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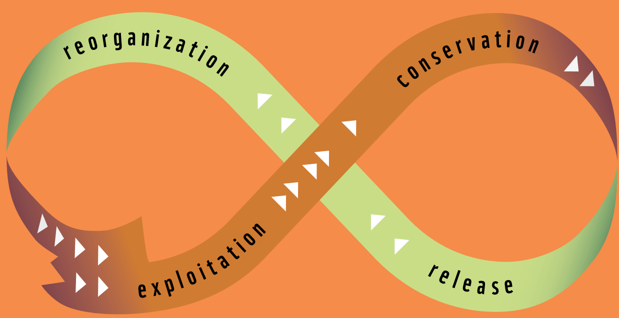
THE CIRCLE

LIVING WITH CHANGE



RESILIENCE APPROACHES FOR MANAGING THE ARCTIC

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Contents

Photo: Andrew S. Wright/WWF-Canada

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COVER: A four-phase conceptual model of ecosystem dynamics (see p. 8 for more).

ABOVE: An Inuit hand line fishing off the rocks for Arctic char in the Sylvia Grinnell River, Sylvia Grinnell Territorial Park, Iqaluit, Nunavut, Canada.

Managing arctic natural resources in times of rapid change

TO DATE, THE REALISATION THAT RAPID CHANGE will be the new constant in the Arctic has failed to find its operative answer in almost every aspect of how we manage arctic lands and seas, and the natural resources they comprise. This is all the more surprising as the world looks to the Arctic to learn lessons of how people can address change so that they – we all in fact – can safeguard the functioning of ecosystems granting us the goods and services we all depend upon. In many places of the transforming Arctic, traditional ways to manage places and resources will become increasingly mute.

What is holding us back? I think that James Pokiak, subsistence hunter, guide and author, from Tuktoyaktuk, Canada, hits a nerve when he summarised his thoughts about the challenges ahead as "it's harder to know what's coming" (p. 14). After all, it is not the changes in the environment alone that must be taken into account; it is the societal and economic changes as well, and how they interact with each other. Further contributing to a perceived paralysis to tackle rapid arctic change is the awareness that the natural resources people use are increasingly elusive to direct management because their fluctuations are driven from elsewhere, either from above (e.g. climate change), or from below (e.g. feed supply for harvested animals).

> "IT'S HARDER TO KNOW WHAT'S COMING"

Resilience-thinking offers a path out of this dilemma, by guiding action through the complex interplay of people and environment, along a line where the overall system can develop side by side with the change and collapse is avoided. Sounds curious yet somewhat abstract? Yes it might, but I think mostly because resilience-thinking hasn't yet been applied much in the Arctic, so we are often lacking concrete examples of practice and the benefits achieved.

The current issue of *The Circle* seeks to identify ways forward by looking at resilience-related approaches and tools for arctic natural resource management.

MARTIN SOMMERKORN, Head of Conservation, WWF Global Arctic Programme

While Ellen Inga Turi and Svein D. Mathiesen point out that much could be learnt from traditional reindeer-herding, Gary Kofinas looks at resilience with an ecosystem service lens, and Raul Primicerio and Michaela Aschan outline the possibilities and challenges from an ecosystem-based management perspective. Highlighting the very timely nature of this topic, we also present the recently initiated Arctic Resilience Report, and WWF's new RACER project. Finally, Donald McLennan looks at how these tools and ideas could be applied in the concrete case of Canadian national parks, before Ambassador Andreas von Uexkull points out the role the Arctic Council could play in the future to link theory and practice in this area.

Ultimately, the aim of this important discussion is to contribute towards better conservation practice and management of arctic resources. I do hope you enjoy the read as much as I do. ○

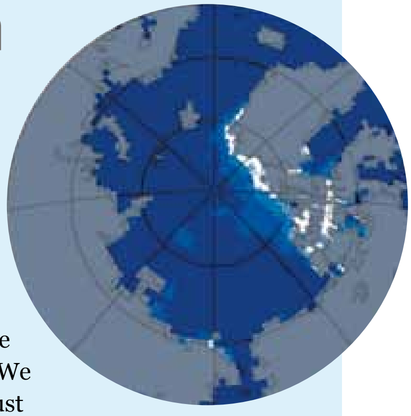
Reducing the oil spill risk in Canada

IN LIGHT OF EARLIER reports that arctic oil spills are all but impossible to clean up, Canadian policy updates that minimize the risk of a spill off the country's arctic coast are welcome news. In December, Canada's National Energy Board (NEB) released a review of offshore arctic drilling that sets a high international standard for international regulations.

WWF welcomed the results and was in particular pleased that the NEB maintained the Same Season Relief Well policy, an important precaution to minimize the risk of a multi-year spill. With this report, the NEB has established comprehensive filing requirements for offshore drilling in the Canadian Arctic. This report is an important step toward the kind of robust regulatory system needed to prevent disasters like the 2010 Gulf of Mexico spill in Canada's arctic waters. It will also enhance industry transparency by requiring oil and gas companies to make their safety, emergency and contingency plans public.

"We're pleased that the NEB chose to maintain its same season relief well policy in the face of industry requests to remove it. This precautionary approach could prevent the irreparable damage of a multi-year blowout," said Rob Powell, Director of WWF's Mackenzie River Basin Program.

A future for the Last Ice Area



AT THE END of January, WWF gathered representatives of key Inuit organizations and governments to consult on the Last Ice Area project. The project, officially launched last year, looks at the future of the area of summer sea ice projected to last the longest in the race of climate change.

"This consultation meeting was a key milestone in the project," says Clive Tesar, project leader. "We have been clear from the beginning that Inuit must play a defining role in deciding on any future management for this area. During this meeting, the Inuit representatives helped us identify knowledge gaps around the area, gaps that we hope to fill with their help."

Almost every summer, the amount of remaining arctic sea ice gets smaller. That summer ice is vitally important to a whole range of animals from tiny shrimp to vast bowhead whales, and to local people. One stretch of ice is projected to remain when all other large areas of summer ice are gone, in northern Greenland and Canada.

"World's most unnecessary coal mine"

THE NORWEGIAN government recently gave the go-ahead to a new coal mine in Svalbard, a high-arctic archipelago off the northern coast of Norway, despite clear objections from WWF and an acknowledgement from all Norway's political parties that climate change is the greatest challenge of our time.

"The climate change issue is not determined by yes or no to a new coal mine on Svalbard, but the sum of what all countries are doing. This coal mine is completely unnecessary, and a prosperous country like Norway should have set a good example", said WWF-Norway's Secretary-General.

WWF believes the project is the world's most unnecessary coal mine, and is asking the government to present a plan for Svalbard to be a renewable society. The planned mine will produce 1.9 million tonnes of coal per year, creating 5.5 million tonnes of new CO_2 emissions per year when it is burned in power plants – equivalent to ten percent of Norway's total emissions per year. After a start up phase of two years, the mine will be fully operational for 4-5 years, and will be exhausted by 2020.

Coke and ice

COKE CANS in the US and Canada had a new look this winter. Coca-Cola and WWF partnered to turn the company's familiar polar bear marketing campaign into a boon for the bears, with the Arctic Home campaign. Funds raised by Arctic Home went to support WWF's polar bear conservation work including the Last Ice Area project (see above).

First-hand accounts of orca predatory behaviour

IN THE FIRST STUDY of its kind, University of Manitoba researchers interviewed over 100 Inuit living in the Canadian Arctic, to catalogue traditional knowledge of orca predation and prey. This may be proof that the science community is finally warming up to traditional Inuit knowledge, said a Nunavut Tunngavik Inc. wildlife adviser to Nunatsiaq Online in January.

Although little was known about the animal's behaviour in new regions, scientists were able to hear first-hand from hunters who have observed the animals in action for many years. The study suggests that melting sea ice is attracting more orcas, or killer whales to Nunavut, where the whales are preying on mammals like seals, belugas, narwhals and even the much larger bowhead whale. It also gives a voice to Inuit hunters' concerns that, as the sea ice continues to melt, they will have to compete with the giant predators for the marine wildlife they hunt for food, reported Nunatsiaq Online.

"Inuit traditional knowledge is essential to scientific research," said Paul Irngaut, a wildlife adviser with Nunavut Tunngavik Inc. "Our hope is that [other Arctic-based research] will take traditional Inuit knowledge more seriously".

Photo: Natalie Bowes / WWF-Canada

Russian fisheries move towards certification

WITH WWF'S SUPPORT, Russia's Union of the Fishing Industry in the North has decided to meet MSC certification on more than half of the country's cod and haddock quota. Cod and haddock represent the main catch in the Barents Sea and the current stock is said to be the most significant in ten years. Barents fishermen hope to finish the certification process by the end of 2012.

Protecting America's Arctic

NEARLY 10,000 PEOPLE signed a WWF petition earlier this year asking the US federal government to remove America's Arctic from the proposed offshore oil and gas leasing plan for 2012-2017. In February, a group of Alaska Natives travelled to Washington, DC to meet with leaders of the Obama Administration. The goal of the campaign is to convince the US government to permanently protect Bristol Bay in Alaska. The bay –referred to as America's Fish Basket – is home to a fishing industry that produces almost 40 percent of the wild-caught seafood eaten in the United States, including salmon and halibut, but is also a prime target for offshore oil and gas drilling.

Resilience, adaptation and transfo

'Resilience' is becoming commonplace in policy and planning documents, portraying somewhat different meanings when used by psychologists, engineers, ecologists, social scientists, and recently even corporations. This can be a good thing in a developing field but it can also lead to confusion, especially when (as is happening in this case) loose usage tends to relegate it to 'buzzword' status. The need for resilience, however, and current changes in resilience, are of increasing importance in the world; and nowhere more so than in the Arctic, says BRIAN WALKER.

BRIAN WALKER is an internationally experienced scientist working on ecological sustainability and resilience in social-ecological systems. He is currently a Research Fellow with CSIRO (Commonwealth Scientific and Industrial Research Organisation) Sustainable Ecosystems and is also Program Director and Chair of the Board of the Resilience Alliance, an international research group working on sustainability of social-ecological systems.

A PRIMARY CAUSE of confusion arises from the fact that the term is being used both in a particular sense and in a very general sense. The definition I follow is 'the ability of a system to absorb a disturbance, to re-organise, and to continue functioning in the same kind of way'. In the particular sense, resilience has to do with the existence in many systems of regime shifts from one configuration (stability domain) to another, as a consequence of crossing threshold levels of particular controlling variables. It is about the resilience 'of what', 'to what'– the resilience of a fish stock to fishing pressure, for example.

In a general sense resilience has to do with the idea of coping capacity and, whatever the shock, the capacity to recover and keep going. It is determined by a number of system attributes, such as diversity, openness, strengths and tightness of feedbacks, which apply to both the ecological and social domains of the system, plus a number of social system attributes, in particular leadership, trust and the strength and nature of social networks. Operationalising the assessment of general resilience is difficult and leads to some disenchantment with the concept, even though its importance is acknowledged.

