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A risk analysis framework: Key risks from permafrost thaw in Arctic coastal areas

EGU General Assembly 2022

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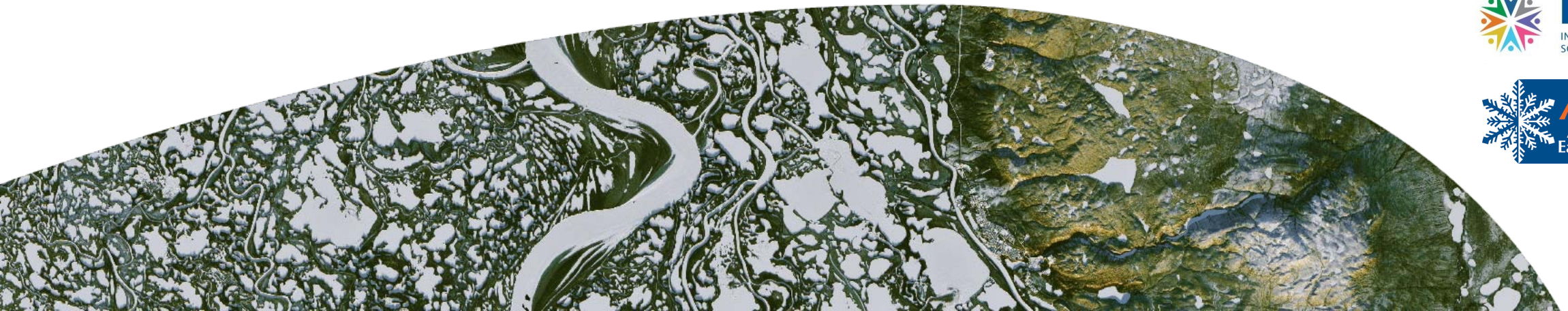
IASSA INTERNATIONAL ARCTIC SOCIAL SCIENCES ASSOCIATION

