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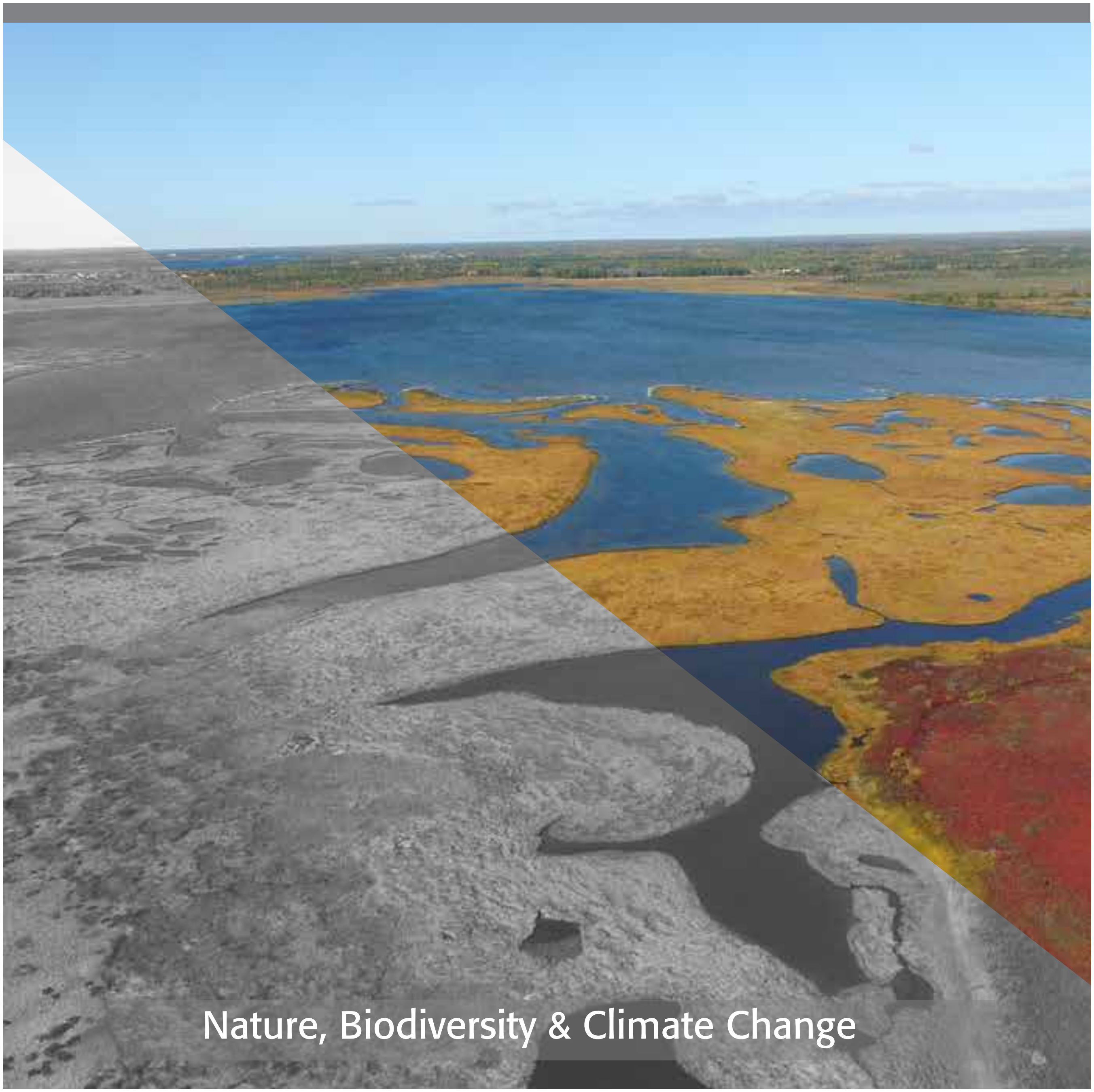

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Nature NB

259 rue Brunswick St. Suite 103, Fredericton, NB E3B 1G8

Nature NB is a non-profit, charitable organization whose mission is to celebrate, conserve and protect New Brunswick's natural heritage, through education, networking and collaboration. (The former name of Nature NB – New Brunswick Federation of Naturalists / Fédération des naturalistes du Nouveau-Brunswick is retained for legal purposes.)

Nature NB est un organisme de bienfaisance à but non-lucratif qui a comme mission la célébration, la conservation et la protection du patrimoine naturel du Nouveau-Brunswick par l'éducation, le réseautage et la collaboration. (L'ancien nom de Nature NB, soit « Fédération des naturalistes du Nouveau-Brunswick / New Brunswick Federation of Naturalists », demeurera le nom légal de l'organisme.)

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In This Issue

Front cover photo, Saltmarsh at Grand Passage, *Photo: L. Richardson*

Nature, Biodiversity and Climate Change
Special edition

Please submit articles to Vanessa Roy-McDougall, executive.director@naturenb.ca.
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Nature in a Changing Climate

Dr. Tony Diamond
Dr. Sabine Dietz

Today's changing climate is already having severe impacts on human and natural systems, and will continue to do so at an accelerating pace. Temperatures in New Brunswick are predicted to increase from 2.5 to 6.5 °C by 2080, cities such as Saint John and Moncton are expected to have more hot days (10 to 35 more), and the growing season is predicted to lengthen by 29 to 81 days (Roy & Huard 2016). Precipitation is also expected to increase, primarily in winter and spring. By 2050, coastal flood levels are expected to increase by 40 cm (Daigle 2012). We sort of understand the risks these impacts pose directly to human health and infrastructure, but what do they mean for nature?

Higher temperatures means cold-loving species may not be able to persist, and species from regions further south may move north, if intensively-managed landscapes allow them to migrate. Droughts may become an issue in certain regions, or may cause water to become too warm for some species (e.g., salmon). An extended growing season (starting earlier, ending later) may cause a de-synchronization of life events in certain species (e.g., birds and their breeding times disassociated from insect emergence). Increased heavy precipitation events will increase severe flooding, which may cause erosion, and introduce harmful substances into water (e.g., from sewage overflows). Coastal floods and storm surges will damage beaches, dunes and salt marshes, and cause landowners to harden banks, further threatening coastal ecosystems and reducing coastal resilience. Many of these changes are already being observed across the world, and some of them here in New Brunswick.

If we are locked into the impacts from excessive emissions for the foreseeable future, what can we do beyond reducing our own emissions to limit damage to both human and natural systems?

Nature is inherently resilient, and although we often ignore it, is able to buffer us from many of the effects of climate change: planting trees in cities can reduce heat islands; coastal marshes buffer coastal infrastructure from effects of storm surges; healthy, diverse forests reduce runoff and thus reduce flooding; wetlands retain water during heavy rainfall events. In order for nature to do her work, though, we need to ensure that we do not reduce her ability to function. We know how to do this, it's nothing new: whether it's sustainable forestry, connecting wildlife habitats, maintaining ecosystems, protecting wetlands, restoring dunes and marshes, managing resource extraction (whether it's trees, fish, oil, or gravel), we can reduce or mitigate many impacts that decrease the resilience of ecosystems….if we want to. And we know enough about the indicators in nature that tell us when something is wrong, i.e., when nature's resilience is impacted: fish stocks that disappear (e.g., Atlantic Cod); birds that can no longer feed their young (e.g., Atlantic Puffin); species at risk (521 in Canada); insect infestations that the forest cannot handle due to tree composition and age structure (e.g., Spruce Budworm); Atlantic Salmon not doing so well in overly warm pools along our famous salmon rivers…all warning signs of reduced resilience in nature.

As a society we have the tools to foster true ecological sustainability in our landscapes; we know how to grow food and trees, and harvest the riches of the ocean, in ways that will sustain these resources for our descendants; we simply do not do so to nearly the extent required. Until now we have lacked a sense of urgency to employ those tools more vigorously; impending climate change provides that sense of urgency. The impacts of a changing climate are additive to the stresses our way of life already imposes on our landscapes: over-use of chemicals (pesticides and fertilisers), reducing richly diverse forests to boreal monocultures that will not survive in a rapidly-warming climate, building on erodible shorelines, increasing hard surfaces (concrete, tarmac) incapable of absorbing increasingly torrential storms, draining and filling the wetlands that reduce flooding, fishing down the food-chains of the ocean, etc. The added strains that rapid climate change will impose on natural systems are best mitigated by raising the priority of conservation programs to levels of provincial and national urgency that have been sadly lacking up to now.

This edition of the NB Naturalist is intended to provide information on how nature – animals, plants, and ecosystems – is reacting to the changing climate, what we expect to see happening, how we should incorporate nature into our thinking about climate change and how we may increase nature's resilience. The articles we have included in this edition explore many changes we are observing in New Brunswick and highlight what we can expect in the future. The information provided is certainly not exhaustive, but it provides a look at what we are facing. It provides some ideas and directions on how we can incorporate nature into addressing climate change, for carbon storage as well as adaptation.

Swallows (Barn left, Tree right) are decreasing, which has been associated with climate change. Photos by Paul Mansz

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A Personal Perspective

Mike Lushington

Providing food and adequate protection from hostile elements are essential to all forms of life. Together with the biological imperative of any species to reproduce, they may be so defined, and all else may be considered by other values. So many of the things with which we surround ourselves come to be considered as necessities, whereas they are, to one degree or another, luxuries or add-ons. Regardless of one's economic, social, political, philosophical, or theological bent, most of us would agree that, should we have to choose two considerations for sheer survival, those choices would have to be an adequate food supply, and adequate shelter from the weather.

How then are we to regard those things that define "quality of life'? How many automobiles, or electronic devices, do we need? Is music essential? What about art? Sport or other forms of recreation? Philosophy, or theology, or any of the other intellectual or emotional stimuli that are considered to make life "meaningful"? The jobs that we define as essential are very often valued as much for providing us with the luxuries that make our lives more pleasant as they are for providing those absolute necessities.

I am no primitivist. I have no desire to retreat to a cave, or to hunt my food with a spear. (However I do cherish our large vegetable garden as much for the esthetic value of its produce as for its practical aspect). I consider many of the luxuries with which I surround myself to be fundamental to my own sense of well-being. I have my own list of ideas, concepts, even basic things and activities that contribute to this well-being. It is on this level that I value my own engagement with the physical world around me. And if one considers the role that "nature" plays in the collective life of human beings, past as well as present, I am unique only, perhaps, in my choices; the basic desire to appreciate things beyond our own physical existence is universal. Thus a polar bear, or a tiger, or a Monarch Butterfly, or the Song Sparrow that nests in the scrub behind our house is important to me, as much as a symbol as a being that I can actually appreciate. I associate with the more than seventy percent of Canadians who express value in the fact of our National Parks, even though (or perhaps "because") I will never get to actually experience a great many of them.

Hermit Thrush
Photo by Paul Mansz

I am diminished spiritually when I read of another great loss in the natural world – another species gone extinct, or another ecosystem compromised to the point of sterility. And, in a smaller and much more immediate way, I am, too, when I look for the Alder Flycatchers that used to share that patch of scrub with the Song Sparrows, but do so very rarely now, and some years not at all. I am diminished when I can no longer show my grandchildren the great flocks of swallows that used to line rural fences and power lines each fall, or when I can no longer show them the beaver pond that has been removed in the face of "progress". Thus, diminishing biodiversity affects us all in ways that we often don't even consider but that eat insidiously at our ability to value those creatures that constitute it in the first place, a value that is measured not only by practical or pragmatic scales, but intrinsically.

The sounds of a Mozart sonata and of a Hermit Thrush in the cedar swamp both linger in my soul long after the physical experience has passed. I do not want to accept that we must lose either, whatever the rationale.

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Climate Change Impacts on Birds

Peter W. Thomas
Becky Whittam
Greg Campbell

The impacts of climate change on plants and animals are real and growing. Impacts on birds are being documented at various life stages and are resulting in changes in abundance and distribution across varied landscapes. This article provides a brief overview of some of the known impacts, with a focus on boreal species and a New Brunswick rarity, the Bicknell's Thrush (*Catharus bicknelli*).

Birds are returning from their wintering areas earlier than ever. One Canadian study examined 63 years of data and determined that 27 of 96 species at Delta Marsh, Manitoba, had significantly altered their arrival dates (Murphy-Klassen et al. 2005). The timing of birds ar-

Bicknell's Thrush
Photo by Paul Mansz

riving from migration is often closely linked to peak resource availability, and changes in arrival dates can lead to a lack of food for feeding nestlings. A European study highlighted the mis-timing of food and nesting in the Pied Flycatcher (*Ficedula hypoleuca*). This species showed a 90% population decline over 20 years at sites where food available for feeding nestlings shifted to peak earlier in the season, but only a weak decline in areas with a late food peak (Both et al. 2006). Changes in phenology (life cycle events) can also result in some migrating species being out-competed for resources by non-migrating ones (Wittwer et al. 2015). Since resident birds do not migrate, they may more easily adjust to the effects of increasing spring temperatures than long-distance migrants. However, this is not always the case (see Gray Jay story, below).

In addition to timing mismatches, breeding distributions have also shifted for many species. A study by Hitch and Leberg (2007) indicated that the northern limit of birds with a southern distribution had shifted northward by an average of 2.35 km per year.

Boreal Birds

The boreal forest is one of the largest biomes on earth and provides ecosystem services on a local, national and global stage. While the boreal forest is traditionally considered to be found north of the 50th parallel and thus north of New Brunswick, our province does feature boreal-like forest in highland regions where species like Bicknell's Thrush, Boreal Chickadee (*Poecile hudsonicus*) and Blackpoll Warbler (*Setophaga striata*) breed. Two thirds of the worldwide boreal forest is managed by the forestry industry and thus, in some areas, has become heavily homogenized and less able to react to dramatic environmental changes (Gauthier et al. 2015). Scientific studies indicate that climate change within the boreal forest has increased wetland dry-

Boreal Chikckadee
Photo by Peter Thomas

Boreal New Brunswick
Photo by Peter Thomas

ing (Klein et al. 2005) and tree mortality caused by drought and insects (Allen et al. 2010). Correspondingly, wildfires have also increased across the biome (Soja et al. 2007). This may lead to a reduction in the overall area of the boreal forest as the southern limit pushes farther and farther north, providing less breeding habitat for boreal bird species.

Modeling and predicting the impacts of climate change on the boreal forest are difficult as the factors being modeled are extensive and have a high level of uncertainty. Stralberg et al. (2015) launched a comprehensive modeling effort for the boreal forest of Canada and incorporated as many variables as possible while also accounting for the variability and uncertainty involved in a modeling exercise of this scale. They noted a wide range of projected changes and uncertainty across species. Their results stress that climate change responses by birds will be very species-based and a one-size-fits-all approach to species conservation will be difficult to implement. Multiple adaptive approaches will be needed, which will greatly challenge governments, scientists, and conservation organizations involved in habitat and species conservation.

One example of the complexities involved with assessing climate impacts on boreal birds can be seen in the recently appointed national bird of Canada by the Canadian Geographic – the Gray Jay (*Perisoreus canadensis*). The Gray Jay is uncommon but widely distributed across Canada's northern forests, including New Brunswick. They maintain a permanent, all-purpose territory within challenging boreal environments, and use scatter-hoarding (hiding of food in various locations such as behind bark or tufts of lichen) as a tool to get them through the leaner times of the year. It has been widely believed that their hoarding behaviour may help buffer Gray Jays against changes in food availability. However, Sechley et al. (2015) highlighted that Gray Jays are susceptible to 'hoard-rot' when their food stashes are exposed to warming temperatures during the fall, which greatly decreases the caloric content. This loss of food resources in the fall could impact winter survival, but has also been linked to a delayed start to breeding in the spring, resulting in lower productivity (Waite and Stickland 2006).

Gray Jay
Photo by Peter Thomas

The Stralberg et al. (2015) model for the Gray Jay indicates relatively high density being maintained as far south as the North Shore of Quebec until about 2040 when density drops significantly over the subsequent 60 years. By the year 2100, the Gray Jay is projected to be virtually gone south of Schefferville, Quebec in eastern Canada, and with densities far below present levels in the north. Indeed, the second Atlas of Breeding Birds of the Maritime Provinces shows declines in Gray Jays in New Brunswick since the 1980s, which may be evidence of climate impacts here (Elliot 2015).

Climate change and the Bicknell's Thrush in New Brunswick

Moving to a more local scale and context, the Bicknell's Thrush is a rare neotropical migrant that is limited to high elevation spruce-fir habitat in northeastern North America, with a population numbering somewhere between 40,000-50,000 individuals in Canada (Townsend et al. 2015), including about 2,000 individuals in the high elevation forests of New Brunswick. Because of its reliance on high elevation habitat, and its very restricted range and low population size relative to other neotropical migrant birds, this species is seriously threatened by climate change. In fact, habitat loss due to climate change is ranked as one of the three most significant threats to Bicknell's Thrush, according to the International Bicknell's Thrush Conservation Group (Lloyd and McFarland 2017). Models predict that most or all breeding habitat for Bicknell's Thrush is at risk from climate change due to the sensitivity of Balsam Fir to increased temperature (Rodenhouse et al. 2007, Irfan Ashraf et al. 2015, Boulanger et al. 2016). In New Brunswick, some climate models predict that Balsam Fir could virtually disappear from the province in as little as 80 years.

