CHAPTER 3: THE COASTAL CHALLENGE

Lead Authors:
Colleen S.L. Mercer Clarke (*University of Ottawa*), Patricia Manuel (*Dalhousie University*) and Fiona J. Warren (*Natural Resources Canada*)

Contributing Authors:
Michael Davies (*Coldwater Consulting Ltd.*), Thomas S. James *(Natural Resources Canada)*, Stéphane O'Carroll (*Geo Littoral Consulting*), Danika van Proosdij (*Saint Mary's University*), Jean-Pierre Savard (*Ouranos*) and Nathan Vadeboncoeur (*University of British Columbia*)

Recommended Citation:
Mercer Clarke, C.S.L., Manuel, P. and Warren, F.J. (2016): The coastal challenge; *in* Canada's Marine Coasts in a Changing Climate, (ed.) D.S. Lemmen, F.J. Warren, T.S. James and C.S.L. Mercer Clarke; Government of Canada, Ottawa, ON, p. 69-98.

TABLE OF CONTENTS

1 INTRODUCTION

Canada's coasts, the longest in the world, are a defining element of our national identity. Canadian port cities have been and continue to be gateways to our nation for international trade and immigration, and as our link to the larger world. Coasts are important to Canadians whether or not they live near the shore, for their natural beauty, biodiversity, resources or the contributions made to human society, culture and the economy.

Inuit and First Nations people have throughout history depended on coastal areas for food, and have deep spiritual and cultural ties to the shore. Early Europeans first settled along the Atlantic and Pacific coasts, where they developed farms, fisheries and industries, and built military and mercantile trade cities, before venturing further inland. Historically, Canada's coastal economies were largely based on the processing and distribution of important goods and services (e.g., food, transportation, mineral resources and energy). In recent times, however, coastal communities have become increasingly urban, consumer-driven spaces and centres of research, technology and innovation that provide goods and services to the global marketplace.

As climate and seasonal weather continue to change, coastal environments are being altered over a relatively short period of time (Lane et al., 2013; *see also* Chapter 2). Anticipating the implications of, and understanding the challenges associated with, these changes are first steps toward preparing to respond. Coastal communities in Canada are already taking action to reduce risks associated with changing conditions and to promote the benefits of new or expanding opportunities (*see* Chapters 4–6). Additional information on sectoral impacts and adaptation responses can be found in Warren and Lemmen (2014).

This chapter provides an overview of ongoing and projected changes in climate and other environmental factors that could cumulatively affect the sustainability of coastal environments and coastal societies. The chapter also summarizes key elements in planning approaches to adaptation, and describes how planning for adaptation is being used in some coastal areas to plan for, and respond proactively to, altered weather patterns and a changing climate. More detailed information on each of Canada's coastal regions (East, North and West) is found in Chapters 4–6.

2 CHANGING COASTS

The coastal landscapes of Canada are a diverse array of terrestrial, aquatic and marine environments that link the land to the Atlantic, Arctic and Pacific Oceans (*see* Chapter 1). Human activities have significantly altered terrestrial coastal landscapes and shorelines in all regions of the country. For instance, changes in land cover and land use include replacement of natural land cover with harvested forests, cultivated farmlands, and villages, towns and cities. Rivers, lakes and estuarine areas have been altered by the construction of dams and reservoirs, by water extraction for irrigation and drinking water, and by infilling, dredging and channelization. Intertidal and nearshore areas have been reclaimed (i.e., diked) or infilled for farming or development. Shorelines themselves, which are by nature highly dynamic systems (*see* Chapter 2), have also been reshaped by the construction of dikes and seawalls, breakwaters, causeways and dock facilities, and by dredging and infilling. Even along remote northern coasts, human impacts are increasingly evident as the Arctic becomes more accessible for development (Forbes, 2011; Keeling, 2012; ArcticNet, 2013).

Climate change is putting additional stress on coastal regions, and areas and ecosystems already under pressure from human activities may be impacted the most. The widespread effects of these cumulative stresses on coastal regions throughout the world have been summarized into impact categories that include (Munang et al., 2009; Simpson et al., 2012; Arlington Group et al., 2013; Lane et al., 2013):

- altered ecosystems and landscapes, and loss or reduction in ecosystem services;
- increasingly unstable shorelines;
- inundation of and damage to lands, residences, infrastructure, industries and cultural assets;
- contamination of water supplies;
- increasing costs for protection, maintenance, upgrading, restoration and insurance;
- reduced investment potential and/or emerging new economic opportunities; and
- altered life styles, impacts to health and well-being, and loss of life.

Depending on local factors (e.g., exposure, vulnerability), some or all of these impacts will be observed in coastal environments and communities throughout Canada. This section provides an overview of how different shifts in climate (e.g., increased temperature, sea-level rise, changes in storminess) would affect ecosystem health and social and economic well-being by magnifying the effects of existing trends, and presenting new challenges and opportunities in Canada's coastal regions.

2.1 ECOSYSTEM HEALTH

Throughout the world, coastal ecosystem health has been deteriorating in response to both direct and indirect impacts of human activity (Millennium Ecosystem Assessment, 2005a, b; European Environment Agency, 2006a, b; Lotze et al., 2006; UNEP, 2010). Ecosystems and species can be directly impacted through deforestation, overfishing, introduction of invasive species and development in the nearshore region (e.g., hardening shorelines, diking saltmarshes for agriculture, infilling nearshore waters for waterfront development and constructing bridges and causeways). Chemical and biological pollutants (including nutrients) generated by land-cover changes and land-use activities in the watershed, or as discharges from marine activities, can indirectly impact coastal ecosystems. Damming or channelization of surface water can change the volume and timing of fresh-water flows to marine coasts. In Canada, the magnitude of human impact on coastal systems can be significant, particularly in southern, more populated areas of the country (Ban and Alder, 2008). For example, more than two-thirds of the coastal salt marshes in the Atlantic Provinces have either been drained and converted to agricultural land or diminished by industrial or urban development (Austen and Hanson, 2007).

RESILIENT ECOSYSTEMS

Ecosystems, populations and species are considered healthy if they demonstrate resilience to stress and are capable of managing their structure and functioning over time (Haskell et al., 1992; Costanza and Mageau, 1999). Resilience is a measure of an ecosystem's ability to withstand stress from outside influences, the capacity for recovery from pressures and stress, and the degree to which restoration of pre-stress conditions can be attained (Costanza and Mageau, 1999; Rapport and Whitford, 1999).

Ecosystems are continually adjusting to natural changes in internal and external physical, chemical and biological factors that occur temporally and spatially, and affect ecosystem structure and function. Resilience can determine whether the effects of change are negative, positive or merely different. Changes in ecosystem health can affect the ecosystem services (e.g., food, water, transportation, resources) upon which human society depends.

For much of Canada's coasts, the state of ecosystem health remains poorly documented and/or understood (Mercer Clarke, 2010, 2011). Although data on the environmental effects of industrial operations are collected to meet regulatory requirements, information on broader coastal conditions can be limited even in populated areas of the coast, and is especially sparse for much of northern Canada. Available information is also often outdated, spatially and temporally fragmented, and/or collected using nonstandardized research and reporting methods, making it difficult to render broad conclusions on the current status and trends in the health of coastal ecosystems, population and species (Hutchings et al., 2012). Increased stresses on coastal ecosystems arising from climate change, when added to the pressures of human use, may overwhelm the capacity of natural systems to absorb impacts without potentially being permanently and negatively altered.

2.1.1 ECOSYSTEM SERVICES

Ecosystems provide services and benefits that support the well-being of society through a combination of ecological, chemical and physical processes (Thrush and Dayton, 2010). Ecosystem services can be grouped into four categories (Lotze and Glaser, 2009; Snelgrove et al., 2009; de Groot et al., 2010): 1) provisioning services (e.g., food, energy and transportation); 2) supporting services (e.g., photosynthesis, carbon storage, water and habitat); 3) regulating services (e.g., climate regulation, water purification, waste treatment and protection from physical hazards); and 4) cultural services (e.g., spiritual support, aesthetics, recreation, education). Unsustainable resource use can decrease the quantity, quality and access to ecosystem services, and climate change will likely exacerbate the impacts of other stressors, such as overfishing, disposal of contaminants, nutrient enrichment and loss of habitat to deforestation and urbanization (Figure 1; Mooney et al., 2009; Federal, Provincial and Territorial Governments of Canada, 2010; Hounsell, 2012).

Despite increasing reports of deterioration within oceanic and coastal environments, the value of ecosystem services continues to be largely unrecognized, and there has been little work in Canada to identify the economic contributions of services such as protection from coastal storms, waste reception and filtering, and oxygen production. At the global scale, one study (Costanza et al., 2014) estimated that, in 2011, the total annual worth of ecosystem services to the global economy was US$125 trillion. The impacts of changes in climate on specific ecosystem services, such as food security (Rice and Garcia, 2011) and coastal tourism (Scott et al., 2012), have also been studied. Although Canadian economic studies have reported on the value of ocean services (e.g., fisheries, transportation) to the nation's economy (Gardner Pinfold Consulting Economists Ltd., 2009a, b), it is difficult to extract information on the value of less tangible services, such as waste disposal and protection from weather events.

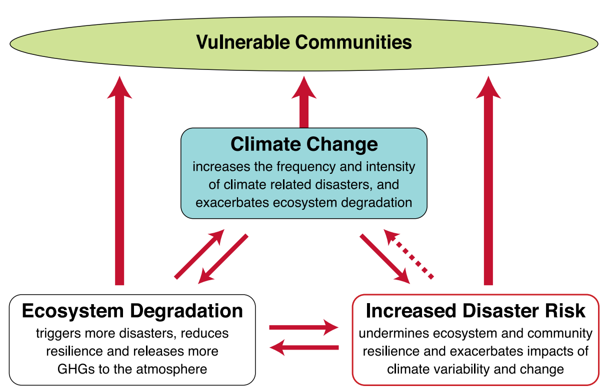
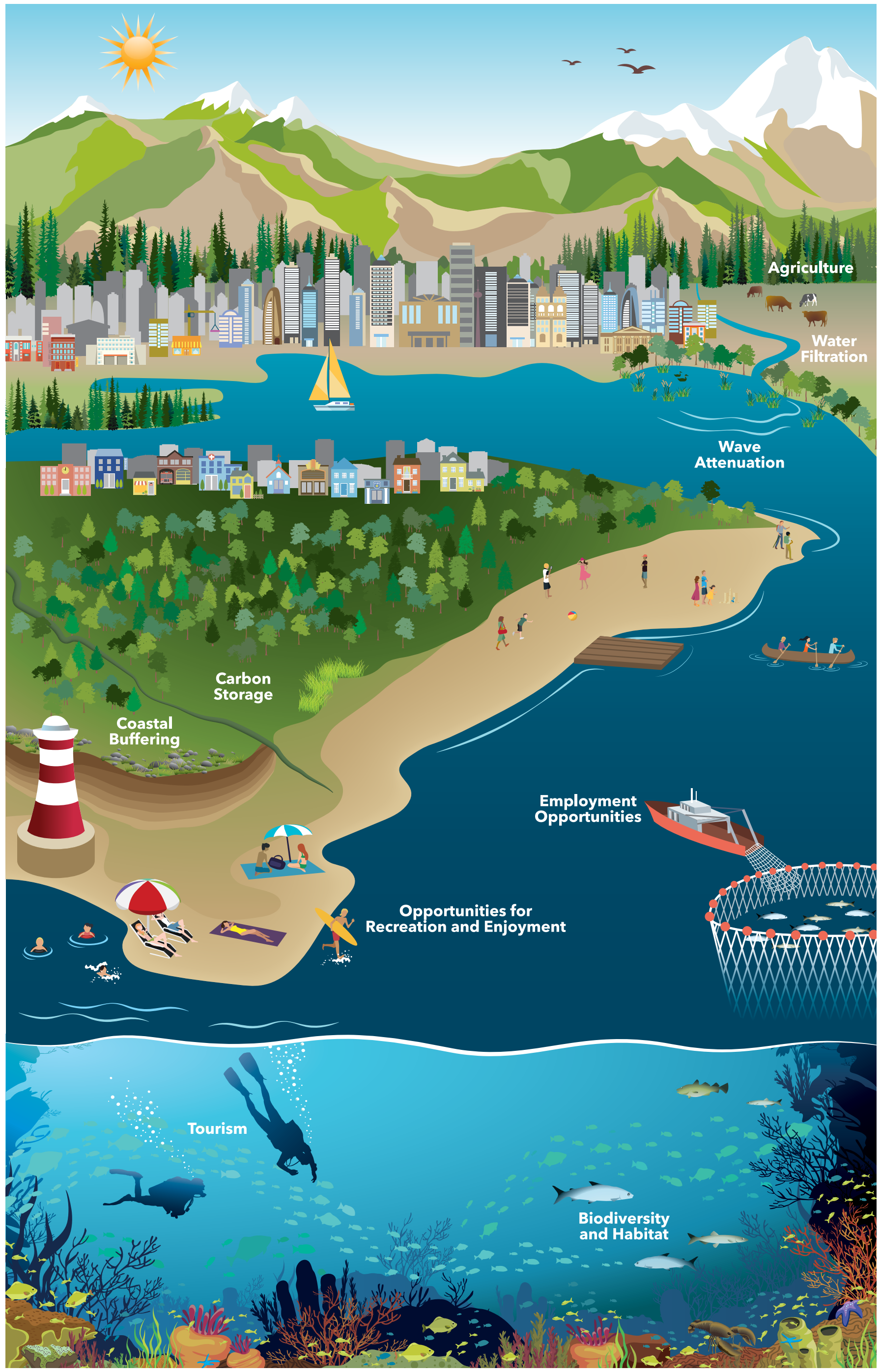


FIGURE 1: Linkages among climate change impacts, ecosystem degradation and increased risk of climate-related disasters (Nantel et al., 2014, *modified from* Munang et al., 2009).

Impacts on Canadian coastal biodiversity resulting from physical and biological changes associated with climate change, when coupled with other anthropogenic pressures, have implications for the sustainability of ecosystem services and ultimately for the social and economic well-being of coastal communities (Berteaux et al., 2010; Hutchings et al., 2012). Conservation of coastal biodiversity can include the management of existing protected areas, as well as the development and implementation of new parks, wildlife reserves and marine protected areas. Guidance for the design of networks of resilient marine protected areas in Canada (Commission for Environmental Cooperation, 2012), and adaptation planning for existing coastal protected areas (Parks Canada, 2007), are examples of early attempts to prepare ecosystems and communities for climate change.

Planned adaptation that uses an ecosystem-based approach employs environmentally sustainable land-planning techniques that focus on maximizing the resilience in both natural and human communities through protection of biodiversity, restoration of ecosystem functioning and sustainable use of resources (Nantel et al., 2014). Nantel et al. (2014) summarized the following core adaptation actions for supporting ecosystem resilience:

- protect intact ecosystems, species diversity and ecosystem function
- link protected areas using sustainably managed landscapes and waterscapes
- restore degraded ecosystems and support species recovery
- maintain or restore natural variability in the ecosystem of interest
- protect and manage range limits
- use active management approaches, such as assisted migration, where appropriate



COASTAL AND MARINE ECOSYSTEM SERVICES (FIGURE 2)

Although often taken for granted, the goods and services provided by coastal and marine ecosystems would be difficult—if not impossible—to replace. These benefits include protection from coastal storm damage, the filtering of toxic substances and nutrients, production of oxygen, and sequestration of carbon dioxide. In addition, fishing, tourism, and recreation provide economic benefit, and support ways of life that contribute to the social and cultural wealth of the nation (Pew Oceans Commission, 2003, p. 7).

FIGURE 2: Coastal ecosystem services (*modified from* Moser et al., 2014).

2.2 COASTAL SOCIETY

In the context of this report, a coastal society comprises communities situated on or near a marine shoreline, as well as the people who have important economic and/or cultural links to the shore. Coastal society in Canada is characterized by complex settlement patterns, population densities and human use of landscapes. Many Canadian coastal communities have demonstrated both resilience to environmental and economic stresses, and a willingness and capacity to adapt. Resilience, as applied to society, refers to the ability of human communities to withstand and recover from stresses or shocks, such as environmental change or social, economic or political upheaval (Adger, 2000; Stockholm Resilience Centre, 2015). Resilience is the capacity of the system to rebuild itself if it is damaged, and can include positive alterations to key elements if those alterations contribute to reducing vulnerability and improving well-being.

Although statistics on Canada's coastal populations can be difficult to obtain, Manson (2005) estimated that more than 13% of Canada's population resides within 20 km of a marine shoreline, on only 2.6% of Canada's total land area. Throughout Atlantic Canada and on much of the coast of British Columbia, population density drops with distance from the shore (Manson, 2005). In Nunavut, all but one of the 25 communities are located on the coast. Aging population is a significant trend in some regions, particularly in parts of British Columbia and rural areas of Atlantic Canada (CBCL Ltd., 2009; Natural Resources Canada, 2014b). In contrast, the population of the North is younger, with only 3.3% of the people in Nunavut being more than 64 years old (Statistics Canada, 2012). Coastal demographics in some areas may also have been affected by restructuring in national and international economics and trade, as well as by economic changes in local primary industries, such as the closure of the Atlantic groundfish fisheries, exploration for and development of offshore deposits of oil and gas, and increased interest and investment in coastal tourism (Dolan et al., 2005).

Since the early 1900s, Canada's coastal populations have, like those throughout much of the rest of the country, been shifting from predominantly rural to predominantly urban. Coastal cities, such as Victoria and Vancouver, BC, Québec, QC, Saint John, NB, Charlottetown, PE, Halifax, NS and St. John's, NL, are hubs of economic and cultural activity. In the North, Inuvik, NT, Iqaluit, NU and Happy Valley–Goose Bay, NL are important regional service centres, as well as essential ports for the import and export of goods. Iqaluit and other northern communities are responding to rapid societal and cultural change resulting, in part, from economic growth and diversification, while also dealing with increasing rates of change in the local environment.

The following sections provide an overview of the potential effects of a changing climate on important elements of coastal society.

2.2.1 INFRASTRUCTURE

Canadian coasts support an array of ports, harbours and marinas located in cities, towns and villages. Larger ports, under the jurisdiction of individual marine Port Authorities, handle more than $160 billion in cargo each year (Association of Canadian Port Authorities, 2007). Small-craft harbours in towns and villages contain more than $2 billion in infrastructure, which is vital to the fishing and transportation sectors, with nearly 90% of all fish landings in the country taking place at a small-craft harbour (DFO, 2014a). In recognition of the potentially significant economic impact that climate change presents to coastal industrial infrastructure, the Province of Nova Scotia commissioned the development of a tool to assess the vulnerability of infrastructure used for fishing and aquaculture activities (CBCL Ltd., 2012).

