



Louise Swanson, Vice President GTA NSW & ACT

This is a comparative study between Heard Island and McDonald Islands Reserve and World Heritage Site, (Australian Territory) and Churchill Wildlife Management Area, (Canada).

Heard and McDonald Islands are located at approximately 53°S and 73°E.

Subantarctic refers to the region in the Southern Hemisphere which is just north of the Antarctic Circle.

Churchill Wildlife Management Area is located at approximately 58°N and 93°W.

Subarctic refers to the region in the Northern Hemisphere which is just south of the Arctic Circle.

Part A: Biophysical Processes

A range of biophysical processes are essential to the functioning of subarctic and subantarctic tundra environments.

- Lithospheric processes – volcanism, glaciation, erosion and weathering
- Hydrospheric processes – ocean currents, water cycle, sea ice
- Atmospheric processes – climate – air pressure, temperature, humidity, cloud cover, etc.
- Biospheric processes



Heard and McDonald Islands Reserve and World Heritage Site

Lithospheric processes

The subantarctic islands are volcanically active, and allow for the study of volcanic processes and glacial dynamics.

Volcanism

The Heard and McDonald Islands have been formed by the Kerguelen Hotspot, a site of volcanic activity in the Southern Ocean. Big Ben is an active volcanic summit that dominates Heard Island. Volcanoes involve the process of molten rock from the mantle being forced up onto the earth's surface. The magma moves up from the volcano chamber into the cone. When the magma exits the volcano cone it is called lava. Volcanic eruptions can be explosive or gentle. Heard Island experiences a gently oozing of lava, while McDonald Island has had explosive volcanic eruptions. Heard Island has experienced volcanic activity and fresh lava flows in the last few decades. This activity is continuing to shape the island including increasing its size and elevation. A two kilometre wide lava flow moved down Big Ben from the summit in a south-west direction. As a result of volcanic activity all vegetation on the island has been lost. The volcano on McDonald Island, thought to dormant, has erupted several times since 1992. Over the long term volcanic material gradually erodes and adds valuable nutrients to soils including phosphorous, potassium, calcium, magnesium and sulphur. Lava flows create extremely fragmented and irregularly shaped landforms.

Glaciation

Heard Island has twelve major glaciers and several smaller ones. About 70% of the island is covered by glaciers. Glacial processes include abrasion, plucking and freeze-thaw. Abrasion refers to frozen rocks in the side and base of a glacier scraping the bedrock. This creates striations or scratches in the bedrock. Plucking refers to the process where individual pieces of bedrock are picked up and transported by a moving glacier, and deposited in other locations. Freeze-thaw weathering occurs when ice melts, fills cracks in the rocks and then expands when it refreezes. On Heard Island, glacial activity has eroded soft, fragmental volcanic rocks to create rock buttresses. There has been a substantial reduction in glacial cover in the past century, and this is resulting in the creation of lagoons and extra ice-free ground for colonisation of plants and animals. There are no glaciers located on McDonald Islands.

Erosion and weathering

Erosion is the wearing away of materials (soils, rocks, etc) by natural forces such as wind and water. Weathering is when materials (soils, rocks, etc) or broken down or dissolved by environmental factors. There are three

types of weathering: physical, chemical and biological. Physical weathering can occur when water freezes and expands. The tundra environment on Heard and MacDonald Islands is particularly affected by strong winds and the erosion caused by it. The removal of this fragile soil is influenced by the limited vegetation in tundra environments.

Hydrospheric processes

Ocean currents

The islands are part of the Southern Indian Ocean Islands Tundra ecoregion. The mid-latitude location of the islands in the Southern Ocean is south of the Antarctic Polar Front, also known as the Antarctic Convergence. Heard Island and the McDonald Islands are located south of the Antarctic Convergence. The Antarctic Convergence is a marine zone where cold waters of the Antarctic sink under the lightly warmer waters of the subantarctic. It is a circumpolar strip (the current creates a ring around the globe) that lies approximately between 45° and 60° South. Its location varies seasonally, and is an approximate boundary for the Southern Ocean. The mixing of the cold and slightly warmer water creates local variations in weather, such as fog. The current is associated with strong, westerly winds.

Water cycle

Annual precipitation on Heard Island is between 1.3 –1.9m. Most of this precipitation is in the form of snow. Any rainfall generally soaks into the ground and then freezes becoming permafrost, or is absorbed by plants. Permafrost is a barrier to infiltration and percolation. The water in the uppermost layer of permafrost is stored until it melts in spring and summer. During winter, snow, river and lake ice accumulate, and in summer, meltwater forms many wetland areas, ponds and lakes. River flow increases when snow, river and lake ice melts. Surface and soil water is frozen for most of the year so there is little evaporation and low stores of water in the atmosphere. There is limited transpiration due to the limited amount of vegetation.

Atmospheric processes

Climate

Air temperature

Seasonal and daily temperature ranges are low, and monthly average temperatures range from 0.0 to 4.2°C. The latitude of the Heard and McDonald Islands impacts on the intensity of the light and heat from the sun. Locations in high latitudes receive less intense sunlight and it is spread over a large area of land.



Volcano, Heard Island Source: https://www.nasa.gov/sites/default/files/images/745684main_heard_ali_2013110_geo-full_full.jpg

Air pressure and wind

This is an area of strong, persistent westerly winds, and associated with a deep low pressure system. East moving depressions move across the islands throughout the year creating persistently severe weather such as strong regional, westerly winds, frequent precipitation, and low seasonal and daily temperature ranges.

Humidity

Surface and soil water is frozen for most of the year so there is little evaporation from the land, but water is evaporated over the ocean.

Cloud cover

Cloud cover is persistent, but low due to relatively high humidity, mountainous topography and strong winds.

Precipitation

Annual precipitation on Heard Island is between 1.3 – 1.9m. Most of this precipitation is in the form of snow.