While habitat loss is the most serious impact of climate change, increasing temperatures may also have indirect effects on Bicknell's Thrush. Climate change may disrupt an important interaction between Red Squirrels and Bicknell's Thrush on the breeding grounds. In a warmer climate, Balsam Fir may produce cones more frequently, and allow larger populations of Red Squirrel to exist across the Bicknell's Thrush breeding range. Predation on eggs and young by Red Squirrels can cause widespread reproductive failure among Bicknell's Thrush in some years, and any ecological change that allowed Red Squirrel populations to increase in high elevation forests within the breeding range could cause steep and rapid declines (Townsend et al. 2015).

Climate change may also lead to more interactions between Swainson's Thrush (*Catharus ustulatus*) and Bicknell's Thrush on the breeding grounds. Swainson's Thrush numbers have been increasing significantly in high elevation forests in northeastern North America, while Bicknell's Thrush numbers have been decreasing (Ralston et al. 2015). Overlap in breeding habitat of Swainson's Thrush, which may be a superior competitor, and Bicknell's Thrush is thought to be limited by lower tolerance to cold in Swainson's Thrush. Climate change may allow greater degree of overlap and potential for increased interspecific competition. However, competition between the species has yet to be proven.

Like for other bird species, warmer springs may lead to a disconnect between the phenology of important insect species eaten by Bicknell's Thrush and the date at which Bicknell's Thrush return to the breeding grounds, causing mis-timing of maximum prey availability and Bicknell's Thrush nesting. Although studies of other species have implicated phenological mis-timing as a cause of steep and rapid declines (Both et al. 2006, Jones and Cresswell 2010), other studies have shown that some species are able to adapt to mismatched phenology at a population level (Reed et al. 2013). This suggests the consequences of changing phenology may be species-specific, and no information is available regarding this phenomenon in Bicknell's Thrush.

Potential impacts of climate change on individual species are difficult to predict. There is often a range of interacting factors that can influence any demographic parameter (Crick 2004). However, in the case of Bicknell's Thrush, all signs are pointing towards a population decrease and potential extirpation of the species in New Brunswick.

The Future – Planning for climate change

The amount of literature on the potential impacts of climate change on species and ecosystems is substantial and growing, but there is relatively little information on landscape planning in preparation for changing climatic conditions. Conservation strategies for birds and other wildlife are often established by specialists and specialized institutions without fully considering the potential impacts of climate change, usually because accounting for the variability and scale of impact is challenging and difficult to incorporate. The longstanding approach to conservation and protection of species and habitats has been focused on habitat preservation and historical restoration. It may be time to shift these paradigms to one that is more open to anticipating change, and perhaps even facilitating landscape-level change in anticipation of climate-driven changes. There is still much to be learned about the birds of our region and how landscapes (and changes to those landscapes) drive their distribution and abundance. There are fundamental questions around change thresholds in ecological systems that will dictate whether we can and should manage for change or for maintaining existing ecosystem structure. More research and investigation is required to seek out these thresholds, and to gain more insight into how and when to switch our paradigm of conservation management in Maritime Canada in the face of climate change impacts.

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Invasive Species and Climate Change

David Mazerolle

Humans have always carried other organisms along on their travels, whether they be plants, animals, bacteria or viruses. Our recent mastery of ocean and air travel, however, has caused this mixing of the world's biota to occur at an ever-increasing pace.

A substantial portion of New Brunswick's wildlife is made up of relative newcomers, brought here intentionally or accidentally through human movements. In fact, over 30% (roughly 600!) of all plant species now found in the province didn't exist here before European settlement. While most new arrivals don't survive in our climate, some do become established and a small portion thrive in their new environment, becoming abundant and spreading into natural areas, predating on or out-competing native species, causing disease and becoming agents of change in our ecosystems. These invasive species can cause irreparable ecological damage and are considered one of the foremost threats to biodiversity worldwide.

Those of us who track the status of rare species and work to protect our natural heritage know that a considerable number of invasives have already had a profound impact in our region. There is no shortage of examples. Diseases caused by introduced fungi and insects, such as Dutch Elm Disease, Beech Bark Disease and Butternut Canker have changed the very composition of our forests. Glossy Buckthorn, a European shrub, is aggressively spreading in many counties, crowding out native woodland and wetland plant communities. European Green Crab is now established in many of our estuaries, where it feeds on shellfish and tears up the Eelgrass beds that provide shelter to numerous aquatic animals. Some particularly destructive species lie just beyond our borders. Such is the case for the Asian beetle Emerald Ash Borer, which will foreseeably spread to our province within a decade and by all indications may effectively eliminate all three of our native ash species.

As a driver of change in species distributions, direct human intervention is perhaps second only to climate change. Indeed, the spread of some invasives in our province, such as the European Green Crab and tunicates, is known to have been facilitated by warming trends. Many problematic species found in southern Quebec and New England have largely been kept at bay by our harsher winters. Ongoing warming of our air and water temperatures will undoubtedly allow some to settle here and spread. As such, we must keep an eye to the south in anticipation of future invaders.

Glossy Buckthorn
Photo by David Mazerolle

At present, human-caused climate change is allowing native New England species to extend their ranges northward into our province, blurring the line between natural migration and exotic species invasions. Should these species be considered welcome additions to our flora and fauna? What of our commitment to the rare species and ecological communities that may be further imperiled by their arrival? Global warming is affecting profound changes in the composition and function of our ecosystems, which may require us to rethink our perception of the "natural" world. Addressing these questions will be key in our adaptation to climate change.

Faced with the enormity of this situation, it's difficult to keep a positive outlook. But there is hope; as public awareness grows, federal and provincial agencies are increasing their commitment, environmental NGOs are becoming increasingly active in survey and control efforts, and new tools for detection and control are becoming available. On a local level, the recent revival of the NB Invasive Species Council is also a promising development.

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Health Risks and Climate Change

Dr. James P. Goltz

Climate change will undoubtedly pose risks to human and animal health, as experiences and observations are verifying predictions made through foresight exercises and climate change modelling. The major health risks associated with climate change are likely to be physical (e.g., hyperthermia and/or hypothermia related to extreme temperatures; traumatic injury from extreme weather events such as flooding, wind and storms; cardio-respiratory problems from allergens and smog) and infectious diseases, especially those borne by arthropod vectors, or resulting from water contamination after intense rainfall or food contamination during hot weather (PHAC, 2017).

Vectors of disease are organisms that transmit disease from one living organism to another. The arthropod vectors of disease of greatest concern to humans in regard to climate change are mosquitoes and ticks. Arthropod vectors and the diseases they can potentially carry are likely to spread poleward as climate warms in temperate areas; tropical and subtropical vector-borne diseases are more likely to be introduced into and become established in areas that are currently temperate; sustained warmer temperatures will increase the likelihood of vectors and vector-borne diseases being spread by increased human migration related to climate change, and surviving throughout the year and becoming more abundant in new areas; and new genetic variants of vector-borne pathogens are likely to emerge and become established as dynamics between animal hosts and vectors change in the new environments (Ogden & Lindsay 2016).

Populations of ticks and mosquitoes (and the diseases they carry) are likely to be affected by climate change, although in somewhat different ways. Mosquitoes are highly mobile and can be dispersed by wind and air, have a short life cycle of several weeks, and can respond quickly to short-term changes in weather and climate; mosquito populations can explode in response to rainfall and warm temperatures, resulting in emerging and re-emerging epidemics of the diseases they can transmit (e.g., West Nile Virus, Eastern Equine Encephalitis). Ticks rely on dispersal via mammalian and avian hosts, have a multi-year life cycle, tend to be generalists with respect to their hosts and suitable woodland habitats, and spend much of their life in habitat refuges; tick populations do not respond rapidly to rainfall and temperature due to long life cycles, so the risk of tick-borne diseases is usually long-term with little variation from year to year (Ogden & Lindsay 2016).

Which arthropod vectors and their diseases are of greatest concern to us as climate changes? The Asian Tiger Mosquito (*Aedes albopictus*) has spread from Asia to all continents except Antarctica, breeds in sheltered containers (e.g., water pooled in water storage

Left: Black-legged Tick (Ixodes scapularis)
Right: American Dog Tick (Dermacentor variabilis)
Online images (Flickr by Lennart Tange, Wikimedia Commons)

tanks, tires, bottles, or aquaponics containers) and is capable of transmitting at least 11 different diseases including dengue, West Nile virus, chikungunya, Japanese Encephalitis and Eastern Equine Encephalitis. The Yellow Fever Mosquito (*Aedes aegypti*) spread from Africa to become established worldwide in tropical and subtropical areas, thrives in areas of human cohabitation where it breeds in artificial containers, and is capable of transmitting diseases such as yellow fever, dengue, Zika and chikungunya (NCCID 2017). Small sporadic outbreaks of malaria have been transmitted by local species of anopheline mosquitoes in New York and New Jersey in the 1990s; malaria caused nearly 500,000 deaths globally in 2015 (WHO 2017). The Black-legged Tick (*Ixodes scapularis*) is capable of transmitting Lyme disease, several other Lyme-like Borrelioses, human granulocytic anaplasmosis and Babesiosis; this tick species is annually dispersed throughout New Brunswick by migrating birds, but the greatest risk for exposure to Black-legged Ticks and the diseases they carry is currently in the vicinity of Saint John, Grand Manan and St. Stephen. The American Dog Tick (*Dermacentor variabilis*) is capable of transmitting Rocky Mountain spotted fever, ehrlichiosis and tularemia; this tick species is well-established in Nova Scotia and southern Maine and reports from New Brunswick are increasing.

The best tools and strategies to help prevent health problems related to climate change are knowledge, education (including preventing arthropod bites), surveillance, and collective action by individuals, municipalities, provinces and countries around the globe to help reduce the risk of climate change.

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Life's a Gas

The Story of our 4.5-Billion-Year-Old Atmosphere(s)

Donald MacPhail

In the beginning, there was no climate. The Earth was without atmosphere and void of oceans. Our planet was too hot to touch and incapable of supporting life.

As the Earth crusted over, volcanic activity became intense. Volcanoes, as they do today, spewed far more gas and steam than lava. These gases formed our early atmosphere and the steam, as it condensed, formed our oceans. But this atmosphere was not the comfy cushion of gases we take for granted today.

Our atmosphere today, if we ignore a dozen gases that make up about 1% of it, is 80% nitrogen and 20% oxygen. But volcanoes primarily spew carbon dioxide, methane, water vapour and minor amounts of nitrogen.

So how did our atmosphere get to be like it is today?

It evolved. Just as we have evolved, our atmosphere has evolved. Recent research into our planet's past, coupled with what we now know about the atmospheres of other planets, indicates a fascinating history. Maybe surprisingly, life and our atmosphere have heavily influenced each other; they appear to have co-evolved.

It wasn't long after our oceans formed that life first appeared in them. All life for the first couple of billion years was single-celled and microscopic. It thrived in the oceans that were kept warm by the dense carbon dioxide and methane-rich atmosphere and the greenhouse-like conditions those gases created. In fact, it is likely that without these greenhouse conditions the Earth's temperature would not have been within the so-called "habitable zone" where life is possible.

Starting about two and a half billion years ago, certain living organisms began to have an impact on the atmosphere that had enabled them to exist. These were not modern, large, highly complex organisms; they were microscopic, aquatic organisms. These first climate changers were the blue-green algae, now known as cyanobacteria. Around three billion years ago, half a billion years after life first appeared on Earth, they "invented" photosynthesis.

Photosynthesis was a good idea, but, like many good ideas, it had consequences. The major consequence is that photosynthesis produces oxygen as a waste product. For half a billion years or so, the oxygen was absorbed by the abundant iron that was found on the surface of the Earth or in the water. Eventually though, with the cyanobacteria continuing to thrive and produce oxygen, but with no more iron to oxidize, something had to change. With nowhere else to go, the oxygen stayed in the atmosphere, increasing slowly to about 20% of the atmosphere like it is today. This oxygenated air became our present Earth's atmosphere – but triggered what biologists refer to as the Great Oxygen Catastrophe.

It was a catastrophe because oxygen was lethal to most organisms and many went extinct. Of course, other species, including our direct ancestors, adapted and thrived on the new opportunities provided by the oxygen-rich environment.

The basic ingredients of this atmosphere have not changed since the addition of oxygen starting more than two billion years ago. What has varied considerably is the relative abundance of the gases. Two of those gases – oxygen and carbon dioxide – have been critical to the development of life.

Oxygen, a waste product of photosynthesis, has been increasing for more than two billion years, but only slowly. Even 500 million years ago, at what has become known as the Cambrian Explosion when multi-cellular life became abundant, the oxygen content of our atmosphere was just 15-20% of its current level. Cambrian-aged New Brunswickers would have had less oxygen to breathe than those who get to the top of Everest today.

Many scientists believe that large complex life could not move onto the land until oxygen levels in the air increased even further. The level of oxygen in Earth's atmosphere which was required to support the metabolism of such creatures was reached "just" 350 million years ago – approximately the age of the oldest known amphibian fossils.

Carbon dioxide levels have varied too, but have been more variable than oxygen. Comprising as much as 25% of our atmosphere at one time, carbon dioxide has been on a long, generally downwards, decline towards the trace amount of around 0.04% today. Even within the last few million years, carbon dioxide levels have, at times, been several times higher than they are today. Much field research is going on in this area now, but there is evidence from 30 million years ago that there were palm trees in the Arctic and from 10-15 million years ago that there was a short period of +10°C average summer temperatures in the Antarctic.

The geological record often shows that changes in carbon dioxide occurred very gradually, but it also shows instances of very rapid changes. Changes have been linked to the start or end of ice ages, variations in solar activity, movements of tectonic plates which periodically cause increases or decreases in volcanic activity, and occasional cataclysmic impacts with asteroids. And now to us as well.

For 3.5 billion years, life on Earth has been shaped by our atmosphere and oceans; in the last one-tenth of that time, life has increasingly shaped the oceans and the atmosphere in a process that is accelerating exponentially in this industrial age.

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Lack of Plankton, Climate Change and its Implications for Right Whales

Laurie Murison

A warming trend in 2012 saw higher than normal winter temperatures, hardly any snow, and therefore little spring runoff carrying essential nutrients for phytoplankton into the Bay of Fundy, Gulf of Maine and coast of Nova Scotia. This led to a severe reduction in the phytoplankton bloom that year which has sent continuing ripples through the Bay. Subsurface water temperatures increased by 2.5°C in 2012 as recorded by tags towed by basking sharks (Koopman et al. 2014). Variations in water temperature also change circulation patterns which can change the quantity and location of summer/fall accumulation of zooplankton produced in the Bay, and brought in from other areas such as the Gulf of Maine and Scotian Shelf. Water temperatures did decline after the abnormal 2012 readings, with 2017 1° C colder than normal.

Following 2012, summer/fall *Calanus* copepods, which eat phytoplankton and are important zooplankton prey for such species as herring, storm petrels, phalaropes, basking sharks and Right Whales, began to decline in the Grand Manan Basin between Grand Manan and Nova Scotia, where they typically accumulate in a counter current gyre (spiral). *Calanus* numbers remained low until 2016 when higher densities of copepods were measured, only to fall again in 2017. From 2013 to 2015, the normally pinkish-orange copepods were pale, without the necessary oil globule that allows them to overwinter, mature in the spring to reproduce, and to be nutritious prey. The energetic value of the copepods declined 23% during that time (Grand Manan Whale & Seabird Research Station, unpublished data). The quantity of copepods was also reduced during this period by invasions of jellies and comb jellies that are voracious plankton eaters, less in 2016 but returning in 2017. Zooplankton in 2016 and 2017 looked darker in colour although in 2016, the samples started to become paler as the fall approached.

Basking Sharks, as determined by satellite telemetry (Grand Manan Whale & Seabird Research Station, unpublished data), were not staying in the Bay for any length of time during this period. Herring were also affected by the warmer water temperatures with the fish staying in deeper, cooler waters. As a result, the distribution of seabirds and herring-eating whales adapted, concentrating in areas where prey could be found, such as off White Head Island and further south. In 2016 there was an unusually consistent occurrence of humpback whales from June through late December south of Gannet Rock. The ferry ride between Blacks Harbour and Grand Manan became a meagre trip for wildlife sightings, until 2016 when more wildlife moved north of Grand Manan following the herring. Unfortunately, this was also when nesting puffins failed to find sufficient appropriately-sized fish to feed their pufflings, and chick survival rates plummeted. In July 2017, an area south of the Wolves Islands had a brief influx of Right Whales, followed in August by Humpback and Finback whales.