There are numerous recent examples of damage to coastal transportation infrastructure and transport delays caused by extreme weather events and seasonal conditions (Andrey et al., 2014). Heavy weather has caused damage and delays for ferries and cargo ships, and, in some cases, resulted in periods of isolation (e.g., Îles de la Madeleine ferries were trapped in ice during the 2014–2015 winter; CBC News, 2015). Many coastal roadways were constructed to closely follow shorelines and rivers, and often use bridges and causeways to complete their linkages. These transportation systems are proving to be particularly vulnerable to extreme climate events, especially when higher sea levels and storm surges are coupled with heavy precipitation (Case Study 1).

CASE STUDY 1

HURRICANE IGOR, NEWFOUNDLAND, 2010

(Environment Canada, 2014; Masson, 2014)

In September 2010, Hurricane Igor arrived just off the coast of the Avalon Peninsula on the Island of Newfoundland. When it hit Newfoundland, the system was still classified as a hurricane but was rapidly downgraded to become a post-tropical storm. Nevertheless, hurricane-force winds (120–140 km/h) ripped through parts of Newfoundland, forcing 22 towns and villages to declare states of emergency. As Igor continued its path north, roads and bridges across the island were washed away, isolating more than 150 towns (Figure 3).

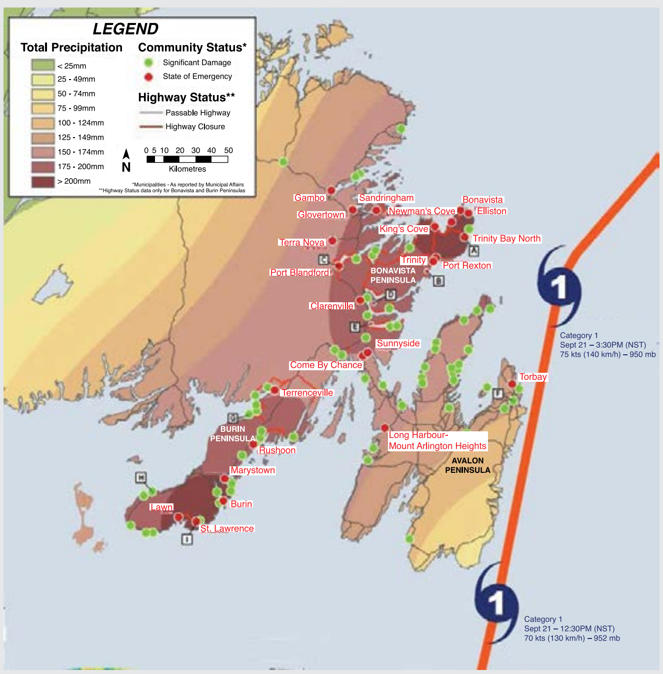


FIGURE 3: Storm track for Hurricane Igor in eastern Newfoundland, September 2010, including areas that suffered significant damage (Government of Newfoundland and Labrador, 2010).

Igor's force was supplemented by a strong upper-air weather front that was tracking west to east across the Island, creating a complex weather system of wind and rain that had a massive circulation and reach. Peak winds reached 172 km/h in some locations. New 100-year records were set for rainfall, including 239 mm that fell in only 2 hours in the community of St. Lawrence on the Burin Peninsula. Approximately 70 000 people lost power, fuel supplies ran short, and there were boil-water advisories across the province. The heavy rains washed out roads, bridges and causeways (Figure 4). The Trans-Canada Highway and main access roads (in some places, the only road access) were closed because of washouts, flooding and damage to asphalt.

FIGURE 4: Washout of highway and bridge near Port Rexton, NL. *Photo courtesy of Fire and Emergency Services, Newfoundland and Labrador.*

In a province famous for its storms, Igor was a destroyer. The storm permanently altered the landscape and changed the lives of many families. Insurance claims exceeded $65 million, the largest weather-related set of claims in the province's history. Uninsured losses have been estimated to be as high as $200 million. Damage to the environment was not calculated. In recognition of the intensity of this weather event, Environment Canada and the World Meteorological Organization have officially retired the name Igor from the rotating list of names for Atlantic hurricanes.

Other public infrastructure in Canada, such as potable water supplies, storm-water management and disposal systems, government buildings and cultural assets, provide needed services upon which communities and industry depend. Recent studies have revealed that much of the public infrastructure in Canada's coastal regions is currently in poor condition and vulnerable to the negative impacts of climate change (Stanton et al., 2010). In their assessment of Canadian municipal infrastructure (drinking-water systems, waste-water and storm-water networks, and municipal roads) for Canada as a whole, Félio (2012) reported that 30% was ranked between 'fair' and 'very poor'. More than half of the roads were determined to be in fair to very poor condition, with an estimated cost to repair of $91.1 billion (2012 dollars; Félio, 2012).

Changing climate exacerbates many risks to existing infrastructure (Andrey et al., 2014). For example, most waste-water treatment systems in coastal areas are located close to the shore to facilitate gravity feed of waste-water to the plant (reducing pumping costs), as well as disposal of the treated effluent into nearby receiving waters (J.D. Clarke, personal communication, 2014). Existing plants in these locations are vulnerable to sea-level rise and to flooding from climate change–enhanced storm surges and wave action. Although spending on public infrastructure in Canada has increased (Figure 5; Infrastructure Canada, 2011), much remains to be done. Future investment in both repairs and new construction would benefit from consideration of existing and anticipated changes in environmental conditions resulting from climate change (e.g., sea-level rise, storminess, increasingly intense precipitation events).

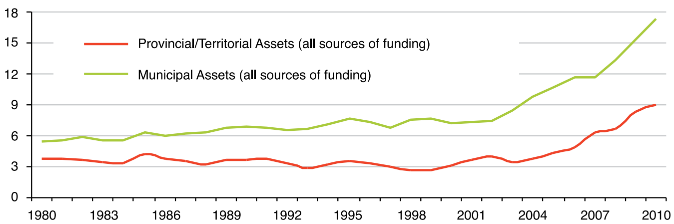


FIGURE 5: Government investments ($ billion) in core public infrastructure (bridges, roads, water, waste-water, transit, and cultural and recreational facilities; Infrastructure Canada, 2011).

Historically in coastal regions, buildings such as homes, businesses, schools and churches were generally constructed short distances inland of the shore on lands that were considered to be reasonably safe from marine hazards (such as high tides and storm surges) and favourable for other reasons (e.g., farming activities and road access). In many communities, early routes for coastal roads followed shorelines and river valleys. Many of these roads have been improved but not relocated to higher ground. Over time, some shorelines have been dramatically altered as a result of coastal dynamics, storm events, rising sea level and human construction (*see* Chapter 2), resulting in loss of land that acted as a natural buffer for communities against wave action, or deterioration of constructed protective measures such as breakwaters and seawalls. Many of the oldest cultural assets and historical sites (e.g., Fortress Louisburg, Cape Breton, NS) are increasingly threatened as a result of sea-level rise.

In recent decades, changing social norms and increasing demands for waterfront living have resulted in considerable alterations to settlement patterns. Many coastal communities are now characterized by significant residential and commercial waterfront development that has replaced traditional docks, wharves and warehouses. These new developments are, in many ways, more vulnerable to rising sea levels and severe weather. Even in areas protected by dikes or seawalls, there is a growing potential for higher waves, tides and/or storm surges to overtop existing structures (*see* Chapter 2). Coastal provinces such as British Columbia have been addressing changes in sea level and have developed new guidelines for maintenance and repair of existing dikes that consider future sea-level rise (*see* Chapter 6; Bornhold, 2008; Ausenco Sandwell, 2011c; Delcan, 2012).

Climate change poses an array of challenges both to aging infrastructure and to the codes and criteria by which new facilities will be sited, designed, constructed and maintained (Box 1; Félio, 2012; Boyle et al., 2013). Most modern infrastructure has been designed and built to standards based on historical climatic conditions. These criteria may no longer be sufficient to withstand expected changes in such parameters as wind and snow loading, or to respond safely to more severe weather events (Auld and MacIver, 2007). Since 2005, there has been a growing body of peer-reviewed literature focused on the process of adapting Canadian infrastructure to climate change (Figure 6). Use of tools such as the engineering-protocol assessments of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) has shown that well-maintained infrastructure is more resilient to a changing climate, as gradual changes in temperature and precipitation patterns can often be addressed through regular maintenance and upgrade cycles, or through adjustments to operation and maintenance policies and procedures (Andrey et al., 2014).

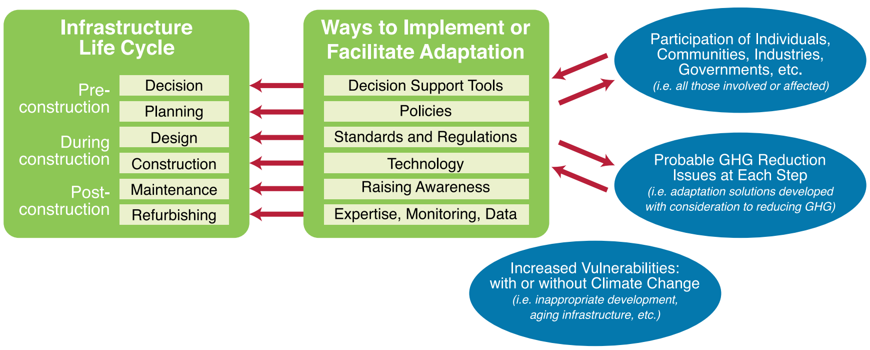


FIGURE 6: Adaptation in the infrastructure life cycle (Larrivée and Simonet, 2007).

BOX 1
CODES, STANDARDS AND RELATED INSTRUMENTS (CSRI)

(Andrey et al., 2014, p. 239)

The Public Infrastructure Engineering Vulnerability Committee (PIEVC), led by Engineers Canada, reviewed its water-resource–infrastructure case studies to identify recommendations for changes to Codes, Standards and Related Instruments (CSRI). Water-resource infrastructure is subject to many types of CSRI, including regulations, codes and standards, local government bylaws and national guidelines. The PIEVC found that the climate information used in the development of CSRI was not always readily available or identified, meaning that updating CSRI is not just a matter of updating the climate information contained within them. Recommendations for action on CSRI reflect the loss of stationarity in climate and the need to enable adaptation, and include 1) improving climate data; 2) addressing incremental options over the life cycle of infrastructure; 3) expanding the scope of CSRI to cover physical, functional and operational performance; and 4) increasing the flexibility in design to adapt to climate change (Public Infrastructure Engineering Vulnerability Committee, 2012).

2.2.2 ECONOMIC CHALLENGES

In general, recent attempts to assess the direct and indirect economic benefits of coastal areas to local and national well-being have been difficult (e.g., Mandale et al., 1998, 2000; Canmac Economics et al., 2002; Roger A. Stacey Consultants Ltd., 2003; Atlantic Provinces Economic Council, 2004; Gardner et al., 2005, 2009; Newfoundland and Labrador Department of Finance, 2005; GSGislason & Associates Ltd., 2007; Heap, 2007; Kildow et al., 2009; Kildow and McIlgorm, 2010). Identification and economic evaluation of coastal sectors are often complicated by conflicting interpretations of coastal boundaries and what constitutes coastal industries. In Newfoundland and Labrador, for example, the mining sector grew from $967 million in 2000 to $4.584 billion in 2010 (Stothart, 2011). A significant proportion of the mining industry ships its product by sea, but the industry is generally not considered 'coastal'.

In British Columbia, an economic assessment of the oceans sector that included forestry, ship-building and ocean recreation estimated the annual GDP value for the sector to be $5.7 billion, generating 84 000 person years in employment (GSGislason & Associates Ltd., 2007; Gardner Pinfold Consulting Economists Ltd., 2009a, b). In 2013, commercial sea fisheries throughout Canada generated in excess of $2.25 billion in total landed value (89% of this from the East Coast region), and aquaculture contributed another $935 million in production (DFO, 2014b).

Throughout Canadian coastal regions, economic sectors have historically faced upswings and downswings in the prosperity of industrial sectors such as forestry, ship-building, fisheries, pulp and paper, and base-metal extraction and smelting. New extractive industries (e.g., oil and gas) have arisen in some areas, and a number of Canada's coastal cities are now hubs for higher education, research and technology development. For some of these endeavours, changes in climate will bring additional challenges to compete in the local, national and global markets.

Fisheries

Some capture fisheries in Canada are highly sensitive to climate variability and change (Barange and Perry, 2009; Rice and Garcia, 2011), whereas marine aquaculture is generally considered to be more adaptable to changing conditions (Campbell et al., 2014). Along southern coasts, many fishing communities have experienced reductions in fishable populations, closure of fisheries and/or shifts to new target species (Campbell et al., 2014). Climate change impacts fish behaviour (e.g., changes in vertical and geographic range, daily migrations), species composition and food chains. For regions where communities are largely dependent on a single fishery, adaptation includes diversification, such as changes in target species and shifting to other industries (e.g., coastal tourism), and/or immigration out of the area, which can affect community demographics and community structure. Along northern coasts, biodiversity shifts and changes in the ranges and distribution of many marine and terrestrial species impact the availability, accessibility and quality of traditional food sources upon which many communities depend (Furgal and Prowse, 2008; Hansen et al., 2008; Wheeler et al., 2010).

In a national-scale assessment of Canadian fisheries and climate change, Campbell et al. (2014) found that continuing climate change could result in significant impacts on the biodiversity and biota that support regional fisheries; that cascading effects of changes in ecosystem production could lead to disruptions in key life-history stages in species that support fisheries; that shifts may take place in the ranges of species and populations; and that there could be increased competition from invasive species. Despite these anticipated challenges, they concluded that Canada will likely remain a net exporter of aquatic foods, with anticipated increases in the total biomass of production from wild-capture fisheries as a result of climate-induced shifts in fish distributions.

Forestry, Mining, Energy

Along the coasts, exploration, development, processing and shipment of both land- and sea-based natural resources are vulnerable to hazardous environmental conditions, which are likely to increase with climate change. Although the biophysical impacts of climate change on many aspects of natural resources are fairly well understood, steps to integrate climate change considerations into business planning and management have thus far been limited (Lemmen et al., 2014).

Forestry, mining and energy contribute significantly to the economy of both the West Coast and East Coast regions of Canada, although information specific to coastal areas is limited. For example, mining in coastal landscapes includes base-metal mines and quarrying operations for structural materials for use in construction and road-building. Coastal landscapes provide easy access to sea transport for operating goods and extracted bulk materials. Climate-related challenges and opportunities identified to date relevant for natural resource sectors in coastal regions (Lemmen et al., 2014) include the following:

- Reductions in Arctic sea ice will open marine-transportation corridors, improving access for exploration and development of new mines and emphasizing the importance of collaboration between mining companies and traditional users of the land and sea (e.g., Lemmen et al., 2014, Case Study 4, p. 79).
- Changes in precipitation may compromise the integrity and viability of tailings ponds and waste-water–treatment facilities, potentially increasing the risk of contaminants polluting rivers and nearshore waters.
- In areas where product is shipped from bulk-loading facilities, changes to onland storage and dock facilities (including loading and/or offloading facilities) may be required to address changing conditions, such as higher winds, heavy precipitation, sea-level rise and storm surges.

Demand for and transmission of energy resources in coastal areas will be affected by climate variability and change (Figure 7), and by sea-level rise. Energy resources, including imported and domestic coal and offshore oil and gas are shipped or offloaded at coastal locations in British Columbia, Quebec, New Brunswick, Nova Scotia, and Newfoundland and Labrador. Within the sector, considerable attention is being given to the siting of proposed major pipeline termini and energy-shipping facilities on both the East and West coasts. Many new renewable energy projects, including hydroelectric, wind and tidal power, could also be located in coastal areas. Large wind farms have already been installed at locations such as the Tantramar Marsh in the upper Bay of Fundy; Lower West Pubnico in southwestern Nova Scotia; and North Cape, the most northwesterly point of Prince Edward Island. Tidal-power development in the Bay of Fundy has been proceeding through early stages of environmental assessment and prototype installation.

Recent extreme weather has wreaked havoc with the transmission of electricity throughout Canada's coastal regions, especially the East Coast (e.g., from Hurricanes Juan and Igor), affecting tens of thousands of people, resulting in costly interruptions in power supplies and requiring major repairs to local and regional transmission infrastructure. The oil-and-gas sector has begun studying the potential risks to offshore exploration and production facilities as a result of increased storminess and changes in ice risk (e.g., National Energy Board, 2011; Lemmen et al., 2014).

Tourism

With the decline of traditional economic sectors (such as fisheries and forestry) in some regions, tourism has emerged as an important industry for many parts of coastal Canada and is the primary industry for many small communities (Table 1; Beshiri, 2005; Scott, 2011; Government of Canada, 2012a, b).

The impact of rising sea levels on tourism resources and infrastructure is a concern in some coastal regions. Some cultural resources (e.g., the Fortress of Louisburg and in Haida Gwaii) are under threat from higher water levels, and beaches in certain regions (e.g., Prince Edward Island National Park) may diminish or disappear. Higher temperatures are also a factor for tourism; a warming climate will affect winter activities such as skiing and snowmobiling (e.g., in Whistler, BC and Gros Morne National Park, NL) and increase the length of the warm-weather tourism season in most areas. Longer summer seasons could result in additional visitation pressures on national and provincial parks, and other protected areas (e.g., visitation could increase 30% by 2050 in the national park system; Jones and Scott, 2006). Where tourism owners and operators are able to anticipate climate impacts and adapt effectively, climate change will present opportunities for economic growth in many areas of Canada. To date, however, the tourism sector in Canada is generally felt to be poorly prepared for changes in climate (Scott et al., 2008, 2012; KPMG, 2010), in part because business planning tends to involve short-term scenarios within which climate change is generally seen to be insignificant relative to climate variability and other factors.