Radiation Fog

Radiation fog is common. It is a type of fog that forms overnight as the air near the ground cools, stabilises and reaches saturation point. Radiation fog will begin to form near the surface and then thickens as the air continues to cool.

Biological processes

Vegetation

Vegetation is impacted by the harsh climate and limited ice-free ground available. Due to the diversity of landscapes on the islands a range of different vegetation communities can be found. Most of the vegetation on the islands occurs in low-lying areas along the coast. Plant diversity is low, and the diversity of flowering plants is particularly low. No trees or ferns are found on Heard and McDonald Islands. In the tundra areas vegetation is minimal and includes low shrubs, mosses and liverworts. Mosses and lichens make up a large proportion of plant communities.

Vegetation covers about 20km² of Heard Island. Plant communities on Heard Island include open cushion carpet, mossy fieldmark, wet mixed herbfield, coastal biotic, salt spray and closed cushion carpet. A total of 44 moss and 12 liverwort are found on Heard Island. Lichens are also common, with 34 species. There are no known introduced plants species on the islands.

Recent volcanic activity on McDonald Island has altered vegetation.

Animals

Heard Island is considered to be a biological hotspot. There are large colonies of penguins and petrels, and harems of fur seals and elephant seals. There are also high numbers of seabirds and marine mammals. Heard Island contains breeding sites for a large number of seabirds. These include the Heard Island Cormorant, The Heard Island Sheathbill, the South Giant Petrel, Antarctic Tern and Wandering Albatross. There are also four species of penguin and three species of seals that breed on the island. There are some terrestrial invertebrates (animals without backbones for example worms), but no native land mammals on the islands.

McDonald Islands had large numbers of penguins breeding, but recent volcanic activity on McDonald Island may have affected bird populations.

Nitrogen and phosphorous cycle

The nitrogen cycle involves green plants taking in chemicals such as nitrogen and phosphorous from soil. During the growing seasons (spring and summer), plants put carbon-rich litter into the soil. This will be made up of dead leaves, sticks, etc. However, due to low temperatures, the decomposition of the litter will be much slower than in other ecosystems. Guano (bird droppings) is very nitrogen and phosphorous rich. The breeding seabirds and their chicks produce huge amounts of droppings that are able to soak into the ground and provide nutrients for plants.



Macquarie island Source: <https://commons.wikimedia.org/w/index.php?curid=7137164>

Churchill Wildlife Management Area

Lithospheric processes

Glaciation

The most recent ice age occurred during the Pleistocene, beginning about 2 million years ago and ending around 10,000 years ago. During this time glacial activity shaped the topography around Churchill. Glaciers form when snow falling in winter is greater than snow melts the following summer. The following winter, snow weighs down the remaining snow and it turns to ice. Over time, following further accumulation of ice, gravity pulls the ice and it slowly moves downhill. The most extensive Pleistocene ice mass was the Laurentide ice. The Laurentide ice covered Canada and a large part of north east United States.

Bedrock and soils

Churchill is located on the Canadian Shield. The Canadian Shield is a rock structure from hundreds of millions of years ago by mountain-building activity. The Canadian Shield stretches over 8 million square kilometres. It has been shaped by glacial processes. As the ice moved south it scraped the land of weathered rock, and created a landscape that is rocky, with smoother, low hills, basins, lakes and swamps.

Churchill is built on an outcrop of Proterozoic sedimentary bedrock of subgreywacke and conglomerates. Subgreywacke is a dark-coloured sedimentary rock with grains 0.06-2 mm in diameter containing free quartz, a low mud content and high carbonate content. The wider Churchill province contains sedimentary, metamorphic and volcanic rock. Glaciation, marine inundation and weathering have covered these bedrocks with gravel, silt, boulders, sand, clay, and organic materials.

Soil properties and vegetation

Close to the Hudson Bay Coast, salt marshes and mangroves are found, but soil properties are different as you move further inland. Tundra vegetation, bogs and boreal forests are supported by better developed soils inland. Permafrost is widespread and the region also contains ice-related coastal features as a result of sea ice.

Hydrospheric processes

Hydrology

Churchill is located at the mouth of the Churchill River where it feeds into Hudson Bay. The Churchill River flows 487km east to west from Saskatchewan, through Manitoba to where it drains into the Hudson Bay.

The river is made up of a large number of lakes joined together by rapids and waterfalls. Hudson Bay completely freezes over in winter. The river is located within a drainage basin called the Canadian Shield. Both sea ice and river water contribute to the region's freshwater budget.

Sea Ice

Churchill Wildlife Management Area is located on the western edge of Hudson Bay. Hudson Bay is seasonally covered in sea ice for 5 to 10 months of the year. Sea ice accumulates between September and December and melts between May and August. The amount and timing of sea ice is determined by atmospheric temperatures, wind, the freshwater and sea water mix, precipitation and currents. It is also impacted by an ice-albedo feedback loop. This is when the heat stored in the water impacts on the accumulation and/or melting of sea ice. The ice can be mobile (shifted by water currents) or landfast (attached to land in some way and immobile).

Atmospheric processes

Climate

The latitude of Churchill is significant because it impacts the climate. Being just south of the Arctic Circle it experiences a Continental Subarctic climate. Hours of daylight vary between 6 hours in December to approximately 18 hours of sunlight in June. These climatic conditions are integral to providing the conditions suitable for polar bears, belugas and arctic foxes, etc.

Air temperatures

Mean monthly temperatures are below zero for six to eight months and on average 50-90 days in a year are frost free. Temperatures can vary from -30°C to 17°C. Winters tend to be long and bitterly cold, while summers are short and mild. The warmest month is July and coolest month is January.

Air pressure and wind

Winds blow continuously over the Hudson Bay into Churchill. High winds occur between September and May, with average wind speeds of about 20 km/hr during this period. Wind mostly comes into Churchill from the north, but Churchill experiences westerly winds during October and March. High winds result in the krummholz effect on any trees in the Churchill Wildlife Area. The krummholz effect results in trees exposed to winds having stunted growth on one side.