Since 2012 Right Whale occurrence in the Bay has been unpredictable. Right Whales usually visit the Bay to feed on copepods but in 2013 and 2015 few Right Whales were seen in the Bay of Fundy; in 2014 Right Whale numbers were normal for three weeks

Right Whale
Photo by Laurie Murison

Right Whale, scarred tail
Photo by Laurie Murison

prompted the Canadian government to require vessels 20m and longer to slow to 10 knots in parts of the Gulf where Right Whales were present. Several vessels have been fined for exceeding the speed limit and some cruise ships have opted not to stop at Charlottetown, PE, in September and October. Growing numbers of Right Whales have recent entanglement scarring, have been observed dead when entangled in fishing gear in the Gulf, or have been disentangled. For example, Right Whale "FDR" in 2016 had a complicated tangle of rope that the whale brought to the Bay of Fundy from the Gulf. Fisheries and Oceans Canada reacted to the deaths by closing the snow crab fishery a week early, and restricting other fixed-gear fisheries to near shore and shallow waters. Regrettably in mid-July, 2017, disentanglement of Right Whales was suspended in Canada and the U.S. pending an investigation into the death of one of the disentanglers after he was accidentally hit by the whale's tail. Joe Howlett, co-founder of the Campobello Whale Rescue Team, had successfully freed the Right Whale off northern New Brunswick before he was killed in the ill-fated accident.

only, and it wasn't until 2016 that they stayed in the Bay from July through October. In 2017 Right Whales were present initially in July but then disappeared. Low prey availability has long-term effects on Right Whales since thin females will not get pregnant. Only five Right Whale calves were recorded in 2017, reflecting this. The large increase in the Right Whale population, from under 300 in 2000 to over 500 individuals during a baby boom, has stopped and is now declining.

For the podcast "Deep Trouble" please visit:

http://www.cbc.ca/radio/podcasts/new-brunswick/deep-trouble/

WHERE DID THE RIGHT WHALES GO TO FEED? Large numbers were found in the Gulf of St. Lawrence, a former traditional area for Right Whales before their numbers were reduced by whaling, and, prior to 2012, used by small numbers of Right Whales. Research efforts were increased in the Gulf of St. Lawrence to try to document this. Unfortunately, vessel traffic and fixed fisheries, such as snow crab, were also common where Right Whales were feeding. In 2017 alone, at least eleven dead Right Whales have been discovered in the Gulf, with an additional three in U.S. waters, approaching 3% of the population. Three of the initial necropsies showed vessel strike and entanglement as the causes of death which

With systems constantly in flux, and many additional complex interactions and variables such as jet stream abnormalities, melting ice caps and changes in the North Atlantic Oscillation (index based on the surface sea-level pressure difference between the Subtropical High and the Subpolar Low), consequences of warmer waters may mean species occur in new areas and are replaced by other species in former areas. It is not fully understood what new equilibrium will be established and at what cost.

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Living and Working on Changing Waters

Management Complexity in the Bay of Fundy and Climate Change

Olivia DeYoung
Matthew Abbott

Change is the norm in coastal waters. Anyone involved in fishing, whale watching, bird watching, or any outdoor activity on the Bay of Fundy knows this well. Even when things are relatively stable, it takes a great deal of local knowledge, and some luck, to track down marine animals, be it fish, whales, or birds. Human activity has affected our coastal waters significantly, but the real and growing impacts of climate change create increasing challenges for conservation efforts, marine tourism, and fisheries.

Climate change occurs when long-term weather patterns are altered. This change means that marine species are now up against rising ocean temperatures and acidity levels, and decreasing salinity and oxygen levels, which can lead to changes in spatial distribution, community assemblages, and timing of key life events (Brzeski, 2013). Habitat suitability for many species will change, resulting in opportunities for invasion and range expansion.

There are different ways organisms respond to changes in temperature and salinity, but a shift in spatial distribution is one of the predicted first responses. If waters warm and habitat becomes unfavourable, mobile marine organisms may move to more favourable habitat. There have been shifts in the spatial distribution of fish that have been detected in the Northwest Atlantic - fish stocks studied have shifted their center of biomass northward or are now found at deeper depths, but the temperature at which these species have been found has not changed (Nye, 2010).

As temperatures warm, the timing of ecological events may also change. Spring conditions may arrive earlier for marine organisms and fall conditions may arrive later. There is evidence this is already occurring in the Gulf of Maine and Bay of Fundy. Many organisms time their migration and spawning to changes in ocean temperature, meaning that, as temperature and salinity change, organisms will shift the timing of spawning and migration. Species may shift these events so that they are out of sync with other elements of the ecosystem, such as the occurrence of prey, leading to situations where, for instance, key prey species may remain abundant but are not present when their predators have historically needed them.

Species such as Atlantic Cod, Pollock, Plaice, and Winter and Yellowtail Flounder have all retreated to cooler waters in the southeastern part of the Gulf of Maine in the past decade (Woodard, 2015a). Northern Shrimp are declining, with increasing water temperatures and a decline in phytoplankton abundance identified as possible culprits (Lapointe, 2013). Ocean acidification could also have a significant impact on the lobster and clam fisheries through changes in calcium carbonate availability in the environment, which can impact shell development and growth.

Another ecosystem change affecting the Gulf of Maine and Bay of Fundy is the addition of new invasive species, which will also impact

Green Crab
Online image (Wikimedia Commons)

Bay of Fundy
Photo by Meredith Clayden

the region's commercial fisheries. Green Crab has been taking over parts of the Gulf of Maine since 2012, tearing up Eelgrass and coastal mudflats and eating almost every clam and mussel they can find (Woodard, 2015b). The crabs were fueled by record-high water temperatures in 2012 and a mild winter in 2013. The Pancake Batter Tunicate is another species which is becoming more common in New Brunswick waters. These blob-like sea squirts grow in dense colonies that spread across the seafloor and smother native creatures. It is believed that the tunicate was brought to New England by shellfish farmers using Asian Oysters (Woodard, 2015b). The tunicate used to die back each winter, but with warmer waters, has expanded its range over large swaths of bottom from the Passamaquoddy Bay to Georges Bank.

Fisherman loads traps on the first day of lobster season
Photo by Matt Abbott

Some of the more southern species beginning to show up in the Gulf, like Black Sea Bass and Longfin Squid, may present a new opportunity for commercial harvest. What impact these fish will have on native species remains largely unknown.

Responsible management of marine waters has always been difficult and it will only get harder. It is critical that the conservation community work with fisheries, the tourism sector, and government to do the important work of making tough decisions in a changing Bay. Despite these challenges, though, the Bay of Fundy has a lot going for it. It has the building blocks of a vibrant and dynamic ecosystem: high tides driving strong nutrient flows, diverse sea bottom habitat, and, importantly, the Bay of Fundy has a lot of people in its corner.

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BiotaNB

Counting Life while New Brunswick Burns (or at Least Warms)

Dr. Donald F. McAlpine

Climate change is upon us; increased temperatures, more intense precipitation, rising sea levels, coastal erosion and storm surges. Average annual New Brunswick temperature has risen by 1.5° C over the past century, with 1.1° C of that increase taking place over the past 30 years. "Earth is a planet in upheaval due to human-caused changes in the atmosphere," says Jeffrey Kargel, a glaciologist at the University of Arizona. Research suggests the world is warmer now than it has been in 115,000 years and that it has been 4 million years since atmospheric carbon dioxide levels were as high as they now are. The evidence is indisputable, even for the most ill-informed. So what will this mean for the life-forms that we share the province with? Tree species are predicted to change, forest fires to increase, and we will likely see an increase in new and invasive species. Reports of increasing infections of sea lice on penned salmon in New Brunswick have been attributed to warming waters. But the details remain murky and the short answer is that we really don't know how climate change will affect biodiversity in New Brunswick. Measuring environmental change requires a baseline, and in many respects the biodiversity baseline for New Brunswick is woefully inadequate.

Although we have a pretty good idea, in some cases even a detailed understanding, which green plants (trees, shrubs, wildflowers) and which vertebrates (fish to mammals) populate New Brunswick, where they might be found, and their relative abundances, green plants and vertebrates make up only about 6% of the biological diversity of the region. Most of our biodiversity is found among the arthropods (insects, mites, spiders; 72%) and the fungi (mushrooms, molds, lichens; 12%), groups that remain poorly known, in spite of their tremendous influence on the ecosystems around us. In fact, researchers are still discovering and describing entirely new species of insects and fungi from New Brunswick.

Many of these recent discoveries are outcomes of BiotaNB, a biodiversity project organized out of the New Brunswick Museum that was initiated in 2009 and that will conclude in 2029. The project was designed specifically to help lay the groundwork for a New Brunswick biodiversity baseline that is still largely lacking. But even if we had already documented every fungus and every creeping and crawling thing in New Brunswick there would still be good reasons to keep counting. Biological diversity is in a constant state of flux, and with climate change now clearly underway, tracking changes in biodiversity has become ever more important.

BiotaNB includes four components; scientific discovery, student mentoring, an artist-in-residence program, and enhanced public stewardship. The project focuses on New Brunswick's Protected Natural Areas (PNAs), of which there are now 208, nearly all on Crown Land. But it is the 10 largest PNAs, ranging from 2,823 to 26,022 hectares in size that are the priority for BiotaNB. These are large areas; consider, for comparison, that Fundy National Park encompasses 21,000 hectares. Working in PNAs makes strategic sense.

Kendra Driscoll, a young lichenologist who has worked closely with Dr. Stephen Clayden (background), samples lichens in the Grand Lake Meadows PNA in 2014. With others, they described a new species of lichenicolous fungus from New Brunswick cedar swamps in 2016. Over-harvesting has greatly reduced the cool-climate cedar swamp habitats of New Brunswick on which these species depend.

The expectation is that these sites will be conserved, largely undisturbed, in the long-term. This means they can be re-visited and the biodiversity of each re-assessed in the future. PNAs include some of the last old growth forest stands in New Brunswick and therefore may harbour unique assemblages of species. The New Brunswick PNA inventory includes sites representative of many different forest and freshwater wetland types, spread geographically across the province. However, while the focus for BiotaNB may be the PNAs, as the climate warms the data collected can also be applied across the larger New Brunswick landscape.

In each of two consecutive field seasons, generally of 14 days each year, 50-70 BiotaNB participants converge on a PNA. Participants have ranged in age from 17-78 and have journeyed from across North America and beyond – a lichenologist from Maine, a mycologist from Prince Edward Island, a slime mold specialist from Pennsylvania, mollusc experts from British Columbia and France, earthworm and ant experts from Ontario, mammalogists from Texas and Kansas, and of course all the local expertise that can be mustered. Locally rented space provides accommodation and mess hall areas, and most importantly, room for a well-equipped field lab that requires months of prior planning and preparation.The goal is to document and study intensively a wide a range of fungal, green plant, and animal taxa, but especially those groups of organisms that are most diverse but also most poorly known. And the results have been impressive – every year since 2009, initially with the support of the Salamander Foundation and others, BiotaNB participants have discovered species new to New Brunswick, new to Canada, new to North America, and yes, even entirely new to science.

Operating on a budget of $80 -100,000 annually (with principal recent support from the New Brunswick Environmental Trust Fund and New Brunswick Wildlife Trust Fund and the New Brunswick Fish and Wildlife Branch) the project has now contributed data for some 33 papers in scientific journals. The work has generated $1.3 million in volunteered time, mainly from biodiversity experts. An estimated 2,600 field days have been spent in the four PNAs investigated so far (that's about 7 years of time!).

While generating new biodiversity information is the primary goal of BiotaNB, providing students with an opportunity to work with world-class biodiversity experts is also an increasingly important aspect of the work. If New Brunswick is to meet its Climate Change Action Plan goal of building knowledge through data collection, monitoring, and research it will need to draw on biodiversity expertise well into the future. We know, though, that the average age of

Gart Bishop and Jim Goltz exploring the Caledonia PNA in 2011 Photo by Sabine Dietz

biodiversity experts in Canada is increasing. Many are near or past retirement age. Annually 6-10 students, both graduates and undergraduates, have had an opportunity to work with BiotaNB biodiversity experts. Some of these students have pursued further studies in the biodiversity sciences and some have continued to be involved with BiotaNB, now returning as young experts themselves.

If people don't care, even the best Climate Change Action Plan or the most detailed PNA management document can't guarantee the protection of our wild places and their biodiversity. Science is certainly one way to look at the world, but art is another. Art can touch people emotionally in a way that science rarely can. Without emotional connections to our PNAs it's hard to imagine the long-term future of these sites is assured. With this in mind, BiotaNB introduced an artist-in-residence program in 2010. Since then, 2-5 artists have joined researchers in the field each year. Most of these have been visual artists such as painters and photographers, but a poet and a quilt-maker have also been among them. BiotaNB has made special efforts to engage with the First Nations Community and several indigenous artists have joined us. The premise behind this program is that artists document the landscape, the flora, and the fauna; all central features of New Brunswick PNAs that warming temperatures may change irrevocably. So far the New Brunswick Museum has purchased 55 artworks produced during the BiotaNB project, with the intention that this art will be used in future public exhibits about PNAs and biodiversity. A book of BiotaNB poetry is on the way.

Enhancing the public stewardship of New Brunswick's conservation lands needs to be a high priority. Each year, near the end of the BiotaNB field period, a four hour open house for the general public is held at the BiotaNB lab. This provides an opportunity for those resident near the PNA under study to meet and talk with researchers, artists and students, share in discoveries, and see completed artwork or artwork in progress. A documentary produced for CBC TV, filmed during the 2013-14 BiotaNB program in the Grand Lake PNA, is being screened in communities across New Brunswick. The film was shown recently at a United Nations Biodiversity meeting in Mexico, and there have been several European screenings. With a national biological inventory program (Bioblitz Canada 150; www.bioblitzcanada.ca) being launched this year, 2017 will provide additional opportunities to introduce the public to New Brunswick biodiversity and the impacts that climate change will have on the life around us.

The BiotaNB 2015 participants gather in the Nepisiguit River. The Nepisiguit PNA was inventoried biologically in 2015-16. Rare and new species discovered on cool talus and mountain tops within this PNA will be under threat as temperatures rise.

Over the past decade, Dr. Reginald Webster, a Fredericton-based entomologist, has been responsible for documenting many hundreds of beetle species new to New Brunswick, including new species from cool-climate microhabitats that may well disappear as climate warms. Here, having poured water over a mossy boulder in Crooked Creek in the Caledonia Gorge PNA in 2011, he examines the rock for small beetles exiting the moss habitat.

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Safety Concerns in Nature Preserves

Climate Change Impacts, Public Access and Recreation

Anne Henderson

The Nature Trust of New Brunswick (Nature Trust), an established charitable, not-for-profit organization, works to conserve lands across the province. Since 1987 the organization has managed to help protect over 7000 acres on 50 nature preserves throughout the province with a vision of maintaining habitat for many of New Brunswick's at-risk and native species in perpetuity. As a manager of these lands, the Nature Trust permits visitors on their preserves at their own risk. The Nature Trust wants to ensure that public safety remains a priority for their visitors, volunteers, land stewards, and staff. There is a growing concern that the impacts from climate change may pose threats to public safety on some of these preserves now and into the future.

This report presents potential risks and hazards that climate change may pose to the visiting public on Nature Trust preserves and offers low-impact management options.

Shoreline erosion, for example, is a naturally occurring phenomenon which has been accelerated by some of the effects of climate change, including sea-level rise, flooding, storm surges, and extreme rainfall events (Atkinson et al. 2016). Wave heights have also increased due to sea-level rise during storm surges, and this has an impact on erosion rates especially in low lying areas (Pereira and Coelho 2013). Coastal preserves vulnerable to erosion are often frequented by visitors who follow trail systems to gain access to coastal views, but eroded and undercut cliffs and banks can be very unstable creating hazardous conditions. Increasing native vegetation can reduce this risk; however the success of planting vegetation to mitigate erosion is highly dependent on the choice of plant, shore type, and expected wave heights. Sites with a diversity of vegetation are less vulnerable to erosion. Plant root systems help stabilize soils and the above-ground growth slows the movement of flood waters allowing sediment to settle rather than being washed away (Harris 2010).

Storm surges have become more frequent and intense in Atlantic Canada over the past decade (Daigle 2012). While storms can be tracked and paths can be predicted, the potential impacts are often unknown. Travelling through the woods during and after a storm poses many risks. Trees and large branches can cause injury, flooding could prevent escape from the area, and coastal waves can create extremely dangerous scenarios.

Minich Preserve
Photo by Anne Henderson

Appropriate stormwater management strategies on inland preserves can be an effective way to reduce the impacts from flooding and extreme precipitation, as predicted by climate change. Low-impact strategies such as improving the function of existing ditches and culverts or increasing the water flow can help mitigate flood risks.