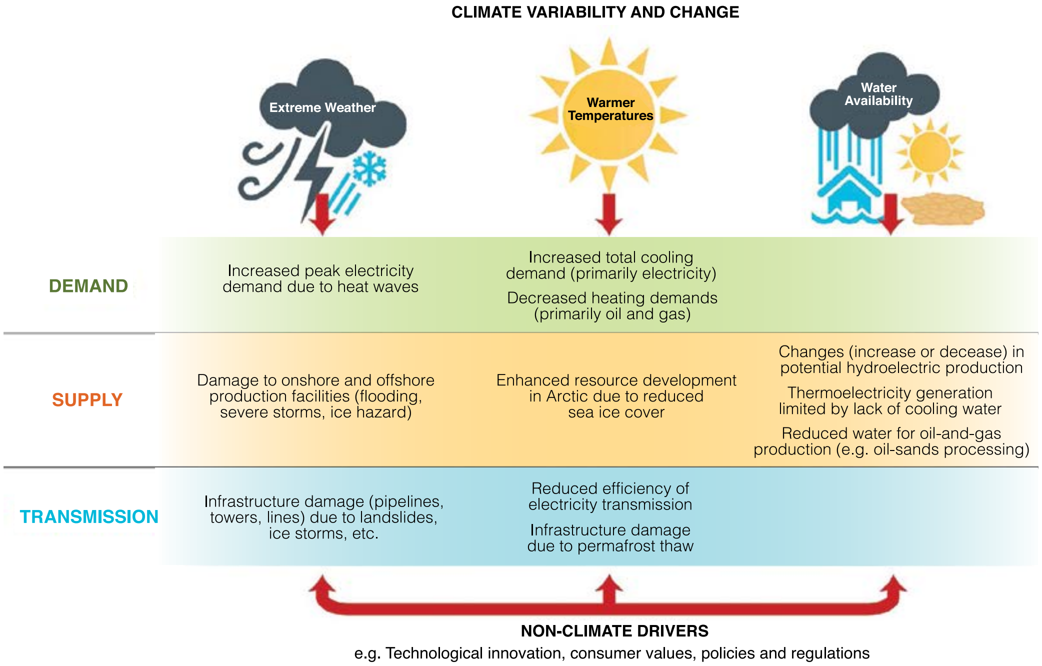


FIGURE 7: Potential climate change impacts on the energy sector, affecting supply, transmission and demand (Lemmen et al., 2014).

TABLE 1: Economic contribution of tourism in Canadian coastal provinces and territories (*adapted from* Tourism Industry Association of Canada, 2012). Data are reported for the entire jurisdiction, not just the coastal component; in a number of the provinces, however, tourism is primarily reliant on coastal landscapes and amenities.

Province and territory	2011 gross domestic product (2002 constant $)	2011 tourism employment (jobs)
Newfoundland and Labrador	$316 million	8 136
Prince Edward Island	$121 million	2 866
Nova Scotia	$683 million	16 636
New Brunswick	$438 million	12 090
Quebec	$5 357 million	130 018
British Columbia	$4 913 million	96 877
Yukon–Northwest Territories–Nunavut	$147 million	Data not available
Total	**$11.975 billion**	**266 623**

Insurance and Investment

In Canada, as elsewhere, the insurance and reinsurance industries are reacting to the rapid increase in losses associated with extreme climate events (Figure 8; Kovacs and Thistlethwaite, 2014; Robinson, 2015). Globally, losses are particularly notable in coastal environments (H. John Heinz III Center for Science, Economics and the Environment, 2000; Keillor, 2003; Heap, 2007; Nicholls et al., 2008; Simpson et al., 2012). In Canada, the risk of catastrophic losses due to storm-surge flooding increases with sea-level rise and increasing severe weather (McBean and Henstra, 2003; Feltmate and Thistlethwaite, 2012). Stanton et al. (2010) estimated that, by the 2020s, annual economic damages to Canada's coasts from sea-level rise and storm surges could be in the range of $2.6 to $5.4 billion, increasing to an estimated $48.1 billion by 2080. Throughout Canada and elsewhere in the world, organizations and institutions responsible for emergency management and disaster-risk reduction are seeking changes to planning and design practices to promote proactive adaptation so they can more effectively manage risks to environments, services and human safety and well-being (H. John Heinz III Center for Science, Economics and the Environment, 2000; McBean and Henstra, 2003; Sussman and Freed, 2008; World Bank, 2008; Yohe et al., 2011; Feltmate and Thistlethwaite, 2012).

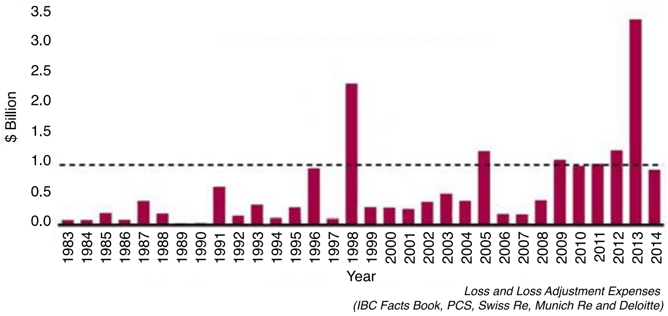


FIGURE 8: Insured losses from natural catastrophic events, 1983–2014. Values in 2014 $ CAD. Dashed line denotes $1 billion in insured losses. Losses in 1998 were the result of ice storms in eastern Canada. Those in 2013 were related to flood events in Alberta and the Greater Toronto Area (*modified from* Robinson, 2015).

2.2.3 HUMAN HEALTH AND WELL-BEING

The threats posed by climate change to human health and well-being are a function of many factors, including exposure to climate hazards, the sensitivity of individuals and populations to environmental changes (with the elderly and persons with pre-existing health conditions generally more sensitive), and the capacity of the individuals or populations to proactively plan for change and/or to respond to disaster (Seguin, 2008; Seguin and Berry, 2008; Costello et al., 2009). Both psychological and physical health can be affected by the stress and anxiety induced by extreme weather events and damaged assets and livelihoods.

There has been limited climate change–related health research specific to coastal Canada (Dolan et al., 2005; Dolan and Walker, 2006). Events such as Hurricane Igor in Newfoundland (Case Study 1) demonstrate how local capacity for emergency response, acute health care and services for displaced families can be stressed by extreme climate events (Public Safety Canada, 2013). Climate change can also affect the quantity and quality of drinking-water supplies, which are impacted by increased temperatures, drought, heavy precipitation events causing contaminated surface runoff, and salinization of groundwater as a result of increasing demand and/or intrusion of seawater due to sea-level rise (Lemmen et al., 2008). Atlantic Canada jurisdictions have been studying the risk of saltwater intrusion, especially in Prince Edward Island, which is entirely dependent upon groundwater to supply potable water. Saltwater intrusion has already been documented in some areas, and the combined pressures of increasing coastal development and projected sea-level rise suggest the problem will only increase in the future (Prince Edward Island Department of Environment, Labour and Justice, 2011). Additionally, in parts of Atlantic Canada, rural coastal populations are aging, which increases their vulnerability to climate change.

3 PREPARING FOR CHANGE

Climate change will affect different regions and communities in different ways, as detailed in the subsequent chapters of this assessment. The magnitude of impact is related to a large number of biophysical and human factors (*see* Chapters 1 and 2), including the capacity of human society to adapt (Boateng, 2008; Simpson et al., 2012). This section discusses factors that affect community response, such as the complexities of coastal governance and the role played by perceptions and values. It also provides an overview of key elements in the adaptation process and discusses adaptation approaches. Adaptation to climate change has been defined by the Intergovernmental Panel on Climate Change (IPCC, 2014, p. 5) as:

> *The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.*

3.1 COASTAL GOVERNANCE

In Canada, governance of coastal areas is often complex, with different aspects managed by a wide array of institutions and organizations, including federal and provincial departments, local governments, nongovernment organizations, and independent corporations and agencies. These institutions operate on specific criteria, with defined roles and responsibilities bounded by jurisdictional authority. Departments and programs from all levels of government address specific goals related to the development, conservation and/or management of coastal assets and activities. In some circumstances, these goals may not align across jurisdictions. For example, federal and provincial regulations can support local government policies and objectives; can, in some situations, pose barriers to local decision-making; or may even require alterations to local development restrictions (Burton, 2008). It can also be challenging for communities to access the data and expertise needed to manage climate risks effectively, as technical information on coastal conditions is often distributed throughout different orders of government, departments and agencies (Savard et al., 2009; Anthony and Sabatier, 2013).

In general, federal, provincial and territorial governments regulate coastal transportation infrastructure, such as ports and harbours, ferries, airports, road networks and railways. They are also responsible for legislated environmental assessment and review processes; for regulating the installation of shoreline protection measures; and for managing such sectors as health, transportation and natural resources, as well as aspects of others, such as fisheries, mining and oil and gas. Local governments and First Nations communities are responsible for managing most of the commercial, retail, institutional and residential land development on coasts through instruments such as master planning, zoning, construction standards, building inspection and occupancy permits (e.g., Richardson and Otero, 2012). Many other organizations are also active on the coast, including port authorities, hospital boards, industrial-park corporations and, increasingly, public-private partnerships that own and/or operate water, waste-water, solid-waste management and energy infrastructure. Environmental conservation and advocacy groups, local service clubs and other volunteer organizations can also have significant impact on local planning and management goals and practice.

The absence of formal coastal management structures to oversee and/or co-ordinate coastal governance in Canada has been noted frequently and, for more than 25 years, a more integrated approach to coastal management has been recommended (Hildebrand, 1989, 1995; Hildebrand and Norrena, 1992; Ricketts and Harrison, 2007). However, little progress has been made toward developing the institutional and regulatory instruments that are likely needed to compel such an approach (Mercer Clarke, 2010).

3.2 PERCEPTIONS AND VALUES

Despite experience with severe weather in coastal areas, people remain attracted to coasts as a highly valued space for living and working (Spalding et al., 2014). The perception of risk, and the value ascribed to a threatened natural or built asset, can vary considerably (Niven and Bardsley, 2013). Although extreme climate events are often expressed in terms of the probabilistic recurrence intervals (e.g., once-in-100-years storm), it is hard for people to conceptualize the severity of such an event, or to understand the ramifications. When Hurricane Juan struck Halifax in September 2003, the Canadian Hurricane Centre warned of hurricane forecasts and high waves. The local CBC News program reported that these warnings of the storm's arrival did not appear to be taken seriously, and even had the adverse effect of attracting a number of people to the coast to view the higher waves (CBC News, 2003). By 2009, attitudes had changed: 82% of Nova Scotians surveyed believed that severe weather had become more frequent and indicated that they checked weather reports daily and took precautions as advised (Silver and Conrad, 2010). Differing perceptions of the risks presented by climate change can influence the choice and the success of adaptation measures (Eyzaguirre and Warren, 2014).

3.3 ADAPTATION GOALS AND OBJECTIVES

The primary goals of adaptation are to reduce the adverse impacts of climate change, and capitalize on emerging opportunities (Box 2 addresses other goals specific to coastal regions). Effective adaptation enhances resilience and sustainability, improves health and well-being, and/or enhances economic value and competitiveness. Establishing goals and objectives helps focus adaptation efforts, so as to prioritize activities, avoid unrealistic expectations and achieve needed support from a wide array of stakeholders.

Broad goals of adaptation can be advanced through targeted objectives that (Simpson et al., 2012):

- use science-based assessment of changing coastal vulnerabilities and risks;
- enhance emergency preparedness and response;
- protect valued public infrastructure and assets of ecological and cultural significance;

BOX 2

ADAPTATION GOALS IN COASTAL REGIONS

The following list of adaptation goals has been adapted from Simpson et al. (2012) and other national and international studies (Ballinger et al., 2000; Field et al., 2001; New Brunswick Department of the Environment and Local Government, 2005; UNEP/GPA, 2005; United Kingdom Department for Environment, Food and Rural Affairs, 2006a, b; Tomlinson and Helman, 2006; International Oceanographic Commission, 2009; Munang et al., 2009; Organization for Economic Co-operation and Development, 2009; United Kingdom Department for Communities and Local Government, 2010; Government of Western Australia, 2012):

- reduce risks to human health and safety
- maintain the health of coastal ecosystems
- reduce vulnerability of, and risks to, the built environment
- secure public access and use of coastal resources
- maintain and diversify livelihood options and opportunities
- strengthen governance frameworks
- avoid shifting the costs of private risks to public resources

- reduce non–climate-related stresses on vulnerable systems and assets;
- zone hazardous lands to prevent new development and constrain use;
- promote development in less vulnerable areas; and
- integrate key stakeholders in adaptation decision-making processes.

Collaboration is fundamental to many adaptation initiatives (Eyzaguirre and Warren, 2014). Experience in coastal areas suggests adaptation is often best pursued as multistakeholder, iterative activities that attempt to work with, rather than in opposition to, natural coastal processes (Lane et al., 2013; Macintosh, 2013; Niven and Bardsley, 2013). There are increasing examples of collaborative efforts in planning at the local level for climate change that cross government, academic, institutional, sectoral and professional boundaries (*see* Chapters 4–6; Bowron and Davidson, 2012; Lane et al., 2013).

Two emerging concepts in the academic discussions on adaptation to climate change are 'transformational change' and 'limits to adaptation'. At present, most adaptation action in Canada and elsewhere consists of incremental changes to existing systems (Eyzaguirre and Warren, 2014). Transformational change refers to changes in the fundamental attributes of a system, and may be necessary where limits to adaptation are encountered. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007, p. 733) defined limits to adaptation as:

> *…the conditions or factors that render adaptation ineffective as a response to climate change and are largely insurmountable.*

The concepts of adaptation limits and transformational change have received only limited attention in Canadian research to date (Warren and Lemmen, 2014) but may be particularly applicable to some coastal issues.

3.4 REDUCING VULNERABILITY AND MANAGING RISK

The management of risk is a process by which communities, organizations and/or individuals assess their vulnerabilities; identify their options; and prioritize the implementation of both short and long-term actions for avoiding, reducing or eliminating those vulnerabilities (Noble et al., 2005; Simpson et al., 2012). Assessing risk involves considering both the likelihood of the impact occurring (probability) and the magnitude of the impact (consequence). Finding an effective adaptation response strategy requires consideration of both desired and undesired consequences (Lane and Stephenson, 1998). The choices made in adaptation planning may be a reflection of risk tolerance: the level of risk that an individual or society is willing (and able) to accept. Adaptation planning must also consider the impact of time on planning processes, recognizing that, as conditions and available knowledge change, adaptation options may also change. Iterative planning processes that address these realities in a time-based context may have the greatest potential to provide communities with cost-effective alternatives for managing their risks. For example, when designing barriers to protect against high water levels, it is often appropriate to build flexibility into the structures so as to allow for adjustments over time as sea level rises (Aerts and Botzen, 2013).

One of the considerations for managing risk is the clear assignment of costs (as well as benefits) of nearshore development to the individuals and organizations making the decision to develop in those areas (Titus, 1998; United States Climate Change Science Program, 2009; Titus et al., 2009). As Simpson et al. (2012, p. 89) concluded, there is a need for "[p]olicies and practices that specifically warn property owners that protection will neither be provided nor permitted and that no restitution will be made for damages or losses incurred…" should they be determined to develop and/or to occupy hazardous areas. While humanitarian assistance will always be provided during times of crisis, risk management involves asking why public funds should be used to compensate for damages incurred when individuals defy known hazards to enjoy the benefits of development on shores that are at risk from current or anticipated threats (e.g., storm surge and high winds; Titus, 1998; United States Climate Change Science Program, 2009; Grannis, 2011). Decisions not to build, or to relocate existing structures and uses, in areas now determined to be hazardous can be difficult and contentious, whether they are made privately or required through changes in zoning and/or occupancy requirements.

3.5 ADAPTATION PLANNING

Planning for adaptation to coastal climate change involves monitoring changing conditions (trends and projections); assessing new science and knowledge; and applying the insights to benefit policy, decision-making and practice (Lane et al., 2013; Macintosh, 2013; Niven and Bardsley, 2013; Eyzaguirre and Warren, 2014). Adaptation planning focuses on assessing vulnerabilities, advancing risk management and identifying approaches and instruments that can best promote sustainability and resilience (Burby et al., 1999, 2000; Simpson et al., 2012).

Adaptation-planning efforts are generally iterative processes that can take many different pathways and may include elements such as updating policy, legislation and regulations; modifying operational practices; applying new tools and technologies; revising investment and insurance practice; and altering social behaviour and expectations (Figure 9; Eyzaguirre and Warren, 2014). In many cases, adaptation is most effectively undertaken as part of existing policy and planning processes, which is known as the mainstreaming of climate change adaptation into the broader planning process.

Changes will occur across a range of spatial and temporal scales, and often require flexible strategies that prepare communities to better address new realities related to increased hazards and shortened building lifespans (Figure 10). Proactive approaches to planning recognize that it is generally more effective and economical to avoid or prevent damage from severe weather and a changing climate than to respond to adverse, and sometimes catastrophic, impacts (Nicholls et al., 2007; Stern, 2007; Tescult Inc., 2008; Anthoff et al., 2010; Stanton et al., 2010; Brown et al., 2011; Doiron, 2012; IPCC, 2014).

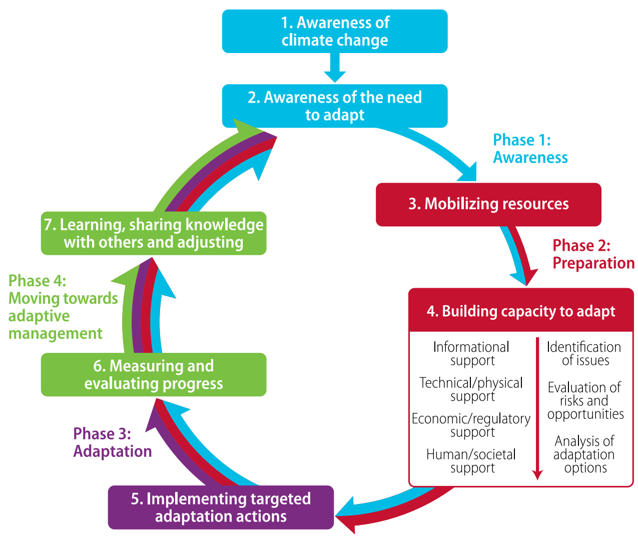


FIGURE 9: Steps in the adaptation planning process (Eyzaguirre and Warren, 2014).

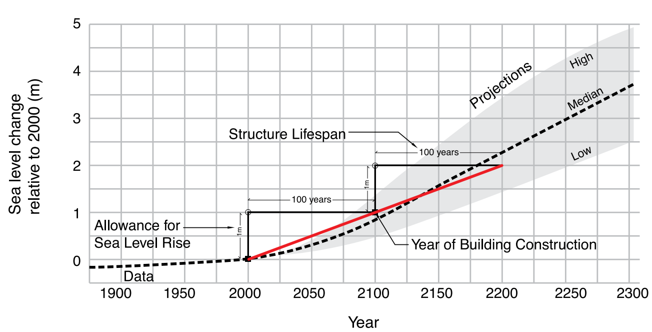


FIGURE 10: Incremental effects of sea-level rise on planning for structures within a 100-year projected life span (*modified from* Ausenco Sandwell, 2011b). The allowance for sea-level rise depends on when a structure is built and the projected sea-level change during the expected lifetime of the structure, and is the baseline for considering other effects, such as storm surge and wave run-up, that contribute to extreme water levels.

