, unpredictability, and dynamism characterize natural systems—traits that prevent competitive dominance by any one species—human-dominated systems seek predictability and stability to ensure uninterrupted provision of resources for human use. The need for resolution of the paradox arises from society’s desire to preserve, restore, and rehabilitate natural ecosystems that are defined by disorder in key factors (see below), *while at the same time* ensuring the provision of reliable, predictable, and stable supplies of goods and services (Roe & van Eeten, 2001; Weinstein et al. 2007). The acceptance and/or resolution of this paradox is at the forefront of the sustainability transition.

Challenge 6: Ecosystem Resilience

Sustainability implies maintaining the capacity of ecosystems to support social and economic systems over the long term. This capacity for ecosystem resilience is an underlying feature of sustainable systems (Gunderson & Holling, 2002) that cannot be predicted or understood simply by understanding its parts. As Berkes et al. (2003) note, it has three defining features: 1) the change that a system can experience, but still retain the previous controls on structure and function and degree of attraction within a sustainable trajectory; 2) the capability of the system for self-organization; and, 3) the ability to optimize capacity for learning and adapting. Resilience is a promising concept because it provides a framework for maintaining stability in the face of change, and as Berkes et al. (2003) comment, “[I]t’s synonymous with ecological, economic and social stability.” But it is also important to note that ecosystem resilience is not defined as a return to equilibrium; rather as a consequence of complexity, multiple states, or domains of attraction and multiple equilibria coexist *simultaneously* in ecosystems. Understanding and promoting ecosystem resilience is another key chal-

lenge of the sustainability transition.

These six challenges (C1–C6) together constitute a substitute narrative for the present paradigm. The new paradigm effectively confines a worthwhile goal of developing human potentialities with a shallow economic framework (C1) functioning within present (and frequently unknown) complexities (C2) that involve precarious dependencies on energy (C3) that in turn drive massive urbanization at the planetary scale (C4). Working our way toward a high-quality sustainable system requires the acceptance of uncertainties of the natural system, even as predictability in the social goals is sought (C5), along with formal appreciation in the governance structure and function of ecosystem resilience as a precondition for societal well-being (C6).

Meeting the Challenge(s): Systems Thinking

Because of the complex relationships among people, ecosystems, and the biosphere, human health and well-being are closely linked to the integrity of local, regional and global ecosystems.

National Science Foundation (2002)

The challenges described herein are significant and deeply-rooted, so that *any* worthwhile sustainability transition will require a comprehensive understanding of the complexity and interactions within coupled human-environment systems (CH-ESs), and an ability to forecast the consequences of our actions. Knowing the challenges is one thing, but addressing them makes it necessary to develop the specific tools and processes that will help us design better policies, facilitate social learning, and catalyze the technical, economic, social, political, and personal changes needed to create a desirable and sustainable society.

It is a challenge to synthesize new knowledge emanating from sustainability science in policy-relevant ways (Carpenter et al. 2009), because this requires problem solvers at all levels to harness science and technology from anywhere in the world (Steffen et al. 2005). Synthesizing new knowledge also addresses the widely recognized problem of the application of scientific results for decision support and decision making. The decision process itself needs analysis (Anderies et al. 2010) and it is absolutely essential to understand what kinds of institutions can best perform these complex bridging roles, i.e., act as *boundary organizations* between science and policy across multiple scales and across the social and natural science disciplines and do this under a wide range of social circumstances (Steffen et al. 2005).

Partnerships are needed to facilitate the engagement of scientific, technological, and political and

social sectors to support environmentally sustainable human development globally and to build a truly international community for sustainable development. It is important to engage nontechnical with technical fields and lay and professional communities in ways that allow all to participate meaningfully and at different scales and dimensions. Doing this is a task of sustainability science, a new field of formal inquiry with immediate relevance. It is worthwhile, we think, to look at its origins to understand its potential for further development.

The Emergence of Sustainability Science and Systems Thinking

Today's challenges are the result of systems that we have created...it is the unanticipated side-effects of our own actions, side-effects created by our inability to understand and act in consonance with our long-term goals and aspirations...[To address this issue] system dynamics will help us expand the boundaries of our mental models...help people see themselves as part of a larger system, so that we become aware of and take responsibility for the feedbacks created by our decisions...that shape the world in ways large and small, desired and undesired.

John Sterman (2002)

Two insightful and influential reports from workshops held at Friibergh (Sweden) and at the Air-lie Center, Warrenton, Virginia (United States), in 2000 and 2009, respectively, summarized the global sustainability challenges and led to a formal definition of sustainability science (Kates et al. 2001; Levin & Clark, 2010). The discussion at Friibergh revealed profound differences in perspectives among scientists in developed countries versus those in developing countries (Kates, 2012). Scientists in the former focused primarily on global issues, whereas their colleagues in the latter addressed principally local matters. The two groups were separated by a variety of economic, technological, and capacity divides. Northern scientists worried about the effects of affluence and consumption as well as climate change and its causes, and undertook theory-driven research. Southern scientists, in contrast, worried about the effects of poverty and underconsumption and the impacts of climate change, and pursued action-driven investigations. Such differences notwithstanding, the workshop also reflected broad agreement that science and technology have an enormous potential to facilitate a sustainability transition. As Kates (2012) notes, realizing that potential will require serious efforts to promote a science for sustainability.

At the more recent event in Virginia (Levin & Clark, 2010), six sets of thematic research were iden-

tified, including the necessary tradeoffs between natural and human systems and the need for rigorous evaluation of sustainability trajectories focused on a systems approach and a new generation of models. Emphasis on CH-ES tradeoffs and sustainability trajectories was an underlying theme of the workshop. Both the Friibergh and Airlie Center meetings identified the basic need for better theory and models to bridge the gap between scholars with expertise in modeling (but not in CH-ES) and empirical scientists knowledgeable about CH-ES (but not modeling complexity). Participants suggested that only in climate modeling had there been a significant improvement in the merger of theory and models.

The participants at Airlie Center noted that “the time is ripe for developing a general characterization of how alternative patterns and processes in the human use of nature result in different tradeoffs, with the goal of understanding how maximal human well-being can be secured from the available ‘natural capital’” (Clark & Levin, 2010). The attendees concluded that advances in agent-based and network approaches to the modeling of complex systems “offer promise of doing better as do several approaches to the nonlinear systems and the development of [transdisciplinary], multi-scale scenarios.” Attending scientists expected major gains from employing new modeling approaches to a few well understood human-environmental systems, and similar benefits might be realized by developing model systems such as those employed in ecological and medical research (Clark & Levin, 2010). The “technology transfer” of forecast outcomes of CH-ES interactions would, for example, be facilitated by adaptive governance, collaboration, and institutional flexibility (Armitage et al. 2007).

One of the key challenges in forecasting future trajectories was also discussed at Airlie Center: What are the likely unintended consequences—both social and environmental—of adaptation and diffusion of new technologies and how well can these consequences be predicted before wide-scale adoption and diffusion of new technology? (Chan et al. 2010). It is here that the systems approach and systems thinking take center stage.

Systems Theory and Complex Adaptive Systems

Systems theory is concerned with both *wholes* and *wholeness*. It emphasizes connectedness, context, and feedback as underlying components and processes. The understanding arising from systems theory comes from integrating knowledge of how parts of the system work together, rather than how they work in isolation. Of particular interest to sustainability scientists is the observation that complex adaptive systems (CAS) also have emergent properties

and phase transitions not normally observed in simpler systems: nonlinearity, uncertainty, multiscale interactions, emergence, hierarchy, and self-organization (Levin, 1998; Anderies et al. 2010; Solé, 2011). CAS structure is often hierarchical or nested. Phenomena at each level tend to have their own emergent properties that are coupled by feedback loops and allow the system to be self-organizing and buffered against external forcing. Most importantly, because of the multiplicity of scales, there is no one “correct” perspective on a complex system. CASs are comprised of agents that interact locally based on information they use to adaptively respond to their environment. Behaviors typically emerge from such interaction that are not imposed or predetermined (Levin, 1998; 2010). Unlike their linear counterparts, numerous potential equilibria may co-occur as multiple stable states or stability domains in CASs (Holling, 2001).

The concept of CASs may be extended further to address the interrelationships between humankind and nature in CH-ESs (Gunderson & Holling, 2002; Berkes et al. 2003; Anderies et al. 2010). CH-ESs can also organize around one of several equilibrium states (or “attractors”). When conditions change, feedback loops act to maintain the current state, but at a certain threshold the system may move to a new stable state. Like any CAS, CH-ESs are often unpredictable. An important observation of the behaviors in CH-ESs is that they cannot be understood, let alone managed, through scientific activity organized along traditional disciplinary lines (Jasanoff et al. 1997), but require a transdisciplinary approach. While sustainability science focuses on macroscopic interactions between humans and their environment, it must be recognized that control may rest at lower levels of organization (Levin, 2010). Thus, a more complete, more systemic understanding of emergent behavior in CH-ESs is critical to unraveling how such systems can promote sustainable development (Anderies et al. 2010).

Where Do We Go From Here?

If the “naïve” narrative is abandoned by governance institutions and decision makers, as it should be, then a stronger, more appealing sustainability narrative must take its place. A potent vision is needed, therefore, to maintain the compass heading, and there is nothing quite like an “unfair” system to undermine cooperation and a sense of community (Turner, 2012). For instance, Wilkinson & Pickett (2009a; 2009b) have shown in myriad of ways how economic stratification is correlated with social dysfunction, e.g., teenage pregnancies, imprisonment, health problems, educational disparities, and other social problems including mental illness, incarceration, obe-

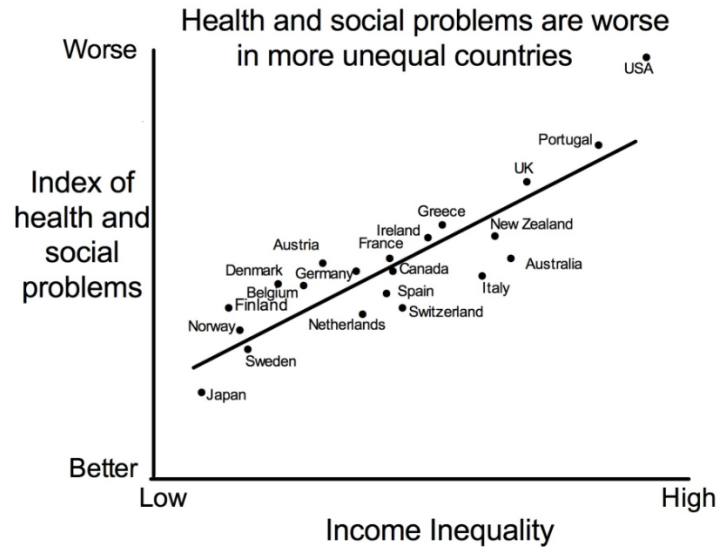


Figure 2 Wilkinson & Pickett (2009a; 2009b) discuss numerous direct relationships between the scale of income disparity and negative social attributes. Source: <http://www.slideshare.net/equalitytrust/the-spirit-level-slides-from-the-equality-trust>.

sity, illiteracy, drug abuse, and diminished education performance among developed and underdeveloped countries (Figure 2).

Developing public understanding of the problems and alternatives is essential. An economy is embedded in a social and political context which, in turn, is embedded in ecosystems upon which all life depends. The interests of business, society, and the environment should therefore align at a fundamental level(s). However, as Sterman (2012) observes

[W]e cannot have healthy firms, a healthy economy and healthy people if growth and the pursuit of profit destroys the environment, and we cannot have a healthy environment if people live in poverty, are ill-fed, [and] without decent housing, healthcare, education or economic opportunity.

At some threshold, or series of thresholds, we lose the time and resources to make wise choices.

There is no learning without feedback or without knowledge of the results of our actions. Traditionally, scientists generate that feedback through controlled experimentation, an iterative process through which intuitions are challenged, hypotheses tested, insights generated, and new experiments run. However, reductionist methods and experiments are impossible to deploy in many of the most important complex systems, including several critical for sustainability. When actual experimentation is impossible, scientists rely on models and simulations that enable controlled investigations in virtual worlds (Steffen et al. 2005;

Andersson et al. 2010). Our inability to accurately predict the weather or economic trends without improved models are just two examples.

Simulation models have long been central in sustainability and environmental research; however, simulations are not only useful in knowledge creation, but must also become a main tool in knowledge communication. They are already powerful tools to support management approaches. Integrated earth-system models, for example, allow many scenarios of interacting natural and human-driven changes to be developed and evaluated. In addition, the models and scenario development that follow from them must evolve further through integrated transdisciplinary research and in continuing dialogues between the scientific community and policy makers at a variety of levels (NRC, 2002; Steffen et al. 2005; Kates, 2012). More use-inspired research is needed, however, to support sustainable development at the global scale (Levin & Clark, 2010; Kates, 2012).

There is much more, of course. Carpenter et al. (2009) summarize studies including the Millenium Ecosystem Assessment's attempts to synthesize scientific knowledge about the capacity of global ecosystems to support human well-being.¹ The authors call for a new generation of integrated quantitative models across a range of coupled social-ecological systems that would be essential for research, synthesis, and projections of the consequences of management actions. Topics would include addressing non-linear changes and improving the assessment and

¹ See <http://www.maweb.org>.

communication of uncertainty. Moreover, these new models would have the capacity to consider spatial boundaries of systems, units of analysis, time horizons, inputs and drivers, scale, as well as key components of the system and their relationships and outputs (Carpenter et al. 2009). Finally, the authors conclude that a great deal of work is still needed to make these models an operational part of the sustainability scientist's "toolkit" that might also include scenario methods coupled with the evolving models.

To move beyond slogans about interconnectedness and systems, however, we also need specific tools and methods to develop our systems thinking capabilities, methods that avoid both self-defeating pessimism and mindless optimism, while simultaneously embracing the values of the scientific method and ecological realities (Chapin et al. 2010; Graedel, 2010). Interactive, transparent simulations for learning, grounded in the best available science, now exist for a wide range of sustainability issues. To enable learning, Steffen et al. (2005) comment,

[T]hese management flight simulators must give people control over assumptions and scenarios, encourage wide-ranging sensitivity analysis, and run nearly instantly online or on ordinary desktop and laptop computers, so that people receive immediate feedback. When experimentation is too slow, too costly, unethical, or just plain impossible, when the consequences of our decisions take years, decades or centuries to manifest, that is, for most of the important issues we face in building a sustainable world, simulation becomes the main—perhaps the only—way we can discover for ourselves how complex systems work, where the high leverage points may lie.

A new generation of systems models will be required that address 1) spatial and temporal heterogeneity; 2) nonequilibrium properties and scale dependence, and 3) the coupling of pattern and process. In a recent treatise, Liu et al. (2007) review six case studies that explicitly examine complex interactions and feedback in CH-ESs. The authors conclude that future research on complex systems must include not only individual site-specific studies, but also "coordinated, long-term comparative projects across multiple sites [and scales] to capture a full spectrum of variation."

Education in a Sustainable World

Education is critical for promoting sustainable development and effective public participation in decision-making.

United Nations (1992)

Sustainability science is both problem driven and solution oriented, and is underpinned by "use inspired" research (Stokes, 1997). Grounded by traditional educational goals, among them critical thinking and social learning, sustainability science goes beyond these fundamentals to introduce and apply "new" knowledge as transformational action in participatory, deliberative, and adaptive settings.² More than ever, the skill profile of future graduates will be those of problem solvers, change agents, and transition managers. By acquiring "key competencies" for problem solving in a complex world, sustainability science graduates will be set apart from traditional bounded disciplines (Wiek et al. 2011).

Much has been written about emerging sustainability curricula in higher education, but these skills generally fold into a new toolkit that can address multiple interacting stresses on CH-ESs. In addition to "use inspired research" and transdisciplinary curricula, the new education and outreach paradigm will take many forms: 1) improved communication with government, decision makers, the media, and the general public to convey the urgency of sustainability challenges; 2) development of new policy-formulation tools, including systems modeling and other simulations, visualization methods, and appropriate metrics, that recognize the complex, interconnected nature of ecological and socioeconomic systems; 3) introduction of an awareness of ecological systems into commerce, as in the emergence of integrated energy-management services and sustainable architectural practices; and 4) development of mechanisms for integrated dialogue among industry, government, and academia, shifting from an adversarial to a cooperative approach.

What Skill Set and Knowledge Do Students Need to Acquire?

First, many scientists and decision makers have suggested that achieving sustainability will require a "solutions orientation" that includes addressing tradeoffs among different solution pathways. A useful description of the difficulty is that when:

² Social learning is vetted in the slow, interactive accumulation of scientific knowledge, technical capacity, management institutions, and public concern over extended periods (generations).

[M]ultiple desirable but competing objectives exist, it is not possible to maximize each...[and] in any system with multiple competing objectives, it will not be possible to meet every one.

United States Commission on Ocean Policy
(2004)

Second, sustainability science graduates should be skilled in moving beyond a limited focus on immediate problems to constructively reframing challenges within complex systems in terms of overall success (Basile, 2011; Vincent & Focht, 2011). That is, they should be able to address challenges not only in classic ways, such as on the factory floor or within institutional reach, but also in terms of success at increasing scales in both the short and long term.

Finally, the competencies gained will function in complex systems when future graduates are engaged with experts and nonexpert decision makers in contexts with inherent uncertainty, i.e., in almost any real-world situation where one seeks sustainable solutions.

Graduates with this mix of skills can help others understand, think, and act across multiple parts of a system. A graduate in sustainability understands mixing use-inspired research with values and cultural and ethical decision-making perspectives across the natural and social sciences as part of the process of building lasting strategic outcomes in the effort to achieve a sustainable world (Basile, 2011; Vincent & Focht, 2011). Rather than the “silo” mentality that has placed us in this untenable situation in the first place, it becomes a matter of the following:

- Redefining planning boundaries and horizons in terms of sustainable success.
- Understanding and managing resource potentials, and handling tradeoffs and compromises while minimizing new sustainability problems.
- Integrating the growing knowledge and tool base into increasingly robust and flexible strategic pathways.
- Supporting cross-sector collaboration and cooperation.
- Embracing uncertainties inherent in our emerging planning reality.
- Translating all of this into practicality given today’s context of unsustainable concepts and institutions.

To be clear, this transition is not limited to higher education. It can be used spectacularly in the K–12 classroom. Peter Senge (2012) tells the story of a 12-year old, Annalise, and her classmates, who,

after gaining approval from the school principal, parents, mayor, and town council, built a wind turbine at her school as part of a sustainability teaching module. Following a four-minute project presentation to 250 local residents, she “set aside her notes and standing calmly, some 75 pounds of fierce determination, said, ‘We children are often hearing that “you children are the future.” We don’t agree with that. We don’t have that much time. We need to make changes now. We kids are ready, are you?’”

Sustainable Governance Incubators

Annalise’s sentiment about being “ready” is worthy of further commentary. If a system is too complex to reduce to its component pieces without losing sight of the whole system’s behavior, and if there are more unknowns than knowns, then we are led to the challenges of assembling a new sustainability paradigm. When would we be ready? As we move forward, rather than thinking of a stepwise process of ending one phase (preparation) and beginning another (implementation) we might think of an ongoing integrated process. In other words, we will not be ready all at once, but in stages. Because the clarity of science is an essential component of decision making, and because we are also influenced by our experiences internally and externally, we need to look at the transition as an evolving social contract. The path of transition, therefore, is wide, incorporating social, economic, political, and other fields traditionally engaged less intensely than they need to be.

Numerous initiatives are underway or in planning stages that increase the “what, why, and when” of sustainability in practice as part of this ongoing process (Table 1). The idea is to build something like social incubators, experimental social sets, demonstration organizations, or quality centers that bring all the issues out in the open for the community to work with, and with recognizable consequences. The country of Bhutan, for example, is on a path that seeks to integrate equitable social opportunity and economic development with environmental conservation and participatory governance. The country’s young king has substituted the concept of “gross national happiness” for GDP to indicate priorities in a national program embracing sustainable systems as the goal.

Several watershed-sized agricultural projects in the American Midwest are working on sustainable practices, but with a suite of governance tools restricted by national farm policies, global commodity pricing, and historical precedents. One proposal suggests that society needs to build on the entrepreneurial and innovative energy of Midwestern farm communities by creating examples of shared governance

Table 1 Examples of programs and experiments in CH-ES system transitions to sustainability.

Content/Subject	Scale	Infrastructure Support
Global Visions and Cooperation	Rio+20 Summit	National governments, United Nations
Strategic visions for biodiversity and ecosystem services	Global	DIVERSITAS
Global Visions and Cooperation	Global	Rockefeller Brother's Fund, Sustainable Development Program
Global Visions and Cooperation	Global	Tellus Institute, Widening Circle Campaign for a Global Citizen Movement
Consortium on relationships between climate change, agriculture and food security	Low- and middle-income countries	Consortium of International Agricultural Research Centers, United States Agency for International Development, Canadian International Development Agency, European Union, and others
Gross National Happiness Index	National	Royal Government of Bhutan
Interdisciplinary research on coupled human-environmental systems	National	United States National Science Foundation, CH-ES Program
Study and understand sustainability issues	Qualitative and quantitative analysis of the institutions, infrastructure, and developing issues	United States National Academy of Sciences, Sustainability Science Section
Biophysical couplings within agricultural policy	Mississippi River watershed	United States National Science Foundation, CH-ES program
Agricultural Landscape: shared governance of sustainable landscapes to restore Gulf of Mexico	5,000 km ²	Pew Foundation Recommendation, Macondo Oil Spill
Creating community peace at the local level, including with the natural world	Newark Peace Education	Tibet House, Foundations, Office of the Mayor of Newark, New Jersey
Institutional collaboration for sustainable systems	Global	Stockholm Resilience Center, Arizona State University, Portland State University, Australian National University, and Uppsala University
Sustainability programs in higher education	Arizona State University, Portland State University	Traditional
Multi-institutional courses in sustainability	Arizona State University, Cornell University, Florida International University, Harvard University, University of Minnesota, National University of Mexico, Princeton University	National Center for Ecological Analysis and Synthesis
Professional journals	<i>Solutions; Current Opinion in Environmental Sustainability; Sustainability: Science, Practice, & Policy; International Journal of Agricultural Sustainability</i>	Foundations, individuals, public agencies, professional societies; for profit publishers

that others can follow (Peterson et al. 2011). The participants would have nearly complete oversight over their watershed. This approach can simultaneously address water-quality problems contributing to the “dead zone” in the Gulf of Mexico *and* increase the productivity and resilience of Midwest agriculture. How might this be accomplished at the level of the whole landscape? Start at a meaningful scale; learn what works; put trust in regional democracy. Do it by creating watershed-scale “incubator” projects that build on the smaller-scale projects. But, at the same time, these projects must be large enough (5,000 square kilometers) to capture the ecological, social, economic, and political complexities of mod-

ern farming. They should have watershed-scale governance based on shared responsibilities for clean water, a healthy environment, a robust economy, and equitable access to resources.

Conclusion

The underlying principles of sustainability science and the new “social contract” for science (Lubchenco, 1998) contend that a sustainable biosphere is not only necessary, but economically feasible, socially just, and ecologically sound. With “use inspired” research as its underpinning, the discipline must be broadened to encompass the overarching

question: at multiple scales and over succeeding generations, how can the Earth, its ecosystems, and its people interact toward the mutual benefit and sustenance of all? Creating an effective science of sustainability and building the public understanding required for action requires us to develop the skills to recognize the boundaries of our mental models and then to expand them so that we become aware of, and take responsibility for, the feedbacks created by our decisions (Sterman, 2012). And these feedbacks are not static. Westley et al. (2011) referred to human shortcomings as an “ingenuity gap” between the increasing seriousness of global sustainability problems and the lagging supply of solutions. We come to the realization that knowledge about our role in the environment cannot keep pace with the presently poorly understood consequences of our actions.

John Sterman (2002) wrote that “overcoming policy resistance and building a sustainable world requires meaningful systems thinking coupled with community engagement in promoting the common good.” It requires new knowledge gained from use-inspired research (Stokes, 1997; Kates, 2012) and rigorous applications of that research to expose our hidden assumptions and biases. It entails engagement of all scientists to face the ethical issues raised by growth and inequality and to speak out for a just, equitable, and sustainable world (NRC, 2002; Steffen et al. 2011). It obliges us to listen with respect and empathy to others. It compels humility and the courage needed to lead in the face of uncertainty. Sterman (2012) said it so very well: “If we devote ourselves to that work we can move past denial and despair to create the future we truly desire—not just for us, but for our children. Not just for our children, but for all the children.”

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APPENDIX VI

**A REPRINT COPY OF DR. FOGARTY'S
PAPER ENTITLED *THE ART OF
ECOSYSTEM-BASED FISHERY
MANAGEMENT***

The art of ecosystem-based fishery management

Michael J. Fogarty

Abstract: The perception that ecosystem-based fishery management is too complex and poorly defined remains a primary impediment to its broadscale adoption and implementation. Here, I attempt to offer potential solutions to these concerns. Specifically, I focus on pathways that can contribute to overall simplification by moving toward integrated place-based management plans and away from large numbers of species-based plans; by using multispecies or ecosystem models and indicators that permit the simultaneous and consistent assessment of ecosystem components while also incorporating broader environmental factors; and by consolidating individual administrative and regulatory functions now mostly dealt with on a species-by-species basis into a more integrated framework for system-wide decision-making. The approach focuses on emergent properties at the community and ecosystem levels and seeks to identify simpler modeling and analysis tools for evaluation. Adoption of ecosystem-based management procedures relying on simple decision rules and metrics is advocated. It is recommended that we replace static concepts for individual species focusing on maximum sustainable yield with a dynamic ecosystem yield framework that involves setting system-wide reference points along with constraints to protect individual species, habitats, and nontarget organisms in a dynamic environmental setting.

Résumé : La perception voulant que la gestion écosystémique des pêches soit trop complexe et mal définie demeure un des principaux obstacles à son adoption et son application à grande échelle. Je tente donc d'offrir des pistes de solution à ces préoccupations. J'aborde plus particulièrement des avenues qui pourraient contribuer à simplifier globalement cette approche en l'orientant sur des plans de gestion intégrés axés sur l'emplacement plutôt que sur un grand nombre de plans axés sur des espèces données; en utilisant des modèles et indicateurs multi-espèces ou écosystémiques qui permettent l'évaluation simultanée et cohérente de différents éléments de l'écosystème tout en intégrant des facteurs environnementaux plus larges; et en consolidant les différentes fonctions administratives et de réglementation qui, à l'heure actuelle, font principalement l'objet d'une approche espèce-par-espèce, en un cadre décisionnel plus intégré à portée systémique. L'approche met l'accent sur les propriétés émergentes à l'échelle de la communauté et de l'écosystème et cherche à cerner des outils de modélisation et d'analyse simplifiés pour les fins d'évaluation. L'adoption de procédures de gestion écosystémique reposant sur des règles de décision et des paramètres simples est préconisée. Il est recommandé de remplacer les concepts statiques visant des espèces individuelles et axés sur le rendement équilibré maximum par un cadre de rendement écosystémique dynamique qui comprend l'établissement de points de référence d'échelle systémique et de contraintes visant la protection des différentes espèces, des habitats et des organismes non ciblés dans un contexte environnemental dynamique. [Traduit par la Rédaction]

Introduction

Despite long-standing calls for incorporation of broader ecological principles in fisheries management, implementation on a global scale remains slow and tenuous (Pitcher et al. 2009). The scientific foundations for ecosystem-based fishery management (EBFM) have been established over the last several decades (see, for example, Watt 1968; Wagner 1969; Cushing 1975; Regier 1978; Stroud and Clepper 1979; Mercer 1982; Pitcher and Hart 1982; May 1984; Caddy and Sharp 1986; Daan and Sissenwine 1990; Mooney 1998; AKSGP 1999; Hall 1999; Jennings et al. 2001; Sinclair and Valdimarsson 2003; Walters and Martell 2004; Browman and Stergiou 2004; and contributions therein). Recent books, symposia, and dedicated journal volumes reveal a very active and productive field of inquiry (Fowler 2009; Link 2010; Christensen and McLean 2011; Belgrano and Fowler 2011; Glazier 2011; Essington and Punt 2011; Fanning et al. 2011; Stephenson et al. 2012; Bundy et al. 2012; and Kruse et al. 2012). These advances notwithstanding, important concerns have been raised related to the overall tracta-

bility, cost, and potential effectiveness of incorporating ecosystem considerations in tactical fisheries management strategies (e.g., Longhurst 2006, 2010; Hilborn 2011; Rice 2012; Cowan et al. 2012). In the following, I attempt to provide some possible pathways toward resolution of these concerns.