APECS Association of Polar Early Career Scientists

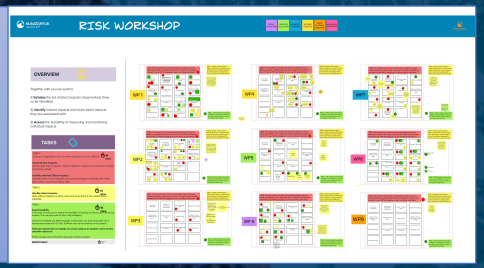


Hermeneutical Process of Risk work

2019 RELATED RISK(S) : NICE

2019 COPENHAGEN: RISK ARTICLE WITH FRAMEWORK

2021 MURAL : DIRECT AND INDIRECT RISKS



2021 COPENHAGEN/LYNGBY : RISK & INDICATORS

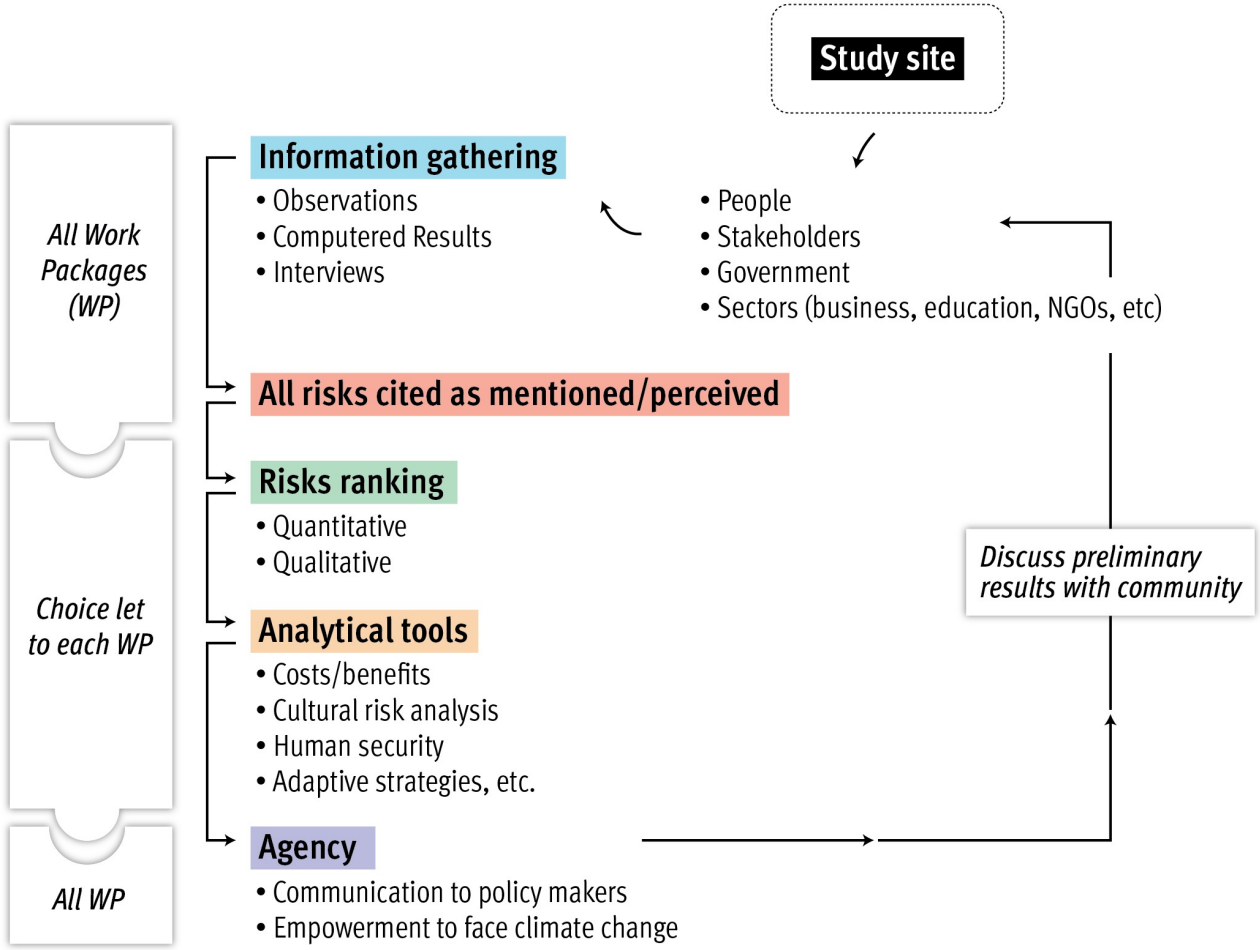
Fieldwork in Arctic Costal Communities

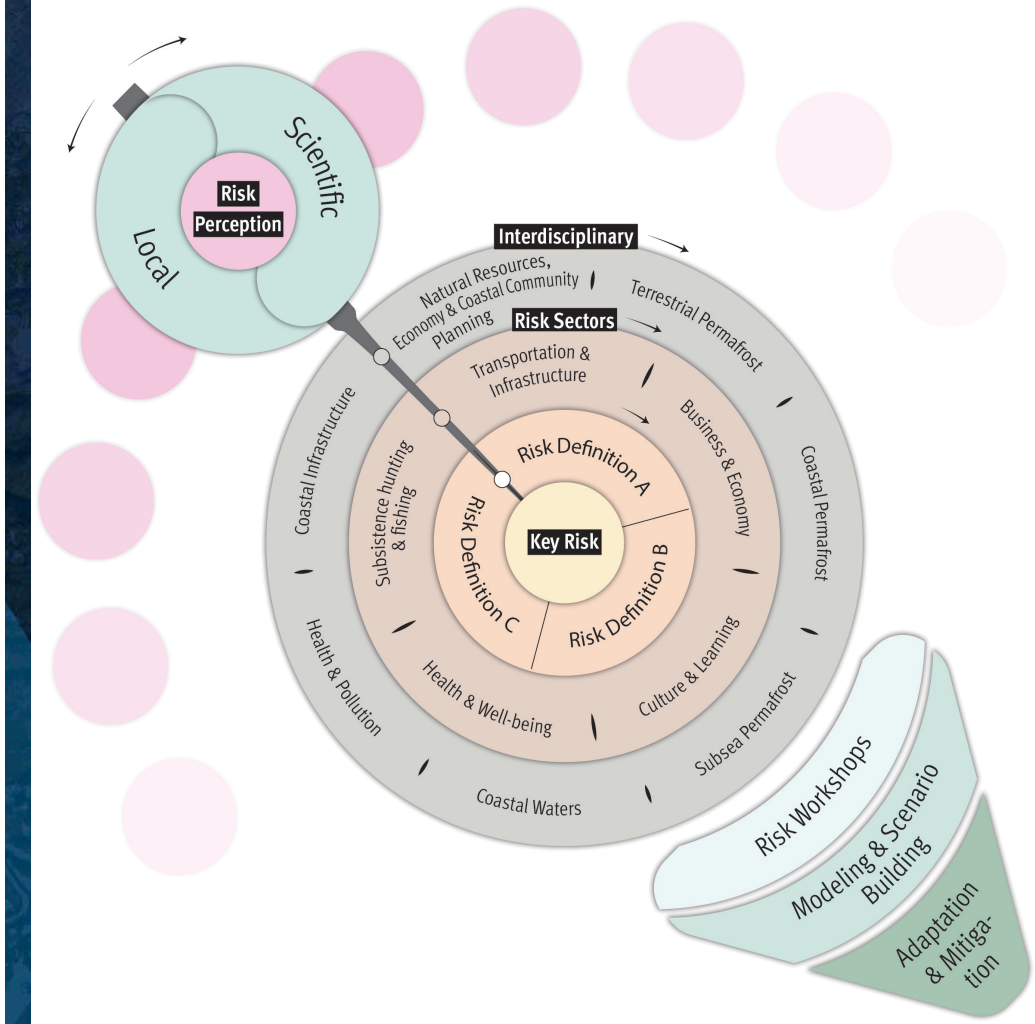
2022 SESIMBRA – ECR RISK WORKSHOP 5 EXAMPLES

