Geo Factsheet

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THE TUNDRA BIOME

Introduction

The Tundra Biome is a cold treeless region found mainly polewards 60° N and includes areas of Alaska, Canada, Greenland, Scandinavia and Russia. It is found between the polar ice cap and the coniferous forests biome (taiga). In the Southern Hemisphere, tundra is only found on some islands at the edge of Antarctica, as there is very little land at or beyond 60° S except for the frozen continent itself.

Tundra can also be found at high altitudes in mountain ranges such as the Rockies and the Himalayas. This is known as **High Altitude** or **Alpine Tundra**. In these regions there are not long periods without sun but the climate is very harsh because of the environmental lapse rate so adaptations are very similar to that found in the Northern Tundra biome.

Fig. 1 World map of tundra regions.

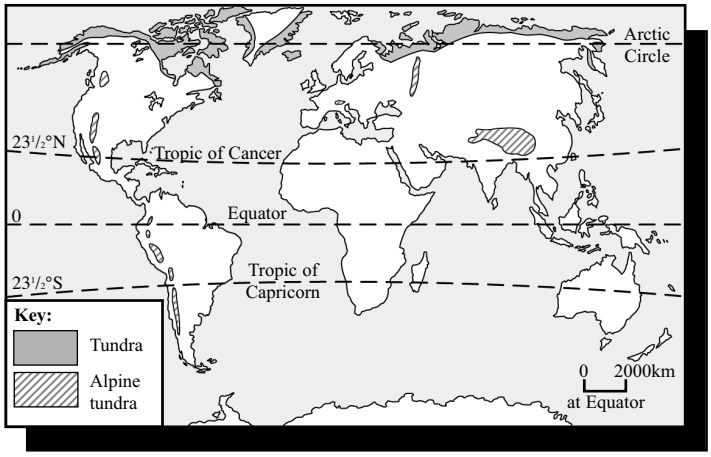
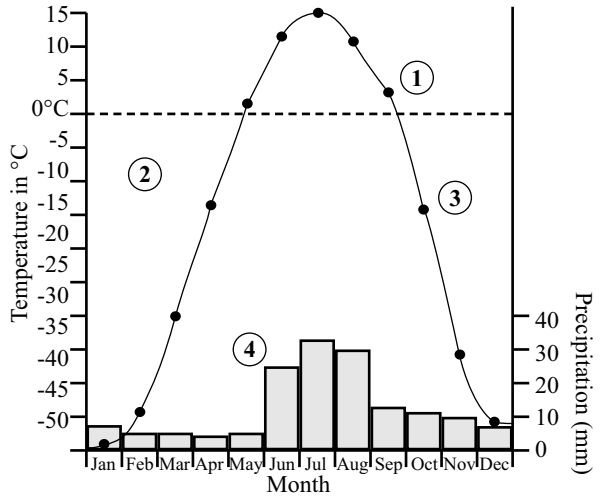


Fig. 2 Climate graph of Verkoyansk

1. *Short growing season. Only 5 months where average temperature is above freezing, 3 when above 6°, Upper layers of soil will thaw.*
2. *Large temperature range of 64°. Show impact of continentality.*
3. *7 months when average temperatures are below freezing.*
4. *Low annual precipitation. Peak coincides with peak temperatures. Convectional rainfall.*



Climate

The climate of tundra regions is characterised by very long, cold winters with the sun hardly above the horizon. The summers are brief and cool with average temperatures rarely above 10° C. Precipitation levels are low and are comparable to those of deserts found at lower latitudes. However, in the case of the tundra, the low levels of evaporation mean that much of the rainfall and snowmelt is theoretically available for use by plants. However, for much of the year there is physiological drought as the moisture is frozen.

Fig. 2 shows the climate of Verkoyansk which is situated in the tundra region of eastern Russia. It experiences temperatures below freezing for much of the year so that the majority of the soil layer is permanently frozen (**permafrost**). During the brief summer, when the sun is continuously above the horizon, the temperatures rise above freezing, giving a short growing season for plants. In winter much of the limited incoming solar radiation is reflected back by the snow cover before it can warm the surface. The region has a high **albedo** (the proportion of solar energy reflected from a surface).

Exam Hint: A rough sketch of a climate graph for a tundra area, annotated with the main features, is a useful shortcut in an exam question.