INVESTIGATIVE STUDY: ENVIRONMENTAL CHANGE

Humidity

Humidity in Churchill ranges from 70% to 89%, with higher humidity in November. The average annual humidity is 82%.

Cloud Cover

There is significant seasonal variation in cloud cover in Churchill. Clearer skies occur from April to November, while the cloudier part of the year is between November to April. At its cloudiest (January), Churchill is overcast or mostly cloudy 87% of the time.

Precipitation

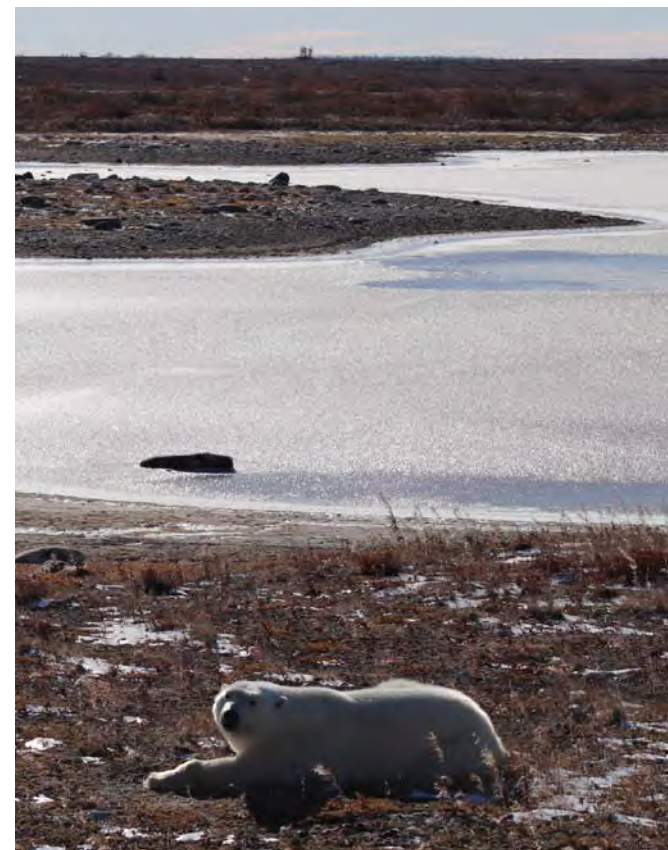
The wettest months occur from April to November.

August is the wettest month. February is the driest month.

The snowy period occurs between September and June.

Aurora Borealis

The latitudinal location of Churchill corresponds with the location of the Aurora Borealis. The Aurora Borealis (also known as the northern lights) is a display of coloured lights in the night sky. The shades of red, green, blue and violet occur above the magnetic pole and are the result of gas particles colliding. The Aurora Borealis is best viewed in locations which are not affected by light pollution in places that are latitudinal relatively close to the magnetic north pole. Churchill's latitude and isolation make it an excellent site for viewing the Aurora Borealis.



Biological processes

Churchill is in close proximity to Wapusk National Park and Caribou River National Park. Organisms found in this area include polar bears, beluga whales, and more than 270 bird species including the snowy owl, gyrfalcon and ptarmigan.

Plants

Plants in tundra of Churchill wildlife Area occur in ground-hugging, dense clumps. In some areas there is considerable bare ground. Permafrost can extend up to 1,500 metres below the ground. Tundra plants are a mix of low plants including dwarf shrubs, mosses, lichens, grasses, and forbs. No trees occur in tundra environments because the summer is so short that the conditions don't allow their growth. However, as Churchill is a convergence of tundra, forest, freshwater and marine ecosystems, there are some trees in close proximity to the tundra environments in Churchill. Plants are perennial, meaning they survive for several years or are long lasting. During the brief summer season, plants quickly complete their annual cycles. They have short reproduction cycles and some plants reproduce asexually. This is enabled by the moisture in the soil during this time. Seeds are dispersed by the strong winds. Many of the plants have small leathery leaves to reduce moisture loss. A variety of fungi can be found amongst the tundra heaths.

Animals

Birds and insects (including mosquitoes and flies) dominate animal life in the tundra during summer. Insects eggs are able to survive the winter. Tundra becomes an important site for nesting in summer, for birds migrating south in winter. While there are very few species of reptiles and amphibians, there are some species of mammals and freshwater fish. Tundra animals in the Churchill region include hares, foxes, polar bears, ringed seals, foxes, birds. There are 75 mammals, 240 bird species, 5 amphibians, 2 reptiles, and 3,300 insect varieties. Many animals migrate to warmer locations in autumn.

Polar bears are attracted to Churchill in the ice free season, in search of food. They are attracted by seasonal berries and often food scraps in rubbish. Polar bears access seasonal ice areas for hunting. As sea ice is melting faster each year, polar bears are spending more time on land, thus increasing human and bear interactions.

For more information and images of tundra environments visit National Geographic – <https://www.nationalgeographic.com/environment/habitats/tundra-biome/>