To address current and future well-being effectively, adaptation planning should also consider a wide spectrum of linked and often cascading effects on regions, communities and individuals (e.g., economic impacts to primary industries, unemployment, damage to parks, and changes to human health and well-being). Identification and analysis of trickle-down impacts on the four pillars for sustainability (environment, economy, society, culture) will help ensure that issues affecting sustainability are understood by all sectors of society, and that appropriate and timely efforts minimize negative effects and maximize emerging economic opportunities.

When adaptation processes are not well informed, or where insufficient attention has been paid to planning and design, they can lead to maladaptation—actions that can be expensive and inadequate in the longer term and ultimately increase vulnerabilities to environmental change (e.g., poorly designed seawalls; Bernatchez et al., 2008; Brown et al., 2011; Bernatchez and Fraser, 2012; IPCC, 2013, 2014). Maladaptive short-term measures can also prevent future implementation of more appropriate activities by consuming available financial resources and occupying valuable lands.

There is an expanding number of examples of practical experience with adaptation planning in Canada, particularly at the community scale (e.g., Forbes et al., 2009; Vasseur, 2012; Lane et al., 2013; Natural Resources Canada, 2014a). Further examples are provided in the regional chapters of this assessment (*see* Chapters 4–6).

3.5.1 LOCAL DEVELOPMENT POLICY, PLANNING AND DESIGN

In Canada, planning and managing land development and use occurs across a range of governments and sectors but is often the responsibility of local governments. Governing instruments can include formal regional and town plans, bylaws, zoning and protective easements, and local building codes (e.g., Richardson and Otero, 2012). In working with these instruments, there are many opportunities to better address risks associated with climate change. Communities may have the authority to adjust their planning (e.g., to designate areas such as flood plains as not appropriate for development) and to establish guidelines for development and design. They often must also meet provincial/territorial and/or federal regulations and guidelines.

The risk of legal liability and the potential for associated financial impacts can be factors in the selection of adaptation options (*see* Chapter 6). Liabilities could potentially be associated with existing zoning approvals of new development in areas anticipated to be affected by sea-level rise, as well as with the development of more restrictive zoning regulations aimed at limiting development in areas at risk of inundation or damage from storm surges or other weather-related hazards. Because of the long lifespan and cost of many infrastructure investments, good technical information about climate vulnerability is important for allocating resources for expansions and upgrades appropriately. Updating of building codes and best-practice guidelines to reflect changing environmental conditions can assist in establishing proactive design criteria.

3.5.2 PLANNING FOR SEA-LEVEL CHANGE

For coastal communities in Canada's East Coast and West Coast regions, and the Beaufort coastline of the North Coast region, rising sea level is a significant challenge for adaptation planning. As mean sea level rises, the risk of flooding increases (Hinkel et al., 2014) and, as nearshore waters deepen, larger and more damaging waves will reach exposed areas of the coast (*see* Chapter 2). Risks include degradation and loss of coastal ecosystems, damage to infrastructure (e.g., roads, buildings, ports) and associated threats to human health and safety (*see* Chapters 4–6). In general, the more sea level rises, the greater the risks.

Assessing vulnerability to sea-level rise and developing effective adaptation strategies is directed by, among other things, the risk tolerance for damage a decision maker (i.e., community, industry, government) is willing to accept. Risk tolerance is an informed assessment, which can be subjective and is generally based on numerous factors, including the value and lifetime of assets at risk; the economic, social and environmental consequences of negative impacts (e.g., flooding); and the capacity of a system to adjust to, or to recover from, the impacts. Jurisdictions in coastal areas with irreplaceable or vital assets, or structures with long life spans, would have a low tolerance for risk from flooding. In contrast, jurisdictions where little coastal infrastructure is present or planned would have a higher risk tolerance (Box 3; Parris et al, 2012).

Climate change scenarios provide a range of plausible projections of sea-level rise. Knowing the level of tolerance for risk determines which projection of sea-level rise (as determined by climate change scenarios) to plan for. For example, the likely range of mean global sea-level rise by 2100, as presented in the IPCC Fifth Assessment Report and used in this report and by James et al. (2014, 2015) to project relative sea-level changes in Canada (*see* Chapter 2, Box 8 for detailed discussion), is 28 to 98 cm by 2100 (Table 2). An additional scenario considered in this report and by James et al. (2014, 2015), the 'high-emissions plus Antarctic ice-sheet reduction' scenario, projects an even greater sea-level rise (Table 2). Even larger amounts of sea-level rise are possible, although the IPCC Fifth Assessment Report placed *low confidence* in 'semi-empirical' sea-level projections (*see* Chapter 2; IPCC, 2013). This relationship between risk tolerance and sea-level scenarios is well described in Parris et al. (2012).

Although there is a fairly large spread in the anticipated changes in sea level by 2100 among the scenarios, most of the divergence takes place in the latter half of the 21st century (*see* Chapter 2, Figure 21). The choice of sea-level–rise projections does not greatly affect the risk tolerance for impact in short- to medium-term planning horizons (e.g., one to three decades). However, since global sea levels are projected to rise throughout this century and well beyond 2100 (*see* Chapter 2; IPCC, 2013), planning efforts will generally want to consider the longer term implications.

BOX 3

SEA-LEVEL RISE SCENARIOS AND THE UNITED STATES NATIONAL CLIMATE ASSESSMENT

Scenarios for global sea-level rise were developed for the United States National Climate Assessment by the United States National Oceanic and Atmospheric Administration (Parris et al., 2012). The scenarios are to be used "to consider multiple future conditions and devise multiple response options" to "initiate actions that may reduce future impacts." Thus, no specific probabilities or likelihoods are assigned to individual scenarios, and the report emphasizes that no scenario is to be used in isolation. The four scenarios, which range from 20 to 200 cm above mean 1992 sea level, are intended to encompass the full range of plausible future sea-level change by 2100, with the probability of sea level rising by at least 20 cm, and by no more than 200 cm, assessed at greater than 90% (Parris et al., 2012).

In decision-making, the lowest projections of sea-level rise (least amount of increase in global mean sea level) are appropriate for use where the tolerance to risk is high, and the highest projections (highest amount of increase in global mean sea level) are appropriate for use where the tolerance to risk is low. For example, a situation with very low tolerance to risk could be planning for new infrastructure with a long anticipated life cycle, such as a power plant (Parris et al., 2012).

TABLE 2: Relationship between tolerance of risk and projected sea level changes by 2100.

Tolerance to risk of sea-level rise	Climate change scenarios*	Global sea-level rise** by 2050 (cm)	Global sea-level rise by 2100 (cm)	Comments	Range of projected changes in relative sea level across Canada at 2100*** (cm)
Higher	Low emissions (RCP2.6)	Median: 22 cm Range: 16–28 cm	Median: 44 cm Range: 28–61 cm	28 cm is the lower end of the likely**** range defined by the IPCC Fifth Assessment Report	–109 to 62
High	Intermediate emissions (RCP4.5)	Median: 23 cm Range: 17–29 cm	Median: 53 cm Range: 36–71 cm	—	–100 to 71
Low	High emissions (RCP8.5)	Median:25 cm Range: 19–32 cm	Median: 74 cm Range: 52–98 cm	98 cm is the upper end of the likely range defined by the IPCC Fifth Assessment Report	–84 to 93
Lower	High emissions plus Antarctic ice-sheet reduction	Not specified	139 cm	Includes additional contribution from the West Antarctic Ice Sheet	–13 to 168

* *See* Chapter 2, Box 7 for description of scenarios

** Climate and sea-level projections in the IPCC Fifth Assessment Report are synthesized from computer-model results from a number of climate-modelling centres. The combined, or ensemble, results are frequently presented in terms of the average (median) and a confidence range given as percentiles. The range presented here refers to the 90% confidence range [5th percentile to 95th percentile]. The 5th percentile is the level where 5% of the model runs were smaller, and the 95th percentile is the level where 95% of the model runs were smaller. Although not true bounds, the 5th and 95th percentiles are often treated as effective lower and upper bounds of projections for a scenario.

*** Based on projections at 59 locations on Canada's three coasts. Values are the range in median projections for each scenario and illustrate the strong influence of vertical land motion on projections of relative sea-level change in Canada.

**** The likely range is defined in the IPCC Fifth Assessment Report as having a 66–100% probability. Hence there is up to a 33% chance that the actual change observed will lie outside of this range. For global sea-level rise, most of this uncertainty is associated with the upper limit.

Cost is often a key factor in adaptation decision-making. In many cases, selecting higher planning levels (i.e., assuming a larger amount of sea-level rise) would increase the costs associated with adaptation options. For example, at the global scale, Hinkel et al. (2014) found that the 'dike costs' (which include building, upgrading and maintaining newer dikes) in 2100 varied with the climate scenarios applied, with an estimate of US$12–31 billion under the low-emissions scenario (RCP2.6) and US$27–71 billion under the high-emissions scenario (RCP8.5). Iterative and flexible planning, which involves selecting and implementing options that can be revisited and updated over time, is a way to reduce current costs and allow for future changes in scientific understanding of projected sea level and other changes in circumstances to be integrated into decision-making processes when available. An example of the iterative nature of planning for sea-level rise, and the time that it can take to make informed policy changes, is the experience of the Province of British Columbia (Case Study 2; *see* Chapter 6).

CASE STUDY 2

PLANNING FOR SEA-LEVEL RISE IN BRITISH COLUMBIA

(from BC Ministry of Environment, 2013; Andrey et al., 2014)

During the past several years, a series of actions in British Columbia have facilitated the incorporation of new scientific information about changes in sea level into policy and planning processes (Figure 11; *see* Chapter 6). Analysis of regional vertical land motion and global projections of sea-level rise produced new estimates of future sea-level changes (Bornhold, 2008; Thomson et al., 2008), with significant implications for the current system of sea dikes that protect important infrastructure and property (Figure 12). Subsequent analyses, undertaken by the BC Government, the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) and others, were intended to assist policymakers and planners to incorporate sea-level rise into flood-risk assessment, coastal-floodplain mapping, sea-dike design and land-use planning (e.g., Delcan, 2012). The work to develop guidelines for planning was undertaken with an explicit recognition that they would need to be revisited periodically, in response to new information and practical experience.

Some of the outputs from the various analyses undertaken to date include:

- a recommendation that coastal development should plan for sea-level rise of 0.5 m by 2050, 1.0 m by 2100 and 2.0 m by 2200, adjusted for local vertical land motion;
- technical reports to guide calculation of sea-dike–crest elevation and flood construction levels, considering sea-level rise, wind set-up, storm surge and wave run-up;
- guidance for sea-level–rise planning, including designation of 'sea-level–rise planning areas' by local governments;
- a report on simulations of the effects of sea-level rise and climate change on Fraser River flood scenarios (BC Ministry of Forests, Lands and Natural Resource Operations, 2014);
- a report comparing the costs of a variety of adaptation options, ranging from dike construction to flood proofing and managed retreat (Delcan, 2012); the study estimated that the cost of upgrading infrastructure works required along 250 km of diked shorelines and low-lying areas in Metro Vancouver to accommodate a 1 m rise in sea level, including necessary seismic upgrades, would be about $9.5 billion;
- professional-practice guidelines for engineers and geoscientists to incorporate climate change in flood-risk assessments; and
- seismic design guidelines for dikes, focusing on factors to be considered in the seismic design of high-consequence dikes located in southwestern BC.

These analyses have spurred municipal action. For example, the City of Vancouver offered workshops to

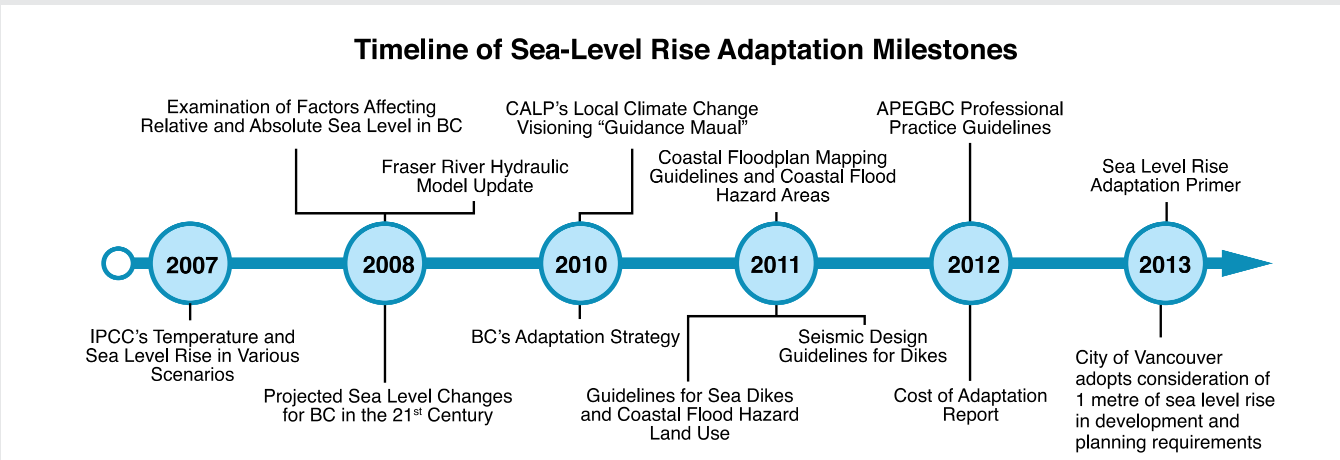


FIGURE 11: Timeline of milestones for adaptation to sea-level rise in British Columbia (*modified from* Sustainability Solutions Group and MC3, 2013). Abbreviations: APEGBC, Association of Professional Engineers and Geoscientists of British Columbia; CALP, Collaborative for Advanced Landscape Planning.

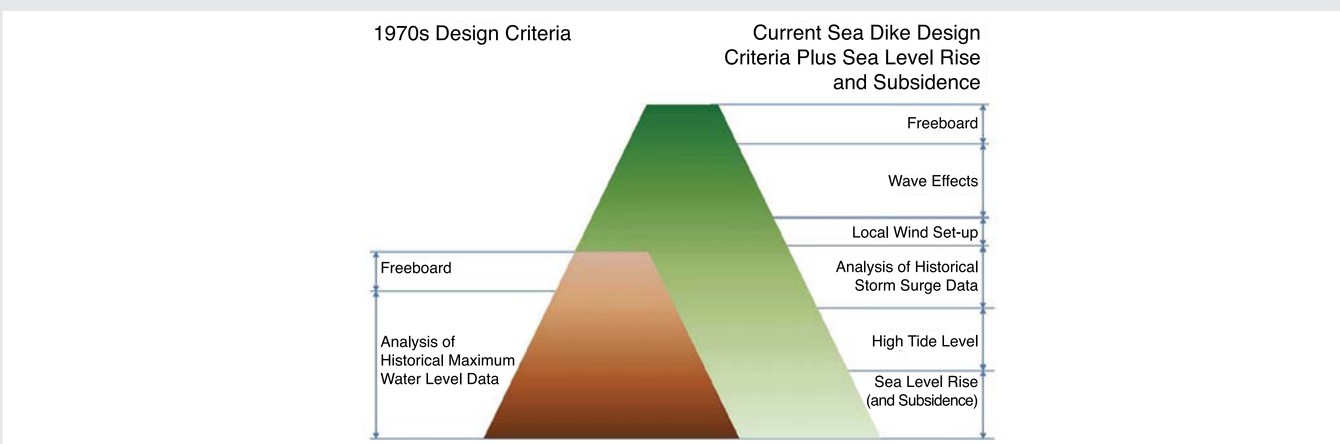


FIGURE 12: Conceptual differences between old and new approaches to sea-dike design (Delcan, 2012).

engineers, developers and municipal staff on adapting coastal infrastructure. In turn, these workshops led the city to review their flood-proofing policies and, in 2013, Vancouver became the first city in BC to adopt formal consideration of 1 m of sea-level rise in development and planning requirements. The city is currently considering a number of other development-planning options.

To allow others to benefit from the many years of work and outputs developed for BC, a working group that included local, provincial and federal government representatives, industry, academia and practitioners worked together to develop a national Sea Level Rise Primer (http://www2.gov.bc.ca/assets/gov/environment/climate-change/policy-legislation-and-responses/adaptation/sea-level-rise/slr-primer.pdf), with examples from BC, Quebec and the Atlantic Provinces. The primer helps communities to identify, evaluate and compare adaptation options, and showcases planning and regulatory tools, land-use change or restriction tools, and structural and nonstructural tools.

An emerging concept relevant to risk tolerance and sea-level change and flooding involves determining the change in elevation at which future storm-surge flooding will occur with the same frequency as present flooding. This information can inform planning elevations for developments or projects. Recent research has developed methods to determine these elevation values (e.g., Thompson et al., 2009; Hunter, 2010; Hunter et al., 2013; Zhai et al., 2013, 2014). These values are larger than the simple projected change in mean sea level, due to uncertainties in projected relative sea-level rise combined with the recurrence properties of storm surges.

3.5.3 TOOLS TO ASSIST ADAPTATION

The suite of instruments and tools available to assist adaptation planning and action along coasts has increased in recent years. Research involving academia and professional practice is increasingly providing more tools to aid decision-making. Recent Canadian examples include the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol (Box 4); the *Sea Level Rise Primer* (Case Study 2; Arlington Group et al., 2013); climate change adaptation guidelines for sea dikes and coastal–flood-hazard land use in British Columbia (Ausenco Sandwell, 2011a–c); and risk-management guidelines for nearshore development in Halifax, NS (Halifax Regional Municipality, 2007). In addition, there are increasing examples of coastal communities (e.g., Gibsons, BC and Charlottetown, PE) that have used the outputs of new research on anticipated changes in sea level and storm surges to inform their harbour- and waterfront-planning processes (*see* Chapters 4–6).

BOX 4

USING THE PIEVC PROTOCOL TO ASSESS VULNERABILITY OF INFRASTRUCTURE

The Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol is an important tool to help evaluate the vulnerability of infrastructure. The goals of the PIEVC, which comprises governments, engineering professionals and nongovernmental organizations, include ensuring the integration of climate change into the planning, design, construction, operation, maintenance and rehabilitation of public infrastructure in Canada (Public Infrastructure Engineering Vulnerability Committee, 2014). Their protocol is a formalized process that can be applied to any type of infrastructure (e.g., buildings, roads, water systems) to assess engineering vulnerability to, and risk from, current and future climate impacts. Of the case studies completed to date, coastalrelevant examples include studies on:

- sewage infrastructure in the Vancouver, BC area (Kerr Wood Leidal Associates Ltd., 2008);
- water-resources infrastructure in Placentia, NL (Catto, 2008); and
- the sewage-treatment plant in Shelburne NS (ABL Environmental Consultants Limited, 2011).

