Review of Possible Tools for Local Adaptation to Climate Change in Alberta

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Prepared by Guy Greenaway, Tracy Lee, Greg Chernoff and Ken Sanderson

MIISTAKIS INSTITUTE

Prepared for:

The Alberta Biodiversity and Climate Change Team

Preface

This report is a project milestone document required under the agreement between the Climate Change and Emissions Management Corporations (CCEMC) and the Alberta Biodiversity Monitoring Institute (ABMI). It is intended to inform the Project Team (and the Steering Committee) of the Miistakis Institute Sub-project team's research to date and recommended future direction, and to ensure that early decisions are agreed upon by all parties. The Project Team is requested to review this document and assess how it meshes with the mandates, information needs and currently on-going work of the other sub-projects. It is primarily intended as a basis for further discussions.

The Alberta Biodiversity and Climate Change Team is comprised of the following members:

Dr. Dan Farr	Project Manager, Alberta Biodiversity Monitoring Institute
Ms. Angele Vickers	Alberta Environment and Sustainable Resource Development
Ms. Shauna-Lee Chai	Alberta Biodiversity Monitoring Institute
Mr. Guy Greenaway	Miistakis Institute
Dr. Erin Bayne	University of Alberta
Dr. Scott Nielsen	University of Alberta
Dr. Chris Shank	Consultant, Alberta Biodiversity Monitoring Institute

Ad hoc, but critically important members of the Project Team are:

Ms. Tracy Lee	Miistakis Institute
Mr. Greg Chernoff	Miistakis Institute
Mr. Tom Habib	Alberta Biodiversity Monitoring Institute
Ms. Diana Strahlberg	University of Alberta
Ms. Jessica Stoller	University of Alberta

Executive Summary

The *Biodiversity and Climate Change Adaptation Project* addresses the need to define the scope of change required to effectively manage biodiversity under a changing climatic regime, and to support Alberta's biodiversity management system with essential knowledge and tools for successful adaptation to a changing future climate. The goal of the *Local adaptations for biodiversity-related ecosystem services* sub-project is to support Alberta communities by developing a map-based decision support system (DSS) to better understand climate-related risks and adaptations in the context of ecosystem services and biodiversity. This report is intended to summarize the information gathered thus far in the *Local Adaptations* sub-project, but also as a basis for engaging the broader project team.

This report describes several cases and examples, and in doing so attempts to clarify what are the key considerations for the development of such a tool / approach. This report is divided into four sections: Exploring Community[1] Approaches for Addressing Climate Change Adaptation, Approaches to Mapping Ecosystem Services and Climate Change Adaptation, Review of Data Sources that are Potential Tool Inputs, and Conclusions.

The conceptual bases which underlie the report, and the sub-project, include a series of key concepts (climate change adaptation, decision suites, ecosystem services, local community, natural capital, resilience, and others), the impact climate change has on biodiversity. To help guide this sub-project, a conceptual model was developed for the integration of biodiversity and climate change in the context of ecosystem services and local communities.

The authors reviewed examples of how communities are addressing climate change adaptation and, more specifically, how biodiversity is considered in relation to climate change adaptation. Case studies found to be informative to the development of a community climate change adaptation project were reviewed base on applicability to Alberta communities, consideration of biodiversity, solution/action oriented, useful functionality, and user friendliness.

The literature review found an increasing number of articles on the topic of climate change adaptation (CCA) and biodiversity management, few suggestions around a process for developing climate change adaptation plans, an emphasis on mitigation rather than adaptation, a need for CCA tools and resources at all levels, a need to integrate biodiversity management and CCA in land use and policy, and that many recommended biodiversity management strategies in relation to CCA are already 'in the toolbox.'

Within Alberta, several Government of Alberta ministries are undertaking targeted CCA strategies, tools, or related programs, but may suffer from the challenges of cross-ministry coordination, lack of staff, and competition with other Government of Alberta goals. A review of efforts by Alberta municipalities to address climate change adaptation produced very few results.

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[1] Unless otherwise stated, 'community' in this report refers to a human community rather than an ecological community

[2] Unless otherwise stated, 'community' in this report refers to a human community rather than an

Outside of Alberta, a number of provincial, state and municipal governments have development climate change adaption plans. These typically assess vulnerabilities and risks of climate change and lead to the development of strategies or actions needed to enable a community to respond to climate change impacts. The restoration, maintenance and management of biodiversity are not comprehensive within most CCA plans, although many of the strategies complement this goal. Examples include ReTooling for Climate Change in British Columbia, Climate Ready in Ontario, ICLEI Canada (Local Governments for Sustainability).

Potentially applicable decision support tools were reviewed and categorized as analytical tools, educational tools, and process oriented tools. There is a plethora of tools available, and priority was given to those focused on climate change adaptation or sector-specific approaches which could inform development of CCA and biodiversity decision support tools. Analytical tools reviewed included the Ecosystem Valuation toolkit, Plan@Adapt, and the Water Conservation Calculator; Educational tools included Building Coast-Smart Communities and ICLEI Canada's Biodiversity program; and Process oriented tools included CRiSTAL and UKip Adaptation Wizard.

Mapping ecosystem services (ES), climate change adaptation (CCA), and biodiversity is an important step in visualizing, analyzing and identifying knowledge gaps of both current and projected landscapes. The use of mapping tools was reviewed to determine current activity, lessons to be learned, and limitations.

Mapping tools are divided into the three major areas of use: 1) process, 2) analysis, and 3) education and delivery. Examples of process-based mapping tools reviewed were DataBasin, and the Wildlife Observation Mapping Tool; analysis-based tools were SimCLIM, InVEST, ARIES, the Developable Lands tool; education and delivery tools reviewed were Ecosystem Services Carbon Calculator, NatureServe Explorer, and Environment Canada's Scenario Maps.

An important distinction was found between *online tools* (used largely through a web browser), and *GIS-based tools* (used either stand alone or through a GIS software application), with advantages and disadvantages to both. A significant issue identified with providing tools to a large user group is dealing with the different (and often low) levels of capacity.

Although specific data sets cannot be identified yet, as the tools/processes they inform have not been ascertained, some initial conclusions can be drawn about types of data required, and associated challenges. Data will be needed that characterizes present conditions (land cover, land use and biodiversity) and future conditions (climate change, population growth and natural ecological change). Potential sources of data for land cover include ABMI's Wall-to-Wall Land Cover Map, Grasslands Vegetation Inventory (GVI), and Alberta Vegetation Index (AVI); for land use include ABMI's Human Footprint Map, Base Features, and Digital Integrated Disposition System (DIDS), CanVec, and new data; and for biodiversity include the other sub-projects, ABMI, Alberta Conservation Information Management System (ACIMS), and the Miistakis Institute.

The eventual tool development and associated data scoping will have to consider that access to spatial data for Alberta is generally less accessible and more expensive than in other jurisdictions, potential tools are often developed in regions with higher-quality data than Canada, and the quality and availability of data is not uniform across the province.

The authors summarize their observations around decision support, data and information, mapping tools as it relates to biodiversity management and CCA in local communities. Recommendations are made that the this sub-project use the development of community-based climate change adaptation action plans as an entry point to incorporating biodiversity management, that 'community' be defined geographically around a rural municipality, that a mapping 'toolkit' be developed rather than a single all-purpose tool, and that ecosystem services be actively explored as the most viable way to connect biodiversity and local decision making.

The Miistakis team will deliver the second report, *Proposed Tool Structure for Local Adaptation for Climate Change in Alberta*, on February 28, 2013. Based on the research in the first report, and the feedback from the project team, this second report will propose a tool architecture and supporting approach to be pursued during years two and three of the project. The identified next steps leading to the release of Report 2 focus around immediate steps in designing a community-based climate change adaptation approach, matching mapping toolkit needs to the process steps, and clarifying the linkages between the Government of Alberta policies and local community CCA plan.

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INTRODUCTION

Project background

'Biodiversity and Climate Change Adaptation' project overview

The *Biodiversity and Climate Change Adaptation Project* was conceived by the Alberta Biodiversity Monitoring Institute (ABMI) in response to the need to define the scope of change required to effectively manage biodiversity under a changing climatic regime, and to support Alberta's biodiversity management system with essential knowledge and tools for successful adaptation to a changing future climate.

The rationale for this initiative rests on the importance of biodiversity to Albertans, and the complex relationship between climate and biodiversity. Biodiversity, which includes species and their ecosystems, supports the delivery of numerous ecosystem services. These include provisioning services (e.g., food, fibre, fuel, water), regulating services (e.g. water and air filtration, flood regulation), cultural services (e.g., nature recreation, wildlife viewing) and supporting services such as soil formation and wildlife habitat. Because these biodiversity-related services are impacted by a changing climate, and because the relationship between climate and biodiversity is uncertain, knowledge gaps constrain effective adaptation. Proactive investments in the knowledge and tools for effective biodiversity management under a changing climate regime will deliver significant benefits to people and avoid crisis-driven interventions that are by their nature reactive, costly and often ineffective.

The project consists of **five integrated sub-projects** divided into **two parts**:

- Part One: Assess the change required to effectively manage biodiversity in a changing climate
    1. Vulnerability assessment and action plan
- Part Two: Knowledge and tools for adaptation
    2. Management systems for biodiversity in a changing climate
    3. Local adaptations for biodiversity-related ecosystem services
    4. Invasive species control in a changing climate
    5. Species at risk considerations for climate change adaptation

'Local Adaptations' sub-project overview

The Miistakis Institute is taking the lead on sub-project #3: *Local adaptations for biodiversity-related ecosystem services* (concisely, the Local Adaptations sub-project).

The goal of this sub-project is to support Alberta communities by developing a map-based decision support system (DSS) to better understand climate-related risks and adaptations in the context of ecosystem services and biodiversity. The role of this DSS is to raise awareness of the biodiversity-related ecosystem services relied upon by the community, represent how those services would be affected by climate change, and characterize potential adaptation strategies that satisfy community goals in a manner beneficial to biodiversity. The form of the DSS is envisioned to be a map-based interactive tool.

The central challenge of this sub-project will be to connect the vast realm of biodiversity and climate change data to the everyday world of a local community decision-maker. The approach is intended to be pragmatic, seeking a rigorous method while recognizing limits in relevant data and the needs of affected communities, thus ensuring that databases and information are accessible to local decision makers.

This sub-project is currently conceived in three parts, two which take place in Year 1, the remaining one to take place over Years 2 and 3 . The first year's tasks are marked by two milestone reports, and represent the *design* phase of the sub-project; the *implementation* phase will take place over Years 2 and 3.

The Implementation phase will be based on specific recommendations contained in Report 2 (for Milestone 2): *Proposed Tools Structure for Local Adaptation for Climate Change in Alberta*. Drawing from the information gathering reflected in Report 1, this second report will choose a specific community, specific decision suite, and specific approach / tool. This will become the basis of the work plan in Years 2 and 3.

What success looks like

Success for this sub-project can be measured in terms of the desired output and the desired outcome.

The ultimate product (*output*) of this sub-project is a map-based, interactive decision-support system usable by southern Alberta communities. This tool would serve the function of assisting the local community decision-maker:

- See the impact a climate-modified landscape has on their decisions;
- See how their decision process can respond to the climate-changed landscape; and
- Readily visualize and wield information in support of their decisions.

Success of the *output* will be measured against these criteria.

The desired *outcome* of this project will be to help the identified local decision makers better understand climate-related risks and adaptations in the context of ecosystem services and biodiversity by:

- Raising awareness of the biodiversity-related ecosystem services relied upon by the community;
- Representing how those services would be affected by climate change; and

- Characterizing potential adaptation strategies that satisfy community goals in a manner beneficial to biodiversity.

Success of the *outcome* will be measured against these criteria.

Assumptions, constraints and limitations

The challenge of making global, continental and regional environmental phenomenon relevant and compelling to a local-level decision maker is fundamentally one of scoping. Much of that scoping is in a sense artificial; all biodiversity elements have relevance, all communities have a role to play, numerous tools will ultimately need to be employed.

It is therefore critical to proactively (and transparently) identify the assumptions, constraints and limitations that are both imposed externally, and which the Miistakis team is generating internally in an effort to scope this project to a realistic, yet useful, scale. The authors recognize that these will evolve.

- *This is a 'Proof of concept' approach* – the process/tool created within this sub-project cannot integrate all biodiversity information, portray all climate-change-adaptation scenarios, apply to every type of local community, and inform every potential decision. However, as a proof of concept, the trail of breadcrumbs left by this sub-project as it seeks to connect the local user with the wealth of climate-change-related biodiversity information will inform others, and the intent is that this be a replicable process/tool.
- *Report 1 is an incomplete summary* – The authors recognize that the list of processes, tools and resources reviewed will not be complete, nor even adequate to inform the task at hand. From the outset, It was conceived as a record of the review to date, and a basis for discussion, with full anticipation ideas would be forwarded without full confidence of their value
- *Balance between full replicability and no replicability requires pragmatism* – The Miistakis team recognizes that as a proof of concept, there is a balance to be made between full replicability of this tool/process in all communities (an unrealistic goal) and being overly community-specific (not replicable at all). That is, the community and circumstances chosen must be representative, but there must also be a reasonable assurance of the success to prove the concept. This will require decision criteria to at times be very pragmatic (e.g., a community with whom the Miistakis team is familiar, decision-making framework that is well understood, community with a stated desire to promote biodiversity, etc.)
- *Use of a decision-focused approach* – There are several ways from which one could approach linking local communities and management of climate-impacted biodiversity. Using the utilitarian philosophy that underlies the ecosystem services approach, the Miistakis team will seek to use the decisions which communities are already making as the entry point into the community. Although the background goals and outcomes for the sub-project are framed around biodiversity management, the tactical approach will be to

understand the strategies, protocols, plans, and visions already in use within the community as the route to successfully engaging the community.

- *Need for clarity on the concept of community* – The Miistakis team recognizes the term 'community' is very vague, yet its conception within this sub-project will be critical. A key (and early) need of this initiative will be to scope that concept down to a manageable and useful form.
- *Ecosystem services may be the most viable way for connecting local communities with biodiversity management* – This sub-project has been framed with relation to ecosystem services from the beginning, so that paradigm will be a touchstone throughout. However, the efforts thus far suggest that the underlying role of biodiversity in ecosystem services, and the utilitarian perspective it represents make it a promising route for connecting climate-impacted biodiversity with local community decision making.
- *'Adaptation' will refer to communities as much or more than species* – Our tool/process will ultimately be about helping communities adapt to climate change, whereas biodiversity data and information are about wild species adapting to climate change; our tool needs to bridge this divide.
- *A tool without a defined process is very likely to be unsuccessful* – At this stage, the terms 'tool' and 'process' are mostly used interchangeably, but as this sub-project evolves, they will become more distinct. Although the defined deliverable (output) of this project is a map-based DSS tool, the contextual process is as or more important. Ultimately, the tool must support the approach not the other way around.
- *This sub-project may directly incorporate only a small subset of the data generated in the other sub-projects* – Only a fraction of the data created in the other sub-projects will be inputs for the *Local Adaptations* sub-project. This arises from the scope and scale issues discussed above: this sub-project operates at a much different scale and extent (local vs. provincial/regional/continental/global). That said, the tool's ultimate data inputs are as yet unknown, and the use of indices (such as the vulnerability index) in the tool may make this assertion, in fact, less the case.

RELATION TO OTHER SUB-PROJECTS

Despite the challenges of doing so at this early stage, the authors feel it is important to begin identifying the potential linkages between the *Local Adaptations* sub-project and the other sub-projects. This discussion will evolve, and the goal of these early statements is to generate amongst the project partners. At least conceptually, the authors can identify the following areas of inter-project integration:

Tool / approach selection

- Feedback is being sought from project partners on the approach taken by the Miistakis team thus far in identifying the local adaptations tools and/or approaches that would be most effective. It is the authors intention that such feedback would be solicited/provided on an on-going basis as the sub-project moves toward selecting a specific community, an adaptation framework, and DSS tool architecture.

Data inputs

- As mentioned previously, this sub-project is not designed to accommodate all biodiversity and climate change data generated in the other sub-projects. However, it is also implausible and inefficient for the local adaptations sub-project *not* to see the sub-projects as the most obvious source of input data. As well, the Miistakis team would look to the other project partners for expert opinion on other relevant data and information sources from outside the project.

Decision suite

- A key challenge in the *Local Adaptations* sub-project will be identifying the compelling links (for a local community) between climate-impacted biodiversity and the local decisions that affect it. The decision suite(s) chosen will ultimately be based on how well those connections can be made. The Miistakis team will look to the subject experts on the project team for assistance in identifying those credible linkages between the suite of local decisions and the relevant elements of biodiversity.

Vulnerability assessment

- The first phase of the overall project, the Vulnerability Assessment, creates a frame for the entire project. Although the *Local Adaptations* sub-project and the vulnerability assessment operate at fundamentally different scales, the need for the local-level DSS to integrate and represent the information at the scale of the vulnerability assessment is almost a metaphor for the challenge of helping communities address biodiversity management and climate change at the local level. For that reason, the Miistakis team will be looking to the Vulnerability Assessment on an on-going basis to (for example) see if the index developed there could become part of a background representation, visualization, etc., or if/how individual data sets gathered for the index could be scaled for use at the local level.

Policy integration

- A key rationale for taking a 'proof of concept' approach in creating a DSS for local communities addressing climate-impacted biodiversity is the ability to apply the tools and lessons learned at a policy level. In particular, the approach/tool must integrate with the Government of Alberta's goals and strategies on climate change adaptation and biodiversity management. For that reason, the Miistakis team will look to the Government of Alberta representative, as well as the Steering Committee, for on-going exchange regarding that link.

Milestone One / Report 1

Year 1 of the *Local Adaptations* sub-project involves a series of tasks which will be undertaken and reported on in two discrete blocks. This report is the deliverable for the first of those two milestones.