SEE APPENDIX 1 for student activity worksheets linked to biophysical processes

Churchill Wildlife Management Area

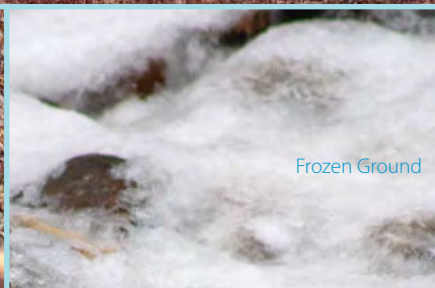
Photographs by Louise Swanson



Stunted vegetation



Ptarmigan



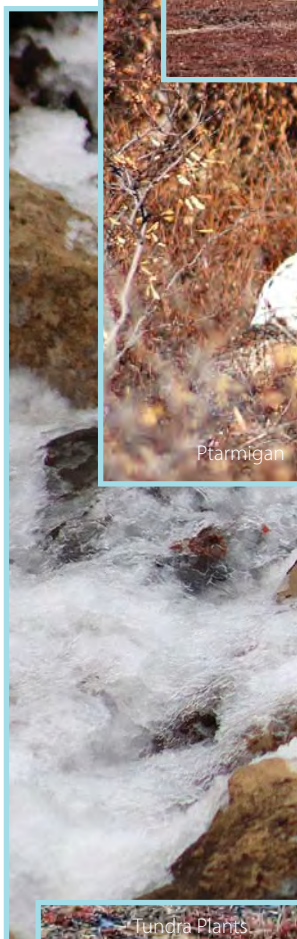
Frozen Ground



Snowy Owl



Polar Bear



Tundra Plants



Tundra Landscape



Tundra Plants



Tundra Vegetation

Part B: Causes of Change

Heard and McDonald Islands Reserve and World Heritage Site

Climate change

There has been an increase in the average annual air temperature of nearly 1 degree C between 1948 to 1954 and 1997 to 2001. This is resulting in glacial retreat and the creation of lagoon and lakes. Many glaciers at Heard Island have retreated dramatically. Brown Glacier on Heard Island has reduced in size by 33% in the past 50 years. The Southern Ocean is demonstrating a corresponding warming.

This year there has been an occurrence of sudden stratospheric warming above the South Pole during August. This involves temperatures rapidly heating and a reversal of wind direction. This will result in further loss of sea ice between October and January. This is likely to disrupt normal ocean circulation, reduce the albedo effect, and result in more extreme weather.

Natural processes

Natural processes are an ongoing cause of change to Heard and McDonald Islands. Processes such as volcanism, glacial retreat and advance and storms can change the landscape. Animal population change such as increase in fur seal populations could lead to changes such as competition over breeding or nesting sites and food sources, vegetation trampling and eutrophication of water.

Human contact

The first recorded visit to Heard Island occurred in 1855. Since that time there have only been about 240 shore-based visits, and only two visits to McDonald Islands. The purpose of visits include sealing (in the past), research and management, private expeditions and surveillance. Visitors must apply to the Australian Antarctic Division for a permit to visit Heard Island. It's vast distance from populated areas, extreme weather and sailing conditions and high cost to visit deter many visitors. No commercial tours operate to Heard Island.

Introduced Species

An alien species is an organism that has been introduced to the Heard Island and McDonald Islands as a result of direct or indirect human activity. Many of the Southern Ocean islands have been affected by introduced species such as cats, rabbits, rodents, etc. which can impact on

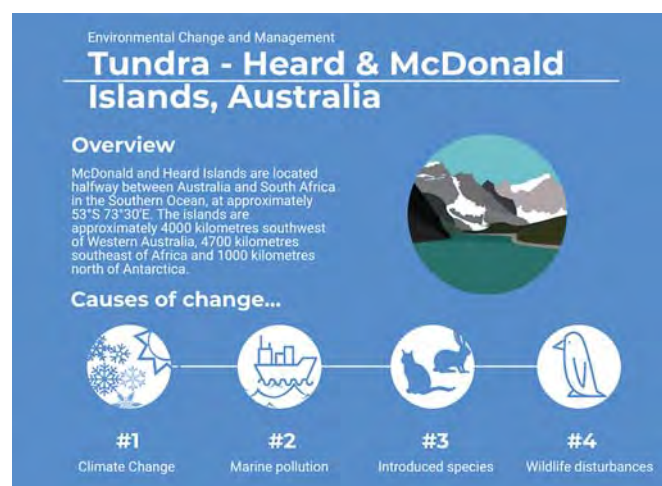
breeding populations of endemic species and result in reductions of biodiversity and local extinctions. McDonald Island has no alien species currently. Heard Island has two plants and two insect species that have been introduced. Heard Island and McDonald Islands are some of the least biologically-disturbed regions on the planet.

Physical disturbance

Physical disturbance could include pathways, soil and vegetation compaction, damage to geological features, buildings or destruction of cultural artefacts. Most of Heard and McDonald Islands are free from physical disturbance as a result of a limited number of recorded visits. This is one of the islands' greatest values.

Wildlife disturbances

In locations where human activity and wildlife habitat overlap, wildlife disturbances such as burrow collapses, changes to wildlife movements or breeding can occur. Wildlife colonies on Heard and McDonald Islands are concentrated in the ice-free coastal areas. These are also the most popular sites for human activities. Wildlife may react to disturbances by relocating or refraining from breeding, or deserting certain locations. It can also result in increased likelihood of mortality rates. In marine environments disturbances may take the form of boat collisions, or interference through noise and lights. Illegal fishing can also impact on population numbers and diversity.



Marine pollution

Fuel spills, discharge of waste water and sewage and rubbish disposal can result from shipping activities. Marine mammals and seabirds can become entangled in floating debris such as discarded fishing nets. This can result in reduced mobility, starvation, amputation, smothering or drowning.

Terrestrial pollution

Pollution on land can include grey water and sewage, which may increase nutrients or risk of disease. Fuel and chemical spills could result in long lasting impacts such as soil contamination, vegetation degradation or harm to wildlife.



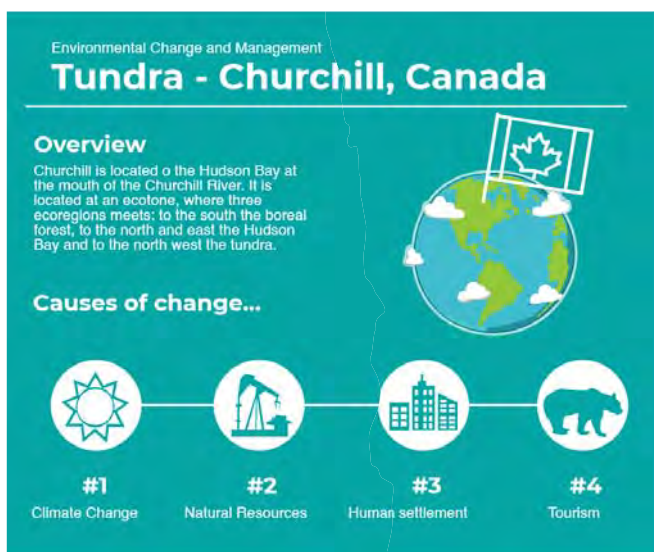
The reduction in the thickness of sea ice, is making it difficult for polar bears to hunt for their primary dietary staple seals. In turn, this is changing polar bear feeding patterns, migration paths and many are experiencing a reduction in body weight. Bears are staying on shore longer to wait for the ice to form. Ice on the Hudson Bay is forming more slowly and melting more quickly, and as a result polar bears are struggling to hunt for food. Polar bears generally hunt seals on the pack ice, and the last of ice is resulting in some bears starving or being underfed, and the survival rates of cubs declining.