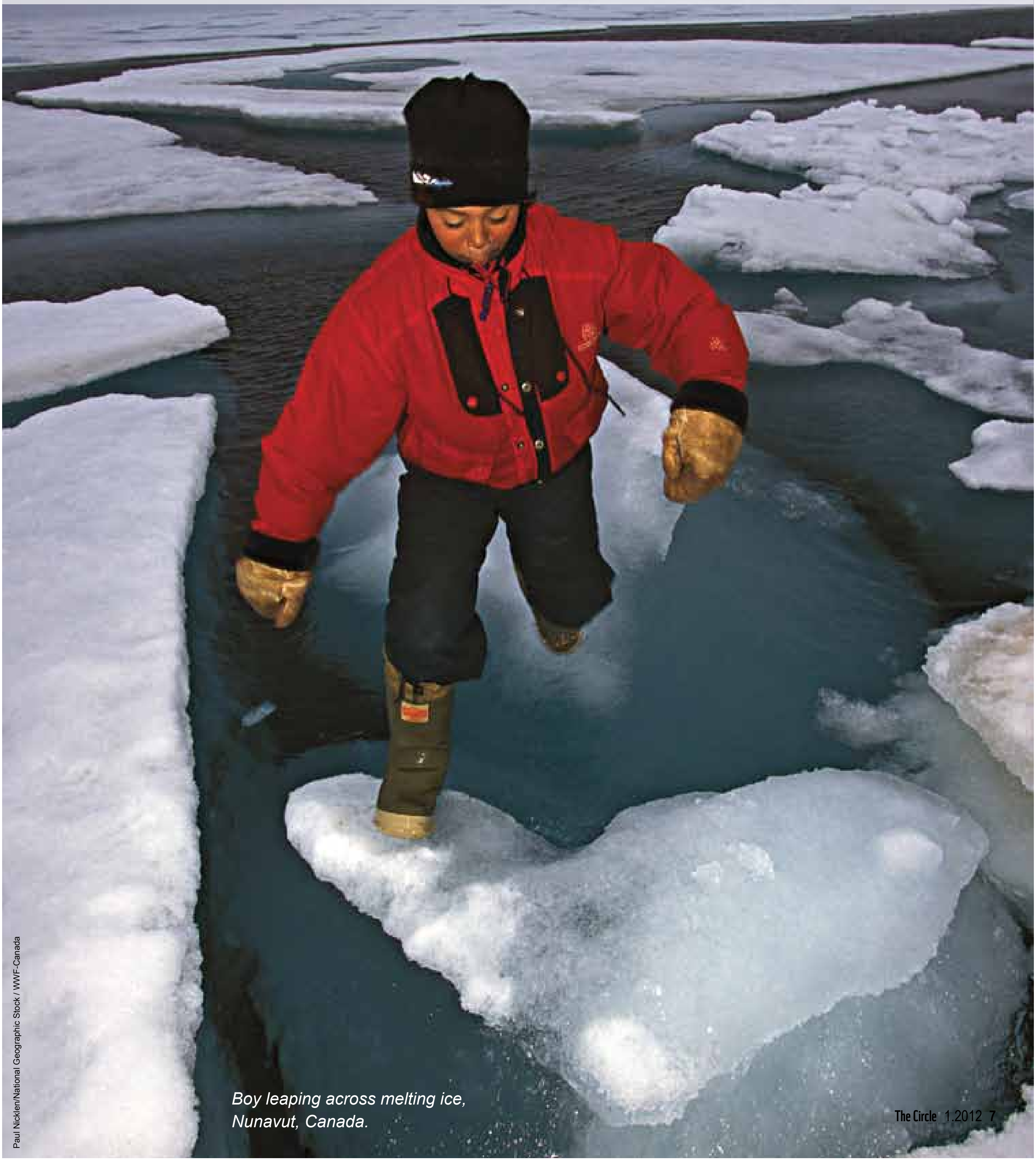
WHAT RESILIENCE IS ALL ABOUT

A basic requirement for understanding resilience is understand and appreciating the importance of feedbacks in the dynamics of complex systems. If a change in A causes a change in B, and the change in B then causes a further change in A, that's a direct feedback effect. Most people get this, and some take it into account when they make management plans. Fewer people take into account secondary feedbacks – A affects B affects C which then feeds back to affect A. And in the full complexity of social-ecological systems (SES) it is very hard to try to work out all the feedbacks that are occurring and that together act to make the SES a self-regulating (self-organising) system. Some are more important than others, however, and a primary aim of a resilience analysis is to identify the set of important, controlling feedbacks. Most changes in resilience that lead to unexpected regime shifts are due to changes in unrecognised feedbacks. Thinking about feedbacks and the likely consequences of any development or policy proposal for important known or likely feedback changes is a first step towards resilience thinking.

IN A GENERAL SENSE RESILIENCE HAS TO DO WITH THE IDEA OF COPING CAPACITY AND, WHATEVER THE SHOCK, THE CAPACITY TO RECOVER AND KEEP GOING.

Feedback changes can have surprising outcomes and, once understood, can lead to counter intuitive responses in management. The introduced brook trout (*Salvelinus fontinalis*) in California, for example, successfully spawns in alpine lakes where it overpopulates, causing a reduced size of adult fish. Conventional wisdom suggests that lowering trout densities would mean more food for adult trout, and so lead

rmation in light of arctic changes



Paul Nicklen/National Geographic Stock / WWF-Canada

Boy leaping across melting ice, Nunavut, Canada.

to improved angling. However, experimental removal of adult trout caused no improvement or even reductions in adult trout growth. But there was a dramatic improvement in the survival of young trout, due to reduced cannibalism by the larger trout. The resulting large juvenile cohorts spread all over the lake, rather than being confined to edge areas (where they previously sought refuge from adults), competed with adults for food, and negated the expected improvement in adult fish growth. As pointed out by Pine and others in a 2009 article in *Fisheries*, the management 'model' did not take into account the feedback from adult trout density to juvenile survival and distribution.

Comparative assessments of SESs of different kinds in different parts of the world highlight the following features that are helpful to have in mind when beginning an assessment of resilience.

i) In a social-ecological system it is often unrecognised feedbacks between the ecological and social domains that lead to unexpected and unwanted regime shifts.

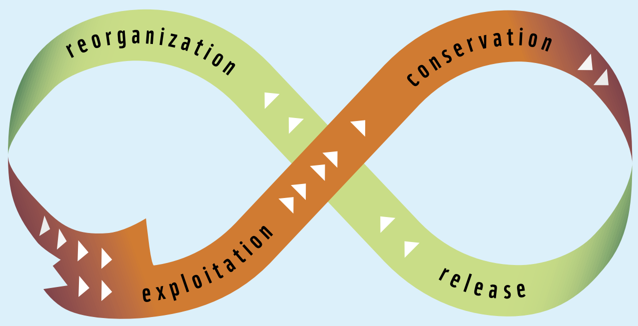
THERE IS A COST TO MAINTAINING OR BUILDING RESILIENCE, IN THE FORM OF FOREGONE EXTRA PROFITS, REDUCED EFFICIENCIES, OR DIRECT INVESTMENT.

ii) There is a need to probe the boundaries of resilience. Only by being exposed to a disturbance does a system maintain its resilience to that kind of disturbance.

iii) There are inevitable resilience trade-offs
a) between different parts of the system and to different kinds of shocks; making a system very resilient to one kind of disturbance can inadvertently cause it to become less resilient to other kinds.
b) across scales. Trying to maintain the resilience of a SES at one scale can cause it to lose resilience at other scales.

iv) There is a cost to maintaining or building resilience, in the form of foregone extra profits, reduced efficiencies, or direct investment. Because resilience is about the long-term and resource use/production is about the short term, resilience issues (when recognised) tend to get lower priority status.

The panarchy loop



In 1986 C.S. Holling (see back cover) developed the adaptive four-phase figure eight panarchy model of ecosystem dynamics and postulated that collapse and the following system renewals, which indicate the resilience of ecosystems, are at least as important as the exploitation and conservation stages of such systems.

Source: Wikipedia

APPLYING RESILIENCE

A resilience framework encompasses three interconnected aspects of a system – i) resilience in the specified sense, involving particular threshold effects with alternate stability domains, ii) adaptability (the capacity to manage resilience), involving many of the attributes of general resilience, and iii) transformability - the capacity to change into a different kind of system, when a shift into an alternate undesirable regime is inevitable or has occurred. It is this last aspect that deserves special consideration in the context of arctic change. Transformational change involves the notion of changing in order not to change (or to be changed), and addresses the concept of changing and maintaining identity.

Arctic changes are now at the forefront of global changes because of the exceptional rate of climate change in the region, driving a host of other environmental and social changes. It warrants special attention and the proposed Arctic Resilience Report will need to drive forward the current state of putting resilience theory ideas into practice. The Arctic, as a social-ecological system, does not represent mainstream society in the world today. It relies predominantly on old tried and trusted ways that are now threatened by rapid change, and hence the aspect of transformational change needs special

AS UNCOMFORTABLE AS IT IS TO MANY, THE WORLD (AND THE ARCTIC REGION IN PARTICULAR) NEEDS TO EMBRACE THE IDEA OF CONTINUOUS TRANSFORMATIONAL CHANGE.

attention. Adaptation alone cannot work. The question is how to envisage and implement transformational changes that are necessary in order to avoid declines in human wellbeing?

A grave potential danger is to fall into the trap of using some particular scenario of change by some date, and then using that to work out the next 'optimal' state of the system for that environment. Climate change will be ongoing and an adaptation approach (to one or other kinds of environment) is therefore inappropriate. As uncomfortable as it is to many, the world (and the Arctic region in particular) needs to embrace the idea of continuous transformational change; changing the defining variables that describe the arctic social-ecological system as changes in the natural, social (and technical) environment demand.

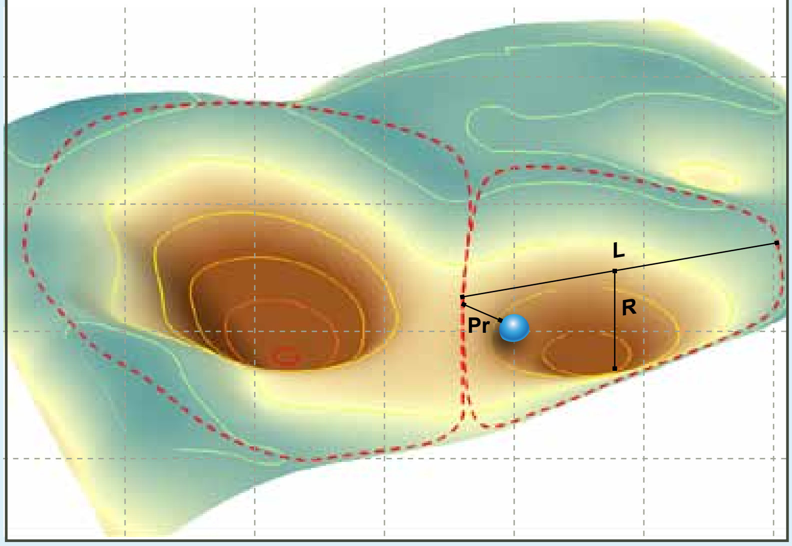
ARCTIC TRANSFORMATIONAL CHANGE

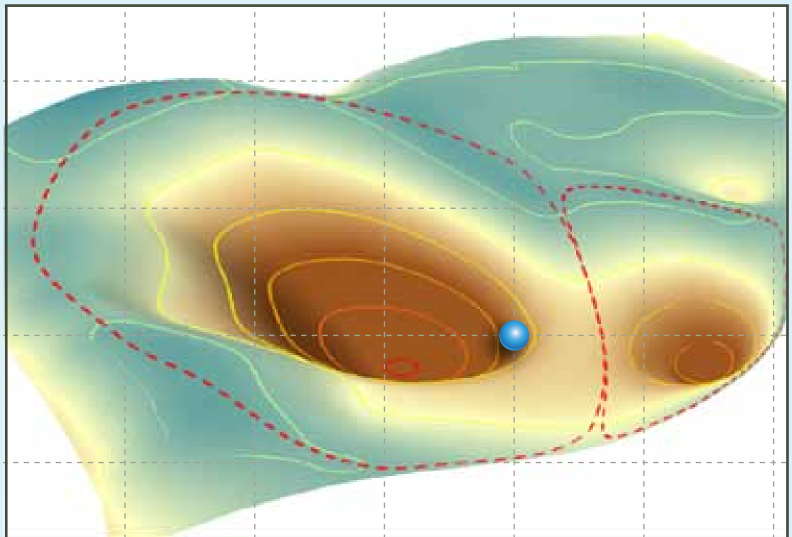
Transformational change does not mean having to effect a complete change at the scale of the Arctic at one time. Transformability has three components: i) getting beyond the state of denial, and accepting that radical change is needed; ii) having or creating options for change; and iii) the capacity to change. Creating options for change is appropriately done at fine scales, by encouraging local experiments and novel ventures at local scales, where failure can be tolerated and absorbed. Successes will feedback to the higher scales, and collectively will effect a transformational change that occurs at a speed that allows people to accept it – a speed that allows their (the system's) identity to evolve; not from one particular

Aspects of resilience and changes in stability landscapes

Original stability landscape

Depicts a three-dimensional stability landscape with two basins of attraction showing, in one basin, the current position of the system and three aspects of resilience, L = latitude, R = resistance, Pr = precariousness.