Protecting tidal marshes and wetlands in coastal preserves is vital for mitigating some of the impacts of climate change. Ensuring available land exists to compensate for inland migration of these habitat types, as a result of sea level rise, will not only provide wildlife habitat into the future but will also act as buffers protecting valuable coastlines from climate change impacts such as flooding and storm surges (Savard et al. 2016).

Temperature rise is also causing concern, as summer months will be hotter, and winter snow and ice packs could be less stable. Visitors to preserves who are unprepared for extreme heat could be at risk of suffering from heat stroke, dehydration, exhaustion, and other heat-related illnesses. Advising recreational users on appropriate measures to take in extreme heat such as proper outerwear and having adequate amounts of water will decrease their risks in extreme heat.

The risk of forest fires across Canada is predicted to increase as a direct result of the changing climate, although this risk is not predicted to be uniform across all regions (Boulanger et al. 2013). The Nature Trust does not allow campfires on their preserves, but monitoring and enforcement of this rule can be challenging at some of the more remote preserves. Studies suggest that factors such as tree death due to an increase in insect invasion, severe winds or stress will add to a buildup of dead wood on the forest floor increasing the potential fuel load (Aponte et al. 2016). The unpredictability of standing dead wood near trail systems also puts unsuspecting visitors at risk of serious injury if a weakened tree were to fall and strike a person. Removal of dead wood and blow-downs may not be an option since they provide valuable ecosystem services and removal would disturb the area; however, eliminating the amount of tall standing dead wood near trails may reduce the potential spread of fires and the likelihood of injury.

Expected composition changes within New Brunswick forests will require further research and monitoring to fully grasp the province's future wildfire risk. Nature Trust preserves and other conservation areas provide excellent resources to conduct such research.

Many organizations are taking a proactive approach to adaptation and mitigation measures in the face of the uncertainty presented by the risks and hazards of climate change. For the Nature Trust this could be as simple as placing warning signage in areas where a potential hazard is noted but the likelihood of occurrence is rare. Applying this approach to risk management would also ensure due diligence on the part of the organization and provide awareness of potential safety concerns to recreational users.

Erosion on easement
Photo by Anne Henderson

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Birds in a Warming World

What Can we Expect?

Dr. Tony Diamond

The Gulf of Maine is warming faster than almost any other part of the global ocean, and changes have already been recorded in distribution of several species of marine fish and invertebrates such as lobsters, with troubling consequences for those making their living from the sea. Seabirds obviously fall into this category, and my research on the Maritimes' most diverse seabird colony on Machias Seal Island (MSI) is showing some unexpected changes in that seabird community. MSI sits in the middle of the "Grey Zone" between the U.S. and Canadian borders and the waters of the Gulf of Maine and the Bay of Fundy. One prediction of most climate change models is an increase in rainfall, and we have seen that on MSI; summer rainfall (June and July) has nearly doubled since 2005. One consequence of this is that chicks of ground-nesting species such as Arctic and Common Terns are more likely to succumb to exposure before they develop waterproof plumage that can keep them warm; if food is also short, parents are caught between the "rock" of staying ashore to protect the chicks and the "hard place" of foraging in bad weather to provide food to warm the growing chick.

Perhaps the component of the climate showing the most dramatic change is the length of the summer season. The "spring bloom" of phytoplankton that kick-starts the marine food-web now occurs two weeks earlier than it did when we began our research (in 1995), and the fall bloom three weeks later, so the "growing season" extends for five weeks more than it did 20 years ago. Overall production though has not increased – if anything it has declined – so the amount of food available to seabirds at any one time is now significantly diminished. In addition, the stock of the main prey of MSI seabirds – Atlantic Herring - has also declined substantially; the quota for the herring fishery is at its lowest in the history of the fishery (some 50 years). Seabirds feed mostly on young herring less than a year old, spawned the previous fall; the abundance of this age-class is not measured directly because fish this size are not harvested commercially, but evidence from both the seabirds' diet and fishery models suggests that recruitment to the fishery from this age-class is greatly reduced. The amount of herring in the diet of puffins at MSI since 2005 is half what it was in the previous decade. The over-winter survival of Atlantic Puffins is tied to the abundance of herring (Breton and Diamond 2014) , and other components of puffin population dynamics, such as productivity (down by 26% since 2005), the weight of fledglings (down 7%) and their subsequent

Seabird colony on Machias Seal Island
Photo by Tony Diamond

recruitment to the breeding population at 5-7 years (down by 29%), are declining.

Earlier onset of primary production (growth of phytoplankton) is a common result of climate change; some birds are breeding earlier as a result, others not. On MSI the only change in timing is in the opposite direction – puffins are actually breeding later, on average, than they did 20 years ago. Time of laying is variable in puffins, ranging between May 3 and May 28 in our 22 years of data, and the delay over time accounts for very little of this variation (13%) so other factors are clearly driving it, but the fact that it is changing in the opposite direction to the change in timing in the climate is puzzling, to say the least. None of the other species we follow is changing its time of breeding, and we still struggle to explain why this is. Atlantic Puffins, like the other species breeding on MSI, are essentially cold-water (boreal) in their distribution and are close to the southern edge of their breeding range in North America; theory predicts that their breeding distribution should move north. But there is no sign of this; Common Murres colonised the island in 2003 and have increased to around 500 pairs, and the Razorbill population is over four times what it was in 2000. Northern Gannets – another boreal species – have also nested several times since 2010, though less successfully as they have not yet raised a chick.

Climate change proceeds by slow but inexorable change in some measures, such as temperature and spring bloom date; but it can also be punctuated by extreme events such as hurricanes and other violent storms. In fall of 2012, unprecedentedly warm sea-surface temperatures led to hurricane Sandy striking the entire coast of the southeastern U.S. from Florida to Massachusetts, churning up the coastal waters of the continental shelf that are the normal winter range of part of the Razorbill population; juvenile Razorbills swarmed into Florida in unprecedented numbers in the following winter, most in very poor condition and apparently looking for food. Early in 2013 a succession of storms battered Cape Cod and over 200 Razorbills – all adults – were washed ashore dead. Some of the victims wore bands; two found in Florida had been banded the previous July in the Gulf of Maine (one at MSI) whereas four recovered in other states later in the same winter were adults from colonies in Quebec (2), MSI (2) and Maine (1). The population on MSI increased between 2012 and the next count in 2015, suggesting the breeding population had not been affected by the storms; but there was a detectable decline in 2016 when the 2012 cohort should have joined the colony, suggesting the juvenile population had been reduced by the mortality in Florida that resulted from the extreme disturbance by Hurricane Sandy of their winter fishing grounds further north.

Atlantic Puffin: earthworms are for robins, not puffins! Puffin diet is degraded by scarcity of herring. Photo by the Atlantic Lab for Avian Research

Shorebirds, making their living from invertebrates in the intertidal zone, are vulnerable (like all long-distance migrants) to changes in their breeding, migration, and winter habitats. Red Knots are declining steeply on both sides of the Atlantic; in Europe, earlier springs in the Arctic breeding grounds lead to slowed bill-growth in juveniles, with the result that juveniles in winter cannot reach the invertebrates buried deep in the sands of their winter habitat off West Africa (van Hils et al. 2016). These shorter-billed birds have to subsist on less nutritious food nearer the surface, and show reduced survival over the winter. Thus the changing climate on Arctic breeding grounds reduces survival by reducing the birds' ability to find adequate food in winter. The complexity of the life-cycles of long-distance migrants multiplies the opportunities for the changing global climate to affect their

Common Tern feeding chick
Photo by ALAR, UNB

survival. Polar regions are warming faster than temperate ones; the bird most subject to changes in its environment is one that spends most of its life in both polar regions. The Arctic Tern winters in Antarctica; most breed in the Arctic, and the colony on MSI is close to the southern end of the breeding range. The few remaining birds (remnants of the colony lost in 2006, for reasons unconnected with climate change) spend more of their lives in rapidly-changing climates than any other species in the Maritimes.

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Long-term Monitoring

Understanding the Effects of Climate Change

Dr. Laura Tranquilla
Sue Abbot
Amy-Lee Kouwenberg
Greg Campbell
Holly Lightfoot

From the emergence of insects in the boreal forest to the ocean's spring bloom of plankton, many migratory birds depend on seasonal food abundances to successfully raise their young. Yet climate change can disrupt this natural cycle of abundance, with ripple effects being felt up the food chain.

One of the major impacts of climate change on bird populations is the mismatch in the timing of spring prey abundance with the arrival of migratory birds and their subsequent efforts to lay eggs and fledge young. Other effects include: rising sea levels and receding shorelines, which impact marine and coastal-nesting birds; more frequent and severe storms, floods, and droughts, which impact migrating and breeding species and can damage habitat; higher air and water temperatures, which can directly affect prey availability for some bird species; and gradual shifts in the composition of vegetation, resulting in less suitable habitat.

Some of the impacts of climate change on birds will depend greatly on how humans respond – for example, how we respond to sea-level rise and coastal erosion here in Atlantic Canada. A beach specialist, the Piping Plover depends on wide areas of open dry sand above the high tide line for safe nesting. Overwashing of beaches during storm events is particularly effective in creating this habitat, but by hardening coastlines with armour rock, important natural processes like overwashing are restricted. By contrast, if we respond to the changing coastline by retreating from the coast where possible, we can allow natural coastal processes to occur, thereby maintaining healthy, dynamic habitats for nesting plovers.

Biologists at Bird Studies Canada have been monitoring bird populations since 1970. Monitoring is important because it is really the only way to document population changes. Anecdotal information can be useful in identifying which species might be declining, but we cannot determine the magnitude of change without a standardized monitoring effort.

Monitoring programs can also help identify species at risk, suggest possible causes of population changes, and test the effectiveness of conservation efforts in the recovery of species. Sometimes the changes we record are positive – as in improved nesting success for the endangered Piping Plover due to better stewardship of beach habitat – and sometimes they are negative, as in the precipitous decline of aerial insectivores. A better understanding of the root causes of bird population changes can lead to positive conservation action.

Wherever possible, Bird Studies Canada looks for ways to implement these actions. In Atlantic Canada, we focus on several groups of birds that are of conservation concern due to the impact of climate change on habitat and food supply, and also due to degradation of wetlands, habitat fragmentation, and human disruption or destruction of nesting and roosting sites. Our programs include work on:

Marsh Monitoring – tracking changes to populations of wetland birds over time and identifying how wetland management and conservation might be improved to the benefit of these birds;

Swifts and Swallows – measuring changes to populations of roosting Chimney Swifts over time and determining how landowners can be better stewards of swift and swallow habitat in chimneys, homes, and barns;

Piping Plover – monitoring changes to plover populations over time and discovering how beach use can influence their nesting success;

Shorebirds – determining how human beach use can be mitigated to improve shorebird habitat at key migratory stopovers, where shorebirds must build up energy reserves to continue migration;

High Elevation Landbirds (Bicknell's Thrush) – tracking changes to populations over time and examining how habitats may be changing at a landscape level, including the effects of environment and human-caused habitat fragmentation;

Owls – monitoring changes to populations over time and exploring how this may be influenced by changes in forest cover and landscape structure;

Seabirds – understanding seabird populations and the impact of multiple risks (oiling, marine traffic, accidental bycatch, fish depletion, and pollution) at key coastal locations in the Maritimes.

The effects of climate change are complicated and interconnected, providing yet another example of how in ecology, there is almost never a single pathway explaining a conservation threat. Likewise, there is never an easy "fix." Yet, over time, monitoring bird populations can help us better understand the scale of the problem, highlight potential conservation solutions, and provide us with the means to document recovery at regional and national scales.

Marsh monitoring in the Grand Lakes Meadows
Photo by Bird Studies Canada

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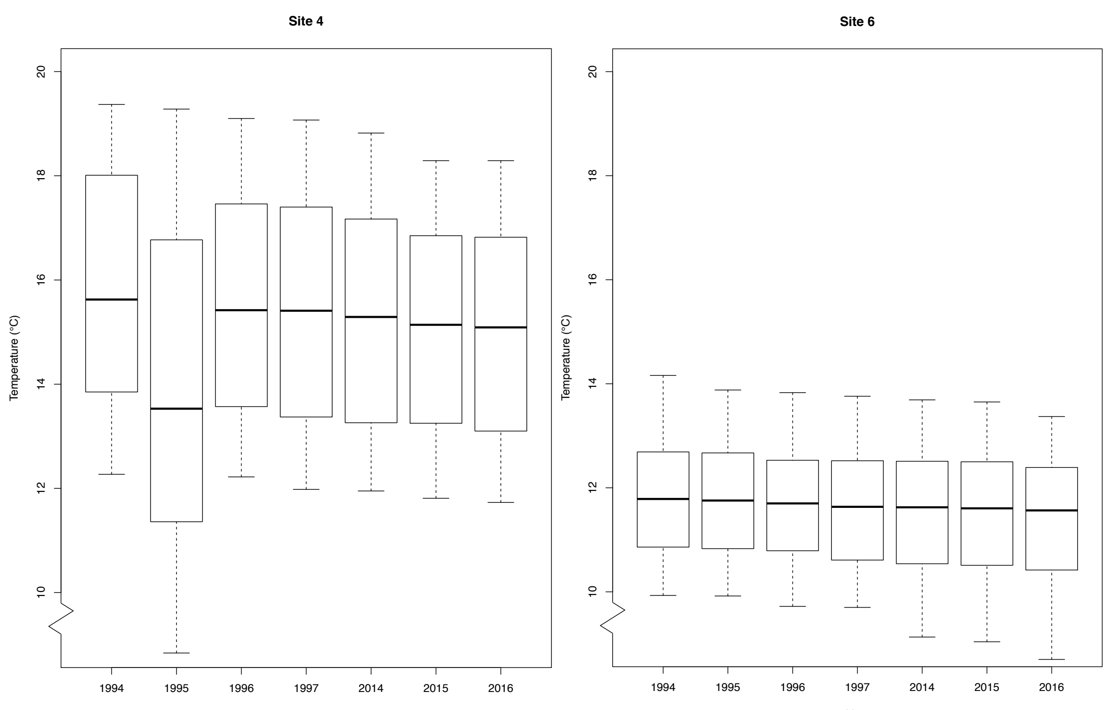
Fish in Hot Water

The Effectiveness of Groundwater Streams in Providing Critical Habitat in a Warmer Climate

Dr. Alyre Chiasson

In New Brunswick, Brook Trout (*Salvelinus fontinalis*) and Atlantic Salmon (*Salmo salar*) are important recreational fish. Both are cold-water species, with optimal growth occurring between 10 and 20 °C (Butryn et al. 2013; Danie et al. 1984). As ectotherms, the metabolic rate of fish fluctuates with the temperature of their environment. Growth, spawning and development are highly influenced by temperature. The same can be said of their food sources: the seasonal hatching and growth of aquatic insects are also closely linked to temperature. In 2007 Sharma et al. (2007) predicted that rising water temperatures in Canada would drive fish farther north, potentially opening the door to invasive species. In four streams in Western Massachusetts, Bassar et al. (2016) found that the rate of climate change was outpacing the ability of Brook Trout to adapt, affecting in particular the survival of the youngest year class.

We now recognize that the effects of climate change on stream temperatures must be added as a compounding factor when looking for population trends over time. In a study that looked at the effects of climate change on the native range of Brook Trout in the United States, Schlee (2014) predicted a 1 to 4 °C increase in water temperatures by 2056. Habitat for cold- and cool-water fish might be reduced by 50% throughout their range based upon predicted increases in air temperatures (Eaton and Scheller 1996). The connectivity of streams to cooler headwaters is important, as a 3.8 °C increase in mean annual air temperature in the next century in the southern part of the native range of brook trout in the United States would have to be compensated by a movement of fish to a higher altitude of 714 m to remain within their thermal tolerance (Meisner 1990). A northward shift in Brook Trout range is foreseen in the future (Mohseni et al. 2003), with predictions of an average 1 to 3 °C increase in the maximum and minimum weekly stream temperatures in the central United States. In another study, the authors indicate that ephemeral streams in the future will be subjected to more "flashy" periods, alternating between very wet and dry periods (Brooks 2009).



Water temperatures for the 10 highest values per year for the warmest (left) and coldest (right) streams in our study of the Hayward and Holmes Brooks watersheds.