Year One task overview

The work plan for Year 1 (across both milestones) consists of the following tasks:

Review

- *Similar approaches / tools* – Alberta is not the first to explore climate change adaptation at the local level, so there will be much to learn from other initiatives.
- *Potential data inputs* – To a large degree, the tool will be defined by data and information inputs that are available and accessible.

Understand

- *Role of map-based tool* – Before conceiving the structure of the tool, it will be critical to understand its intended role.
- *Sub-project integration* – How this sub-project integrates with the other sub-projects and co-projects will be explored in an on-going fashion.

Determine

- *Local community(s)* – Conception of "local community" that makes sense for this project will be based on the other sub-projects and a pragmatic assessment of potential communities.
- *Decision suites to be supported* – A useful decision support system (DSS) supports the decisions people are actually making; those must be identified.
- *Biodiversity / ES features to map* – As not all biodiversity / ecosystem service features are mappable, those suitable for this project will be determined for the project.

Conceive

- *Level of functionality for Tool V.1* – As a starting point, an outline of what base functionality is for Version 1 of the DSS tool is required.
- *Data integration* – How data and information from a variety of sources is integrated and incorporated into the tool is a key consideration.
- *Accessibility* – The physical and conceptual user interface will dictate if the tool truly supports the local adaptation decisions being made.

Purpose of Report 1

There are two purposes the report is intended to serve.

First, this report recaps what the Miistakis sub-project team has reviewed in pursuit of the tasks associated with the research thus far. Those have focused on reviewing: 1) different approaches local communities have taken to managing for climate change adaptation, biodiversity protection or enhancement, and ecosystem service production or maintenance; 2) the tools which have been developed to visualize and map these in support of local decision making; and 3) the data and information needs and opportunities that support or confound these efforts.

Second, the research identifies more questions than it answers. Some of those questions will be answered by further research and tool exploration on the part of the Miistakis team. However, the

Miistakis team will also be looking to the other project partners to provide general feedback on the potential approaches reviewed, but also on the specific data needs and possible interconnections with other parts of the project.

As such, the report has been conceived and structured to clarify by describing the avenues of research thus far, and to better frame the research questions going forward. The intent is that this will help the Miistakis team better articulate: 1) how data and information can flow from climate change and biodiversity experts to local community decision makers (and vice versa); 2) how that information can best be used by local community decision makers to better manage for biodiversity in the context of adapting to a changing climate; and 3) what are the potential roles of and options for support tools and processes to assist connecting this information to local decisions.

Audience for Report 1

Ultimately, the audience for this research and tool development will be local community decision-makers, and the policy makers who guide them. However, that is not the audience for this report.

As indicated by the purpose above, there are two key audiences. The first is the *Biodiversity Management and Climate Change Adaptation* project team (see *Relation to other sub-projects*, above). By extension, this will also include the Steering Committee, and the Government of Alberta representatives.

As this is a record of the information collected thus far, the second key audience is the Miistakis Institute sub-project team in the sense that this reports serves as a record. It will be a key planning resource as the Miistakis team moves into the final design phase (culminating with *Report 2*) and ultimately the implementation phase, and as such, the information it contains will be continually updated.

It is also important to note that some of this information, in another form and at a later date, will also be intended to inform Government of Alberta policy makers and local communities addressing biodiversity management and climate change. In that sense, it is raw material that will be used to create future resource materials.

Report 1 format and approach

This report lays out several cases and examples, and in doing so attempts to clarify what are the key considerations for the development of such a tool / approach. This report is divided into four sections:

- **Exploring Community Approaches for Addressing Climate Change Adaptation:** Identifies and reviews existing tools that equip local communities to understand and use climate change adaptation information in the context of their own decision making, especially as that relates to biodiversity;

- **Approaches to Mapping Ecosystem Services and Climate Change Adaptation:** Identifies and analyzes the different approaches to mapping ecosystem services and climate change adaptation;
- **Review of Data Sources that are Potential Tool Inputs:** Identifies and reviews the various data and information sources that are potential inputs to such processes and tools; and
- **Conclusions**: Summarizes the issues, challenges and interim recommendations arising out of the research thus far, and identifies the steps leading to Report 2.

REPORT 2 PURPOSE

Based on the research in Report 1, and the feedback from the project team, Report 2 would propose a tool architecture and supporting approach to be pursued during years 2 and 3. It is provisionally titled: *Proposed Tool Structure for Local Adaptation for Climate Change in Alberta* and will be delivered February 28, 2013.

CONCEPTUAL BASES

Key Concepts and Definitions

This report – and this sub-project – use a number of concepts and terms that, while in common use, may have unique connotations depending on the circumstance, or may be vague and prone to misunderstanding.

The authors have gathered several of those terms here with the intent of 1) explaining how they are used here, and 2) identifying interconnections or particular facets that are relevant to this discussion.

The terms are:

- *Adaptation*
- *Biodiversity*
- *Climate Change*
- *Data and Information*
- *Decision Suites*
- *Decision Support Systems*
- *Ecosystem Services*
- *Human Well-being*
- *Local Community*
- *Natural capital*

- *Resilience*
- *Tools*

Adaptation

Similar to resilience, 'adaptation' can be considered in ecological (natural systems changing or adapting) or anthropogenic (human systems changing or adapting) terms. In all cases in this report, adaptation is considered in the context of climate change. Definitions of adaptation tend to span a spectrum from those that imply that the natural systems will necessarily degrade, to those that imply human activity (in synergy with ecological resilience) can ameliorate that degradation.

Most definitions emphasize the themes of coping or exploiting changes, through action of some sort. Lim et al (2004) describe adaptation as "a process by which strategies to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, and implemented." The IPCC (2001b) definition emphasizes the potential benefits: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderates harm or exploits beneficial opportunities." And ICLEI Canada (accessed 2012) emphasize the types of systems that are affected: "Includes any initiatives or actions in response to actual or projected climate change impacts which reduce the effects of climate change on built, natural and social systems."

Two other concepts of adaptation are important to consider. First, there is the perception that adaptation has *various types* based on their proactiveness and effectiveness. These include reactive, planned, and maladaptive adaptations:

- *Reactive Adaptation*: Adaptation that takes place after impacts of climate change have been observed. (Bizikova et al 2008)
- *Planned Adaptation*—Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state. (Bizikova et al 2008)
- *Maladaptation* – Any changes in built, natural, or human systems that inadvertently increases vulnerability to climate stimuli; an adaptation that does not succeed in reducing vulnerability but instead increases it. (ICLEI Canada)

Second, is the emerging concept of '*ecosystem-based adaptation*.' This, and similar definitions, focus on adaptation as a function of resilience. Groves et al (2012) describe it as a term favoured by the International Union for the Conservation of Nature (IUCN; www.iucn.org) and the Climate Action Network (www.climatenetwork.org) and defined as:

> ''*a range of local and landscape scale strategies for managing ecosystems to increase resilience and maintain essential ecosystem services and reduce the vulnerability of people, their livelihoods and nature in the face of climate change*'' (CAN 2009).

Biodiversity

Biological diversity can be considered as narrowly as the diversity of species (species richness) or as broadly as "the variation of all life on earth the ecological complexes in which they occur" (Leadley et al 2010). For the purposes of this report, and this sub-project, biodiversity is defined in the broadest sense including genes, species, ecosystems and ecosystem function.

As this sub-project is tasked with consideration of ecosystem services, it is important to note that there is a clear but indirect connection between biodiversity and ecosystem services. As Scholes et al (2010) point out, "biodiversity is in general not an ecosystem service itself but a necessary condition for ecosystem services to be delivered." They continue (perhaps more importantly) to note that "a key value of biodiversity may be in reducing the variability of ecosystem services, (equivalently, reducing the uncertainty or risk), especially in the face of disturbances or changes in the environment."

Climate Change

The Intergovernmental Panel on Climate change (IPCC 2001a) describes climate change as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

Data and Information

Data: For the purpose of this project, "data" refers exclusively to digital spatial (GIS) data. Data is in one of three formats: vector (points, lines, or polygons), raster, or tabular (point, line or raster data only). In order for data to be useable, it requires four components: topology, thematic (attribute) data, spatial reference, and metadata

Information: For the purposes of this project, "information" refers to anything that contributes to our understanding of the natural, cultural, or other features of a landscape (and that is NOT "data" as described above). These are sources that tell us about the state of the landscape and how it is used, managed, and/or assessed. Information can take a number of forms, including documents, frameworks, assessments, analyses, policies, anecdotal or local knowledge, maps, tools, or scripts.

Decision Suites

Though Decision Support Tools or Systems are ultimately aimed at providing support for individual choices made in a management context, they are rarely targeted at such a specific level. Rather, they tend to target "decision suites." Decision suites are collections of determinations (or the need for such determinations) that have an internal cohesiveness.

Whereas individual *decisions* might include discrete development approvals, budgetary allocations, policy enactments, or operational deployments, *decision suites* might include groupings of decisions based on ecological management issue (riparian health, pollution management), municipal mandate (infrastructure development, agricultural services), land use planning realm (residential, light industrial, transportation corridor), or geographic area (village, watershed). These decision suites can be characterized by common desired outcomes, similar information needs, common stakeholders, common jurisdictional boundaries, or various combinations thereof.

A key success factor in this sub-project is getting engagement from the identified community. This engagement depends on understanding the kinds of decisions the community is already making, and understanding how the information provided can support those decisions. Identifying decision suites rather than individual decisions in need of support allows the investigation to be outcome oriented, and to take a more comprehensive, systems-focused approach. This results in two desirable conditions: 1) a greater ability to address complex, multi-input, multi-impact issues; and 2) a greater ability to identify multiple entry points into the decision matrix and – by extension – into the community on whose behalf the decision maker is operating.

Decision Support Systems

Decision support is defined broadly as a "generic term that encompasses all aspects related to supporting people in making decisions" (Nižetic et al 2007). There are three fundamental components to consider when designing a decision support system: the knowledge base (data you plan to use); the decision context (model); and the user interface. Common decision support system purposes include to:

- Support/inform a process;
- Support/inform rather than automate decision making; and
- Enable a rapid response to changing needs of decision makers. (Nižetic et al 2007)

Ecosystem Services

The concept of ecosystem services (also called *ecological goods and services* or EG&S) derives from a utilitarian view of nature, considering the function of ecological systems in terms of the explicit benefits they provide humans. The term has been succinctly defined as "the benefits humans derive from ecosystems" (Costanza et al 2012).

Ecosystem services can be said to be comprised of two elements: ecological function (the activity of the system regardless of its value), and human benefit (the human-based assessment of the value being derived). In other words, an ecological function can only be said to provide an ecosystem service if there has been an explicit articulation of the benefit that function is providing to humans.

Two seminal works provide the most credible descriptions. Costanza et al (1997) described ecosystem services in this way: "Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions."

Secondly, the Millennium Ecosystem Assessment (2010) collated the global body of work on the topic. They identifying a list of 31 services (which have since become accepted as the most authoritative list), and equated ecosystem services to a broad concept of human well-being, broadening the discussion beyond simple food and fiber to provisioning, regulating, cultural and supporting services.

HUMAN WELL-BEING

The concept of "human well-being" arose in the context of valuing the full breadth of services humans sought from natural, human, social and built capital; or as Costanza et al (2012) characterize it, "Sustainable human well-being rather than merely GDP growth".

The concept of human well-being or sustainable human well-being (SWB) arose before Millennium Ecosystem Assessment, but that global assessment standardized and popularized it in academic, policy and human services circles. TEEB (2010) summarize it as, "a context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience." This is based on the fuller MEA (2005) articulation of the main dimensions of well-being:

- The necessary material for a good life
    - including secure and adequate livelihoods, income and assets, enough food at all times, shelter, furniture, clothing, and access to goods;
- Health
    - including being strong, feeling well, and having a healthy physical environment;
- Good social relations
    - including social cohesion, mutual respect, good gender and family relations, and the ability to help others and provide for children;
- Security
    - including secure access to natural and other resources, safety of person and possessions, and living in a predictable and controllable environment with security from natural and human-made disasters; and
- Freedom and choice
    - including having control over what happens and being able to achieve what a person values doing or being.

Local Community[2]

Although the term "local community", as well as the terms "local" and "community" separately, are used quite commonly in this field, it is important to be clear on what is intended by the authors in using these terms.

In common usage, the term 'community' tends to indicate two primary principles. The first is that there is a group with common interests or origins, and second, that there is a geographic commonality among the people of that group (OED 2012).

The term 'local' is often used as qualifier on community, but in common usage the two terms are erroneously considered interchangeable. As well, the term 'local' is often used to indicate a presumed geographic scale. In fact, 'local' does not denote any sort of absolute limitation on geographic scale, simply a relative scale; 'local' indicates the geographic place that is a smaller subset of a particular larger whole (OED 2012).

Therefore, when considering climate change adaptation at the *community* level, 'community' could refer to a group with common interests (agricultural producers, environmental non-government organizations, academics, oil and gas companies, etc.), a group who live in a common location (a town, region, neighbourhood, etc.), or both.

Further, when considering a *local* community, 'local' is a relative measure meaning there must be reference to the whole. Examples could include one of several regional planning districts, one village within a municipal district, one watershed within a basin, one town within a province, etc.

Natural capital

Natural capital is now a relatively common term in resource management and ecological conservation policy. At its base, 'capital' is "wealth owned by a person or organization or invested, lent or borrowed" (OED 2012), and generally refers to a stock of assets. The concept of *natural capital* expands the concept of wealth to include the bounty of ecosystems, and extends the concept of assets into the ecological world. TEEB (2010) defines it as: "An economic metaphor for the limited stocks of physical and biological resources found on earth. Also referring to the capacity of ecosystems to provide ecosystem services."

For the purposes of this research, the authors have adopted the characterization of Costanza et al (1997) of *natural capital* being juxtaposed with three other types of capital: social and cultural, human, and built (see sidebar). There are five important points that emerge from this relationship:

- These four categories of assets overlap and interact in complex ways to produce all human benefits (Costanza et al 2012)

[2] Unless otherwise stated, 'community' in this report refers to a human community rather than an ecological community.

- All other asset categories depend entirely on natural capital (Costanza et al 1997, 2012)
- Natural capital has limited capacity and is non-substitutable (Costanza et al 1997,TEEB 2010)
- Natural capital stocks can be depleted through anthropogenic activity; and
- Natural capital stocks can be replenished ecologically.

The first of these points illustrates the relationship between natural capital and ecosystem services. Costanza et al (1997) described this in more detail: "Ecosystem services consist of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare."

In its simplest terms, 'natural capital' can be considered synonymous with 'ecosystems.'

Resilience

The authors consider two concepts of resilience in the context of this report: one is the resilience of ecosystems and the other is the resilience of communities. Though they are inextricably connected, there are important distinctions.

With regard to ecosystems, there are several definitions of resilience with broad commonalities. In the context of climate change research, the International Panel on Climate Change defines resilience as the "amount of change a system can undergo without changing state" (IPCC 2001a). The Economics of Ecosystems and Biodiversity group goes further and

Four types of overlapping and interacting capital:

- **Natural capital**: The natural environment and its biodiversity. Among other things, natural capital is needed to provide ecosystem goods and services. These goods and services are essential to basic needs such as survival, climate regulation, habitat for other species, water supply, food, fiber, fuel, recreation, cultural amenities, and the raw materials required for all economic production.
- **Social and cultural capital**: The web of interpersonal connections, social networks, cultural heritage, traditional knowledge, and trust, and the institutional arrangements, rules, norms, and values that facilitate human interactions and cooperation between people. These contribute to social cohesion; strong, vibrant, and secure communities; and good governance, and help fulfill basic human needs such as participation, affection, and a sense of belonging.
- **Human capital**: Human beings and their attributes, including physical and mental health, knowledge, and other capacities that enable people to be productive members of society. This involves the balanced use of time to fulfill basic human needs such as fulfilling employment, spirituality, understanding, skills development, creativity, and freedom.
- **Built capital:** Buildings, machinery, transportation infrastructure, and all other human artifacts and services that fulfill basic human needs such as shelter, subsistence, mobility, and communications. (from Costanza et al 2012)

suggests that resilience is the "capacity of an ecosystem to tolerate disturbance without collapsing" (TEEB 2010). All definitions reflect the concepts of pressures on a system, response to those pressures, and a measure of the ability to withstand fundamental change in the face of those pressures.

With regard to communities, those same parameters apply. The United Nations' Inter-Agency Secretariat of the International Strategy for Disaster Reduction, for example, expands the borders of the resilience concept to include the "capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure" (UN/ISDR, 2004). This definition also makes the important link between the concepts of resilience and adaptation.

In terms of action taken to bolster resilience, this report considers those actions to coarsely fall into one of two categories: *natural resilience* and *engineered resilience*. Natural resilience refers to the capacity of ecological systems to generate resilient capabilities in the face of pressures. Engineered resilience refers to the efforts of humans to recreate the ecological functions subjected to pressure, or to change human expectations around the benefits provided by those functions.

Natural resilience is not free of anthropogenic influence in that humans can take action to protect or augment natural resilience. These approaches tend to be fundamentally *proactive* in that they seek to limit disturbance pressures. Engineered resilience tends to be *reactive*, and arise when an identified ecosystem service is seen to be degraded.

Tools

The authors use the concept of "tools" in a very broad sense; something used to help perform a job. A 'tool' can, therefore, be conceived as a very concrete device, such as a computer program, or as a more intangible device, such as a process, protocol or framework. The use or implementation of a given tool will likely encompass all of these at some point. In the context of a decision-support tool, this can refer to any concrete or intangible device used to support that decision-making task.

Impacts of climate change on biodiversity

The 2012 *Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment* provides a concise summary of the known and anticipated impacts of climate change on biodiversity. Ultimately, this kind of information will provide the path that the Miistakis sub-project team explores to understand how to make these climate change/biodiversity connections compelling for local community decision makers.

