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DECEMBER 2017
NEWSLETTER

RESEARCH UPDATES

FROM THE WESTERN AND CENTRAL CANADIAN ARCTIC

Brought to you by the ArcticNet Integrated Regional Impact Study of the western and central Canadian Arctic (IRIS 1)

IRIS 1 Lead and Coordinator's Message

Hello and welcome to our newsletter!

December 2017 marks the 8th anniversary of the first IRIS 1 consultation for its Regional Impact Assessment. On December 11, 2009, we held our first workshop at the ArcticNet Annual Scientific Meeting in Victoria, BC. The workshop was attended by 25 participants who helped identify topics for inclusion into the assessment, such as Community Conservation Plans, Arctic Borderlands, and the Beaufort Regional Environmental Assessment. One year later we held our first steering committee meeting in Ottawa, ON during the ArcticNet Annual Scientific Meeting, December 14, 2010. Nearly five years later we published the IRIS 1 Regional Impact Assessment in 2015.

So, what have we been doing over the last couple of years?

1. We shared the results of the IRIS 1 Regional Impact Assessment with our partners and other stakeholders at various venues in the North;
2. We translated and published the report's *Synthesis and Recommendations* booklet into four Inuit dialects;
3. Then we mailed out the translated booklets to over 50 organizations in the North and a few internationally;
4. We conducted a questionnaire on the impacts, relevancy, accessibility and gaps of the report; and
5. We stayed in touch with our steering committee.

Over the last year we received several requests to showcase new and updated research results from the western and central Canadian Arctic. Thanks to the many talented and generous researchers who contributed the articles in this newsletter, we have been able to answer this call. On behalf of our contributors, we are pleased to present the IRIS 1 *Research Updates* newsletter. Enjoy!

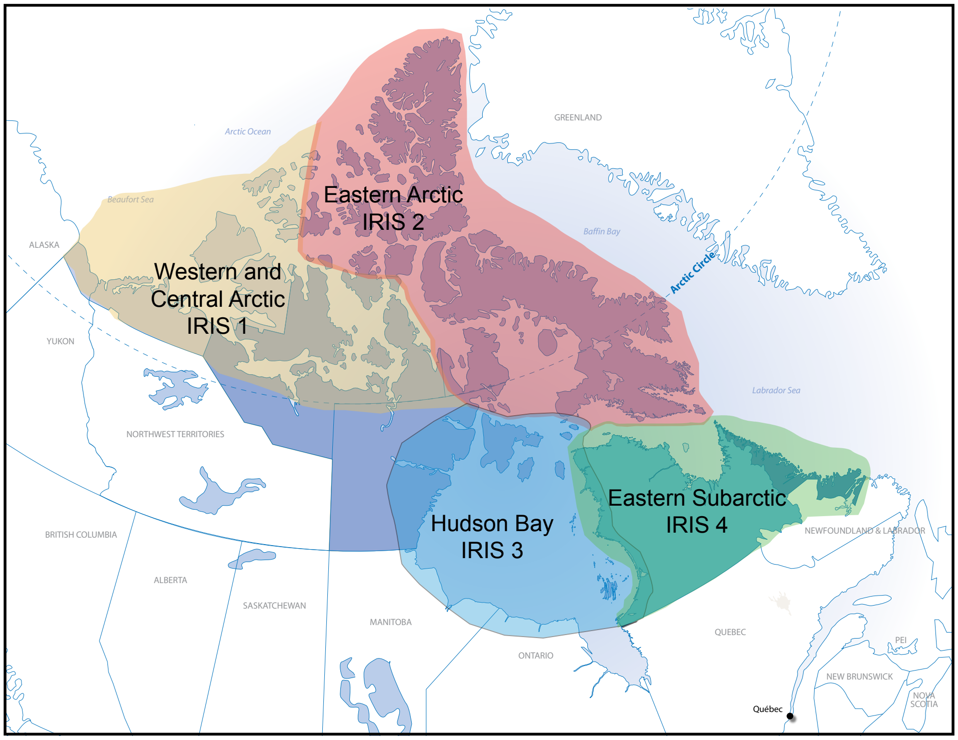
- Gary Stern (IRIS 1 lead) and Ashley Gaden (IRIS 1 coordinator)

Did you know?

All ArcticNet IRIS Regional Impact Assessments are freely available on the ArcticNet website at www.arcticnet.ulaval.ca/media/iris_reports.php

Thank you!

A big thank you to all our newsletter contributors! This production would not have been possible without your support.



The IRIS 1 area encompasses the Inuvialuit Settlement Region of the Northwest Territories and the North Slope of Yukon, and the Kitikmeot region of Nunavut (yellow region in figure above).

By the numbers: the IRIS 1 Regional Impact Assessment

6	Languages of the *Synthesis and Recommendations* article	**15**	Steering Committee/ Kitikmeot sub-committee meetings	**432**	Pages
4	*NEW* 2-page Highlights Summaries, available on the ArcticNet website	**13**	Consultation/Outreach stakeholder meetings	**100**	Authors

The East Whitefish Weather and Oceanographic Observation Station – an aid to navigation and a tool for science

D. Whalen[1], A. Gordon[2], S. Macphee[3], L. Loseto[3]

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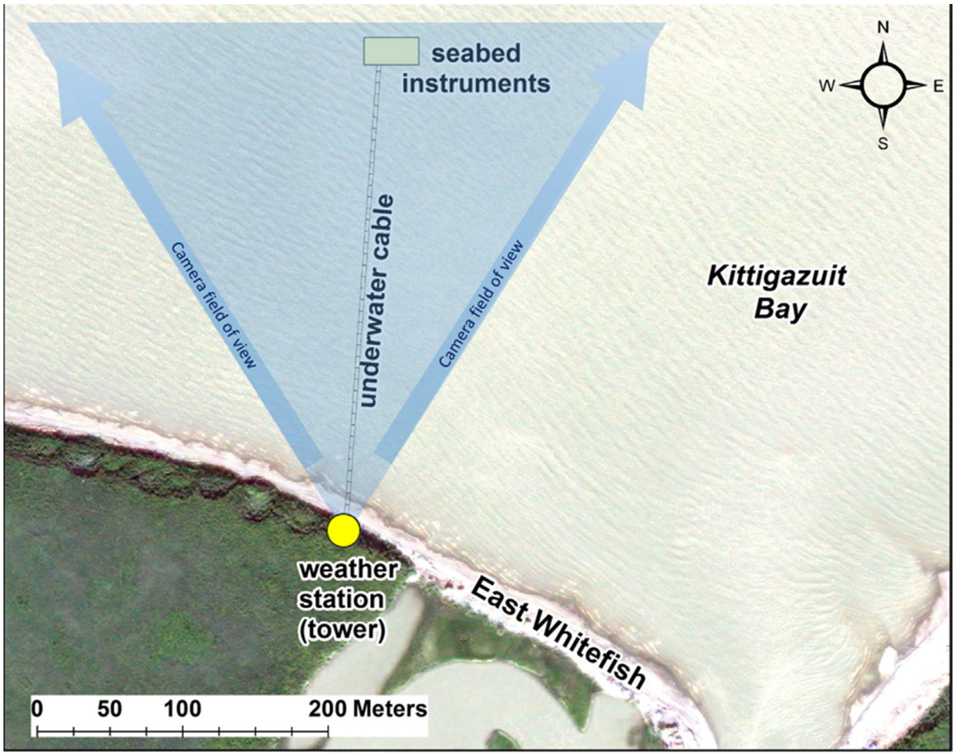
The capability to broadcast data on a near real-time basis provides communities and other travelers to the region access to current data. East Whitefish, located in the southwest corner of Kugmallit Bay (Beaufort Sea), is used as a hunting and subsistence whaling camp during the summer months. This area known as Kittigazuit Bay is situated just a few kilometers from the one and only navigable channel connecting the Mackenzie River to the Arctic Ocean, and this location sees a fair share of coastal and marine ship traffic. During the summer months, Inuvialuit, the Inuit of the Western Arctic, travel to the area (East Whitefish and Hendrickson Island) to hunt beluga whales. This subsistence hunt is an important part of Inuvialuit culture and has been for thousands of years. Traditional knowledge regarding wind speed and direction in Kugmallit Bay, and how it can relate to water levels, has been passed down over the generations. Climate driven changes to sea ice cover, air temperatures, and wind oscillation patterns have changed the wave climatology and subsequent water levels, making them less predictable. To explore and understand these changes and their impacts on travel and subsistence, a weather station was set up at the East Whitefish harvesting camp.

