PRINCE EDWARD ISLAND Climate Change Adaptation

RECOMMENDATIONS REPORT

University of Prince Edward Island
Climate Research Lab

UNIVERSITY of Prince Edward ISLAND

Recommended citation:

Arnold, S. and A. Fenech. (2017, October). Prince Edward Island Climate Change Adaptation Recommendations Report. University of Prince Edward Island Climate Lab. Charlottetown, Canada. Report submitted to the Department of Communities, Land and Environment, Government of Prince Edward Island, 172p.

ISBN 978-1-988692-13-5

COVER PHOTOS: Top left photo: Government of PEI; Three remaining photos: Don Jardine (all used with permission)
DESIGNED BY: Graphically Speaking PEI (www.gspeak.ca)

October 31, 2017

Dear Islanders,

The UPEI Climate Research Lab was commissioned by the Government of Prince Edward Island to develop the *Prince Edward Island Climate Change Adaptation Recommendations Report.* This report studies the impacts of climate change on ten sectors across the Island and recommends a total of 97 adaptation actions to address those impacts. The sectors are: Agriculture, Education and Outreach, Energy, Fish and Aquaculture, Forestry and Biodiversity, Insurance, Properties and Infrastructure, Public Health and Safety, Tourism, and Water.

The recommended adaptation actions were developed in five stages. First, the public and sector stakeholders were consulted on their concerns regarding climate change and adaptation. Second, anticipated climate change impacts and adaptation approaches used in other jurisdictions regionally, nationally and internationally were reviewed to prepare a discussion document for each sector. Third, roundtable discussions with sector stakeholders were held to review the relevance and practicality of the proposed approaches and to develop additional recommendations. Fourth, the sectors' input was incorporated in the discussion documents, which form the sector chapters of the draft report. Last, the public's input on the draft report was sought via online submissions and consultation meetings and incorporated in this final report.

Throughout this process, the focus was on suggesting adaptation actions that are science-based, relevant to the needs of the Island, and practical to implement. The needs of the Island will change as the climate and the environment, society, and economy of the Island change. Therefore, the intent was to make the recommendations as robust as possible without being overly prescriptive. The leads responsible for the adaptation actions will need to gauge the state and needs of the Island and the data available at the time the decisions are made and consult with collaborators to determine the best way forward.

Climate change is a shared problem that requires shared responsibility from everyone – individuals, businesses, research institutions, non-governmental organizations, sectors, different levels of government, etc. Planned adaptation takes time and the work to develop an informed, forward-looking, comprehensive adaptation strategy must begin immediately. Concerted effort from every Islander will be required for Prince Edward Island to successfully minimize the impacts that climate change will invariably bring.

Sincerely,

Dr. Adam Fenech
Director, Climate Research Lab
University of Prince Edward Island
upei.ca/climate

Acknowledgements

This work was supported by the Government of Prince Edward Island Department of Communities, Land and Environment.

This Report was developed by Stephanie Arnold of the University of Prince Edward Island Climate Research Lab with the input of many individuals and organizations. We would like to thank them for their expertise and time. Please note that their participation does not imply their endorsement of this Report and the information presented does not necessarily reflect the views of the participants or the organizations they represent.

Dr. Bishnu Acharya
Peter Boswall
Dr. Laura Braden
Jessica Brown
Darren Chaisson
John Cunniffe
Rosemary Curley
Andrew Daggett
Alex Dalziel
John Dewey
Greg Donald
Brian Dunn
Darrell Evans
Dr. Aitazaz Farooque
Kelley Farrar
Shaman Ferraro
Mary Finch
Alex Forbes
Bill Glen
Melanie Griffin
Dr. Daryl Guignion
Dr. Helen Gurney-Smith
Dr. Matthew Hall
Janice Harper
Scott Harper
Amber Jadis
Don Jardine
Jim Jenkins
Dr. Yefang Jiang
Bill Kendrick
Pooja Kumar
Evan MacDonald
James MacDonald
Rosanne MacFarlane
Bob MacGregor
Heather MacLeod
Shaun MacNeill
John MacQuarrie
Ken Mayhew
Dan McAskill
Kim McBurney
Matthew McCarville
Dr. Lyndsay Moffat
Kevin Mouflier
Tanya Mullally
Samantha Murphy
Tom O'Handley
Angus Orford
Hope Parnham
Dr. Heather Pringle
Mike Proud
Betty Pryor
Aaron Ramsay
Matt Ramsay
Bruce Raymond
Brad Romaniuk
John Rowe
Corinne Rowswell
Peter Rukavina
Dawn Runighan
Dr. Marina Silva-Opps
Brenda Simmons
Ritchie Simpson
Shirley Smedley Jay
Ira Smith
Kyra Stiles
Dr. Andrew Swingler
Barry Thompson
Brian Thompson
Julie Vasseur
Jonathan Veinot
Ron Waite
Peter Warris

Photo Credits:

All photographs in this publication were used with permission from:
Don Jardine, Government of Prince Edward Island, and Atlantic Green Contractors.

Table of Contents

PHOTO CREDIT: DON JARDINE

Executive Summary

Humanity is conducting an unintended, uncontrolled, globally pervasive experiment, whose ultimate consequences are second only to global nuclear war.

—Closing statement of the World Conference on the Changing Atmosphere in Toronto, 1988

Executive Summary

Introduction

Global climate change is seen as one of the greatest threats posed to the future of humankind and the world. Changes in our climate are often so small as to take decades, centuries, or millennia to be observable. These small changes in climate, however, can have significant impacts on the environment, society, and economy of Prince Edward Island. While climate mitigation strategies are necessary to reduce greenhouse gas emissions from anthropogenic sources, those alone are unlikely to be sufficient to eliminate the negative impacts of climate change. The impacts of climate change from emissions of greenhouse gases over the past 150 years will have to be confronted by all jurisdictions now. Therefore, pursuing a complementary strategy of enabling jurisdictions to adapt to climate change and negate many of the expected adverse impacts is equally, if not more, urgent. ***This report focuses solely on climate change adaptation***.

Effective adaptation requires coordinated effort from individuals, businesses, sectors, non-governmental organizations, and all levels of government. The approach must be based on the best evidence available and a spirit of openness and partnership. Joint action also has the added benefit of combining resources, experiences, perspectives, and expertise from different groups to tackle a shared problem. Therefore, the recommended adaptation actions proposed in this document are the responsibilities of different groups, with many of them requiring a collaborative effort from two or more groups.

Climate Change Impacts

Temperature

Climate change is projected to warm most regions of Canada. Over the past fifty years, annual mean temperatures rose in Atlantic Canada (e.g., 0.5°C in Charlottetown, PE) (Fenech, 2015). This trend is expected to continue; using a statistically-downscaled global climate model average, Fenech (2015) forecasts a rise in annual mean temperatures by 0.7°C on average by the 2020s, 1.6°C on average by the 2050s and 2.4°C on average by the 2080s. These may seem small increases in annual average temperatures; however, these small increases have dramatic effects on our environment, society, and economy.

Precipitation

Over the past fifty years, annual total precipitation (e.g., rain, snow, sleet) decreased (e.g., -5% in Charlottetown, PE) (Fenech, 2015). This trend is expected to continue. While precipitation is expected to generally increase for Atlantic Canada, Prince Edward Island is forecasted to experience a decrease from today's normal (1981-2010) by 6% on average by the 2020s (2011-2040), making it drier and more susceptible to drought conditions. Over time, models show precipitation returning to today's normal by the 2080s (2071-2100) (Fenech, 2016).

PHOTO CREDIT: DON JARDINE

Extreme Weather Events

Precipitation events are expected to decrease in frequency and increase in severity under a changing climate. That means there will be fewer events but they will be much more intense such as the December 2014 rainstorm, where over 180-mm fell causing $9 million in damages as a result of runoff, inland flooding, road washouts, etc.

Sea Level Rise

According to the most recent assessment by the U.S. National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, U.S. Geological Survey, Rutgers University, and the U.S. Department of Commerce, global mean sea-level could rise in the range of 2.0 to 2.7 metres by 2100 (Sweet *et al.*, 2017). Sea levels do not rise uniformly across the globe. Over the last several decades, the sea levels in the Atlantic coast have risen above the global average. Rising sea-levels will lead to an increase in the reach and severity of coastal flooding and coastal erosion.

Wind

Fenech and Su (2014) applied statistical downscaling techniques to global climate model output to predict similar average wind velocities as over the past thirty years for Prince Edward Island, Canada. Trends in wind velocity and direction, however, are difficult to determine conclusively, in part because datasets are not as complete as for air temperature (Natural Resources Canada, 2016).

Sea Ice

Senneville and Saucier (2007) estimated that a 2°C increase in air temperature could translate to a decrease of up to 28% in ice cover and 55% in ice volume. Savard *et al.* (2016) estimated that sea ice cover in the east-coast region will likely decrease by more than 95% by the end of this century. Within the Gulf of St. Lawrence, sea ice will continue to decrease in area, thickness, concentration, and duration until it ceases to form (Savard *et al.*, 2016). Even though climate change can be expected to bring many ice-free winters, interannual variability will likely ensure that ice will be present during at least some of the winters in the coming decades (Benoît *et al.*, 2012).

Air Quality

Ground-level ozone (O_3) is a human toxin and a plant toxin. It is created when two other air pollutants – nitrogen oxides (NO_x) and volatile organic compounds (VOCs) – react in sunlight and air. Almost all of Prince Edward Island's NO_x comes from on-island burning of diesel and gasoline for transportation and heavy fuel oil at industrial facilities (Government of Prince Edward Island, 2016). Projections modeled by Kelly *et al.* (2012) forecast an increase of O_3 concentrations for the Island by the middle of the century as a result of climate change only, with anthropogenic air pollution emissions held constant. However, with an upward trend in air pollution, combined with increasing formation of O_3 with rising temperature (Myers *et al.*, 2017), future levels of O_3 could exceed the target set by the Canadian Ambient Air Quality Standards.

Recommended Adaptation Actions

A total of 97 climate change adaptation actions were recommended for the ten sectors studied and consulted: Agriculture, Education and Outreach, Energy, Fish and Aquaculture, Forestry and Biodiversity, Insurance, Properties and Infrastructure, Public Health and Safety, Tourism, and Water. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

Table 1: Summary of all adaptation actions recommended for ten sectors within Prince Edward Island.

Agriculture

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
1. Commission a comprehensive study of crop opportunities and challenges under warming conditions over the next thirty years.	Leads: Sector, Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
2. Build an understanding of water requirements, anticipated drought conditions, and common methods used to address them.	Leads: Sector, Provincial Government Collaborators: Experts, Other sectors	Fill knowledge gaps; Reduce non-climatic factors	Short-term (0 to 5 years)
3. Reduce the amount of contaminated runoff reaching water bodies by managing stormwater onsite and reducing the amount of inputs used.	Leads: Sector, Farmers Collaborators: Experts, Other sectors	Increase resilience	Ongoing
4. Conduct on-farm demonstrations of best practices to showcase effective adaptation measures and provide producers with practical guidance.	Lead: Sector Collaborators: Farmers	Fill knowledge gaps; Engage in outreach	Medium-term (6 to 10 years)
5. Add and maintain 100 climate stations across the Island to improve the collection of climate data, including soil temperature, to develop a baseline for the analysis of climate trends at higher resolutions	Lead: Sector Collaborators: Farmers, Experts	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years); Ongoing maintenance
6. Integrate climate change considerations in the agricultural insurance framework (e.g., offer insurance for new crop varieties expected to thrive and adjust the framework for exiting crops anticipated to struggle under a changing climate).	Lead: Agriculture Insurance Corporation Collaborators: Experts	Fill knowledge gaps; Mainstreaming climate change	Ongoing
7. Commission a comprehensive study of diseases and pathogens that could be introduced to the Island, the types of livestock at risk, and the common methods used in their management.	Leads: Sector, Provincial Government Collaborators: Experts	Fill knowledge gaps; Reduce non-climatic factors	Medium-term (6 to 10 years)

Education and Outreach

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
8. Integrate climate change in the curriculum for lower grades where interdisciplinary and inquiry-based learning is already taking place (e.g., identify resources and activities).	Lead: Provincial Government Collaborators: Experts	Address knowledge gaps; Promote climate change mainstreaming	Short-term (0 to 5 years)
9. Integrate climate change in the curriculum for higher grades, focusing on increasing the skills, competencies, and knowledge of students across all subject areas.	Lead: Provincial Government Collaborators: Experts	Address knowledge gaps; Promote climate change mainstreaming	Short-term (0 to 5 years)
10. Support teachers by implementing small-scale initiatives to introduce climate change to the students in the near-term (e.g., host full-day workshop during PD days, provide inquiry-based activities to teachers).	Lead: Provincial Government Collaborators: Experts, Informal education providers	Address knowledge gaps; Promote climate change mainstreaming; Increase collaboration	Short-term (0 to 5 years)
11. Identify ways to increase experiential learning without leaving the school grounds (e.g., design and build a rain garden to manage stormwater onsite).	Lead: Provincial Government, Public Schools Branch, French Language School Board, Private Schools Collaborators: Experts, Home and School Federation	Address knowledge gaps; Engage in outreach	Ongoing
12. Increase exposure to climate change, interdisciplinary-learning, and inquiry-based learning at the post-secondary level.	Lead: Post-secondary institutions Collaborators: Experts	Address knowledge gaps	Short- to medium-term (0 to 10 years)
13. Increase awareness of opportunities to learn outside of the classroom.	Leads: Informal education providers, Provincial Government Collaborators: Parents and guardians	Engage in Outreach; Increase collaboration	Short-term (0 to 5 years)
14. Develop new informal education programming to expand the students' knowledge.	Leads: Informal education providers Collaborators: Parents	Address knowledge gaps; Engage in outreach	Short-term (0 to 5 years)
15. Place more emphasis on inspiring action and less on improving in-depth understanding of scientific knowledge when engaging the public.	Leads: All levels of government, All sectors	Engage in outreach	Ongoing
16. Encourage knowledgeable provincial government staff to communicate with colleagues (e.g., lunch and learns) and citizens (e.g., school workshops, roundtable discussions) about their areas of expertise.	Lead: Provincial Government Collaborators: Public	Address knowledge gaps; Engage in outreach	Ongoing
17. Identify different segments of the population (e.g., 'unconcerned and dismissive' versus 'most concerned and motivated') and generate public outreach approaches accordingly.	Leads and collaborators: All levels of government, All sectors	Engage in outreach	Ongoing
18. Create communication networks (e.g., websites, social media, flyers) and provide public forums for information sharing, roundtable discussions with experts, etc. on different themes to enhance public engagement.	Lead: Provincial Government Collaborators: Public, Experts	Engage in outreach	Ongoing
19. Leverage best practices in outreach from other sectors and jurisdictions (e.g., EMO is effective in educating the public of risks).	Leads and collaborators: All levels of government, All sectors	Engage in outreach; Increase collaboration	Ongoing

Energy

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
20. Commission studies to form a foundation for evidence-based adaptation planning (e.g., climate forecasts, vulnerability assessments, cost-benefit analysis).	Leads: Utilities Collaborators: Experts	Fill knowledge gaps; Promote climate change mainstreaming	Short-term (0 to 5 years)
21. Relocate, retrofit, and/or protect critical energy infrastructure and equipment vulnerable to climate change impacts (e.g., move infrastructure located in areas vulnerable to erosion, add guying to utility poles to avoid cascades of falling poles).	Leads: Utilities Collaborators: Experts	Increase resilience	Ongoing
22. Lower energy demand as a complementary approach to addressing peak capacity (e.g., develop an alert system with suggested actions to reduce consumption when system is near peak capacity to avoid rolling brownouts).	Leads: Provincial Government, Utilities Collaborators: Public	Increase resilience; Reduce non-climatic factors; Engage in outreach; Leverage regulation	Short- to medium-term (0 to 10 years)
23. Decentralize, diversify, and develop redundancy in the sector to increase its capacity to cope with hazardous events and avoid large-scale system failures (e.g., solar panels, energy storage equipment, district energy systems).	Leads: Utilities, Provincial Government Collaborators: Public, Businesses, Municipal governments	Increase resilience; Engage in outreach; Address financial concerns	Medium-term (5 to 10 years)
24. Implement policies and regulations to foster climate change adaptation in areas such as design and safety standards, permitting, siting and zoning.	Lead: Provincial Government Collaborators: Utilites, Experts	Increase resilience; Promote climate change mainstreaming; Leverage regulation	Short- to medium-term (0 to 10 years)
25. Integrate climate change impacts into day-to-day operations as well as planning, risk assessment and management, and decision-making processes (e.g., load and demand forecasting, training, investment planning).	Leads: Utilities	Promote climate change mainstreaming	Ongoing
26. Plan new developments with climate change in mind (e.g., make buildings "solar ready", site new developments in areas with low vulnerability to coastal erosion and flooding).	Leads: Utilities, Businesses, Individuals	Increase resilience; Promote climate change mainstreaming	Ongoing
27. Increase collaboration and communication among sector stakeholders (e.g., share information such as climate risks and best practices).	Leads: Utilities	Increase collaboration	Ongoing

PHOTO CREDIT: DON JARDINE

Fish and Aquaculture

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
28. Form a foundation for evidence-based adaptation planning by conducting research and collecting data (e.g., create and maintain an inventory and map of habitats of significant marine species and environmental variables, study effective responses against invasive species).	Leads: Sector, Provincial Government, Federal Government Collaborators: Experts, Watershed groups	Fill knowledge gaps	Short-term (0 to 5 years); Ongoing maintenance
29. Increase the ability of aquatic life to adapt to climate change impacts by reducing non-climatic stressors (e.g., widen the watercourse and wetland buffer zone, reduce runoff, restore coastal habitats).	Leads: Sector, Provincial Government, Federal Government Collaborator: Fishers, Experts, Public	Increase resilience; Reduce non-climatic factors; Engage in outreach	Medium-term (6 to 10 years)
30. Reduce stream water temperatures by reducing solar heating (e.g., increasing canopy cover in riparian zones) and improving water flow (e.g., limiting irrigation during times of high temperatures and low stream flows). Target areas where flow retention times are longer and large heat loads can accumulate in the absence of shade.	Leads: Sector, Provincial Government, Watershed Groups Collaborators: Private land owners, Experts	Increase resilience	Short-term (0 to 5 terms)
31. Increase support to watershed groups via funding for training, data collection and habitat improvement programs (see Recommended Adaptation Actions #28, #29, and #30 and #36).	Leads: Provincial Government, Federal Government, Sector Collaborators: Watershed groups	Increase resilience; Reduce non-climatic factors; Fill knowledge gaps; Increase collaboration	Ongoing
32. Manage risks and adapt to increased variability in the sector via diversification (e.g., diversify livelihoods, decentralize and spread out locations of facilities).	Leads: Fishers, Sector Collaborators: Experts	Increase resilience	Medium-term (6 to 10 years)
33. Invite other jurisdictions to share best practices (e.g., seek ways to cope with green crab, share local methods of transferring mussel seed from an infested area to a new area).	Leads: Fishers, Sector Collaborators: Experts	Increase collaboration	Ongoing
34. Relocate, retrofit, and/or protect existing properties and infrastructure and design new properties and infrastructure to reduce flooding and erosion vulnerabilities.	Leads: Infrastructure owners Collaborators: Experts	Increase resilience	Medium- to long-term (6+ years)
35. Facilitate adaptation and harmonize adaptation objectives and approaches among different stakeholders that are reliant on the same resource by using regulatory measures (e.g., prioritize sustainability of the industry and the environment over short-term profit and yield).	Leads: Provincial Government, Federal Government Collaborators: Fishers, Sectors, Other sectors	Leverage regulation; Promote climate change mainstreaming; Increase collaboration	Short- to medium-term (0 to 10 years)
36. Identify and address gaps in tools, guidelines, training, and skills (e.g., habitat restoration, vulnerability and risk assessments, training materials).	Leads: Sector, Provincial Government	Fill knowledge gaps; Increase resilience; Promote climate change mainstreaming	Ongoing
37. Limit business losses caused by climatic events by employing financial mechanisms such as insurance and other innovative instruments (e.g., create a co-operative that offers insurance against production losses).	Leads: Sector, Provincial Government Collaborators: Fishers, Experts	Address financial concerns; Increase collaboration	Medium-term (6 to 10 years)

Forestry and Biodiversity

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
38. Form a foundation for evidence-based adaptation planning by conducting research and collecting data (e.g., forecast precipitation patterns, determine current state of biodiversity).	Leads: Sector, Provincial Government Collaborators: Environmental groups, Experts	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years)
39. Keep forests healthy and productive and maintain biodiversity by reducing non-climatic stressors (e.g., reduce pollution, promote development of ground cover).	Leads: Sector, Provincial Government, Woodlot owners Collaborators: Environment groups, Municipal governments	Reduce non-climatic stressors; Increase resilience	Short- to medium-term (0 to 10 years)
40. Increase natural connectivity among natural areas (e.g., preserve core habitat areas, increase hedgerows).	Lead: Provincial Government Collaborators: Sectors, Municipal governments, Public, Environmental groups	Increase resilience	Medium- to long-term (6+ years)
41. Increase natural areas to sustain enough suitable habitats for diverse and healthy populations, particularly where natural connectivity is lacking, biodiversity is under threat, and future species may thrive (e.g., restore abandoned agricultural fields, sell tree saplings as school fundraisers).	Leads: Provincial Government, Environmental groups Collaborators: Public	Increase resilience	Medium- to long-term (6+ years)
42. Promote needed adaptation where existing incentive is lacking by using regulatory frameworks (e.g., widen the watercourse and wetland buffer zone). Increase compliance with added enforcement efforts and stricter penalties.	Lead: Provincial Government Collaborators: Sectors	Leverage regulation; Reduce non-climatic factors	Short-term (0 to 5 years)
43. Demonstrate the importance of forestry and biodiversity conservation and enhancement initiatives by assigning an economic value to the ecosystem services they provide (e.g., pollination and carbon storage services). These benefits and their economic values should be highlighted when generating support for adaptation actions in the sector.	Lead: Provincial Government Collaborators: Experts	Address financial concerns	Short-term (0 to 5 years)
44. Generate additional support for adaptation actions by engaging in outreach (e.g., frame the benefits of forests and biodiversity in ways that resonate with the public).	Lead: Provincial Government Collaborators: Sector, Environmental groups, Experts	Engage in outreach; Increase collaboration; Fill knowledge gaps	Short-term (0 to 5 years)
45. Improve the efficiency and effectiveness of adaptation activities by connecting with other environmental groups, community groups, and sectors (e.g., coordinated habitat restoration for Fish and Aquaculture and Forestry and Biodiversity sectors).	Leads: Environmental groups, Sectors Collaborators: Provincial Government, Experts	Increase collaboration	Ongoing
46. Collaborate with local Indigenous groups to incorporate Traditional Ecological Knowledge.	Lead: Sector, Indigenous groups Collaborators: Provincial Government, Environmental groups	Increase collaboration; Fill knowledge gap	Short-term (0 to 5 years)
47. Increase capacity within the Provincial Government (e.g., dedicate more staff to outreach).	Lead: Provincial Government	Fill knowledge gap; Engage in outreach	Short- to medium-term (0 to 10 years)
48. Develop a coordinated approach to implement the Recommended Adaptation Actions for the sector (#38 to #47) (e.g., stakeholder meetings, onsite demonstrations).	Leads: Provincial Government, Sector / Collaborators: Woodlot owners, Environmental groups, Outreach groups	Increase collaboration; Engage in outreach; Fill knowledge gaps	Ongoing

Insurance

Recommended Adaptation Actions	Responsibility	Themes	Suggested Timelines
49. Gather required data to address concerns of risk exposure (e.g., create and update flood risk maps).	Leads: Sector, Insurers Collaborators: Experts, Federal Government	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years)
50. Improve public understanding on the different types of flooding, levels of risk, types of insurance coverage available, and circumstances under which government financial aid is available.	Leads: Sector, Insurers	Engage in outreach	Ongoing
51. Look for opportunities to develop new insurance products (e.g., insure against coastal flooding).	Lead: Sector Collaborators: Insurers, Experts	Fill knowledge gaps; Increase collaboration	Ongoing
52. Promote adaptation actions, especially where insurance coverage is limited or unavailable (e.g., use visualization techniques to inspire adaptation, encourage relocation from areas of high flood risk).	Leads: Sector, All levels of government Collaborators: Other sectors, Experts	Engage in outreach	Short- to medium-term (0 to 10 years)

PHOTO CREDIT: DON JARDINE

Properties and Infrastructure

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
53. Relocate, retrofit, and/or protect properties and infrastructure vulnerable to climate change impacts (e.g., move infrastructure located in areas vulnerable to erosion, flood proof homes located in flood risk zones).	Leads: Property and infrastructure owners (e.g., individuals, businesses, governments) Collaborators: Experts	Increase resilience	Ongoing
54. Address budgetary constraints through financial planning (e.g., create an inventory of roads and bridges within the coastal zone area and perform a cost-benefit analysis to prioritize adaptation).	Leads: Property and infrastructure owners	Address financial concerns; Promote climate change mainstreaming	Ongoing
55. Make available erosion and coastal and inland flood risk maps accessible to all asset owners.	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Ongoing
56. Set a future climate scenario to establish design standards (e.g., should roads be built to withstand 1-in-50 year or 1-in-100 year rain events and are the events taking place in 2020, 2050 or 2100?)	Lead: Provincial Government Collaborators: Experts	Promote climate change mainstreaming	Short-term (0 to 5 years)
57. Update coastal erosion rates continuously to inform horizontal setbacks (i.e., 60 times the annual rate of erosion or 75 feet from the coastline, whichever is greater). Given that erosion rates are expected to accelerate, updated rates are critical in protecting buildings and Islanders.	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Ongoing
58. Incorporate future climate considerations into land use and building regulations (e.g., increase horizontal and vertical setbacks, require additional information during the development permit process).	Leads: Provincial and municipal governments Collaborators: Other sectors, Experts	Leverage regulation; Promote climate change mainstreaming	Short-term (0 to 5 years); Ongoing maintenance
59. Develop guidelines on shore stabilization and flood mitigation techniques as part of a comprehensive shoreline plan.	Lead: Provincial Government Collaborators: Experts, Public	Fill knowledge gaps	Short-term (0 to 5 years)
60. Explore the issue of liability surrounding developments and real estate transactions within flooding and erosion risk zones.	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
61. Utilize complementary green infrastructure when upgrading or designing stormwater management systems (e.g., rain gardens).	Leads: Stormwater management system managers and owners, Property owners Collaborators: Experts, Other sectors	Increase resilience	Medium- to long-term (6+ years)
62. Encourage a bottom-up approach by making property and infrastructure owners and managers aware of projected climate change impacts, adaptation actions available to them, and how those actions should be implemented.	Lead: Provincial Government Collaborators: Educators, Other sectors	Engage in outreach; Fill knowledge gaps	Short-term (0 to 5 years)
63. Provide a forum for asset and infrastructure owners and managers to learn and share best practices.	Lead: Provincial Government Collaborators: Municipal governments, Sector, Public	Fill knowledge gaps; Engage in outreach; Increase collaboration	Ongoing

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

Public Health and Safety

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
64. Invite other jurisdictions to share best practices and innovative approaches (e.g., WHO developed a tool to estimate costs and benefits of adaptation decisions).	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps; Increase collaboration	Ongoing
65. Integrate climate change impacts in all existing vulnerability assessments, management activities, policies, programs, etc. (e.g., adjust the operating budget to allow for increased demand for services).	Lead: Provincial Government Collaborators: Experts	Promote climate change mainstreaming	Ongoing
66. Help the public adapt to climate change by developing an outreach strategy. The information should be practical and relevant on a personal level and does not have to discuss climate change.	Lead: Provincial Government Collaborators: Educators	Engage in outreach, Fill knowledge gaps	Short-term (0 to 5 years)
67. Evaluate the knowledge gaps in the existing system and identify data, skills, or expertise required to address climate change impacts; develop multidisciplinary partnerships; and support interdisciplinary research.	Lead: Provincial Government Collaborators: Educators, Other sectors	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years)
68. Monitor and map environmental factors and other events related to public health to identify high-risk areas (e.g., harmful algal bloom outbreaks, fish kills, water temperature, air quality,).	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
69. Reduce non-climatic factors (e.g., prevent chronic disease so Islanders will become more resilient and able to cope with climate change impacts).	Lead: Provincial Government Collaborators: Health care professionals, Educators	Increase resilience; Engage in outreach	Ongoing
70. Create a mechanism at the community-scale to identify and assist vulnerable groups when emergencies arise so first responders can focus on those with the greatest needs.	Leads: Municipal governments, EMO Collaborators: Public	Increase collaboration	Short-term (0 to 5 years)
71. Conduct training exercises involving emergency services and local responders to respond to severe, wide area flooding and improve delivery of service and response time.	Lead: EMO Collaborators: First responders	Fill knowledge gap	Short-term (0 to 5 years)
72. Recommend dual access to properties when possible to assist in the emergency management response should one access route become impassable (e.g., flooded, washed out, surrounded by forest fire).	Lead: EMO Collaborators: Property owners	Increase resilience	Ongoing
73. Create lists of safe spaces within communities and establish a mechanism to communicate the choice before/during/after the event.	Leads: Municipal governments, EMO Collaborators: Public	Increase resilience; Increase collaboration	Short-term (0 to 5 years)

Tourism

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
74. Forecast future climate for variables that impact tourism (e.g., number of "comfort days" for golf, soft adventure).	Leads: Sector, Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
75. Develop more offerings for the shoulder seasons (e.g., festivals, events, experiential products).	Lead: Sector Collaborators: Tourism operators	Increase resilience	Medium-term (6 to 10 years)
76. Promote Prince Edward Island as an escape from urban heat.	Lead: Provincial Government Collaborator: Sector	Increase resilience	Short-term (0 to 5 years)
77. Relocate, retrofit, or protect assets and infrastructure that are vulnerable to the effects of flooding and erosion (e.g., relocate at-risk tourist accommodations, protect scenic routes, site new attractions away from flood and erosion risk zones).	Lead: Provincial Government, Asset and infrastructure owners Collaborator: Sector, Tourism operators, Experts	Increase resilience	Ongoing
78. Consider new methods of meeting water needs (e.g., improving water efficiency, decreasing turf area, harvesting rainwater, etc.) and different turfgrasses that would be suitable under a changing climate.	Lead: Golf course operators Collaborators: Experts	Increase resilience	Medium-term (6 to 10 years)
79. Diversify the product offering (e.g., eco-tourism, cultural heritage, and culinary experiences) to include more all-weather products.	Leads: Tourism operators Collaborator: Sector	Increase resilience	Short-term (0 to 5 years)
80. Determine the viability of storm-watching as an attraction on the North Shore.	Lead: Parks Canada Collaborators: Sector, Tourism operators, Experts	Increase resilience	Short-term (0 to 5 years)

PHOTO CREDIT: DON JARDINE

Water

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
81. Identify and address gaps in data, training, knowledge and tools (e.g., install weather stations, improve understanding of groundwater recharge and discharge rates, provide training on watershed monitoring and restoration).	Lead: Provincial Government, Water infrastructure owners Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
82. Integrate climate change considerations in financial planning. Water infrastructure owners and managers need to consider the costs and timing of adaptation actions in relation to the costs associated with the increase in liability, increase in maintenance, shorter lifespan, etc.	Leads: Water infrastructure owners Collaborators: Experts	Address financial concerns; Promote climate change mainstreaming	Ongoing
83. Set a future climate scenario to establish design standards and analyze the resilience of existing infrastructure (e.g., should stormwater management systems be built to withstand 1-in-50 year or 1-in-100 year rain events and are the events taking place in 2020, 2050 or 2100?)	Leads: Provincial Government, Water infrastructure owners and managers Collaborators: Experts	Promote climate change mainstreaming	Short-term (0 to 5 years)
84. Put back-up systems in place to limit disruptions to service during extreme weather events (e.g., spare flood pumps, back up electricity source).	Leads: Water infrastructure owners and managers	Increase resilience	Short-term (0 to 5 years)
85. Prompt the development of natural and manmade climate-resilient water infrastructure by incorporating future climate considerations and using land use planning policies and regulations (e.g., limit ditch filling).	Lead: Provincial Government Collaborators: Experts	Leverage regulation; Promote climate change mainstreaming	Short- to medium-term (0 to 10 years)
86. Reduce demand on water infrastructure (e.g., sensitize public to the challenges facing groundwater, provide practical recommendations on how to reduce demand).	Lead: Provincial Government Collaborators: Educators, Public	Increase resilience	Short-term (0 to 5 years)
87. Actively maintain, restore, enhance and create wetlands to increase natural protection of coastal areas and improvements in water quality and quantity.	Lead: Provincial Government Collaborators: Property owners, Sectors, Experts, Watershed groups	Increase resilience; Promote climate change mainstreaming	Medium- to long-term (6+ years); Ongoing maintenance
88. Utilize complementary green infrastructure to manage stormwater (e.g. green roofs, rain gardens, ditches, detainment ponds).	Leads: Property owners, Water infrastructure owners and managers Collaborators: Provincial and municipal governments, Experts	Increase resilience	Short- to medium-term (0 to 10 years)
89. Create a pilot project to demonstrate bioretention techniques (see Recommended Adaptation Actions #62d and #88).	Leads: Provincial Government, Educators	Engage in outreach; Fill knowledge gaps	Short-term (0 to 5 years)
90. Develop and supply flood risk maps to municipalities with water infrastructure.	Lead: Provincial Government Collaborators: Municipal governments	Fill knowledge gaps	Short- to medium-term (0 to 10 years)
91. Engage in public outreach. Provide guidance on how to minimize the risk of flooding and improve water security.	Lead: Provincial Government Collaborators: Municipal governments, Educators	Engage in outreach	Ongoing

Water (continued)

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
92. Provide financial incentives to property owners to manage stormwater on site (e.g., ditches, permeable surfaces).	Leads: Provincial Government, Municipal governments, Water infrastructure owners and managers	Address financial concerns	Short-term (0 to 5 years)
93. Coordinate with other sectors and share best practices in maintaining water quality and sustaining water quantity.	Lead: Provincial Government Collaborators: Water infrastructure owners and managers, Other sectors	Increase collaboration	Ongoing
94. Decommission unused wells to prevent risk of contamination.	Leads: Provincial Government, Property owners	Increase resilience	Ongoing

Moving Forward

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
95. Educate elected officials and decision-makers on the importance and urgency of climate change adaptation.	Lead: Provincial Government Collaborators: Municipal governments, Experts	Fill knowledge gaps	Ongoing
96. Issue a clear directive to all provincial government departments to incorporate climate change in all decision-making, planning, budgeting, etc. Strong leadership and a clear directive will be vital for meaningful adaptation work to begin.	Lead: Provincial Government	Increase resilience; Promote climate change mainstreaming	Short-term (0 to 5 years)
97. Build a provincial-wide framework for cooperative and coordinated climate change adaptation response across sectors, leads, and collaborators.	Lead: Provincial Government Collaborators: Federal Government, Municipal governments, Sectors, Experts, Businesses, Non-governmental organizations, Public	Increase collaboration	Ongoing

Despite the unique characteristics of each sector, common themes emerged from the recommended adaptation actions: fill knowledge gaps, increase resilience, reduce non-climatic factors, promote climate change mainstreaming, increase collaboration, engage in public outreach, leverage regulation (e.g, land use planning), and address financial concerns.

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

Conclusion

Throughout the sector consultation sessions, the consensus on climate change and the need to adapt was clear. There were high levels of awareness and adaptive capacity observed at the consultation sessions. However, there exist barriers across all groups and sectors that are preventing efficient adaptation from taking place. The common barriers include: uncertainty, lack of funding, insufficient incentive, lack of guidance, requirement for high levels of coordination, and gradual nature of climate change. Potential solutions include collaboration with experts, data gathering, long-term financial planning, demonstrations of successful approaches, and interdisciplinary collaboration.

To move forward, it must be recognized that climate change is a shared problem that requires shared responsibility from everyone – individuals, businesses, research institutions, non-governmental organizations, sectors, different levels of government, etc. Joint action is required in instances where different groups and sectors are impacted. The provincial government could play a critical role in leading the development of a medium- and long-term strategy in adapting to climate change. They have expertise across all sectors, the authority to compel action, and ability to coordinate and implement large-scale initiatives.

Gradual and incremental changes to the status quo alone will be insufficient in the face of future climate. Meaningful and successful climate change adaptation for the Island will require coordinated, collaborative, complementary, and parallel approaches by the different leads and collaborators identified by this report (e.g., sectors, Provincial Government, municipal governments, individuals). To achieve this, a clear vision of sustainability, the willingness to disrupt the status quo, a commitment to work together, and the urgency to act swiftly are needed from everyone. Planned adaptation takes time and the work must begin immediately. It is insufficient to “prioritize” climate change adaptation; adapting to climate change must be considered a normal way of life.

PHOTO CREDIT: DON JARDINE

REFERENCES

Benoît, H.P., J.A. Gagne, C. Savenkoff, P. Ouellet, and M-N. Bourassa (eds.). (2012). *State-of-the-Ocean Report for the Gulf of St. Lawrence Integrated Management (GOSLIM) Area*. Retrieved from http://www.dfo-mpo.gc.ca/Library/345310.pdf

Fenech, A. (2016, December 6). *Climate, Weather and Canadian Agriculture* [Presentation at 2016 Atlantic Agrology Workshop].

Fenech, A. (2015). The Changing Climate of the Atlantic Region of Canada [Conference Proceedings]. *Aquaculture Association of Canada Bulletin*. Retrieved from http://aquacultureassociation.ca/wp-content/uploads/2017/01/AC14-Proceedings-Bulletin-2015-1.pdf

Fenech, A. and X. Su. (2014). *Wind at North Point, PEI: Preliminary Results* [Presentation to the Wind Energy Institute of Canada on December 17, 2014].

Government of Prince Edward Island. (2016, September 19). *Air Quality Monitoring* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/air-quality-monitoring

Kelly, J., P.A. Makar and D.A. Plummer. (2012, June 22). Projections of mid-century summer air-quality in North America: effects of changes in climate and precursor emissions. *Atmospheric Chemistry and Physics, 12,* 5367–5390. doi:10.5194/acp-12-5367-2012

Myers, S.S., M.R. Smith, S. Guth, C.D. Golden, B. Vaitla, N.D. Mueller, A.D. Dangour, and P. Huybers. (2017, March 20). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health,* 20(38), 259-277. doi:10.1146/annurev-publhealth-031816-044356.

Natural Resources Canada. (2016). *Climate Change Coastal Assessment*. Retrieved from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/Coastal_Assessment_Chapter4_EastCoastRegion.pdf

Savard, J.P., D. van Proosdij, and S. O'Carroll. (2016). Perspectives on Canada's East Coast region. In: *Canada's Marine Coasts in a Changing Climate*, (eds.) D.S. Lemmen, F.J. Warren, T.S. James, and C.S.L. Mercer Clarke; Government of Canada, Ottawa, ON, p. 99-152. Retrieved from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/Coastal_Assessment_Chapter4_EastCoastRegion.pdf

Senneville, S. and F. Saucier. (2007). *Étude de sensibilité de la glace de mer au réchauffement climatique dans le golfeet l'estuaire du Saint-Laurent.* Ouranos Report. 30 pp

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas. (January 2017). Global and Regional Sea Level Rise Scenarios for the United States. *NOAA Technical Report NOS CO-OPS 083.* Retrieved from https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

1

In the face of an absolutely unprecedented emergency, society has no choice but to take dramatic action to avert a collapse of civilization. Either we will change our ways and build an entirely new kind of global society, or they will be changed for us.

—Blue Planet Laureates

1 INTRODUCTION

1.1 Climate Change

Global climate change is seen as one of the greatest threats posed to the future of humankind and the world. Climate is not weather. Weather is short-term changes (hours, days) in temperature, cloud cover, precipitation (rain, snow, sleet), humidity or wind at the local or regional scale. Climate, on the other hand, is long-term changes (months, seasons, years, decades) in these variables at the global, regional or local scale. Changes in our climate are often so small as to take decades, centuries, or millennia to be observable. These small changes in climate, however, can have significant impacts on the environment, society, and economy of Prince Edward Island.

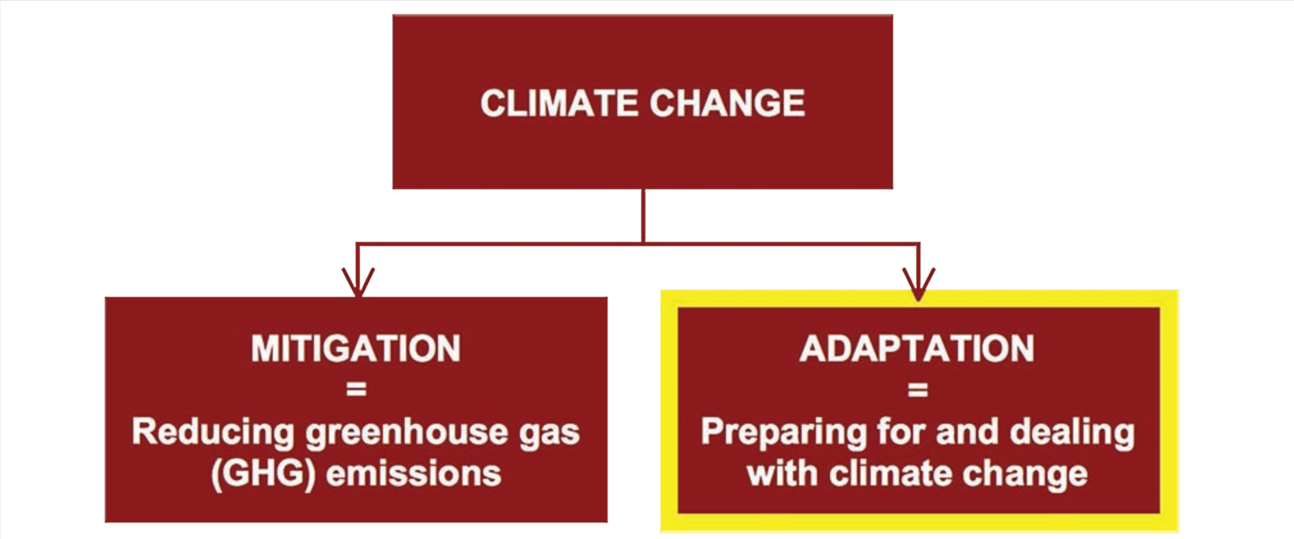


Figure 1.1: Climate change mitigation versus climate change adaptation.

There are two main responses to addressing climate change: mitigation and adaptation (see Figure 1.1). Mitigation looks to combat climate change by reducing greenhouse gas emissions, the root cause of climate change. Adaptation addresses the symptoms of climate change by adjusting decisions, activities, behaviours, and mentalities to take advantage of the opportunities arising from climate change and to reduce the negative consequences of climate change.

While climate mitigation strategies are necessary to reduce greenhouse gas emissions from anthropogenic sources, those alone are unlikely to be sufficient to eliminate the negative impacts of climate change. The impacts of climate change from emissions of greenhouse gases over the past 150 years will have to be confronted by all jurisdictions now. The climate is changing and the impacts are already affecting the environment, society, and economy of the Island. Therefore, the pursuit of a complementary strategy of adapting to unavoidable climate change impacts while reducing greenhouse gas emissions to lessen climate change impacts is urgently needed. ***This report focuses solely on climate change adaptation.***

1.2 Climate Change Adaptation

Climate change adaptation is necessary to survive and thrive under a changing climate. Unlike coping, which is primarily reacting to immediate damages associated with climate impacts, adaptation requires developing an informed, forward-looking, comprehensive strategy that supports broader goals such as the resiliency and sustainability of the environment, society, and economy. Adaptation can take many forms: physical, technological, operational, institutional, financial, sociological, or regulatory/administrative (Johnson, 2012).

Effective adaptation requires coordinated effort among the public, businesses, sectors, non-governmental organizations, research institutions, and all levels of government. The approach must be based on the best science and evidence available and a spirit of openness and partnership. Private adaptation actions are essential given the highly localized nature of climate change impacts and their effects on different parts of the society and economy. Government adaptation actions are critical in addressing barriers to timely and effective adaptation. Joint action also has the added benefit of combining resources, experiences, perspectives, and expertise from different groups to tackle a shared problem. Therefore, the recommended adaptation actions proposed in this document are the responsibilities of all Islanders, with many of them requiring a collaborative effort from two or more group.

PHOTO CREDIT: GOVERNMENT OF PEI

This report is not intended to be a detailed climate change vulnerability assessment or an operational plan for climate change adaptation. It identifies anticipated climate change impacts and recommends relevant adaptation actions to address them. It suggests "why, what, who, and when" but leaves "where and how" to the decision-makers of each recommended adaptation action.

1.3 Report Format

This report contains thirteen chapters and an Executive Summary. This introduction (Chapter 1) is followed by an overview of Prince Edward Island's Changing Climate (Chapter 2), which provides observed and projected changes in temperature, precipitation, extreme weather events, sea level rise, etc. Chapter 3 to Chapter 12 constitute the main body of this report, with one chapter dedicated to each of the ten sectors studied and consulted: Agriculture, Education and Outreach, Energy, Fish and Aquaculture, Forestry and Biodiversity, Insurance, Properties and Infrastructure, Public Health and Safety, Tourism, and Water. These chapters address the sectors' sensitivities to climate, outline the risks and opportunities presented by climate change, and provide recommended adaptation actions to address them. These adaptation recommendations were developed in five stages. First, the public and sector stakeholders were consulted on their concerns regarding climate change and adaptation. Second, anticipated climate change impacts and adaptation approaches used in other jurisdictions regionally, nationally and internationally were reviewed to prepare a discussion document for each sector. Third, roundtable discussions with sector stakeholders were held to review the relevance and practicality of the proposed approaches and to develop additional recommendations. Fourth, the sectors' input was incorporated in the discussion documents, which form the sector chapters of the draft report. Last, the public's input on the draft report was sought via online submissions and consultation meetings and incorporated in this final report. The conclusion (Chapter 13) of this report examines adaptation themes and barriers common to all sectors and the initiatives required to move forward collectively.

REFERENCES

Johnson, T. (2012). *Fisheries Adaptation to Climate Change*. doi: 10.4027/facc.2012.

2

On climate change, we often don't fully appreciate that it is a problem. We think it is a problem waiting to happen.

—Kofi Annan

2 PRINCE EDWARD ISLAND'S CHANGING CLIMATE

2.1 Temperature

Climate change is projected to warm most regions of Canada. Over the past fifty years, annual mean temperatures rose in Atlantic Canada (e.g., 0.5°C in Charlottetown, PE) (Fenech, 2015). This trend is expected to continue; using a statistically-downscaled global climate model average, Fenech (2015) forecasts a rise in annual mean temperatures by 0.7°C on average by the 2020s (2011-2040), 1.6°C on average by the 2050s (2041-2070) and 2.4°C on average by the 2080s (2071-2100). These may seem small increases in annual average temperatures; however, these small increases have dramatic effects on the Island's environment, society, and economy.

These seemingly minute increases in annual mean temperatures will influence the extremes of temperature significantly – the number of days exceeding extreme hot temperatures (>27.5°C) will likely increase from our current normal of 8 per year on average to 16 per year on average in the 2020s, to 22 per year on average in the 2050s (2041-2070) and to 35 per year on average in the 2080s (see Figure 2.1). The number of days exceeding extreme cold temperatures (<-20°C) will likely decrease from our current normal of 6 per year on average (1981-2010) to 5 per year on average in the 2020s, to 4 per year on average in the 2050s, to 3 per year on average in the 2080s (see Figure 2.2).

PHOTO CREDIT: DON JARDINE

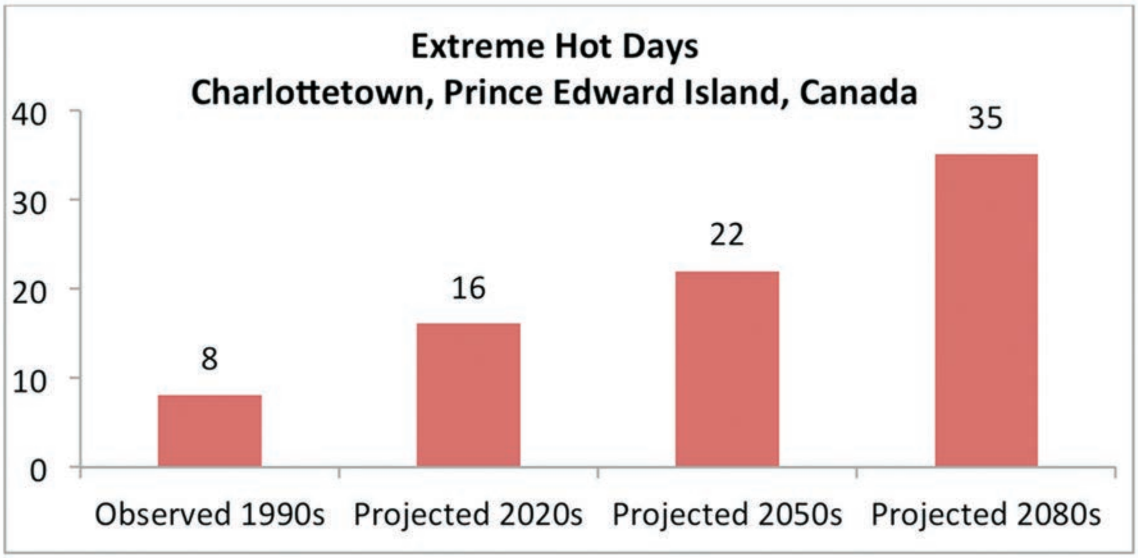


Figure 2.1: Projected number of days exceeding extreme hot temperatures (>27.5˚C) for Charlottetown, PE, Canada (Source: Preliminary results from statistically downscaled averages from Fenech and Jien (2015) using SDSM).

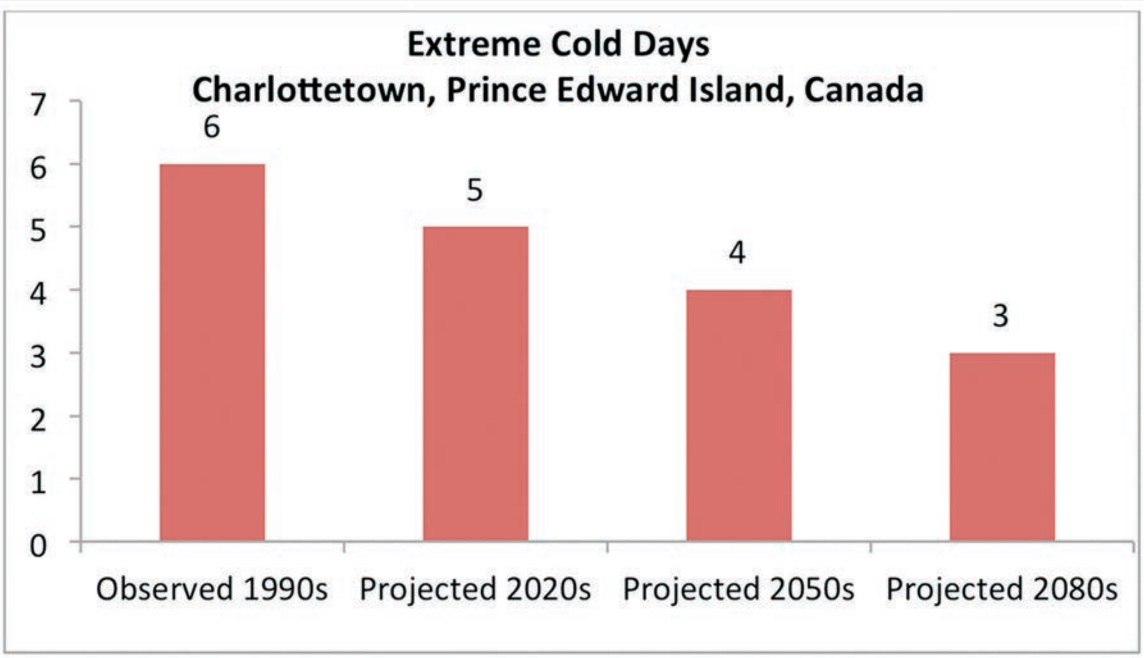


Figure 2.2: Projected number of days exceeding extreme cold temperatures (<-20˚C) for Charlottetown, PE, Canada (Source: Preliminary results from statistically downscaled averages from Fenech and Jien (2015) using SDSM).

2.2 Precipitation

Over the past fifty years, annual total precipitation (e.g., rain, snow, sleet) decreased (e.g., -5% in Charlottetown, PE) (Fenech, 2015). This trend is expected to continue. While precipitation is anticipated to generally increase for Atlantic Canada, Prince Edward Island is forecasted to experience a decrease from today's normal (1981-2010) by 6% on average by the 2020s, making it drier and more susceptible to drought conditions (see Figure 2.3). Over time, the models show precipitation returning to today's normal by the 2080s (Fenech, 2016).

