T4.1 POST-GLACIAL CLIMATIC CHANGE

During the last billion years there have been ice ages at approximately 250-million-year intervals. For about nine-tenths of this period, the climate has been more congenial than it is today. Exact causes for climatic change are not known, but the range of possibilities fall into three categories:

1. astronomic and solar causes, e.g., sun-spot activity or changes in the orbit of the earth
2. geophysical causes, e.g., continental drift
3. atmospheric causes, e.g., particulate matter from volcanoes affecting radiation

Large-scale climatic changes shifted the ranges occupied by the different air masses and consequently changed the boundaries of the major vegetation regions. As the ice sheet melted, tundra vegetation colonized the bare ground. Temperatures gradually rose, and this vegetation was replaced, first by birch, then by spruce, and finally (in the warmest part of Hypsithermal Interval) by pine, hemlock and oak. A gradual cooling then saw the return of spruce, birch and beech.

Climatic change in Nova Scotia since the most recent retreat of the continental ice sheet occurred in distinct time periods. The picture is pieced together from evidence from a variety of sources. Cores have been taken from a number of lakes and bogs, the sediment layers dated, and the pollen found within them analysed and counted.[1] Fossils of marine molluscs and crustaceans and disjunct distributions of present-day fauna provide evidence of changing oceanic climates. Current climatic conditions in Nova Scotia are described in more detail in T5 (Climate).

11,000 TO 10,000 YEARS BEFORE PRESENT (YR. BP): THE YOUNGER DRYAS

Following the retreat of the main ice bodies around 11,000 years ago, the climate abruptly cooled. The cooling lasted for approximately 200 years and strongly affected the landscape and its vegetation cover.[2,3] This cooling period is known as the Younger Dryas and is named after a plant (*Dryas*) in the rose family whose return during this time in northern Europe indicated tundra conditions. Younger Dryas ice is interpreted to have covered parts of the Scotian Shelf as well.[4]

Landscape changes in Nova Scotia resulted from the formation of glaciers and permanent snowfields.[5] Vegetation that had colonized after the glacial retreat disappeared, leaving a barren landscape, and large land mammals, such as the mastodon, became extinct. Today, the Younger Dryas is thought to provide clues to the earth's response to global warming.

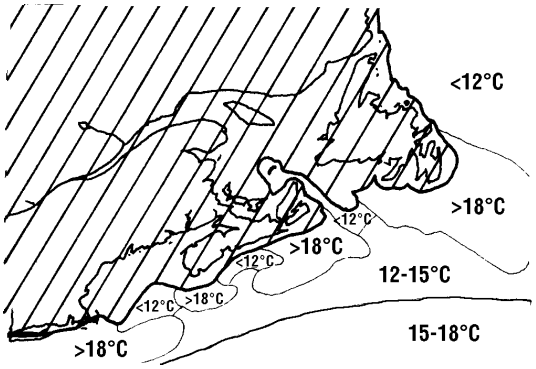
10,000 TO 8000 YR. BP: EARLY HYPSITHERMAL

The next 2000 years saw rapid increases in temperatures followed by a change in vegetation trends. The shrub willow and herbaceous plant communities which dominated the landscape in the Younger Dryas were replaced by pine forests.

8000 TO 4000 YR. BP: HYPSITHERMAL INTERVAL

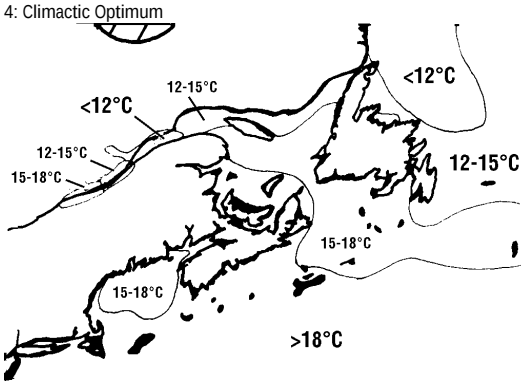
The Hypsithermal Interval was the warmest post-glacial period: temperatures rose to as much as 2°C above present temperatures, precipitating a dramatic rise in sea level. Nova Scotia's forests changed to hemlock-dominated forest, with maple and beech as major components. The culture known as the Maritime Archaic began during this time.