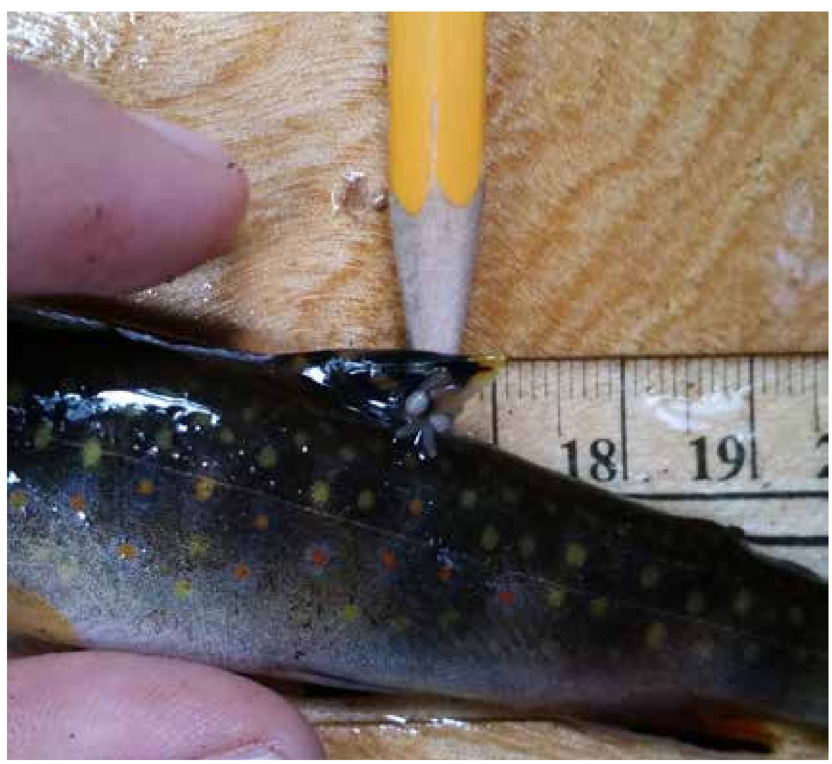
Twenty years ago, (1994-1997) my students and I sampled several small tributaries of Hayward and Holmes Brooks located near Petitcodiac Village in southeast New Brunswick. We looked at fish abundance and aquatic habitat, including water temperature. We resampled twenty years later in 2014, 2015 and 2016. These are groundwater fed streams. Regardless of sampling period, the highest 10 water temperatures in any given year fell within the range of 12 to 16 °C. Figure 1 shows the warmest and the coldest sites that we sampled from 1994 to 2016.

In terms of physical habitat, collectively both studies indicate a rather stable environment for Brook Trout within the headwaters of both brooks. This does not negate the potential impact of climate change on stream temperatures but perhaps a better ability of groundwater-fed streams to buffer against increases in air temperature. In a study published in 2016 by Isaak et al., streams in the mountainous northwestern United States showed an average warming of only 0.101°C per decade between 1968 and 2011. The authors point out that the dire predictions of cold-water species loss might be less than predicted because of strong local temperature gradients associated with topography. Habitats like Hayward and Holmes Brooks may merit a special level of protection for their ability to buffer against predicted increases in air temperatures. Streams not benefiting from groundwater will most likely show greater increases in water temperatures as air temperatures rise. In the interior United States, Wenger, Isaak et al. (2011) predicted that Brook Trout and Brown Trout (*Salmo trutta*) will decline by 77% and 48%, respectively, driven by increases in temperature and winter flood frequency caused by warmer, rainier winters.

Brook Trout numbers can vary substantially from year to year (Platts and Nelson 1988). Overall water temperatures in 2015 and 2016 were well within the tolerance range of Brook Trout. However, we did see a decrease in Brook Trout numbers from 232 in 2015 to 99 in 2016 across all sites. However, numbers were still above the lowest values seen in both time periods. What was different was the presence of a copepod parasite in 2015 and 2106, not seen in the early sampling period of 1994 to 1997. The parasite was identified as *Salmincola edwardsii*, which is specific to Brook Trout. Infected fish frequently have secondary fungal infections, were weak and had poor color. There is no doubt that the *Salmincola edwardsii* can have severe impacts on Brook Trout. Brook Trout were nearly extirpated from Ash Creek, Wisconsin after three consecutive years of high parasite numbers (Mitro 2016). The parasite's life cycle is accelerated by warmer water temperatures (Mitro 2016) but our sites showed relatively constant temperatures through time. Brook Trout are known to move out of warmer summer waters to the cooler waters offered by tributaries (Petty et al. 2012). Fish stressed by warmer temperatures are more vulnerable to parasite infections. As a hypothesis, we propose that infected fish from farther downstream are moving into the cooler headwaters during the summer. A secondary result of this movement into the headwaters could be an increase in density, conditions that can cause stress and potentially facilitate transfer and attachment of the parasite to otherwise healthy resident fish.

The New Brunswick fishing regulations advise that gear should be checked cleaned and dried to prevent the spread of invasive species. Although *Salmincola edwardsii* appears native to New Brunswick (Frimeth 1987), measures that would prevent spread to new habitats seems well advised. For this reason,

Brook Trout with copepod parasites attached behind dorsal fin. A smaller one is attached below (white blob) at the junction of the pelvic fin.
Photo by Alyre Chiasson



in New Zealand and some parts of the US, waders with felt soles have been banned. Some research on mechanisms of spread and susceptibility of Brook Trout could indicate whether further measures are required. Finally, although cold-water streams will provide critical habitat as water temperatures increase, this role will be compromised if infected fish move into waters that were previously disease or parasite free.

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Measuring Resilience

Critical to Effective Adaptation in Natural (and other) Systems

Sue Evans
Simon J. Mitchell

Communities in the St. John River watershed are experiencing the harmful impacts of climate change, including an increase in extreme flooding, blizzards, ice and wind storms. Since 2014, WWF Canada has been working with the municipalities of Woodstock, Hartland and Florenceville-Bristol, as well as the Western Valley Regional Service Commission, to develop a community climate change vulnerability assessment (completed 2016) and now an adaptation strategy. The communities, their residents and the natural systems around them, have been predominantly impacted by rain events and extreme storms, leading to excessive spring freshets and extreme storm events for example (Tropical Storm Arthur in July 2014). This has negatively affected the ability of these communities to manage assets and services, leading to secondary impacts for businesses, residents and the natural systems they rely on.

As a way to support ecosystems and human communities facing rapid environmental change WWF has worked directly with stakeholders in Woodstock to understand their capacity to respond to climate-related disturbance, and integrate resiliency concepts into adaptation action planning. Exploring resilience through the lens of climate adaptation highlights the role nature provides in buffering against impacts and building adaptive capacity. It also focuses on managing the interactions between people and nature that underpin the capacity of these highly linked social-ecological systems to respond to change and uncertainty.

Community resilience relates to the preparedness and capacity to respond to emergencies, as well as gradual change. The degree of resiliency is a measure of the specific capitals (the combination of assets and services in the region), capacities (ability to anticipate, absorb or adapt) and qualities (the characteristics that allow for learning, inclusion, resourcefulness, flexibility) the community has access to.

WWF worked with community stakeholders in Woodstock to identify the six capitals (broadly categorized as social, natural, built, economic, political and human) that contribute to their resiliency. Understanding these capitals allows for recognition of seemingly abstract assets, such as river health, as important to the planning process, and ensures adaptation actions at the community level contribute to securing the breadth of values within the community.

Using the six capitals, a series of indicators were developed to guide actions towards increasing climate resilience over the next decade. Indicators were both process and outcome-based, and qualitative as well as quantitative in nature.

Measuring progress toward climate resilience is difficult and uncharted territory. WWF and the communities we are working with have developed an approach to identify resilience indicators that employs social-ecological systems thinking and builds on (1) global knowledge of assessing and measuring urban resilience to climate change; (2) information on community climate change vulnerability; (3) local insights on qualities and actions taken that made the community resilient to past climate-related hazards; and (4) local insights on capabilities, assets and relationships that the community needs to have to successfully adapt to long-term changes. As a result, localized solutions can be identified that support multiple values, thus ensuring healthy communities for both people and nature.

Climate resilience is "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation." (IPCC, 2014)

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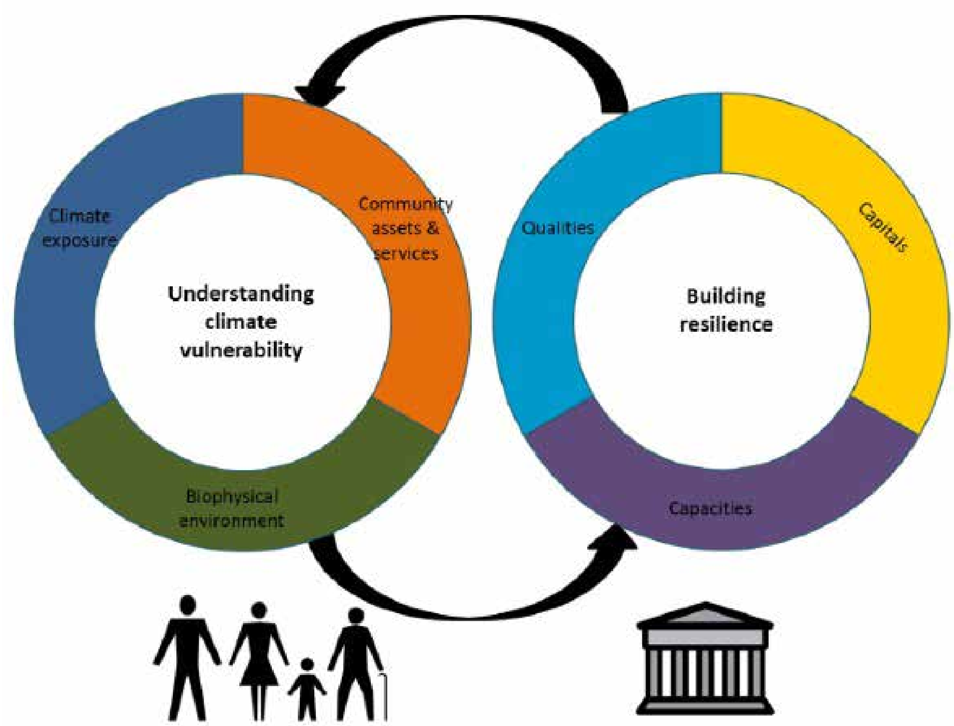
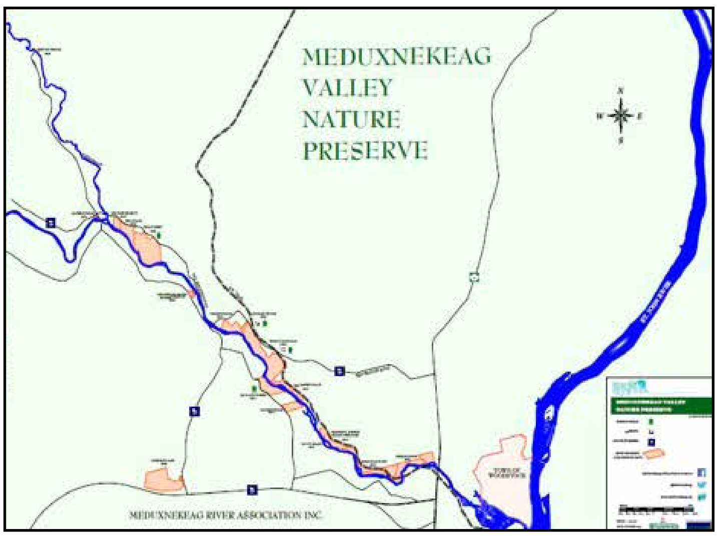


Research framework adapted from Tyler and Moench, 2012.

Watershed Protection and Climate Change

George Peabody

When the Meduxnekeag River Association began buying riparian property for a nature preserve in 1998, climate change wasn't front and centre in our minds. The 130 acre Wilson Mountain property we bought had just come on the market and had we not made the purchase, it almost certainly would have been clear cut for the mature forest which covers it. Some of that forest is the type known as Appalachian Hardwood Forest, containing numerous species of provincially-rare plants. Almost as important for the Association – which had begun life the previous decade as the Meduxnekeag Trout Association – was the nearly two kilometres of riparian frontage and a well-known deep water trout pool.



Since 1998, the Association has been steadily adding property to the Meduxnekeag Valley Nature Preserve which now totals just over 850 acres, most of it riparian zone. The Meduxnekeag, which rises in Maine, crosses the border and flows into the St. John at Woodstock, is characterized, especially in its New Brunswick portion, by steep slopes in its immediate valley. Much of this remains forested, with agricultural land, often in intensive potato production, in the uplands. So, with the projected changes in climate in this area, what can we anticipate from our having protected 850 riparian acres (and more, as fast as we can raise the funds to acquire more)? The changing climate is expected to bring more and larger rain events: a riparian forest will buffer these better than cleared land can, holding back run-off and lessening the potential for downstream flooding.

The Appalachian Hardwood Forest which we are protecting gets its name from its resemblance to forest typically found much further south; a warming climate improves conditions for the spread of this forest type forest type that includes rare plant species that are not near their northern limits.

The protected forests of the Meduxnekeag will be reservoirs for expansion of AHF.

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Renewables for Nature Tool

Habitat Friendly Renewable Energy

Simon Mitchell

Left unchecked, climate change could push one in six species to extinction. Because fossil fuels are the single biggest contributor to greenhouse gas emissions, WWF-Canada is committed to seeing Canada use 100 percent renewable energy by 2050.With tremendous wind, solar, hydro and biomass potential, as well as the longest coastline in the world and some of the highest tides, Canada is home to significant renewable energy reserves. We can make renewable energy Canada's source of power, creating jobs at home and expertise to export. It is possible.

Last Fall WWF-Canada launched Renewables for Nature (renewables4nature.wwf.ca), a new interactive decision-making tool to help identify regions with high renewable-energy potential and comparatively low conflict with nature. The tool aims to speed the transition to a low-carbon future while ensuring key habitats and ecosystems thrive for wildlife and communities. If planning doesn't account for biodiversity, migratory patterns or sensitive habitats, renewable projects, like other forms of development, can have major – and sometimes irreparable – consequences on nature.

For this effort WWF adapted the High Conservation Value framework – well known in Canada for its use in Forest Stewardship Certification – to the renewable-energy landscape and created this first-pass tool for regional-scale, strategic decision-making of larger-scale, community-led or industrial energy projects, beginning first with New Brunswick and Bay of Fundy. The conservation values included in the analysis are:

- Species that are endangered, at-risk or of cultural relevance;
- Habitats with high species diversity;
- Large ecosystems that haven't been fragmented;
- Smaller ecosystems such as old-growth forest, provincially significant wetlands, areas that are home to rare, threatened or endangered flora or fauna;
- Ecosystem services: areas that provide those unaccounted natural services such as erosion control, buffering against floods, purification of air and water, etc;
- Community needs: resources that are basic necessities for local communities, including First Nations; and,
- Cultural values: sites of national or global cultural, historical or archaeological significance; of religious/sacred importance for traditional cultures.

Applied in New Brunswick and the Bay of Fundy region, the tool captures data on 728 species at risk, as well as detailed information on biodiversity, habitat and other conservation and community environmental uses for the entire area. Combined with renewable energy potential from wind, offshore wind, solar, tidal, hydro, and biomass, the tool reveals which energy types are best suited to particular areas - to quickly and clearly see where energy potential is high and impact on environment or communities is low.

Wind turbine
Online image (Pexels)

This habitat-friendly renewable energy approach allows investors and developers to analyze their proposed landscape for species at risk, determine if they are biodiversity hotspots or if they're of cultural significance for Indigenous or other peoples – and then, before investing further, determine if they should select another less harmful and conflict-prone area that also has significant renewable energy reserves. The ultimate goal of developing such a tool is the use and uptake by regional energy stakeholders including industry, government and communities. Using the tool at early stages of planning for major renewable energy projects can potentially reduce the risk of conflicts with nature and community values and facilitating smoother transition to habitat-friendly renewable energy.

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Think Globally, Conserve Locally

Paula Noel

Unlike many other nations in the world, much of Canada's natural habitat is still intact. Our globally significant natural areas not only conserve our biodiversity, they store enormous amounts of carbon. With more than a quarter of the world's northern forests and a quarter of its wetlands, Canada has an important role to play globally in the response to climate change by protecting these critical carbon sinks. But that's not all that these lands and waters provide. In addition to holding massive stores of carbon, by maintaining these natural systems intact, we increase the resiliency of nature to respond to change. Intact landscapes act as important buffers against some of climate change's most serious effects and, of equal importance, they provide opportunities for species to adapt. And resilient landscapes also help our communities adapt in the face of a changing, and unpredictable, climate.

Here in New Brunswick we are fortunate that 85% of the province is forested, and our wetlands, coasts and river valleys remain relatively intact compared to many places in the world. However this does not mean we are immune to the impacts of climate change. Extreme climate-related events, such as flooding, storm surges, and heightened erosion have already occurred, and they are expected to occur with even greater frequency in the future. New Brunswick's coastlines, where many of our communities are located, offer a significant first line of defence against rising sea levels, violent storms and storm surges. Investing in their conservation is both an economic investment and an environmental investment. We believe that investing in green infrastructure – in natural capital – is one of the best investments that we can make in the province.

