SUMMARY OF RESILIENT ECOSYSTEMS WORKSHOP:

POSSIBLE IDEAS FOR A SOLUTIONS-FOCUSED RESEARCH AGENDA

Held by the
Pacific Institute for Climate Solutions

Victoria, BC
December 7-8, 2009

Workshop led by Dr. Eric Higgs, Professor and Director of School of Environmental Studies, University of Victoria
Report prepared by Carol Hall

About PICS

The Resilient Ecosystems research theme is one of four (Resilient Ecosystems, the Low-Carbon Emissions Economy, Sustainable Communities, and Social Mobilization) being developed by the Pacific Institute for Climate Solutions (PICS). PICS was established in March 2008 by a $90 million endowment from the BC Ministry of Environment, the single largest endowment to a university in Canadian history. Hosted and led by the University of Victoria, PICS is a unique collaboration among BC's four research-intensive universities (University of Victoria, Simon Fraser University, University of British Columbia and the University of Northern British Columbia). PICS brings together the Province's specialists from all disciplines and sectors to develop innovative climate change solutions, understand and respond to ecological change, seek new opportunities for positive adaptation, and lead the way to a vibrant low-carbon emissions economy. More information can be found at: http://www.pics.uvic.ca/.

EXECUTIVE SUMMARY

This report summarizes a workshop held by the Pacific Institute for Climate Solutions (PICS) in Victoria, British Columbia from December 7 to 8, 2009 as a major input to formulating a new Resilient Ecosystems research theme. The workshop, led by Dr. Eric Higgs, Professor and Director of School of Environmental Studies, University of Victoria, on behalf of PICS, brought together thirty scientists and policy experts from BC and elsewhere. It offered an extraordinary opportunity to contribute to a new research agenda that will distinguish BC as a leader in solutions-oriented research and policy to address climate change. The research theme is one of four being developed by PICS: Resilient Ecosystems, the Low-Carbon Emissions Economy, Sustainable Communities, and Social Mobilization.

The failure to make meaningful progress on mitigation at the recent COP 15 United Nations Climate Change conference in Copenhagen has heightened the urgency to understand how climate change will impact ecosystems and how humans need to respond. The Resilient Ecosystems workshop discussions centered on this challenge and identified possible areas for research that would make major contributions to understanding and responding to climate change.

Four Starting Questions

This report begins with a summary of the workshop's four "starting" questions, which were chosen to stimulate creative thinking around the most salient issues: (1) What is resilience? (2) How will human relationships to ecosystems change? (3) What is the role of historical knowledge? and (4) What is appropriate intervention?

In the first session, centered on the deceptively simple question of "what is resilience?", concepts like uncertainty, complexity, and learning were identified as integral to resilience. Resilience thinking provides a tool for understanding ecosystem response to rapid environmental change. A recurrent theme revolved around how to operationalize resilience. It was suggested that adaptive capacity is easier to measure and it - or another term - may better fit the research focus.

The question of how human relationships to ecosystems will change served as a catalyst for a discussion about adaptive management and governance systems. Uncertainty (characterized by thresholds, unpredictability and irreversibility) was singled out as a key characteristic of ecosystems change. Learning and adjusting are essential elements of how humans need to respond. New models of adaptive management and governance that emphasize innovation, risk management, co-production of knowledge, and learning are required.

Historical knowledge can play an important role in understanding ecological and social-ecological systems response to climate change, but to be more useful must focus on dynamic changes and take a longer view of the past. One area for immediate action is to preserve the knowledge that is rapidly disappearing from the historical record. Furthermore, the limitations of historical knowledge clearly illustrate the need for long-term ecological studies to observe changes that are occurring today.

Rapid environmental change characterized by uncertainty and transformation complicates questions of appropriate intervention and is changing the ground rules for management. This discussion, which raised whether there is a limit to the degree of intervention that is acceptable, brought to light an unease about the role of values in decision making. There was a general caution about hubris when intervening at the landscape scale, and humility in how knowledge is used as a necessary requirement for moving forward. Key next steps were identified, including thinking about a framework for intervention and developing guiding principles.

Possible Research Questions

During the workshop many research ideas emerged that offer a rich input into the formulation of the PICS research agenda. For purposes of this report, overall research areas are organized into five broad categories: (1) syntheses of existing knowledge, (2) building knowledge, (3) predicting change, (4) adaptive management and governance, and (5) protected areas, stewardship and landscape level management.

As PICS formulates a research agenda it will want to consider several overarching issues that generated a great deal of discussion. The first is to what extent this research theme should focus on ecological systems or social-ecological systems. This theme presents an opportunity within the PICS research agenda to close enormous knowledge gaps on the ecological side. On the other hand, many participants argued that a focus on social ecological systems and ecosystem services is better aligned with BC government priorities. Research likely needs to integrate thinking about both. A second overarching issue is the need to communicate research results effectively, particularly in the context of uncertainty associated with climate change. Communication, broadly, is critical to bridging the gap between scientists and policy makers and implementing effective solutions.

Mechanisms for Research

The workshop concluded with a discussion about mechanisms for research programs to consider in carving out a niche that is focused on BC, but also competitive on an international scale. The proposed mechanisms would promote the co-production of knowledge across sectors and disciplines, for example, embedding scientists within government and industry. The creation of a centre of excellence is a larger initiative that participants suggested as a way to attract visiting experts from academia, government, and communities. At this stage PICS may not have the resources to undertake a large-scale effort, but it can start to establish the foundation to generate support toward such a goal. Partnerships and additional funding are important to leverage PICS core resources.

1. INTRODUCTION

The Pacific Institute for Climate Solutions (PICS) held a workshop in Victoria, British Columbia from December 7 to 8, 2009 as a major input to a new research theme on resilient ecosystems and climate change. The workshop was led by Dr. Eric Higgs, Professor and Director of School of Environmental Studies, University of Victoria, on behalf of PICS. Thirty scientists and policy experts from BC and elsewhere came together for this extraordinary opportunity to contribute to a major new research agenda that will distinguish BC as a leader in solutions-oriented thinking about climate change. A full list of workshop participants is in Appendix A.

1.1. Outline of Report

This report follows the structure of the workshop agenda (Appendix B). The agenda was designed (and modified during the workshop) to encourage open discussion and insights for issues that PICS should tackle in its Resilient Ecosystems research theme. Figure 1 illustrates how the workshop agenda builds toward the proposed research theme.

Section 2 summarizes the discussions related to the four starting questions: (1) What is resilience? (2) How will human relationships to ecosystems change? (3) What is the role of historical knowledge? and (4) What is appropriate intervention? The bulk of the agenda (1.5 days) immersed the group in these questions to generate an open discussion toward developing a research theme that will address the most salient issues related to resilient ecosystems.

Section 3 highlights proposed research questions that emerged during the workshop. A summary of a research question exercise is found in Appendix D. Section 4 summarizes possible mechanisms for developing a PICS research program that will be distinctive, solutions-oriented and internationally recognized for excellence.

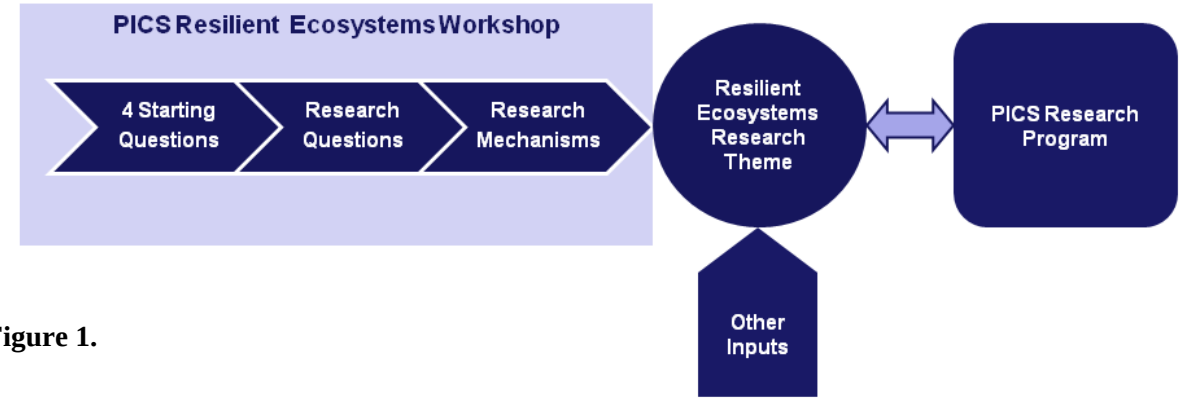


Figure 1.

1.2. Purpose of Workshop

The purpose of the workshop was to provide a key contribution to the development of a robust research theme of resilient ecosystems, centered on ecosystems and human relationship to them in the context of climate change. It offered a unique opportunity within Canada to bring together experts to shape a new research theme supported by an exceptional endowment. The research theme is one of four being developed by PICS: Resilient Ecosystems, the Low-Carbon Emissions Economy, Sustainable Communities, and Social Mobilization.

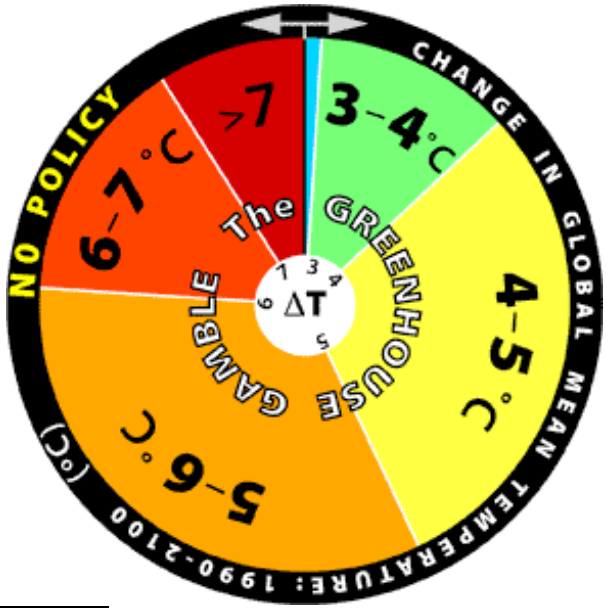
Three external specialists were invited to give presentations that brought valuable outside perspectives to the workshop: Dr. Richard Hobbs, University of Western Australia; Dr. Erika Zavaleta, University of California; and Dr. Fikret Berkes, University of Manitoba. Secondary input into the research theme may include additional consultations, review of other research programs within BC, as well as further one-on-one discussions with experts. As the lead in developing the PICS resilient ecosystems research theme, Dr. Higgs will use these inputs to develop a proposal for a research agenda. This proposal will guide PICS as it devises its research plan and decides how to strategically allocate funding. PICS seeks to develop a theme that is distinctive, policy-oriented, and relevant to BC.