Kugmallit Bay, near East Whitefish, is a popular travel destination and accurate information and the ability to check water levels and weather conditions ensures safe travels to the area. The data can be viewed through a publicly accessible webpage (http://dataservices.campbellsci.ca/nrcan/index.php). This weather station will continue to provide updated scientific data and oceanographic observations for many years to come, but it is the capacity to share all of this information on a near real-time basis that could actually be seen as the real benefit. The weather station was installed in the summer of 2015 to measure air temperature, wind direction, and amplitude data. The station was upgraded in 2016 and 2017 to capture oceanographic conditions via an underwater cable connected to an instrumented mooring on the seabed. The mooring has the capacity to measure water temperature, salinity, water depth, waves, and turbidity. In addition, the weather station now includes a time-lapse camera to collect photography and videos. Together, this provides the scientific baseline information necessary to gain a better understanding of changing conditions in this sensitive environment.

During a 4 day period in July 2016, strong west winds averaging 42 km/hr (gusts up to 60 km/hr) caused water levels to surge to 2.2 m, measuring 1.2 m above normal level for that location. The surge of cold ocean water into the bay during ideal wind conditions also has tended to decrease the overall temperature. In the storm mentioned above, temperatures fell almost 12°C in just 48 hours. The weather station provided real-time information on extreme conditions to not only ensure the safety of travelers but also capture scientific observations of these unprecedented events.

On average, the web page has been viewed 5 times per day, with noticeable increases throughout the summer, which may signify when people were checking conditions more frequently prior to travel to the area. In July 2017, there were over 400 views to the web page, which is again the busiest time for subsistence whale hunting and travels through the area.



Top: Weather and Oceanographic Monitoring Station. Photo by Dustin Whalen. Bottom: Map showing location and camera field of view towards the ocean and main navigation channel in Kittigazuit Bay, NT.

The acceleration of change – how UAV technology is being used to better understand coastal permafrost landscapes in the Mackenzie-Beaufort Region, NT

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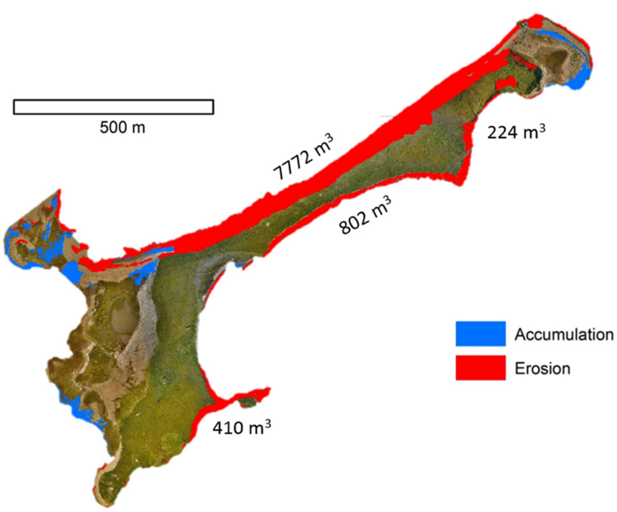
Left: Pelly Island Digital Surface model (DSMs) 2016 created from UAV aerial imagery. Large blocks eroding from the cliff have produced erosion rates up to 35 m in just one year.

The coastline of the Yukon and the Northwest Territories in the Mackenzie –Beaufort region is characterised by low (~2 m) to high (> 10 m) ice-rich cliffs predominantly comprised of glacially derived clastic sediments and abundant excess ground ice. These cliffs encompass 62% of the backshore region and are experiencing rapid erosion as a result of widespread thermal abrasion and thermal denudation of shorelines. Much of the coastline is known to be eroding at long-term rates of 1-2 m/yr with rates in excess of 22 m/yr in some places. Past studies using historical air photos have suggested that decadal rates of change for this region have remained relatively constant over the last 50-60 years. However, new data targeted along coastal sections characterised by high (>10 m) ice-rich cliffs suggest an acceleration of coastal erosion in the last decade or two. Since 2013, over 50 coastal monitoring sites have been visited and resurveyed in the region. This new data suggests an acceleration of coastal erosion in the last decade or two at some key sites along the Yukon coast (Komakuk) just seaward of the Mackenzie Delta and Richard Island (Garry Island, Pelly Island, Hooper Island, Pullen Island) and along the Tuktoyaktuk Peninsula (Tuktoyaktuk Island, Toker Point and MacKinley Bay). Critical areas like Tuktoyaktuk Island are seeing change that is 0.2-0.3 m/yr faster than earlier observations, while the most extreme rates come from Pelly Island with rates that are now 13-16 m/yr faster (or twice as fast) than previously recorded. This change in erosion rate will substantially increase the volume of sediment, nutrients and organic carbon exported to the marine ecosystem on an annual basis and will have a dramatic affect on communities and infrastructure along the coastline.

The people who live within the Inuvialuit Settlement Region of the Northwest Territories, and especially the residents of the coastal community of Tuktoyaktuk, are all too aware of this rapid erosion. Tuktoyaktuk Island serves as a natural breakwater between the community's harbour and the Beaufort Sea. However the island is eroding at a rate of 2.1 ± 0.2m/yr (2000-2017), up from 1.9 ± 0.3 m/yr (1947-2000). The island is the main source of new sediment to the system fronting Tuktoyaktuk Harbour, contributing 9220 m^3 of new sediment to the system on an annual basis. It should be noted that ice content of the cliff (30-100%) has been factored in for each segment of the cliff when calculating sediment volumes. The average yearly erosion rate of Tuktoyaktuk Island (measured from 1947 to present) is 2.3 m/yr. If Tuktoyaktuk Island were to erode away, this valuable natural harbour would be more exposed to wave action, with varied severity depending on the morphology of any resulting shoal in the harbour mouth. Widening of the harbour entrance would also lead to accelerated siltation and shoaling. The stability of the harbour entrance channel(s) under these conditions is difficult to predict, but the utility of the harbour for offshore re-supply, for subsistence activities, and a critical component of the Canadian Arctic marine transportation corridor could be significantly compromised over the next 20-25 years. Because of the island's importance to the long-term stability of the harbour, community residents would like to see action taken to stabilize Tuktoyaktuk Island, and several possible adaptation measures are being considered.