Coastal tree planting and volunteer event at Tabusintac (beach cleanup and birding)
Photo by the Nature Conservancy of Canada

For example, New Brunswick's extensive coastal saltwater marshes are highly productive, carbon-rich ecosystems. These marshes provide very important flood mitigation services through their capacity to absorb large amounts of water. They also serve as critical habitat for many species of mammals, birds and fish, some of which are highly threatened. However it is estimated that more than 65% of our coastal marshes have been drained and or developed, starting with the arrival of the Acadians in the 1600's. Without conservation of the remaining marshes and the lands surrounding them, the impacts of climate change will erode their resiliency and threaten their very existence, and impact the communities nearby.

The Nature Conservancy of Canada (NCC) has created coastal nature reserves from Miscou Island to Grand Manan. One such site is NCC's Tabusintac Estuary Nature Reserve: a globally significant wetland that supports species at risk. Since 1993, NCC has protected nearly 1,200 acres of land surrounding the Estuary, including most of the offshore barrier beach and salt marsh, which in turn protects the villages behind the beach from the impacts of storm surges.

Many of our most sensitive and threatened natural habitats along our coasts and rivers are privately owned. These are also the areas that provide tremendous benefits to our communities by providing carbon storage and sequestration, clean water, reduced impacts of flooding and reduced erosion on residential properties. NCC, and other land trusts in the province, work with private landowners to protect these lands and the significant ecological services they provide.

Where habitats are degraded, conservation and restoration can provide opportunities to enhance carbon storage and intensify carbon sequestration. For example, NCC has been developing ways of restoring the Maritimes' original Acadian forest and we are piloting a restoration project at our Baie Verte Nature Reserve near Port Elgin. Replanting a variety of native trees will not only restore the biodiversity of the site, it will enhance the site's ability to adjust to an uncertain future, and continue to provide ecological services for future generations.

We need to help nature so that nature can help us. By adding new protected areas and making sure they are connected across the landscape, by supporting the recovery of threatened species and species at risk, and by restoring habitats, we can create healthy and resilient natural systems, not just for the Province of New Brunswick, but for Canada and the world.

Chignecto nature reserve signage
Photo by Sabine Dietz

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Shifting Trees

Modelled Potential Tree Species Distribution for Current and Projected Future Climates

Dr. Charles P.-A. Bourque

ABSTRACT

In promoting the sustainability of forests, one key concern for forest practitioners is to understand the role changing environmental site conditions has on affecting site quality, species distribution, and ultimately plant growth. As examples, we provide potential species distribution for seven tree species native to New Brunswick for both current (1950-2005) and projected mean climatic conditions for 2006-2035, 2036-2065, and 2066-2100. Tree distribution projections indicate that habitat of cold-hardy species in the province, such as balsam fir and white birch, will deteriorate with further climate warming. Level of deterioration is projected to be greatest with RCP8.5 (extreme) climate-change scenario. Isolated pockets of suitable habitat for these species is expected to persist longer in cooler areas of the landscape, i.e., adjacent to cold water bodies (e.g., Bay of Fundy and next to large, deep lakes) and in higher elevation areas of the province. Under similar climatic conditions, hardwood species like yellow birch and sugar maple are expected to benefit from elevated growing degree days in the second tri-decade (2006-2035) and potentially face some decline in the third and fourth tri-decade (i.e., 2035-2065 and 2066-2100) due to increases in soil water content. Suitable habitat for red maple and red oak in the province is projected to ameliorate/expand over the next 83 years with climate warming under both climate-change scenarios, RCP4.5 and RCP8.5, with the greatest changes expected under RCP8.5 scenario.

Forests are an important resource due to their roles in (i) controlling local-to-global carbon budgets, (ii) supporting socio-economic activities in many rural and urban communities, (iii) conserving biodiversity, and (iv) controlling atmospheric

In the legends, the empty colour represents unfavourable conditions and potential absence of species, while red represents the most favourable conditions and probable presence of the species; blue, green, and yellow represent intermediate conditions and associated species presence. The horizontal colour bar associated with modelled potential species distribution indicates percentage of New Brunswick occupied by individual habitat categories listed in the legend. Background grayscale colours vary with variation in terrain elevation.

gas composition. As Canada possesses about 10% of global forests (Anonymous, 2007), developing further understanding of the geo-biophysical and ecological processes of forests and forested landscapes is important to Canadians. The focus of this report is to relate a number of vital attributes of selected tree species and their modelled response to potential species distribution in New Brunswick for current and projected future climatic conditions. Knowing where specific tree species may have the potential to grow is important for the sustainable management of forests (e.g., Smith et al., 1997).

Biophysical variables known to affect tree species distribution, potential occurrence, abundance, and growth, include (i) incident photosynthetically active radiation, (ii) growing degree days, (iii) soil water content, and (iv) soil fertility (Smith et al., 1997; Aussenac, 2000; Bourque et al., 2000; Gustafson et al., 2003). There are many additional factors with potential to influence the presence or absence of tree species in the landscape, including minimum winter temperatures, winter thaw-freeze severity (Bourque et al., 2005), number of frost-free days, snow accumulation, windiness, alkaline soils, soil acidification, forest floor thickness, soil composition and compaction, intra- and inter-specific competition, disturbance regimes (including harvesting), and time since disturbance, all exerting their own level of control on species distribution. None of these factors is included in our climate-based definition of modelled potential species distribution.

Methods that relate potential species occurrence to physical site conditions can be quite effective, but are limited in terms of capturing spatial variation. Attempts to upscale site suitability indices, such as potential species distribution, and related ecological variables from tree plot or transect sources to landscapes are greatly affected by the data and methods used in geospatial interpolation. Remote sensing data and process-based models to estimate values for temperature-mediated variables, such as growing degree days and soil water content, assist with spatial representation due to their ability to generate near-continuous data of the earth's surface. In this work, values of potential species distribution range from 0 to 1, where 0 represents unfavourable site conditions and, thus, potentially low probability of species occurrence, and 1, superior site conditions and high probability of species occurrence.

We employ the species-distribution formulation described in Bourque et al. (2000) to derive potential species distribution surfaces for seven tree species native to New Brunswick for current (1950-2005) and projected future climate scenarios for 2006-2035, 2036-2065, and 2066-2100. The species investigated include two softwood species, i.e., Balsam Fir (*Abies balsamea* (L.) Mill.) and Black Spruce (*Picea mariana* (Mill.) B.S.P.)], and five hardwood species, i.e., Yellow Birch (*Betula alleghaniensis* Britton), White Birch (*Betula papyrifera* Marsh.), Sugar Maple (*Acer saccharum* Marsh.), Red Maple (*Acer rubrum* L.),

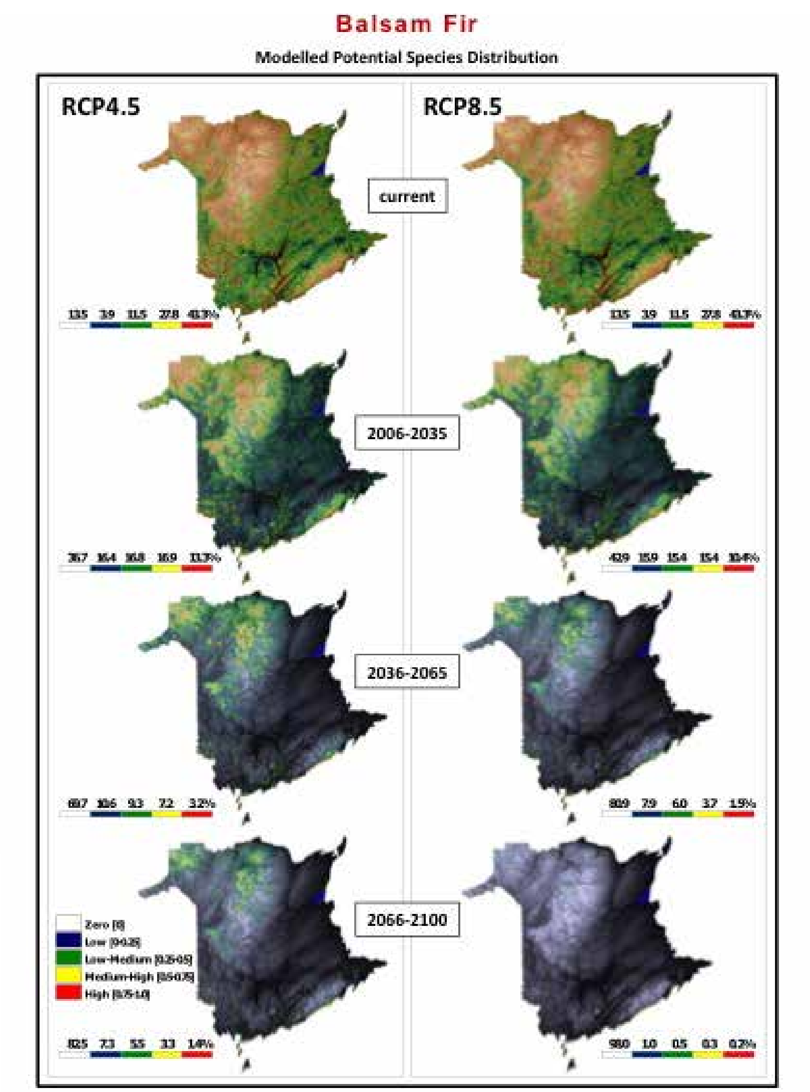


Figure 1. Distribution of Balsam Fir for current climatic conditions and future conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.

and Red Oak (*Quercus rubra* L.). We exclude soil fertility in this work as no suitable information exists at our particular resolution needs. Also, we make no attempt to examine the northeastward migration of tree species growing outside New Brunswick. Interaction between these species and those native to New Brunswick forests (those not eliminated by climate warming) will define the future dynamics of forest development in New Brunswick in a transitioning climate regime.

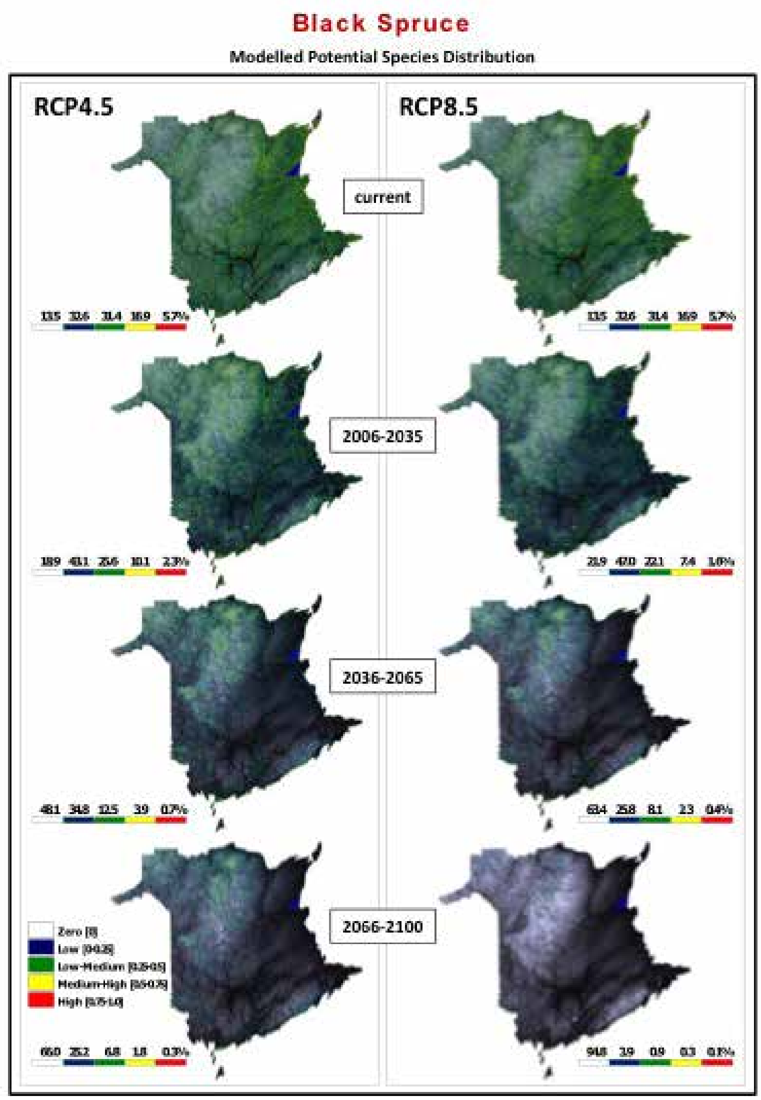
Climate change scenarios for future environmental conditions and species distribution for New Brunswick are based on gridded climate projections (at 49×49 km^2 resolution) from Environment Canada's fourth generation regional climate model. Climate change scenarios are based on the Intergovernmental Panel on Climate Change representative concentration pathways (RCP) of 4.5 and 8.5 (IPCC Fifth Assessment Report, 2014). RCP4.5 represents a scenario that stabilizes global radiative forcing at 4.5 W m-2 prior to the end of the 21st century. This scenario assumes that global annual greenhouse gas emissions peak around 2040, and then decline afterward; whereas, RCP8.5 represents a significantly more aggressive scenario of rising global radiative forcing, reaching 8.5 W m-2 by the end of the century. RCP 8.5 assumes global emissions continue to rise throughout the 21st century. Species vital attributes defining potential species response to modelled long-term climatic conditions and soil water content are based on values reported in the scientific literature.

Model Projections

Figures 1 through 7 illustrate potential species distribution for the seven tree species for both current and future climatic conditions with projected temperature and precipitation shifts under the RCP4.5 and RCP8.5 climate scenarios. We summarise the prominent features of projected potential species distribution as follows:

Balsam Fir is an aggressive species that grows practically everywhere in New Brunswick as in the other Atlantic Provinces (Ritchie, 1996); this is borne out by the distribution of potential species habitat for current conditions (86.5% of New Brunswick; Figure 1). Under current climatic conditions, Balsam Fir habitat is most suitable (red and yellow colours; Figure 1) in the northwestern and southern highlands of New Brunswick and other cooler parts of the province adjacent to major inland waterbodies. In the warmer and potentially wetter parts of the landscape (e.g., lowlands of New Brunswick) Balsam Fir is not expected to fare as well; sub-optimal potential species distribution index values (represented by the empty, blue, and green colours) occur on 28.9% of New Brunswick. Under projected climate change in 2006-2035 (Figure 1), Balsam Fir is predicted to be restricted mostly to the highlands. With continued warming (2036-2065 and 2066-2100), species habitat (mostly of low to low-medium quality) is predicted to persist in the high-elevation areas of the province. By 2100, Balsam Fir habitat is projected to persist on only 17.5% or 2% of

Figure 2. Distribution of Black Spruce for current climatic conditions and future conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.



In the legends, the empty colour represents unfavourable conditions and potential absence of species, while red represents the most favourable conditions and probable presence of the species; blue, green, and yellow represent intermediate conditions and associated species presence. The horizontal colour bar associated with modelled potential species distribution indicates percentage of New Brunswick occupied by individual habitat categories listed in the legend. Background grayscale colours vary with variation in terrain elevation.

New Brunswick, depending on the climate scenario (RCP4.5 or RCP8.5). Greatest determinant of species-habitat change with climate change is growing degree days; however, slight increases in soil water content (0-16% from current conditions) can also be expected to have some influence on the distribution of Balsam Fir over the next 83 years, albeit at reduced levels.

As with Balsam Fir, Black Spruce habitat is most suitable in the cooler parts of the province (Figure 2). Currently, Black Spruce habitat occupies 86.5% of New Brunswick, with 22.6% supporting moderately-high to high site quality. Over time, Black Spruce habitat, like its Balsam Fir counterpart, is predicted to decline with climate change (from 2006-2035 to 2066-2100; Figure 2). Under both climate scenarios, Black Spruce habitat is predicted to deteriorate throughout New Brunswick, potentially relegating Black Spruce to the cooler portions of the landscape by 2066-2100. By 2036-2065, 4.6% of the province (2.7% of New Brunswick, under the RCP8.5 scenario) is projected to have suitable habitat (yellow + red coloured sites) for Black Spruce regeneration and growth. In the following tri-decade (2066-2100), low to moderately-low quality black spruce habitat is projected to occupy approximately 34% of New Brunswick (or 5.2%, under the RCP8.5 scenario), mostly in pockets in the highlands and along the coast of New Brunswick.

Projection of Yellow Birch habitat shows some amelioration from the first to third tri-decade (2006-2065; Figure 3) under RCP4.5 scenario. Under the RCP8.5 climate scenario, Yellow Birch habitat improves until the second tri-decade and undergoes significant deterioration during the third and fourth tri-decade, particularly in the lowlands of New Brunswick. Species range in New Brunswick

Figure 3. Distribution of Yellow Birch for current climatic conditions and uture conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.