Altered stability landscape

Changes in the stability landscape have resulted in a contraction of the basin the system was in and an expansion of the alternate basin. Without itself changing, the system has changed basins.

Source: Wikipedia, Walker, Holling et al 2004. Design: Ketill Berger, Film & Form.

form to another, but in an evolutionary way. The speed of change in the arctic environment is such that the process of transformational change will have to occur faster than it has happened before, but if it is guided, in the sense of enabling it to self-organise amongst the possible acceptable trajectories while avoiding shifts onto negative, undesired trajectories, it can succeed.

Success, however, will depend very much on the third component of transformability – the capacity to change. It is in large measure determined by support (or lack thereof) from higher scales and common problems here are either outdated strictures against change, or higher scale support *not* to change rather than support *to* change.

All three aspects of a resilience approach demand attention in the Arctic. It is important to try to identify possible regime shifts and their associated thresholds as soon as possible. Learning how to avoid unwanted shifts is a priority, especially those at higher scales – the big boundaries that determine the trajectory of the Arctic at a regional scale. Building general resilience and the capacity to manage thresholds (all scales), and learning how to adapt within viable systems regimes is a natural follow-up. Dealing with the rapid changes, however, will certainly require a continuous process of transformational changes, at various scales in different parts of the Arctic.

I finish with a suggestion for those about to embark on an arctic resilience assessment.

Put a strong emphasis on both the ecological and social domains and extend the consideration of the system from a SES to a STES (or SETS, if you prefer), where 'T' refers to how technology influences the future evolution of the system; in two ways: i) as an external, dangerous influence from higher scales, leading to consequences such as transport-related and energy mining disasters, and ii) positively, as a source of potential new technology solutions for transformational change, allowing for resilient outcomes. ○

ARCTIC RESILIENCE REPORT

Assessing resilience when change is the only given

One of the concrete, ongoing projects to assess arctic resilience is the Arctic Council-approved Arctic Resilience Report (ARR). The ARR process will help create links between scientific knowledge and policy-makers in order to help guide crucial decisions, say ANNIKA E. NILSSON and JOHAN ROCKSTRÖM.

THE ARCTIC REGION is changing rapidly, on many levels, which increases the risk for abrupt social and ecological change due to crossing of 'tipping points' with dramatic impacts on ecosystems and people's lives. For those charged with managing natural resources and public policy in the region, identifying potential tipping points of change can help in planning for the future. Resilience provides a scientific framework to assess risks, understand the implications of simultaneous social and environmental changes, and to identify strategies for building strong societies that can face the challenges of increasing social and environmental changes in the Arctic.

This is the context of the ARR, which was approved last November as an Arctic Council project. The initiative is led by the Stockholm Resilience Centre and the Stockholm Environment Institute, with financial support from the Swedish government and in collaboration with several arctic organizations. Resilience is the long-term capacity of a system to deal with change and continue to develop and adapt without crossing critical thresholds. The term has been used for many years in research on environmental change and is now increasingly coming up also in policy circles. But like other broad concepts, resilience is an abstract, even elusive term, easily filled with different meanings depending on who is speaking.

THREE MAJOR TASKS

For the ARR, assessing resilience is about three major tasks: to identify the risk for shocks and large shifts in ecosystems services that affect human well-being in the Arctic; to analyze how different drivers of change interact in ways that affect the ability to withstand shocks; and to evaluate strategies for adaptation and transformation in the face of rapid change.

The ARR grew out of a discussion within the Resilience Alliance, an international network of scientists with focus on systems ecology and the interactions between ecosystems and society. A range of studies, mainly at the local level, has shown that environmental changes are often driven by interactions among several different forces – and some of those changes can be very rapid and radical. In such cases, the consequences can be much greater than what would be expected if each part of the system were studied separately. For example, rich fish stocks may rapidly decline, or a coniferous forest may change to a deciduous forest.

The 'systems' approach has led to an

interest in identifying the conditions that can trigger such large and rapid changes – as well as the opposite, what enables a social-ecological system to keep its identity. Thus the focus shifts to change and the conditions for change, rather than assuming stability. When stability is not a given, several new questions come to the fore: What makes a system resilient in the face of shocks, and how is this resilience itself affected by other changes? What enables it to transform into something new? The rapid environmental changes and social development in the Arctic today make it increasingly relevant to look at the region from such a perspective.

THE ARCTIC AS A LENS

The process for the ARR is designed to create links between scientific knowledge and policy-makers in order to make sure that the assessment can help guide crucial decisions. It uses workshops to engage experts and stakeholders, with the purpose of identifying ongoing changes, potential tipping points, and how policy and governance choices can provide support in navigating these rapid changes. It will also draw on the expertise in other projects focusing on different aspects of arctic change, including other Arctic Council activities.

The ARR builds on and further develops the methodology developed by research partners in the international network of researchers within the Resilience Alliance, summarized in the Resilience Assessment workbook, which has never before been applied to a whole international region. Some may question whether this is even feasible, given the large differences in social contexts and ecosystems across the circumpolar North. However, there are many common change drivers, and we believe that it can be an advantage to use the Arctic as a whole as a lens to bring together insights from different regions and subject areas. The project will thus combine case studies on specific issues and geographic areas with 'big-picture' activities. There will also be capacity-building activities to help different stakeholders use and adapt the material to meet their own needs.

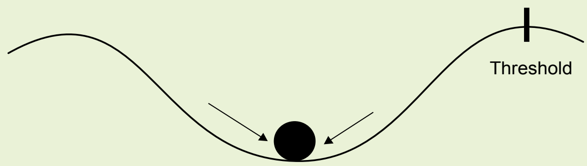
The ARR project is just getting off the ground, and it is too early to present any results. However, we see this science-based assessment as a way to help the region prepare for large-scale and interconnected shifts – and by doing so, enhance the resilience of its people and ecosystems. ○

What is resilience?

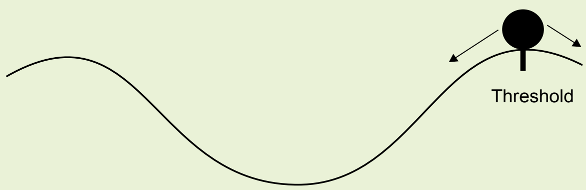
Resilience is the long-term capacity of a system to deal with change and continue to develop and adapt, yet remain within critical thresholds. The purpose of assessing resilience is to prepare for change. A stable resilient system can cope with shocks and disturbances and keep its identity.

A 'ball-in-basin' illustration of resilience

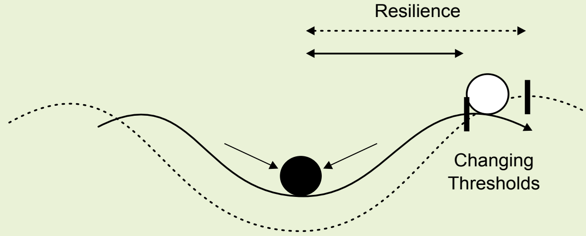
A **stable resilient system** can cope with shocks and disturbances and keep its identity.



In an **unstable system**, a small disturbance can push the system over a threshold or tipping point.



Environmental and social changes can make a system less resilient.



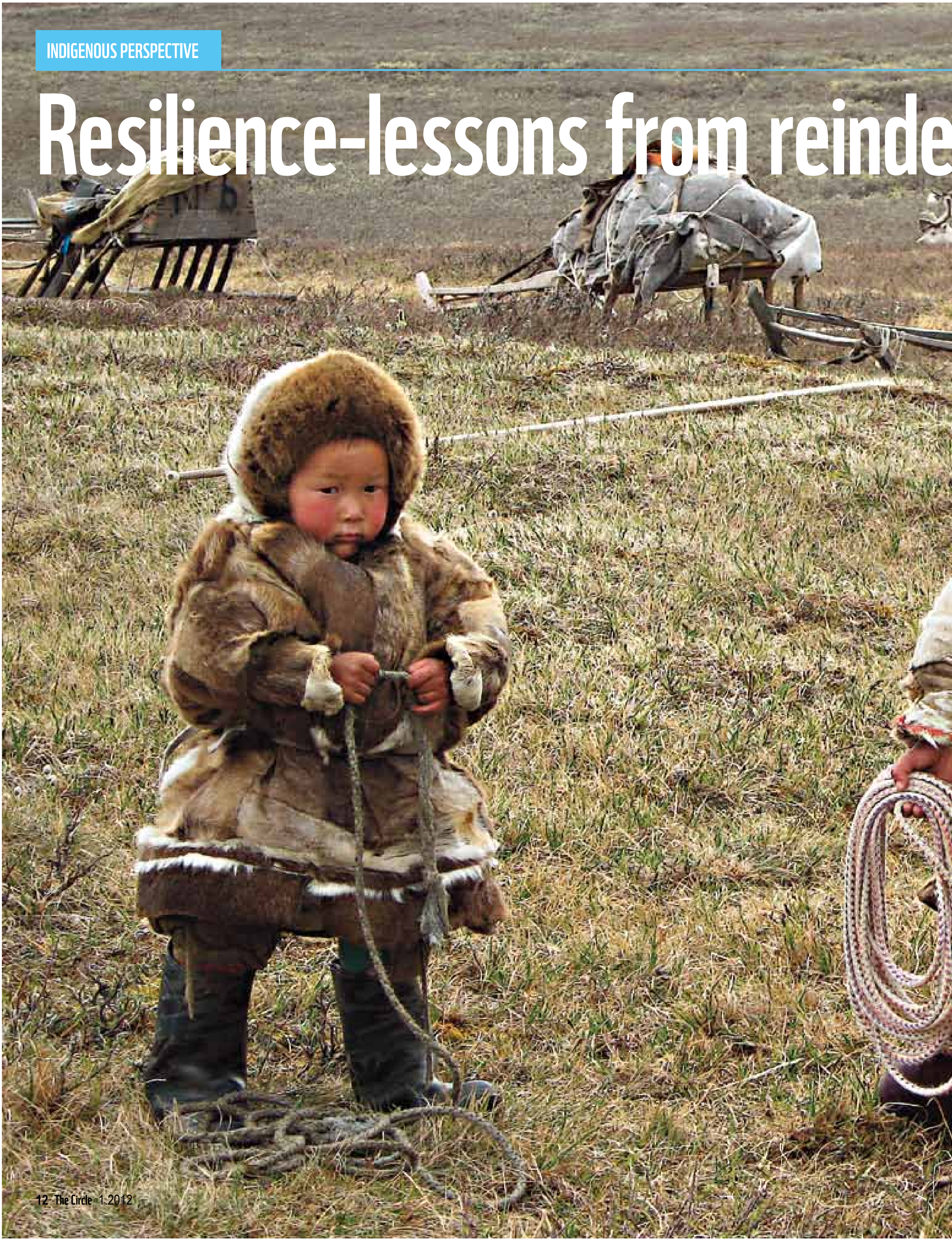
Graphic: Richard Clay,Stockholm Environment Institute

ANNIKA E. NILSSON is Senior Research Fellow at Stockholm Environment Institute, where she is project leader for the Arctic Resilience Report. She has a background as a science writer and a PhD in environmental science. Her research is about communication at the science-policy interface, with a special focus on the Arctic, and the relationship between arctic change and international politics. As a science writer she has participated in several assessments about the Arctic, focusing on pollution and on human development.

