

IPY Collaborative Research: Is the Arctic Human Environment Moving to a New State?

According to the Study of Environmental Arctic Change (SEARCH) *Plans for Implementation During the International Polar Year and Beyond*, the goal of SEARCH is to “understand the nature, extent, and future development of the system-scale changes presently observed in the Arctic [such as] increasing average annual surface air temperatures, decreasing summer sea ice extent and sea ice mass, changing ocean circulation, northward movement of tree lines and vegetation zones, thawing glacial ice masses and permafrost, and changing socioeconomic dynamics” (SEARCH 2005, vii). A main question for SEARCH is whether the Arctic system is moving to a new state. The *Plans for Implementation* notes key secondary questions that must be addressed to answer this main question, including “How do cultural and economic systems interact with Arctic environmental change?”

Our long-range goal under SEARCH is to understand how socio-economic systems respond to rapid environmental change, and how local response interacts with broad forces of development and government policies to affect the well-being of Arctic residents. We propose as first steps toward this long-range goal: (1) developing a Phase One integrated pan-Arctic human dimension observation system based on existing information pertaining to the marine mammal environment and subsistence hunting, Arctic/subarctic commercial and community fisheries environment, and the Arctic economic development environment, including petroleum, mining, tourism, and well-being; and, (2) based on the Phase One observation system, analysis, and modeling, designing a Phase Two human-dimensions observation system that includes primary data collection as needed.

The proposed research responds to the NSF IPY Announcement of Opportunity calling for development and deployment of a science-driven pan-Arctic observing system that will enable SEARCH by measuring the full range of continuing changes now underway. This Human Dimension Observation System is designed to become part of a network of measurement systems developed within SEARCH. We also take into account the recommendations of the National Academy of Sciences Committee on Designing an Arctic Observing Network, by integrating existing data for key variables identified by the Committee—population size and structure, births, deaths, migration, health measures, cultural diversity, education, and economic indicators, including employment, subsistence, and government structure.

The approach taken in this proposal builds directly upon the priorities and strategies contained in the SEARCH *Plans for Implementation* (2005:43): “A key goal then of the Responding to Change component of SEARCH is to identify the specific knowledge necessary to make informed decisions about adaptive and mitigative strategies at the level of the individual, the community, the region, and outside the Arctic. Wherever possible, scientific activity should be undertaken with appropriate stakeholder groups.” We have identified stakeholder groups in each of the “arenas of climate-human interaction” (i.e. marine mammal hunting, fisheries, resource development) and we have formed an advisory group made up of representatives of the following indigenous organizations: RAIPON, Inuvialuit Regional Corporation, Saami Council, Maniilaq, North Slope Borough, Makivik Corp., and the Labrador Inuit Association.

Intellectual Merit: Ninety-five members of the Arctic science community participated in the workshop resulting in the SEARCH *Plans for Implementation*. Dozens more scientists have contributed to the development of SEARCH science questions and research priorities. Our proposal is directly derived from the science questions and research priorities contained in the SEARCH *Plans for Implementation*. The consensus of the science community is that long-term observations are necessary to understand the pan-Arctic changes now being observed. This proposal focuses on the human dimensions-related components of the observation system.

Broader Impact: Our proposal identifies 68 stakeholder groups likely to be interested in the results of SEARCH. We propose to involve such stakeholder groups in the identification and incorporation of existing data in a phase one observation system. We also propose to involve them in the assessment of the adequacy of existing information and in the identification of the most useful data and predictions. Such involvement of stakeholder groups is one of the high priorities of SEARCH. Educational applications will be developed from project results, and shared with schools in Arctic regions as well.

Project Description

Integration with the Goals of SEARCH

According to the *SEARCH Plans for Implementation* (2005:vii), “The overall goal of the Study of Environmental Arctic Change (SEARCH) is to understand the nature, extent, and future development of the system-scale changes presently observed in the Arctic.” The overarching SEARCH science question, “Is the Arctic system moving to a new state?” leads to six other science questions, one of which is, “How do cultural and socioeconomic systems interact with environmental change?” Both of these questions drive the science in this proposal.

The implementation of SEARCH is being directed by a Science Steering Committee and three panels: Observing Change, Understanding Change, and Responding to Change. The NSF/IPY Announcement of Opportunity calls for proposals that “develop and deploy a pan-Arctic observing system that will enable SEARCH by measuring the full range of continuing changes now underway. Special emphasis will be given to establishing a research-driven network of measurement systems during IPY 2007–2008, including a network of human observations and indigenous knowledge in the Arctic. Proposals to develop and implement components should be driven by science questions that underline the need for a long-term observation system.” The *SEARCH Plans for Implementation* integrates observation, understanding change, and responding to change activities. This integration reflects the conclusion of the science community that the SEARCH goal of using an understanding of the Arctic system changes to develop adaptive responses requires collaboration with stakeholder groups in all phases of SEARCH, including the design and implementation of observation systems (SEARCH 2005:43,46).

Design Principles for an Observation System

Based on the *SEARCH Plans for Implementation*, we propose to apply the following design principles:

1. Include elements in the observation system that are: (a) useful to stakeholders; (b) relevant to understanding interactions; (c) critical to making predictions
2. Involve stakeholders in identification of observations relevant to adapting to ongoing changes
3. Design the observation system to take maximum advantage of existing data sources
4. Design observation databases to maximize access of stakeholder groups and the scientific community
5. Design observation databases to support analysis of observations collected at different time and geographic scales
6. Recognize that there are different “arenas” in which climate-human interactions are likely to occur. Those highlighted in *SEARCH Plans for Implementation* include: marine mammal environment and subsistence hunting, the Arctic commercial fisheries environment and Arctic community fisheries, and the Arctic resource development environment, including petroleum, mining, and tourism.
7. Recognize that changes in the human environment result from an interaction with multiple forces for change, including government policies. The observation system needs to be designed to yield the data necessary to differentiate between the effects of multiple forces for change.

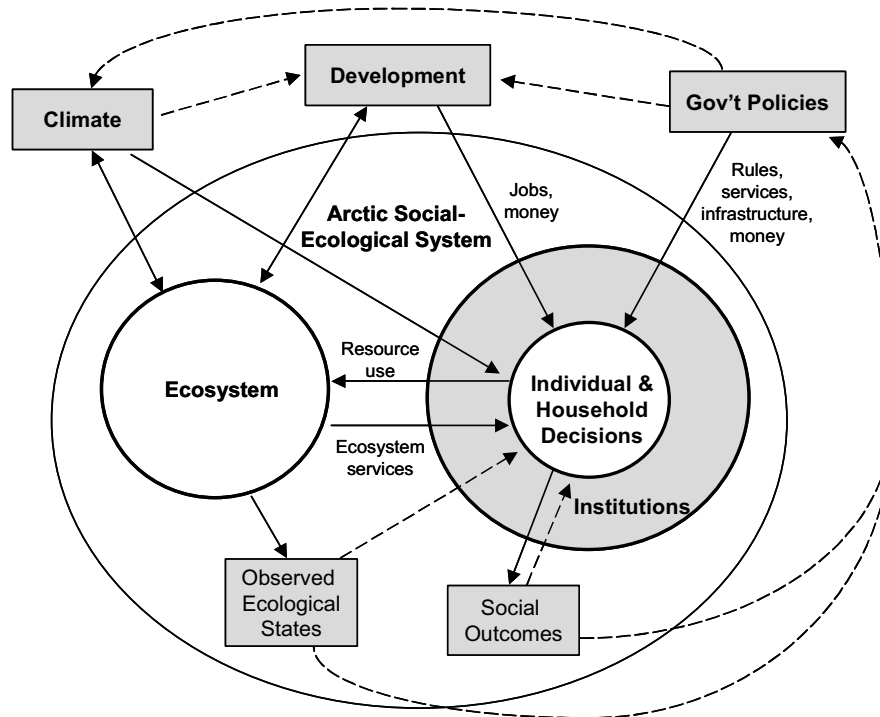
Science Questions and Activities

Climate shifts are creating a host of rapid environmental changes that directly affect people living and working in the Arctic. Observed changes include:

1. Increased temperature and reduced extent of permafrost (Lachenbruch and Marshall, 1986);
2. Decreased extent and thickness of sea ice (Rothrock et al., 2003; Stroeve et al., 2005);
3. Increased Arctic river discharges (Peterson et al., 2002);
4. Changes in land surface cover, including increased wildfires (Chapin et al., 2003) and conversion of tundra to shrubs (Sturm et al., 2001);
5. Increased ocean temperatures (Levitus et al., 2000; Steele and Boyd 1998);
6. Shorter snow cover season and longer growing season (Stone et al., 2002; Dye, 2002);
7. Reduced mass of Arctic and subarctic glaciers (Arendt et al., 2002);
8. Increased coastal erosion, threatening infrastructure and communities (O’Harra, 2004).