EBFM is intended to provide an integrated framework for the sustainable delivery of a key ecosystem service. It takes into account interrelationships among the elements of the system, considers humans as an integral part of the ecosystem, and accounts for environmental influences. As defined here, EBFM is a place-based rather than a species-based approach. EBFM is designed to be adaptive in response to changing conditions and as scientific understanding accrues. It accounts for uncertainty and the mix of different (and potentially competing) societal goals and objectives. EBFM differs from what is sometimes referred to as an ecosystem approach to fishery management (EAFM), which retains a primary focus on individual species, stocks, or fisheries while incorporating ecosystem considerations into the whole.¹ In con-

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¹The proliferation of terms related to the general concept of holistic approaches to fishery management often masks a basic commonality of concepts and intent (Arkema et al. 2006). Here I simply wish to distinguish between approaches that focus on integrated management plans for defined ecological regions and those in which species and their associated fisheries remain the focal points for management in the context of broader ecological considerations.

trast, the spatial orientation of EBFM fits more naturally within the broader domain of ecosystem-based management (EBM) (Fogarty and McCarthy 2014). EBM addresses the cumulative impacts of the broad spectrum of human activities affecting ecosystems. The clear direction of national and international initiatives now underway is toward EBM and away from a sole focus on individual issues such as fisheries, coastal development, water quality, etc. In this context, EBFM is just one element of EBM; within this framework, objectives for EBFM must be reconciled with those of other sectors.

An overarching goal of EBM is to protect ecosystem structure and function to ensure the continued flow of ecosystem services. This utilitarian framework is not intended to downplay the intrinsic importance of these systems but rather to focus attention on our responsibility to actively manage the spectrum of human activities affecting aquatic ecosystems. Preservation of diversity in biological, social, and economic subsystems emerges as a critical element in meeting this goal. Palumbi et al. (2009) propose that preservation of biodiversity can serve as a cornerstone for EBM. Parallel considerations for the human dimension of EBM and EBFM are no less important. Management strategies that constrain options of fishers to adapt to changing conditions can lead to unintended consequences and increased stress on aquatic ecosystems. For social-ecological systems, maintaining diversity at all levels provides a buffer against uncertainty and a hedge against future change.

The point of departure for this essay is not that conventional fisheries management has universally failed but rather that it is necessarily incomplete. It can only take us so far. When clearly defined targets and limits for management have been established and enforced, it has stemmed the tide of overexploitation in a number of fishery ecosystems around the world (e.g., Mace 2001; Worm et al. 2009; Worm and Branch 2012). Single-species approaches, however, ultimately do not lead to an internally consistent framework for management of assemblages of interacting species. Further, they do not generally account for changing environmental conditions or for the broader human dimensions of fishery systems (Charles 2001; Garcia and Charles 2008). For reasons described below, as fishing mortality rates are brought under control, EBFM becomes more rather than less important. Conventional management approaches unavoidably set up conflicts among individual management plans by ignoring interactions among species and the trade-offs that inevitably emerge. Here it is argued that we must build on the hard-won insights and successes of conventional assessment and management approaches and take the next steps toward a more holistic ecosystem framework to address these issues.

Fishery science is often described as principally focusing on individual species and their dynamics. A brief tour through the literature in fisheries journals, some in continuous publication for over a century, should be sufficient to quickly dispel this view. The origins of fishery science rest in a multidisciplinary framework as reflected in the founding principles of a number of aquatic research and management institutions established in the 19th century (Smith 1994). It is unquestionably true that fisheries "management" has largely centered on individual species and stocks. In this, fisheries management shares a connection with other areas of applied ecology such as conservation biology in which modeling efforts in support of management have often concentrated on individual species of concern. The rich tradition of broader-based multidisciplinary research in the ecology of exploited aquatic systems, however, does provide a strong founda-

tion for addressing the scientific requirements for EBFM. In a real sense, EBFM entails coming full circle to the roots of the discipline.

Viewed in the proper light, adoption of EBFM offers avenues to simplification of current management approaches.² The broader EBFM perspective affords opportunities for consolidating assessments and management plans for a very large number of individual species or stocks into a more cohesive and integrated set for defined ecological regions. Successful implementation of EBFM will ultimately depend on finding ways of managing scientific, administrative, and regulatory complexity. It will require skill in the arts of effective communication, stakeholder engagement, and simplification in the face of apparent complexity. The art of negotiation will be no less essential as trade-offs are identified and resolution is sought.

Background

The fundamental limitations of the prevailing single-species approach and associated management reference points have long been appreciated. Interspecific interactions, environmental and climate influences on system-wide productivity, and other factors all have a direct effect on the appropriate choice of limits and targets for management. These considerations call for a dynamic rather than static concept of management reference points. Three early perspectives will suffice to highlight the recognized limitation of single-species maximum sustainable yield (MSY) as a management objective:

... it is very doubtful if the attainment of maximum sustainable yield from any one stock of fish should be the objective of management except in exceptional circumstances. (Gulland 1969)

... it seems improbable that the perfect strategy would be to take MSY from each species. (Larkin 1977)

... common sense should lead us to dismiss a concept of optimum yield drawn from a series of single-species MSYs. (Sissenwine 1978)

Ignoring interspecific interactions is identified by each of these authors as a central limitation of the single-species approach. An important corollary is that natural mortality is not constant with age or size, nor is it time-invariant. Yet analyses embodying these assumptions remain prevalent. Incorrectly specifying a constant natural mortality rate in a single-species system introduces a scaling error that can be largely offset in the specification of management reference points. However, in a multispecies context as assemblages of interacting species change in response to management actions and (or) natural fluctuations, resulting in time-varying natural mortality rates, a much more insidious problem is introduced.

Single-species MSY continues to be a cornerstone of current management practices in many parts of the world. The early concentration on single-species management models no doubt arose from legitimate concerns related to analytical and regulatory tractability. Adoption of the MSY concept in national and international conventions also appears to have been strongly driven by geopolitical imperatives (Finley 2008, 2010). As noted by Mace (2001), the switch to considering MSY as a limit rather than a target reference point has played an invaluable role in reducing overexploitation in many areas. An unquestionable merit of MSY-related reference points has been the adoption of clearly defined standards for assessment and management. In the United States, under the provisions of the Magnuson-Stevens Fishery Conserva-

²This is not meant to imply that it is a simple problem. It is in fact a "wicked" problem (Berkes 2012) in which predictability is limited and unanticipated change is likely. It is nonetheless necessary to find pathways toward simplification if EBFM is to be tenable. The problems identified here do not go away if ignored. If not directly confronted, they will lead to unintended consequences.

tion and Management Act, optimum yield is defined as maximum sustainable yield as **reduced** by relevant social, economic, and ecological considerations. However, it remains relatively uncommon for reference points to be adjusted in this way based on ecological considerations. While the early concerns cited above refer specifically to MSY-related metrics, they are relevant to many of the MSY-proxy reference points now commonly in use that also ignore interspecific interactions, environmental variability, and other ecological considerations.

When ecosystems have been degraded by intensive fishing, resulting in stock collapses and alterations in ecosystem structure and function, the first steps for remedial action are effectively identical under both single-species and ecosystem approaches to management: sharply reduce fishing pressure (Mace 2001). This has led many commentators to note with justification that effective single-species management goes a long way toward meeting the needs of EBFM. But the issue is ultimately deeper and more systemic than controlling fishing pressure on individual species viewed in isolation. As fishing mortality rates are brought under control, interspecific interactions, climate and environmental forcing, and other factors become more important relative to the effects of fishing and therefore more critical to address. They are no longer masked by the overriding effects of overexploitation. If biological interactions are important, then trying to optimize the yield from individual species without accounting for these effects can only result in misleading management advice and expectations. When interacting species are covered by separate management plans, these plans unavoidably and actively work at cross-purposes in their attempts to achieve biomass levels corresponding to (single-species) MSY or to meet related objectives.

Results from a wide spectrum of multispecies and ecosystem models support the view that simultaneously extracting single-species MSYs from an assemblage of interacting species is not possible (e.g., Brown et al. 1976; Collie and Gislason 2001; Mueter and Megrey 2006; Steele et al. 2011; Walters et al. 2005; Mackinson et al. 2009; Fogarty et al. 2012; Heath 2012). The problem is etched in sharp relief when considering mixed-species fisheries where species-specific catchability and vulnerability to fishing result in different outcomes for each under a common level of fishing effort. We cannot fully control the fishing mortality rates separately for the individual species composing the multispecies assemblage. Differential mortality rates for different parts of the system will in turn lead to changes in community structure. Adopting the EBFM perspective does not obviate this problem; it does ensure, however, that it will be dealt with in a transparent way and not ignored. The centrality of the mixed-species problem was recognized over 50 years ago by McHugh (1959), who called for “management en masse” — a perspective that anticipated the use of aggregate production models described below (see also McHugh 1988).

If EBFM is to successfully replace current single-species approaches, unambiguous reference points and standards at the community and ecosystem levels must be established. It has long been recognized that, within limits, total fish yield, size structure, and biomass levels often reflect remarkably conservative properties of aquatic ecosystems and communities (Kerr and Ryder 1988). The apparent greater stability at the system level may reflect overall energetic constraints on system dynamics. We can take advantage of these properties to establish system-wide protocols for EBFM to ensure that system resilience can be maintained.

Coping with complexity

Whether we can deal with the daunting complexity of ecosystems and the associated management challenges is indeed a legitimate concern. We need to recognize limits to our understanding, precision, and control in the assessment and management of fishery systems. Substantial increases in administrative and regulatory

efficiency are possible by replacing large numbers of management plans for individual species or stocks with a much smaller number of fully integrated place-based plans. Here, a focus on system-wide production potential is advocated. The productivity of any ecosystem is ultimately set by the amount of energy fixed at the base of the food web, placing constraints on the production of all species, including ones of economic importance. This production is further conditioned on changing environmental states and must be viewed in a dynamic context. By shifting from a single-species to a community or ecosystem perspective but developing production-based ecosystem reference points, a natural bridge to current management practices can be established.

Scientific complexity

Models in support of EBFM can be arrayed along a continuum of complexity involving trade-offs in realism, mechanistic detail, and parameter and (or) model uncertainty. A central lesson in forecasting drawn from a diverse set of fields is that bigger, more complex models are not necessarily better and that model overfitting is a pervasive and pernicious problem (Silver 2012; Pilkey and Pilkey-Jarvis 2007). Gunderson and Holling (2002) indicate that a model should have no more than a handful of variables if it is to remain tractable and understandable. Single-species assessment models and approaches have arguably grown too complex with respect to data availability and quality, transparency to stakeholders, and other concerns (Cotter et al. 2004). For obvious reasons, these problems can be considerably amplified under EBFM unless a strategy for deliberately coping with complexity is adopted (Hill et al. 2007).

Models of low to intermediate complexity can often outperform more complicated models in forecast skill (e.g., Silvert 1981; Ludwig and Walters 1985; Walters 1986; Costanza and Sklar 1985; Fulton et al. 2003; Grimm et al. 2005; Hannah et al. 2010; Plagányi et al. 2012). This general point has been framed in different but interrelated ways including the trade-off between systematic bias and measurement error (Walters 1986), interconnectedness (Costanza and Sklar 1985), and “payoff” (Grimm et al. 2005), all as a function of model complexity. Grimm et al. (2005) adapted the concept of the Medawar zone to describe the region of optimal payoff at intermediate levels of model complexity. This designation honors Sir Peter Medawar, who memorably described science as the “art of the soluble” (Medawar 1967). In this context, payoff refers to levels of model complexity that provide higher levels of predictability (Grimm et al. 2005).

Models for EBFM

The approach taken to assessing the status of communities and ecosystems for EBFM will ultimately depend on the choice of management objectives and the nature of the scientific information and infrastructure available in different areas. These elements will differ substantially in different parts of the world. A range of methods and approaches that can span a broad spectrum of needs and available resources is therefore required.

The appropriate choice of modeling approaches depends critically on these issues and the specific requirements the model is intended to meet (Silvert 1981). The models described below span a range of complexities that can be tailored to the needs and scientific resources available in different areas. Because models at the more complex end of the spectrum have been nicely covered in recent reviews (e.g., Plagányi 2007), here I will focus on simpler models with modest data requirements that may be broadly applicable in regions where data availability and scientific resources are more constraining.

Even in extremely data-limited situations, it is nevertheless possible to make first-order estimates of expected system-level yield using broadly available data. The simplest approaches to estimating potential fish yields are based on empirical models. Predictive models relating total yields to chlorophyll concentration and (or) primary production have been applied in both marine (e.g., Ware

and Thomson 2005; Frank et al. 2006; Chassot et al. 2010; Friedland et al. 2012) and freshwater systems (e.g., McConnell et al. 1977). When applied on a regional basis, these predictors reveal strong evidence for bottom-up controls on fish yields in many ecosystems. These empirical statistical descriptors are very much in the spirit of macro-ecological approaches (Brown 1995; Maurer 1999) designed to complement experimental approaches and other modeling perspectives. Simple food chain models have also been used to assess fishery production potential in marine ecosystems (Pauly 1996; Ware 2000). Extensions to this approach using new information on energetic pathways and refinement of key inputs such as ecological transfer efficiencies have been developed (Fogarty et al. in press). In freshwater systems, a strong tradition of empirical yield models incorporating geomorphological characteristics, nutrients, and other factors has been established (Ryder 1965; Kerr and Ryder 1988).

Predictive models capitalizing on new developments in nonlinear time series analysis are also now being applied to catch and abundance series to characterize system dynamics and to develop short-term forecasts (Glaser et al. 2013). They build on the crucial insight that for systems exhibiting nonlinear dynamics, information on the system as a whole is encoded in time series for one or more individual parts. For systems with an important deterministic component, this broader system information can, in principle, be recovered by reconstructing the underlying attractor in a time-delayed coordinate system (Takens 1981; Deyle and Sugihara 2011). The method uses out-of-sample forecast skill as the measure of model performance and is consonant with earlier calls for the development of a predictive science of ecology (Peters 1991). Nonlinear time series analysis has been used to assess co-predictability in multispecies systems, where a model developed for one species of a potentially interacting pair is applied to the other and forecast skill is assessed (Liu et al. 2012). Full multivariate nonlinear times series methods afford opportunities to examine causal linkages among ecosystem components (Sugihara et al. 2012) including the effects of fishing and climate forcing on system dynamics (Deyle et al. 2013). These nonparametric models offer an alternative approach to dealing with model uncertainty.

In data-rich regions of the globe a broader range of options for analysis is possible, including application of multispecies biomass dynamics models, biomass- and size-spectrum models, size- and age-structured multispecies models, and full ecosystem models. Multispecies production models in which pairwise interactions between species are specified have been applied in both freshwater and marine systems (Walter and Hoagman 1971; Pope 1976; May et al. 1979; Sissenwine et al. 1982; Sullivan 1991). This approach is likely to be most tractable in systems with relatively few species. For example, Sullivan (1991) applied this method to a three-species Baltic Sea fish community and found evidence for both direct and indirect species interactions. In models of this type, the magnitude and sign of empirically determined interaction terms are used to assess the type of interaction involved (competition, predation, etc.). In systems of higher dimensionality, the data requirements with respect to time series length become more constraining for our ability to detect interactions (Sissenwine et al. 1982).

With appropriate care, the complexity of the system can be reduced by applying different aggregation strategies. Hilborn and Walters (1992, p. 449) noted that a "lump the species together" approach offered perhaps the best prospects for success for multispecies assessment and management among the alternatives they considered. It has the twin virtues of simplicity and broad

applicability to fishery systems throughout the world because of its modest data requirements. Although the method has been employed to remedy data limitations and (or) address system complexity (Sugihara 1984), the potential to implicitly account for interspecific interactions has also been a motivating factor in its use (Brown et al. 1976). In this approach, the trajectory of the whole is taken to integrate the effects of fishing and species interactions on the parts. For recent examples, see the contributions in Bundy et al. (2012).

It is essential to recognize that development of models for aggregate-species groups is not directed at understanding the dynamics of the individual species in the assemblage. Rather, we are seeking to base our assessment on the properties of the assemblage as a whole. These properties cannot be reconstructed by studying the parts in isolation. For nonlinear systems, the properties of the whole are not the same as those of its parts. In particular, understanding emergent properties (von Bertalanffy 1968) is a critical consideration. I believe that the primary rationale for focusing on functional groups is not mere convenience; rather, they are key structural elements in the way that the system operates. It must also be stressed that if we use aggregate models to set reference points, it will also be necessary to continue to track individual species (where feasible) and to set precautionary buffers to protect vulnerable species within aggregate groups (e.g., Fogarty et al. 2012; Gaichas et al. 2012; Nessler and Wilberg 2012).³ See Tyler et al. (1982) for a related discussion of management of assemblage production units.

Aggregate-species production models have been applied to entire fishery ecosystems (e.g., Brown et al. 1976; FAO 1977; Mueter and Megrey 2006), individual functional groups (Sparholt and Cook 2010; Fogarty et al. 2012), and a collection of functional groups with explicit interaction terms connecting the groups (Ralston and Polovina 1982; Bell et al. in press). These simple multispecies biomass dynamics models can readily accommodate environmental covariates to account for changing physical or ecological conditions (Mueter and Megrey 2006; Fogarty et al. 2012). More complex models for guilds or functional groups that incorporate broader demographic or ecological features have also been developed (Collie and DeLong 1999; Steele et al. 2011; Heath 2012).

Membership rules for defining functional groups are critically important. It is recommended here that functional groups should comprise species that are caught together, have similar life history characteristics, and occupy similar trophic positions. Such groups will, inter alia, often share similar size characteristics, habitat preferences, and history of anthropogenic and environmental perturbation. This definition therefore extends the guild concept in fisheries management (e.g., Austen et al. 1994) to accommodate a broader set of fishery-related and scientific considerations. A functional group can be thought of as a portfolio of species sharing certain common characteristics (see Hanna 1998; Edwards et al. 2004; and Sanchirico et al. 2008 for more on the portfolio concept in a multispecies fishery context). As with financial instruments, constructing a portfolio containing elements with negative covariances among at least some components can provide an important hedge against uncertainty and risk.

Methods of aggregation based on size or biomass structure have also been successfully used to represent multispecies systems (see Kerr and Dickie 2001). The approach takes advantage of the conservative properties of demographic structure in fishery systems (e.g., Murawski and Idoine 1992). Pope et al. (2006) and Jennings et al. (2008) provide recent size-based analyses that show considerable promise in capturing key ecosystem characteristics and

³This does not imply that full single-species analyses are required. Metrics that have been aggregated to represent system properties should also always be carefully examined in their disaggregated form to track the status of the component parts and to identify the need for corrective measures to protect individual parts of the system where necessary.

dynamics while focusing on a restricted number of parameters to define the system.

At the next level of complexity, multispecies and ecosystem models tracking individual species have been developed for fishery systems (see reviews in [Hollowed et al. 2000](#); [Whipple et al. 2000](#); [Plagányi 2007](#)). A substantial global initiative in applying the EcoPath with EcoSim (EwE) modeling framework has been developed and is being used to support EBFM in many parts of the world. [Christensen et al. \(2009\)](#) provide initial results for a prototype EwE “database-driven” system for each of the 66 currently designated Large Marine Ecosystems around the world. The analysis draws on a set of global databases to provide an initial parameterization of EwE models that can then be subsequently refined by local experts. End-to-end models such as Atlantis ([Fulton et al. 2011](#)) have also been developed for more than 30 systems around the world (B. Fulton, CSIRO, personal communication).

The simpler models described above are principally “top-down” ([Silvert 1981](#)) approaches that focus on higher levels of ecological organization. Depending on their internal structure, they may or may not be able to represent complex dynamical behaviors. Agent-based models provide an alternative “bottom-up” approach. These methods can be computationally intensive but employ simple decision rules for individual elements of the system (e.g., [Grimm et al. 2005](#); [Railsback and Grimm 2012](#)). These simple rules can in some cases generate quite complex dynamics (e.g., regime shifts) at the system level. In fisheries ecology, their use has most often been in the form of individual-based models. [Grimm et al. \(2005\)](#) note that direct consideration of observed patterns in the dynamics of these systems can substantially aid in guiding and constraining complexity in agent-based models. Here, we would focus on properties such as stationarity, variability, and resilience for the whole and the parts. Increasing interest in the potential utility of agent-based and multi-agent models by social scientists (e.g., [Gilbert 2008](#)) may provide one avenue for a fuller integration of the social and natural sciences for EBFM and EBM. To date, ways of quantitatively connecting broad social and ecological considerations in EBFM have been limited ([Garcia and Charles 2008](#); but see [Hennessey and Sutinen 2005](#) and [Holland et al. 2010](#)).

Indicators

Indicators are central components of the methods and modeling approaches for EBFM. They serve as key elements of Integrated Ecosystem Assessments (IEAs; [Levin et al. 2008, 2009, 2013](#)) and ecosystem-based management procedures (EBMPs; [Sainsbury et al. 2000](#)). Guidelines for selection of informative indicators have been set forth by a number of authors (e.g., [Jennings 2005](#); [Rice and Rochet 2005](#); [Link 2010](#)). Here I will focus on the role of indicators to supplement some of the modeling methods described above and as elements of IEAs and EBMPs. Models that do not explicitly include consideration of demographic structure, spatial dynamics, environmental drivers (or other externalities), and social drivers can be complemented by consideration of available indicators that reflect these dimensions. Metrics that can provide leading indicators of rapid shifts in state (e.g., increases in variance and (or) autocorrelation) can be an important adjunct to models that cannot otherwise represent complex dynamical behavior.⁴ Finally, given the importance ascribed earlier to maintaining diversity in biological, social, and economic subsystems, indicators that track changes in diversity of these components can be invaluable.

A list of candidate indicator categories to meet these requirements might include:

- Key environmental and climate indicators for oceanographic and (or) atmospheric conditions

- Catch and landings by species and (or) functional groups and fishing effort (where available)
- Biomass, abundance, or production by species and (or) functional groups at a number of trophic levels from plankton to apex predators
- Species diversity of biological communities and catches and diversity of fishing fleet characteristics
- Diversity in size and (or) age composition size or biomass spectra of biological communities and in catch or landings
- Spatial concentration indices for biological communities and for fishing fleets
- Ecosystem-balance indicators (e.g., the ratio of piscivores to planktivores)
- Mean trophic level in the ecosystem and in the catch
- Levels of employment, net revenues, and (where possible) profits
- Measures of social well-being in fishing communities
- Change in variance and (or) autocorrelation in space and time for any of these indicators

Although availability of this entire suite of indicator categories will vary widely in different settings around the world, elements of the uppermost tier in this list should be broadly accessible. When both ecosystem pressure and state variables are available, it may be possible to directly establish reference points and control rules for EBFM within an indicator framework. [Samhoury et al. \(2012\)](#) provide examples of how this might be accomplished for indicators encompassing a range of levels of complexity and ability to represent ecosystem pressures and states (see also [Large et al. 2013](#)). Qualitative depiction of indicators in the form of traffic light-style representations can be readily adapted for use in EBFM ([Caddy 2002](#)), and decision rules can be devised and implemented using fuzzy control systems or other methods. If analysis of a set of indicator variables indicates vulnerabilities not detected or represented in multispecies assessment models, appropriate precautionary measures should be adopted.

Administrative and regulatory complexity

The current structure supporting the machinery of single-species stock assessment and management in the developed world is an immensely complex enterprise. National fisheries agencies and international bodies support a very large number of working groups, each involving substantial representation and charged with developing stock assessments for individual species. The assessment process further entails a formal peer review process for each of the individual assessments. Collectively, these assessment and review elements incur very significant administrative costs in the developed world.

A full EBFM approach would consolidate the number of required working groups and modeling structures into a much more tractable number charged with developing integrated assessments for defined ecoregions (see below). Group membership, representing a wider array of disciplines ranging from climatology, physical science, and fisheries ecology to social science, would be larger and much more diverse than a typical individual species or stock working group. It is very likely that increased diversity in scientific and stakeholder representation in working groups will present new challenges in reaching consensus and expert facilitators will be essential in finding common ground. It must be anticipated that this process initially will be very time consuming as protocols are developed and agreement is sought.

A focus on regulatory complexity will be particularly important in EBFM. Conventional single-species approaches with strong top-down controls have inexorably led to increasing complexity in management, often with adverse outcomes (e.g., [Healey and Hennessey 1998](#); [Cochrane 1999](#)). The pursuit of perceived levels of fairness in allocation procedures ultimately breaks down un-

⁴For potential limitations related to time series length and precision, see [Perretti and Munch \(2012\)](#).

der the demands placed on data and regulatory control (Healey and Hennessey 1998). Rigid command and control systems lead to brittle management structures that are prone to failure (Gunderson and Holling 2002). Simple decision rules for EBFM coupled with adaptive management structures informed by strong input from stakeholder groups representing a range of interests will again be essential. The temptation to add complexity should be resisted and only adopted after costs and benefits are carefully evaluated (Cochrane 1999).

Cost considerations

In addition to cost considerations related to the administrative and regulatory systems, the overall issue of cost of ecosystem monitoring is an important concern. For the simplest of the modeling approaches described above, requisite satellite-derived information on chlorophyll concentration is broadly available, as is catch or landings data (although data quality may not be consistent among areas). It is worth noting that the Global Environment Facility is now investing heavily in capacity building and providing the resources needed to guide sustainable development and management of fishery systems in the developing world under the aegis of the Large Marine Ecosystem concept (Sherman 2005; see also <http://www.thegef.org/gef/news/recovering-ocean-health>).

In many parts of the developed world, fisheries agencies and other institutions have implemented far-reaching observing programs that encompass some or all of the following: operational physical oceanography, plankton dynamics, trophic interactions, habitat, protected and nontarget species monitoring, and other ecosystem elements. The long-standing recognition that we require broader-based ecological understanding for effective fisheries management guided the establishment of these programs, providing a very rich source of ecological information to inform EBFM and its elements (IEAs, EBMPs, etc.). Fishery-independent trawl surveys are underway in many parts of the world and are now being used in single-species and multispecies models (for a compilation, see Ricard et al. 2012; <http://ramlegacy.marinebiodiversity.ca/>). Other invaluable long-standing ecosystem monitoring programs include the Continuous Plankton Recorder surveys operated by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS). Collectively, these trawl and plankton surveys go far beyond immediate needs for single-species assessment models and have been used in the development of ecosystem indicators and multispecies or ecosystem models. Further, the information collected in these fishery-observing programs is now routinely being used to provide important insights into a much broader array of issues, including assessing ecosystem changes related to climate variability.

When this information is not used in the development of management advice, we are not capitalizing fully on our research investments. In these instances, the problem is not that we cannot afford to collect the information needed for EBFM, but rather that we are not effectively using it. It is of course possible that the cost of these programs cannot be borne indefinitely. In this case, it will be necessary to identify the programs that provide the most informative data and match them to management objectives in different regions to assign priorities.

Ecosystem-based management procedures

The issues of cost and complexity in conventional fishery assessment and management have been motivating factors in developing a simpler management procedure approach (Butterworth et al. 1997; Butterworth 2007; Rademeyer et al. 2007).⁵ Management procedures (MPs) entail the specification of a potentially

simple set of rules for translating information from an assessment model into a management action. There is binding agreement beforehand on factors such as the model choice, associated data, and the actions to be taken if a management threshold is crossed. Ways of adaptively coping with unanticipated change can be built into the procedure. MPs can remain in place for multiyear (3–5 years) time frames and can be explicitly structured to enhance prospects for stability in the fishery by modulating the amount of change from one time step to the next, providing a more manageable time horizon for business, scientific, and administrative planning. The performance of alternative MPs is rigorously evaluated by simulation with respect to factors such as yield and (or) profitability, uncertainty, and risk before any actual implementation is considered. A key question is, Can simpler approaches provide a workable solution with acceptable performance characteristics?