1: Wisconsin Close



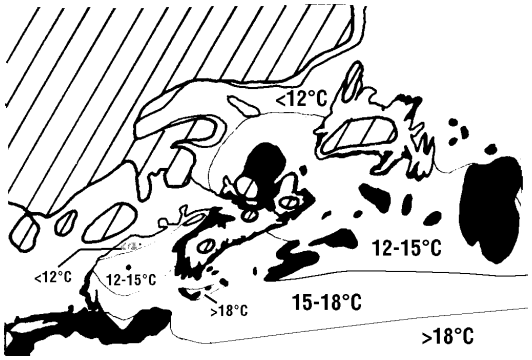
15,000 Years Ago: Ice sheet beginning to retreat • 10–15°C below present, cold and dry • Sea levels 150 m below present levels • Tundra

4: Climactic Optimum



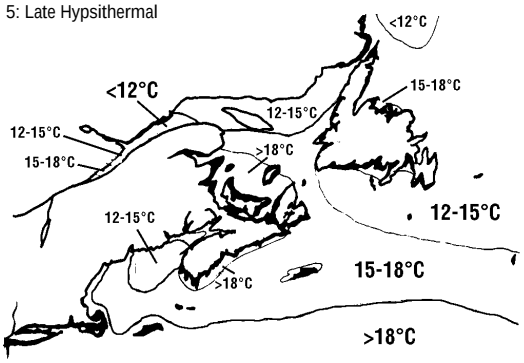
7000 Years ago: Continental ice virtually gone • At least 2.5°C above present • Sea levels 30 m below present levels, water warm in summer. Low tidal amplitudes • Pine, birch and oak.

2: Early Post-glacial



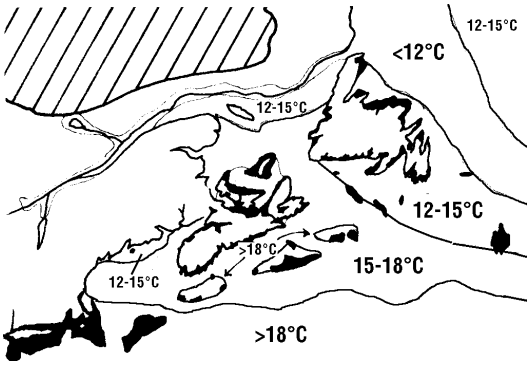
12,500 Years Ago: Ice pockets remain in SW, on the north shore and in the Bras d'Or Lake. • 5–10°C below present • Sea levels 100 m below present levels, cold Labrador Current deflected eastward by raised Grand Banks • Water column stratified in summer • Tundra

5: Late Hypsithermal



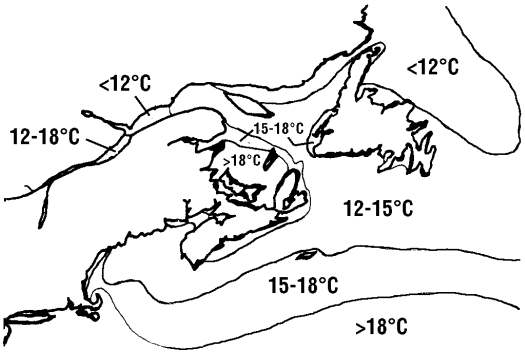
5000 Years Ago: Temperatures cooling • Sea level 15 m below present • Stratification breaks up • Labrador Current flowing in over submerged Grand Banks • Hemlock and oak

3: Early Hypsithermal



9500 Years Ago: Ice gone from Nova Scotia • Temperatures similar to present • Sea levels 50 m below present levels • First closed boreal forests — spruce, fir, birch