The use of incentives and disincentives to encourage adaptation planning and/or discourage development and human use in areas at risk are also useful tools for governments and for the insurance and financial sectors, who can assign higher costs for insurance or not provide insurance for properties considered to be at higher risk (Aid Environment, 2004; Grannis, 2011; Simpson et al., 2012). Types of incentives include:

- **positive incentives** that encourage beneficial activities (e.g., lower taxes on the development of property inland of coastal setbacks);
- **disincentives** that penalize developers for activities considered as unsustainable (e.g., fines for infilling coastal marshes or mining sand from beaches); and
- **indirect incentives** to effect positive change through application of progressive planning and design (e.g., treating waste water to ensure sustainability of coastal vegetation and using beach nourishment as opposed to groins and seawalls).

Incentives can also be unintentional, such as perverse incentives that reward unsustainable behaviour (e.g., inadequate land-use zoning, or inadequate enforcement of zoning, leading to uncontrolled coastal development; agricultural benefits for draining marshlands; and funding for replacing but not enlarging damaged storm-water infrastructure).

The Government of Nova Scotia has used positive incentives to encourage communities to develop Municipal Climate Change Action Plans (MCCAPs) that document efforts toward mitigation and adaptation. As part of the Municipal Funding Agreement and the extension to the 2010–2014 Federal Gas Tax Fund agreement, the province required communities seeking access to gas tax revenues to prepare an MCCAP as an amendment to their Integrated Community Sustainability Plan (*see* Chapter 4; County of Richmond, 2013).

3.6 ADAPTATION APPROACHES

The available suite of options for coastal adaptation are often grouped into four broad categories: 1) no active intervention, 2) accommodation, 3) protection, and 4) avoidance/retreat (Boateng, 2008; Chouinard et al., 2008; Vasseur and Catto, 2008; Intergovernmental Oceanographic Commission, 2009; Linham and Nicholls, 2010; Nicholls, 2011; Simpson et al., 2012; Arlington Group et al, 2013; Niven and Bardsley, 2013). Although these categories are used predominantly in discussions related to anticipated coastal impacts of sea-level rise and storm surge (Figure 13), they can also apply to a broader range of hazards and risks associated with severe weather events and environmental change (e.g., more intense precipitation events or droughts; extreme heat or cold events; landslides).

Most adaptation plans will involve a number of initiatives from one or more of these response categories, selected to respond to a range of local vulnerabilities and risks that

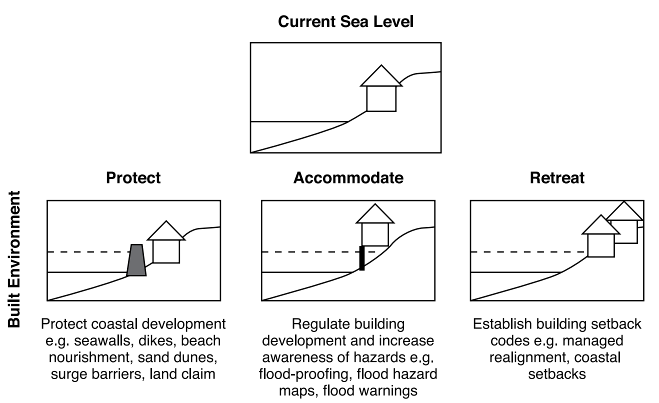


FIGURE 13: Schematic representation of protection, accommodation and retreat responses to sea-level rise (*modified from* Linham and Nicholls, 2010, based on IPCC, 1990)

will change over time. For example, beach nourishment combined with coastal-protection structures can be a reliable and cost-effective option in some situations but often only for a limited period of time.

3.6.1 NO ACTIVE INTERVENTION

'No active intervention' refers to conscious decisions by decision makers to take no action at this time, based on a thorough understanding of the risks involved. No active intervention responses are appropriately employed when there is no significant risk, where little can practically be done to avoid or reduce coastal hazards, or when action taken now is an inappropriate allocation of resources against the potential of a future threat. They are inappropriate when they are the result of apathy, but can be applied where communities are constrained by limited resources. Uncertainty is generally not a good justification for delaying efforts on adaptation (e.g., Lemmen et al., 2008; Macintosh, 2013; Niven and Bardsley, 2013).

3.6.2 ACCOMMODATION

Accommodation responses seek to lower the risks of hazards on continued human use of infrastructure, lands and waters. Generally, accommodation allows for occasional, short-term impacts (e.g., impacts from storm events or seasonal flooding) and is an appropriate response when the practicality of protecting coastal assets is outweighed by the costs, and/or the effectiveness would be limited to a relatively short period of time. Accommodation responses may include modifications to planning and design guidelines and standards to better prepare for extremes of heat and cold; to improve flood resistance (e.g., elevating buildings, ensuring alternative transportation links); and to augment design and construction standards through improved codes and regulations, as well as restrictions imposed through insurance and financial institutions (Arlington Group et al., 2013).

Examples of accommodation responses include flood-proofing buildings and improving storm-water management (e.g., installing larger diameter piping in storm-water collection and disposal systems to reduce the risk of flooding, and implementing low-impact development to reduce runoff into storm-water systems and improve groundwater regeneration). Accepting temporary flooding of nonessential areas (e.g., parking areas, recreational fields) is another example. Accommodation responses on the coast often utilize a range of no-cost/no-regret actions, such as protection of local salt marshes, or low-cost/low-regret actions, such as restrictive use of designated areas (Füssel, 2007).

3.6.3 PROTECTION

Protection responses have been used for centuries to reduce risk and improve security in nearshore environments, and have traditionally been the preferred method for dealing with shoreline erosion throughout most of Canada's coasts. Protection responses include both hard-armouring and soft-armouring measures.

Hard-armouring measures can reduce vulnerabilities and risks by protecting coastal infrastructure in its existing location, by ensuring that the shoreline does not move from its current position, and/or by maintaining current uses (Bijlsma et al., 1996). Hard-armouring measures include:

- shoreline armouring, such as seawalls or bulkheads built of armour stone, concrete or sheet piling; and
- flood protection, such as dikes, tide gates and storm-surge barriers, to prevent flood waters from entering the upper reaches of an estuary or river.

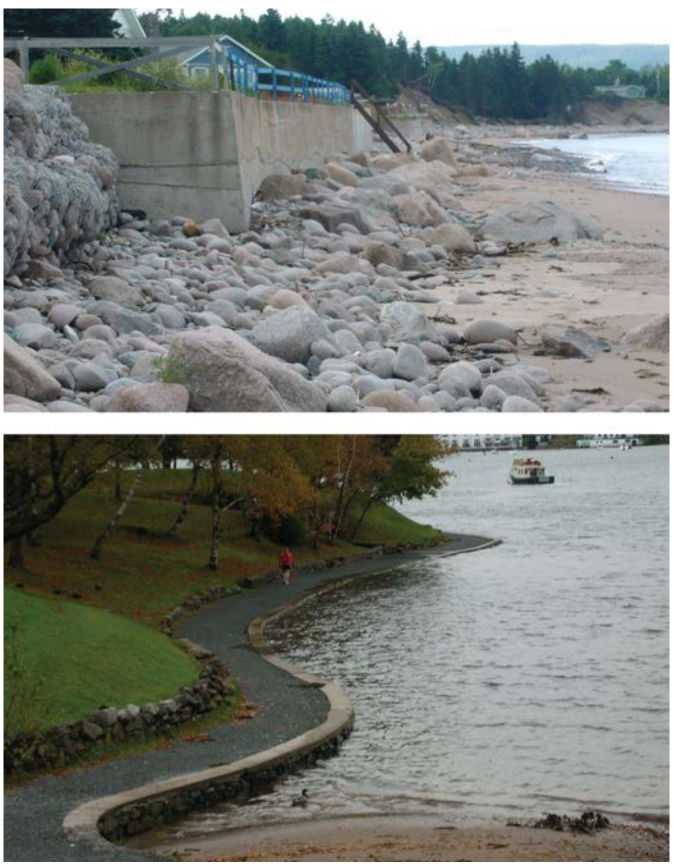


FIGURE 14: Hard armouring of the shoreline, Nova Scotia. *Photo courtesy of M. Davies.*

Hard armouring has historically been a common feature of settled coasts throughout Canada (Figure 14). Examples of shoreline armouring include the dike systems of the British Columbia coast, the seawalls along the Northwest Arm of Halifax Harbour, NS and the Stanley Park seawall in Vancouver, BC. Where hard armouring has been used to extend usable land, it can increase nearshore water depths and vulnerability to wave action and interfere with established coastal erosion cells and longshore current patterns. Most efforts to place hard-armouring measures require professional expertise to examine alternatives, obtain the necessary regulatory approvals and ensure that measures are adequately and expertly designed and constructed to prevent unanticipated negative effects on local natural and built environments (Case Study 3).

CASE STUDY 3

COW BAY CAUSEWAY, HALIFAX REGIONAL MUNICIPALITY, NOVA SCOTIA

(Davies et al., 2010b)

North of Halifax, NS, along the eastern shore, the Cow Bay Road runs on top of a 500 m causeway built over a cobble barrier beach. Protected by an armour stone revetment, this causeway has experienced maintenance problems in the last decade. Storm waves overwash the road, carrying large stones and debris (Figure 15). The asphalt road surface is now more frequently being damaged by waves. Rising relative sea levels have reduced the causeway's freeboard, increasing the frequency and severity of damage, while intensifying offshore storms have resulted in larger waves reaching the shoreline in this area.

FIGURE 15: Effects of storm-wave overwash on Cow Bay Road, Halifax Regional Municipality, NS. *Photo courtesy of R.B. Taylor.*

An analysis was undertaken to evaluate the relative merits of building a more effective armour stone barrier or raising the roadbed. Using a life-cycle costing approach (Davies et al., 2010a), a design was developed for the causeway that minimizes total costs (combined capital and maintenance costs) during the next 30 years. In the longer term, it is likely that the causeway will have to be abandoned and the road routed further inland. However, the most cost effective approach for the next 30 years was determined to be rebuilding the protective barrier to withstand higher water levels and larger waves.

Soft-armouring measures for eroding shorelines include approaches that lessen the damaging effects of tides, currents, waves and storms, while improving nearshore sediment stability. Examples include maintaining and/or restoring beaches and marshes, and the protection and/or restoration of coastal vegetation. When soft armouring is properly designed and implemented, it supports the continuation of existing coastal processes, such as the replenishment of beach and dune sand and the stabilization of salt marshes.

Beach replenishment can be a component of soft-armouring initiatives, used in conjunction with other protection measures (Figure 16). Sources for replenishment sand can be either offshore or land-based deposits. The longevity and effectiveness of replenishment measures are directly related to ongoing coastal geomorphological processes and the impact of storm events.

FIGURE 16: Hybrid protection at Basin Head, PE. Buried revetment covered with sand dune and marram grass. *Photo courtesy of M. Davies.*

In areas where historical dikes created agricultural land that is no longer used for farming, breaching the dikes to allow restoration of the original salt marshes is a soft-armouring response that can improve the capacity of the local shoreline to resist erosion (Bowron et al., 2012; van Proosdij et al., 2014). Establishment of salt marshes seaward of dikes and other hard-armouring projects can also assist in reducing wave energy. Although the effectiveness of such approaches is promoted by technical experts (e.g., Lamont et al., 2014), the measures appear to be largely invisible and poorly understood by the general public. In British Columbia, the Green Shores Program (Lamont et al., 2014) promotes policy and practice for the use of soft armouring as a means to protect against sea-level rise and floods. On Quebec's North Shore, local perceptions of the benefits of hard-armouring measures affected decision-making such that a soft-armouring proposal of beach nourishment was only acceptable to residents if it was combined with a seawall (Bernatchez et al., 2008).

Hard armouring (e.g., seawalls and dikes) can result in a heightened, and sometimes false, sense of protection from coastal flooding. In the past, when weather patterns were established over decades, well-designed and constructed hard armouring could provide a high degree of security from waves and storm surges. As the climate changes and sea level rises, there is less surety in the degree of protection provided by hard armouring, especially as time advances. Some forms of hard armouring can also (at times) increase flooding risks, if structures are breached during high-water events and flood waters become trapped behind them (Mercier and Chadenas, 2012).

3.6.4 AVOIDANCE AND RETREAT

Avoidance and retreat responses are appropriate where the risks to infrastructure or to human health and safety are determined to be unacceptably high, and where protection or accommodation responses are considered impractical. Avoidance is practiced when no new development is allowed in an area, especially in low-lying or exposed areas where construction is traditionally avoided. Retreat responses encompass situations where existing assets are either abandoned or removed from areas under threat (short or longer term) and human activities and uses are constrained. Managed retreat (Titus, 1998; Tomlinson and Helman, 2006; Turner et al., 2007; Forsythe, 2009) seeks to respond to climate-induced coastal risks through planned abandonment and gradual relocation.

Retreat responses can have considerable economic and cultural costs to society and to individuals. Along built shorelines, assets often form the oldest features of a community or have considerable commercial value. Whether the asset is a feature of historical, cultural or environmental value, or individual homes, the trauma of abandonment can be severely felt throughout a community. As a result, retreat responses are generally one of the last options considered in adaptation planning. The unpopularity of retreat as a response to coastal risks often results in action being delayed until the threats materialize (Macintosh, 2013; Muir et al., 2013). Resulting damages can provoke decision makers to take immediate and potentially costly actions without the appropriate science and professional advice, resulting in ineffective solutions (Cooper and Pile, 2014).

Managed retreat is being used in a number of communities throughout Canada whose adaptation-planning efforts are based on avoidance of impacts associated with higher sea levels and severe weather. Harbour and waterfront plans developed for Gibsons, BC (Town of Gibsons, 2012) and Charlottetown, PE (Ekistics Planning and Design, 2012) have included provisions for new development that address predictions for sea-level rise and for increased storm surges. In Halifax, NS, a guideline for coastal development requires new structures to avoid low-lying areas with a potential for flooding from sea-level rise and severe weather (Halifax Regional Municipality, 2007).

3.7 EMERGENCY PREPAREDNESS

Another element of preparing for climate change is improving emergency preparedness. As the frequency and/or intensity of extreme-weather events increase as a result of climate change, there is greater need to undertake procedural changes to improve preparedness for disaster response. 'Preparedness' refers to any pre-disaster activity undertaken to enhance a community's ability to respond to, and cope with, storm conditions (UN/ISDR and UN/OCHA, 2008). In Canada, local, provincial and federal emergency measures organizations co-ordinate with police, fire and emergency medical responders, and other organizations (e.g., Canadian Red Cross), to collaborate and share operations and resources.

Within communities, emergency measures organizations have important roles in planning for adaptation. As environmental conditions change, protocols for emergency response, evacuation routes and storage of disaster-relief supplies may need to be revisited to ensure that they remain adequate. As the prediction of severe-weather events improves, communities can reduce risks through improved preparedness for disaster response, early evacuation of populations at risk and provision of temporary protection for buildings, property and natural resources (Case Study 4).

CASE STUDY 4

LITTLE ANSE, ISLE MADAME, CAPE BRETON, NOVA SCOTIA

(Chung, 2014a)

Little Anse is a small coastal village of approximately 125 inhabitants located on the eastern coast of Petit-de-Grat Island of the Isle Madame archipelago in Cape Breton, NS (Figure 17). In recent years, fishing activity that was once based in the village has moved to the larger harbour of Petit-de-Grat. The road that connects the village to the larger community is subject to flooding during storm events, isolating local residents, many of whom are elderly. The breakwater at Little Anse, which once protected the cove and the low-lying road from storm effects, has been damaged and has fallen into disrepair.

FIGURE 17: Aerial photo of Little Anse, Nova Scotia (*modified from* Digital Globe and Google, 2016).

Repair or replacement of the damaged breakwater (estimated at roughly $1–5 million) or construction of an alternative road are expensive responses that would pose significant, and potentially prohibitive, financial burdens on the municipality and the province (Camare, 2011). To alleviate the threats to human health and safety that occur when the road access is flooded, participants in an International Community–University Research Alliance (ICURA) project (C-Change: Managing Adaptation to Environmental Change in Coastal Communities, Canada and the Caribbean) have been working with emergency responders, community leaders and the Canadian Red Cross to identify and locate those individuals at greatest risk, to ensure that emergency preparedness and response procedures are adequate and to identify alternative measures to ensure the safety and well-being of the residents during storm periods (Lane et al., 2013; Chung, 2014a, b).

Plans are underway to develop short-term evacuation options for those most at risk. When severe weather forecasts anticipate a storm surge that could flood the road, residents would voluntarily be moved to a safe location (community centre) to ride out the storm in safety. Planning for this accommodation operation will engage public-health workers, emergency services, local pharmacists, and service and faith-based groups to provide assistance, meals and comfort during their stay.

4 CONCLUDING THOUGHTS

Rockström and Klum (2015) have stated that humanity is struggling against four main pressures: population growth and affluence, ecosystem degradation, climate change and surprise. Surprise is the product of catastrophic or creeping changes that occur when thresholds are crossed and wide-ranging impacts are felt throughout environments and societies. They have also noted that society has tremendous ability, through creativity and innovation, to adjust and adapt to these stresses and to thrive in a rapidly changing world. While this chapter presented a high-level overview of the challenges that climate change presents for Canada's coastal regions and the approaches for adaptation, the following regional chapters provide more detailed discussions of innovation at work across the country.

5 REFERENCES

ABL Environmental Consultants Limited (2011): Vulnerability of Sandy Point STP upgrade to climate change; Municipality of the District of Shelburne – From Ocean to Forest, 57 p., <http://www.pievc.ca/sites/default/files/shelburne_sewage_treatment_plant_report.pdf>.

Adger, W.N. (2000): Social and ecological resilience: are they related?; Progress in Human Geography, v. 24, p. 347–364.

Aerts, J. and Botzen, W. (2013): Climate adaptation cost for flood risk management in the Netherlands; *in* Storm Surge Barriers to Protect New York City Against the Deluge, (ed.) D. Hill, M.J. Bowman and J.S. Khinda; Conference Proceedings, Brooklyn, New York, March 30–31, 2009, p. 99–113. doi:10.1061/9780784412527.007

Aid Environment (2004): Integrated marine and coastal area management (IMCAM) approaches for implementing the convention on biological diversity; Secretariat of the Convention on Biological Diversity, CBD Technical Series, no. 14, 51 p., <https://www.cbd.int/doc/publications/cbd-ts-14.pdf>.

Andrey, J., Kertland, P. and Warren, F.J. (2014): Water and transportation infrastructure; *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 233–252, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter8-Infrastructure_Eng.pdf>.

Anthoff, D., Nicholls, R.J. and Tol, R.S.J. (2010): The economic impact of substantial sea-level rise; Mitigation and Adaptation Strategies for Global Change, v. 15, no. 4, p. 321–355. doi:10.1007/s11027-010-9220-7

Anthony, E.J. and Sabatier, F. (2013): Chapter 12: France; *in* 2013: Coastal Erosion and Protection in Europe, (ed.) E. Pranzini and A. Williams; Routledge, New York, New York, p. 227–253.