To better understand the response of coastal landscapes to changing environmental conditions in this highly dynamic environment, the Geological Survey of Canada has deployed Unmanned Aerial Vehicles (UAVs) for modelling the landscape at selected sites. The combination of UAV-based aerial imagery with derived high-resolution digital surface models provides unprecedented capability to monitor change along the Beaufort Sea coast. UAVs are efficient, low-cost, and unlike traditional remote sensing imagery, allow for controlled date and time of imagery acquisition. Their ease of use and compact size make them particularly suitable for remote or poorly accessible areas. Digital Surface Models (DSMs) created from UAVs will allow for a better understanding of the geomorphologic and volume change on a seasonal, annual and even decadal scale.



Right: A comparison of surface models between 2004 and 2016 of Tuktoyaktuk Island show that erosion accounts for 75% of the volume change contributing 9200 m^3 of sediment to the marine ecosystem on an annual basis.

Changing tundra ecosystems - Research by Team Shrub from the University of Edinburgh and Yukon Parks

I. Myers-Smith, H. Thomas, G. Daskalova, J. Assmann, A. Cunliffe, S. Angers-Blondin and other members of Team Shrub

University of Edinburgh, Edinburgh, Scotland

Over the past five years 'Team Shrub" has been investigating how climate warming is affecting tundra vegetation communities in the western Canadian Arctic. From increasing shrubs to eroding islands, we have been documenting the changes occurring as temperatures rise and growing seasons lengthen. Here, we summarise our key findings to date.

Vegetation change

We have been monitoring long-term plots on Qikiqtaruk-Herschel Island, off the north coast of the Yukon to investigate vegetation change since 1999. Over the 18 years, we have seen an increase in biomass of plants, an increase in shrub, grass and sedge cover, and the colonisation of plots by two tall grass species that are becoming more abundant in the area. The average canopy height of plants has also increased four-fold since 1999, both due to an increased abundance of taller species, and because existing individuals are growing taller.

Recently, we have also been working to understand how plant traits – that is, the characteristics of plants such as their height or leaf size – might be changing and how that will influence different functions that tundra ecosystems provide such as carbon storage. Using data collected from across the tundra, we have identified strong correlations between temperature, moisture, and many of the important characteristics of vegetation communities. While so far, we only see clear evidence for an increase in plant height over the past two to three decades of ecological monitoring, these climate-trait relationships give us a good indication of the changes we expect to see as the climate continues to warm.

Earlier phenology

The ecological monitoring programme on Qikiqtaruk has been studying tundra plant phenology - the timing of spring green up, flowering and start of the fall colours - for nearly two decades. These data, collected by the Herschel Island - Qikitaruk Territorial Park rangers, are documenting the changing growing season in the Western Arctic. Plants are both leafing out and flowering earlier over time.

An increase in shrubs is one of the types of vegetation change observed on Qikiqtaruk - Herschel Island on the Arctic coast of the Yukon.

The date of senescence, when leaves turn brown, might also be getting a bit earlier. Snow melt and spring temperatures are the factors that best explain the earlier plant phenology. As the growing seasons continue to get longer with sea ice melting earlier and spring temperatures becoming warming over time, we expect plant phenology to continue to get earlier.

Increased plant growth

We have been sampling tundra shrubs from across the Yukon Territory, in Northern Quebec and around the Arctic with our collaborators to test how climate influences shrub growth. We have found that tundra shrub growth is most responsive to early growing season temperatures, suggesting that as temperatures warm, tundra shrubs will respond by growing more. We have also investigated how recruitment of new shrub plants from seed might be influenced by temperature and interactions with other species. Tundra shrubs might respond to summer temperatures by growing more, but recruitment of new shrubs from seed might be limited by cold conditions and interactions with other plant species.

Drones are providing a new way to monitoring tundra vegetation change across the landscape, from the loss of bare ground, increases in shrub cover to the thaw of permafrost. We are using drones as tools to monitor the greenness of the landscape which helps us to observe patterns in vegetation in space and time. Drone data helps us to extrapolate our findings from individual- and plot-scale observations to get a bigger picture understanding of vegetation change. We also use drones to monitor rapid changes in permafrost disturbances such as retrogressive thaw slumps and eroding coastlines (see p.4, opposite page).

Changing ecosystem functions

As plant communities change, so does the impact they have on the surrounding environment. One key aspect of change may be decomposition – a critical factor in the tundra since more than half of the world's soil carbon is stored in northern soils. Together with collaborators we have been using tea bags, buried at over 300 sites all around the tundra biome, to understand how climate affects decomposition rates, and how important warming is compared to vegetation change. So far, we have found that both temperature and moisture are key controls on decomposition, but that community composition (i.e., the quality of plant litter) is even more important. As vegetation changes in tundra ecosystems, we can expect influences of this change on the carbon cycle.

Thawing permafrost

One important driver of tundra vegetation change could be the deepening of the active layer (the topsoil which thaws each summer). As the permafrost thaws, more nutrients become available to plants, potentially leading to more plant growth and/or favouring certain species. In 2017, we established a protocol to monitor active layer depth through the growing season on Qikiqtaruk adjacent to the ecological monitoring plots. We hope that this work and our data collection using drones will allow us to quantify the impacts of thawing permafrost on Qikiqtaruk. Active layer depths were historically around 50 cm deep on Collinson Head on Qikiqtaruk, and in 2017 we recorded a maximum active layer depth of 87 cm in this area. It is too early to say how quickly the active layer is increasing, but the extent of permafrost thaw observed in retrogressive thaw slumps and coastal erosion seem to be increasing on the island, along the Yukon Coast and in the Western Arctic Region.

For more information on our research: https://teamshrub.wordpress.com/

The Kitikmeot Marine Ecosystems Study: first key results

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[1]*Université Laval, Quebec*

The Kitikmeot Marine Ecosystems Study, a partnership with Parks Canada jointly funded by the W. Garfield Weston Foundation and ArcticNet, is a four-year research program focusing on the southern Kitikmeot. The project generates a wealth of new scientific information about the marine ecosystems of the region and their fate under climate change.

The southern Kitikmeot has a rich history. Archaeological sites on southeast Victoria Island indicate human occupation dating back several millennia. In recent history, Roald Amundsen and his small crew on *Gjøa* spent two years in the east of Queen Maud Gulf during his successful first traverse of Canada's Northwest Passage from 1903 to 1905. Around the sheltered bay now called Gjøa Haven, Amundsen learnt from the Netsilik Inuit essential survival skills allowing him to win the race to conquer the South Pole. More tragic was the death of all members of the Franklin lost expedition in its earlier search of the Northwest Passage in the middle of the 19th century. The two shipwrecks from this doomed expedition, the HMS *Erebus* and *Terror*, have only recently been discovered in the eastern sector of Queen Maud Gulf. Nowadays, most of the rapidly growing ship traffic in the Northwest Passage passes through the relatively shallow and narrow Queen Maud Gulf. The increased human activity linked with mining and tourism development, combined with effects of climate change, augments the risks of noise disturbance, contamination, invasion of foreign species, and habitat disruption of the marine fauna and flora, with potentially important impacts on the marine ecosystems and therefore on the Inuit communities of the region. However, these ecosystems have been identified as among the least known of the Canadian Arctic.

The Canadian Coast Guard's amazing night shift crew Hugo, Vincent and Jasmin (yellow hard hats) are pausing with a member of the Kitikmeot Marine Ecosystems Study, Thibaud (red hard hat), after recovering a plankton net deployed from the CCGS Amundsen *in August 2017 in the central Canadian Arctic. Photo by Gérald Darnis.*

The 2015 report of the ArcticNet Integrated Regional Impact Study for the western and central Arctic (IRIS 1) stressed the critical need to inventory and expand information on the marine ecosystems of the Kitikmeot region. Such work will contribute to a better understanding of ecosystems functioning and response to the ongoing changes, and also of the role of the region in the ecological connection between the western and eastern Canadian Arctic.