6: Post-hypsithermal



3000 Years Ago: Temperature almost at present levels • Sea levels almost to present • Spruce, birch, beech

Figure T4.1.1: Areas of continental shelf exposed and ocean temperatures during post-glacial time.[6]

4000 YR. BP TO PRESENT: POST-HYPSITHERMAL

The Hypsithermal Interval was followed by a gradual cooling. The moister climate favoured the recolonization of Nova Scotia by spruce trees (see Figure T4.1.1).[6]

1450–Late 1800s "Little Ice Age"
The Little Ice Age marks a short-term fluctuation in climatic regime during which temperatures dropped. Globally, glacial advance was recorded by moraine deposits. In Nova Scotia, the cooler temperatures enabled skaters to enjoy the frozen Bedford Basin.

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Associated Topics

T2.1 Introduction to the Geological History of Nova Scotia, T3.3 Glaciation, Deglaciation and Sea-level Changes, T4.2 Post-glacial Colonization by Plants, T4.3 Post-glacial Colonization by Animals, T5.2 Nova Scotia's Climate, T12.1 Colonization by People, T12.5 Climate and Resources.

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T4.2 POST-GLACIAL COLONIZATION BY PLANTS

PRE-GLACIAL VEGETATION IN EASTERN CANADA

Roland and Smith[1] suggest that "there is no reason to think that the vegetation [of Nova Scotia] just before the last glaciation was substantially different from that existing at the present time." The pre-glacial vegetation of the region had evolved in a number of major centres over millions of years. Plants of our shade-tolerant deciduous forests, for example, show closer relationships with those of eastern Asia than they do with western Europe, indicating that a long period of separation had existed between the North American and European landmasses. It is thought that a mild climate led to the existence of a wide deciduous-vegetation belt ranging from the eastern United States and Canada to Alaska and down the eastern Asia coast until late in the Tertiary. A number of our present herbaceous species, e.g., Mayflower, Clintonia, Blue Cohosh and Northern Bedstraw, either exhibit disjunct distributions encompassing eastern North America, western North America and eastern Asia, or have closely related species which together exhibit such a disjunct distribution. During the recent period of glaciation in North America, the species of our present flora remained in refugia south of the glacial margin.

The other major group of plants which existed in the region prior to glaciation were those typical of our present coniferous forests. There is, however, no evidence to indicate that a wide band of coniferous forest, similar to our present boreal forest, existed prior to the Pleistocene. Some of the evergreen species existed in more northerly latitudes, some occurred along the windswept coast, and others existed in alpine areas and in refugia on mountain tops further south.

GLACIATION

During the Pleistocene, glaciers completely eradicated all pre-glacial vegetation from the landmass that is now Nova Scotia. During interglacial periods, the nature of the vegetation recolonizing the exposed landmass has been documented through pollen-profile studies conducted on organic sediments in Cape Breton[2] and mainland Nova Scotia.[3,4] However, all such vegetation was eradicated by subsequent ice advances.

POST-GLACIAL FLORAL ELEMENT IMMIGRATION

The general trends in post-glacial vegetation change in Nova Scotia have been documented through pollen-profile studies. Generally, from about 10,000 years ago until about 7300 years ago, tundra vegetation gave way to boreal vegetation, where fir, birch and spruce predominated. Pine and oak became more important in the forest vegetation of much of the province until about 6000 years ago. Following the pine maximum, pollen of hemlock, beech and other deciduous species became more significant in the pollen profiles over much of the province.

Roland describes the flora of Nova Scotia in the following manner: "The plants of Nova Scotia may be divided into a number of groups called floral elements, with each floral element composed of those plants which have more or less the same distribution outside the area and therefore somewhat the same phytogeographic history. All of our floral elements may be considered extraneous as they have migrated into the area from outside the Province, although their earlier evolution undoubtedly occurred in a northern climate before glaciation occurred."