The climate-driven environmental changes are widespread and diverse, and may interact with other important drivers of change in Arctic societies, notably development and government policies (see Figure 1). Designing an observation system capable of advancing our understanding the combined effects of these changes requires an integrated approach to environmental, economic, and social change in an Arctic social-ecological system (Kofinas et al., 2005).

Figure 1: Conceptual Model



Climate-linked environmental changes will directly affect ecosystems that provide services to people—including processes that support human life. Social drivers of change in the Arctic, such as development and government policies, affect individual and collective decisions about resource use and harvests, creating feedbacks that may change the ecosystems. Development—mainly resource development and tourism—provides flows of jobs and money, while government policies affect services, infrastructure, money, and rules. These factors all influence resource use decisions (Kruse et al.,

2004; Berman et al., 2004). Climate change also impacts development activities in the Arctic, along with infrastructure, transportation, and provision of government services. Studying the interactions within these arenas of change, and evaluating the coping capacity of communities, will advance the systematic assessment of Arctic societies' vulnerability to climate change (Polsky et al., 2003; Ford and Smit, 2004).

Our long-range goal under SEARCH, however, goes beyond measuring vulnerability. We seek to understand the way that the socio-economic system responds to environmental change in the Arctic, and how this affects the well-being of residents. Local and regional institutions influence decisions people make, mitigating climate impacts on Arctic societies (Berkes et al. 2003). We therefore need to observe changing social outcomes and local institutions, as well as individual activities (see Figure 1). Resource management bodies and local institutions mediate outcomes for specific arenas of change such as marine mammal harvests and wage jobs. But Martin (2005) found that these “domain-specific” outcomes were only indirectly associated with Arctic residents' subjective overall satisfaction. What did matter directly were strength of family ties, wellness, and social connectedness. That is, observations of arena-specific changes, even after mediation by local institutions, are insufficient to predict social outcomes. We also need to observe changes in social support systems.

Figure 1 is intended to apply to the complete array of Arctic system activities and to more specific “arenas” expected to experience strong interactions with climate change. The *SEARCH Plans for Implementation* highlighted three such arenas for early attention: (1) Arctic and subarctic fisheries; (2) marine transportation and associated resource development; and, (3) subsistence harvests (SEARCH 2005:44). In keeping with the priorities of the scientific community and stakeholders, we propose to focus observation system development on fisheries, resource development (including tourism), and marine mammal hunting.

Fisheries Arena Observation Subsystem

Climate and ocean variations have affected many historical fisheries (Beamish, 1995; Jakobsson et al., 1994; Laevastu, 1993), and played roles in recent North Atlantic disasters (Drinkwater, 2002; Rose, 2003; Vilhjálmsson, 1997). Although it is difficult to isolate the effects of climate on changing fisheries and fishing communities, there is no doubt that climate affects ecosystems (Stenseth and Ottersen 2004, in collaboration with James W. Hurrell and Andrea Belgrano). Global climate change poses an obvious challenge for the future. Recent studies include a sea-by-sea analysis by Vilhjálmsson and Hoel for the *Arctic Climate Impact Assessment* (2005), and two diverse edited volumes about climate-change impacts on pelagic fisheries (Hannesson et al., 2006) and cod (Drinkwater and Brander, forthcoming). The global history of commercial fishing offers ample evidence that changes in fisheries resource abundance have economic, social and political consequences. In any given region climate change is likely to reduce the abundance of some species while increasing that of others, affecting commercial harvests over varying time scales (e.g., Knapp et al., 1998; Drinkwater, 2005). The larger consequences of climate change are more complicated than warming temperatures that could shift a species' range northwards (Drinkwater and Brander, forthcoming). Other variables such as currents, stratification, seasonality, waves and storminess affect important species both directly and through food-web interactions, making prediction a daunting task. Fisheries pressure, too, can interact with climate-driven change, sometimes with negative consequences. On land, the consequences of climate change for fisheries-dependent societies will be even more contingent and complex (e.g., Hamilton et al. 2000, 2001, 2003, 2004a, 2004b, 2006).

Atlantic cod illustrate the negative synergy of environmental adversity coming atop overfishing. West Greenland stocks were reduced by peak fishing in the early to mid-1960s. The fall after this peak coincided with the abrupt arrival in 1969–70 of a pulse of cold, fresh Arctic water—the Great Salinity Anomaly of the 1970s (GSA'70s; see Dickson et al., 1988). Although warmer conditions eventually returned to West Greenland, they were punctuated by further salinity anomalies related to circulation changes and Greenland Ice Sheet attrition (Belkin et al., 1998; Belkin, 2000) that created conditions off West Greenland periodically too cold for local spawning. Moreover, wind and North Atlantic Oscillation (NAO) related shifts in flow of the Irminger Current resulted in fewer cod being imported from Icelandic waters (Buch, 2000; Buch et al., 2001). After a small terminal spike in fishing, 1988–90 (mainly exploiting a cohort brought by the Irminger Current in one good year, 1984), Atlantic cod virtually disappeared from West Greenland. Several other demersal species had declined steeply as well (Rätz, 1992, 1999). After cod declined, northern shrimp (*Pandulus borealis*) became more abundant, a trophic-level shift consistent with Pauly et al.'s (1998) description of “fishing down food webs.” An emerging shrimp fishery took the place of cod as Greenland's economic staple (Hamilton et al., 2000, 2003; Rasmussen & Hamilton, 2001).

The 1990s collapse of Newfoundland's cod fishery followed a similar pattern of overfishing compounded by adverse climate, near-disappearance of the dominant species, then a new ecological and economic prominence for crustaceans. Biological analyses point to overfishing, first by international fleets in the postwar years, then after 1977 mainly by Canadian vessels, as the primary cause of the cod collapse (Hutchings & Myers, 1994, 1995; Sinclair & Murawski, 1997). Cod stocks eroded to historically low levels in the mid-70s, and made no more than a partial recovery before the Canadian effort ramped up. Climate added to the resumed fisheries pressure in the late 80s and early 90s, when unusually cold, icy waters off east, north and northwest Newfoundland (Drinkwater, 2002) reflected some of the same NAO/wind and salinity anomalies that beset the final years of Greenland's cod fishery. Cod abundance, size-at-age and catches all began falling after the mid-80s peak in catches that Palmer and Sinclair's (1997) northwest Newfoundland fishermen described as their “glory years.” Not only cod stocks, but the entire ecosystem was in flux (Rose, 2003).