1.3. Setting the Context

Dr. Tom Pederson, Director of PICS, opened the workshop by providing background on PICS, the BC policy framework and the current understanding of climate change. In 2008, the BC government established PICS with a $90 million endowment, the single largest endowment to a university in Canadian history, to seek innovative solutions related to understanding, mitigating and adapting to climate change. PICS was created as part of a BC leadership initiative to reduce greenhouse gases and implement North America's first legislated carbon tax.

Leadership at the provincial level is all the more important with the failure of national governments to reach a comprehensive agreement on mitigation at the conclusion of the COP 15 United Nations Climate Change conference. This failure underscores the urgency of understanding how climate change will impact ecosystems and how best to respond to these impacts. Under the current scenario of minimal or "no action" on global climate mitigation, there is a 50 percent chance that the maximum temperature change by 2100 will exceed 5 degrees Celsius (Figure 2).[1] It is uncertain what impact such a magnitude of change will have on ecosystems and social-ecological systems. Pointing to "the fierce urgency of now"(W. Churchill, 1936), Dr. Pedersen concluded his remarks by asking the group to focus on solutions - the "S" in PICS - because the impacts of climate change are so profound for current and future generations.

Figure 2.
Greenhouse Gamble: No Action Scenario



[1]Figure 2 comes from MIT Joint Program on the Science and Policy of Global Change (Derived from: A.P. Sokolov et al, Journal of Climate, Volume 22, October 2009, pp. 5175–5204.) Cited by Dr. Tom Pedersen, PICS presentation based on December 2009 calculations. Updated at http://globalchange.mit.edu/resources/gamble/no-policy.html.

2. FOUR STARTING QUESTIONS

The workshop centered around four starting questions to prompt thinking that would contribute to the formulation of the PICS resilient ecosystems theme. A backgrounder distributed prior to the workshop highlighted these four questions (Appendix C):

- What is resilience?
- How will human relationships to ecosystems change?
- What is the role of historical knowledge?
- What is appropriate intervention?

The main ideas that arose around each question are summarized below. The intent of the starting questions and catalyst presentations was to encourage creative discussion rather than necessarily arrive at a consensus for a research agenda. As the workshop progressed, the discussion became more focused on possible research questions and solutions.

2.1. WHAT IS RESILIENCE?

Resilience, as both metaphor and theory, has emerged as a concept that offers a fruitful way forward. Resilience is the ability to recover and learn from disturbance. The work of the Resilience Alliance, and many others, has shown that our duty is to build or rebuild resilience in socioecological systems. This much seems evident and appealing. The devil is in the details, of course.

- Dr. Eric Higgs, Workshop Backgrounder

The deceptively simple question of "what is resilience?" stimulated thinking that perhaps raised more questions than were answered. Participants revisited this question during the workshop, and views ranged from the sense that resilience is the best tool for understanding ecosystem response to climate change, to thinking that resilience should not be the research focus and an alternative term would be better. Highlights from this diverse conversation are reflected in the summary below. Ideas harvested from this discussion offer a valuable input to PICS as it shapes its research agenda.

A few common themes related to resilience surfaced during this discussion. Uncertainty, complexity, and learning were concepts identified as integral to resilience thinking. There was a consensus to use the following definition:

The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks.

-Walker et al, 2004, *Ecology and Society*

A recurring theme revolved around how to operationalize resilience and whether resilience was the appropriate term to be thinking about. How do scientists measure the resilience of an ecosystem? How can resilience provide a tool to inform managers at key decision points? As a start, resilience needs to be more narrowly defined in terms of scale (spatial and temporal), ecosystem attributes, specific species, etc. Adaptive capacity might be easier to measure, and perhaps would make a better focus. On the other hand, given the magnitude of likely environmental change, should the focus be on transformability instead?

An underlying tension surfaced between whether research should focus on ecological processes/functions or ecosystem services. Resilience has offered a path away from an emphasis on ecosystem services, which typically have been defined narrowly (e.g. extractive industries). A more comprehensive view of ecosystem services is needed. Alternatively, one participant suggested that it would be prudent to focus instead on a broader goal of adaptive capacity.

Similarly, a major issue arose around the extent to which the PICS research focus should be on ecological systems, social-ecological systems (SES), or both. Resilient Ecosystems is the only one of four research themes to address ecosystems, presenting the most logical opportunity under PICS to attend to the enormous knowledge gaps on the ecological side. On the other hand, participants argued that the BC government cares about or values SES and ecosystem services, suggesting these receive priority. While the group remained split, most participants agreed that the research theme should incorporate both. Ecological and social systems in BC have been coupled for 10,000 years, making it difficult, if not impossible, to think about them in isolation. This remains an important issue for PICS to weigh as it develops its research agenda.

Finally, it was noted that while "resilience" is often used in a normative sense, the term is not always positive and can be neutral or negative (e.g. 1992 collapse of Newfoundland cod fishery resulted in a less desirable but nonetheless resilient series of alternate species fisheries). These recurrent themes are reflected in the below highlights from three catalyst presentations followed by a list of specific comments from the broader discussion.

2.1.1. Catalyst Presentation: Kai Chan, University of British Columbia

This presentation submitted three core ideas for possible research programs that fit with “ecosystem resilience” and suggested that the scope needs to be broader if we are to make progress toward what BC cares about.

1. *Resilience of SES principally, and the resilience of ecological systems when helpful for long-term positive social outcomes.*
   A research focus on SES would reflect what the BC government cares about. Such research could study the conditions under which ecological resilience is conducive to valued social outcomes. Complementary research efforts (possibly outside scope of PICS theme) are needed to make this knowledge useful: (a) create conditions for adaptive governance/ management, and (b) integrate research focused on the human side of SES, including governance and decision-making/management.

2. *Resilience of the provision of ES, which would involve research related to ES production functions and cumulative impacts from multiple drivers.*
   A research program can provide understanding of ES through a study of (a) the ecological production functions, and (b) how they vary with changing biophysical conditions and management (including climate change). To understand the latter, much more information is needed on ecological production functions for a comprehensive range of ecosystem services.

3. *Robustness to uncertainty and change rather than specificity in solutions.*
   Most research in BC related to climate change and ecosystems currently involves making specific predictions without adequately representing uncertainty. This research generally fails to include consideration of system complexity and species interactions that underpin much of resilience thinking. We need adaptive management and governance that is robust to both uncertainty and change.

2.1.2. Catalyst Presentation: Shannon Hagerman, University of Washington

The notion of general resilience – that is, ecosystems that are resilient in the face of any and all disturbances for all purposes (production, species diversity, aesthetic value, and so on) – is not achievable, and the quest for it clouds understanding. -Walker & Abel (Gunderson and Holling 2002: 295)

The challenges in applying resilience in practice and several open questions to spur thinking forward formed the basis for this presentation. “Resilience” is an appealing concept, but the “devil is in the details”. It is not clear how to move forward with applying the notion of general resilience. This is the elephant in the room: how do we operationalize resilience?

In order to start to think about measuring resilience, there is a need to be more specific. No single measure of resilience exists for all attributes and processes to all drivers at all scales. Tradeoffs will be required in light of climate change impacts. Difficult decisions that involve species tradeoffs may be required (or possibly are inevitable). These questions of values sometimes masquerade as questions of uncertainty.

Given the magnitude of climate change and cumulative effects of other drivers, it may be more appropriate to be thinking about transformability. Is our task about recognizing when resilience (of specific attributes at specific scales for specific purposes) is tenable, when transformation is implied, and to adjust our management accordingly?

2.1.3. Catalyst Presentation: Sybille Haeussler, UNBC

This presentation showed a series of photographs from different regions in BC to illustrate concepts of complexity, order, and disorder. It pointed to resilience as a fractal problem; it is just as complex a problem at any scale. After ten years of trying to measure resilience in disturbed forest ecosystems, Dr. Haussler has concluded that it is not possible to satisfactorily measure the resilience of an ecosystem because it will always depend on the spatial and temporal scale of measurement, the ecosystem component, the index is used, etc. It is essential to specify scale in talking about resilience and complexity of BC landscapes. For example, the impacts of mountain pine beetle look quite different at the stand level (where revegetation is occurring) versus the landscape level (where widespread mortality is apparent).

BC is distinct in its diversity and complexity of ecosystems. It is unusual in its confluence of mountainous terrain, mid to upper latitude position, transition between temperate and boreal, glacial activity, and historical human activity, etc. Complexity is non-linear in nature and is actually highest just at the transition between order and chaos. In BC, that complexity is at risk from the combined effects of climate change and other disturbances, threatening to push many ecosystems to a state where they lose their self-organized pattern. Scientists have a responsibility to study self-organized ecosystem complexity in BC and share that knowledge with the rest of the world.

2.1.4. Highlights of Discussion: What is Resilience?

Specific highlights from the general discussion are listed below.

1. *Concepts such as uncertainty, complexity, and learning are integral to resilience thinking, which can contribute to an understanding of response to climate change.*
    - Resilience is characterized by the ability of a system to absorb shocks and stresses, self-organize, and learn and adapt.
    - Resilience involves processes and functions. It is not the same as “stability”.
    - Resilience thinking offers us a better understanding of the complexity of ecosystems and how they might respond to climate change, including identification of thresholds and non-linear change.
    - It can lead us to think more holistically about managing systems versus a focus on individual species.
    - It is probably the best tool for thinking about dynamics of change and multiple equilibria.