The main centres from which plants radiated into newly exposed areas are those immediately outside of the glacial front, either from reservoirs of plants south of the terminal limits of the ice advance, from plants pushed southward by the advancing glaciers or from the exposed areas on the outer limits of the coastal plain.

FLORAL ELEMENTS

Roland identified six floral elements: Arctic-Alpine and Boreal Disjunct, Boreal, Canadian, Alleghanian, Southwestern and Plants of the Seashore.

Arctic-Alpine and Boreal Disjunct

The sixty-one plant species of these elements were the first to migrate into the area under the cool climatic conditions following glaciation. They have a scattered distribution, often only being known from one or two locations. This suggests that they are relic elements of a flora which was widespread immediately following glaciation but which is now better represented further north. The presence of many of the plants at high elevations further south indicates that they moved northwards into Nova Scotia following the retreat of the ice. Some of them may have survived on the exposed coastal plain.

T4.2 Post-glacial Colonization by Plants

In the early stages of colonization, soils would have been more alkaline before extensive leaching had taken place, competition would have been less on the newly exposed areas, and the climate would have been more severe. As these conditions changed, the plants of these elements survived only in locations favourable to them: cool areas, headlands around the coast, the Cape Breton Plateau (Region 100), deep ravines or shaded cliffs.

Some of the plants are found at sea level around the coast (Region 800). These include

Sedum rosea —Rose-root
Claytonia fontana
Lycopodium selago —Fir Club-moss
Betula michauxii
Geum peckii

Over twenty species are found in the Bay of Fundy–Cobequid area (District 310), including five unusual ferns. Examples of this group include

Woodsia ilvensis —Rusty Woodsia
Woodsia glabella —Smooth Woodsia
Asplenium trichomanes —Maidenhair Spleenwort
Asplenium viride —Green Spleenwort
Dryopteris fragrans —Fragrant Fern
Arabis hirsuta, A. drummondii —rock cress

These and additional species also occur in the highlands of northern Cape Breton, usually along moist, steep-walled river gorges (District 220). Four species are plants of the high barrens and bogs in Region 100 and District 210:

Betula glandulosa, B. borealis, B. michauxii —birch
Vaccinium uliginosum —Alpine Whortleberry

Other species, relatively rare and only found in northern Cape Breton (District 210), include

Saxifraga aizoides —Saxifrage
Diapensia lapponica
Pinguicula vulgaris —Butterwort

Another group of plants appears to be characteristic of boreal deciduous woods rather than coniferous woods. Part of this group may be called the Cordilleran element because the plants are common in similar cool, moist habitats on the Pacific coast or in the Rocky Mountains. Examples of this group are the two ferns: *Dryopteris filix-mas* (Male Fern, and *Polystichum braunii*.

Boreal

The boreal forest is the most extensive forest type in Canada. The typical plants of the boreal element are found in coniferous woods, swamps, swales and bogs. Their distribution is more uniform than that of more southern plants, sometimes occurring around the northern hemisphere. Common examples include

Typha latifolia —Broad-leaved Cat-tail
Habenaria hyperborea —Green Habenaria
Myrica gale —Sweet Gale
Alnus crispa —Downy Alder
Moneses uniflora —One-flowered Shinleaf
Chamaedaphne calyculata —Leather-leaf
Linnaea borealis —Twinflower

Plants of this element with a more northern or Hudsonian range are found chiefly on headlands and barren areas in cooler parts of the province (Regions 100, 200 and 800). Examples include the junipers and the Bakeapple.