As a result of the harsh climate, until relatively recently only scattered groups of nomadic people were to be found in these regions. Since the development of mineral resources, such as oil, settlements have been created. The underlying permafrost has caused some problems as when houses are built in these areas, heat from the buildings can melt the frozen layers and cause the buildings to sink and pipes to crack. Special building systems have been developed with homes being built on insulated stilts and all pipes such as sewage and water being carried above ground in insulated coverings called **utilidors**.

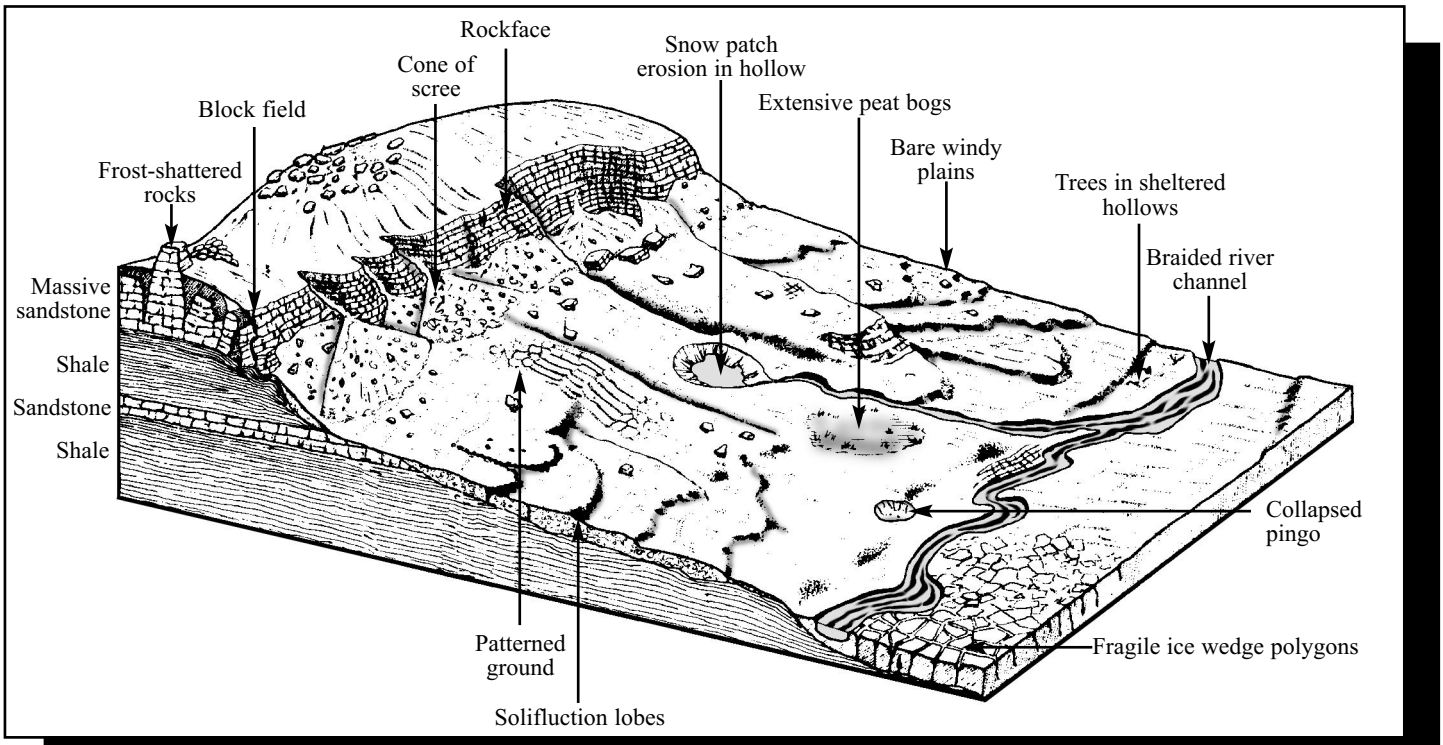
The tundra landscape

● *Physical features*

Tundra regions experience extreme conditions of frost and waterlogging and this impacts on soil development. Permafrost underlies 25% of the earth's land surface in total. In Russia 50% and in Alaska 82% of land area is underlain by permafrost. In summer only the upper layers (the active zone) thaw. This leads to waterlogging as the permafrost acts as an impermeable barrier. As the soil is full of moisture, it leads to downslope movement even on gentle gradients, known as **solifluction**. In low-lying waterlogged areas the low oxygen conditions give rise to the eventual development of peat. In better-drained areas, a shallow brown earth may develop known as tundra brown soil.