- We may be underestimating adaptive capacity of species to environmental change, e.g. genetic plasticity, species movement.
- We need to recognize vast uncertainty and put into place an adaptive governance structure that will deal with it.

2. *How do we operationalize resilience?*
   - At some level defining resilience is not as critical as measuring it. How do we measure resilience? How do we measure it easily in the short-term?
   - There are limitations to resilience in practice. Resilience to what? At what temporal and spatial scales? How do we make decisions about tradeoffs? Resilience thinking itself does not tell us who or how to decide to intervene.
   - We need to narrow the scope when thinking about resilience. Identify the time and spatial scales, specific species, and focus on specific sectors, e.g. forestry, agriculture.

3. *Is "adaptive capacity" or "transformation" a more appropriate research focus?*
   - Adaptive capacity may be easier to measure. What does adaptive capacity mean in ecological and institutional terms?
   - The distinction between resilience and transformation is important because the policy implications are very different depending which one we are facing.
   - Transformation at one scale (e.g. reserve) may be resilience at another scale (e.g. region). The two are on a continuum and caution is needed in treating them as a dichotomy.
   - It may not be possible to identify whether systems are transformed or resilient until after the fact and need to be prepared for both.

2.1.5. Resilience Redux

Later in the workshop, the group considered whether PICS should change the Resilient Ecosystems title to one that might better reflect the research focus and be more intuitive, technically clear, and meaningful to decision makers. Proposed alternatives included: healthy ecosystems, ecological integrity, sustainable ecosystems, and ecosystem stewardship. No consensus surfaced around an alternative and a few participants argued that resilient ecosystems best fit the intentions of the proposed research area. PICS may want to revisit this issue going forward.

With questions remaining around the concept of resilience, one participant concluded that we are not going to come to a single unified goal of what we mean no matter what term is used, but that this should not stop us. It is important to move forward now to build adaptive capacity, to learn and experiment, before having all the answers.

2.2. How will Human Relationships to Ecosystems Change?

It is surprising that you can bring so many ecologists together and there is so much focus on governance and policy. I suspect this… is because we all realize a real frailty in how science interacts with policy and the challenge in solving something as monumental as climate change and changing ecosystems.
-Dr. Eric Higgs, PICS workshop, 2009

The above observation by Dr. Higgs perhaps best summarizes this next discussion. There was a sense of urgency that human relationships need to change and that new models of management and governance are required in response to ecosystems change.

Based on the two catalyst presentations and general discussion, several common themes came into focus that will contribute to shaping a research theme. Uncertainty (characterized by thresholds, irreversibility, and surprises) was identified as a common characteristic of ecosystems change. Learning and adjusting

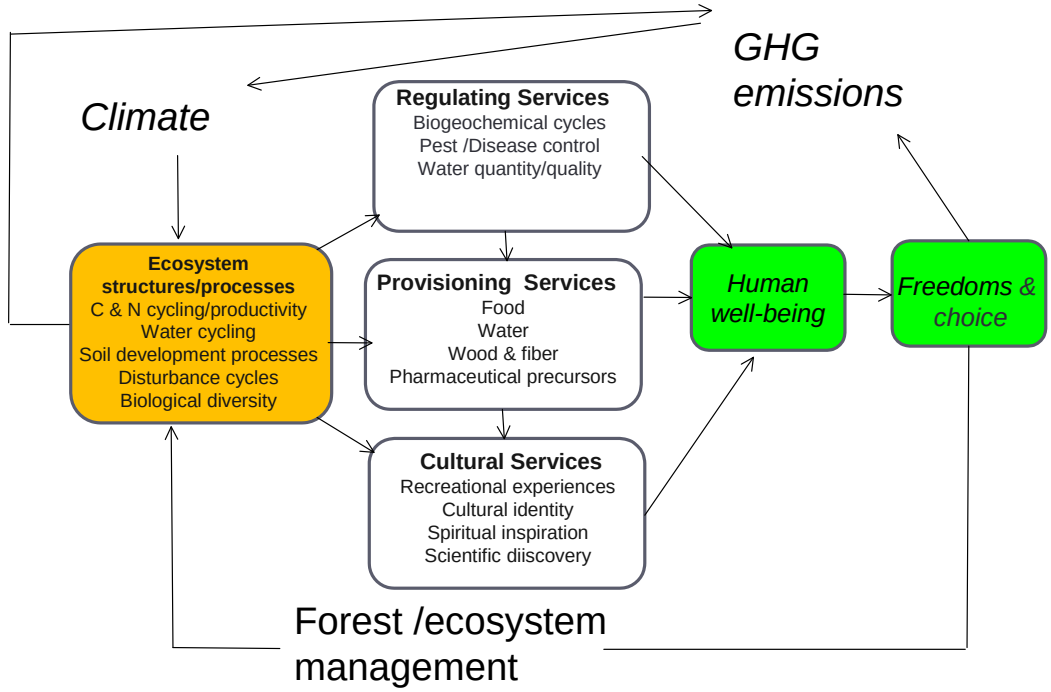
are essential elements of how humans need to respond. New models of adaptive management that emphasize innovation, risk management, co-production of knowledge, and learning are required. Decision makers need to monitor and adjust their policies and management tools as they continue to learn. In the face of uncertainty, risk analysis approaches will become more important to inform priorities for policy formulation.

The existing policy, legal and institutional framework was identified as the largest barrier to an effective response to climate change. A major shift in this framework is required. Yet institutions have a tendency to not only resist change but also to undertake counterproductive measures to avoid change (e.g. subsidies to mills to prop up forest product companies and communities in unsustainable economic activities). This resistance often moves systems in a less resilient direction.

Given this resistance, two paths should be pursued to move toward adaptive governance. The first is to determine the "ideal path" policy wise. The second identifies small policy changes within existing budgetary, legal and political constraints that decision-makers can make to incorporate adaptive management into their actions. It is important to ask – rather than just tell - decision makers about constraints and needs and how to make recommendations workable.

Communication was another recurrent theme. There was concern that scientists need to become better at communicating research to inform policy and management decisions, particularly in light of uncertainty associated with rapid environmental change. The reluctance of decision makers to implement adaptive management approaches, which are perceived as costly, is exacerbated by declining agency budgets. Research findings need to be framed and communicated in a way that recognizes this reluctance and advances solutions.

Figure 3. Ecosystem management & climate change feedbacks
This slide served as a catalyst for a discussion about knowledge gaps



Source: E. Campbell, PICS presentation 2009. Adapted from F.Stuart Chapin et al. (eds.), Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World (2009); Millenium Assessment (2005).

One idea that gained traction during the workshop was the need for BC to develop guiding principles for management. Suggested criteria for guiding principles include complexity, costs, benefits, pilotability, amenable to measurement, effectiveness, scalable, irreversibility, robustness to uncertainty and potential for unintended consequences. A next step would be to undertake syntheses from BC and elsewhere of what is known about adaptive governance, examples of guiding principles and how policy and management decisions affect ecosystems. Despite significant knowledge gaps, it was pointed out that there is enough existing knowledge to do a better job of management (see Figure 3).

A striking example of recent policy response to ecosystems change is found in Australia, where last year the government overhauled its fire policy due to more frequent and severe bushfires associated with historically high temperatures. The government reclassified the fire danger rating system to include a "Code Red - castastrophic" category to reflect more severe fires and rewrote its "stay or go" policy to no longer encourage people to stay with their houses.

2.2.1. Catalyst Presentation: Fikret Berkes, University of Manitoba

Social and ecological systems are sufficiently complex that our knowledge of them, and our ability to predict their future dynamics, will never be complete. We must work to reduce uncertainties when possible, improve assessments of the likelihood of various important future events, and learn.
Nature and Society, a report to the National Science Foundation (NSF), Nov. 2000.

Uncertainty, complexity, and non-linearity are key concepts in understanding how human relationships to ecosystems will need to change. The very definition of uncertainty and complexity in social-ecological systems means that it is not possible to predict future changes. There is an increasing likelihood of more frequent non-linear changes (e.g. fisheries collapse, eutrophication and hypoxia, disease emergence, species introductions and losses, and climate-related change). These changes may be irreversible with major consequences for human well-being.

Ecological and social systems cannot be decoupled. Human response to rapid environmental change involves short-term (coping) and long-term (cultural) adaptation. Will these adaptation strategies be sufficient as ecosystems move outside the historical range of variability? If not, we need to stimulate approaches to (i) reduce vulnerability, (ii) increase adaptive capacity, (iii) co-produce knowledge, and (iv) learn. Learning is a key concept that needs to be part of the discussion.

Resilience thinking provides a framework to deal with uncertainty and change. It is not good at predicting, but it offers a tool to evaluate policy options and support the ability of SES to deal with shocks and stresses (Figure 4). Governance needs to be part of it. We need to enthusiastically involve more partners and stakeholders in management.

Figure 4. Case Study: How resilience thinking can inform government policy
Dr. Berkes shared a study based on a project (not yet published) at the University of Manitoba, jointly undertaken with the International Institute for Sustainable Development (IISD) that looked at how farmers in Canada's Prairie agro-ecosystem responded to recent climate-related shocks and stresses. Combining vulnerability analysis with resilience analysis, the study asked farmers how they responded to these shocks and stresses. The findings were surprising.

Rather than diversify crops in response to risk and uncertainty, farmers often opted to plant monocultures. It is believed this is because of "perverse incentives" of government policy. A high-risk crop either makes a good return or, in the event of crop failure, is covered by crop insurance. Whereas diversifying crops to reduce risk neither makes a good return nor attracts substantial crop insurance. In such ways, government policy can hinder resilient responses by resource producers. This research is an example of how resilience analysis can inform governance and policies to increase future adaptive capacity.