REFINE AND CREATE VISUALIZATION

2022 (VALIDATION THROUGH) RISK WORKSHOPS IN FIELD SITES

Risk Analysis : Compass Model & Flow chart





Categorization

1. Key physical **processes/drivers** lead to
2. physical, chemical and biological **impacts**
3. that sometimes create **hazards** (5 examples of key hazards) and have
4. direct and indirect **consequences for various spheres of human lives:**
    a. impacts on technical and health science domain
    b. impacts on socio-cultural & political domain, finances, planning etc.
5. which in turn change /feedback on human **perceptions**
6. And might create the need to implement **adaptation and mitigation actions** (on impacts, hazards, consequences, perceptions)

9 Domains

1. (HW) Risk to H**ealth and Wellbeing (**Mental & Physical Health, including risks to overall safety)
2. (MW) Risk to **Material Wellbeing** (economics, financial security)
3. (I) Risk to **Infrastructure**
4. (FCP) Risk to **Fate control**, including **Planning** (all scales: Community, Regional, National, Global)
5. (BIN) Risk to **Being in nature** (including recreational and subsistence)
6. (C) Risk to **Culture** & Knowledge (cultural tangible and intangible heritage, cultural vitality, language retention, knowledge transfer and learning, spirituality)
7. (FWS) Risk to **Food and Water security**
8. (ES) **Environmental security** (risks to flora and fauna), Non-human Health, Wellbeing and Safety (Aquatic, Coastal and Terrestrial Ecosystems): Habitat, Bio-Diversity, Vegetation
9. (TT) Risk to **Travel and Transportation**