The full text of this report's synthesis is included in *Appendix 1: Staundinger et al (2012) Summary of Impacts of Climate Change on Biodiversity*. The key points include in the synthesis are:

- Climate change is causing many species to shift their geographical ranges, distributions, and phenologies at faster rates than were previously thought; however, these rates are not uniform across species.
- Increasing evidence suggests that range shifts and novel climates will result in new community assemblages, new associations among species, and promote interactions that have not existed in the past.
- Differences in how organisms respond to climate change determine which species or populations will benefit (winners), and which will decline and possibly go extinct (losers) in response to climate change.
- The potential for biodiversity to respond to climate change over short (plasticity) and long (evolutionary) time scales is enhanced by increased genetic diversity; however, the rate of climate change may outpace species' and population's capacity to adjust to environmental change.
- Identifying highly vulnerable species and understanding why they are vulnerable are critical to developing climate change adaptation strategies and reducing biodiversity loss in the coming decades.
- As species shift in space and time in response to climate change, effective management and conservation decisions require consideration of uncertain future projections as well as historic conditions.
- Broader and more coordinated monitoring efforts across Federal and State agencies are necessary to support biodiversity research, management, assessment, and policy.

A model for integrating biodiversity and climate change in the context of ecosystem services and local communities

Climate change, biodiversity, local communities, natural capital, resilience and ecosystem services are common terms in the field of conservation science and design, and they have intuitive conceptual linkages. However, developing applied programs that promote conservation by effectively wielding these concepts is challenging without explicitly articulating the connections between them.

To help guide the authors' efforts in making these connections – and in making these connections clear for the communities who will be engaged – the Miistakis team developed a simple conceptual model. That model, described in *Appendix 2: Integrating biodiversity and climate change in the context of ecosystem services*, relies heavily on the terms and concepts included in the *Key concepts and definitions*, above.

COMMUNITY-BASED APPROACHES TO CLIMATE CHANGE ADAPTATION

Introduction

In this section, the authors review how communities are addressing climate change adaptation and, more specifically, how biodiversity is considered in relation to climate change adaptation. To undertake this review, definitions for biodiversity, climate change adaptation and communities referred to earlier in this report provide important context. The ultimate goal of this section is to review case studies and decision support tools currently in use that assist a community in adapting to climate change.

Within the context of this review the authors prioritized the search on how provincial and local governments are addressing climate change adaptation and then considered examples where the community is defined as a group with common interests. This is mainly due to the notion that climate change adaptation is a complex problem with profound societal and ecosystem impacts and the need for government direction is beneficial to ensure integration of strategies at multiple planning levels and across disciplines. Different communities are often at different stages in addressing climate change adaptation and it is important for this sub-project to identify the stage at which communities are within the southern Alberta context.

Approach and methodology

As noted earlier, the authors see the separation of climate change adaptation (CCA) processes (strategy development, risk assessment, community engagement, etc.) and the decision support tools as an artificial one, as it is rarely successful to deploy one without the other. However, they do have distinct roles to play, drawn on unique skill sets, have different architecture and development needs, and may be created in different contexts. For this reason, 'process' and 'tools' are considered within this review as 'separate but linked.'

As a first step the authors undertook a generalized web search to evaluate how communities within Alberta are addressing climate change adaptation. This included an assessment of provincial and municipal initiatives but also included groups with common interests such as agricultural, forestry or a watershed groups. Where possible, the authors identified how different approaches to climate change adaptation incorporate biodiversity. Case studies found to be informative to the development of a community climate change adaptation project were identified and reviewed using the following criteria:

- Applicability to other communities in Alberta;
- Attention to and consideration of biodiversity;
- Solution and action oriented;

- Exhibits functionality deemed useful for helping communities learn, assess and plan for climate change adaptation and biodiversity; and
- Visually appealing and user- friendly interface

This same methodology was used for a broader global search.

The authors also reviewed decision support tools aimed at helping communities with climate change adaptation in relation to one of or a combination of analytical, educational or process based approaches. In addition, mapping tools were reviewed at a broad scale to investigate functionality and role of the tool in informing climate change adaptation, ecosystem services and biodiversity initiatives.

Climate change adaptation and biodiversity strategies

To better understand how climate change adaptation and biodiversity have been linked in strategies at the community level, the authors broadly reviewed the literature on the topic, clarified key concepts for the purpose of this sub-project, and identified a series of lessons learned to guide the detailed review of CCA processes and tools.

KEY CONCEPTS

Biodiversity

Biodiversity is defined in the broadest sense including genes, species, ecosystems and ecosystem function, with a desirable project goal to maintain and restore ecological diversity. Biodiversity is heavily impacted by direct human pressures (e.g. urban sprawl, pollution, water use, energy use, forestry, invasive species and roads) and will be further exacerbated by impacts of climate change on biodiversity (Kimmel 2009). Considerations of climate are important for biodiversity management as the Intergovernmental Panel on Climate Change 4th Assessment Report (IPCC AR4) indicates climate change will have a significant impact on all levels of biological diversity including species, genetics within species, ecosystems and ecological interactions (Campbell et al. 2009). The Millennium Ecosystem Assessment, states "the most important direct drivers of biodiversity loss and ecosystem service changes are habitat change (such as land use changes, physical modification of rivers or water withdrawal from rivers, loss of coral reefs, and damage to sea floors due to trawling), climate change, invasive alien species, overexploitation, and pollution" (Millennium Ecosystem Assessment 2005).Continued loss of biodiversity reduces the ecosystems' ability to respond to climate change, and therefore maintaining biodiversity an important consideration in climate change adaption (Kimmel 2009). Biodiversity also plays an important role directly and indirectly in the human economy by providing an essential life support system and the provision of goods and services.

Climate change adaptation

There are two broad policy areas of response to climate change, mitigation and adaption, which address respectively the causes and impacts of climate change. Although both policy areas are important, within this review the authors are most interested in communities responding to the impacts of climate change through the development of adaption strategies. UNDP (2005) defines climate change adaptation as "a process by which strategies to moderate, cope with and take advantage of consequences of climate events are enhanced, developed and implemented." In addition, the authors consider the concept of *ecosystem-based adaption*, which consists of strategies aimed at "increasing the resilience and reducing the vulnerability of ecosystems and people in the face of climate change. It identifies and implements a range of strategies for the management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of changing temperatures, precipitation patterns, sea level rise, CO^2 concentrations and exposure to extreme events (CBD 2009)." Ecosystem resilience is an important concept in relation to biodiversity management and climate change as a biologically diverse system is better able to adapt to climate change impacts.

Community

The term 'community' tends to indicate two primary principles. The first is that there is a group with common interests or origins, and second, that there is a geographic commonality among the people of that group (OED 2012). Therefore, when considering climate change adaptation at the *community* level, 'community' could refer to a group with common interests (agricultural producers, environmental non-government organizations, academics, oil and gas companies, etc.), a group who live in a common location (a town, region, neighbourhood, etc.), or both. It is important to note that a common location, such as a town or municipality, also can be distinguished between those who hold positions of authority (local government staff and elected officials) versus all individuals within a defined geographical space.

Literature review

A 2009 review of literature on climate change adaptation and biodiversity management indicates a recent increase in articles published on this topic (Heller and Zavaleta). Some relevant findings of the review include: 33% of the papers mention biodiversity conservation in conjunction with ecosystem services; 70% of recommendations where classified as general principals, vague in nature (consider restoration); and very few papers suggest processes for developing a CCA plan.

A review by Mawdsley et al. (2009) of policy documents and scientific literature relating to climate change adaptation from Canada, United States, Mexico , England and South Africa identified strategies relating to the conservation of species and ecosystems. Those authors found 16 climate change adaptation plans which had strategies relating to conservation of species and ecosystems. They grouped them into four categories: land and water protection and management; direct species management; monitoring and planning; and law and policy tools. Within these broader categories they identified 17 strategies. For example, two of the strategies within the land and water protection and management category included "improve matrix by increasing landscape permeability to species movement" and "manage and restore ecosystem function rather than focus on species composition and assemblages". These authors found many of the tools needed to help species and ecosystems adapt to climate change are already in the toolbox. Unfortunately, not one of the climate change adaption plans reviewed included a comprehensive list of strategies to adequately conserve biodiversity (Mawdsley et al. 2009).

In a similar assessment, Heller and Zavaleta (2009) reviewed recommendations in the scientific literature for managing biodiversity in light of climate change impacts. Although there was consistency in the recommendations, similar to those identified by Mawdsley et al (2009), details on how to operationalize the strategies is still lacking. Climate change adaptation is considered a new approach, as many conservation managers have and continue to focus on mitigation programs to reduce emissions. As a case in point, this review was inspired by discussions at a California Invasive Plant Council meeting whereby participants expressed concern about climate change and the need to adapt but could not identify practical steps to take.

These reviews suggest an emphasis on adapting existing plans and policy's to incorporate CCA strategies. The authors concluded that resources and tools to guide a climate change adaptation planning process where biodiversity is considered at all scales are desperately needed. They noted some large scale initiatives by institutions (such as Parks Canada, or NGO's such as The Nature Conservancy and Wildlife Conservation Society) to develop climate change adaptation plans show promise, but smaller scale plans are needed and resources and tools and processes need to be developed and shared (Heller and Zavleta 2009).

LESSONS LEARNED

To summarize the lessons learned from a scientific literature review:

- CCA is a relatively new area of consideration, with most climate change attention focused on mitigation;
- CCA plans are a relatively new approach with most of the examples occurring within the last five years; therefore there is a steep learning curve when it comes to developing processes for and implementation of adaptation strategies;
- Tools and resources to help develop CCA plans are needed at all scales;
- Many of the recommended biodiversity management strategies in relation to CCA are already in the toolbox;
- There is a need to help decision makers at the local and regional level integrate climate change adaptation and biodiversity management into existing land use plans and policy documents.

Climate change adaptation in local communities

CLIMATE CHANGE ADAPTATION IN ALBERTA

The Alberta Government, specifically Alberta Environment and Sustainable Resource Development (AESRD)[3] is responsible for addressing climate change adaptation in Alberta. The 2008 Alberta Climate Change Strategy identified an action to develop a Provincial Adaptation Strategy, but it is still in development (Alberta Environment 2008, J.H. Archibald Consulting 2011). In addition, The Alberta Climate Change Adaptation Team (ACCAT), a cross-ministerial group was formed to coordinating climate change work across Alberta and assess the risk and vulnerability of different areas of government.

Alberta Environment's (AENV) focus on climate change adaptation was traditionally through grassroots initiatives around water management and protection. Alberta Sustainable Resource Development (ASRD) released a Climate Change Adaption Framework Manual and decision support tool with the aim of helping an organization adapt to climate change, through a risk assessment approach. The approach focuses on helping an organization understand the organizational risks from climate change (how will climate change effect their ability to meet their mandate) and the development of strategies to increase an organization's capacity to address challenges relating to climate change (ASRD 2010).

Other departments within the Government of Alberta are addressing climate change adaptation but to the best of our knowledge they are not tied to a provincial climate change adaptation program (though efforts are underway to systematically make these linkages). For example Alberta Agriculture and Rural Development (AARD) has a number of projects relating to adapting agricultural practices to variability and extreme weather events, such as drought management programs, that are in essence climate change adaptation projects but are not labeled as such. This makes it difficult to track how the Alberta government is addressing climate change adaptation.

A review of climate change adaptation projects within the prairie region highlighted the lack of discourse around climate change adaption in Alberta at both the political and government staff level (J.H. Archibald Consulting 2011). Other gaps identified in this report include: organizational capacity; staff not being specifically assigned to climate change adaption; competition between efforts to incorporate climate change adaptation into policy processes and other interests and priorities in Alberta. In addition, there is a need for a cross-ministerial approach to climate change adaptation as impacts affect all sectors of government and society. This may be occurring through The Alberta Climate Change Adaptation Team (ACCAT).

[3] In 2011, Alberta Environment (AENV) became Alberta Environment and Water (AENVW); in 2012, Alberta Environment and Water was merged with Alberta Sustainable Resource Development (ASRD) to become Alberta Environment and Sustainable Resource Development (AESRD).

A review of efforts by Alberta municipalities to address climate change adaptation produced very few results, with the exception of the Municipal Climate Change Action Center (MCCAC). The MCCAC has identified Alberta municipalities interested in addressing climate change adaptation, and is working with the International Council for Local Environment Initiatives (ICLEI). The ICLEI has developed a process for developing climate change adaptation plans for local municipalities which is reviewed later in the report (MCCAC 2012).

It the authors' impression that climate change adaptation is not high on the priority list for municipalities in Alberta, likely due to lack of direction from the province and other priorities taking precedence. This can be highlighted by a recent study in the M.D. of Pincher Creek No. 9 whereby residences were asked to rank 38 value statements. Five of the top 15 value statements were related to natural environment: *conserving and protecting water resources*, *protecting natural environment within the MD*, *protecting the natural environment around the MD*, *maintaining fish and wildlife populations*, and *practising sustainable agriculture*. In contrast, the value statement "*reducing our impact on and adapting to climate change*" was ranked much lower, sixth from the bottom (The Praxis Group 2012), despite its fundamental impact on the higher value statements. In addition, when asked to identify one concern they have for the future, climate change did not make the list.

Climate change adaptation in local communities outside of Alberta

A number of provincial, state and municipal governments have development climate change adaption plans. These plans typically assess vulnerabilities and risks of climate change and lead to the development of strategies or actions needed to enable a community to respond to climate change impacts. Typically these plans are inclusive of how climate change will impact land use, water use, ecosystem/natural, infrastructure, emergency/hazards, food security and economics. The restoration, maintenance and management of biodiversity are not comprehensive within most CCA plans, although many of the strategies complement this goal.

Below are three representative case studies conducive to helping a community design a climate change adaption plan. The examples highlight the different scales where climate change adaptation is occurring, from provincial, coalition of municipalities, a municipality to a small town.

ReTooling for Climate Change in British Columbia

URL: http://www.retooling.ca

The ReTooling for Climate Change website developed by BC Regional Adaptation Collaborative (BC RAC) – a partnership program of the Fraser Basin Council and the BC Ministry of Environment – Climate Action Secretariat – helps elected officials, staff of local governments, first nations or an individual learn about climate change adaptation. The website is a resource for highlighting efforts in BC at a small scale to address CCA.

The website identifies a simple process for a community to go through to help them learn about CCA. The steps include: identifying local impacts; assessing and prioritizing risk and vulnerability; and taking adaptive action (integrating the results into community action and planning processes). Some communities like to integrate CCA strategies into existing plans while others have developed separate CCA Action Plans.

The Columbian Basin Trust worked with the following communities in SE British Columbia to develop CCA Action Plans: the District of Elkford, City of Kimberley, City of Rossland, City of Castlegar and Regional District of Central Kootenay (Area D) in partnership with the Village of Kaslo. The CCA Action Plans for each of these communities is focused on developing actions based on the priority areas identified as most vulnerable to climate change. For example, the District of Elkford, identified three priority areas to develop CCA strategies around, wildfire, flooding and water supply (Gorecki et al. 2010). Within this process a number of adaptation focus areas were identified to help local communities think through and identity most vulnerable area, including land use, water use, ecosystem/natural, infrastructure, emergency/hazards, food security and Economics.

Although some of the strategies benefit and relate to biodiversity management, these plans do not identify all strategies likely need to restore and protect biodiversity at a small scale. Likely this is due to the prioritization of vulnerabilities that directly impact the people living in the community and the actions focused on strategies to address priority vulnerabilities.

Climate Ready: Ontario

URL http://www.ene.gov.on.ca/environment/en/resources/STDPROD_081665.html

The government of Ontario has developed a climate change action plan for 2011-2014, which resulted in five broad goals and 37 action initiatives developed from expertise of ministries across government. Many of the broad goals and action initiatives relate to biodiversity conservation. For example, one of the goals is to “take all reasonable and practical measures to increase climate resilience of ecosystems”; an example of a specific action includes “conserve biodiversity and support resilient ecosystems.” Although these goals are very broad and generalized, they provide direction to government agencies and local governments, and there are strategies within the broader plan to help local communities operationalize the strategies.

To assist smaller communities in adapting to climate change, Ontario has established the Ontario Regional Adaptation Collaboration (Ontario RAC) which currently has a three year mission to undertake three initiatives: extreme weather events, water resource management and community planning and policy. There are a number of case studies where local communities within Ontario have developed CCA plans, including greater Sudbury and the Hamilton Conservation Authority.

The Ontario Ministry of Natural Resources has developed a “Practical Guide to Climate Change Adaptation in Ontario Ecosystems” aimed at natural resource managers to help them understand how climate change risk and vulnerability can be integrated into decision making. Some examples of CCA plans include Ontario Parks, Lake Simcoe watershed and Northeast Clay Belt (Ontario MNR 2012).

A more detailed review of the Lake Simcoe watershed CCA planning process highlights the number of partners, experts and time to develop a comprehensive CCA plan (Douglas et al. 2011. The planning process included a partnership between Ontario Ministry of Environment (MOE), Ontario Ministry of Natural Resources (OMNR), Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA), First Nations and Métis communities, the Lake Simcoe Region Conservation Authority (LSRCA), municipalities, and interested academic institutions. The partners went through a seven step process: 1) Build team; 2) Identify experts and indicators; 3) Assess current vulnerability; 4) Estimate future scenarios for both climate change and non-climate change stressors; 5) Estimate future vulnerability; 6) Develop a method to generate adaptation ideas using a Delphi approach; and 7) Evaluate adaptation recommendations and Implementation of adaption measures. Within the future vulnerability assessment, system components were divided into natural environment and built environment. The natural environment included hydrology, vegetation cover, aquatic habitat, natural heritage areas, species at risk, invasive species, agriculture and tourism. Each of these areas was assessed by an expert and reported back to the broader team. The CCA plan resulted in 30 action strategies. This particular example seems to be comprehensive of biodiversity management, but is also a fairly extensive process engaging multiple communities, organizations and governments in the region.