2.2.2. Catalyst Presentation: Elizabeth Campbell, Ministry of Forests and Range

This presentation looked at links between resilience and the BC government's forest management in response to rapid climate change. While forestry is the focus, lessons apply to other sectors as well. A substantial shift in forest management is needed in the face of uncertain future forest conditions and the possibility of abrupt ecosystem change with catastrophic losses in ecosystem services. On-the-ground practices need to take a "risk-management portfolio" approach. Examples of how to do this include facilitating tree population and species migration, resetting successional trajectories and restoring areas that serve as buffers to climate change.

Adaptive management requires more experimental management trials, observing the outcomes, and adjusting as necessary. In practice, this entails (i) rethinking existing policies such as free to grow standards and seed transfer guidelines, (ii) scientific and technological innovation (e.g. timber supply analyses, wood processing techniques), and (iii) a revision of expectations around future lumber supplies, uses for non-timber forest products, and conservation goals. Resilience-based management involves strong feedbacks between social and ecological systems. Attempts to resist change are unrealistic. Innovation and learning are essential.

In reality, only a small portion of the vast BC land base can be managed in a given year, making it impossible to keep pace with climate change. Governments will need to adjust. Legal and policy frameworks present one of the biggest obstacles in responding to climate change.

2.3. WHAT IS THE ROLE OF HISTORICAL KNOWLEDGE?

It's not the strongest…that survives, nor the most intelligent that survives.
It is the one that is the most adaptable to change.
- Charles Darwin (cited by Dr. Zavaleta)

This starting question served as a launching point for a dialogue on the second day of the workshop about the role of historical knowledge in understanding change outside of historical ranges. In general, there was a sense that historical knowledge continues to have an important, if limited, role in understanding ecosystem change. To be more useful, historical research needs to shift toward an emphasis on dynamic changes and past response to extreme events or shocks. It also needs to take a much longer view of the past.

A number of areas emerged for a possible research agenda related to lessons from history. An immediate priority is the need to preserve what knowledge can still be captured from the rapidly disappearing historical record. At the same time, the limited role of historical knowledge places greater importance on long-term ecological studies to observe the changes that are happening and catch them early. This need for long-term observation evolved as a key research area. Finally, another research sub-theme emerged around protected areas, recognizing the role of reserves as integrators of centuries of historical knowledge. The three catalyst presentations are summarized below, followed by comments on a potential protected areas research sub-theme.

2.3.1. Catalyst Presentation: Erika Zaveleta, University of California, Santa Cruz

This presentation focused on the role of historical knowledge in stewarding resilient ecosystems. As discussed below, Dr. Zaveleta concluded that historical knowledge is important and needed, but perhaps in a different way than it currently is being used.

Three goals for stewardship are: (i) what was, (ii) what will be, and (iii) what we want. "What was" of historical knowledge has limitations, but the other two goals are even more challenging.

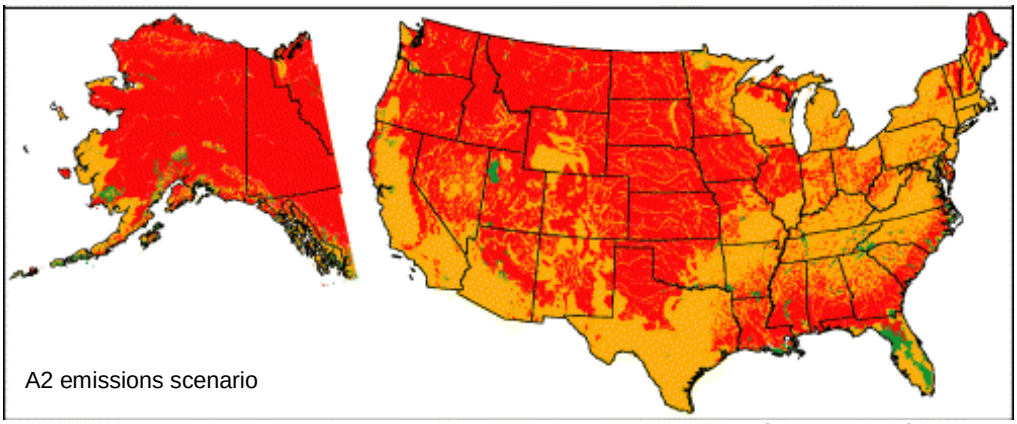
The trouble with "what was" or history

Most research on historical records has focused on static characteristics such as landscapes, scenery, community compositions, and structure. These do not contribute to the understanding of dynamic change and adaptive capacity. Research also tends to use too short a timeframe to provide meaningful information. Deeper perspectives on change and variability are needed.

We cannot know what will be

A review of the literature related to predicting how climate change and other drivers impact species underscores that "we cannot know what will be". And even if we could know what will be, we might not like it. Climate change is projected to change existing combinations of local climate, soil, and topographic condition across most of the U.S. (Figure 5).

Figure 5. Climate change: the future cannot look like the past



Saxon *et al.* 2005, *Ecol. Lett.*

Conditions that will disappear from U.S.
Conditions that will decrease in extent in U.S.
Conditions that will increase in extent in U.S.

The danger with what we want

Stewardship decisions based on "what we want" are problematic as well. It is unclear *who* decides what we want (i.e. who is "we"?) and how to define what we want, especially since this will change in the long run. As we encounter the limits of historical range of variability and move to system transformation, there is danger of returning to an engineering paradigm –listing a narrow set of desired functions or services and managing for that. Resilience thinking allows us to move away from engineering ecosystems. Decision makers should be careful not to default to using "what we want" as a new goal post because so much change is happening.

History as guide to resilience and transformation
Historical knowledge is a guide, not necessarily to return to "what was", but to inform stewardship strategies based on how altered a system is from its historical state. Historical research should focus on processes, transitions, and adaptive capacity (e.g. past coping, native diversity, complexity (trophic, landscape), evolutionary capacity, rates, and pressures). A longer time scale (paleo-ecological vs human historical) offers a truer picture of variability in the past.
A long view of past adaptive capacity of ecosystems should be combined with a short-term view of how humans have changed them. Species that have a relatively minor role in an ecosystem today could have adaptive capacity to respond to future climate changes. For example, the *Dudlyea setchellii* is a US federally-endangered serpentine grasslands species occurring on south facing rocky slopes in Santa Clara Valley, CA. It is part of an assemblage of species with desert traits adapted to dry, hot sites and so is very restricted right now in distribution. In the future, in a hotter and/or drier future specifically, a species like this may be more widespread, dominant, and important for conferring ecosystem functions such as cover, productivity, and habitat.

While studies to predict future responses and identify thresholds are useful, one of the most effective things to do is to build a strong network to monitor and observe closely what is happening right now.

2.3.2. Catalyst Presentation: Ken Lertzman, Simon Fraser University

This presentation looked at how historical knowledge contributes to understanding of ecosystem change. It suggests that history offers lessons from the past about adaptive capacity, irreversible change and feedbacks between ecological and social-ecological systems (Figure 5).

Historical knowledge is useful in a number of ways such as offering perspective on fast and slow variables and their relative dominance over time, as well as a perspective on shifting baselines. Our perception of what is normal is constrained by our knowledge. This means a degraded ecosystem may become the new baseline for normal, as is the case in many fisheries where biomass was historically much higher. Historical knowledge also provides the only empirical evidence of long-term persistence of species and communities. It is important in helping us consider the mechanisms of recovery, response and adaptation and identifying threshold responses and boundary conditions in the past.

What are lessons from history?
History helps us understand the main ways ecosystems have responded to past change and offers lessons that can inform management practices.

- The historical range of variability offers a reference point for management. This is still

Figure 5. Lessons from History: Case study of coupled response to climate change
A study of the fire history in the mountain hemlock zone of mainland BC during the Holocene offers an example of the long-term coupling of ecological and social responses to climate change. The study uncovered a striking correlation between a period of significant cultural change (based on recorded Marpole sites) and changing climate (warmer and drier summers inferred from an increase in forest fires 1200-2400 years ago, as shown by records of lake sediment and soil charcoal). It found that ecological changes resulted in great variation across the region in the predictability and productivity of marine, freshwater, and terrestrial resources, leading to a period of adaptation involving cultural and technological changes and greater social interaction across the region

This history provides insights into how regional landscape diversity allowed for ecological and social resilience. What lessons can be drawn from this period? How does environmental degradation (e.g. fisheries, landscape fragmentation) affect resilience and the present capacity to respond to climate change?
Source: *K. Lertzman PICS presentation (based on Lepofsky et al., Climate Change and Culture Change on the Southern Coast of British Columbia 2400-1200 Cal. B.P.: An Hypothesis, 2005)*

useful, though less so, as climate change drives ecosystems out of current states.

- Ecological systems responded dynamically with lags and hysteresis, incremental changes and major regime shifts.
- It helps us understand the key mechanisms for ecosystem response to change at various scales. For example, there was a lag in movement of tree species over the past 1000 years in the Great Lakes areas as the lakes served as barriers to some species (e.g. wind dispersed), but not to others (e.g. bird dispersed).
- History holds examples of both resilience and transformation. What were processes and boundary conditions of transformation in the past?
- Ecological and social systems have been coupled in this region for 10,000 years.

Concluding thoughts

- Need to do a better job of building historical data sets in BC, e.g. permanent plot network, LTER equivalents.
- Need to address the huge loss of data from the historical record (MPB, fires, glaciers, as well as First Nations elders).
- Create a compendium of "lessons" from historical dynamics. What are lessons to help think about management under uncertainty?
- Build atlas of case studies. *Adaptation, Resilience, & Transformation …*
- Reframe the policy discussion in the context of resilience.

2.3.3. Catalyst Presentation: Tory Stevens, Ministry of Environment

This presentation approached the question of the role of historical knowledge from the perspective of protected areas. Unmanaged (or lightly managed) landscapes are integrators of centuries of historical knowledge. This knowledge tells us how human influences can alter ecosystems in ways that isolate populations and prevent movement. A protected areas focus can provide the means for continual reorganization of ecosystems to maintain adaptive capacity, by preserving options for movement and evolution of ecosystem elements. To maximize future options, it is necessary need to keep as much genetic variety as possible and provide room to reorganize.