Other climate/fishery interactions have been studied as well. The huge collapse of NE Atlantic herring fisheries in the late 1960s also followed the pattern of climatic adversity coming atop overfishing (Vilhjálmsson 1997; also see Hamilton et al. 2004b, 2006). Around Iceland, the effects of sea ice intermittently obstructing access to cod fisheries has been documented since the 18th century (Ogilvie and Jónsdóttir 2002). In the Bering Sea, a climate–ecosystem regime shift resulted in a proliferation of groundfish, creating new opportunities including shoreside processing and local economic development in the Aleutian Islands (Grebmeier et al. 2006).

The implications of climate change for future Arctic commercial fisheries appear difficult to predict in detail. Consequences will vary with ecological dynamics and the new seasonality, as well as ocean currents and physical geography, while being shaped by distant economic, technological and regulatory forces. Even so, research on 20th-century fisheries suggests a number of hypotheses about the 21st-century Arctic. Issues of jurisdiction will be an immediate challenge for management if valuable resources appear in waters outside current 200-mile Economic Exclusion Zones in areas of boundary dispute, or in the likely case that fish migrate across political boundaries. New fisheries in the Arctic will be far from their markets, and probably far from their home ports as well. Such conditions favor a high-tech, capital-intensive fleet. Deepwater ports with good access to the north, such as Akureyri, Tromsø or Murmansk, could be well-positioned to benefit if Arctic fisheries open up. As for the fish themselves, even a warmer Arctic Ocean will be a cold place, where large species mature slowly and small species are volatile—making both dangerously vulnerable to overfishing, as seen with deepwater (Devine et al. 2006) and pelagic (Hannesson et al. 2006) species to the south. Fisheries management regimes could either learn from or repeat past mistakes.

The difficulties in separating the past impacts of climatic variation from fishing pressure and management regimes, and in understanding how these processes worked in combination, highlight the importance of monitoring human adaptation to a changing Arctic Ocean. Most attention to date has considered the possible physical effects of climate change on fisheries, with less research on how climate change might affect *and interact with* the social organization of fisheries activities. This component of the project will focus on human adaptation to changing resources, including individual, enterprise and management decisions, shifting economic opportunities, consequences for dependent communities and regions (including some far from the fishing grounds), and how human dimensions feed back to the ecosystem.

Identification of Observation System Elements

For the purposes of this project, we consider “Arctic” commercial fisheries to be those of the Arctic Ocean and main subarctic seas—Bering, Chukchi, Labrador, Nordic and Barents. The long-established subarctic fisheries provide empirical models founded on intensive research, and hard-won practical lessons. Moreover, subarctic seas are a likely source of species for Arctic fisheries if climate change shifts their range northwards. Much climate/fishery research has been done in the northern Atlantic, for example. Fluctuations in fish and climate around Norway have a long history of documentation (Institute of Marine Research Annual reports about the state of the resources and the state of the environment; www.imr.no). Other studies are in fisheries management. There have been fewer attempts, however, to cross the divide between natural and social science. We will look for synergies between our research and the efforts of management progress at institutions in Europe (e.g., Iceland’s MRI, Canada’s DFO, US NOAA/NMFS, Greenland’s Natural Resource Institute) and by other researchers. Ecosystem and precautionary approaches have increasingly been suggested for fisheries management.

There is also growing awareness of the importance of integrating human dimensions and social science alongside natural-science fisheries research (e.g., Dolan 2005; Hamilton et al. 2003, 2004a, 2004b; Ommer 2002). Such integration will be a goal of this project. Time series assembled for the Fisheries Observation Subsystem, for example, will be linked to the place/time database built for the Social Outcomes Observation Subsystem. We expect further synergies between our fisheries and social-indicators research, and work elsewhere on ecosystem-based management approaches. The anticipated boom in energy development off Canada and in the Barents sea will also drive research and surveillance programs for the environment, with potential implications for fisheries and coastal communities (e.g., Storey & Hamilton 2004).

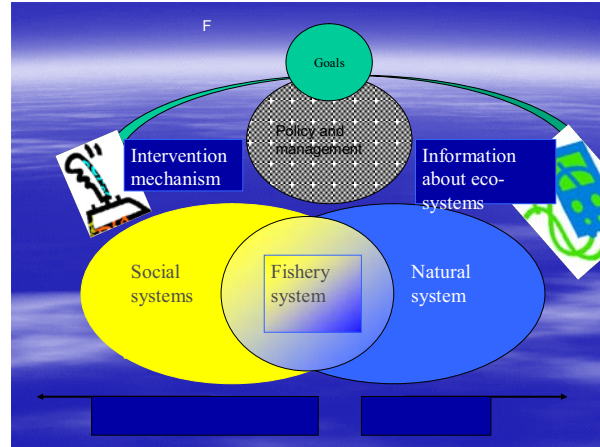
Fisheries can be seen as an interaction between the social and the natural system and where information about the natural system is transformed through policy and management to intervention mechanisms that can regulate the actors in the fishery system. This cybernetic feedback system (from Johnsen et al. 2005) is depicted in Figure 2. For fisheries, the primary goal of our observation system is to assemble and integrate state-of-the-art data and findings from diverse ongoing studies that bear on three questions:

1. How are fisheries resources (distribution, abundance) changing in the Arctic, and to what extent can changes be attributed to climate change?

2. How is exploitation of fisheries resources (commercial, recreational, and traditional/subsistence) changing in the Arctic, in response to (and feeding back to) shifts in resources and other factors?
3. How are fisheries managers and political institutions responding to changes in fisheries resources, and how are these responses modifying the impacts of climate change?

Individual studies on related questions most often take a focused regional view; we will also take a step-back circumpolar view.

The starting point will be to determine practical geographical units for characterizing Arctic fisheries, and for which it is possible to obtain comparable data at different “levels” (see definition below). The geographic units should correspond roughly to the geographical definitions of fish stocks, modified as these are by political jurisdictions and “management areas.” Initially, we will focus on particular geographic units, but the goal is to observe at some level fisheries throughout the Arctic. Within each geographic unit we propose to assemble, integrate and analyze indicators at four “levels”



LEVEL 1: ECOLOGICAL CONDITION INDICATORS — A range of oceanographic factors hypothesized to affect commercial fishery resources, including broad climate indices as well as place-specific data on temperature and salinity, nutrient conditions, ice extent, primary production.

LEVEL 2: FISHERIES STOCK INDICATORS — State of the fishery resources, such as estimates of biomass, recruitment, and returns (of anadromous fish). (Fisheries stock indicators are distinct from harvests—which are “Level 3”—they might be thought of as measures of harvest potential).

LEVEL 3: FISHERY INDICATORS — Exploitation of fishery resources, such as catches (metric tons or numbers of fish) by geographic area, species, gear, use (commercial, recreational, traditional), and commercial fleet (distant foreign, distant national, local non-Native, local Native, local Guided) or recreational user (foreign, national non-local, local Native, local non-Native).

LEVEL 4: MANAGEMENT INDICATORS — Nature of the management system and rules in place, and how these are responding to change. Management behavior (apart from quotas) is less subject to quantification. We will monitor changes across the Arctic, particularly as they are related to potentially climate-related changes in fisheries resource abundance and harvests.

Examples of Potential Stakeholder Groups
Bering Sea Fishermen’s Association, Central Bering Sea Fishermen’s Association, Kawerak, Inc., North Pacific Fisheries Management Council, Fisheries Joint Management Committee, Alaska Department of Fish and Game, Westward Region, NOAA National Marine Fisheries, Alaska Region, Fisheries and Oceans Canada, Arctic Fish Ecology and Assessment Research (AFEAR), Northwest Atlantic Fisheries Organization, International Council for Exploration of the Sea, Arctic Fisheries Working Group, Pacific Seafood Processors Association, Alaska Peninsula Coastal Fisherman’s Association, North East Atlantic Fisheries Commission

Organization of Fisheries Observation Subsystem Work

Gunnar Knapp and Jahn Petter Johnsen will lead this work. Collaborating senior investigators include Rasmus Rasmussen, and Anna Karlsdóttir. Marie Lowe will have lead responsibility as a post-doc for three months per year to identify and compile fisheries-related data together with Thijs Christiaan van Son, who will provide expertise as a fisheries ecologist five months per year.

