Rapid Arctic Transitions due to Infrastructure and Climate (RATIC):

Sustainable Arctic Infrastructure Forum

Arctic Science Summit Week 2017

Clarion Congress Hotel
Aquarius Room

Prague, Czech Republic
3 April 2017

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Financial support for this workshop came from International Arctic Science Committee (IASC) Terrestrial Working Group, the U.S. National Aeronautics and Space Administration (NASA) Land-Cover and Land-Use Change Program (Grant No. NNX09AK56G) and the NASA Arctic-Boreal Vulnerability Experiment (ABoVE) (Grant No. NNX14A0905). Administrative support came from the Conservation of Arctic Flora and Fauna (CAFF), IASC, and the University of Alaska Fairbanks, Institute of Arctic Biology.

[IASC, NASA, NSF, AGC logos]

http://www.geobotany.uaf.edu/ava

SAIF Meeting agenda

Meeting agenda: Monday, 3 April

Overview

Morning: Welcome, goals for the workshop, brief orientation talks, student keynote, and charge for the workshop

Facilitator – Jana Peirce

- **09:00 Welcome, introduction of participants:** *Elena Kuznetsova*
- **09:15 Logistics:** *Jana Peirce*
- **09:25 RATIC and goals of the workshop:** *Skip Walker*
- **09:45 Social effects of infrastructure:** *Peter Schweitzer*
- **10:05 Adaptive management and cumulative effects:** *Gary Kofinas*
- **10:25 Ecological effects of infrastructure:** *Bruce Forbes*
- **10:45 Coffee Break**
- **11:00 Keynote student presentation:** "Cumulative effects of environmental change on culturally significant ecosystems in the Inuvialuit settlement region": *William Tyson*
- **11:20 Charge for the workshop:** *Skip Walker*
- **11:40 Breakout groups by infrastructure systems**
- **13:00 Lunch**

Afternoon:

- **14:00 Continue breakout groups**
- **15:30 Coffee Break**
- **15:50 Plenary to present breakout groups 1 & 2 results (powerpoint template)**
- **16:20 Plenary to present breakout groups 3 & 4 results (powerpoint template)**
- **16:50 How to organize results of workshop into a RATIC strategy document**
- **17:20 Discussion of journal publication**
- **17:40 ADJOURN**

Evening: Dinner at local restaurant

Rapid Arctic Transitions due to Infrastructure and Climate (RATIC) initiative

Definitions

Infrastructure: "The basic physical and organizational structures and facilities (e.g., buildings, roads, and power supplies) needed for the operation of a society or enterprise."

Arctic social-ecological systems:

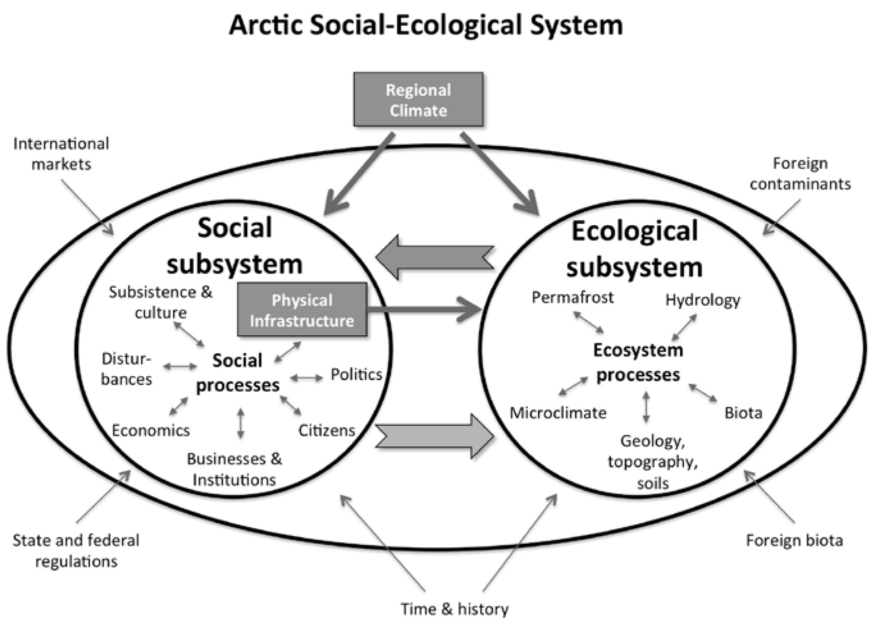

Figure 1. Arctic social-ecological system (SES). The Arctic SES consists of ecological and social subsystems that strongly influence one another at local and regional scales. This diagram emphasizes the roles of climate and physical infrastructure, and the feedback to the social subsystem from the ecological subsystem. For each subsystem there are external factors (e.g. regional climate and international markets) that are not influenced by local conditions (known as state factors by ecologists) and internal factors (e.g. institutions or disturbances), which respond to external factors and which both affect, and are affected by local processes (known as interactive controls by ecologists). Climate operates directly on both the social and ecological systems. Infrastructure is a product of the social system that influences other social processes and also directly influences permafrost, microclimates, biota, etc. of the Arctic ecological system. (Based on Whiteman et al., 2004).

Cumulative effects: The impact on [social-ecological systems] which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non- Federal) or person undertakes such other actions (modified from 40 CFR 1508.7).

Scope of RATIC

Cumulative social-ecological effects and interactions between infrastructure and climate change, including:

Drivers of change (historical, social, economic, political, and ecological)
Effects (social and ecological)
Sustainable management of changes

Toyama Infrastructure Resolution

Whereas:

- Northerners and Arctic socio-ecological systems are strongly impacted by changes in infrastructure and climate;
- The drivers and consequences of infrastructure development in the Arctic are not adequately addressed by the Arctic research community;
- The complexity of the Arctic infrastructure challenges requires a multi-disciplinary and circumpolar collaboration approach involving all Arctic countries and implementation of an integrated social-ecological-system approach.

Therefore:

We propose that ICARP-III identify sustainable infrastructure development and maintenance as a key research theme that requires a multidisciplinary collaborative approach involving scientists, local communities, governments, and industry.

Signed by members and Fellows of the IASC Cryosphere Working Group, Social & Human Working Group, and the Terrestrial Working Group, 25 April 2015.

Infrastructure systems

Arctic infrastructure comes in many different forms and sizes (Table 1), from the camps, trails, and migration corridors of indigenous people to urban infrastructure of cities and networks of roads, pipelines, powerlines, and construction camps associated with oil and gas development, and urban infrastructure in cities. Certain forms of physical infrastructure are a precondition for contemporary life in the Arctic, while others do not seem to benefit local residents. Thus, the question about sustainable infrastructure development and maintenance involves choices, costs, and benefits.

Table 1. Major infrastructure systems.
*Indigenous infrastructure (camps, trails, corrals, migration corridors, etc.)
*Onshore oil & gas fields
*Urban (cities)
*Rural (villages and subsistence infrastructure)
*Corridors (highways, railroads, pipelines)
Mining and smelting
Off shore oil & gas
*to be addressed in this workshop

Sustainable Arctic Infrastructure Forum (SAIF)

Primary goal

Address ICARP III's Research Priority 3: To "understand the vulnerability and resilience of Arctic environments and societies to the cumulative effects and interactions between infrastructure and climate change."

Tasks

1. **Identify and coordinate the RATIC-related research activities of the five IASC working groups** (Atmospheric, Cryosphere, Marine, Social & Human, Terrestrial) (Fig. 2).
2. **Examine each infrastructure system** (see Table 1) in terms of drivers, effects and constraints on CEs, key unanswered science questions, policy/ advocacy question, and tools for addressing the questions (Table 2).
3. Review the international state of knowledge **(history)** regarding cumulative effects and socio-economic and biophysical processes for each infrastructure system (e.g. Table 3).
4. Organize these activities into a **RATIC strategy document.**
5. Develop **a journal paper** focused on RATIC.