Lastly, Ontario has developed a toolbox hosted on the Ontario MNR website (http://www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_092481.html), to guide communities in adapting to climate change. The tool box includes guides, datasets, mapping tools and models to help communities adapt to climate change.

ICLEI Canada (Local Governments for Sustainability)

URL: http://www.icleiusa.org/tools/adapt/adaptation-database-and-planning-tool-adapt

> *"Adapting to climate change is the new reality…Many local governments are already at the centre of this reality; dealing with the effects of thawing permafrost, damaged infrastructure and heat waves. As practitioners of good governance, local governments must develop responses that protect their local citizens, environment and economy."* – Megan Meaney, Director, ICLEI-Canada

ICLEI Canada is the Canadian chapter of an international non-profit association (also called Local Governments for Sustainability)[4] of local governments, including cities, towns and counties. Their "mission is to achieve tangible improvements in global sustainability through cumulative local activities." They highlight some of the reasons why working with a local government on sustainability issues is important, such as, they are the government closest to residents, and they

[4] The 'International Council for Local Environmental Initiatives' became 'ICLEI - Local Governments for Sustainability' with a broader mandate to address sustainability issues (ICLEI web site).

are best able to develop locally tailored and integrated plans. Mechanisms available to a local government to help operationalize strategies include land use planning, licensing and regulation, community service delivery, community engagement, leadership, facilitation and workforce development. These are the mechanisms that enable the integration of climate change adaptation into community planning.

The ICLEI has program areas for both climate change adaption and biodiversity. Within the climate change adaption program area, the ICLEI has developed a process to help communities develop a climate change adaptation plan. In addition, they developed the Adaption Tool an interactive web-based tool that takes users through the Five Milestone process outlined in the ICLEI Canada Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation. There are currently 16 local communities across Canada participating in the ICLEI climate change adaption planning process. Most are large urban centers, like Calgary), or metro-municipal associations, like the Capital Regional District, an association of 13 municipalities on the southern tip of Vancouver Island (ICLEI 2012). The MCCAC website highlights Alberta municipalities interested in developing a CCA plan that will be using the Adaptation Tool.

Within their Biodiversity program area, the ICLEI has also worked with large urban centers to develop biodiversity strategies. It is, however, not clear how the two program areas are integrated as many urban centers have developed both biodiversity and climate change adaptation plans.

Decision support at the local level

Decision support is defined broadly as a “generic term that encompasses all aspects related to supporting people in making decisions" (Nižetic et al 2007). There are three fundamental components to consider when designing a decision support system: the knowledge base (data you plan to use); the decision context (model); and the user interface. Common decision support system purposes include to:

- Support/inform a process;
- Support/inform rather than automate decision making; and
- Enable a rapid response to changing needs of decision makers. (Nižetic et al 2007)

In this section the authors present tools that can support the decision making process in the context of local communities managing for biodiversity and climate change adaptation. Examples are divided into three categories based on whether they are analytical, educational/ data delivery and process oriented decision support tools. Other important considerations when assessing decision support tools include:

- Accessibility (freely available or proprietary, cost, support needs)
- Level of user engagement (level of user interaction); and
- User friendliness (ease of operation, training requirements)

There is a plethora of decision support tools available to help communities adapt to climate change. The tools highlighted below were selected because they either provide information important to climate change adaptation or they represent a sector specific approach that may be informative for developing a climate change adaptation and biodiversity decision support tool. Likely a small community striving to adapt to climate change will use a variety of decision support tools to help inform or lead the decision process.

Mapping tools were not included in this section but are described later in the report.

ANALYTICAL TOOLS

Analytical tools typically enable a user to manipulate data and or a model and produce information to inform a decision.

Ecosystem Valuation toolkit

URL: http://esvaluation.org/

The Ecosystem Valuation toolkit is being developed by Earth Economics, in collaboration with The Ecosystem Services Partnership, academic institutions, governments and NGOs across the globe. Formally known as SERVES it is an easy to use, collaborative, extensible platform for tracking, vetting, and reporting authoritative monetary values for ecosystem services. Earth Economics states the "SERVES v 1.0 beta release in December 2012 will be the world's first global values exchange platform allowing ecosystem service researchers to see and comment on each other's work. It will also be a tool enabling community planners and natural resource managers to access the latest values to support their work investing in natural capital at the local, state and national scales."

Plan2Adapt

URL: http://pacificclimate.org/tools-and-data/plan2adapt

Plan2Adapt is a resource on the ReTooling Climate Change website described above. The Plan2Adapt tool generates maps, plots, and data describing projected future climate conditions for regions throughout British Columbia. It is designed to help users assess climate change in their region based on a standard set of climate model projections. Users can select a desired time period into the future, a region within British Columbia, and a season. The tool produces a summary overview of the expected climate change impacts based on the selected criteria. There are also tabs with more specific information on projected changes to precipitation, temperature, snowfall, growing days, heat degree days, frost free days and impacts. Within then impacts tab, sectors that will be influenced by impacts are listed. For example, a decrease in the snowpack will impact biodiversity, forestry and land use planning.

Water Conservation Calculator

URL: http://waterconservationcalculator.ca/

The Water Conservation Calculator (WCC) is an innovative free, web-based decision-support tool used to illustrate how specific water conservation measures can yield both fiscal and physical water savings for communities in British Columbia. It is an innovative way to help communities more accurately target conservation efforts, thereby increasing the cost effectiveness of conservation programs. This tool is highlighted as it has a user-friendly interface on the web, consisting of a series of forms and data entry points for the user, and produces a series of reports to help decision makers understand cost effectiveness of different water conservation actions.

EDUCATIONAL

The examples below are highlighted as relevant approaches for educating people about climate change adaptation and biodiversity. One of the greatest challenges to climate change adaption is the difficult trade-offs and decisions that will have to made to address the impacts of climate change. The Building Coast-Smart Communities example below is a game-based tool, designed to help stakeholders learn how to negotiate tough agreements related to climate change adaptation. The other example is an innovative way to provide information.

Building Coast-Smart Communities - Wining Public Support for Addressing Climate Change

URL: http://maryland.coastsmart.org/?page_id=114

To help Maryland coastal communities adapt and respond to climate change, Maryland DNR's Chesapeake and Coastal Program (CCP) has initiated the "Building Coast-Smart Communities" project in partnership with the M.I.T. – U.S.G.S. Science Impact Collaborative (M.U.S.I.C.) and the Consensus Building Institute (CBI). MIT developed a role play simulation game designed to help decision makers and community members better relate to and understand climate change adaptation. The purpose of the simulated negotiation is to engage key local and state leaders in difficult conversations about the steps coastal communities can take to adapt to climate change impacts such as sea-level rise, storm inundation and coastal erosion. The simulation is based on a hypothetical Maryland community that reflects the reality of many of our coastal towns and cities.

ICLEI Canada

URL: http://www.icleicanada.org/resources/publications/biodiversity/48-infographic-collection

The **ICLEI- Canada** developed a slogan, `Biodiversity Conservation Starts at a Local Level`` and info-graphic aimed at cities to promote the importance of planning for biodiversity. This was followed by an initiative to help cities develop biodiversity strategies.

Process oriented tools

A number of decision support tools focused on climate change adaptation are process-oriented, helping organizations, local governments or project planners and managers understand the impacts of climate change on a community, assess the vulnerability of the impacts, develop action strategies and integrate the actions into the appropriate processes. The most comprehensive process tool reviewed is the ICLEI, called Adaptation Tool described above ((http://www.icleiusa.org/tools/adapt/adaptation-database-and-planning-tool-adapt). Their Adaptation Tool consists of a series of worksheets with five milestones that result in the development of a climate change adaption plan.

Two others are highlighted here – CRiSTAL and UKip Adaptation Wizard – to show the different needs of user groups. All the examples use a workbook approach, are not spatial and require access to experts and data to inform the process. In other words these tools provide a framework and resources that will help in the generation of information needed by a community to prepare an adaptation strategy.

ICLEI Adaptation Tool

URL: http://www.icleiusa.org/tools/adapt/adaptation-database-and-planning-tool-adapt

See description above.

CRiSTAL

URL: http://www.iisd.org/cristaltool/

The Community-based Risk Screening Tool – Adaptation and Livelihoods) is designed to help project planners and managers integrate climate change adaptation and risk reduction into community-level projects. CRiSTAL is primarily targeted at project planners and managers working at the community level on sustainable livelihoods and ecosystem management and restoration. An example of a project in Kenya concerned sustaining school children's access to safe water in Garissa District.

CRiSTAL consists of a user manual and worksheets in excel and is a free download.

UKip Adaptation Wizard

URL: http://www.ukcip.org.uk/wizard/

The Adaptation Wizard is a web-based tool that is designed to take help users gain a basic understanding of climate change as well as integrate climate risks into their decision-making. It is a high-level, generic tool that is valuable to newcomers to the climate change issue, as well as those who are preparing to adapt. The tool is specifically aimed at the UK context. It is more a decision-support than decision-making tool, and plays a valuable awareness-raising and educational role. The tool does walk users through an economic analysis of adaptation options and scenarios.

APPROACHES TO MAPPING ECOSYSTEM SERVICES, CLIMATE CHANGE ADAPTATION AND BIODIVERSITY

Introduction

Mapping ecosystem services (ES), climate change adaptation (CCA), and biodiversity is an important step in visualizing, analyzing and identifying knowledge gaps of both current and projected landscapes. The purpose of this section is to review the use of mapping tools in a broad sense to determine what is already being done, what lessons can be learned and what limitations exist.

Mapping tools, for the purposes of this section, can be divided into the three major areas of use: 1) process, 2) analysis and 3) education and delivery. Overlap exists across these areas, but in general most mapping tools fit within these uses.

An important distinction is also found in the type of mapping tool for the purposes of this section: *online tools* (used largely through a web browser), and *GIS-based tools* (used either stand alone or through a GIS software application). Online tools tend to be more publicly orientated with a reduced need for specific skills. GIS-based tools tend to be built for and by people with specific skill sets and/or knowledge.

Review process

The internet and literature were reviewed, coarsely, to look for a variety of mapping tools being used in the areas of ecosystem services, climate change adaptation, and biodiversity, with a particular interest in any that worked in one or more of these areas.

The goal of the review was to identify tools the Miistakis team can use, build or learn from as in moving forward with our community level approach to biodiversity management and climate change adaptation in Alberta. Given that the end focus is a community level approach, tools were looked at for their applicability for that purpose.

Given the vast amount of tools available and the preliminary nature with which each tool was reviewed, the authors opted at this stage to compare each tool against a vision of a ‘perfect tool.’ While it is unlikely there is such a thing, conceptually, the perfect tool is defined as one which will:

- Work at a variety of local scales, specifically at a community level in Alberta;

- Be accessible, both financially and technically, to a wide assortment of capacity levels that mirror the realities of communities within Alberta;
- Require data that is readily available and simple to compile;
- Provide what the local community needs, while utilizing what they bring to the table, such as local knowledge;
- Be visually appealing with a friendly and intuitive user interface; and
- Incorporate the needs of ecosystem services, biodiversity management and climate change adaptation

Mapping tools were broken into general types based on observed trends during the review process. The roles of process, analysis and education or delivery were identified and are detailed further below. Further, the difference between online and GIS based mapping tools is considered at a broad level.

Mapping tools

A mapping tool in it's simplest form is any tool that creates a map. Most of these tools will have the ability to view the map interactively with common functionality such as zooming in and out, panning, and identifying features. Mapping tools designed to generate static inputs for analysis may provide no functionality for interactively viewing the output, instead focusing on providing interaction with the decisions driving the analysis.

The use of computers to interactively work with maps and spatial data has been around almost as long as computers, but Geographic Information Systems (GIS) did not gain wider use till approximately 15 years ago. In the last 7 years, since the release of Google Maps API, the increased access to spatial data, reduction in required technical capacity, and an increasing availability of free desktop and online mapping tools, has created a dramatic increase in the use of spatial data in decision making. As a result, the internet contains many examples and approaches on how to use mapping tools, both effective and ineffective.

Online and GIS-based mapping tools

In a broad context the authors differentiate between online and GIS based mapping tools.

Online tools are those that largely use a web browser for interaction and delivery of the mapping tool. GIS based tools are those that utilize a GIS application for the interaction and delivery of the mapping tool.

Online tools tend to be more user friendly for the average user as they are intended for a wider distribution in most cases. Online tools contain less functionality to learn and understand, but as a result, there are fewer ways to utilize the map.

GIS based tools are those that use full spatial tool sets provided by one of the many GIS software applications and toolkits. These tools generally contain the many features required to widely use and manipulate spatial data. They tend to be more complicated and thus not as user friendly for the average user, and typically they are often designed for wide distribution.

As technology continues to progress there is an increasing number of ways to merge Online and GIS based tools, blurring the differences between them, the important goal for the Miistakis team's work with local communities is achieving this while keeping the application user friendly to a wider audience.

PROCESS BASED MAPPING TOOLS

Process based mapping tools are those that facilitate the process being undertaken by the local community and often blend the lines between analysis and education and delivery. These mapping tools help facilitate the discussion primarily through data gathering or visualization.

Two common forms include community-based mapping and citizen science. Community-based mapping is the combined use of GIS tools and facilitated discussion to capture the knowledge of a community spatially. Citizen science is the process of using all interested local citizens to capture specific pieces of spatial information.

Very few tools were found that were specific to the roll of facilitating a process. Community-based mapping is largely done within a GIS environment and as such few tools have been developed. Citizen science on the other hand has many, though very similar, mapping tool examples. Two have been highlighted for further review as they best meeting our ideal criteria.

DataBasin

URL: http://databasin.org/

The DataBasin website describes itself as:

> *Data Basin is a free system that connects you with spatial datasets, non-technical tools, and a network of scientists and practitioners. You can explore and download a vast library of datasets, connect to external data sources, upload and publish your own datasets, connect to experts, create working groups, and produce customized maps that can be easily shared.*

While the DataBasin toolset can easily and effectively be used for education and delivery as well, it is more unique in its roll as a process tool by providing several tools to assist with community-based mapping.

The DataBasin works at any scale, providing the ability to upload your own data or access data shared by others. While available data for Alberta is limited, this is not an unusual situation. Capacity requirements for a local community are low with the tool being free and easy to use with a simple and friendly user interface. Data requirements would depend greatly on the process within which you are working, and be more dependant on the local community than the tool itself.

The DataBasin has a Climate Change Center where information and tools related to climate change have been collected. Ecosystem Service tools are also mentioned as being in development and a wealth of bio-diversity information is available, though often not at an Alberta specific scale.

The tools specific to community-based mapping are somewhat limited at this time. While you can draw features on the map, there are no tools to add information to the feature or export it.

DataBasin is a great tool for its purposes and depending on future needs, this tool should be considered for further investigation.

Wildlife Observation Mapping Tool

URL: http://www.rockies.ca/lib_tools.php

The Wildlife Observation Mapping Tool is a web mapping application created to capture user observations of wildlife related events on a highway, trails, within communities or any landscape where a group wants to monitor wildlife.

This tool was created by the Miistakis Institute and while it does not specifically relate to climate change or ecosystem services, it is a process related tool for the collection of biodiversity and contains the bulk of the features used in the many similar web based applications, many of which were created based on the original version created for Road Watch in the Pass.

The tool works at any scale and was developed in Alberta. It uses readily, and freely available data, with no limits on what local data that a community would wish to add. It is free and easy to use, with a minimal first time install of about 15-30 minutes for someone with basic web programming skills. The interface is simple and friendly to use, with many changes to refine the user experience made over the years.

The success of this tool with the Road Watch in the Pass program (www.rockies.ca/roadwatch) was directly related to the accompanying support, specifically a local community coordinator that was instrumental in the successful use, delivery and promotion at the grass roots level.

This tool and the lessons learned from the Road Watch in the Pass project provide a stable foundation for many possible process related applications.

Analysis based mapping tools

Analysis mapping tools are those that assist a local community with evaluating spatial and spatially-related information. These tools put that information in a local context considering priority, what to include / exclude, and any other required decisions. The outputs of this analysis then become a data source that is used as part of the process, or for education and delivery.

Analysis tools are largely more complex and require a greater understanding of the different issues being considered and the technology being used to run the analysis. These tools often work best in a collaborative and facilitated environment, allowing for a wide use of the application by the stakeholders, while at the same time limiting the technical and informational requirements to just what is needed to run the analysis, based on the feedback of the stakeholders.

Analysis tools are more commonly GIS-based tools that run within specific software applications. This better facilitates the complex operations required to run some analyses.

There was a moderate number of tools available that provided support in this area for one or more of climate change adaptation, biodiversity and ecosystem services.

SimCLIM

URL: http://www.climsystems.com/simclim/

The SimCLIM website describes itself as follows:

> *SimCLIM is an integrated modeling system for assessing climate change impacts and adaptation. SimCLIM is designed to support decision making and climate proofing in a wide range of situations where climate and climate change pose risk and uncertainty.*

As SimCLIM is a purchasable, GIS based, software program it is hard to review, beyond what could be found on the website and the user manual. Overall, the tool seems very interesting in regards to modeling, however there are a number of issues when compared to our 'perfect' tool.

The price tag and technical capacity to run the model would certainly be an issue with some local communities. Scalability is unclear at this point, it appears that users can edit the climate change data, but spatial data is treated as an overlay and not used by the analysis unless you create a custom build of the application for your area. If it is possible to change the underlying data sources to something more locally specific, it is unclear what that data would be and if it is readily available. There was no immediate indication that there was any component in SimCLIM that considered biodiversity.

Overall while this tool looks very interesting from an academic standpoint, there is likely little of value for a program aimed at local communities.