Currently 14 percent of BC lands are within the protected area network. That network is only as good as the functional capacity of the areas between the protected areas or the matrix. There are a number of potential areas within BC to create new reserves of 270,000 hectares or more[2], a minimum threshold that is likely too small to support adaptive capacity in response to climate change. Valley bottoms are mostly fragmented. A snapshot of valley lands less than 500 meters from a road suggests that development is quickly eroding future options around creating protected areas (Figure 6).

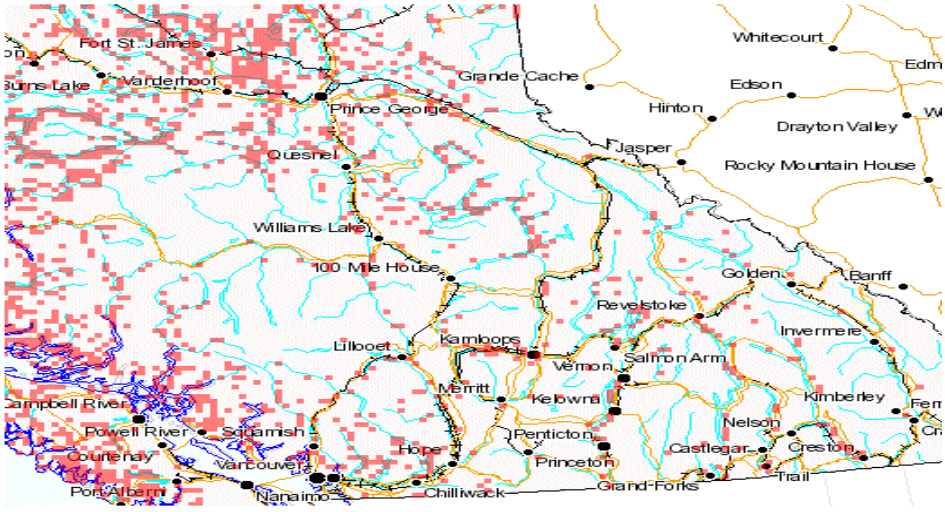
A number of questions lend themselves to immediate research:

- Where are pinch points on the landscape?
- Where are areas of highest biodiversity?
- Where are likely climate refugia? (e.g. accounting for topographic complexity and other features that support future biodiversity)
- Where should disturbances be avoided? (e.g. no road building where potential for reserves)
- Where should connectivity be restored?
- How can the protected areas network be amended to be more effective?

[2] Minimum reserve size to support terrestrial mammal species cited in *Conservation of Mammals in Eastern North American Wildlife Reserves: How Small is Too Small?* Gurd, Nudds & Rivard, Conservation Biology, Vol. 15, No. 5, 2000.

Little is known about individual species; it is estimated that only one-tenth of species that occur in BC are known.[3] This underscores the need to stop trying to manage species by species and start reconnecting landscape.

Figure 6. Fragmentation of BC Habitat
T. Stevens PICS presentation. Pink shows valley areas > than 500m from a road (HectaresBC.org)



2.3.4. Highlights of Discussion: Protected Areas

The presentation on protected areas led to a discussion specific to criteria for developing priorities for conservation that will help maintain adaptive capacity in response to climate change.

- BC has highly distinctive biodiversity and rare potential for connectivity. This needs to be better understood and shared with the rest of the world.
- An important criterion for identifying priorities for protection should be the provision of ecosystem services, particularly carbon stewardship.
- To contribute to thinking about adaptation at a regional scale, the criteria should include a layer specific to biota: what species can move over the landscapes and at what time scales and rates? Some species can make use of connectivity yet many cannot.
- Province wide mapping of enduring (abiotic) features that will change very slowly in response to climate change should be an immediate research priority. The physical landscape is the template on which biota are rearranging and reassembling.

2.4. WHAT IS APPROPRIATE INTERVENTION?

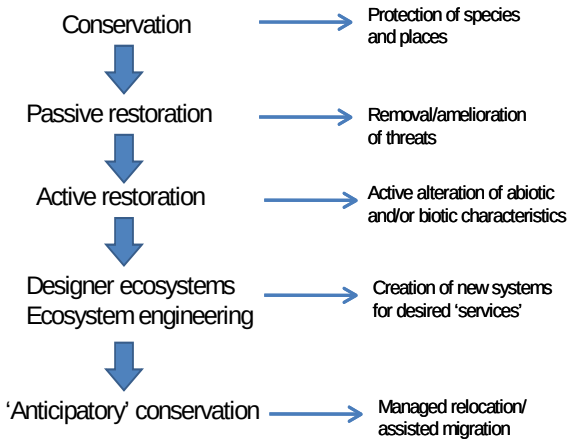
The fact of change need not mean we accept any change.
-Dr. Erika Zavaleta, PICS workshop, 2009

Rapid environmental change characterized by uncertainty and transformation is changing the ground rules for management. There is a shift from focusing on historical ecosystems or trying to return a system to its earlier state to managing novel ecosystems. This raises some bigger picture questions: What are the goals of intervention? As decision makers consider options around creating new systems for desired ecosystem services, is there a limit to the degree of intervention that is acceptable?

[3] Austin, M.A., D.A. Buffett, D.J. Nicolson, G.G.E. Scudder and V. Stevens (eds.). 2008. Taking Nature's Pulse.: The Status of Biodiversity in British Columbia. Biodiversity BC, Victoria, BC. 268 pp.

Central to the idea of appropriate intervention was an underlying unease with the role of values in decision making. This was a recurrent theme that was raised in earlier discussions related to thinking about tradeoffs and managing for "what we want". As managers consider moving toward ecosystem engineering, there was a general caution about hubris in thinking about intervening at the landscape scale, and humility in how knowledge is used as a necessary requirement for moving forward.

Figure 7. Intervention Continuum
R. Hobbs, PICS presentation, 2009



Another common tension was around moving from managing for species to managing for systems. A number of participants noted that given the complexity of ecosystems, it is not feasible to manage for species individually. Dr. Richard Hobbs pointed out that managers and scientists have gone from focusing on processes and functions (1970s) to species (1980s and 90s) back to processes and flows, and wondered whether there is a way to bring the two together, particularly since so much of the legislative and policy framework is based on species and places.

Three catalyst presentations, summarized below, contributed ideas for steps forward, including thinking about a framework for intervention decisions and the need for guiding principles.

2.4.1. Catalyst Presentation: Richard Hobbs, University of Western Australia

This presentation offered a framework for beginning to think about the question of appropriate intervention in the context of uncertainty and no-analogue ecosystems. The level of intervention has evolved over time, moving along a continuum from conservation and passive restoration to more pro-active restoration that involves ecosystem engineering for desired services (Figure 7).

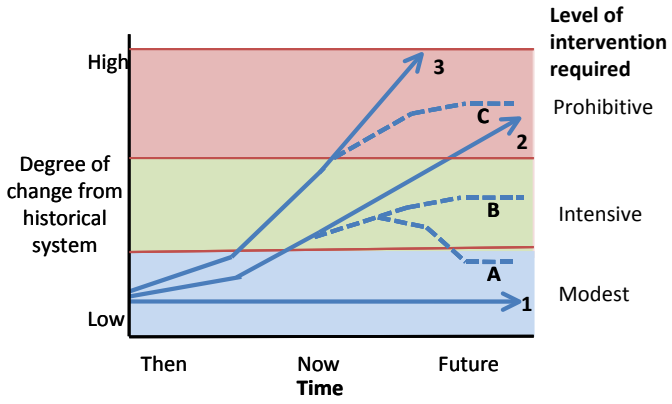
In southwest Australia, where large scale clearing for agriculture has altered landscapes, private partners are intervening on a broad scale (Figure 8). Synergistic drivers such as fragmentation, land use conversion, nitrogen enrichment, invasive species, and climate change interact to degrade the landscape in surprising ways that are not yet fully understood. The cumulative impacts of these drivers may result in novel ecosystems and alternative futures, leading to difficult questions about if and how to intervene.

A manager might start with basic questions: Should we intervene? If so, where? How? At what scale? The option of "no intervention" should be an active management decision rather than a default. At a more refined level, thinking about the extent of degradation, whether thresholds (biotic and abiotic) have been

Figure 8. Solutions that can be seen from space - Landscape scale intervention
Gondwana Link, a private partnership in southwest Australia, is similar to the Yellowstone to Yukon Conservation Initiative in its far-reaching efforts to reconnect and restore habitat at a large-landscape scale. Climate change adds a further layer of complexity to intervention that is already enormously challenging at such a massive scale.

The Gondwana Link vision is to restore and reconnect 146,000 sq km of landscape where concerns of salinity, water quality decline, and biodiversity loss (due to conversion to agriculture and other drivers) are being exacerbated by climate change. Partners are applying innovative conservation tools and actively engaging local farmers and the aboriginal community to bring environmental, economic and social benefits to the region. Projects are providing farmers with new business opportunities such as the commercialization of native plants and carbon offsets. Eucalypt planting to sequester carbon offers a 3-in-1 solution by reconnecting lands for wildlife, mitigating climate change, and attracting new funding.

Figure 9. Intervention required by degree of change from historical system
R. Hobbs PICS presentation, 2009



(Jackson & Hobbs, Science, 2009)

crossed, and the level of effort, cost and feasibility of restoring an ecosystem to its earlier state can inform intervention decisions.

In practice, interventions to prevent crossing a threshold will be less difficult than those to cross back over a threshold. Similarly, it is harder to push a degraded system back and restore it than it is to degrade it in first place. In addition, the trajectory of a system from its past state can provide a framework for intervention decisions. In some cases, intensive intervention can push a system across a threshold back to its past state (Figure 9, Line 2, A & B). At some point, though, the degree of change from a past state makes the level of intervention required to return to it prohibitive (Figure 9, Line 3).