Processes such as **frost heave** help to create landscape features typical of the tundra regions such as **pingos** and **polygons**. Pingos are conical hills formed by the freezing of water under pressure. An area of unfrozen soil, part of the active layer, is frozen within the permafrost and exerts great pressure. The pressure causes the water to push upwards until it is under the vegetation layer where it freezes and a small hill is formed. If the heart of the pingo is exposed by the vegetation cover cracking open, the pingo begins to melt and collapse.

Fig. 3 The tundra environment.



Polygons are formed from the effects of frost heave. Although the active layer thaws in the summer, in winter it freezes and shrinks causing cracks to form. During warm spring days, melted water seeps into the cracks and is then frozen. The temperatures fall due to the surrounding frozen soil and the ice expands. This continues year after year, the wedges grow in size and above the wedges the soil forms ridges which, seen from the air, form polygonal shapes.

Other processes that operate within the tundra landscape are those of **freeze-thaw** which can break down rocks as moisture gets into cracks and then freezes. During the brief summer fluvial processes can erode, transport and deposit material. These result in **braided channels** which are typical of tundra areas, e.g. the Mackenzie River. *Fig. 3* shows a typical tundra landscape. Some of the features are extremely fragile and easily damaged.

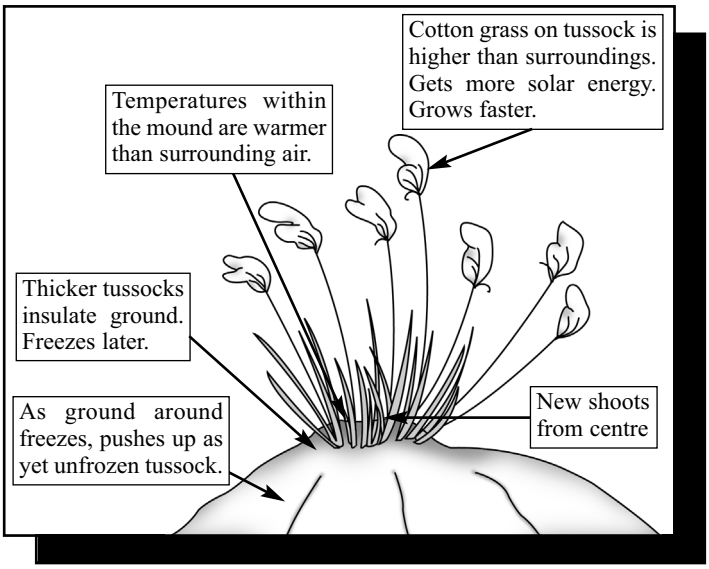
Table 1 Adaptations of plants to tundra conditions.

Adaptation	*Explanation*
Hollow stems	*This means the temperature is warmer within the stem.*
Corms/bulbs	*Many species keep much of living tissue below ground to help survival.*
Small seeds	*Can be easily wind-borne. Can lie dormant for years.*
Hairy covering	*Fine hairs over stems and buds protect from wind and low temperatures.*
Rosettes of leaves	*Can warm up faster. Also deflect the wind.*
Dark leaves	*Red colour helps absorb more radiation.*
Fast growing	*Many can grow, flower and set within 6 weeks.*
Some flowers follow the sun	*Cup-shaped flowers turn and follow the track of the sun in the sky. Maximum warmth onto developing seed. Ripens fast. Arctic poppy.*
Low height	*Ground-hugging enables plants to cope with strong, drying winds.*

● ***Vegetation***

- The tundra biome has low NPP (**Net Primary Productivity**), typically less than 250g/m^2/year.
- The growing season is 3 months or less and plants have had to adapt to the harsh conditions including low levels of sunlight, strong winds and limited moisture.
- Nutrient cycling is slow due to low temperatures.
- Nearly all the tundra plants are perennials as the growing season is too short to support many annuals.
- There are no trees but dwarf species of willow and birch exist which are only a few centimetres high but spread along the ground.
- Some plants, such as cotton grass and tussock grass, create their own microclimates by the way they grow *(Fig. 4)*.