JOHAN ROCKSTRÖM is Professor and director of the Stockholm Resilience Centre. He is the chair of the Arctic Resilience Report, and an internationally leading scientist on global sustainability and resilience for sustainable development.

INDIGENOUS PERSPECTIVE

Resilience-lessons from reinde

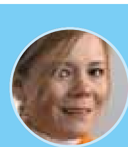


eer herding

Photo: Ellen Inga Turi/UArctic EALAT Institute

Young reindeer herders on the Yamal Peninsula.

The core survival strategy of reindeer communities is based on knowledge about how to live in a changing environment. Traditional knowledge, culture, and language provide a central foundation for adaptation and building resilience to the rapid changes in the Arctic, emphasize ELLEN INGA TURI and SVEIN D. MATHIESEN.



ELLEN INGA TURI is a UArctic EALAT institute Phd student (Umeå University and Sámi Uniersity College), researching on governance regimes and resilience in reindeer herding.

SVEIN D. MATHIESEN is a professor at the UArctic EALAT Institute, at the International Centre for Reindeer Husbandry and the Norwegian School of Veterinary Science.

REINDEER HUSBANDRY is a traditional livelihood in Eurasia, carried out by more than 20 different ethnic Indigenous arctic peoples in Norway, Sweden, Finland, Russia, Mongolia and China. The livelihood involves close to 100 000 herders and 2.5 million semi-domesticated reindeer, covering some four million square kilometers of pastures.

Reindeer herding is a system based, as a rule, on continuous change due to the practice of seasonal migrations and day-to-day changes. The core survival strategy of reindeer communities is founded on knowledge about how to live in a changing environment. The concept of 'stability' is foreign in the languages of reindeer herders. Their search for adaptation strategies is not connected to stability in the normal meaning of this word, but instead is focused on constant adaptation to changing conditions. Reindeer herding has thus developed an integrated resilience for coping with climatic uncertainty based on traditional ecological knowledge accumulated over generations – conserved, developed and adapted to the climatic, political and economic systems of the North.

Climate change is already having, and will continue to have diverse effects on the practice of reindeer pastoralism. For Sámi reindeer herders in Guovdageaidnu in Norway, winter temperatures may increase significantly, while changes in precipitation and wind will affect snow patterns.

The effects are now aggravated as reindeer people's established operating practices for dealing with environmental and climatic variation and change are challenged because of non-climatic factors such as degradation or loss of grazing land due to the rapid industrial development in the Arctic, and governance models failing to accomodate the traditional knowledge of reindeer herding societies.

Any vision of resilience related to the arctic reindeer herding areas must take account of the knowledge and lessons learned by those who practice reindeer husbandry and related subsistence activities in the region. The future for these communities is dependent on reindeer herders' use of traditional knowledge, integrated with scientific knowledge in both research and the management of arctic reindeer herding areas. An interdisciplinary and multicultural approach to the factors that influence how climate change affects landbased ecosystems in northern regions is therefore important.

In facing rapid changes, we must use all available knowledge - scientific and especially Indigenous peoples' traditional ecological knowledge - in order to understand the changes and develop new management models. This will require a new type of cooperation between industry, research, management and politics. Indigenous and local community participation in research is the key to improving the management of nature in the North and avoid conflicts related to the use of nature.

In order to facilitate resilience-building in reindeer herding societies, the Association of World Reindeer Herders, the International Centre for Reindeer Husbandry and Sámi University College founded the University of the Arctic (UArctic) EALÁT Institute. This is a virtual institute established as a Legacy of the International Polar Year (IPY) to maintain networks established in the circumpolar North during IPY and to increase the cooperation on information exchange, research and education in circumpolar reindeer pastoralism. The Institute recruits Indigenous youth to scientific work and arctic leadership positions and focuses on building competence locally through research on themes important for reindeer husbandry, and community-based workshops, seminars and conferences in circumpolar reindeer herding areas. ○

THE CONCEPT OF 'STABILITY' IS FOREIGN IN THE LANGUAGES OF REINDEER HERDERS.

A personal account

JAMES POKIAK'S VISIONS OF ARCTIC change have been subtle glimpses so far. The 57-year-old Inuvialuit hunter and guide says decades of rising global temperatures have brought warmer winters and windier summers to his Beaufort Sea coastal community of Tuktoyaktuk in Canada's Northwest Territories.

"The animals are still out there," he says. Pokiak, who spent much of his adult life trapping on the land, is one of thousands of arctic residents whose intimacy with the Arctic represents not just a means of earning a livelihood and finding food but also a cultural link to generations of Inuit tradition: Pokiak was barely a teenager when he was taught to harpoon beluga whales in nearby Kugmallit Bay; his children learned the skill from him when they reached the same age.

Climate-affected shifts in temperature, rain, snow and ice can affect the ecological characteristics and processes that drive productivity and diversity of the Mackenzie River Delta landscape around Tuktoyaktuk. Small changes here or there can affect this ecological vitality and make eco-systems more susceptible to other environmental impacts.

The uneasy result is a world more vulnerable than Pokiak and his community are used to. Climate change may not have tipped any ecological balance yet. But Pokiak worries that other threats and continued warming may combine and accumulate: Ecosystems stressed by climate are more at the mercy of the potential impact of industrial exploration and development.

"In a sense, as a people, from generation to generation, all the wildlife management and things like that have been automatic things that are done here," Pokiak explains. But the combination of environmental change and recent, growing interest in development mean "it's harder to know what's coming."

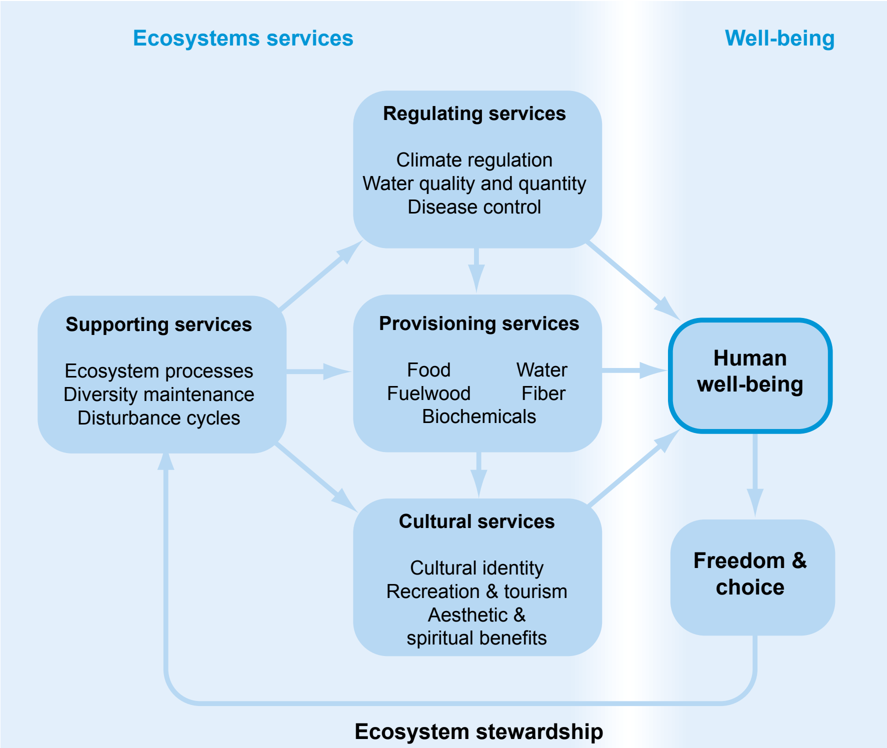
(Adapted from WWF's RACER handbook)

Changes in ecosystem services and their links to social-ecological resilience

Ecosystem services have historically supplied basic needs of northern livelihoods and essential elements for human well-being. What are the opportunities for building the resilience of northern social-ecological systems in the face of today's conditions of rapid change, asks GARY KOFINAS.

STUDIES AND ASSESSMENTS such as the Arctic Climate Change Impact Assessment, the RACER report and findings from the International Polar Year have documented in detail many of dramatic and unprecedented changes in northern ecosystems. As witnessed by residents of the North, the benefits provided by the local ecosystems are in a state of transition that is of great concern. These benefits, termed 'ecosystem services', have historically supplied basic needs of northern livelihoods and essential elements for human well-being. Today's conditions of rapid change raise a number of questions about possible future regime shifts in northern ecosystems, their effects on societies that have co-evolved with these ecosystems, and the capacity of those systems to adapt in ways that sustain northern ways of life.

From the framework of sustainability science, ecosystem services occur in four categories. *Supporting services,* such as the ecological processes that maintain soil resources, and carbon cycling, are foundational to all other services. *Regulating services,* such as climate regulation of pest, invasions, and diseases, provide important underlying controls to ecosystem functions. *Provisioning services* are those things from ecosystems directly used by people, such as food, water, fibre, and fuel wood. And *cultural services* provide a set of intrinsic and non-material benefits, such as cultural identity, recreational and tourism experiences, aesthetic values, and spiritual connections shaping people's worldview. Initially advanced by ecological economists seeking to articulate the value of ecosystems shaping, the concept of ecosystem services has proven especially helpful in emphasizing the 'coupledness' or interconnectivity of social-ecological systems. Building on those ideas, the 2005 Millennium Ecosystem Assessment highlighted the overall decline in ecosystem services at the planetary scale and developed an understanding of the linkages between ecosystem services, ecosystem stewardship, and the well-being of society (see figure).



Adapted from the MEA 2005

INTERACTING FORCES

In the northern context, the nature of social-ecological coupledness is related to the long and close relationship be-

FOR SOME VILLAGES, LOWER RIVER LEVELS HAVE REQUIRED A SHIFT FROM PROPELLER OUTBOARD MOTORS ON BOATS TO JET SYSTEMS THAT ALLOW BOATS TO TRAVEL IN LESS WATER DEPTH, WHILE ALSO REQUIRING SIGNIFICANTLY MORE FUEL.

tween people, land, and resources. The drivers of changing northern ecosystem services, climate change, changes in land use, and changing socio-economics, are best represented as a suite of interacting and often interrelated forces. For example increases in mean annual temperature of 2-3 degrees Celsius in arctic and subarctic regions have resulted in a thawing of permafrost, an increase in fire frequency, a change in hydrological dynamics, and a drying of boreal ecosystems. The ecological consequences have been a shift in the structure and function of the boreal system, including invasions of new plant species and animal pathogens, a shift in the distribution of several important wildlife species such as moose and caribou, and damage to village infrastructure (i.e. buildings, roads, and airport runways, particularly in areas of discontinuous permafrost). For hunters and fishers of the boreal forest, large-scale fires have modified caribou habitat, in some cases displacing this food source away from villages over several decades following the fire event. Fire has also damaged traditional trails systems because of downfall, making some nearby hunting grounds inaccessible. For some villages, lower river levels have required a shift from propeller outboard motors on boats to jet systems that allow boats to travel in less water depth, while also requiring significantly more fuel. Trappers report that increasingly furs, such as martin and mink, are not getting in prime condition during milder winters, and therefore do not fetch a good value when sold. These climate-related changes are concurrent with global spikes in fuel prices that resulted in a 600% increase in costs for some Alaskan villages.