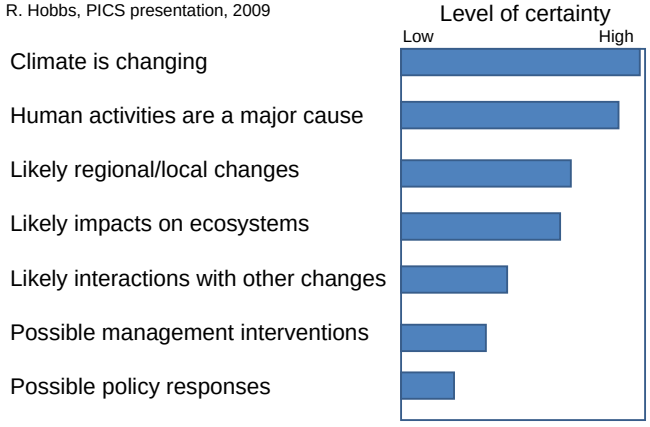
Dr. Hobbs also revisited earlier concerns about the need for better communication. Scientists should acknowledge uncertainty as a basis for rational decision making. The "uncertainty cascade" (Figure 10) illustrates the relative degree of confidence in knowledge related to climate change: there is a high certainty that climate change is human caused and less certainty about possible management interventions and policy responses.

The presentation concluded with some bigger picture questions around appropriate intervention: What, actually, are we trying to achieve? To what lengths will we go to achieve it? Is there a limit to the degree of intervention that is acceptable? Is there a line between maintaining a "natural system" and creating an artificial one? Does it matter anyway? (On a human time scale, probably.)

2.4.2. Catalyst Presentation. Brian Starzomski, University of Victoria

This presentation looked at how rapid environmental change is affecting the ground rules of management. Adaptive management originally was focused on making small inputs to keep a system from crossing a threshold and move it back to its historical state. Cumulative impacts of climate change and other drivers are leading to a re-thinking of this approach. As a first step, we need definitive syntheses of what is already known about ecosystems and protected areas to identify the knowledge gaps. Questions to close these knowledge gaps are important in understanding how to maintain the adaptive capacity of ecosystems and ultimately may be answerable.

Figure 10. The "uncertainty cascade"
R. Hobbs, PICS presentation, 2009



In Canada, there is little in the scientific literature related to adaptive management strategies for changing climate. Just-developing strategies for terrestrial biodiversity adaptation tend to include attempts to understand the impacts of climate change on biodiversity, minimize the impacts of identified threats, incorporate this knowledge into natural resources management activities, and develop new habitat monitoring programs with identification of thresholds for management input.

Gaps in existing knowledge related to terrestrial

biodiversity and climate change in British Columbia provide an input into possible areas for research:

- Species studies are not comprehensive and in fact most species have not even been identified.
- Individualistic responses make it difficult to predict what might happen at a regional scale.
- There is a lack of regional and local studies specific to BC.
- Monitoring programs to track impacts of climate change on biodiversity are needed.
- There is a great deal that is known and meta-syntheses of this knowledge should be undertaken.

2.4.3. Catalyst Presentation. John Volpe, University of Victoria

This presentation approached the question of appropriate intervention by considering a systems approach and how to quantify system dynamics. All systems, whether ecological, human, or co-evolved, comprise multiscale adaptive cycles of growth, accumulation, restructuring and renewal. These are nested in each other in increasing scales of time and space. Researchers should quantify and measure attributes of the system as a whole first before filtering down to look at the species level. A systematic framework is needed to measure adaptive capacity reflecting perspectives from different disciplines.

The presentation reviewed a series of assumptions leading to a model to quantify resilience and adaptive capacity: Resilience, Adaptive Capacity, and Ecosystem Function are at a maximum when Total System Throughput (ability of system to process energy) equals the System Overhead. The ratio of system throughput to system overhead will rise or fall as a system's adaptive capacity changes.

An illustration of the need to think at a systems-wide level (rather than a species level) is the role of the seal in the decline of the Hake population in South Africa. A resource manager might decide that a decrease in seal population will increase Hake, and yet Hake and seals are linked through countless connections. It is challenging to think it is possible to effectively manage using a species-by-species approach. Management should focus on system characteristics by integrating explicit quantitative targets with more qualitative approaches.

4.4. Highlights of Discussion: What is Appropriate Intervention?

In addition to the common themes identified at the start of this discussion, specific comments related to a possible PICS research agenda are highlighted below.

One conversation revolved around the importance of quantitative targets. It would be valuable to have quantitative measurable targets (to manage for variability around those targets) come out of future research. One participant noted that while it does not readily lend itself to measurement, resilience thinking enables managers to look at a lot of variables in a very quick way.

There was a suggestion to undertake a case study to test a framework for intervention decisions in BC. One such potential topic is the Mountain Pine Beetle (MPB). A *Case Study of Appropriate Intervention: Lessons from the MPB* could investigate questions such as: Could the MPB event have been predicted and, if so, could intervention have occurred earlier and would that have made a difference? What were the barriers to intervening in this case? This case also ties in the potential role of lessons from history. In the 1980s the beetle was stopped by a cold winter. Since then, in face of rapid climate change, scientists and managers might have explored what would have happened in the absence of a cold winter.

Other comments related to potential research questions around appropriate intervention included:

- Compile syntheses of existing knowledge around intervention, e.g. what works and what does not, what is measurable, and the costs, etc.
- Develop measurable quantitative targets to manage for variability around those targets.
- Identify where are the known knowledge gaps? Where are there likely knowledge gaps we don't know anything about? What is the potential for unintended consequences?

- What are effects of different management practices on the carbon cycle? Specific attention to carbon storage was identified as a possible win-win management/policy strategy because it combines adaptation and mitigation.
- Climate-related events like MPB might be caught earlier with “rapid response teams” which could be developed along a model in the U.S. to identify invasives.
- Develop guiding principles to inform how we steward ecosystems through climate change (e.g. irreversibility, costs, benefits, amenable to measurement, effectiveness, scalable, , precautionary).

3. POSSIBLE RESEARCH QUESTIONS

There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don’t know. But there are also unknown unknowns. These are things we do not know we don’t know.
-United States Secretary of Defense Donald Rumsfeld, 2002

During the workshop possible research ideas emerged that offer rich input into the formulation of the PICS resilient ecosystems research theme. Prior to developing a proposal for the theme additional one-on-one meetings with additional specialists may be pursued. In addition, a review of relevant research priorities identified by government agencies (e.g. *Adapting to Climate Change: Ministry of Environment's Research and Information Need*s) as well as existing research programs within BC (e.g. Future Forest Ecosystems Initiative, Future Forest Ecosystems Scientific Council) will inform how the PICS research agenda can best complement such efforts.

Research topics

This section provides an overview of the research areas identified, organized into five broad (and overlapping) categories:

1. Syntheses of existing knowledge and identification of knowledge gaps,
2. Building knowledge (lessons from history, case studies, long-term monitoring),
3. Predicting change or “what will be”,
4. Adaptive management and governance, and
5. A distinct sub-theme related to protected areas, stewardship and landscape level management.

In the short term, based on comments of participants, priorities for research might include: (i) syntheses of existing knowledge; (ii) long-term ecological monitoring; and (iii) preservation of disappearing knowledge from the historical record, with an emphasis on historical dynamics. Furthermore, a research sub-theme focusing on protected areas may lend itself readily to practical solutions on the ground. Finally, many participants identified the need for adaptive management and governance as a key concern. Policy adaptation requires a coordinated and strategic response to predict climate change impacts on ecosystems, develop a risk analysis approach to assess priorities, and formulate and implement policy change. Research that builds knowledge in these areas will lead to solutions.

Participants also concluded that with more uncertainty and less predictability associated with rapid environmental change, researchers need to be better not just at understanding the "known unknowns" but also at anticipating "unknown unknowns".

Overarching issues to consider

Three overarching issues surfaced as important for PICS to weigh early in formulating its research agenda. One issue revolved around resilience. While resilience is an appealing concept, how is the resilience of ecosystems operationalized? Furthermore, is resilience the best focus for research? As PICS

develops its resilient ecosystems theme, how (and if) to integrate resilience questions into the research deserves further consideration.

A second issue for PICS to weigh carefully is to what extent the focus should be on ecological systems or social-ecological systems (see discussion in Section 2.1). Research needs to integrate thinking about both, yet addressing both broadens the scope substantially with implications for PICS resources. One suggestion was to identify one or more research question with social-ecological aspects that overlap with other research themes to explore under a larger umbrella.

A third issue for PICS to consider is the need to effectively communicate research results, particularly in the context of the uncertainty associated with climate change. How are research findings effectively communicated to advance solutions? There is a real disconnect between the research community and decision makers, as well as between natural and social scientists. Communication is critical to bridging these function areas and implementing effective solutions.

3.1. Syntheses of Existing Knowledge & Identification of Gaps

A major prospective research area is the synthesis of existing knowledge for scientists and policy makers. There is a great deal we already know about BC ecosystems and social-ecological systems and this knowledge needs to be brought together in one place. These syntheses would provide the basis for identifying and prioritizing knowledge gaps for further research.

Suggestions for syntheses include:

- What do we already know about the diversity and complexity of ecosystems in BC? What do we know about ecological processes/functions and ecosystem services?
- What do we already know about how they are being affected by climate change and thresholds for key processes/services?
- What do we already know about adaptive capacity in BC (e.g. species movement, genetic plasticity)?
- What management interventions are being used in response to climate change? (One article cited on this topic was Heller & Zavaleta, 2009.[4])
- What do we know from BC and elsewhere about how we build adaptive institutions? How do institutions incorporate such possible management interventions into assessment, planning, and implementation?

3.2. Building Knowledge

Learning from history, case studies and long-term monitoring were identified as three useful approaches for building knowledge about ecological and socio-ecological systems and response to climate change.