Fig. 4 Impact of cotton grass on microclimates.



● ***Animals of the tundra***

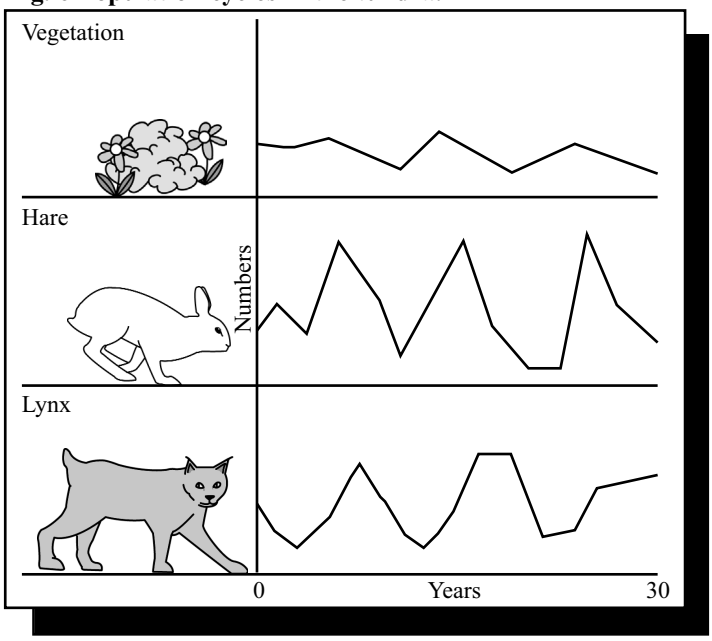
Within the tundra biome there is a low diversity of species, linked to the short growing season and extreme climatic conditions. Low diversity means a more fragile ecosystem, one that can easily be upset, as it does not recover quickly from change. During the short summer billions of insects emerge as the land thaws and these provide food for huge numbers of breeding birds. The Canadian Arctic is the breeding ground for over 100 species of bird including the Arctic Tern. Few birds live in the tundra all year. Exceptions are the Rock Ptarmigan and the Snowy Owl which hunts the Ptarmigan, hares and lemmings *(Fig. 5)*. Large mammals such as the caribou (reindeer) and the musk ox are herbivores. The caribou feed mainly on mosses and lichens during winter when they shelter within the great coniferous forests. In summer they migrate in huge numbers to the open tundra where their diet is supplemented by grasses. Caribou have large spreading hooves that allow them to walk on snow or boggy ground and they have a thick coat of hollow hairs which gives them excellent insulation. Under natural conditions caribou are constantly on the move and no overgrazing results.

Animal populations are marked by boom and bust cycles. The best known are the population explosion of lemmings every 7-10 years when they go on the move to find more food. The example in *Fig. 6* is of the snowshoe hare and the lynx. Over a period of 10 years as the population of the hare increases the fragile tundra vegetation is over grazed and declines. This impacts on the hare numbers which then impacts on the number of lynx as their main food source suddenly declines. After the crash in numbers, the grazing recovers, the hare numbers increase and the number of lynx grows to match the food source.

Table 2 Adaptations of animals to tundra conditions.

Adaptation	*Explanation*
Compact bodies	*more efficient at retaining heat*
Short limbs and bills	*to conserve heat*
Burrowing	*to keep warm and avoid the wind*
Thick fur coats	*to trap insulating air*
Feathered feet	*to insulate and to stop sinking into snow, e.g. ptarmigan*