Canadian

The plants of this element are widely distributed and can be said to form the background flora of northeastern North America. They range from Nova Scotia and Newfoundland to Manitoba, south to Pennsylvania, and in the mountains in North Carolina and Tennessee. They are commonly found in open woods, pastures, barrens or old fields. The element includes a range of shrubs, such as Wire Birch, Chokecherry, Mountain Maple, Witherod and Meadowsweet (Hardhack, *Spiraea latifolia*); also a number of ericaceous or heath plants, such as Rhodora, Lambkill, and various blueberries. Other common examples include

Onoclea sensibilis —Sensitive Fern
Pontederia cordata —Pickerel-weed
Maianthemum canadense —Wild Lily-of-the-valley

Clintonia borealis —Blue-bead Lily
Habenaria psychodes —Purple-fringed Orchid
Epigaea repens —Trailing Arbutus (Mayflower)
Gaultheria procumbens—Teaberry (Wintergreen)

Alleghanian

The plants of the Alleghanian element are mainly associated with the deciduous forests far to the south. The range is from Nova Scotia to Minnesota and south to the Gulf States. In Nova Scotia, they are usually found growing in rich soils in the best deciduous woods or along river intervales in the northern part of the province from Annapolis County to Cape Breton (Regions 500, 600). Some of the species are widespread, but many are rare. These plants presumably migrated along the Chignecto Isthmus (Unit 523) when this area was at a higher elevation above sea level than it is now. Examples include

Athyrium thelpyterioides —Silvery Spleenwort
Allium tricoccum —Wild Leek
Erythronium americanum —Dog's-tooth Violet
Trillium erectum —Purple Trillium
Ostrya virginiana —Hop-hornbeam
Sanguinaria canadensis —Bloodroot

Southwestern

The southwestern part of the province, south of a line from Digby Neck to Musquodoboit Harbour, has a distinctive flora. The plants typical of this region are usually absent from other quartzite and granitic regions. A characteristic feature is the mingling of northern and southern plants.

The plants of the southwestern flora are believed to have survived during the last glaciation in a refugium off the Atlantic coast or to have moved northward over the exposed coastal plain while the glacier was retreating. The exposed land, with its ponds, sandy or peaty soils, and stream edges, presented a suitable area for colonization by more southern plants. As the sea level rose, these plants gradually became isolated from their range further south, and they are not found today in New Brunswick, Maine or Massachusetts.

The following are examples from the group of plants now found from Florida to Louisiana or Texas (some even to Mexico or the West Indies) and north along the coast to New England, before jumping to southwestern Nova Scotia. These plants represent the coastal-plain element of our flora:

Woodwardia areolata —Dwarf Chain Fern
Lachnanthes tinetoria —Redroot
Smilax rotundifolia —Green Brier
Hydrocotyle umbellata —Water-pennywort

Other plants which are distinctly coastal plain in nature and are very common in southwestern Nova Scotia have developed a wider distribution and also occur inland, in Cape Breton, and often in southern Newfoundland. These include

Juncus militaris —rush
Calopogon pulchellus —Grass-pink
Drosera intermedia —Narrow-leaved Sundew
Viola lanceolata —Lance-leaved Violet
Gaylussacia dumosa —Bog Huckleberry

Plants of the Seashore

About fifty species are restricted to beaches, cliffs and salt marshes along the seashore. A few of these plants have a more southern origin and range, analagous to the coastal-plain flora. Examples include

Spartina patens —Saltmarsh Cord-grass
Limonium nashii —Sea-lavender
Solidago sempervirens —Seaside Goldenrod

Many of the most common seaside plants have a northerly distribution similar to plants of the boreal floral element. This group includes

Hierochloe odorata —Sweet-grass
Juncus balticus —rush
Juncus gerardii —rush
Mertensia maritima —Sea-lungwort
Plantago maritima —Seaside Plantain

A smaller number of species— American Beach-grass *Ammophila breviligulata*, Sea-rocket *Cakile edentula* and Scotch Lovage *Ligusticum scothicum*— are found only in eastern North America and in Europe. Their range is somewhat less northern, extending southward from the warmer areas around the Gulf of St. Lawrence.

INTRODUCTIONS

The contemporary flora also includes an introduced component. The direct or indirect importation of species may go back as far as 1000 years. Introduced species may be commonly found in native, as well as anthropogenic, habitats (see T12.2 Cultural Landscapes).