Marine Mammal Hunting Observation Subsystem

The annual advance and retreat of Arctic seasonal sea ice has long been recognized as a key aspect of the physical forcing that leads to high intra-annual variability in Arctic marine ecosystems (Niebauer and

Day 1989). Sea ice is important to marine mammals as a habitat on which pinnipeds mate, feed, molt and bear young (Fay 1974, Burns *et al.* 1981, DeMaster and Davis 1995), and as winter habitat for species such as bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whales (Burns *et al.* 1981). The distribution and foraging success of marine mammals are closely linked to the maintenance of suitable sea ice conditions, and may be sensitive to any change in climate (Tynan and DeMaster 1997).

Reductions in extent and thickness of Arctic sea ice, coincident with warming trends, have already occurred (Maslanik *et al.* 1996; Martin *et al.* 1996; Comiso 2002), and may indicate the onset of long-term polar warming predicted by climate models. Changes in sea ice extent have been non-uniform; therefore, the effects on marine mammals are likely to occur on regional scales. Observing local changes in marine mammal abundance and distribution, local subsistence harvest results, and regional environmental data such as sea ice will improve our ability to detect and predict potential changes in ecosystem dynamics due to climate change or other environmental impacts.

Alaska Natives have reported that patterns of seasonal weather and marine mammal distribution, abundance, and condition have been changing at an accelerated rate in recent decades (e.g., Pungowiyi 2000, Krupnik 2000, Huntington *et al.* 2000). Several of these changes are almost certainly related to shifting climate, and the impacts have already affected marine mammal hunting by subsistence hunters. For example, access to walrus (*Odobenus rosmarus*) and seals has been curtailed because lack of sea ice results in rougher seas that make it too dangerous to venture out to hunt; walrus are currently of poorer condition (skinny) than 30 years ago; spotted (*Phoca largha*) and ringed seal (*Phoca hispida*) pups seem to be having poorer survival, perhaps due to early breakup of coastal sea ice. The dramatic thinning of sea ice over the past twenty-five years suggests that large ecological changes can be anticipated in the future for marine mammal populations associated with sea ice communities, as well as with the subsistence hunters who rely on these marine mammals.

Identification of Observation System Elements

The marine mammal hunting observation subsystem will be supported by information from three system elements: 1) Native subsistence harvests, 2) traditional ecological knowledge (TEK) of local hunters, and 3) scientific monitoring. One significant, though often under-utilized, source of information is the TEK of Native subsistence hunters. Such knowledge, based upon individual experiences evaluated in terms of the information passed on from other hunters and one's elders, can form a coherent perspective of the ecology of local regions. TEK for a specific area is comprised of information integrated by hunters who have been active in that region for extended periods, and who routinely stake their livelihood on its accuracy and utility. Documenting TEK about Arctic marine mammals provides insight into a local area's hunters' and elders' knowledge of the distribution, abundance, and natural history of marine mammals and any changes that have occurred in the region. For scientists, TEK can serve an important role in providing temporally complementary information as well as suggesting scientifically testable hypotheses for research on species for which there is relatively little scientific information. We have coordinated our proposal with a proposal being submitted by Gearheard *et al.* entitled, "Exchange for Local Observations and Knowledge in the Arctic" or ELOKA (see attached letter of collaboration). The two proposals are complementary, with this proposal primarily focusing on quantitative measures. We appreciate the value of TEK and other qualitative measures and would work with the ELOKA team to incorporate our TEK information in their system.

A broad variety of scientific research and monitoring on marine mammals has been conducted throughout the Arctic. In addition to work by science agencies and universities, several collaborative international efforts are underway that will be relevant to the work proposed here. For example, under the auspices of the Arctic Council, CAFF's Circumpolar Biodiversity Monitoring Program has established circumpolar expert monitoring networks based on species, species groups and habitats of key ecological, economic, and national interests. For marine mammals, these currently include ringed seals, beluga whales, and polar bears (in collaboration with the IUCN Specialist Group on Polar Bears).

There are many stakeholders and potential collaborators who may become involved in this project. The following table is intended to illustrate possibilities, but it is intended to be neither exhaustive nor fixed. The process of establishing collaborators will be dynamic and will evolve as the project moves forward.

Examples of Stakeholder Groups

ChukotTINRO, Russia; Association of Traditional Marine Mammal Hunters of Chukotka, Russia; Russian Academy of Sciences; All-Russia Research Institution of Game Management and Fur Farming, NOAA National Marine Fisheries Service, Fish and Wildlife Service, U.S. Geological Survey, Alaska Department of Fish and Game, North Slope Borough Department of Wildlife, Indigenous Peoples Council on Marine Mammals, Alaska Nanuuq Commission, Alaska Eskimo Whaling Commission, Alaska Beluga Whale Committee, Eskimo Walrus Commission, Alaska Ice Seal Committee, Canadian Wildlife Service, Canada Department of Fisheries and Oceans, Nunavut Wildlife Management Board, Inuvialuit Beluga Whale Committee, North Atlantic Marine Mammal Commission; Greenland Institute of Natural Resources; Institute of Marine Research, Norway; Norsk Polar Institute, Norway; Marine Research Institute, Iceland

Organization of Marine Mammal Hunting Observation Subsystem Work

John Bengtson will lead this work. Collaborating senior investigators include Jack Kruse and Rasmus Rasmussen. A post-doc will be recruited to work six months per year on this subcomponent. This project's initial focus will be to survey past and present sources of information on marine mammal hunting throughout the circumpolar Arctic and to create a meta-database of such information. As this database is assembled, an emphasis will be placed on identifying the relationships among the human- impact, ecological, and geographic aspects of climate change associated with marine mammal hunting. This work will be accomplished with the assistance of collaborators from both governmental agencies as well as Native groups. The effort will be led by a U.S. scientist working under the direction of NOAA's National Marine Mammal Laboratory, which already has good working relationships with many of the relevant collaborators throughout the Arctic.

Subsistence harvest information will be documented from available sources. For example, in Greenland, there are long-term records (over a 150 year period) with yearly regional information and 50 years of yearly community based information regarding the results from hunting. There are also monthly records since 1987 of information regarding commercial hunting and fishing including information regarding number of animals, value, and hunting intensity. Similar records (but with varying degrees of spatial and temporal coverage) exist for other areas of the Arctic. Relevant information is likely to include: harvest patterns, species, numbers taken, seasonal timing, shifts in location (distribution), hunting methods and success rates, quality or condition of marine mammals, and prey habits (e.g., stomach contents).

A second step in this project will be to identify opportunities for analyses and syntheses of data represented in the database. It is intended that this project will become a catalyst for actions to implement such analyses through collaboration or workshop settings. Information from subsistence harvests will be compared with TEK to elucidate potential climate impacts on wildlife (e.g., migration, prey habits, condition, abundance, distribution) and human hunting patterns (e.g., hunting methods, success rates, animal availability).