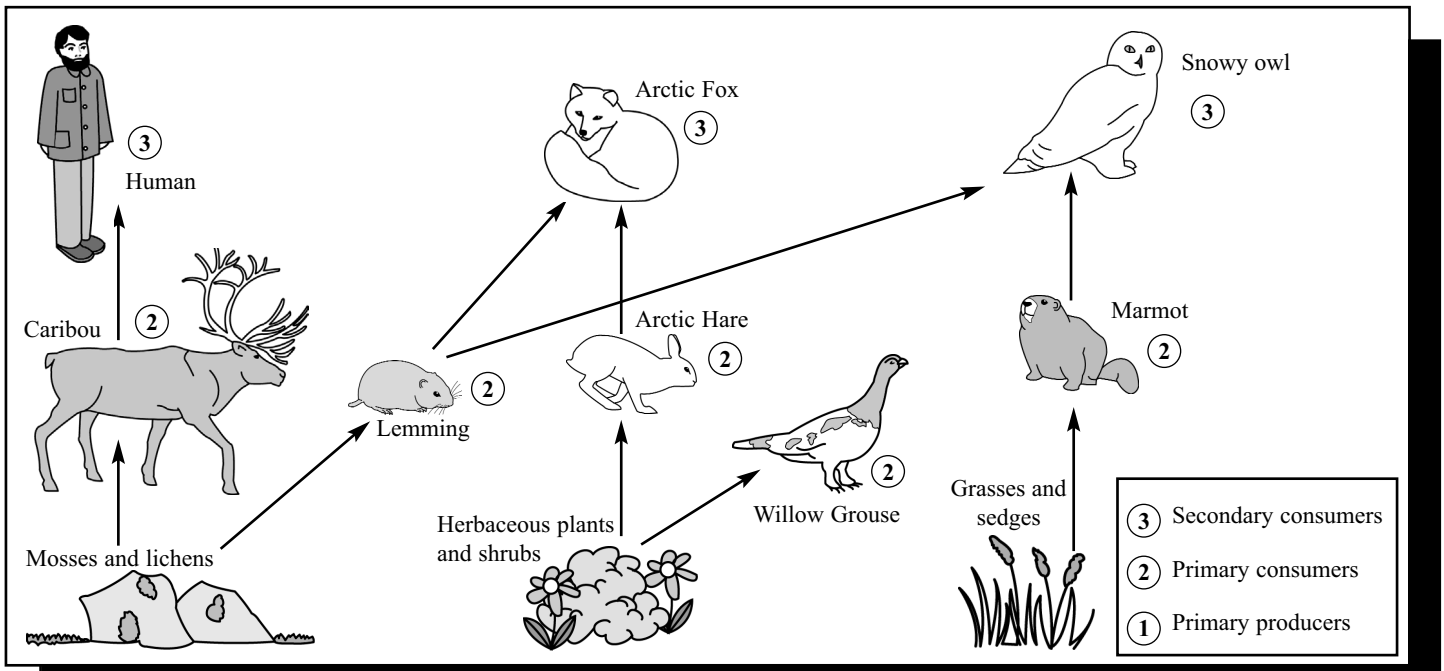
Fig. 6 Population cycles in the tundra.



Economic value of the tundra ecosystem

Although the tundra biome has low productivity, it has supported groups of indigenous nomadic borders for thousands of years. The groups such as the Saami of Scandinavia and the Nenets and Chukchi of Russia's Siberia, follow herds of reindeer on their migration from their winter feeding grounds of the boreal coniferous forests to the open tundra grazing areas in spring. Here they breed and put on fat for winter. The huge populations of blackfly and mosquito cause some distress and the reindeer migrate to the coast in order to find relief from those biting hordes in the coastal breezes and the salt water. In Eurasia most reindeer are semi-domesticated and provide meat, clothing, transport, skins to make shelters and wealth. The economic system has been in balance with the ecosystem until the twentieth and twenty-first centuries when other factors have come into play, for example reduced access to traditional grazing grounds causing overgrazing in other areas. Animals such as the Arctic fox have been hunted for their furs for many years and form an important part of the economy of indigenous groups in Alaska. In some areas they are shot as a pest.