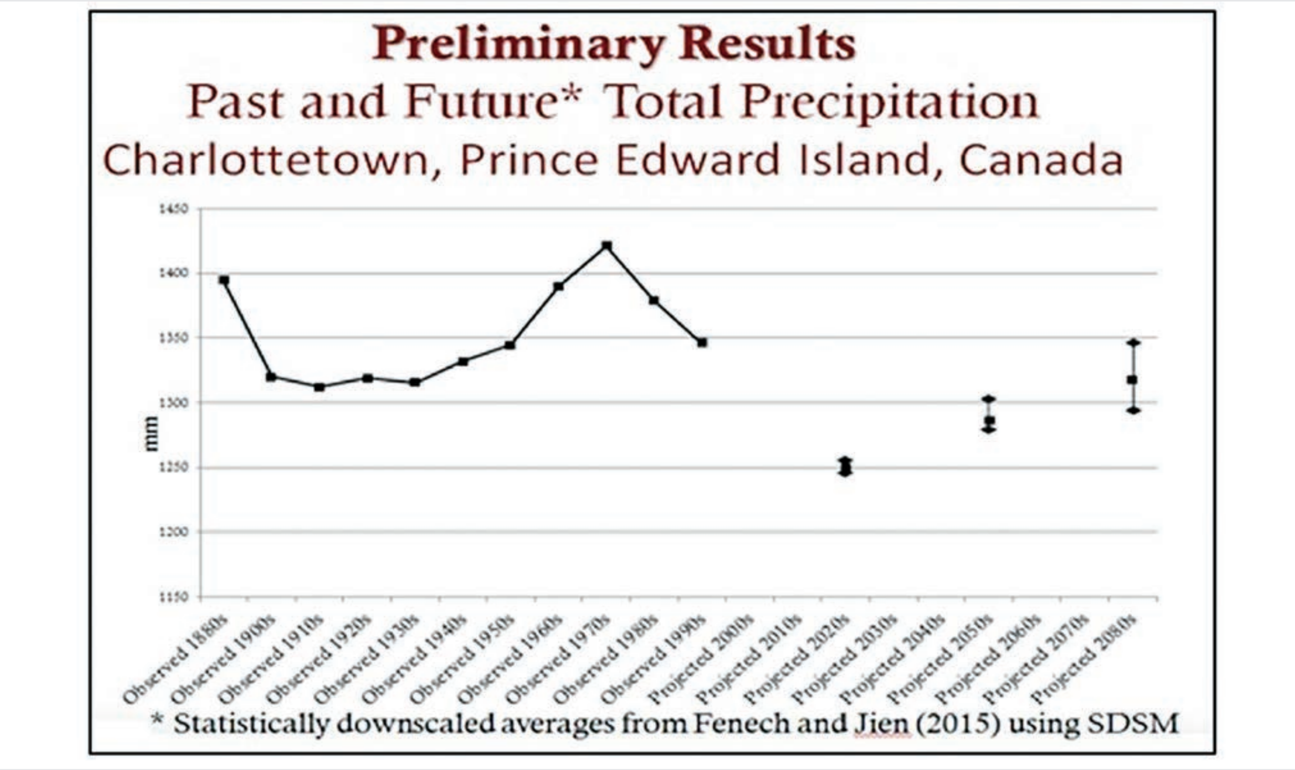
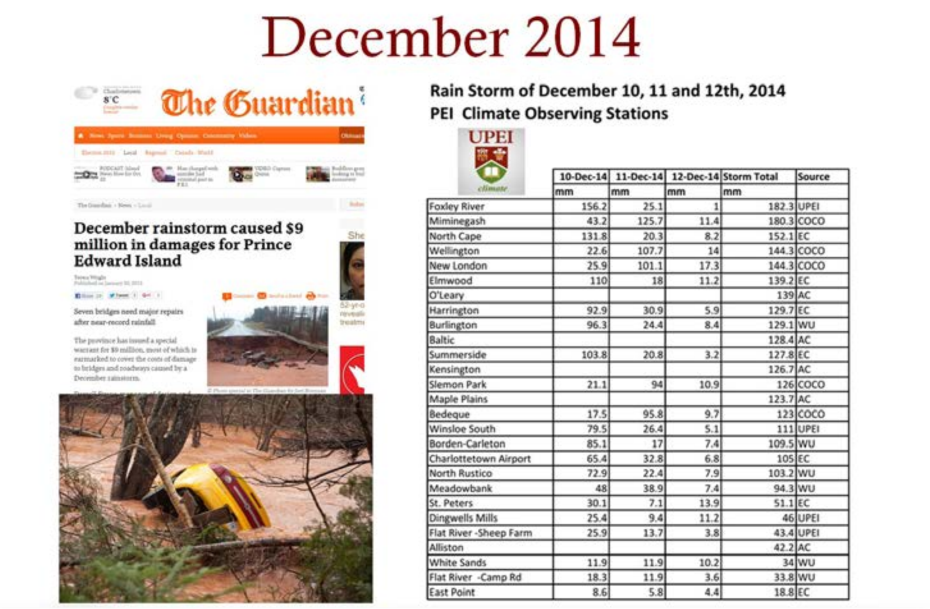


Figure 2.3: Historical observations and preliminary projections for total precipitation in Charlottetown, PE, Canada (Source: Fenech, 2016).

2.3 Extreme Weather Events

Precipitation events are expected to decrease in frequency and increase in severity under a changing climate. That means there will be fewer events but they will be much more intense, such as the December 2014 rainstorm that brought over 180-mm of rain, causing $9 million in damages as a result of runoff, inland flooding, road washouts, etc.

PHOTO CREDIT: DON JARDINE



Rain Storm of December 10, 11 and 12th, 2014
PEI Climate Observing Stations

	10-Dec-14	11-Dec-14	12-Dec-14	Storm Total	Source
	mm	mm	mm	mm	
Foxley River	156.2	25.1	1	182.3	UPEI
Miminegash	43.2	125.7	11.4	180.3	COCO
North Cape	131.8	20.3	8.2	152.1	EC
Wellington	22.6	107.7	14	144.3	COCO
New London	25.9	101.1	17.3	144.3	COCO
Elmwood	110	18	11.2	139.2	EC
O'Leary				139	AC
Harrington	92.9	30.9	5.9	129.7	EC
Burlington	96.3	24.4	8.4	129.1	WU
Baltic				128.4	AC
Summerside	103.8	20.8	3.2	127.8	EC
Kensington				126.7	AC
Slemon Park	21.1	94	10.9	126	COCO
Maple Plains				123.7	AC
Bedeque	17.5	95.8	9.7	123	COCO
Winsloe South	79.5	26.4	5.1	111	UPEI
Borden-Carleton	85.1	17	7.4	109.5	WU
Charlottetown Airport	65.4	32.8	6.8	105	EC
North Rustico	72.9	22.4	7.9	103.2	WU
Meadowbank	48	38.9	7.4	94.3	WU
St. Peters	30.1	7.1	13.9	51.1	EC
Dingwells Mills	25.4	9.4	11.2	46	UPEI
Flat River -Sheep Farm	25.9	13.7	3.8	43.4	UPEI
Alliston				42.2	AC
White Sands	11.9	11.9	10.2	34	WU
Flat River -Camp Rd	18.3	11.9	3.6	33.8	WU
East Point	8.6	5.8	4.4	18.8	EC

Figure 2.4: Extreme precipitation event on Prince Edward Island, Canada in December 2014 (Source: Fenech, 2017).

2.4 Sea Level Rise

Sea levels increased 0.32 metres per century from 1911-2008 (see Figure 2.5) at Charlottetown Harbour, Prince Edward Island. Sea levels continue to rise, as do future projections calculated by scientists. According to the most recent assessment by the U.S. National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, U.S. Geological Survey, Rutgers University, and the U.S. Department of Commerce, global mean sea-level could rise in the range of 2.0 to 2.7 metres by 2100 (Sweet *et al.*, 2017).

Sea levels do not rise uniformly across the globe due to factors such as changes in winds, air pressure, air-sea heat and freshwater fluxes, and ocean currents (Sweet *et al.*, 2017). Over the last several decades, the sea levels in the Pacific coast have risen less than the global average but those in the Atlantic coast have risen above the global average (see Figure 2.6). Rising sea-levels will lead to an increase in the reach and severity of coastal flooding and coastal erosion.

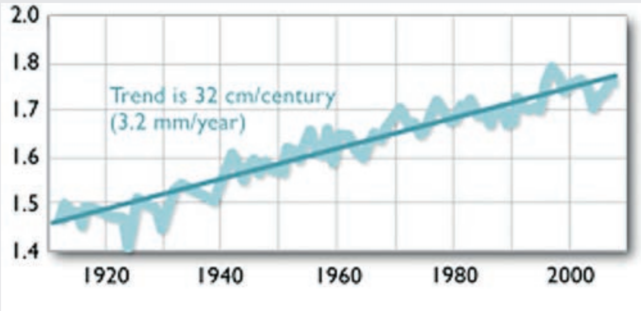


Figure 2.5: Observed increase in water level (metres above reference level on land) 1911–2008 at Charlottetown Harbour, PE, Canada (Source: Biodiversity Canada, 2014).

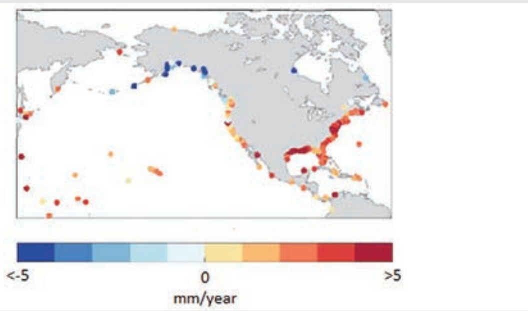


Figure 2.6: Differences in sea level trends globally based on full records (at least 30 years of data) measured and published for NOAA tide gauges through 2015 (Source: Sweet et al., 2017).

2.5 Wind

Fenech and Su (2014) applied statistical downscaling techniques to global climate model output to predict similar average wind velocities as over the past thirty years for Prince Edward Island, Canada. Trends in wind velocity and direction, however, are difficult to determine conclusively, in part because datasets are not as complete as those for air temperature (Natural Resources Canada, 2016)

2.6 Sea Ice

Ocean temperatures in the Magdalen Shallows ocean region where Prince Edward Island sits (see Figure 2.7) have increased over the past thirty years (see Figure 2.8). Senneville and Saucier (2007) estimated using numerical modelling that a 2°C increase in air temperature could translate to a decrease of up to 28% in ice cover and 55% in ice volume. While such winter temperature increases might seem far off into the future, the current inter-annual variability is already of this magnitude (Galbraith *et al.*, 2011). Savard *et al.* (2016) estimated that sea ice cover in the east-coast region will likely decrease by more than 95% by the end of this century. Within the Gulf of St. Lawrence, sea ice will continue to decrease in area, thickness, concentration, and duration until it ceases to form (Savard *et al.,* 2016).

While the much larger anomaly of 4.7°C observed in the winter of 2010 coincided with the almost complete absence of ice in the Gulf of St. Lawrence, the anomaly during the winter of 2011 was only 1.7°C and a similar lack of ice cover occurred, much lower than foretold by such models. Even though climate change can be expected to bring many ice-free winters, inter-annual variability will likely ensure that ice will be present during at least some of the winters in the coming decades (Benoît *et al.*, 2012).

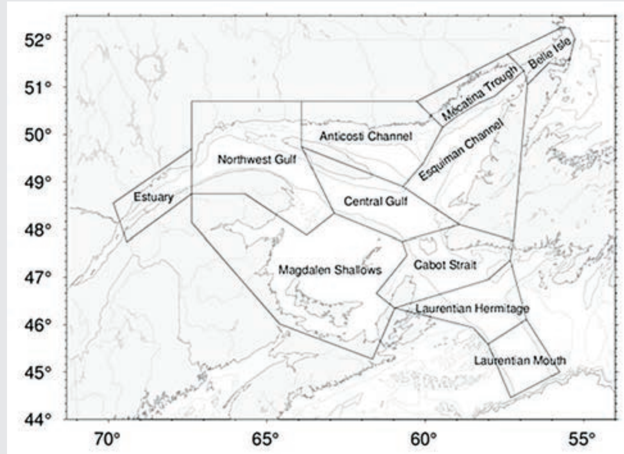
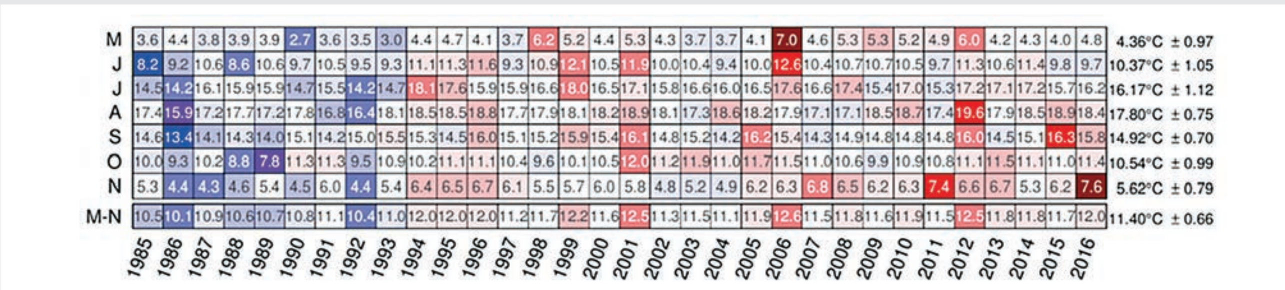


Figure 2.7: Canadian Department of Fisheries and Oceans (DFO) Gulf of St. Lawrence Ocean Regions (Source: Galbraith et al., 2017).



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
M	3.6	4.4	3.8	3.9	3.9	2.7	3.6	3.5	3.0	4.4	4.7	4.1	3.7	6.2	5.2	4.4
J	8.2	9.2	10.6	8.6	10.6	9.7	10.5	9.5	9.3	11.1	11.3	11.6	9.3	10.9	12.1	10.5
J	14.5	14.2	16.1	15.9	15.9	14.7	15.5	14.2	14.7	18.1	17.6	15.9	15.9	16.6	18.0	16.5
A	17.4	15.9	17.2	17.7	17.2	17.8	16.8	16.4	18.1	18.5	18.5	18.8	17.7	17.9	18.1	18.2
S	14.6	13.4	14.1	14.3	14.0	15.1	14.2	15.0	15.5	15.3	14.5	16.0	15.1	15.2	15.9	15.4
O	10.0	9.3	10.2	8.8	7.8	11.3	11.3	9.5	10.9	10.2	11.1	11.1	10.4	9.6	10.1	10.5
N	5.3	4.4	4.3	4.6	5.4	4.5	6.0	4.4	5.4	6.4	6.5	6.7	6.1	5.5	5.7	6.0
M-N	10.5	10.1	10.9	10.6	10.7	10.8	11.1	10.4	11.0	12.0	12.0	12.0	11.2	11.7	12.2	11.6

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
M	5.3	4.3	3.7	3.7	4.1	7.0	4.6	5.3	5.3	5.2	4.9	6.0	4.2	4.3	4.0	4.8	4.36°C ± 0.97
J	11.9	10.0	10.4	9.4	10.0	12.6	10.4	10.7	10.7	10.5	9.7	11.3	10.6	11.4	9.8	9.7	10.37°C ± 1.05
J	17.1	15.8	16.6	16.0	16.5	17.6	16.6	17.4	15.4	17.0	15.3	17.2	17.1	17.2	15.7	16.2	16.17°C ± 1.12
A	18.9	18.1	17.3	18.6	18.2	17.9	17.1	17.1	18.5	18.7	17.4	19.6	17.9	18.5	18.9	18.4	17.80°C ± 0.75
S	16.1	14.8	15.2	14.2	16.2	15.4	14.3	14.9	14.8	14.8	14.8	16.0	14.5	15.1	16.3	15.8	14.92°C ± 0.70
O	12.0	11.2	11.9	11.0	11.7	11.5	11.0	10.6	9.9	10.9	10.8	11.1	11.5	11.1	11.0	11.4	10.54°C ± 0.99
N	5.8	4.8	5.2	4.9	6.2	6.3	6.8	6.5	6.2	6.3	7.4	6.6	6.7	5.3	6.2	7.6	5.62°C ± 0.79
M-N	12.5	11.3	11.5	11.1	11.9	12.6	11.5	11.8	11.6	11.9	11.5	12.5	11.8	11.8	11.7	12.0	11.40°C ± 0.66

Figure 2.8: Sea Surface Temperature monthly anomalies based on the 1985-2010 climatologies for each month (numbers are the monthly average temperatures in degrees Celsius) at the Magdalene Shallows, Canada. The 1985-2010 mean and standard deviation are indicated for each month on the right side of the table The May to November average is also included (Source: Galbraith et al., 2017).

2.7 Air Quality

Air quality in Canada is measured using the Air-Quality Health Index (AQHI), a three pollutant health metric designed by Health Canada in conjunction with Environment Canada, to convey the effects of air pollution on acute human health outcomes to the public (Stieb *et al.,* 2008). The AQHI is a function of three chemical species: ground-level ozone (O_3), particulate matter less than 2.5 microns (PM2.5), and nitrogen dioxide (NO_2).

Ground-level ozone (O_3) is a human toxin and a plant toxin. It is created when two other air pollutants – nitrogen oxides (NO_x) and volatile organic compounds (VOCs) – react in sunlight and air. Almost all of Prince Edward Island's NO_x comes from on-island burning of diesel and gasoline for transportation and heavy fuel oil at industrial facilities (Government of Prince Edward Island, 2016). VOCs are generated from many different sources; 36% of it originated from the burning of wood for home heating in 2014 (Government of Prince Edward Island, 2016). The levels of O_3 in Prince Edward Island in 2011-2013 were between 54ppb (Southampton) and 55ppb (Charlottetown and Wellington), all below the target of 63 ppb set by the Canadian Ambient Air Quality Standards (PEI Department of Communities, Land and Environment, 2016). However, projections modeled by Kelly *et al.* (2012) forecast an increase of O_3 concentrations for the Island by the middle of the century as a result of climate change only, with anthropogenic air pollution emissions held constant. An upward trend in air pollution combined with increasing formation of O_3 with rising temperature (Myers *et al.,* 2017) could see future levels of O_3 exceed the set target.

REFERENCES

Benoît, H.P., J.A. Gagne, C. Savenkoff, P. Ouellet, and M-N. Bourassa. (eds). (2012). *State-of-the-Ocean Report for the Gulf of St. Lawrence Integrated Management (GOSLIM) Area.* Retrieved from http://www.dfo-mpo.gc.ca/Library/345310.pdf

Biodiversity Canada. (2014, July 3). *Coastal* [website]. Retrieved from http://www.biodivcanada.ca/default.asp?lang=En&n=30769AD0-1&offset=1&toc=show

Daigle, R. (2012). *Sea Level Rise and Storm Surge Projections for Prince Edward Island* [Presentation at PEI's Changing Climate: Results of the Atlantic Regional Adaptation Collaborative on Climate Change on April 17, 2012].

Fenech, A. (2016, December 6). *Climate, Weather and Canadian Agriculture* [Presentation at 2016 Atlantic Agrology Workshop].

Fenech, A. (2015). The Changing Climate of the Atlantic Region of Canada [Conference Proceedings]. *Aquaculture Association of Canada Bulletin.* Retrieved from http://aquacultureassociation.ca/wp-content/uploads/2017/01/AC14-Proceedings-Bulletin-2015-1.pdf

Fenech, A. (2017, February 27). *UPEI Climate Lab* [Presentation to the Honourable Kirsty Duncan].

Fenech, A. and J. Jien. (2015). *Application of Statistical Downscaling to Global Models for Agroclimatic Indicators in Atlantic Canada* [Document submitted to Agriculture Canada as part of the Farms to Regions research project].

Fenech, A. and X. Su. (2014). *Wind at North Point, PEI: Preliminary Results.* [Presentation to the Wind Energy Institute of Canada on December 17, 2014].

Galbraith, P.S., J. Chassé, D. Gilbert, P. Larouche, D. Brickman, B. Pettigrew, L. Devine, A. Gosselin, R.G. Pettipas, and C. Lafleur. (2011). *Physical oceanographic conditions in the Gulf of St. Lawrence in 2010*. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/045: iv + 82 pp.

Government of Prince Edward Island. (2016, September 19). *Air Quality Monitoring* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/air-quality-monitoring

Kelly, J., P.A. Makar, and D.A. Plummer. (2012, June 22). Projections of mid-century summer air-quality in North America: effects of changes in climate and precursor emissions. *Atmospheric Chemistry and Physics,* 12, 5367–5390. doi: 10.5194/acp-12-5367-2012

Myers, S.S., M.R. Smith, S. Guth, C.D. Golden, B. Vaitla, N.D. Mueller, A.D. Dangour, and P. Huybers. (2017, March 20). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*, 20(38), 259-277.doi: 10.1146/annurev-publhealth-031816-044356.

Natural Resources Canada. (2016). *Climate Change Coastal Assessment.* Retrieved from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/Coastal_Assessment_Chapter4_EastCoastRegion.pdf

PEI Department of Communities, Land and Environment. (2016, September). *2014 Air Quality Report For the Years 2011-2013.*

Savard, J.P., D. van Proosdij, and S. O'Carroll. (2016). Perspectives on Canada's East Coast region. In: *Canada's Marine Coasts in a Changing Climate,* (eds.) D.S. Lemmen, F.J. Warren, T.S. James, and C.S.L. Mercer Clarke; Government of Canada, Ottawa, ON, p. 99-152. Retrieved from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/Coastal_Assessment_Chapter4_EastCoastRegion.pdf

Senneville, S. and F. Saucier. (2007). *Étude de sensibilité de la glace de mer au réchauffement climatique dans le golfeet l'estuaire du Saint-Laurent.* Ouranos Report. 30 pp

Stieb, D.M., R.T. Burnett, M. Smith-Doiron, O. Brion, H.S. Hwashin, and V. Economou, (2008). A new multipollutant, no-threshold air quality health index based on short-term associations observed in daily time-series analyses, *J. Air Waste Manage.,* 58, 435–450

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas. (2017, January). Global and Regional Sea Level Rise Scenarios for the United States. *NOAA Technical Report NOS CO-OPS 083.* Retrieved from https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

3

We are stewards, not masters of our earth.

—Pope Francis

3 AGRICULTURE SECTOR

3.1 Background

Agriculture has been an integral part of Prince Edward Island's history, economy, and identity for generations. Out of the Island's 1.4 million acres of land, approximately 0.6 million acres are cleared for agricultural use (see Figure 3.1). There were a total of 1,353 farms reported in the 2016 census; they range in size from a few acres to over 3,500 acres (Statistics Canada, 2017a). In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion, with the agriculture sector contributing $152 million or 3.2% (see Figure 3.2)[1]. In 2016, the agriculture and aquaculture industries employed approximately 3,100 people, out of 71,000 across all industries in the province (see Figure 3.3). The sector's contribution to the provincial Gross Domestic Product or GDP increases to 10% (Campbell *et al.*, 2014) and it becomes the largest provincial employer if food processing is included (see Figure 3.4)

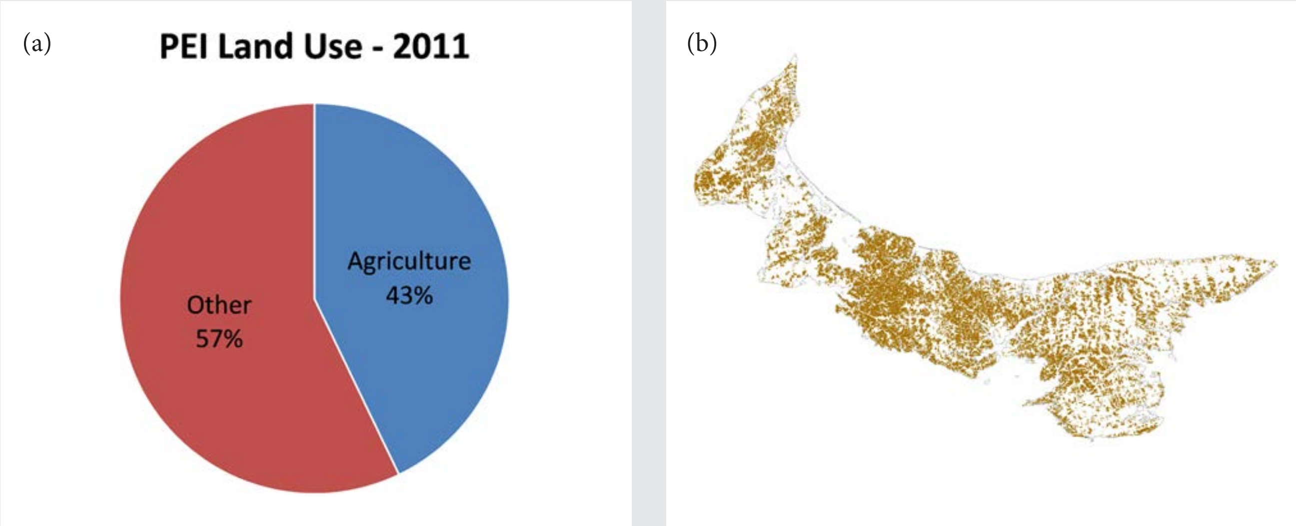


Figure 3.1: (a) Agricultural land use in 2011 (Data source: PEI Department of Agriculture and Fisheries [PEI AF], 2015) (b) Distribution of agricultural land in 2010 (GIS data source: Government of Prince Edward Island, 2010).

1 GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

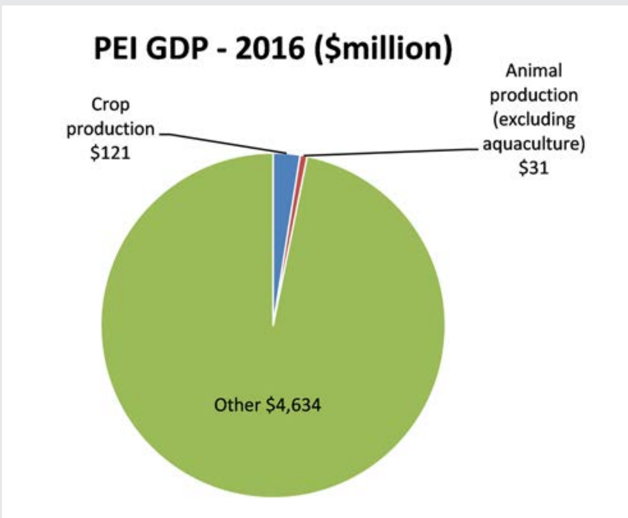


Figure 3.2: Prince Edward Island GDP of crop and animal production in 2016 (in $million chained 2007 dollars) (Data source: Statistics Canada, 2017c).

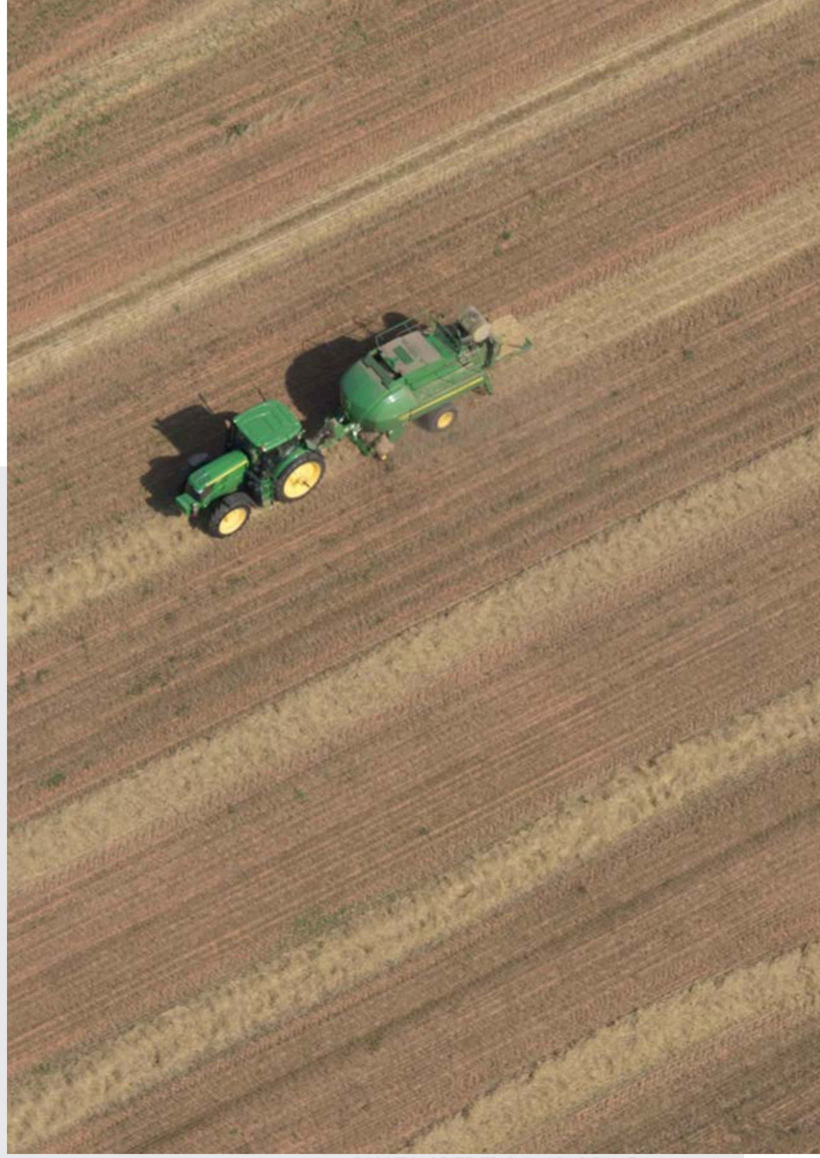


PHOTO CREDIT: DON JARDINE

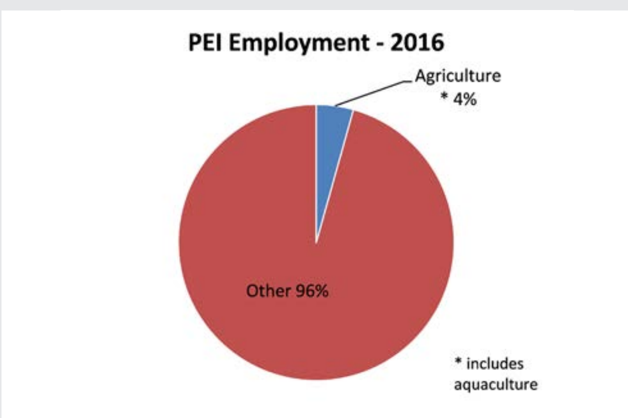


Figure 3.3: Employment in the agriculture sector compared to total employment as of January 2017 (Data source: Statistics Canada, 2017b). Note: Data for "agriculture" includes aquaculture.

Figure 3.4: Contribution of food processing plus primary agriculture to GDP in 2011, excluding beverage and tobacco processing (preliminary data) (Source: Campbell et al., 2014).

3.1.1 Crop Production

The 1,353 farms on Prince Edward Island are primarily used for growing crops and raising livestock. Out of all crops, potatoes generate the highest farm cash receipts[2]. In 2015, 89,500 acres of potatoes were harvested (PEI Statistics Bureau, 2016), which generated farm cash receipts of approximately $223.8 million (see Figure 3.5). Potatoes are sold as table potatoes, seed potatoes to other potato-producing regions, "fresh for processing" potatoes to processing plants around the world, and processed potato products (e.g., french fries and other frozen potato products). Some are also stored as local seed for the next crop. PEI potatoes are sold in the Maritimes, across Canada, the United States and overseas (PEI AF, 2015). Grains (e.g., wheat, barley, oats) and oil seeds (e.g., soybeans) are primarily grown in rotation with potatoes. In 2015, 89,000 acres of grains and 58,000 acres of oilseeds were harvested (PEI AF, 2015), generating farm cash receipts of approximately $33.9 million (see Figure 3.5). The remaining crops are fruits ($10.7 million) such as blueberries, cranberries, strawberries, apples, grapes, etc. and "other" ($24.6 million), which include floriculture and nursery products.

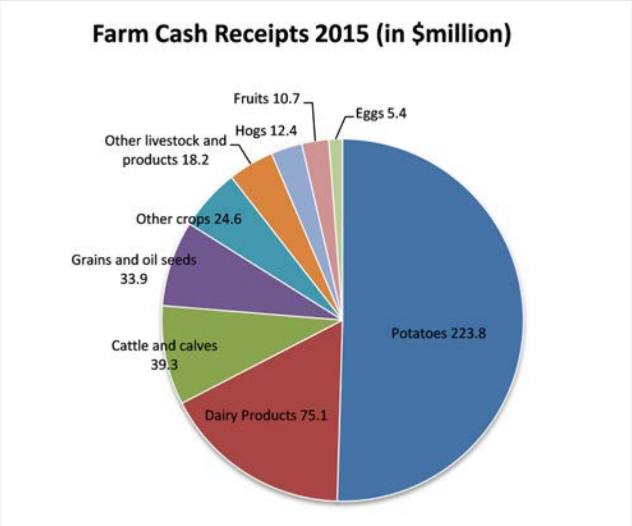


Figure 3.5: 2015 PEI farm cash receipts (Data source: PEI Statistics Bureau 2016).

PHOTO CREDIT: DON JARDINE

3.1.2 Animal Production

Out of all livestock and livestock products, dairy products generate the highest farm cash receipts. In 2015, approximately 180 dairy farms produced more than 100 million litres of milk (PEI AF, 2015) and generated farm cash receipts of $75.1 million (see Figure 3.5). Most of the milk is used to produce dairy products such as cheese, butter and ice cream; the remainder is used to supply the fresh market (PEI AF, 2015). Cattle and calves farms are second in farm cash receipts with approximately $39.3 million in 2015 (see Figure 3.5). Approximately 40% of farms on Prince Edward Island engage in beef production (PEI AF, 2015). This industry is tightly linked with the potato sector because they purchase cull potatoes and crops used in potato

2 Farm cash receipts are total monies paid to the farmer (e.g., revenues from sales, payments from insurance programs, payments from government agencies) before expenses (e.g. operating expenses, depreciation).

rotation as part of the beef feed ration. The remaining livestock and livestock products categories are hogs ($12.4 million), eggs ($5.4 million) and "other" ($18.2 million) (see Figure 3.5).

3.2 Climate Change Impacts

Climate change will bring about warmer weather, changes in precipitation patterns, more intense storms, and rising sea levels in Prince Edward Island.

It is critical to note that opportunities and challenges resulting from climate change cannot be taken in isolation. While there are anticipated impacts both positive and negative, the extent of them has not been quantified. For example, the advantages of a longer growing season from warmer temperatures could be offset by the impacts of invasive pests and diseases that those temperatures bring.

3.2.1 Temperature

OPPORTUNITIES

First, Fenech's (2016) preliminary forecast shows 50 additional frost free days and 25 more days in the growing season (see Figures 3.6 and 3.7). This could potentially result in a double harvest for short season crops (e.g., soy beans followed by peas), increased yields for longer season crops, and better establishment of cover crops in the fall following row crop harvest.

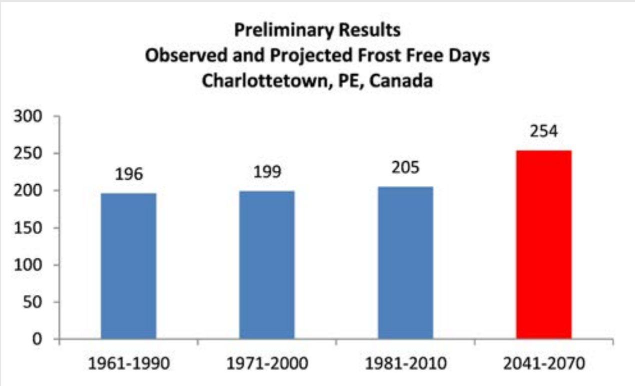


Figure 3.6: Historical observations and preliminary projections for the number of frost free days in Charlottetown, PE, Canada (Source: Fenech, 2016).

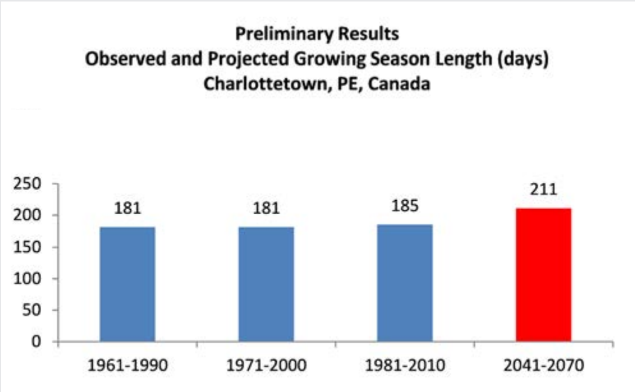


Figure 3.7: Historical observations and preliminary projections for the length of growing seasons in Charlottetown, PE, Canada (Source: Fenech, 2016).

Second, the rise in temperatures and will also increase the number of growing degree days over 5°C by 500 by the 2050s (see Figure 3.8), which may be conducive to the planting of new and possibly more profitable crops that require more heat units (e.g., pulses such as lentils, dry peas, chickpeas, dry beans). In other areas of Canada, pulses are almost exclusively grown as a rotational crop with varieties such as wheat and canola (Bekkering, 2014).

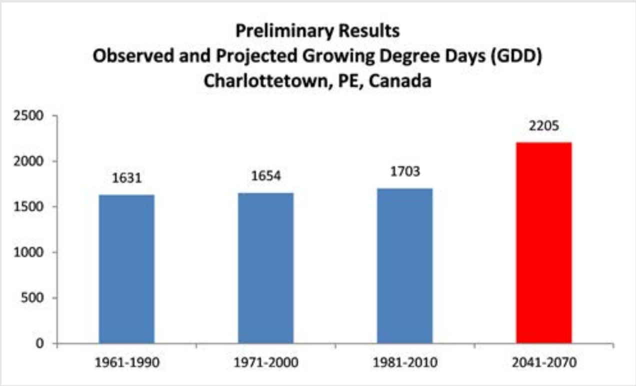


Figure 3.8: Historical observations and preliminary projections for the number of growing degree days (>5˚C) in Charlottetown, PE, Canada (Source: Fenech, 2016).

PHOTO CREDIT: GOVERNMENT OF PEI

Third, the milder winter and spring seasons would be less harsh on pollinators. It would increase winter survival of honey bees and encourage build-up of colonies in the spring (Currie, n.d.).

Fourth, shorter and milder winters will provide more opportunities for livestock to graze and be fattened outdoors, lower feed requirements, and increase survival rate of young (Agriculture and Agri-Food Canada [AAFC], n.d.).

CHALLENGES

First, warmer temperatures will increase the severity of outbreaks of existing pests and diseases (Campbell *et al.,* 2014), increase the winter survival rates of insect pests and shift the range of new pests and diseases northward (Myers *et al.,* 2017). Crops are often unable to defend against non-native pests and pathogens (Myers *et al.,* 2017). Animal health could be impacted by the presence of more ticks, mosquitoes, parasites, and bacteria (Campbell *et al.,* 2014).

Second, pollinators will face increased pest and disease activity, undermining their health. Their diet will also be disrupted by the change in timing of flowering due to warmer weather, the northward migration of plant communities, and the reduction in nutritional value of pollen due to increasing carbon dioxide concentrations (Myers *et al.,* 2017). These changes limit the breadth and quality of their diet and could also lead to the poor pollinator health, reduction in population, and possibly the eventual extinction of plants and pollinators (Myers *et al.,* 2017).

Third, the added heat will increase evaporation, causing water stress and lowering crop productivity (Campbell *et al.,* 2014). Rain-fed crops will be especially vulnerable (Myers *et al.,* 2017).

Fourth, the milder winter and spring seasons could increase the likelihood of winter bud kill, especially for fruit trees and vines (Campbell *et al.,* 2014). Plants that are normally dormant could begin to grow when unseasonably warm temperatures occur and begin to sprout leaves, flowers, and fruits. When temperatures suddenly return to freezing temperatures, the new growth could be damaged. It is possible that fruit and flower buds may not be able to bloom again later that year.

Fifth, warmer summers could increase heat-wave deaths of livestock and decrease milk production, beef cattle weight gain, and reproduction in the dairy industry (AAFC, n.d.).

Sixth, livestock feed may be impacted as the cropping sector adapts to warmer temperatures (Campbell *et al.,* 2014).

Seventh, warmer temperatures encourage the growth of weeds (Campbell *et al.,* 2014).

Eighth, warmer temperatures increase the survival rates of "volunteers" – potatoes that remain in the field after harvest. When winter frost does not penetrate the soil deeply, the volunteers can survive and regrow the next season, becoming a source of disease for neighbouring fields (B. Simmons, personal communication, September 15, 2017)

3.2.2 Precipitation

CHALLENGES

Reduced precipitation combined with greater evapotranspiration from warmer temperatures could lead to greater water requirements for crops.

3.2.3 Extreme Weather Events

CHALLENGES

First, extreme weather events can greatly decrease crop yields by as much as 50% of the average yield during normal conditions (AAFC, n.d.). For example, PEI's summer growing season of 2012 saw less than half the normal amount of rainfall, reducing low levels in streams and creeks and nearly caused a revocation in irrigation permits (Brennan, 2012). This could have impacted yield of some potato varieties by 25% (Fenech, 2012). In 2001, severe drought caused average potato yield reductions of 40% across the Island, with some farms experience greater losses (B. Simmons, personal communication, September 15, 2017).

Second, these events can compromise crop defences and allow pests and weeds to establish themselves (Myers *et al.*, 2017).

Third, heavy rain events and storm surge could also cause increased bank erosion and runoff, transporting sediment and chemicals such as pesticides and nutrients to water bodies, potentially causing eutrophication, fish kills, and other environmental damage.

Fourth, extreme weather events such as droughts and floods can also decrease the availability of pasture and the amount of forage for herds.

3.2.4 Sea Level Rise

CHALLENGES

First, the likelihood of salt water intrusion in coastal aquifers could increase.

Second, bank erosion rates will increase.

Third, low-lying areas will become permanently inundated. Erosion and flooding will decrease the availability of agricultural land.

3.2.5 Carbon Dioxide

Although the increasing concentrations of atmospheric carbon dioxide is the primary driver of climate change and is responsible for the impacts described above, the carbon dioxide itself also impacts the agriculture sector

OPPORTUNITIES

The increase in concentration of carbon dioxide in the atmosphere can improve crop yield in three ways: accelerating the rate of photosynthesis, raising the efficiency of water use in plants, and strengthening plant defences against pests and pathogens (Myers *et al.,* 2017).

CHALLENGES

First, increasing carbon dioxide concentrations in the atmosphere encourages the growth of weeds. Herbicides are not as effective in reducing weed growth that is induced by elevated CO_2 concentrations (Myers *et al.,* 2017).

Second, carbon dioxide changes the nutritional composition of crops. Experiments have shown a 7–15% decrease in the protein content within the edible portion of wheat, barley, and potatoes (Myers *et al.,* 2017).

PHOTO CREDIT: GOVERNMENT OF PEI

3.2.6 Ground-level Ozone

CHALLENGES

Ground-level ozone (O_3) is a human toxin as well as a plant toxin. It hampers crop photosynthesis and growth, and reduces grain weight and yields (Myers *et al.,* 2017). Experiments have shown that yields of wheat and soybean can decrease by 8-25% when O_3 levels are between 54 ppb and 75 ppb (Myers *et al.,* 2017). The levels of O_3 in Prince Edward Island in 2011-2013 were between 54ppb (Southampton) and 55ppb (Charlottetown and Wellington) (PEI Department of Communities, Land and Environment, 2016) and are expected to increase under climate change (Kelley *et al.,* 2012; Myers *et al.,* 2017).

3.2.7 Indirect Impacts

There are other indirect impacts of climate change that will affect the agriculture sector. For example, rising temperatures could open the Northwest Passage and impact trade routes. This could open new markets for export and/or raise competition. Food access and security will become increasingly valued with climate change. Model simulations have shown the global prices of staple grains such as wheat would increase 31-106% by 2050 (Myers *et al.*, 2017).

Efforts in climate change mitigation and adaptation in other sectors could have a significant impact on the agriculture sector as efforts to reduce energy use, water use, runoff, and greenhouse gas emissions gain momentum.

PHOTO CREDIT: DON JARDINE

3.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

1 Commission a **comprehensive study of crop opportunities and challenges** under warming conditions over the next-thirty years. The study should include:

- **a.** high resolution forecasts of temperature for different parts of the Island so the agriculture sector can plan accordingly;
- **b.** high resolution forecasts of precipitation during the growing season for different parts of the Island;
- **c.** a list of new and existing crop varieties, cover options, and rotation crop options that would best allow farmers to take advantage of the added heat from warmer temperatures and the lengthening of the growing season;
- **d.** an analysis of existing crop varieties that would produce lower yields in higher temperatures. For example, the yield of Russet Burbank potatoes in the State of Washington decreased in areas experiencing higher temperatures (University of Nebraska-Lincoln, n.d.);
- **e.** a list of new pests and pathogens that could be introduced to the Island under the future climate, the types of crops that are at risk, and the common methods used in their management;
- **f.** a list of new technologies available to help crops adapt to the expected changes in climate (e.g., new crop protection products);
- **g.** an analysis of how the competitive landscape (e.g., markets, pricing) of the main crop varieties will change under future climate; and,
- **h.** a review of how other jurisdictions producing the main crop varieties are adapting to a changing climate.

Suggested timeline: short-term (0–5 years)

2 Build an **understanding of water requirements** by commissioning a study to investigate past, present and anticipated drought conditions and common methods used to address them. The study should include:

- a. correlations between past yield and precipitation, if any;
- b. crop-specific drought forecasting models for main crop varieties on PEI;
- c. high resolution forecasts of precipitation trends (e.g., length and severity of dry conditions, timing and severity of intense rain events) for different parts of the island so the sector can plan accordingly;
- d. anticipated water requirements for the forecasted future climate;
- e. water management practices and structures suitable for future climate (e.g., use of mulching, contoured hedgerows and buffers, soil features, rainwater harvesting, manmade ponds, desalination, water efficiency and conservation strategies, conservation tillage);
- f. the role of soil health and composition in moisture preservation and suitable soil management techniques;
- g. the role of cultivation methods; and,
- h. a cost-benefit analysis of the water management practices and structures and soil management techniques (see Recommended Adaptation Actions #2e and #2f).

Suggested timeline: short-term (0–5 years)

3 **Reduce the amount of contaminated runoff** reaching water bodies by managing stormwater onsite (e.g., see Recommended Adaptation Actions #2e and #2f) and reducing the amount of inputs used (e.g., apply inputs to targeted areas using data collected by unmanned aerial vehicles).
Suggested timeline: ongoing

4 Conduct on-farm **demonstrations of best practices** developed in the studies suggested above (see Recommended Adaptation Actions #1,#2, and #3) to showcase effective adaptation measures and provide producers with practical guidance.
Suggested timeline: medium-term (6–10 years)

5 **Add and maintain 100 climate stations** across the Island to improve the collection of climate data, including soil temperature, to develop a baseline for the analysis of climate trends at higher resolutions. The data and analysis should be made available in an easily accessible format (e.g., mobile device application).
Suggested timeline: short-term (0–5 years); ongoing maintenance

6 **Integrate climate change considerations in the agricultural insurance framework**. The Agricultural Insurance Corporation should build a series of agriculture indicators to guide the timing of climate derivatives from year to year. The climate varies from one season to the next so the utilizing of derivatives based on climate rather than calendar dates would be more appropriate. The Agriculture Insurance Corporation should also use the suggested study of crop opportunities and challenges to begin building the framework to offer insurance for new crop varieties anticipated to thrive in warming conditions and adjust the framework for existing crops anticipated to struggle under changing climate conditions.
Suggested timeline: ongoing

7 Commission a comprehensive **study of diseases and pathogens** that could be iintroduced to the Island under the future climate, the types of livestock that are at risk, and the common methods used in their management (e.g., adjust stock density, change shearing and breeding patterns, supplement feeding).
Suggested timeline: medium-term (6–10 years)

The collaboration of farmers, sector (e.g. industry organizations), experts (e.g., climate scientists, biologists, engineers), and the government will be critical in achieving effective adaptation. The table below summarizes the seven recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: GOVERNMENT OF PEI

Table 3.1: Summary of recommended adaptation actions for the agriculture sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
1. Commission a comprehensive study of crop opportunities and challenges under warming conditions over the next thirty years.	Leads: Sector, Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
2. Build an understanding of water requirements, anticipated drought conditions, and common methods used to address them.	Leads: Sector, Provincial Government Collaborators: Experts, Other sectors	Fill knowledge gaps; Reduce non-climatic factors	Short-term (0 to 5 years)
3. Reduce the amount of contaminated runoff reaching water bodies by managing stormwater onsite and reducing the amount of inputs used.	Leads: Sector, Farmers Collaborators: Experts, Other sectors	Increase resilience	Ongoing
4. Conduct on-farm demonstrations of best practices to showcase effective adaptation measures and provide producers with practical guidance.	Lead: Sector Collaborators: Farmers	Fill knowledge gaps; Engage in outreach	Medium-term (6 to 10 years)
5. Add and maintain 100 climate stations across the Island to improve the collection of climate data, including soil temperature, to develop a baseline for the analysis of climate trends at higher resolutions	Lead: Sector Collaborators: Farmers, Experts	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years); Ongoing maintenance
6. Integrate climate change considerations in the agricultural insurance framework (e.g., offer insurance for new crop varieties expected to thrive and adjust the framework for exiting crops anticipated to struggle under a changing climate).	Lead: Agriculture Insurance Corporation Collaborators: Experts	Fill knowledge gaps; Mainstreaming climate change	Ongoing
7. Commission a comprehensive study of diseases and pathogens that could be introduced to the Island, the types of livestock at risk, and the common methods used in their management.	Leads: Sector, Provincial Government Collaborators: Experts	Fill knowledge gaps; Reduce non-climatic factors	Medium-term (6 to 10 years)

3.4 Conclusion

The importance of the agriculture sector in Prince Edward Island cannot be overstated. Aside from its role in the Island's economy, its provision of healthy and affordable food is critical. Agriculture is inherently sensitive to climate and the lead times for adaptation are long. Therefore, the sector must be proactive in its adaptation strategy. Studies have shown that adaptation actions such as altering planting and harvest dates, changing crop varieties, and altering irrigation practices can lead to a 7-15% increase in yield (Myers *et al.,* 2017). Building adaptive capacity as soon as possible will make the sector more resilient to manage the known and unknown impacts that climate change will inevitably bring.

REFERENCES

Agriculture and Agri-Food Canada. (n.d.). *Impact of climate change on Canadian Agriculture* [website]. Retrieved from http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/agriculture-and-climate/future-outlook/impact-of-climate-change-on-canadian-agriculture/?id=1329321987305

Bekkering, E. (2014). Pulses in Canada. *Statistics Canada*. Catalogue no. 96-325-X — No. 007. ISSN 0-662-35659-4. Retrieved from http://www.statcan.gc.ca/pub/96-325-x/2014001/article/14041-eng.pdf

Brennan, R.J. (2012, July 23). P.E.I. potato farmers may be forced to stop irrigating. *The Toronto Star*. Retrieved from https://www.thestar.com/news/canada/2012/07/23/pei_potato_farmers_may_be_forced_to_stop_irrigating.html

Campbell, I.D., D.G. Durant, K.L. Hunter, and K.D. Hyatt. (2014). Food Production. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation,* (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 99-134.

Currie, R. (n.d.). *Pollinating Insects – Native and Managed Pollinators*. Retrieved from https://umanitoba.ca/faculties/afs/ncle/pdf/Ag2050_Essay_Currie.pdf

Fenech, A. (2016, December 6). *Climate, Weather and Canadian Agriculture* [Presentation at 2016 Atlantic Agrology Workshop].

Fenech, A. (2012, December 29). P.E.I.'s top three wild weather stories of 2012. *The Guardian*. Retrieved from http://projects.upei.ca/climate/files/2017/01/2012-12-29c-cache-PEIs-top-three-wild-weather-stories-of-2012.pdf [cached copy]

Fenech, A. (2015). The Changing Climate of the Atlantic Region of Canada [Conference Proceedings]. *Aquaculture Association of Canada Bulletin*. Accepted. Retrieved from http://aquacultureassociation.ca/wp-content/uploads/2017/01/AC14-Proceedings-Bulletin-2015-1.pdf

Kelly, J., P.A. Makar, and D.A. Plummer. (2012, June 22). Projections of mid-century summer air-quality in North America: effects of changes in climate and precursor emissions. *Atmospheric Chemistry and Physics*, *12*, 5367–5390. doi:10.5194/acp-12-5367-2012

Myers, S.S., M.R. Smith, S. Guth, C.D. Golden, B. Vaitla, N.D. Mueller, A.D. Dangour, and P. Huybers. (2017, March 20). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health,* 20(38), 259-277. doi:10.1146/annurev-publhealth-031816-044356.

PEI Department of Agriculture and Fisheries. (2015, July). *2015 Agriculture at a Glance* [fact sheet]. Retrieved from http://www.gov.pe.ca/photos/original/af_agataglance.pdf

PEI Department of Communities, Land and Environment. (2016, September). *2014 Air Quality Report For the Years* 2011-2013.

PEI Statistics Bureau. (2016, June). *Prince Edward Island 42nd Annual Statistical Review 2015*. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/stats2015.pdf

Simmons, B. (2017, September 15). Email.

Statistics Canada (a). (2017, May 10). *Table 004-0201 – Census of Agriculture, farms classified by total farm area*. Retrieved on October 18, 2017.

Statistics Canada (b). (2017, February 2). *Table 282-0088 - Labour force survey estimates (LFS), employment by North American Industry Classification System (NAICS), seasonally adjusted and unadjusted.* Retrieved on May 12, 2017.

Statistics Canada (c). (2017, April 28). *Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories.* Retrieved on May 3, 2017.

University of Nebraska-Lincoln. (n.d.). Russett Burbank: Characteristics [website]. *CropWatch*. Retrieved from http://cropwatch.unl.edu/potato/russetburbank.