Resource Development and Marine Transportation Observation

According to the *Arctic Climate Impact Assessment* (ACIA, 2004), in general, reduced sea ice is likely to increase marine transport and access to marine-based resources as the navigation season is increased. There is speculation, however, that changes in ice movement patterns may directly and indirectly impact some operations. In addition, increases in storm activity as a result of climate change will negatively impact marine transportation and resource development as ships are forced to alter routes and schedules to avoid unsafe working conditions. Although reductions in sea ice should facilitate marine transportation/resource development, it is important to note that land-based resource development will be hindered as melting ice roads continue to shorten the exploration season in the northern tundra. Brigham and Ellis (2004) discuss the implications of climate change for shipping in the Arctic, as well as voyages for tourist, governmental and research purposes. In 2004 there were 103 voyages in the Canadian Arctic, while on the Northern Sea Route (Russian Arctic), voyages have declined from a peak of 1306 in 1987 to 160 in 2003. Marine transport of oil and gas from the Kara and Barents seas is anticipated in the next decade. Over the next several decades longer ice-free seasons may increase shipping in several regions, and transshipment ports may be developed in Alaska, Iceland and the European Arctic.

Although there has been much speculation about the qualitative impacts of climate change on resource development and marine transportation, there is little (if any) quantitative analysis on the potential economic impacts to this important sector of the Arctic economy. Researchers at the Institute of Social and Economic Research (ISER) are in the initial phases of developing economic tools to assess and quantify the impacts of climate change on these and other sectors of the regional economy. The observation activities described in this proposal complement the development of economic tools for assessment and quantification of impacts funded elsewhere.

Identification of Observation System Elements

The *Arctic Human Development Report* (AHDR, 2004) provides a description of resource development in the circumpolar Arctic and the questions it raises for human development. World-class oil and gas fields and hard-rock mines in particular provide major but unstable sources of employment and revenue for Arctic regions. Not only are these finite, non-renewable resources, but they are subject to wide variations in market price. Moreover, they are managed by multinational corporations that are more responsive to global forces than to local concerns. While the Arctic is characterized by both settler and indigenous societies, it is the indigenous societies relying on traditional, small-scale resource use such as hunting, gathering, and herding that are uniquely challenged by industrial development. The forthcoming *Assessment of Potential Effects of Oil and Gas Activities in the Arctic* (AMAP 2007) describes in greater detail the status and trends for oil and gas development in the Arctic, and their impacts on local populations. It highlights the differences in scale between costs and benefits, where the costs are disproportionately local and the benefits disproportionately regional or national, and the asymmetries in power between local and national or multi-national decision-makers.

Rasmussen and Koroleva (2003) provide a methodological framework for socio-economic impact assessment in the Arctic. AMAP (2007) follows and expands on the dimensions of Arctic human development introduced in AHDR: health, education, standard of living, fate control, cultural integrity, and contact with nature. In AMAP these become nine categories of effects: macroeconomic, microeconomic, demographic, health, education and training, governance, cultural integrity, contact with nature, and social health. The Canadian National Roundtable on the Environment and the Economy (NRTEE, 2001) used a sustainable development framework to develop principles for non-renewable resource development in aboriginal communities. Their indicators fall in five categories: economic, social and cultural well-being, equity, control over natural resources, and environmental integrity. The inclusion of equity follows other sustainable development theorists (Langhale; 2006; Duhaime and Godmaire, 1999; Diamond 2004; WCED 1982). The NRTEE goes on to recommend improved baseline data collection, ongoing monitoring of the effects of resource exploitation and the systematic evaluation of individual projects. (NRTEE, 2001: 25-26). The U.S. National Research Council and the North Slope Borough likewise call for comprehensive research on the local economic, social and cultural effects of oil and gas development in the Arctic. (NRC 2003; Ahmaogak, 2003)

O'Faircheallaigh (1991) provides the most comprehensive framework for analyzing the effects of resource exploitation on indigenous people. He reviews the empirical literature through 1990, discussing economic impacts (employment and wages both direct and indirect, royalties, equity participation and joint ventures, supplying goods and service, new infrastructure), social and cultural effects (loss of land, impact of immigration, impact of consumer goods, income inequities and social divisions, impact on structures of authority, dependence and economic uncertainty, loss of self esteem, social dislocation and social disintegration, positive social effects of cash incomes and new social infrastructure), environmental impacts and theoretical constructs, then concludes with a call for systematic, comparative work examining the impact of resource projects across a range of different social, economic and political settings. More recently he has discussed the effects of inequality and of long distance commuting to remote work sites for Native peoples working in resource industries. (O'Faircheallaigh, 1995, 1997)

Authors of the AMAP report chapter assessing socio-economic effects of Arctic oil and gas development wrote richly qualitative and quantitative case studies of the social and economic effects of oil and gas development projects in the circumpolar Arctic. (Baffrey et al., forthcoming 2007) Given the resource constraints for that report, they were unable to develop comparable quantitative data for direct comparison across cases. Nor were they able to develop data (beyond Alaska) to profile the lifecycle patterns of economic effects, or the division of the economic pie across local, regional and national jurisdictions. Although there are several case studies of effects of mining on Arctic populations, no effort to date has

been made to compile or codify them in a common framework. (Crate, 2006; Bielawski, 2003; Northern Economics; Hobart, 1982; Macpherson, 1978; Williamson, 1974.)

Just as stormy weather arises at the front between high and low pressure systems, social dynamics arise from emerging social differences. The observation system we propose seeks to monitor emerging economic differences over time, between groups, and across scale as a result of major resource development. Specifically, what is the time profile of economic activity associated with a project? How are the economic benefits—employment, income, profits and rents—distributed among indigenous, settler and new migrant groups? Within these groups, is inequality increasing? How are the economic benefits distributed across local, regional, national and international levels?

We will begin with an inventory and description of past, present and prospective, large scale resource development projects in the circumpolar Arctic, from 1970 to 2020. The AMAP report does this for oil and gas, but it remains to be done for hard rock mining. Then we will map out and assemble a circumpolar data base documenting the economic effects of these projects. For each of these projects and the administrative units that contain them, our data structure will include demographic change, direct and indirect employment and wages, royalties and public revenues, equity participation and joint ventures, supplying goods and services, infrastructure changes, and changes in the cost of living. We will aim to establish consistent definitions for these measures to facilitate comparative analysis. A feasible subset of the projects will include time series data beginning before project inception and continuing up through the most recent reporting period to facilitate lifecycle analysis. We will also select a cross-section of projects for breakdowns describing the distribution of economic effects by demographic groups, interest groups and across geographic scale. Collaterally with this, we will electronically compile available data sources on social, cultural and environmental effects of each project. We will also monitor indicators of shipping activity in Arctic sea lanes and associated developments.

Examples of Potential Stakeholder Groups
Institute of the North, Arctic Council, the municipal and county governments local to each of the identified projects, Canadian Aboriginal Minerals Association, Norwegian Petroleum Directorate, Statens Noringsutviklings fond (SND), Statoil, Hydro, Oil and Gas International, Aker Arctic Technology Inc., Sakhalin Energy, Canadian Association of Petroleum Producers (CAPP), American Petroleum Institute, Norsk Petroleumsforening, Interprise Barents, World Wildlife Fund

Organization of Resource Development and Marine Transportation Observation Subsystem Work

These tasks will be executed through a combination of electronic, library and telephonic search, research travel, and contracts with local research assistants. Sharman Haley will lead this work. Rasmus Rasmussen will collaborate as a senior investigator. Stephanie Martin will be the postdoc responsible for field and database activities.

Tourism Observation Subsystem

Arctic climate change is already affecting tourism through channels such as rapid retreat of glaciers and increased duration and prevalence of forest fires and associated smoke. For example, both Portage and Columbia Glaciers in Alaska were major tourist attractions during the mid-1980s but have since retreated out of view for the vast majority of visitors to South-central Alaska (Colt et al. 2002). Scientific synthesis documents, notably the Arctic Climate Impact Assessment, suggest that expansion of tourism is a “likely outcome” of decreased sea ice, which will allow more ships to travel farther and over a longer season. (ACIA 2004 *Overview Report*, p. 16). Although hard data are not generally available, most observers agree that there has been an upsurge in travel to smaller and indigenous communities in many parts of the Arctic during the past 15 years (Nuttall 2005, Nordic Council of Ministers 2003). As and if climate changes reduce subsistence and commercial harvest opportunities (ACIA 2004:19), these smaller communities could feel pressure to further embrace tourism as a development strategy.