There is a compelling connection between this question and an approach advanced by Herbert Simon, a Nobel Laureate in Economic Sciences, who coined the term “satisficing” (Simon 1956, 1996).⁶ Simon questioned whether a complex optimization framework is in fact preferable to simpler heuristic methods when the full costs involved with the former are considered. Simon argued that we often cannot fully evaluate all alternatives and that we frequently do not have all the necessary information to make “optimal” decisions — a recognition of the need for a system based on “bounded rationality”. A satisficing solution is one that yields a defensible outcome that meets defined objectives and is satisfactory to the end users. It resonates with Alec MacCall’s concept of “Pretty Good Yield” (Hilborn 2010), in which analytical limitations in defining optima are clearly recognized. It is entirely consistent with the viewpoint adopted in developing management procedures, where pragmatism is a critically important consideration. Given the complexity of ecosystem dynamics, uncertainties in our understanding, and the interwoven strands of a diverse set of human activities affecting aquatic ecosystems, it may in fact be appropriate to acknowledge that we are, at best, in a position to offer satisficing solutions. One could argue that current management, while considering results based on optimization procedures in stock assessment, often defaults to a satisficing solution when integrating broader social and economic considerations with conservation needs. Satisficing solutions involve an evaluation of past experience and application of rules of thumb, although more sophisticated approaches involving game theory (Sterling 2003), fuzzy logic (Goodrich et al. 1999), and agent-based models (Railsback and Grimm 2012) can be applied. When we are dealing with trade-offs involving incommensurable objectives, a satisficing approach might be the most fruitful avenue to pursue.

One of the earliest and perhaps best-known EBMPs was developed for krill (*Euphausia superba*) in the Southern Ocean by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (De la Mare 1996; Constable 2002). The overarching goal of CCAMLR is to maintain ecological relationships among harvested, dependent, and related species and to restore depleted populations within the convention area. Krill occupy the nexus of the Southern Ocean food web and many fish, mammal, and bird species are dependent on krill as prey. The objective for the krill management procedure is to maintain spawning stock biomass (SSB) at three quarters of the unexploited level to ensure adequate food supplies for predators. A stochastic population model serves as the operating model. The decision rule for selecting a target exploitation rate involves consideration of the probability that the median SSB escapement level will be 75% over a 20-year period and the probability that SSB will be driven below

⁵For caveats see Rochet and Rice (2009).

⁶For an early discussion of satisficing in a fishery context, see Opaluch and Bockstael (1984).

20% of the target escapement level at the end of the 20-year period with no more than a 10% probability (Constable 2002). The lower of the two exploitation rates meeting these requirements is selected for implementation. Other objectives and decision rules explicitly considering krill-dependent species have also been proposed (Constable 2002).

Elements of a prototype EBMP

Although many potential paths for specifying EBMPs can be identified, here I will focus on one example that I believe may be broadly applicable and can accommodate the broad spectrum of information and scientific resources in different parts of the globe. The approach centers on a hierarchical specification of system-wide limit reference points to set overall harvest constraints and then establishing constraints on catch levels and practices to protect individual ecosystem components. Additional ecological, social, and economic considerations will also be factored into the constraints at this latter stage.

The main elements are:

- Select spatial management units
- Establish specific management objectives, reference points, and decision rules
- Agree on tactical modeling approaches and associated data to assess ecosystem status
- Test the entire management process through simulation using defined performance measures
- Identify and reconcile trade-offs

Spatial domains

One possible starting point for defining spatial management units is adoption of currently designated Large Marine Ecosystems (e.g., Sherman and Duda 1999). An important advantage of the LME option is that clearly defined spatial domains have already been identified in the 66 designated LMEs. As noted above, preliminary ecosystem models have already been developed in each of these areas. Further subdivision of LMEs may be desirable to account for finer-scale productivity patterns or other considerations (e.g., Fogarty et al. 2011). In general, we can envision a nested hierarchical structure of spatial management considerations within LMEs. For example, protected areas designed to meet multiple ecosystem objectives, including protection of vulnerable habitats, biodiversity hotspots, and (or) concentrations of threatened or endangered species or stocks, can be nested within LMEs (Fogarty 1999). In ocean basins, additional spatial units will have to be specified, perhaps using deep-water portions of defined biomes (e.g., Longhurst 1998) or FAO statistical areas, etc.

Objectives and reference points

The central objective is to maintain system-wide productivity within defined bounds and establish mechanisms to protect individual ecosystem components. Decision rules might then be framed to ensure that the sum of the catches of individual species will not exceed a system-wide limit and that no species will be driven below specified threshold levels for each. The system-level constraint is based on estimates of productivity levels. This approach borrows from the “two-tier” management strategy established by the International Commission of the Northwest Atlantic Fisheries (ICNAF) for the Northeast US continental shelf (ICNAF 1974). A similar system-level constraint has been in place for the Bering Sea–Aleutian Islands fishery (BSAI) since 1984 (Witherill et al. 2000; D. Witherell, NPFMC, personal communication). System-wide “target” reference points can then be established to accommodate precautionary buffers to account for uncertainty. The

protection thresholds for individual species⁷ can be established based on knowledge of life history characteristics, insights from earlier single-species assessments and analysis, or on a purely precautionary basis. LeQuesne and Jennings (2012) show how insights into vulnerability can be obtained even in data-limited situations (see also Costello et al. 2012).

Additional objectives will be specified for non-harvested components of the ecosystem and ones subject to incidental catch (nontarget and protected species) or collateral damage (e.g., habitat). By-catch limits can be specified and counted against the allocation for targeted assemblages. More qualitative measures to protect habitats through the use of protected areas can be enacted if information on the relationship between habitat and productivity is not available. Finally, social and economic objectives can be specified in the context of the conservation objectives. For example, given two or more management procedures with comparable conservation benefits, we would seek one entailing the greatest social and (or) economic benefits.

Data requirements and tactical models

The approach taken to establish the system-wide productivity levels will necessarily be tailored to the available scientific information and resources. The approaches described in the section Models for EBFM can be used to set system-level “limit” reference points to guide management actions. Minimum data and monitoring requirements will include information on the catch, primary production (from satellites or other sources), or estimates of the abundance or relative abundance of the species in the assemblage. More extensive data resources will of course be required if more complex models are selected. Local experts will be in the best position to ascertain the most effective approaches and models for setting the upper catch limit under prevailing environmental conditions. In areas with a broader range of available modeling options, a multi-model inference approach would be desirable. In some cases, indicators may be the best choice to guide the establishment of the cap.

The original system-level cap for the northeastern US was established based on the results of an aggregate-species production model (Brown et al. 1976). The system-level limit for the BSAI was originally established on a precautionary basis based on examination of proposed allocations developed using single-species assessments (Mueter and Megrey (2006) subsequently re-evaluated the system-wide limit using an aggregate production model approach). In both the northeastern US and Alaska, the overall cap was approximately 25%–30% lower than the sum of the individual species MSY levels. In the northeastern US, the allowable catch for individual species was set using a linear programming approach incorporating penalties for by-catch. In the BSAI, catch allocations for individual species are determined by negotiation among stakeholders, provided that the upper cap is not exceeded; if agreement cannot be reached, the council makes the determination (D. Witherell, NPFMC, personal communication).

Simulation testing

Multispecies and full ecosystem models can be used as operating models to test performance of the proposed management procedure. It will be desirable where possible to employ several operating models for this purpose (Sainsbury et al. 2000). Testing the performance of the assessment model(s) and identifying potential weaknesses is critical. For example, Gaichas et al. (2012) used a multispecies model to test the performance of simpler assessment models employing different aggregation strategies for defining functional groups. Attempting to take the maximum total yield from the entire assemblage resulted in the collapse of

⁷There will be cases where in highly diverse systems that information on individual species is simply unavailable. Indeed, one motivation for the use of aggregate species models is to address this situation.

approximately 40% of the species in each of two different systems (Georges Bank and Gulf of Alaska). However, reducing exploitation to a level resulting in 90% of the maximum total catch provided a very sharp reduction in the number of species being driven to collapse (to 10% or less of the species).⁸ The remaining species still in trouble are predictably those with “slow” life histories and these will require additional forms of protection. Worm et al. (2009) show very similar results for Georges Bank using a length-structured multispecies operating model. These analyses reveal the dynamic tension between maintaining biodiversity and extraction of yield and point to the utility of adopting a precautionary harvest level (see also Brander 2010). Performance measures based on the distance between an indicator level and a reference point are vital in assessing the overall success of the management process.

A number of different incentive–disincentive structures can be put in place to adjust the exploitation patterns as part of the overall management procedure. For example, tax (Appolonio and Dykstra 2008), tariff (Kraak et al. 2012), and point (Anderson 2010) systems have been proposed to influence exploitation patterns. They can be used to “nudge” exploitation rates away from critical levels for vulnerable species.

Trade-offs

The trade-offs that emerge naturally when we adopt the EBFM perspective are typically not taken into account in conventional management. Unfortunately, trade-offs do not go away when ignored. They do, however, lead to suboptimal decisions and outcomes. We can readily define the trade-offs involved in many instances, but the information on societal preferences that managers need to attach weights to different courses of action is often lacking. There is of course a well-developed framework for coping with trade-offs arising from competing objectives, dealing with uncertainty, and explicitly incorporating values and preferences in management decisions (e.g., Keeney and Raiffa 1993). It is clear that there is considerable value in following a formal decision-theoretic process to frame the problem and its dimensions even if a satisfying solution is ultimately chosen. The decision-theoretic framework goes far beyond simply identifying that conflicts and trade-offs exist. It essentially entails (a) specifying a set of policy alternatives for a carefully bounded problem, (b) defining a set of attributes against which management actions will be evaluated, (c) assigning weights to the attributes that reflect both objectively defined characteristics and values and preferences, and (d) assigning each policy alternative a score against each attribute (Healey 1984). Adopting a decision table framework (Hilborn and Walters 1992) can be invaluable in understanding trade-offs.

Summary

In their seminal monograph, Beverton and Holt (1957, p. 24) called for “... the investigation not merely of the reactions of particular populations to fishing, but also of the interactions between them and the response of each marine community to man’s activity”. Our current single-species approaches maintain a convenient fiction: that we can keep individual species at biomass levels supporting single-species MSY (or related reference points) while ignoring interactions among species and environmental change. These approaches do provide clearly defined reference points and their implementation has helped significantly in controlling fishing pressure, which is critical to rebuilding depleted stocks. But they mask an inconvenient truth: that to the extent that MSY can be specified for an individual species, it is conditioned on the abundance of other species, management actions

affecting these species, and changes in ecological and environmental conditions (including climate change). From this perspective there is no fixed single-species MSY — it rests on a multidimensional surface that is continually changing.

A commonly voiced concern is that the scientific, analytical, and regulatory frameworks for EBFM (and EBM) remain untried and therefore risky. It must be recognized that pathways toward EBFM are steadily evolving and will continue to develop as challenges are successively identified and solutions found. The current single-species management approach of course underwent a comparable development and evolution (Hilborn 2012). If we had waited until all issues and uncertainties had been resolved before implementing rigorous single-species management, we would now be facing much greater problems in the state of world fisheries. It is not necessary that we possess full knowledge of ecosystem structure and function before acting to incorporate ecosystem principles in fishery management if appropriate precautionary measures are adopted.

When contrasted with our ability to assess the status of individual species or stocks on a global basis, relatively simple multispecies and ecosystem models offer opportunities for broader coverage of fisheries systems. Detailed stock assessments are currently possible for only a small fraction of exploited fish populations (Costello et al. 2012), and most of these are concentrated in the developed world. Some of the simpler community-level or ecosystem models and approaches described above may offer avenues to addressing this problem. The proposed focus on maintaining diversity in these systems can address the recognized problems that accompany highly selective fishing patterns under conventional management. These practices often inadvertently result in imbalances in system structure and other problems (Fogarty and Murawski 1998; Zhou et al. 2010; Rochet et al. 2011; Garcia et al. 2012). Tactical tools for EBFM must be selected that avoid similar unintended consequences. Fogarty and Murawski (1998) noted that species-selective harvesting and discard practices that ignored community and ecosystem structure resulted in dramatic changes in fish community composition on Georges Bank and called for “... harvesting patterns encompassing a broader suite of species at much lower exploitation rates than at present”. Garcia et al. (2012) identify the need for “balanced” harvesting strategies, echoing concepts developed by Swingle (1950) for freshwater systems.

I have primarily concentrated on possible solutions to concerns related to the natural science dimensions of EBFM. Many of the reservations concerning the feasibility of implementing EBFM have arisen in this sphere. However, we cannot lose sight of the fact that fisheries represent a ubiquitous form of social-ecological system involving a diverse set of physical, biological, economic, cultural, and governance considerations. They are best considered as complex adaptive systems (e.g., Allen and McGlade 1987; Liu et al. 2007; Gaichas 2008). Sudden shifts in state are a hallmark of such systems (Holling 2001; Mangel and Levin 2005; Mullan et al. 2005; Vert-pre et al. 2013) that require careful attention to the interplay of both social and ecosystem dynamics. Glaser et al. (2013) suggest that the layered complexity of fishery systems is evident in the higher incidence of nonlinear dynamics in metrics of fishery performance (e.g., catch or landings) relative to underlying ecosystem metrics as revealed by nonlinear time series analysis. These features are not captured in conventional assessment and management approaches that almost invariably consider fishery systems as involving a one-way interaction between humans and fishery resources and characterized by globally stable equilibrium points. In this case, choices of model structures can

⁸Collapse was defined in this study as reduction to below 10% of the maximum population level. In practice we would carefully consider the threshold level for collapse and likely choose a more precautionary level.

sharply constrain understanding. Adoption of EBFM, with its focus on humans as an integral part of fisheries ecosystems, provides a clear avenue for incorporating these perspectives and approaches into management. There can be little question that direct consideration of human motivations, needs, and values must be an integral part of the EBFM framework and a much broader adoption of strategies for co-management is essential if we are to avoid the past mistakes in management in which the human dimension was downplayed and the management problem was treated as "simple" ecological engineering (Charles 2001; Garcia and Charles 2008; Berkes 2012).

Rather than conceiving of fishery ecosystems as involving fixed-point equilibria (or even averages and fluctuations around fixed points) for individual species that are independent of other species and of the environment, we need to shift our focus to a perspective that seeks to provide sufficient resilience to allow the system as a whole to remain within stochastic bounds defined by past levels of variability. See Cury et al. (2005) for related discussions framed in the context of viability analysis, in which the preservation of viable (sustainable) ecosystem states remains the focal point for management decisions. We should replace the concept of single-species MSY, with its focus on time-invariant equilibrium processes, with a dynamic ecosystem yield concept that recognizes shifting environmental states and the probabilistic nature of production processes at different levels in the food web.

In framing the arguments presented above, I have of course done nothing more than to restate the insights and perspectives offered by a succession of commentators over the last several decades. It is long past time to act on their recommendation that we adopt a more holistic perspective in fisheries management. Because I have fallen into most of the traps I have described related to conventional modeling and management approaches, I am acutely aware of their allure, apparent justification, and the need to avoid them. While ecosystems are unquestionably complex, carefully chosen pathways toward EBFM can afford opportunities for simplification relative to management approaches now focusing on individual species or populations while side-stepping the limitations of single-species management.

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APPENDIX VII

**A REPRINT COPY OF DR. HECHT ET AL.
PAPER ENTITLED *WORKING TOWARD A
SUSTAINABLE FUTURE***



COMMUNITY ESSAY

Working toward a sustainable future

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How can our society address the complex interaction of environmental, social, and economic problems in the 21st century? We propose that federal agencies in the United States complement their existing regulatory framework with new initiatives based on the “innovation cycle” for sustainability. This approach includes engaging stakeholders, advancing sustainability science and systems thinking, encouraging public-private partnerships, and developing decision-support capabilities to enable sustainable and resilient solutions. The United States Environmental Protection Agency (USEPA) is moving in this direction through new actions defined in the agency's Strategic Plan for 2014–2018. In this Community Essay, we highlight examples of how the innovation cycle enables progress on critical issues facing USEPA and other agencies, and we argue for increased government-business collaboration, federal agency coordination, and public involvement.

Introduction

How can contemporary society address the complex interaction of environmental, social, and economic forces? What factors are currently limiting the sustainability of business enterprises? How can federal and state agencies break down silos and work together to pursue sustainability? What is the preferred model for business-government collaboration and engagement with civil society and nongovernmental organizations (NGOs)? We raise these questions because in the 21st century all sectors of society must confront the challenge of sustaining economic development while protecting critical environmental resources.

In 1970, when the modern environmental movement was coalescing and the United States Environmental Protection Agency (USEPA) was created, environmental protection focused mainly on addressing issues related to industrial emissions and occupational health and safety. Most environmental challenges were highly visible and easy for the public to understand. For instance, on June 22, 1969, an oil slick and debris in the Cuyahoga River in Cleveland caught fire, drawing national attention to environmental problems in Ohio and elsewhere in the United

States. *Time* magazine wrote on August 1, 1970, “Some River! Chocolate-brown, oily, bubbling with subsurface gases, it oozes rather than flows.”

Congress addressed the obvious problems of air, water, and land pollution in the United States through media-specific environmental legislation. In the late 1960s and early 1970s, there was significant bipartisan popular demand for federal leadership in ameliorating pollution problems (Andrews, 2011). The Clean Air Act of 1970, the Clean Water Act of 1972, the Safe Drinking Water Act of 1974, the Resource Conservation and Recovery Act of 1976, and the Comprehensive Environmental Response, Cleanup, and Liability (Superfund) Act of 1980 yielded great progress in improving the quality of the environment. These initiatives relied on federal regulations that set maximum pollutant limits and heavily fined businesses that did not comply. The success of these laws and subsequent regulations is evident today: our air and water are cleaner, less hazardous waste is produced, and contaminated sites are being remediated. Existing regulations provide a strong “safety net” against the domestic impacts of pollution, although the potential remains for environmental problems to be “exported” across global supply chains.

Table 1 Evolving environmental problems and policy approaches in the United States.

	19th Century	20th Century	21st Century
Problem focus	Land use	Safety & health risks; Media/site/problem-specific	Complex regional/global problems
Outcome	Land preservation	Pollution control; Management of human-caused ecological risk	Sustainable development; Resilient society
Principal Activity	Land/water regulation; Contaminant controls	Compliance/remediation with technological emphasis on problem solving	Integration of social, economic, and technological information for holistic problem- solving
Economic Approach	Assure value of land use and development	Cost/benefit analysis; Emphasis on efficiency	Investments in natural capital; Concern for long-term societal well- being
Regulatory Approach	Narrow scope	Intensive, broad scope; Media-centric risk assessment	Flexible, including market-based incentives and community engagement
Conceptual Model	Expansion vs. preservation	Command-and-control	Systems/life cycle approach; Innovation and adaptation
Research Methods	Disciplinary; Insular	Multidisciplinary	Integrative; Transdisciplinary

Source: Adapted from Fiksel et al. (2009).

Despite these significant accomplishments, newly emerging pressures are threatening the well-being and resilience of human society and the natural environment, thus jeopardizing economic prosperity. The urgency of dealing with today's problems is evident. Worldwide population growth and urban development, as well as globalization of industrial production, have driven increased consumption of energy, water, materials, and land. The consequences include increased greenhouse-gas emissions, decreased biodiversity, and threats to vital natural resources including water bodies, soils, forests, wetlands, and coral reefs. The Millennium Ecosystem Assessment found that fifteen of 24 global ecosystem services are being degraded or exhausted (Hassan et al. 2005). A study by the Stockholm Center for Resilience suggests that on a planetary scale we have exceeded our "safe operating boundaries" in terms of greenhouse-gas emissions, nitrogen flows, and biodiversity (Rockström et al. 2009). The Global Footprint Network has estimated that if current trends continue, by the 2030s, we will need the equivalent of two Earths to support the world's population.¹ Planetary ecosystems will experience even greater pressures by 2050, when global population could reach 9 billion, some 30% more than the 2000 level (UNDESA, 2012), while rapid economic growth and urbanization in developing nations will exacerbate resource demands.

Table 1 provides an overview of the evolving nature of environmental problems and policy responses in the United States. The focus has shifted from land conservation in the 19th century to risk management in the 20th century to broader sustaina-

bility concerns (requiring a systems approach) in the 21st century. By anticipating future challenges, we can embark on a new era of cooperation, coordination, and public support for achieving sustainable development (Hecht et al. 2012). We need to think ahead, and this Community Essay outlines positive steps toward a resilient and sustainable future.

Strategies for a Sustainable Future

Addressing the problems of the 21st century will require a combination of strategies, including creative use of existing environmental policies and regulations, innovative application of science and technology, and collaboration among stakeholders. These are not easy challenges given the rigid nature of government operations, the tensions between business and government, and the potential conflicts between local and national interests.

Fortunately, major institutions are beginning to respond positively to these challenges. As Figure 1 shows, the confluence of economic and environmental risks, regulations, financial investment and public reporting, and international forces have propelled business and government leaders toward adoption of more sustainable practices (Hecht, 2012). There is clear evidence of this transition in the business community—in one recent survey of nearly 3,000 company officials, two-thirds confirmed that "sustainability was critically important to being competitive in today's marketplace" (Kiron et al. 2013).

In June 2012, the "Rio+20" United Nations Conference on Sustainable Development emphasized the importance of strong public-private partnerships to assure that the economy provides social benefits such as job creation, poverty alleviation, and improved environmental conditions. The conference resulted in

¹ See <http://www.footprintnetwork.org/en/index.php>.

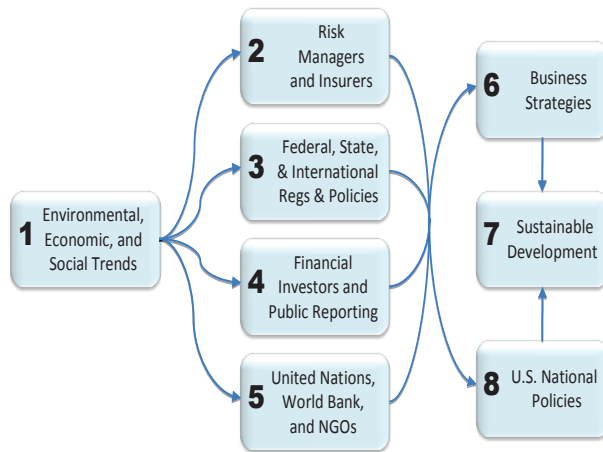


Figure 1 Business-government convergence on sustainability (Hecht, 2012).

the commitment of over US\$513 billion by businesses and governments to address critical sustainability issues, including energy and food security, access to drinking water, and management of the oceans.² For example, the United States government announced US\$2 billion in grants and loans to advance clean-energy technology. The following are examples of commitments from private enterprises:

- Microsoft committed to achieve carbon neutrality in its operations in more than 100 countries by 2030.
- Bank of America set the goal of allocating US\$50 billion for low-carbon energy financing over the next ten years.
- DuPont committed US\$10 billion by 2020 to research and development, and plans to launch 4,000 new products by the end of 2020 to produce more food, to enhance nutrition, and to improve farming sustainability worldwide.
- The Consumer Goods Forum, a partnership of more than 600 companies, agreed to “zero net deforestation” in their supply chains by 2020.

Despite these positive signals, the United States and the world as a whole face daunting challenges that will not be resolved by the actions of a few progressive organizations or changes in some practices of even major corporations. Collective action will be needed on a broad scale to reverse current unsustainable trends and to prevent a global “tragedy of the commons.”

² See Rio+20 Voluntary Commitments (<http://www.uncsd2012.org/voluntarycommitments.html>) and Action and Accountability at the Rio+20 Earth Summit and Beyond (<http://www.cloudofcommitments.org>).

The Innovation Cycle, Systems Thinking, and Resilience

A classic definition of a sustainable society is “one that can persist over generations, one that is far-seeing enough, flexible enough and wise enough not to undermine either its physical or its social system of support” (Meadows et al. 1992). Today more than ever, the creative power of innovation is necessary to meet the challenges of reducing humanity’s global footprint and balancing economic growth with social and environmental concerns. Technological innovation must be accompanied by innovative business models and governance approaches.

For a start, we need to embrace new approaches that apply systems thinking and transdisciplinary research to capture the full scope of environmental, social, and economic problems and to identify potential solutions. In particular, we need to apply advanced decision-support tools, such as life-cycle assessment, to help decision makers evaluate alternative responses. Second, we need to promote effective engagement and collaboration among federal agencies, businesses, local communities, NGOs, and other stakeholders to understand and address their respective goals.

All of these activities contribute to what we call the “Innovation Cycle for Sustainability,” which draws upon well-established principles of innovation. The following are key elements of this cycle:

- Engaging stakeholders to understand their needs, constraints, and priorities.
- Using sustainability science and systems thinking to enable integrated problem solving.
- Encouraging transdisciplinary collaboration among government, business, academia, and NGOs to design innovative technologies and practices.
- Developing comprehensive decision-support tools to help policy makers and decision makers implement sustainable and resilient solutions.

The innovation cycle relies heavily on collaboration in defining and responding to stakeholder needs, as well as integrating across research disciplines. It builds on the concept of “sustainability science,” which aims to link many scientific disciplines to create an integrated systems approach to problem assessment and management (Kates & Parris, 2003). As John Sterman (2002) notes, “overcoming policy resistance and building a sustainable world requires meaningful systems thinking coupled with community engagement in promoting common good.”

Systems thinking leads to a better understanding of resilience, defined as “the capacity to survive,

adapt, and flourish in the face of turbulent change and uncertainty” (Fiksel, 2007). Over the past several years, attention to resilience and sustainability has increased significantly as a consequence of natural disasters such as Superstorm Sandy, which ravaged large portions of the New York metropolitan area in October 2012. According to the insurance company Munich Re, North America has seen the world’s sharpest increase in the cost of natural catastrophes during the past 32 years, a trend that appears to correlate with climate change. While climate adaptation is an important aspect of resilience, equally important is anticipation of future disruptions such as infrastructure breakdown.

The concepts of sustainability and resilience are interrelated (National Research Council, 2012a). Sustainability tends to focus on long-term goals and strategies, while resilience is oriented to preparing for unexpected disruptions that may destabilize an otherwise sustainable system. Generally, approaches taken to address one concept would also be supportive of the other, although there may be tradeoffs. The more sustainable we are, the less we expose ourselves to unpredictable disruptions; the more resilient we are, the less we risk compromising our future well-being (Fiksel et al. 2014).

A recent National Academies report, *Disaster Resilience: A National Imperative* (National Research Council, 2012b), recommends that “Federal government agencies should incorporate national resilience as a guiding principle to inform the mission and actions of the federal government and the programs it supports at all levels.” As noted above, resilience strategies are needed not only for coping with disasters but also for addressing slower-moving threats, such as sea-level rise, that can make us more vulnerable to disruptive events.

Further evidence of the growing importance of resilience is the creation of ResilientCity, a network of urban planners, architects, designers, engineers, and landscape architects that seeks to develop creative and practical planning and design strategies to increase the resilience of cities and communities.³ The group aims to deal with the potential impacts associated with climate change, environmental degradation, and resource shortages. Similarly, the Rockefeller Foundation has launched a worldwide grant program called “100 Resilient Cities,” helping cities to better address the increasing shocks and stresses of the 21st century.⁴

³ See <http://www.resilientcity.org>.

⁴ See <http://100resilientcities.rockefellerfoundation.org>.

Decision-Support Tools

A key element of the innovation cycle is the use of decision-support tools and indicators to help decision makers assess the combined social, economic, and environmental impacts of alternative policies, technologies, and practices. The USEPA and other agencies have a long history of applying such tools (e.g., cost-benefit analysis). Today, using modern technologies such as geographic information systems, new applications and indicators are being developed to integrate diverse data sources and models, enabling a systems approach. As a result, decision makers at all levels—federal, state, and community—will be better equipped to understand the overall consequences of proposed actions in terms of sustainability and resilience.