4

The public—the electorate—needs to understand causes and effects of actions and inactions, [and have] a better knowledge of how science works. Science literacy is the artery through which the solutions of tomorrow's problems flow.

—Neil deGrasse Tyson

4 EDUCATION AND OUTREACH SECTOR

4.1 Background

4.1.1 Formal Education

Education in Canada lies within provincial or territorial jurisdiction. The Prince Edward Island Department of Education, Early Learning and Culture (PEI EELC) develops programs and curriculum for Islanders from birth to Grade 12 in English and French (PEI EELC, n.d.). In 2014, there were 19,133 students enrolled in 56 schools covering grades K to 12 within the English Language School Board, 825 students enrolled in 6 schools covering grades K to 12 within La Commission scolaire de langue française, and 226 students enrolled in 2 private schools (PEI EELC, 2015a). The department budget for fiscal year 2014-2015 was $232 million. As of February 2015, there were 76 licensed early learning and child care centres and 38 licensed family home and school age centres/programs across the province (PEI EELC, 2015b). There are 3 post secondary education institutions on the Island: University of Prince Edward Island, Holland College, and College Acadie I.P.E.

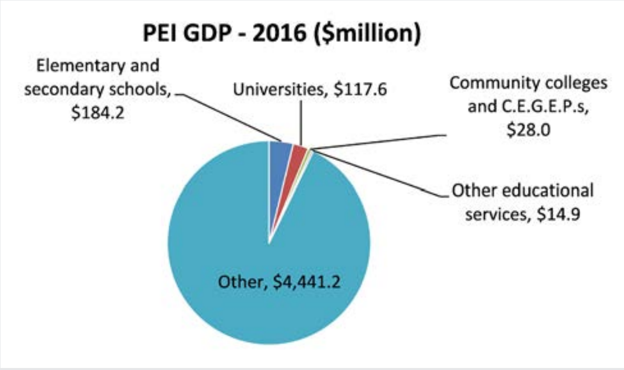


Figure 4.1: Prince Edward Island GDP of various education subsectors in 2016 (in $million chained 2007 dollars) (Data source: Statistics Canada, 2017b).

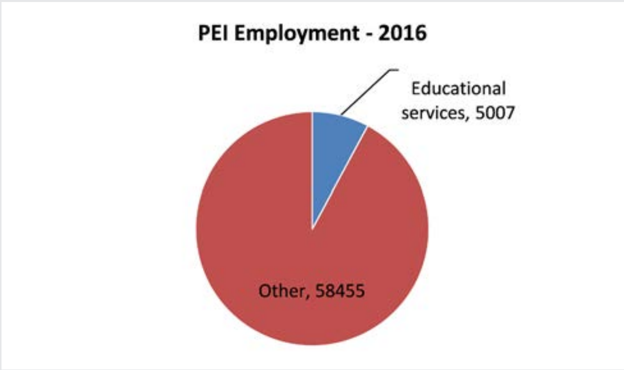


Figure 4.2: Employment in the Education sector compared to total employment as of January 2017 (Data source: Statistics Canada, 2017a).

In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion with the education sector (e.g., elementary and secondary schools, universities, community colleges and other educational services) contributing approximately $345 million, or 7% (see Figure 4.1)[1]. Of the 58,455 people employed in Prince Edward Island, 5,007, or 8.6%, were employed in educational services as of January 2017 (see Figure 4.2).

4.1.2 Informal Education and Public Outreach

Learning happens at all ages and can be cultivated outside the formal structure described above. Individuals can learn at home, in community-based organizations (e.g., watershed groups), museums, libraries, etc. In addition, organizations often reach out to the public to raise awareness, engage them in decision-making, inspire action, etc.

1 GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

PHOTO CREDIT: DON JARDINE

4.2 Climate Change Impacts

All other sector chapters in this report outline the different ways a sector is affected by direct climate change impacts such as rising temperatures, changing precipitation patterns, more intense and frequent storms, rising sea levels, etc. For the formal education subsector, these impacts will affect the operations of schools. For example, storms can disrupt the energy supply or make travel conditions unsafe, forcing school closures. These types of impacts, and corresponding adaptation actions, are analyzed in the chapters on the energy, properties and infrastructure, and water sectors[2]. Unique to the education and outreach sector, however, is the impact of the nature of climate change. The remainder of this chapter will focus on the characteristics of climate change and how they impact the sector.

Climate change will bring about opportunities and challenge to the sector. It is critical to note that none of them can be taken in isolation. For example, the opportunity to explore complex issues using novel study methods may be offset by the lack of expertise to address the complexity of climate change.

4.2.1 Multiple Facets

Climate change is a multifaceted topic, with studies ranging from its causes and effects to the corresponding mitigation and adaptation actions. These studies span across natural sciences (e.g., geology, chemistry), applied sciences (e.g., engineering, education), social sciences (e.g., economics, politics), and beyond. This presents a number of opportunities and challenges for the sector.

OPPORTUNITIES

First, climate change education can serve as the conduit to impart the skills and experiences that society and employers demand. Students are increasingly expected to have a wide range of personal and social skills with interdisciplinary experience so they can be effective in the 21st century workforce (McCright, 2012). The sector has the opportunity to help students meet these demands by supporting the study of climate change across subject areas using multifaceted approaches.

Second, this is an opportunity for the sector to incorporate fields of knowledge that have not been widely used in the past. Tackling climate change is an endeavour that requires "all hands on deck". For example, Traditional Ecological Knowledge (TEK) – built on generations of insights, experience, and knowledge – provides "an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change" (United Nations University, 2011).

2 Refer to these chapters for additional information on climate change impacts and recommended adaptation actions.

Third, the study of climate change can ignite the interest of students in subjects they have not been drawn to in the past. For example, a student previously uninterested in language arts can become engaged by studying it through a lens that resonates with them:

> *my great great grandchildren*
> *ask me in dreams*
> *what did you do while the Planet was plundered?*
> *what did you do when the Earth was unravelling?*
> *surely you did something*
> *when the seasons started failing?*
> *as the mammals, reptiles, birds were all dying?...*
> *what did you do*
> *once*
> *you*
> *knew?*
>
> —Excerpt from Drew Dellinger's 'What Did You Do Once You Knew?'
> (Alliance for Sustainable Communities Lehigh Valley, 2017)

Fourth, the wide range of impacts climate change has on society has compelled leaders outside of the scientific community to speak up, adding new avenues for public outreach and engagement. For example, Pope Francis, head of the Roman Catholic Church, addressed climate change in his encyclical on the environment, Laudato si', in which he describes man's destruction of climate as a sin and the role of climate change in worsening the refugee crisis (McKenna, 2016). Studies have shown that political orientation, worldviews, and religious view influence the level of public engagement (Wibeck, 2014).

CHALLENGES

First, the delivery of climate change education using a cross-curricular approach will be challenging. The current systems have been designed to effectively and efficiently promote learning by subject area as evidenced by how a school day is structured, a curriculum is developed, and the students are assessed. Supporting learning across subject areas in a holistic manner could require new methods of delivering formal education.

Second, actors in public outreach and engagement will increasingly require a broad knowledge base and skill set to effectively promote action in climate change mitigation and adaptation.

4.2.2 Complexity

The study of climate change is viewed as a complex field; topics such as greenhouse gas interactions, global climate modelling, and ocean acidification may seem overwhelming. Many educators and public outreach and engagement actors feel unprepared to participate in climate change education and outreach due to their lack of deep scientific knowledge in physical sciences. Meanwhile, many students and members of general public lack the scientific literacy required to digest the technical concepts being disseminated. These gaps in knowledge provide both opportunities and challenges for the sector..

OPPORTUNITIES

In addressing the knowledge gap, there is an opportunity to apply well-studied approaches that currently exist within the education sector. To make climate change education less daunting for the teachers and the learners, inquiry-based learning and place-based learning could be utilized to engage both sides. For example, the teachers can become co-learners as they guide open discussions around students' concerns and questions with an emphasis on real-life context over study within disciplines.

CHALLENGES

First, climate change education is a relatively new field and teachers likely have limited exposure within their own schooling and professional training (Henderson *et al.*, 2017). The lack of in-depth knowledge of the complex science concepts and effective ways to impart that knowledge in a digestible manner could cause hesitation in promoting climate change education in the classrooms (McNeal *et al.*, 2017).

Second, many scientists lack the necessary communication skills to disseminate complex scientific information in plain language, making public engagement difficult. Despite the availability of the extensive knowledge on climate change, only a fraction of it is presented in a digestible manner or customized for use by specific groups (e.g., educators, governments).

Third, low levels of scientific literacy in the general public have lead to doubt regarding climate science. Action on climate change has been limited by ideological polarisation on the subject (McNeal *et al.,* 2017). Despite the fact that over 97% of climate scientists agree on the anthropogenic nature of recent climate change (McNeal *et al.,* 2017), there is still public skepticism on the true consensus of climate scientists, contributing to a misunderstanding of the causes of climate change and giving rise to the role of a "belief" system in discussions surrounding climate change.

Fourth, to fill the gap between the communications failure from scientists and the low scientific literacy of the general public, mass media and the internet have played decisive roles in shaping the public's understanding of climate change by acting as a bridge (Wibeck, 2014). The challenge is that the opinion of the general public and policy makers can be heavily influenced by how actors outside of climate science frame the issues. For example, the news media in countries such as Sweden, France, and Germany provides a frame of certainty – "human-induced global warming is a direct cause of climate change, bringing with it dramatic consequences already at hand" (Wibeck, 2014) – but this is not always the case. In the United States, the news media provides a frame of scientific uncertainty and uses the journalistic practice of a balanced view by giving both sides equal weight in a debate (Wibeck, 2014). This further exacerbates public uncertainty and misunderstanding of the causes of climate change.

PHOTO CREDIT: GOVERNMENT OF PEI

4.2.3 Spatial and Temporal Scales

Research has shown that while climate change may be regarded as a serious risk, individuals perceive it as an issue that is distant in space (e.g., global warming) and time (e.g., sea level rise). This creates both opportunities and challenges for the sector.

OPPORTUNITIES

Public apathy is partly caused by the perception that climate change is not relevant to them or their communities (Hu and Chen, 2016). In Prince Edward Island, many impacts of climate change are visible; damage caused by coastal erosion, flooding, and extreme storm events can be observed first-hand. This provides an opportunity for educators and public outreach actors to engage students and the public by exploring the spatial impacts of climate change in a meaningful and experiential way.

PHOTO CREDIT: GOVERNMENT OF PEI

CHALLENGES

First, the public needs to balance day-to-day concerns with the medium- to long-term impacts of climate change. It is easy to think of climate change as a slow, gradual process with increases in loss occurring incrementally (Canadian Electricity Association, 2016), making the promotion of immediate and necessary climate change action difficult.

Second, the overwhelming scope of climate change creates “bigger-than-self problems” which reduce incentive for people to act (Wibeck, 2014). In these instances, the general public often feel overwhelmed, disengage, and look to the government to address their concerns.

Third, the integration of a complex and wide-ranging issue such as climate change into school curriculum requires resources (e.g., time, money, expertise), above and beyond the day-to-day operations of the schools and maintenance of the status quo. It involves establishing guidelines, supporting new curriculum documents and specific instructional strategies, (re)training teachers, etc. Improving knowledge on climate change requires its integration in the curriculum review process, the timing of which is dictated by the PEI Department of Education, Early Learning and Culture.

4.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

4.3.1 Formal Education

8 **Integrate climate change in the curriculum for lower grades** where interdisciplinary and inquiry-based learning is already taking place (e.g., Kindergarten to Grade 6). Begin by identifying resources and developing activities for teachers. For example, the children's book, Kataq: Journey of our Eels, is a Mi'kmaq story that teaches the interdependencies that exist within an ecosystem, lifecycle of eels, impact of runoff on marine life, and need for sustainability.
Suggested timeline: short-term (0 to 5 years)

9 **Integrate climate change in the curriculum for higher grades,** focusing on increasing the **skills, competencies, and knowledge** of students across all subject areas (e.g., Grade 7 to Grade 12). For example,

a. incorporate teaching methods that promote multidisciplinary, interdisciplinary, and transdisciplinary learning;
b. develop an interdisciplinary course for Grade 9 students;
c. include subject matter beyond natural sciences and social sciences (e.g., language arts), even those not historically taught within the school system (e.g., TEK concepts such as seven generations);
d. focus on skills and competencies (e.g., problem solving, creative thinking, effective collaboration, critical thinking, scientific literacy) as much as knowledge;
e. leverage existing initiatives (e.g., use "Is it science?" to increase critical thinking and address any uncertainty surrounding climate change); and,
f. excite and engage students by making climate change relevant (e.g., hands-on learning such as erosion monitoring and coastal restoration).

Suggested timeline: short-term (0–5 years)

10 **Support teachers by implementing small-scale initiatives** to introduce climate change to the students in the near-term while the integration of climate change across the curriculum (see Recommended Adaptation Actions #8 and #9) is taking place. For example:

a. host a full-day workshop during professional development days. The agenda could include a question and answer period with a panel of experts in climate science, mitigation, and adaptation, a presentation of potential career paths for students, a field trip to exemplify place-based learning (e.g., visit flood- and erosion-risk zones), and a roundtable discussion with teachers across all subject areas;
b. invite outside groups to the classrooms to share their expertise (e.g., workshops hosted by informal education provides and government staff – see Recommended Adaptation Action #16); and,
c. provide examples on how inquiry-based learning can be implemented. Sample sets of questions could demonstrate how to involve different subject areas. This could make coordination among subject teachers easier if each teacher could build upon the topic. For example:

Figure 4.3: Example of armouring (Photo credIt: Don Jardine - with permission).

Scenario: Jill's property has been experiencing erosion for years. The shoreline is creeping closer and closer to her house.

Economics:	Perform a cost-benefit analysis by comparing the cost of putting armouring in place today against the cost of losing property and infrastructure over time.
Physics:	Once the armouring is in place, how will this impact the wave energy of the water? (See Figure 4.3)
Environmental science:	Armouring a coastline leads to the loss of sandy beach in front of the structure. How will this affect wildlife? Should there be a "cost" associated with this?
Political science:	How can Jill's predicament be shared with other coastal property and infrastructure owners to encourage support for government policy that increases setback limits for new developments.
Etc.	

Suggested timeline: short-term (0–5 years)

11 Identify ways to **increase experiential learning** without leaving the school grounds. For example, design and build a rain garden to help manage stormwater onsite.
Suggested timeline: ongoing

12 **Increase exposure to climate change, interdisciplinary-learning, and inquiry-based learning at the post-secondary level**. For example, in 2017, the Maritime Provinces Higher Education Commission approved a Bachelor of Science program in climate change and adaptation to be offered by the University of Prince Edward Island. At a smaller scale, a course in interdisciplinary-learning could explore different topics (e.g., climate change) using subjects relevant to the students' studies.
Suggested timeline: short- to medium-term (0–10 years)

PHOTO CREDIT: GOVERNMENT OF PEI

4.3.2 Informal Education

13 Increase awareness of opportunities to **learn outside of the classroom**. Complete an inventory of existing programs offered by the Provincial Government and other groups. Work with other sectors to raise awareness of existing programs.
Suggested timeline: short-term (0–5 years)

14 **Develop new programming** to expand the students' knowledge of climate change outside of the formal education system and address gaps in existing programming (e.g., consideration of other subjects and perspectives such as TEK and its respect for the carrying capacity of ecosystems). For example, host an interdisciplinary one-week summer camp for grade nine and ten students using climate change as a topic to give students a chance to further develop core skills and competencies. The flexibility of a summer camp could address the limitations of the formal education structure (e.g., experiential learning in the field, operating drones to collect environmental data, focusing on areas of students' interest). Another example is the Think Big initiative in the United Kingdom. Sponsored by public and private funds, the initiative is hosting The Environment Now Challenge to encourage students to use technology to tackle pressing environmental issues by providing grants, mentoring, work experience, and insight days with industry professionals to bring their projects to life.
Suggested timeline: short-term (0–5 years)

4.3.3 Public Outreach

15 Place **more emphasis on inspiring action** and less on improving in-depth understanding of scientific knowledge when engaging the public. For example:

a. use place-based approaches and visualization techniques to demonstrate the impacts of climate change in a local and relevant context;
b. demonstrate how climate change adaptation actions could benefit them and how inaction can cost them personally to encourage action. For example, the use of rain barrels and rain gardens by homeowners will reduce the risk of flooding during intense rain events; and,
c. frame climate change in other contexts to strengthen the message and encourage action. For example, use a public health perspective to encourage reductions in emissions by promoting the health benefits of cycling and walking over driving (e.g., improve cardiovascular health and air quality).

Suggested timeline: ongoing

16 **Encourage knowledgeable provincial government staff to communicate** with colleagues and citizens about their areas of expertise and what adaptation strategies can be initiated and provide opportunities to do so. For example:

a. list the staff members' specific relevant expertise and experience (e.g., restoring wetland, monitoring environmental variables, using statistical downscaling models), on the online employee directory and make it queryable so individuals in need of help can quickly and easily connect with the relevant expert(s);
b. host internal and external "lunch and learns" by themes and invite staff with different expertise to present; and,
c. host workshops in schools (see Recommended Adaptation Action #10b).

Suggested timeline: ongoing

17 **Identify different segments of the population and generate public outreach approaches accordingly**. The communication strategy for the 'unconcerned and dismissive' segment should be drastically different than that for the 'most concerned and motivated' segment. For example, the focus for the 'unconcerned and dismissive' segment should be on the benefits of adaptation, rather than the cause and effect of climate change (see Recommended Adaptation Action #15). The City of Charlottetown hosted a Fix It Fair, where Islanders saw saving money by learning to repair broken equipment rather than buying a replacement as the primary benefit and the diversion from landfills as an unintended or secondary benefit.
Suggested timeline: ongoing

18 **Create communication networks** (e.g., websites, social media, flyers) and **provide public forums** for information sharing, roundtable discussions with experts, etc. on different themes to enhance public engagement.
Suggested timeline: short-term (0–5 years)

19 **Leverage best practices in outreach** from other sectors and jurisdictions. For example, emergency management organizations are effective in educating the public of present and anticipated risks and hazards.
Suggested timeline: ongoing

The collaboration of educators within the formal and informal education systems, parents and guardians, experts (e.g., climate scientists), and governments will be critical in achieving effective adaptation. The table below summarizes the twelve recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

Table 4.1: Summary of recommended adaptation actions for the education and outreach sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
8. Integrate climate change in the curriculum for lower grades where interdisciplinary and inquiry-based learning is already taking place (e.g., identify resources and activities).	Lead: Provincial Government Collaborators: Experts	Address knowledge gaps; Promote climate change mainstreaming	Short-term (0 to 5 years)
9. Integrate climate change in the curriculum for higher grades, focusing on increasing the skills, competencies, and knowledge of students across all subject areas.	Lead: Provincial Government Collaborators: Experts	Address knowledge gaps; Promote climate change mainstreaming	Short-term (0 to 5 years)
10. Support teachers by implementing small-scale initiatives to introduce climate change to the students in the near-term (e.g., host full-day workshop during PD days, provide inquiry-based activities to teachers).	Lead: Provincial Government Collaborators: Experts, Informal education providers	Address knowledge gaps; Promote climate change mainstreaming; Increase collaboration	Short-term (0 to 5 years)
11. Identify ways to increase experiential learning without leaving the school grounds (e.g., design and build a rain garden to manage stormwater onsite).	Lead: Provincial Government, Public Schools Branch, French Language School Board, Private Schools Collaborators: Experts, Home and School Federation	Address knowledge gaps; Engage in outreach	Ongoing
12. Increase exposure to climate change, interdisciplinary-learning, and inquiry-based learning at the post-secondary level.	Lead: Post-secondary institutions Collaborators: Experts	Address knowledge gaps	Short- to medium-term (0 to 10 years)
13. Increase awareness of opportunities to learn outside of the classroom.	Leads: Informal education providers, Provincial Government Collaborators: Parents and guardians	Engage in Outreach; Increase collaboration	Short-term (0 to 5 years)
14. Develop new informal education programming to expand the students' knowledge.	Leads: Informal education providers Collaborators: Parents	Address knowledge gaps; Engage in outreach	Short-term (0 to 5 years)
15. Place more emphasis on inspiring action and less on improving in-depth understanding of scientific knowledge when engaging the public.	Leads: All levels of government, All sectors	Engage in outreach	Ongoing
16. Encourage knowledgeable provincial government staff to communicate with colleagues (e.g., lunch and learns) and citizens (e.g., school workshops, roundtable discussions) about their areas of expertise.	Lead: Provincial Government Collaborators: Public	Address knowledge gaps; Engage in outreach	Ongoing
17. Identify different segments of the population (e.g., 'unconcerned and dismissive' versus 'most concerned and motivated') and generate public outreach approaches accordingly.	Leads and collaborators: All levels of government, All sectors	Engage in outreach	Ongoing
18. Create communication networks (e.g., websites, social media, flyers) and provide public forums for information sharing, roundtable discussions with experts, etc. on different themes to enhance public engagement.	Lead: Provincial Government Collaborators: Public, Experts	Engage in outreach	Ongoing
19. Leverage best practices in outreach from other sectors and jurisdictions (e.g., EMO is effective in educating the public of risks).	Leads and collaborators: All levels of government, All sectors	Engage in outreach; Increase collaboration	Ongoing

4.4 Conclusion

The education and outreach sector plays an important role in the response to climate change. By developing effective approaches to raising awareness and promoting knowledge and skills development, the students, other sectors, and the general public will all benefit.

REFERENCES

Alliance for Sustainable Communities Lehigh Valley. (2017, May 12). *Interdisciplinary Teaching on Climate & Calculating Your School's GHG Emissions* [website]. Retrieved from http://www.sustainlv.org/blog_posts/interdisciplinary-teaching-on-climate-calculating-your-school%e2%80%99s-ghg-emissions/

Canadian Electricity Association. (2016). *Adapting to Climate Change: State of Play and Recommendations for the Electricity Sector in Canada.* Retrieved from https://electricity.ca/WP-CONTENT/UPLOADS/2016/02/ADAPTING_TO_CLIMATE_CHANGESTATE_OF_PLAY_AND_RECOMMENDATIONS_FOR_THE_ELECTRICITY_SECTOR_IN_CANADA.PDF

Henderson, J., D. Long, P. Berger, C. Russell, and A. Drewes. (2017). Expanding the Foundation: Climate Change and Opportunities for Educational Research. *Educational Studies.* 53(4): 412-425. doi:10.1080/00131946.2017.1335640

Hu, S. and J. Chen. (2016). Place-based inter-generational communication on local climate improves adolescents' perceptions and willingness to mitigate climate change. *Climatic Change.* 138:425–438. doi:10.1007/s10584-016-1746-6.

McCright, A.M. (2012, December). Enhancing students' scientific and quantitative literacies through an inquiry-based learning project on climate change. *Journal of the Scholarship of Teaching and Learning.* 12(4):86–102.

McKenna, J. (2016, September 1). Pope Francis says destroying the environment is a sin. *The Guardian.* Retrieved from https://www.theguardian.com/world/2016/sep/01/pope-francis-calls-on-christians-to-embrace-green-agenda

McNeal, P., H. Petcovic, and P. Reeves. (2017). What is motivating middle-school science teachers to teach climate change? *International Journal of Science Education.* 39(8): 1069–1088. doi:10.1080/09500693.2017.1315466

PEI Department of Education, Early Learning and Culture. (n.d.). *About us* [website]. Retrieved from https://www.princeedwardisland.ca/en/topic/education-early-learning-and-culture

PEI Department of Education, Early Learning and Culture (a). (2015). *Annual Report 2014-2015.* Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/eelc_annual_report_2014-15_2.pdf

PEI Department of Education, Early Learning and Culture (b). (2015, February). *Directory of Licensed Early Childhood Programs.* Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/eelc_directory_ecd_programs.pdf

Statistics Canada (a). (2017, April 7). *Table 282-0088 - Labour force survey estimates (LFS), employment by North American Industry Classification System (NAICS), seasonally adjusted and unadjusted.* Retrieved on May 4, 2017.

Statistics Canada (b). (2017, March 30). *Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories.* Retrieved on May 4, 2017.

United Nations University. (2011, December 13). *Why Traditional Knowledge Holds the Key to Climate Change*. Retrieved from https://unu.edu/publications/articles/why-traditional-knowledge-holds-the-key-to-climate-change.html

Wibeck, V. (2014). Enhancing learning, communication and public engagement about climate change – some lessons from recent literature. *Environmental Education Research.* 20(3): 387-411. doi:10.1080/13504622.2013.812720

5

Rather than subsidize the past, we should invest in the future.

—Barack Obama

5 ENERGY SECTOR

5.1 Background

Energy is an essential part of our daily lives – public health and safety, access to clean drinking water, heating, lighting, transportation, economy, etc. depend on it. Currently, 7% of energy comes from biomass (e.g., wood), 21% of energy use comes from electricity (generated from coal, hydroelectricity, oil, diesel, wind power, and nuclear power) and the rest from fuel sources such as gasoline, light fuel oil, diesel, natural gas, and propane (see Figure 5.1).

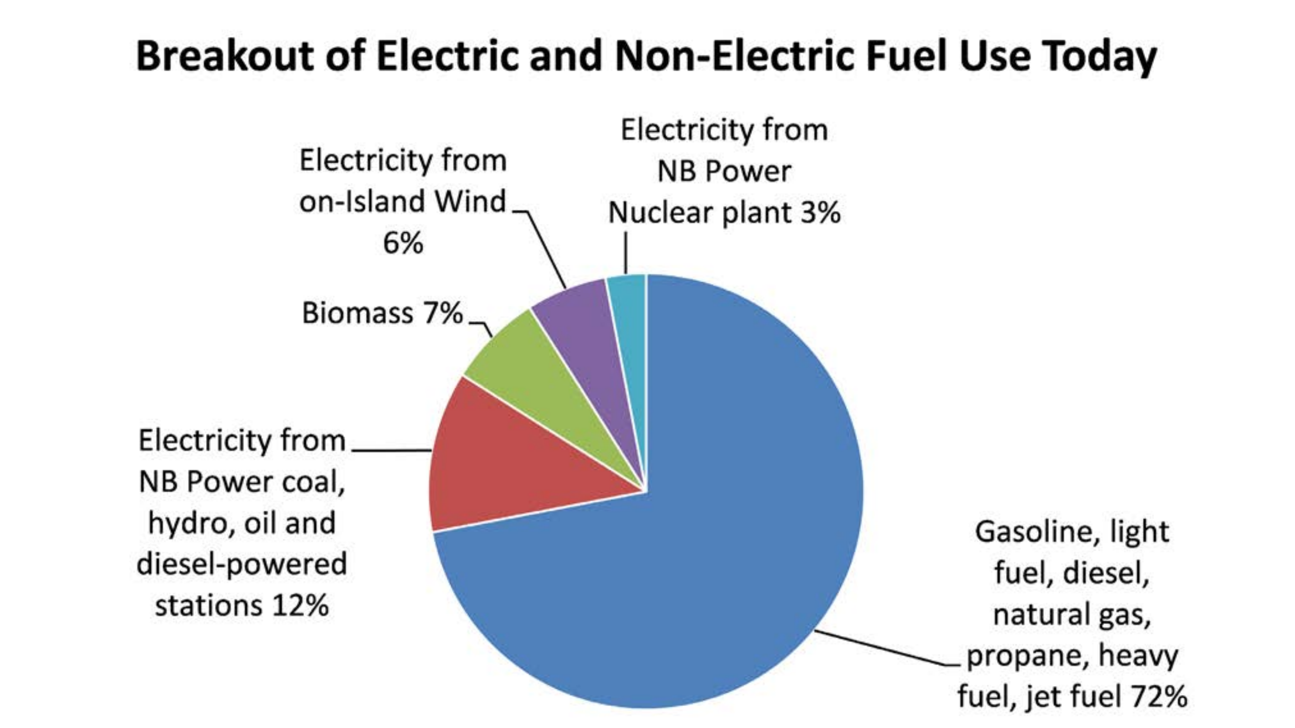


Figure 5.1: Breakout of electric and non-electric fuel use in Prince Edward Island today (Data source: Government of Prince Edward Island [PEI], 2017).

In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion, with the electric power generation, transmission and distribution subsector contributing $81 million or 1.7% and gas stations (retail) subsector contributing $18 million or 0.4% (see Figure 5.2)[1]. Statistics Canada does not collect data specifically on the sale of home heating fuels but it is part of the "non-store retailers" of the retail sector, which contributed $26.7 million in 2016 (Statistics Canada, 2017a). GDP figures specific to biomass are unavailable.

1 GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

PHOTO CREDIT: DON JARDINE

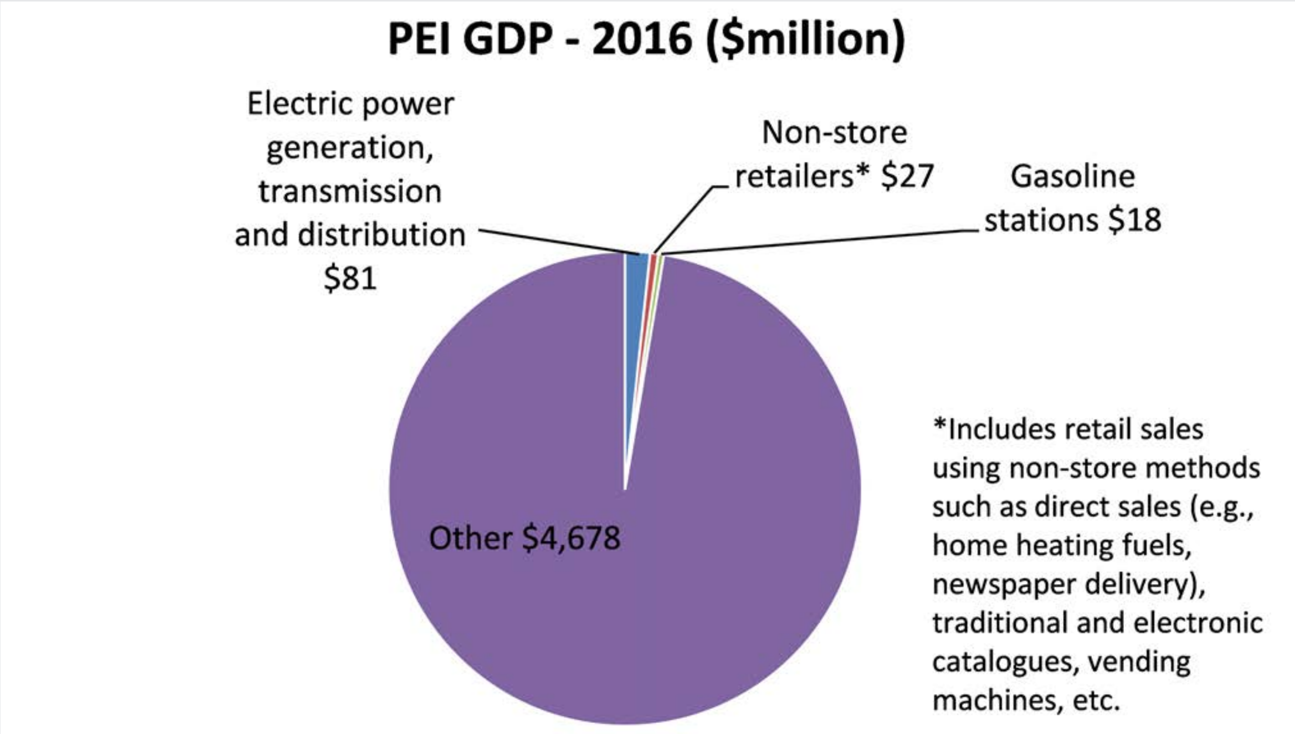


Figure 5.2: Prince Edward Island GDP of various energy subsectors in 2016 (in $million chained 2007 dollars). Please note that "non-store retailers" includes retail sales using non-store methods such as direct sales (e.g., home heating fuels, newspaper delivery), traditional and electronic catalogues, vending machines, etc. Please also note that GDP figures for biomass is unavailable (Data source: Statistics Canada, 2017c).

There were 63,642 equivalent annual full time jobs in 2016 across all industries in Prince Edward Island (Statistics Canada, 2017a). Gasoline stations employed 666 of those jobs (Statistics Canada, 2017a). Data specific to the generation, transmission and distribution of electricity is unavailable but in March 2017, the utilities industry, which includes electricity, natural gas, water, and sewage, employed 300 people (Statistics Canada, 2017b). Data for biomass and home heating fuels were unavailable.

5.1.1 Electricity

MARITIME ELECTRIC

Maritime Electric supplies electricity for 90% of Prince Edward Island. The electricity is transmitted and distributed across the province using approximately 5,000 km of power lines (see Figure 5.3). The electricity supply capacity for the province is approximately 275 MW in 2017 (J. Cunniffe, personal communication, September 7, 2017).

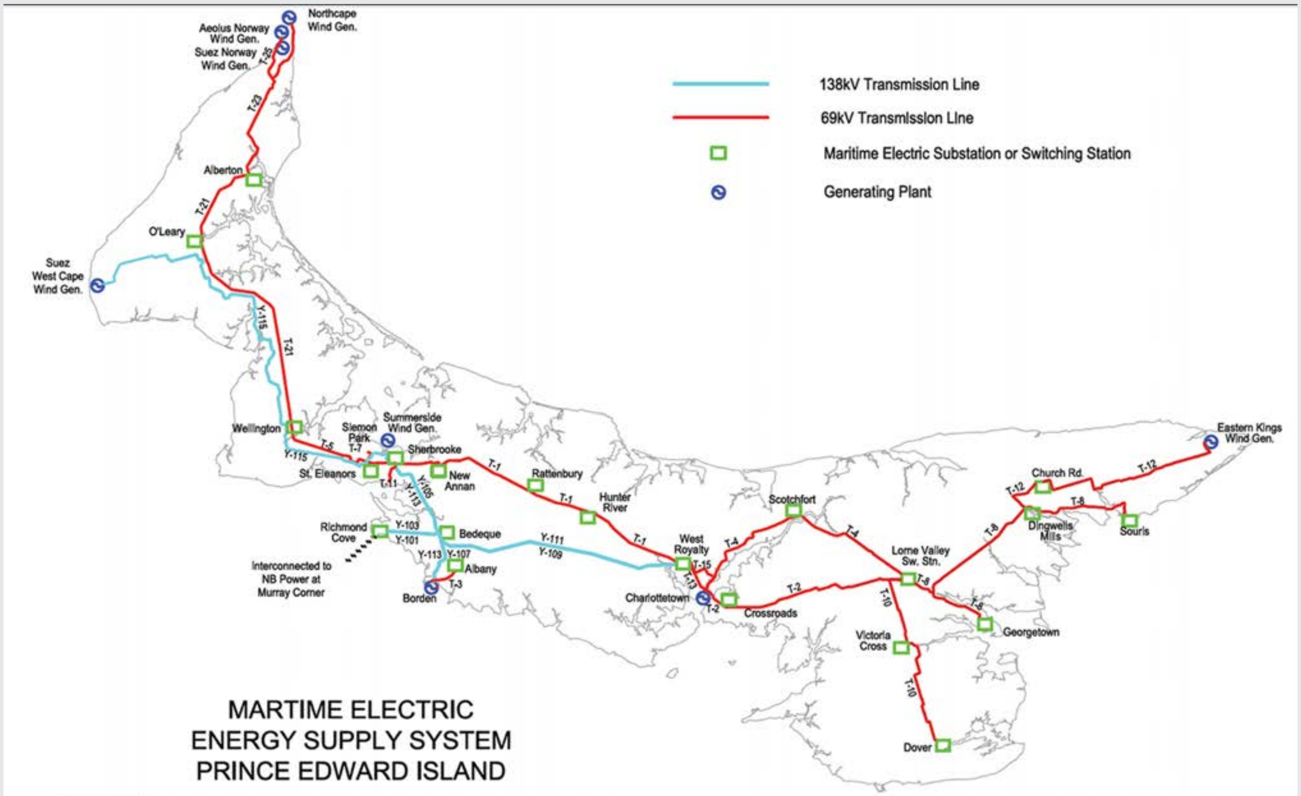


Figure 5.3: Maritime Electricity energy supply system map (Source: PEI Energy Commission, 2012).

Maritime Electric procures most of its electricity from NB Power (see Table 5.1), which supplies electricity from coal, hydro, oil, natural gas, diesel, wind, and nuclear sources (NB Power, n.d.; J. Cunniffe, personal communication, September 7, 2017). The off-island electricity is delivered via four submarine transmission cables under the Northumberland Strait. The two original 95MW cables were installed approximately forty years ago. The installation of two new 180MW submarine cables was completed in July 2017 (J. Cunniffe, personal communication, September 7, 2017).

The other electricity source Maritime Electric purchases from is on-Island wind farms. Currently, there are eight wind farms on the Island, with one additional wind farm proposed (see Table 5.2).

Maritime Electric owns and operates the Charlottetown Thermal Generating Station (CTGS), which generates electricity using heavy oil (55 MW) and diesel (49 MW) and the Borden Generating Station, which generates electricity using diesel (40 MW) (Maritime Electric, n.d.). These two electricity generating stations are mainly put in operation when there are interruptions to off-Island supplies of electricity or when increased capacity is required during peak periods. The heavy oil generators at the CTGS are expected to be placed in long-term layup in 2018 (J. Cunniffe, personal communication, September 7, 2017).

PHOTO CREDIT: DON JARDINE

Table 5.1: Maritime Electric electricity supply for 2014 (Data source: Maritime Electric, 2015).

Electricity Supply	Supply %
On-Island oil-fired generation	0.6
On-Island wind generation	23.1
Point Lepreau (nuclear), NB Power	16.5
System purchases from NB Power	59.8
Total	100.0

Table 5.2: Prince Edward Island wind farms (Data sources: The Maritimes Energy Association, n.d.; Wind Energy Institute of Canada, n.d.; PEI Department of Transportation, Infrastructure and Energy [PEI TIE], 2015; PEI Energy Corp, 2017; H. Macleod and M. Proud, personal communication, September 29, 2017).

Wind Farm	Owner	Number of Turbines	Capacity
Hermanville/Clear Spring Wind Farm	PEI Energy Corp	10	30 MW
East Point Wind Farm	PEI Energy Corp	10	30 MW
North Cape Wind Farm	PEI Energy Corp	16	10.6 MW
North Cape Wind R&D Park	Wind Energy Institute of Canada	5	10 MW
Norway Wind Farm	Suez Renewable Energy Corp	3	9 MW
Summerside Wind Farm	City of Summerside	4	12 MW
Aeolus Wind Farm in Norway	PEI Energy Corp	1	3 MW
West Cape Wind Farm	Suez Renewable Energy Corp	55	99 MW
Proposed wind farm	PEI Energy Corp		30 MW

Figure 5.4: Locations of wind farms on Prince Edward Island (Imagery source: DigitalGloble, Data SIO, NOAA, U.S. Navy, NGA, GEBCO; Map data source: Google).

CITY OF SUMMERSIDE

The City of Summerside, through Summerside Electric, supplies the remaining 10% of the province's electricity needs, mainly servicing customers within its municipal boundaries. Most of the electricity is generated by four wind turbines at the 12 MW Summerside Wind Farm (PEI TIE, 2015). Summerside Electric purchases some electricity from NB Power and owns a generating station that it commissions when there are interruptions to the energy supply (City of Summerside, n.d.).

5.1.2 Home Heating

Oil, biomass (e.g. wood), and electricity are the main energy sources for space heating. Firewood is the cheapest home heating option (PEI, 2017). In 2014, 1.4% of households used wood pellets as their primary heating source and 30% used firewood as a supplementary heating source (PEI, 2017). Currently, 22 facilities (e.g., schools) are heated using wood chips with 3 more planned for 2017 (PEI, 2017). Wood chips constitute half of Charlottetown district heating system's fuel input (PEI, 2017). Wood is a renewable source and considered to be carbon-neutral. Over 50% of households use oil as their primary heating source, with 70% of households using oil in some way (PEI, 2017). Oil is currently exempted from HST.

Table 5.3: PEI heating cost calculations as at October 15, 2017. See source for calculation details. (Data source: PEI TIE, 2017).

Fuel Type (Heating System Type)	Price	Cost $MMBtu	Average $/month	Heating System Cost (w/o distribution syst.)	Additional $/month on mortgage	Total cost of ownership	Efficiency ratings
Electricty (ground source heat pump)	$0.16 /kWh	$13.44	**$106.40**	$25,000.00	**$146.15**	**$252.54**	COP 3.5 heat pump
Wood (furnace/ boiler)	$228.00 /cord	$13.41	**$106.18**	$5,000.00	**$29.23**	**$135.41**	68% efficient
Electricity (air source heat pump)	$0.16 /kWh	$18.46	**$146.15**	$14,000.00	**$81.84**	**$228.00**	HSPF 8.696- 3 units/whole house
Wood Pellet (boiler/furnace)	$6.27 /bag	$24.49	**$193.90**	$6,000.00	**$35.08**	**$228.97**	80% efficient
Oil (condensing furnace)	$0.85 /litre	$24.67	**$195.29**	$7,500.00	**$43.84**	**$239.14**	94% efficient cond. oil furnace
Oil (cold start boiler)	$0.85 /litre	$26.05	**$206.27**	$7,500.00	**$43.84**	**$250.11**	89% efficient cast iron oil boiler
Oil (regular boiler or furnace)	$0.85 /litre	$27.28	**$215.97**	$4,000.00	**$23.38**	**$239.36**	85% efficient oil boiler or furnace
Propane (condensing boiler or furnace)	$0.88 /litre	$38.65	**$306.00**	$7,500.00	**$43.84**	**$349.85**	94% efficient cond. gas boiler/furnace
Propane (regular furnace or boiler)	$0.88 /litre	$40.37	**$319.60**	$5,000.00	**$29.23**	**$348.83**	90% efficient gas furnace
Electricity (resistanace element)	$0.16 /kWh	$47.04	**$372.39**	$3,000.00	**$17.54**	**$389.92**	100% efficient

5.1.3 Solar Energy

While some homes and businesses utilize solar panels, solar energy is not currently used to produce electricity at a utility-scale due to the high cost. However, costs are decreasing and solar is expected to be competitive with wind generation eventually (PEI, 2017).

5.1.4 Motor Vehicles

Gasoline and diesel are used to fuel motor vehicles. There were approximately 74,000 cars and 25,000 trucks registered in Prince Edward Island in 2014 (PEI, 2017). In that year, approximately 200 million litres of gasoline and 40 million litres of diesel were sold within the province for use in road motor vehicles (Statistics Canada, 2016).

5.1.5 PEI Energy Initiatives

The 2016 Provincial Energy Strategy is a 10-year plan to reduce energy use, establish cleaner energy sources, increase locally produced energy, and moderate future energy price increases. This would make the Island stronger, more sustainable, and more resilient. Its goals include ensuring energy can be provided reliably to meet current and future needs, becoming more self-sufficient so the province is less affected by external influences (e.g., market prices), leveraging current skills and capacity to be innovative, and creating a plan that is appropriate for the local context (e.g., demographics). It will achieve these goals in a way that lowers greenhouse gas emissions, recommends actions that are cost-effective, and generates local economic opportunities. The Strategy focuses on four key areas: energy efficiency and conservation, power generation and management, biomass and heating, and transportation.

The provincial government established Efficiency PEI to help Islanders reduce their energy consumption by providing programs, rebates, and information. It provides financial assistance in conducting energy audits for homes and commercial buildings as well as upgrading equipment (e.g., energy efficient heating systems) and building envelope (e.g., adding insulation, windows and doors). Improving energy efficiency lowers greenhouse gas emissions.

PHOTO CREDIT: DON JARDINE

5.2 Impacts of Climate Change

Climate change will bring about warmer weather, more intense storms, and rising sea levels in Prince Edward Island.

It is critical to note that the opportunities and challenge resulting from climate change cannot be taken in isolation. While there are anticipated impacts both positive and negative, the extent of them has not been quantified. For example, the increase in revenues from more electric vehicles using the electrical grid could be offset by the increase in costs from damage caused to energy infrastructure by more intense storms.

5.2.1 Temperature

CHALLENGES

First, fewer heating degree days and more cooling degree days will cause a shift in the energy mix. There will be a higher reliance on electricity for air conditioning during the summer months and a lower reliance on heating oil for heating during the winter months.

Second, the increase in the number of extreme hot days will place more strain on the electrical system during the summer months.

Third, higher temperatures can reduce the capacity of the electrical distribution system. When outside temperature rises beyond a certain level, the capacity of the power lines to carry electrical current is reduced (Braun and Fournier, 2016; Canadian Electricity Association [CEA], 2016). The heat from higher ambient temperatures combined with the additional heat generated by the increase in electricity conducted through the lines in the summer months could create two issues. One, the extra heat will increase the likelihood of the load on the line reaching and surpassing the design temperature. Two, the extra heat will increase sag in power lines.

5.2.2 Extreme Weather Events

CHALLENGES

First, extreme weather events may disrupt the supply of fuels and heating oil due to closures of transportation infrastructure (e.g., roads, bridges).

Second, high winds brought on by extreme storm events can damage wind turbines (Statham *et al.,* 2014) and cause production to shut down when wind speeds exceed the design maximum (Ebinger and Vergara, 2011).

Third, high winds brought on by extreme storm events can damage power lines. An increase in tree contacts can lead to widespread damage and power loss (Ebinger and Vergara, 2011; CEA, 2016).

Fourth, storm surge during intense storms can increase the risk of damage to energy infrastructure from coastal flooding and coastal erosion. Damage to power poles, electricity substations, generation plants, storage tanks, etc. located close to the coast can cause supply interruptions.

Fifth, ice storms can damage energy infrastructure. Icing on turbine blades can limit their performance and longevity (Ebinger and Vergara, 2011) and even cause damage (CEA, 2016). Ice storms can snap power lines, bring down utility poles, and increase tree contacts (CEA, 2016).

5.2.3 Sea Level Rise

CHALLENGES

The rising sea levels will threaten an increasing number of energy infrastructure and equipment located near the coast, including power lines, electricity substations, generation plants, storage tanks, etc., leading to power outages and damage to assets.

5.2.4 Indirect Climate Change Impacts

OPPORTUNITIES

First, other jurisdictions, such as the United States, are experiencing an increase in electricity demand (CEA, 2016). This provides a potential opportunity for the export of electricity. Electricity generated by renewable resources such as wind will be in higher demand as other jurisdictions look to meet greenhouse gas emission targets of their own.

Second, the increasing popularity of electric vehicles in a low-carbon economy will increase off-peak demand of electricity (Finley and Schuchard, n.d.), increasing revenue for utility companies and providing a network to potentially establish a smart grid of energy storage across the Island.

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

CHALLENGES

First, the sector will be impacted by regulations put in place to address climate change. For example, mitigation efforts by the Canadian Government include putting a price on carbon pollution in provinces and territories that do not have their own carbon pricing structures. The federal price starts at $10 per metric tonne of greenhouse gas emissions in 2018 and increases by $10 per year until 2022 when it reaches $50 per metric tonne (Environment and Climate Change Canada, 2017).

Second, with the expectation of mitigation and adaptation policies and regulations imposed by governments, investors could become increasingly concerned about energy companies' ability to thrive in a low-carbon economy (Finley and Schuchard, n.d.).

Third, climate change impacts on other sectors could change their demand for energy. Agriculture and food processing industries are two examples. The increased need for irrigation for the agriculture sector under a changing climate will raise the use of energy for pumping (Ebinger and Vergara, 2011). For food processing plants that require continuous cooling processes, especially those that exchange heat with the outdoor air, the increasing temperatures under a changing climate will raise the use of energy for cooling (Ebinger and Vergara, 2001). While increases in the demand for energy could be an opportunity for increased revenue, it could pose a significant challenge if the increased energy use strains the system capacity during peak periods.

5.2.5 Unknowns

While climate modelling is able to forecast how climate change will impact temperature, precipitation, sea level rise, etc. with high levels of confidence, there are limitations to these models. For example, wind energy generation will be impacted by changes in wind speed, patterns, density, quality, distribution, and variability (Ebinger and Vergara, 2011; Asian Development Bank, 2012; Audinet *et al.,* 2014, Gaetani *et al.*, 2015), none of which can be forecasted with a high degree of accuracy. The same applies to cloud cover and atmospheric turbidity, which impacts solar energy generation (Asian Development Bank, 2012) and lightning strikes, which could cause damage to energy infrastructure such as electrical substations and create operational challenges such as the maintenance of wind turbines.

In 2014, about 76% of electricity supplied on Island was procured from NB Power. While new submarine transmission cables increased the transmission capacity, this critical source of electricity is subject to the reliability of the NB Power system, which will be tested by direct climate change impacts as well as operational challenges (e.g., increase in demand). The reliability of this supply will be dependent on how well NB Power copes with these challenges.

The increasing popularity of air source heat pumps for their dual heating and cooling capabilities will change the energy mix and electricity demand during winter and summer seasons.

5.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

20 Commission studies to **form a foundation for evidence-based adaptation planning**. For example:

- **a.** determine the anticipated changes in the number of heating degree days and cooling degree days under future climate and incorporate results in future planning;
- **b.** create and maintain inventories of energy assets and infrastructure and perform vulnerability assessments; and,
- **c.** perform cost-benefit analysis to help select and prioritize the relocation, strengthening, retrofitting, and/or protection of vulnerable energy assets and infrastructure. There is growing evidence that the cost of adaptation far outweighs the cost of inaction (CEA, 2016). Costs of inaction extend beyond damaged assets; they include reduced revenue, higher operational costs, higher insurance premiums, increased regulatory obligations, and legal liabilities (CEA, 2016).

Suggested timeline: short-term (0 to 5 years)

21 **Relocate, retrofit, and/or protect** critical energy infrastructure and equipment vulnerable to climate change impacts. For example:

- **a.** relocate, where appropriate, infrastructure located in areas at risk of flooding and/or erosion now or within its lifetime. It may be a higher cost option but for infrastructure with a long life span, it is the most sustainable and long-lasting, often generating more cost-benefit advantages than building flood-protection for infrastructure (Braun and Fournier, 2016);
- **b.** add guying to poles or install special pylons at regular intervals in high risk areas to avoid cascades of falling power poles during high ice load events (Audinet *et al.*, 2014);
- **c.** increase the height of power poles, reduce the spans of power poles, or tighten the power line conductors to compensate for line sagging and meet minimum requirements for distance above the ground for safety reasons; and,
- **d.** protect infrastructure (e.g., elevate, armour) at risk of flooding and/or erosion, where relocation from risk zones is inappropriate or impossible. Choose a

PHOTO CREDIT: DON JARDINE

design beyond the current 1-in-100 year events since those will become more severe over the lifetime of the infrastructure (e.g., 1-in-200, 1-in-1000, etc.), taking into account other factors such as sea level rise, storm heights, and wind speed under a changing climate.

Suggested timeline: ongoing

22 **Lower energy demand** as a complementary approach to increasing peak capacity. Reduction in energy consumption is quicker and more cost effective than increasing capacity (Braun and Fournier, 2016). For example:

- **a.** educate and sensitize the public to the challenges facing the electricity industry. Make the case that it is in everyone's interest –individuals', businesses', society's, utilities' – to lower demand as much as possible. Demonstrate the financial benefit of reducing energy use;
- **b.** give the public practical recommendations on how to reduce energy use via energy conservation and energy efficiency. Industry and the Provincial Government should increase support to and work with efficiencyPEI to raise awareness on how to reduce energy usage in homes and businesses. Small behavioural changes by residents and businesses collectively across the Island would have a big impact. For example, using less room cooling by adjusting the thermostat settings by a degree or two would mean a significant reduction on demand for the electrical system (Braun and Fournier, 2016).
- **c.** demonstrate the effectiveness of the recommendations made to the public (see Recommended Adaptation Action #22b). The government and the utility companies should lead by example and incorporate these initiatives in their operations; savings generated from their efforts should be reinvested in additional conservation and efficiency initiatives to continually lower energy use;
- **d.** develop a system indicating the current state of the grid to its users and suggesting actions based on the type of alert. Maritime Electric can look to ÉcoWatt, a system put in place in France in 2012 that provides alerts via its website, email, text messages, and social media when the grid moves from green (no risk of outage) to orange (moderate risk of outage) or red (high risk of outage) (Braun and Fournier, 2016). When the system moves to orange or red, subscribers to the program receive alerts with suggested actions to reduce consumption based on the type of alert. The public was engaged because it was motivated to help avoid rolling brown-outs;
- **e.** deploy direct load control devices to subscribers to allow the utility companies to cycle off and on air conditioning units/heat pumps during peak demand periods for short periods of time (Morand *et al.,* 2015). This initiative was implemented in Washington D.C., USA to help utilities manage demand during peak period. Homeowners, who voluntarily participated, saved up to 10% on heating and cooling costs and they noticed little or no temperature change in their homes (Morand *et al.,* 2015); and,
- **f.** review the pricing structure for electricity. For example, peak-demand pricing could be used to encourage a shift of usage during off-peak powers, whereas a higher second-block price for electricity will incentivize energy conservation and efficiency.