Identification of Observation System Elements

The tourism sector of an economy is inherently difficult to measure because tourist activities cut across conventional sectors such as transportation, lodging, and eating and drinking establishments. For the Nordic countries as a group, a recent synthesis document states that “it is difficult to find comprehensive statistics for ship-based tourism in the Nordic Arctic region,” and that “data availability showed to be [sic]

all too lacking.” (Nordic Council 2003:37). Only recently have some—but not all—countries developed tourism satellite accounts (TSAs) by which tourism as an industry can be properly isolated and measured (World Tourism Organization 2001). In some key areas, such as Alaska, a TSA system has been developed in principle but not implemented due to the formidable data-collection requirements imposed by this methodology (Global Insight 2004).

Even in countries where sound TSA systems have been implemented and populated with data (such as Finland), there remains the significant problem of aggregation across the Arctic/non-Arctic boundary into national reporting units. For example, the Finnish TSA data, when further analyzed, reveal that 66 percent of foreign overnights were spent in the southern areas. Similarly, Johnston (1995) reports Snepenger’s (1989) observation that only three percent of Alaska tourists visit the arctic part of the state.

For these reasons, we propose to implement a two-tiered observation system. Tier one will include all national and regional tourism accounts that are publicly available and regularly reported. These would include: (1) data from fully-implemented TSA systems that are compatible with WTO guidelines; (2) national and regional tourism office data, such as provincial statistics within Canada; and, (3) and compilations of international arrivals reported through the WTO *Tourism Factbook* series.

Tier two data will be collected at a finer geographic and temporal scale from at least ten representative regions using a replicable protocol that we develop and make available to interested collaborators. The goal of collecting tier two data is to develop an internally consistent tourism observation system that allows for tracking over time of key interactions between tourists, the economy, and the changing ecosystem.

Examples of Tier two *regions* would be Alaska’s Northwest Arctic Borough and Lapland. Each region has a relatively distinct regional economy, culture, and ecosystem. Tier two *variables* would include unbiased (although perhaps statistically noisy) indicators of visitation (both international and inter-regional), types of tourist products consumed, and direct economic impact. This scheme is broadly consistent with the conceptualization in economics of growth as the sum of *scale*, *composition*, and *technique* effects (Copeland and Taylor 1994). Visitation indicates scale—how much is produced. Product mix reflects both composition and technique effects—what is produced and how is it produced. For example, one person-day of helicopter flightseeing has vastly different socioeconomic implications than one person-day of guided birdwatching on foot. In our scheme, collecting detailed data on the mix of products consumed is not feasible; instead we must rely on arrival mode and other simple indicators such as car rental tax receipts to indicate both composition and technique. Finally, data on direct economic impacts provides additional insight into the resource-intensity of each tourist-day and places growth and change of tourism within the larger socioeconomic system.

Examples of Potential Stakeholder Groups
NWT Tourism, North West Cruise Ship Association, International Council of Cruise Lines, The Alaska Travel Industry Association, Alaska Wilderness Recreation And Tourism Association, SMART – Sustainable Model for Arctic Tourism, Victory in the Arctic and Antarctic Research, WWF International Arctic Programme, Nunavut Tourism, Vacances Tourbec Infotouriste, 50 Plus Expeditions, Choosing Cruising UK, Norwegian Tourist Board, FörTur The Association for Swedish Tourism, Finnish Tourist Board (MEK), Russian Union of Travel Industry (formally RATA), Greenland Tourism - The National Tourist Board of Greenland, The Icelandic Travel Industry Association (SAF), Tourism Industry Association of Canada, Canadian Tourism Commission

Organization of Tourism Observation Subsystem Work

Steve Colt will lead the tourism observation subsystem research. Collaborating senior investigators include Rasmus Rasmussen and Anna Karlsdóttir. Regional collaborators will be solicited to nominate specific regions to become Tier Two statistical areas. Stephanie Martin will be the postdoc responsible for field and database activities.

Social Outcomes Observation Subsystem

Referring back to our conceptual model illustrated in Figure 1, we hypothesize that social outcomes are the result of decisions by individuals, households, and institutions made in response to changes in the environment. These environmental changes are produced by an interaction of forces for change including

climate, development, and government policies coupled with feedbacks of past individual, household and institutional responses to change. We can envision that environmental changes and human responses operate to influence social outcomes within each of the four arenas described above (fisheries, resource development, tourism, and marine mammal hunting). The social outcomes we observe can therefore be expected to be a cumulative result of what we observe in these four arenas plus what we might observe in other arenas (e.g. caribou/reindeer grazing systems). We therefore need to design the social outcomes observation system to test hypothesized relationships within individual arenas, to understand the relative importance of different arenas, and to measure how well the arenas being observed account for changes in social outcomes as a whole.

Identification of Observation System Elements

The core product for this subsystem will be development and analysis of an Indicator Database of Arctic Community Change (INDACC). INDACC is designed for dynamic, multivariate analysis—to help detect and understand complex patterns as well as striking exceptions across Arctic communities. At its most detailed level, observations will be by place (community) and year. Our initial selection of observation system elements is based on the recommendations of the Committee on Designing an Arctic Observing Network to build the system initially from existing data, including key human dimension variables: population size and structure, births, deaths, migration, health measures, cultural diversity, education, and economic indicators, including employment, subsistence, and government structure (NRC 2006). A preliminary version of INDACC with region/year (not yet place/year) resolution for the entire Pan-Arctic is currently under development. This provides an advanced takeoff point for additional work that will extend resolution down to place/year level, starting with a subset of Arctic regions. For example, the preliminary version covers all regions of Alaska (27), Iceland (8) and Greenland (17). For this project, we will add place/year data describing all Census places in Alaska, all municipalities in Iceland, and all municipalities (subdivided into towns and settlements) in Greenland, for the years 1990–2005 (updateable). Data will be filled in for the four Inuit settlement regions of Canada as well, and wherever practical for places within the other Pan-Arctic regions (municipalities of Scandinavia; federal regions of Russia) already represented in INDACC.

INDACC observations begin with basic geographic identifiers that support integration with (1) other social-science datasets (e.g., FIPS codes for US places) and (2) geophysical data (e.g., latitude–longitude for settlement “point” locations; links to shape files for regional areas). Each observation is indexed by year, so that multiple years form time series within each place or region. Time provides another integrating dimension for interdisciplinary analysis. Human-dimensions variables begin with basic and relatively well-measured demographics and vital statistics—yearly population, births and deaths, for example, from which net migration can be approximately inferred, and rates of change modeled. Other social, economic and health indicators will be added as research proceeds. INDACC is open-ended, with the number of potential variables limited only by available information. For example, it would be straightforward to merge INDACC’s Alaska regional information with the roughly 7,000 county-level variables on the U.S. Census Counties 1998 CD, or perform similar operations with numerically-indexed datasets from other countries. The number of variables is limited theoretically limited only by available information. More focused expansion could occur as INDACC analyses identify important gaps in our information.

INDACC’s multilevel, longitudinal structure supports many kinds of analysis, including integration with other types of data—starting with other subsystems of this project. Time and place provide integrating dimensions for merging INDACC’s social-indicators data with the time series assembled under the Fisheries, Marine Mammal Hunting, Resource Development and Marine Transportation, and Tourism Observation subsystems described above. The NAArc project developed an informal approach to such integration (e.g., Hamilton et al. 2006); more formal models will be sought here as well.