Since 2015, the multidisciplinary team of the Kitikmeot Marine Ecosystems Study has been using the NGCC *Amundsen* as a research platform during the last three ArcticNet annual expeditions to study several levels of the marine food web including phytoplankton, zooplankton, fish and animals at the seafloor (benthos). Furthermore, divers from Parks Canada carried out the collection of organisms attached to the *Erebus* wreck in 2016 to study its function as an artificial reef and as a vector of foreign organisms in the waters of south Kitikmeot. Two moorings carrying oceanographic instruments in central Queen Maud Gulf and close to one of the wrecks, respectively, record since 2016 seasonal variations in water properties and circulation within the gulf, sinking organic particles, and zooplankton communities. As part of the project, one recent scientific publication provides first evidence that a boreal fish species, the Pacific sand lance, has invaded the Kitikmeot and is expanding its range in the Canadian Arctic Archipelago, a region far outside the species temperate-boreal traditional range south of the Bering Strait (see p.11). Two studies about to be published tested the hypothesis that the shallow waters of the Queen Maud Gulf act as a west-east bottleneck for important large zooplankton and the arctic cod (*Boreogadus saida*) that are crucial links in the high-Arctic marine food web. The low biomass of the Arctic *Calanus* zooplankton species, a major prey of pelagic fish such as the arctic cod, seabirds and the bowhead whale, may explain in part the low populations of marine vertebrate predators in the south Kitikmeot. In the Queen Maud Gulf, benthos biomass and biodiversity are relatively high compared with surrounding areas, a pattern contrasting with the low zooplankton biomass in the region. Our understanding of the Kitikmeot and of the future of the ecosystem services it provides to local communities continues to soar.

Beaufort Regional Ecosystem Assessment – Update on Marine Fishes Projects

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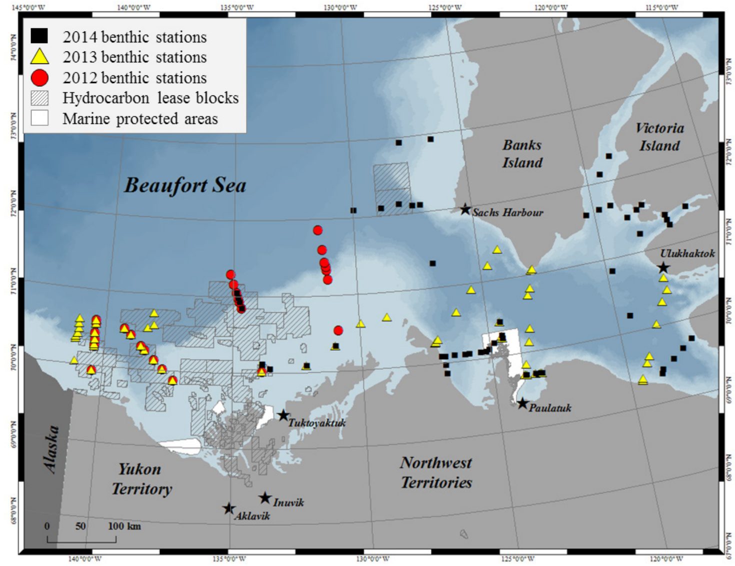

Right: Sampling stations for the BREA-MFP, 2012-2014.

Background: A significant knowledge gap, identified in 2011 for the Canadian Beaufort Sea, prompted the request for Fisheries and Oceans Canada to develop understanding of the marine fishes in deeper offshore waters. Between 2011 and 2016, several projects examined marine fishes, their habitats, and trophic relationships, including linkages with shelf and coastal systems. Over three field years (2012-2014), the Beaufort Regional Environmental Assessment marine fish project (BREA-MFP) sampled 184 stations in depths of 20-1515 meters (m) for bottom-dwelling fishes, epibenthic (above bottom) and infaunal (in the sediment) invertebrates, and plankton (water column plants and animals) (see map above). A hydroacoustic assessment of pelagic animals (fishes and large invertebrates living in the water column) was conducted along sampling transects and key features (i.e., shelf break/slope) and concentrations of pelagic organisms were sampled (see p.8). A summary of marine fish diversity, habitat associations and predator-prey relationships is presented here.

Marine Fish Diversity in the IRIS 1 area: Prior to the BREA-MFP work about 70 species of fishes were known to occur in the Canadian Beaufort Sea and Kitikmeot sub-areas, with the documentation of these primarily restricted to the shelf and shallower habitats (i.e., <200 m depths). Sixteen species of fishes are newly recorded for the area bringing the number documented to about 86 species from 20 families. Twenty of these exhibit anadromy (i.e., move between fresh and marine waters during life histories). Seventy-nine species occur in the Northwest Territories (NT) marine areas and 62 in waters of Kitikmeot, Nunavut. Fifty-eight species occur in waters of both sub-areas, 23 are unique to NT waters, and six are found only in Kitikmeot waters. These numbers and distributions are biased by limited sampling in Kitikmeot and/or by limited deep-water habitats in this sub-area, thus very likely will change as more research is conducted. These tallies include four species of Pacific salmons that regularly occur in the area as vagrant adults, but which are not yet known to have established reproducing populations. An additional 21 marine species from 10 families occur in adjacent waters of the Alaskan Beaufort Sea but have not yet been observed in Canadian waters. A further 17 species from nine families occur in adjacent fresh waters (primarily the Mackenzie River basin), thus may occasionally occur in coastal brackish-water habitats in the area.

Habitat Associations of Marine Fishes in the Canadian Beaufort Sea: Research confirmed that, beyond the immediate coastal habitats, most fishes were associated with bottom habitats with only a few species present in the water column. Offshore marine fish species were delineated into four groups associated with specific depth-defined habitats and relative abundances of shared species changed over the depth categories. Absolute abundances also decreased beyond 500 m depth. Arctic Cod was present in all habitats, however, the age/sizes of fish associated with particular habitats differed as did the absolute abundances. Additionally, while adult Arctic Cod were particularly abundant and geographically widespread along the shelf-break and slope drop-off (i.e., 200-400 m depths) in both 2012 and 2013, they were present only in very low numbers in these habitats in 2014. These results indicate that inter-annual variation occurs in cod abundance in the area, however, whether this is due to life cycle variation of the cod or to variation in their environment is unknown. The implications of this to predators that depend upon the cod are also uncertain.

No significant differences in community compositions or structuring by depth were noted between 2012 and 2013 sampling, nor among east to west situated on- to off-shore transects. Follow-on work in 2014 further east in Amundsen Gulf suggested that species compositions differed from those in the southern Beaufort Sea, however, Arctic Cod were also abundant in this area. Regional-scale habitat associations and depth structuring of fish communities provide the basis for follow-on identification of key habitats worthy of conservation efforts and better understanding of trophic associations and fish movements.

Trophic (food web) Relationships of Offshore Fishes: Predator-prey relationships of offshore fish species were determined by analyzing chemical markers (e.g. stable isotope ratios of carbon and nitrogen, and essential fatty acids). Although high variability in diets inferred from these markers was observed both within and among fish species, general patterns appeared to be present. First, *Calanus* spp. (i.e., small invertebrates in the upper water column) were present in the most abundant benthic fish species (i.e., eelpouts, sculpins) suggesting either direct consumption of deep overwintering copepods (i.e., off-bottom feeding) or indirect consumption via feeding upon benthic invertebrate prey items. Second, the analyses indicated that benthic fishes were typically low- to mid-trophic level predators with generalist benthic diets. Third, feeding patterns of Greenland Halibut (present in the upper- and lower-slope habitats) indicated that Arctic Cod formed most of the diet in the upper slope, whereas Gelatinous Snailfish and zoarcids (*Lycodes* spp.) characterized diets in the lower slope. Fatty acid markers characteristic of the pelagic habitat (e.g., *Calanus* spp.) were important, thus indicating the significance of Greenland Halibut in pelagic-benthic coupling in the Canadian Beaufort Sea.