Suggested timeline: short- to medium-term (0 to 10 years)

23 **Decentralize, diversify, and develop redundancy** in the sector to increase its resilience to climate impacts. Having different types of energy generation, multiple sources of the same type of energy, and generation capacity distributed throughout the Island gives the system more capacity to cope with hazardous events and avoid large-scale system failures. For example:

- **a.** encourage individuals and businesses to install energy storage equipment to shift electricity consumption away from peak hours. The stored energy can also serve as back-up power during power outages and store wind- or solar-generated electricity when it is produced but not needed. For example, the City of Summerside's "Heat for Less Now" program has been helping it maximize its use of wind energy for five years. Homeowners who install electric thermal storage water heaters, room heaters, and furnaces receive a discount of $0.0596/kWh in exchange for allowing the utility control when the home should use energy from the grid versus the storage equipment, depending on existing wind levels (Tattrie, 2016). The cost of the equipment ranges from $1,400 to $2,200 each (Tattrie, 2016);

b. encourage individuals and businesses to install solar panels with onsite energy storage by providing financial incentives. Solar is a renewable resource that has a more stable output profile than wind. The ability to produce power on site, coupled with onsite energy storage, will make Islanders more resilient against power outages, especially during extreme weather events (e.g., high winds); and

c. increase the use of high-efficiency biomass (e.g., wood chips) and Combined Heat and Power (CHP) as sources for energy at multi-unit residential, commercial, institutional and industrial sites or a combination of these sites (i.e., district energy systems). CHP equipment can be fueled by propane and can generate electricity and hot water heating in a way that is 50% more efficient than conventional methods (Morand *et al.,* 2015). Using alternate sources to generate electricity will lower reliance and demand on the electricital system and increase resilience during extreme weather events.

The government and the utilities should lead by example and begin incorporating these actions at their facilities, begin ning with essential services.

Suggested timeline: medium-term (5 to 10 years)

24 Implement policies and regulations to **foster climate change adaptation in areas such as design and safety standards, permitting, siting and zoning**. Regulatory measures can be used to drive businesses to act in a timely manner. To provide harmonization and clarity in its policies, the government should establish a position on climate risk so the energy companies can plan appropriately. For example:

a. require utility companies to submit climate change vulnerability analysis and adaptation plans, along with updates to its adaptation activities;

PHOTO CREDIT: DON JARDINE

b. update design and safety standards to ensure new equipment and infrastructure can withstand current and future climate conditions within their lifetimes. For example, increasing the rated design temperature of transmission lines and planning new or refurbishing existing infrastructure to withstand 1:200 storm events based on 2080s forecasts and protect them from projected sea level rise and erosion for their lifetime; and,
c. include in the permitting process an assessment of climate vulnerabilities and require necessary adjustments to ensure planned infrastructure will be resilient to anticipated climate change impacts.

The government should also assist utilities in achieving its adaptation goals. The rate structure should be reviewed to offset some costs of adaptation. It is important to note that this review needs to factor in the savings from the utilities' own energy efficiency and conservation initiatives and the inherent cost savings of adaptation actions versus the costs of inaction.
Suggested timeline: short- to medium-term (0 to 10 years)

25 **Integrate climate change impacts into day-to-day operations** as well as planning, risk assessment and management, and decision-making processes. Examples include load and demand forecasting, risk auditing, training, emergency response, asset refurbishment, vegetation management, supply interruption management, project screening, and investment planning.
Suggested timeline: ongoing

26 **Plan new developments with climate change in mind**. As new assets and infrastructure are needed to increase capacity and renewable sources of energy increase its contribution to the energy mix, space for development is required (e.g., wind farm, solar farm). Identify areas suitable for new developments that are at low risk of damage from climate change impacts during the planning process. New buildings could be designed to be "solar ready" (e.g., design the roof to support the additional weight of solar panels, put necessary wiring in place).
Suggested timeline: ongoing

PHOTO CREDIT: DON JARDINE

27 **Increase collaboration and communication** among sector stakeholders (e.g., share information such as climate risks and best practices).
Suggested timeline: ongoing

The collaboration of the public, utilities, sector (e.g. industry organizations), experts (e.g., climate scientists, engineers), and the government will be critical in achieving effective adaptation. The table below summarizes the eight recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

PHOTO CREDIT: DON JARDINE

Table 5.4: Summary of recommended adaptation actions for the energy sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
20. Commission studies to form a foundation for evidence-based adaptation planning (e.g., climate forecasts, vulnerability assessments, cost-benefit analysis).	Leads: Utilities Collaborators: Experts	Fill knowledge gaps; Promote climate change mainstreaming	Short-term (0 to 5 years)
21. Relocate, retrofit, and/or protect critical energy infrastructure and equipment vulnerable to climate change impacts (e.g., move infrastructure located in areas vulnerable to erosion, add guying to utility poles to avoid cascades of falling poles).	Leads: Utilities Collaborators: Experts	Increase resilience	Ongoing
22. Lower energy demand as a complementary approach to addressing peak capacity (e.g., develop an alert system with suggested actions to reduce consumption when system is near peak capacity to avoid rolling brownouts).	Leads: Provincial Government, Utilities Collaborators: Public	Increase resilience; Reduce non-climatic factors; Engage in outreach; Leverage regulation	Short- to medium-term (0 to 10 years)
23. Decentralize, diversify, and develop redundancy in the sector to increase its capacity to cope with hazardous events and avoid large-scale system failures (e.g., solar panels, energy storage equipment, district energy systems).	Leads: Utilities, Provincial Government Collaborators: Public, Businesses, Municipal governments	Increase resilience; Engage in outreach; Address financial concerns	Medium-term (5 to 10 years)
24. Implement policies and regulations to foster climate change adaptation in areas such as design and safety standards, permitting, siting and zoning.	Lead: Provincial Government Collaborators: Utilites, Experts	Increase resilience; Promote climate change mainstreaming; Leverage regulation	Short- to medium-term (0 to 10 years)
25. Integrate climate change impacts into day-to-day operations as well as planning, risk assessment and management, and decision-making processes (e.g., load and demand forecasting, training, investment planning).	Leads: Utilities	Promote climate change mainstreaming	Ongoing
26. Plan new developments with climate change in mind (e.g., make buildings "solar ready", site new developments in areas with low vulnerability to coastal erosion and flooding).	Leads: Utilities, Businesses, Individuals	Increase resilience; Promote climate change mainstreaming	Ongoing
27. Increase collaboration and communication among sector stakeholders (e.g., share information such as climate risks and best practices).	Leads: Utilities	Increase collaboration	Ongoing

5.4 Conclusion

Risks to the energy system will be amplified by the impacts of a changing climate. Changes to the climate can affect how much energy is produced, delivered and consumed. The system must build resilience in order to continue providing a secure and reliable supply of energy to Islanders. Climate change is often thought of as a gradual phenomenon, with changes occurring slowly and losses taking place evenly and incrementally over time (CEA, 2016). This coupled with the sector's long planning horizons make it easy to put off adaptation initiatives. However, there is no room for complacency. Fortunately, there is ample evidence from adaptation actions taken in other jurisdictions that demonstrate the effectiveness and affordability of taking a proactive stance against climate change impacts. Mitigation has thus far been the primary focus of the energy sector in terms of climate change. More emphasis needs to be placed on adaptation because its long-term planning and investment horizons, sensitivity to weather conditions, and dependence on extensive infrastructure make the sector particularly vulnerable to climate change impacts (Government of Canada, 2009).

REFERENCES

Asian Development Bank. (2012, January). *Sector Briefing on Climate Change Impacts and Adaptation: Energy*. Retrieved from https://www.adb.org/sites/default/files/publication/29552/cc-sector-brief-energy.pdf

Audinet, P., J.C. Amado and B. Rabb. (2014). Climate Risk management Approaches in the Electricity Sector: Lessons from Early Adapters. In: *Weather Matters for Energy*. doi:10.1007/978-1-4614-9221-4_2.

Braun, M. and E. Fournier. (2016, September). *Adaptation Case Studies in the Energy Sector – Overcoming Barriers to Adaptation.* Report presented to Climate Change Impacts and Adaptation Division, Natural Resources Canada, 114 p. Retrieved from https://www.ouranos.ca/en/programs/energy-adaptation-case-studies/

PHOTO CREDIT: GOVERNMENT OF PEI

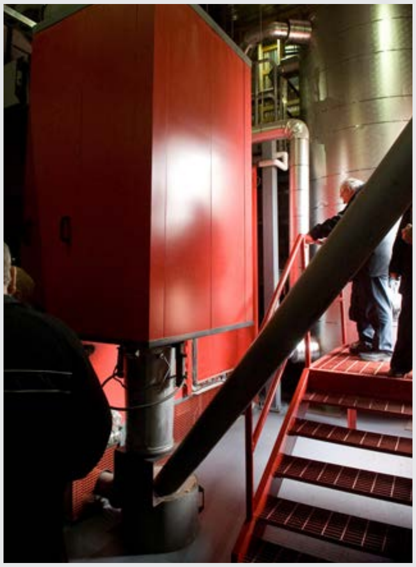


PHOTO CREDIT: GOVERNMENT OF PEI

Canadian Electricity Association. (2016). *Adapting to Climate Change: State of Play and Recommendations for the Electricity Sector in Canada*. Retrieved from https://electricity.ca/wp-content/uploads/2016/02/Adapting_to_Climate_Change-State_of_Play_and_Recommendations_for_the_Electricity_Sector_in_Canada.pdf

City of Summerside. (n.d.). *Our Summerside Electricity* [website]. Retrieved fromhttps://summerside.ca/residents/electricity/community/our_summerside_electricity

Cunniffe, J. (2017, September 7). Email.

Ebinger, J. and W. Vergara. (2011). *Climate Impacts on Energy Systems: Key Issues for Energy Sector Adaptation*. The World Bank. Washington, DC. doi:10.1596/978-0-8213-8697-2.

Environment and Climate Change Canada. (2017, June 21). *Pricing Carbon Pollution in Canada: How it will Work* [Website]. Retrieved from https://www.canada.ca/en/environment-climate-change/news/2017/05/pricing_carbon_pollutionin-canadahowitwillwork.html

Finley, T. and R. Schuchard. (n.d.). *Adapting to Climate Change: A Guide for the Energy and Utility Industry*. Retrieved from https://www.bsr.org/reports/BSR_Climate_Adaptation_Issue_Brief_Energy_Utilities.pdf

Gaetani, M., E. Vignati, F. Monforti, T. Huld, A. Dosio, and F. Raes. (2015). *Climate Modelling and Renewable Energy Resource Assessment.* European Commission Joint Research Center. Retrieved from https://ec.europa.eu/jrc/sites/jrcsh/files/reqno_jrc95440_reqno_jrc95440_renew_gaetani_report_2015_final.pdf

Government of Canada. (2009, January). *Climate Change Adaptation in the Energy Sector: Workshop Report*. Retrieved from http://www.horizons.gc.ca/sites/default/files/Publication-alt-format/2009-0004-eng.pdf

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

Government of Prince Edward Island. (2017, March). *Prince Edward Island Provincial Energy Strategy 2016/17*. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/pei_energystrategymarch_2017_web.pdf

Macleod, H. and M. Proud. (2017, September 29). Email.

Maritime Electric. (n.d.). *Our Island Electricity* [website]. Retrieved from http://www.maritimeelectric.com/about_us/ab_our_island_electricity.aspx

Morand, A., R. Hennessey, J. Pittman, and A. Douglas. (2015). *Linking Mitigation and Adaptation Goals in the Energy Sector: A Case Study Synthesis Report*. Report submitted to the Climate Change Impacts and Adaptation Division, Natural Resources Canada, 122p.

NB Power. (n.d.). *Generation* [website]. Retrieved from https://www.nbpower.com/en/about-us/divisions/generation

PEI Energy Commission. (2012, September). *Final Report: Charting Our Electricity Future*. Retrieved from http://www.gov.pe.ca/photos/original/NRGCommish_13.pdf

PEI Department of Transportation, Infrastructure and Energy. (2017, March 30). *Heating System Costs* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/transportation-infrastructure-and-energy/heating-system-costs

PEI Department of Transportation, Infrastructure and Energy. (2015, August 31). *Wind Energy in Prince Edward Island* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/transportation-infrastructure-and-energy/wind-energy-prince-edward-island

Statham, B., C. Frei, N. Bartlett, S. Gilfillan, D. Reinerand, and E. Whittington (eds.). (2014, June). *Climate Change: Implications for the Energy Sector*. Retrieved from https://www.worldenergy.org/wp-content/uploads/2014/06/Climate-Change-Implications-for-the-Energy-Sector-Summary-from-IPCC-AR5-2014-Full-report.pdf

Statistics Canada. (2016, November 14). *Sales of fuel used for road motor vehicles, by province and territory (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick)*. Retrieved on March 17, 2017 from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/trade37a-eng.htm

Statistics Canada (a). (2017, March 20). *Table 281-0024 – Survey of Employment, Payrolls and Hours (SEPH), employment by type of employee and detailed North American Industry Classification System (NAICS)*. Retrieved on May 3, 2017.

Statistics Canada (b). (2017, April 6). *Table 282-0088 - Labour force survey estimates (LFS), employment by North American Industry Classification System (NAICS), seasonally adjusted and unadjusted*. Retrieved on May 3, 2017.

Statistics Canada (c). (2017, April 28). *Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories*. Retrieved on May 3, 2017.

Tattrie, J. (2016, July 14). Summerside's Heat for Less program may expand across P.E.I. *CBC*. Retrieved from http://www.cbc.ca/news/canada/prince-edward-island/summerside-heat-for-less-program-may-expand-across-pei-1.3679966

The Maritimes Energy Association. (n.d.). *Prince Edward Island* [website]. Retrieved from https://ww.maritimesenergy.com/page.asp?ID=61

Wind Energy Institute of Canada. (n.d.). *Facilities* [website]. Retrieved from http://www.weican.ca/facilities

6

The wealth of the nation is its air, water, soil, forests, minerals, rivers, lakes, oceans, scenic beauty, wildlife habitats and biodiversity… that's all there is. That's the whole economy. That's where all the economic activity and jobs come from. These biological systems are the sustaining wealth of the world.

—Gaylord Nelson

6 FISH AND AQUACULTURE SECTOR

6.1 Background

Fishing has been an integral part of Prince Edward Island's history, economy, and identity for generations. More recently, aquaculture, the production or culturing of aquatic organisms (e.g., fish, shellfish, plants) has also become an important part of the Island's social and economic fabric. The province is cradled in the Gulf of St. Lawrence within the Magdalen Shallows, a plateau within the Gulf (Fisheries and Oceans Canada [DFO], 2005b) (see Figure 6.1). The Gulf is partially isolated from the North Atlantic, has the furthest regular annual extension of sea ice in the North Atlantic during the winter, and the warmest surface water temperatures in Atlantic Canada during the summer. Its diverse ecosystem is a product of its unique physical and chemical conditions.

Species fished and cultured in PEI include crustaceans (e.g., lobster, snow crab, rock crab, spider crab); molluscs (e.g., mussels, oysters, quahaugs, bar clams, soft shell clams, scallops); pelagics and estuarials (e.g. herring, mackerel, silversides, bluefin tuna, eels, gaspereau, cultured finfish such as salmon and trout); and groundfish (e.g. halibut, winter flounder and cod). Seafood is an important source of protein, minerals, vitamins, fatty acids, and nutrients required for normal growth and development; building and repair of body tissues; formation of red blood cells, bones, and teeth; upkeep of immune system health; and prevention of heart disease (DFO, 2012a).

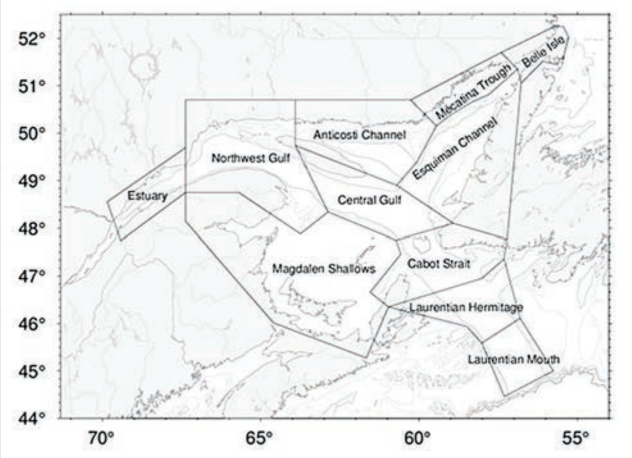


Figure 6.1: Regions within the Gulf of St. Lawrence (Source: Galbraith et al., 2017).

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: DON JARDINE

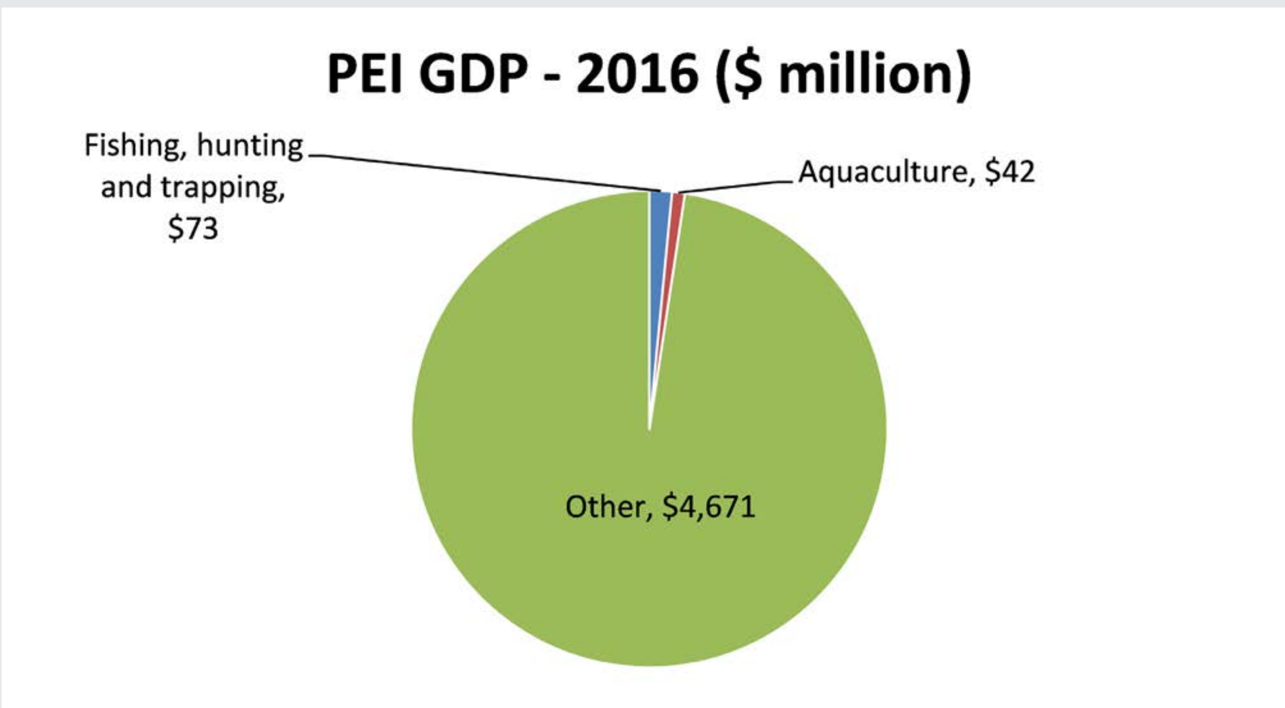


Figure 6.2: Prince Edward Island GDP of fishing (including hunting and trapping) and aquaculture (excluding food processing) in 2016 (in $million chained 2007 dollars) (Data source: Statistics Canada, 2017a).

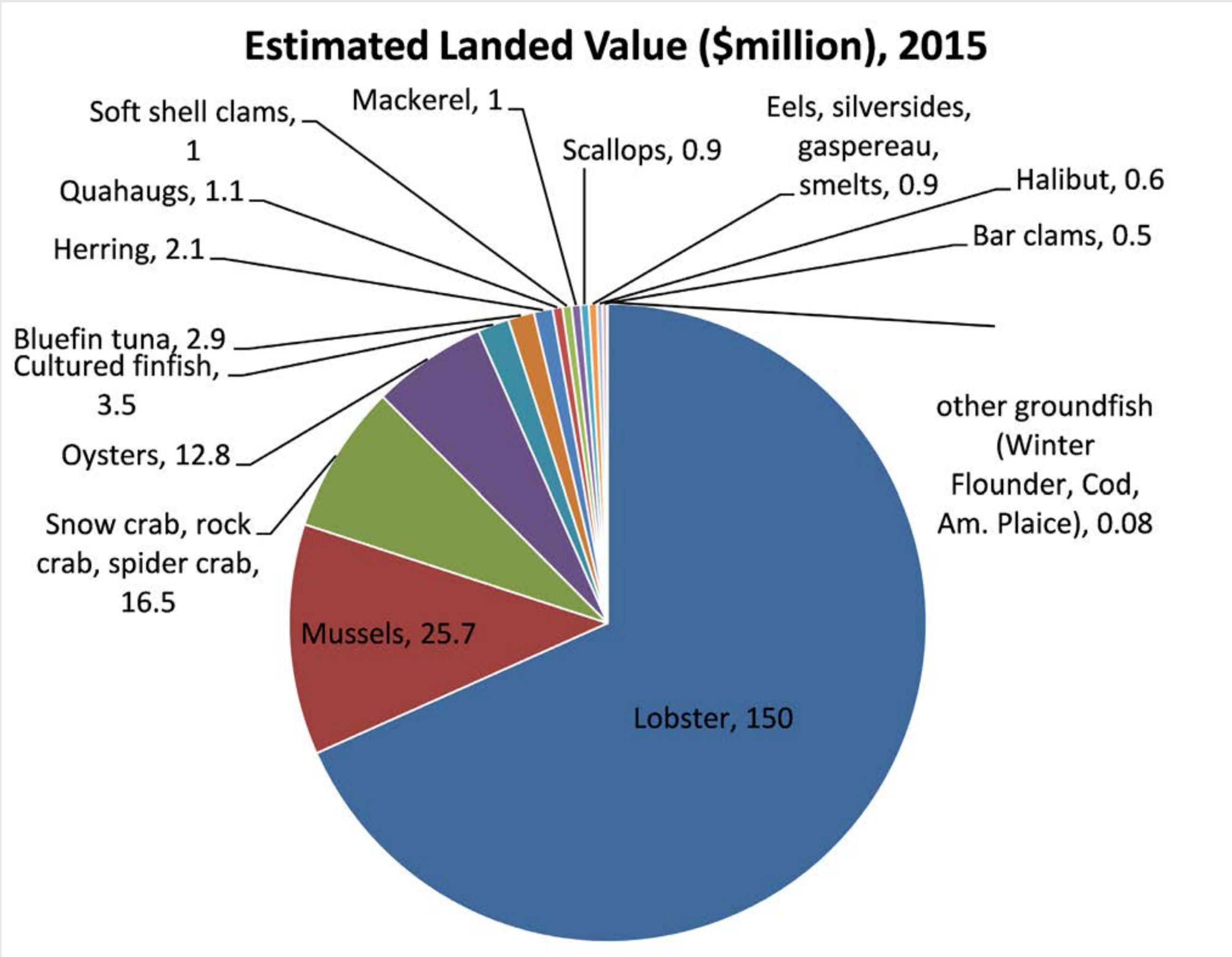


Figure 6.3: Estimated landed value by species in 2015 (Data source: PEI Department of Agriculture and Fisheries [PEI AF], n.d.).

The fish and aquaculture sector, along with its secondary industry of seafood processing, is the third largest industry in Prince Edward Island, contributing almost $300 million to the province's gross domestic product (Prince Edward Island Seafood Processors Association [PEISPA], n.d. a)[1]. The estimated landed value from the fishing and aquaculture industries was $219.6 million in 2015, with lobster (68%) and mussels (12%) accounting for 80% of the total (see Figure 6.3). In 2015, mussel leases spanned 11,233 acres and oyster and clam leases spanned 7,853 acres (PEI AF, n.d.). Seafood processing generates over $200 million in export revenue (PEISPA, n.d. b). Together, fishing, aquaculture, and food processing employed, 8,500 employees worked during peak production in 2015 (PEI AF, n.d.).

[1]GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

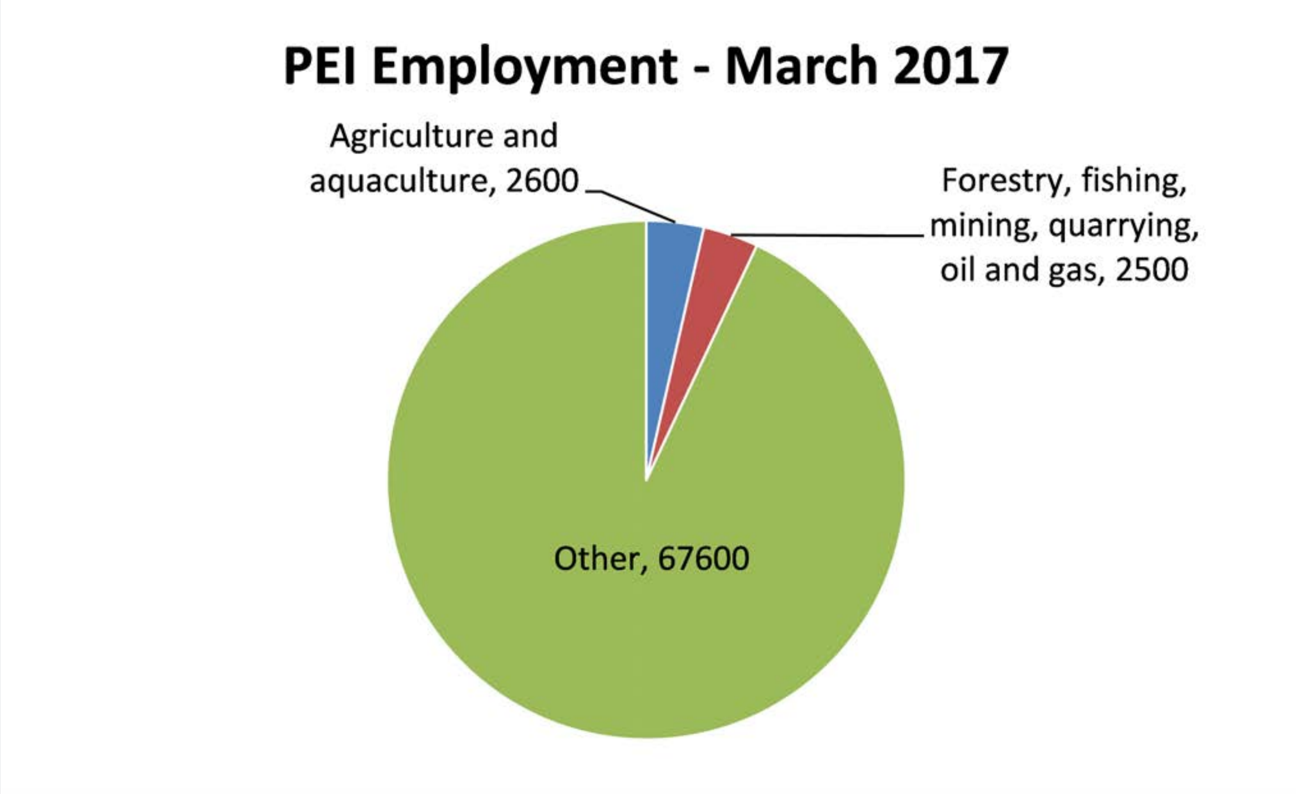


Figure 6.4: Seasonally adjusted employment in the fishing and aquaculture sectors (combined with agriculture, forestry, and natural resources sectors; excluding food processing) compared to total employment in March 2017 (Data source: Statistics Canada, 2017b).

Table 6.1: Commercial fishery statistics for the East Coast region, 2011 (Data source: Savard et al., 2016).

Province	Small-craft harbours (fishing)	Live weight (metric tonnes)	Landed value ($million)	Landed value ($/tonne)
Prince Edward Island	46	30,789	111.1	3609
Nova Scotia	163	258,677	732.0	2830
Quebec	57	55,381	154.9	2797
Newfoundland and Labrador	264	283,923	642.0	2261
New Brunswick	68	81,760	175.2	2143

There were 46 small-craft fishing harbours operating on the Island in 2011, bringing in over 30,000 metric tonnes and $111 million of catch (see Table 6.1). While these numbers were the lowest within the East Coast region given the size of the province and the industry, the landed value per tonne of catch is by far the highest. There are also a number of fish hatcheries and production facilities on the Island. The hatcheries develop and hatch eggs to help replenish fish stocks; the production facilities grow the fish until they reach market size.

Recreational fishing refers to non-commercial fishing. It includes recreational angling and sport fishing. There were a total of 8,680 anglers in Prince Edward Island in 2010, with 6,779 or 78% of them residents of the Island. Anglers in Prince Edward Island spent $9.6 million in direct expenditures (e.g., transportation, food, lodging), fishing services, fishing supplies, other direct recreational fishing expenditures (e.g., boat rentals, guide services, licence fees, lures, bait, lines), and major purchases and investments (e.g., boats, motors, camping gears, fishing equipment) in 2010 (DFO, 2012b). In the same year, the top three species fished by anglers were freshwater brook trout, mackerel, and sea-run brook trout (DFO, 2012b). Other species fished by anglers include rainbow trout, Atlantic salmon, striped bass, white perch, smelts, cod, flounder, and brown trout. Fishing for freshwater species was more popular, with over 120,000 days spent fishing for freshwater species and almost 60,000 days spent fishing for saltwater species (DFO, 2012b). Anglers on PEI fished more on average than those in any other province or territory at 20.9 days per angler in 2010 (DFO, 2012b).

6.2 Impacts of Climate Change

PHOTO CREDIT: DON JARDINE

Climate change will bring about warmer weather, changes in precipitation patterns, changes in sea level ice, more intense storms, and rising sea levels.

It is critical to note that opportunities and challenges resulting from climate change cannot be taken in isolation. While there are anticipated impacts both positive and negative, the extent of them has not been quantified. For example, the advantages of the increase of food conversion efficiency and growth rate from warmer sea temperature could be offset by the increased productivity of parasites that those temperatures bring.

6.2.1 Temperature

Rising air temperatures do not translate to a uniform rise in water temperatures. For example, the water in the Gulf of St. Lawrence is made up of three distinct layers: the surface layer (0 to 50 m), a cold intermediate layer (50 to 150 m), and a deeper layer (exceeding 150m) (Benoît *et al.*, 2012; Savard *et al.*, 2016). Since the surface layer waters are warmed by solar radiation, this layer is affected by rising air temperatures. Studies have shown that increases in surface-water temperature in the Gulf are comparable to the increases in air temperature over the same region (Savard *et al.*, 2016). The cold intermediate layer waters originate primarily from the cooling of water within the Gulf in the winter as well as from the transport of cold water from the Labrador Shelf through the strait between the Labrador peninsula and the island of Newfoundland (Drinkwater *et al.*, 2002). The deeper layer contains warmer waters from the Atlantic Ocean between the continental shelves and the Gulf Stream (Drinkwater *et al.*, 2002). Although the waters in the deeper layer are warmer than that in the cold intermediate layer, their density is higher because of the higher salinities (Drinkwater *et al.*, 2002).

The term "temperature" described in the remainder of this chapter refers to water temperature, unless otherwise indicated.

OPPORTUNITIES

First, an increase in temperature will accelerate the growth rate of some species (e.g., Atlantic salmon) (Pinnegar *et al.*, 2012; Savard *et al.*, 2016), as long as it remains within the thermal tolerances of those species and growth is not limited by other factors such as food availability (Reid and Jackson, 2014).

Second, warmer waters could reduce winter natural mortality (Savard *et al.,* 2016).

Third, the spatial distribution of species will shift. Generally, the centres of commercial production and harvest of important fish species (e.g., tuna, mackerel) will shift northward or inshore (Campbell *et al.*, 2014). There is a potential for greater access to these species (Campbell *et al.*, 2014).

PHOTO CREDIT: DON JARDINE

CHALLENGES

First, it will negatively affect the growth of some organisms, such as cold-water species (e.g., cod, Atlantic halibut) (Pinnegar *et al.*, 2012) in multiple ways. As temperature nears the limits of a species' tolerance range, the energy allocated towards its growth and reproduction declines, thus diminishing its size and abundance. For example, increasing temperatures were found to decrease Atlantic cod size (Brennan *et al.*, 2016). The increase in temperature could also impair immune function of cold-water species and make them more prone to disease (Pinnegar *et al.*, 2012; Doubleday *et al.*, 2013; Reid and Jackson, 2014). Increases in temperature during spawning could affect egg mortality and hatching, reducing survival rates in some

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

species (Savard *et al.*, 2016). Globally, increased surface level temperatures in high latitudes caused most of the ocean productivity decline since the early 1980s (Savard *et al.*, 2016).

Second, it will shift the timing and sensitivities of the species' lifecycle stages. For example, some lobsters begin their molting process earlier in warmer waters, which can affect the quality and value of the meat as well as the traditional harvest period (PEI Department of Communities, Land and Environment, 2016a). Similarly, the soft-shell phase for crabs could increase, during which they cannot be harvested or processed (Brennan *et al.*, 2016). This shift in timing also impacts food availability and the relationships among species (Pinnegar *et al.*, 2012). The timing of life events may change relative to their predators, prey, and competitors (Brennan *et al.*, 2016). For example, the later arrival of mackerel creates a mismatch in the spring lobster fishing season (Savard *et al.*, 2016). Since mackerel is a staple bait species, it may have to be purchased elsewhere, increasing the cost of transportation and refrigeration (Savard *et al.*, 2016). Furthermore, reduced success of adult migration and spawning as well as juvenile production of freshwater fish have been documented in other jurisdictions (Campbell *et al.*, 2014).

Third, the spatial distribution of species will shift. Native species could move away from their current locations to maintain their preferred temperature range. For marine species, there is a general poleward shift of species. Species requiring the coldest temperatures – such as the snow crab and Greenland halibut – would experience the most drastic declines (Benoît *et al.*, 2012; Brennan *et al.*, 2016). For freshwater fish, however, there are very limited options, if any, to disperse given the physical boundaries and topographic fragmentation of freshwater ecosystems (Bush *et al.*, 2014). Once the stream temperatures exceed the thermal tolerance of those species, the populations of these fish will disappear. Watercourse temperatures above the optimal temperature ranges for fish such as brook trout, rainbow trout, and Atlantic salmon, primarily in flatter regions where impoundments (e.g., manmade dams, beaver dams) exist, have already been observed in Prince Edward Island (R. MacFarlane, personal communication, October 5, 2017). In Chesapeake Bay in the United States, a rise in maximum summer temperatures was an important driver in the disappearance of marine eelgrass near its southern distribution limit (Savard *et al.*, 2016). Healthy eelgrass beds provide food, shelter, and protection for many species, especially juvenile fish. Meanwhile, non-indigenous invasive species and diseases currently south of the Island could be introduced to and proliferate within the region. Non-indigenous invasive species cause harm to the ecosystem by destabilizing the conditions of native species (Benoît *et al.*, 2012). They are considered a leading cause of biodiversity loss and a threat to fishing and aquaculture industries worldwide (Benoît *et al.*, 2012). Since 1998, four new tunicate species have established in the Gulf of St. Lawrence (see Figure 6.4). These filter feeders attach themselves to rocks, surfaces of the sea floor, mussel socks, aquaculture equipment, etc. They impact the aquaculture industry operationally and economically – the increased weight of tunicates growing on mussel socks and other equipment and structures requires increased handling costs and leads to loss of mussels that fall off the socks (Benoît *et al.*, 2012). The green crab is another important non-indigenous invasive species found in Island waters (see Figure 6.5). It is notorious for its aggressiveness and severe impacts on a wide variety of prey, especially molluscs, even damaging and modifying

Figure 6.5: The distribution of six types of non-indigenous invasive species as of February 2012 (Source: Benoît et al., 2012).

the habitat when it digs for prey (Benoît *et al.*, 2012). It competes with baby lobsters for food and destroys eel grass beds. Its introduction to the local ecosystems coincides with the steep decline of a unique strain of Irish moss that can only be found in Basin Head of Prince Edward Island, designated a marine protected area, and is therefore suspected to be responsible for the decline (Benoît *et al.*, 2012; Yarr, 2017). Given the lack of natural predators, abundance of food availability (mussels), lack of human market demand, and its tolerance of a wide temperature range (0 to 35˚C) (Brennan *et al.*, 2016), the green

PHOTO CREDIT: DON JARDINE

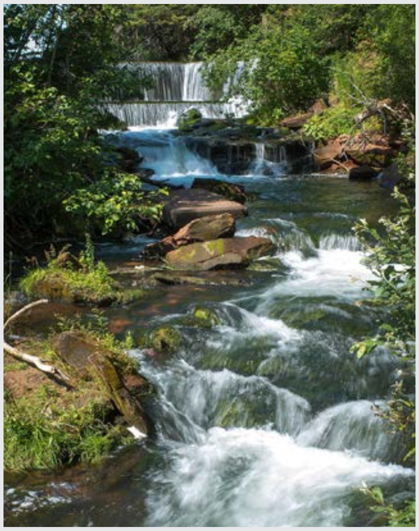


PHOTO CREDIT: GOVERNMENT OF PEI

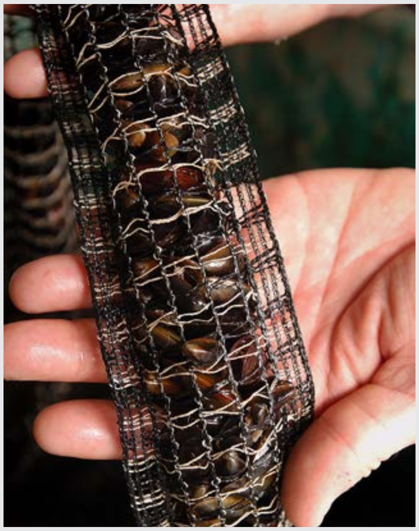


PHOTO CREDIT: GOVERNMENT OF PEI

crab is expected to continue to thrive. Furthermore, by disturbing the ecosystem, an initial invasion of non-native species lays the groundwork for subsequent non-native species to establish themselves (Benoît *et al.*, 2012). This is of considerable concern since they are better adapted to the new aquatic conditions than the native species (DFO, 2005b).

Fourth, the transmission, productivity, immigration, virulence and impact of parasites and pathogens increase in warmer waters. The higher temperature increases metabolic rates, improves survivability, quickens disease spread and extends transmission potential of parasites and pathogens (Reid *et al.*, 2016). For example, sea lice eggs need temperatures above 4˚C to complete their lifecycle (Reid and Jackson, 2014). This is evident in lower incidences of infection during winter months and reduced time to complete their life-cycle in warmer months (Reid and Jackson, 2014). Their population growth and attachment rates also increase exponentially with rising temperatures of a few degrees (Benfey, 2016). To exacerbate these issues, the impact of parasites and pathogens increases in hosts experiencing environmental stress (e.g., fish at their upper thermal tolerance). For example, rapid changes in temperature have been linked to outbreaks of endemic diseases (St-Hillaire, 2016).

Fifth, increasing air and water temperatures will increase the melting of Arctic ice cover. This cold freshwater flow into the Gulf will lead to stronger stratification of the water layers, inhibiting the upward flow of nutrients from the deeper waters (DFO, 2005a; Bush *et al.*, 2014) to the near-surface waters where phytoplankton grows and influencing the vertical exchange of important dissolved and suspended materials (e.g., reduced dissolved oxygen in subsurface waters) (Bush *et al.*, 2014).

Sixth, as water temperature increases, the solubility of oxygen decreases. Aquatic fish and animals depend on dissolved oxygen to survive.

Seventh, warmer winter temperatures are expected to reduce snowcover, affecting stream flow and salinity by changing the temperature, amount, duration, distribution, and timing of snowmelt in the spring (National Fish, Wildlife and Plants Climate Adaptation Partnership [NFWPCAP], 2012; Bush *et al.*, 2014). This can impact life events of aquatic life such as the spawning and migration of salmon (NFWPCAP, 2012).

Eighth, studies show that warming temperatures lead to reduced long-chain polyunsaturated fatty acid content in phytoplankton and cold-water pelagic fish (Myers *et al.*, 2017). The nutrient content of marine life has consequent effects up the food chain (Myers *et al.*, 2017).

6.2.2 Sea Ice

CHALLENGES

In the east coast region, sea ice cover has decreased over the last century and will likely decrease by more than 95% by the end of this century (Savard *et al.*, 2016). Within the Gulf of St. Lawrence, sea ice will continue to decrease in area, thickness, concentration, and duration until it ceases to form (Savard *et al.*, 2016). Winter air temperatures over the Gulf account for more than half of the inter-annual variability of sea ice coverage in thicker areas (Benoît *et al.*, 2012).

PHOTO CREDIT: GOVERNMENT OF PEI

First, fewer nutrients will be available to primary producers such as phytoplankton as sea ice formation decreases. Sea ice plays an important role in water-convection processes, which assist in the production of phytoplankton (Savard *et al.*, 2016), the foundation of the marine food web (Myers *et al.*, 2017). As surface water forms sea ice, the salt content of the water is released from the ice as dense brine. This sinks to deeper waters, displacing the less dense and nutrient-rich water, bringing it toward the surface. This upwelling brings nutrients for primary producers (Savard *et al.*, 2016). The reduction in nutrients can affect the timing of the spring phytoplankton bloom, impacting the recruitment of species. A study estimated that the changes in size and distribution of plankton communities would decrease fish catch potential by 3-13% globally by 2050 compared to recent decades (Myers *et al.*, 2017).

Second, changes in ice cover could lead to other changes in the habitat such as salinity levels, water quantity, composition and quality, silt deposits, river flows, etc. (DFO, 2005a).

6.2.3 Precipitation

CHALLENGES

First, fewer precipitation events will result in longer dry periods when freshwater flow in streams will diminish and estuary salinity will increase, affecting fish habitats. Decreased stream flow will also increase pollutant loading levels, since there is less water to dilute the contaminants and maintain flushing rates, which lead to the development and persistence of eutrophication (Coffin *et al.*, 2017).

Second, increased variability in stream flows will affect stream persistence and morphology (Government of British Columbia, 2016). Small streams may be more vulnerable to variable flow and decreasing habitat stability (Government of British Columbia, 2016).

6.2.4 Extreme Weather Events

CHALLENGES

First, heavy precipitation events could introduce significant amounts of sediments and contaminants via runoff, harming or killing aquatic species. Large amounts of sediments that run off from agricultural land each year fill in freshwater bodies and suffocate salmonoid eggs in streams (R. MacFarlane, personal communication, October 5, 2017). Similarly, there have been 51 documented fish kills proven or suspected to have been caused by pesticide runoff since 1962 (PEI Department of Communities, Land and Environment, 2016b). Another important species impacted by runoff is seagrass, which can be damaged or killed by polluted runoff containing herbicides. In addition, contaminated runoff promotes the growth of unwanted species. Extreme events provide ideal conditions for sea lettuce to grow. Sea lettuce quickly proliferates in areas of substrates cleared of other organisms by disturbances such as storms (Capital Region District, n.d.). Sewage and agricultural contaminants in the runoff further encourage sea lettuce growth, which thrive in moderate levels of nutrient pollution while other plants suffocate (University of Rhode Island Environmental Data Centre [URI EDC], n.d.). For Prince Edward Island, the predominant source of nutrient inputs is the agriculture sector (Coffin *et al.*, 2017). The growth of sea lettuce can lead to anoxic events (i.e., complete depletion of oxygen below the water surface). Where there is a bloom or high concentration of sea lettuce, sunlight to submerged vegetation such as eelgrass is blocked, preventing photosynthesis and killing the vegetation (URI EDC, n.d.). When the sea lettuce eventually dies and rots, the bacteria feeding on it uses up a significant amount of oxygen in the water, depleting the oxygen available to other species (e.g., mussels), suffocating them or driving them away (URI EDC, n.d.). In the past, anoxic events caused by sea lettuce would happen once per season within any given area on the Island. Recently, there have been incidences of these events occurring twice per season within the same area. Another unwanted species that benefit from runoff is blue-green algae,

PHOTO CREDIT: DON JARDINE

or cyanobacteria. It is a non-indigenous invasive species that produces potent nerve and liver toxins (NFWPCAP, 2012), affecting human and animal health. Nutrients from runoff, along with increasing temperatures, increase the frequency of harmful algal blooms (Gillette and Myvette, 2008; NFWPCAP, 2012), potentially resulting in the lost productivity or mortality of other aquatic life (Campbell *et al.*, 2014). When the algae die and sink, they are also consumed by bacteria, which use up oxygen in the deep water (NFWPCAP, 2012). In addition, the presence of harmful algal blooms has also been linked to an off-flavour in fish in other regions (Reid and Jackson, 2014).

Second, to address concerns regarding the sanitation of shellfish sold for export after "unusual weather events", flooding, spills of sewage, etc., a protocol for emergency closure of shellfish growing areas have been put in place jointly by the Canadian Food Inspection Agency (CFIA), Environment and Climate Change Canada, and Fisheries and Oceans Canada (CFIA *et al.*, 2014). A rainfall-based closure will be determined based on a number of factors, including the amount and intensity of precipitation, duration, time of year, ground saturation, likelihood of flooding and sewage overflows, and adjacent land use activities (CFIA, 2014). Once the protocol is enacted, the closure of the area will be in place for a minimum seven days to allow for proper cleansing of shellfish (CFIA, 2014). After that time, water sampling and shellstock testing will be conducted to ensure sanitation requirements are met before the area can be reopened (CFIA *et al.*, 2014). As extreme weather events increase in frequency, these closures are expected to increase in frequency as well.

Third, extreme events bring about increased wave action that could cause damage to infrastructure and equipment such as small craft harbours, aquaculture facilities, vessels, traps, etc. As a result, the cost of insurance, maintenance, repair, and adaptation of infrastructure and equipment will increase under a changing climate. As the severity of extreme weather events continue to intensify and sea levels continue to rise, barrier islands will eventually be breached or overwhelmed, leaving aquaculture leases, harbours, facilities, etc. behind the barrier islands more vulnerable to wave action.

PHOTO CREDIT: DON JARDINE

Fourth, extreme weather events limit the fishers' and producers' access to their sites. Change in sedimentation from runoff and wave action could increase the need to dredge channels for boat access. Access to harbours and land-based aquaculture sites such as hatcheries could be temporarily restricted due to road closures.

Fifth, an increase in storm activity and wave energy could reduce the catch through a reduction in the number of fishing days (e.g., fishers unable to go out) and availability of fish (Gillett and Myvette, 2008; Holbrook and Johnson, 2014).

6.2.5 Sea Level Rise

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: DON JARDINE

CHALLENGES

First, rising sea levels could damage properties and infrastructure within the near-coastal area via flooding and erosion. As a result, the cost of insurance and maintenance, repair, and adaptation of infrastructure (e.g., adjusting harbours) and equipment will increase under a changing climate.

Second, rising seas could increase salinity in bays and estuaries via salt water intrusion (DFO, 2005a). Fish and shellfish each have a defined tolerance of salinity levels. If the levels reach or exceed the upper limits of their tolerance, their ability to thrive and survive will be threatened.

Third, any coastal wetlands and habitats that serve as nurseries could be compromised or lost (Gillett and Myvette, 2008). The changes in esturarine dynamics can limit seedstock availability (Gillett and Myvette, 2008).

Fourth, rising water levels could reduce the amount of sunlight available to submerged aquatic vegetation (United States Environmental Protection Agency [EPA], 2009).

Fifth, a change in sea levels will permanently inundate low-lying areas, increasing the water area and potentially prompting a change in aquaculture zoning (Savard *et al.*, 2016) (e.g., revised designated zones).

Sixth, bridge clearance will decrease as sea levels rise. This would impact shellfishers and pleasure boaters, who need to pass underneath.

6.2.6 Ocean Acidification

Some of the carbon dioxide in the atmosphere is absorbed by marine waters, changing the chemical composition of the water and lowering the pH level, making the water more acidic. Globally, it is estimated that since pre-industrial times, about one-third of the carbon dioxide produced by human activities has been absorbed by the oceans (Benoît *et al.*, 2012). If the emissions continue at their present rates, a 100% increase in acidity is anticipated by the end of the century, to a level possibly unseen over the last 55 million years (Benoît *et al.*, 2012). The ability of marine life to adapt is unknown. The acidification of marine waters will present challenges to the sector.

CHALLENGES

First, an increase in the acidity of marine waters raises the solubility of calcium carbonate, which forms the shells and skeletons of shellfish, making it more difficult for shellfish to develop hard shells and affecting production of other species. Shell deformation has also been observed in other jurisdictions – a potential issue for the marketability of shellfish.

Second, the growth and health of fish and shellfish are jeopardized. For example, the increase in acidity can lower the hatching success, survival, final weight, growth rate, swimming performance, calcification rate, development rate, settle success, cellular activity, respiratory activity, protein synthesis, and feeding efficiency of fish and shellfish (Brennan *et al.*, 2016). Acidification can also change species composition and dominance within an ecosystem (Savard *et al.*, 2016).

Third, some planktons cannot survive in increasingly acidic waters (NFWPCAP, 2012). Plankton serves as the base of the marine food chain and changes in its availability would disrupt the entire food chain.

6.2.7 Indirect Climate Change Impacts

CHALLENGES

First, warmer temperatures could lead to an increase in tourism and recreational use of waterways, leading to more human activity and traffic. Pollution from these activities can result in contamination of the water bodies and the potential introduction of invasive species from ballast water (DFO, 2005a) negatively impacting local marine life.

Second, the human response to climate change could exacerbate existing stressors like habitat loss and degradation. For example, the increased use of armouring to protect properties and infrastructure from flooding and erosion would alter the shoreline and can impact aquatic habitats (DFO, 2005a) by restricting the exchange of sediment between land and sea (NFWPCAP, 2012). Another example is the increased reliance on irrigation in the agriculture and tourism sectors (e.g., golf courses), which could negatively impact river flow rate, affecting freshwater biodiversity (Xenopoulos *et al.*, 2005) and increasing the concentration of any pathogens and contaminants in the water.

6.2.8 Unknowns

Under a changing climate, food access and security will become increasingly valued. However, the impact on the sector in Prince Edward Island is difficult to project. Recent assessments by DFO suggest that drastic changes in fisheries yield and value are unlikely over the next decade (Campbell *et al.*, 2014). However, over the longer term, catch and production of individual species locally and in other regions will vary and remain uncertain. For example, in 2012, an ocean heat wave resulted in a glut in the supply of lobsters from the New England states before the close of the Canadian lobster season, driving the price of lobster down (Savard *et al.*, 2016).

6.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

28 **Form a foundation for evidence-based adaptation planning** by conducting research and collecting data. Determine critical data gaps for informed decision making and prioritize data collection. Standardized equipment and methodology should be used, and the data should be made accessible from a centralized database. For example:

- **a.** create and maintain an inventory and map of habitats of significant marine species, water temperatures, and population numbers, where possible;
- **b.** create and maintain an inventory and map of habitats of significant freshwater species, population numbers, and stream and river water temperatures, flow rates, and conditions, where possible;
- **c.** create and maintain an inventory of the major species' ranges in temperatures, pH tolerance, salinity tolerance, etc. for optimum growth and for survival;
- **d.** monitor changes in water temperature, quality, turbidity, levels, and flow volumes and patterns;
- **e.** develop a set of climate indicators to monitor the impacts of climate change and the effectiveness of adaptation actions;
- **f.** enhance surveillance of existing and emerging pathogens;
- **g.** enhance surveillance of existing and emerging non-indigenous invasive species;
- **h.** identify genes that affect susceptibility and resistance to specific pathogens;
- **i.** investigate preventive treatments of anticipated diseases;
- **j.** model groundwater recharge and discharge rates and timing under a changing climate;
- **k.** calculate the impact of industrial use of groundwater on baseflow inputs into streams and creeks;
- **l.** identify alternative feeds and feeding practices;
- **m.** monitor habitat conditions, species distribution, and changes in plankton;
- **n.** assess the resiliency and ability to disperse for plant and animal species;
- **o.** study effective responses against non-indigenous invasive species; and,

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: GOVERNMENT OF PEI

- **p.** perform climate change vulnerability assessments on major marine and freshwater species with consideration of related species and keystone species at the ecosystem-scale.

Suggested timeline: short-term (0 to 5 years); ongoing maintenance

29 Increase the ability of aquatic life to adapt to climate change impacts by reducing non-climatic stressors. Climate change introduces stress to the natural systems (e.g., changes in temperature, pH, salinity), impacting the native species' ability to survive and thrive. Since some of these stresses cannot be easily counteracted, increasing the resilience of aquatic life is essential. For example,

- **a.** reduce land-based sources of pollution (e.g., sedimentation, agricultural and sewage runoff) by widening and increasing enforcement of rules related to the watercourse and wetland buffer zone, increasing vegetation within the watercourse and wetland buffer zone, increasing the use of green infrastructure such as berms, rain gardens, ditches, etc.;
- **b.** improve stream and coastal embankments;
- **c.** prevent translocation of pathogens and non-indigenous invasive species;
- **d.** manage fish stocks by monitoring changes in recruitment, growth, survival, and reproductive success (Shelton, 2014), limiting overfishing, and incorporating climate change into fisheries models, ideally creating multispecies models which can account for the impact of any decreases in prey items. Well managed fish stocks are more resilient, better handle climate impacts (HM Government, 2013), and provide a more sustainable future for the sector;
- **e.** restore degraded habitats that will provide essential ecosystem services to facilitate adaptation under a changing climate;
- **f.** protect critical areas such as nursery grounds, spawning grounds, and areas of high species diversity;
- **g.** limit cumulative effects of multiple land-use activities;
- **h.** avoid water withdrawals from sensitive wetlands;
- **i.** provide thermal and hydrological buffers;
- **j.** maintain and enhance habitat connectivity for freshwater fish;
- **k.** reduce habitat loss. Local watershed groups can be engaged to improve and restore coastal habitats. For example, a small levy can be applied to fund coastal/wetland restoration training and projects with known benefits to the environment and the sector (e.g., plant eel grass beds, remove/harvest sea lettuce overgrowth, monitor harmful algal blooms); and,
- **l.** raise public awareness on the importance of healthy and diverse coastal systems. For example, demonstrate the use of wetlands, rain barrels, living shorelines techniques, berms, etc. to adapt to flooding and erosion rather than hard structures (e.g., seawalls, armouring), which decrease fisheries habitat and biodiversity. The public can be incentivized to help by demonstrating to them how the consequences of poorly managed ecosystems (e.g., marine diseases, harmfulalgal blooms, runoff) can negatively impact recreational use of coastal areas and human health.