The expanding database will become analyzable by the end of year 1, but it will never be “complete.” Empty cells, reflecting variables known for some places or years but not for all, remain inevitable. Cells can be filled in and new variables added indefinitely as information becomes available. Although demographics and vital statistics have reasonably clear international meanings, many other variables do not, or are reported unevenly. Government programs and focused research often generate dense data for particular times or places, such as subsistence activities in some Alaska villages (e.g., Magdanz 2002,

2005). The INDACC framework accommodates both limited data (i.e. columns that are populated only for particular place/years) and complete data providing a broad, dynamic context for specialized studies.

The data needed to build INDACC already exist, but are scattered across different agencies, formats and literally thousands of separate files. Such data are available to the public, but through file structures and delivery media (e.g., CD or Web interfaces) tailored for users who just need particular statistics, or want to tabulate a distribution. A member of our team, Gerard Duhaime, directs ARCTICSTAT, a initiative to make such web-based data more accessible (Duhaime 2006). As stated in Dr. Duhaime's letter of collaboration, he will help us to take maximum advantage of Arcticstat's capabilities. INDACC will not supplant or compete with such existing data systems, but instead will open new doors for modeling and analysis. The initial contents will cover four circumpolar states, but others can be added to this framework. There is nothing intrinsic limiting the INDACC framework to high latitudes.

Organization of Social Outcomes Observation Subsystem Work

INDACC builds upon work underway for the NSF-funded Arctic Synthesis project Humans and Hydrology at High Latitudes (H3L). H3L investigators Hamilton and Lammers, with others, are assembling region/year human-dimensions data covering all regions of the pan-Arctic, and developing specific methods to integrate such data with 25x25 km gridded hydrometeorological data with strong linkages to the existing ArcticRIMS data analysis and archive system (<http://RIMS.unh.edu>). INDACC will begin from the H3L framework, adding variables and individual-community level data for Alaska, Greenland and Iceland, then applying H3L's analytical toolkit for integrating INDACC information with geophysical data. Such integration will provide new empirically-grounded ways to study the intersection of global change with changing Arctic social systems.

Integration with other types of social-science data will be a second application for INDACC. The Survey of Living Conditions in the Arctic (SLiCA), for example, has generated detailed individual-level survey data from many Arctic communities (Poppel et al 2002). INDACC's community-level time series provide context for SLiCA in several respects. Relationships between community characteristics and individual survey responses can be studied through multilevel modeling techniques—a class that includes growth curve analysis, hierarchical linear models or HLM, and other more general approaches. Multilevel models are well suited for complex nested data designs (e.g., McCulloch and Searle 2001; Rudenbush and Bryk 2002; Searle et al 1992; Skrondaly & Rabe-Hesketh 2004; Verbeke & Molenberghs 2000). To the best of our knowledge, these state-of-the-art methods have not previously been applied to Arctic research in either social or natural science.

The Stata statistical program will be our main tool for developing INDACC. Stata is ideal for this purpose due to its combination of unified command syntax, data management, analytical graphics, and state-of-the-art statistical modeling capabilities (Hamilton 2006; Rabe-Hesketh & Skrondal 2005), which are unmatched by other programs such as SAS and SASS. Although Stata will be the workhorse for INDACC development, INDACC itself can be translated easily to alternative formats. In accessible formats, INDACC data will be freely available through Web portals.

Lawrence Hamilton will lead the development of INDACC. Richard Lammers will design the integration of INDACC with gridded geophysical data. The Greenland elements of INDACC will be built by Per Lyster and others at Statistics Greenland, working together with Hamilton. The Canadian component will be assembled by Jack Kruse and Gerard Duhaime. Craig Gerlach and Craig Fleener will contribute to data collection (including health indicators), educational applications, and dialogs with local and regional institutions in Alaska. A graduate student will manage the database, publish a graphical library visualizing the first findings, and write a related thesis.

Design of a Phase Two Observation System

The Phase One human dimensions subsystem is deliberately limited to a compilation of existing data into an integrated data system. Reliance on existing data where possible is cost-effective. In addition, limited funding available to meet the broad scope of SEARCH/IPY needs makes a focus on existing data appropriate as a Phase One activity. It is anticipated, however, that existing data will not meet all SEARCH

human dimension data needs. With this in mind, we propose to design a Phase Two Observation System that incorporates primary data collection where necessary.

Designing a Phase Two observation system involves developing a set of indicators that collectively measure the status of Arctic people and economies and permit quantification of human dimensions of Arctic change. In order to facilitate updating and increase accessibility to the general public, the Phase Two observation system will focus on a relatively small set of indicators—perhaps a dozen—supported by a larger set of background data series collected for each region of the Arctic. To achieve the objective of quantification of the human dimensions of Arctic change, the observation system must include each of the following properties:

- ability to generate comparable outcomes across Arctic nations with diverse economies and cultures;
- ability to observe effects of climate change if they occur;
- contain elements that are: useful to stakeholders, relevant to understanding interactions, and helpful for making predictions;
- address effects observed across different temporal and spatial scales;
- address a broad spectrum of human dimensions of Arctic change, including economic development and social and cultural change;
- reflect change for indigenous and non-indigenous Arctic residents; and
- measure outcomes that reflect the ability of institutions to mitigate and accommodate change.

The Arctic Council recently initiated the Arctic Social Indicator project (ASI), a follow-up project to the Arctic Human Development Report (AHDR). The intent of this project is to devise a limited set of indicators that reflect key aspects of human development in the Arctic, that are tractable in terms of measurement, and that can be monitored over time at a reasonable cost in terms of labor and material resources. Four members of our project team have been invited to be project participants: Kruse, Hamilton, Duhaime, and Rasmussen (see letter of collaboration). Work of the ASI will inform the design of the Phase Two Observation System. We also propose to build on the experience of the United Nations Development Index (UNDP, 2005), along with recent studies of Arctic change. These Arctic studies include the Arctic Climate Impact Assessment (ACIA), The Arctic Human Development Report (AHDR 2004), the Arctic Monitoring and Assessment Program (AMAP), the Millennium Assessment (Chapin et al., 2005) and the Survey of Living Conditions in the Arctic (Poppel et al 2002). The UN Human Development Index (UNHDI) contains three basic components: standard of living, public health, and acquisition of knowledge. The categories certainly apply to Arctic people, but the actual measures of each of the components need to be broadened and adapted to represent Arctic conditions. For the Arctic, the AHDR expanded on these components to include fate control, cultural integrity, and contact with nature, but did not identify suitable measures.

Developing these measures for the Arctic is our first task. We need a measure of participation in activities that produce traditional foods, such as hunting, fishing, and reindeer herding. In the Arctic, transmission of traditional knowledge and cultures is a critical component of knowledge acquisition (Kruse et al., 2004), so the index should include some measure of cultural transmission, such as indigenous language retention. Arctic nations also differ in their approach to education (Darnell and Hoem, 1996), so measures of formal education should track settler populations and indigenous populations separately. An index of the health status of Arctic people should also include a mental or behavioral health indicator (Berner et al., 2005; Berner, 2003; WHO, 2001).

To accomplish the Phase Two observation system design, we will start with the existing data sources, paying special attention to data that are currently being collected by national regional governments that provide results at a community or subregional scale. In the first year of the project, we will hold a series of meetings with stakeholders to engage their participation in the identification of indicators that are meaningful to them, and potentially useful for adapting to change as it occurs. We anticipate that stakeholders will push us to recognize the different “arenas” in which climate-human interactions are likely to occur, as well as the importance of non-climate forces for change, including government policies. For example, some Arctic people specialize in marine mammal hunting, and might see interactions with offshore oil and shipping development as well as direct effects from changes in sea ice conditions. In

other places, people may be concerned that tourism or mining development may alter the local terrestrial environments.