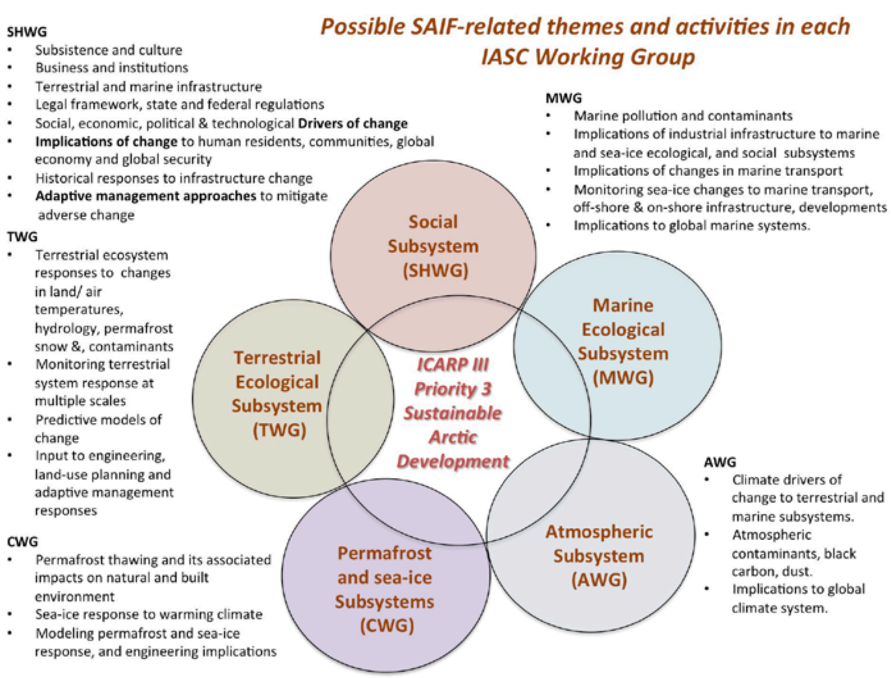

Figure 2. Preliminary conceptual framework for the SAIF meeting. The diagram shows themes and activities of each working group that could contribute to addressing ICARP III Priority 3 research related to sustainable Arctic infrastructure development.

Deliverables

1. RATIC strategy document to IASC Secretariat by 31 Dec 2017.
2. Journal paper focused on Rapid Arctic Transitions due to Infrastructure and Climate change.
3. Website and publically accessible information materials

Table 2. Example breakout group worksheet for oil & gas fields.

Infrastructure system: Oil & gas fields						
Key references	**Examples**	**Effects on physical and social subsystems**	**Drivers, effects and constraints (specific examples)**	**Example key science questions**	**Example policy questions**	**Approaches (Tools, institutions or groups to answer questions)**
NRC 2003; AMAP 2010	Overview of circumpolar O&G activities: AMAP 2010, Section 2.1 to 2.4	**Physical systems:** Summary in AMAP 2010; Section 2.6.1: ▪ Permafrost ▪ Soil ▪ Vegetation ▪ Water resources ▪ Fish and wildlife ▪ Atmosphere **Social systems:** Summary in AMAP 2010, Section 3.3.3: • Macroeconomic • Microeconomic • Demographic • Health • Education & training • Governance • Cultural integrity • Contact with nature • Social health • Interactions	**Drivers:** • What are the major climate-change interactions with each infrastructure system? • What are the major interactions between permafrost, hydrology, infrastructure, and climate change? **Effects:** • Where can we expect serious transitions in physical and social systems (list possibilities)? • Where are the systems resilient or more vulnerable? • How will increasing fragmentation and degradation of the landscapes and ecosystems affect impacts of climate change? • What are the implications of climate-infrastructure interactions to society (cultural, economic, political, regulatory)? **Constraints:** • How does geologic and geographic heterogeneity (climate, soils, topography, cultures) affect the responses to climate and infrastructure? • How does the availability of resources for infrastructure (e.g., sand vs. gravel for roads) affect response to climate change? • How does proximity to local population centers affect the cumulative impacts?	• What are the effects of increased ice-wedge thermokarst on wildlife, hydrological systems, and access for subsistence? • How do we predict the extent and cumulative landscape effects of expanding networks of roads and pipelines and their interactions with climate change? • How do different landscape settings, cultural settings, and historical factors affect the cumulative outcomes of development? • How do we minimize landscape fragmentation by networks of roads and pipelines?	• How do we protect areas of high cultural and ecological value? • How do we develop more effective planning tools for adaptive management. • Where is the concept of adaptive management working? • How do we more effectively involve local communities and government in this conversation? • What are successful strategies for coping with climate change in oil & gas infrastructure systems?	• Best practices, best available technology, new technology summarized in AMAP 2010, Section 2.5. • Adaptive management , “cradle-to-grave” approaches to exploration, developpment, operation, and abandonment of infrastructure (Gary or Tracie examples?) • Deep histories exploring the geological, ecological, cultural, social, & economic sources of the impacts and transformations to SESs (e.g., Colorado coal development, Andrews, 2014). • Future scenarios models (e.g. Tyson et al. 2016). • Cross-disciplinary studies involving natural sciences, social sciences, engineering and education (e.g. U.S. ArcSEES projects; Finland ENSINOR project; Canada ADAPT and IRISs). • Satellites & remote sensing monitoring of change (e.g. Raynolds et al. 2014, Kumpula et al. 2010)