Currently, USEPA is taking a systems approach to address serious water-quality problems in the Narragansett Bay watershed.⁵ The health of the bay is jeopardized by excessive releases of nutrients—primarily nitrogen and phosphorus—from agriculture, wastewater treatment, and stormwater runoff, among other sources. Excessive nutrient overloads cause algae blooms that can degrade or destroy aquatic ecosystems and interfere with fishing, recreation, and tourism. The USEPA is collaborating with many regional stakeholders to consider a portfolio of possible solutions, such as septic and sewage-treatment technologies, low-impact development, and green infrastructure, as well as to assess the long-term outcomes of these measures.

To support this effort, USEPA has developed a policy analysis and decision-support tool based on a systems framework called the Triple Value Model (Fiksel, 2012). A user-friendly, dashboard-style visualization interface enables users to construct alternative intervention scenarios aimed at reducing adverse nutrient impacts to the watershed, and to project over a 40-year time horizon the expected changes in a variety of environmental, economic, and social indicators such as water clarity, tourism revenue, and property values (Fiksel et al. 2013). The underlying model uses system dynamics to integrate relevant data and scientific relationships across the economic, social, and environmental spheres (see Figure 2).

The above example illustrates how the innovation cycle can extend beyond the “safety net” of current legislative mandates and address a complex set of problems that requires integrated thinking. For instance, why aim merely to treat toxic waste when we can limit its creation through the use of more benign materials, the design of innovative conversion

⁵ See <http://www.epa.gov/research/docs/3vs-tool-nutrient-mgt-narr-bay.pdf>.

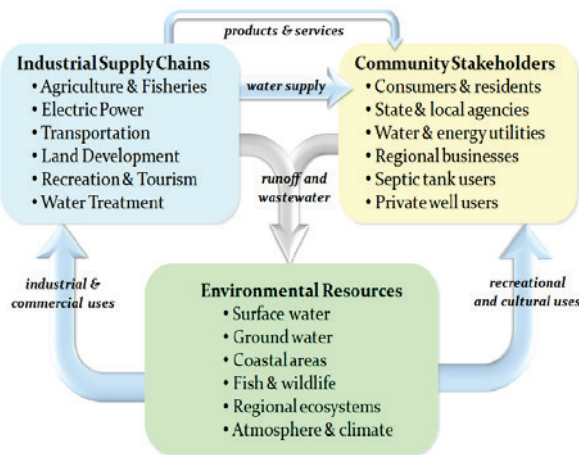


Figure 2 Systems modeling for nutrient impairment in New England.

processes, and the establishment of a regulatory system favoring recycling and reuse? As Michael Weinstein et al. (2013) and others have pointed out, the global sustainability transition is “more than changing light bulbs”; it involves changing our approach to decision making.

Government Linkages

Effective implementation of the innovation cycle requires collaboration among federal and state agencies, transcending regulatory boundaries and coordinating existing sustainability programs. Statutes, budgets, and government culture often encourage federal agencies in the United States to focus on a single area (e.g., energy, water, occupational safety) with little attention to how these areas affect one another. It is essential to overcome this “stovepipe” or “silo” effect to address sustainability issues that cut across agency boundaries.

One successful example of effective interagency collaboration is the partnership between USEPA, the Department of Housing and Urban Development (HUD), and the Department of Transportation (DOT) (USEPA, 2009). In 2009, the three agencies agreed to work together to support sustainable community development by applying federal transportation, water infrastructure, housing, and other investments in a coordinated manner. The agencies are also working collaboratively on tools and metrics to benchmark existing conditions, measure progress toward achieving community visions, and increase accountability. For example, the HUD-EPA-DOT partnership has launched a project in Gary, Indiana to revitalize four decaying neighborhoods, including clean-up of

contaminated brownfield sites and development of green infrastructure.⁶

Building on this kind of multi-agency engagement, seven federal agencies, two private entities, and two foundations asked the National Research Council (NRC) to study how agencies could better consider complex and cross-cutting sustainability challenges. The NRC established an expert committee to review the literature, hold public fact-finding meetings, and explore examples in three landscapes: urban, suburban, and rural. The study’s basic premise was that sustainability is a systems problem, and rather than separately optimizing its pieces one must understand the “nexus” where domains intersect but existing institutions and disciplines do not. The final study report, *Sustainability for the Nation: Resource Connections and Governance Linkages*, produced a number of important recommendations (Committee on Sustainability Linkages in the Federal Government et al. 2013):

- Adopt a decision framework that emphasizes preparing and planning, designing and implementing, evaluating and adapting, and assessing long-term outcomes.
- Support innovative efforts to address sustainability issues by identifying key administrative, programmatic, funding, and other barriers and by developing ways to reduce these barriers.
- Legitimize and reward the activities of individuals who engage in initiatives that “cross silos” in the interest of sustainability, both at the staff and leadership level.
- Support long-term, interdisciplinary research underpinning sustainability.
- Support scientific incentives to collaborate on sustained, cross-agency research.
- Adopt a National Sustainability Policy to provide clear guidance to executive agencies on addressing governance linkages related to complex sustainability problems.

The last recommendation is a formidable but achievable challenge. The objectives of a National Sustainability Policy would be to encourage coordination among agencies, reduce “silos,” and improve integration of research and operations. Furthermore, the policy would enhance communication among agencies and between the federal government and stakeholders, while reducing duplication and improving cost effectiveness. One example of such an initiative is the United States Global Change Research Program (USGCRP), mandated by Congress

⁶ See <http://www.garycommunity.com>.

in 1990 to coordinate research across thirteen agencies.⁷

Making sustainability an explicit policy goal at all levels of government, as well as the private sector, can send a clear message about the need for innovative practices and creative regulatory approaches that serve the collective interests of the public, business, and government. Jordan & Benson (2013) note that sustainability is more than a vision, but an *organizing principle* for the future of policies and governance. Their focus is on the Gulf of Mexico where the population has nearly doubled between 1970 and 2000, placing significant pressures on natural resources. In the Gulf Coast region, federal policies, regulations, and management programs apply to a complex suite of issues, including human health, water and air quality, waste management, marine fisheries, endangered species, fossil-fuel extraction, oil pollution, ocean dumping, ports and waterways, and public access to beaches. In some cases, federal policies are administered by the states, in others (e.g., air quality) by national mandates, and in yet others (e.g., marine fisheries) by multi-state entities.

These authors describe the experience of Tampa Bay, which by 1970 was experiencing deteriorating water quality and loss of sea grasses due to increased nutrient concentrations. Without intervention, these trends could have altered the estuarine ecosystem irreversibly. Combined action by citizens groups and the federal government led to advanced wastewater treatment, greatly reducing nitrogen discharges into the bay. Subsequent accomplishments included major reductions in nutrient loads from other sources, along with preserving and restoring mangrove and tidal marsh habitats. Thus, stakeholders working together had significantly addressed critical environmental needs.

The successes of Tampa Bay highlight the importance of anticipatory and proactive strategies. Future challenges, including climate change, sea-level rise, and population growth, are now being addressed comprehensively by a diverse regional network of stakeholders and authorities. In contrast, serious problems exist along the Louisiana coast, where there have been persistent failures to address the complexities of environmental change in the context of competing economic and social interests. For example, while fisheries policies strive explicitly for sustainability, critical habitats are being lost because of failures to account for cumulative impacts over space and time. To prevent further deterioration of the coastal zone, the state of Louisiana recently updated its coastal master plan to emphasize comprehensive,

sustainable approaches. While many stakeholders were engaged in development of this master plan, an effective governance network comparable to Tampa Bay has not yet been instituted; this remains a clear challenge for the future.

More recently, following the Deepwater Horizon oil spill in 2012, the Restore Act established a Gulf Coast Ecosystem Restoration Council to coordinate funding of restoration actions. The Act mandates that 80% of recovery funding be allocated to activities contributing to the environmental and economic well-being of the Gulf Coast and its residents. The council, chaired by the United States Secretary of Commerce, includes the five Gulf-state governors and the leaders of relevant federal agencies. Continued stakeholder collaboration will be crucial for dealing with ongoing problems throughout the region.

Stakeholder Collaboration

The examples in Narragansett Bay and the Gulf of Mexico illustrate the need for broad engagement of government agencies with NGOs, academic institutions, the business community, and civil society. Common to all stakeholders is the recognition that energy, water, land use, and material consumption are interrelated, and that these linkages must be understood to enable effective policy formation. Many in the business and financial communities view sustainability as a means to reduce long-term risk, enhance economic competitiveness, and promote social well-being. Many consumers are also becoming more aware of sustainability issues and expect manufacturers to develop greener and/or safer products. The goal of sustainability can be pursued most effectively when business, government, and other stakeholders collaborate to identify critical issues and common goals, adopting a systems approach to innovative resource management.

As noted earlier, contrary to the traditional view that environmental responsibility is a burden on industry, leading companies are now embracing sustainability as a core strategy for long-term success. The World Business Council for Sustainable Development (WBCSD) has formulated an ambitious agenda to assist global industries in moving toward sustainable growth. The Council's *Vision 2050* report coined the phrase "green race" and outlines a "pathway that will require fundamental changes in governance structures, economic frameworks, business and human behavior." The report argues that these changes are "necessary, feasible and offer tremendous business opportunities for companies that turn sustainability into strategy" (WBCSD, 2010).

Business and government have identified a number of common objectives, one example being waste

⁷ See <http://www.globalchange.gov>.

reduction. The WBCSD report cited above set forth a vision for 2030: “not a particle of waste.” Many prominent companies, including Disney, General Motors, and Unilever, have established zero-waste goals. For example, Unilever recycles 97% of its waste through its waste contractor Veolia Environment. At the same time, federal, state, and local governments are grappling with approaches for limiting both the volume and toxicity of waste. The fact that business and government share common themes—such as zero waste—creates an opportunity for collaboration on 1) developing the needed science and innovation to design products with minimal waste and 2) removing regulatory barriers that impede the effective recycling or reuse of materials.

Innovation can emerge in surprising ways. One inspiring example involves Veronika Scott, a 23-year-old Detroit resident who had the radical idea of making coats out of scrap material and delivering them to the homeless. She envisioned no ordinary garment—and her material came from no ordinary source. She created a coat that converts in seconds into a sleeping bag, and much of the material comes from waste products of General Motors, which donated 2,000 yards of scrap material from the doors and dashboards of newly manufactured vehicles. This was enough to make 400 coats produced by homeless women in Detroit. The USEPA’s Tom Murray wrote a blog about this, linking sustainability’s three dimensions: “John Bradburn (from GM) and Veronika’s efforts are a classic example of sustainability. Scrap material is diverted from the landfill (environment) and is being used instead to help a fledgling non-profit enterprise grow (economy) while offering a helping hand to the homeless (social).”⁸ Veronika’s efforts have not gone unnoticed by those outside of Detroit. She became the youngest person ever to receive the New Frontier Award from the John F. Kennedy Library Foundation.

An example of USEPA efforts at collaboration is the creation of “technology clusters,” which engage businesses, federal agencies, local governments, universities, investors, and others to promote environmentally sustainable economic development and technological innovation. This initiative has led to formation of a water-technology cluster linking Ohio, Kentucky, and Indiana (USEPA, 2011). Likewise, many companies and industry associations are encouraging collaboration among business, government, and NGOs. For example, IBM and the World Environment Center established the Innovations for Environmental Sustainability Council, involving some of the world’s leading companies, to identify

next-generation technologies and best practices, addressing critical sustainability challenges (Silicon Republic, 2012). Dow Chemical is collaborating with the Nature Conservancy to advance the science and practice of valuing ecosystem services (Walsh, 2011). Industrial consortia such as the Sustainable Apparel Coalition, the Outdoor Industry Association, and the Sustainability Consortium are actively engaged with academia, NGOs, and government to establish voluntary sustainability standards for commercial products (Golden et al. 2011).

USEPA: Evolving from Regulator to Innovative Problem Solver

While existing laws and regulations are crucial for protecting human health and the environment, they alone cannot ensure a sustainable future. To achieve beneficial changes, regulatory agencies must adopt a broader and more systems-oriented approach. The above examples from Narragansett Bay and the Gulf of Mexico illustrate the evolving role of USEPA from environmental regulator to innovative problem-solver. It is important that the agency gain understanding and support from both the public and the business community for this continuing evolution.

When USEPA was created in 1970, it was characterized as “the federal government’s watchdog, police officer, and chief weapon against all forms of pollution” (Shabecoff, 1993). While at first the agency had bipartisan support, it “quickly became the lightning rod for the nation’s hopes of cleaning up pollution and its fears about intrusive federal regulations” (Andrews, 2011). By the mid-1980s, USEPA had expanded its regulatory role based on the practice of risk assessment. In 1983, the National Academies published a landmark report, *Risk Assessment in the Federal Government: Managing the Process* commonly known as the *Red Book* (National Research Council, 1983). Today, the challenge for USEPA, as well as other federal agencies, is to augment the risk-based paradigm by adopting a new role as an innovative problem solver focused on environmental stewardship. Richard Andrews (2011) notes that the future challenge for USEPA is “not simply to regulate individual pollutants and facilities, but to lead in transforming existing government policies into more effective incentives to create a greener, economically efficient, and environmentally sustainable economy.”

Former Administrator Lisa Jackson (2008–2013), like many of her predecessors, was sensitive to the complex problems of the 21st century. She reached out to the National Academy of Sciences for guidance at the time of USEPA’s 40th anniversary. “As we celebrate 40 years of incredible accomplishments, we find ourselves at a critical juncture,” she

⁸ See <http://blog.epa.gov/blog/2012/12/veronika-scott-and-her-amazing-dream-coat>.

stated. “We have a new awareness of environmental complexity and, at the same time, we have new tools, insights, and experiences to guide our mission.” The resulting Academy report affirmed that a “sustainability approach can strengthen USEPA as an organization and a leader in the nation’s progress toward sustainability. Adopting a vision for sustainability as a goal will provide a unifying and forward looking stimulus to the Agency” (Committee on Incorporating Sustainability in the United States Environmental Protection Agency et al. 2011). The NRC report specifically called for USEPA to develop a sustainability framework for decision-making. This study was carefully reviewed by other federal agencies, many of which have begun incorporating sustainability practices into their own operations. For instance, the United States Army has established a “net zero” program to manage water, energy, and waste at all of its facilities. The Department of Agriculture is advancing sustainability objectives in food and agricultural practices as well as in forest management. The National Oceanic and Atmospheric Administration (a unit of the Department of Commerce) is working with stakeholders to better manage the nation’s fish stocks.

The title of this Community Essay reflects a theme emphasized by USEPA Administrator Gina McCarthy, explicitly included in the agency’s Strategic Plan for the period 2014–2018. In describing the goal of “working toward a sustainable future,” McCarthy notes that “our traditional approaches to risk reduction and pollution control can only go so far to deliver the long term and broad environmental quality we seek.”

Enhancing Public Understanding of Sustainability

A key role of government and NGOs is to better inform decision makers and the public of existing trends, stressors, and threats to health and the environment. The public, in turn, must recognize the value of proposed actions without fearing loss of jobs or other adverse social impacts. A key step in this direction is the development of indicators and metrics that help to justify policy changes. The USEPA, along with other agencies of the federal government, has been actively engaged in developing such tools. For example, the agency’s *Report on the Environment* (ROE) regularly describes the current state of the environment and observes national trends (USEPA, 2008). The latest version of ROE (to be published online in 2014) will be the first to include a set of sustainability indicators that quantifies the changing *intensity* of energy, water, and waste relative to economic and population growth. Another

example is *EnviroAtlas*, a web-based mapping tool that will provide an easy-to-use, visual way to explore and better understand the benefits of natural ecosystems and how they can be protected to assure a sustainable future (USEPA, 2013).

The wealth of available indicators from federal and state agencies is overwhelming. The challenge ahead is not further development of such measures but their application and use. Such metrics are most effective when they serve as drivers of change. One example of an overarching strategic indicator is the ecological footprint of the United States, which reveals that certain regions of the country are already stressed with respect to the “biocapacity” of their ecosystem assets (see Figure 3). This indicator provides a method for understanding current burdens, projecting future stressors, and determining how decision makers can best anticipate and respond to these challenges (Wackernagel, 2013).

Similarly, regional studies are assessing the “water footprint” of society; for example, California’s total water footprint is estimated to be 64 million acre-feet per year (Pacific Institute, 2012). This is more than double the annual volume of water that flows down the state’s two largest rivers, the Sacramento and San Joaquin. An estimated 38 million acre-feet of water is used to produce goods and services within California, about half of which is exported and consumed outside the state. An additional 44 million acre-feet is required to produce goods and services imported into California, so that the state is a net importer of “virtual” water. Collaborative actions by industry, agriculture, government, consumers, and other sectors can potentially help California to achieve a sustainable balance between the availability, allocation, and use of natural resources.

The value of these studies is both to assess the current state of the environment and to stimulate a discussion about potential actions in anticipation of future changes. Society must take a longer-term view to consider emerging pressures on ecosystems at different scales of resolution and how the built environment and ecosystems can be managed in a synergistic way. For industrial innovators, the long view involves thinking about how business models can be transformed so that materials and energy are used more effectively in product and process life cycles and wastes and hazardous residuals are reduced or eliminated. A key challenge for all states is to engage federal, state, and local agencies, as well as academic and business leaders, to analyze future stresses on ecosystems and water resources and to identify science and technology needs and appropriate partnerships to best deal with these challenges.

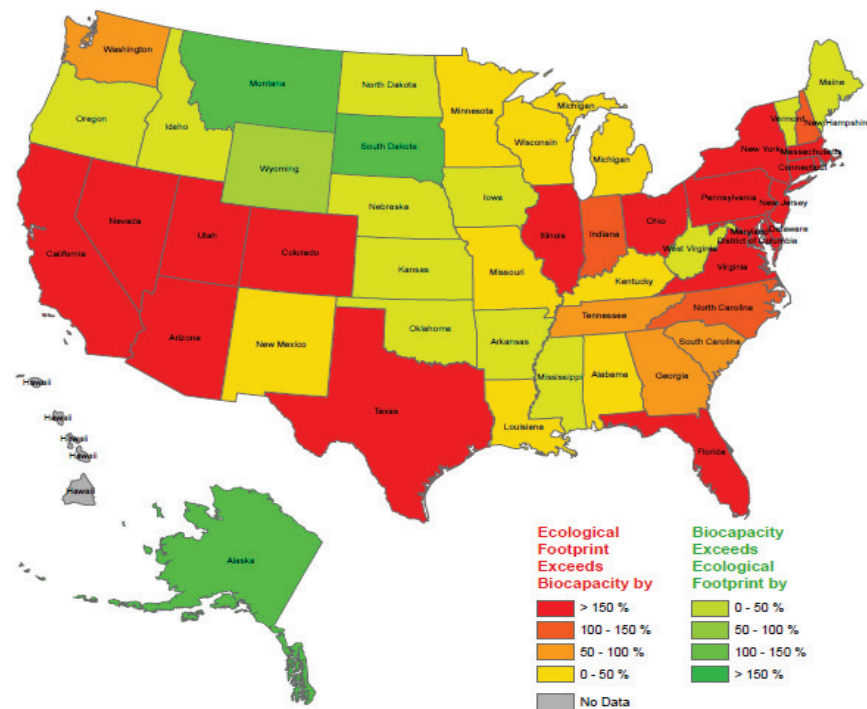


Figure 3 National Comparison of Ecological Footprint to Biocapacity (Source: Global Footprint Network).

Summary: The Path Forward

Returning to the questions posed at the beginning of this Community Essay, we again ask: How can today's society address the complex interaction of environmental, social, and economic forces? In other words, how can we ensure a balance among economic development, social well-being, and environmental protection?

We believe that sustainable development is a crucial objective for all levels of government in both developed and developing countries. Population growth, economic development, and globalization of industry have led to greater consumption of energy and materials and wide-ranging changes in land use. These pressures not only increase greenhouse-gas emissions, but also threaten biodiversity, natural resource integrity, human health, and social well-being. The increasing stresses on natural resources have resulted in damage to natural capital, including water resources, soils, forests, wetlands, and coral reefs, which will create serious challenges in the decades ahead.

Quality of life in the United States will likely decline unless we adopt innovative approaches to transform our production and consumption patterns. We are fortunate that both government and business leaders view sustainability as the appropriate lens for envisioning enhanced competitiveness and social well-

being. For the business world, sustainability has become the “mother lode” of organizational and technological innovations. Firms increasingly realize today that “there is no alternative to sustainable development” (Nidumolu et al. 2009). For federal agencies, regulatory policy and research must augment media-specific risk assessments by adopting a systems approach to address these sustainability problems. While fulfilling their core mandates to minimize risks to human health and the environment, government bodies must also evolve to develop science-based, integrated approaches that address the complex challenges of the new century. This evolution can be facilitated by what we call the “innovation cycle for sustainability.”

The path forward can build on strategic business imperatives and strong recommendations from the National Research Council. A new model for sustainability in the 21st century requires a convergence of 1) advances in science, technology, and innovation; 2) business practices that promote sustainable solutions; 3) greater coordination across federal agencies; 4) effective business and government collaboration; and 5) public support, understanding, and behavior change. All sectors of society will need to work together to pursue this model and assure continued American prosperity and competitiveness. The public must come to understand that sustainability provides both the vision and approach to achieve outcomes

that enhance the economy and protect health and the environment. By anticipating and responding proactively to future challenges, we can disprove Benjamin Franklin's adage, "It is not until the well runs dry that we know the worth of water."

Authors' Note

The views expressed in this article are those of the authors and do not necessarily reflect the views or policies of the United States Environmental Protection Agency (USEPA) or the National Research Council (NRC). Mention of trade names or commercial products does not constitute agency endorsement or recommendations for use. Special thanks to Edward Fallon (USEPA) for editorial assistance and to Mathis Wackernagel (Global Footprint Network) for Figure 3.

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APPENDIX VIII
SPEAKER POWER POINT
PRESENTATIONS

APPENDIX VIII-A

Forum on Ecosystem Based Management (EBM) and Allied Topics - Preamble Presentation

FORUM ON ECOSYSTEM BASED MANAGEMENT (EBM) AND ALLIED TOPICS

Hosted by:

New Jersey Department of Environmental Protection
Office of Science

Convened by:

NJIT, Center for Natural Resource Development and Protection

Participating Agencies:



THREE CERTITUDES IN LIFE:

- Humankind is Not Living Sustainably.

We Extract Resources from Ecosystems Faster than they
can be Replaced.

**These Actions Threaten the Life Support Systems that
Sustain Us**

The Challenge

*Reconciliation of Human Domination of the Earth's
Natural Resources with the Planet's Ability to Provide
Them Over the Long-Term*

Addressing the Challenge

*Increasingly Clear that the Transition to Sustainability
Lies in Understanding the **Interactions among
Environmental Issues and Human Activities** ... We will
see Problem-solving Shift in Focus **From Single Issues
to Multiple Interacting Stresses***

US National Research Council

**“Where Desirable but Competing Objectives Exist,
it is not Possible to Maximize Each...[and] in any
System with Multiple Competing Objectives, it will
not be Possible to Meet Every One”**

U.S Commission on Ocean Policy 2004

The KERNAL ISSUE

**How do we Achieve Consensus on the **Sacrifices,
Compromises and Tradeoffs** that will Be
Necessary to **Balance Ecology and Economy**?**

Breaking Down the “We versus Them” Mentality

Anthropo-Centrism vs Eco-Centrism

Anthropocentrism

The View that the Nonhuman World has value Only Insofar as it
Directly or Indirectly Serves Human Interests.

Humans Have a Duty to Restructure Nature for their Survival

Freeman Dyson, 29 March 2009

Ecocentrism

The View that Nature has an Inherent Value Regardless of Its Usefulness
to Humans

*The Environment has to be Balanced Against the Economy, Puts the Truth
Exactly Backwards*

Jared Diamond 2004

**“It is an Open Question Whether Ecosystem
Management will become a Passing Fad, an Expansion
of Rigid Bureaucratic Procedures, or a Sustaining
Foundation for Learning to Deal with Interactions
Between People, Nature, and Economic Activities”**

Holling 1996

APPENDIX VIII-B

A Field Guide to the Properties of Human Coupled Complex Adaptive Systems Peter Morin

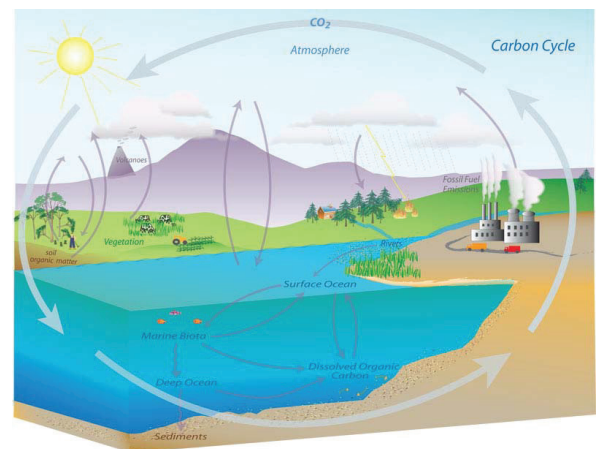
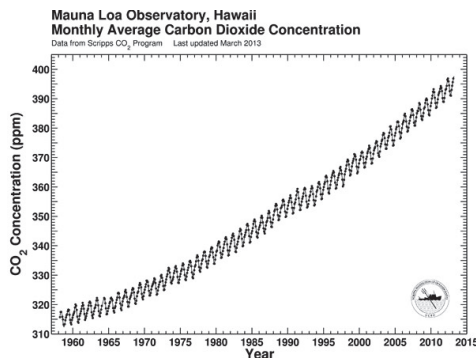
A Field Guide to The Properties of Human-Coupled Complex Adaptive Systems

Peter Morin
Ecology, Evolution, & Natural Resources
Rutgers University
New Brunswick, NJ 08901
pjmorin@rci.rutgers.edu

All natural systems are coupled to human activity – the only difference is in degree



"Everything is connected to everything else". - Barry Commoner
e.g., The Keeling Curve



Ecosystems and Ecological Networks as Complex Adaptive Systems

- Complex – emergent properties, self-organization, regime shifts
- Adaptive – not adaptive in the Mendelian/evolutionary sense; responsive to changes that affect the system
- Systems - natural (ecosystems) or not (artificial intelligence, social and economic systems, adaptive management systems)

Implementing Ecosystem-based Management

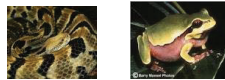
Development of theory, practice, and research for planning and managing a region

D. Scott Slocombe

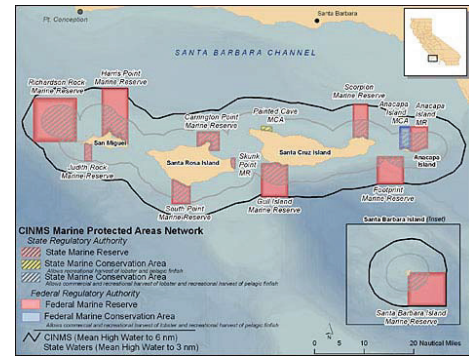
- BioScience (1993) Vol. 43:612-622

Ecosystem Based Management

- Differs from traditional species-specific approaches in the focus on the system and its functional integrity, rather than particular species or political boundaries.
- Implementation in marine/coastal areas often involves geographically bounded marine reserves with limited/no harvesting, with respect to flagship species.
- The NJ Pinelands Comprehensive Management Plan & the Pinelands Commission involve some aspects of EBM, however some management still has an emphasis on individual species – Timber Rattlesnakes, Pine Barrens Treefrogs.