GARY KOFINAS is Associate Professor at the Department of Humans and Environment and Institute of Arctic Biology at the University of Alaska in Fairbanks. He is responsible for extensive research and a number of publications related to resilience and sustainability in northern rural communities.

BUILDING RESILIENCE

Climate change models of the Scenarios for Alaska and Arctic Planning (SNAP) research program at the University of Alaska project that Interior Alaska will continue to experience an increase in fire frequency and drying of the boreal forest, with a likely regime shift from the present-day coniferous forest of white and black spruce to a deciduous forest of birch/aspen and grassland dominated landscape. The implications of these changes to rural social-ecological systems will depend on many factors, including the resilience of northern people. The children of today's hunters of the North may experience shifts in their use and dependence on the suite of ecosystem services, such as burning less wood in their stoves due to warmer winters, harvesting vegetables from a community garden as a non-store bought food supplement, and hunting buffalo instead of moose and caribou. Given the novelty of these changes and the past rigidity of resource management bureaucracies to respond to rural peoples' needs, the extent to which current systems of governance will facilitate adaptation is questionable.

What then are the opportunities for building the resilience of northern social-ecological systems in the face of these changes? The RAYS (Resilience Alliance Young Scholars) group has recently completed a study identifying seven strategies for enhancing the resilience of ecosystem services. Among the strategies are maintaining the diversity and redundancy of systems, fostering an understanding of complex adaptive systems, encouraging learning and experimentation in resource governance, and promoting polycentric (overlapping and not hierarchical) governance systems. One important component for enhancing community resilience is the inclusion of local and traditional knowledge in northern monitoring, research, and decision-making. The ongoing relationship of northern peoples to land and resources provides an extraordinary opportunity for future science-community collaborations that will increase our collective ability to observe, understand and respond to changes. While the uncertainties are great and concerns regarding degraded and lost ecosystem services are considerable, new approaches in northern science and adaptive governance are signs of hope as people of the North seek to grow and prosper in the future. ○

THE DRIVERS OF CHANGING NORTHERN ECOSYSTEM SERVICES, CLIMATE CHANGE, CHANGES IN LAND USE, AND CHANGING SOCIO-ECONOMICS, ARE BEST REPRESENTED AS A SUITE OF INTERACTING AND OFTEN INTERRELATED FORCES.

The research vessel Jan Mayen sampling in Hornsund, Svalbard

Photo: rudicaeyers.com – BFE/UIT

RESILIENCE-BASED EBM

Fostering robust arctic ecosystems

An ecosystem based management that accounts for global environmental change impact is an imperative if we are to strive for a sustainable development in the Arctic, say RAUL PRIMICERIO and MICHAELA ASCHAN. Yet, global environmental change impact on ecosystems is difficult to address due to lack of ecological understanding.

WITHOUT THEORY to guide us, impact is hard to assess, let alone forecast or mitigate. In the Arctic, the task is even more challenging due to lack of data. Without long term ecosystem studies to inform us, we have no baseline for assessment of change, nor reference for restoration.

The goal of an ecosystem approach to management is to preserve robust ecosystems that can cope with the pressure posed by human activities. Global environmental change modifies ecosystem vulnerability and the character of environmental perturbation. Vulnerable ecosystems under heavy pressure from environmental perturbation are exposed to strong impact. Ecosystem based management (EBM) can avoid or at least mitigate ecological impact by dealing with ecosystem vulnerability.

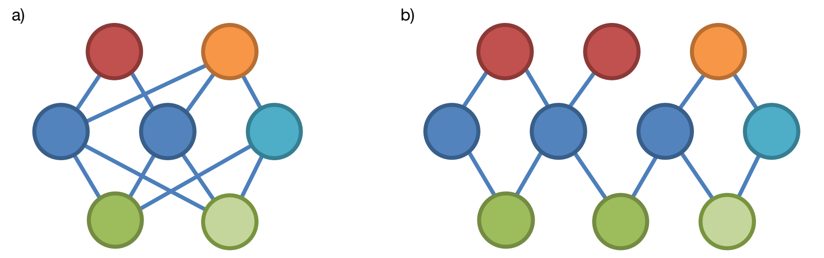
Photo: rudicaeyers.com – BFE/UIT

Wolf fish caught by the research vessel Jan Mayen while eating a shrimp. Ecosystem based management must consider not only the species but also their interactions with other members of the ecological community.

The problem then is to identify which properties of an ecological system influence its vulnerability to environmental stress. Those properties will be the focus of ecosystem based management. Vulnerability to environmental perturbation depends on an ecosystem's adaptability, i.e. its ability to maintain function while changing structure due to perturbation, and sensitivity, i.e. its tendency to change state in response to perturbation. More robust ecosystems are less sensitive and more adaptable.

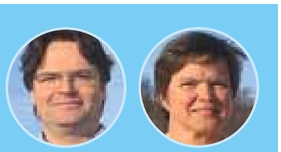
Although the adaptability of an

Food web representation of ecosystems



Circles are species, lines are feeding relationships. The ecosystem depicted in panel a) is expected to be more vulnerable to environmental perturbation than that in b) because it has fewer species, with little functional overlap (similar color implies similar function), and it is less modular (in B species on the left hand side do not interact with those on the right).

ecosystem is difficult to characterize and quantify, we know that biological diversity contributes to it. Diverse ecosystems can still function in spite of the loss or substitution of some of their component species. Sensitivity to perturbation depends on ecosystem resistance, or buffer capacity, on stability, and on resilience, or return tendency. More resistant, stable and resilient ecosystems are less sensitive and therefore less vulnerable to perturbations. The technical definition of resilience as tendency to return to an original state after perturbation is somewhat narrow relative to its more colloquial uses. Ecologists and environmental managers often use a less technical interpretation of resilience and equate it with robustness.



RAUL PRIMICERIO and **MICHAELA ASCHAN** currently work at the Faculty of Biosciences, Fisheries and Economics at the University of Tromsø in Norway. Associate professor Raul Primicerio is a quantitative biologist working with applications of ecology, epidemiology and evolutionary biology to environmental and public health. Professor Michaela Aschan is a marine ecologist studying the impact of human activity on fish and benthos communities. The authors collaborate on projects dealing with fisheries sustainability under global environmental change.

OPERATIONALIZING IDEAS

Putting aside disputes of definition, what matters is whether we can operationalize these ideas in order to assess and manage ecosystem vulnerability. The pressing need for sustainable fisheries has promoted a pragmatic approach to ecosystem based management in aquatic ecosystems. Although the tools for an ecosystem approach to fishery management are still being developed, we can already focus our research and management on properties that are known to affect the robustness of ecosystems. Three such structural properties were singled out in 2008 by Levin and Lubchencko: diversity, redundancy and modularity.

Whereas higher diversity promotes adaptability, as mentioned above, species' functional redundancy and food web modularity reduce an ecosystem's vulnerability by increasing its buffer capacity. Higher redundancy implies that more species have similar functional traits and can substitute each other in performing specific ecosystem functions. Higher modularity implies that species interact within separate compartments, thereby preventing the impact of perturbation on few species from propagating across an entire food web.

WHAT MATTERS IS WHETHER WE CAN OPERATIONALIZE THESE IDEAS IN ORDER TO ASSESS AND MANAGE ECOSYSTEM VULNERABILITY.

If the above properties can be quantified in arctic ecosystems, they could be monitored and integrated in ecosystem based management practice. Our own research on the robustness and resilience of the Barents Sea ecosystem gives us reason to be moderately optimistic. Structural properties influencing ecosystem vulnerability are measurable but require a considerable sampling and processing effort. The data on which we base our ongoing work were produced by the Barents Sea ecosystem survey which involves the dedicated effort of many expert Russian and Norwegian colleagues.

SPARSE DATA

In addition to focusing on structural properties of ecosystems related to their vulnerability, we can assess resilience by analyzing time series of ecological data. The latter approach looks at the dynamics of populations and communities, calculating statistics that inform us about the speed with which an ecological system recovers after a perturbation. Faster return tendency implies higher resilience. These informative estimates can even provide early warning signals of impending regime shifts, but come at a cost: time series must be long, spanning several decades. For many arctic ecosystems this approach can only be the way to the future, because for the time being long term ecological data are rare.

At present, few empirical studies are sufficiently comprehensive to inform decisions, and the sparse data on arctic systems force us to rely on expert judgment for ecosystem based management. But expert judgment is only reliable when based on ecological understanding. Ecological research and ecosystem based management in the Arctic will have to progress together. ○

An innovative tool for guiding arctic conservation

In these times of rapid arctic change, effective stewardship of natural resources requires a new way of thinking. WWF's new RACER project challenges the way we deal with change in the Arctic and provides a missing tool, says MARTIN SOMMERKORN.

RECOGNIZING THE FUTURE value of arctic natural resources is vital to safeguard the livelihoods and cultural identity of northern communities. It is equally important on a global scale, due to the Arctic's influence on the atmosphere and oceans, on world fisheries and on migrating birds and mammals.

As we've seen elsewhere in this issue, resilience-thinking provides an answer to this stewardship challenge by providing a road-map to navigating the Arctic which accepts that people and ecosystems develop along with the changes. But what does that concretely mean for arctic conservation and for the management of arctic spaces and natural resources on land and at sea? How can the concept of resilience be translated into conservation-relevant practice, and how can it point us to concrete places on the map?

MISSING TOOLS

These were the kind of questions that led WWF to undertake the RACER project – a Rapid Assessment of Circum-arctic Ecosystem Resilience – keenly aware that traditional conservation efforts targeting vulnerable arctic habitats and species will soon not keep pace with accelerating climate change. What emerged from the work of an international group of arctic experts from WWF, academia, and conservation practitioners, was a tool – missing until now – for identifying and mapping places of conservation importance throughout the Arctic that first and foremost *comprise the future capacity of ecosystems to adapt*.

This is done through a two-step approach. The first part maps the current location of land or sea features (such as mountains, wetlands, polynyas, upwellings, river deltas, etc.) that are home to exceptional growth of vegetation and animals (productivity) and varieties of living things and habitats (diversity), often through the use of satellite images. Productivity is important because it provides energy to food webs and people. Diversity is all about interactions and future options – living things can adjust when conditions change and still interact to form functioning ecosystems.

HOW CAN THE CONCEPT OF RESILIENCE BE TRANSLATED INTO CONSERVATION-RELEVANT PRACTICE, AND HOW CAN IT POINT US TO CONCRETE PLACES ON THE MAP?

These so-called key features are especially productive and diverse because the characteristics that make them up (e.g., sea ice, slopes, soils, currents, etc.) act as drivers of ecological vitality. Their exceptional vitality is what makes them local sources of resilience for the ecosystems and the ecosystem services of their wider regions (ecoregions). Importantly, RACER describes key features as the local combination of characteristics that *drive their exceptional productivity and diversity*, rather than as the species and habitats that currently exist there.

The second part of RACER tests whether these key features will continue to provide region-wide resilience despite predicted climate-related changes to temperature, rain, snowfall, sea ice, and other environmental factors important to living systems. Changes to these climate variables affect the drivers of ecologi-

MARTIN SOMMERKORN is the Head of Conservation at the WWF Global Arctic Programme. An ecosystem ecologist with 15 years on-the-ground research experience in the circumpolar Arctic, he now leads WWF's work on resilience-based natural resource management and stewardship approaches to conservation in the Arctic.