Lessons from History

There is a need to do a better job at building historical data sets in BC and learning from the historical record, particularly in areas where it is rapidly disappearing (e.g. old growth forests and receding glaciers as well as First Nation elders). Research should take a longer view of the past, focusing on dynamic changes and past response to extreme events or shocks. PICS could create a compendium of “lessons" from history. What do we know from past evidence about adaptive capacity within BC? How is it compromised and what does that imply for the ability of ecosystem components to persist under climate change? A key question to tease out is threshold response/boundary conditions in the historical record.

[4] Heller & Zavaleta, *Biodiversity management in the face of climate change: A review of 22 years of recommendations, Biological Conservation 142 (2009) 14-32.*

Case Study Approach
Case studies were identified as a concrete way to learn about response of ecological and social-ecological systems to climate change in BC. PICS might build an atlas of case studies of *Adaptation, Resilience, & Transformation.*

There were several suggestions for different case studies. A few suggestions revolved around examining how ecological and socio-ecological systems respond to climate change (and other drivers) and feedbacks between them. Another idea involved a series of case studies to test different management interventions, their relative costs and benefits, and measure their success. One topic that appeared to gain traction was a case study to examine the Mountain Pine Beetle infestation in BC. Such a study could advance thinking about an intervention framework. What are the lessons learned? Was earlier intervention possible and would it have made a difference?

Long-term Ecological Monitoring Studies
A critical need was identified for long-term observation and monitoring in BC to understand the nature and extent of climate related ecological change. One model cited to explore is NEON, Inc., a U.S.-based nonprofit created to manage long-term ecological observing systems and experiments on behalf of the scientific community.

Specifically, it was suggested that monitoring could be undertaken in southeastern BC, where transformation is predicted to occur, to understand threshold behavior and ecosystem dynamics. In addition, a long-term monitoring program in BC might target ecosystems other than forests, which are currently being addressed, at least in part, by other programs (e.g. EMAN, GLORIA).

3.3. Predicting Change

Modeling impacts on ecosystems
A number of research questions emerged related to predicting how climate change and other drivers will impact ecological systems.

- How are BC ecosystems likely adapt to climate change? What BC ecosystems are most vulnerable? Predicting thresholds and non-linear change were viewed as particularly critical.
- A useful starting block would be to use and expand upon existing mapping and analysis of "enduring features" (the geo-physical template upon which ecosystems are based) and layer with climatic, biota and other factors relevant to predicting likely changes.

Compiling databases
Availability of and access to quality data is essential to predicting impacts of climate change. Several suggestions arose around the need for data compilation and sharing. PICS could explore a potential role in collecting and providing access to long-term ecological and social data. In particular, integrating databases from Alberta and the US is necessary to gain a more complete picture how systems will adapt to climate change, e.g. species ranges that currently or are predicted to cross political boundaries.

3.4. Build Adaptive Management/Governance

A clear priority emerged around building adaptive governance systems. How does climate change affect the ground rules for management? How do current government policies create incentives and disincentives related to adaptive capacity? Three possible topics for a short-term focus might be to undertake syntheses on what we already know about adaptive governance systems, refine potential frameworks for intervention decisions, and develop guiding principles for management starting with a review of examples from other governments (e.g. New Zealand) that might be tailored to BC.

Two additional broader research questions to consider:

- How do we build institutions that experiment, learn and pass on knowledge?
- How robust are governance systems and policies for the long-term provision of ecosystem services to uncertainty and transformational change associated with climate change?

3.5. Protected Areas and Landscape Level Stewardship

A theme area emerged around protected areas that would likely lead to answerable research questions with immediate applications. Research would examine places in BC that are most suitable to maintain and support adaptive capacity. Such research would guide where to avoid disturbances, such as road building, and where intervention and stewardship efforts should be focused. Province wide mapping of enduring features was identified as an immediate priority. In addition to those questions identified in section 2.3.3, research might include:

- Where are the areas best suited for carbon stewardship and provision of other ecosystem services?
- What are the thresholds at a landscape level for species, habitat, groundwater, pollution, roadlessness, etc.?
- What species can move over the landscapes and at what time scales and rates?

4. MECHANISMS FOR RESEARCH SUPPORT

Ecosystems are not only more complex than we think,
they are more complex than we can think.
-Frank Egler (quoted in Barbour, 1996)

What models of research programs lead to excellence? Given modest but long-term funding, what program model would have the greatest impact? What can research focused on BC contribute nationally and internationally? Inspiration for thinking about these questions came from a 2009 MIT Compton Lecture by Stephen Chu, Secretary of the U.S. Department of Energy. In his presentation, Chu considered how the U.S. could build research capacity to be a leader in alternative energy, pointing to the example of Bell laboratories where a number of scientists, including himself, went on to receive the Nobel Prize.[5] What were features of those labs that led to excellence? What can we take from that to stimulate excellence in research?

4.1. Possible Research Mechanisms

With the above context in mind, workshop participants identified seven possible mechanisms for a solutions-focused PICS research program.

Embedding. A research program would embed post docs within government, and government within academia to encourage the co-production of knowledge. Other combinations could be encouraged including embedding scientists within sector/industry/NGO(e.g. Columbia Basin trust, Y2Y), First Nations within academia, and between natural and social scientists.

Case Study-Experiment. Focal case studies of the long-term resilience of ecological systems and SES in specific communities could be undertaken not only to study resilience, but also to enhance the resilience of the communities. In this way, it would be both a research project and an experiment in itself. It could start small and grow as it attracted interest. Such a program would create a way for PICS to invest related to the resilient ecosystems theme as well as overlap with other themes.

Mentorship program. A mentorship program would build on existing investments in grad and post doc fellowship programs by bringing the fellows together on a group project. Mentors might come from

[5] http://compton.mit.edu/images/uploads/steven-chu-slides.pdf

industry, government, NGOs and other sectors. This program would encourage contribution in areas of interest to PICS outside the fellowship research focus, while also adding value to the investment in education. The Smith Fellows program based in the U.S. (http://www.conbio.org/smithfellows) was identified as one model to consider.

Forums. Forums and other creative examples of how to promote interchange could be considered. For example, PICS could hold workshops for young emerging leaders in science and management and annual forums to convene researchers around specific topics.

Definitive syntheses. Based on syntheses of existing information to identify knowledge gaps, RFPs could then be distributed to a broader community. "Communities" (e.g. a sector or region) need to be engaged to recognize their information needs.

Skunk works. This concept is taken from the private sector where researchers are allowed to operate with autonomy and minimal bureaucracy to encourage innovation. It was suggested that a group of researchers be allowed to self organize as a way to build institutions that experiment, learn and pass on that knowledge. The Resilience Alliance has experience with this model. The best research labs have a "light touch" and relatively unstructured approach.

Centre for Excellence. PICS could create a research program similar to the model of NCEAS at the University of California, Santa Barbara. NCEAS draws outside researchers to synthesize existing data in ecology and related fields. Rather than have permanent faculty it relies on attracting the best researchers through its resident and visiting researcher programs on an ongoing basis. NCEAS has been cited as in the top one percent of institutions worldwide (of 38,000 institutions) in terms of total citations in the field of environment/ecology.[6] PICS might look at adapting such a model to fit BC with an emphasis on the applied side of research. It was suggested that it could be created as a hybrid think tank/public participation entity that would engage with communities and other stakeholders in addition to natural scientists. PICS is potentially in a position to support a long-term program of this nature.

4.2. Leverage

A number of suggestions related to how to leverage PICS resources:

- Engage stakeholders, decision makers, and other potential partners in the process early on. They can bring resources, including funding, to the table.
- Explore the possibility of one project that integrates the four PICS theme areas. Identify a region where foundation money is available and where there is a good fit from a socio-ecological perspective.
- Focus on making strategic investments to leverage PICS funding, e.g. Future Forest Initiative, Columbia Basin Trust, etc.
- Seek international partnerships and collaboration with research centres around the world where there is a mutual benefit. For example, Dr. Richard Hobbs mentioned his Ecosystem Restoration Laboratory, a $500,000 annual research program, as a potential collaborator.

These ideas offer input as PICS considers how to carve out a niche that is relevant to BC but also distinctive and competitive on an international scale. Participants acknowledged that there is a difficult balance between immediate policy relevance and intellectual excellence. At this stage PICS may not have the resources to undertake a large-scale initiative, but it can start to generate recognition and create long-term value. Adoption of the most effective mechanisms for research will shape PICS legacy on a longer time horizon.

[6] http://www.nceas.ucsb.edu/impact#ranked

APPENDIX A: LIST OF PARTICIPANTS

Name	Institution
Diana Allen	Simon Fraser University (SFU), PICS Program Committee
Fikret Berkes	University of Manitoba
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Jenny Feick	Ministry of Environment
Jenny Fraser	Climate Action Secretariat, Ministry of Environment
Sybille Haeussler	University of Northern British Columbia
Shannon Hagerman	University of Washington
Evelyn Hamilton	Ministry of Forests and Range
Richard Hebda	Royal BC Museum
Eric Higgs	University of Victoria
Richard Hobbs	University of Western Australia
Ben Kangasniemi	Climate Action Secretariat, Ministry of Environment
Ken Lertzman	Simon Fraser University
Andy MacKinnon	Ministry of Forests and Range
Trevor Murdock	Pacific Climate Impacts Consortium
Tom Niemann	Ministry of Forests and Range
Tom Pedersen	Pacific Institute for Climate Solutions
Jim Pojar	Ministry of Forests and Range (ret'd)
Terry Prowse	Water & Climate Impacts Research Center, University of Victoria
Anna Rozwadowska	Pacific Institute for Climate Solutions
Dan Smith	University of Victoria
Dave Spittlehouse	Ministry of Forests and Range
Brian Starzomski	University of Victoria
Tory Stevens	Ministry of Environment
John Volpe	University of Victoria
Vivienne Wilson	Shell Canada
Erika Zavaleta	University of California, Santa Cruz

APPENDIX B: WORKSHOP AGENDA

Resilient Ecosystems Workshop

December 6-8, 2009
Inn at Laurel Point | Victoria, BC
Sunday December 6th

1900-2100 (Executive Suite 551)

Welcome reception

Opening remarks by Peter Keller (PICS Executive Committee, UVic)

Roundtable introduction of participants

Monday December 7th

All meeting and meal rooms are on the main floor. All breaks are in the meeting room.