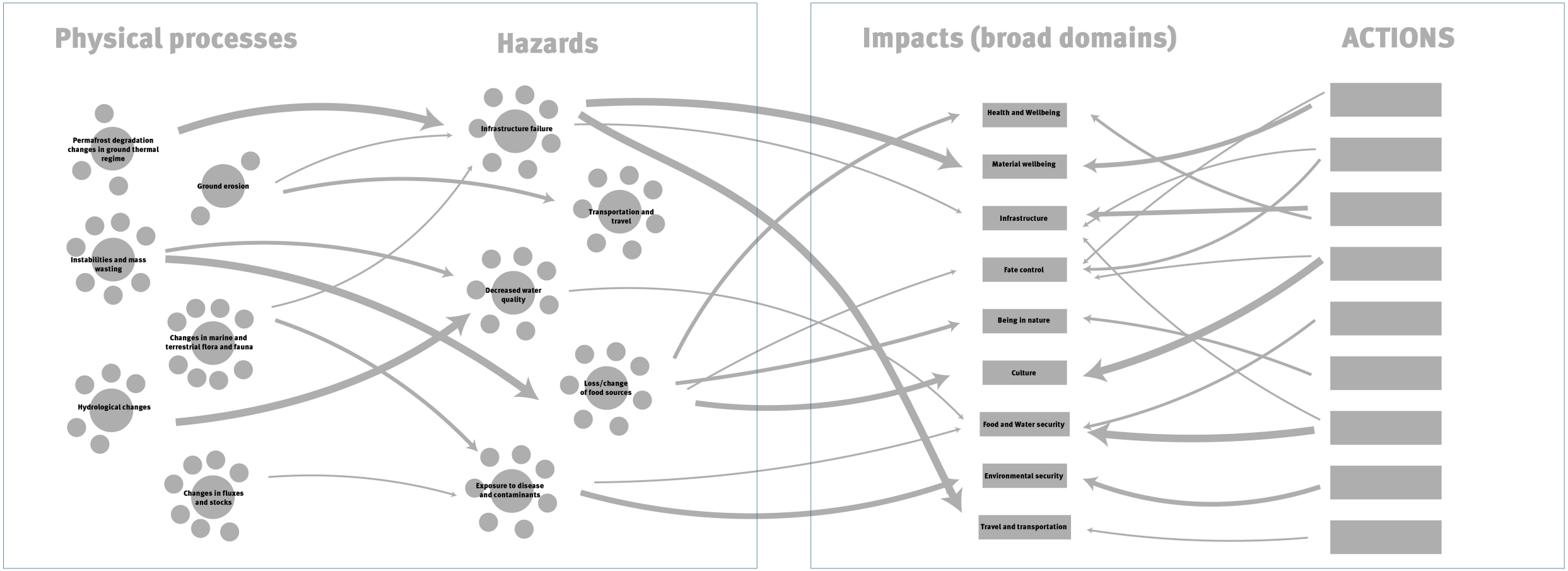
Key physical processes	Impacts	Hazards	Consequences	Perceptions	Actions	Broad Domains
GLOBAL/GOVERNING PROCESSES (Changes in Climate and Weather Conditions & Anthropogenic disturbances) PERMAFROST DEGRADATION PROCESSES GROUND EROSION INSTABILITIES & MASS WASTING CHANGES IN FLORA HYDROLOGICAL CHANGES	Sea Level Rise, increased frequency of storms, less Sea Ice Increase in Ground Temperature Melting of Ground Ice Active Layer Deepening Coastal, fluvial and terrestrial erosion Differential settlements Mass wasting Removal or changes in vegetation Flooding Drainage of Tundra Lakes Changes in ground water and surface water regime (increased freshwater discharge, etc.)	**INFRASTRUCTURE FAILURE** Destruction or destabilization of Infrastructures, f.e. collapsing, subsiding, etc. Damages to transport and industrial infrastructures and water/power supply facilities, f.e. roads, harbours/ports, pipelines, mine sites or platforms, offshore infrastructure, ice cellars, caches and water facilities Damages to residential buildings, f.e. doors, windows not closing, etc. Damage to and loss of cultural heritage, f.e. cemeteries, cultural heritage sites, etc.	Reduced quality of Living including reduced quality of Indoor environment, f.e. development of mould Safety concerns, f.e. injuries, loss of lives, etc. Disruption or loss of serviceability Economical losses,f.e. repair, decommission costs, etc. Employment creation Housing shortage Impact on Mental Health Impact on Health	concern about loss of cultural heritage uncertainty regarding future investment, potential loss of home, or need for relocation safety concerns concern for impacts on culture, identity, language more work for carpenters	In case of bad engineering: Invest more funds for better constructions Invest more in adaptation and protective measures such as: Relocation Removal, Repair Build new infrastructure and Flood control Adapted land use, community and urban planning Monitoring Invest in strengthening culture, language Strengthen / Use local (Indigenous) knowledge	I, C, MW, FWS, HW, TT, FCP

Key physical processes	Impacts	Hazards	Consequences	Perceptions/Observations	Actions	Broad Domains
GLOBAL/GOVERNING PROCESSES (Changes in Climate and Weather Conditions) GROUND EROSION PERMAFROST DEGRADATION PROCESSES INSTABILITY & MASS WASTING HYDROLOGICAL CHANGES	Increase in frequency and magnitude of extreme meteorological events (f.e. increased precipitation, storms, etc.), changes in winds and in freeze/thaw cycles River Bank and Coastal Erosion Changes in sedimentation/erosion patterns, f..e. sediment deposition in river channels, etc. Active Layer Deepening Landslides, rock falls, RTS, active layer detachments, etc. Flooding Changes in Snow cover Changes in moisture conditions (f.e. wetter lowlands)	**RISKS FOR TRANSPORTATION AND TRAVEL** Problems with sea ice, airstrips, roads, ice roads, navigable river and marine channels/transport Destruction/Disruption of navigation routes , f.e changes in navigational river channels due to sedimentation/silting, etc. Destruction/Disruption of roads and tracks, f.e. road damages, potholes, landslides, etc.	Increased Costs Physical Safety Concerns Impact on livelihood and subsistence like hunting/fishing, reindeer husbandry, forestry Disrupted Mobility, f.e. due to shorter winter road seasons Loss of connectivity between settlements and camps, f.e. roads may get closed because of landslides Possible disruption of chains of supply and irregularity of supply	Calling for help can be a problem Access to camps is more complicated People get stuck on sand bars during river travel Tundra gets wet making it harder to walk outdoors or travel across Concern about impact on culture, language, identity	Adapt technology & communication , f.e. using GPS and Phones (ensure communication and letting people know where you are going) Repair and/or build new roads etc. Adapt reindeer herding and hunting techniques Adapt monitoring and planning Invest in strengthening culture, language and identity, which can be assets to meet challenges	I, BIN, C, MW, FCP, HW,