RACER IS A TOOL FOR IDENTIFYING AND MAPPING PLACES OF CONSERVATION IMPORTANCE THAT FIRST AND FOREMOST COMPRISE THE FUTURE CAPACITY OF ECOSYSTEMS TO ADAPT.

cal vitality at the key features. RACER uses forecast changes to these climate variables to predict the future vitality of key features and the likely persistence of ecosystem resilience for arctic ecoregions through the remainder of this century.

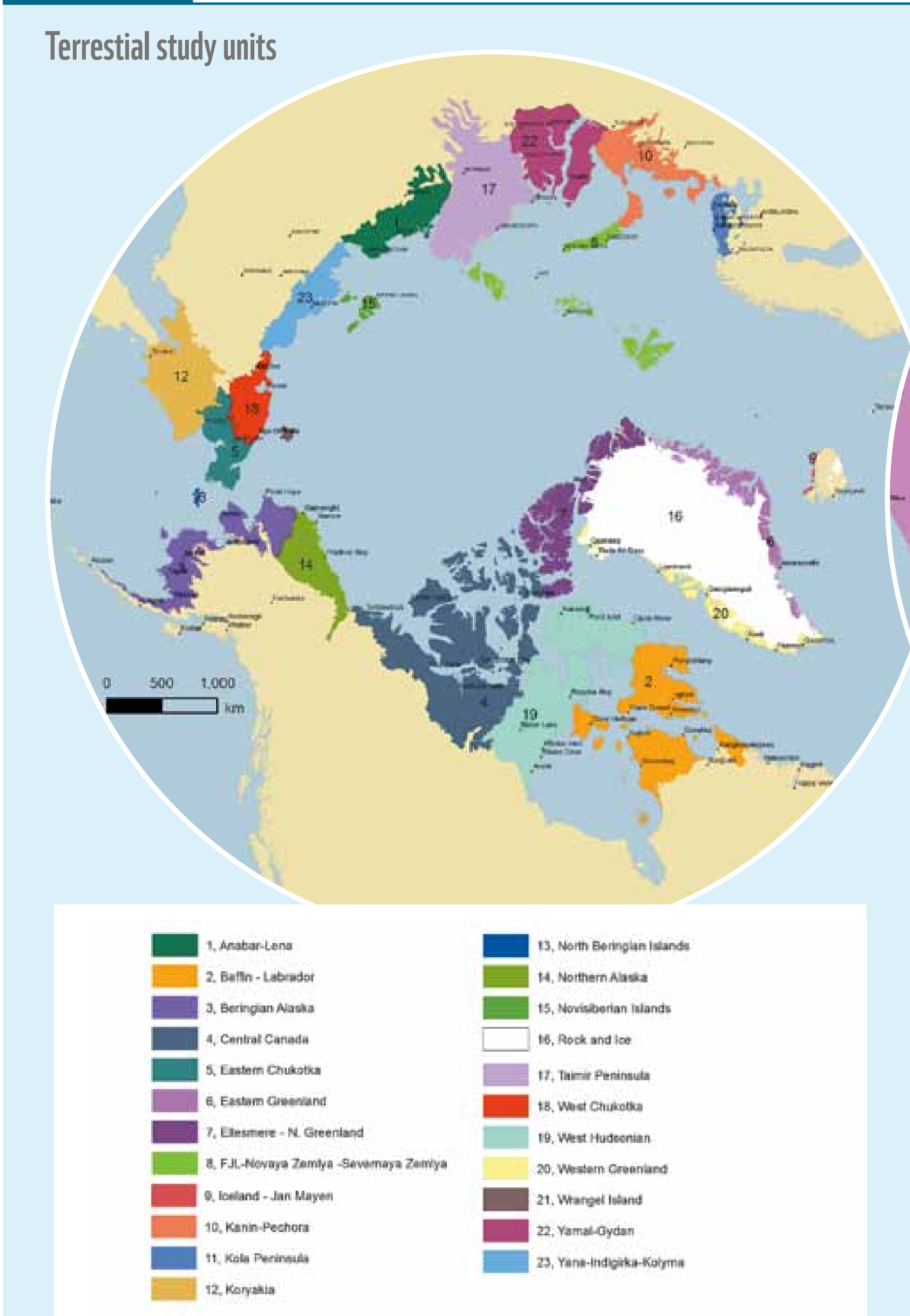
CONSERVATION, EXPANDED

RACER's innovative method translates future threats and pressures to the arctic environment into forward-looking action. It allows us to act now, before more development in the Arctic forecloses strategic conservation options. As such, the purpose of RACER is to change the way we deal with change in the Arctic.

RACER critically widens the focus of conventional arctic conservation by placing centre stage people's influence and dependency on the enduring values and services that functioning ecosystems provide. RACER facilitates maintaining the ecological machinery responsible for the conditions that living things – and northern communities – need. When this machinery is working well, ecosystems have the resilience to adapt to change – to cope with shocks and respond to opportunities while continuing to function in much the same kind of way.

By mapping ecological functions and describing them as key features RACER draws management and planning attention to the forces behind the productivity and diversity important to arctic living systems. By applying resilience-thinking and using scientifically established scenarios of future

RACER study units



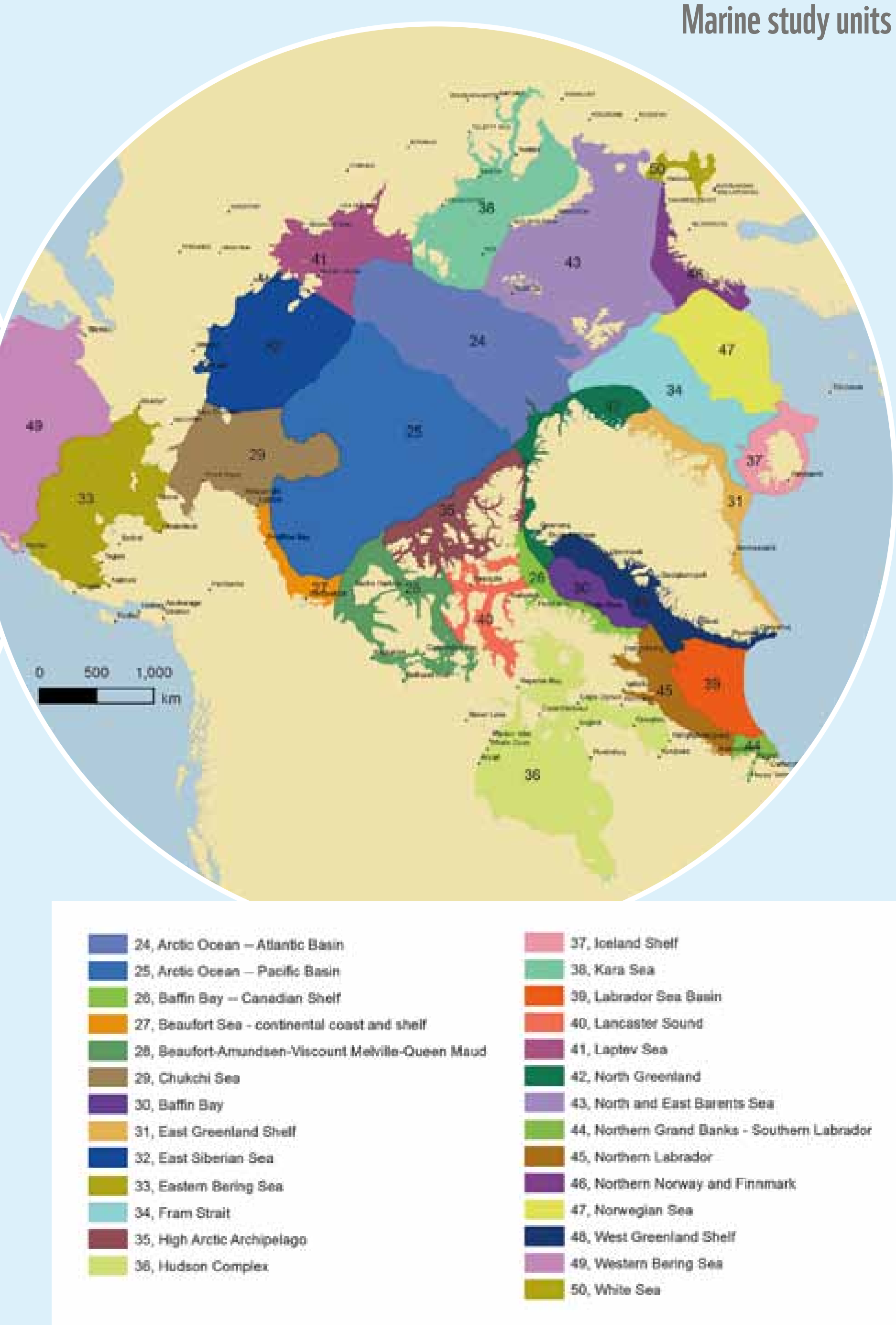
Adapted from the Circumpolar Arctic Vegetation Mapping (CAVM), Floristic Provinces (2003), WWF Terrestrial Ecoregions (2007), Isachenko Landscape Divisions (1985) and Alexandrova Vegatation Zones (1970)

conditions, RACER strategically equips today's decisions with conservation targets that are ecologically meaningful and geographically discrete. Last but not least, RACER embraces the fact that key features – the regional sources of ecosystem resilience – may move across the map when conditions will change.

NEXT STEPS

WWF has plans to assess more ecoregions in addition to the two used to

Marine study units



Adapted from the Marine Ecoregions of the World (MEOW), 2007

provide case studies for the RACER tool, with some of these plans already taking shape. But first and foremost, RACER should be seen as an invitation to discussions among stakeholders as it empowers arctic peoples to address the challenges that rapid arctic change poses to their environment and their way of life.

To the Arctic Council and its associated groups, RACER offers an instrument for understanding and applying the concept of resilience. Its practical application promises to stimulate policies that will improve the management of arctic natural resources at a time of mounting pressure from climate change, industrial development, and other interests. To regional and local planners and managers RACER offers a tool for identifying geographically discrete conservation targets that will remain significant through this climate-altered century, and for initiating stakeholder discussions about how to manage and safeguard these targets. Finally, to experts involved in biodiversity research, monitoring, and conservation, RACER provides a framework for advancing our understanding of the functional role of biodiversity for arctic ecosystems, for the services they provide, and for people. Ultimately, through all this, the hope is that RACER will seed a new way forward for safeguarding the functioning ecosystems that are at the heart of arctic life. ○

Note: The RACER handbook and supporting material is available at www.panda.org/arctic/racer

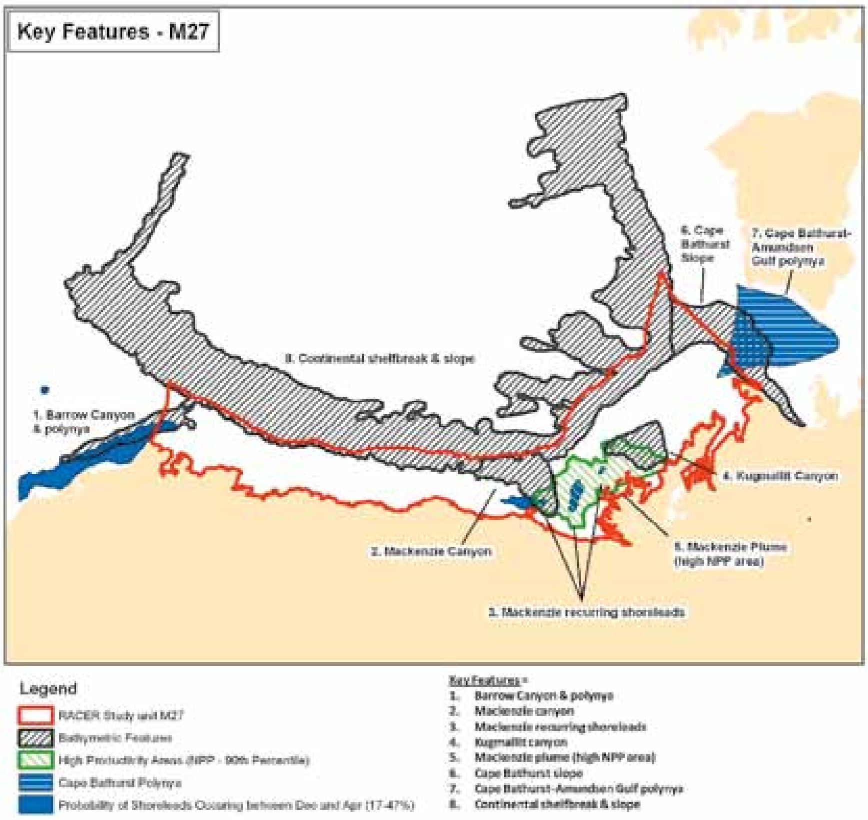
RACER launch

THE RACER PROJECT was launched at a meeting of Senior Arctic Officials November last year.The project was embraced by some Senior Arctic Officials. After the presentation by project lead Martin Sommerkorn, a Norwegian representative called it “an excellent contribution from long-time observer WWF”. The United States Senior Arctic Official noted that the RACER project could be useful for the just-adopted Arctic Council project on resilience, and for the Council's work on ecosystem-based management. Representatives from Greenland and Canada also expressed interest in the project. An updated version of the RACER handbook will be available in April.