Suggested timeline: medium-term (6 to 10 years)

PHOTO CREDIT: DON JARDINE

30 **Reduce stream water temperatures** by reducing solar heating (e.g., increasing canopy cover in riparian zones, maintaining narrow and deep stream beds) and improving water flow (e.g., removing impoundments, limiting irrigation during times of high temperatures and low stream flow, increasing water infiltration rates on land to boost discharge rates of cooler groundwater during summers when flow conditions are low). Target thermal hot spots where flow retention times are longer and large heat loads can accumulate in the absence of shade.
Suggested timeline: short-term (0 to 5 years)

31 Increase support to watershed groups via **funding for training, data collection, and habitat improvement programs** (see Recommended Adaptation Actions #28, #29, #30, and #36).
Suggested timeline: ongoing

32 **Manage risks and adapt to increased variability** in the sector via diversification. For example:
- **a.** diversify sources and types of fish meal and fish oil;
- **b.** diversify sources and types of seed (e.g., wild-caught seed versus propagated seed);
- **c.** diversify livelihoods (e.g., ecotourism, fishing tours);
- **d.** avoid investing heavily in specialized equipment;
- **e.** diversify product range (e.g., algae cultivation);
- **f.** decentralize and spread out locations of hatcheries, storage facilities, food processing plants, etc. Should one location be impacted environmentally (e.g., pollution) or physically (e.g., flooding), other sites can continue to operate; and,
- **g.** diversify markets for products. Proactively seek out and establish new markets to prevent impacts from a glut in traditional market driving down prices.

Suggested timeline: medium-term (6 to 10 years)

33 Invite other jurisdictions to **share best practices**. Other regions are facing similar challenges brought on by climate change. Long-term sustainability and adaptive capacity need to be the goal, rather than yield or profit maximization. By sharing best practices with other regions (e.g., immerse mussel seed in a continuous flow of freshwater before transferring them from an infested area to a new area), they could reciprocate with adaptation strategies of their own (e.g., ways to cope with green crab, use of oyster reefs as breakwaters). It would be mutually beneficial for ecosystems and sectors to be as healthy and sustainable as possible.
Suggested timeline: ongoing

PHOTO CREDIT: DON JARDINE

34 **Relocate, retrofit, and/or protect** existing properties and infrastructure and design new properties and infrastructure to reduce flooding and erosion vulnerabilities. In cases where relocation, retrofitting, or protection is cost-prohibitive, planned abandonment and consolidation of infrastructure should be explored. Green measures should be used where possible (see Recommended Adaptation Action #29l). For example:

- **a.** raise harbours over time to cope with sea level rise;
- **b.** build onshore storage facilities for boats and gear to prevent damage and loss during extreme events; and,
- **c.** include climate change considerations during the siting and design of new infrastructure. For example, building an aquaculture production facility that requires saltwater for its operation as close to the coast as possible will reduce the cost of piping and trenching during the construction stage and the use of electricity for pumping during its operation stage. However, the cost of protecting it from increasing rates of flooding and/or erosion overtime will overwhelm the initial capital and operational savings.

Suggested timeline: medium- to long-term (6+ years)

35 **Facilitate adaptation and harmonize adaptation objectives and approaches among different stakeholders** that are reliant on the same resource by using regulatory measures. The government should collaborate with stakeholders to design clear and transparent policies that promote adaptive capacity and the sustained resilience and success of natural resources and the industries that depend on them. For example:

- **a.** review regulations and policies to identify ways to improve their ability to address climate change considerations, where appropriate;
- **b.** design flexibility into the policies, by incorporating climate change into fisheries management where possible. For example, fishing season start and end dates can be adjusted to biology changes from climatic factors, extended to compensate for closures due to shellfish sanitisation regulations, etc.;
- **c.** seek the input of indirect stakeholders. For example, collaborate with the agriculture sector to reduce inputs before a forecasted extreme precipitation to reduce contaminants in run off. This also benefits farmers, since inputs are costly and any that leave the crop area are wasted;
- **d.** prioritize the sustainability of the industry and the environment over short-term profit and yield. It would be a lose-lose scenario for all stakeholders if the long-term sustainability of the industry was sacrificed for short-term gain; and,
- **e.** address overcapacity proactively. For example, promote diversification, provide lead time on new harvestable species that may be entering the habitat, and facilitate market awareness and access.

Suggested timeline: short- to medium-term (0 to 10 years)

36 **Identify and address gaps in tools** (e.g., vulnerability and risk assessments, online repository of information on climate change impacts and adaptation strategies), **guidelines** (e.g., monitoring protocols, outreach strategies), **training** (e.g., wetland restoration, habitat restoration, stream health management), **and skills** (e.g., scenario planning, information management).
Suggested timeline: ongoing

37 **Limit business losses** caused by climatic events by employing financial mechanisms such as insurance and other innovative instruments. Establish a committee with the industry, Department of Fisheries and Aquaculture, and Department of Finance to discuss establishing a co-operative that offers fishing and aquaculture insurance. It could provide insurance against production losses related to natural hazards, diseases, invasive species, damage to vessels from weather-related events, and more. Incentives (e.g. lower premiums) could be put in place to encourage adaptation. Co-financing may be required during the pilot stage but this program was implemented in another jurisdiction and the cooperative became self-sustaining. Profits from the insurance program could be used by the cooperative in ways that benefit the industry (e.g. invest in raising awareness of climate change impacts and adaptation, purchase safety equipment)
Suggested timeline: medium-term (6 to 10 years)

The collaboration of fishers, environmental groups, watershed groups, sector (e.g. industry organizations), experts (e.g., climate scientists, biologists, engineers), and the government will be critical in achieving effective adaptation. The table below summarizes the ten recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

PHOTO CREDIT: DON JARDINE

Table 6.2: Summary of recommended adaptation actions for the fish and aquaculture sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
28. Form a foundation for evidence-based adaptation planning by conducting research and collecting data (e.g., create and maintain an inventory and map of habitats of significant marine species and environmental variables, study effective responses against invasive species).	Leads: Sector, Provincial Government, Federal Government Collaborators: Experts, Watershed groups	Fill knowledge gaps	Short-term (0 to 5 years); Ongoing maintenance
29. Increase the ability of aquatic life to adapt to climate change impacts by reducing non-climatic stressors (e.g., widen the watercourse and wetland buffer zone, reduce runoff, restore coastal habitats).	Leads: Sector, Provincial Government, Federal Government Collaborator: Fishers, Experts, Public	Increase resilience; Reduce non-climatic factors; Engage in outreach	Medium-term (6 to 10 years)
30. Reduce stream water temperatures by reducing solar heating (e.g., increasing canopy cover in riparian zones) and improving water flow (e.g., limiting irrigation during times of high temperatures and low stream flows). Target areas where flow retention times are longer and large heat loads can accumulate in the absence of shade.	Leads: Sector, Provincial Government, Watershed Groups Collaborators: Private land owners, Experts	Increase resilience	Short-term (0 to 5 terms)
31. Increase support to watershed groups via funding for training, data collection and habitat improvement programs (see Recommended Adaptation Actions #28, #29, and #30 and #36).	Leads: Provincial Government, Federal Government, Sector Collaborators: Watershed groups	Increase resilience; Reduce non-climatic factors; Fill knowledge gaps; Increase collaboration	Ongoing
32. Manage risks and adapt to increased variability in the sector via diversification (e.g., diversify livelihoods, decentralize and spread out locations of facilities).	Leads: Fishers, Sector Collaborators: Experts	Increase resilience	Medium-term (6 to 10 years)
33. Invite other jurisdictions to share best practices (e.g., seek ways to cope with green crab, share local methods of transferring mussel seed from an infested area to a new area).	Leads: Fishers, Sector Collaborators: Experts	Increase collaboration	Ongoing
34. Relocate, retrofit, and/or protect existing properties and infrastructure and design new properties and infrastructure to reduce flooding and erosion vulnerabilities.	Leads: Infrastructure owners Collaborators: Experts	Increase resilience	Medium- to long-term (6+ years)
35. Facilitate adaptation and harmonize adaptation objectives and approaches among different stakeholders that are reliant on the same resource by using regulatory measures (e.g., prioritize sustainability of the industry and the environment over short-term profit and yield).	Leads: Provincial Government, Federal Government Collaborators: Fishers, Sectors, Other sectors	Leverage regulation; Promote climate change mainstreaming; Increase collaboration	Short- to medium-term (0 to 10 years)
36. Identify and address gaps in tools, guidelines, training, and skills (e.g., habitat restoration, vulnerability and risk assessments, training materials).	Leads: Sector, Provincial Government	Fill knowledge gaps; Increase resilience; Promote climate change mainstreaming	Ongoing
37. Limit business losses caused by climatic events by employing financial mechanisms such as insurance and other innovative instruments (e.g., create a co-operative that offers insurance against production losses).	Leads: Sector, Provincial Government Collaborators: Fishers, Experts	Address financial concerns; Increase collaboration	Medium-term (6 to 10 years)

6.4 Conclusion

The fish and aquaculture sector is vital to Prince Edward Island. Aside from its role in the Island's economy and society, its provision of healthy food is critical. The sector is inherently sensitive to climate and specific timing and manifestation of impacts are unknown. However, the sector can act proactively, such as restoring and improving natural systems via biodiversity enhancement and diversification, to increase the resilience of marine life and its ability to cope with the challenges that the future climate will bring.

REFERENCES

Benfey, T. (2016, April). Warming waters presentation summary. In: Proceedings of the Atlantic and Pacific Climate Change and Aquaculture Workshops, (eds.) G.K. Reid and H.J. Gurney-Smith. *Bulletin of the Aquaculture Association of Canada*. 2015-2. ISSN 0840-5417.

Benoît, H.P., J.A. Gagné, C. Savenkoff, P. Ouellet, and M.-N.Bourassa. (eds.). (2012). State-of-the-Ocean Report for the Gulf of St. Lawrence Integrated Management (GOSLIM). *Area. Can. Manuscr. Rep. Fish. Aquat. Sci*. 2986: viii + 73 pp. Retrieved from http://www.dfo-mpo.gc.ca/Library/345310.pdf

Brennan, C.E., H. Blanchard, and K. Fennel. (2016). Putting Temperature and Oxygen Thresholds of Marine Animals in Context of Environmental Change: A Regional Perspective for the Scotian Shelf and Gulf of St. Lawrence. *PLoS ONE*. 11(12): e0167411. doi:10.1371/journal.pone.0167411

Bush, E.J., J.W. Loder, T.S. James, L.D. Mortsch and S.J. Cohen. (2014). An Overview of Canada's Changing Climate. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 23-64.

Campbell, I.D., D.G. Durant, K.L. Hunter, and K.D. Hyatt. (2014). Food Production. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 99-134.

Canadian Food Inspection Agency, Environment and Climate Change Canada, and Fisheries and Oceans Canada. (2014, July 18). *Appendix VIII: Protocol for Emergency Closure of any Shellfish Area*. Retrieved from http://www.inspection.gc.ca/DAM/DAM-food-aliments/STAGING/text-texte/fish_man_shellfish_app8_1363878475685_eng.pdf

Capital Region District. (n.d.). *What is sea lettuce* [website]? Retrieved from https://www.crd.bc.ca/education/our-environment/wildlife-plants/marine-species/sea-lettuce

Coffin, M.R.S., K.M. Knysh, E.F. Theriault, C.C. Pater, S.C. Courtenay, and M.R. van den Heuvel. (2017, March). Are floating algal mats a refuge from hypoxia for estuarine invertebrates? *PeerJ*. 5:e300. doi:10.7717/peerj.3080

Doubleday, Z.A. , S.M. Clarke, X. Li, G.T. Pecl, T.M. Ward, S.Battaglene, S. Frusher, P.J. Gibbs, A.J. Hobday, N. Hutchinson, S.M. Jennings and R. Stoklosa. (2013, March 20). Assessing the risk of climate change to aquaculture: A case study from south-east Australia. *Aquaculture Environment Interactions*. 3: 163–175. doi:10.3354/aei00058.

Drinkwater, K.F., R.G. Pettipas, and W.M. Petrie. (2002). *Physical Environmental Conditions in the Southern Gulf of St. Lawrence during 2001*. Research Document 2002-0147. Retrieved from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2002/RES2002_047_B&W.pdf

Fisheries and Oceans Canada (a). (2005, May). *Climate Change Risk Assessment for Fisheries and Oceans Canada*. Retrieved from www://www.dfo-mpo.gc.ca/science/oceanopgraphy-oceanopraphie/accasp-psaccma/profile-2005-eng.html

Fisheries and Oceans Canada (b). (2005). *The Gulf of St. Lawrence: A Unique Ecosystem*. Retrieved from http://www.dfo-mpo.gc.ca/library/318989_e.pdf

Fisheries and Oceans Canada (a). (2012). *Aquaculture in Canada 2012: A Report on Aquaculture Sustainability*. Retrieved from http://www.dfo-mpo.gc.ca/aquaculture/lib-bib/asri-irda/pdf/DFO_2012_SRI_AQUACULTURE_ENG.pdf

Fisheries and Oceans Canada (b).(2012). *Survey of Recreational Fishing in Canada 2010*. ISBN 978-1-100-54196-9. Retrieved from http://www.dfo-mpo.gc.ca/stats/rec/can/2010/index-eng.htm

Galbraith, P., J. Chassé, C. Caverhill, P. Nicot, D. Gilbert, B. Pettigrew, D. Lefaivre, D. Brickman, L. Devine, and C. Lafleur. (2017). *Physical Oceanographic Conditions in the Gulf of St. Lawrence in 2016*. Retrieved at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_044-eng.pdf

Gillett, V. and G. Myvette. (2008, May).*Vulnerability and Adaptation Assessment of the Fisheries and Aquaculture Industries to Climate Chan*ge. Retrieved from http://www.hydromet.gov.bz/climate-change?download=28:vulnerability-and-adaptation-assessment-of-the-fisheries-and-aquaculture-industries-to-climate-change

Government of British Columbia. (2016, June 8). *Climate Change Vulnerability of BC's Fish and Wildlife: First Approximation*.

HM Government. (2013, July). *The National Adaptation Programme: Making the Country Resilient to a Changing Climate*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209866/pb13942-nap-20130701.pdf

Holbrook, N.J. and J.E. Johnson. (2014, June). Climate change impacts and adaptation of commercial marine fisheries in Australia: a review of the science. *Climatic Change*. 124(4): 703–715.

Myers, S.S., M.R. Smith, S. Guth, C.D. Golden, B. Vaitla, N.D. Mueller, A.D. Dangour, and P. Huybers. (2017, March 20). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*. 20(38), 259-277. doi:10.1146/annurev-publhealth-031816-044356.

National Fish, Wildlife and Plants Climate Adaptation Partnership. (2012). *National Fish, Wildlife and Plants Climate Adaptation Strategy*. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, DC. Retrieved from https://www.wildlifeadaptationstrategy.gov/pdf/NFWPCAS-Final.pdf

PEI Department of Agriculture and Fisheries. (n.d.). *2015 Statistical Review*: *Prince Edward Island Seafood*. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/af_2015_fisheries_statistics.pdf

PEI Department of Communities, Land and Environment (a). (2016, July 7). *Climate Change and Island Fisheries* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/climate-change-and-island-fisheries

PEI Department of Communities, Land and Environment (b). (2016, March 9). *Fish Kill Information and Statistics* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/fish-kill-information-and-statistics

Pinnegar, J., T. Watt, and K. Kennedy. (2012, January). *Climate Change Risk Assessment for the Marine and Fisheries Sector*. Retrieved from http://randd.defra.gov.uk/Document.aspx?Document=CCRAfortheMarineandFisheriesSector.pdf

Prince Edward Island Seafood Processors Association (PEISPA) (a). (n.d.). *PEI Seafood Processors Association* [website]. Retrieved from http://www.peispa.com/

Prince Edward Island Seafood Processors Association (PEISPA) (b). (n.d.). *The Industry* [website]. Retrieved from http://www.peispa.com/index.php?page=main&menu=main&mainid=12

Reid, G.K. and T. Jackson. (2014, March 11). *Climate Change Implications for Aquaculture Management and Research* [Presentation]. Presented to Science Symposium on Climate Change and Aquaculture. Charlottetown, PE, Canada. http://www.aquaculturepei.com/media/pdfs/3_Jackson.pdf

Reid, G.K., H.J. Gurney-Smith, K.E.B. Dalton, A. Garber, C.T. Smith, and L. Cooper. Climate change and aquaculture: literature review presentation summary. In: Proceedings of the Atlantic and Pacific Climate Change and Aquaculture Workshops, (eds.) G.K. Reid and H.J. Gurney-Smith. *Bulletin of the Aquaculture Association of Canada. 2015-2*. ISSN 0840-5417.

Savard, J.P., D. van Proosdij, and S. O'Carroll. (2016). Perspectives on Canada's East Coast region. In: *Canada's Marine Coasts in a Changing Climate*, (eds.) D.S. Lemmen, F.J. Warren, T.S. James and C.S.L. Mercer Clarke; Government of Canada, Ottawa, ON, p. 99-152. Retrieved from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/Coastal_Assessment_Chapter4_EastCoastRegion.pdf

Shelton, C. (2014). Climate change adaptation in fisheries and aquaculture – compilation of initial examples. *FAO Fisheries and Aquaculture Circular No. 1088*. Rome, FAO. 34 pp. Retrieved from http://www.fao.org/3/a-i3569e.pdf

St-Hilaire, S. (2016, April). Effects of climate change on fish and shellfish health presentation summary. In: Proceedings of the Atlantic and Pacific Climate Change and Aquaculture Workshops, (eds.) G.K. Reid and H.J. Gurney-Smith. *Bulletin of the Aquaculture Association of Canada. 2015-2*. ISSN 0840-5417.

Statistics Canada (a). (2017, April 6). *Table 282-0088 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories*. Retrieved on May 4, 2017.

Statistics Canada (b). (2017, April 28). *Table 379-0030 – Labour force survey estimates (LFS), employment by North American Industry Classification System (NAICS), seasonally adjusted and unadjusted*. Retrieved on May 4, 2017.

United States Environmental Protection Agency. (2009, January). *Synthesis of Adaptation Options for Coastal Areas*. Climate Ready Estuaries Program. EPA 430-F-08-024. Retrieved from https://www.epa.gov/sites/production/files/2014-04/documents/cre_synthesis_1-09.pdf

University of Rhode Island Environmental Data Center. (n.d.). *Sea Lettuce (Ulva lactuca)* [website]. Retrieved from http://www.edc.uri.edu/restoration/html/gallery/plants/sea.htm

Xenopoulos, M.A., D.M. Lodge, J. Alcamo, M. Marker, K. Schulze, and D.P. van Vuuren. (2005). Scenarios of freshwater fish extinctions from climate change and water withdrawal. *Global Change Biology*. 11:1557-1564. doi:10.1111/j.1365-2486.2005.01008.x

Yarr, K. (2017, August 8). Rare Irish moss threatened, and green crabs suspected. *CBC News*. Retrieved from http://www.cbc.ca/news/canada/prince-edward-island/pei-irish-moss-green-crab-research-1.4238503

7

Biodiversty is the greatest treasure we have. Its diminishment is to be prevented at all cost.

—Thomas Eisner

7 FORESTRY AND BIODIVERSITY SECTOR

7.1 Background

Forests are an important resource. Not only are they a home for plants and animals, they are also a source of timber (e.g., softwood for lumber and hardwood for fuelwood), food (e.g., maple syrup), and medicine (e.g., dwarf ginseng). Forests also act as natural carbon sinks, support socio-economic activities, provide cultural services (e.g., spiritual, educational), conserve biodiversity, control flood and erosion, filter water, regulate climate and atmospheric composition (Bourque and Hassan, 2010), and conserve anadramous fish (i.e., via stream preservation) and other wetland species. In turn, biodiversity supports nature's capacity to deliver these services (e.g., pollination, forest productivity) (Nantel *et al.,* 2014). The diversity of animals, plants, soils, and microbial species impact the function of an ecosystem. Biodiversity loss decreases plant production, diminishes the ecosystem's resistance to environmental disturbances (e.g., drought), and increases variability in soil nitrogen levels, water usage, and pest and disease cycles (Naeem *et al.*, 1999). Biodiversity also contributes to human health. Studies have tied declines in local and regional biodiversity to increasing rates of allergies in adolescents and increasing population of carriers of the West Nile virus and Lyme disease (Nantel *et al.,* 2014).

Across Canada, only 6% of forest land is privately owned; the rest are owned by the federal, provincial, or territorial governments (Natural Resources Canada, n.d.). On Prince Edward Island, however, over 86% of forest land is privately owned by approximately 16,000 individuals and organizations (Dunsky Energy Consulting, 2017). Out of the Island's 1.4 million acres of land, approximately 0.62 million acres of it is forest land (see Figure 7.1). Causes of the decline in the area of forest land include forest harvesting and land clearing for European land settlement, development patterns, and agricultural use. Land clearing created fragmented small woodlots from large contiguous forest (PEI Department of Agriculture and Fisheries [PEI AF], 2013)

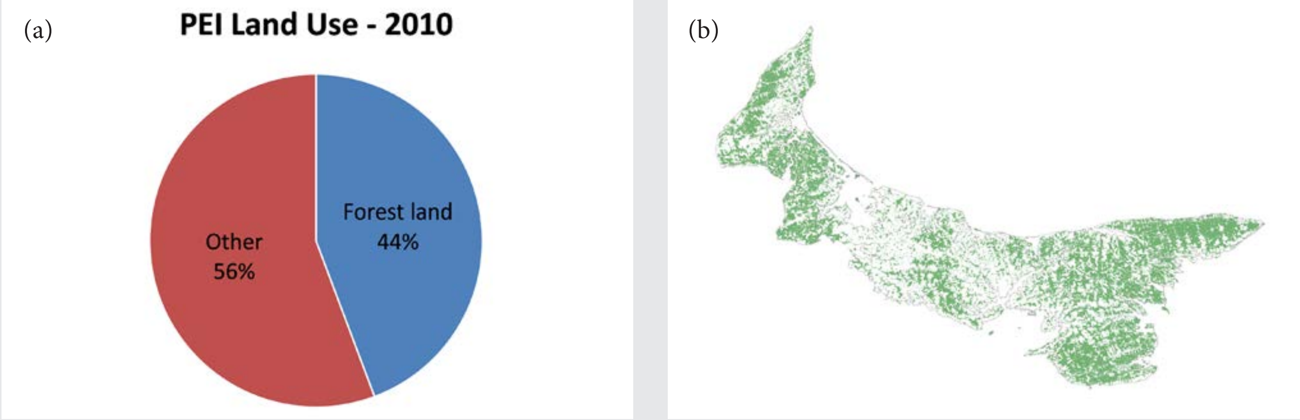


Figure 7.1: (a) Forestry land use in 2010 (Data source: PEI AF, 2013) (b) Distribution of forest land in 2010 (GIS data source: Government of Prince Edward Island, 2010).

PHOTO CREDIT: GOVERNMENT OF PEI

In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion, with the forestry, hunting, trapping, and fishing subsectors contributing $79.2 million or 1.7% (see Figure 7.2)[1]. In March 2017, the forest and fishing subsectors employed approximately 2,500 people, out of 70,200, or 3.6% across all industries in the province (see Figure 7.3). Commercial fishing would constitute the majority of the GDP and employment figures; unfortunately, Statistics Canada does not separate fishing from these categories[2]. In addition, the intrinsic, social, ecological, environmental, etc. value of forestry and biodiversity is not captured in GDP data. Placing an economic valuation of ecosystem services is a relatively new area of study. The Rouge National Urban Park and its surrounding water sheds in the Greater Toronto Area, for example, are expected to contribute $28.2 million per year in pollination services, $17.8 million per year in carbon storage, and $17.1 million per year in wetland habitat (Nantel *et al.*, 2014). In the United States, a study showed that wetlands prevented $625 million in direct flood damages during Hurricane Sandy (Narayan *et al.*, 2017).

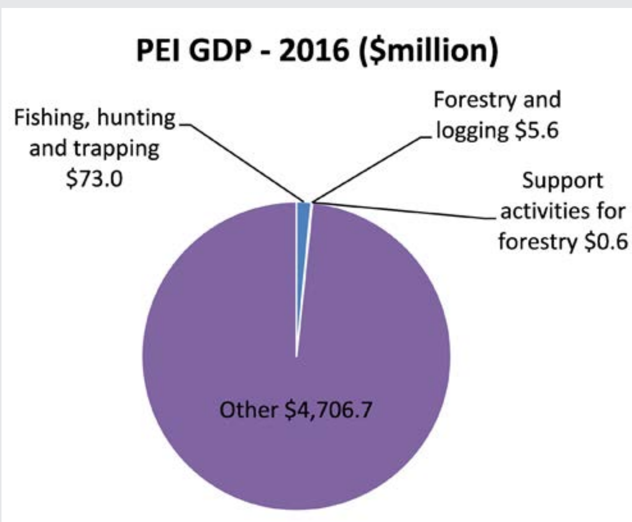


Figure 7.2: Prince Edward Island GDP of forestry, fishing, hunting, and trapping in 2016 (in $million chained 2007 dollars) (Data source: Statistics Canada, 2017b).

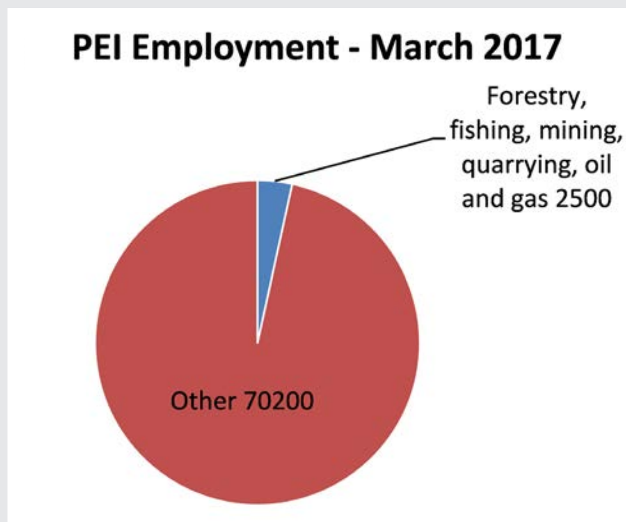


Figure 7.3: Employment in the forestry and wildlife sector in PEI for March 2017 (Data source: Statistics Canada, 2017a).

[1]GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.
[2]Refer to the Fish and Aquaculture Sector chapter for additional details on commercial fishing.

7.2 Climate Change Impacts

Climate change will bring about warmer weather, changes in precipitation patterns, more intense storms, and rising sea levels in Prince Edward Island.

It is critical to note that opportunities and challenges resulting from climate change cannot be taken in isolation. While there are anticipated impacts both positive and negative, the extent of them has not been quantified. For example, the advantages of increased productivity in warmer temperatures could be offset by the impacts of invasive pests and diseases that those temperatures bring.

7.2.1 Temperature

OPPORTUNITIES

First, warmer temperatures could increase forest productivity, lengthen growing seasons (Nantel *et al.*, 2014), add growing degree days for some hardwood species, and expand suitable habitat for others (Bourque and Hassan, 2010).

Second, bird species that currently breed in the northern portion of eastern United States could expand north into Canada, increasing bird species richness (Nantel *et al.*, 2014).

CHALLENGES

First, the suitable range for cold-hard species such as white spruce (see Figure 7.4), balsam fir, and white birch could shift northward in search for cooler temperatures (Bourque and Hassan, 2010; Nantel *et al.*, 2014). The suitable habitats for these species could become fragmented, or contract, causing a decline of the existing population (Nantel *et al.*, 2014). Loss of habitat at stopover sites for migratory birds is a threat to their species (North American Bird Conservation Initiative Canada, 2012)

Second, pests (e.g., bark beetle) and pathogens that are currently limited by winter temperatures will increase in productivity, expanding the range and increasing the severity of diseases and pest outbreaks (Nantel *et al.*, 2014).

Third, lifecycles of some species will be affected, potentially decoupling important ecological relationships. The increase in metabolism of some insects may see their population peak earlier in the season, potentially causing a phenological mismatch to the arrival of migratory birds, affecting hatchling growth and development (Nantel *et al.*, 2014). The change in timing of the spring bloom can affect the successful pollination of plants if pollinators do not arrive at the right time.

Fourth, an earlier start to the growing season could increase frost exposure for plants (Nantel *et al.*, 2014)

Fifth, shorter winter seasons could shorten the winter soil water recharge period (Glen, 2008).

Sixth, higher temperatures increase evapotranspiration, intensifying water stress (NFWPCAP, 2012).

PHOTO CREDIT: GOVERNMENT OF PEI

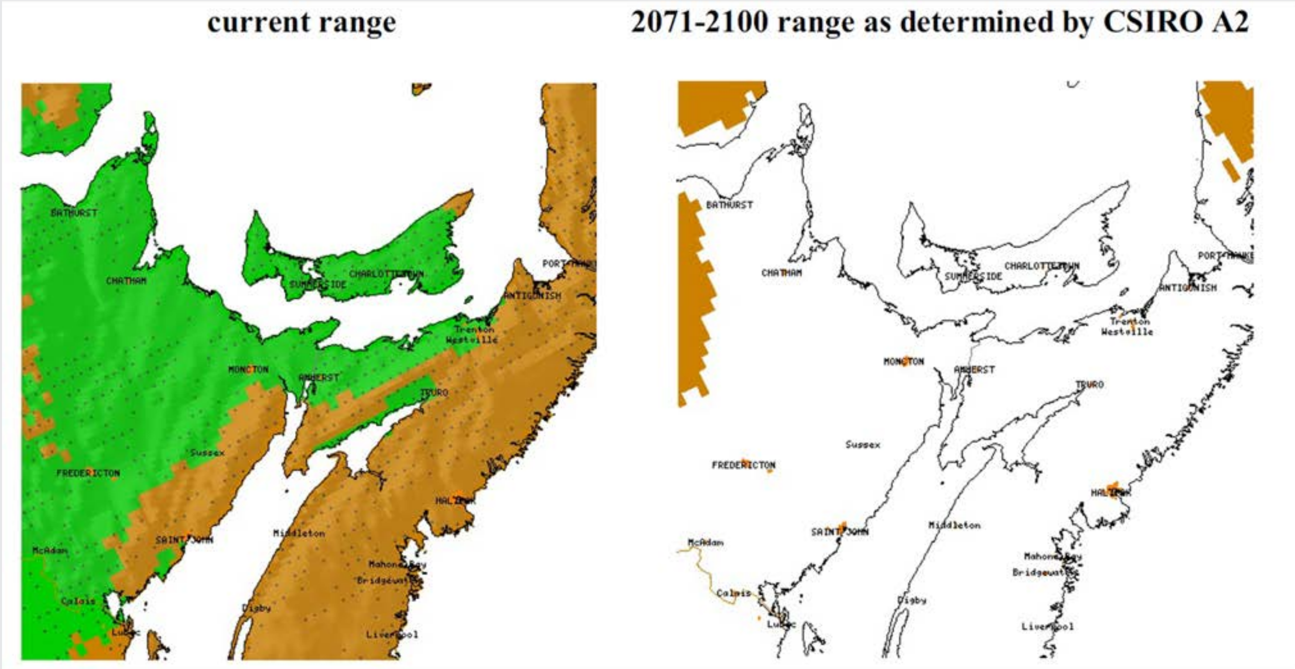


Figure 7.4: The current and potential range of white spruce using the CSIRO model and A2 scenario. Green represents the core range of the species; brown represents the extremes of the range of the species; and white represents areas outside the range of the species (Source: Glen, 2008).

7.2.2 Precipitation

CHALLENGES

First, tree species suited to the future climate of the Island may move here from the south but if local soil properties do not suit (e.g., dryer soils from changing precipitation patterns), assisted tree migration could be unsuccessful.

Second, with an overall decrease in precipitation and number of rain events, drought-like conditions could occur with greater frequency in the future. In turn, this could increase the occurrence of forest fire. Not only do fires kill trees, intense fires can change the soil composition of a forest.

7.2.3 Extreme Weather Events

CHALLENGES

First, the increasing intensity and frequency of extreme weather events such as windstorms and ice storms could increase damage to public forest land and private woodlots (Nantel *et al.*, 2014).

Second, storm surge and coastal flooding could inundate and kill trees.

Third, intense rain storms could cause inundation of trees in areas where the water cannot drain away.

7.2.4 Carbon Dioxide

OPPORTUNITIES

Although the increasing concentrations of atmospheric carbon dioxide is the primary driver of climate change and is responsible for the impacts described above, the carbon dioxide itself can also benefit the productivity of trees. The carbon dioxide accelerates the rates of photosynthesis, raises the efficiency of water use in plants, and may strengthen plant defences against pests and pathogens (Myers *et al.*, 2017).

CHALLENGES

The presence of carbon dioxide can reduce timber strength and may cause nutrient imbalances (Glen, 2008).

7.2.5 Indirect Climate Change Impacts

OPPORTUNITIES

First, the sector could be impacted by regulations put in place to address climate change. For example, mitigation efforts by the Canadian Government include putting a price on carbon pollution in provinces and territories that do not have their own carbon pricing structure. The federal price starts at $10 per metric tonne of greenhouse gas emissions in 2018 and increases by

PHOTO CREDIT: GOVERNMENT OF PEI

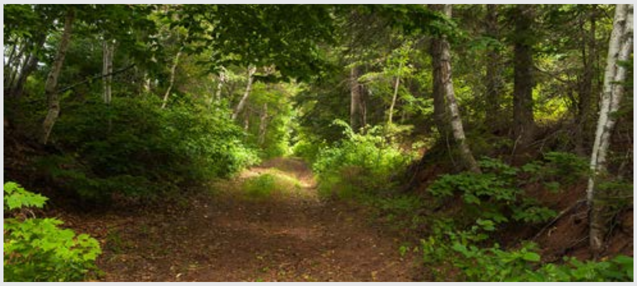


PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: DON JARDINE

$10 per year until 2022 when it reaches $50 per metric tonne (Environment and Climate Change Canada, 2017). This could encourage better forest management as it would give owners financial incentive to sequester more carbon with their lands.

Second, the mitigation efforts describe above could increase the use biomass as a fuel source for heating, since it is considered to be carbon-neutral.

7.2.6 Non-climatic Multipliers

There are two noteworthy characteristics of the sector that multiplies the challenges posed by the climate change impacts discussed above.

AWARENESS

There is a general lack of awareness among the general public of the services that forests and biodiversity provide. As a result, there is less attention paid and fewer resources allocated to the monitoring, research, and reduction of the detrimental impacts caused by climate change in this sector.

FRAGMENTATION

Fragmentation is one of the major non-climatic stressors within the sector. The small fragmented nature of woodlots in Prince Edward Island may cause habitat loss and impede the range expansion by birds, colonization of forest plants, migration of native species to maintain genetic diversity, and adaptation success in some species (Nantel *et al.*, 2014). This problem is most acute in areas of intensive agriculture.

7.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

38 **Form a foundation for evidence-based adaptation planning** by conducting research and collecting data. For example:

- **a.** study precipitation patterns (e.g., number of intense rain events, number of days between rain events);
- **b.** establish a baseline to determine the current state of biodiversity;
- **c.** develop strategies to help wildlife (e.g., terrestrial and avian species) adapt;
- **d.** assess plant and animal species' resilience and ability to disperse;
- **e.** conduct vulnerability assessments under a changing climate for critical species, considering related and keystone species at the ecosystem-scale;
- **f.** collaborate with other groups and experts (e.g., PEI Invasive Species Council) to monitor climate variables, collect and map data on invasive species, and develop a comprehensive invasive species management strategy; and,
- **g.** assess the value of the ecosystem, including the socio-economic and cultural services provided by the sector.

Suggested timeline: Short-term (0 to 5 years)

39 **Keep forests healthy and productive and maintain biodiversity** by reducing non-climatic stressors. This will increase their resilience to climate change. For example:

- **a.** maintain or increase genetic diversity (e.g., seeding or sowing multiple species of native plants) (Nantel *et al.*, 2014);
- **b.** limit overharvesting;
- **c.** create small canopy gaps to promote development of ground cover (Diamond Head Consulting, 2014);
- **d.** reduce pollution (e.g., increase fines and enforce penalties for dumping of waste in natural areas);
- **e.** restore the environment of natural wooded areas. Assess areas where natural recovery is feasible and where intervention (e.g., assisted migration) or human engineering actions are required. Develop strategies and priorities for these areas and ensure they are sustainable under a future climate (e.g., select species with some drought tolerance for seed transfer);
- **f.** review natural areas to identify zones critical for the conservation of biodiversity and regulate activities in those areas. For example, protect migratory routes from harvesting and development;
- **g.** establish a voluntary conservation covenant or easement, which prohibit development on a portion or all of the property or removal of native vegetation, in areas that are sensitive to climate change impacts in exchange for a property tax reduction or credit (Richardson and Otero, 2012). The owner could continue to own the land, live on it, sell it, or pass it on but the covenant would continue regardless. This should be reviewed on a case-by-case basis and entered into only when the preservation of land has measurable benefits (e.g., protect migratory routes); and,
- **h.** promote the use of the municipal power 'tree preservation and protection' among municipalities by increasing awareness of the benefits of regulating activities related to trees.

Suggested timeline: short- to medium-term (0 to 10 years)

PHOTO CREDIT: DON JARDINE

40 **Increase natural connectivity** among natural areas. Isolated habitat patches limit the movement of certain species across the landscape (Diamond Head Consulting, 2014). The reduction of landscape fragmentation facilitates migration, gene flow, and other autonomous adjustments (Nantel *et al.*, 2014). This can be accomplished by preserving large core habitat areas, ensuring connectivity between the habitat areas (e.g., hedgerows), and providing a diversity of habitat features (Diamond Head Consulting, 2014) (see Figure 7.5). Considerations for connecting edge habitats, which are more common across the Island, should be given. Abandoned agricultural areas within the network can be actively restored into wood lots. Types of habitat areas include: forests, parks, wetlands, marine foreshore, oldfields, and agricultural land.
Suggested timeline: medium- to long-term (6+ years)

41 **Increase natural areas** to sustain enough suitable habitats for diverse and healthy populations, particularly where natural connectivity is lacking, biodiversity is under threat, and future species may thrive. For example:

- **a.** encourage biodiversity in the urban environment;
- **b.** increase canopy cover, especially over streams to reduce evaporative loss and promote water recharge;
- **c.** regrow forests on abandoned agricultural fields;
- **d.** select trees that are suitable under the future climate when planting, using the study completed by Glen (2008) for the Prince Edward Island National Park; and,
- **e.** promote the sale of tree saplings as school fundraising activities.

Suggested timeline: medium- to long-term (6+ years)

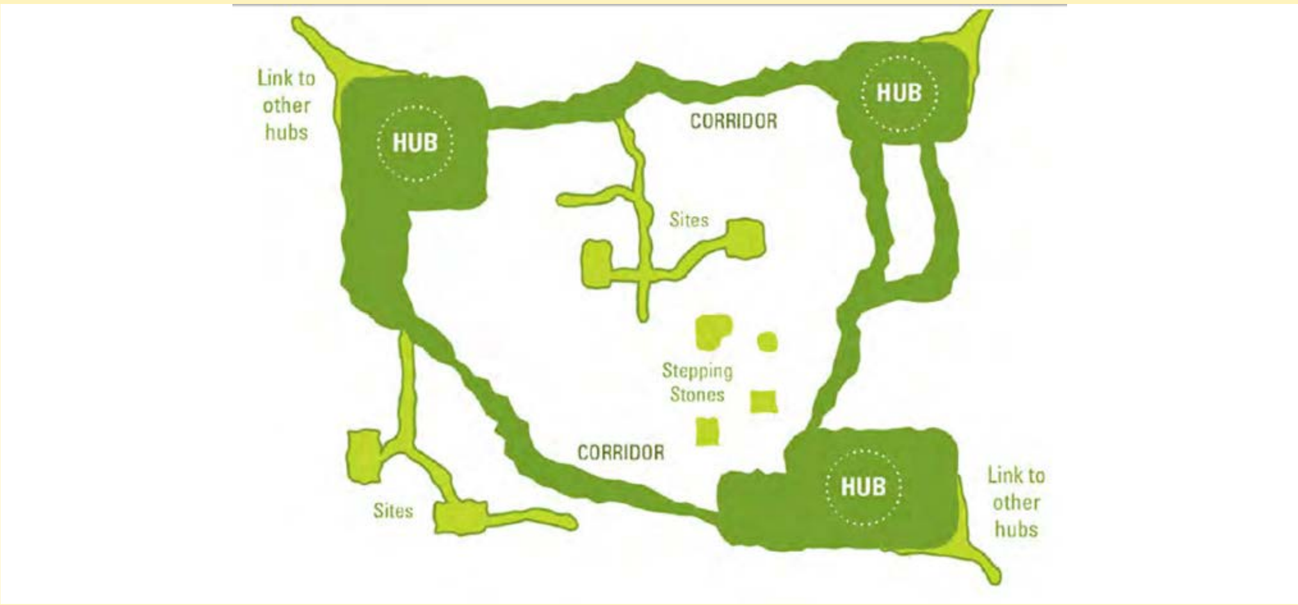


Figure 7.5: Example of a green infrastructure network showing how natural areas can be connected to improve biodiversity (Source: Diamond Head Consulting, 2014).

42 **Promote needed adaptation where existing incentive is lacking** by using regulatory frameworks. Increase compliance with added enforcement efforts and stricter penalties. For example:

- **a.** prevent the draining of wetlands to retain their ability to reduce flooding;
- **b.** limit hedgerow removals, which is important for connectivity and water retention;
- **c.** plan urban sprawl development with connectivity and biodiversity in mind (e.g., developers must submit multi-year forestry plans to maintain or re-establish green spaces and trees, avoid disruption of connectivity among habitats);
- **d.** review the effectiveness and objectives of “cash in lieu” land use planning options;
- **e.** limit cutting in areas (e.g., watersheds) where canopy coverage is low; and,
- **f.** protect and widen the watercourse and wetland buffer zone.

Suggested timeline: short-term (0 to 5 years)

43 **Demonstrate the importance of forestry and biodiversity conservation and enhancement initiatives** by assigning an economic value to the ecosystem services they provide (e.g., pollination and carbon storage services). These benefits and their economic values should be highlighted when generating support for adaptation actions in the sector. This will help ensure that the functions and services provided by the ecosystems will not be taken for granted or be overlooked in decision-making.

Suggested timeline: short-term (0 to 5 years)

44 **Generate additional support for adaptation actions** by engaging in outreach. For example:

- **a.** frame the benefits of forests and biodiversity in ways that resonate with the public (e.g., their impact on public health);
- **b.** develop visitor experience programs at provincial parks that include hands-on activities such as restoration efforts;
- **c.** develop training programs in provincial and municipal departments to raise awareness of new biodiversity objectives and provide opportunities for interdepartmental and intergovernmental cooperation to implement biodiversity initiatives; and,
- **d.** make the public and woodlot owners aware of the adaptation strategies available (e.g., augment the Forest Enhancement Program to incorporate climate change adaptation).

Suggested timeline: short-term (0 to 5 years)

45 **Improve the efficiency and effectiveness of adaptation activities** by connecting with other environmental groups, community groups, and sectors. There are parallels that provide an opportunity to collaborate, cooperate, and share

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: DON JARDINE

resources. For example, habitat restoration by watershed groups under the Fish and Aquaculture sector fits well with prevention of wetland draining under the Forestry and Biodiversity sector and creation of wetlands to improve water quality and quantity under the Water sector. These sectors could combine resources and expertise and work together on wetland restoration and construction.
Suggested timeline: ongoing

46 Collaborate with local Indigenous groups to **incorporate Traditional Ecological Knowledge** (TEK) in designing climate change adaptation actions. This knowledge consists of generations of observations and experiences and its holistic approach could help alter typically linear methods used by Western cultures into complex ecological system management (University of Manitoba Aboriginal Planning Program, n.d.). For example, a talking circle can be used to:

- **a.** discover the observations, concerns, and perspectives of the First Nations;
- **b.** understand how TEK could be applied in maintaining healthy forests and biodiversity; and,
- **c.** discuss what TEK-informed adaptation looks like.

Suggested timeline: short-term (0 to 5 years)

47 **Increase capacity within the Provincial Government** to augment the sustainability of forests and biodiversity. For example, dedicate more staff to outreach efforts, capture institutional knowledge of staff, etc.
Suggested timeline: short- to medium-term (0 to 10 years)

48 **Develop a coordinated approach** to implement the Recommended Adaptation Actions (#38 to #47) for the Forestry and Biodiversity sector. Host ongoing meetings among sector stakeholders (e.g., woodlot owners, land use planners, parkland conservationalists, educators) and conduct onsite demonstrations (e.g., data collection, restoration).
Suggested timeline: Ongoing

The collaboration of woodlot owners, sector (e.g. industry organizations), experts (e.g., climate scientists, biologists, engineers), and governments will be critical in achieving effective adaptation. The table below summarizes the eleven recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

PHOTO CREDIT: DON JARDINE

Table 7.1: Summary of recommended adaptation actions for the forestry and biodiversity sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
38. Form a foundation for evidence-based adaptation planning by conducting research and collecting data (e.g., forecast precipitation patterns, determine current state of biodiversity).	Leads: Sector, Provincial Government Collaborators: Environmental groups, Experts	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years)
39. Keep forests healthy and productive and maintain biodiversity by reducing non-climatic stressors (e.g., reduce pollution, promote development of ground cover).	Leads: Sector, Provincial Government, Woodlot owners Collaborators: Environment groups, Municipal governments	Reduce non-climatic stressors; Increase resilience	Short- to medium-term (0 to 10 years)
40. Increase natural connectivity among natural areas (e.g., preserve core habitat areas, increase hedgerows).	Lead: Provincial Government Collaborators: Sectors, Municipal governments, Public, Environmental groups	Increase resilience	Medium- to long-term (6+ years)
41. Increase natural areas to sustain enough suitable habitats for diverse and healthy populations, particularly where natural connectivity is lacking, biodiversity is under threat, and future species may thrive (e.g., restore abandoned agricultural fields, sell tree saplings as school fundraisers).	Leads: Provincial Government, Environmental groups Collaborators: Public	Increase resilience	Medium- to long-term (6+ years)
42. Promote needed adaptation where existing incentive is lacking by using regulatory frameworks (e.g., widen the watercourse and wetland buffer zone). Increase compliance with added enforcement efforts and stricter penalties.	Lead: Provincial Government Collaborators: Sectors	Leverage regulation; Reduce non-climatic factors	Short-term (0 to 5 years)
43. Demonstrate the importance of forestry and biodiversity conservation and enhancement initiatives by assigning an economic value to the ecosystem services they provide (e.g., pollination and carbon storage services). These benefits and their economic values should be highlighted when generating support for adaptation actions in the sector..	Lead: Provincial Government Collaborators: Experts	Address financial concerns	Short-term (0 to 5 years)
44. Generate additional support for adaptation actions by engaging in outreach (e.g., frame the benefits of forests and biodiversity in ways that resonate with the public).	Lead: Provincial Government Collaborators: Sector, Environmental groups, Experts	Engage in outreach; Increase collaboration; Fill knowledge gaps	Short-term (0 to 5 years)
45. Improve the efficiency and effectiveness of adaptation activities by connecting with other environmental groups, community groups, and sectors (e.g., coordinated habitat restoration for Fish and Aquaculture and Forestry and Biodiversity sectors).	Leads: Environmental groups, Sectors Collaborators: Provincial Government, Experts	Increase collaboration	Ongoing
46. Collaborate with local Indigenous groups to incorporate Traditional Ecological Knowledge.	Lead: Sector, Indigenous groups Collaborators: Provincial Government, Environmental groups	Increase collaboration; Fill knowledge gap	Short-term (0 to 5 years)
47. Increase capacity within the Provincial Government (e.g., dedicate more staff to outreach).	Lead: Provincial Government	Fill knowledge gap; Engage in outreach	Short- to medium-term (0 to 10 years)
48. Develop a coordinated approach to implement the Recommended Adaptation Actions for the sector (#38 to #47) (e.g., stakeholder meetings, onsite demonstrations).	Leads: Provincial Government, Sector / Collaborators: Woodlot owners, Environmental groups, Outreach groups	Increase collaboration; Engage in outreach; Fill knowledge gaps	Ongoing

7.4 Conclusion

Forests and wildlife have autonomous processes to adapt to climatic changes. However, it is uncertain how these processes will affect ecosystem composition, structure and function (Nantel *et al.*, 2014). For some species, the rates of climate change may overwhelm their natural ability to adapt, threatening biodiversity. Given the long generation times of tree species, decisions made today will continue to be felt in the sector for over 100 years (Nantel *et al.*, 2014). It is important to the environment, society and economy that the decision is to act quickly to maintain the sustainability of the sector.

PHOTO CREDIT: DON JARDINE

REFERENCES

Bourque, C.P.A. and Q.K. Hassan. (2010). *Modelled Potential Tree Species Distribution for Current and Projected Future Climate for Prince Edward Island, Canada*. Submitted to Prince Edward Island, Department of Environment, Energy and Forestry. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/climate_change_2010._pei_full_report.pdf

Diamond Head Consulting. (2014, January). *Biodiversity Conservation Strategy*. Retrieved from http://www.surrey.ca/files/Surrey_BCS_Report.pdf

Dunsky Energy Consulting. (2017, March). *Recommendations for the Development of a Climate Change Mitigation Strategy*. Submitted to Prince Edward Island, Department of Communities, Land and Environment. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/pei_climate_change_mitigation_recommendations.pdf

Environment and Climate Change Canada. (2017, June 21). *Pricing Carbon Pollution in Canada: How it will work* [website]. Retrieved from https://www.canada.ca/en/environment-climate-change/news/2017/05/pricing_carbon_pollutionin-canadahowitwillwork.html

Glen, B. (2008). *Climate Change and its Potential Effects on the Trees of the Prince Edward Island National Park*.

Government of Prince Edward Island. (2010). *Corporate Land Use Inventory 2010*.

Myers, S.S., M.R. Smith, S. Guth, C.D. Golden, B. Vaitla, N.D. Mueller, A.D. Dangour, and P. Huybers. (2017, March 20). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*, 20(38), 259-277. doi:10.1146/annurev-publhealth-031816-044356.

Naeem, S., F.S. Chapin III, R. Costanza, P.R. Ehrlich, F.B. Golley, D.U. Hooper, J.H. Lawton, R.V. O'Neill, H.A. Mooney, O.E. Sala, A.J. Symstad, and D. Tilman. (1999). Biodiversity and Ecosystem Functioning: Maintaining Natural Life Support Processes. *Issues in Ecology* (4). Ecological Society of America.

Nantel, P., M.G. Pellatt, K. Keenleyside and P.A. Gray. (2014). *Biodiversity and Protected Areas. In: Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 159-190.

Narayan, S., M.W. Beck, P. Wilson, C.J. Thomas, A. Guerrero, C.C. Shepard, B.G. Reguero, G. Franco, J.C. Ingram, and D. Trespalacios. (2017, August 31). *Scientific Reports 7*. Article number: 9463. doi: 10.1038/s41598-017-09269-z

Natural Resources Canada. (n.d.). *Forest land ownership*. Retrieved from http://www.nrcan.gc.ca/forests/canada/ownership/17495

North American Bird Conservation Initiative Canada. (2012). *The State of Canada's Birds, 2012*. Environment Canada, Ottawa, Canada. 36 pages.

PEI Department of Agriculture and Forestry. (2013). *State of the Forest Report 2010*. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/2010_state_of_the_forest_report.pdf

Richardson, G.R.A. and J. Otero. (2012). *Land use planning tools for local adaptation to climate change*. Ottawa, Ont.: Government of Canada, 38 p.

Statistics Canada (a). (2017, April 6). *Table 282-0088 Labour force survey estimates (LFS), employment by North American Industry Classification System (NAICS), seasonally adjusted and unadjusted*. Retrieved on May 3, 2017

Statistics Canada (b). (2017, April 28). *Table 379-0030 Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories*. Retrieved on May 3, 2017

University of Manitoba Aboriginal Planning Program. (n.d.). *Traditional Ecological Knowledge: Introduction* [website]. Retrieved from http://www.umanitoba.ca/architecture/cp/app/sections/issues/other/tek/index.html

8

Disasters are never natural. They are the intersection of factors other than physical. They are the accumulation of the constant breach of economic, social and environmental thresholds.

—Yeb Sano

8 INSURANCE SECTOR

8.1 Background

Insurance provides a financial safety net by transferring some of the risk of large financial losses associated with unpredictable events such as automobile accidents and natural disasters. The insurance industry in Canada is over 200 years old (Kovacs and Thistlewaite, 2014). The property and auto insurance industry is Canada's most competitive financial industry, with several hundred companies providing coverage (Kovacs and Thisthlewaite, 2014).