0730 European breakfast (Harbour Room)

0900 Setting the stage (Spirit Room)

Tom Pedersen, Director, Pacific Institute for Climate Solutions
Eric Higgs, Resilient Ecosystems theme leader

0930 What is resilience?

Catalyst presenters:

- Kai Chan University of British Columbia
- Shannon Hagerman University of Washington
- Sybille Haeussler University of Northern British Columbia

1030 Break

1100 What is resilience? (continued)

1230 Lunch & free time (Harbour Room)

1430 How will human relationships to ecosystems change?

Catalyst presenters:

- Fikret Berkes University of Manitoba
- Elizabeth Campbell BC Ministry of Forests and Range

1730 End

1900 Dinner (Spinnakers)

We have arranged dinner upstairs at Spinnakers, a "gastro brewpub" that puts out some of the best craft beer in Victoria and has embraced local food and wine. It's casual, but I think you'll find t he food very good. http://spinnakers.com/brewpub/. 308 Catheriune Street (almost directly opposite the harbour from the Inn at Laurel Point). It's a lovely long walk (1/2 hour) around the Inner Harbour, and we will also look into other travel arrangements.

Tuesday December 8th

0730 European breakfast (Harbour Room)

0830 Recap of Day 1 (Spirit Room)

Eric Higgs University of Victoria

0845 What is the role of historical knowledge?

Catalyst presenters:

- Erika Zavaleta University of California
- Ken Lertzman Simon Fraser University
- Tory Stevens BC Ministry of Environment

1015 Break

1045 Historical knowledge (continued)

1200 Lunch (Harbour Room)

1300 What is appropriate intervention?

Catalyst presenters:

- Richard Hobbs University of Western Australia
- John Volpe University of Victoria
- Brian Starzomski University of Victoria

1530 Effective models of research support

What research funding programmes work well?
Given modest but long-term funding, what programme model would have the greatest impact?
What can BC-focused research contribute nationally and internationally?

1630 Close

APPENDIX C: WORKSHOP BACKGROUNDER

PICS Resilient Ecosystems

BACKGROUNDER

"Discovery consists of seeing what everybody has seen.....and thinking what nobody has thought."

Albert Szent-Gyorgyi

When we gather on Monday December 7th, representatives from most nations will meet in Copenhagen to kick off the COP 15 United Nations Climate Change conference. Until recently significant hope was vested in these meetings to arrive at a workable agreement that would step ahead of the Kyoto Protocols. At the just-finished meeting of APEC countries in Singapore, world leaders were agreed that a legally binding treaty would not emerge in Copenhagen, but a comprehensive political treaty might.

While not a failure, it brings up short the promise of a robust international agreement that would enforce new practices, regulatory programs, and technologies. Most important, it delays the date by which we can mark a significant turnaround of worsening climate change.

Urgency marks much of what we do as scholars and officials concerned with understanding and mitigating climate change impacts. The urgency of action must be tempered by awareness that long-term research is required to understand a long-term challenge.

Having entered the anthropocene era, our obligations to ecosystems have become especially unclear. Conserving, preserving, and restoring rapidly moving assemblages is unprecedented. However flawed the models, anchor points in history or reference conditions are no longer reliable. Or, are they? What is the role of historical knowledge? How, much intervention is appropriate? What role do people play in resolving these matters? Will new models of human relationships with natural processes be required?

Resilience, as both metaphor and theory, has emerged as a concept that offers a fruitful way forward. Resilience is the ability to recover and learn from disturbance. The work of the Resilience Alliance, and many others, has shown that our duty is to build or rebuild resilience in socioecological systems. This much seems evident and appealing. The devil is in the details, of course. Is this concept broadly applicable? What counts as an appropriate level of disturbance? Will resilience give too much license to human intervention?

PURPOSE OF WORKSHOP

We are looking for the one deceptively simple penetrating question that gets us to the fundamental unknown in this area. It need not be focused directly on *resilience*. In fact, resilience may be an answer to a different question, a question that we haven't sorted yet, or a powerful metaphor. Resilience is a starting point, but not necessarily the end point. How do we respond to ecosystems under conditions of rapid environmental change? That's perhaps the more basic question.

Whatever question emerges from this process will necessarily be distinctive. Many groups and organizations around the world are focused intently on research programs in this area. What can PICS contribute that is distinctive to British Columbia and consistent with allopatric programs?

It is unlikely that we will emerge at the end of this workshop with a single coherent question or direction (I tend to be conservative). My specific goal is to propose a robust proposal for a new research program by June 1, 2010 (earlier, if possible). Following our December workshop, I will assess whether further conversations are needed, or perhaps another meeting (similar or different configuration of participants).

It is important at our December workshop that you feel your way along in this conversation. If possible, park your well-developed answers and focus on (dare I write it?) *resilient* responses. Concentrate on the elusive. Pretend you're in the old section of a European city: will following that alluring alley lead you to a memorable moment or a blind spot? There will be moments when the conversation seems circular or uninteresting. There will be moments of disagreement. My experience with consultations on emergent ideas is that a considerable amount of openness and flexibility is required to arrive at a bold and effective result.

ABOUT PICS

The Resilient Ecosystems research theme is one of four (Resilient Ecosystems, the Low-Carbon Economy, Sustainable Communities, and Individual Action/ Social Mobilization) being developed by the Pacific Institute for Climate Solutions (PICS). PICS was established in March 2008 by a $90 million endowment from the BC Ministry of Environment, the single largest endowment to a university in Canadian history. Hosted and led by the University of Victoria, PICS is a unique collaboration among BC's four research-intensive universities (University of Victoria, Simon Fraser University, University of British Columbia and the University of Northern British Columbia). PICS brings together the Province's specialists from all disciplines and sectors to develop innovative climate change solutions, understand and respond to ecological change, seek new opportunities for positive adaptation, and lead the way to a vibrant low-carbon emissions economy. More information can be found at: http://www.pics.uvic.ca/.

This exceptional endowment supports research funding in perpetuity. This means that we have the rare opportunity to look forward to a longer-term stream of support. That's the good news. The sobering news is that the annual net amount available will be relatively modest. It is likely the resilient ecosystems theme will support collaboration more effectively than individual research. In any case, *resilient ecosystems* will join three other research themes and an existing program that supports graduate students and postdoctoral fellows (as well as administration and governance of PICS).

I am keen on having your thoughts on what *mode*/of research program will be most effective.

THE STARTING QUESTIONS

The right question will be one that will animate ecosystem-based research for PICS for several years and create a research theme that is distinctive, policy-relevant, and British Columbia-based.

But, where do we start?

I propose the following four questions to guide our initial conversations:

What is resilience?

What is the role of historical knowledge?

How will human relationships to ecosystems change?

What is appropriate intervention?

I have asked some of you to prepare very brief "catalyst" presentations to keep the conversation rolling. However, everyone is invited to participate.

Please see the schedule for more details. If you have any questions, please do not hesitate to contact me.

BACKGROUND READING

I am reluctant to prescribe background readings for the workshop. All of you are coming with particular knowledge of the literature on climate change and ecosystems, and many of you are familiar with writings on resilience. Here are a few links to materials that may be helpful. I'm happy to provide more if you like.

A very recent publication from the BC Ministry of Forests and Range: Campbell et al. *Ecological Resilience and Complexity: A Theoretical Framework for Understanding and Managing British Columbia's Forest Ecosystems in a Changing Climate.* (2009) pp. 1-43. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr055.htm.

A reservoir of articles on resilience in theory and practice by members of the Resilience Alliance: http://www.resalliance.org/

APPENDIX D. RESEARCH EXERCISE & QUESTIONS

Research Question Exercise

In a session facilitated by Dr. Richard Hobbs, participants were asked to write down their key research question based on three ground rules: think about where the "rubber hits the road", need to know versus nice to know, and what is BC-relevant but not necessarily BC-centric.

The research areas submitted by participants provide additional input to PICS as it formulates its research agenda. Below is a list of general themes and recurrent topics based on the responses.

General Themes

•Generic overall questions relating to resilience and what it means (+ in a BC context)
•Synthesis/laundry lists of current knowledge/understanding from BC and elsewhere
•BC climate knowledge/modelling + known relationships with processes/biota
•Development of principle-based approach
•Case-study approach
•Setting up long-term/NEON sites

Recurrent Topics

•How does climate change alter the management/stewardship rules?
•Threshold changes
•Cross-scale relationships/scaling issues
•What system elements confer/demonstrate resilience?
•Examples of system collapse and what we can learn from this
•Connectivity/permeability/adaptive capacity
•Robust strategies to reduce/delay/restore loss of biocomplexity arising from cumulative impacts
•Current and potential locations most suitable for biodiversity/ecosystem services/carbon stewardship
•Test typology of interventions in specific contexts
•Framing policy/regulation in a resilience context

Sub-questions

Participants were also asked to answer four sub-questions. The questions and summary of response are below.

1. Should we focus on ecosystems or social ecological systems?
Responses were split 50:50, with about half saying we should focus on both.

2. Should we focus on conservation/ecosystem services/how humans deal with changing ecosystems?
These responses were also split, with about one-third saying research should focus on all three. Another third said the focus should be on ecosystem services and another third on how humans deal with changing ecosystems.

3. Should we include: conservation/forestry/agriculture/fisheries/ marine/freshwater?
All, but focus on particular sector for case studies

4. Who else needs to be involved?

- Fisheries/aquatic expertise
- BC government/Policy makers

- Social scientists (e.g. specialist in social adaptation) to ensure understanding from biophysical and social perspectives
- Communities (local government)
- NGOs
- First Nations
- Industry (extractive, forest and other large land-uses) AKA “the pointy end”
- Other resilience experts particularly from region (e.g. Buzz Holling)
- Other reps from other PICS theme areas (overlap)
- Experts/specialists from other parts of the world to ensure continued infusion of outside ideas.