ArcticNet (2013): Annual report 2011–2013; Université Laval, Québec, Quebec, 88 p., <http://www.arcticnet.ulaval.ca/pdf/media/2013_annual_report_en.pdf>.

Arlington Group Planning + Architecture Inc., Tetra Tech EBA, De Jardine Consulting and Sustainability Solutions Group (2013): Sea level rise adaptation primer: a toolkit to build adaptive capacity on Canada's south coasts; BC Ministry of Environment, 149 p., <http://www2.gov.bc.ca/gov/DownloadAsset?assetId=41DCF41B26B4449D8F-54FAA0A8C751A9&filename=slr-primer.pdf>.

Association of Canadian Port Authorities (2007): Port industry facts; Association of Canadian Port Authorities, Public Relations, <http://www.acpa-ports.net/pr/facts.html>.

Atlantic Provinces Economic Council (2004): An agenda for growth and prosperity in Atlantic Canada; Atlantic Provinces Economic Council (APEC), Halifax, Nova Scotia, 24 p.

Auld, H. and MacIver, D. (2007): Changing weather patterns, uncertainty and infrastructure risks: emerging adaptation requirements; Environment Canada, Adaptation, Impacts Research Division, Occasional Paper 9, 18 p., <http://publications.gc.ca/collections/collection_2011/ec/En57-41-9-2007-eng.pdf>.

Ausenco Sandwell (2011a): Climate change adaptation guidelines for sea dikes and coastal flood hazard land use: draft policy discussion paper; BC Ministry of Environment, 45 p., <http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/draft_policy_rev.pdf>.

Ausenco Sandwell (2011b): Climate change adaptation guidelines for sea dikes and coastal flood hazard land use: guidelines for management of coastal flood hazard land use; BC Ministry of Environment, 22 p., <http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/coastal_flooded_land_guidelines.pdf>.

Ausenco Sandwell (2011c): Climate change adaptation guidelines for sea dikes and coastal flood hazard land use: sea dikes guidelines; BC Ministry of Environment, 59 p., <http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/sea_dike_guidelines.pdf>.

Austen, E. and Hanson, A. (2007): An analysis of wetland policy in Atlantic Canada; Canadian Water Resources Journal, v. 32, no. 3, p. 163–178.

Ballinger, R.C., Potts, J.S., Bradly, N.J. and Pettit, S.J. (2000): A comparison between coastal hazard planning in New Zealand and the evolving approach in England and Wales; Ocean and Coastal Management, v. 43, no. 10–11, p. 905–925.

Ban, N. and Alder, J. (2008): How wild is the ocean? Assessing the intensity of the anthropogenic marine activities in British Columbia, Canada; Aquatic Conservation: Marine and Freshwater Ecosystems, v. 18, no. 1, p. 55–85. doi:10.1002/aqc.816

Barange, M. and Perry, R.I. (2009): Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture; *in* Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge, (ed.) K. Cochrane, C. De Young, D. Soto and T. Bahri; Food and Agriculture Organization of the United Nations (FAO), Fisheries and Aquaculture Technical Paper 530, p. 7–106, <http://www.fao.org/docrep/012/i0994e/i0994e00.htm>.

BC Ministry of Environment (2013): Sea level rise and storm surges on the BC coast; Government of British Columbia, Climate Change, Policy, Legislation and Programs, <http://www2.gov.bc.ca/gov/topic.page?id=F09F1EC7576643CEB5FB1536913730BA>.

BC Ministry of Forests, Lands and Natural Resource Operations (2014): Simulating the effects of sea level rise and climate change on Fraser River Flood scenarios: final report; BC Ministry of Forests, Lands and Natural Resource Operations, Flood Safety Section, Victoria, British Columbia, 202 p., <http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/Simulating_Effects_of_Sea_Level_Rise_and_Climate_Change_on_Fraser_Flood_Scenarios_Final_Report_May-2014.pdf>.

Bernatchez, P. and Fraser, C. (2012): Evolution of coastal defense structures and consequences for beach width trends, Quebec, Canada; Journal of Coastal Research, v. 28, no. 6, p. 1550–1566.

Bernatchez, P., Fraser, C., Friesinger, S., Jolivet, Y., Drejza, S. and Morissette, A. (2008): Sensibilité des côtes et vulnérabilité des communautés du golfe du Saint-Laurent aux impacts des changements climatiques; report prepared by the Laboratoire de dynamique et de gestion intégrée des zones côtières, Université du Québec à Rimouski (UQAR) for Ouranos and the Fonds d'action pour le changement climatique (FACC), 256 p., <http://www.ouranos.ca/media/publication/145_Bernatchezetal2008.pdf>.

Berteaux, D., DeBlois, S., Angers, J.-F., Bonin, J., Casajus, N., Darveau, M., Fournier, F., Humphries, M.M., McGill, B., Larivée, J., Logan, T., Nantel, P., Périé, C., Poisson, F., Rodrigue, D., Rouleau, S., Siron, R., Thuiller, W. and Vescovi, L. (2010): The CC-Bio Project: studying the effects of climate change on Quebec biodiversity; Diversity, v. 2, p. 1181–1204

Beshiri, R. (2005): A visit to Canada's countryside: rural tourism; Rural and Small Town Canada Analysis Bulletin, v. 6, no. 5, 25 p., <http://www.statcan.gc.ca/pub/21-006-x/21-006-x2005005-eng.pdf>.

Bijlsma, L., Ehler, C. Klein, R. Kulshrestha, S., McLean, R., Mimura, N., Nicholls, R., Nurse, L., Nieto, H.P. and Stakhiv, E. (1996): Coastal zones and small islands; *in* Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses (Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change), (ed) R.T. Watson, M.C. Zinyowera and R.H. Moss; Cambridge University Press, Cambridge, United Kingdom, p. 289–324, <https://www.ipcc.ch/ipccreports/sar/wg_II/ipcc_sar_wg_II_full_report.pdf>.

Boateng, I. (2008): Integrating sea-level rise adaptation into planning policies in the coastal zone; Coastal Zone Administration, Integrating Generations, FIG Working Week 2008, Stockholm, Sweden, 22 p., <http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/422/UK_SLR_Adaptation_&_Planning_-_Boateng_2008.pdf>.

Bornhold, B.D. (2008): Projected sea level changes for British Columbia in the 21st century; Government of British Columbia and Government of Canada, 9 p., <http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/452793/sea_level_changes_08.pdf>.

Bowron, B. and Davidson, G. (2012): Climate change planning: case studies from Canadian communities; report prepared for the Canadian Institute of Planners, 65 p., <https://www.cip-icu.ca/files/resources/case-studies-from-canadian-commmunities-final>.

Bowron, T., Neatt, N, van Proosdij, D. and Lundholm, J. (2012): Salt marsh restoration in Atlantic Canada in restoring tidal flow to salt marshes; *in* Tidal Marsh Restoration: A Synthesis of Science and Management, (ed.) C.T. Roman and D.M. Burdick, Island Press, Washington, District of Columbia, p. 191-210, <http://islandpress.org/book/tidal-marsh-restoration>.

Boyle, J., Cunningham, M. and Dekens, J. (2013): Climate change adaptation and Canadian infrastructure: a review of the literature; International Institute for Sustainable Development (IISD), Winnipeg, Manitoba, 35 p., <http://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf>.

Brown, S., Nicholls, R., Vafeidis, A., Hinkel, J. and Watkiss, P. (2011): Sea-level rise: the impacts and economic costs of sea-level rise on coastal zones in the EU and the costs and benefits of adaptation; ClimateCost Project, Technical Policy Briefing Note 2, 43 p., <http://www.sei-international.org/mediamanager/documents/Publications/sei-climatecost-sea-level-rise.pdf>.

Burby, R.J., Beatley, T., Berke, P.R., Deyle, R.E., French, S.P., Godschalk, D.R., Kaiser, E.J., Kartez, J.D., May, P.J., Olshansky, R., Paterson, R.G. and Platt, R.H. (1999): Unleashing the power of planning to create disaster-resistant communities; Journal of the American Planning Association, v. 65, no. 3, p. 247–258. doi:10.1080/01944369908976055

Burby, R.J., Deyle, R.E., Godschalk, D.R. and Olshansky, R.B. (2000): Creating hazard resilient communities through land-use planning; Natural Hazards Review, v. 1, no. 2, p. 99–106. doi:10.1061/(ASCE)1527-6988(2000)1:2(99)

Burton, I. (2008): Moving Forward on Adaptation; *in* From Impacts to Adaptation: Canada in a Changing Climate, (ed.) D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, p. 425–440, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2007/pdf/ch10_e.pdf>.

Camare, H.M. (2011): Multi-criteria decision evaluation of adaptation strategies for vulnerable coastal communities; M.Sc. thesis, University of Ottawa, 331 p., <https://www.ruor.uottawa.ca/bitstream/10393/20112/1/Mostofi_Camare_Hooman_2011_thesis.pdf>.

Campbell, I.D., Durant D.G., Hunter, K.L. and Hyatt, K.D. (2014): Food production; *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 99–134, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter4-Food-Production_Eng.pdf>.

Canmac Economics, School for Resource and Environmental Studies, Enterprise Management Consultants and the Secretariat of the Atlantic Coastal Zone Information Steering Committee (2002): The value of the ocean sector to the economy of Prince Edward Island; report prepared for the Government of Prince Edward Island and the Government of Canada, Charlottetown, Prince Edward Island, 101 p., <http://www.dfo-mpo.gc.ca/Library/266991e.pdf>.

Catto, N. (2008): Water resources public infrastructure vulnerability assessment for Placentia, Newfoundland; report prepared by Cameron Consulting Incorporated for the Public Infrastructure Engineering Vulnerability Committee (PIEVC), 161 p., <http://www.pievc.ca/sites/default/files/town_of_placentia_newfoundland_final_report.pdf>.

CBCL Limited (2009): The 2009 state of Nova Scotia's coast – summary report; Province of Nova Scotia, 22 p., <http://www.novascotia.ca/coast/documents/state-of-the-coast/WEB_SummaryReport.pdf>.

CBCL Limited (2012): Assessment of infrastructure relevant to the fishing and aquaculture industries; Atlantic Climate Adaptation Solutions Association (ACASA), 137 p., <http://atlanticadaptation.ca/sites/discoveryspace.upei.ca.acasa/files/Fisheries%20and%20Aquaculture%20Infrastucture_0.pdf>.

CBC News (2003): Hurricane Juan a wakeup call: experts; CBC/Radio-Canada, <http://www.cbc.ca/news/canada/nova-scotia/hurricane-juan-a-wakeup-call-experts-1.359547>.

CBC News (2015): Ice-bound P.E.I.–Îles-de-la-Madeleine ferry now heading to N.S.; CBC/Radio-Canada, <http://www.cbc.ca/news/canada/prince-edward-island/ice-bound-p-e-i-%C3%AEles-de-la-madeleine-ferry-now-heading-to-n-s-1.2974986>.

Chouinard, O., Plante, S. and Martin, G. (2008): The community engagement process: a governance approach in adaptation to coastal erosion and flooding in Atlantic Canada; Canadian Journal of Regional Science, v. XXXI, no. 3, p. 507–520.

Chung, A.Q.H. (2014a): Emergency preparedness and response planning: a value-based approach to preparing coastal communities for sea level rise; M.Sc. thesis, University of Ottawa, 212 p., <https://www.ruor.uottawa.ca/bitstream/10393/31446/3/Chung_Alexander_Quoc_Huy_2014_thesis.pdf>.

Chung, A.Q.H. (2014b): Operation Breakwater: table-top exercise for the Municipality of the County of Richmond Emergency Operations Centre: the case of Little Anse breakwater failure – after action report; Municipality of the County of Richmond, Arichat, Nova Scotia, 46 p.

Commission for Environmental Cooperation (2012): Guide for planners and managers to design resilient marine protected areas networks in a changing climate; Commission for Environmental Cooperation, Montreal, Quebec, 32 p., <http://www3.cec.org/islandora/en/item/10856-guide-planners-and-managers-design-resilient-marine-protected-area-networks-in-en.pdf>.

Cooper, J. and Pile, J. (2014): The adaptation-resistance spectrum: a classification of contemporary adaptation approaches to climate-related coastal change; Ocean and Coastal Management, v. 94, p. 90–98.

Costanza, R. and Mageau, M. (1999): What is a healthy ecosystem?; Aquatic Ecology, v. 33, no. 1, p. 105–115. doi:10.1023/A:1009930313242

Costanza, R., Kubiszewski, I., de Groot, R., van der Ploeg, S., Sutton, P., Anderson, S.J., Farber, S. and Turner, R.K. (2014): Changes in the global value of ecosystem services; Global Environmental Change, v. 26, p. 152–158.

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M., Lee, M., Levy, C., Maslin, M., McCoy, D., McGuire, B., Montgomery, H., Napier, D., Pagel, C., Patel, J., Puppim de Oliveira, J.A., Redclift, N., Rees, H., Rogger, D., Scott, J., Stephenson, J., Twigg, J., Wolff, J. and Patterson, C. (2009): Managing the health effects of climate change; The Lancet, v. 373, no. 9676, p. 1693–1733. doi:10.1016/S0140-6736(09)60935-1

County of Richmond (2013): Municipal climate change action plan; report prepared by the Marine Research Centre, University Sainte-Anne for the Municipality of the County of Richmond, Arichat, Nova Scotia, 80 p.

Davies, M., MacDonald, N. and Boyd, G. (2010a): Development of a life-cycle costing approach for roads exposed to storms and sea level rise; Transportation Association of Canada, Annual Conference, 19 p.

Davies, M., MacDonald, N. and Wiebe, D. (2010b): Cow Bay causeway restoration study: technical report; report prepared by Coldwater Consulting Ltd. for Halifax Regional Municipality, 82 p.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. (2010): Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making; Ecological Complexity, v. 7, no. 3, p. 260–272. doi:10.1016/j.ecocom.2009.10.006

Delcan (2012): Cost of adaptation – sea dikes and alternative strategies – final report; BC Ministry of Forests, Lands and Natural Resource Operations, 23 p., <http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/cost_of_adaptation-final_report_oct2012.pdf>.

DFO [Fisheries and Oceans Canada] (2014a): About small craft harbours; Fisheries and Oceans Canada, <http://www.dfo-mpo.gc.ca/sch-ppb/aboutsch-aproposppb-eng.asp>.

DFO [Fisheries and Oceans Canada] (2014b): Canada's fisheries fast facts 2014; Fisheries and Oceans Canada, <http://www.dfo-mpo.gc.ca/stats/facts-Info-14-eng.htm>.

Doiron, S. (2012): From climate change plans to by-laws: it's time to act; Plan Canada, Canadian Institute of Planners, p. 30–34.

Dolan, A.H. and Walker, I.J. (2006): Understanding vulnerability of coastal communities to climate change related risks; Journal of Coastal Research, Special Issue 39, p. 1317–1324.

Dolan, A.H., Taylor, M., Neis, B., Ommer, R., Eyles, J., Schneider, D. and Montevecchi, B. (2005): Restructuring and health in Canadian coastal communities; EcoHealth, v. 2, no. 3, p. 195–208. doi:10.1007/s10393-005-6333-7

Ekistics Planning and Design (2012): City of Charlottetown: comprehensive waterfront management plan – final report; City of Charlottetown, 94 p., <http://city.charlottetown.pe.ca/pdfs/Charlottetown-Waterfront-Final-2012_12_19.pdf>.

Environment Canada (2014): Vigorous Igor; Environment Canada, Canada's top ten weather stories of 2010, <http://ec.gc.ca/meteo-weather/default.asp?lang=En&n=BDE98E0F-1>.

European Environment Agency (2006a): The changing face of Europe's coastal areas; European Environment Agency, European Union, Copenhagen, Denmark, EEA Report No 6/2006, 112 p., <http://www.eea.europa.eu/publications/eea_report_2006_6>.

European Environment Agency (2006b): The continuous degradation of Europe's coasts threatens European living standards; European Environment Agency, European Union, Copenhagen, Denmark, 4 p., <http://www.eea.europa.eu/publications/briefing_2006_3>.

Eyzaguirre, J. and Warren, F.J. (2014): Adaptation: linking research and practice; *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 253–286, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter9-Adaptation_Eng.pdf>.

Federal, Provincial and Territorial Governments of Canada (2010): Canadian biodiversity: ecosystem status and trends 2010; Canadian Councils of Resource Ministers, Ottawa, Ontario, 142 p., <http://www.biodivcanada.ca/A519F000-8427-4F8C-9521-8A95AE287753/EN_CanadianBiodiversity_FULL.pdf>.

Félio, G. (2012): 2012 Canadian infrastructure report card: municipal roads and water systems; Canadian Construction Association, Canadian Public Works Association, Canadian Society for Civil Engineering and Federation of Canadian Municipalities, <http://www.canadainfrastructure.ca/en/report.html>.

Feltmate, B. and J. Thistlethwaite (2012): Climate change adaptation: a priorities plan for Canada; Climate Change Adaptation Project (Canada), Waterloo, Ontario, 122 p., <https://uwaterloo.ca/environment/sites/ca.environment/files/uploads/files/CCAP-Report-30May-Final.pdf>.

Field, J.C., Boesch, D.F., Scavia, D., Buddemeier, R., Burkett, V.R., Cayan, D., Fogarty, M., Harwell, M., Howarth, R. and Mason, C. (2001): The potential consequences of climate variability and change on coastal areas and marine resources; *in* Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change; United States Global Change Research Program; Cambridge University Press, Cambridge, United Kingdom, p. 461–487.

Forbes, D.L., editor (2011): State of the Arctic coast 2010: scientific review and outlook; International Arctic Science Committee, Land-Ocean Interactions in the Coastal Zone, Arctic Monitoring and Assessment Programme, and International Permafrost Association; Helmholtz-Zentrum, Geesthacht, Germany, 168 p., <http://library.arcticportal.org/1277/1/state_of_the_arctic_coast_2010.pdf>.

Forbes, D.L., Manson, G.K., Charles, J., Thompson, K. and Taylor, R.B. (2009): Halifax harbour extreme water levels in the context of climate change: scenarios for a 100-year planning horizon; Geological Survey of Canada, Open File 6346, 22 p., <http://ftp2.cits.rncan.gc.ca/pub/geott/ess_pubs/248/248196/of_6346.pdf>.

Forsythe, P.J. (2009): Planning on a retreating coastline: Oamaru, North Otago, New Zealand; Institute of Geological and Nuclear Sciences Limited, Dunedin, New Zealand, GNS Science Report 2009/25, 53 p., <https://www.massey.ac.nz/massey/fms/Colleges/College%20of%20Humanities%20and%20Social%20Sciences/Psychology/Disasters/pubs/GNS/2009/SR_2009_25_Planning_for_retreating_coastline-Oamaru.pdf?E4F35A0E9E4030C92B105B82EAB3BC34>.