Thawing permafrost

Increased temperatures are resulting in sea ice melts and reduced ice cover on Hudson Bay. Permafrost melts are likely to result in increased decomposition and microbiotic activity and release of greenhouse gases like carbon dioxide and methane.

Tourism

Tourism in and around Churchill focuses on polar bears, beluga whales, nature photography and the Aurora Borealis. While activities are intended to minimise human impacts on wildlife, the actions of individuals are difficult to predict and control. In the Churchill Wildlife Management Area two companies are permitted to take visitors for viewing by tundra buggy. The buggies allow access on the difficult terrain, but also provide protection from the polar bears for visitors. Permission has been sought for more permits for vehicles to operate on the tundra.

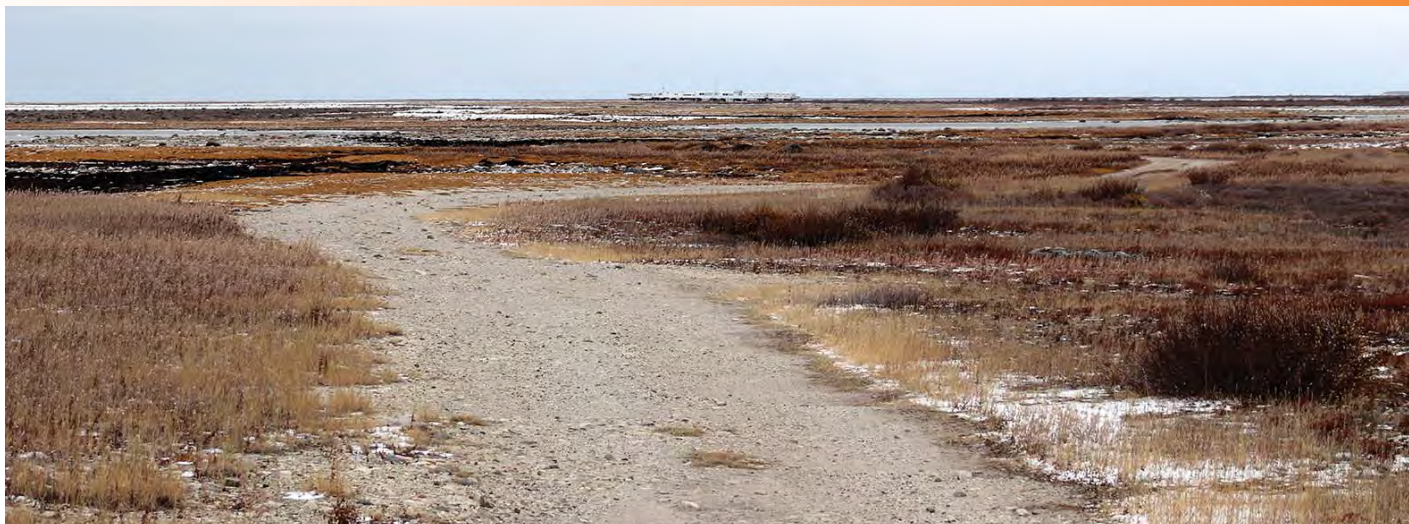


Churchill Wildlife Management Area

Climate change

Climate change is resulting in a milder, shorter winter season and longer, warmer summers. Average yearly arctic temperatures are increasing. The shrubs are growing taller on the tundra and the surface temperature of water in Hudson Bay has increased by 3 degrees in the past 20 years. In the long term Churchill is expected to continue experience warming air temperatures. Wetter conditions are resulting from increased annual precipitation, permafrost is thawing and degrading. There has been an increase in the number of natural disasters impacting Churchill.

Climate change is likely to change migratory patterns, population numbers and physical characteristics of species. Organisms are increasingly moving north into the Churchill Wildlife Management Area such as red fox. Migratory birds are changing their movement patterns.



Some passengers, in trying to attract the attention of bears for better photographs may bang on the side of the tundra buggy, hiss or whistle to encourage the bear to move. Bears are exposed to the tundra vehicles from around 9am to 3pm each day. In periods where there are low polar bear numbers, multiple vehicles will crowd around the one bear or family of bears.

In attempts to ensure polar bear viewing tundra buggies may use any tracks or trails that are available rather than using the roads designed for the purpose. This could result in erosion of tracks or destruction of vegetation.

Some operators have tundra buggy lodges that provide accommodation for tourists and researchers for part of the year. These are mobile structures made up of customised buggies, with sleeping quarters, kitchens and bathrooms. The number, location and disposal of waste and treatment of wastewater are all impacts which must be carefully managed.

Resource extraction and industry

Canada has considerable natural resources, and Manitoba has world-class deposits and large underexplored remote regions of mineral potential. Extensive oil fields are located in northern Manitoba. The coast of Manitoba, along Hudson Bay, has been proposed for an energy corridor (pipeline development) for shipping oil, Alberta bitumen, with Churchill is a possible port location due to its deep water port and railway line.

Natural resource exploration and extraction can impact greatly on tundra environments. Activities can result in the thawing of permafrost, damage to soil and vegetation. There is also increased risk of toxic spills. Climate change and reduced sea ice would make the use of Churchill's port more economically feasible and logistically easier from the water, and less land ice cover may make developments easier on land.