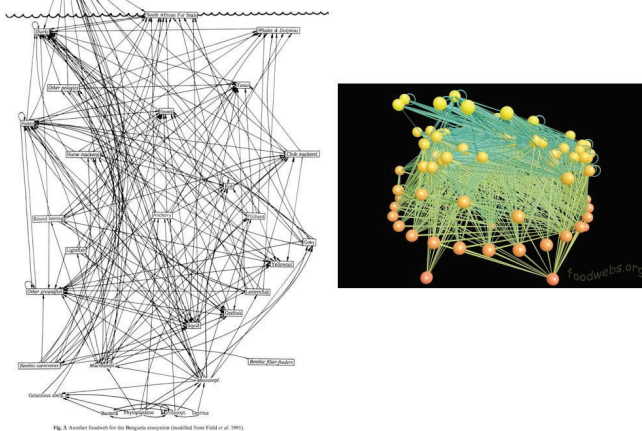


CA Channel Islands Marine Protected Areas



<http://channelislands.noaa.gov/marineres/main.html>

All populations are embedded in food webs, which are complex adaptive systems



Journal of Animal Ecology 1998, 67, 635–658

Local trophodynamics and the interaction of marine mammals and fisheries in the Benguela ecosystem

PETER YODZIS

Department of Zoology, University of Guelph, Guelph, Ontario, N1G 2W1 Canada

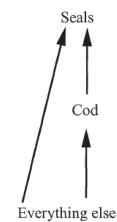
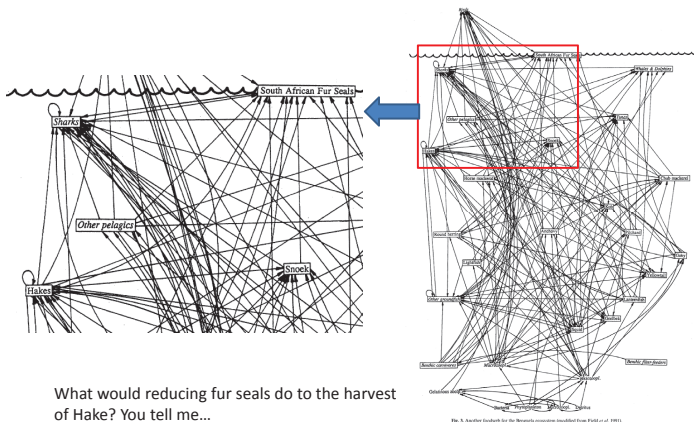


Fig. 1. A foodweb for the Benguela ecosystem.

Details of the Benguela Food Web, From Yodzis (1998) JAE



What would reducing fur seals do to the harvest of Hake? You tell me...

North American Journal of Fisheries Management 19:356–375, 1999
American Fisheries Society 1999

A Case History of Effective Fishery Management: Chesapeake Bay Striped Bass

R. ANNE RICHARDS* AND PAUL J. RAGO

National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, Massachusetts 02543, USA

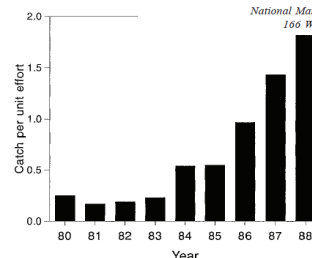


FIGURE 3.—Catch per unit effort (number caught/836 m² of gill nets set per hour) of striped bass in the Hudson River gill-net fishery for American shad *Alosa sapidissima*, 1980–1988. The shad fishery coincides with the striped bass spawning season in the Hudson River. Sources: Kahle and Stang (1986, 1987); USDO and USDOC (1990).

There are single species success stories, e.g., striped bass.

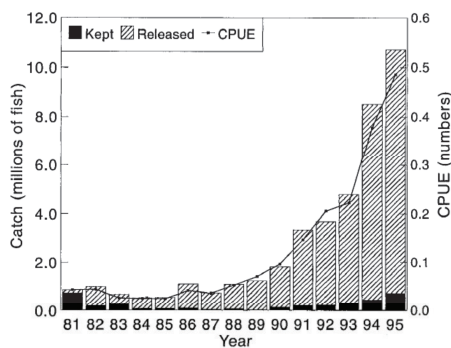
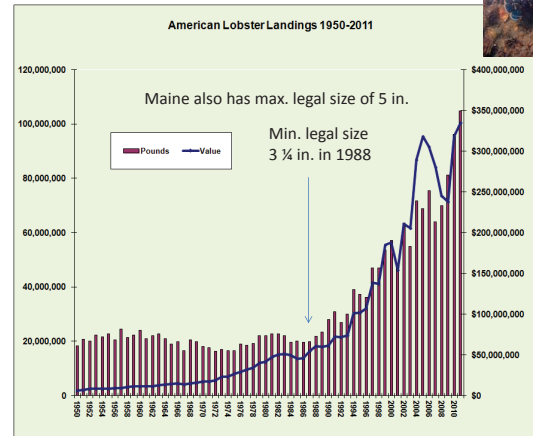
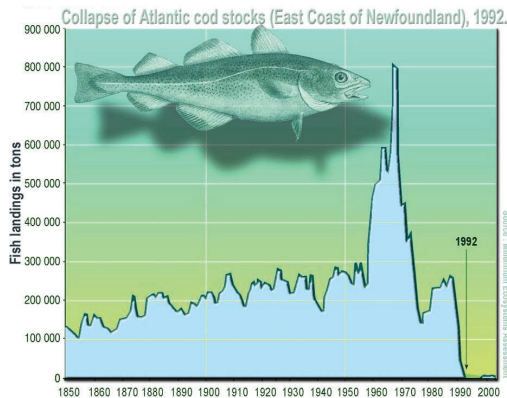


FIGURE 4.—Recreational catch (millions of fish) and catch per unit effort (CPUE) of striped bass along the Atlantic coast from North Carolina through Maine, 1981–1995. The CPUE is the number of striped bass caught per recreational fishing trip along the Atlantic coast. Source: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Marine Recreational Fisheries Statistics, Washington, D.C., <http://www.st.nmfs.gov/st1/recreational/database/index.html>.

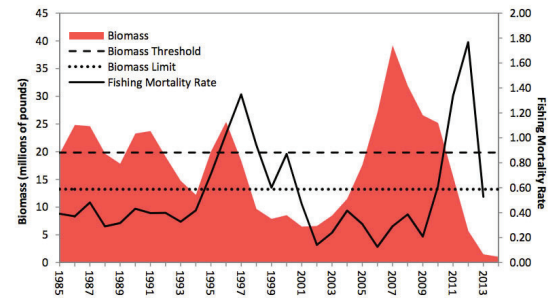
Another single species success story, the sustainable lobster fishery in the Gulf of Maine.



Some failures: Regime shifts - Cod



Another Failure: Regime Shifts – Northern Shrimp, Gulf of Maine



Gulf of Maine Northern Shrimp Total Stock Biomass and Fishing Mortality
Source: ASMFC Assessment Report for the Gulf of Maine Northern Shrimp, 2013

Resilience

- C. S. “Buzz” Holling (1973) A.R.E.S.
- Refers to the tendency of a system to withstand or recover from large scale perturbations, but not for the system to remain at a fixed equilibrium state.
- You can have resilient systems that do not appear to exhibit anything like a stable equilibrium.
- Factors that confer resilience remain somewhat controversial, but diversity is likely to be important.

Stability is not the same thing as resilience

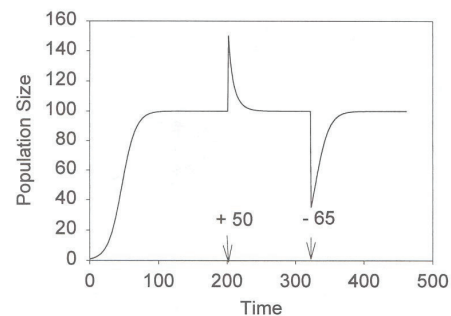
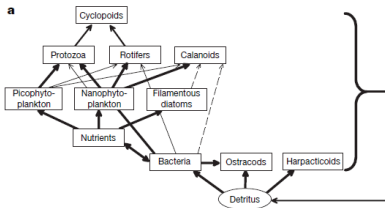


FIGURE 12.2. An example of how a model population with a stable equilibrium responds over time to perturbations that increase (by 50 individuals) or decrease (by 65 individuals) population size. The model assumes logistic growth ($r = 0.5$) and a stable equilibrium size of $k = 100$.

Chaos in a long-term experiment with a plankton community

Elisa Benincà^{1,2,*}, Jef Huisman^{1*}, Reinhard Heerkloss³, Klaus D. Jöhnk^{1,†}, Pedro Branco¹, Egbert H. Van Nes², Marten Scheffer² & Stephen P. Ellner²



Resilient, but not particularly stable

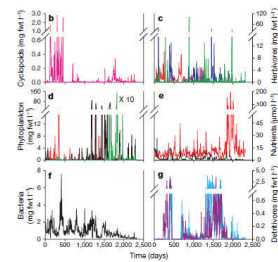


Figure 1 Description of the plankton community in the mesocosm experiment. **a**, Food-web structure of the mesocosm experiment. The thickness of the arrows gives a first indication of the food preferences of the species, as derived from general knowledge of their biology. **b–e**, Time series of the functional groups in the food web (measured as freshweight biomass). **b**, Cyclopoid copepods; **c**, copepods (red), rotifers (blue) and protozoa (dark green); **d**, pico-phytoplankton (black), nano-phytoplankton (red) and filamentous diatoms (green); note that the diatom biomass should be magnified by 10; **e**, dissolved inorganic nitrogen (red) and soluble reactive phosphorus (black); **f**, heterotrophic bacteria; **g**, harpacticoid copepods (violet) and ostracods (light blue).

C. S. Holling (1973) ARES

“**Resilience** determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters and still persist. In this definition resilience is the property of the system and persistence or probability of extinction is the result. **Stability**, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is.”

Biodiversity and Resilience

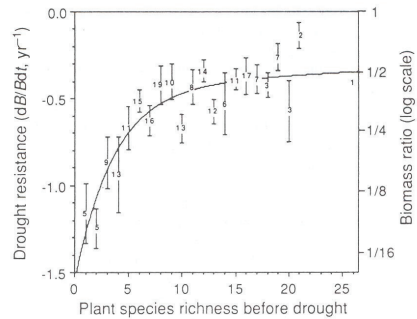
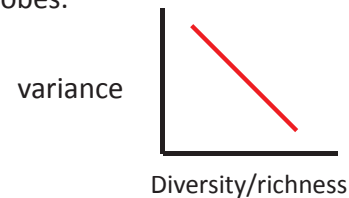


FIGURE 12.11. Relations between plant species richness before a natural disturbance (drought) and plant biomass after the disturbance. Communities with more species display greater resistance to disturbance. (Reprinted with permission from Nature 367: 363–365, D. Tilman and J. A. Downing. © 1994 Macmillan Magazines Limited.)

Biodiversity and Ecosystem Reliability/Predictability (variance)

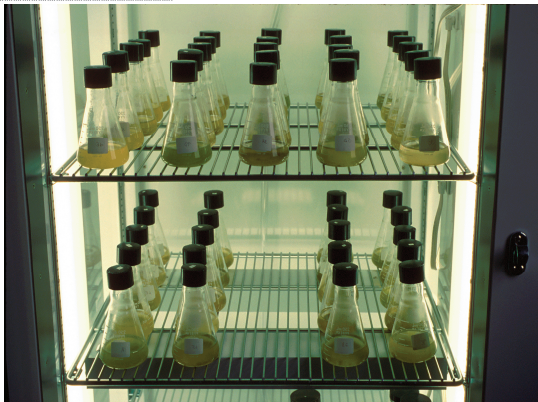
- Naeem et al. (1994) – old fields
- Tilman et al. (1996) - grasslands
- Naeem and Li (1997)- aquatic microbes
- McGrady-Steed et al. (1997) –aquatic microbes.



Biodiversity regulates ecosystem predictability

Jill McGrady-Steed, Patricia M. Harris & Peter J. Morin
Department of Ecology, Evolution & Natural Resources, PO Box 231,
Cook College, Rutgers University, New Brunswick, New Jersey 08903-0231, USA

Nature 390: 162-165 (1997)

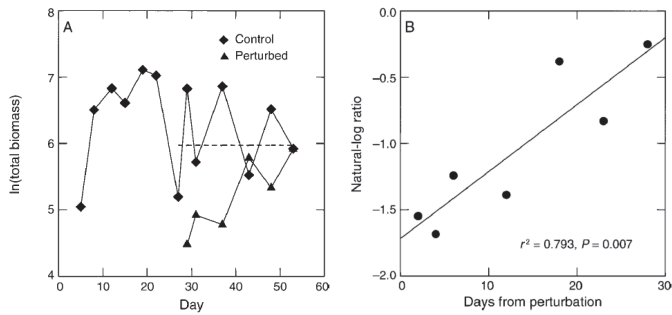


Resilience as a Rate of Ecosystem Recovery Experimental Design

Steiner et al. 2005 Ecology Letters 8: 819-828, Steiner et al. 2006 Ecology 87: 996-1007

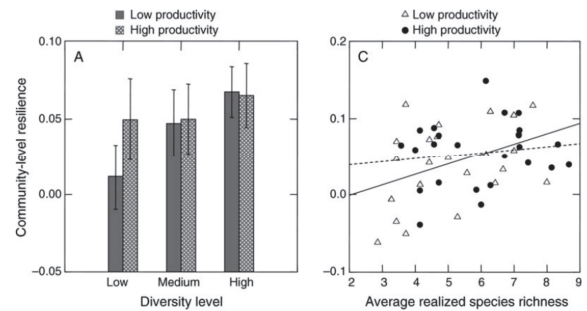
- Factor 1: Diversity (1, 2, or 4 species per trophic group).
Four Different Compositions nested within each level of diversity.
- Factor 2: Enrichment (low or high, corresponding to a 10 fold difference in nutrient concentration).
- Resilience – experimentally dilute a sample from each community by 1/10, measure rate of convergence in biomass to control.

Measuring Community Level Resilience



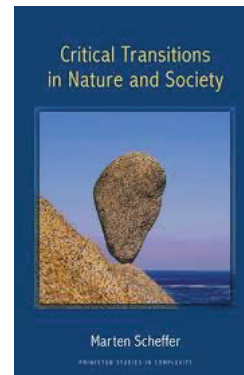
Natural-log ratio = average ln (biomass in control) – ln(biomass in perturbed)

Community-Level Resilience Measured for Aggregate Biomass

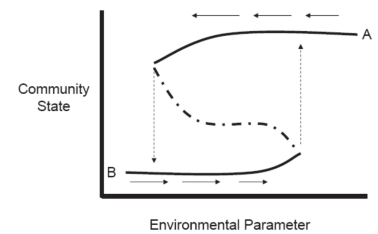


There is a weak positive effect of diversity, mostly in the low productivity treatments.

Regime Shifts / Alternate Stable States



Hysteresis; Alternate Stable States, Regime Shifts



The Management of Fisheries and Marine Ecosystems

Louis W. Botsford, Juan Carlos Castilla, Charles H. Peterson

SCIENCE • VOL. 277 • 25 JULY 1997

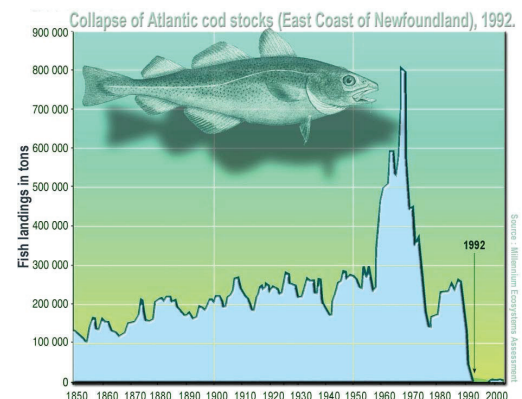
509

There are dramatic shifts in species composition in exploited systems that are consistent with alternate stable states, or regime shifts. E.g., shrimp to gadoids in the Alaska.

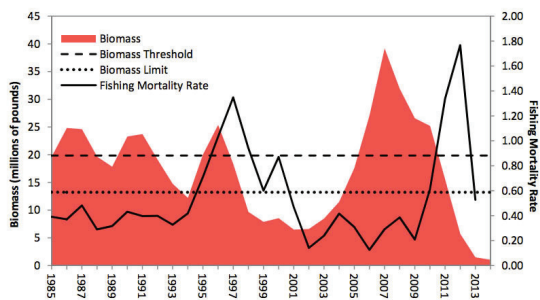


Fig. 5. Graphic depiction of changes in species composition of catches in a small-mesh bottom trawl in Foul Bay, Alaska, through the regime shift of the mid-1970s. Commercial catches over a wider area reflect the same trends (reproduced from Anderson (37)).

Regime shifts – Cod –note the variance



Regime Shifts – Northern Shrimp Gulf of Maine – note the variance



Gulf of Maine Northern Shrimp Total Stock Biomass and Fishing Mortality
Source: ASMFC Assessment Report for the Gulf of Maine Northern Shrimp, 2013

Increasing Ecosystem Variance as an early warning sign of regime shifts

VOL. 175, NO. 4 THE AMERICAN NATURALIST OCTOBER 2011

Conditional Heteroscedasticity as a Leading Indicator of Ecological Regime Shifts

David A. Seekell,^{1,*} Stephen R. Carpenter,² and Michael L. Pace¹

¹ Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22904; ² Center for Limnology, University of Wisconsin, Madison, Wisconsin 53706

Submitted March 25, 2011; Accepted June 30, 2011; Electronically published August 25, 2011

Online enhancement: zip file. Dryad data: <http://dx.doi.org/10.5061/dryad.2jv4g>.

Take Home Points

- Complex adaptive systems are everywhere, and all are influenced by human activity. We call some of these ecosystems. Hence the need for ecosystem based management. In the absence of critical information about managed populations, the best course is to manage/protect the host ecosystem.
- Important properties include resilience, predictability/reliability, and hysteresis.
- There may be important warning signs of dramatic shifts in system states/properties, one of which is increased variance. There may be others.

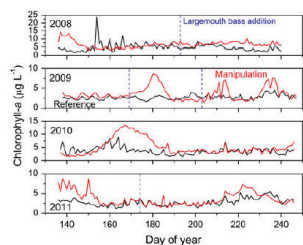
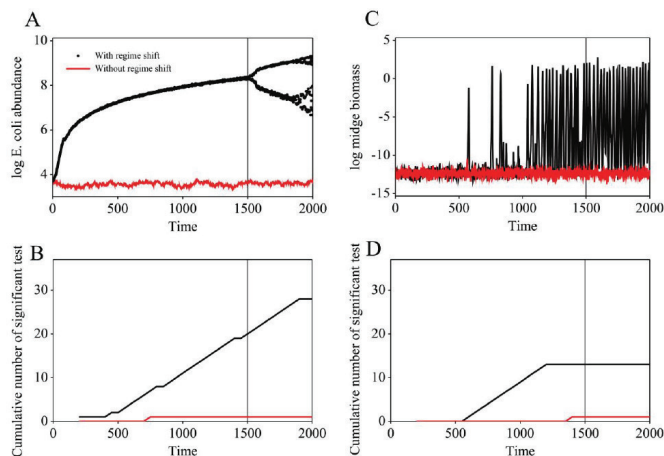


Figure 1. Daily chlorophyll-*a* measurements ($\mu\text{g l}^{-1}$) from the mixed layer of the manipulated Peter Lake (red) and reference Paul Lake (black) systems. Vertical dashed blue lines denote the timing of largemouth bass additions to the manipulated Peter Lake. Note the vertical axis scales are different between years for display purposes.

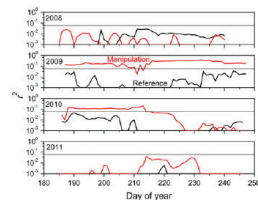
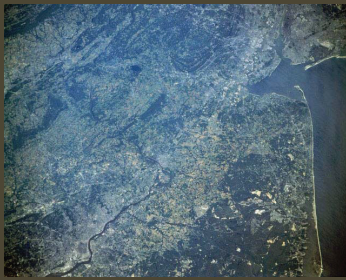


Figure 2. Rolling window (window width = 50 days) conditional heteroscedasticity tests for chlorophyll-*a* time series from the manipulated Peter Lake (red) and the reference Paul Lake (black). The black horizontal line represents the critical value for the conditional heteroscedasticity test. Values above the horizontal line indicate significant ($P < 0.1$) conditional heteroscedasticity. Values below the horizontal line indicate non-significant ($P > 0.1$) conditional heteroscedasticity. For display on the $\log_{10}$ scale, values below 0.001 have been plotted as 0.001.

APPENDIX VIII-C

Spatial Dimensions of Ecosystem-Based Management: a Landscape Ecology Perspective Brian J. Clough

Spatial dimensions of ecosystem-based management: a landscape ecology perspective



Brian J. Clough

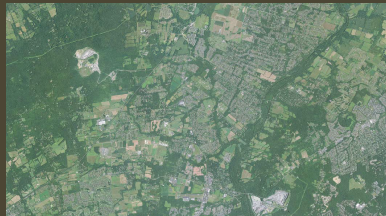
Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA)
Rutgers University

Overview:

- Introduction to landscape ecology
- Principle characteristics of landscapes
- Hierarchy and scale
- Challenges for ecosystem-based management
- Model-based solutions

What is landscape ecology?

- Emphasizes the interaction between spatial pattern and ecological processes (nutrient cycling, animal movement, disturbance regimes, etc., etc.).
- Roots in geography and vegetation science; motivated by 20th century technology.
- Typically considers 'landscapes' as heterogeneous mosaics of two or more ecosystems.
- Typically operates at a larger spatial scale than traditional ecological studies.



The typical landscape of New Jersey: a mosaic of forest, agricultural fields, and low density residential areas.

Three principle characteristics of landscapes.

- **Structure:** How are habitats arranged within the landscape mosaic, and how can we quantify this configuration?
- **Function:** How are ecological processes (habitat use, nutrient cycling, etc.) influenced by landscape structure?
- **Change:** How do natural and anthropogenic influences cause landscape structure and function to change over time?

Landscape structure



When quantifying landscape structure, a 'thematic' map is useful.

- Refers to spatial relationships among distinct ecosystems within the landscape mosaic.
- Many methods for quantifying structure:
 - Connectivity
 - Richness
 - Av. Patch size.
 - many more!

Landscape function

Example: Patch occupancy and distribution of Spring Peepers (*Pseudacris crucifer*).

Yellow: occupied vernal pools

Red: unoccupied vernal pools

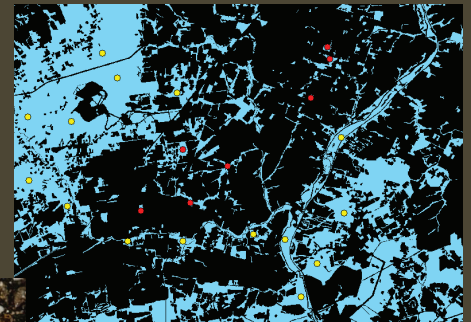


Photo by Tim Bales
www.vernalpool.org

Landscape Change

1933



2013



Hierarchy and scale

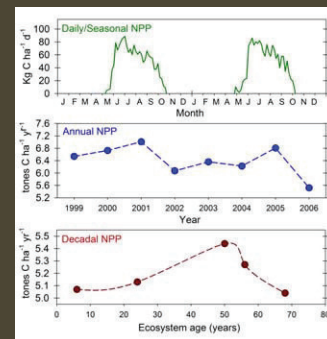
- Typically we view the landscape as a hierarchical construct where small units (i.e. trees) are nested within larger units (patches, watersheds, etc.).
- The scale, or the level of the hierarchy, at which an investigation is approached will influence our understanding of landscape structure, function, and change.
- Thus, identifying the appropriate scale is vital to making informed landscape management decisions.

Example: controls over forest net primary production (NPP).



Climate
Geology
Regional Management

Ecological processes also exhibit different temporal scales.



Gough *et al.* 2007, 2008.

The landscape perspective: Challenges for EBM.

- Acquiring appropriate data & data management.
 - Accessing data for the relevant scale(s).
 - Organization and integration (GIS)
- Model-based forecasting & prediction.
 - Representing complex systems on the landscape mosaic
- Quantifying uncertainty.
 - Identifying and quantifying sources of variance
 - Risk assessment
- Connecting landscape analysis to management decisions.
 - Understanding the landscape impacts of multiple policy/management decisions.
 - Adaptive decision-making based on model results.

Publicly available data across spatial scales.

1. **Ecological observatories:** fine scale, limited geographic coverage, high temporal resolution.



2. **Public inventories:** fine scale, high geographic coverage, low temporal resolution.

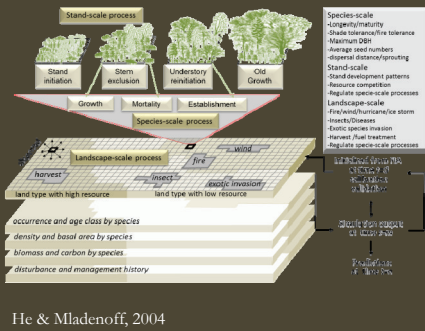


3. **Remotely sensed data:** broad scale, high geographic coverage, medium temporal resolution.



Predictive models for simulating complex processes across the landscape.

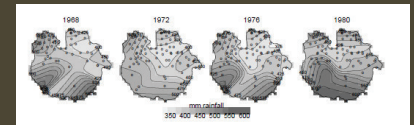
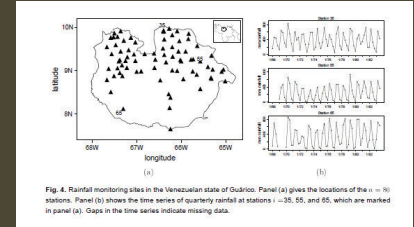
- Spatially-explicit simulation models place complex ecological systems within the landscape mosaic.
- Pros: Convenient to run; Capable of considering multiple management options and forecasting effects through time.
- Cons: Require careful parameterization; Deterministic approach makes it difficult to track prediction uncertainty.



Quantifying prediction uncertainty: dynamic spatiotemporal models.

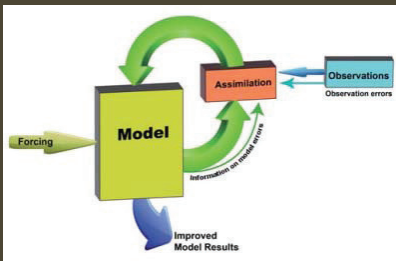
Sources of uncertainty:

- Input data
- Model parameters
- Spatial and temporal "random effects"
- Everything else / "white noise"



Stroud et al., 2012

Representing complex systems with uncertainty: data assimilation and synthesis.

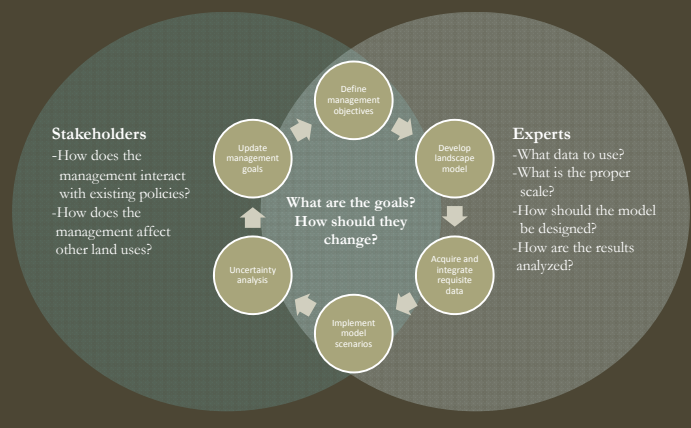


Schroeder, 2012

* For landscape models, this is an active area of research

- Designing an appropriate predictive model is only the first step.
- Models will only be useful to managers if the 'forecasts' are relevant to the problem at hand.
- This means incorporating stakeholder and expert input at **all stages** of the analysis.
- An "adaptive" approach, where models are updated to reflect new results, data, and/or shifting management decisions, allows models to incorporate stakeholder input.

A conceptual model for adaptive landscape management:



To summarize:

- Landscape ecology considers how ecological processes are influenced by the spatial arrangement of ecosystems, and how natural and anthropogenic influences act on these processes at broad spatial scales.
- Given that EBM is typically enacted at the landscape scale, considering these factors is important to making successful management decisions.
- Predictive models are an important tool for landscape management, but their use presents several challenges.
- Incorporating the input of stakeholders, as well as experts, into the modeling process will improve workflow and ensure that model results are relevant to the problems at hand.

Questions?



bclough84@gmail.com
Thanks for listening!