InVEST: Integrated Valuation of Environmental Services and Tradeoffs

URL: http://www.naturalcapitalproject.org/InVEST.html

The InVEST website describes itself as follows:

> *"InVEST is a family of tools to map and value the goods and services from nature which are essential for sustaining and fulfilling human life."*

InVEST is a GIS-based mapping tool that takes spatial and thematic data as inputs, and estimates the value of ecosystem services. While not specific to climate change, the tool integrates biodiversity and ecosystem services.

While InVEST does require a lot of local data and values to run, it is very scalable and will work at the Alberta local community level. The data and technical needs required to run InVEST do create a capacity issue for some local communities. However, it is designed to run in a stakeholder-driven decision support process and as such not everyone involved would be required to understand and use InVEST as long as they understood the outputs.

InVEST is a great tool for its purposes and depending on future needs, this tool should be considered for further investigation.

ARIES: ARtificial Intelligence for Ecosystem Services

URL: http://www.ariesonline.org/

The ARIES website describes itself as follows:

> *"**ARIES** is a web-based technology offered to users worldwide to assist rapid ecosystem service assessment and valuation (ESAV). Its purpose is to make environmental decision making easier and more effective. ARIES helps users discover, understand, and quantify environmental assets and the factors influencing their values, for specific geographic areas and based on user needs and priorities."*

ARIES looks very promising and incorporates all three themes of climate change adaptation, ecosystem services and biodiversity. The online mapping tool on preliminary view looks user friendly and easy to use. The application however is still in alpha stage of testing and has no Canadian – let alone Alberta – case studies. Further all attempts to use the mapping application resulted in an error, making it hard to evaluate to any level of detail.

This application is worth looking at again in more detail, depending on future needs, though it may be this application will not be ready to be used in time.

Developable Lands Mapping Tool

URL:
http://www.rockies.ca/files/reports/Developable%20Lands%20Mapping%20Tool%20Report.pdf

Developable Lands is a GIS-based application developed by the Miistakis Institute, to facilitate a stakeholder decision support process in the Crowsnest Pass to determine where best to develop when evaluating a set of economic and environmental priorities.

While this tool was not designed with relation to climate change adaptation or ecosystem services, it is an excellent example of a mapping tool designed for use at the local community level. Simple and easy to use, with a friendly and appealing interface, the application was designed to use with stakeholders to analyze a series of input layers based on the priorities of the group. The data requirements are low, with a small amount of technical capacity required to setup the data for use by the mapping tool.

Originally developed for use within ArcGIS, a future version of the application was built in a free and open source application, Quantum GIS. This allowed the application to be shared freely with all stakeholders. A web version was determined to be feasible, but not developed.

While this tool will not be directly useful for the future needs of this sub-project, the lessons learned and the underlying structure will provide a solid foundation if any new tools need to be developed.

EDUCATION AND DELIVERY MAPPING TOOLS

Education and delivery mapping tools make up the most common and often used type of online mapping tools, and the most widely-used form of maps in general. These tools allow data to be displayed in a way that allows for the visualization of complex spatial themes in a manner that is easily observed and understood by a user group. They come in many forms, either as printable or electronic maps and images and interactive mapping applications. They tend to be easy to use, understand and share.

In general these mapping tools are all very scalable and used in a wide variety of ways. The technical and financial capacity requirement is very low, with little more then basic internet required. Data requirements are specific to the data you wish to share and as such assumed to be readily available. To be useful and serve their purpose these tools are required to be visually appealing and user friendly, though not all of them succeed at this goal.

Most of these tools are fairly straight forward, often allowing the user to view the important data in relation to other data. However some provide interactive interfaces by asking a series of questions about the data, and then tailoring the data to the user’s needs.

Very few tools served the needs of more then one of ecosystem services, biodiversity, and climate change adaptation.

A few examples of related sites are:

Ecosystem Services - Carbon Calculator

URL: http://www.carbon-biodiversity.net/Interactive/CarbonCalculatorNotes

The website describes itself as follows:

> *"This innovative tool provides users with initial estimates of carbon values for existing protected areas or any polygon drawn on a global map."*

NatureServe Explorer

URL: http://www.natureserve.org/explorer/

The website describes itself as:

> *"an authoritative source for information on more than 70,000 plants, animals, and ecosystems of the United States and Canada. Explorer includes particularly in-depth coverage for rare and endangered species."*

Environment Canada Scenario Maps

URL: http://www.cccsn.ec.gc.ca/?page=viz-maps

This is not a particularly visually appealing or user friendly interface, but it displays the variety of climate change information available and creates map outputs based on the users inputs.

Local community capacity

A significant issue with providing tools to any large user group is dealing with the different levels of capacity. ArcGIS for example is a powerful and commonly used GIS application. It is also propriety, expensive, and relatively complex to use. Many smaller local communities would not be able afford or use ArcGIS.

In order to ensure a tool is useful to all levels of capacity, it may be desirable to stick with free and open source based applications. It is entirely feasible to use propriety software to create information to deliver to local communities. For example, on might use a proprietary software to create climate change data that is shared with communities, but the community would not need to purchase or use the software unless they wished to make their own modifications.

Many of the issues surrounding climate change adaptation, ecosystem services and biodiversity are complex and require expert knowledge to fully understand. A mapping tool will need to distill that expert knowledge and provide the result in manner that is clear and concise to the average decision maker.

Summary

Mapping tools are most widely used to deliver results or educate the user by providing a means to visualize the results of the overall process it was designed for. Mapping tools availability and focus varied based on the topic, as outlined below.

Biodiversity mapping tools are largely educational in nature, providing the user with access to information about the spatial distribution of species. This could be for specific species like NatureServe, or it could be models that calculate species richness or hotspots. Biodiversity tools are common in both online and GIS based forms. There are more biodiversity tools than climate change or ecosystem services tools.

Ecosystem Service mapping tools seem to be in their infancy with a much smaller volume of available examples. This could be the newer nature of the topic of Ecosystem Services, but also because it is a harder concept to convey easily in a mapping tool. Data requirements of Ecosystem Services are fairly high, specifically on valuing services on the landscape. Most Ecosystem Service map tools are GIS based at this time.

Climate change related mapping tools were largely focused on displaying complex climate data in various ways that impact the user. As the topics are complex, the mapping tools themselves were very complex. Simple online mapping tools were mostly limited to displaying climate data back in various forms, with GIS based mapping tools predicting change and climate change adaptation risks. For the most part, climate change adaptation referred to the adaptation of humans and society to the risks of climate change, not the adaptation of the natural world.

Conclusions

There is a wide variety of potentially-applicable mapping tools in existence, many of which do an excellent job representing various areas impacting climate change adaptation, biodiversity and ecosystem services. It is important, given the varying capacity levels of the local communities, that tools are user friendly and easy to use by a wide audience. One of the common mistakes observed is attempting to make one tool do all things.

As such it appears the best approach for this sub-project would be to create a mapping toolkit, rather then a specific mapping tool. In any process, different tools will be required at different stages. Rather then create one tool that bundles every feature each of those processes requires, it could be beneficial to create or identify multiple tools designed for specific purposes. This allows the tools to be smaller, more focused to the specific task and as a result easier to use and understand.

Creating a toolkit of different tools, rather then one big tool, also provides the opportunity to leverage existing tools that work well for specific purposes, but not others. In other words, there is no one tool that will do everything required, but there may be (e.g.) four tools that do 90% of what is required.

The next step moving forward would be to identify the steps of the process that require mapping tools, identify specifically what those needs are at each step, then go back over our review to see what tools, if any, fit those needs. Tools can then be modified or created as required to meet the needs of the project.

PRELIMINARY REVIEW OF POTENTIAL DATA SOURCES

Several choices remain to be made around the decision support tool that is developed: identification of a local community, selection of biodiversity/climate change aspects to address, functionality and features of the tool, etc. Regardless of the choices ultimately made, some initial broad conclusions can be drawn about the general types of data that will be required, and some of the challenges that can be expected in meeting these data needs.

It bears mention at the outset that the lists of possible data sources below are not intended to be complete or exhaustive. As the Miistakis team's approach becomes more clearly defined, the search for suitable data and information can be directed with a clearer focus. The next report (Report 2) will include a list of the actual data sets that will be used, a description of their relative strengths and shortcomings, and an identification of any data gaps.

What follows is intended to give a sense of the types of data available, and some of the options that exist.

General data requirements

Several general types of data will be required by any tool. These can be divided into two broad categories: present conditions and future conditions.

PRESENT CONDITIONS

'Present Conditions' data can be characterized as data that describes the current conditions of the landscape around the local community. These will include: land cover data, land use data, and biodiversity data.

Land cover data

Land cover data are data that depict the soils, geology, vegetation, plant communities, wetlands, water, snow and ice, and other natural elements of the landscape. Potential sources for this data include:

ABMI Wall-to-Wall Land Cover Map

In 2012, the Alberta Biodiversity Monitoring Institute(ABMI) released version 2 of its Wall-to-Wall Land Cover Map[5] describing it as the "best-available complete representation of Alberta's land cover currently available". The ABMI product combines two land cover data sets (EOSD for the forested areas, and AAFC (formerly PFRA) for the agricultural zones), and augments these data with anthropogenic features (primarily roads, urban areas, and industrial areas). The Alberta landscape is mapped according to 18 land cover classes. The ABMI product is less thematically detailed (and possibly lower spatial resolution) than the other two options listed below, but it is reasonably accurate and possesses the advantages of covering the entire province and of being easy to use and interpret.

Grasslands Vegetation Inventory (GVI)

Alberta Environment and Sustainable Resource Development (AESRD) is in the process of creating a detailed Grasslands Vegetation Inventory (GVI) for the grassland regions (White Zone) of the Province of Alberta (ASRD 2010). The GVI covers most of the grassland region of southern Alberta, and provides current and detailed land cover data (composition of plant communities, native prairie, etc.) that may be of use to this project. There are challenges associated with using the GVI data, most notably coverage (GVI does not cover all of southern Alberta), specificity of the data (GVI is very good at describing grassland ecosystems, but not useful in describing forested landscapes), and ease of use (GVI is a complex data set that can be difficult to interpret and apply to some situations).

Alberta Vegetation Index (AVI)

Alberta Sustainable Resource Development (ASRD) produced the Alberta Vegetation Index (AVI) in the late 90's (Nesby 1996). AVI covers portions of the Green Zone of the province, and was developed for Government of Alberta conservation initiatives and for administration and monitoring of the Provincial Forest Management Agreements. The AVI data is somewhat dated, but could be augmented with data from other sources to make it more current (e.g. forestry cut block data, fire history maps, etc.). The limitations of AVI mirror those of the GVI, described above: it was designed for mapping forested landscapes and thus describes grassland ecosystems quite poorly; and its coverage is limited to portions of Alberta's Green Zone. Also, deriving certain types of information from AVI polygons can be challenging.

[5] Available at http://www.abmi.ca/abmi/rawdata/geospatial/landcoverdownload.jsp

Land use data

Land use data are data that describe the anthropogenic footprint. Since different types of land use correspond to markedly different impacts, it is important to have data that differentiates between land uses. Furthermore, different land uses may impact specific factors related to biodiversity or ecological function very differently (e.g., clear-cuts may be detrimental to deer, but somewhat advantageous to bears). It will therefore be important to carefully consider how land use data is incorporated into whatever mapping applications are developed. Numerous sources for land use data exist. Some of the key ones are described below.

ABMI Human Footprint Map

ABMI is working on compiling data from various sources into a uniform, standardized, province-wide Human Footprint Map[6] (ABMI 2011). The beta version is completed for the eastern (up to the 5th Meridian) and far northern portions of Alberta. A full updated (current to 2011) version is in progress, and may be available for use in this project. If so, this would be the best land use data for this sub-project's mapping applications, as any other data sources listed below were used to create the ABMI data set (ABMI 2011).

Base Features

The Spatial Data Warehouse, through AltaLIS, maintains Base Features layers depicting many aspects of land use throughout the province (transportation infrastructure, pipelines, seismic cutlines, etc.). These data are not free, except through special agreement with the Government of Alberta which may be obtainable for work on this project.

Digital Integrated Disposition System (DIDS)

The Government of Alberta maintains a spatial data record of every disposition that occurs on public lands, and stores these data in the Digital Integrated Disposition System (DIDS). DIDS only covers public (Crown) lands within the province, and may not be available.

CanVec

Natural Resources Canada's Centre for Topographic Information has released the CanVec data product freely to the public, through the GeoGratis[7] web site. CanVec creates a nation-wide standardized set of reference layers (topography, administrative boundaries, land use, etc.) from the NTDB (National Topographic Data Base – a digital version of NTS topographical maps) and

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[6] Available at http://www.abmi.ca/abmi/rawdata/geospatial/humanfootprintdownload.jsp

[7] Available at http://geogratis.cgdi.gc.ca/geogratis/en/collection/detail.do?id=5460AA9D-54CD-8349-C95E-1A4D03172FDF

various other sources. The data are general and not current (currency varies for each NTS map sheet), but it is free and may be a suitable option for gap-filling if higher-quality data is not available.

NEW DATA

If data that accurately describes land use is unavailable, Miistakis has the capacity to create new data for the specific purposes of this project. This is usually done through the analysis of satellite imagery, the processing and digitization of information from other sources (hard copy maps, reports, tables, etc.), or field-collection/surveying using a GPS (e.g., delineating fence lines).

Biodiversity data

Biodiversity Data are data that relate to the current ecology of the landscape. Linking these data to the ecosystem services (ES) that they provide may increase the potential utility of the mapping tool for local communities; however, this would require an additional level of analysis, since no ES-related spatial data currently exist for Alberta.

Data in this category may relate to the habitat requirements or ranges for plant or wildlife species, and may be drawn from a variety of sources, including those described below.

OTHER SUB-PROJECTS

The other sub-projects of the Biodiversity Monitoring and Climate Change Adaptation Project are aimed at compiling biodiversity data that will likely be useful to the development of the sort of mapping tool envisoned by the Miistakis team. For example: Chris Shank is leading the compilation of range data for 125 priority species; Erin Bayne and Scott Nielson (with Diana Stralberg and Jessica Stolar) are collecting data and building distribution models related to avian and terrestrial wildlife and plant species; and Shauna-Lee Chai is leading the mapping of invasive plant species throughout the province. The utility of each of these data sets will hinge on the choice of local community, the application of the proof-of-concept, the mapping tool approach chosen, and the ultimate form of the data sets.

ALBERTA BIODIVERSITY MONITORING INSTITUTE (ABMI)

Through its regular grid of sample locations and rotational survey schedule, ABMI maintains a series of biodiversity data. Depending on the location and application chosen, these data may be used in the mapping application.

Alberta Conservation Information Management System (ACIMS)

Alberta Tourism Parks and Recreation (ATPR) maintains the Alberta Conservation Information Management System (ACIMS)[8], a member program of NatureServe Canada. ACIMS is a province-wide repository for observations of rare plant and animal species, ecological communities, and landform elements. ACIMS data relies on input of observations from various sources, and since it is not created through a systematic or exhaustive survey, is challenging to use as a continuous input data layer. However, it may be pragmatic to use ACIMS observations combined with other ancillary data (topography, landform, soils, landcover, etc.) to infer the potential distributions of species/communities of interest Nielson, pers. Comm. 2012).

Miistakis Institute

In portions of southern Alberta, Miistakis has been active in the establishment of community-based monitoring or citizen science projects, the goal of which is to generate useful data on the distribution of wildlife or plant species. Some of the data already collected may be useful to this project; alternatively, this sub-project may consider the creation of a new community-based monitoring tool as a means to create useful data, or augment existing data resources.

Future conditions

'Future conditions' data can be characterized as spatial data that predict the anticipated future changes to land use, land cover, or biodiversity. The temporal scale of future forecasting is an important consideration here, and will be determined by the choice of local community and aspects of biodiversity on which to focus.

Future conditions can be linked to three root causes, each worthy of consideration.

Climate change

Changes to the natural landscape that result from human-induced climate change. These will rely heavily on the results of Chris Shank and his team's work on climate change vulnerability, and will tie into anticipated changes to the priority species' distributions in response to the climate changes predicted by the chosen model.

Population growth

With anticipated population growth in Alberta, and regardless of the land-use planning that occurs in our province, significant changes to the anthropogenic footprint can be expected. The

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[8] Available at http://www.albertaparks.ca/albertaparksca/management-land-use/alberta-conservation-information-management-system-%28acims%29/overview.aspx

work of the ALCES® Group (www.alces.ca) may prove useful in allowing us to forecast and capture the impacts of population growth. Other potentially useful resources include the work of the Provincial Land Use Secretariat[9], or of broader-scale population growth forecasting initiatives like the Gridded Population of the World (GPW) database[10].

Natural ecological change

Independent of response to a changing climate, a certain amount of change in the composition and distribution of plant or wildlife species and communities may be expected. The significance of this type of change will likely vary depending on the species or ecological factors being considered, and on the location of the selected community. Incorporation into our mapping tool will rely on the expertise of regional and local ecologists, from both within and outside of this project.

General data considerations

The quality and availability of spatial data will be key factors that influence the specific tool, model, and approach the Miistakis team chooses to develop. The following are some important considerations regarding spatial data.

The Alberta context

Even in instances where good-quality data is available, access to spatial data in the Province of Alberta has been a perennial challenge. Data sets that are free and accessible through the internet in neighbouring jurisdictions (British Columbia, Saskatchewan, or especially the United States) are sometimes challenging to discover in Alberta; when discovered, they often come at a substantial or prohibitive cost. ABMI and other organizations are working to remove barriers to data access within Alberta, and the Government of Alberta is making tentative first steps into the realm of open access. Furthermore, our partnership with the Provincial Government on this project should allow for easier access to Government of Alberta data products. Our objective is to build a functional and effective map-based decision support tool with the best data that can be found and obtained freely, or at an acceptable cost.