Source: Wikimedia Commons

Part C: Management of environmental change

Heard and McDonald Islands Reserve and World Heritage Site

The Australian Antarctic Division of the Australian Department of Environment and Energy manages Heard Island and McDonald Islands and the HIMI (Heard Island and McDonald Islands) Marine Reserve. A management plan is in place for the HIMI Reserve. The management plan sets out rules and guideline of the Reserve, objectives for managing the area, and specific management strategies including permits, zoning and environmental impact assessments.

Legislation and agreements

The most relevant legislation is:

- Environmental Protection and Biodiversity Conservation Act 1999
- Environmental Protection and Biodiversity Conservation Regulations 2000
- Environmental Protection and Management Ordinance 1987

These provide a national framework for environmental protection.

Click to read about:

[EPBC Act and regulations](#)

[National agreements](#)

[International agreements](#)

World Heritage

Heard and McDonald Islands are listed on the UNESCO World Heritage list. To be listed as a World Heritage Site, a location must meet UNESCO's WHS criteria.

The HIMI Reserve and World Heritage Site provides an opportunity to observe ongoing geomorphic processes, as they are the only volcanically active subantarctic islands. It meets criteria (viii) to be an outstanding example representing major stages of earth's history including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.

The HIMI Reserve and World Heritage Site has no record of introduced species and is extremely isolated. Its natural processes include glacial dynamics and coastal change. HIMI will be an important place to monitor the impacts of climate change, and as such meets criteria (ix) to be an outstanding example representing

significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.

Click to read more information about [World Heritage criteria](#).

Zoning

Zoning is used to divide areas of the Heard Island and McDonald Islands Marine Reserve into sections where particular activities are allowed. Zoning allows some more susceptible areas of the reserve to be afforded greater protection than others, while more human activities are allowed in less susceptible areas.

The zones are:

Main Use Zone – located at Atlas Cove and Spit Bay. This is where long-term facilities are located and access and support operation can be conducted.

Visitor Access Zone – allows for low impact, short-term, land-based visitor activities, e.g. tourist ships. This zone provides relatively safe landing sites and access to attractions within walking distance, e.g. heritage sites, wildlife colonies, landscape features.

Wilderness Zone – allows for some human activities, but with the purpose to maintain the wilderness qualities of the terrestrial environment. Activities must not cause long-term impacts. Access is primarily for scientific research and monitoring.

Heritage Zone – an area of special protection, this is the location of the Atlas Cove Station site from 1947–1955. It restricts activities that may impact on the heritage value on the site.

Restricted Zone – areas highly sensitive to human activities. Access is highly restricted. This includes areas containing highly unstable lava tubes and sinkholes,

cushion plants, significant numbers of South Georgian diving petrels and breeding sites for Antarctic prions.

Inner Marine Zone – includes areas within 12 nautical miles of the high tide mark on shore. Vessel and small craft use is regulated, to reduce the threats from boat discharges and movements.

Outer Marine Zone – includes areas beyond 12 nautical miles from shore to the edge of the Reserve. Regulations are less strict in this area, but still allow for protection in line with the objectives of the Reserve. A permit is not required into the Outer Marine Zone.

Environmental Approvals

Permits to visit the HIMI Reserve need to be submitted 4 months in advance. Visitors may only enter the Reserve in accordance with the permit. Permits state that people must not take, injure and interfere with organisms, except under very specific circumstances. Permits restrict visitors from interfering with scientific experiments underway and/or introduction of live species to the islands. Permits forbid bringing a diseased organism or live poultry into the Reserve, or mineral extraction and/or fishing. Before a permit is issued an environmental impact report must be submitted. Permit holders also have to be completely self-sufficient while in the Reserve, and must provide a compliance report within 60 days of the permit expiring.

Visitors rules:

- all wastes generated must be removed on departure.
- food must be secured to limit foraging and dispersal by wildlife
- no overnight stays are allowed
- only set numbers of visitors are allowed on site
- foot travel is the only form of transport allowed within the Visitor Access Zone, Main Use Zone and Heritage Zone.
- visitors onshore must be able to maintain two-way communication with their vessels.
- shore landings can only take place in the Main Use Zone and the Visitor Access Zone.
- boats/vessels must minimise lights to avoid disturbance to birds.
- no ballast water can be discharged within 12 nautical miles of the shore.
- vessels entering the Territory must have come directly from an Australian Quarantine Inspections Service and have a deratting certificate.
- all visitors are provided with the Environmental Code of Conduct for Visitors to Heard Island.



Polar Bear Briefing Facility mural.

Churchill Wildlife Management Area

Specific management strategies are employed to limit interactions between humans and the largest tundra animal the polar bear. The most unique of these is the polar bear jail.

Zoning

A set of zones have been set up in the area around Churchill to provide layers of protection for the tundra environments (and associated environments in close proximity). Wapusk National Park is located to the south east of Churchill, and few activities are allowed there. This is an important denning site of female polar bears. Between Wapusk National Park and the town of Churchill is the Churchill Wildlife Management Area which is a buffer zone. In this buffer zone, several tour operators run tundra buggy polar bear tours, aurora borealis tours and photography tours. The site is also the base of a range of conservation organisations such as Polar Bears International. In and around the town of Churchill are natural resource extraction operations, tour businesses, homes and local businesses.





Polar Bear Alert Program

The Polar Bear Alert Program is a multi-pronged approach to raise awareness of polar bears safety and deter polar bears from the town of Churchill. It is made up of:

- Public Awareness campaign – artwork, training and individual precautions
- Signage
- Armed Conservation Officers
- Polar Bear Holding Cells.



Public awareness

Raising public awareness through art or creative endeavours, creates a focal point for the town, and an added tourist attraction for visitors. Sculpture and murals around the town depict key species of the region such as polar bears, beluga whales, etc. Children are trained in polar bear safety and people are encouraged to carry bear spray.