Aerial imagery courtesy Earth Sciences and Image Analysis Laboratory (NASA) & USGS

APPENDIX VIII-D

Urban Seascapes: A Complex Management Challenge

Michael P. Weinstein

URBAN SEASCAPES: A COMPLEX MANAGEMENT CHALLENGE

Michael P. Weinstein
New Jersey Institute of Technology
Center for Natural Resource Development and Protection

Presented at:

A Forum on Ecosystem Based Management (EBM) and Allied Topics
NJDEP
Trenton, NJ

22 January 2014

 Center for Natural Resources Development and Protection

Humans in the Coastal Landscape

- Mankind Is One of the *Most Coastally Dependent* Species in the Biosphere

Schubel and Hirschberg 1978

- About *One-Half of the Nation's GNP, \$4.5 Trillion*, Originates in the Coastal Zone;
- Humans Use the Shore Zone for Activities That May Be in *Conflict*.

 Center for Natural Resources Development and Protection

Notion of the Coastal "Commons" Goes Way Back:

Greek Common Law

By the Law of Nature These Things are *Common to all Mankind* - The Air, Running Water, the Sea, and Consequently the Shores of the Sea

Anonymous, Greek Philosophers

 Center for Natural Resources Development and Protection

... *Ports [and Rivers] are Public*, ... [the] *Right of Fishing ...is Common to All...* and by Law...and by *Natural Right ...any Person has a Right to Build on the Shore*, or by Piles, upon the Sea, and *Retain the Ownership of the Construction* so Long as it Lasts

Institutes of the Emperor Justinian, Liber 2, Tract 1, Section 1

 Center for Natural Resources Development and Protection

By Middle of this Century:

- *5.5 Billion* People in the Coastal Zone;
- Most Clustered in "*Mega-Cities*" of Eight Million People or More;
- *Eight of the Ten Largest Cities* on Sea Coasts

Yet the Coastal Zone Is Only About 11% of the Earth's Land Surface!

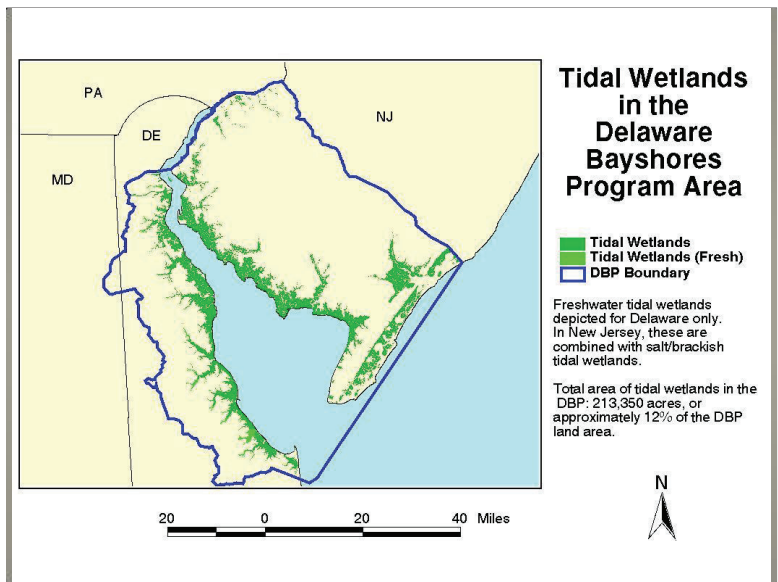
 Center for Natural Resources Development and Protection

Coastal Economy

International Trade Will Nearly Triple This Century, With More Than *90% Waterborne* and Requiring Ever-Larger Ports and Services;

Most International Commerce Is Shipped Through Coastal Waters; *>99% by Weight and > 80% by Value.*

 Center for Natural Resources Development and Protection



The Kernel Issue:

“Where Multiple Desirable but Competing Objectives Exist, it is **Not Possible to Maximize Each...**[and] in any System with Multiple Competing Objectives, it will **Not be Possible to Meet Every One**”

U.S Commission on Ocean Policy 2004

It will also Require Fundamental Advances in our Ability to Address Such Issues...as the Responses, **Some Irreversible** [emphasis added], of the Nature-Society System to Multiple and Interacting Stresses.

Kates et al. 2001

Paradox of the Dual Mandate

Natural Systems: Change (Dynamicism), Surprises, Uncertainty, and Unpredictability are the Norms;

Human Dominated Systems: Stability and Predictability are not only Necessary, but Essential.

The Paradox

How Do We Preserve Ecosystems, and Buffer Core Technologies Against Natural Variation and Unpredictability While Ensuring the Reliable Provision of Goods and Services?

Human Dimensions of Natural Resource Management

- Ways People **Value, Utilize and Benefit** from Coastal (and Other) Ecosystems;
- Made up of the **Political, Economic and Social** Systems;
- Ultimate Success of **EBM** will be based on **Societal Values**; i.e., is Fundamentally A Human Endeavor;
- Values are Expressed Through **Laws, Congressional Budgets, Volunteerism, Voting Behavior, etc.**

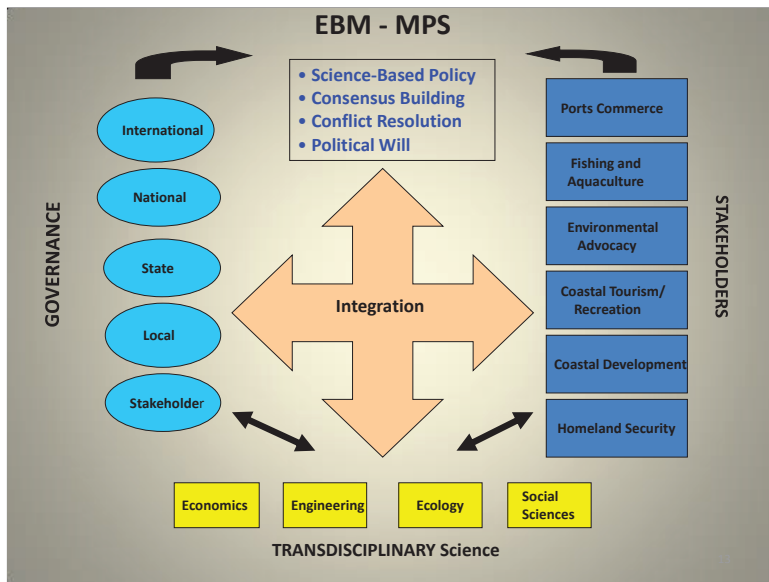
ECOLOGICAL RESTORATION

Cairn's (1975) “ECOSOCIETAL” Context

Restored Ecosystems are Bound by Two Criteria

- **Scientifically Documented Restoration**
– Recovery to Original Structure and/or Function
- **Publicly Perceived Restoration**
– Recovery to “Usefulness”

Cairn's Model Forces the Recognition that **Restoration Practices Manifest Societal Values**



CONFLICT MANAGEMENT!

Heretical Suggestion:

Ocean “Zoning” for the United States
Should Include *Commerce Managed Areas*

Estuary Type

**Urban - Industrial
(Functional)**

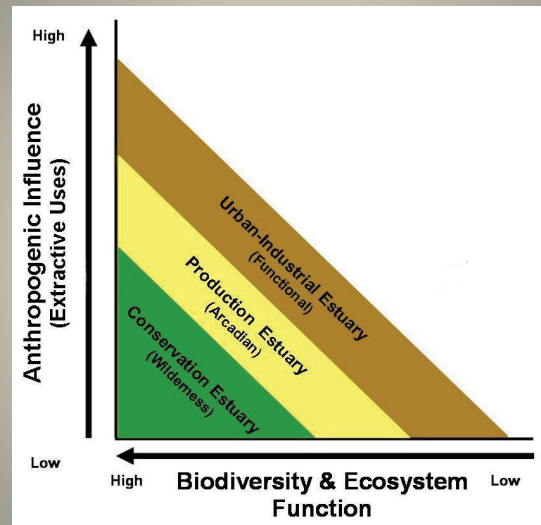
**Human Domination & Regular
Extractive Uses (High Reliability
Management & Predictability of
Ecosystem Services)**

**Production
(Arcadian)**

**Moderately Colonized by Humans with
Regular Extractive Uses (“Semi-
Natural”; Intermediate Predictability of
Ecosystem Services)**

**Conversation
(Wilderness)**

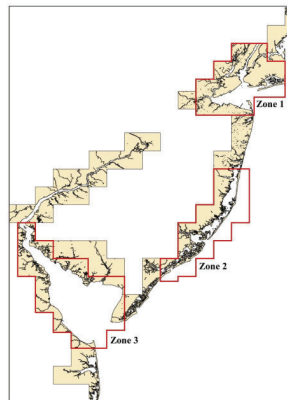
**Relatively Un-Dominated by Humans &
Their Needs (Self-Sustaining)**



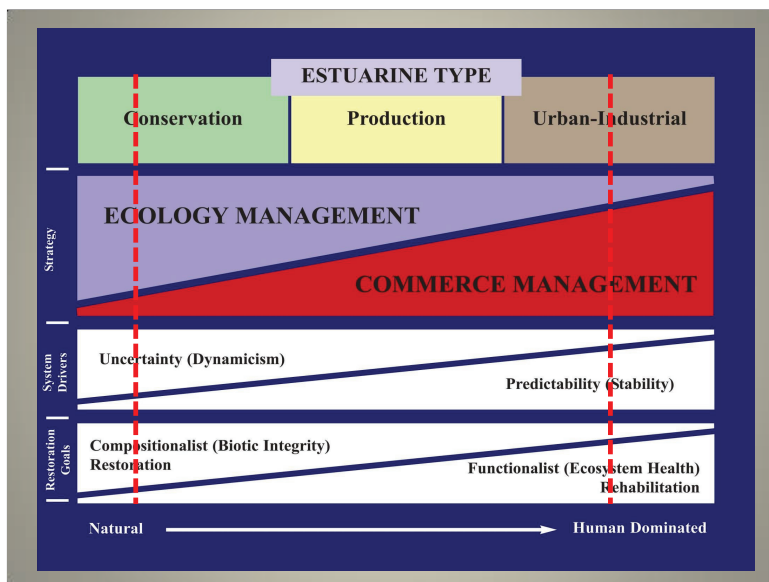
Zone 1
New York-New Jersey Harbor

Zone 2
Barnegat Bay

Zone 3
Delaware Estuary



ESTUARY TYPE	PERCENT OF TOTAL SHORELINE			
	Tidal Marshes	Beaches + Other	Armored Shoreline	Human Population Density (km ²)
Urban-Industrial Estuary New York-New Jersey Harbor	49.2	5.5	45.3	14,587
Production Estuary Barnegat Bay	57.3	8.0	35.0	2,562
Conservation Estuary Delaware Estuary	88.2	3.1	8.7	1,308
	NATURAL COMPONENTS		“HUMAN” COMPONENTS	



ADDRESSING THE “HARD” QUESTIONS

- What are the Appropriate **Baselines** for Urban-Industrial and Production Estuaries?
- What are the Acceptable **Compromises and Sacrifices** in Biotic Integrity that Must Accompany Urbanization and Industrialization?
- How do we **Compete** Globally With the Nations **Not Expected** to Make These Sacrifices?
- How do we **Identify** and **Quantify** Species and their Population Dynamics When we Speak of Taxa “Adapted to the Presence of Humans”? How do we Manage from the “Bottom Up”?
- How do we Achieve **Consensus** and **Break Down the “We vs. Them” Mentality**?

Achieving Reasonable Balance and Resolving Conflict

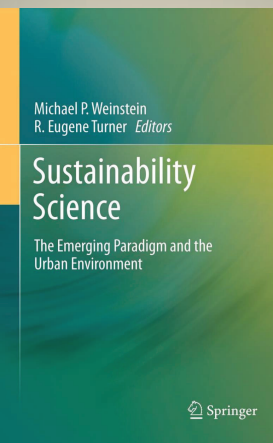
Will require:

- Satisfactory Resolution of the **Paradox of the Dual Mandate**;
- Maturation of **Sustainability Science** as a Means of Placing Humans In the Landscape;
- Incorporating **Human Dimensions** Into Coastal Zone Management;
- Using **Spatial Planning** to Help Resolve Conflicts;
- Implementing **Ocean Zoning** Practices;
- Establishing **Realistic Baselines** that Reflect Human Domination In Coastal Systems; and
- Managing Species **Adapted To Human Colonization**.

Weinstein, M.P. and D.J. Reed. 2005. Sustainable coastal development: the dual mandate and a recommendation for “commerce managed areas”. *Rest. Ecol.* 13:174-182.

Bibliography

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APPENDIX VIII-E

Sustainability Science
Malin Pinsky



Sustainability science

Malin Pinsky
Dept. of Ecology, Evolution, and Natural Resources
Rutgers University



What does *sustainability* mean?

[sustainable development] meets the needs of the present without compromising the ability of future generations to meet their own needs

- Brundtland Commission 1987

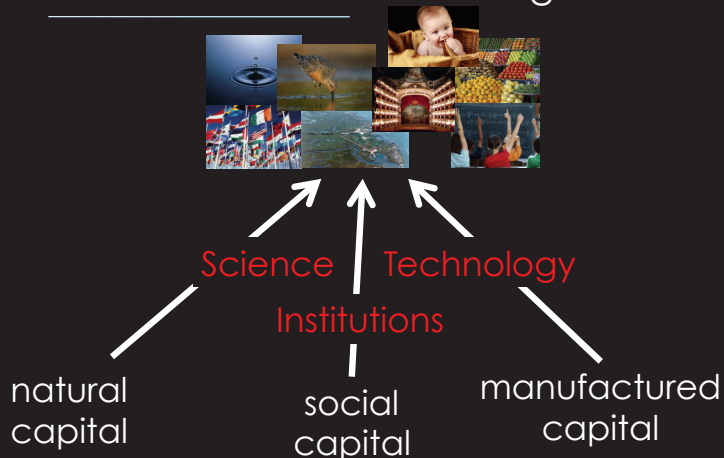
Question: what is to be...

sustained?

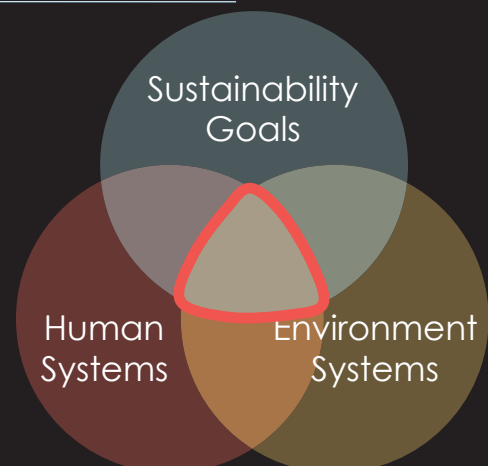
developed?



How to maintain well-being?



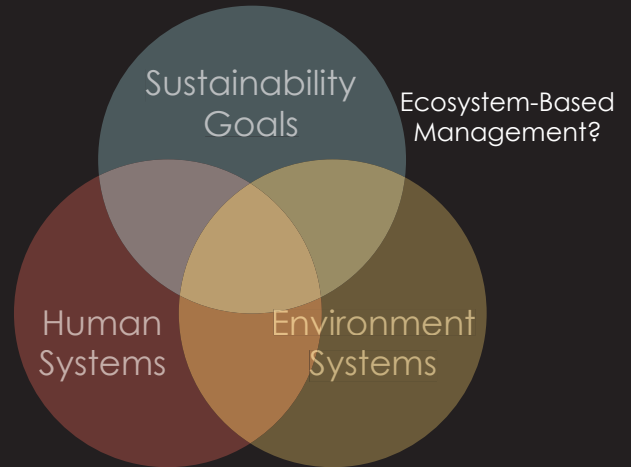
An integration of fields



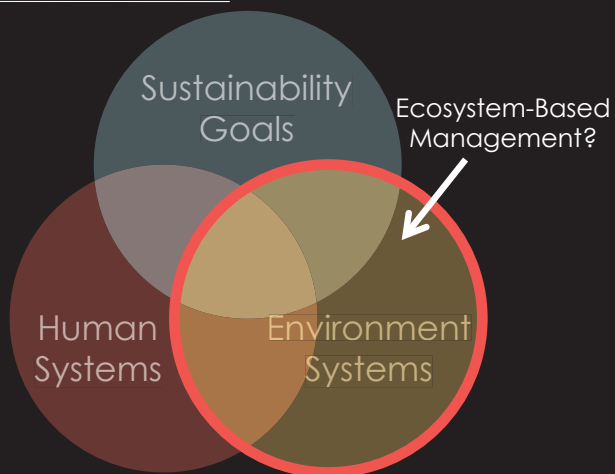
An integration of fields



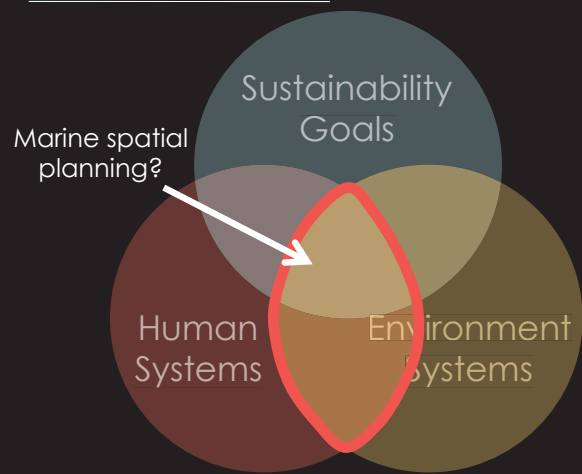
An integration of fields



An integration of fields



An integration of fields



Topics

- Features of sustainability science
- Ecosystem service example
- Human adaptation example

Features of sustainability science

Problem-driven



Features of sustainability science

Cross-scale linkages



vs.



Features of sustainability science

Cross-scale linkages

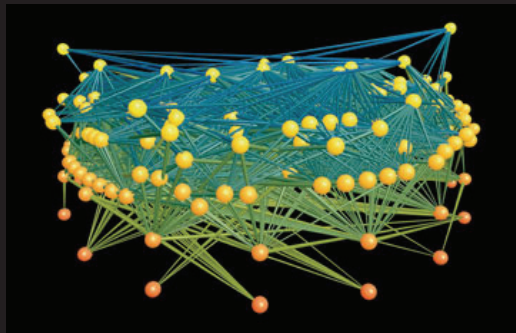


vs.



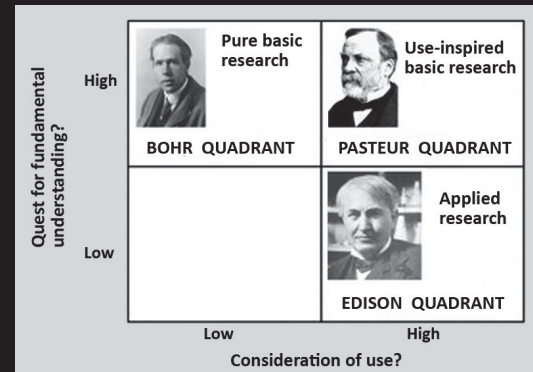
Features of sustainability science

Complex adaptive systems



Features of sustainability science

Integrated research and practice



adapted
from
Stokes
1997

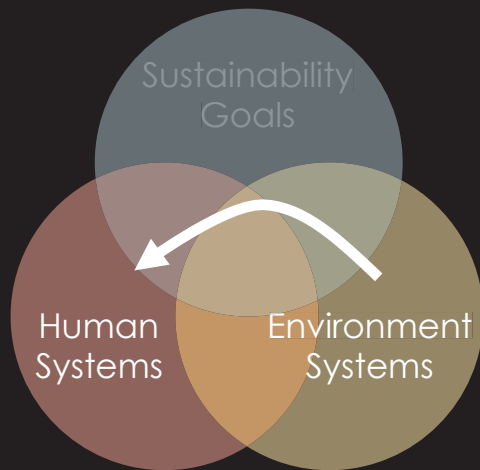
Topics

- Addresses the feedbacks between society and the environment
- Ecosystem service example
- Human adaptation example

Topics

- Addresses the feedbacks between society and the environment
- Ecosystem service example
- Human adaptation example

Ecosystem services



InVEST

Integrated Valuation of Ecosystem
Services and Tradeoffs

natural
capital
PROJECT



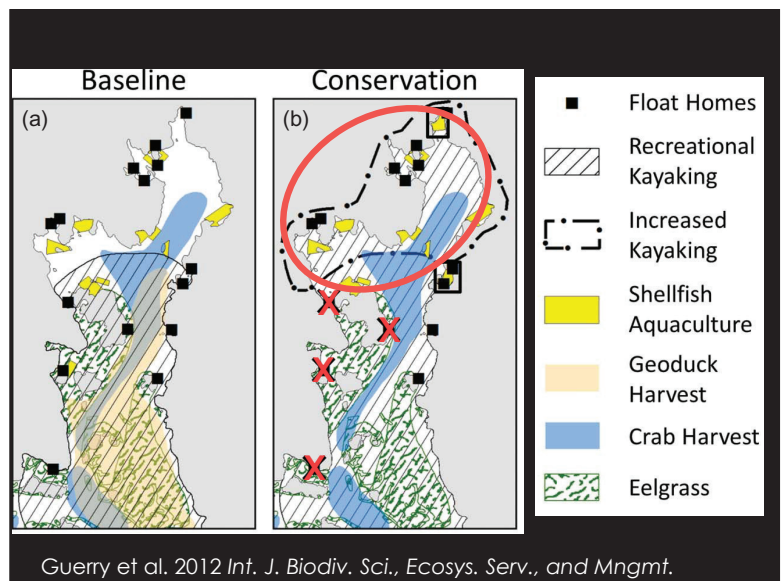
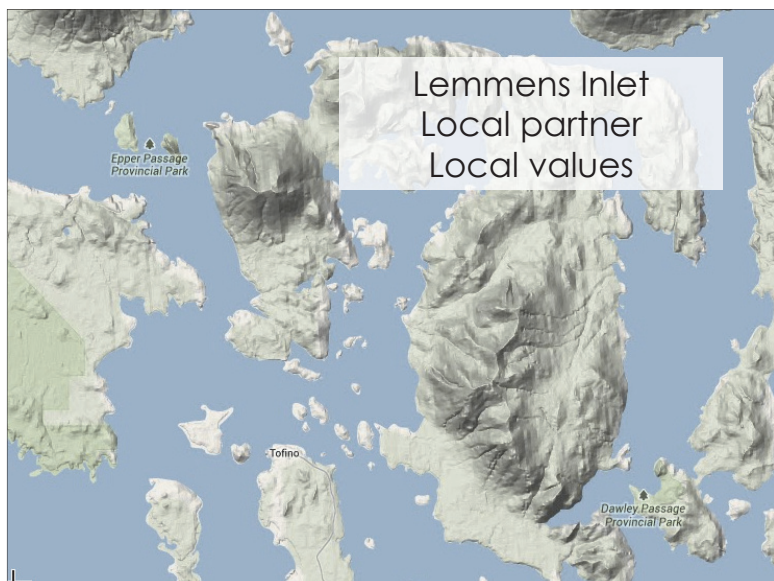
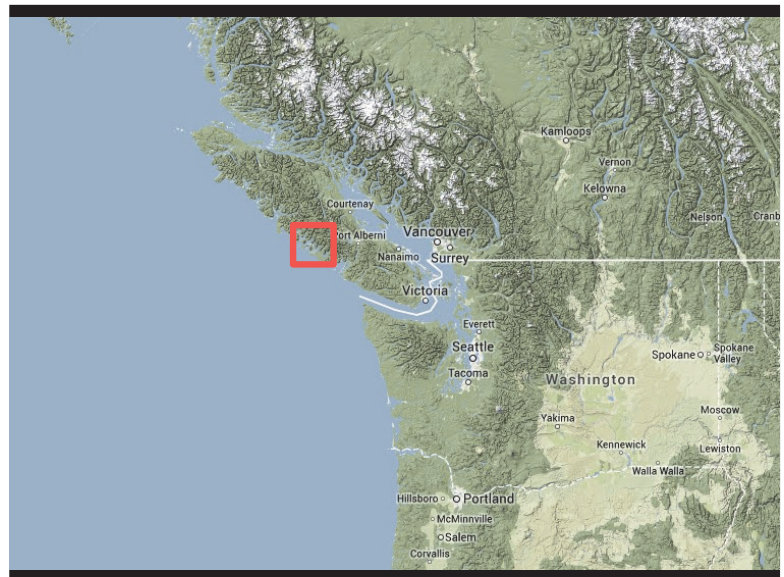
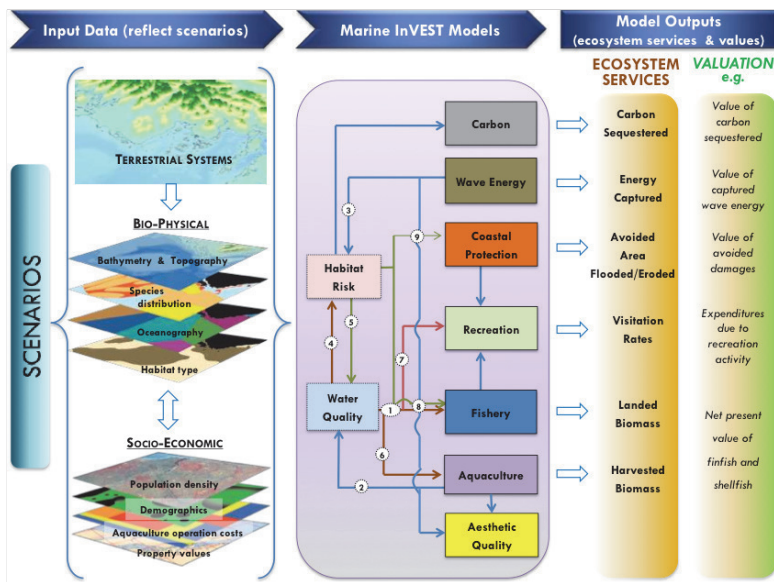
Stanford
WOODS
INSTITUTE for the
ENVIRONMENT