Data richness

In general, the spatial data that is available in Canada is inferior to that of many other regions of the developed world (e.g. United States, Europe, Australia, etc.). In some cases, the decision support tools that have been developed in other regions have a heavy bias towards, and reliance on, this higher-quality data. This presents an interesting challenge when trying to apply tools in

[9] Available at https://www.landuse.alberta.ca/Pages/MapsShapefiles.aspx

[10] Available at http://sedac.ciesin.columbia.edu/data/collection/gpw-v3

Alberta that have been developed in other, more data-rich environments. In order of preference, our solution to this challenge lies either in: 1) the selection of an appropriate, data-scalable model that can employ lower-quality data; 2) the adaptation or modification of an existing model/approach to the data constraints faced in Alberta; or 3) the development of a new approach that is constrained by the quality and availability of data.

Ubiquity

The quality and availability of data is not uniform across the province. Some regions have exceptionally high-quality data (e.g., Rockyview County's Wetland Inventory, or southern Alberta's GVI (see above)), whereas others have only the most basic, provincial- or national-scale data. In the context of developing a decision support tool that demonstrates a proof-of-concept that is accessible, achievable and replicable, this sub-project faces a dilemma: develop an application that works in one local community because they have exceptionally good data, or opt for a tool that works with the "lowest common denominator" of Alberta data.

The best solution lies in finding the proper balance between these two extremes. The goal is to create a 'pilot' application that has the capability to be replicated in a broad range of communities, to address a broad range of questions. However, this sub-project will seek to take advantage of superior data if it is available, and perhaps even use the creation of this tool as leverage to encourage other regions of the province to create higher-quality data.

CONCLUSIONS

This report is an interim report, intended to recap the research undertaken thus far, articulate the decisions and conclusions made, and provide a basis for the next steps. This section is the bridge between this report (*Review of Possible Tools for Local Adaptation for Climate Change in Alberta*) and Report 2 (*Proposed Tool Structure for Local Adaptations for Climate Change in Alberta*). The following are general observations made to date (including identified challenges) regarding models for decision support, data and mapping in the context of local communities seeking to manage for biodiversity in the face of a changing climate.

The recommendations included are preliminary and cross-cutting, seeking to establish a realistic yet useful scope for this sub-project as it moves forward.

Observations

In general, the review found that literature on climate change adaptation and biodiversity management is increasing, though very few papers suggest processes for actually developing a climate change adaptation plan. The review also found that change adaptation is considered a new approach, as many conservation managers have and continue to focus on *mitigation* programs to reduce emissions. Tools and resources to help develop CCA plans are needed at all scales, and many of the recommended biodiversity management strategies in relation to CCA are already available. Ultimately, there is a need to help decision makers at the local and regional level integrate climate change adaptation and biodiversity management into existing land use plans and policy documents.

Decision Support

There is a plethora of decision support tools available to help communities adapt to climate change; the challenges revolve around effectively applying them. Arguments for biodiversity conservation and climate change adaptation are not intrinsically compelling for local decision makers as they are in many ways antithetical: these two concepts are necessarily described at a large scale, and local decision makers are by definition focused on the smaller scale. Few tools marry biodiversity management and climate change adaptation, and even fewer further consider ecosystem services. Those focused on climate change, tend to favour emissions reduction versus proactive adaptation strategies.

Structurally, there are three fundamental components to consider when designing a decision support system: the knowledge base (data you plan to use); the decision context (model); and the user interface. However, these are often not adequately addressed, or are inequitably addressed (e.g., a focus on the knowledge with little focus on the interface).

The public, political and government discourse in climate change adaptation is still in the early phases in Alberta. The Government of Alberta's 2008 Alberta Climate Change Strategy identified an action to develop a Provincial Adaptation Strategy, but it is still in development. Alberta Environment's (AENV) focus on climate change adaptation was traditionally through grassroots initiatives around water management and protection. Other departments are addressing climate change adaptation, but appear not to be tied to a provincial climate change adaptation program (e.g., Alberta Agriculture and Rural Development (AARD) projects). The review of Alberta climate change adaptation projects highlighted the lack of discourse around climate change adaption at both the political and government staff level, and a need for a cross-ministerial approach to climate change adaptation (which may be occurring through the Alberta Climate Change Adaptation Team (ACCAT)).

A review of efforts by Alberta municipalities to address climate change adaptation produced very few results, with the exception of the Municipal Climate Change Action Center (MCCAC). It is the authors' impression that climate change adaptation is not high on the priority list for municipalities in Alberta, likely due to lack of direction from the province and other priorities taking precedence.

Data and information

Although this sub-project has not moved into active data collection, there are some general observation that can be made.

The quality and availability of data is not uniform across the province. Some regions have exceptionally high-quality data, whereas others has only the most basic, provincial- or national-scale data. Access to spatial data in the Province of Alberta has been a perennial challenge, as data sets that are free and accessible in neighbouring jurisdictions are sometimes challenging to discover in Alberta, and often come at a prohibitive cost. In general, the spatial data that is available in Canada is inferior to that of many other regions of the developed world. In some cases, the decision support tools that have been developed in other regions have a heavy bias towards, and reliance on, this higher-quality data.

Ultimate decisions on the data needed, and thus the extent to which these challenges will be a factor, will be dependent on the decision and mapping tools chosen.

Mapping tools

Mapping biodiversity, climate change adaptation and ecosystem services is an important step in visualizing, analyzing and identifying knowledge gaps of both current and projected landscapes. However, many of the issues surrounding climate change adaptation, ecosystem services and biodiversity are complex and require expert knowledge to fully understand. A mapping tool will need to distill that expert knowledge and provide the result in manner that is clear and concise to the average decision maker.

Biodiversity mapping tools are largely educational in nature, providing the user with access to information about the spatial distribution of species. This could be for specific species like NatureServe, or it could be models that calculate species richness or hotspots. Biodiversity tools are common in both online and GIS based forms. There are more biodiversity tools than climate change or ecosystem services tools.

Ecosystem Service mapping tools seem to be in their infancy with a much smaller volume of available examples. This could be the newer nature of the topic of Ecosystem Services, but also because it is a harder concept to convey easily in a mapping tool. Data requirements of Ecosystem Services are fairly high, specifically on valuing services on the landscape. Most Ecosystem Service map tools are GIS based at this time.

Climate change related mapping tools were largely focused on displaying complex climate data in various ways that impact the user. As the topics are complex, the mapping tools themselves were very complex. Simple online mapping tools were mostly limited to displaying climate data back in various forms, with GIS based mapping tools predicting change and climate change adaptation risks. For the most part, climate change adaptation referred to the adaptation of humans and society to the risks of climate change, not the adaptation of the natural world.

Mapping tools can be broadly classified as *Online tools* or *GIS-based tools*. Online mapping tools tend to be more user friendly, are intended for a wider distribution, but contain less functionality and have fewer ways to utilize the map. GIS based tools contain the many features required to widely use and manipulate spatial data, but tend to be more complicated, less user friendly, and more expensive for the community user. In the last 7 years, since the release of Google Maps API, the increased access to spatial data, reduction in required technical capacity, and increasing availability of free desktop and online mapping tools, has created a dramatic increase in the use of spatial data in decision making. As technology continues to progress there is an increasing number of ways to merge Online and GIS-based tools, blurring the differences between them.

A significant issue with providing tools to any large user group is dealing with the different levels of capacity. ArcGIS for example is a powerful and commonly used GIS application. It is also propriety, expensive, and relatively complex to use. Many smaller local communities would not be able afford or use ArcGIS. As well, very few tools were found that were specific to the roll of facilitating a community-based process.

Recommendations

Community-based Climate Change Adaptation Action Plan

During this review, the authors noted that several communities (e.g., local towns, municipal districts or watersheds) have developed climate change adaptation action plans. These plans state the direction forward for a community to adapt to a changing climate and address strategies in consideration of land use practices, water use, transportation, infrastructure and economy. Many of the plans the authors reviewed had developed strategies that are beneficial to the maintenance or restoration of biodiversity. An action plan is an initial step in helping communities adapt to climate change. Alberta appears to be lacking a framework for local governments to address climate change and the authors did not find examples of CCA plans in Alberta. The authors feel this an important gap to fill in Alberta as CCA action plans will enable communities to plot a path forward.

Community = geographically-defined, rural municipality

Because climate change adaptation is a complex problem with profound societal and ecosystem impacts, and the need for government direction is beneficial to ensure integration of strategies at multiple planning levels and across disciplines, the authors prioritized the review of cases on how provincial and local governments are addressing climate change adaptation, and then considered examples where the community is defined as a group with common interests. This approach reflects the following conclusions:

- Community selection should be geographic in scope as many community associations (watershed groups, agriculture, energy industry) are already exploring climate change adaptation;
- The results of CCA plans for different sectors will be important resources for developing small scale community CCA plans;
- Rural municipalities represent a very important player in the successful implementation of climate change adaptation strategies on the ground, because they are responsible for land use planning and policy decisions at a local level; and
- There are gaps in Alberta at the rural municipal level, because land use planning decisions and policy at the scale of municipality are currently not considering climate change adaptation in Alberta.

For these reasons, the authors feel that the 'community' chosen for the purposes of this project should be a rural municipality, and should be considered jurisdictionally first (i.e., County X), but also geographically (i.e., the diverse community that lives within the county boundary).

Mapping toolkit

The authors opted at this stage to compare each mapping tool against a vision of a 'perfect tool.' While it is unlikely there is such a thing, conceptually, the perfect tool was defined as one which will:

- Work at a variety of local scales, specifically at a community level in Alberta;
- Be accessible, both financially and technically, to a wide assortment of capacity levels that mirror the realities of communities within Alberta;
- Require data that is readily available and simple to compile;
- Provide what the local community needs, while utilizing what they bring to the table, such as local knowledge;
- Be visually appealing with a friendly and intuitive user interface; and
- Incorporate the needs of ecosystem services, biodiversity management and climate change adaptation.

The review of mapping tools found many high-quality, single-issue tools, and conversely several comprehensive, low-resolution or low-function tools. As such it is recommended that the approach taken be to create a *mapping toolkit*, rather than a specific mapping tool. In any process, different tools will be required at different stages. Rather then create one tool that bundles every feature each of those processes requires, it could be beneficial to create or identify multiple tools designed for specific purposes. This allows the tools to be smaller, more focused to the specific task and as a result easier to use and understand.

Ecosystem services

Ecosystem services may be the best way to connect biodiversity and local decision making. The 'utilitarian' character of the ecosystem services approach resonates with the majority of Albertans (who do not consider themselves active conservationists). This characteristic also resonates with local decision makers, and they can more readily equate existing plans and policies with ecosystem services. Though relatively new, the concept is already well ingrained in provincial policy discussions.

Ecosystem services are also based almost entirely on biodiversity, and could be key to proactive adaptation strategies that seek to increase the resilience of the ecological systems.

Many communities are already taking actions that promote maintaining/restoring biological resilience (conservation plans that protect key linkages, riparian restoration projects, etc.), but CCA is not the reason. Linking biodiversity data to the ecosystem services (ES) that they provide may increase the potential utility of the mapping tool for local communities; however, this would require an additional level of analysis, since no ES-related spatial data currently exist for Alberta.

Next steps

Several choices remain to be made around the decision support tool that is developed including identification of a local community, selection of biodiversity/climate change aspects to address, selection of community-based climate change adaptation approach, and functionality and features of the mapping tool. Report 2 will also include a list of the actual data sets that will be used, a description of their relative strengths and shortcomings, and an identification of any data gaps.

These tasks will require solidifying the approach for selecting a local community and doing so, identifying a suite of local-level decisions and their links to biodiversity health, and determining how to identify data needs.

The goal is to have a process, a community, and a conceptual tool design completed for the end of year one; all of which will be described in Report 2. Some known next steps are described below.

Community-based climate change adaptation

Immediate steps in designing a community-based climate change adaptation approach would include:

- Following up with MCCAC about Alberta municipalities interested in working with the ICLEI and their Climate Change Adaptation Process;

- Exploring more formally ways to engage communities in climate change adaption and biodiversity (i.e., BC Simone Fraser ACT recommendation of using an ecosystem goods and services approach).
- Undertaking a more detailed review of CCA plans for smaller communities.
- Following up with the ICLEI to explore how Climate Change Adaptation Plans and Biodiversity Plans are integrated; and
- Interviewing Alberta municipalities to understand their interest in developing climate change adaption plans.

Mapping toolkit

The next steps in the development of an applicable mapping toolkit approach will be to identify the steps of the process that require mapping tools, identify specifically what those needs are at each step, then go back over the review to see what tools, if any, fit those needs. Tools can then be modified or created as required to meet the needs of the project.

Policy linkages

The Miistakis team will follow up on the progress of Alberta Climate Change Adaption Plan spearheaded by AESRD, and explore other initiatives addressing climate change adaptation within the Government of Alberta. The goal will be to better understand the potential linkages between the local-level decision support tool and the policy level goals of the Government of Alberta.

Report Two

The Miistakis team will deliver the second report on February 28, 2013, *Proposed Tool Structure for Local Adaptation for Climate Change in Alberta*. Based on the research in the first report, and the feedback from the project team, this second report would propose a tool architecture and supporting approach to be pursued during years two and three.

There are numerous ways that a decision-support tool for local adaptation for climate change could be framed. The role of this report would be to narrow that range, and make specific statements about the parameters to bound the approach to be taken by this project. The report would reflect final decisions on the:

- Discrete role the decision support tool for this project would play;
- Suitable “local community” for the purposes of this project;
- Appropriate decision suite which this tool would support;
- Suite of biodiversity / ecosystem service features to be mapped as part of decision support tool;
- Data inputs best suited to this tool; and
- Conceptual tool structure and interface.

As well, this report would outline how this tool relates to the vulnerability assessment, and how it responds to the articulated Government of Alberta policy goals on climate change adaptation.

It is important to note that this tool would *not* integrate all climate change adaptation data and information made available through the other sub-projects, and would *not*, in its detailed form, be usable for all climate-change-related decisions, nor all communities that might be seeking support in those decisions.

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APPENDIX 1: STAUNDINGER ET AL (2012) SUMMARY OF IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

Quoted from Staudinger et al (2012); p.2-37 – 2-39

2.6. SYNTHESIS OF IMPACTS ON BIODIVERSITY

Climate change is having, and will continue to have, widespread and varied impacts across all components of biodiversity. The wealth of information gained from recent studies reinforces the main conclusions of the 2009 national Climate Assessment, and provides a more comprehensive understanding of the complex ways that biodiversity is responding and adapting to climate change. New technologies and approaches have largely been responsible for increasing our abilities to detect and evaluate biological and evolutionary responses to climate change, and have enabled new insights into past impacts on modern biogeography (Hoffmann and Sgro, 2011; Sandel and others, 2011). Here we summarize our knowledge of the current and future impacts of climate change on biodiversity, key vulnerabilities and risks, and potential strategies that may be implemented to reduce risk.

Climate change is causing many species to shift their geographical ranges, distributions, and phenologies at faster rates than were previously thought however, these rates are not uniform across species. In the Northern Hemisphere, springtime temperatures are advancing by an average of 2.08 days/decade in the oceans and by 1.46 days/decade on land; most, but not all, marine and terrestrial populations are advancing their springtime phenologies to track these warming patterns. The velocity of range shifts for marine taxa exceeds those reported for terrestrial organisms, leading to numerous local extinctions in sub-polar regions, the tropics, and semi-enclosed seas. Together with invasions from warmer latitudes, these extinctions are expected to result in species turnover of greater than 60 percent in the world oceans. New evidence suggests that terrestrial organisms are moving up in elevation at rates 2 – 3 times greater than was previously estimated (Burrows and others, 2011; Chen and others, 2011).

However, geographical range and distribution shifts are not consistent among species and populations, and some are not shifting at all. Species and populations that are unable to shift their geographic distributions or have narrow environmental tolerances are at an increased risk of extinction.

Increasing evidence suggests that range shifts and novel climates will result in new community assemblages, new associations among species, and promote interactions that have not existed in the past. Shifts in the seasonal and spatial distributions of flora and fauna within marine, aquatic, and terrestrial environments would result in trophic mismatches, asynchronies, and altered population dynamics. New species assemblages would substantially alter the structure, function, and flow of energy through ecosystems. Biological interactions are complex, difficult to predict, and have resulted in counterintuitive outcomes.

Differences in how organisms respond to climate change determine which species or *populations will benefit (winners), and which will decline and possibly go extinct (losers) in response to climate change.* There is increasing evidence of population declines and localized extinctions that can be directly attributed to climate change. This is in part because there are both biotic (for example, genetic) and abiotic (for example, habitat) limits to the degree to which organisms and systems can cope with climate change. Environmental and ecological shifts caused by climate change may be favorable to some elements of biodiversity thereby promoting range and population growth. Species turnover is projected to be greatest at high latitudes and at high altitudes as organisms move poleward, up in elevation, and decline due to loss of suitable habitat. The cumulative effect of climate change is projected to result in a net loss of global biodiversity.

The potential for biodiversity to respond to climate change over short (plasticity) and long (evolutionary) time scales is enhanced by increased genetic diversity; however, the rate of climate change may outpace species' and population's capacity to adjust to environmental change. Climate induced range shifts and population declines are expected to increase the prevalence of population bottlenecks, and reduce genetic diversity within and among species. Long-lived species are particularly vulnerable to climate changes because they experience longer generation times, lower population turnover rates, and slower rates of evolution. The potential for biodiversity to cope with the impacts of climate change can be maximized by maintaining high genetic diversity among and within species and population, conserving environmental heterogeneity, and reducing barriers to dispersal.

Identifying highly vulnerable species and understanding why they are vulnerable are critical to developing climate change adaptation strategies and reducing biodiversity loss in the coming decades. Biodiversity's exposure, sensitivity, and adaptive capacity to climate change is very likely to be non-uniform across the United States, thus different organisms and ecosystems face greater risk of loss than others. Ecological specialists, species that live at high altitudes and latitudes, and species that live at or near their thermal limits are particularly vulnerable to climate change. Climate-induced changes in species' abundance, can lead to local and global extinctions that have consequences for ecosystem function and services. Human responses to climate change have the potential to exacerbate impacts on biodiversity; therefore, mangers need to integrate risk-based analyses and adaptation principles into their decision making process.