Furgal, C. and Prowse, T.D. (2008): Northern Canada; *in* From Impacts to Adaptation: Canada in a Changing Climate 2007, (ed.) D. Lemmen, F.J. Warren, J. Lacroix, and E. Bush; Government of Canada, Ottawa, Ontario, p. 57–118, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2007/pdf/ch3_e.pdf>.

Füssel, H.M. (2007): Adaptation planning for climate change: concepts, assessment approaches, and key lessons; Sustainability Science, v. 2, no. 2, p. 265–275. doi:10.1007/s11625-007-0032-y

Gardner, M., Fraser, R., Milloy, M. and Frost, J. (2005): Economic value of the Nova Scotia ocean sector; report prepared by Gardner Pinfold Consulting Economists Ltd and MariNova Consulting Limited for the Government of Canada, Government of Nova Scotia and Nova Scotia Fisheries Sector Council, Dartmouth, Nova Scotia, 63 p., <http://www.dfo-mpo.gc.ca/Library/314642e.pdf>.

Gardner, M., MacAskill, G. and DeBow, C. (2009): Economic impact of the Nova Scotia ocean sector 2002–2006; report prepared by Gardner Pinfold Consulting Economists Ltd. for the Government of Canada, Government of Nova Scotia and Nova Scotia Fisheries Sector Council, Dartmouth, Nova Scotia, 27 p., <http://lunenburgregion.ca/images/uploads/English_-NS_Ocean_Sector_FINAL_Report_(March,_2009).pdf>.

Gardner Pinfold Consulting Economists Ltd. (2009a): Economic impact of marine related activities in Canada; Fisheries and Oceans Canada, Economic Analysis and Statistics Branch, Statistical and Economic Analysis Series, No. 1-1, 78 p., <http://www.dfo-mpo.gc.ca/ea-ae/cat1/no1-1/no1-1-eng.pdf>.

Gardner Pinfold Consulting Economists Ltd. (2009b): Economic impact of marine related activities in Large Ocean Management Areas; Fisheries and Oceans Canada, Economic Analysis and Statistics Branch, Statistical and Economic Analysis Series, No. 1-2, 79 p., <http://www.dfo-mpo.gc.ca/ea-ae/cat1/no1-2/no1-2-eng.pdf>.

Google (2015): Google Maps™ satellite image of Little Anse, Nova Scotia; Google, image, URL <http://maps.google.ca/maps> [©2015 Google - Imagery, ©2015 TerraMetrics, map data, May 2015].

Government of Canada (2012a): Industry overview: tourism; Government of Canada, Supporting Tourism, <http://www.tourism.gc.ca/eic/site/034.nsf/eng/h_00003.html>.

Government of Canada (2012b): Canada's federal tourism strategy: welcoming the world; Government of Canada, Supporting Tourism, <http://www.ic.gc.ca/eic/site/034.nsf/eng/00216.html>.

Government of Western Australia (2012): State coastal planning policy guidelines: draft state planning policy 2.6; prepared under Part Three of the Planning and Development Act 2005, Western Australian Planning Commission, Perth, Australia, 28 p.

Grannis, J. (2011): Adaptation tool kit: sea-level rise and coastal land use – how governments can use land-use practices to adapt to sea-level rise; Georgetown Climate Centre, Washington, District of Columbia, 90 p., <http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/456/SLR_Adaptation_Tool_Kit_-_Grannis_2011.pdf>.

GSGislason & Associates Ltd. (2007): Economic contributions of the oceans sector in British Columbia; report prepared for the Canada/British Columbia Oceans Coordinating Committee, Vancouver, British Columbia, 77 p., <http://www.env.gov.bc.ca/omfd/reports/oceansector-economics.pdf>.

Halifax Regional Municipality (2007): ClimateSMART – climate change: developer's risk management guide; Halifax Regional Municipality, Halifax, Nova Scotia, 26 p., <http://ccap.org/docs/resources/394/DevelopersGuidetoRiskManagment.pdf>.

Hansen, J.C., Deutch, B. and Odland, J.Ø. (2008): Dietary transition and contaminants in the Arctic: emphasis on Greenland; Circumpolar Health Supplements 2008, v. 2, 96 p., <http://www.circumpolarhealthjournal.net/public/journals/32/chs/CHS_2008_2.pdf>.

Haskell, B.D., Norton, B.G. and Costanza, R. (1992): What is ecosystem health and why should we worry about it?; *in* Ecosystem Health: New Goals for Environmental Management, (ed.) R. Costanza, B.G. Norton and B.D. Haskell; Island Press, Washington, District of Columbia, p. 239–256.

Heap, N. (2007): Hot properties: how global warming could transform B.C.'s real estate sector; David Suzuki Foundation, Vancouver, British Columbia, 32 p., <http://www.davidsuzuki.org/publications/downloads/2007/DSF_HotProperties_final1.pdf>.

Hildebrand, L.P. (1989): Canada's Experience With Coastal Zone Management; Oceans Institute of Canada, Halifax, Nova Scotia, 118 p.

Hildebrand, L.P. (1995): Canadian coastal and ocean management: the emergence of a new era; Ocean Policy Research, v. 10, p. 37–72.

Hildebrand, L.P. and Norrena, E.J. (1992): Approaches and progress toward effective integrated coastal zone management; Marine Pollution Bulletin, v. 25, no. 1–4, p. 94–97. doi:10.1016/0025-326X(92)90194-B

Hinkel, J., Lincke, D., Vafeidis, A.T., Perrette, M., Nicholls, R.J., Tol, R.S.J., Marzeion, B., Fettweis, X., Ionescu, C. and Levermann, A. (2014): Coastal flood damage and adaptation costs under 21st century sea-level rise; Proceedings of the National Academy of Sciences of the United States of America, v. 111, no. 9, p. 3292–3297.

H. John Heinz III Center for Science, Economics and the Environment (2000): The hidden costs of coastal hazards: implications for risk assessment and mitigation (2nd edition); H. John Heinz III Center for Science, Economics and the Environment, Island Press, Washington, District of Columbia, 252 p.

Hounsell, S. (2012): Biodiversity; *in* Climate Change Adaptation: A Priorities Plan for Canada, (ed.) B. Feltmate and J. Thistlethwaite; Intact Foundation and University of Waterloo, report of the Climate Change Adaptation Project (Canada), p. 37–48.

Hunter, J. (2010): Estimating sea-level extremes under conditions of uncertain sea-level rise; Climatic Change, v. 99, p. 331–350.

Hunter, J., Church, J.A., White, N.J. and Zhang, X. (2013): Towards a global regionally varying allowance for sea-level rise; Ocean Engineering, v. 71, p. 17–27.

Hutchings, J.A., Côté, I.M., Dodson, J.J, Fleming, I.A., Jennings, S., Mantua, N.J., Peterman, R.M., Riddell, B.E., Weaver, A.J. and VanderZwaag, D.L. (2012): Sustaining Canadian marine biodiversity: responding to the challenges posed by climate change, fisheries, and aquaculture; Royal Society of Canada: Academies of Arts, Humanities and Sciences of Canada, Ottawa, Ontario, 315 p., <https://rsc-src.ca/sites/default/files/pdf/RSCMarineBiodiversity2012_ENFINAL.pdf>.

Infrastructure Canada (2011): Building for prosperity: public infrastructure in Canada; Infrastructure Canada, 30 p., <http://www.infrastructure.gc.ca/alt-format/pdf/Plan-Booklet-Livret-eng.pdf>.

International Oceanographic Commission (2009): Hazard awareness and risk mitigation in integrated coastal area management (ICAM); UNESCO, Intergovernmental Oceanographic Commission, Manuals and Guides, no. 50, ICAM Dossier no. 5, 143 p., <http://unesdoc.unesco.org/images/0018/001832/183253e.pdf>.

IPCC [Intergovernmental Panel on Climate Change] (2007): Climate Change 2007: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) M. Parry, O. Canziani, J. Palutikof, P. van der Linden and C. Hanson; Cambridge University Press, Cambridge, United Kingdom and New York, New York, 976 p., <http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf>.

IPCC [Intergovernmental Panel on Climate Change] (2013): Glossary; *in* Climate Change 2013: The Physical Science Basis (Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) T.F. Stocker, D. Quin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Migdley; Cambridge University Press, Cambridge, United Kingdom and New York, New York, p. 1447–1465, <http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_AnnexIII_FINAL.pdf>.

IPCC [Intergovernmental Panel on Climate Change] (2014): Summary for policymakers; *in* Climate Change 2014: Impacts, Adaptation, and Vulnerability (Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White; Cambridge University Press, Cambridge, United Kingdom and New York, New York, p. 1–32, <http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf>.

James, T.S., Henton, J.A., Leonard, L.J., Darlington, A., Forbes, D.L. and Craymer, M. (2014): Relative sea-level projections in Canada and the adjacent mainland United States; Geological Survey of Canada, Open File 7737, 67 p., <http://ftp2.cits.rncan.gc.ca/pub/geott/ess_pubs/295/295574/of_7737.pdf>.

James, T.S., Henton, J.A., Leonard, L.J., Darlington, A., Forbes, D.L. and Craymer, M. (2015): Tabulated values of relative sea-level projections in Canada and the adjacent mainland United States; Geological Survey of Canada, Open File 7942, 81 p. doi:10.4095/297048

Jones, B. and Scott, D. (2006): Climate change, seasonality and visitation to Canada's National Parks; Journal of Parks and Recreation Administration, v. 24, no. 2, p. 42–62.

Keeling, A. (2012): Adaptation, industrial development and Arctic communities; ArcticNet Annual Research Compendium (2011–2012), 8 p., <http://www.arcticnet.ulaval.ca/pdf/compendium2011-12/3.8_industrial_development.pdf>.

Keillor, P., editor (2003): Living on the coast: protecting investments in shore property on the Great Lakes; United States Army Corps of Engineers and University of Wisconsin, Detroit, Michigan, 49 p., <http://www.seagrant.umn.edu/downloads/ch002.pdf>.

Kerr Wood Leidal Associates Ltd (2008): Vulnerability of Vancouver sewerage area infrastructure to climate change; Metro Vancouver, 126 p. <http://www.metrovancouver.org/services/air-quality/AirQualityPublications/Vulnerability_climate_change.pdf>.

Kildow, J.T. and McIlgorm, A. (2010): The importance of estimating the contribution of the oceans to national economies; Marine Policy, v. 34, no. 3, p. 367–374. doi:10.1016/j.marpol.2009.08.006

Kildow, J.T., Colgan, C.S. and Scorse, J.S. (2009): State of the U.S. ocean and coastal economies; National Ocean Economics Program, 56 p., <http://www.miis.edu/media/view/8901/original/NOEP_Book_FINAL.pdf>.

Kovacs, P. and Thistlethwaite, J. (2014): Industry; *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 135–158, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter5-Industry_Eng.pdf>.

KPMG (2010): Climate change and sustainability services; KPMG, Topics, <http://www.kpmg.com/global/en/topics/climate-change-sustainability-services/pages/default.aspx>.

Lamont, G., Readshaw, J., Robinson, C. and St-Germain, P. (2014): Greening shorelines to enhance resilience, an evaluation of approaches for adaptation to sea level rise; guide prepared by SNC Lavalin for the Stewardship Centre for BC and submitted to Natural Resources Canada, 46 p. <http://www.stewardshipcentrebc.ca/PDF_docs/reports/Greening_Shorelines_to_Enhance_Resilience.pdf>.

Lane, D.E. and Stephenson, R.L. (1998): A framework for risk analysis in fisheries decision making; ICES Journal of Marine Science, v. 51, no. 1, p. 1–13.

Lane, D., Clarke, C.M. Forbes, D.L. and Watson, P. (2013): The gathering storm: managing adaptation to environmental change in coastal communities and small islands; Sustainability Science, v. 8, no. 3, p. 469–489. doi:10.1007/s11625-013-0213-9

Larrivée, C. and Simonet, G. (2007): Testing the assumptions: assessing infrastructures vulnerability to climate change; Municipal World, v. 117, no. 6, p. 27–28.

Lemmen, D.S., Johnston, M., Ste-Marie, C. and Pearce, T. (2014): Natural resources; *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 65–98, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter3-Natural-Resources_Eng.pdf>.

Lemmen, D.S., Warren, F.J., Lacroix, J. and Bush, E., editors (2008): From Impacts to Adaptation: Canada in a Changing Climate; Government of Canada, Ottawa, Ontario, 448 p., <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2007/pdf/full-complet_e.pdf>.

Linham, M.M. and Nicholls, R.J. (2010): Technologies for climate change adaptation – coastal erosion and flooding; TNA Guidebook Series, United Nations Environment Programme (UNEP), 150 p., <http://www.unep.org/pdf/TNAhandbook_CoastalErosionFlooding.pdf>.

Lotze, H. and M. Glaser. (2009): Ecosystem services of semi-enclosed marine systems; *in* Watersheds, Bays, and Bounded Seas: The Science and Management of Semi-Enclosed Marine Systems, (ed.) E.R. Urban, B. Sundby, P. Malonotte-Rizzoli and J.M. Melillo; Island Press, Washington, District of Columbia, p. 227–249.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H. and Jackson, J.B.C (2006): Depletion, degradation, and recovery potential of estuaries and coastal seas; Science, v. 312, no. 5781, p. 1806–1809.

Macintosh, A. (2013): Coastal climate hazards and urban planning: how planning responses can lead to maladaptation; Mitigation and Adaptation Strategies for Global Change, v. 18, no. 7, p. 1035–1055. doi:10.1007/s11027-012-9406-2

Mandale, M., Foster, M. and Chiasson, P.Y. (2000): The economic value of marine-related resources in New Brunswick; prepared for New Brunswick Department of Fisheries and Aquaculture and Fisheries and Oceans Canada, 73 p., <http://www.dfo-mpo.gc.ca/Library/245997e.pdf>.

Mandale, M., Foster, M. and Plumstead, J.E. (1998): Estimating the economic value of coastal and ocean resources: the case of Nova Scotia; Atlantic Coastal Zone Information Steering Committee, Canada Department of Fisheries and Oceans, Environment Canada, Nova Scotia Departments of Economic Development and Tourism, Environment, and Fisheries and Aquaculture, Chester, Nova Scotia, 54 p.

Manson, G.K. (2005): On the coastal populations of Canada and the world; *in* Proceedings of the 12th Canadian Coastal Conference, 6–9 November 2005, Dartmouth, Nova Scotia, 11 p.

Masson, A. (2014): The extratropical transition of Hurricane Igor and the impacts on Newfoundland; Natural Hazards, v. 72, no. 2, p. 617–632. doi:10.1007/s11069-013-1027-x

McBean, G. and Henstra, D. (2003): Climate change, natural hazards and cities; report prepared by the Institute for Catastrophic Loss Reduction for Natural Resources Canada, ICLR Research Paper Series, no. 31, 16 p., <http://www.iclr.org/images/Climate_Change,_Natural_Hazards_and_Cities.pdf>.

Millennium Ecosystem Assessment (2005a): Ecosystems and human well-being: synthesis; Island Press, Washington, District of Columbia, 137 p., <http://www.millenniumassessment.org/documents/document.356.aspx.pdf>.

Millennium Ecosystem Assessment (2005b): Living beyond our means: natural assets and human well-being – statement from the board; Island Press, Washington, District of Columbia, 24 p., <http://www.millenniumassessment.org/documents/document.429.aspx.pdf>.

Mercier, D. and Chadenas, C. (2012): La tempête Xynthia et la cartographie des zones noires sur le littoral français: analyse critique à partir de l'exemple de La Faute-sur-Mer (Vendée); Norois, no. 222, p. 45–60.

Mercer Clarke, C.S.L. (2010): Rethinking responses to coastal problems: an analysis of the opportunities and constraints for Canada; Ph.D. thesis, Dalhousie University, Halifax, Nova Scotia, 352 p., <http://dalspace.library.dal.ca/handle/10222/12841?show=full>.

Mercer Clarke, C.S.L. (2011): A proposed framework for assessing and reporting on the status and trends in oceans and coastal health in Canada; The Canadian Healthy Oceans Network (CHONe), Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, 150 p.

Mooney, H., Larigauderie, A., Cesario, M., Elmquist, T., Hoegh-Guldberg, O., Lavorel, S., Mace, G.M., Palmer, M., Scholes, R. and Yahara, T. (2009): Biodiversity, climate change, and ecosystem services; Current Opinion in Environmental Sustainability, v. 1, no. 1, p. 46–54. doi:10.1016/j.cosust.2009.07.006

Moser, S.C., Davidson, M.A., Kirshen, P., Mulvaney, P., Murley, J.F., Neumann, J.E., Petes, L. and Reed, D. (2014): Coastal zone development and ecosystems; Chapter 25 *in* Climate Change Impacts in the United States: The Third National Climate Assessment, (ed.) J.M. Melillo, T.T.C. Richmond and G.W. Yohe; United States Global Change Research Program, p. 579–618, <http://s3.amazonaws.com/nca2014/low/NCA3_Climate_Change_Impacts_in_the_United%20States_LowRes.pdf?download=1>.

Muir, D., Dawson, A.G., Gagnon, A.S. and O'Mahony, C. (2013): Vulnerability and adaptation to extreme coastal flooding: an example from the South Ford area, Scottish Outer Hebrides; *in* Coasts, Marine Structures and Breakwaters: From Sea to Shore – Meeting the Challenges of the Sea; Institution of Civil Engineers, 18–20 September 2013, Edinburgh, United Kingdom, conference proceedings, p. 1–11.

Munang, R., Liu, J. and Thiaw, I. (2009): The role of ecosystem management in climate change adaptation and disaster risk reduction; UNEP Copenhagen discussion series, Paper 2, 7 p., <http://www.unep.org/climatechange/Portals/5/documents/UNEP-DiscussionSeries_2.pdf>.

Nantel, P., Pellatt, M.G., Keenleyside, K. and Gray, P.A. (2014): Biodiversity and protected areas; *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 159–190, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter6-Biodiversity_Eng.pdf>.

National Energy Board (2011): Review of offshore drilling in the Canadian Arctic; National Energy Board, Calgary, Alberta, 54 p., <http://www.neb-one.gc.ca/nrth/rctcffshrdrllngrvw/2011fnlrprt/2011fnlrprt-eng.pdf>.

Natural Resources Canada (2014a): Community adaptation case studies; Natural Resources Canada Adapting to Climate Change: An Introduction for Canadian Municipalities, <http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/case-studies/11082>.

Natural Resources Canada (2014b): Web information on census (2006); Natural Resources Canada, Atlas of Canada, <http://atlas.nrcan.gc.ca/site/english/maps/population.html#population>.