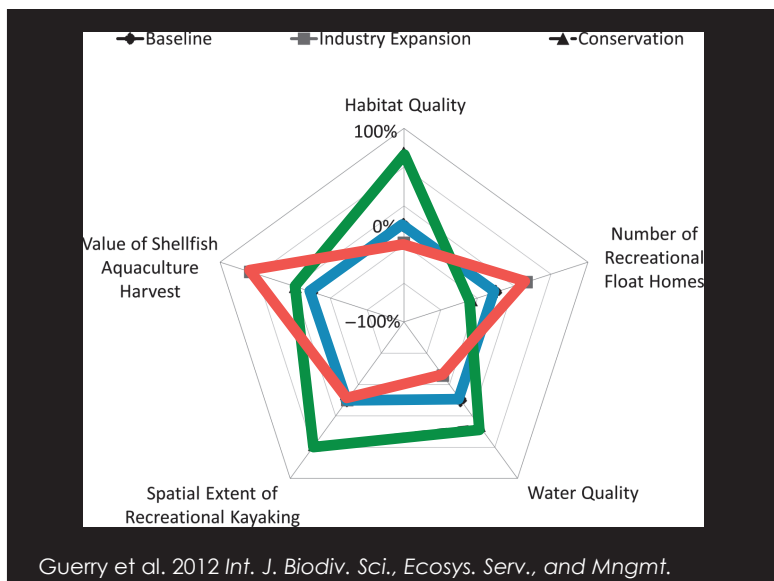
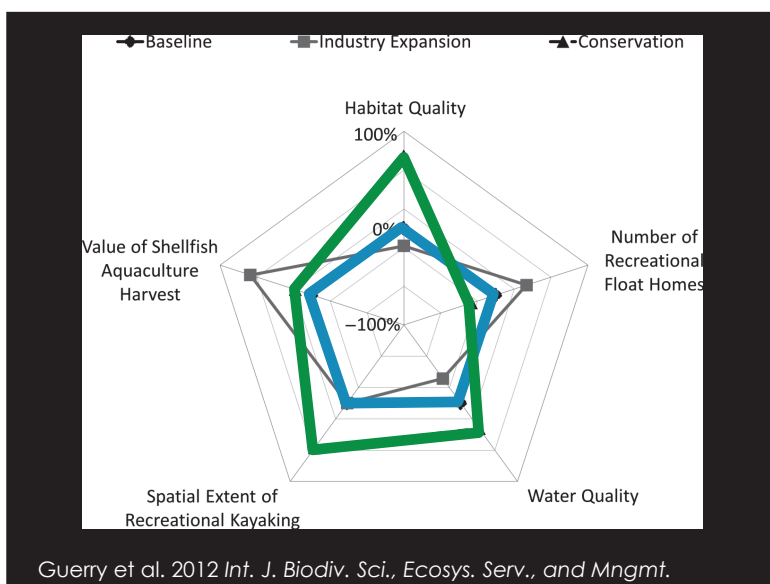
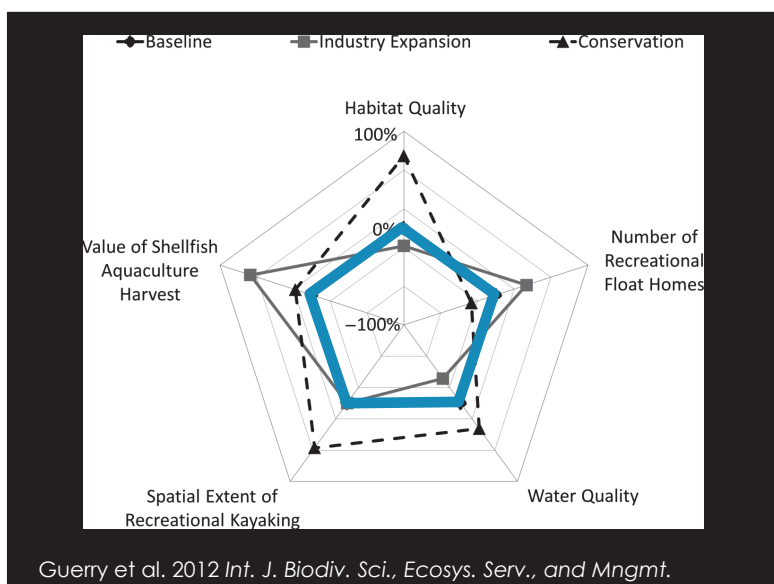
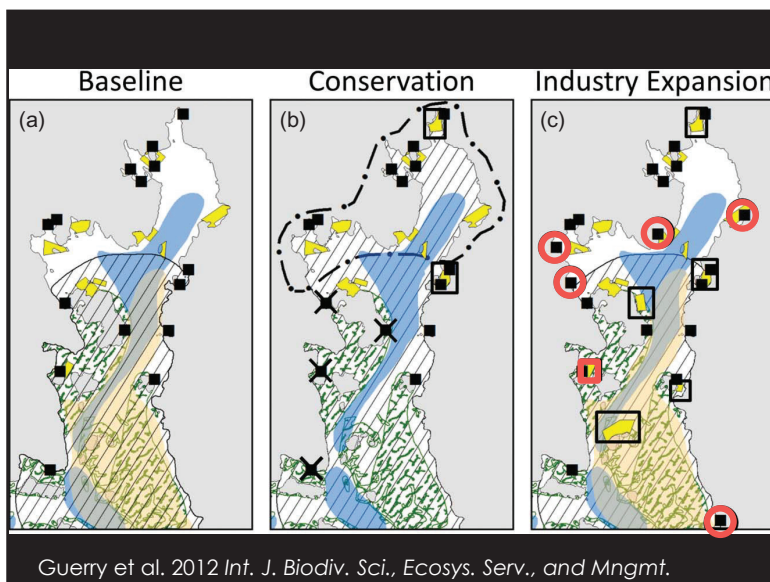
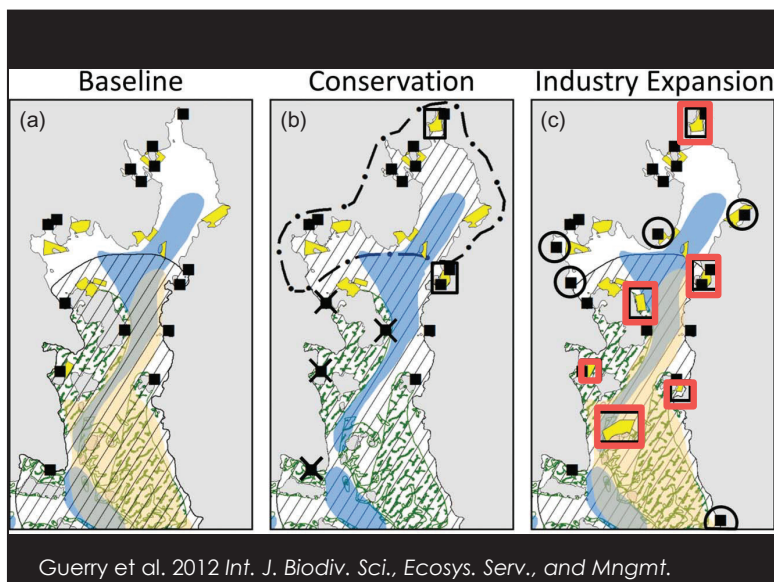
The Nature
Conservancy



INSTITUTE ON THE
ENVIRONMENT
UNIVERSITY OF MINNESOTA
Driven to Discover™



Guerry et al. 2012 *Int. J. Biodiv. Sci., Ecosys. Serv., and Mngmt.*



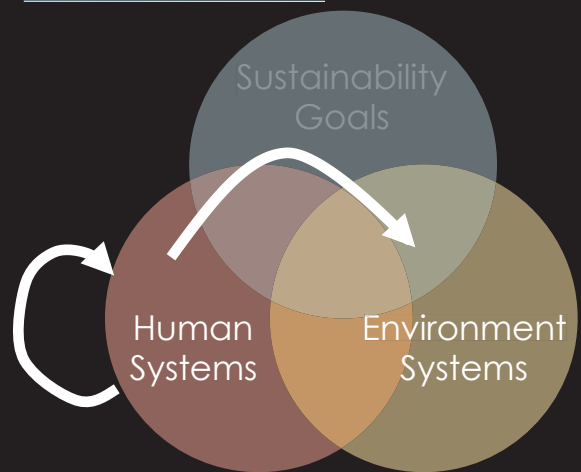
Topics

- Addresses the feedbacks between society and the environment
- Ecosystem services link environmental state to human well-being
- Human adaptation example

Topics

- Addresses the feedbacks between society and the environment
- Ecosystem services link environmental state to human well-being
- Human adaptation example

Adaptive behavior



Summer flounder



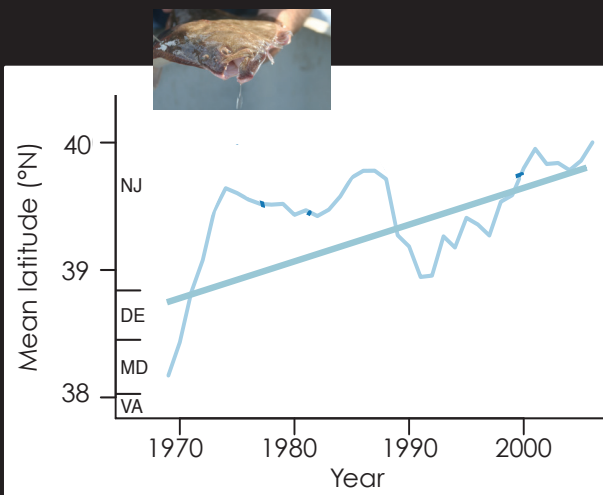
Summer flounder



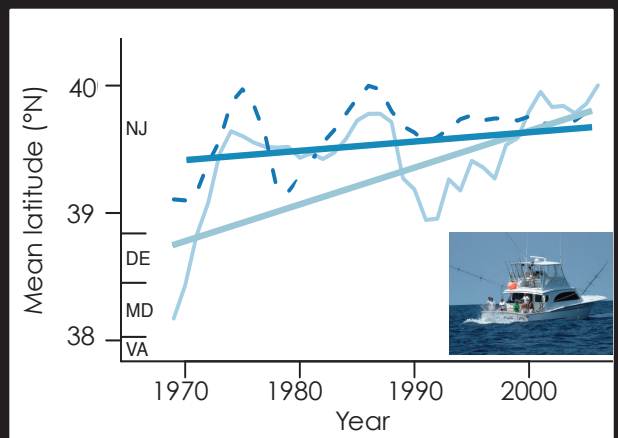
Commercial fishing
(summer flounder):
\$5.5 million revenue
(NJ, 2011)



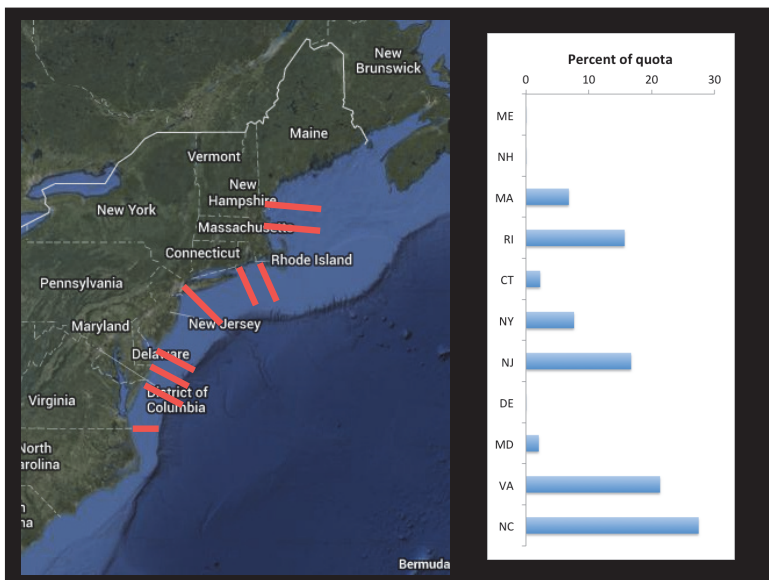
Recreational fishing
(all species):
\$1.7 billion in sales
(NJ 2011)



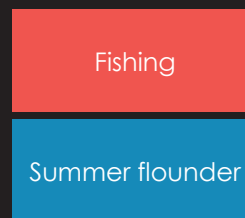
Pinsky & Fogarty 2012 *Climatic Change*



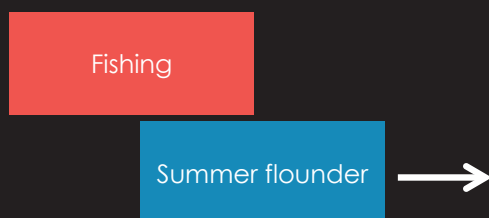
Pinsky & Fogarty 2012 *Climatic Change*



Fishing the trailing edge...



Fishing the trailing edge...



Fishing the trailing edge...



Fishing the trailing edge...

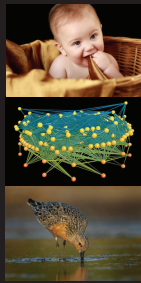


Summary

- Problem-driven science to address the feedbacks between society and the environment, including...
- links from environmental state to human well-being, and...
- role of social dynamics in determining the impacts of humans on the environment

Very active areas of research...

- Quantifying ecosystem services
- Complex adaptive dynamics
- Managing human-environment systems for sustainability
- Measuring progress



APPENDIX VIII-F

Sustainability Science and the EPA

Alan D. Hecht

**New Jersey Department of Environmental Protection
Forum on Ecosystem-Based Management**
March 26, 2014



Sustainability Science and the EPA

Alan D. Hecht, Ph.D.

Director for Sustainable Development
Office of Research and Development U.S. EPA

Outline

- Urgency of Achieving Sustainability
- NAS Reports and Recommendations (2011,2013)
- EPA Strategic Plan 2014-2018
- Sustainability Science / Example: Narragansett Bay
- WBCSD/ORD Training for Ecosystem Services
- Next Steps

Drivers of Change

- Economic & population growth
- Urban development
- Global economic volatility
- Competitive business pressures
- Social responsibility expectations
- Climate change & sea-level rise
- More extreme natural disasters
- Poverty, disease, malnutrition
- Environmental degradation



Land use change lies at the heart of many of New Jersey's environmental problems.

Land use change, in the view of experts, produced by a wide margin the largest negative ecological and socioeconomic impacts.



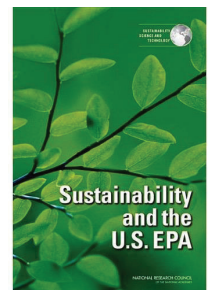
Cities and Urban Development

"Our struggle for sustainability will be won or lost in cities." —Ban ki-moon



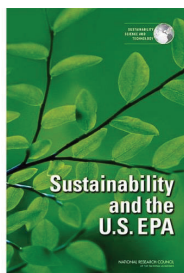
EPA Charge to NAS, 2011

- What should be the operational framework for sustainability for EPA?
- What scientific and analytical tools are needed to support the framework?
- How can the EPA decision making process rooted in the risk assessment/risk management (RA/RM) paradigm be integrated into this new sustainability framework?
- What expertise is needed to support the framework?



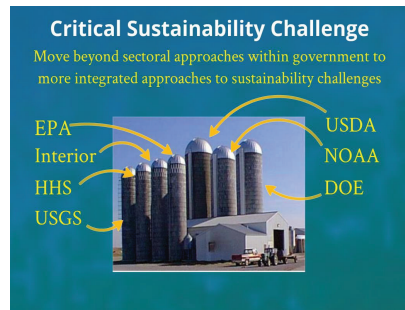
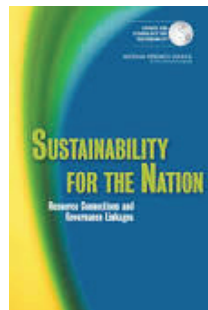
Recommendations from National Academy of Sciences (“Green Book”)

1. Sustainability enhances EPA mission.
2. Sustainability is both a goal and process.
3. Set several strategic 3-5 year breakthrough objectives for the programs.
4. Develop performance indicators and associated metrics.
5. Incorporate into its decision making upfront consideration of sustainability options and analyses that cover the three sustainability domains as well as trade-off considerations.
6. Develop tools, methods and approaches for advancing sustainable development .



NAS Study, 2013: “Sustainability for the Nation”

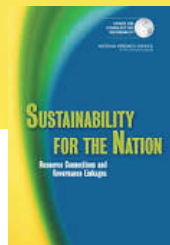
“A National Sustainability Policy should be developed that will provide clear guidance to the executive agencies on addressing governance linkages on complex sustainability problems and inform national policy on sustainability.”



8

High Priority Sustainability Challenges

- Connections among energy, food, and water
- Diverse and healthy ecosystems
- Enhancing the resilience of communities to extreme events
- Human health and well-being



4

Success on sustainability issues in the federal government is dependent on several key factors: engaging stakeholders throughout the process; including and integrating environmental, economic, and social dimensions; using a strong science base and processes that link science and decision making; and reaching stakeholder agreement on the nature of important connections

Administrator’s Themes 2014-2018

- Making a Visible Difference in Communities across the Country
- Addressing Climate Change and Improving Air Quality
- Taking Action on Toxics and Chemical Safety
- Protecting Water: A Precious, Limited Resource
- Launching a New Era of State, Tribal and Local Partnerships
- Embracing EPA as a High Performing Organization
- **Working Toward a Sustainable Future**



EPA Strategic Plan, 2014-2018

Sustainability as a Cross-Cutting Fundamental Strategy

“EPA will advance more sustainable environmental outcomes and optimize economic and social outcomes through Agency decisions and actions, consistent with statutory obligations, priorities, and available resources by engagement of diverse stakeholders.”

Priority Areas:

- Sustainable products and purchasing
- Green Infrastructure
- Sustainable materials management
- Energy efficiency

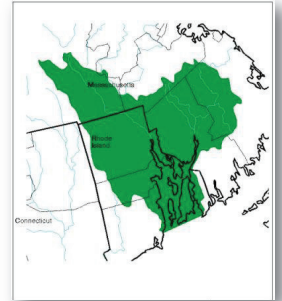
Integrated ORD Research Programs



13

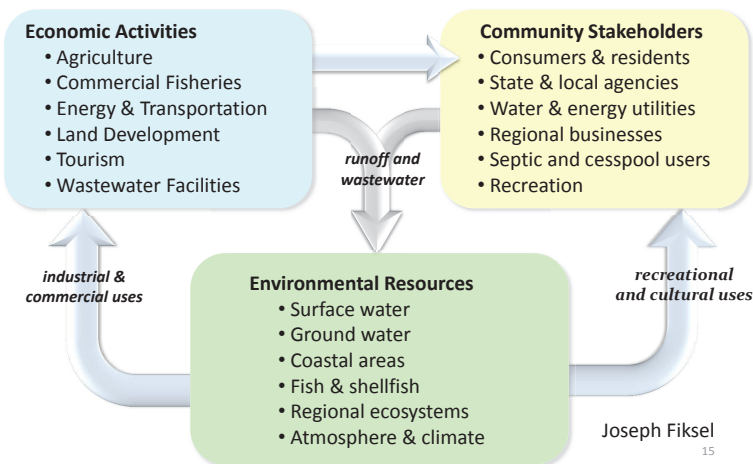
Narragansett Pilot Project

- Apply “systems thinking” to the problem of nitrogen and phosphorus pollution in New England waters.
- Collaborate with stakeholders to address sustainability goals.
- Explore integrated strategies for nutrient mitigation.
 - Regulatory influence
 - Voluntary innovation
- Provide a replicable approach for other EPA Regions.
- Coordinate with other projects in Narragansett Bay watershed.



14

Modeling the Nutrient Cycle



business solutions for a sustainable world



wbcd business ecosystems training

Business Ecosystems Training U.S.

Understanding and Managing the Links between Ecosystem Services and Business

Main Presentation

June 2013



How are companies addressing this issue?

Unilever:

"By 2020 we will source 100% of our agricultural raw materials sustainably."
Source: <http://www.unilever.com/sustainability/environment/agriculture/index.aspx>

Walmart:

"A pledge: to protect one acre of conservation land for every acre occupied by Walmart's US facilities."
Source: <http://walmartstores.com/Sustainability/5127.aspx>

Kimberly-Clark:

"25 percent reduction in manufacturing water use by 2015"
Source: http://www.cms.kimberly-clark.com/UmbracoFileMedia/2010SustainabilityReport_umbracoFile.pdf

The Coca-Cola company:

"Work to safely return to nature and communities an amount of water equivalent to what we use in our beverages for their production" (by 2020).
Source: http://www.thecoca-colacompany.com/citizenship/water_main.html

Walt Disney:

"Long term objective of having a net positive impact on ecosystems"
Source: <http://corporate.disney.go.com/citizenship/2010/environment/overview/ecosystems/>



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Ecosystem Tools Being Developed by EPA – 1

EnviroAtlas

- Interactive tool for mapping, analyzing, and downloading indicators of ecosystem services at multiple scales (Beta version online: June 2013)

Eco-Health Relationship Browser

- Interactive tool illustrating documented links between ecosystem services and human health

Component of EnviroAtlas Decision Analysis for a Sustainable Environment, Economy and Society (DASEES)

- Interactive framework for involving stakeholders and decision-makers in the analysis of environmental problems (Online: September 2013)



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Ecosystem Tools Being Developed by EPA – 2

Well-Being Conceptual Network

- *Interactive utility showing relationships between economic, social and ecological services and human well-being (Online: July 2013)*

Final Ecosystem Goods and Services Classification System

- *Standardized lists of final ecosystem goods and services, with defined beneficiaries, to facilitate valuation (Online: June 2013)*

Ecological Production Function Library

- *A compendium of ecological models for estimating the production of ecosystem services (Online: March 2015)*



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Next Steps

“Working Toward Sustainability”

<http://sspp.proquest.com/archives/vol10iss2/communityessay.hecht.html>.

- Engaging stakeholders to understand their needs/constraints
- Advancing sustainability science and systems thinking
- Reduce silos and encouraging trans-disciplinary collaboration among government, business, and non-governmental organizations to design comprehensive approaches
- Developing decision support tools to help policy makers and decision makers implement sustainable and resilient solutions.

A. Hecht, J. Fiksel, M. Moses

APPENDIX VIII-G

Marine Ecosystem Based Management for the Northeastern United States

Vincent Saba and Michael Fogarty

Marine Ecosystem-Based Management for the Northeastern United States

Vincent Saba
and
Michael Fogarty

Ecosystem Assessment Program
Northeast Fisheries Science Center

Ecosystem-Based Management Forum
Trenton, NJ
March 26, 2014

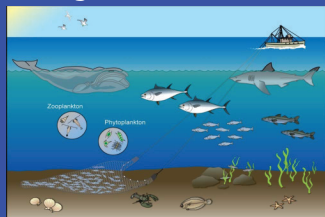


Preview of Coming Attractions

- What is EBM?
- Ecosystem Services, Threats, and Impacts Framework
 - Ecosystem Services
 - Threats to Ecosystem Services
 - Impacts
 - Status Determination
- Models and Indicators
- Spatial Management Options

Ecosystem-Based Management

“U.S. ocean and coastal resources should be managed to reflect the *relationships* among all ecosystem components, including *human* and nonhuman species and the *environments* in which they live.

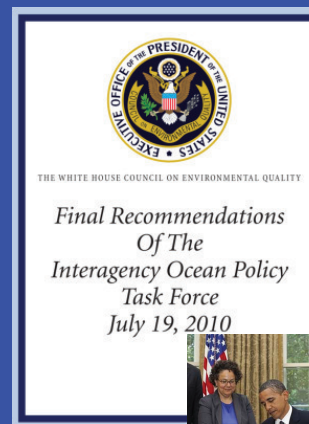


Applying this principle will require defining relevant *geographic management areas* based on ecosystem, rather than political, boundaries (USCOP 2004)”

National Ocean Policy

Establishes:

- National Ocean Council
- Ecosystem-Based Management (EBM) as a Core Principle
- Regional Ocean Planning as Key Management Tool
- Regional Planning Bodies



Marine Ecosystem Services are Subject to a Wide Spectrum of Threats and Impacts



Natural Products

Capture Fisheries



EcoTourism



Ecosystem Services



Energy

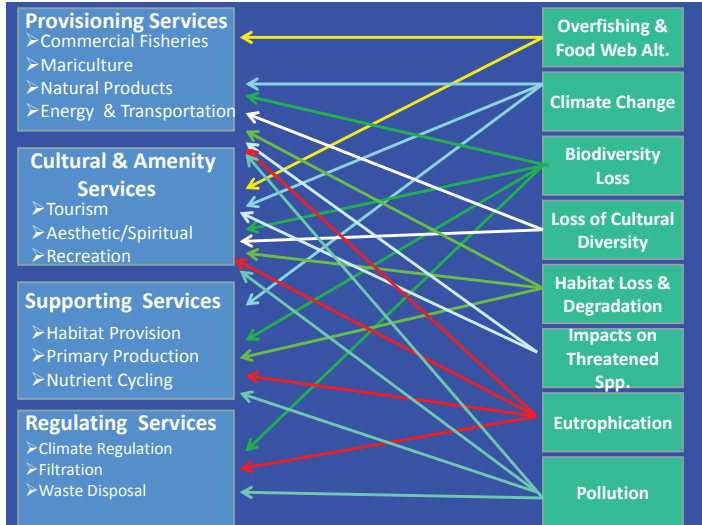


Recreation

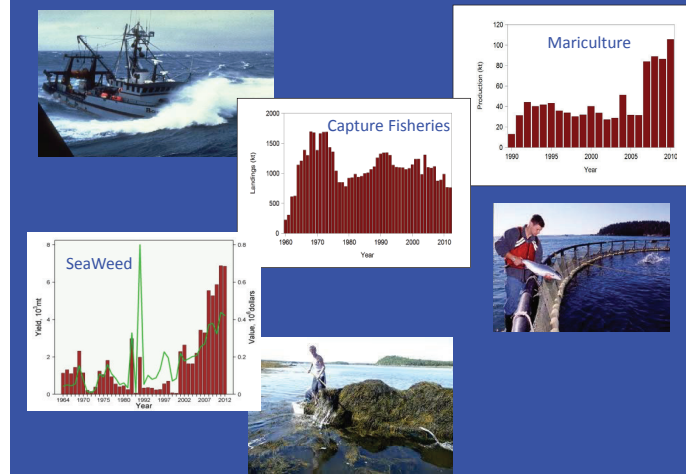


Aquaculture

EBM provides an integrated framework for the sustainable delivery of ecosystem services



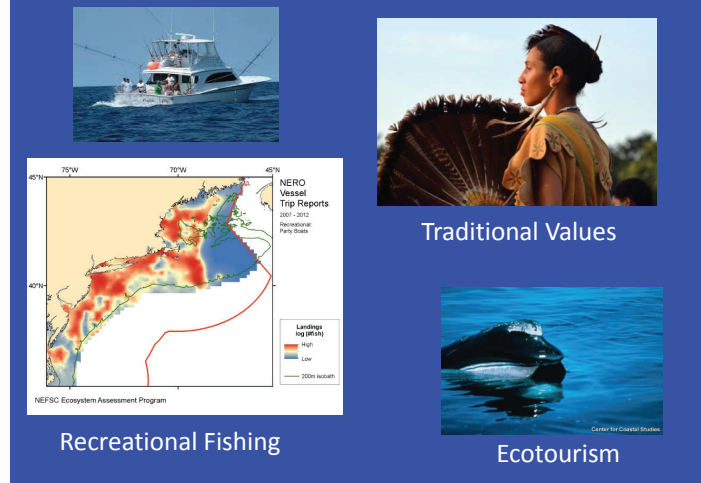
Provisioning Services: Examples



Transportation

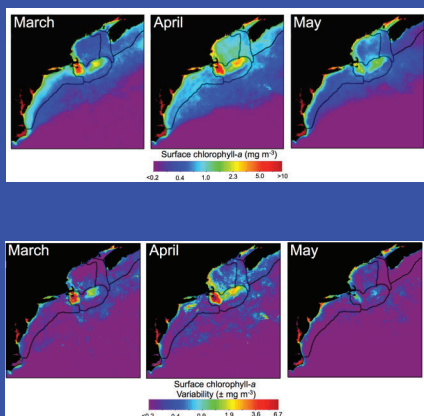


Cultural Services:



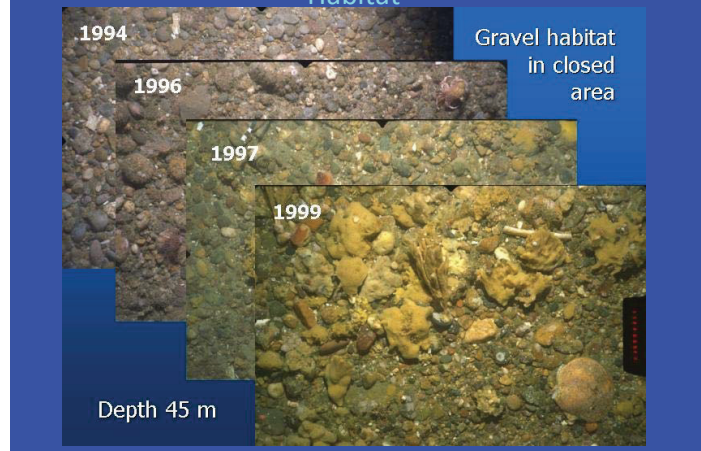
Supporting Services:

Phytoplankton – Base of the Marine Food Web

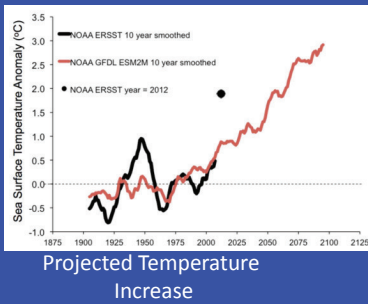


Supporting Services:

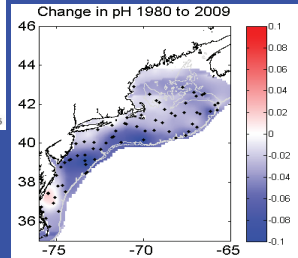
Habitat



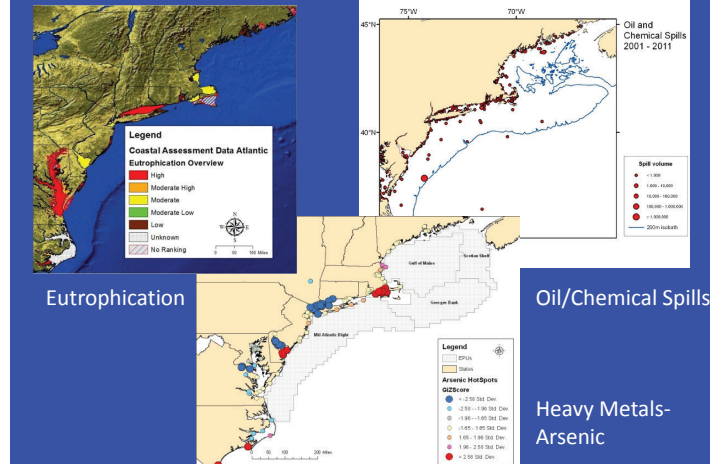
Threats: Climate Change



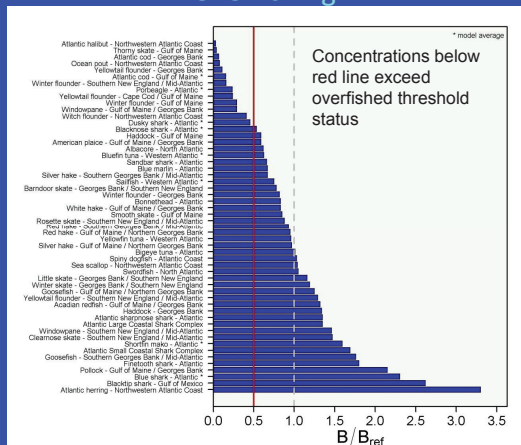
Ocean Acidification



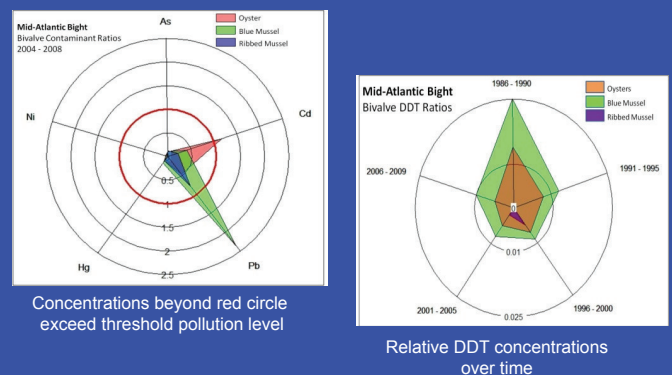
Threats: Pollution



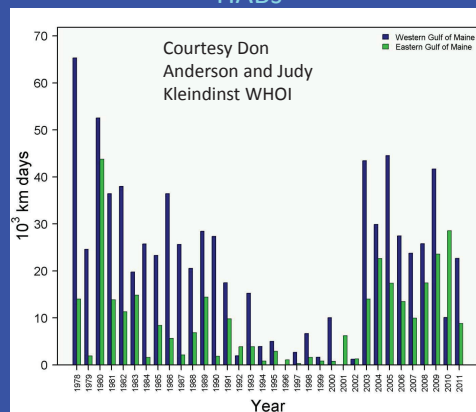
Status Determinations: Overfishing



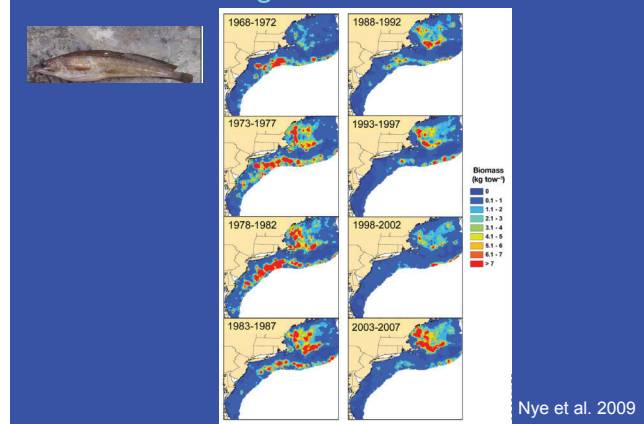
Status Determinations: Pollution – Heavy Metal and DDT Concentrations



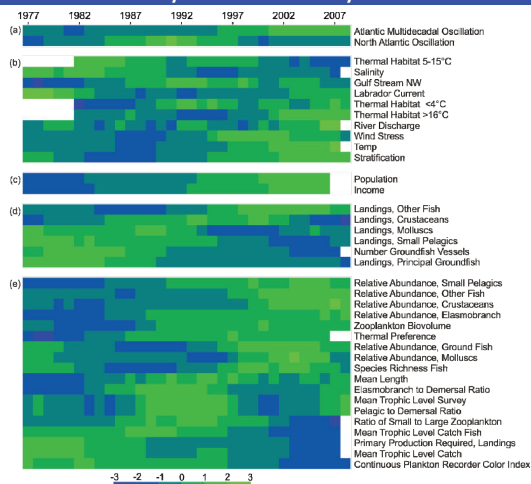
Impacts: Beach/Shoreline Shellfish fishery Closures - HABs



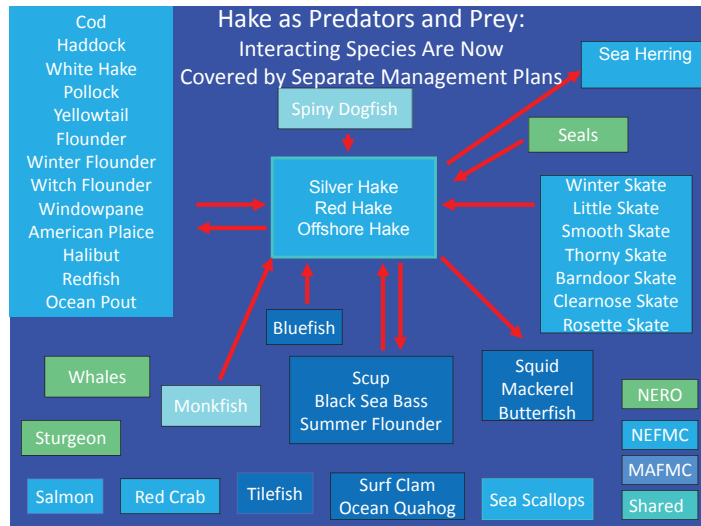
Impacts: Shifting Distribution Patterns



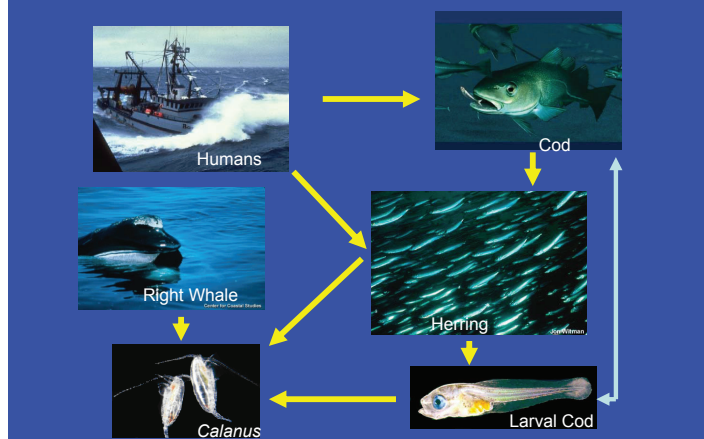
Tools for Synthesis: Ecosystem-Indicators



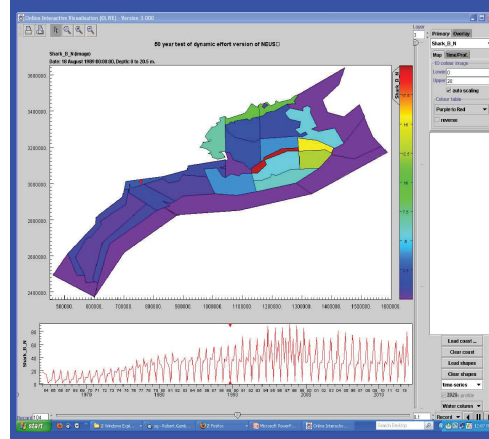
Hake as Predators and Prey: Interacting Species Are Now Covered by Separate Management Plans



Human Activities have Direct & Indirect Effects on Marine Ecosystems: Need Integrated Management Strategies

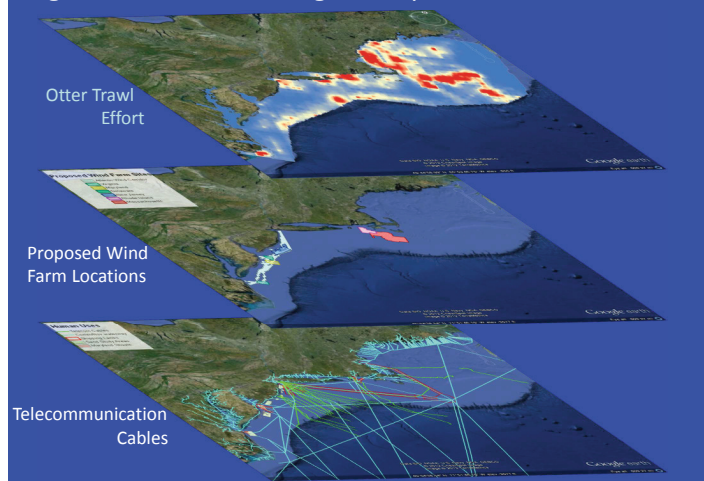


Tools for Synthesis: Ecosystem Models

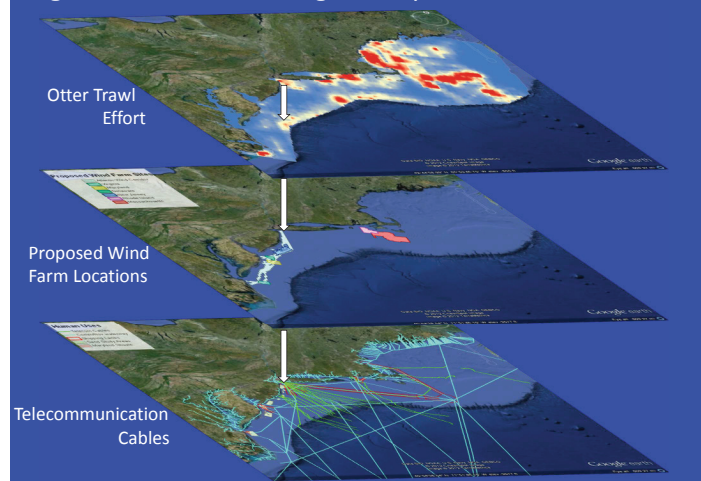


ATLANTIS tracks thousands of factors from climate and physics through social and economic considerations

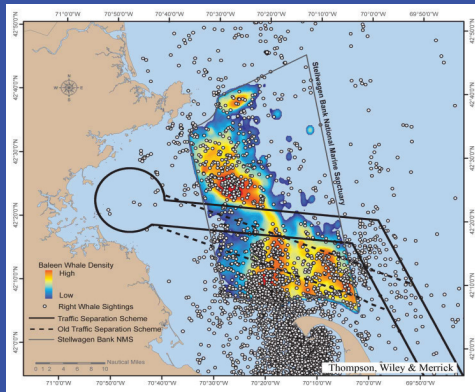
Regional Ocean Planning: Multiple Ocean Use Patterns



Regional Ocean Planning: Multiple Ocean Use Patterns



Spatial Management in Action



Courtesy SBNMS, NMFS PSB

Ecosystem Status Report

For the Northeast Shelf Large Marine Ecosystem

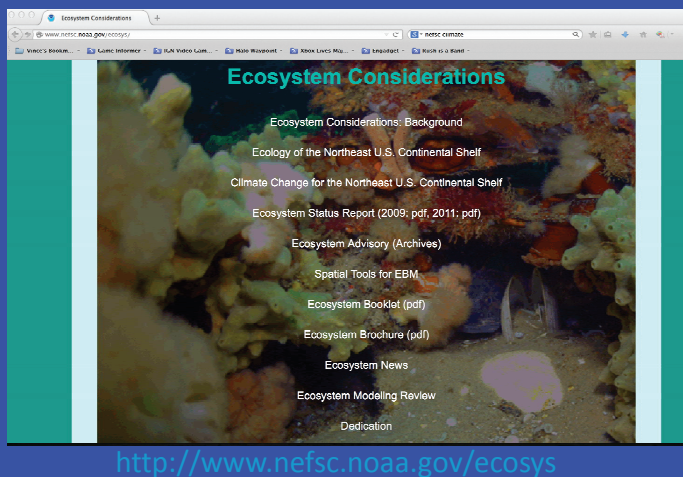
Northeast Fisheries Science Center

2011

Main Findings

- The Northeast Shelf Large Marine Ecosystem (NESLME) can be divided into four Ecological Production Units, which can in turn provide spatial domains for Ecosystem Based Fisheries Management.
- Atlantic basin scale climate indices, the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation, are at extreme levels, which is reflected in local scale changes in temperature and precipitation, among other parameters.
- The physical nature of the NESLME continues to change, notably there has been a decline in Labrador origin water, which influences salinity and food web processes in the ecosystem, and, there has been an increase in water column stratification, which affects the vertical transport of nutrients.
- Recent increases in primary phytoplankton production are not matched by increases in secondary zooplankton production raising the concern that the phytoplankton community structure is shifting to species that fail to effectively enter the food web.
- Many benthic resources have increased in recent years, which can be attributed to both fishery management strategies and environmental effects. The total biomass of fish species remains high reflecting the response of interacting species groups to fully utilize the available energy in the ecosystem.
- Though revenues have remained at high levels in the commercial fishing industry, employment in marine-related employment sectors has declined in recent years.

For Further Information See :



Extra Slides

Develop Overarching Goals

Define Ocean Management Areas

Select Strategic Objectives

Develop Integrated Management Plan

Coastal Protection

Fisheries

Transportation

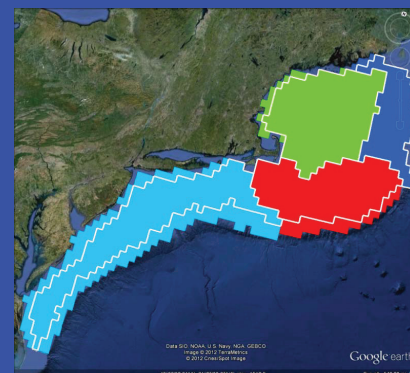
Recreation & Tourism

Aquaculture

Natural Products

Energy

Ecological Subregions of the Northeast Continental Shelf



EcoRegions are Open and Interconnected
Spatial Management Options can be Nested within EcoRegions

NEFSC Ecosystem Monitoring and Observing Program Elements



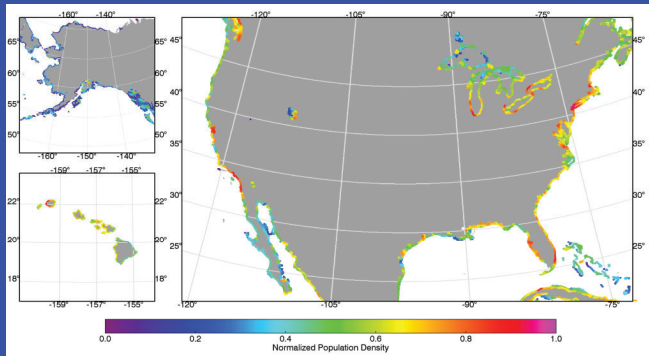
NOAA FSV Henry B. Bigelow

- Satellites
- Oceanographic Buoys
- Standardized Surveys
 - Trawl & Acoustics
 - Plankton
 - Shellfish Dredges
 - Longlines
 - Air Craft
- Ships of Opportunity
- Observer Program
- Cooperative Industry Research
- Fishery Reporting System
- Fishermen Interviews

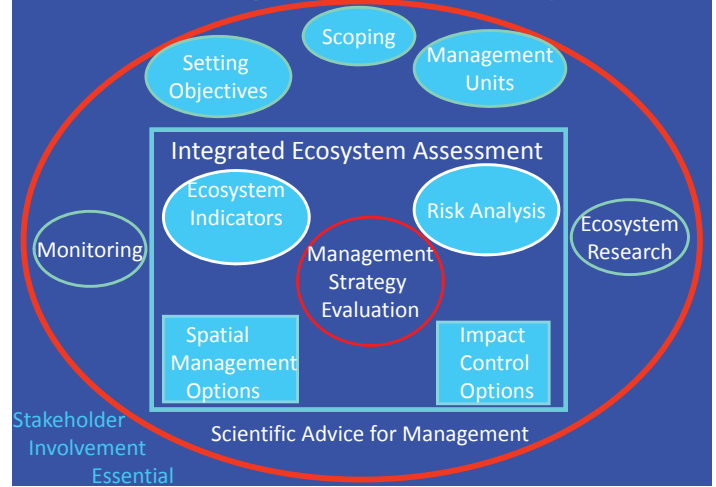
Integrated Ecosystem Assessment Process



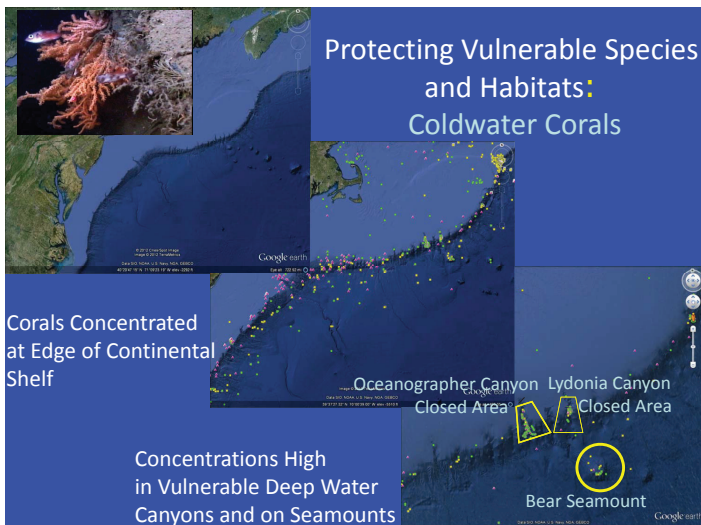
Coastal Human Population Densities are High on the Northeast Coast



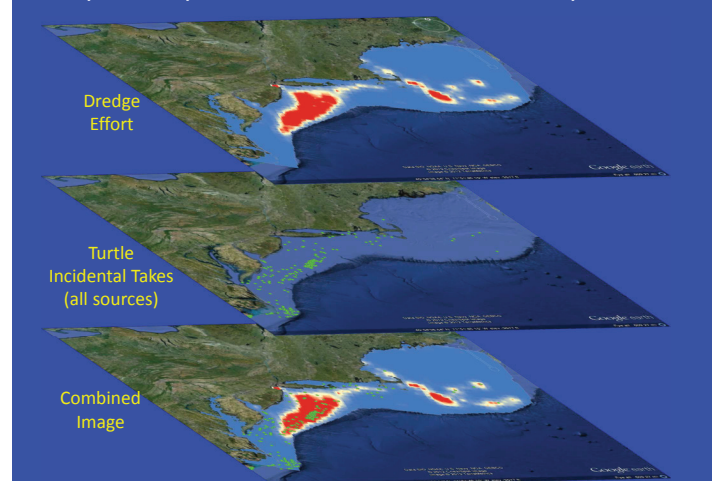
Marine Ecosystem-Based Management



Protecting Vulnerable Species and Habitats: Coldwater Corals



Spatial Options to Protect Threatened Species



APPENDIX VIII-H

The Role of Ocean Planning in the Mid-Atlantic Region

Kris Ohleth

The Role of Ocean Planning in the Mid-Atlantic Region

Kris Ohleth
Executive Director



March 26, 2014

Ocean-Related Opportunities and Challenges in our Region

- Our Mid-Atlantic ocean waters and ecosystems are economic engines and cultural treasures.
- Ocean activities and ecosystem components are managed separately by many jurisdictions. But they are interconnected!

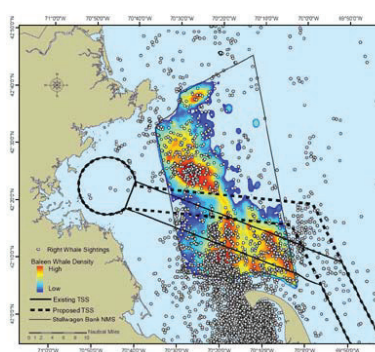


What is Ocean Planning?

- A process for bringing together ocean managers and stakeholders
- A science- and information-based tool



Ocean Planning Case Study: Stellwagen Bank



Reduce risk of shipstrikes to

- Endangered right whales by 58%
- All baleen whales by 81%



State-based Efforts for Ocean Planning

Many states have already undertaken ocean planning efforts

- Massachusetts Ocean Plan
- Rhode Island Special Area Management Plan (SAMP)
- Oregon Ocean Resource Management Plan



Mid-Atlantic Regional Council on the Ocean (MARCO)

To address this new era of ocean challenges and opportunities, the Governors of New York, New Jersey, Delaware, Maryland, and Virginia in 2009 signed an agreement that established MARCO

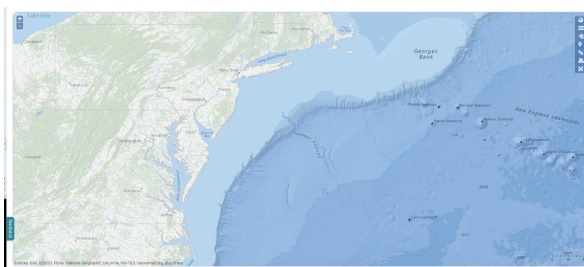


MARCO's Four Priority Areas

- Climate change adaptation
- Offshore renewable energy
- Marine habitats
- Water quality

MARCO
MID-ATLANTIC REGIONAL
COUNCIL ON THE OCEAN

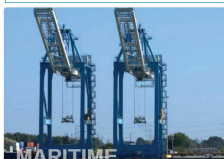
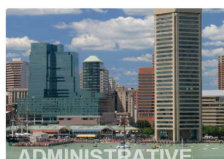
MARCO's Data Portal



MARCO
MID-ATLANTIC REGIONAL
COUNCIL ON THE OCEAN

Seven

Data themes

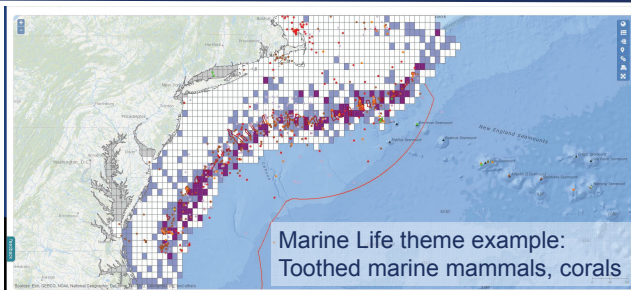


MARCO's Data Portal



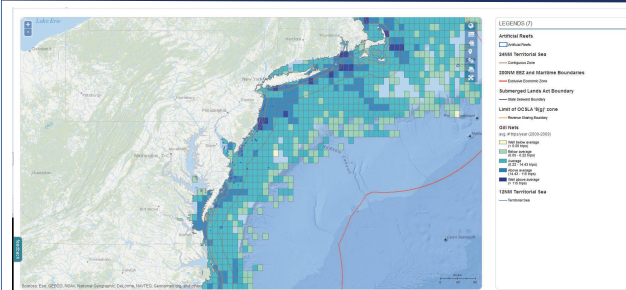
MARCO
MID-ATLANTIC REGIONAL
COUNCIL ON THE OCEAN

MARCO's Data Portal: Marine mammals, corals



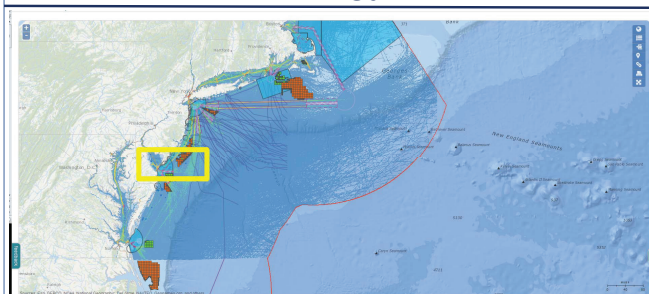
MARCO
MID-ATLANTIC REGIONAL
COUNCIL ON THE OCEAN

MARCO's Data Portal: Gill nets, artificial reefs



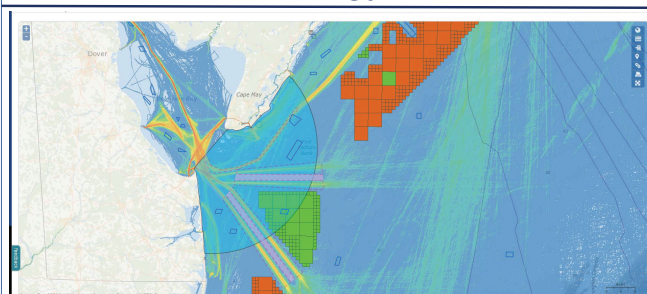
MARCO
MID-ATLANTIC REGIONAL
COUNCIL ON THE OCEAN

MARCO's Data Portal: Wind Energy Areas



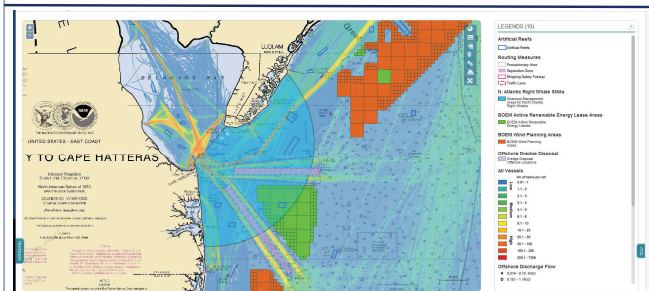
MARCO
MID-ATLANTIC REGIONAL
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MARCO's Data Portal: Wind Energy Areas



MARCO
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MARCO's Data Portal: Wind Energy Areas, Chart

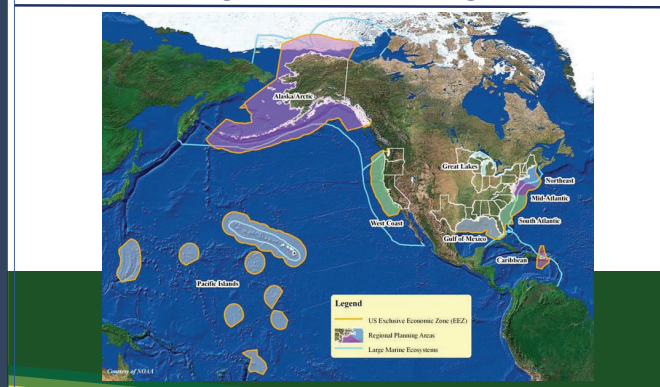


MARCO
MID-ATLANTIC REGIONAL
COUNCIL ON THE OCEAN

MARCO's Data Portal: Many Data Providers



National Ocean Council: Nine Regional Planning Bodies



Mid-Atlantic Ocean Users Provide:

- Missing Data
- Expert Review
- Expert Advice

Mid-Atlantic Regional Planning Body (MidA RPB)

- Established in April 2013
- Intergovernmental group created to coordinate and implement regional ocean planning
- Includes representatives of:
 - Six Mid-Atlantic states (NY, NJ, PA, DE, MD and VA)
 - Shinnecock Indian Nation
 - Mid-Atlantic Fishery Management Council
 - Eight federal agencies



What is the purpose of the MidA RPB?

To coordinate among State, Federal, Tribal, and
Fishery Management Council representatives



What will the MidA RPB do?

- Develop a work plan
- Assess and identify capacity
- Complete a regional ocean assessment
- Engage stakeholders and improve coordination
- Consider developing an ocean plan



MidA RPB Timeline

- 2013-2014** Organize and identify goals/products
- 2015-2016** Complete first iteration products and implement actions
- 2017-2018** Implement, adapt, and iterate

- Ongoing activities during this timeline
 - Stakeholder engagement
 - Data collection/sharing/integration
 - Adaptation of planning products



Ocean-Related Opportunities and Challenges in our Region

- Our Mid-Atlantic ocean waters and ecosystems are economic engines and cultural treasures.
- Ocean activities and ecosystem components are managed separately by many jurisdictions. But they are interconnected!



Thank You

Kris Ohleth
Executive Director
KOhleth@MidAtlanticOcean.org