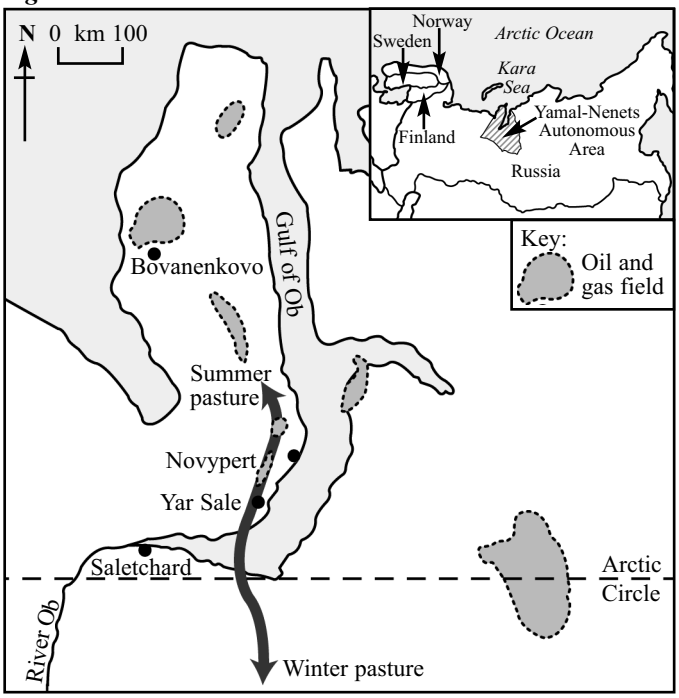
Fig. 5 The tundra food web.



Case study: The Nenets of the Yamal Peninsula – an area of change

The Nenets are a nomadic herding people who live on the Yamal Peninsula in Siberia. The area is one of deep permafrost and has a reindeer population of 200,000, although most are now part of state farms. A few clans from within the Nenets still herd in the traditional way in that they do not use snowmobiles. Their whole economy is based on the reindeer, which provide them with all their needs, and they live in harmony with the environment. An example is their use of birch pulp, scraped from beneath the bark of the tree, which is used as toilet paper and also as a truly disposable nappy!

Fig. 7 The Yamal Peninsula



After the 1930s there was a move by the communist authorities to settle all the Nenets in order to control them. Their children were sent away to boarding school to be educated and many did not then wish to return to the hard life on the tundra. Today most Nenets are paid workers within the state reindeer enterprises. About 200 still try to maintain the traditional way of life although this is increasingly hard as outside influences are being felt more and more since the discovery of oil and gas in the region.

The Yamal Peninsula has the largest natural gas reserves in the world (300 billion cubic feet). In the 1980s the Bovanenkova field was discovered. Roads, railways and barrack-type housing were built and workers came in from outside the area. The developments have meant the destruction of large areas of pasture with little or no consultation with the reindeer herders.

Areas to the south of the Yamal have already been devastated by oil production with a third of the summer pasture being taken over. This has led to overgrazing of the limited remaining tundra pasture. The waters of the rivers have also been affected with a decrease in fish stocks.

Now that Russia is becoming market-orientated there is pressure to fully develop the Yamal Peninsula with its associated degradation of the land. Grazing land is damaged even if only used to build a stretch of pipeline as the vegetation is destroyed. The installations need to be carried out in winter when there would be minimal damage.

Coupled with the oil and gas development is the problem of a market for reindeer meat. Since the end of communism there has been a decline in the demand for venison. Without state support the price is too expensive so herds are not being slaughtered and their numbers are growing, impacting on their grazing. The children of the Nenets may find that the well paid jobs in oil and gas tempt them away from a life that has remained little changed for hundreds of years and a sustainable way of life will give way to one of extraction and damage to the environment.

Threats to the tundra ecosystem

1. **Ozone thinning** – caused by use of CFCs all over the globe. Allows more UV light through, causing death and mutation of lichens and impacting on phytoplankton, the base of the productive marine systems.
2. **Climate change** – the greatest temperature changes are being experienced at high latitudes. In some areas the permafrost is melting causing tundra to dry out, vegetation to die and insects pests to multiply.
3. **Pollution** – found in lakes, rivers, snow, soil and lichens. Transboundary pollution. Pesticides have been found. The lichens in northern Scandinavia are still affected by the fallout from the Chernobyl nuclear disaster. Many lakes have been **acidified** as a result of acid precipitation.
4. **Mineral and energy development** – exploration and development of resources. Damage to fragile ecosystems. Permanent settlements associated with installations. Possible leakage, e.g. Trans-Alaskan pipeline which cuts across migration routes of caribou.
5. **Military installations** – like the DEW system in North America - Distant Early Warning System to warn of Soviet attack. 63 radar bases. Now largely obsolete because of end of the Cold War. Abandoned. Areas contaminated with PCBs.
6. **Wilderness tourism** – tourists want to go somewhere different (the pleasure periphery). Increase in off-road exploration. Damages the lichens for hundreds of years. The ecosystem cannot cope with large numbers, as the activity is concentrated in June/July.