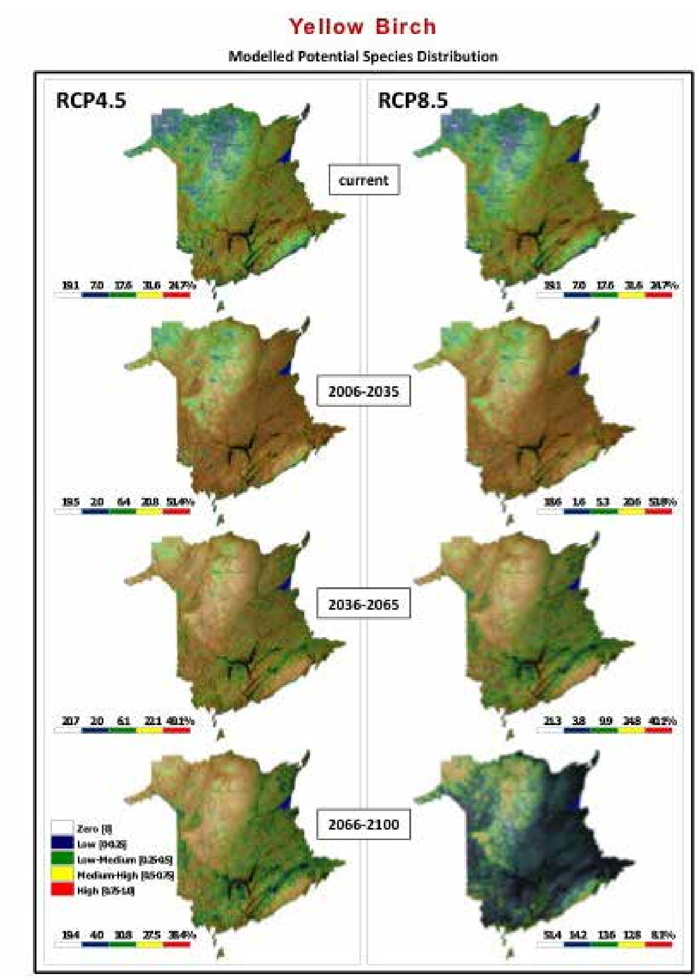
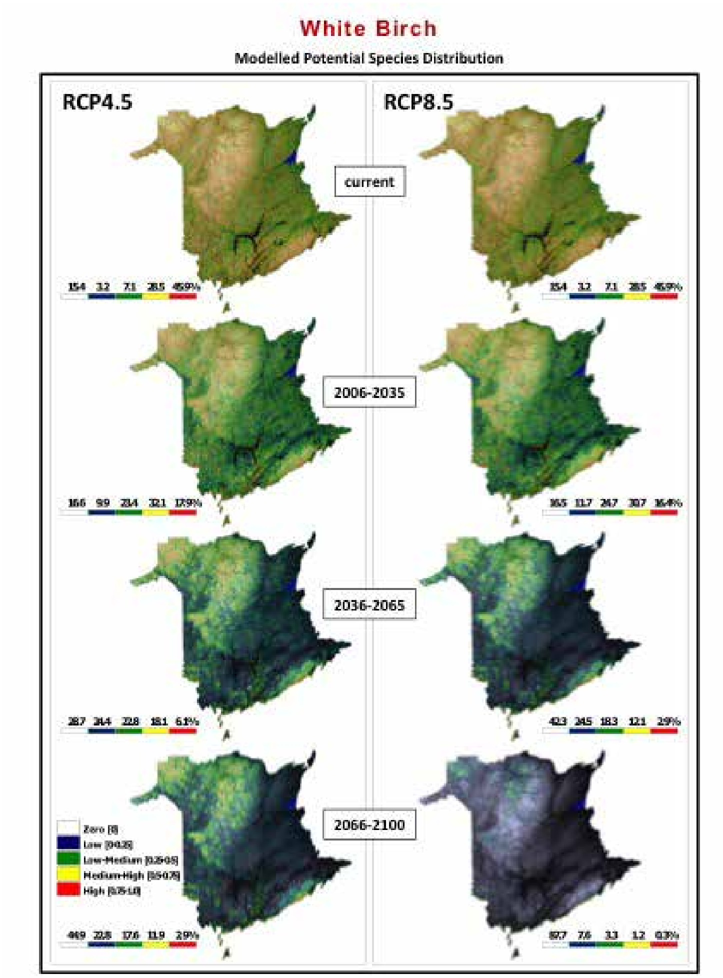


Figure 4. Distribution of White Birch for current climatic conditions and future conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.



is projected to remain mostly unchanged during the second tri-decade (80.9% of New Brunswick to 80.5% or 81.4%, under the RCP8.5 climate scenario), while high quality habitat is projected to increase from 24.7% of New Brunswick to 51.4% or 53.8%, under the RCP8.5 climate scenario, during the same time period. At the end of the 21st century, the extent of Yellow Birch habitat under the RCP8.5 scenario is projected to decrease from 80.9% to 48.6% of New Brunswick.

White Birch habitat, like Balsam Fir habitat, will undergo significant decline with climate warming (Figure 4). In 83 years, White Birch habitat is projected to decrease from an initial coverage of 84.6% to 55.1% of New Brunswick (or 12.3%, under the RCP8.5 climate scenario). In the fourth tri-decade localised persistence of species' habitat in the cooler areas of New Brunswick is projected, but at greatly reduced quality. By the fourth tri-decade (2066-2100), amount of medium-high to high quality sites is projected to decrease from an initial (current) value of 74.4% to 14.8% (RCP4.5) or 1.5% of New Brunswick, under the RCP8.5 climate scenario.

Range of Sugar Maple is projected to remain mostly unaffected during the first 60 years (Figure 5). In the third and into the fourth tri-decade, Sugar Maple habitat is predicted to undergo some decline, from an initial (current) coverage of New Brunswick of 85.5% to 84.5% (RCP4.5) or 51.7%, under the RCP8.5 climate scenario. High quality sites (red and yellow coloured sites) will decrease from 77.4% to 63.4% of New Brunswick (or 18.2%, under the RCP8.5 climate scenario) over the next 83 years.

Figure 5. Distribution of Sugar Maple for current climatic conditions and future conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.

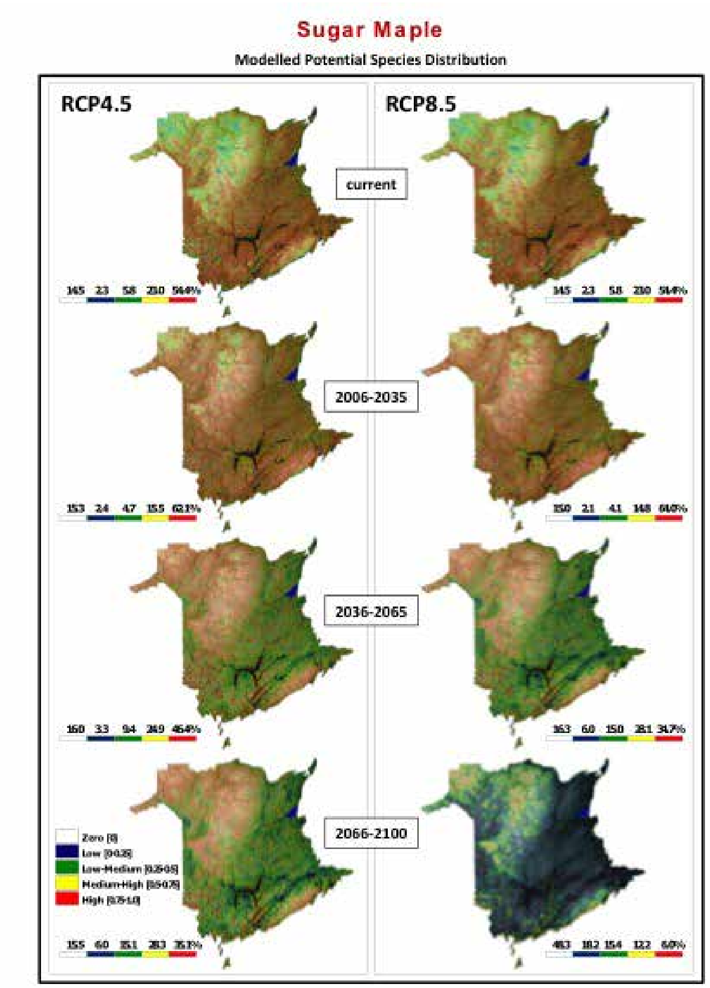
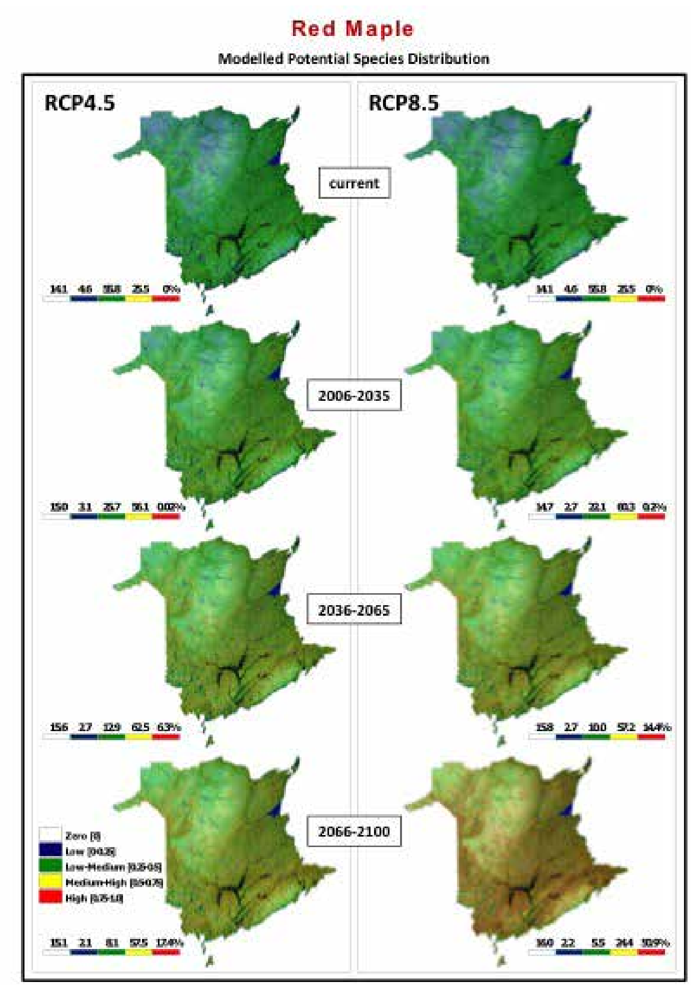


Figure 6. Distribution of Red Maple for current climatic conditions and future conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.



In the legends, the empty colour represents unfavourable conditions and potential absence of species, while red represents the most favourable conditions and probable presence of the species; blue, green, and yellow represent intermediate conditions and associated species presence. The horizontal colour bar associated with modelled potential species distribution indicates percentage of New Brunswick occupied by individual habitat categories listed in the legend. Background grayscale colours vary with variation in terrain elevation.

Red Maple habitat will benefit with climate warming (Figure 6). Over 83 years, high quality Red Maple habitat will increase from an initial (current) coverage of New Brunswick of ~0% to 17.4% (RCP4.5) or 50.9%, under the RCP8.5 climate scenario. The range of Red Maple habitat in New Brunswick (85.9%) is projected to remain mostly unaffected with climate warming.

Red Oak habitat is predicted to ameliorate/ expand over the next 83 years (Figure 7) with climate warming, from 0.1% of medium-high to high quality habitat to 14.6% (RCP4.5) or 21.8% (RCP8.5), with an overall range expansion of 14.2% (RCP4.5) or 20.9% (RCP8.5) across the province, because of improved species response to higher temperatures.

Projected shifts in tree species distribution illustrated in Figures 1 through 7 are consistent with species response and projected habitat shifts from similar climate change-tree species impact studies for eastern Canada and continental USA using different global climate models and emission scenarios, e.g., McKenny et al. (2007), Bourque and Hassan (2010), Mohan et al. (2009), and Dombroskie et al. (2010).

Potential species distribution for current and future climates indicate that habitat of cold-hardy species in the province, such as Balsam Fir and White Birch, will deteriorate with further climate warming. The level of deterioration is projected to be the greatest under the RCP8.5 climate scenario. Isolated pockets of suitable habitat for these species are expected to persist longer in cooler areas of the landscape. Under similar climatic conditions, hardwood species like Yellow Birch and Sugar Maple are expected to benefit from elevated growing degree days in the second tri-decade (2006-2035) and potentially face some decline in the third and fourth tri-decade (i.e., 2035-2065 and 2066-2100) because of increase in soil water content. Suitable habitat for Red Maple and Red Oak in the province is projected to ameliorate and/or expand over the next 83 years with climate warming under both climate scenarios, with the greatest changes expected under the RCP8.5 scenario.

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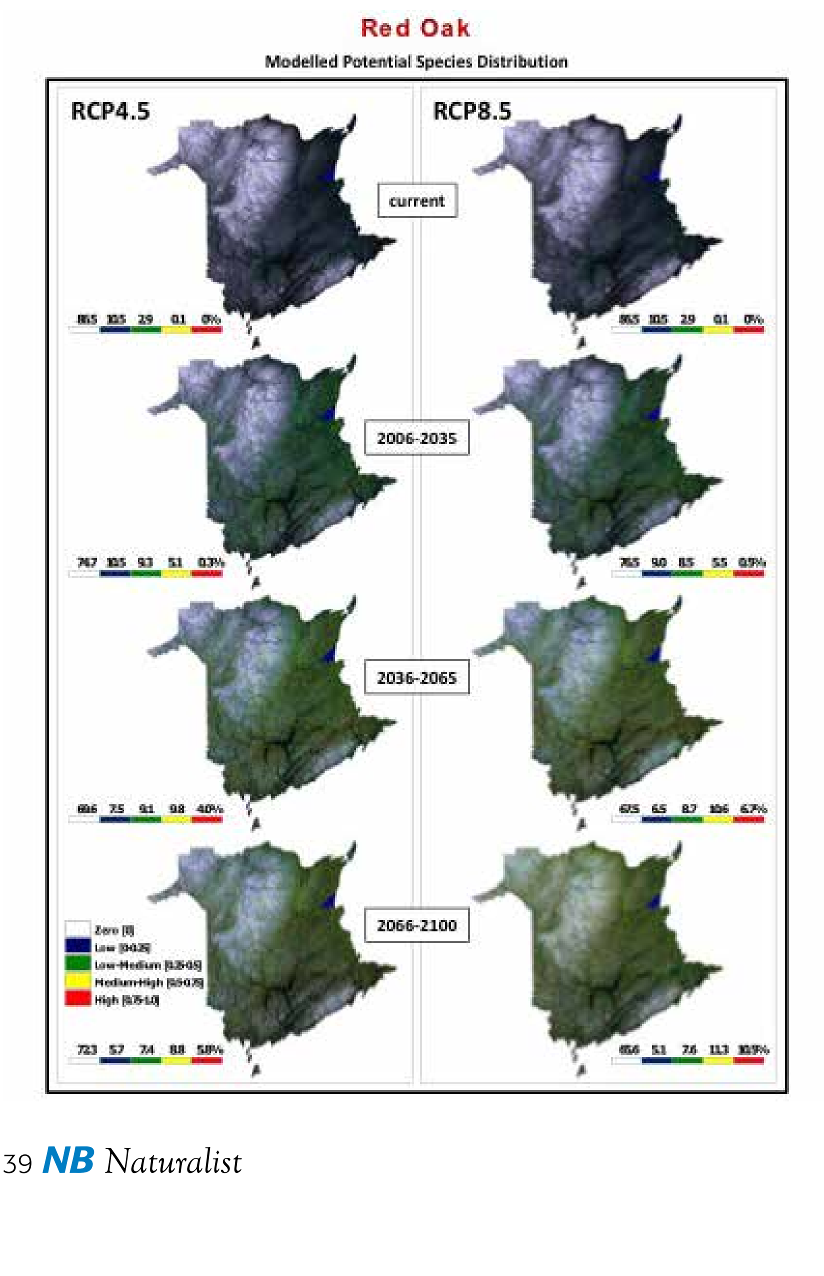

Figure 7. Distribution of Red Oak for current climatic conditions and future conditions for 2006-2035, 2036-2065, and 2066-2100, for both the RCP4.5 and RCP8.5 climate scenarios.

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Protecting Nature's Safety Net

Resilient Forests and Oceans

Roberta Clowater

Climate change is forcing on us a degree of uncertainty and unpredictability that is not easy to accept. When managing natural resources, or conserving forests, rivers or oceans, past performance is no longer a predictor of future performance. We will be spending a lot more money and effort trying to replace the ecosystem services we now take for granted – like the cooling effects of green spaces and water bodies, the natural flood and erosion control provided by forests and wetlands, and the natural water filtration done by natural areas.