Associated Topics

T3.3 Glaciation, Deglaciation and Sea-level Changes, T4.1 Post-glacial Climatic Change, T4.3 Post-glacial Colonization by Animals, T9.3 Biological Environment, T10.1–T10.12 Plants, T12.10 Plants and Resources

Associated Habitats

H2.1–H2.6 Coastal, H3.1–H3.6 Freshwater, H4.1–H4.4 Freshwater Wetlands, H5.1–H5.5 Terrestrial Unforested, H6.1–H6.3 Forests

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T4.3 POST-GLACIAL COLONIZATION BY ANIMALS

As with the flora, the pre-glacial fauna of Nova Scotia is believed to have been essentially similar to that of the present day. The successive glaciations completely obliterated animals from the area now above sea level, but it is believed that refugia existed, seaward of the terminal moraines of the ice sheet, along the edge of the continental shelf. As the climate warmed during the post-glacial hypsithermal period, the subarctic tundra began to be colonized by boreal forest. However, this was set back for a period of about 200 years by a sudden cooling event. Many species had to begin colonization again and eventually a warm-temperate fauna was established which included some "southern" or continental species, such as Blanding's Turtle, Ribbon Snake, the freshwater snail *Menetus dilatatus*, the quahog *Mercenaria mercenaria* and the oyster *Crassostrea virginica*. A second cooling event, in historic times (1150 to 1860 AD), was the "Little Ice Age." Many southern species were affected at this time, either being reduced to isolated populations in the south of the province (e.g., Southern Flying Squirrel) or lost completely for a time (e.g., White-tailed Deer).

The routes by which animals could colonize Nova Scotia are shown in Figures T4.3.1 and T4.3.2.

LAND AND FRESHWATER FAUNA

The Chignecto Isthmus (Unit 53)

This has existed continuously since the end of the last glaciation but was more substantial when the sea level was lower. As the climate warmed, species were able to migrate freely from the continent. Some salt-tolerant species could move from one river system to another due to the fresh water on the coast that was coming from the melting ice sheet. Species diversity of freshwater fish decreases with distance into Nova Scotia from the landbridge. A similar pattern for freshwater mussels has also been reported. More than half of the sixty-two terrestrial snail and slug species migrated to Nova Scotia across the land bridge during the hypsithermal period.[1] The recent establishment of coyote in Nova Scotia demonstrates that this migration route is still active.

Coastal-plain Refugia

Limited refugia were believed to have existed along the continental shelf and were occupied by arctic and boreal plants and animals during the ice age. Modern geological evidence does not fully support the theory that refugia existed along the edge of the