Oil development in Alaska – trying to minimise the impacts

In the late 60s the North Slope oilfield was discovered and in 1977 the Trans-Alaskan Oil Pipeline was built. This development is an area of fragile tundra and much damage resulted. However, much was learned about environmental impact from this development and it is now estimated that the North Slopes "footprint", i.e. the amount of land it impacts on, would be reduced by 64% if it was developed today.

The Trans-Alaskan Pipeline was developed taking into account its impacts. Examples include:

- a pipeline suspended above ground level to allow passage of Caribou beneath.
- pipes buried under rivers to minimise visual impact.
- a zigzag path which was followed to allow for flexing due to freeze thaw and earthquake tremors.

There have been new developments since then, such as:

- smaller production well pads
- directional drilling. Drill down and then angle towards reservoir. One pad can access several areas, as far as 3 miles.
- building of pipelines is now done from ice roads in winter which melt away in spring.
- continuous monitoring of wildlife in the area.

Alpine Tundra – Niwot Ridge, Colorado, USA

Niwot Ridge is situated in the Rocky Mountains near Denver and is about 3525m in length. The only plants that can grow there are low growing ones, similar to those growing in Arctic Tundra. The climate is similar too, being cold and windy with short cool summers although there are not the long periods of winter darkness or total daylight in summer. The soils are thin as alpine tundra is characterised by steep slopes. Marmots are one of the most numerous mammals in the area, which survive the harsh climate by living in burrows.

There is a tundra laboratory on Niwot Ridge which is studying the changes to the ecosystem caused by global climate change and other factors (you can access this and its Tundracam to learn about alpine tundra – see the website details at the end of the article).

There is evidence that nitrogen deposition is increasing from human sources and being deposited at high altitudes. This is impacting on the vegetation with some plants responding positively to the increase in nitrogen and growing faster. This is changing the dominant species in the ecosystem. Other impacts in the alpine tundra region include eutrophication and acidification of waters and a resultant change in biodiversity. These problems are being repeated in many alpine tundra areas. In some tundra areas there is an increasing pressure for the development of further ski runs and lodges with associated infrastructure such as roads and ski-lifts. Alpine tundra zones are under more threats because of their greater accessibility.

Conclusion

The tundra biome is under increasing threat from local and global factors. We can minimise some impacts but drive to find more oil and gas may lead to further degradation of the biome. Increased oil exploration in Alaska highlights the conservation – development conflict.

Further research

National Geographic August 2001 – Oil field or sanctuary (The Arctic National Wildlife Refuge)

Websites

http://thssps.lane-edu.biomes/tundra5/tundra5.html for general information on the tundra.
Tundracam – you can control the web cam and watch changing alpine tundra at *http://tundracam.colorado.edu/*

Exam questions

a) Using an example of a biome you have studied, outline the factors that have led to its distribution globally.

(12 marks)

b) To what extent are its unique features threatened by development?

(13 marks)

Answers

a) Comment on:
- low levels of insolation at high latitudes.
- development of permafrost.
- low levels of precipitation.
- poorly developed soils - giving treeless plain, dominated by low growing plants.
- mainly in the Northern Hemisphere as no large areas of land at 60° S.
- Also found at high latitudes, tops of mountain regions such as the Rockies.
- similar conditions but without the permafrost layer developed.
- thin soils and steep slopes.
- insolation at high latitudes not as limited.

Use a rough sketch of a typical tundra climate.

b) 1. Economic development elsewhere has led to an increase in leisure time and disposable income. Wilderness tourism. Damaging if not controlled. Fragile landscapes. Alaska.

2. Development globally has meant increase in carbon dioxide emissions and global warming. Melting of the permafrost and a change in the ecosystem.

3. Mineral/energy development. Threats to fragile landscapes and the traditional lifestyle of these areas. May have serious impacts on wildlife due to disruption and pollution – Yamal Peninsula and Alaska.

4. Alpine areas – damage caused by excess nitrogen deposition changing the plant communities. Also damage from use by increase in ski development.

5. Plus side is that we are becoming more aware of our impacts. Lots of research going on (Niwot Ridge, North Slope Alaska etc.). Trying to minimise impact.

Acknowledgements
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