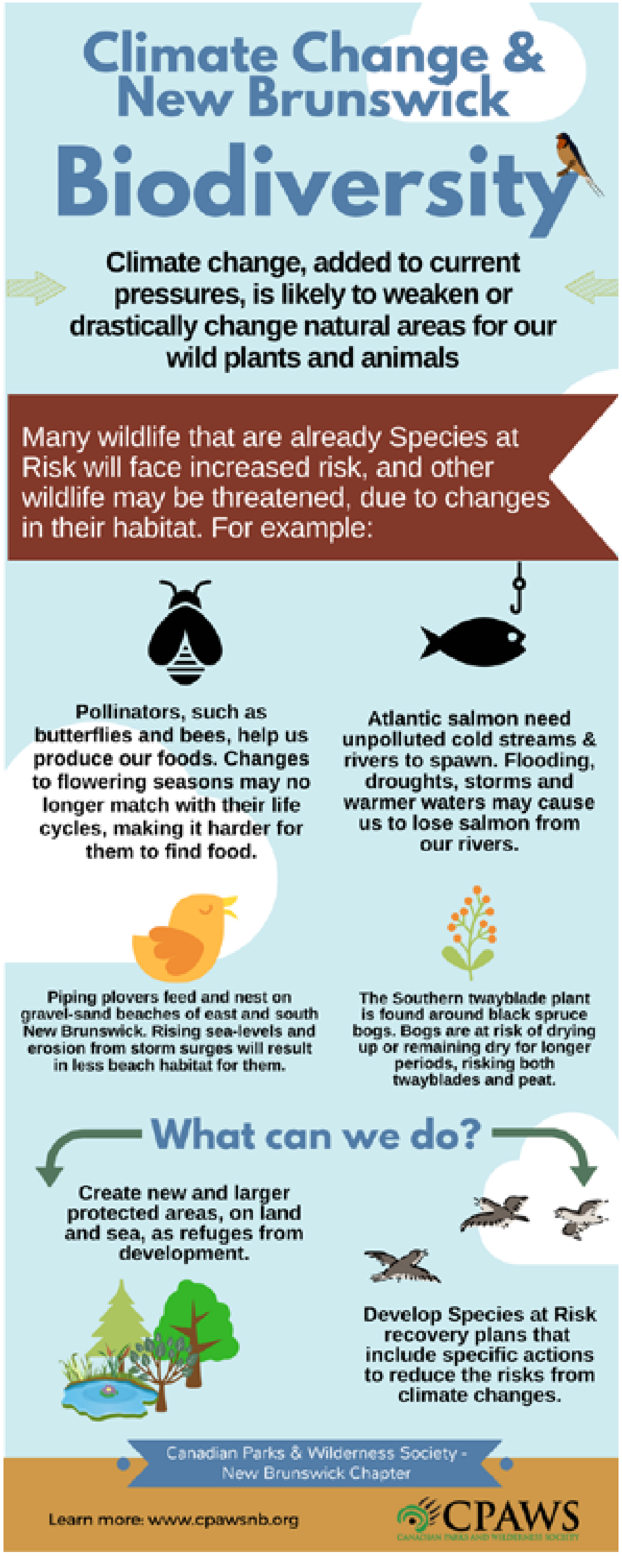
New Brunswick's remaining intact natural areas are becoming much smaller and further apart due to large scale industrial activity and smaller piecemeal development. We lack an adequate system of protected areas, and this weakens the ecological safety net that we need to be resilient to climate change impacts.

Solutions for New Brunswick Crown lands and waters:

Functional ecosystems with the full range of native species will be more likely to respond and shift with climate change than stressed ecosystems where species populations have significantly declined. The first step to resilience is to conserve large tracts of intact, relatively undisturbed natural areas in permanent protected areas. This will allow us to ensure a diversity of habitats that are large enough to conserve ecological integrity. Protected areas that are connected to other suitably conserved habitats will provide the kind of ecological safety net that will allow forests, rivers and oceans to respond resiliently to climate change.

New Brunswick would need to set a new target and timeline for protected areas establishment, which other provinces have already done. CPAWS New Brunswick recommends we try to at least meet the national average of 10% of the province in permanently designated protected areas (up from our current 4.7% protected).

The second step will be to manage our Crown forests to conserve diversity and resilience. We will need to set new rules for conserving older forests, multiple canopy and understory layers, and the natural patterns



of native species abundance and distribution. This would be more likely to result in forests that are resilient in the face of new or increased pests and diseases, droughts, floods and fires. The current approach to forest management is not considering this element of climate change preparation, so we risk a long transition period where forests may partially die off or have very little productivity. Government would need to make changes to the Crown forest management strategy to integrate these objectives.

The third step will be to plan and manage all Crown land and oceans uses with consideration for the combined impacts of climate change, forest harvesting, biomass removal, mining, wind energy development, aquaculture, and agriculture. If we don't, we risk weakening natural areas at the very time when we need to strengthen their resilience.

Solutions for Provincial Parks and Protected Areas:

We need to develop management plans for all provincial parks and protected areas to maintain ecological integrity and decrease future development. The few parks and protected areas we have are providing some of the only locations in the province where natural processes are relatively undisturbed. They provide the core areas necessary for the long-term conservation of biodiversity across the province. There have been instances where development may have affected the ecological integrity of the parks, possibly reducing their resilience to climate change.

How You can Help with these Solutions:

The solutions that will help us adapt to climate change will require us to break free from old models of resource management and use. We cannot simply tinker around the edges of existing land and resource management systems and hope to keep up with the changes around us. For our governments to take leadership and make decisions that will allow us to live within nature's limits, they need to have the vocal support of a critical mass of citizens.

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Storing Carbon

Saving and Restoring Healthy Forestss

Dale Prest

I believe that the best shot we have at restoring the ecological integrity and health of our province's forest and freshwater habitats lies in placing an economic value on the amount of carbon stored in our forests.

And I'd like to convince you of the same.

My belief lies in two contentions: one, that stored carbon is one of our best approximations of ecological integrity of the Acadian Forest; and two, that we have a better political shot at executing province-wide ecological restoration by focusing on stored carbon than we do on any other single measure.

I'll do my best to explain both of these.

One: stored carbon as one of our best proxies for ecological integrity in the Acadian Forest

The Acadian Forest, a forest with high levels of stored carbon, also tends to have high ecological integrity, with a complex physical structure, high biodiversity, intact habitats, and functioning ecosystem services. By contrast, forests with low levels of stored carbon, almost without exception, have low levels of ecological integrity. While there are some exceptions, in the majority of cases this rule holds true. The direct relationship between stored carbon and ecological integrity is a characteristic of many temperate forests, be they Coastal Temperate Rainforests in BC or the Great Lakes Forest. This has been backed up in the scientific literature time and again. The forest that stores the most carbon in New Brunswick is the old-growth, archetypal climax Acadian Forest composed of a diversity of hardwood and softwood species, diversity of ages and with lots of dead wood, both standing and downed (Luyssaert et al. 2008; Nunery and Keeton, 2010).

Managed forests that most closely mimic this old forest type store multiple times more carbon than do, say, simplified softwood plantations managed on rotation. The additional carbon stored in wood products from such a plantation doesn't come close to making up the difference.

Ecosystem services tend to function better in forests with higher levels of stored carbon. Water retention and regulation, air filtration, nutrient retention and regulation, biodiversity: all of these ecosystem services function at a level more optimal to life in forests that store more carbon than they do in forests that store relatively less carbon. Think about it: what type of forest better regulates extreme rain events? A 30-year-old softwood plantation or an 80-year-old mixedwood forest with lots of coarse woody debris? Which provides more habitat types? Which provides greater recreational opportunities? Carbon storage is not a perfect analog for ecological integrity, but it is the most all-encompassing and easiest to measure one that I've come across yet.

Two: carbon is an easier political sell

The drivers of loss of ecological integrity exist almost exclusively within a socio-economic context. Given that most of our measures of ecological integrity are borne of conservation biology, out of the gate our ecological restoration strategies are put in conflict and tension with these socio-economic drivers of ecological degradation. There is ample evidence of this in NB, especially within our shrinking "conservation forest". When deer-wintering habitat is pitted against the expansion of mills, we know who wins that fight. The concept of carbon storage, while still abstract to most, has already had much of the hard lifting done to translate its value into the socio-economic realm. Through years of climate change science and climate change mitigation efforts in public policy, it is relatively easy to talk about the value of carbon storage to society and to our civilisation. While not ubiquitous, carbon storage as a value holds greater penetration into the political zeitgeist than, say, habitat connectivity.

Paying people to store more carbon will restore our province

Let's be clear about the key driver of ecological degradation in our province: the widespread, indiscriminate use of clearcutting. Also, let's be clear about why clearcut-

Harvester
Photo by Community Forests International

Workshop participants
Photo by Community Forests International

ting is so widespread: because the way you make the most money is to cut all your trees down in the most inexpensive way possible. Our economy awards no Brownie Points for conserving nutrients in soil, respecting that nesting pair of raptors or not silting up a brook. Valuing the carbon stored in a forest fundamentally breaks this cycle. By bringing stored carbon into the economics of forest management, people can be rewarded for growing more than they cut. Spread across the province and throughout the forest economy, we can begin to turn the clock back on the ecological degradation of our province by growing more trees and storing more carbon. We'll have a higher quality and a higher quantity of forest and freshwater habitats, less flooding in our towns and more opportunities to enjoy in the woods.

At Community Forests International we've been a broken record on this since 2011: valuing carbon stored in our forests is the best shot we've got at restoring our province. And with all provinces mandating carbon pricing schemes, it's a realistic possibility in the short term.

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Kedgwick River forest
Photo by Roberta Clowater

Working with Nature to Adapt

Adam Cheeseman

The impacts of human-caused climate change are becoming more frequent. For instance, in recent years New Brunswickers have experienced more intense storms and flooding events, which have resulted in millions of dollars in damages. As the costs of human-caused climate change rise, the need to develop solutions that save money, protect our communities and nature, and reduce impacts to human health are becoming increasingly important.

Climate change adaptation strategies aim to protect communities, economies, and the environment from climate change. Traditional methods of adaptation include engineered or "grey" approaches, such as constructing sea walls or larger culvert systems, or dredging rivers to deal with the impacts of flooding. While these are useful strategies, engineered solutions tend to be expensive, disrupt natural landscapes (e.g., beaches, rivers, forests), and avoid the underlying problem. For example, culverts do not slow or soak up floodwater, they simply transport it to downstream communities and property, who then have to manage the issue.

To avoid these disadvantages, new adaptation practices are being explored that work directly with the natural landscape. Natural areas, such as wetlands and forests, can provide cost saving, multi-benefit solutions that help protect our communities for generations. For example, in 2011 Tropical Storm Irene caused widespread flooding throughout Vermont, but the town of Middlebury was barely affected. Later, it became clear that floodwaters travelling through Otter Creek were slowed and stored by a large network of swamps upstream of Middlebury. One study produced by the Gund Institute and University of Vermont found that these natural swamps acted as a flood control mechanism, which saved Middlebury approximately $2.4 m (CAD) in damages from Irene alone (Watson et al., 2016).

Working with nature also provides additional benefits to communities. For example, creating natural buffers along riverbanks reduces flood risk and increases recreational opportunities (e.g. hiking, bird watching), while also preserving local habitat and biodiversity. While flood risk could be reduced through grey infrastructure methods, such as river dredging and bank armouring, these engineered approaches do not offer the same additional benefits provided by nature.

Finally, natural systems, if managed appropriately, can last for generations. It has been said that a sea wall's "first day is its best day." In other words, as sea walls buffer the shoreline against waves, the concrete deteriorates and eventually requires replacement. On the other hand, when a dune system is in a healthy,

Top: healthy river banks
Photo by Sabine Dietz
Bottom: wetland
Photo by Roland Chiasson

natural state, "its first day is its worst day," as sand and vegetation continually build to strengthen the dune and better buffer coastlines against storm surge and erosion events.

Climate change has and will continue to bring about many challenges to our communities. While traditional solutions can help address these challenges, working with nature can ensure that adaptation solutions save our communities money while providing additional benefits to both humans and wildlife.

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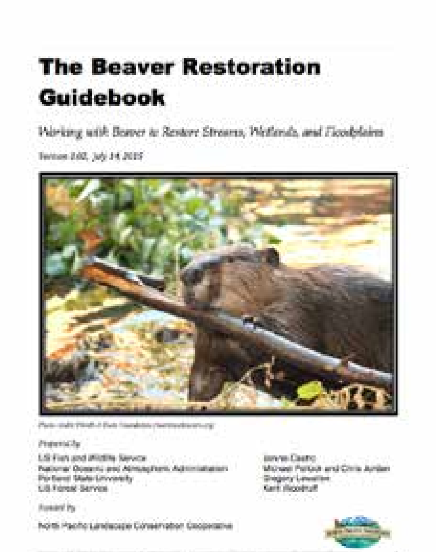
Beavers

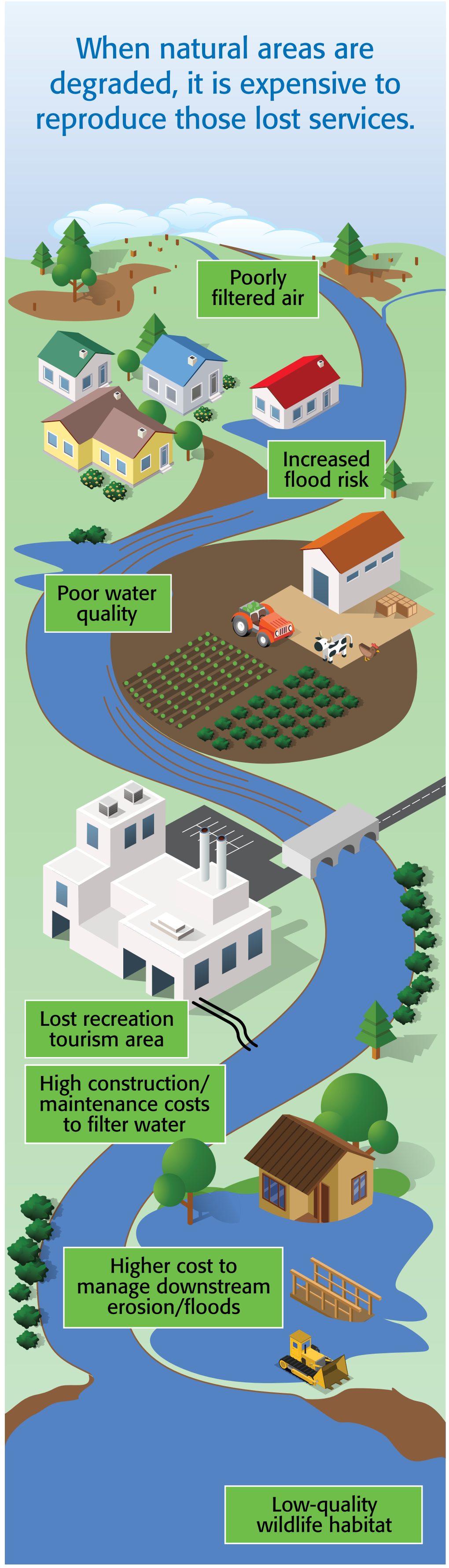
Flood Control Specialists

Sabine Dietz

Beavers are considered nature's architects. They change the landscape in their need for food and shelter. Sometimes, beavers are perceived as a nuisance, when they flood roads as a result of their dam construction projects. Yet beavers can be partners in habitat restoration, and can change the landscape so that it can better manage heavy rainfall events. As these events are becoming more and more unpredictable, and increasingly damaging, maybe we should look to the beavers for more help. The "Beaver Restoration Guidebook" is a great publication and reference to learn more about working with beavers to restore habitats, and manage climate change impacts (www.fws.gov/oregonfwo/promo.cfm?id=177175812).

American Beaver
Photo by Roland Chiasson





This graphic shows the benefits of balancing natural features (e.g., forests and wetlands) with development to provide benefits such as decreased flood risk, recreation/ tourism opportunities, and clean, inexpensive drinking water.

It was developed with partners through the Maritime Natural Infrastructure Collaborative (www.naturenb.ca/climate-change-adaptation).

Education - Conservation - Protection

Nature NB is a provincial charitable organization working toward the conservation and protection of and education about our natural heritage. It collaborates and networks with other organizations and provides exceptional educational programs, many of which are directed toward educating youth about nature – sowing seeds of awareness, curiosity and appreciation designed to last a lifetime. Our magazine provides broad information about nature in New Brunswick.

Information about Nature NB (http://www.naturenb.ca/)

Becoming a Member (http://www.naturenb.ca/get-involved/membership/)

Donations (http://www.naturenb.ca/get-involved/make-a-donation/)

Nature NB

Éducation - Conservation - Protection

Nature NB est un organisme de bienfaisance provincial qui œuvre à la conservation, la protection et l'éducation en rapport avec notre patrimoine naturel. Nature NB collabore et entretient des réseaux avec d'autres organismes et offre des programmes éducatifs exceptionnels. Bon nombre de ces programmes visent à initier les jeunes à la nature en semant des graines de sensibilisation, de curiosité et d'appréciation conçues pour durer toute une vie. Notre magazine fournit de l'information générale sur la nature au Nouveau-Brunswick.

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