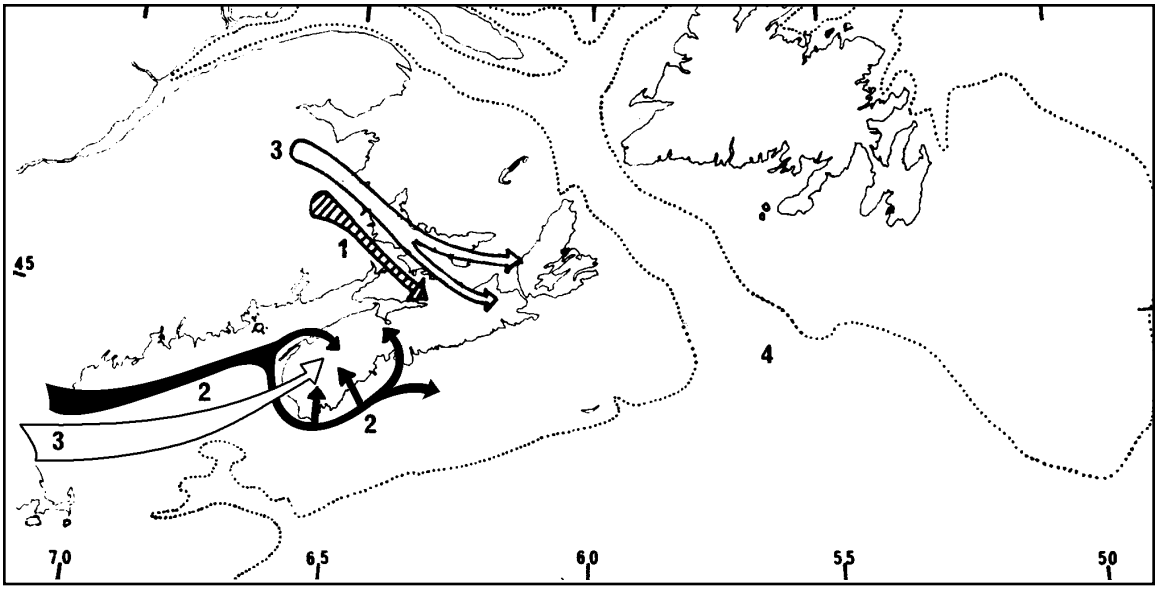

Figure T4.3.1: Post-glacial colonization of Nova Scotia by land and freshwater animals. 1: Chignecto land bridge; 2: continental shelf refugia; 3: aerial migration and transportation. Species were also introduced through direct and indirect importation by Europeans (post 1000 AD).

continental shelf for the duration of the ice age. However, botanists and entomologists consider the existence of such refugia to be essential to an explanation of the present-day distributions of arctic and boreal species in Nova Scotia and Newfoundland.[2] As the climate warmed and the ice withdrew, these species were able to colonize the new land, but they have since been limited in their distribution by rising sea level. They now occur largely along the cooler Atlantic coastline, where competition from temperate species is reduced. Coastal-plain refugia are not an explanation for the occurrence of southern or continental species such as the Atlantic Whitefish and freshwater isopod *Caecidotea communis*. These are more likely to have spread northwards along a more extensive coastal margin as the climate improved. Their current disjunct populations are probably a result of climatic change or habitat loss.

Aerial Migration and Transportation

Most flying animals experience few physical barriers and thus were able to colonize Nova Scotia as soon as climate and habitats were suitable. Birds, bats and flying insects are the groups best able to follow this route, and present distribution patterns (with modification due to climate and habitat change) have probably been established for a long time. Flying animals are known to transport sessile animals, such as pea clams (*Pisidium* spp.), and are important agents in their distribution.

In the last 100 years twenty-eight species of birds are known to have established populations in Nova Scotia.[3] This is due to the creation of more favourable habitat and/or to climatic changes.

Introductions

The contemporary fauna also includes an introduced component of growing significance originating from other parts of North America, Europe, South America and Asia. The direct or indirect importation of species by Europeans may go back as far as 1000 years. Initial introductions came with cultivated plants and ships' ballast, and some species experienced rapid spreading with land clearance and agriculture. This type of introduction has caused widespread displacement of native species. Introduced species may be found in natural habitats, however they are more common in disturbed areas.

MARINE FAUNA

The marine fauna was originally arctic/boreal in nature, associated with the predominately cool water-temperatures of the area. However, species with more southerly affinities have colonized the area in the past. Following the last glaciation, warm water (18°C) more characteristic of areas south of Cape Cod extended northwards in coastal areas into the Bay of Fundy, the continental shelf and the southern Gulf of St. Lawrence (Region 900).[4] This enabled