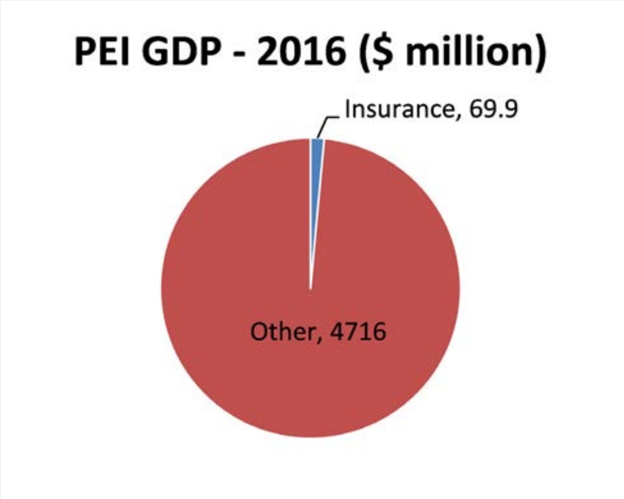


Figure 8.1: Prince Edward Island GDP of the insurance sector in 2016 (in $million chained 2007 dollars) (Data source: Statistics Canada, 2017b).

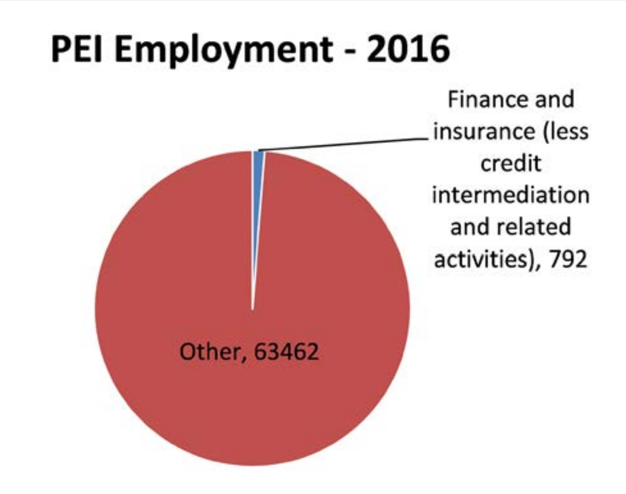


Figure 8.2: Employment in the finance and insurance sector compared to total employment as of January 2017 (Data source: Statistics Canada, 2017a).

In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion, with the insurance sector contributing $70 million or 1.5% (see Figure 8.1)[1]. There were 63,642 equivalent annual full time jobs in 2016 across all industries in Prince Edward Island and the finance and insurance sector provided 792, or 1.2% of those jobs (see Figure 8.2). In 2015, the Island received $20 million in taxes and levees from the property and casualty insurers (Insurance Bureau of Canada [IBC], 2017). The insurers paid approximately $125 million in direct claims in 2015 in Prince Edward Island for damaged home and business repairs, replacement of stolen property, and benefits for motor vehicle collision victims (IBC, 2017). The industry has been active in the promotion of road safety, building code improvements, and coordinated preparation and response to natural disasters (IBC, 2017).

[1]GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

8.1.1 Insurance Coverage for Weather-related Impacts

Currently, the Insurance Bureau of Canada, an industry association representing private home, car, and business insurers across Canada, is advocating the development of a National Flood Strategy. It is important to understand how the sector defines and insures different types of floods (see Table 8.1). Coverage is available for certain types of water damage only, and even then, not all insurance companies offer it.

Table 8.1: Availability of coverage for different types of water damage to buildings in Canada.

Event	Type of Coverage	Availability of Coverage
Water damage to buildings caused by burst pipes and appliances	Home insurance	Usually covered by all homeowner and business insurance policies
Water damage to buildings caused by back up through sewers, floor drains, toilets, and showers	Sewer back up coverage	Most homeowner and business policies do not cover sewer back up unless it is specifically added to the policy
Water damage to buildings caused by water entering through sudden openings caused by wind or hail (e.g., flying debris, falling tree branch)	Home insurance	Most homeowner and business policies cover wind or hail damage
Water damage to buildings caused by seepage of surface water from rain or snowmelt overwhelming drainage systems	Overland flood coverage	Some insurers are offering the coverage but availability varies across Canada
Water damage to buildings caused by seepage of overflow from bodies of (fresh)water such as rivers and dams	Overland water coverage	Some insurers are offering the coverage but availability varies across Canada
Water damage from coastal (saltwater) flooding	N/A	No coverage exists for this type of event in Canada

Flood damage is costly; a 6-inch flood in a 2,000-square-foot home could cause approximately $40,000 in damage (Aviva, n.d.). Canada was the last G8 country to have overland flood coverage made available to homeowners (Thistlewaite and Feltmate, 2013). It was first introduced to the market in 2015 by Aviva; coverage is currently available in all provinces except Quebec (Nadarajah, 2016). Before then, Canadians relied on physical defences, disaster relief programs, and flood plain maps to minimize their risk of flood damage (Thistlewaite and Feltmate, 2013).

Coverage for other climate-related impacts (e.g., coastal flooding, coastal erosion) is unavailable at this time.

8.2 Impacts of Climate Change

Climate change will bring about changes in precipitation patterns, more intense storms, and rising sea levels in Prince Edward Island.

For the insurance sector, it is difficult to separate opportunities and challenges. For insurers providing coverage against events affected by climate change impacts (e.g., inland flooding), there is an opportunity to increase revenue. However, for insurers unable to fully assess the risk of such events and impacts, they are limiting their exposure to financial risks by not offering coverage but could suffer from reputational risk.

8.2.1 Temperature

CHALLENGES

Rising temperatures will result in warmer winters. When winter precipitation occurs in the form of rain, the frozen ground cannot absorb any water so it becomes runoff, causing inland flooding. This was the case in Prince Edward Island in December 2014, when a rain storm cost the province $9 million in damages, mainly from runoff washing out roads and bridges (Wright, 2015). These types of events could become more commonplace.

8.2.2 Extreme Weather Events

CHALLENGES

First, the increasing intensity and frequency of extreme weather events could increase incidents of property damage. Payouts from extreme weather doubled, or more, nationally every five to ten years from 1980s until present (The Co-operators, n.d.).

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: DON JARDINE

As damages from coastal flooding and coastal erosion increase, homeowners and businesses may look to insure against these impacts. However, no such coverage exists. These types of events are not well-suited for the industry, which traditionally provides insurance for high-risk low-frequency events. But as the public and private sector become increasingly concerned about coastal flooding and coastal erosion, reputational risk for insurers who do not offer such coverage may rise.

Second, the likelihood of car accidents could increase as extreme weather events can cause poor visibility and vehicle traction.

8.2.3 Sea Level Rise

CHALLENGES

Rising sea levels will permanently flood coastal properties and infrastructure that have experienced coastal flooding only occasionally in the past. They will also begin to inundate properties and infrastructure that never experienced coastal flooding in the past. Properties that had not been considered as high risk may find insurance coverage increasingly less available and affordable, placing increased stress on property owners and government disaster financial aid programs. Since no product exists for damage caused by coastal flooding, reputation risk for insurers may rise as the public and private sector become increasingly concerned about these impacts.

8.2.4 Unknowns

CHALLENGES

While climate modeling is able to forecast how climate change will impact temperature, precipitation, sea level rise, etc. with high levels of confidence, there are limitations to these models. For example, freezing rain is one of the most difficult events to forecast: it occurs in very narrow bands, usually less than 50 km wide, and a change in temperature as small as tenths of a degree could turn freezing rain into rain, sleet, or snow (University of Illinois, n.d.). Generally speaking, warmer winters are associated with an increased occurrence of freezing rain and black-ice conditions (Rapaport *et al.*, 2017). Freezing rain adds weight to trees and power lines, causing them to break or fall, potentially damaging a nearby car or building. It also creates dangerous operating conditions for vehicles and airplanes, reducing traction/stability.

Overall, the public's reaction to natural disasters such as extreme storm events is reactive, rather than preventive, in nature. In 2011, the reputational risk for insurers increased substantially after policyholders realized they had no coverage for damage from floods in Queensland, Australia (Thistlewaite and Feltmate, 2013). The federal government responded by launching a review of the industry and recommended that insurance contracts include river and creek flooding (Thistlewaite and Feltmate, 2013). A change in public opinion and regulations from increasing climate change impacts could negatively impact unprepared insurers.

8.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

49 **Gather required data to address concerns of risk exposure**. Under a changing climate, there will likely be a growing demand for overland water coverage. Some insurers are hesitant to offer it – reasons include the inability to effectively assess risk. Insurers depend on accurate risk assessments to develop products. However, the lack of coverage could increase reputational risk and result in loss of policyholders should this coverage become regulated. To overcome these challenges, the sector should:

- **a.** collaborate with experts (e.g., climate science, hydrologists) and governments to improve flood risk maps using available data (e.g., LiDAR data) and update them periodically as climate change projections are updated;
- **b.** continue to support mitigation efforts through public awareness and partnerships. For example, IBC supplied 1,000 rain barrels to residents in Stratford, PEI, where extreme weather events have flooded basements and roads;
- **c.** educate consumers on available mitigation actions to minimize risk exposure (e.g., install a back water valve to prevent sewer back up);
- **d.** work with policyholders and communities to access information about risk mitigation activities; and,
- **e.** work with government to balance the need for disaster relief with the need for mitigation. Disaster relief is a reactive measure that is much needed, especially for high risk or uninsurable areas (e.g., floodplains). However, it can create a false sense of security and hamper mitigation efforts. For example, the federal government could use a portion of its disaster relief funds to help individuals relocate from flood risk zones or support adaptation action at the community level.

Suggested timeline: Short-term (0 to 5 years)

50 **Improve public understanding** on the different types of flooding, levels of risk, types of insurance coverage available, and circumstances under which government financial aid is available. A recent national survey of 2,300 homeowners living within a designated flood risk areas showed that 50% expressed no concern about flood risk, 6% were aware they lived within designated flood risk areas, and 21% believed that the risk of flooding will increase over the next quarter-century (Thistlewaite *et al.*, 2017). Another study showed that 70% of Canadian homeowner believed they had full flood coverage (Nadarajah, 2016). Just as importantly, the sector should make clear to policy holders what types of coverage are unavailable (e.g., coastal flooding) and why. Policy language and nuances/specificities in industry terms (e.g., flood coverage versus overland water coverage) make it difficult for policyholders to navigate their policies on their own.
Suggested timeline: ongoing

51 **Look for opportunities to develop new insurance products**. Demand for coverage from other weather-related impacts could arise as damages to homes and businesses become more frequent and severe under a changing climate (e.g., coastal flooding, coverage for saltwater intrusion in drinking wells, wind damage). The sector should identify these prospects by understanding the needs of the general public and reviewing how other jurisdictions have taken advantage of such opportunities. For example, the sector could organize a workshop to bring together climate and coastal scientists and

PHOTO CREDIT: DON JARDINE

insurance companies to discuss what coastal science data is available for coastal flooding so the insurance companies can make an informed decision on the possibility of extending coverage for coastal flooding or coastal erosion.
Suggested timeline: ongoing

52 **Promote adaptation actions**, especially where coverage is limited or unavailable. For example:

- **a.** collaborate with the water sector to share best practices in stormwater management. This would benefit many stakeholders beyond the homeowners (e.g., infrastructure owners). This information, along with mitigation initiatives, should be made public and available at a centralized location (e.g., website);
- **b.** utilize visualization techniques to encourage adaptation (e.g., CoastaL Impacts Visualization Environment);
- **c.** work with governments to develop codes and standards to make communities and properties more resilient to weather extremes;
- **d.** collaborate with the Outreach and Public Safety sectors on effective communication strategies and platforms; and,
- **e.** discourage development in and encourage relocation from areas of high flood risk.

Suggested timeline: Short- to medium-term (0 to 10 years)

The collaboration of the public, insurers, sector (e.g. industry organizations), experts (e.g., climate scientists, engineers), and the government will be critical in achieving effective adaptation. The table below summarizes the four recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

Table 8.2: Summary of recommended adaptation actions for the insurance sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
49. Gather required data to address concerns of risk exposure (e.g., create and update flood risk maps).	Leads: Sector, Insurers Collaborators: Experts, Federal Government	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years)
50. Improve public understanding on the different types of flooding, levels of risk, types of insurance coverage available, and circumstances under which government financial aid is available.	Leads: Sector, Insurers	Engage in outreach	Ongoing
51. Look for opportunities to develop new insurance products (e.g., insure against coastal flooding).	Lead: Sector Collaborators: Insurers, Experts	Fill knowledge gaps; Increase collaboration	Ongoing
52. Promote adaptation actions, especially where insurance coverage is limited or unavailable (e.g., use visualization techniques to inspire adaptation, encourage relocation from areas of high flood risk).	Leads: Sector, All levels of government Collaborators: Other sectors, Experts	Engage in outreach	Short- to medium-term (0 to 10 years)

8.4 Conclusion

It is easy to think of climate change as a slow, gradual process with increases in loss occurring incrementally (Canadian Electricity Association, 2016). However, the recent extreme storm events in Prince Edward Island, including the December 2014 rainstorm, demonstrate that near-record setting events and significant damages could occur at any time. In Prince Edward Island, more than 1 in 10 homes are at risk of river or storm water flooding (IBC, 2017). Therefore, adaptation needs to be implemented as soon as possible. As Islanders brace themselves for climate change impacts, they will increasingly look to the insurance sector and disaster relief programs for help in transferring some of that risk, especially after a major disaster.

REFERENCES

Aviva. (n.d.). *Flood Insurance: Why you need it* [website]. Retrieved from https://www.avivainsurance.ca/blog/why-you-need-flood-insurance

Canadian Electricity Association. (2016). *Adapting to Climate Change: State of Play and Recommendations for the Electricity Sector in Canada.* Retrieved from https://electricity.ca/WP-CONTENT/UPLOADS/2016/02/ADAPTING_TO_CLIMATE_CHANGE-STATE_OF_PLAY_AND_RECOMMENDATIONS_FOR_THE_ELECTRICITY_SECTOR_IN_CANADA.PDF

Insurance Bureau of Canada. (2017, June). *Building a Stronger Prince Edward Island Response to Climate Change.*

Kovacs, P. and J. Thistlethwaite. (2014). Industry. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 135-158.

Nadarajah, I. (2016, March). Flood Insurance in Canada. *Advantage Monthly*. Retrieved from http://www.insuranceinstitute.ca/en/cipsociety/information-services/advantage-monthly/0316-flood-insurance

Rapaport, E., S. Starkman and W. Towns. (2017). Atlantic Canada. In: *Climate Risks and Adaptation Practices for the Canadian Transportation Sector 2016,* (eds.) K. Palko and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 218-262.

Statistics Canada (a). (2017, March 30). *Table 281-0024 –Survey of Employment, Payrolls and Hours (SEPH), employment by type of employee and detailed North American Industry Classification System (NAICS).* Retrieved on May 4, 2017.

Statistics Canada (b). (2017, April 28). *Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories.* Retrieved on May 4, 2017.

The Co-operators. (n.d.). *Extreme weather in Canada is getting wilder every year* [website]. Retrieved from https://water.cooperators.ca/en/extreme-weather-in-canada.aspx

Thistlewaite, J. and B. Feltmate. (2013, September). *Assessing the Viability of Flood Insurance in Canada*. Retrieved from https://www.cooperators.ca/en/en/-/media/Cooperators-Media/Section-Media/AboutUs/Sustainability/Assessing-the-Viability-of-Flood-Insurance-in-Canada---Eng.pdf

Thistlewaite, J., D. Henstra, S. Peddle, and D. Scott. (2017, April). *Canadian Voices on Changing Flood Risk: Findings from a National Survey.* Retrieved from https://uwaterloo.ca/partners-for-action/sites/ca.partners-for-action/files/uploads/files/canadian_voices_on_changing_flood_risk_fnl.pdf

University of Illinois. (n.d.). *Forecasting Freezing Rain* [website]. Retrieved from http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/prcp/zr/fcst/fcst.rxml

Wright, T. (2015, January 30). December rainstorm caused $9 million in damages for Prince Edward Island. *The Guardian*. Retrieved from http://www.theguardian.pe.ca/news/local/2015/1/30/december-rainstorm-caused-9-million-in-4025578.html

9

Climate change increasingly poses one of the biggest long-term threats to investments.

—Christiana Figueres

9 PROPERTIES AND INFRASTRUCTURE

9.1 Background

Infrastructure systems are indispensable, supporting a wide range of social, economic, and environmental goals. They provide access to essential services, facilitate trade, deliver clean drinking water and prevent contaminants from polluting the environment[1], distribute power to homes and businesses[2], and shelter Islanders from the elements. In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion, with the construction and transportation industries contributing $346 million or 7.8% (see Figure 9.1)[3]. Of the 63,462 jobs in PEI over 2016, 6.5% or 4,128 of them were from the construction and truck transportation industries (see Figure 9.2).

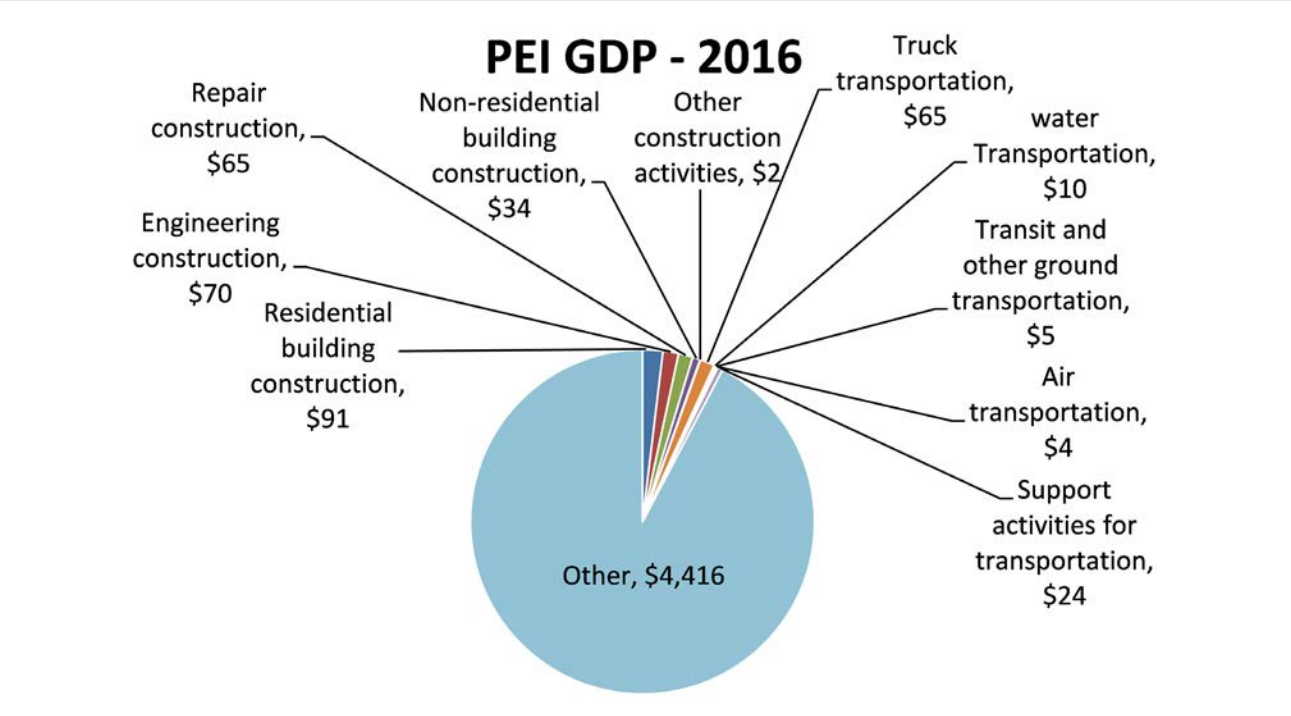


Figure 9.1: Prince Edward Island GDP of construction and transportation activities in 2016 (in $million chained 2007 dollars). (Source: Statistics Canada, 2017b)

1 Refer to the Water Sector chapter for information on water, stormwater, and waste water assets and infrastructure.
2 Refer to the Energy Sector chapter for information on energy assets and infrastructure.
3 GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

PHOTO CREDIT: DON JARDINE

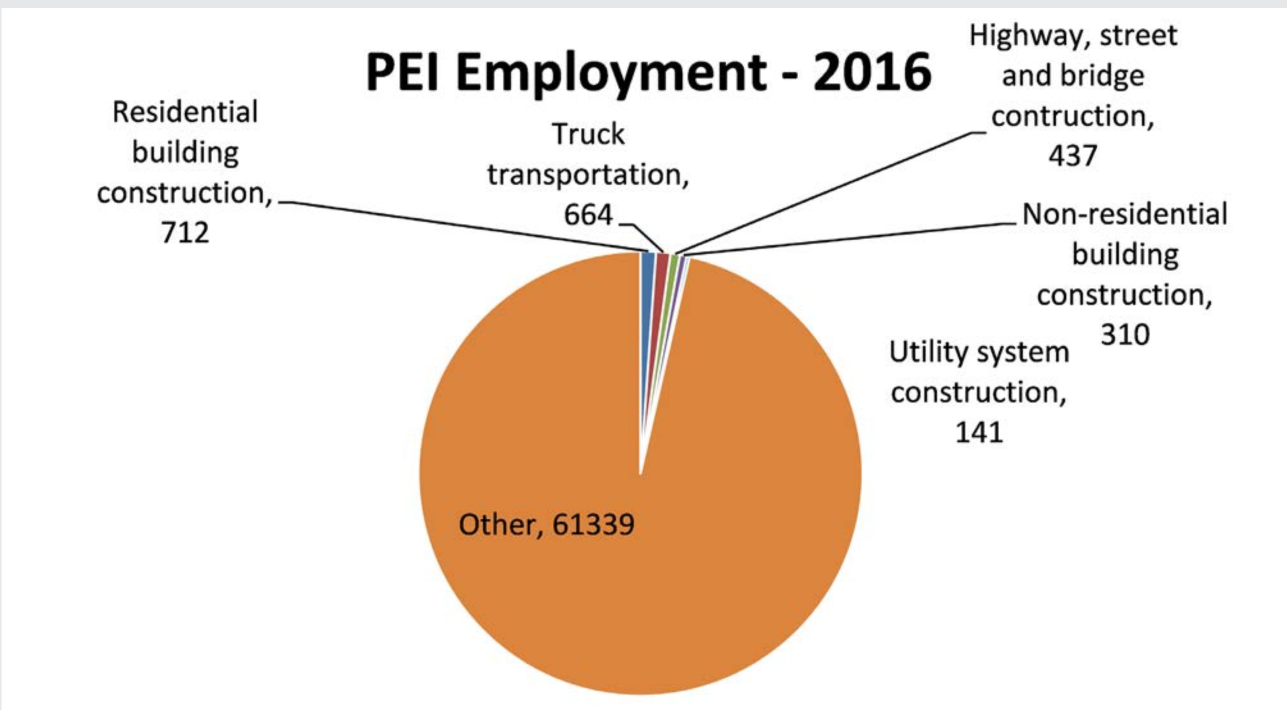


Figure 9.2: Employment in the construction and truck transportation industries compared to total employment in 2016 (Data source: Statistics Canada, 2017a).

9.1.1 Infrastructure

All levels of government, along with the private sector, have a role to play in overseeing and managing assets and infrastructure in a safe, sustainable, and efficient way. For example, the Federal Government's responsibilities include small craft harbours and international and interprovincial transportation (e.g., aviation, marine); the Provincial Government's responsibilities include transportation within the province (e.g., highways, roads); the municipal governments' responsibilities include urban transportation (e.g., transit, local roads); and the private sector act as owners, operators, and managers of various infrastructure and assets (e.g., public and private buildings, energy infrastructure, vehicles, sea vessels, aircrafts) (Andrey and Palko, 2017).

9.1.2 Properties

The majority of land on Prince Edward Island, 88%, is privately owned; the remainder is publicly-owned and managed by the province for the benefit of all Islanders (PEI Department of Communities, Land and Environment, 2015). Public and private buildings and properties will contribute approximately $123.4 million in real property tax and real property transfer tax to the 2017-18 provincial budget (PEI Department of Finance, n.d.).

Within Prince Edward Island, no property is over 16 km from the sea (Rapaport *et al.*, 2017). Over a third of all civic addresses are located in the coastal area (i.e., within 500 m of the coast) and these properties and buildings account for almost half of the total property assessments across the Island (J. Harper, personal communication, August 16, 2017).

PHOTO CREDIT: DON JARDINE

9.2 Climate Change Impacts

Climate change will bring about warmer weather, changes in precipitation patterns, more intense storms, and rising sea levels in Prince Edward Island.

It is critical to note that opportunities and challenges resulting from climate change cannot be taken in isolation. While there are anticipated impacts both positive and negative, the extent of them has not been quantified. For example, the advantages of reduced winter maintenance from warmer temperatures could be offset by the increased damages from the rising sea levels that those temperatures bring.

9.2.1 Temperature

OPPORTUNITIES

First, less salt may be needed to be spread on the road network (Toplis, 2015). This would lead to a reduction of operating costs and corrosion of vehicles and highway assets.

Second, warmer temperatures would also extend the construction season, allowing for additional time for the outdoor maintenance and construction of assets and infrastructure.

CHALLENGES

First, warmer temperatures will lead to less sea ice, which often acts as a buffer between coastal impacts and properties and infrastructure built within the coastal area. The loss of sea ice can lead to increased rates of coastal erosion, sedimentation along marine infrastructure, and incidents of storm surge flooding of coastal properties and infrastructure during the winter months.

Second, warmer winters could lead to more rain events when the ground is still frozen. This was the case in December 2014 when water from an intense rain event could not be fully absorbed by the frozen ground and overwhelmed stormwater management infrastructure. The runoff flooded and washed out roads and bridges.

PHOTO CREDIT: DON JARDINE

9.2.2 Extreme Weather Events

CHALLENGES

First, periods of intense precipitation can cause severe damage to properties, buildings, and infrastructure via flooding, erosion, washouts, and scouring. During an extreme rain event, the ground cannot absorb the water quickly enough and stormwater management systems may not have the capacity to cope. As a result, the excess water, or runoff, can cause gully erosion as it flows over land (see Figure 9.3); create depressions and weak embankments of roads (Palko, 2017); cause slope failure; wash out roads and bridges; and flood buildings and infrastructure. For example, the 2014 December rain storm brought 156 mm of rain in Foxley River within 24 hours, close to the record amount for the Island (Wright, 2015). The intense rain event washed out bridges and roads, causing millions of dollars in damage (Wright, 2015). Extreme snowfall can also cause damage to buildings that were not designed to handle the increased snow loads. As the severity of extreme weather events continues to intensify and sea levels continue to rise, barrier islands will eventually be breached or overwhelmed, leaving properties and infrastructure behind the barrier islands more vulnerable to wave action.

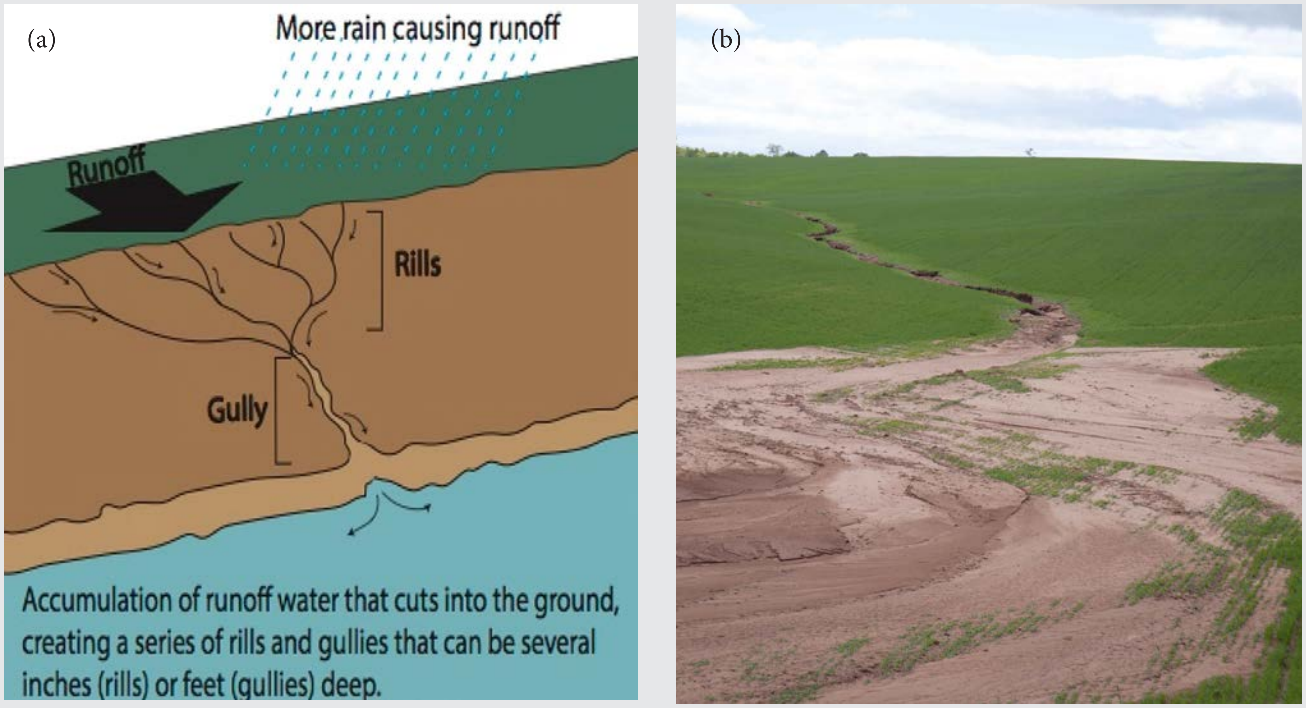


Figure 9.3: (a) Demonstrating how runoff water from rain causes gully erosion (Source: van Proosdij et al., 2016) (b) Evidence of gully erosion in PEI (Photo credit: Don Jardine – with permission).

Second, periods of intense precipitation could disrupt infrastructure from an operational point of view via reduced visibility and vehicle traction. This can create dangerous driving conditions, causing closures of the road network and flight delays (Palko, 2017). This has significant impacts on other sectors. For example, many dairy farmers had to discard milk collected from their herds because trucks could not travel on unplowed roads after a blizzard in February 2015 brought close to 90 cm of snow (CBC News, 2015).

Third, the energy from storm surge and waterflow associated with extreme storm events could lead to bridge scour, damage of causeways and port facilities, coastal erosion, and flooding of buildings and infrastructure. Rates of coastal erosion are expected to increase as storm intensity increases and sea levels rise.

Fourth, wave action from extreme storm events could disrupt transportation from an operational point of view, such as vessel navigation hazards for boats and ferries.

Fifth, high winds from extreme storm events could damage homes, buildings, road structures (e.g., signage and traffic signals), create obstructions (e.g., fallen trees), cause bridge closures and flight delays, and reduce vehicle traction.

9.2.3 Sea Level Rise

CHALLENGES

First, rising sea levels will permanently flood coastal properties and infrastructure that have experienced coastal flooding only occasionally in the past. They will also begin to inundate properties and infrastructure with increasing frequency, affecting some that never experienced coastal flooding in the past.

Second, combined with stronger storm surges, damage caused by coastal erosion will increase as the reach of coastal erosion extends further inland at a more rapid rate than it has in the past. For example, the average erosion rate for the Island increased from 28 cm per year between 1968 and 2010, to 40 cm per year between 2000 and 2010 (Rapaport *et al.*, 2017). For the north shore of Prince Edward Island, it has been projected that almost 10% of coastal properties present in 2001 could be lost within 20 years, increasing to almost 50% by the end of the century (Shaw and CCAF, 2001).

9.2.4 Indirect Climate Change Impacts

CHALLENGES

There are indirect climate change impacts that will affect the sector. As climate change impacts become increasingly felt, there will be a push for more climate resilient buildings and infrastructure – by either customer demand, regulatory pressure, or financial liability (e.g., more stringent lending conditions) (Kovacs and Thistlewaite, 2014). Builders, asset owners and asset managers must be prepared to adapt.

PHOTO CREDIT: DON JARDINE

9.2.5 Unknowns

While climate modeling is able to forecast how climate change will impact temperature, precipitation, sea level rise, etc. with high levels of confidence, there are limitations to these models. For example, impacts on freeze-thaw cycles and freezing rain are more difficult to predict. Nevertheless, it is important to be aware of the associated impacts should these events occur more frequently under a changing climate.

Generally speaking, freeze-thaw cycles are expected to occur more often throughout most of the Atlantic region over the short term, then decline over the long term as winter temperatures rise (Boyle *et al.*, 2013). Freeze-thaw cycles pose risks to the stability of aviation runways (Rapaport *et al.*, 2017); change the timing of spring weight restrictions on roadways; and damage pavement on roads, bridges, and overpasses via deformation, shearing, cracking, and rutting (United States Environmental Protection Agency, n.d.; Palko, 2017).

Freezing rain is one of the most difficult events to forecast: it occurs in very narrow bands, usually less than 50 km wide, and a change in temperature as small as tenths of a degree could turn freezing rain into rain, sleet, or snow (University of Illinois, n.d.). Generally speaking, warmer winters are associated with an increased occurrence of freezing rain and black-ice conditions (Rapaport *et al.*, 2017). Freezing rain adds weight to road structures (e.g., signage and traffic signals), trees, and power lines, causing them to break or fall. It also reduces vehicle traction, creating dangerous operating conditions for cars, trucks, and airplanes.

PHOTO CREDIT: DON JARDINE

9.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

53 **Relocate, retrofit, and/or protect properties and infrastructure** vulnerable to climate change impacts. For example:

- **a.** conduct infrastructure risk assessments to determine the level of vulnerability, if any, of properties and infrastructure to climate change impacts such as coastal erosion, coastal flooding, inland flooding, etc. (e.g., the provincial and municipal governments could create an inventory of all culverts with information such as sizing, current condition, age, traffic intensity; calculate the correct sizing of each one based on an agreed upon future climate scenario; and complete a vulnerability assessment on each one so they could be prioritized based on need and act quickly when there are funds available);
- **b.** relocate, where possible and appropriate, properties and infrastructure located in areas at risk of flooding and/or erosion now or within their lifetime. It may be a higher cost approach but for properties and infrastructure with a long lifespan, it is the most sustainable and long-lasting option, generating more cost-benefit advantages over time;
- **c.** retrofit (e.g., flood proof basements, upsize culverts, install rain gardens[4]) properties and infrastructure at risk or flooding and/or erosion, where relocation from risk zones is inappropriate or impossible; and,
- **d.** protect (e.g., elevate, armour) properties and infrastructure at risk of flooding and/or erosion using hard and/or soft measures, where relocation from risk zones is inappropriate or impossible. Choose a design beyond the current 1-in-100 year events since those will become more severe over the lifetime of the infrastructure (e.g., 1-in-200, 1-in-1000, etc.). Take into account factors such as sea level rise, storm heights, and wind speed under a changing climate.

Suggested timeline: ongoing

54 **Address budgetary constraints through financial planning.** The up-front costs of adaptation are often a barrier to implementing adaptation actions but this could be partly addressed through improved financial planning.[5] This approach applies to individuals, businesses, sectors, and governments. For example, when an individual purchases a home, the age and condition of the roof is often part of the home inspection and factored in the purchase price. The repair and replacement of the roof is an accepted aspect of homeownership. The roof is generally replaced before it deteriorates to a point that rain leaks through. Similarly, asset and infrastructure owners and managers need to consider the costs and timing of adaptation actions in relation to the costs associated with the increase in damage liability, increase in maintenance, shorter lifespan, etc. While implementing adaptation actions incur an upfront cost, it can save a considerable amount of money over the lifetime of assets and infrastructure, often resulting in a net positive financial position overall. For example, the province and municipalities should create an inventory of all roads and bridges within the coastal area with information such as usage, age, type, current condition, availability of alternate routes; determine the cost of different adaptation actions such as abandonment, repair as required, relocation, and upgrade/replacement; perform a cost-benefit analysis for each action; and prioritize adaptation actions. This would allow them to make planning decisions and act quickly when there are funds available.

Suggested timeline: ongoing

---

4 Stormwater management plays an important role in climate change adaptation. Refer to the Water Sector chapter for more details

5 Insurance plays an important role in climate change adaptation. Refer to the Insurance Sector chapter for more details.

55 **Make available erosion and coastal and inland flood risk maps accessible** to all asset owners (e.g., private sector, municipalities, the public) so they can:

- **a.** identify when and how critical assets and infrastructure (e.g., hospitals, major roads, fire stations, waste disposal sites, water and energy infrastructure, homes) will be impacted;
- **b.** determine if the asset should be relocated, retrofitted, protected, or replaced;
- **c.** understand the level of flood and erosion risks before purchasing a property;
- **d.** determine if adaptation actions are required immediately or if they can wait until the next planned upgrade; and
- **e.** prioritize the adaptation actions.

Suggested timeline: ongoing

56 **Set a future climate scenario to establish design standards** based on the expected lifespan of the infrastructure when building, upgrading, or retrofitting assets and infrastructure. A design beyond the current 1-in-100 year events should be chosen since those will become more severe over the lifetime of the infrastructure (e.g., choose 1-in-200, 1-in-1000, etc.). For example, should roads be built to withstand 1-in-200 year or 1-in-500 year rain events? Should they consider these events under the current, 2050, or 2100 time frame? Should the roads be set back from the coast based on 30, 60, or 90 times the historic annual rates of erosion? Asset owners and managers need to choose a future climate scenario and apply it consistently across the system. Since infrastructure is interconnected, weak links created by an inconsistent (i.e., lower) standard will reduce the resilience of the entire network.
Suggested timeline: short-term (0 to 5 years)

57 **Update coastal erosion rates continuously** to inform horizontal setbacks (i.e., 60 times the annual rate of erosion or 75 feet from the coastline, whichever is greater). Given that erosion rates are expected to accelerate, updated rates are critical in protecting properties, infrastructure, and Islanders.
Suggested timeline: ongoing

PHOTO CREDIT: GOVERNMENT OF PEI

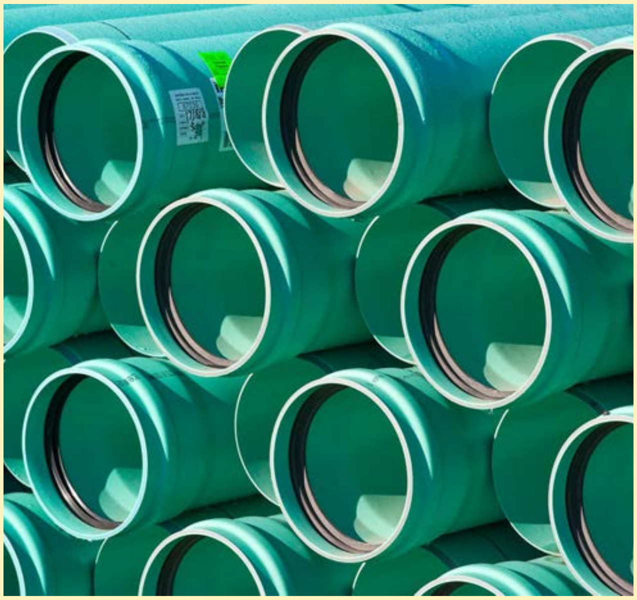


PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: DON JARDINE

58 **Incorporate future climate considerations into land use and building regulations**. Land use planning policies and regulations (e.g., zoning, setbacks, permits) can prompt the development of climate-resilient buildings and infrastructure where incentive for preventive action is not strong enough. The Provincial Land Use Planning Act and Regulations and the Municipal Official Plans and Bylaws should be update to:

- **a.** ensure consistency between the Provincial Land Use Planning Act and Regulations and the Municipal Official Plan and Bylaws;
- **b.** incorporate climate change adaptation in all Municipal Official Plans;
- **c.** set a future climate scenario standard (see Recommended Adaptation Action #56);
- **d.** maintain current projections of climate change impacts (e.g., update flood and erosion risk maps when orthoimagery and LiDAR data for the Island is collected) for use when processing development and subdivision permit applications;
- **e.** establish a vertical setback of 2 metres above higher high water large tide (HHWLT) for habitable space and services on new developments with HHWLT being the average of the past 10 years of high tide elevations for an area;
- **f.** eliminate grandfathered lots where development do not meet all applicable setbacks;
- **g.** build flexibility into minimum provincial standards to cope with a changing climate (e.g., review and update horizontal and vertical setbacks when flood and erosion risk maps are updated);
- **h.** adapt regulations to suit local conditions, where possible (e.g., use site-specific flood and erosion risk maps);
- **i.** identify/re-designate different types of high risk zones with different regulations for each (e.g., no basements allowed in flood prone areas, no development allowed in erosion prone areas). For example, the Council of Beaubassin-est, NB (population 6,200) passed a bylaw in 2011 that identifies a "protection zone" associated with sea level rise, in which the minimum ground floor elevation of new buildings must be at least 1.43 metres above the current 1-in-100 year flood mark (Richardson and Otero, 2012). This new protection zone is an overlay zone, where all previous zoning conditions (e.g., building height restrictions) still apply (Richardson and Otero, 2012);
- **j.** recommend dual access to properties for emergency management purposes;
- **k.** expand setbacks to include servicing (e.g., septic tanks);
- **l.** require additional information during the development permit process to ensure the asset/infrastructure owner has considered climate change impacts and met the future climate scenario standard (e.g., lot drainage plans, survey plans);
- **m.** require an environmental impacts assessment on developments within the coastal area;

n. increase inspections to ensure compliance (e.g., activities and development within the watercourse and wetland buffer zone) and impose higher fees and stricter penalties for non-compliance;

o. establish a voluntary conservation covenant or easement, which prohibit development on a portion or all of the property or removal of native vegetation, in areas that are sensitive to climate change impacts in exchange for a property tax reduction or credit (Richardson and Otero, 2012). The owner could continue to own the land, live on it, sell it, or pass it on but the covenant would continue regardless. This should be reviewed on a case-by-case basis and entered into only when the preservation of land has measurable benefits (e.g., improve climate resilience); and,

p. property owners and developers may be resistant to new regulations. However, they should be made aware that by preventing development in at-risk areas, the regulations are helping to keep assets, infrastructure, people, and the environment safe from climate impacts, creating a net-positive effect in the long run.

Suggested timeline: short-term (0 to 5 years); ongoing maintenance

PHOTO CREDIT: DON JARDINE

59 **Develop guidelines on shore stabilization and flood mitigation techniques** as part of a comprehensive shoreline plan. Consider the effectiveness, cost, longevity, effects on neighbouring properties and the environment (e.g., hard engineered structures could adversely affect wetlands by preventing sediment transport), etc. of each technique.
Suggested timeline: short-term (0 to 5 years)

60 **Explore the issue of liability** surrounding developments and real estate transactions within flooding and erosion risk zones. For example, consult with the sector, industry associations, and experts to understand the legalities and ethics of knowingly building or selling properties within risk zones.
Suggested timeline: short-term (0 to 5 years)

61 **Utilize complementary green infrastructure** when upgrading or designing stormwater management systems. Traditional upgrades of existing equipment and infrastructure are costly but increasingly intense precipitation events leave infrastructure owners/managers with little choice. Studies show that green infrastructure is more cost-effective and less

energy intensive than traditional stormwater management infrastructure (Morand *et al.*, 2015). For example, green roofs (see Figure 9.5) have been successfully used in Basel, Switzerland and New York City, USA. Basel is a town of 195,000 people and has more than 1.2 million square meters of rooftops covered with vegetation as of 2014 (Morand *et al.*, 2015). This adaptation action was driven by the desire to reduce energy costs (green roofs provide added insulation value to buildings) and climate change mitigation but added benefits include stormwater management, local ambient air temperature moderation, increased property values, and public health improvement (Morand *et al.*, 2015). Rain gardens and wetlands are other examples of stormwater management techniques.[6]
Suggested timeline: medium- to long-term (6+ years)

Figure 9.4: Green roof in Charlottetown, PE (Image source: Atlantic Green Contractors - with permission).

PHOTO CREDIT: DON JARDINE

6 These (plus others) are explored further in the Water Sector chapter.

62 **Encourage a bottom-up approach** by making property and infrastructure owners and managers aware of projected climate change impacts, adaptation actions available to them, and how those actions should be implemented. Currently, builders and contractors may not have the necessary knowledge or experience to implement adaptation actions (e.g, armouring coastline, installing green roofs). This would likely change with increasing demand from property and infrastructure owners. Combined with a lag in regulations and policies such as the building code and land use planning, it highlights the need to:

- **a.** increase awareness of climate change impacts;
- **b.** make public and widely available information on the hazards anticipated under future climate (e.g., flood and erosion risk maps);
- **c.** address any gaps in information (e.g., culvert sizing tool/resource for homeowners and contractors);
- **d.** leverage the knowledge of experts that already incorporate climate change in their work (e.g., planners, designers, architects);
- **e.** make public and widely available guidance on adaptation actions to manage different climate change impacts (e.g., best practices for protection from shoreline erosion); and,
- **f.** demonstrate the application of adaptation actions by constructing a demonstration building that incorporates climate resilient design strategies (e.g., green roof, proper building setbacks, extended overhang to protect windows and doors from heavy rain, flood resilient materials such as plastic doors and ceramic tiles in the basement) and landscape design techniques to cope with erosion and coastal flooding (e.g., redirecting water to prevent gully erosion, using living shorelines techniques to reduce erosion). The project could involve students from UPEI Climate Lab, UPEI School of Sustainable Engineering Design, Holland College Environmental Applied Science Technology, and Apprenticeship programs in the design, construction, and maintenance phases. Exhibits with information for the public will be available on site. This demonstration site can incorporate adaptation actions from other sectors as well (e.g., solar energy panels and electricity storage). An interactive display featuring the CoastaL Impact Visualization Environment (CLIVE) could help raise awareness among the public on future coastal flooding and erosion risks.

Suggested timeline: short-term (0 to 5 years)

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

63 **Provide a forum** (e.g., website, Facebook group, monthly workshops, and community schools) for asset and infrastructure owners and managers (e.g., communities, homeowners) to learn and share best practices. For example, clear snow and overgrown vegetation from ditches prior to an intense rain event to prevent flooding; design roads so they are perpendicular to the coast; choose appropriate vegetation for rain gardens that can withstand Island climate; and utilize combination ploughing and salting/sanding vehicles to better react to freezing rain conditions (Langis, 2013).
Suggested timeline: ongoing

The collaboration of property and infrastructure owners, sector (e.g. industry organizations), experts (e.g., climate scientists, engineers), and governments will be critical in achieving effective adaptation. The table below summarizes the eleven recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

PHOTO CREDIT: DON JARDINE

Table 9.1: Summary of recommended adaptation actions for the properties and infrastructure sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
53. Relocate, retrofit, and/or protect properties and infrastructure vulnerable to climate change impacts (e.g., move infrastructure located in areas vulnerable to erosion, flood proof homes located in flood risk zones).	Leads: Property and infrastructure owners (e.g., individuals, businesses, governments) Collaborators: Experts	Increase resilience	Ongoing
54. Address budgetary constraints through financial planning (e.g., create an inventory of roads and bridges within the coastal zone area and perform a cost-benefit analysis to prioritize adaptation).	Leads: Property and infrastructure owners	Address financial concerns; Promote climate change mainstreaming	Ongoing
55. Make available erosion and coastal and inland flood risk maps accessible to all asset owners.	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Ongoing
56. Set a future climate scenario to establish design standards (e.g., should roads be built to withstand 1-in-50 year or 1-in-100 year rain events and are the events taking place in 2020, 2050 or 2100?)	Lead: Provincial Government Collaborators: Experts	Promote climate change mainstreaming	Short-term (0 to 5 years)
57. Update coastal erosion rates continuously to inform horizontal setbacks (i.e., 60 times the annual rate of erosion or 75 feet from the coastline, whichever is greater). Given that erosion rates are expected to accelerate, updated rates are critical in protecting buildings and Islanders.	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Ongoing
58. Incorporate future climate considerations into land use and building regulations (e.g., increase horizontal and vertical setbacks, require additional information during the development permit process).	Leads: Provincial and municipal governments Collaborators: Other sectors, Experts	Leverage regulation; Promote climate change mainstreaming	Short-term (0 to 5 years); Ongoing maintenance
59. Develop guidelines on shore stabilization and flood mitigation techniques as part of a comprehensive shoreline plan.	Lead: Provincial Government Collaborators: Experts, Public	Fill knowledge gaps	Short-term (0 to 5 years)
60. Explore the issue of liability surrounding developments and real estate transactions within flooding and erosion risk zones.	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
61. Utilize complementary green infrastructure when upgrading or designing stormwater management systems (e.g., rain gardens).	Leads: Stormwater management system managers and owners, Property owners Collaborators: Experts, Other sectors	Increase resilience	Medium- to long-term (6+ years)
62. Encourage a bottom-up approach by making property and infrastructure owners and managers aware of projected climate change impacts, adaptation actions available to them, and how those actions should be implemented.	Lead: Provincial Government Collaborators: Educators, Other sectors	Engage in outreach; Fill knowledge gaps	Short-term (0 to 5 years)
63. Provide a forum for asset and infrastructure owners and managers to learn and share best practices.	Lead: Provincial Government Collaborators: Municipal governments, Sector, Public	Fill knowledge gaps; Engage in outreach; Increase collaboration	Ongoing

9.4 Conclusion

Properties and infrastructure have always been vulnerable to damage and disruptions caused by weather events; the risks will be amplified under a changing climate. The cost to maintain existing infrastructure will increase and the effectiveness and lifespan of the built environment will be shortened. Given their long-term nature and critical role in the society and economy, it is important to be proactive in protecting Island assets and infrastructure from the known and unknown impacts that climate change will inevitably bring.

PHOTO CREDIT: DON JARDINE

REFERENCES

Andrey, J., and K, Palko. (2017). Introduction. In: *Climate risks and adaptation practices for the Canadian transportation sector 2016,* (eds.) K. Palko and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 2-10.

Boyle, J., M.Cunningham, and J. Dekens. (2013, November). *Climate Change Adaptation and Canadian Infrastructure: A review of the literature*. Retrieved from http://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf

CBC News. (2015, February 18). *Dairy farms dump milk because roads snow clogged*. Retrieved from http://www.cbc.ca/news/canada/prince-edward-island/dairy-farms-dump-milk-because-roads-snow-clogged-1.2961398

Harper, J. (2017, August 16). Personal interview.

Kovacs, P. and J. Thistlethwaite. (2014): Industry. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 135-158.

Langis, J. (2013, February). *Adaptation measures for floods, storm surges and sea level rise*. Retrieved from http://www8.umoncton.ca/littoral-vie/Adaptation%20measures%20(Littoral%20et%20vie).pdf

Morand, A., R. Hennessey, J. Pittman and A. Douglas. (2015). *Linking Mitigation and Adaptation Goals in the Energy Sector: A Case Study Synthesis Report*. Report submitted to the Climate Change Impacts and Adaptation Division, Natural Resources Canada, 122p.

PEI Department of Communities, Land and Environment. (2015, July 2015). *Public Lands* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/public-lands

PEI Department of Finance. (n.d.). *Prince Edward Island: Estimates 2017-2018*. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/estimates2017_web.pdf

Palko, K. (2017). Synthesis. In: *Climate Risks and Adaptation Practices for the Canada Transportation Sector 2016,* (eds.) K. Palko and D.S. Lemmen; Government of Canada, Ottawan ON, p. 12-25.

van Proosdij, D., B. MacIsaac, M. Christian, and E. Poirier. (2016, March 1). *Adapting To Climate Change in Coastal Communities of the Atlantic Provinces, Canada: Land Use Planning And Engineering And Natural Approaches - Part 1*. Retrieved from https://atlanticadaptation.ca/en/islandora/object/acasa%3A786

Rapaport, E., S. Starkman, and W. Towns. (2017). Atlantic Canada. In: *Climate Risks and Adaptation Practices for the Canadian Transportation Sector 2016,* (eds.) K. Palko and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 218-262.

Shaw, R.W. and CCAF A041 Project Team. (2001, June). *Coastal Impacts of Climate Change and Sea-Level Rise on Prince Edward Island*. Retrieved from http://www.coastalchange.ca/download_files/external_reports/Shaw_(2001)_CoastalImpactsofClimateChangeandSLRonPEI.pdf

Statistics Canada (a). (2017, March 30). *Table 282-0024 - Survey of Employment, Payrolls and Hours (SEPH), employment by type of employee and detailed North American Industry Classification System (NAICS)*. Retrieved on May 12, 2017.

Statistics Canada (b). (2017, April 28). *Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories.* Retrieved on May 3, 2017.

Toplis, C. (2015). *International Climate Change Adaptation Framework for Road Infrastructure*. Retrieved from http://www.cakex.org/sites/default/files/documents/Toplis_International%20climate%20change%20adaptation%20framework%20for%20road%20infrastructure_2015.pdf

United States Environmental Protection Agency. (n.d.). *Climate Action Benefits: Roads* [website]. Retrieved from https://www.epa.gov/cira/climate-action-benefits-roads

United States Environmental Protection Agency. (2009, January). *Synthesis of Adaptation Options for Coastal Areas*. Climate Ready Estuaries Program. EPA 430-F-08-024. Retrieved from https://www.epa.gov/sites/production/files/2014-04/documents/cre_synthesis_1-09.pdf

University of Illinois. (n.d.). *Forecasting Freezing Rain* [website]. Retrieved from http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/prcp/zr/fcst/fcst.rxml

Wright, T. (2015, January 30). December rainstorm caused 9 million dollars in damages for Prince Edward Island. *The Guardian*. Retrieved from http://www.theguardian.pe.ca/news/local/2015/1/30/december-rainstorm-caused-9-million-in-4025578.html

10

Climate change is the biggest global health threat of the 21st century ... the impacts will be felt all around the world — and not just in some distant future but in our lifetimes and those of our children.