Key physical processes	Impacts	Hazards	Consequences	Perceptions/Observations	Actions	Broad Domains
GLOBAL/GOVERNING PROCESSES (Changes in Climate and Weather Conditions) GHG release (?) PERMAFROST DEGRADATION PROCESSES GROUND EROSION CHANGES IN FLUXES (lateral fluxes into aquatic systems, carbon stock) HYDROLOGICAL CHANGES CHANGES IN FAUNA ?	Increase in frequency and magnitude of extreme meteorological events (f.e. storms, changes in winds) Active Layer Deepening (?) Terrestrial, coastal and fluvial erosion Release of Organic matter Nutrient fluxes Change in composition of coastal ocean waters (f.e. higher water turbidity) Drainage of Tundra Lakes Changes in ground water and surface water regime (increased freshwater discharge, etc.) Impacts on riverine and oceanic fish stocks (?)	**DECREASED WATER QUALITY** Increase in ocean acidity Eutrophication and consequent water anoxia Changes in pollutant concentration Higher concentration of mercury in rivers and ocean Adverse effects on marine ecosystem Increased pressure on ecosystem food webs Loss of biodiversity, loss of fish Increase in water stratification hampering vertical mixing or change habitat for anadromous fish	Physical Health impacts Mental Health impacts Impact on recreational outdoor activities and subsistence: fishing, whaling etc. Food security and ecosystem biodiversity may be at risk May impact on fresh water supply	Uncertainty in regards to what effects PFT will have on changing nutrient fluxes Concern about impact on fresh water supply Planning challenges arise (f.e. recruit, retain, and educate qualified staff) Concern about culture, language and identity	Testing, purifying water Finding new sources for water provision Monitoring of fish and sea mammals Regulating water discharge Changes in food consumption (f.e. eating other species) Taking planning actions, f.e. planning/building fresh water facilities Invest in strengthening culture, language and identity, which can be assets to meet challenges	HW, BIN, FWS, MW, ES, FCP, C

Key physical processes	Impacts	Hazards	Consequences	Perceptions/Observations	Actions	Broad Domains
GLOBAL/GOVERNING PROCESSES (Changes in Climate and Weather Conditions) PERMAFROST DEGRADATION PROCESSES GROUND EROSION CHANGES IN FLUXES CHANGES IN FLORA AND FAUNA HYDROLOGICAL CHANGES INSTABILITIES & MASS WASTING	Ground ice melting Active Layer Deepening Coastal, fluvial and terrestrial erosion Changes in Nutrient Fluxes Acidification of Coastal Waters Water Anoxia Water Turbidity (leads to f.e. changes in vertical temperature profiles of waters, in turn causing decrease of success in gill net for predator fish, might also affect micro fauna) Release of diseases, contaminants & pollutants Release of Organic Matter Phytoplankton blooms Impact on food chain and ecosystem Enhanced micro-organism and bacterial activity (leads to changes in air-sea C02 fluxes (?) Drainage of Tundra Lakes Changes in moisture conditions (moister or dryer landscapes) Thaw settlements and ground deformations Mass Wasting	**CHANGE OF LAND AND SEA FOOD SOURCES** Loss of Biodiversity and Population Size Changes in species migration routes (f.e. reindeer, muskox..) Changes in species distribution (f.e. caribou) Changes in Vegetation Composition (f. e. Shrubification, Higher Trees) Habitat Loss Damage to ice cellars and caches	Impact on Ecosystem services such as Subsistence Hunting, Fishing, Herding, Whaling, Gathering etc. F.e. impact on access to hunting grounds, herding pastures, fishing and berry/medicine picking spots etc. F.e. impact on Fisheries, Commercial Hunting etc. F.e. Impact on Recreational Fishing, Hunting, Gathering etc. Greater dependence on external food sources Decreasing reindeer pastures Destruction of food stored in ice cellars and caches Economic challenges and financial loss (f.e. higher costs for store bought food) PFT can have positive effect on species too ☺	Char's color and texture is changing Salmon is an important food source, they follow Char, which will go back to the ocean and feed finding more mercury in bigger and older fish Warmer waters mean more nutrients means more Salmon in the ocean and rivers, can get too warm as well ___ Insecurity what impacts changing nutrient fluxes will have Impacts flexibility and certainty in regards to subsistence: "can't choose the right places for successful hunting, reindeer herding ", "takes longer to hunt moose because willows grow higher (moose can hide better)", may lead to loss of reindeer pastures losing reindeer pastures Concern about impact on culture, language, identity	Replacement of food sources (moose hunting instead of caribou f.e.) Rationing of food sources (f.e. eating less caribou) Increased imports Adaptation of Hunting/herding techniques: such as f.e. changing time to hunt, or planning for and taking more time to hunt Adapt monitoring and planning Invest in strengthening culture, language and identity, which can be assets to meet challenges	FWS, C, BIN, ES, MW, HW