Table 3. Key events in the history of oil and gas cumulative effects analysis.

Event	Publications	Concepts or major contribution	Description
1. Defining Principals of CE	Holling 1973; CEQ 1977, 1979, 1997 Published in the Code of Federal Regulations (CFR)	**Defined key terms of CE analysis and provided guidance for methods of CE assessment**	Key terms defined: Resistance, stability, Time crowding, time lags, space crowding, cross-boundary effects, fragmentation, compounding effects, indirect effects, triggers and thresholds, nibbling. Methods include Scoping for CE, Describing the affected environment, determining the environmental consequences of CE, example methods, techniques, and tools.
2. Cumulative Effects of Prudhoe Bay Oilfield	Walker et al. 1986, 1987	**First focused study on CE of oilfield development**	Mapped visible historical infrastructure and landscape changes 1969-1983 at two scales; Identified thermokarst as an important nonlinear effect likely to have major impact in the future, identified indirect effects as covering a larger area than the direct footprint.
3. Cumulative effects of oil development on caribou in the Kuparuk Oilfield	Nelleman and Cameron 1998	**Examined effects of oilfield infrastructure on caribou**	Examined effects of increased road density on caribou in the Kuparuk oilfield. (i) females and calves are far more sensitive to surface development than adult males and yearlings, (ii) the greatest incremental impacts are attributable to initial construction of roads and related facilities, and (iii) the extent of avoidance greatly exceeds the physical "footprint" of an oil-field complex.
4 GLOBIO, Global methodology for mapping human impacts on the biosphere	Nelleman et al. 2001,	**Circumpolar assessment of road density**	Maps of historical changes and scenarios of arctic-wide network of roads. Infrastructure leading cause of environmental disturbance
5. Cumulative effects of North Slope development	NRC 2003	**Broadened the area of Alaska analysis of CEs. Broadened the scope of impacts. Indentified several knowledge and research gaps**	Focused on developed area of the North Slope, but excluded Dalton Highway/ TAPS corridor and effects on ANWR. included changes to human environment, history of oil development on North Slope, , foreseeable future developments, effects on permafrost, subsurface environment, air quality, freshwater environment, marine environment, effects on vegetation, effects of seismic, effects on animals. Identified need for comprehensive planning, ecosystem-level research, more focused information on human-health effects, off-shore oil spills, research in human communities air contaminants, seismic exploration, caribou and bowhead whales, consequences of water withdrawal, future of abandoned infrastructure.
6. CE & social-ecological systems (SESs)	B. Walker et al. 2004; Chapin et al. 2006	**Defined and sharpened the terms related to directional changes in SESs including resistance, resilience, adaptation, and transformation with examples from Arctic Alaska**	In this article we extend the theory of community pre- diction by presenting seven hypotheses for predicting community structure in a directionally changing world. The first three address well- studied community responses to environmental and ecological change: ecological communities are most likely to exhibit threshold changes in structure when perturbations cause large changes in limiting soil or sediment resources, dominant or keystone species, or attributes of disturbance regime that influence community recruitment. Four additional hypotheses address social-ecological interactions and apply to both ecological communities and social-ecological systems. Human responsiveness to short-term and local costs and benefits often leads to human actions with unintended long-term impacts, particularly those that are far from the site of decision making or are geographically dispersed. Policies are usually based on past conditions of ecosystem services rather than expected future trends. Finally, institutions that strengthen negative feedbacks between human actions and social- ecological consequences can reduce human impacts through more responsive (and thus more effective) management of public ecosystem services. Because of the large role that humans play in modifying ecosystems and ecosystem services, it is particularly important to test and improve social-ecological hypotheses as a basis for shaping appropriate policies for long-term ecosystem resilience.