—The Lancet

10 PUBLIC HEALTH AND SAFETY SECTOR

10.1 Background

Publicly-funded health services in Prince Edward Island are delivered by Health PEI, a crown corporation. Health PEI is overseen by the Health PEI Board, which is composed of appointed directors with a varied range of knowledge and experiences that benefits the health care system. The Board ensures that Health PEI follows the frameworks of the Provincial Health Plan, provincial policy, and applicable legislation. The Provincial Government's Department of Health and Wellness sets standards for health services, institutes accountability framework, creates policy and guidelines for operations and delivery of services, and approves budgets and business plans. Most of Health PEI's operating budget comes from the Department of Health and Wellness, which provided grants totalling $592 million in 2016 (Health PEI, 2016).

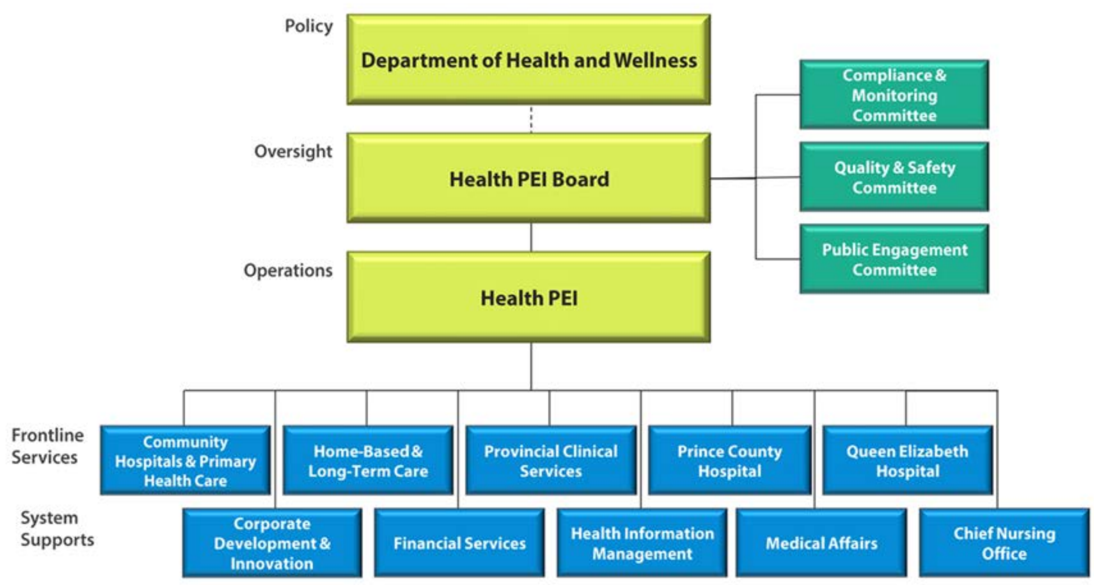


Figure 10.1: Prince Edward Island health system organizational chart (Source: Health PEI, 2013).

In 2016, the total value of all goods and services produced in Prince Edward Island was $4.8 billion, with the health care sector contributing $641 million, or 13% (see Figure 10.2)[1]. In fiscal year 2015-2016, Health PEI employed 4,615 staff members (e.g., physicians, specialists, nurses, lab technicians, management staff, administrative staff, other health professionals) out of an average of 63,100 employees across all industries in the province over 2015 - 2016 (see Figure 10.3).

1 GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

PHOTO CREDIT: GOVERNMENT OF PEI

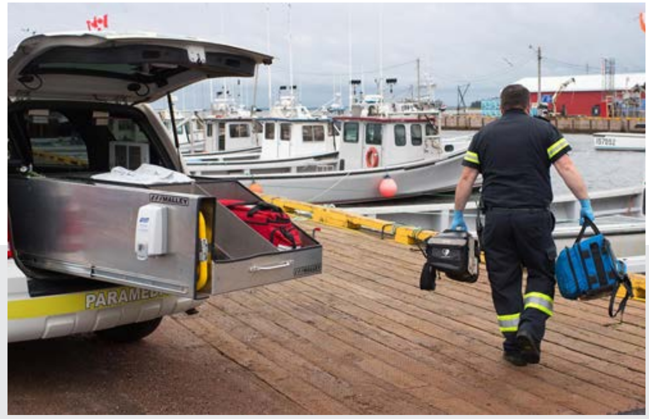


PHOTO CREDIT: GOVERNMENT OF PEI

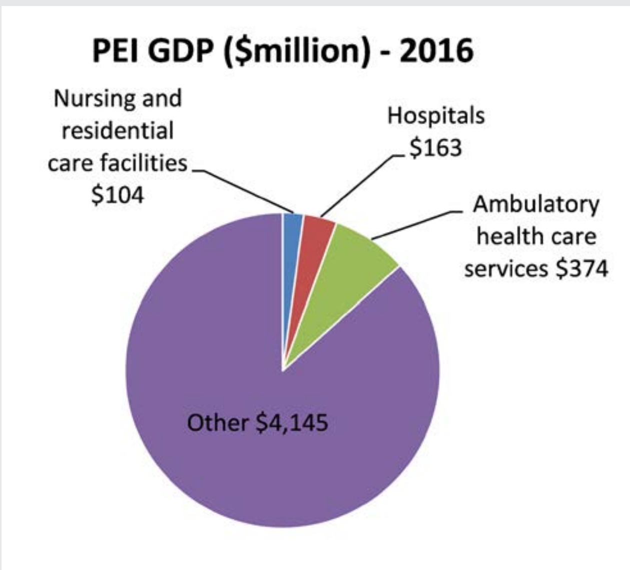


Figure 10.2: Prince Edward Island GDP of the Public Health sector in 2016 (in $million chained 2007 dollars) (Data source: Statistics Canada, 2017b).

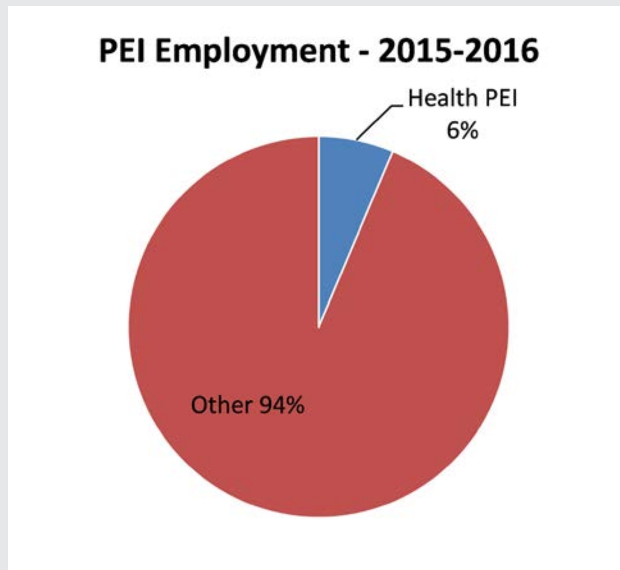


Figure 10.3: Prince Edward Island employment of the Public Health sectorin 2015-2016 (Data sources: Health PEI, 2016 and Statistics Canada, 2017a).

Health PEI operates two main referral hospitals, four community hospitals, one in-patient psychiatric hospital, ten long-term care facilities, the PEI Cancer Treatment Centre, the Youth Recovery Centre, and flu vaccination clinics. It also provides health services such as primary care, chronic disease prevention and management, hospital services, pharmacy services, children's development services, diagnostic imaging, emergency health and planning services, laboratory services, long-term care, pharmacare, home care, palliative care, geriatric care, and mental health and addiction services (Government of Prince Edward Island [PEI], n.d.).

Public safety organizations include police departments, fire departments, and the provincial Emergency Management Organization (EMO). The Emergency Measure Act gives the responsibility of the coordination and management of emergency management activities to the EMO (PEI Department of Justice and Public Safety, 2016). EMO offers emergency management training courses for those acting on behalf of communities during emergencies and provide outreach services to communities, service groups, and businesses.

10.2 Climate Change Impacts

Climate change will bring about warmer weather, changes in precipitation patterns, more intense storms, and rising sea levels in Prince Edward Island.

10.2.1 Temperature

CHALLENGES

First, rising temperatures could increase the risk of vector-borne and zoonotic diseases by changing the geographic distribution of disease-carrying arthropod vectors and animals, extending the transmission season, and increasing the maturation speed of the pathogens (Berry *et al.*, 2004). These changes could potentially introduce new and previously-eradicated diseases to the Island as well as increase the incidence of the diseases (Berry *et al.*, 2014). For example, Lyme disease can be caused by the bacteria *Borrelia burgdoferi*is carried by *Ixodes scapularis* (backlegged ticks). The range of blacklegged ticks has already expanded into central and eastern Canada (PHAC, 2011). Migratory birds carry these and other ticks throughout Canada and the warmer temperatures allow these ticks to reproduce and thrive where they are dropped (PHAC, 2011). The *Ixodes scapularis* vector is likely to emerge from northeastern United States and enter Prince Edward Island within the next decade (see Figure 10.4).

PHOTO CREDIT: DON JARDINE

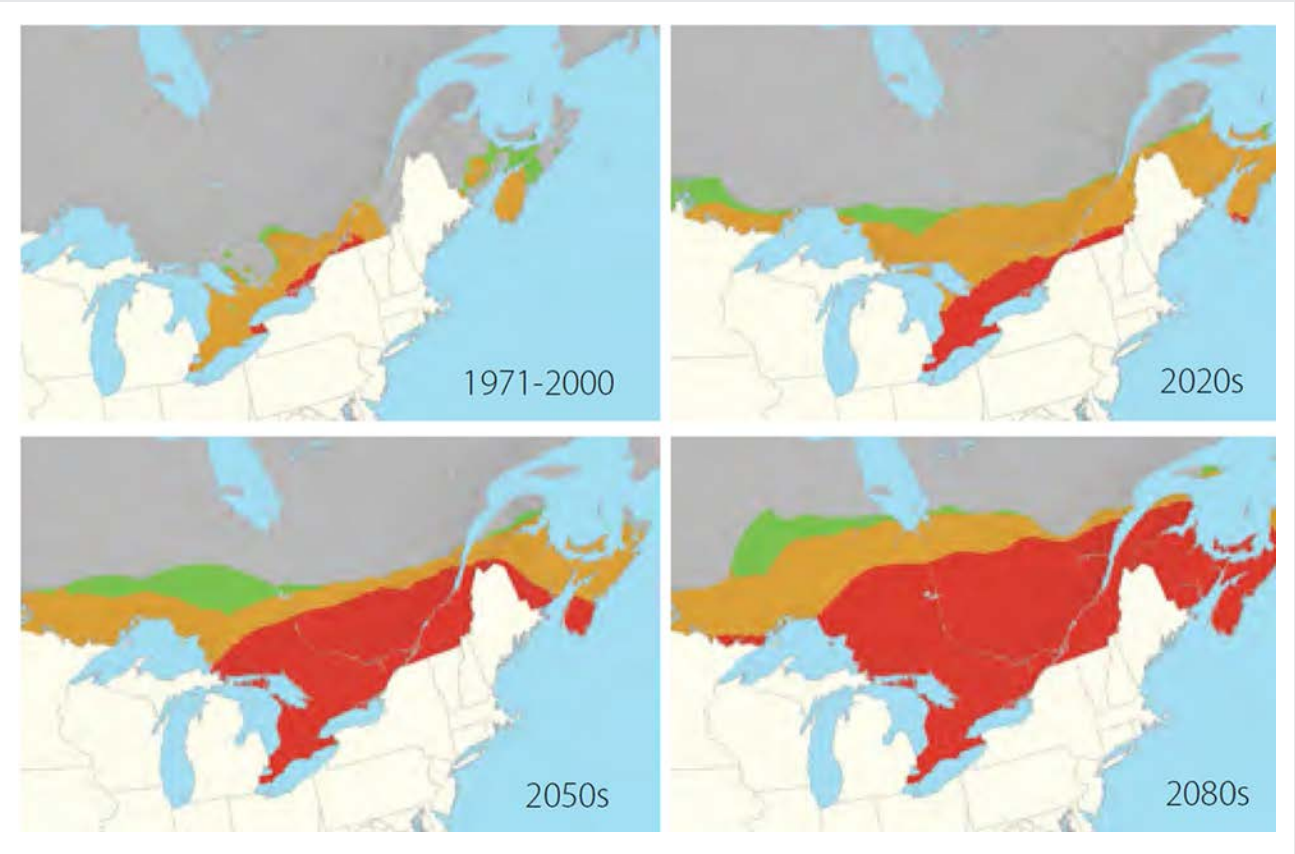


Figure 10.4: Risk maps for the spread of Lyme disease vector Ixodes scapularis under (1971-2000) and future climate change. Orange and red areas indicate increasingly high risk of vector emergence. Green areas indicate possible vector emergence. Gray areas indicate low risk of vector emergence. (Source: Berry et al., 2014)

Second, the formation of ground-level ozone (O_3), a toxin, could increase with rising temperature (Myers *et al.*, 2017). According to the United States Environmental Protection Agency (n.d.), O_3 can "cause shortness of breath; inflame and damage the airways; aggravate lung diseases such as asthma, emphysema, and chronic bronchitis; increase the frequency of asthma attacks; make lungs more susceptible to infection; and cause chronic obstructive pulmonary disease". Children, seniors, those with pre-existing respiratory or cardiac conditions, and those who are active outdoors are at higher risk of adverse effects (PHAC, 2015).

Third, increasing temperatures could lead to the earlier onset and extension of pollen season, provide more favourable growing conditions for trees and plants that give off pollens and allergens, and lead to an increase in the allergenicity of pollen (Berry *et al.*, 2014). The aeroallergens (e.g., dust mites, pollens from trees, grasses, molds) can trigger allergic reactions once inhaled. They can exacerbate respiratory diseases such asthma and chronic obstructive pulmonary disease (Berry *et al.*, 2014).

Fourth, incidence of food-borne bacterial illness could increase with rising temperatures. The replication rates and persistence of pathogens increase with the increasing temperatures of the summer season (Berry *et al.*, 2014). They also have a greater opportunity to survive cooking at barbeques and picnics, which are more common during the summer season (Berry *et al.*, 2014).

Fifth, ultraviolet radiation will increase with increasing temperatures. A warming climate changes the stratospheric ozone chemistry and delays the recovery of the ozone hole (Berry *et al.*, 2014). Rising temperatures could also change human behaviour (e.g., spending more time outdoors), increasing exposure to ultraviolet radiation. Human exposure to ultraviolet radiation could lead to sunburns, skin cancers, cataracts, eye damage, various immune disorders, DNA damage, and immune suppression. Prince Edward Island has the highest age-standardized incidence rate of melanoma among women across all provinces in 2016 at 24.3 cases per 100,000 people compared to the national rate of 15.8 (Canadian Cancer Society, 2016). PEI has the second highest rate of melanoma among men across all provinces in 2016 at 25.4 cases per 100,000 people in compared to the national rate of 20.5 (Canadian Cancer Society, 2016).

10.2.2 Precipitation

CHALLENGES

First, decreasing precipitation, combined with warming temperatures, increase the risk of forest fires (Berry *et al.*, 2014). The primary health consequences of wood smoke from forest fires include smoke inhalation, burns and injury to the respiratory tract, and oxygen deficiency (Berry *et al.*, 2014). It could also exacerbate existing conditions such as asthma, chronic lung diseases, and cardiovascular disease (Berry *et al.* 2014). Secondary impacts of forest fires include injury from radiant heat, heat exhaustion, dehydration, increased likelihood of mortality, anxiety, depression, and post-traumatic stress disorder related to loss of friends, relatives, neighbours, homes, and livelihoods (Berry *et al.*, 2014). It is important to note that beyond the increased risk of forest fires locally, the forecasted increase in the risk, extent, and severity of forest fires in most regions of Canada under a changing climate (Lemmen *et al.*, 2014) may also be of concern. The wildfire in Fort McMurray, Alberta in 2016 caused a spike in air pollution over 4,000 km away in the New England states (McDiamird, 2017).

PHOTO CREDIT: DON JARDINE

Second, the increasing intensity of rain events could increase the transport of pollutants such as silt, chemicals, hydrocarbons, and heavy metals from industrial operations via runoff to uncontaminated drinking water and recreational water areas, impacting water quality. This is especially problematic with drier summers, which may lead to longer periods of low soil moisture and an increase in soil shrinkage cracks, creating a more extensive and connected macropores (i.e., large soil pores) system for runoff to flow through (Boxall *et al.*, 2009). Furthermore, changes in precipitation levels could reduce water levels in rivers, increasing the concentration of pathogens and contaminants in the water.

Third, an increase in nutrient-rich runoff after intense precipitation events increase the proliferation of harmful algal blooms, which produce toxins that are harmful to human health. The growth is also increased by warming temperatures. The toxins can cause irritations of the skin and eyes of swimmers, boaters, or anyone who comes into contact with them (PEI, 2016). Ingesting large amounts of the toxins by drinking the water or eating fish or shellfish from the water can result in nausea, vomiting, cramps, diarrhea, and sore throat (PEI, 2016).

Fourth, an increase in runoff increases the likelihood of outbreaks of waterborne diseases. These diseases are caused by bacteria, viruses, and/or parasites; carried in water; and infect humans via exposure to contaminated water. For example, heavy rainfall played a role in the E. coli *O157:H7* contamination of groundwater via farm runoff in Walkerton, Ontario in 2000. The outbreak caused seven deaths and 2,300 people to fall ill, in a community of fewer than 5,000 (CBC, 2010). Thomas *et al.* (2006) studied waterborne disease outbreaks in Canada from 1975 to 2001 and found rainfall events greater than the 93rd percentile increased the odds of an outbreak by a factor of 2.283.

Fifth, changes in precipitation patterns could affect the rate and timing of groundwater recharge. Combined with sea-level rise, this could affect the saltwater-freshwater interface in groundwater. Elevated levels of saline in drinking water could cause serious health implications such as hypertension and stroke (Vineis *et al.*, 2011). Under a changing climate with rising sea levels, higher storm-surge levels, and drier conditions, incidents of saltwater intrusion could become more commonplace.

10.2.3 Extreme Weather Events

CHALLENGES

An increase in the frequency and intensity of extreme weather events could lead to an increase in the frequency and severity of health and safety impacts related to floods and severe storms. These weather events can cause direct health consequences such as physical injury (e.g., lacerations, sprains); psychological health effects (e.g., stress-related illnesses); heart attacks and strokes from exertion and stress; and death (e.g., motor vehicle accidents). Secondary impacts can include anxiety, depression, and post-traumatic stress disorder related to loss of friends, relatives, neighbours, homes, and livelihoods (Berry *et al.*, 2014). These extreme weather events could also cause indirect health consequences such as interrupting medical care (e.g., power outages, infrastructure damage); dehydration (e.g., power outages prevent drinking well pumps from operating); and respiratory illnesses from mold, bacterial, and fungal growth on water-damaged structures (Berry *et al.*, 2014).

10.2.4 Sea Level Rise

CHALLENGES

First, rising sea levels, along with higher storm surge, could increase incidents of saltwater intrusion of drinking wells by inundating the wellheads.

Second, increasing frequency and severity of coastal flooding and/or coastal erosion as a result of sea level rise could lead to the relocation or loss of homes. This may have secondary impacts such as anxiety and depression.

10.2.5 Carbon Dioxide

CHALLENGES

While the increasing concentrations of atmospheric carbon dioxide is the primary driver of climate change and is responsible for the impacts described above, the carbon dioxide itself also impacts public health. Carbon dioxide changes the nutritional composition of crops. Experiments have shown a 7-15% decrease in the protein content in edible portion of wheat, barley, and potatoes (Myers *et al.*, 2017).

PHOTO CREDIT: DON JARDINE

10.2.6 Indirect Climate Change Impacts

CHALLENGES

First, the impact of climate change on other sectors can indirectly affect public health. The warming temperatures and changing precipitation patterns could increase water requirements for agricultural lands and golf courses. Irrigation could reduce water levels in rivers, potentially increasing the concentration of any pathogens and contaminants in the water.

Second, efforts to mitigate the effects of climate change by shifting to renewable and carbon-neutral energy sources such as biomass (e.g., wood) could affect public health. The burning of wood produces fine particulate matter. Exposure to fine particulate matter can exacerbate asthma, bronchitis, and respiratory symptoms; negatively impact cardiac health; increase lung cancer mortality; and lead to premature mortality (Berry *et al.*, 2014).

Third, the warming temperatures also increase human exposure to vector borne and zoonotic diseases as well as pollutants and diseases in recreational water by bringing about behaviour changes (e.g., extended swimming season) thus elevating the risk to human health (Berry *et al.*, 2014).

10.2.7 Unknowns

CHALLENGES

While climate modeling is able to forecast how climate change will impact temperature, precipitation, sea level rise, etc. with high levels of confidence, there are limitations to these models. For example, freezing rain is one of the most difficult events to forecast: it occurs in very narrow bands, usually less than 50 km wide, and a change in temperature as small as tenths of a degree could turn freezing rain into rain, sleet, or snow (University of Illinois, n.d.). Generally speaking, warmer winters are associated with an increased occurrence of freezing rain and black-ice conditions (Rapaport *et al.*, 2017). Freezing rain could cause slips and falls and reduce access to medical care due to unsafe driving conditions and failure of infrastructure. Milder winters could lead to more freezing rain and wet snow events, which occur close to the freezing mark (0°C). In addition to slip and falls and unsafe road conditions, these types of events are particularly problematic for infrastructure. An accumulation of ice or heavy snow on tree branches or electric equipment could damage conductors or poles, disrupting electrical power to homes, businesses, health care facilities, etc.

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

10.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

64 Invite other jurisdictions to **share best practices and innovative approaches**. Other regions may be facing similar challenges brought on by climate change. By sharing successes in local adaptation efforts, they could reciprocate with strategies of their own (e.g., Peel Region in Ontario developed a mosquito extermination program to reduce the transmission of West Nile virus). There are also numerous resources available online, such as a tool to estimate health and adaptation costs developed by the World Health Organization (WHO) Regional Office for Europe (2013) which assists policymakers compare the costs and benefits of adaptation when making adaptation decisions.
Suggested timeline: ongoing

65 **Integrate climate change impacts** in all existing vulnerability assessments, management activities, policies, programs, etc. For example, the financial management of organizations that provide public health and safety services (e.g., hospitals, clinics, Emergency Measures Organization, police departments, fire departments) should be reviewed to ensure enough resources are allocated in the operating budget to allow for increased demand for these organizations' services under a changing climate.
Suggested timeline: ongoing

10.3.1 Public Health

66 **Help the public adapt to climate change** by developing an outreach strategy. Ensure that they are not provided with mixed messaging on climate-related risks (e.g., exercising later in the day to avoid extreme heat or ultraviolet radiation while remaining indoors at night to avoid contracting West Nile virus) (Berry *et al.*, 2014). The information should be practical and relevant on a personal level and does not have to discuss climate change. Examples include informing those with pre-existing conditions on how to access the Air Quality Health Index score to minimize exposure to poor air quality and developing a flyer on residential home heating best practices to recommend the use of high-efficiency wood stove or fireplace, which could reduce emissions of fine particulate matter by up to 90 percent and burning dry, well-seasoned wood that has been split properly to reduce smoke (Natural Resources Canada, 2002).
Suggested timeline: short-term (0 to 5 years)

67 **Evaluate the knowledge gaps** in the existing system and identify data, skills, or expertise required to address climate change impacts (e.g., environmental health indicators of climate change, risk maps). **Develop multidisciplinary partnerships** across sectors, organizations, levels of government, etc. to recruit/access data, skill sets and knowledge that may not be available within the public health system. **Support interdisciplinary research** to address these knowledge gaps.
Suggested timeline: short-term (0 to 5 years)

68 **Monitor and map environmental factors** and other events (e.g., harmful algal bloom outbreaks, fish kills, water quality, air quality, temperature, precipitation) related to public health so models could be created to identify high-risk areas. Develop strategies to minimize the public health risks.
Suggested timeline: short-term (0 to 5 years)

69 **Reduce non-climatic factors**. Healthy communities are resilient communities. For example, by preventing chronic disease in Islanders, their bodies will become more resilient and able to cope with climate change impacts. Engage in outreach efforts to educate the public on how they could increase their resilience.
Suggested timeline: ongoing

10.3.2 Public Safety

70 Create a mechanism at the community-scale to **identify and assist vulnerable groups** (e.g., elderly, pregnant women, children, the chronically ill, those with compromised immune systems) when emergencies arise so first responders can focus on those with the greatest needs.
Suggested timeline: short-term (0 to 5 years)

71 **Conduct training exercises** involving emergency services and local responders to respond to severe, wide area flooding. For example, consider water levels caused by storm surge under high-tide conditions for 1-in-200 year storms. Use flood risk maps to exclude the use of inundated infrastructure during the exercise to mimic actual impacts. Determine how response time and delivery of service could be improved given the circumstances.
Suggested timeline: short-term (0 to 5 years)

72 **Recommend dual access to properties** when possible to assist in the emergency management response should one access route become impassable (e.g., flooded, washed out, surrounded by forest fire).
Suggested timeline: ongoing

73 **Create lists of safe spaces** within communities where residents can be directed to go during an extreme weather event and establish a mechanism to communicate the choice of safe space to the residents before, during, and/or after the event. These spaces should have dual access roads; be accessible by roads safe from flooding; be able to generate electricity (e.g., diesel generator); and have emergency supplies (e.g., food, water, radio).
Suggested timeline: short-term (0 to 5 years)

The collaboration of the sector (e.g. industry organizations), experts (e.g., climate scientists, engineers), and governments will be critical in achieving effective adaptation. The table below summarizes the ten recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

Table 10.1: Summary of recommended adaptation actions for the public health and safety sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
64. Invite other jurisdictions to share best practices and innovative approaches (e.g., WHO developed a tool to estimate costs and benefits of adaptation decisions).	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps; Increase collaboration	Ongoing
65. Integrate climate change impacts in all existing vulnerability assessments, management activities, policies, programs, etc. (e.g., adjust the operating budget to allow for increased demand for services).	Lead: Provincial Government Collaborators: Experts	Promote climate change mainstreaming	Ongoing
66. Help the public adapt to climate change by developing an outreach strategy. The information should be practical and relevant on a personal level and does not have to discuss climate change.	Lead: Provincial Government Collaborators: Educators	Engage in outreach, Fill knowledge gaps	Short-term (0 to 5 years)
67. Evaluate the knowledge gaps in the existing system and identify data, skills, or expertise required to address climate change impacts; develop multidisciplinary partnerships; and support interdisciplinary research.	Lead: Provincial Government Collaborators: Educators, Other sectors	Fill knowledge gaps; Increase collaboration	Short-term (0 to 5 years)
68. Monitor and map environmental factors and other events related to public health to identify high-risk areas (e.g., harmful algal bloom outbreaks, fish kills, water temperature, air quality).	Lead: Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
69. Reduce non-climatic factors (e.g., prevent chronic disease so Islanders will become more resilient and able to cope with climate change impacts).	Lead: Provincial Government Collaborators: Health care professionals, Educators	Increase resilience; Engage in outreach	Ongoing
70. Create a mechanism at the community-scale to identify and assist vulnerable groups when emergencies arise so first responders can focus on those with the greatest needs.	Leads: Municipal governments, EMO Collaborators: Public	Increase collaboration	Short-term (0 to 5 years)
71. Conduct training exercises involving emergency services and local responders to respond to severe, wide area flooding and improve delivery of service and response time.	Lead: EMO Collaborators: First responders	Fill knowledge gap	Short-term (0 to 5 years)
72. Recommend dual access to properties when possible to assist in the emergency management response should one access route become impassable (e.g., flooded, washed out, surrounded by forest fire).	Lead: EMO Collaborators: Property owners	Increase resilience	Ongoing
73. Create lists of safe spaces within communities and establish a mechanism to communicate the choice before/during/after the event.	Leads: Municipal governments, EMO Collaborators: Public	Increase resilience; Increase collaboration	Short-term (0 to 5 years)

10.4 Conclusion

The health of individuals is affected by a number of factors. They include the social and economic status (e.g., income and education levels); the physical environment (e.g., air and water quality, workplace health); and the person's individual characteristics and behaviour (e.g., genetics, gender, diet) (WHO, n.d.). Climate change will affect the physical environment negatively and its impacts on health will disproportionately affect the elderly, pregnant women, children, the chronically ill, Indigenous groups, those with compromised immune systems, the poor, the socially disadvantaged, and those living in vulnerable geographic areas (e.g., rural areas) (PHAC, 2013). However, the sector can act proactively by engaging citizens, addressing knowledge gaps, adopting best practices, and preparing for larger-scale emergencies.

REFERENCES

Berry, P., K. Clarke, M.D. Fleury and S. Parker. (2014). Human Health. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 191-232.

Boxall, A.B.A., A. Hardy, S.Beulke, T. Boucard, L. Burgin, P.D. Falloon, … R.J. Williams. (2009, April). Impacts of Climate Change on Indirect Human Exposure to Pathogens and Chemicals from Agriculture. *Environmental Health Perspectives*, 117 (4), 508-514.

Canadian Cancer Society. (2016, October). *Canadian Cancer Statistics 2016*.

CBC. (2010, May 10). *Inside Walkerton: Canada's worst-ever E. coli contamination*. Retrieved from http://www.cbc.ca/news/canada/inside-walkerton-canada-s-worst-ever-e-coli-contamination-1.887200

Government of Prince Edward Island. (n.d.). *About: Health PEI* [website]. Retrieved from https://www.princeedwardisland.ca/en/department/health-pei/about

Government of Prince Edward Island. (2016, June 9). *Blue-Green Algae (Cyanobacteria)* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/blue-green-algae-cyanobacteria

Health PEI. (2013, March). *Strategic Plan 2013 - 2016*. Retrieved from http://www.gov.pe.ca/photos/original/hpei_strat-pl_16.pdf?_ga=2.208264594.1079978431.1494605316-943092158.1487768559

Health PEI. (2016, September). *Annual Report 2015 - 2016*. Retrieved from http://www.gov.pe.ca/photos/original/hpei_ar15-16_en.pdf

McDiarmid, M. (2017, September 26). Fort McMurray fires cause air pollution spike on the other side of continent. *CBC News*. Retrieved from http://www.cbc.ca/news/politics/fort-mcmurray-fire-connecticut-ozone-1.4305787

Myers, S.S., M.R. Smith, S. Guth, C.D. Golden, B. Vaitla, N.D. Mueller, A.D. Dangour, and P. Huybers. (2017, March 20). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*, 20(38), 259-277. doi: 10.1146/annurev-publhealth-031816-044356.

Natural Resources Canada. (2002). *A Guide to Residential Wood Heating*. Retrieved from http://www.housing.yk.ca/pdf/wood_guide_nrc.pdf

PEI Department of Justice and Public Safety. (2016). *About EMO* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/justice-and-public-safety/about-emo

Public Health Agency of Canada. (2011, June). *Adapting to climate change: a practical approach to address vector-borne and water-borne disease risk in Canada – Pilot Infectious Disease Impact and Response Systems (PIDIRS).*

Public Health Agency of Canada. (2015, August 11). *Climate Change and Public Health Fact Sheets*. Retrieved from http://www.phac-aspc.gc.ca/hp-ps/eph-esp/fs-fi-a-eng.php

Public Health Agency of Canada. (2013, April 3). *Environmental Public Health and Climate Change*. Retrieved from http://www.phac-aspc.gc.ca/hp-ps/eph-esp/index-eng.php

Rapaport, E., S. Starkman, and W. Towns.(2017). Atlantic Canada. In: *Climate Risks and Adaptation Practices for the Canadian Transportation Sector 2016,* (eds.) K. Palko and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 218-262.

Statistics Canada (a). (2017, March 30). *Table 282-0088 – Labour force survey estimates (LFS), employment by North American Industry Classification System (NAICS), seasonally adjusted and unadjusted*. Retrieved on May 12, 2017

Statistics Canada (b). (2017, May 1). *Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories.* Retrieved on May 3, 2017.

Thomas, K.M., D.F. Charron, D. Waltner-Toews, C. Schuster, A.R. Maarouf, and J.D. Holt. (20016, June). A role of high impact weather events in waterborne disease outbreaks in Canada, 1975 – 2001. *International Journal of Environmental Health Research*. 16(3), 167-80. doi:10.1080/09603120600641326

University of Illinois. (n.d.). *Forecasting Freezing Rain* [website]. Retrieved from http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/prcp/zr/fcst/fcst.rxml

United States Environment Protection Agency. (n.d.). *Health Effects of Ozone Pollution*. Retrieved from https://www.epa.gov/ozone-pollution/health-effects-ozone-pollution

Vineis, P., Q. Chan and A. Khan (2011). Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health*. 1(1), 5-10.

World Health Organization. (n.d.). *The determinants of health*. Retrieved from http://www.who.int/hia/evidence/doh/en/

World Health Organization Regional Office for Europe. (2013). *Climate Change and Health: A Tool to Estimate Health and Adaptation* Costs. ISBN 978 92 890 0023 9.

PHOTO CREDIT: GOVERNMENT OF PEI

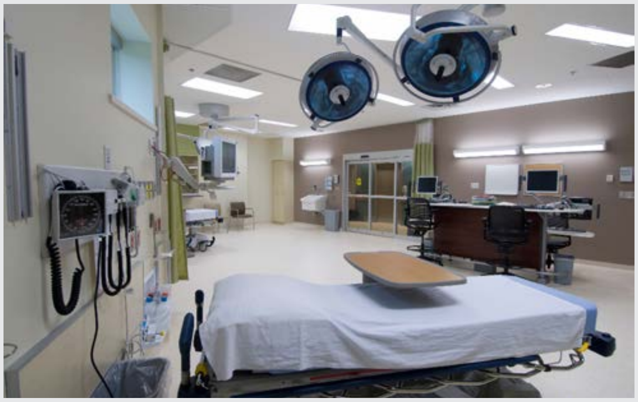


PHOTO CREDIT: GOVERNMENT OF PEI

11

You cannot protect the environment unless you empower people, you inform them, and you help them understand that these resources are their own, that they must protect them.

—Wangari Maathai

11 TOURISM SECTOR

11.1 Background

Tourism is an important industry within Prince Edward Island. In 2016, it generated an estimated $430 million of revenue and attracted an estimated 1.5 million visitors (Tourism Development International, 2016). Over 80% of all visitors in 2015 were Canadian, with the majority of them from New Brunswick and Nova Scotia (see Figure 11.1). Tourism represents 7% of the Island's GDP[1], generating approximately $43 million in provincial tax revenues (Opportunities PEI, n.d.). This sector provides an equivalent of 7,700 full-time year-round jobs (The Employment Journal, n.d.).

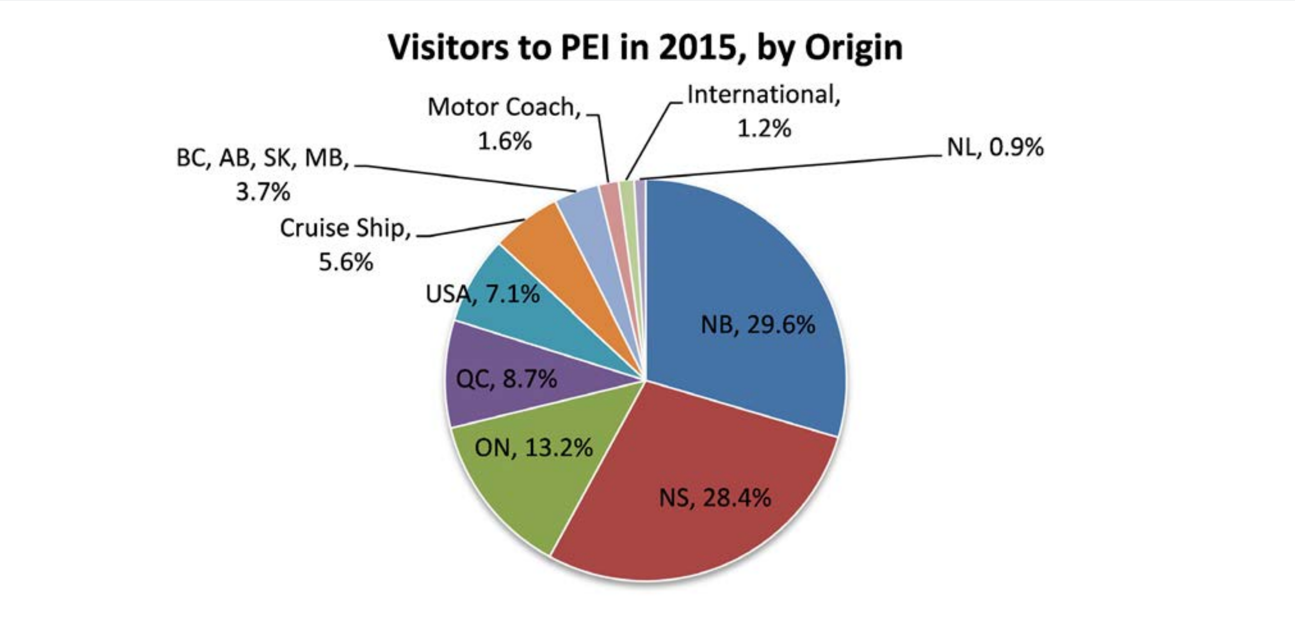


Figure 11.1: Visitors to Prince Edward Island by origin (Data source: Tourism Development International, 2016).

Prince Edward Island's tourism products include beaches, golf, coastal drives, artistic and cultural heritage, and culinary experiences. Motor coaches, cruise ships, and meetings and conventions also attract visitors to the Island. The peak months for tourism are July and August. In 2016, 89% of non-resident revenues were generated in those two months (Tourism Development International, 2016). Most visitors accessed the Island via the Confederation Bridge, followed by the ferry service at Wood Island and air travel via the Charlottetown airport (see Figure 11.2).

1 GDP and employment figures are two commonly used economic development indicators but they alone do not fully depict the sector's contribution to the Island.

11.2 Impacts of Climate Change

Climate change will bring about warmer weather, changes in precipitation patterns, more intense storms, and rising sea levels in Prince Edward Island.

It is critical to note that opportunities and challenges resulting from climate change cannot be taken in isolation. While there are anticipated impacts both positive and negative, the extent of them has not been quantified. For example, the advantages of a longer tourism season from warmer temperatures could be offset by the impact of coastal erosion on beaches that more intense storms bring.

11.2.1 Temperature

OPPORTUNITIES

First, rising temperatures will lead to longer and warmer summers, increasing the number of days suitable for activities such as golfing, biking, hiking, and camping. Visitation to National Parks could increase by 10-40% (Ecology Action Centre [EAC], 2012). The projected increase in golf seasons could be reasonably used to expect potential extension of seasons for theme/water parks, boating, cycling, fishing, and beach recreation (Kovacs and Thistlewaite, 2014). The extension of these seasons could lead to the growth of "shoulder seasons" of May to June and September to October, when capacity is underutilized (Reiling, n.d.).

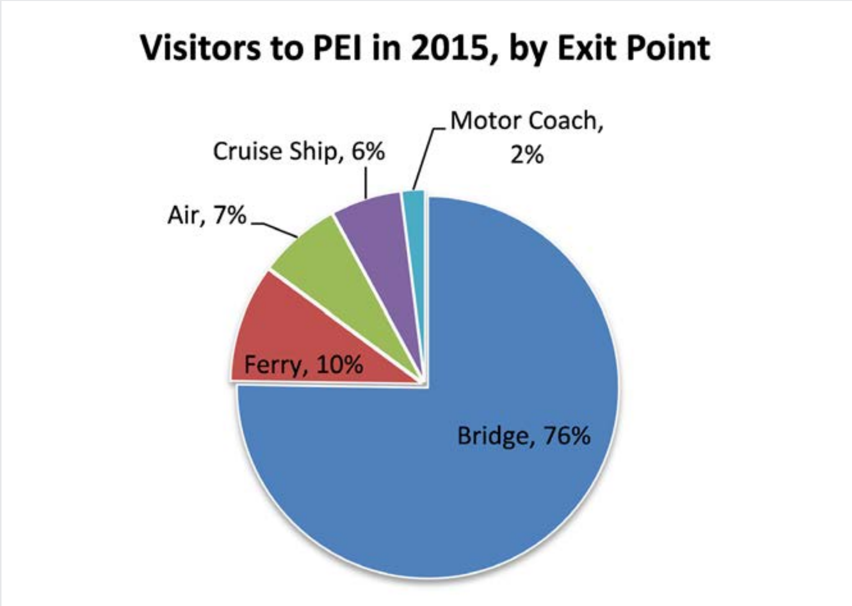


Figure 11.2: Visitors to Prince Edward Island by exit point (Data source: Tourism Development International, 2016).

Second, rising temperatures in hotter regions could boost summer tourism for the Island. With an abundance of beaches and coastline and relatively cooler temperatures, tourists may visit the Island looking to escape the heat. In addition, warmer summer temperatures will encourage locals to enjoy a "staycation", rather than travel to southern destinations (PEI Department of Communities, Land and Environment, 2016). According to the Ecology Action Centre (2012), "domestic tourism may double in colder countries since people won't have to travel as far to find more desirable weather and it may fall by 20% in warmer countries as people try to escape uncomfortably hot temperatures".

Third, a warmer climate may result in the establishment or growth of new tourism products. For example, more vineyards being established could support a tourist industry around wine production (PEI Department of Communities, Land and Environment, 2016).

CHALLENGES

First, in contrast to the boost warmer temperatures bring to summer tourism, winter tourism is expected to be impacted negatively. With increased temperatures, reduced snowfall, and decreased reliability of natural snow cover, winter sports such as skiing and snowmobiling will be affected (Kovacs and Thistlewaite, 2014). The ski seasons will be shortened and resorts will become more dependent on snowmaking, facing decreasing revenue and increasing operating costs.

Second, the additional guests expected to visit the provincial and national parks are likely to leave behind a more significant ecological footprint (Kovacs and Thistlewaite 2014).

PHOTO CREDIT: DON JARDINE

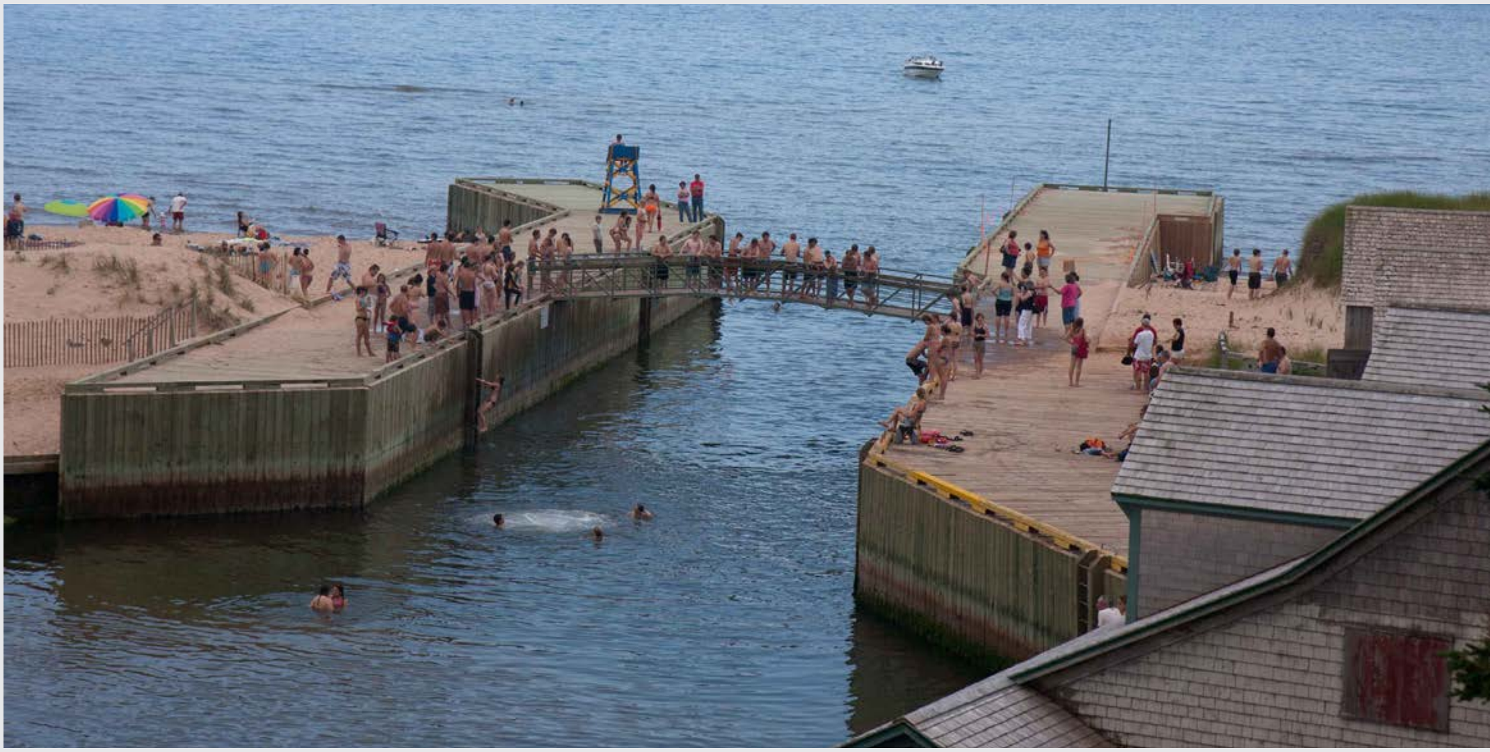


PHOTO CREDIT: DON JARDINE

11.2.2 Precipitation

OPPORTUNITIES

The decrease in precipitation, coupled with the increase in temperatures, could result in more golf rounds played.

CHALLENGES

Dry periods between rain events, combined with an overall reduction in precipitation and greater evapotranspiration from warmer temperatures could lead to higher water requirements to maintain ideal conditions for golf greens and fairways.

11.2.3 Extreme Weather Events

CHALLENGES

The increasing intensity and frequency of extreme weather events, along with rising sea levels, will worsen the severity of flooding and erosion impacts on coastal properties and infrastructure such as beaches, boardwalks, tourist accommodations, scenic routes, wharves, parks, etc. (see Table 11.1). The cost to protect, retrofit, repair, or relocate some of these assets could be cost-prohibitive.

Table 11.1: Projected coastal erosion at various parks across PEI (Data Source: Jardine, 2015).

Park	2010 Area	2040 Area % loss	2070 Area % loss	2100 Area % loss
ARGYLE SHORE	0.1864 km^2	2.86	5.75	8.80
CABOT PARK	1.4649	2.88	6.84	10.13
CAMPBELLS COVE	0.0924	2.75	6.05	9.15
CHELTON BEACH	0.0532	2.53	5.80	9.23
JACQUES CARTIER	0.0636	25.22	46.45	58.88
LINKLETTER	0.1662	0.98	1.79	2.60
PEI NATIONAL PARK	20.679	4.29	8.74	13.50
RED POINT	0.2882	1.71	3.28	4.93
TIGNISH SHORE	0.0196	15.90	31.93	47.32
UNION CORNER	0.0321	9.69	19.86	30.72
VICTORIA PROV.	0.0461	27.88	55.60	77.37

11.2.4 Indirect Climate Change Impacts

CHALLENGES

Beyond the direct impacts of climate on infrastructure and activities, there are indirect consequences of climate change that should also be considered.

First, rural regions may become vulnerable to climate change due to their distance from metropolises and transportation hubs because rising price of fuel from potential carbon offsetting could increase travel costs for visitors (EAC, 2012).

Second, the rising price of fuel could impact the snowmobiling and boating industries (Daniel *et al.*, 2009).

Third, golf course operators will be competing against other major users of water (e.g., farmers) to meet irrigation needs. This could be complicated by restrictions applied to irrigation permits during hot dry summers with low groundwater levels, a scenario that could become more likely under a changing climate.


PHOTO CREDIT: DON JARDINE

11.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

74 **Forecast future climate** for variables that impact tourism. For example, determine the:

- **a.** number of "comfort days" for golf (e.g., greater than 18°C with at least 6 hours of sunshine and no precipitation), soft adventure, etc.;
- **b.** number of frost free days for golf season;
- **c.** change in temperature for the shoulder seasons; and,
- **d.** seasonality of wind affects soft adventure, fishing excursions, etc.

Suggested timeline: short-term (0 to 5 years)

75 **Develop more offerings for the shoulder seasons** (e.g., festivals, events, experiential tourism products) to meet the needs of the higher traffic that warmer temperatures may bring.

Suggested timeline: medium-term (6 to 10 years)

PHOTO CREDIT: DON JARDINE

76 **Promote Prince Edward Island as an escape from urban heat**. Different tourism themes have been used to promote Prince Edward Island as a tourist destination (e.g., "Come to the Island – Stay for the Party", "True Island Flavour", "Come Find your Island", "Only in PEI"). Providing a diverse offering is important in attracting tourists. Data should be collected (e.g., exit surveys) to best determine the ideal markets for this marketing campaign.
Suggested timeline: short-term (0 to 5 years)

77 **Relocate, retrofit, or protect assets and infrastructure** (e.g., attractions, tourist accommodations, scenic routes) that are vulnerable to the effects of flooding and erosion. The asset/infrastructure owners or managers should:

- **a.** identify existing assets and infrastructure that are or will be in flood risk and/or erosion risk zones and determine if they should be relocated, retrofitted, protected or abandoned[2];
- **b.** prioritize and implement the appropriate adaptation actions;
- **c.** site new developments away from flood risk and erosion risk zones; and
- **d.** monitor rates of erosion onsite utilizing methodologies developed by the University of Prince Edward island Climate Lab.

Suggested timeline: ongoing

78 **Consider new methods of meeting water needs** for golf courses (e.g., improving water efficiency, decreasing turf area, harvesting rainwater, etc.) and different turfgrasses that would be suitable under a changing climate.
Suggested timeline: medium-term (6 to 10 years)

79 **Diversify the product offering** (e.g., eco-tourism, cultural heritage, and culinary experiences) to include more all-weather products in order to cope with changing precipitation patterns and more frequent extreme storm events.
Suggested timeline: short-term (0 to 5 years)

2 Refer to the Property and Infrastructure Sector chapter for additional information.

PHOTO CREDIT: DON JARDINE

80 Determine the viability of **storm-watching** as an attraction on the North Shore, similar to what is offered by Tofino or Pacific Rim areas in British Columbia.
Suggested timeline: short-term (0 to 5 years)

The collaboration of tourism operators, sector (e.g. industry organizations), experts (e.g., climate scientists, engineers), and the government will be critical in achieving effective adaptation. The table below summarizes the seven recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

Table 11.2: Summary of recommended adaptation actions for the tourism sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
74. Forecast future climate for variables that impact tourism (e.g., number of "comfort days" for golf, soft adventure).	Leads: Sector, Provincial Government Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
75. Develop more offerings for the shoulder seasons (e.g., festivals, events, experiential products).	Lead: Sector Collaborators: Tourism operators	Increase resilience	Medium-term (6 to 10 years)
76. Promote Prince Edward Island as an escape from urban heat.	Lead: Provincial Government Collaborator: Sector	Increase resilience	Short-term (0 to 5 years)
77. Relocate, retrofit, or protect assets and infrastructure that are vulnerable to the effects of flooding and erosion (e.g., relocate at-risk tourist accommodations, protect scenic routes, site new attractions away from flood and erosion risk zones).	Lead: Provincial Government, Asset and infrastructure owners Collaborator: Sector, Tourism operators, Experts	Increase resilience	Ongoing
78. Consider new methods of meeting water needs (e.g., improving water efficiency, decreasing turf area, harvesting rainwater, etc.) and different turfgrasses that would be suitable under a changing climate.	Lead: Golf course operators Collaborators: Experts	Increase resilience	Medium-term (6 to 10 years)
79. Diversify the product offering (e.g., eco-tourism, cultural heritage, and culinary experiences) to include more all-weather products.	Leads: Tourism operators Collaborator: Sector	Increase resilience	Short-term (0 to 5 years)
80. Determine the viability of storm-watching as an attraction on the North Shore.	Lead: Parks Canada Collaborators: Sector, Tourism operators, Experts	Increase resilience	Short-term (0 to 5 years)

11.4 Conclusion

Tourism is one of Prince Edward Island's main economic drivers. It is easy for tourists to substitute the destination, timing, and activities related to travel so offering consistent and quality products to visitors is critical. Given the climate's large impact on many of the Island's tourism products, the success and sustainability of the sector will depend on its resilience under a changing climate. In the short term, climate change brings many opportunities to the tourism sector. All stakeholders should take advantage of these while planning and bracing for the challenges that climate change inevitably brings.

PHOTO CREDIT: DON JARDINE

REFERENCES

Daniel, H., K.P. Bell, J. Diagle, H. Daniel, T. Gabe, and J. Leahy. (2009). Tourism and Recreation. In: *Maine's Climate Future: An Initial Assessment,* (eds.) G.L. Jacobson, I.J. Fernandez, P.A. Mayewski and C.V. Schmitt; University of Maine, Orono, ME, p. 50-52. Retrieved from http://www.maine.gov/dacf/municipalplanning/docs/Maines_Climate_Future[1].pdf

Ecology Action Centre. (2012). *Climate Change & Tourism: Impacts and Adaptation for Coastal Communities in Nova Scotia*. Retrieved from https://ecologyaction.ca/files/images-documents/file/Coastal/CCCheticamp/tourism_fact_sheet_english.pdf

Jardine, D. (2015). P*EI's Changing Climate Implications for Policy Makers and Regulators*. Retrieved from http://peiwatershedalliance.org/2015AGM/ClimateChangePolicyAGM2015.pdf

Kovacs, P. and J. Thistlethwaite. (2014). Industry. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 135-158.