Climate warming helps Arctic cod – at least for the time being

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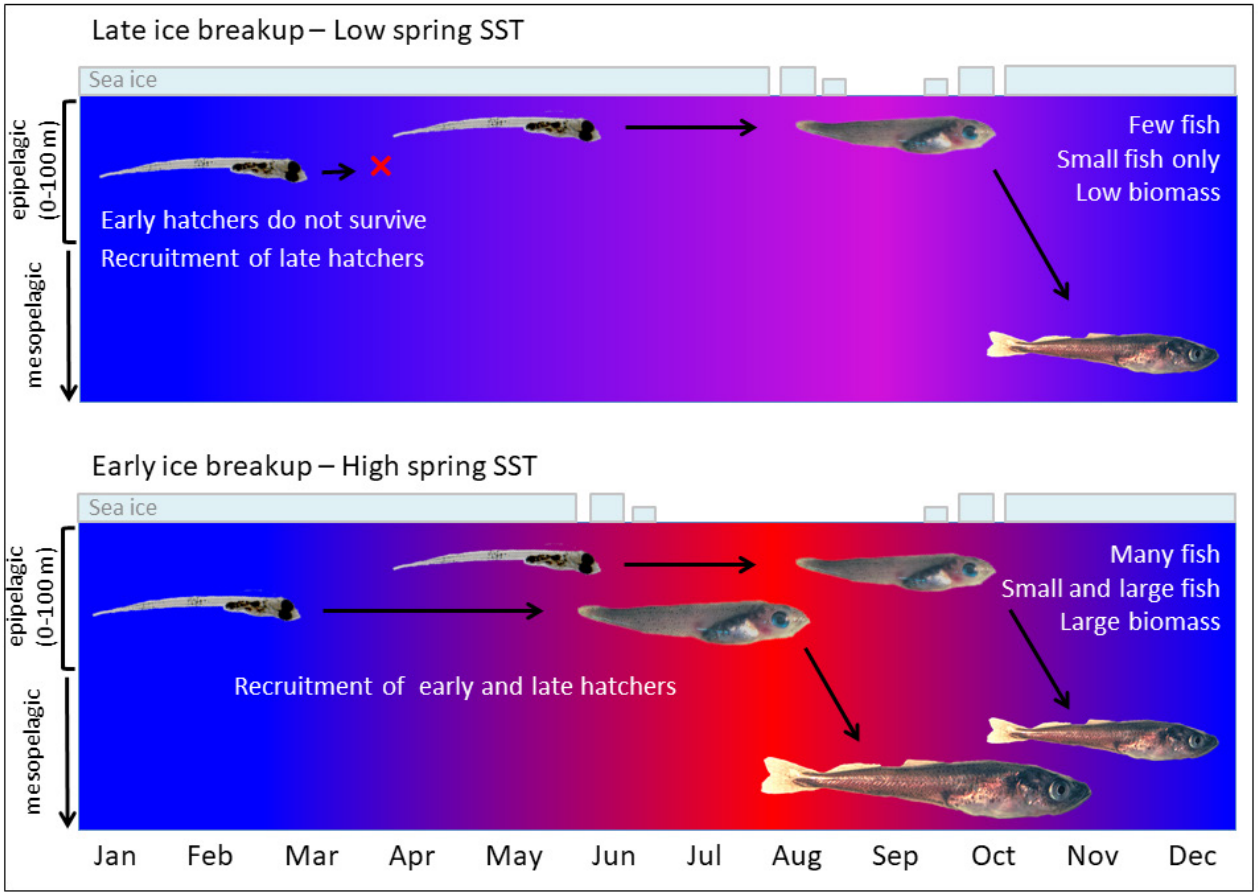
The small Arctic cod is the main prey of many seabirds and marine mammals including the ringed seal, the beluga and the narwhal. It is well adapted to the extreme conditions of low temperature, darkness and low biological productivity found in ice-covered seas. As the Arctic warms up, these extreme conditions are progressively relaxed. For instance, in Canadian Arctic seas, the ice breakup has occurred progressively earlier over the last three decades, which results in warmer surface temperatures, more light in the surface layer of the ocean and increased production of microscopic algae and food for fish larvae. It is then expected that the survival and abundance of Arctic cod should have increased over recent years.

In a recent study, we used satellite images to determine the date of the ice breakup in spring in 9 regions of the Canadian maritime arctic over 9 years from 2006 to 2015 (including the Beaufort Sea and the Kitikmeot region). Corresponding estimates of the number of young Arctic cod in these regions in the fall were obtained from the fish-finding sonar of the scientific icebreaker CCGS *Amundsen* during its annual survey of the Canadian Arctic. We found that in regions and years when the ice breakup is early in spring, the number and size of young Arctic cod in the fall are much greater. For instance, mean biomass of young fish (abundance times average weight) in September is up to 11 times greater for an early sea-ice melt (late May) than for a late melt (early September). Given the importance of Arctic cod as a staple food for other animals, a greater abundance of Arctic cod should favour seabirds and marine mammals.

However, as environmental conditions keep on improving, subarctic fish such as the Pacific sand lance and the capelin are invading the Western and Central Canadian Arctic Region (see p.11). Potential predators of Arctic cod, such as the Atlantic cod, haddock and Atlantic mackerel are already present in the European Arctic and the Greenland Sea. In coming decades or by mid-century, competition and predation from invading subarctic species will likely cancel the ongoing positive effect of a progressively earlier summer sea ice melt on the survival of young Arctic cod. The gradual replacement of Arctic cod by these subarctic species (as seen in Hudson Bay) will result in the establishment of boreal marine ecosystems in the Central Canadian Arctic and in major changes in the services provided to communities by the ecosystem.



In regions and years when the ice breakup is early in spring, the number and size of young Arctic cod in the fall are much greater.

Capelin, a sub-Arctic forage fish in a changing Arctic ecosystem

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Capelin (*Mallotus villosus*) is an important marine forage fish species that typically inhabits sub-Arctic and temperate circumpolar waters. Capelin have recently been reported in greater abundance in Arctic regions, and are considered an indicator for warming climate in northern marine ecosystems. To better understand the role of capelin in a changing Arctic, we investigated the life history and diets of capelin in Arctic regions. Co-occurring capelin and Arctic cod (*Boreogadus saida*) were collected in Darnley Bay, NT by Fisheries and Oceans Canada (Darnley Bay Nearshore Fish Survey and Beaufort Sea Regional Environmental Assessment – Marine Fishes Project). To compare life history traits of capelin between Arctic and sub-Arctic regions, capelin were also collected in Pangnirtung Fjord, NU and Newfoundland and by the Davoren Lab (University of Manitoba) in 2014 and 2015. In addition to life history and diet analyses, a traditional ecological knowledge study was conducted in Paulatuk, NT through collaboration with the Paulatuk Hunters and Trappers Committee. Five community elders, and five local observers were interviewed to gather information on the presence of capelin in Darnley Bay and the role of this fish as a prey source for subsistence species (e.g. Arctic Char; *Salvelinus alpinus*). This study was assisted by Brianna Wolki and the Paulatuk Hunters and Trappers Committee.