RACER has so far been used for assessing the Beaufort continental coast and shelf and the Eastern Chukotka ecoregion. These examples demonstrate how the approach can reveal conservation targets important to spatial planning and management in the Arctic.

Marine case study:

The Beaufort continental coast and shelf



By **PETE EWINS**

PETE EWINS is WWF Canada's Arctic species conservation expert, and has worked and travelled extensively in Canada's northern ecosystems and communities.

THE BEAUFORT CONTINENTAL COAST and shelf is a biologically rich, rectangular undersea ecoregion that lies along the coast of northern Alaska and northwestern Canada.

The ecoregion provides important migratory habitats for various species of marine mammals (whales), fish, and breeding birds. Subsistence hunters have thrived along the Beaufort Sea coast for millennia with traditional camps and settlements often located close to headlands and river mouths to take advantage of seasonally available fish, birds, whales, and other marine mammals. In the past 40 years, industrial oil and gas exploration and development has been gathering momentum.

And now compounded by unprecedented rapid climatic changes in the region, this has added great urgency to the need for a strategic, forward-looking approach to regional natural resource use and fish and wildlife management.

RACER began its pilot rapid assessment of ecosystem resilience in the Beaufort Continental Coast and Shelf ecoregion in 2009. The work—involving an analysis of satellite remote sensing data, the available local knowledge publications and scientific literature, and expert evaluation—has so far identified and located eight marine key features as places of current and future conservation importance for the ecoregion (see above for all eight key features, and more details for two of them on p. 23). ○

Cape Bathurst Slope

The vast majority of the near-surface primary production in this ecoregion is found within this key feature. Although large quantities of dissolved organic material and sediment can be found right at the mouth of the Mackenzie River, the far-larger plume that billows from the river delta across a large area of the continental shelf feeds exceptional plankton growth and other productivity and makes this an important key feature for this ecosystem. Indeed, the plume is responsible for enormous inputs of nutrients and freshwater to the ecoregion and to the entire arctic basin. Water circulation patterns in the area also heavily influence the availability of these nutrients. Large concentrations of many species depend on this key feature, especially during the biologically productive, open-water season. On the other hand, the plume area is characterized by limited habitat variety and its consequent negative impact on species diversity.

The four main drivers at work at this key feature—nutrients, salinity, water currents, and sea surface temperature—enable the remarkable outstanding productivity but also make this feature more susceptible than some others to climate impacts. Climate model forecasts suggest marked changes to surface water and air temperature, salinity, sea ice concentration, and precipitation in the watershed of the Mackenzie River. Experts considered the degree and direction of these impacts on the drivers important to the Mackenzie Plume key feature, and they concluded that the effects of change would not substantially offset the expected ecological performance of this important source of ecoregional productivity. Based on these conclusions, RACER determined that the likelihood was medium-to-high that this key feature would remain an important source of ecosystem resilience for the ecoregion in the decades to come.

Barrow Canyon and Polynya

At the western edge of the ecoregion, the Barrow Canyon is a steep-sided, undersea canyon off Point Barrow, Alaska. Here, relatively warm, salty, and biologically rich Pacific Ocean water circulates northwards through the Bering Strait and contributes to an upwelling of sea-bottom nutrients and minerals caused by the seabed topography. These characteristics also correspond with a large recurring polynya (where waters are deeper than 20 m) during winter and spring. The combined result of these drivers—undersea topography, seasonal ice cover, currents, and sea surface temperature—is a key feature with very significant open water habitat to support high productivity and with varied undersea terrain providing multiple habitats for a diverse array of species. These characteristics, in turn, support large marine mammals and other animals that provide predictable hunting opportunities for local Inuit and other northern residents. Despite substantial expected changes to sea surface water temperature, salinity, and sea ice concentration forecast by relevant General Circulation Models (GCMs), nutrient upwelling and habitat heterogeneity are expected to continue to contribute to exceptional productivity and diversity in a climate-altered future. After consulting with experts, RACER determined that the likelihood was high that this key feature would remain a source of ecosystem resilience for the ecoregion through to 2100.

Terrestrial case study:

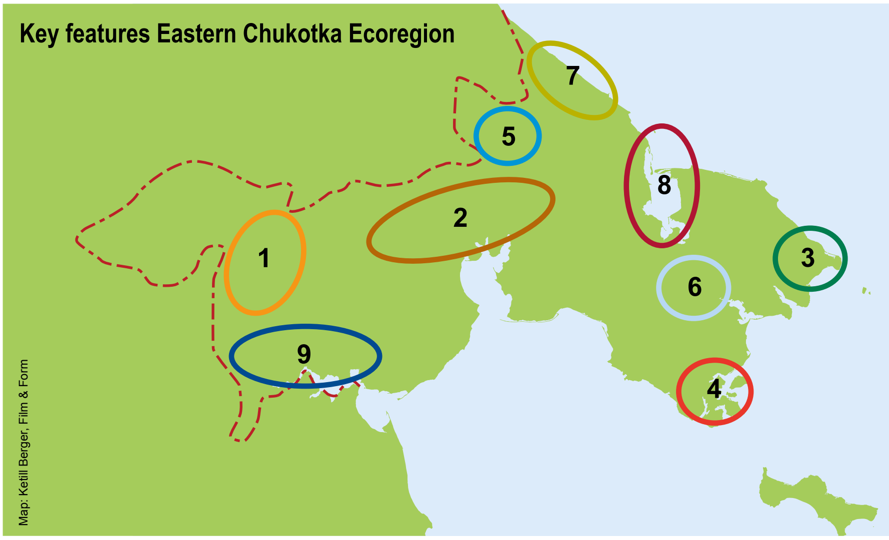
Eastern Chukotka

By **MIKHAIL STISHOV**

THE EASTERN CHUKOTKA ECOREGION is a biologically and geographically varied region at the extreme eastern limits of north-eastern Eurasia. For its northern latitude and widespread permafrost, the ecoregion nevertheless boasts relatively high plant and animal diversity. The region's coasts are well-known as home to polar bears, walrus, whales, seabirds and waterfowl, as well as salmon and whitefish that have been traditionally harvested by Indigenous communities for millennia.

Growing industrial development occurs in patches in the ecoregion. The environmental impact of this industry – including coal, gold, tin and wolfram mining, oil and gas excavation, fisheries, and energy generation – is exacerbated by related construction and local infrastructure. Roads and other means of transportation remain poorly developed, and unrestricted overland travel (in

MIKHAIL STISHOV graduated from Moscow Pedagogical University focusing on geography and biology. From 1982 till 2000 he worked for the Wrangel Island Nature Reserve, as researcher and subsequently Deputy Director for Research, and got a PhD on Wrangel island birds population study. Since 2001 he has been working for several UNDP and UNEP projects and joined WWF in 2010.



- - - Delineation Eastern Chukotka Ecoregion
1. Pekulney Mountain Ridge
2. Southern Ridges of the Chukotka Uplands
3. Coastal Mountains of Cape Dezhnev/Chegitun River
4. Coastal Mountains of Provideniya and Senyavin Strait
5. Amguema River Valley
6. Mechigmen Valley
7. Vancaremskaya Lowlands
8. Kolyuchinskaya Bay
9. Western Anadyr Lowlands

trucks and all-terrain vehicles) affects the ground vegetation.

Nine terrestrial key features were identified during RACER's pilot rapid assessment of ecosystem resilience in the Eastern Chukotka ecoregion from 2009 to 2011 (see above). Below are brief descriptions of two of the key features – and the RACER assessments of their likely persistence in the years to come. ○

Coastal Mountains (of Cape Dezhnev/Chegitun River and of Provideniya and Senyavin Strait)

The coastal mountains of Cape Dezhnev/Chegitun River (key feature #3) and those in the area of Provideniya and Senyavin Strait (key feature #4) occupy the twin tips of the extreme eastern end of the Chukotka Peninsula. The varied landscape of these two key features is characterized by treeless plateaus, valleys, and mountains edged by sea cliffs and rocky shoreline. Patches of bare rocks interrupt large, rolling meadows and areas of remarkably diverse vegetation. While the poor soil and rugged topography make productivity variable or poor for these mountainous key features, the exceptional heterogeneity of the landscape and seashore ensure diversity that is higher than average for the ecoregion. Indeed, these key features are well-known for their species richness and vegetation diversity and are established sites for traditional hunting. They also support many significant seabird colonies considered Important Bird Areas (IBAs) by BirdLife International. Walrus rookeries are also present. This diversity and variety contribute substantially to the capacity of these key features to contribute to ecoregion-wide resilience. Models of climate change (GCMs) predict significant decreases in precipitation and longer dry periods for these coastal mountains as the century progresses. The forecasts also suggest permafrost in these areas will melt to greater depths during the summer. While these changes are expected to have a significant impact on the ecology of these features, the unique and varied terrain is expected to continue to support diversity important to region-wide resilience. RACER experts suggest the likelihood the key features will remain sources of ecosystem resilience throughout this century are "medium to high".

APPLICATION TO PARKS

Resilience-th management

As a warming climate creates even larger changes than are presently occurring, we will not be successful in maintaining ecological integrity as defined in the Canadian National Parks Act, says DONALD MCLENNAN. Adopting a resilience-based, forward looking perspective could refocus the management approach in national parks and facilitate transformation.

PARKS CANADA AND CO-MANAGEMENT partners from northern communities oversee over 200,000 km² of IUCN Level II protected areas, spread across 12 national parks in the Canadian Arctic. Parks Canada has a legislated mandate "to maintain or restore the ecological integrity (EI) of national parks". EI is defined in the Canada National Parks Act as;

"... a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components, and the composition and abundance of native species and biological communities, rates of change, and supporting processes".