Opportunities PEI. (n.d.). *Industries* [website]. Retrieved from http://www.opportunitiespei.ca/working-industries

PEI Department of Communities, Land, and Environment. (2016, July 7). *Climate Change and Island Tourism* [website]. Retrieved from https://www.princeedwardisland.ca/en/information/communities-land-and-environment/climate-change-and-island-tourism

The Employment Journal. (n.d.). *Tourisim* [website]. Retrieved from http://employmentjourney.com/industries/tourism/

Tourism Development International. (2016). *Prince Edward Island Strategic Plan for Tourism 2021 – Final Report*

12

Anything else you're interested in is not going to happen if you can't breathe the air and drink the water. Don't sit this one out. Do something. You are by accident of fate alive at an absolutely critical moment in the history of our planet.

—Carl Sagan

12 WATER SECTOR

12.1 Background

Water is one of the most vital substances on this planet; the existence of plants and animals depend on it. Water security has been defined as "sustainable access, on a watershed basis, to adequate quantities of water of acceptable quality, to ensure human and ecosystem health" (TRCA and ESSA, 2012).

Water infrastructure is necessary to supply water for stormwater management and community, industrial, and agricultural use (Andrey *et al.*, 2014). There are different types of infrastructure related to water. Manmade water infrastructure include wharves, piers, seawalls, docks, dam, reservoirs, aquifers wastewater treatment facilities, culverts, sewers, pipes, storm drains, etc. (Boyle *et al.*, 2013)[1]. Natural water infrastructure include coastal ecosystems and soils. Coastal ecosystems such as wetlands, bogs, and swamps provide many ecological and socio-economic benefits. They can collect and store runoff, moderate and attenuate downstream flood flows, reduce downstream flooding and erosion, clean and purify water, recharge groundwater zones, and provide unique habitats for plants and animals. Soils have the capacity to absorb, retain, and release water to plants and animals. A study showed that wetlands prevented $625 million in direct flood damages during Hurricane Sandy in the United States (Narayan *et al.*, 2017). The services that wetlands provide are lost when they are altered from their natural state to support alternative land uses such as agriculture, urbanization, industrial development, and recreation.

PHOTO CREDIT: DON JARDINE

1 Marine infrastructure (e.g., wharves) is discussed in the Fish and Aquaculture sector chapter.

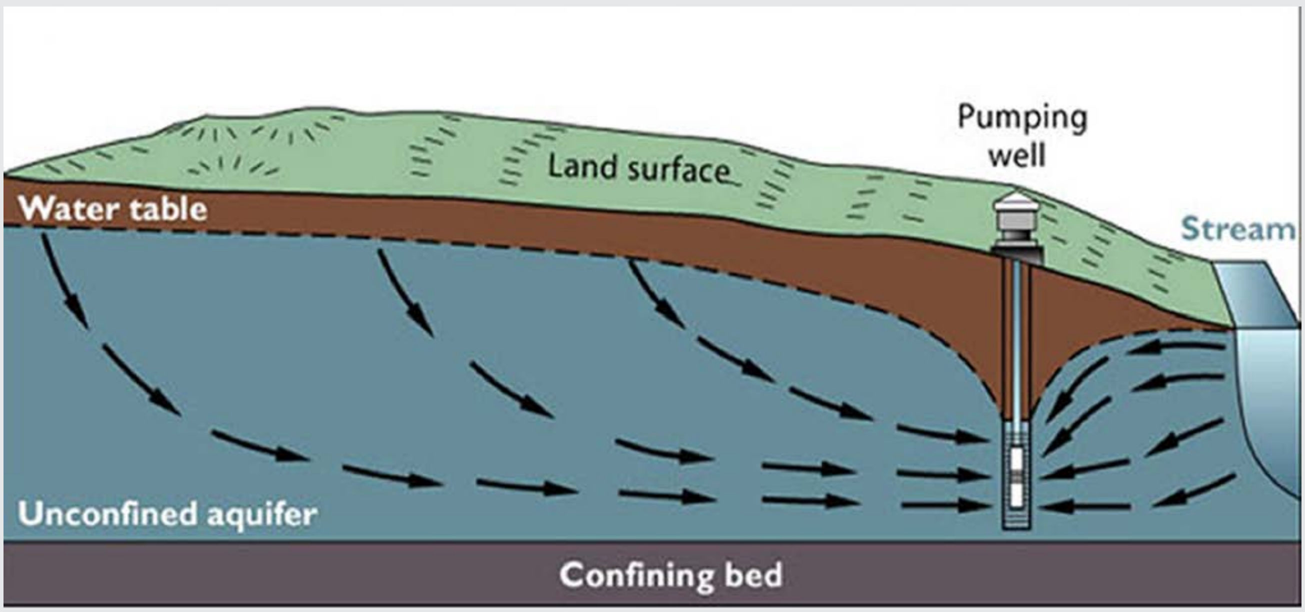


Figure 12.1: Groundwater and aquifer (Source: http://www.livinghistoryfarm.org/farminginthe50s/media/water1201.jpg).

12.1.1 Water Infrastructure

On Prince Edward Island, groundwater is the sole source of drinking water. There are 14 communities on the Island that provide treated water through the water distribution facilities they operate (PEI Department of Communities, Land and Environment [PE CLE], 2017). However, 57% of Islanders depend on private wells, the highest percentage in the country (National Collaborating Centre for Environmental Health [NCCEH], 2014).

There are approximately 250 watersheds on the Island, ranging from a few square kilometres each to approximately 150 km^2. A watershed is an area of land over or under which water flows from the land toward a stream, river, or ocean. Evaporation and transpiration send about 40% of the island's precipitation to the atmosphere; the remaining 60% becomes streamflow (PEI Department of Fisheries and Environment, and Environment Canada, 1996).

In Prince Edward Island, wells and water distribution facilities draw water from groundwater. Wells are drilled into aquifers, the zone beneath the water table that is saturated with water. Aquifers are recharged when precipitation infiltrates down to the aquifer or when water from streams enters the aquifer (see Figure 12.1). Poor water quality can be detrimental to human health. Waterborne diseases, runoff, saltwater intrusion, and cyanobacteria are areas of concern for the Island[2].

12.1.2 Wastewater Infrastructure

Approximately 55% of Islanders rely on central sewage collection and treatment systems (NCCEH, 2014). There are 30 communities on the Island that provide wastewater treatment services through the facilities they operate (PE CLE, 2017). Many industrial sites operate their own treatment facilities (NCCEH, 2014), as do some campgrounds and subdivisions. Islanders not serviced by these systems rely on septic systems, which treat household wastewater before returning it to the environment (see Figure 12.2).

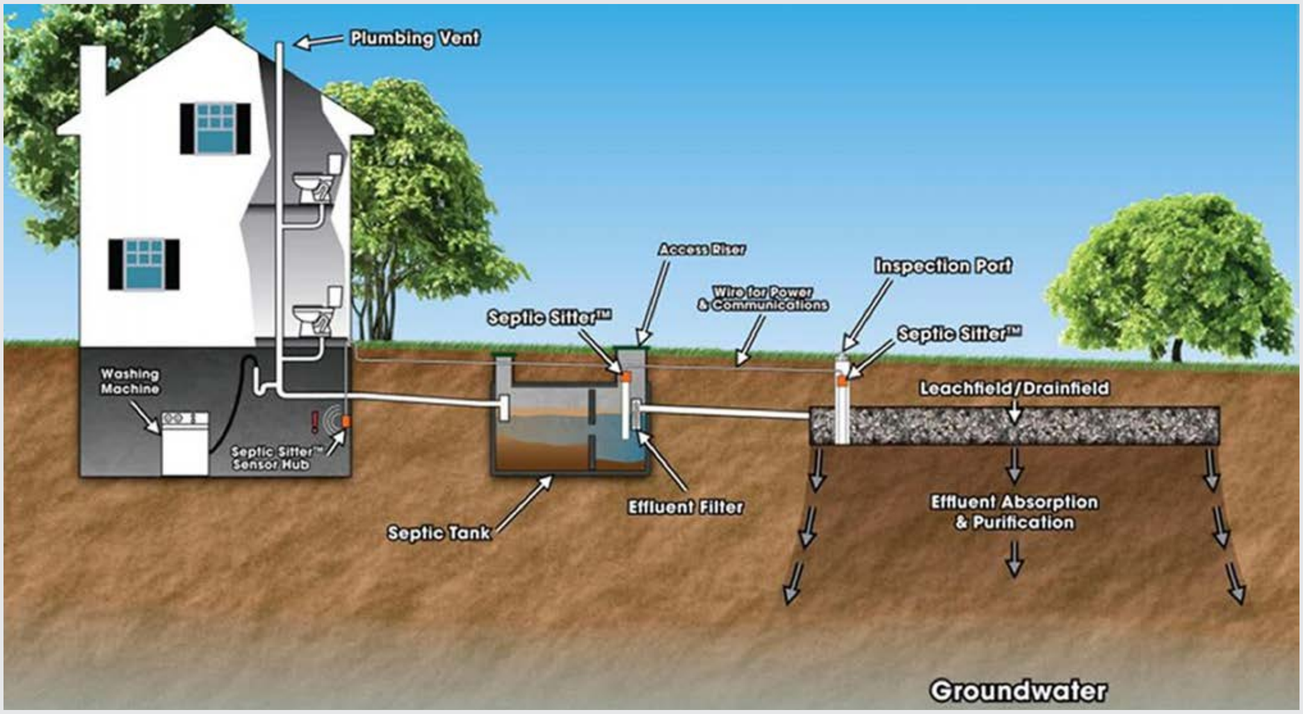


Figure 12.2: Septic system (Source: https://www.hi-techplumbingandair.com/wp-content/uploads/2015/10/Septic-Drainfield.jpg).

2 These are discussed in greater detail within the Public Health and Safety Sector chapter.

12.2 Climate Change Impacts

Climate change will bring about warmer temperatures, changes in precipitation patterns, more frequent and severe extreme weather events, and rising sea levels. These will present a number of challenges to the management of stormwater and the maintenance of water quantity and quality on Prince Edward Island[3].

12.2.1 Temperature

CHALLENGES

First, warmer temperatures will lead to a decrease in the extent and duration of snow cover (Toronto and Region Conservation and ESSA Technologies, 2012). This will reduce the amount of water that infiltrates down to recharge aquifers during spring melt. The timing of this process will also be affected.

Second, warmer temperatures could lead to more rain events in the winter months when the ground is frozen and unable to absorb the rain. This causes the rain water to run off the surface rather than infiltrate down to the aquifer, affecting water quantity. Some of this water will enter wastewater systems, increasing operational costs (Andrey *et al.*, 2014).

Third, rising air temperature increases evapotranspiration (i.e., loss of water to the atmosphere via evaporation and plant transpiration). If the water is lost to the atmosphere before it can filter from the surface down to the aquifer, water quantity in the aquifers would be reduced.

Fourth, winter thaw events could occur more frequently with rising temperatures. In systems where sewer and stormwater management functions are combined, the cold runoff can reduce the system's ability to perform its biological nitrogen removal and secondary clarification functions (Andrey *et al.*, 2014).

Fifth, higher temperatures could affect the taste and odour of treated water (Andrey *et al.*, 2014).

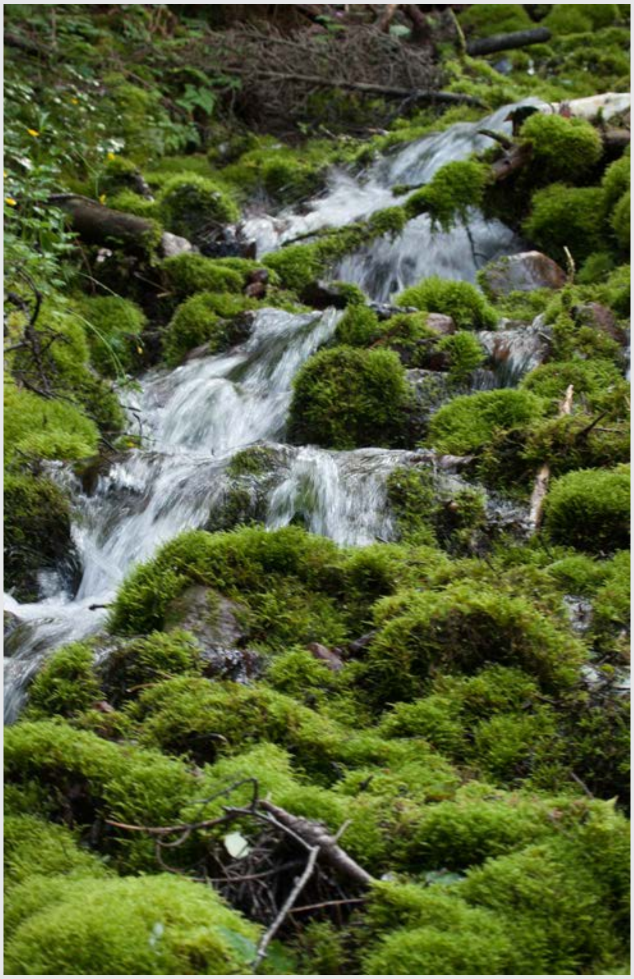


PHOTO CREDIT: DON JARDINE

3 This chapter focuses on the impacts on water infrastructure. Effects of climate change related to other aspects of water are covered in the relevant sector chapters. Topics include irrigation (Agriculture, Tourism), salinity and surface water temperature (Fish and Aquaculture), water-borne diseases (Public Health & Safety), and flooding (Insurance, Properties & Infrastructure).

12.2.2 Precipitation

CHALLENGES

First, reduced precipitation could lead to changes in the extent and timing of stream and aquifer recharge, affecting levels and availability of freshwater.

Second, the increasing intensity of rain events could increase the transport of pollutants such as silt, chemicals, hydrocarbons, and heavy metals from industrial operations to uncontaminated drinking water and recreational water areas via runoff, impacting water quality. This is especially problematic with drier summers, which may lead to longer periods of low soil moisture and an increase in soil shrinkage cracks, creating a more extensive and connected macropores (i.e., large soil pores) system for runoff to flow through (Boxall *et al.*, 2009). Furthermore, changes in precipitation levels could reduce water levels in rivers, increasing the concentration of pathogens and contaminants in the water.

Third, reduced precipitation means less water is available at wastewater treatment facilities for dilution. This could lead to accumulation of solid waste sediments in conduits that could cause clogging (Nedvedova, n.d.).

Fourth, changes in precipitation patterns could lead to a higher risk of wildfires, which can negatively affect the quality of source water for many years (Andrey *et al.*, 2014). For example, the 2003 Lost Creek fire in Alberta caused years of increased turbidity, total organic carbon and nitrogen in runoff, especially during spring melt and after rainstorms (Andrey *et al.*, 2014).

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: DON JARDINE

12.2.3 Extreme Weather Events

CHALLENGES

First, higher wave energy from more intense extreme weather events could damage effluent pipes from wastewater treatment systems. It could also increase coastal erosion, putting water infrastructure located within the coastal area (e.g., septic systems) at risk.

Second, lift stations for wastewater treatment facilities located in the flood risk zone will be more likely to be inundated by higher storm surge.

Third, runoff from extreme rainfall events increases the risk of overwhelming wastewater treatment systems, causing overflows; reduces aquifer recharge, since the water is not absorbed into the ground; and creates runoff that can carry contaminants from land (e.g., silt, chemicals, hydrocarbons, heavy metals) to uncontaminated areas (e.g., wells, rivers, beaches), affecting the quality of drinking and recreational water.

PHOTO CREDIT: DON JARDINE

12.2.4 Sea Level Rise

CHALLENGES

First, rising sea levels could affect the saltwater-freshwater interface in the aquifers, leading to saltwater intrusion of wells (see Figure 12.3). Elevated levels of saline in drinking water could cause serious health implications such as hypertension and stroke (Vineis *et al.*, 2011). Some coastal communities in Prince Edward Island have already experienced saltwater intrusion.

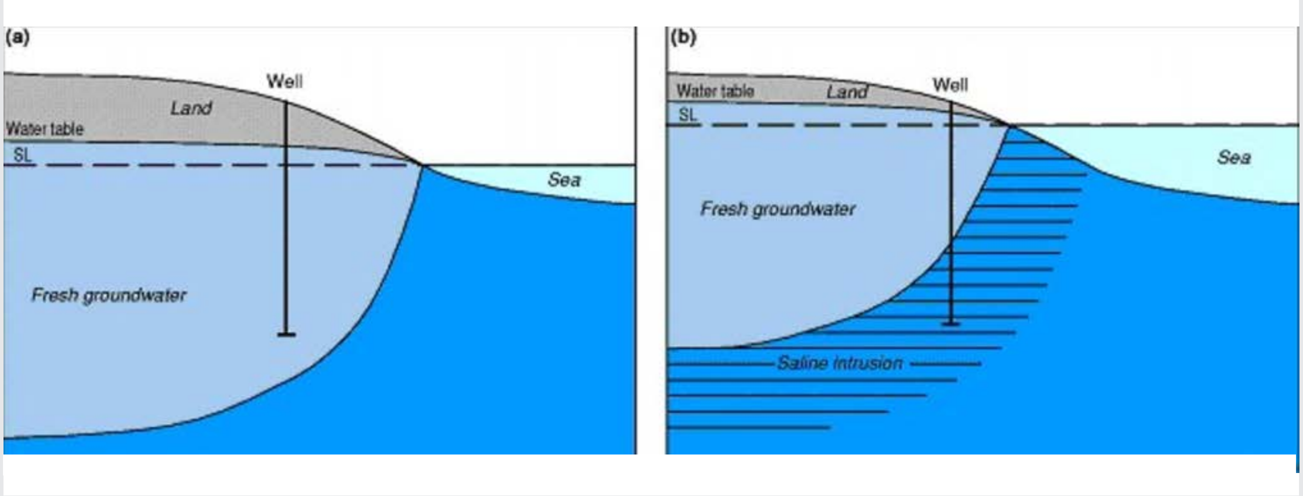


Figure 12.3: The impact or sea level rise on the saltwater-freshwater interface. (a) Water intake before sea level rise (b) water intake after sea level rise (Source: http://www.ozcoasts.gov.au/indicators/images/saltwater_freshwater.jpg).

Second, saltwater intrusion from rising sea levels could degrade sewer conduits and affect the quality of wastewater (Andrey *et al.*, 2014)

Third, rising downstream levels from higher sea levels may necessitate the pumping of effluent (rather than rely solely on gravity flow), increasing operating costs (Danas *et al.*, 2012).

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

PHOTO CREDIT: GOVERNMENT OF PEI

12.3 Recommended Adaptation Actions

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

81 **Identify and address gaps in data, training, knowledge and tools**. For example:

- **a.** additional weather stations to collect local data for accurate high-resolution modeling and projections;
- **b.** improved understanding of groundwater recharge and discharge rates (e.g., impact of snow cover on water supplies) and how they will be affected under a changing climate;
- **c.** forecasting for low water levels and drought conditions;
- **d.** strategies to respond to low water levels (e.g., economic and operational viability of a desalination plant);
- **e.** research on point source pollution and controls;
- **f.** training on watershed monitoring and restoration;
- **g.** visualization model demonstrating groundwater recharge and other issues (for public outreach);
- **h.** soil moisture monitoring; and,
- **i.** downscaling of soil aridity models.

Suggested timeline: short-term (0 to 5 years)

82 **Integrate climate change considerations in financial planning**. This applies to water infrastructure owners and managers. Budgetary constraints are often a barrier to implementing adaptation actions but this could be partly addressed through improved financial planning. For example, when an individual purchases a home, the age and condition of the roof is often part of the home inspection and factored in the purchase price. The repair and replacement of the roof is an accepted aspect of homeownership. The roof is generally replaced before it deteriorates to a point that rain leaks through. Similarly, water infrastructure owners and managers need to consider the costs and timing of adaptation actions in relation to the costs associated with the increase in liability, increase in maintenance, shorter lifespan, etc. While implementing adaptation actions incur an upfront cost, it can save a considerable amount of money over the lifetime of assets and infrastructure, often resulting in a net positive financial position overall.
Suggested timeline: ongoing

83 **Set a future climate scenario** to establish design standards for the building, upgrading, or retrofitting of water infrastructure, based on the expected lifespan of the infrastructure[4]. A design beyond the current 1-in-100 year events should be chosen since those will become more severe over the lifetime of the infrastructure (e.g., 1-in-200, 1-in-1000). For example, should a wastewater treatment be built to withstand 1-in-200 year or 1-in-500 year rain events? Should they consider these events under the current, 2050, or 2100 time frame?
Suggested timeline: short-term (0 to 5 years)

4 Refer to the Properties and Infrastructure Sector chapter for additional considerations when siting new facilities (e.g., coastal erosion).

PHOTO CREDIT: DON JARDINE

PHOTO CREDIT: DON JARDINE

84 Put **back-up systems** in place at water distribution and wastewater treatment facilities (e.g., spare flood pumps, back up electricity source) to limit disruptions to service during extreme weather events.
Suggested timeline: short-term (0 to 5 years)

85 **Prompt the development of natural and manmade climate-resilient water infrastructure** by incorporating future climate considerations and using land use planning policies and regulations (e.g., zoning, setbacks, permits) where incentive for preventive action is not strong enough. The Provincial Land Use Planning Act and Regulations and the Municipal Official Plans and Bylaws should be updated to:

- **a.** ensure consistency between the Provincial Land Use Planning Act and Regulations and the Municipal Official Plan and Bylaws;
- **b.** set a future climate scenario standard (see Recommended Adaptation Action #83);
- **c.** establish a vertical setback of 2 metres above higher high water large tide (HHWLT) for services and water infrastructure with HHWLT being the average of the past 10 years of high tide elevations for an area;
- **d.** preserve and augment natural features to manage flooding (e.g., limit development to allow rivers to expand into side channels and wetland areas);
- **e.** include septic tanks and wells in building setback requirements;
- **f.** require additional information during the development permit process to ensure the asset/infrastructure owner has considered climate change impacts and met the future climate scenario standard (e.g., lot drainage plans, survey plans);
- **g.** require stormwater management at source (i.e., onsite);
- **h.** limit development in areas that would disrupt connectivity in floodplains and aquatic habitats;
- **i.** limit ditch infilling;
- **j.** increase inspections to ensure compliance and impose higher fees and stricter penalties for non-compliance; and,
- **k.** establish a voluntary conservation covenant or easement, which prohibit development on a portion or all of the property or removal of native vegetation, in areas that are sensitive to climate change impacts in exchange for a property tax reduction or credit (Richardson and Otero, 2012). The owner could continue to own the land, live on it, sell it, or pass it on but the covenant would continue regardless. This should be reviewed on a case-by-case basis and entered into only when the preservation of land has measurable benefits (e.g., improve climate resilience).

Suggested timeline: short- to medium-term (0 to 10 years)

86 **Reduce demand on water infrastructure** as a quicker and more cost effective way to increase capacity. For example:

a. educate and sensitize the public to the limitations of and challenges facing groundwater. Canada's wealth in freshwater resources could otherwise make water quantity an afterthought;
b. consider implementing stormwater discharge fees; and,
c. give the public and industries practical recommendations on how to reduce demand (e.g., behavioural changes, low-flow showerheads, rainwater harvesting, water reuse, gray water systems, onsite water retention techniques). Consider the model used by efficiency PEI to promote energy conservation and energy efficiency.

Suggested timeline: short-term (0 to 5 years)

Figure 12.4: Green roof in Charlottetown, PE, Canada (Photo credit: Atlantic Green Contractors – with permission).

87 **Actively maintain, restore, enhance and create wetlands** to increase natural protection of coastal areas and improvements in water quality and quantity. For example:

a. build upon existing inventory of potential sites;
b. prioritize sites based on feasibility and potential benefits;
c. maintain a program to continually monitor wetlands for signs of degradation in ecological integrity, natural structure, natural function, etc.;
d. incorporate wetland protection into infrastructure planning (e.g., transportation planning); and,
e. provide necessary training to landowners, watershed groups, other sectors such as Agriculture and Fish and Aquaculture, and other interested parties to assist with the work.

Suggested timeline: medium- to long-term (6+ years); ongoing maintenance

88 Utilize **complementary green infrastructure** to manage stormwater. Studies show that green infrastructure is more cost-effective and less energy intensive than traditional stormwater management infrastructure (Morand *et al.*, 2015). Some can be installed by individuals and businesses due to their often small-scale, decentralized nature. For example:

a. green roofs, which capture rainfall to reduce runoff. (See Figure 12.4) They also moderate local air temperature, reduce energy costs (they provide added insulation value to buildings), and improve air quality (Morand *et al.*, 2015). They have been successfully used at large scales in Basel, Switzerland and New York City, USA. Basel is a town of 195,000 people and has more than 1.2 million square meters of rooftops covered with vegetation as of 2014 (Morand *et al.*, 2015). This adaptation action was driven by the desire to reduce energy costs and mitigate against climate change (Morand *et al.*, 2015);

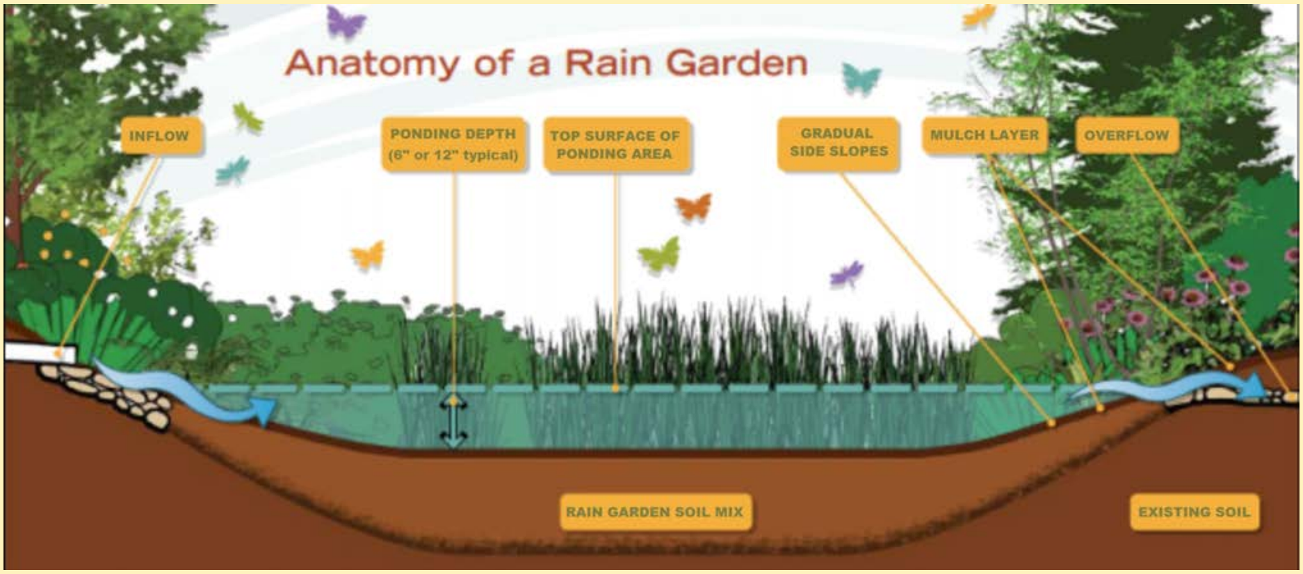


Figure 12.5: Anatomy of a rain garden (Source: http://ext100.wsu.edu/raingarden/wp-content/uploads/sites/74/2016/01/rg-schematic.png).

b. rain gardens, which temporarily store rainwater. This allows the water extra time to evaporate and infiltrate into the ground, thereby decreasing the demand on stormwater management systems (Chisholm, 2008) (see Figure 12.5). This reduces runoff and can remove up to 40-97% of nutrients and metals found in stormwater runoff (Chisholm, 2008). Rain gardens are typically dug below-grade (between 6 to 12 inches) and at a larger scale, overflow drains could be added and connected to municipal wastewater treatment system to handle the excess flow (Chisholm, 2008). The mulch and soil in a rain garden absorb some of the pollutants and provide a habitat for microorganisms that degrade the contaminants (Chisholm, 2008). Water-tolerant vegetation should be chosen to slow runoff, absorb nutrients, and trap sediment (Chisholm, 2008). In urban areas, rain gardens can be placed in the center of roundabouts, alongside streets, etc.;

c. ditches, swales and other pervious surfaces (see Figure 12.6) alongside impervious surfaces such as

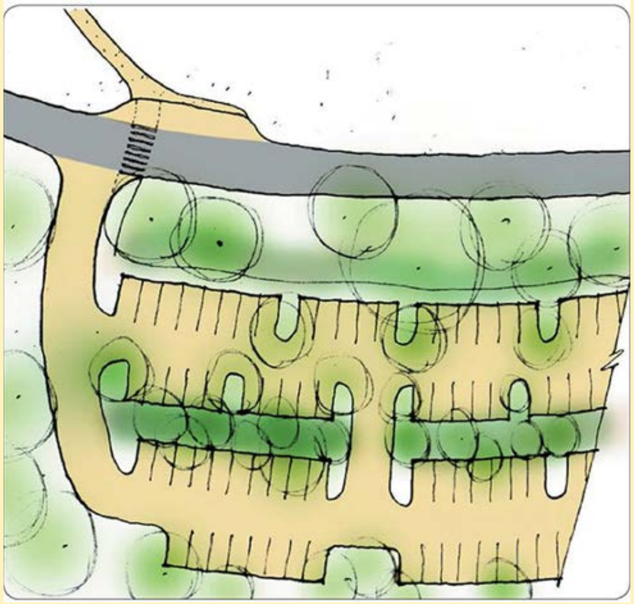


Figure 12.6: The use of green swales around a parking lot (Source: http://ucanr.edu/sites/Rod_Shippey_Facility/Green_Works/Permeable_Parking_Lot/).

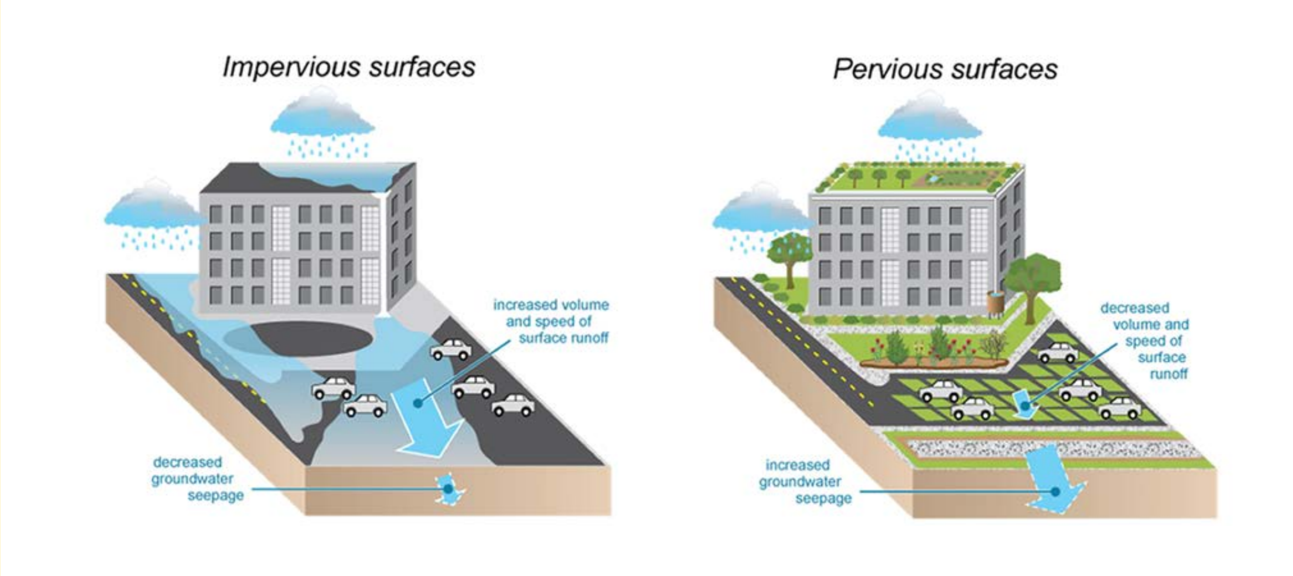


Figure 12.7: Comparing impervious surfaces and pervious surfaces (Source: http://2.bp.blogspot.com/-LRuYBmc8LJU/VAnq6G-1KodI/AAAAAAAAAZE/GbMzmJlefNM/s1600/LID.png).

roads and parking lots to capture rainwater and reduce runoff. These green features slow the flow of runoff and allow it an opportunity to filter into the ground and recharge the aquifer; and,

d. network of drainage ditches and detainment ponds to reduce the extent and intensity of water flow downstream by capturing rainwater and slowing its flow to the natural system.

Suggested timeline: short- to medium-term (0 to 10 years)

89 Create a **pilot project** to demonstrate bioretention techniques (see Recommended Adaptation Actions #62d and #88). Currently, the necessary knowledge or experience to construct green infrastructure may not be commonplace among builders and contractors. The project could involve students from UPEI Climate Research Lab, UPEI School of Sustainable Engineering Design, Holland College Environmental Applied Science Technology, and Apprenticeship programs in the design, construction, and maintenance phases. Exhibits with information for the public will be available on site. This demonstration site can incorporate adaptation actions from other sectors as well (e.g., solar energy panels and electricity storage). An interactive display featuring the CoastaL Impact Visualization Environment (CLIVE) and other outreach tools could help raise awareness of climate change impacts.
Suggested timeline: short-term (0 to 5 years)

90 Develop and supply available **flood risk maps** to municipalities with water infrastructure. Municipalities should complete a **vulnerability assessment** of their water infrastructure components. The map could also be used to identify potential sites for complementary elements such as retention ponds.
Suggested timeline: short- to medium-term (0 to 10 years)

91 **Engage in public outreach**. Provide guidance to individuals and businesses on how to minimize their risk of flooding and improve water security. For example, clear snow and overgrown vegetation from ditches prior to an intense rain event to prevent flooding, choose appropriate vegetation for rain gardens that can withstand Island climate, install sewer backwater valve, etc.
Suggested timeline: ongoing

92 Provide **financial incentives** to property owners to manage stormwater on site (e.g., rain gardens, permeable surfaces, ditches).
Suggested timeline: short-term (0 to 5 years)

93 **Coordinate with other sectors** and share best practices in maintaining water quality and sustaining water quantity (e.g., retention of water to reduce irrigation requirements for golf courses and agriculture lands, drainage strategies for woodlot owners; reduce runoff to aquaculture areas).
Suggested timeline: ongoing

94 **Decommission unused wells** to prevent the risk of contamination (e.g., from runoff or flood waters).
Suggested timeline: ongoing

The collaboration of the public, water infrastructure owners, sector, experts (e.g., climate scientists, engineers), and governments will be critical in achieving effective adaptation. The table below summarizes the fourteen recommended adaptation actions for the sector and proposes how the responsibilities for implementing them could be shared. Leadership in an adaptation action could include championing for the need to implement the action, securing necessary funding, and managing the collaborative efforts. Collaboration in an adaptation action could include providing expertise, resources (e.g., financial, time), and support.

Table 12.1: Summary of recommended adaptation actions for the water sector.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
81. Identify and address gaps in data, training, knowledge and tools (e.g., install weather stations, improve understanding of groundwater recharge and discharge rates, provide training on watershed monitoring and restoration).	Lead: Provincial Government, Water infrastructure owners Collaborators: Experts	Fill knowledge gaps	Short-term (0 to 5 years)
82. Integrate climate change considerations in financial planning. Water infrastructure owners and managers need to consider the costs and timing of adaptation actions in relation to the costs associated with the increase in liability, increase in maintenance, shorter lifespan, etc.	Leads: Water infrastructure owners Collaborators: Experts	Address financial concerns; Promote climate change mainstreaming	Ongoing
83. Set a future climate scenario to establish design standards and analyze the resilience of existing infrastructure (e.g., should stormwater management systems be built to withstand 1-in-50 year or 1-in-100 year rain events and are the events taking place in 2020, 2050 or 2100?)	Leads: Provincial Government, Water infrastructure owners and managers Collaborators: Experts	Promote climate change mainstreaming	Short-term (0 to 5 years)

Table 12.1: Continued.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
84. Put back-up systems in place to limit disruptions to service during extreme weather events (e.g., spare flood pumps, back up electricity source).	Leads: Water infrastructure owners and managers	Increase resilience	Short-term (0 to 5 years)
85. Prompt the development of natural and manmade climate-resilient water infrastructure by incorporating future climate considerations and using land use planning policies and regulations (e.g., limit ditch filling).	Lead: Provincial Government Collaborators: Experts	Leverage regulation; Promote climate change mainstreaming	Short- to medium-term (0 to 10 years)
86. Reduce demand on water infrastructure (e.g., sensitize public to the challenges facing groundwater, provide practical recommendations on how to reduce demand).	Lead: Provincial Government Collaborators: Educators, Public	Increase resilience	Short-term (0 to 5 years)
87. Actively maintain, restore, enhance and create wetlands to increase natural protection of coastal areas and improvements in water quality and quantity.	Lead: Provincial Government Collaborators: Property owners, Sectors, Experts, Watershed groups	Increase resilience; Promote climate change mainstreaming	Medium- to long-term (6+ years); Ongoing maintenance
88. Utilize complementary green infrastructure to manage stormwater (e.g. green roofs, rain gardens, ditches, detainment ponds).	Leads: Property owners, Water infrastructure owners and managers Collaborators: Provincial and municipal governments, Experts	Increase resilience	Short- to medium-term (0 to 10 years)
89. Create a pilot project to demonstrate bioretention techniques (see Recommended Adaptation Actions #62d and #88).	Leads: Provincial Government, Educators	Engage in outreach; Fill knowledge gaps	Short-term (0 to 5 years)
90. Develop and supply flood risk maps to municipalities with water infrastructure.	Lead: Provincial Government Collaborators: Municipal governments	Fill knowledge gaps	Short- to medium-term (0 to 10 years)
91. Engage in public outreach. Provide guidance on how to minimize the risk of flooding and improve water security.	Lead: Provincial Government Collaborators: Municipal governments, Educators	Engage in outreach	Ongoing
92. Provide financial incentives to property owners to manage stormwater on site (e.g., ditches, permeable surfaces).	Leads: Provincial Government, Municipal governments, Water infrastructure owners and managers	Address financial concerns	Short-term (0 to 5 years)
93. Coordinate with other sectors and share best practices in maintaining water quality and sustaining water quantity.	Lead: Provincial Government Collaborators: Water infrastructure owners and managers, Other sectors	Increase collaboration	Ongoing
94. Decommission unused wells to prevent risk of contamination.	Leads: Provincial Government, Property owners	Increase resilience	Ongoing

12.4 Conclusion

Some of the most pervasive impacts of climate change will be related to water (Andrey *et al.*, 2014), one of the Island's most precious resources. Every region in Canada will experience a reduction in water quality and quantity on a seasonal basis (Andrey *et al.*, 2014). Maintaining water quality and sustaining water quantity on Prince Edward Island is critical and everyone's responsibility. It will require a concerted effort to work together to effectively address the challenges that climate change will bring to the sector.

REFERENCES

Andrey, J., P. Kertland, and F.J. Warren. (2014). Water and Transportation Infrastructure. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 233-252.

Boxall, A.B.A., A. Hardy, S.Beulke, T. Boucard, L. Burgin, P.D. Falloon, … R.J. Williams. (2009, April). Impacts of Climate Change on Indirect Human Exposure to Pathogens and Chemicals from Agriculture. *Environmental Health Perspectives*, 117 (4), 508-514.

Boyle, J., M.Cunningham, and J. Dekens. (2013, November). *Climate Change Adaptation and Canadian Infrastructure: A review of the literature*. Retrieved from http://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf

Chisholm, H. (2008, March 31). *Climate Change and Water Resources: An analysis of the applicability of rain gardens in Annapolis Royal, NS*. Retrieved from http://www.cip-icu.ca/Files/Resources/Report1-H-Chisholm

Danas, K., B. Kurdi, M. Stark, and A. Mutlaq. (2012, September 18). *Climate Change Effects on Waste Water Treatment* [Presentation]. Retrieved from http://courses.washington.edu/cejordan/CC%20AND%20WWT.pdf

Morand, A., R. Hennessey, J. Pittman, and A. Douglas. (2015). *Linking Mitigation and Adaptation Goals in the Energy Sector: A Case Study Synthesis Report*. Report submitted to the Climate Change Impacts and Adaptation Division, Natural Resources Canada, 122p.

Narayan, S., M.W. Beck, P. Wilson, C.J. Thomas, A. Guerrero, C.C. Shepard, B.G. Reguero, G. Franco, J.C. Ingram, and D. Trespalacios. (2017, August 31). The Value of Coastal Wetlands for Flood Damage Reduction in Northeastern USA. *Scientific Reports 7*. Article number: 9463. doi:10.1038/s41598-017-09269-z

National Collabrating Centre for Environmental Health. (2014, February). *Small Drinking Water Systems: Who Does What in Prince Edward Island?* Retrieved from http://www.ncceh.ca/sites/default/files/SDWS_Who_What_PEI.pdf

Nedvedova, D. (n.d.). *Adaptation Measures for Drainage, Sewage and Wastewater Treatment in Extreme Weather Events* [Presentation]. Retrieved from https://www.unece.org/fileadmin/DAM/env/water/meetings/TF_EWE/2nd_meeting/power_points/WSS_ixtreme_weather_Czech..pdf

PEI Department of Communities, Land and Environment. (2017, March). *Municipal Water/Wastewater Facility List*. Retrieved from https://www.princeedwardisland.ca/sites/default/files/publications/municipal_water_and_wastewater_system_list.pdf

PEI Department of Fisheries and Environment and Environment Canada. (1996). *Water on Prince Edward Island: Understanding the resource, knowing the issues*. Retrieved from http://www.gov.pe.ca/photos/original/elj_waterpei_rp.pdf

Toronto and Region Conservation and ESSA Technologies. (2012). *Mainstreaming Climate Change Adaptation in Canadian Water Resource Management: The state of practice and strategic directions for action*. Toronto and Region Conservation Authority: Toronto, ON. pp 79.

Vineis, P., Q. Chan, and A. Khan (2011). Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health*, 1(1), 5-10.

13

People tend to focus on the here and now. The problem is that, once global warming is something that most people can feel in the course of their daily lives, it will be too late to prevent much larger, potentially catastrophic changes.

—Elizabeth Kolbert

13 CONCLUSION

13.1 Implementing Adaptation Actions

Different groups – individuals, businesses, sectors, non-governmental organizations, research institutions, various levels of governments, etc. – would likely take different paths in adapting to climate change. However, there are a number of phases that may be common for all groups: becoming aware of climate change, becoming aware of the need to adapt, mobilizing resources, building capacity to adapt, implementing adaptation actions, measuring and evaluating progress, learning and sharing knowledge with others, and adjusting (Eyzaguirre and Warren, 2014). The last phase involves the refinement of adaptation actions and application of knowledge to inform future adaptation actions. This highlights the need to understand that adaptation is an evolving process, requiring planning and research to ensure that it is effective, efficient, cost-effective and equitable (HM Government, 2013).

Throughout the sector consultation sessions, the consensus on climate change and the need to adapt was clear. However, barriers exist across all groups and sectors that are preventing efficient and effective adaptation from taking place. There were high levels of awareness and adaptive capacity observed at the consultation sessions but these do not necessarily translate to effective adaptation. The common barriers and the associated potential solutions include:

1. Uncertainty
   Gaps in knowledge increase the concern of over-, under-, or maladaptation. These gaps can be addressed by collaborating with experts outside of the sector (e.g., climate scientists); gathering customized, user-oriented, and high-resolution data; and using the data to build models to help understand and prevent negative impacts before they occur. In the meantime, sectors can select 'win-win' and 'low-regret' adaptation strategies that provide short-term benefits at low costs.

2. Lack of funding
   Adaptation actions often require up-front investments, which compete for funds already earmarked for day-to-day operations. Many preventive adaptation options are less costly than inaction over the long run. As with other business and personal decisions, growth and sustainability of a business require careful financial planning, with a long-term view in mind.

3. Insufficient incentive
   Motivations to implement adaptation actions are often muted by the overwhelming nature of global climate change (e.g., "bigger than self") or limitations in funding. However, in instances where public health and safety, environmental sustainability or economic sustainability is at risk, adaptation must take place. The different levels of government may need to use regulatory approaches to compel individuals and businesses to adapt.

4. Lack of guidance
   The willingness to adapt must be matched with the availability of guidance, particularly for the public, in order for effective adaptation to take place. This can be accomplished via access to decision support tools, demonstrations of successful approaches, and other outreach initiatives.

PHOTO CREDIT: DON JARDINE

5. High level of coordination
   The need for expertise from various stakeholders within the sector, in other sectors, and across different levels of government makes effective coordination and partnerships challenging. Each sector should nominate a champion, someone with a passion for and knowledge of environmental and sectoral issues as well as the ability to work in an interdisciplinary manner to lead the charge. The champions would be tasked with identifying opportunities for collaboration, pinpointing relevant experts across different sectors, and providing leadership in adaptation.

6. Gradual nature of climate change
   It is easy to think of climate change as a slow, gradual process with increases in loss occurring incrementally (Canadian Electricity Association, 2016), making the promotion of immediate climate change action difficult. Rather than rely on this as an opportunity to delay adaptation, it should be viewed as an opportunity to implement effective adaptation strategies that require long lead-times to develop.

Similarly, despite the unique characteristics of each sector, common themes emerged from the recommended adaptation actions: fill knowledge gaps, increase resilience, reduce non-climatic factors, promote climate change mainstreaming, increase collaboration, engage in public outreach, leverage regulation, and address financial concerns.

13.2 Shared Responsibility

Climate change is a shared problem that requires shared responsibility from all groups. Where joint action from multiple groups and sectors are needed, a clear vision of their shared best interest is essential.

Governments play an important role when existing incentives are insufficient or nonexistent to overcome barriers to timely and effective action critical to the health of the environment, society, and/or economy of their country, province, territory, or community. For example, Canada was the first nation to ratify the Vienna Convention on the Protection of the Ozone Layer in 1986 and negotiated and signed the Montreal Protocol on Substances that Depletes the Ozone Layer in 1987 (Environment and Climate Change Canada [ECCC], 2010). These actions by the federal government were part of a critical global initiative to eliminate the production and import of nearly 100 substances that deplete the ozone layer (ECCC, 2010). Another example is the provincial Waste Watch program launched Island-wide in 2002. Prince Edward Island is the only province that offers all residents a curbside three source separation system (i.e., waste, compost and recyclables) (Government of Prince Edward Island, n.d.). A Statistics Canada report shows that the Island has the country's highest waste diversion rate per capital, reducing the amount of waste going to landfills by half (Yarr, 2017). Similarly, the Provincial Government has a critical role to play in climate change adaptation. Its ability to coordinate and implement large-scale initiatives, authority to compel action, and expertise across all sectors make it the ideal lead in the development of a medium- and long-term strategy in adapting to climate change. For example, water quality impacts all sectors. The

Provincial Government could lead a coordinated plan to reduce runoff, improving the resilience of the Island's environment, society and economy. This would involve a multi-pronged approach: widening watercourse and wetland buffer zones, enforcing watercourse and wetland protection regulations, collecting climate and environmental data, providing guidance on water management to businesses and individuals, and so forth. However, the Provincial Government cannot do it on its own. Successful adaptation requires complementary action by sectors, businesses, research institutions, non-governmental organizations, and individuals, given the localized nature of climate change impacts and the need for private adaptation. For example, farmers can develop water management practices and structures (e.g., rainwater harvesting, manmade ponds, soil feature), home owners and business owners can install rain barrels, rain gardens or green roofs, and maintain or restore drainage ditches. Not only would these efforts improve water quality, it would have additional benefits of increasing biodiversity; improving stream and aquifer recharge; and reducing the need for irrigation, severity of gully erosion, frequency of infrastructure washouts, and flood risk to homes and buildings.

When public and private sectors combine intellectual and other resources, more can be achieved.

—Gro Harlem Brundtland

13.3 Moving Forward

Each recommendation below includes details and examples for clarification purposes. The suggested timelines are based on factors such as the nature and complexity of the recommendation (e.g., information gathering is usually performed in the short-term to inform the implementation of other adaptation actions), the expected timing of the climate change impacts, and the associated cost. It is important to note that the needs of the Island will change as the climate and the environment, society, and economy of the Island change. It will be the responsibility of the leads to gauge the state and needs of the Island, review the data available at the time the decisions are made, and consult with collaborators to determine the best way forward.

95 **Educate elected officials and decision-makers** on the importance and urgency of climate change adaptation. Climate mitigation strategies alone are unlikely to be sufficient to eliminate the negative impacts of climate change. These impacts must be confronted now; adaptation work must begin immediately. It is critical for decision-makers and elected officials to provide leadership as Prince Edward Island transitions from coping with immediate damages to developing and achieving a clear vision of sustainability for the Island's environment, society, and economy in the face of a changing climate.
Suggested timeline: ongoing

96 **Issue a clear directive** to all provincial government departments to incorporate climate change in all decision-making, planning, budgeting, etc. Strong leadership and a clear directive will be vital for meaningful adaptation work to begin.
Suggested timeline: short-term (0 to 5 years)

97 **Build a province-wide framework** for cooperative and coordinated climate change adaptation response across sectors, leads, and collaborators. For example, create a central body to:

- **a.** coordinate the design and implementation of adaptation strategies and actions to ensure that adaptation goals are aligned, efforts are not duplicated, resources are shared effectively, and activities are appropriately sequenced across all sectors;
- **b.** ensure an interdisciplinary approach to climate change adaptation;
- **c.** establish and manage working groups to address recommended adaptation actions with similar goals (e.g., storm-water management working group, habitat restoration working group, public outreach working group)
- **d.** promote accountability to foster commitment and cooperation;
- **e.** facilitate and assist in the development or implementation of adaptation actions by individuals and groups as long as the actions are aligned with the province-wide framework (e.g., provide training, make data available);
- **f.** identify funding opportunities and work with relevant stakeholders to develop proposals;
- **g.** promote awareness and understanding of climate change adaptation;
- **h.** work with climate change mitigation actors to identify co-benefits;
- **i.** revaluate adaptation actions and adaptation plan as technology, data, situation, etc. change; and
- **j.** measure, evaluate, and report on progress and success of adaptation actions.

Suggested timeline: ongoing

Table 13.1: Summary of recommended adaptation actions for moving forward.

Recommended Adaptation Actions	Responsibilities	Themes	Suggested Timelines
95. Educate elected officials and decision-makers on the importance and urgency of climate change adaptation.	Lead: Provincial Government Collaborators: Municipal governments, Experts	Fill knowledge gaps	Ongoing
96. Issue a clear directive to all provincial government departments to incorporate climate change in all decision-making, planning, budgeting, etc. Strong leadership and a clear directive will be vital for meaningful adaptation work to begin.	Lead: Provincial Government	Increase resilience; Promote climate change mainstreaming	Short-term (0 to 5 years)
97. Build a provincial-wide framework for cooperative and coordinated climate change adaptation response across sectors, leads, and collaborators.	Lead: Provincial Government Collaborators: Federal Government, Municipal governments, Sectors, Experts, Businesses, Non-governmental organizations, Public	Increase collaboration	Ongoing

Gradual and incremental changes to the status quo alone will be insufficient in the face of future climate. Meaningful and successful climate change adaptation for the Island will require coordinated, collaborative, complementary, and parallel approaches by the different leads and collaborators identified by this report (e.g., sectors, businesses, Provincial Government, Municipal Governments, research institutions, non-governmental organizations, individuals, etc.). To achieve this, a clear vision of sustainability, the willingness to disrupt the status quo, a commitment to work together, and the urgency to act swiftly are needed from everyone. Planned adaptation takes time and the work must begin immediately. It is insufficient to "prioritize" climate change adaptation; adapting to climate change must be considered a normal way of life.

REFERENCES

Canadian Electricity Association. (2016). *Adapting to Climate Change: State of Play and Recommendations for the Electricity Sector in Canada*. Retrieved from https://electricity.ca/WP-CONTENT/UPLOADS/2016/02/ADAPTING_TO_CLIMATE_CHANGESTATE_OF_PLAY_AND_RECOMMENDATIONS_FOR_THE_ELECTRICITY_SECTOR_IN_CANADA.PDF

Environment and Climate Change Canada. (2010, May 25). *International – Vienna Convention and the Montreal Protocol* [website]. Retrieved from https://www.ec.gc.ca/ozone/default.asp?lang=En&n=D11D2440-1

Eyzaguirre, J. and F.J. Warren. (2014). Adaptation: Linking Research and Practice. In: *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (eds.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 253-286.

Government of Prince Edward Island. (n.d.). *Waste management* [website]. Retrieved from http://www.gov.pe.ca/infopei/wastewatch

HM Government. (2013, July). *The National Adaptation Programme: Making the Country Resilient to a Changing Climate*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209866/pb13942-nap-20130701.pdf

Yarr, K. (2017, April 26). P.E.I. leading the country in recycling and composting. *CBC News*. Retrieved from http://www.cbc.ca/news/canada/prince-edward-island/pei-recycling-composting-leader-1.4085993

PHOTO CREDIT: DON JARDINE

It's a collective endeavour, it's collective accountability and it may not be too late.

—Christine Lagarde

List of Figures

List of Tables