Life history comparisons of capelin from two Arctic regions (Western Beaufort Sea, Cumberland Sound) relative to a sub-Arctic population (Newfoundland) indicated that body size, body condition, growth rate and age-at-maturity vary among these regions. Later age at reproduction and slower growth in Arctic regions suggest that capelin at the northern margins of their distribution display different life history traits relative to the sub-Arctic population. The occurrence of capelin is expected to increase in the Arctic with rising temperatures, thus variation in life history traits in capelin specific to each region may facilitate increased abundance and persistence. These populations in Arctic regions will play pivotal roles in ecosystems as temperatures continue to rise. Such conditions may become more favourable for capelin to increase in abundance, shift in distribution and expand further into the Canadian high Arctic.

Spawning shoal of capelin at Argo Bay, July 2017. Photo by Darcy McNicholl.

The consequence of increased abundance of capelin in Arctic regions could be competition between capelin and Arctic cod, an Arctic species within a similar dietary niche. Stomach contents indicated that both species feed primarily on calanoid copepods and using biotracers (carbon and nitrogen stable isotopes) indicate these species display significant overlap (90%) during the open water season. Potential competition will be particularly important in nearshore and shelf habitats where shifts in availability of intermediate trophic level taxa will influence diet and distribution of key predators such as beluga, sea birds, and anadromous fishes. As the Arctic environment changes with climate shifts, newly dispersed species from sub-Arctic systems are expected to drive shifts in ecosystem structure and function in the marine environment.

Local observations and traditional ecological knowledge gathered over long periods of time provide valuable insights into the historical ecological trends and anomalies in a region. Based on the information obtained from the questionnaires and interviews in this study, capelin (iqalugaq or "cigar-fish") are considered to be an important prey source for marine mammals, seabirds and char, and have been observed in Darnley Bay since the 1960's. Participants in this study suggested that capelin can be found throughout coastal areas and are not restricted to sand-dominated substrates for spawning in southern parts of the bay. Participants noted that they observed capelin during periods when temperatures were above normal in recent years, and when the beaches were free of ice. From this, we predict that as temperatures continue to warm, the conditions for spawning and survival may improve for capelin thus leading to increased abundances and likely shifts in distribution further north. Future research that aims to address these questions will address current knowledge gaps, and understand how the future role of this ecologically important species may change in the coastal Beaufort Sea.

Arctic Salmon: Linking subsistence and science to track and predict changing biodiversity of fishes in the Canadian Arctic

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Background

Pacific salmon (*Oncorhynchus* spp.) are increasing in abundance and distribution in the Canadian Arctic. Subsistence fishers originally noticed an increase in the numbers and species of salmon being harvested, which prompted Fisheries and Oceans Canada in 2000 to begin tracking the relative abundance and distribution of salmon based on subsistence harvests. In 2011, this program expanded to become Arctic Salmon, which is currently the largest community-based monitoring program in the Canadian Arctic.

Subsistence

Through the Aklavik Hunters and Trappers Committee (AHTC), we have been collecting salmon from local fishermen in the community of Aklavik. Each year varies on how many salmon we collect from fishermen. Last year, 2016, we collected about 70 salmon. And for this year, 2017, we are at 24 salmon collected. That's a big difference from last year. It's a good trade for the local fishermen as they get a gift card for trading a salmon, and the gift card helps the fishermen with harvesting supplies such as gas.

From working at the HTC since 2009, I have noticed more salmon being returned to the office. When I talk to local harvesters they mention that they have been catching salmon for years but they would just feed it to their dogs! But they never knew the salmon were so good tasting.

Most fishermen usually harvest salmon during the Summer Season, from July to September. But it depends on the season too as our freeze up is getting later and later each year! When it is ice fishing, we do get some salmon returns but not as many as during the open water fishing season.

In the future, I think more people will eventually take advantage of their harvest and use it in different ways – such as dried salmon, fillet salmon, candied salmon, salmon fish sticks – who knows but the possibilities are endless!

From talking to Elders or knowledgeable fishermen, they say they have been harvesting salmon for years. They are noticing more salmon now and more different salmon, so this salmon collection program is a good way of monitoring change.

The Aklavik HTC and local fishermen of Aklavik would just like to say a big Quyanainni for making this project happen. It's good to hear back positive feedback from local fishermen about salmon.

Science

The Arctic Salmon project has demonstrated that Pacific salmon are effective indicators of ecosystem-level change in the Canadian Arctic. By applying citizen science in a framework that is practical for the Canadian Arctic, and by using tools developed to facilitate reporting, increasing occurrences of salmon abundances and distributions in the Northwest Territories and Nunavut are being documented. These increased occurrences likely reflect underlying variabilities and changes in marine ecosystems that enhance survival at sea and geographic scope of marine habitat usage. Genetic tools were used to establish that chum salmon colonized the upper Mackenzie River early in deglaciation of the western Arctic, and that vagrants are also currently accessing the Mackenzie River via coastal pathways. By thermally characterizing groundwater spring oases, which are critically important to native chars and potentially also for colonizing salmon, we can predict watersheds vulnerable to colonization, and identify the associated risk of competition with native chars. Accordingly, shifting salmon distributions and abundances potentially represent both vulnerabilities and opportunities resulting from climate variability in the Canadian Arctic.

Conclusion

By integrating the subsistence way-of-life with scientific approaches, we can better manage the development opportunities and predict the conservation impacts associated with shifting biodiversity in a future Arctic. This integration involves the sharing of local knowledge and scientific information. Development of outreach materials, the use of social media to facilitate rapid exchange of information (i.e., www.facebook.com/arcticsalmon), and capacity building (e.g., to facilitate installation and data recovery from thermal recorders in key habitats) furthers increased knowledge development. This integrated approach could also be used to effectively monitor shifts in other fish species and biodiversity over wide areas of the Arctic.

Left: Charlie Erigaktoak and Danny Gordon Jr. with a salmon they harvested in 2016 at Shingle Point, Yukon. Photo by Michelle Gruben.

A Pacific fish species, the Pacific sand lance, detected in the western and central Canadian Arctic

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Major shifts in the distribution of marine animals are occurring worldwide in response to warming of global oceans. In the Arctic, ocean warming is more rapid than the global average. This triggers multiple ecosystem changes, including the northward expansion of species coming from southern latitudes. As such, several species from the Pacific and Atlantic oceans can now be found in the Arctic. Those invading species span all trophic levels, from plankton, to fish and marine mammals. In a previous study that was featured in the 2015 IRIS 1 assessment, we showed that Pacific sand lance (*Ammodytes hexapterus*), a species commonly found in Pacific ecosystems, recently established into the Beaufort Sea, a region outside its usual range in temperate and boreal environments south of the Bering and Chukchi seas. In a further study, we found that the species expanded its range into the Kitikmeot region of the western and central Canadian Arctic region. We observed that the number of larval Pacific sand lance increased with time over the 2011-2016 period. This suggests that environmental conditions in the Canadian Arctic are becoming suitable for the species to reproduce and establish.

We detected the species using a variety of methods including larval fish surveys, genetics, and interviews with holders of Inuit local knowledge. Sand lance of early life stages was sampled in a region ranging from the Amundsen Gulf to the west, to the Queen Maud Gulf to the east onboard the scientific icebreaker CCGS *Amundsen*. We used genetic tools to identify larval and juvenile fish to the species. Inuit local knowledge confirmed our biological observations of Pacific sand lance in the Kitikmeot region. Inuit harvesters from Cambridge Bay and Gjoa Haven reported that they first observed sand lance in the region between 2011 and 2014. Some harvesters indicated that the frequency of sand lance observations increased through time. Furthermore, a harvester found several sand lances in the stomachs of Arctic char in 2016 at an important Arctic char fishing area near Cambridge Bay.