Existing environmental regulations currently lack criteria for categorizing the degree of species imperilment posed by climate change, and how those considerations factor into listing or delisting species once they are recognized under governmental protection. Vulnerability Assessments and other decision support tools will be critical to identify species most at risk to climate change, and to develop adaptation strategies that reduce extinction potential; however many of these frameworks are still being tested.

As *species shift in space and time in response to climate change, effective management and conservation decisions require consideration of uncertain future projections as well as historic conditions.* Human responses to climate change can have unintended impacts on biodiversity.

Therefore, risk-based framing, scenario development, and engagement of stakeholders will be essential in enhancing our ability to respond to the impacts of climate change. Furthermore, greater coordination among observations, databases, modeling, and policy mechanisms will increase our ability to detect, track, project, and understand climate induced changes in biodiversity.

Broader and more coordinated monitoring efforts across Federal and State agencies are necessary to support biodiversity research, management, assessment, and policy. Evaluating status, trends, and gaps in national and global biodiversity will require integrated research and monitoring efforts as species and ecosystem boundaries shift due to climate change. Existing monitoring networks could be improved by integrating biodiversity and climate observations, data networks, models, and policy frameworks to detect and attribute the impacts of climate change on biodiversity.

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APPENDIX 2: INTEGRATING BIODIVERSITY AND CLIMATE CHANGE IN THE CONTEXT OF ECOSYSTEM SERVICES

Climate change, biodiversity, local communities, natural capital, resilience and ecosystem services are common terms in the field of conservation science and design, and they have intuitive conceptual linkages. However, developing applied programs that promote ecological conservation by effectively employing these concepts is challenging without explicitly articulating the connections between them.

To help guide the authors' efforts in making these connections – and in making these connections clear for the communities who will be engaged – the Miistakis team developed this simple conceptual model. The following description relies heavily on the terms and concepts included in the *Key concepts and definitions*, above.

Nature and people

The concept of nature as apart from humans has long since been refuted, and modern discussions of conservation tend now to focus on the fundamental reliance humans have on ecological systems. The generator or 'stock' of ecological capacity is often referred to as 'natural

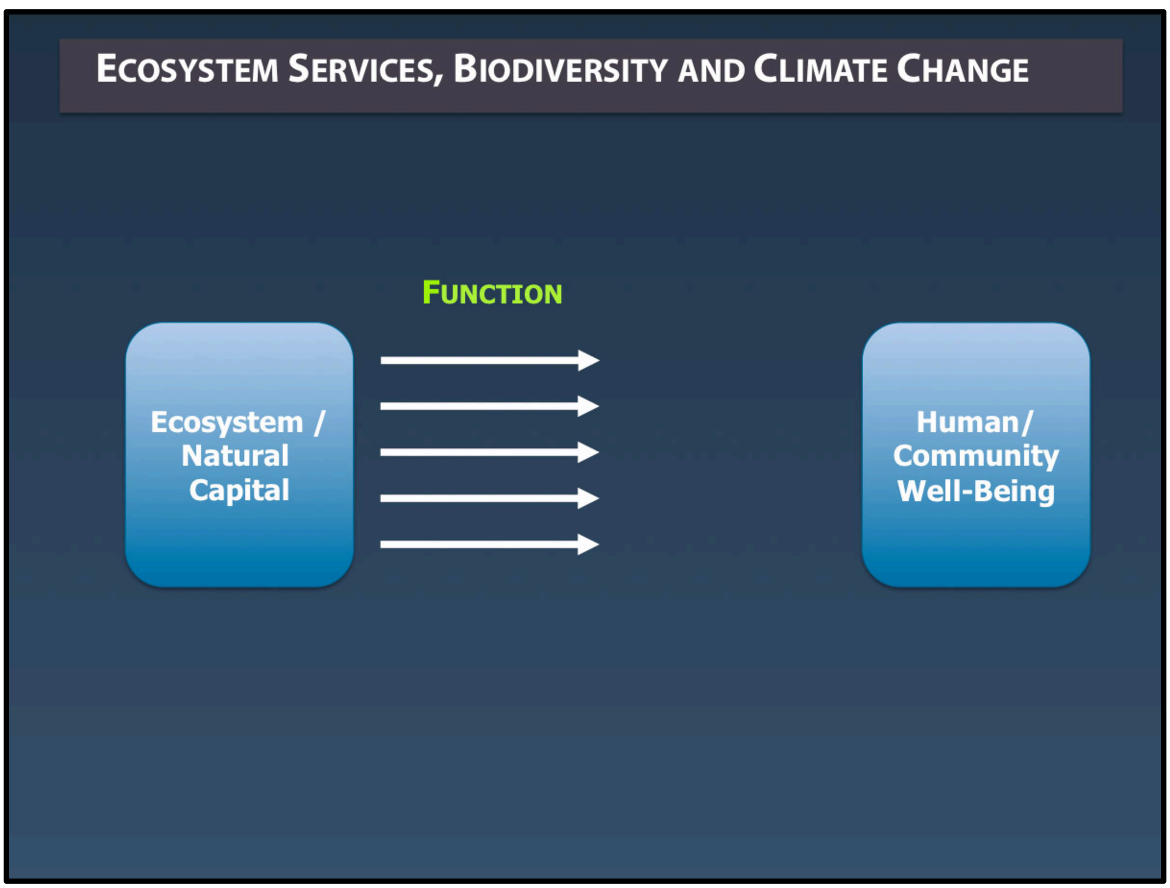

Figure 1: Ecosystems / natural capital and human/community well-being

capital', given its ability to provide a wealth of value to humans.

That ecosystem, or natural capital, is characterized not only by a stock of capacity, but also a flow of advantages that enrich humans at multiple levels, and has been extensively described and defined as "human well-being" by the Millennium Ecosystem Assessment (2010). Those flows, or 'interest' on the natural capital, begin as a series of ecological functions (see Figure 1).

Ecosystem services

Ecosystems services, or the benefits humans derive from nature (Costanza et al 2012), represent an intentionally utilitarian view of the earth's ecosystems – "what's in it for me" as opposed to an intrinsic or moral view of nature's value. The critical piece in viewing ecosystem services as the

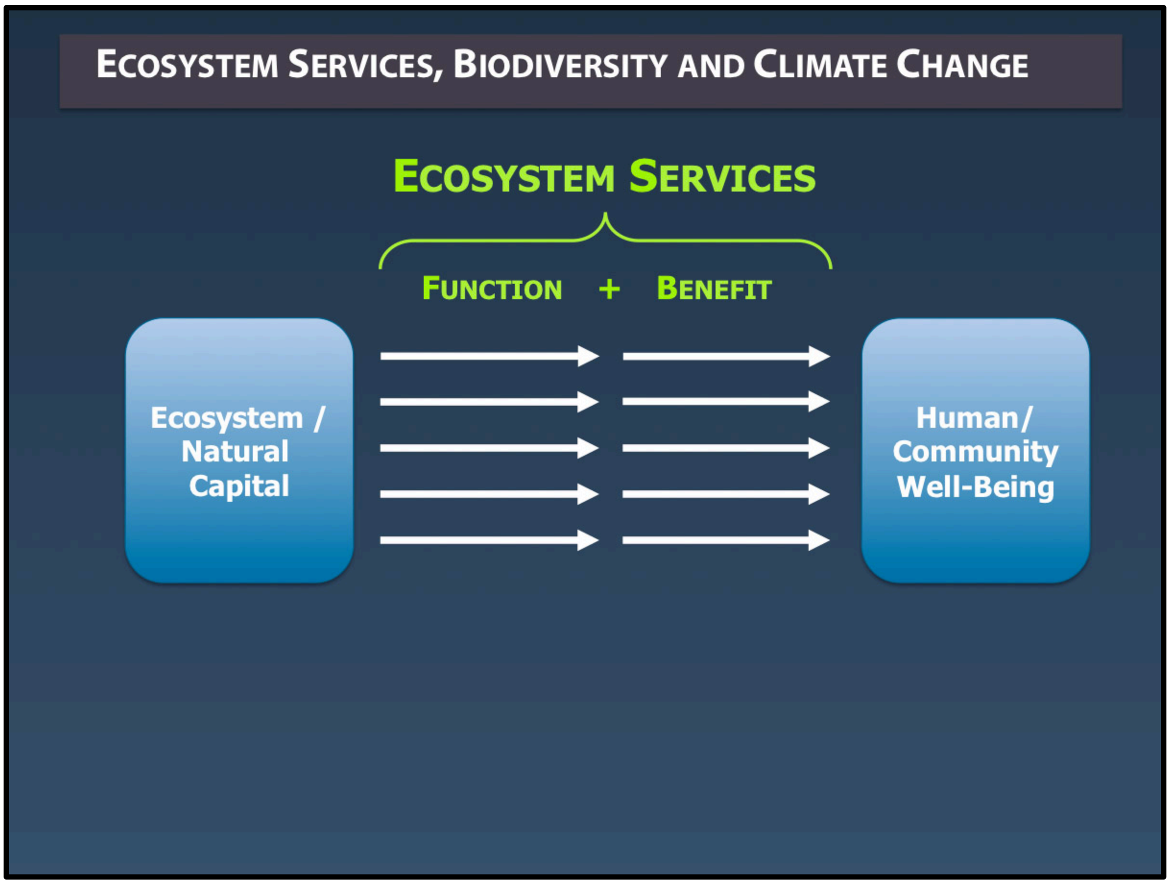

Figure 2: Ecosystem function and benefit = ecosystem services

conceptual link between *ecosystems* and *human well-being* is that an articulation of ecological function is not enough; there must also be a human-defined benefit associated with that ecological function (see Figure 2).

For example, the fact that ecosystem components such as wetlands retain storm water describes an ecological *function*, but not an ecosystem *service*. From an anthropocentric perspective, the flood water control that comes from that function is the benefit (protects people from property damage, human health and safety risk, etc.). The *function* plus the identified *benefit* constitute an ecosystem service.

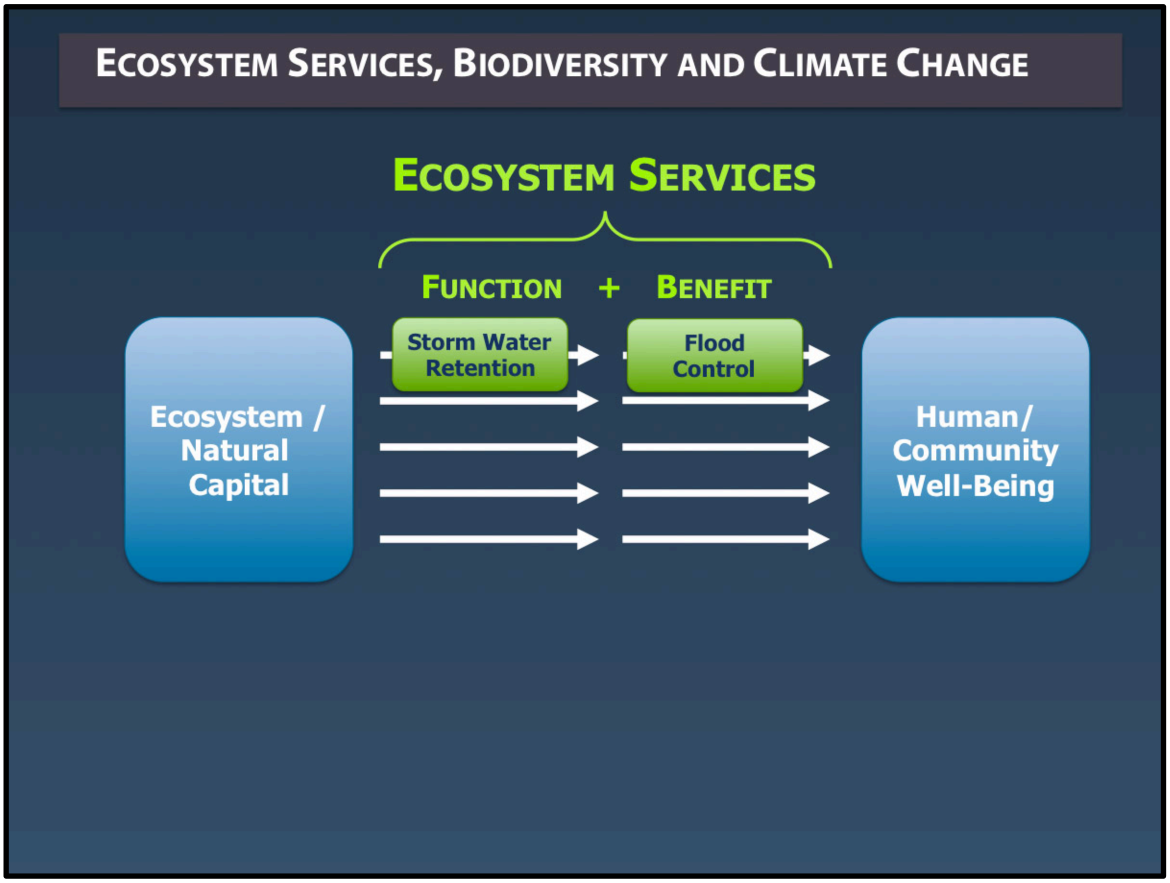

Figure 3: Ecosystem function and benefit example

Ecosystem services and biodiversity

The Millennium Ecosystem Assessment (MEA 2010) was a global effort to clarify the emerging literature and policy around ecosystem services (also known as 'ecological goods and services'). Perhaps the two greatest contributions of that effort were 1) the clear articulation of the connection between ecosystems and human well-being, and 2) the synthesis of ecosystem services research to create a standardized list of ecosystem service areas. This list, and its wide acceptance, served to expand the stunted conservation beyond simply food and fibre all the way to broad social and cultural services (see Table 1).

Table 1: Ecosystem services identified by the Millennium Ecosystem Assessment (2010)

Provisioning	Regulating	Cultural
Food and fiber Fuel Genetic resources Biochemicals, natural medicines, pharmaceuticals Ornamental resources Fresh water	Air quality maintenance Climate regulation Water regulation Erosion control Water purification & waste treatment Regulation of human diseases Biological control Pollination Storm protection	Cultural diversity Spiritual & religious values Knowledge systems (traditional & formal) Educational values Inspiration Aesthetic values Social relations Sense of place Cultural heritage values Recreation & ecotourism

Supporting
Primary production Photosynthesis (production of oxygen) Soil formation & retention Nutrient cycling Water cycling Provisioning of habitat

The services are divided into three main categories: *provisioning*, *regulating* and *cultural*. Underlying all of those are a set of indirect services, categorized as *supporting*, in that the first level ecosystem services could not exist without these support functions.

It is noteworthy that "biodiversity" is *not* an ecosystem service. Scholes et al (2010) explain this relationship as being indirect where biodiversity is "a necessary condition for ecosystem services to be delivered". In terms of ecosystem valuation approaches, they suggest that the "key value of biodiversity may be in reducing the variability of ecosystem services, (equivalently, reducing the uncertainty or risk), especially in the face of disturbances or changes in the environment."

However, the connection between biodiversity and some ecosystem services is still distant enough that it is arguable that not all ecosystem services derive from biologically diverse landscapes; the scenic value of rolling fields of canola crops is derived from natural processes, but is an ecological monoculture (see Figure 4). This makes it incumbent upon scientists, conservationists, and policy makers to identify the most *proximate* connections between biodiversity and ecosystem services.

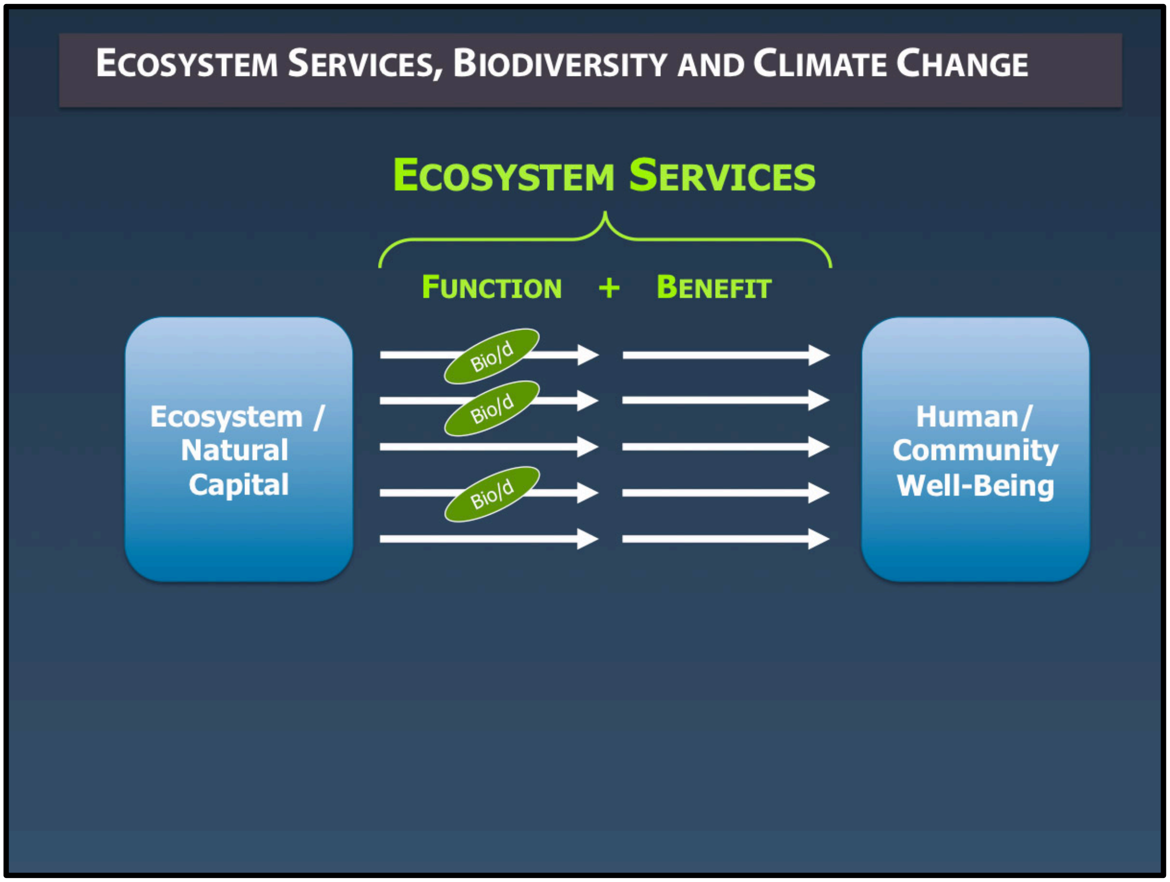

Figure 4: Biodiversity and ecosystem services

Management of ecosystems, functions and benefits

The relationship between human communities and ecosystems is, of course, not unidirectional; human activity has an impact on ecosystems and the services they provide. This feedback flow can be characterized as land and resource management; the collective actions humans undertake in maximizing the benefits they seek from ecosystems (see Figure 5).