New Brunswick Department of the Environment and Local Government (2005): A coastal areas protection policy for New Brunswick; Department of the Environment and Local Government, Sustainable Planning Branch, 15 p., <http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Water-Eau/CoastalAreasProtectionPolicy.pdf>.

Newfoundland and Labrador Department of Finance (2005): Estimating the value of the marine, coastal and ocean resources of Newfoundland and Labrador: updated for the 2001–2004 period; report prepared by Department of Finance for Fisheries and Oceans Canada, Economics and Statistics Branch, 26 p., <http://www.economics.gov.nl.ca/pdf2005/oceans/nl.pdf>.

Newfoundland and Labrador Statistics Agency (2010): Hurricane Igor; Newfoundland and Labrador Department of Finance, <http://www.stats.gov.nl.ca/maps/PDFs/HurricaneIgor.pdf>.

Nicholls, R.J. (2011): Planning for the impacts of sea level rise; Oceanography, v. 24, no. 2, p. 144–157. doi:10.5670/oceanog.2011.34

Nicholls, R.J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Château, J. and Muir-Wood, R. (2008): Ranking port cities with high exposure and vulnerability to climate extremes: exposure estimates; OECD Environment Working Papers, no. 1, 62 p., <http://www.oecd-ilibrary.org/docserver/download/5kzssgshj742.pdf?expires=1437920507&id=id&accname=guest&checksum=53FCAAFED82F47F8F1A701B1E30F175A>.

Nicholls, R.J., Wong, P.P., Burkett, V.R., Codignotto, J., Hay, J., McLean, R., Ragoonaden, S. and Woodroffe, C.D. (2007): Coastal systems and low-lying areas; *in* Climate Change 2007: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) M. Parry, O. Canziani, J. Palutikof, P. van der Linden and C. Hanson; Cambridge University Press, Cambridge, United Kingdom and New York, New York, p. 315–356, <https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter6.pdf>.

Niven, R.J. and Bardsley, D.K. (2013): Planned retreat as a management response to coastal risk: a case study from the Fleurieu Peninsula, South Australia; Regional Environmental Change, v. 13, no. 1, p. 193–209. doi:10.1007/s10113-012-0315-4

Noble, D., Bruce, J. and Egener, M. (2005): An overview of the risk management approach to adaptation to climate change in Canada; Global Change Strategies International (GCSI), Ottawa, Ontario, 28 p.

Organization for Economic Co-operation and Development (2009): Integrating climate change adaptation into development co-operation: policy guidance; OECD Publishing, Paris, France, 193 p., <http://www.keepeek.com/Digital-Asset-Management/oecd/development/integrating-climate-change-adaptation-into-development-co-operation-policy-guidance_9789264054950-en#page1>.

Parks Canada (2007): Prince Edward Island National Park of Canada and Dalvay-by-the-Sea National Historic Site of Canada management plan; Parks Canada, 81 p., <http://www.pc.gc.ca/~/media/pn-np/pe/pei-ipe/o-z/pd-mp_e.ashx>.

Parris, A., Bromirski, P., Burkett, V., Cayan, D., Culver, M., Hall, J., Horton, R., Knuuti, K., Moss, R., Obeysekera, J., Sallenger, A. and Weiss, J. (2012): Global sea level rise scenarios for the United States National Climate Assessment; National Oceanic and Atmospheric Administration, Silver Spring, Maryland, NOAA Tech Memo OAR CPO-1, 37 p., <http://scenarios.globalchange.gov/sites/default/files/NOAA_SLR_r3_0.pdf>.

Pew Oceans Commission (2003): America's living oceans: charting a course for sea change; Pew Oceans Commission, Arlington, Virginia, A report to the nation – recommendations for a new oceans policy, 140 p., <http://www.pewtrusts.org/~/media/Assets/2003/06/02/Full_Report.pdf>.

Prince Edward Island Department of Environment, Labour and Justice (2011): Saltwater intrusion and climate change: a primer for local and provincial decision makers; Atlantic Climate Adaptations Solutions Association (ACASA), Charlottetown, Prince Edward Island, 26 p., <http://atlanticadaptation.ca/sites/discoveryspace.upei.ca.acasa/files/Saltwater%20Intrusion%20and%20Climate%20Change%20in%20Atlantic%20Canada.pdf>.

Public Infrastructure Engineering Vulnerability Committee (2012): PIEVC case studies: codes, standards and related instruments (CSRI) review for water infrastructure and climate change; Engineers Canada, 22 p.

Public Infrastructure Engineering Vulnerability Committee (2014): Welcome to the Vulnerability Committee; Public Infrastructure Engineering Vulnerability Committee, <http://www.pievc.ca/e/index_.cfm>.

Public Safety Canada (2013): Canadian Disaster Database: natural disaster, flood, Duncan and North Cowichan (Vancouver Island) BC; Public Safety Canada, <http://cdd.publicsafety.gc.ca/dtpg-eng.aspx?cultureCode=en-Ca&rovinces=2&eventTypes=%27FL%27&eventStartDate=%2720090101%27%2c%2720091231%27&normalizedCostYear=1&eventId=1030>.

Rapport, D.J. and Whitford, W.G. (1999): How ecosystems respond to stress: common properties of arid and aquatic systems; BioScience, v. 49, no. 3, p. 193–203. doi:10.2307/1313509

Rice, J.C. and Garcia, S.M. (2011): Fisheries, food security, climate change, and biodiversity: characteristics of the sector and perspectives on emerging issues; ICES Journal of Marine Science, v. 68, no. 6, p. 1343–1353.

Richardson, G.R.A. and Otero, J. (2012): Land use planning tools for local adaptation to climate change; Government of Canada, Ottawa, Ontario, 38 p., <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/files/landuse-e.pdf>.

Ricketts, P. and P. Harrison. (2007): Coastal and ocean management in Canada: moving into the 21st century; Coastal Management, v. 35, no. 1, p. 5–22.

Robinson, G. (2015): State of the industry (2015); presentation for the 2015 Canadian Insurance Outlook, 30th Annual Breakfast Meeting, 31 March 2015, Toronto, Ontario, 34 p., <http://media.swissre.com/documents/2015_canadian_bkfst_mtg_robinson_state_industry.pdf>.

Rockström, J. and Klum, M. (2015): Big world, small planet: abundance within planetary boundaries; Max Ström Publishing, Stockholm, Sweden, video, <https://www.cigionline.org/events/big-world-small-planet-abundance-within-planetary-boundaries>.

Roger A. Stacey Consultants Ltd. (2003): Canada's ocean industries: contribution to the economy 1988–2000; Fisheries and Oceans Canada, 78 p.

Savard, J.-P., Bernatchez, P., Morneau, F. and Saucier, F. (2009): Vulnérabilité des communautés côtières de l'est du Québec aux impacts des changements climatiques; La houille blanche, v. 2, p. 59–66. doi:10.1051/lhb:2009015

Scott, D. (2011): Climate change and a healthy, sustainable environment: an opportunity for recreation and parks leadership?; report prepared for the 2011 National Recreation Summit, Lake Louise, Alberta, 28 p., <http://lin.ca/sites/default/files/attachments/Scott_Daniel%5B1%5D.pdf>.

Scott, D., Amelung, B., Becken, S., Ceron, J.-P., Dubois, G., Gössling, S., Peeters, P. and Simpson, M.C. (2008): Climate change and tourism: responding to global challenges; United Nations World Tourism Organization (UNWTO) and United Nations Environment Programme (UNEP), Madrid, Spain, 256 p., <http://www.unep.fr/shared/publications/pdf/WEBx0142xPA-ClimateChangeandTourismGlobalChallenges.pdf>.

Scott, D., Hall, C.M. and Gössling, S. (2012): Tourism and Climate Change: Impacts, Adaptation and Mitigation; Contemporary Geographies of Leisure, Tourism and Mobility, Routledge, London, United Kingdom, 464 p.

Séguin, J., editor (2008): Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity; Health Canada, Ottawa, Ontario, 484 p., <http://publications.gc.ca/collections/collection_2008/hc-sc/H128-1-08-528E.pdf>.

Seguin, J. and Berry, P. (2008): Conclusion; Chapter 9 in Human Health and a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity, (ed.) J. Seguin; Health Canada, Ottawa, Ontario, p. 449–484, <http://publications.gc.ca/collections/collection_2008/hc-sc/H128-1-08-528E.pdf>.

Silver, A. and Conrad, C. (2010): Public perception of and response to severe weather warnings in Nova Scotia, Canada; Meteorological Applications, v. 17, no. 2, p. 173–179. doi:10.1002/met.198

Simpson, M.C., Mercer Clarke, C.S.L., Clarke, J.D., Scott, D. and Clarke, J.A. (2012): Coastal setbacks in Latin America and the Caribbean: a study of emerging issues and trends that inform guidelines for coastal planning and development; Inter-American Development Bank, Technical Note IDB–TN–476, 175 p., <http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=37305263>.

Snelgrove, P.V.R., Flitner, M., Urban, E., Jr, Ekau, W., Glaser, M., Lotze, H., Philippart, C., Sompongchaiyakul, P., Yuwono, E. and Melillo, J. (2009): Governance and management of ecosystem services in semi-enclosed marine systems; in Watersheds, Bays, and Bounded Seas: The Science and Management of Semi-Enclosed Marine Systems, (ed.) E.R. Urban, B. Sundby, P. Malonotte-Rizzoli and J.M. Melillo; Island Press, Washington, District of Columbia, p. 49–76.

Spalding, M.D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L.Z., Shepard, C.C. and Beck, M.W. (2014): The role of ecosystems in coastal protection: adapting to climate change and coastal hazards; Ocean and Coastal Management, v. 90, p. 50–57.

Stanton, E.A., Davis, M. and Fencl, A. (2010): Costing climate impacts and adaptation: a Canadian study on coastal zones; report prepared by Stockholm Environment Institute for the National Round Table on the Environment and the Economy, Somerville, Massachusetts, 106 p., <http://www.sei-international.org/mediamanager/documents/Publications/Climate-mitigation-adaptation/Economics_of_climate_policy/sei-canada-coastal-zones-june-2010.pdf>.

Statistics Canada (2012): Focus on Geography Series, 2011 census; Statistics Canada, analytical products, catalogue no. 98-310-XWE2011004, <http://www12.statcan.gc.ca/census-recensement/2011/as-sa/fogs-spg/Facts-pr-eng.cfm?Lang=eng&GC=35>.

Stern, N. (2007): The Economics of Climate Change: The Stern Review; Cambridge University Press, Cambridge, United Kingdom and New York, New York, 712 p.

Stockholm Resilience Centre (2015): Resilience dictionary; Stockholm Resilience Centre, What is resilience?, <http://www.stockholmresilience.org/21/research/resilience-dictionary.html>.

Stothart, P. (2011): F&F 2011: facts and figures of the Canadian mining industry; The Mining Industry of Canada, 120 p., <http://www.miningnorth.com/wp-content/uploads/2012/04/MAC-FactsFigures-2011-English-small.pdf>.

Sussman, F.G. and Freed, J.R. (2008): Adapting to climate change: a business approach; Pew Center on Global Climate Change, Arlington, Virginia, 35 p., <http://www.pewtrusts.org/~/media/legacy/uploadedfiles/www-pewtrustsorg/reports/global_warming/BusinessAdaptationpdf.pdf>.

Sustainability Solutions Group and MC3 (2013): Sea level rise in BC: mobilizing science into action; Fraser Basin Council, p. 1-8, <http://www.retooling.ca/_Library/docs/bc_sea_level_rise_en.pdf>.

Tecsult Inc. (2008): Analyse coûts-avantages de solutions d'adaptation à l'érosion côtière pour la Ville de Sept-Îles; Ville de Sept-Îles, 150 p.

Thompson, K.R., Bernier, N.B. and Chan, P. (2009): Extreme sea levels, coastal flooding and climate change with focus on Atlantic Canada; Natural Hazards, v. 51, p. 139–150.

Thomson, R.E., Bornhold, B.D. and Mazzotti, S. (2008): An examination of the factors affecting relative and absolute sea level in British Columbia; Fisheries and Oceans Canada, Institute of Ocean Sciences, Canadian Technical Report of Hydrography and Ocean Sciences 260, 49 p., <http://www.dfo-mpo.gc.ca/Library/335209.pdf>.

Thrush, S.F. and Dayton, P.K. (2010): What can ecology contribute to ecosystem-based management?; Annual Review of Marine Science, v. 2, p. 419–441. doi:10.1146/annurev-marine-120308-081129

Titus, J.G. (1998): Rising seas, coastal erosion, and the Takings Clause: how to save wetlands and beaches without hurting property owners; Maryland Law Review, v. 57, no. 4, p. 1279–1400.

Titus, J.G., Hudgens, D.E., Trescott, D.L., Craghan, M., Nuckols, W.H., Hershner, C.H., Kassakian, J.M., Linn, C.J., Merritt, P.G., McCue, T.M., O'Connell, J.F., Tanski, J. and Wang, J. (2009): State and local governments plan for development of most land vulnerable to rising sea level along the US Atlantic coast; Environmental Research Letters, v. 4, no. 4, art. 044008. doi:10.1088/1748-9326/4/4/044008

Tomlinson, R.B. and Helman, P. (2006): Planning principles for local government management of coastal erosion and beaches, with a changing climate – proactive planning guidelines for coastal inundation, erosion and climate change; Griffith Centre for Coastal Management Research, Report 50, 35 p.

Tourism Industry Association of Canada (2012): The Canadian tourism industry: a special report; HLT Advisory Inc., Tourism Industry Association of Canada (TIAC) and VISA Canada, 39 p., <http://tiac.travel/_Library/documents/The_Canadian_Tourism_Industry_-_A_Special_Report_Web_Optimized_.pdf>.

Town of Gibsons (2012): Gibsons Harbour area plan; report prepared for the Town of Gibsons, Gibsons, British Columbia, 59 p., <http://www.gibsons.ca/include/get.php?nodeid=251>.

Turner, R.K., Burgess, D., Hadley, D., Coombes, E. and Jackson, N. (2007): A cost-benefit appraisal of coastal managed realignment policy; Global Environmental Change, v. 17, no. 3–4, p. 397–407.

UNEP [United Nations Environment Programme] (2010): Nagoya Oceans Statement; 10th Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP-10), Nagoya, Japan, 3 p., <https://www.sof.or.jp/en/topics/pdf/201010_nagoya.pdf>.

UNEP-GPA [United Nations Environment Programme–Global Programme of Action for the Protection of the Marine Environment from Land-based Activities] (2005): Guiding principles for post-tsunami rehabilitation and reconstruction: the Cairo principles; Tsunami Disaster Task Force in cooperation with the UNEP Coordination Office of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP-GPA), Cairo, Egypt, 8 p.

UN/ISDR [United Nations Secretariat of the International Strategy for Disaster Reduction] and UN/OCHA [United Nations Office for Coordination of Humanitarian Affairs] (2008): Disaster preparedness for effective response: guidance and indicator package for implementing Priority Five of the Hyogo Framework; UN/ISDR and UN/OCHA, Geneva, Switzerland, 51 p., <http://www.unisdr.org/files/2909_Disasterpreparednessforeffectiveresponse.pdf>.

United Kingdom Department for Communities and Local Government (2010): Planning policy statement 25 supplement: development and coastal change practice guide; United Kingdom Department for Communities and Local Government, London, United Kingdom, 58 p., <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7771/1499049.pdf>.

United Kingdom Department for Environment, Food and Rural Affairs (2006a): Shoreline management plan guidance – volume 1: aims and requirements; United Kingdom Department for Environment, Food and Rural Affairs, London, United Kingdom, 48 p., <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69206/pb11726-smpg-vol1-060308.pdf>.

United Kingdom Department for Environment, Food and Rural Affairs (2006b): Shoreline management plan guidance – volume 2: procedures; United Kingdom Department for Environment, Food and Rural Affairs, London, United Kingdom, 77 p., <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69207/pb11726v2-smpg-vol2-060523.pdf>.

United States Climate Change Science Program (2009): Coastal sensitivity to sea level rise: a focus on the mid-Atlantic region; United States Environmental Protection Agency, Climate Change Science Program, Subcommittee on Global Change Research, Washington, District of Columbia, Synthesis and Assessment Product 4.1, 320 p.

van Proosdij, D. Graham, J., Bowron, T, Neatt, N., MacIsaac, B. and Wrathall, C. (2014): Development and application of guidelines for managed realignment to maximize adaptive capacity and ecosystem services; Environment Canada, 100 p.

Vasseur, L. (2012): Getting started with community resilience planning: a kit to implement dialogue on planning community resilience to environmental and climate changes; training manual prepared for the Southern Gulf of St. Lawrence Coalition on Sustainability and the Coastal Communities Challenges–Community University Research Alliance, 20 p.

Vasseur, L. and Catto, N. (2008): Atlantic Canada; *in* From Impacts to Adaptation: Canada in a Changing Climate, (ed.) D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, p. 119–170, <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2007/pdf/ch4_e.pdf>.

Warren, F.J. and Lemmen, D.S., editors (2014): Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation; Government of Canada, Ottawa, Ontario, 286 p., <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf>.

Wheeler, P., Ford, V., Klokov, K. and Syroechkovskiy, E. (2010): Changes in harvest; in Arctic Biodiversity Trends 2010 – Selected Indicators of Change; CAFF (Conservation of Arctic Flora and Fauna) International Secretariat, Akureyri, Iceland, p. 92–95, <http://www.grida.no/_res/site/file/publications/ABA2010_screen.pdf>.

World Bank (2008): The Caribbean Catastrophe Risk Insurance Facility: providing immediate funding after natural disasters; World Bank: Latin America and Caribbean Region, Operational Innovations in Latin America and the Caribbean, v. 2, no. 1, 15 p., <http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/07/14/000334955_20080714060343/Rendered/PDF/446950NWP0ONS41Box0327407B01PUBLIC1.pdf>.

Yohe, G., Knee, K. and Kirshen, P. (2011): On the economics of coastal adaptation solutions in an uncertain world; Climatic Change, v. 106, no. 1, p. 71–92.

Zhai L., Greenan, B., Hunter, J., James, T.S. and Han, G. (2013): Estimating sea-level allowances for Atlantic Canada under conditions of uncertain sea-level rise; Fisheries and Oceans Canada, Canadian Technical Report of Hydrography and Ocean Sciences 283, 40 p.

Zhai, L., Greenan, B., Hunter, J., Han, G., Thomson, R. and MacAulay, P. (2014): Estimating sea-level allowances for the coasts of Canada and adjacent United States using the Fifth Assessment Report of the IPCC; Fisheries and Oceans Canada, Canadian Technical Report of Hydrography and Ocean Sciences 300, 146 p.