Signage

Signage is an effective strategy to education the general public about the local environments and flora and fauna.



Armed conservation officers

Manitoba Conservation officers carry a range of equipment to scare polar bears away or to shoot them if necessary. Equipment might include scare pistols, paintball guns, air horns, or firecrackers. These extreme options are due to risky behaviour by polar bears, particularly those coming to close to settlements. The aim is to teach the bears to be more scared of humans to discourage them from settlements. Loud noises are used to move them on.

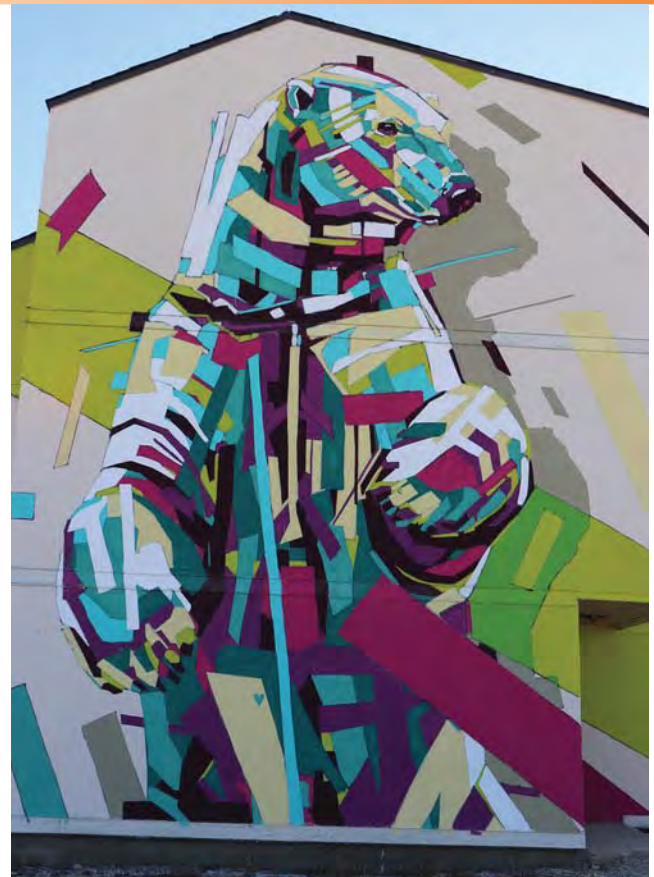


Polar bear holding cells

Polar bears found too close to the town of Churchill are placed in a polar bear jail, where they are held for thirty days before being helicoptered to a more remote location away from humans. This only occurs after attempts are made to scare the bear away from settlements as described above.

Radar and ear-tags

Sophisticated tagging and monitoring strategies help scientists gain a better understanding of where polar bear are located. This provides up-to-date information on polar bear behaviour, feeding and locations. It provides important information about the impact of climate change, pollution and human interactions. At the time of tagging measurements can be taken of fat, hair, blood, etc to provide data on diet, relationships, age, etc.



Arctic Council

The Arctic Council is an inter-governmental forum of Arctic countries. It has established a working group to investigate the spread of introduced species and to work on ways to prevent them. Canada is a member country. The member countries work together on common goals and make recommendations for programs to be implemented in member countries.



Using Twitter to investigate change

Students are very familiar with social media for use in sharing all sorts of details about their personal lives and famous personalities. It can also be a tool that can be used to gain up-to-date information about a research area or topic.

Some examples of experts and organisations to follow on twitter:

@AEDerocher –

Andrew Derocher, Biological Sciences Professor at University of Alberta

@ArcticBeringia –

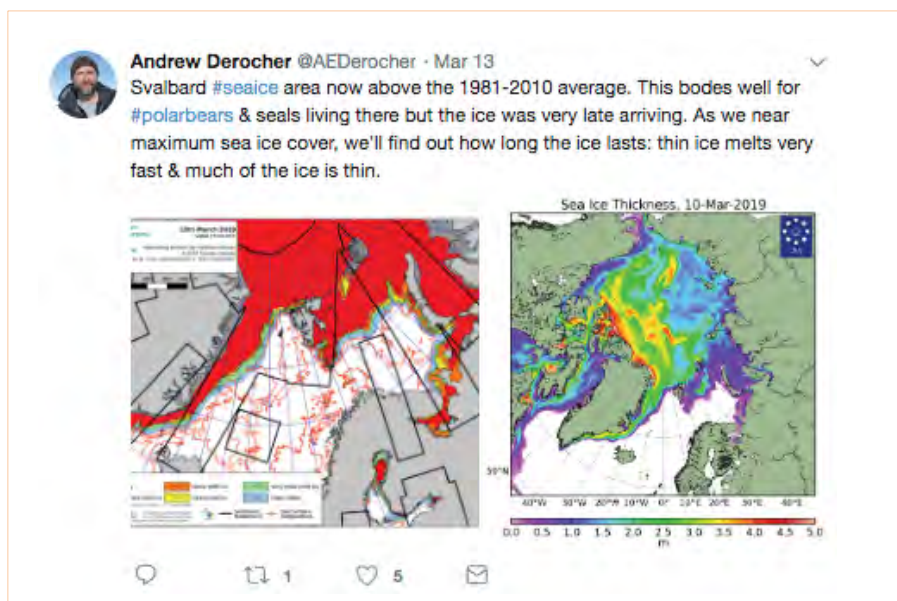
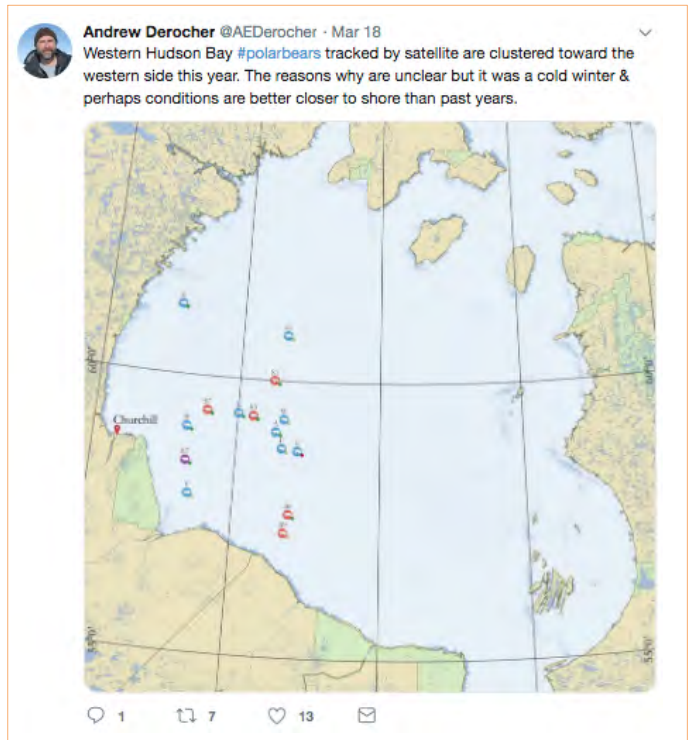
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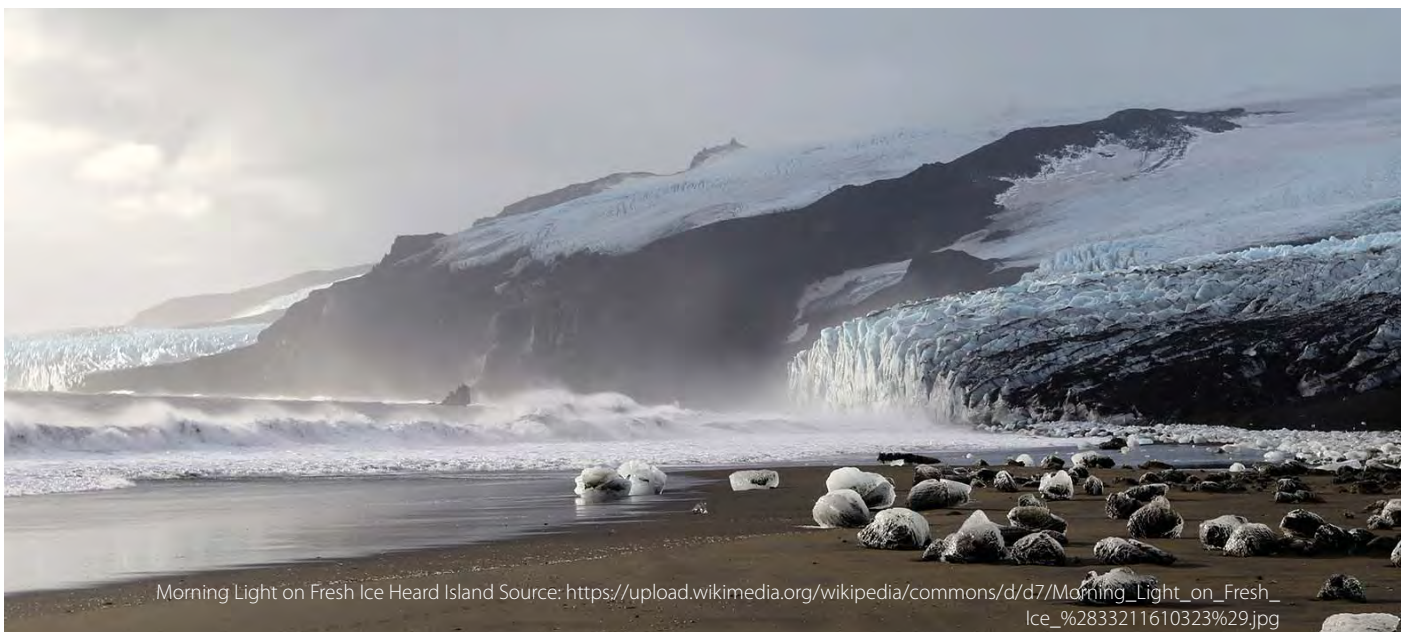
A team of scientists, taking what we know about #Arctic change to the world's most powerful audiences



SEE APPENDIX 1 for student activity worksheets

Tundra Glossary

Albedo	The fraction of solar radiation that is reflected back into space.
Antarctic Circle	The parallel of 66.5 degrees south latitude.
Arctic Circle	The parallel of 66.5 degrees north latitude.
Atmosphere	The gaseous envelope surrounding Earth.
Biosphere	The living organisms of Earth
Boreal forest (taiga)	A needle-leaf forest in sub-arctic regions of Eurasia and North America.
Carrying capacity	In the case of tourism, carrying capacity refers to the number of visitors or activities that can take place in an area without environmental degradation occurring.
Climate	Weather conditions of a long period of time.
Evaporation	When liquid water is converted to gaseous water vapour.
Glacier	A large natural accumulation of land ice that flows downhill, or outwards from the point of accumulation.
Hydrosphere	All water on Earth, including lakes, rivers, oceans, groundwater, etc.
Ice Sheet	A blanket of ice that completely covers the underlying terrain.
Lithosphere	The solid, inorganic portion of the Earth's surface.
Polar High	A high pressure system over either polar region.
Subpolar Low	A zone of low pressure situated at about 50–60 degrees latitude (either North or South). Also known as a polar front.
Taiga	See boreal forest.
Tundra	A treeless region, where low growing plants such as moss, heath and lichens grow and where subsoil is permafrost or permanently frozen soil.
Permafrost	Permanently frozen, impermeable ground (upper layers may thaw during summer). It results when ground surface temperatures remain below freezing point for long periods.
Weather	Short-term atmospheric conditions (day-to-day).



Morning Light on Fresh Ice Heard Island Source: https://upload.wikimedia.org/wikipedia/commons/d/d7/Morning_Light_on_Fresh_Ice_%2833211610323%29.jpg