These effects can occur at three levels. First, they can impact at the 'natural capital' level, where the activities of humans can affect the stocks of ecosystem capacity. Management actions can – and increasingly, do – decrease the ecosystem capital, but they can also serve to maintain, or even enhance those stocks by protecting their capacity to regenerate.

Second, human activities can impact the function of ecological systems, directly or indirectly interrupting the flow of ecological activity. Again, these actions can impair, but can also work to sustain those flows.

Third, and finally, human activity can affect the benefits people derive from ecosystems and their functions, supporting or deceasing them.

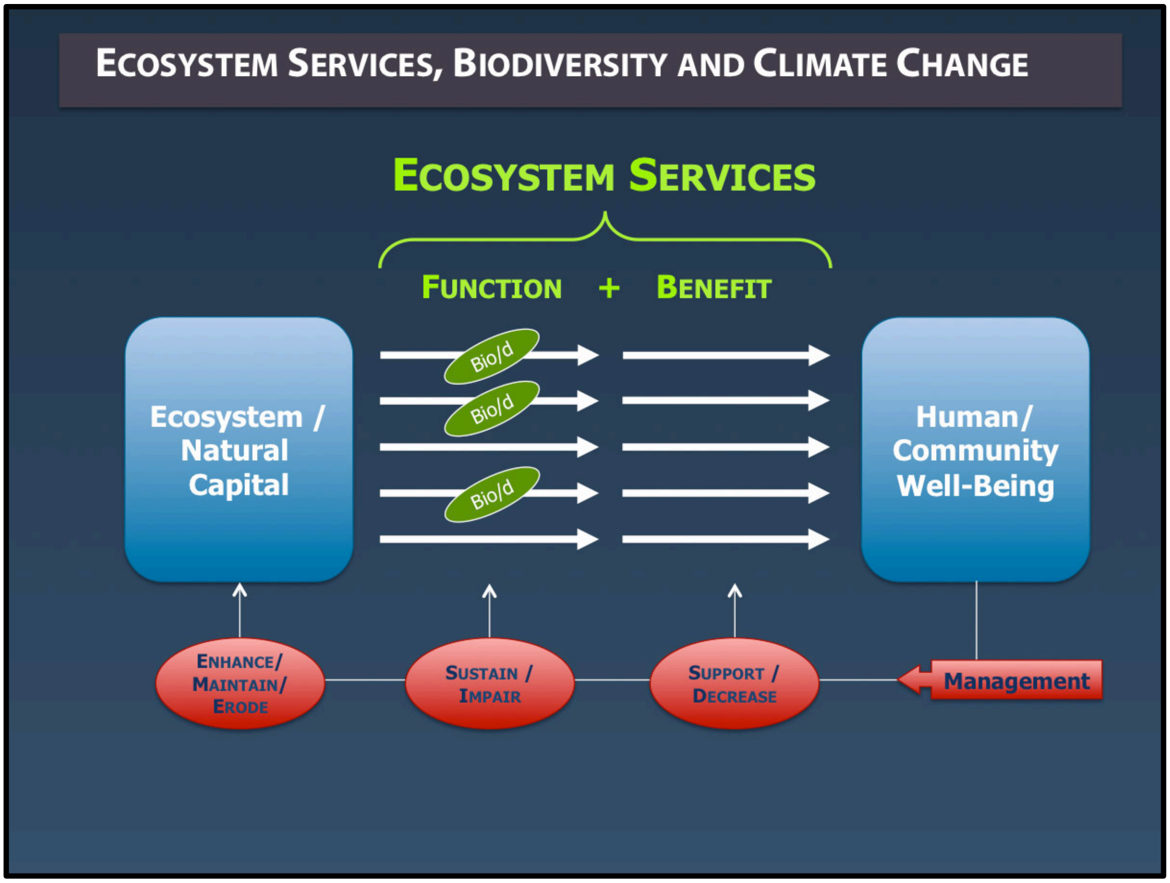

Figure 5: Management impacts of ecosystems, functions and benefits

The following example gives more detail on these interactions.

Climate change and ecosystem services

Climate change offers a strong example of how a perturbation to this system affects the stock and flow of ecosystem services, and illustrates conceptually what are the opportunities and limitations of adaptation.

As with any strong perturbation, climate change affects this system at the *function* level, having a variety of impacts. The model conceptually represents that a given ecological function may be unaffected, altered, or interrupted (see Figure 6). In terms of the resultant benefits to humans, they can be similarly unaffected, positively or negatively altered, or eliminated.

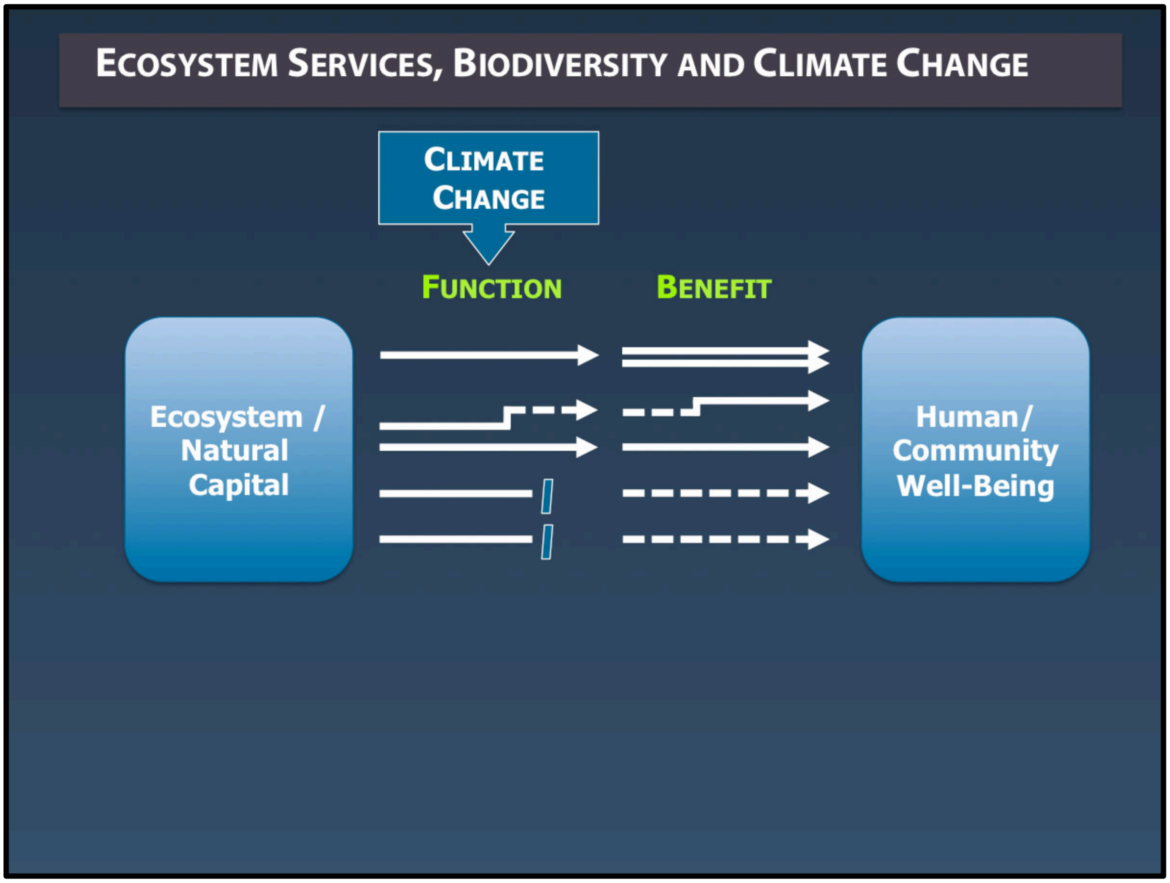

Figure 6: Conceptual impact of climate change on ecosystem function

Climate change adaptation and ecosystem services

In terms of the feedback loop described above, management action in this case can be termed 'adaptation.' And similarly, that adaptation to climate change can be characterized as being directed or having an impact at the ecosystem, function or benefit level (see Figure 7).

At the ecosystem level, human adaptation to climate change can be to 1) maintain or build the ecosystem asset that provides multiple ecological functions, 2) maintain or build the ecological function, 3) replicate the ecological function, and/or 4) modify expectations around the benefits humans derive from those ecological functions. For example, establishing reserves around biodiversity hotspots could be an example of maintaining the self-regenerative capacity of an ecosystem (1), and limiting timber harvest in watershed headwaters could be an example of maintaining the erosion control function in extreme storm events (2). Creating an engineered wetland could be a way of replicating the storm water retention function (3), and focusing recreational hunting and fishing on climate-shifted habitat areas could be an example of changing human expectations around the benefits anticipated from a properly-functioning ecosystem (4).

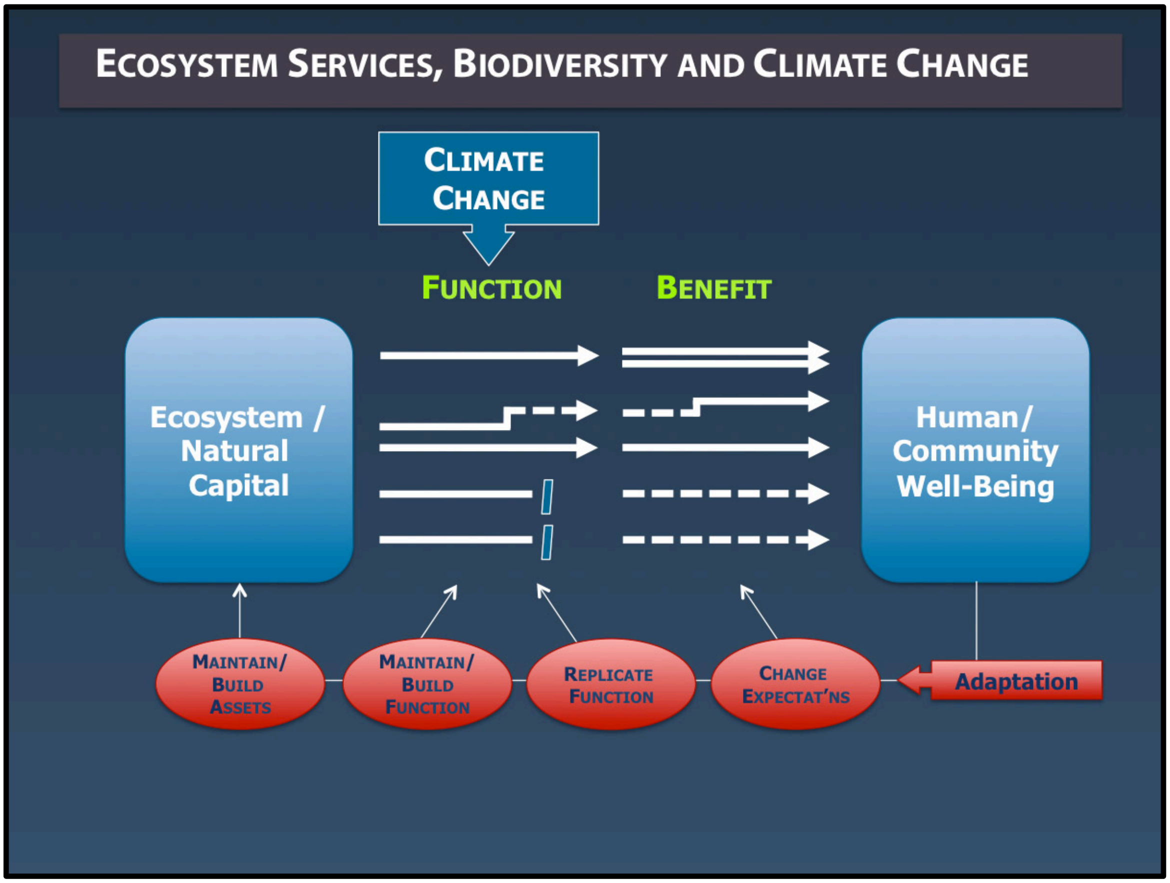

Figure 7: Adaptation to climate change at several levels

Natural and engineered resilience

In each of the cases described above, the goal is to create greater resilience – resilience in the ecological systems, resilience in the human communities that rely on those systems. The adaptation approaches described above can be split into two broad categories of resilience: natural resilience and engineered resilience (see Figure 8).

Natural resilience approaches are those that seek to increase the self-regenerative capacity of the ecosystem (or natural capital stocks), or seek to protect or enhance specific ecological functions. These actions recognize that doing so likely enhances a variety of benefits to human well-being, but perhaps does so without a direct intent to protect the flow of a given benefit.

Engineered resilience approaches seek to replicate a given function specifically with the intent of providing a particular benefit(s), or promote the resilience of a community by re-defining the expectations humans have of nature (e.g., lowering potable water expectations, so there is no anticipation one could drink from natural streams).

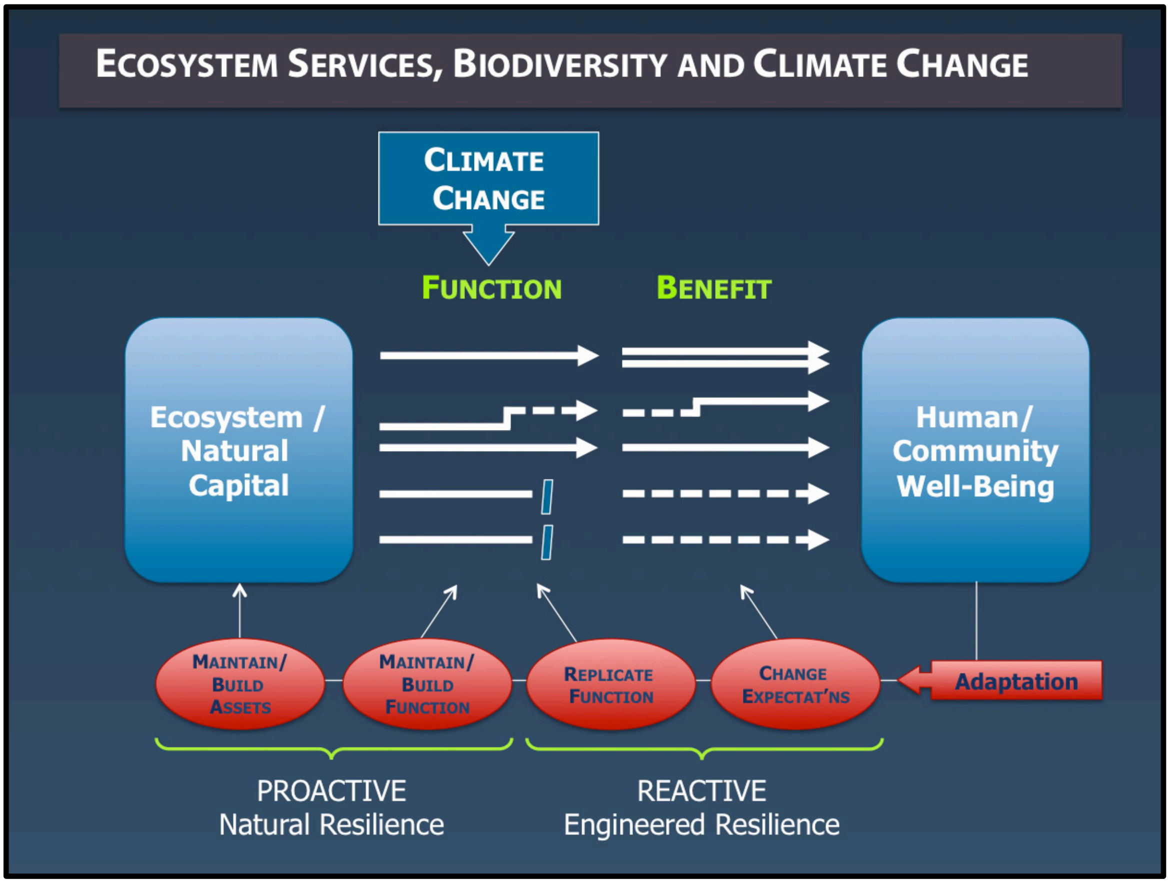

Figure 8: Proactive and reactive resilience approaches

In general, there are three defining characteristics of each approach. First, natural resilience approaches tend to be proactive, whereas engineered resilience approaches tends to be reactive, arising in response to the loss of a desired ecosystem service benefit. Second, natural resilience approaches tend to be more comprehensive and systems-based. Engineered resilience approaches tend to reduce systems to their component parts and parse out discrete benefits. Third, natural resilience approaches tend to be less expensive over time, primarily because the 'work' is being done by a self-organizing ecological system rather than through expenditures of human and built capital.