Biological sampling off the CCGS Amundsen. *Photo by Cyril Aubry.*

He did not recall observing such a thing before (C. Kaiyogana). Local harvesters continue to monitor the occurrence of sand lance. Recently, in September 2017, a harvester found sand lance in an Arctic char stomach at Jayco River, a location near Victoria Strait, further east in the Canadian Arctic Archipelago (D. Kaomayok).

The first records of Pacific sand lance in the western and central Canadian Arctic reported in this research project may indicate a long-term shift in the distribution of this boreal species. Increasing presence of sand lance in marine and coastal ecosystems of the region could cause rapid ecological changes if the boreal invader replaces Arctic cod, a key prey species for Arctic fishes, seabirds and marine mammals. In particular, Pacific sand lance – a fish that is not as rich in energy as Arctic cod – may not be able to meet the energy needs of Arctic top predators. Continued monitoring of the Pacific sand lance expansion in the Arctic will be needed to forecast the potential impacts of this new species on local ecosystems, and the implications for communities of the region.

Linking Inuit and scientific knowledge and observations to better understand Arctic Char (*Salvelinus alpines (L.)*) community monitoring

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[1]*Trent University, Peterborough, ON*

This PhD research project was conducted in collaboration with the community of Sachs Harbour (NWT) in the Inuvialuit Settlement Region from 2008 to 2016. The research examined the question of which community-based monitoring factors and parameters would provide information needed by local resource users and decision-makers to make informed choices for managing Arctic Char populations in light of climate variability and change. This question was investigated through an exploratory research approach and a mixed method research design, using both ecological and social research methods, and quantitative (scientific ecological knowledge and observation) and qualitative (Inuvialuit knowledge and observation) information.

Three study lakes (Capron, Kuptan and Middle lakes) on Banks Island, close to the community of Sachs Harbour, were chosen for the study based on their importance to community fishers. Potential lake habitat parameters that could be used for monitoring landlocked Arctic Char condition in the three lakes were identified and examined (e.g. nutrient input from outside the lake, water temperature, lower trophic level diversity and productivity, and char parasite load as well as taste). Local environmental parameters that could be used for monitoring landlocked Arctic Char growth were also identified and studied (e.g. air temperature and the lake ice-free period). The results demonstrated similarities and differences in char growth and condition within and among the three study lakes, meaning both lake habitat and local environmental monitoring parameters should be used in Arctic Char community-based monitoring programs.

The study also investigated aspects of Arctic Char community-based monitoring programs across the Canadian North, in each of the four Inuit land claim regions, to identify factors that have led to the sustained collection of useful data for management of the resource. One of the results demonstrated that an adaptive monitoring approach is important for subsistence fisheries, meaning a program needs to be prepared for unexpected changes, and needs to evolve iteratively as new information emerges and questions or interests change. These may be environmental changes such as permafrost melt altering the outlet of a river into the ocean, resulting in a sudden change of fishing locations. Unexpected changes to the use of the resource may also occur when fishers choose new harvest locations due to higher costs of fuel for travel. Another result suggested that meaningful incorporation of Inuit Knowledge, as well as Inuit monitoring methods, could be a key to well-founded community-based monitoring, leading to increased community engagement and increased understanding of the study system or population.

The full PhD dissertation can be found at: http://digitalcollections.trentu.ca/objects/etd-573?solr_v%5Bid%5D=9d7b1d12b1818e0c92bf&solr_v%5Bpage%5D=0&solr_v%5Boffset%5D=0nav%5Bid%5D=9d7b1d12b1818e0c92bf&solr_nav%5Bpage%5D=0&solr_nav%5Boffset%5D=0

Trevor Lucas (left) and Kyle Wolki (right) were two of the local monitors working on the project, shown here sampling an Arctic Char from Middle Lake, Banks Island. Photo by Jennie Knopp.

The human face of climate change in the Arctic

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Top: Gilbert Thrasher Sr, Lisa Illasiak and Eric Lede, Paulatuk, NT.

Right: Adam Kudlak and Linnaea Jasiuk, Ulukhaktok, NT.

Inuit of the Canadian Arctic are experiencing rapid changes to their environment, with implications for health, diet, culture, education and general way of life. A team of scientists led by Dr. Tristan Pearce has been working together with communities in the Inuvialuit Settlement Region to better understand how people are experiencing and responding to these changes. Presented here are summaries of each of the six community-based projects, in which data were collected using ethnographic research methods such as semi-structured interviews with community members, free-lists, participant observation, line drawing and analysis of secondary information sources.

1) Hunting under changing conditions: climate change impacts on Inuit subsistence activities over an 11-year period in Ulukhaktok, NT (Fawcett, Pearce, Ford)

This research examined how Inuit in Ulukhaktok adapt to changing climatic conditions over time, with a specific focus on subsistence activities – hunting, fishing, trapping, and gathering. Data were collected with Inuit in Ulukhaktok in 2016 and compared findings with data collected in the community in 2005. Results show that many of the climatic changes recorded in 2005 that were negatively impacting hunting activities have persisted or progressed, such as decreasing sea ice thickness and extent, and stronger and more consistent summer winds. Inuit are responding to these changes by altering travel routes and equipment, taking greater pre-trip precautions, and concentrating their efforts on more efficient and accessible hunts. Rising costs of living and subsistence activities, time-constraints due to wage employment, changes in the generation and transmission of traditional knowledge and land skills, and the concentration of country food sharing networks on fewer hunters were identified as key constraints to adaptation. These findings indicate that the connections between subsistence activities and the wage economy are central to understanding how climate change is experienced and responded to.

2) Inuit women's conceptualizations of, and approaches to, health in a changing climate in Ulukhaktok, NT (Jasiuk, Pearce)

This research employed a community-based analysis to examine Inuit women's conceptualizations of and approaches to health in adaptation to climate change in the Arctic, in a case study of Ulukhaktok, NT. Findings indicate that Inuit women in Ulukhaktok retain a traditional conceptualization of health that is holistic in nature with attention to the mental, emotional, physical and spiritual parts of the self and which prioritizes relationships among family and the environment. As such, Inuit women are sensitive to the health effects of societal and environmental changes that effect food security, water security and barriers to spending time on the land. This research suggests that climate change health interventions rooted in Inuit women's conceptualizations of and approaches to health and mainstreamed amid broader health interventions are most likely to have positive health outcomes for Inuit women.

3) Learning under contradictory systems: perceptions of learning and formal education in Ulukhaktok, NT (Lalonde, Pearce)

This research examined what aspects of culture and modes of learning Inuit desire to have included in education, beyond priorities identified by non- Inuit educators. A conceptual framework for the cultural negotiation of Indigenous education is empirically applied in a case study of Ulukhaktok, NT to identify what Inuit think Inuit youth should learn, how they should learn it, where they should learn it and from whom, and why it is important for them to learn it. Results show that Inuit desire to have native languages, subsistence knowledge, skills and values, and understanding of the local environment included in education, which not only builds competence in subsistence but also provides students with capacity to cope with challenges in the modern world. This involves on-the-land hands-on learning with a skilled person and practical everyday use of native languages in learning. Inuit perceive school as a place for "learning" and the research identifies opportunities to negotiate this space to better integrate Inuit culture and modes of learning.