This is an inclusive definition that accounts not only for park biota, but also for the ecological drivers and dynamic disturbance processes that characterize

inking and National Park in the Canadian Arctic

Photo: Donald McLennan

Sub-arctic forests on warm, south-facing slopes in Ivvavik National Park have persisted for thousands of years well north of the tree line. In the same way, north facing slopes will act as refugia for arctic tundra species as temperatures continue to warm and forest re-invade the park from the south.

park ecosystems. Although at this time arctic parks in Canada are reporting overall high EI, recent monitoring and research shows that lake ice phenology, stream hydrographs, soil temperature, and active layer depths are changing; expanding shrubs are overtaking herbaceous communities; new species of songbirds and small mammals are arriving, and; disturbance from fire, slope instability, and permafrost collapse is increasing. In short, almost all aspects of what we consider to define the EI of a national park have begun to change, and these changes can be expected to accelerate over the next 50-100 years. What is becoming clear is that, as a warming climate creates even larger changes than are presently occurring, we will not be successful in maintaining EI as defined in the National Parks Act. This emerging reality has policy and management implications for Parks Canada, and directly threatens the sustainability of land-based lifestyles that are at the heart of the land claim settlements under which the parks were established.

RESILIENCE-THINKING AND NATIONAL PARKS MANAGEMENT

The introductory article by Brian Walker in this issue of *The Circle* defines resilience as "...the ability of a system to absorb a disturbance, to re-organize, and to continue functioning in the same kind of way". So in the same way that climate-driven ecological change will mean arctic parks will gradually lose EI, so also will park ecosystems not be 'resilient' to these changes. In fact, it can be expected that the changes we are beginning to see in arctic national park ecosystems are the beginning of a "continuous transformational change" that will characterize arctic ecosystems indefinitely. This acceptance of the idea of continuous ecological change represents an important paradigm shift away from the stationarity-based concepts of representation and desirable park species compositions that have driven the establishment and management of arctic national parks. The task for park co-management boards will be to accept this ongoing and accelerating transformation in ecosystem composition, structure and function as the norm, and to develop forward-looking, knowledge–based management ap-

DONALD MCLENNAN is a Senior Science Advisor in the Office of the Chief Scientist at Parks Canada Agency. He is presently leading a team that is conducting process-based ecological inventories across all arctic national parks as the basis for working with park co-management boards to develop scenarios analyses and proactive climate adaptation strategies. The opinions in this article are those of the author and not of Parks Canada Agency.

THE TASK FOR PARK CO-MANAGEMENT BOARDS WILL BE TO ACCEPT THIS ONGOING AND ACCELERATING TRANSFORMATION IN ECOSYSTEM COMPOSITION, STRUCTURE AND FUNCTION AS THE NORM, AND TO DEVELOP FORWARD-LOOKING, KNOWLEDGE-BASED MANAGEMENT APPROACHES THAT WILL HELP NAVIGATE THESE INEVITABLE CHANGES.

proaches that will help navigate these inevitable changes.

There are a number of areas where adopting a resilience-based, forward-looking perspective could refocus our management approach in national parks and facilitate transformation. For example, we presently set thresholds for monitoring measures based on the historical range of variation in processes such as ecosystem productivity, or historical population trends of focal species. Using a resilience approach we could use modelling approaches to project the rate of change of ecosystem productivity or evolving population trends into the future so as to anticipate and plan for these evolving trends. Also, rather than managing for species assemblages typical of the natural area the park was established to represent, we could move to managing for maintaining key ecological processes and functions – so strive to maintain productivity of key areas, and to maintain functional predator-prey systems, regardless of the species making up the ecological system. These ideas are similar in concept to those presented in the RACER process in this issue. Like RACER, it will be important in national parks to interpret and utilize greater knowledge of ecological process to identify key environmental drivers, anticipate important thresholds, and look for opportunities for ecological resistance to climate change. At a regional scale, the assessments of resilience proposed by RACER will make an important contribution to protected areas planning in a changing world.

NAVIGATING AN UNCERTAIN FUTURE

Parks Canada has recently initiated a project called 'Understanding Climate Driven Ecological Change in Canada's Northern National Parks' to explore a proactive adaptive management approach that aligns with many of the principles of the resilience movement. The program aims to develop a 'knowledge engine' that will help park managers understand and anticipate change to make more informed and proactive decisions that will facilitate effective adaptation. Included in the program are co-management board consultations to identify important social-ecological services, process-based park ecological inventories, scenarios analysis to envision a range of possible futures, focused research aimed at understanding key mechanisms and thresholds, interpretation and plain-language communication of research results, process-based ecosystem modelling to project change over 5 and 15 year management cycles, and operational modelling to assess the effects of management interventions and natural change. The proposal is that this process will iterate continuously on a 5-15 year basis as parks develop their State of the Park reports and update their management plans. Such a forward looking management approach, that utilizes many of the concepts of resilience thinking, would create the continuous learning environment that will be required to successfully navigate an uncertain future in the Canadian Arctic. ○

ARCTIC COUNCIL

Linking theory

If governments are unable to adapt to the ongoing changes in the Arctic, they can cause loss of valuable ecosystem services, affect people's livelihoods and affect the economic, political and cultural development of the region. The Arctic Council is in a unique position to take the leading role in supporting the integration of different knowledge traditions aiming at relevant policy recommendations, says Ambassador ANDREAS VON UEXKÜLL.

THE RECEDING ICE CAP combined with technological developments gives increased access to large oil and gas resources and possibilities for new shipping routes in the Arctic. The delimitation of the continental shelves has not been finalized. Access to resources, shipping, and sovereignty over borders are core interests of any state in the world. Subsequently, and not surprisingly, there are several examples in the media describing arctic cooperation as a new 'cold war' or a 'fight for resources'.

But, in fact, arctic cooperation is one of the least known success stories in international politics. The few disputes on continental shelves are well regulated and managed within the Law of the Sea Convention. The signing of the Search and Rescue agreement and the decision

and practice through the Arctic Council

GOVERNMENTS WILL NEED TO KNOW ABOUT THE GREAT 'REGIME SHIFTS' AND POTENTIAL 'TIPPING POINTS' OF CHANGE TO BE ABLE TO PLAN FOR THE MANAGEMENT OF NATURAL RESOURCES IN THE FUTURE.

to establish a standing Secretariat in Tromsø in 2011 clearly demonstrates that the Arctic Council can move from words to action and a more efficient cooperation.

INFORMED DECISIONS

There is a need to focus on the real challenges in the Arctic, such as economic and social development, and protection of the environment. The Arctic is home to around four million people, many of them Indigenous people. The societies are often fragile, located in a fragile environment. A changed climate requires more political cooperation across territorial borders. The Arctic Council should do its share in facilitating positive economic and social change for the people in the region, with respect to the environment and the social situation. But in order to be able to make informed decisions that bring added value it is crucial that governments have access to the best expertise.

Political cooperation within the Arctic Council has played a major role in enhancing the knowledge of the region by supporting scientific assessments with a clear link to policy development. While there is research on different aspects of environmental impacts in the Arctic, the scope of assessments of the implications from social and ecological factors remains limited. Sweden has therefore initiated an assessment of resilience, an Arctic Resilience Report, to better understand the rapid changes that are taking place. It will provide important input for management within national borders, between sectors and for the Arctic in a more global context.

The Arctic Council received a very valuable presentation about the WWF project Rapid Assessment of Circum-Arctic Ecosystem Resilience (RACER) at the latest SAO-meeting in Luleå November 2011. We are looking forward to a dialogue with both WWF and the Arctic Resilience Report initiative on these matters.

POLITICAL COOPERATION WITHIN THE ARCTIC COUNCIL HAS PLAYED A MAJOR ROLE IN ENHANCING THE KNOWLEDGE OF THE REGION BY SUPPORTING SCIENTIFIC ASSESSMENTS WITH A CLEAR LINK TO POLICY DEVELOPMENT.

INTEGRATED VIEW

Governments will need to know about the great 'regime shifts' and potential 'tipping points' of change to be able to plan for the management of natural resources in the future. Inability to adapt to these changes can cause loss of valuable ecosystem services, affect people's livelihoods and affect the economic, political and cultural development of the region. Currently we see the Arctic Resilience Report steering group organizing itself and we are eagerly looking forward to the interim report which will be presented to the Arctic Council in 2013. It is important that all relevant stakeholders and interested parties contribute with their thinking to the study.

The Arctic Council is in a unique position to take the leading role in supporting the integration of different knowledge traditions aiming at relevant policy recommendations. An integrated view will be needed both in relation to sub-regional efforts towards integrated ecosystem management and for decisions that address the Arctic region as a whole.○

Sweden has chaired the Arctic Council since May 2011. Ambassador **ANDREAS VON UEXKÜLL** is Sweden's Senior Arctic Official and leads the Task Force responsible for implementing the decisions in Nuuk to strengthen the Arctic Council. von Uexküll has worked for the Swedish Ministry for Foreign Affairs since 1999 with postings in Estonia and the Permanent Representation to the UN in New York.

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THE PICTURE

The man behind

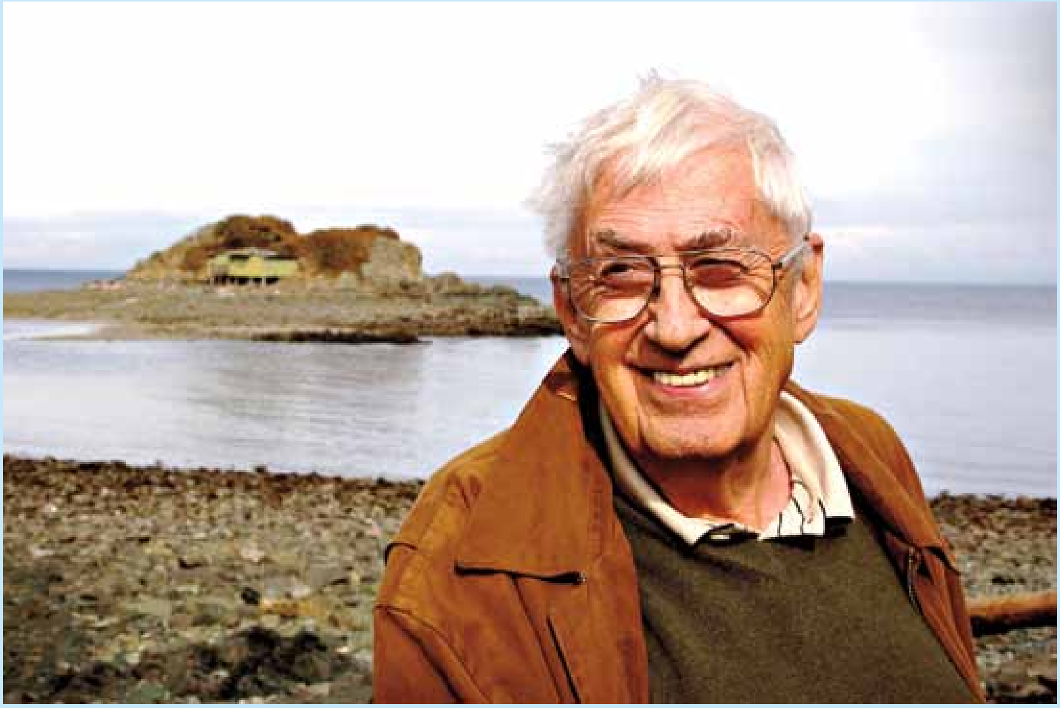

Photo: Flicr/Creative Commons/SFU Public Affairs and Media Relations

THE CONCEPT OF RESILIENCE in ecological systems was first introduced by the Canadian ecologist Crawford Stanley Holling in 1973 to describe the persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes.

C.S. Holling retired from the University of Florida in 1999, but remains on the faculty as an Emeritus Eminent Scholar.

He has introduced important ideas in the application of ecology and evolution, including resilience, adaptive management, and panarchy. He was founding editor-in-chief of the open access on-line journal Conservation Ecology, now renamed Ecology and Society. He was also the founder of the Resilience Alliance, an international science network.

In 2009, he was made an Officer of the Order of Canada "for his pioneering contributions to the field of ecology, notably for his work on ecosystem dynamics, resilience theory and ecological economics".

Source: Wikipedia