In the second year of the project, we will conduct a series of statistical analyses with the existing data sources to understand the degree to which a small set of indicators can predict conditions described by the larger suite of observations. For example, demographic changes are relatively easily observed in periodic censuses collected by all Arctic nations. Components of population change such as birth and death rates and migration flows may be highly predictive of living conditions and public health (Hamilton et al., 2000; Huskey et al., 2004), which are much more costly to measure directly. Tests of hypotheses about population change at the community or subregional level in areas of the Arctic for which more complete data exist may allow us to generalize to other areas (such as portions of the Russian Arctic) where data are less readily available. We will then use the results of statistical modeling to select the set of indicators to include in the index. Finally, we will use the data collected by the project to develop actual baseline measures of the indexes for regions of the Arctic. We will review these measures with stakeholders and our project advisors.

Overall Project Guidance

Potential stakeholder groups range from individual communities, to regional organizations, to national and international organizations. A small group of regionally dispersed advisors will provide overall guidance on the project. The following individuals have agreed to serve as project advisors, Brian Lyall, Labrador Inuit Association; Charles Dorais, Makivik Corporation; Simon Routh, Inuvialuit Regional Corporation; Bob Harcharek, North Slope Borough; Ed Ward, Maniilaq Inc.; Larissa Abruytina, RAIPON; Risstin (Kristina) Lasko, Samicouncil (see letters of collaboration).

Results of Prior Work

Sustainability of Arctic Communities: An Interdisciplinary Collaboration of Researchers and Local Knowledge Holders, OPP 9909156 (2000-2004, Kruse/White Co-PIs). This study addressed the question of how climate change will affect the sustainability of Arctic villages over the next forty years. The project was an interdisciplinary collaboration of 23 researchers and five Arctic communities located within and adjacent to the range of the Porcupine Caribou Herd (PCH). Over 30 journal articles and one-time publications have been published to date. The entire research team co-authored an article in *Ecosystems* (Kruse et al 2004) that provides an overview of the study, "Modeling the Sustainability of Arctic Communities: An Interdisciplinary Collaboration of Researchers and Local Knowledge Holders." Work is continuing on a book, "Sustainability of Arctic Communities: An Integrated Assessment of Change". Over the course of the study, we drew on existing and developing research, as well as local knowledge, to examine the combined potential effects of climate change, petroleum development, tourism, and government spending cutbacks on the sustainability of communities located in the range of the Porcupine Caribou Herd. Data across a variety of disciplines were used to develop a community synthesis model and a regional integrated assessment model.

Survey of Living Conditions in the Arctic: Inuit, Saami, and Indigenous Peoples of Chukotka (SLICA), OPP120174 (2001-2006, Kruse/Cochran Co-PIs). A group of social scientists and indigenous representatives from Greenland, Canada, Russia, the United States, Denmark, Norway, Sweden, and Finland have been working since 1997 to describe and analyze the living conditions of Inuit adults living in Inuit settlement regions of Alaska (Iñupiat settlement regions), Canada, Greenland (also including non-indigenous residents), and Chukotka (also including other indigenous peoples in Chukotka) and the living conditions of Saami adults living in the Saami settlement regions of Norway, Sweden, Finland, and the Kola Peninsula of Russia. Probability sampling techniques have been used in all countries to ensure that the interviews statistically represent all Native adults. The current international data set is constructed from the responses of over 7,000 randomly selected adults to the common set of questions contained in the international core questionnaire. See www.arcticlivingconditions.org

Environment and Social Change in the North Atlantic Arc (NAArc), OPP9912004 (2000–2006 Hamilton PI/PD). The NAArc project involved social scientists working together with marine biologists and oceanographers on an integrated, comparative study of human/environment interactions in fisheries-dependent regions of the northern Atlantic. Refereed articles and book chapters published to date include Haedrich and Hamilton (2000), Rasmussen and Hamilton (2001), and Hamilton et al. (2000a,b; 2001;

2002; 2003a,b; 2004a,b,c; 2006). The articles appeared in diverse journals such as *Climatic Change*, *Society and Natural Resources*, and *Arctic*. A detailed report on *The Development of Fisheries in Greenland* was published under the North Atlantic Regional Studies series at Roskilde University. Presentations of results have been given at scientific meetings in the U.S., Canada, Greenland, Iceland, England, Scotland and Norway. Two Master's theses and one Ph.D. dissertation have been completed, and presented by the students at international meetings. Findings have been used to illustrate the human dimensions of climate change in Morison et al. (2001) and Vörösmarty et al. (2001). A Web page at <http://pubpages.unh.edu/~lch/> provides access to selected articles, downloadable datasets, and abstracts of publications.

Human Adaptation to Large-Scale Ecological Decline OPP-9515380 (1996–99, Hamilton (PI/PD)). This first phase of the NAArc project resulted in six publications, notably "Ecological and population changes in fishing communities of the North Atlantic Arc" in *Polar Research*, and "Management, adaptation and large-scale environmental change" in *Property Rights and Regulatory Systems in Fisheries*. Other articles appeared in such journals as *Population and Environment*, *Human Ecology Review* and *Arctic Anthropology*. A significant contribution of this project was the development and analysis of comparative databases covering more than 1,000 communities around the northern Atlantic.

Education and Outreach

The Education and Outreach section of the *SEARCH Plans for Implementation* (2005:53) calls for reaching the broadest possible audience, including local, regional, state, national and international populations. Among the subpopulations of special interest are stakeholders. This project is best suited to involve stakeholders in a two-way exchange of information and ideas. Stakeholders are likely to have valuable observation data; they are also key intended beneficiaries of an improved understanding of Arctic change. As indicated in the *SEARCH Plans for Implementation* (2005:43) "Wherever possible, scientific activity should be undertaken with appropriate stakeholder groups". Benefits of ongoing interaction between scientific and stakeholder groups include: increased relevance of scientific results, early and effective dissemination of data to stakeholders, and increased participation of stakeholders in identifying and obtaining observation data. Education and Outreach activities with stakeholder groups will therefore include: (1) identification of predictions that stakeholders would find most useful; (2) making available near-real time observations relevant to stakeholder groups; and, (3) the establishment of community and industry networks for exchange of information and ideas. All these are high priority research activities and are logically part of the development of an Arctic Observation Network (SEARCH 2005:45-46).

Summary of Intellectual Merit and Broader Impacts

Intellectual Merit: The intent of this proposal is to implement the highest priority human dimension elements of a pan-Arctic observation system that will form the analytic core for SEARCH. In keeping with the recommendation of the Committee on Designing an Arctic Observing Network, the proposal focuses on the incorporation *and integration* of existing data within the observation system. In keeping with the overall goal of SEARCH to "understand the nature, extent, and future development of the system-scale changes presently being observed in the Arctic", our proposal includes an assessment of the adequacy of existing data in meeting the goals of SEARCH, identifying observation elements to be considered as high priority additions to the observation system.

Broader Impact: The *SEARCH Plans for Implementation* identifies as a high priority working with stakeholder groups associated with Arctic or subarctic fisheries, marine transportation and associated development, and subsistence (SEARCH 2005:45). Our choice of arenas is directly responsive to this recommendation. The *Plans for Implementation* also recommends that all scientific activities be undertaken with appropriate stakeholder groups (SEARCH 2005:43). Many of the stakeholder groups associated with fisheries, development, and subsistence possess, or know the location of, relevant existing data. These same stakeholders are among the prime potential users of the products of a long-term observation system and of SEARCH prediction studies. We will work closely with these stakeholder groups, thereby creating a communication network and basis of trust. Ultimately, involvement of these stakeholder groups will ensure that the results of SEARCH are seen as useful by stakeholders, thus addressing a key question of SEARCH, "How can understanding of Arctic system changes be used to develop adaptive responses" (SEARCH 2005:43).

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