4) The role of multiple stressors in adaptation to climate change in Paulatuk, NT (Lede, Pearce, Furgal)

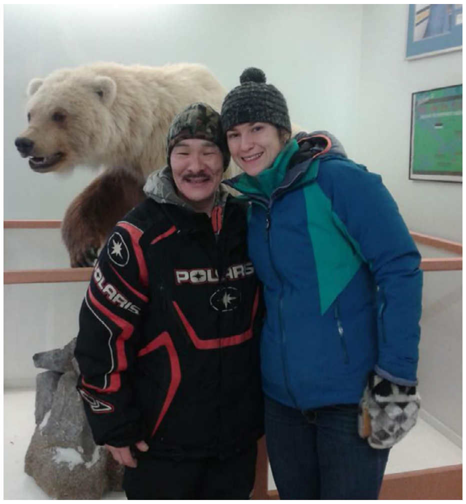
This research examined the role that multiple stressors play in how Inuvialuit respond to changing environmental conditions in the Arctic, with a specific focus on understanding the factors that aid and constrain adaptation. Results show that the key stressors affecting livelihoods in Paulatuk are changing environmental conditions, which affect land-based activities, and socio-economic stressors, including housing shortages, access to financial resources, changes in the generation and transmission of TEK, and addictions. How people prioritise and respond to stressors differs among respondents, which in some instances, depletes resources needed to respond to other stressors. Climate change compounds existing stressors already affecting Inuvialuit livelihoods and challenges the viability of land-based activities for some Inuvialuit. The research findings are intended to contribute to the development of adaptation strategies that go beyond an exclusive focus on climate and better reflect the realities of the Arctic.

5) Vulnerability of an Inuit food system to climate change in the context of climatic and non-climatic stressors: a case study of Ulukhaktok, NT (Parker, Pearce)

This research examined the vulnerability of an Inuit food system to climate change in the context of multiple climatic and non-climatic stressors through a case study of Ulukhaktok, NT. The community-identified collaborative research project was completed to understand how climate and socio-economic change is impacting key attributes of Ulukhaktok's dual food system including food availability, access, quality and storage. Results show that multiple stressors, both climatic and non-climatic, impact food security in Ulukhaktok. Further, the results reveal the need for Inuit food sovereignty as well as the need to reinforce both formal and informal adaptation mechanisms. In terms of its contributions to more universal knowledge, the research establishes the need for a more comprehensive framework to assess food security, which includes attention to food storage.

6) Inuvialuit traditional ecological knowledge (TEK) of beluga whale in a changing climate in Tuktoyaktuk, NT (Waugh, Pearce, Ostertag, Loseto)

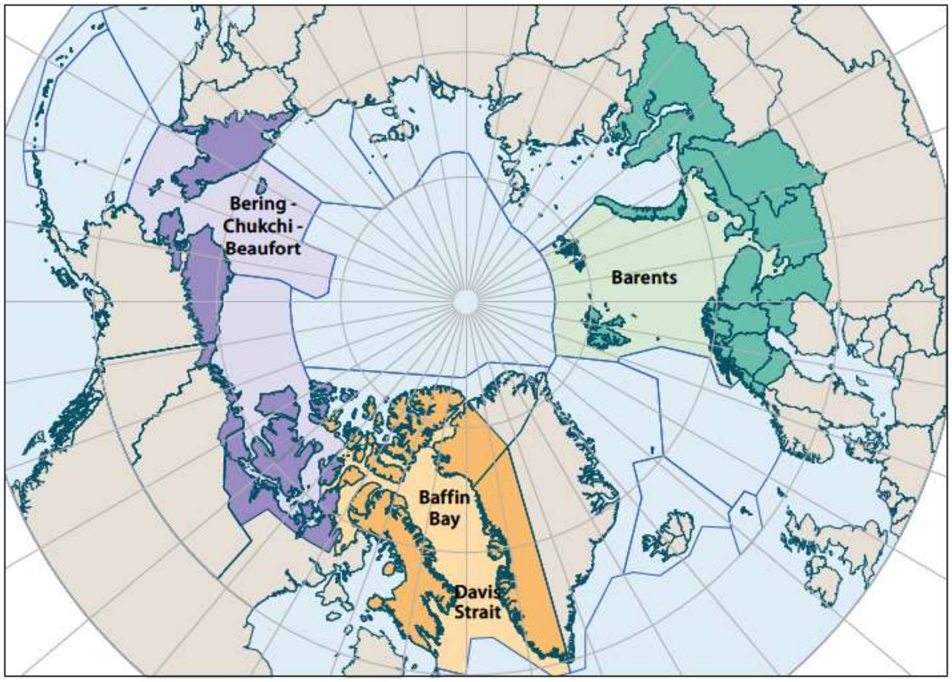
This research documented Inuvialuit TEK about the ecology and behaviour of the beluga whale, hunting techniques, food preparation and values, in the context of changing climatic conditions in Tuktoyaktuk, NT. Results show that Inuvialuit beluga harvesters possess detailed rational knowledge of beluga, particularly regarding hunting techniques and food preparation that is guided by a moral code about how to behave with respect to beluga. Knowledge of beluga ecology and behaviour is limited to reasoning based on generalized observations of beluga and the accounts of others. Inuvialuit are observing rapid changes in the environment, some with implications for beluga hunting and food preparation but are coping thus far.



Jack Akhiatak and Geneviève Lalonde, Ulukhaktok, NT.

Clockwise from right: (1) Colleen Parker, Ulukhaktok, NT. (2) Devin Waugh, Tuktoyaktuk, NT. (3) Adam Kudlak and Tristan Pearce, Ulukahktok, NT. (4) Jack Akhiatak and David Fawcett, Ulukahktok, NT.

New! Upcoming regional assessments of the western and central Canadian Arctic



The three AACA pilot regions, including the Bering-Chukchi-Beaufort region to the left in purple shading. Source: AMAP Secretariat.

Adaptation Actions for a Changing Arctic (AACA)

In an effort to deliver an integrated assessment of multiple drivers of Arctic change, and to enable more informed and responsive decision making in the Arctic, the Arctic Monitoring and Assessment Programme developed three regional assessments covering the Barents Area, Baffin Bay/Davis Strait Region and the Bering-Chukchi-Beaufort Region. Similar to the ArcticNet IRISes, the AACA reports provide climate projections (up to 2030 and 2080). The reports will complement the IRIS assessments by also including projections for oceanic indicators, including sea-ice, and socio-economic scenario modelling. The Barents report is finalized and can be downloaded from the link below. Overview reports for all three regions are also available. The remaining AACA regional reports are scheduled for release in late 2017/early 2018.

Visit www.amap.no for online access to these and other AMAP documents.

Beaufort Regional Strategic Environmental Assessment (BRSEA)

First initiated in 2016 and led in partnership between Indigenous and Northern Affairs Canada, the Inuvialuit Regional Corporation, and the Inuvialuit Game Council, the Beaufort Regional Strategic Environmental Assessment will provide strategic direction and analysis of environmental considerations on future offshore oil and gas activity in the Beaufort Sea. Specifically, the assessment will examine the effects of forecasted development and conservation scenarios, set desired environmental outcomes and thresholds, address regional policy and regulatory issues, and take into account changes in the environment.

For further reading on the 2016-2021 Arctic Regional Environmental Studies, including the Strategic Environmental Assessment in Baffin Bay and Davis Strait, visit www.aadnc-aandc.gc.ca/eng/1492023135343/1492023811012.

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