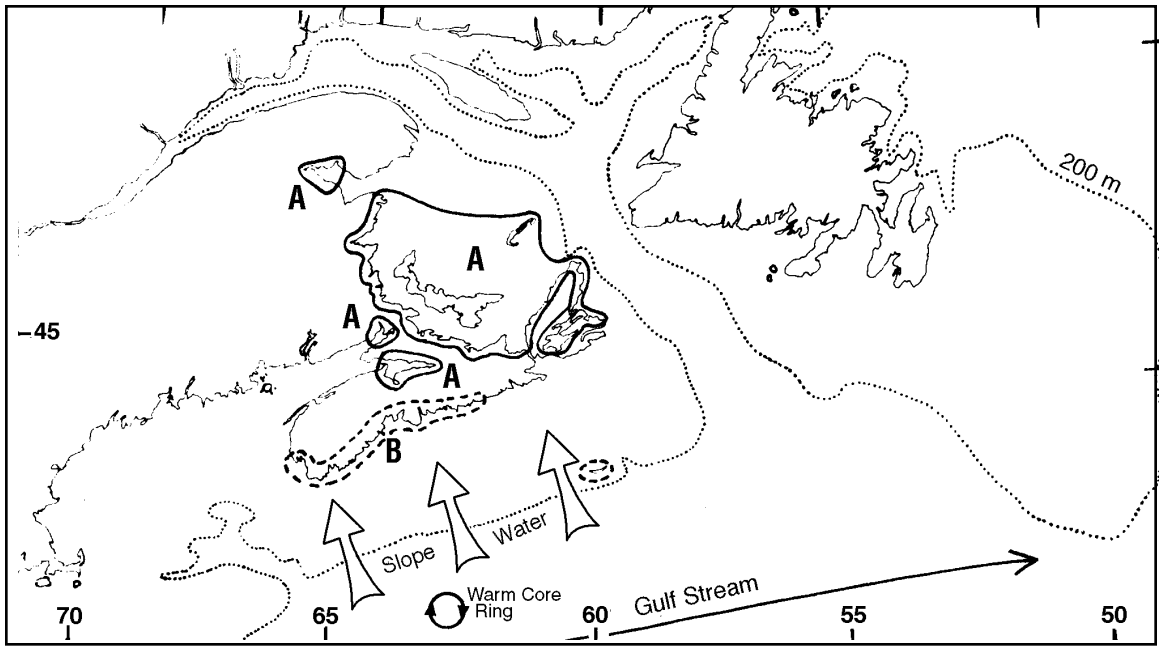

Figure T4.3.2: Post-glacial colonization of Nova Scotia coasts by marine organisms. Key:— A: Main areas of present-day warm-water species established during hypsithermal. B: Areas of warm-water species established during hypsithermal, and currently, in part, maintained or enriched through slope-water exchange.

warm-water species ("oyster-bed fauna") to colonize these areas. As the climate subsequently cooled, areas occupied by the warm-water fauna became isolated. The fauna of Minas Basin and the southern Gulf of St. Lawrence were separated and now differ in character. Warm-water species along the Atlantic coast (Region 800/Unit 911) are isolated in sheltered bays, where temperatures rise sufficiently in summer to permit reproduction. The former warm-water fauna around Sable Island is now largely extinct. Populations of many species are disjunct and are now separated from main populations further south by hundreds of kilometres, e.g., the Boring Clam, *Barnea truncata*, and Lady Crab, *Ovalipes ocelatus*.

The southern Atlantic coast of Nova Scotia (Unit 931e, South Shore and parts of the Eastern Shore) are periodically subjected to incursions of warm water from the continental shelf. This water is partly derived from the Gulf Stream and includes the larvae and adults of marine animals which normally occur further south. During summer the larvae arriving in this way may undergo metamorphosis and become noticeable as part of the fauna of bays and estuaries. Warm-water incursions also bring pelagic species, e.g., Portugese Man-of-war and animals associated with *Sargassum* weed. These animals rarely survive or reproduce, as a result of low winter temperatures. However, populations could become established following some climatic improvement or local warming of water through industrial activity.

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Associated Topics

T3.3 Glaciation, Deglaciation and Sea-level Changes, T3.5 Offshore Bottom Characteristics, T4.1 Post-glacial Climatic Change, T4.2 Post-glacial Colonization by Plants, T6.1 Ocean Currents, T11.1–T11.18 Animals, T12.11 Animals and Resources

Associated Habitats

H1.1–H1.2 Offshore, H2.1–H2.6 Coastal, H3.1–H3.6 Freshwater, H4.1–H4.4 Freshwater Wetlands, H5.1–H5.5 Terrestrial Unforested, H6.1–H6.3 Terrestrial Forests

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