7. Resilience of Nenets socio-economic systems	Forbes et al. 2009	**Effects of infrastructure to indigenous socio-economic systems**	Widely cited publication on socio-economic effects of gas development Nenets people on the Yamal Peninsula, Russia. CEs include effects to tightly integrated arctic social-ecological systems (SESs) . Focused on migratory herders, and domesticated reindeer (*Rangifer tarandus* L.). Found Yamal-Nenets SES highly resilient according to a few key measures. Particularly crucial to success is the unfettered movement of people and animals in space and time, which allows them to alternately avoid or exploit a wide range of natural and anthropogenic habitats. However, expansion of infrastructure, concomitant terrestrial and freshwater ecosystem degradation, climate change, and a massive influx of workers underway present a looming threat to future resilience.
8. Panarctic assessment of oil and gas activities	AMAP 2010	**Arctic-wide assessment of extent and potential effects of Arctic oil and gas development**	2-volume report on the Arctic Council's 2006 assessment of oil and gas activities in the Arctic, including overviews of activities in all regions of the Arctic, best practices, physical impacts and disturbances, noise, oil spills, monitoring and research, social and economic effects of oil and gas activities, several case studies in the Yamal, Nenet Autonomous Okrug, Nuiqsut, Norman Wells, MacKenzie R. delta, Normal Wells, Bent Horn, Canada, Barents Sean, Greenland. Conclusions include comparison of governance and response across case studies, effects on social economic systems. Recommendations include managing oil and gas, gaps in information, monitoring to improve basis for assessment.
9. IASC RATIC white paper	Walker & Peirce (ed.) 2015	**IASC White paper for ICARP III devoted to Rapid Arctic Transitions due to Infrastructure and Climate (RATIC)**	A presentation of five case studies of RATIC workshops at Arctic Change 2014 (Ottawa, Canada) and Arctic Science Summit Week 2015 (Yohama, Japan). Focuses on interactions between infrastructure and climate change. RATIC is a forum for developing and sharing new ideas regarding all forms of infrastructure. Several case studies expand the types of infrastructure considered beyond oil & gas fields to include: urban development (including engineering large buildings on unstable permafrost), major corridors of railways, highways, pipelines, rural land clearing for agriculture, thaw slumps, and other forms of thermal erosion, river erosion and floods, changes in the subarctic. Major themes cutting across all forms of Arctic infrastructure include effects on and of ice-rich permafrost, hydrological effects of changes in hydro-climate and enhanced thermokarst, fragmentation of large intact systems. Conclusions include: (1) The need to examine CE of infrastructure in the context of Arctic social-ecological systems. (2) Changes to permafrost is a pressing ecological issue across all types of infrastructure with large social costs. (3) The indirect effects of infrastructure far exceed the direct effects of the planned footprints. (4) New tools are needed including enhanced GIS/remote sensing capabilities, scenario modeling and other tools of adaptive management.

Abstracts of Talks

RATIC and goals of the workshop: *Skip Walker*

Social effects of infrastructure: *Peter Schweitzer*

Adaptive management and cumulative effects: *Gary Kofinas*

Ecological effects of infrastructure: *Bruce Forbes*

Keynote student presentation: "Cumulative effects of environmental change on culturally significant ecosystems in the Inuvialuit settlement region": *William Tyson*