Key physical processes	Impacts	Hazards	Consequences	Perceptions/ Observations	Actions	Broad Domains
GLOBAL/GOVERNING PROCESSES (Changes in Climate and Weather Conditions) PERMAFROST DEGRADATION PROCESSES CHANGES IN FLUXES CHANGES IN FAUNA HYDROLOGICAL CHANGES GROUND EROSION (?)	GHG release (is methane considered a contaminant?) Increased precipitation and increased air temperature Increase in ground temperature and ground ice melting Release and spread of diseases (f.e., ancient/inactive viruses and bacteria, etc.) Increased risk of anthrax diffusion (related to the presence of contaminated cattle burial sites, from which spores may re-emerge) Release of contaminants Lateral fluxes into aquatic systems and changes in water properties and compositions Release of Organic Matter (bio)availability (?) Negative impacts on ecosystems Increase in microbial and bacterial activity Erosion (?)	**EXPOSURE TO DISEASES AND CONTAMINANTS** EXPOSURE TO INFECTIOUS EXISTING AND ANCIENT DISEASES EXPOSURE TO AND TRANSFORMATION OF ENVIRONMENTAL CONTAMINANTS Increased hazard of Anthrax diffusion Potential increase in tick-borne diseases, tularemia, anthrax, and vibriosis Eroding cemeteries may lead to reappearance of and exposure to plague and other viral infections Thaw of landfills leads to re-emergence of industrial waste which in turn may lead to exposure to environmental contaminants	Diseases and contaminants may affect animal and human health Anthrax disease may affect animals, f.e. herds of domestic herbivores, which are among both the most vulnerable hosts to this disease and the important means of sustenance Humans may thus be exposed indirectly Exposure to environmental contaminants, which is linked TO neurobehavioral, reproductive, cardiovascular, endocrine and carcinogenic May affect mental health	Insecurity in terms of effects on humans/human life Planning challenges arise: More and new planning strategies necessary Difficulties to educate, recruit, retain qualified staff Concern about impact on culture, language, identity	Training of medical personnel Establish (Psychotherapeutic) councillors, support groups Closing off areas Disease control (emergency slaughter and burning of infected animals) Testing, purifying water Find new sources for water provision Adapt monitoring and planning	HW, ES, FWS, BIN, C, FCP, MW


Physical processes
Hazards
Impacts (broad domains)
ACTIONS
Permafrost degradation changes in ground thermal regime
Ground erosion
Instabilities and mass wasting
Changes in marine and terrestrial flora and fauna
Hydrological changes
Changes in fluxes and stocks
Infrastructure failure
Transportation and travel
Decreased water quality
Loss/change of food sources
Exposure to disease and contaminants
Health and Wellbeing
Material wellbeing
Infrastructure
Fate control
Being in nature
Culture
Food and Water security
Environmental security
Travel and transportation

Way forward >>>

- Create visualisation
- Present and work with at risk workshops in communities
- Dissemination: Deliverable, Permafrost Atlas https://nunataryuk.org/news/atlas and publication

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APECS Association of Polar Early Career Scientists

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Thank you