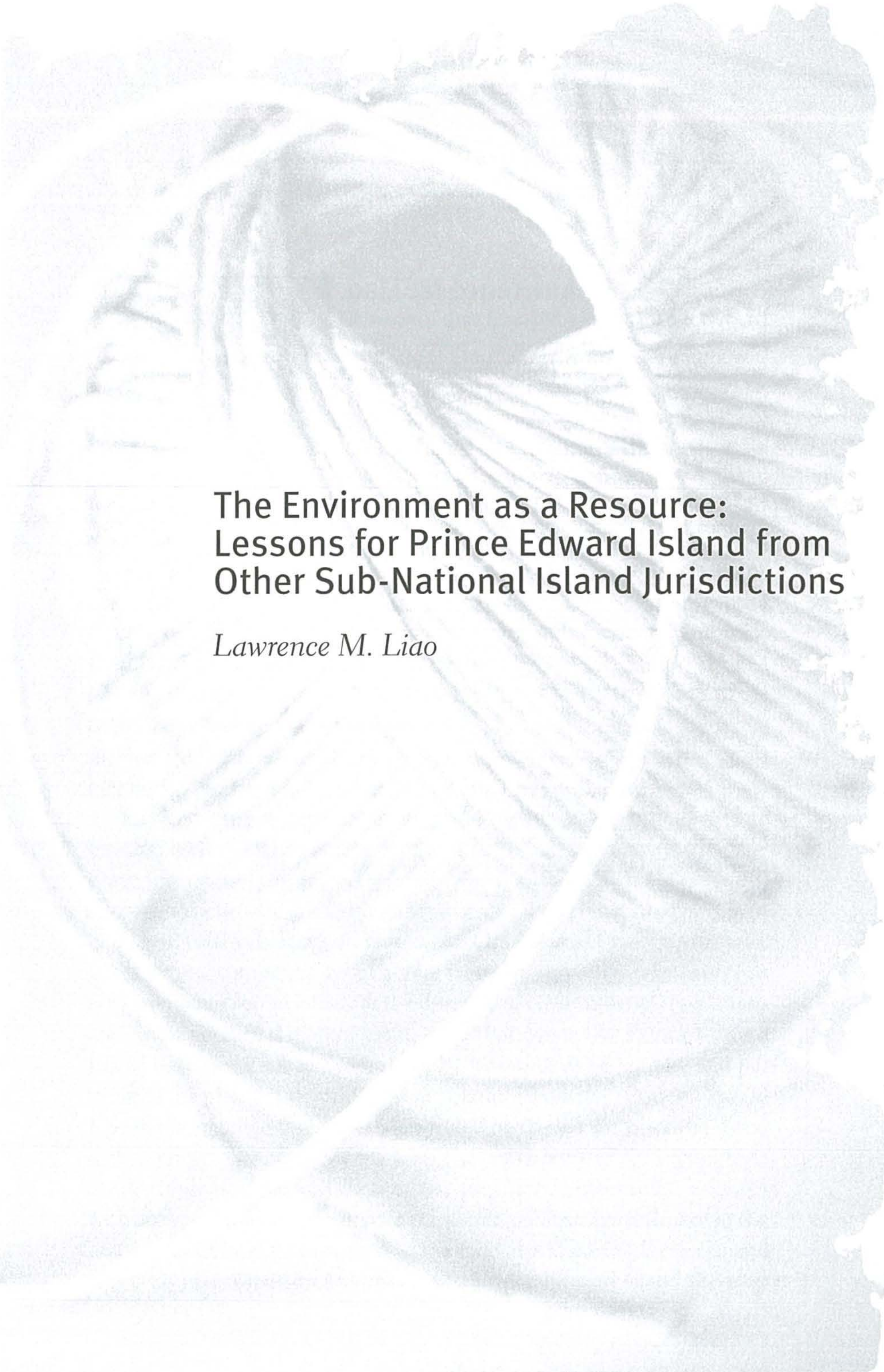
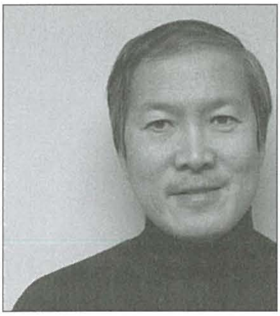


The Environment as a Resource: Lessons for Prince Edward Island from Other Sub-National Island Jurisdictions

Lawrence M. Liao



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Introduction

Islands comprise comparatively well defined environments that correspondingly harbour a set of finite natural resources. This is particularly evident in smaller islands. The size of the physical environment is therefore an important limiting factor affecting resource availability, be it living or non-living. What is becoming apparent is that the wise use or the abuse of such resources is linked to the viability of nations, most specially to island entities worldwide.

Environmental issues have effectively become part of governance concerns at all levels as this is clearly something that can affect everyone. Fiscal policies and allocations directed towards the environment have reached an all time high in many, especially Western, democracies. It has become the business of governments at all levels to seek to better understand the gamut of environmental issues, including ways of addressing the intimate relationship between development and conservation, before it is too late.

Laws governing the environment and the natural resources may be enacted by national or federal legislatures. These may have a wide coverage, particularly in large countries like Canada which span various geographic, climatic and ecological zones. At the sub-national or provincial level, relatively large provinces like Ontario and Quebec comprise different environmental types across latitudes and longitudes, and this necessitates an appreciation for the diversity of environmental conditions and resources. On the other hand, a small province like Prince Edward Island becomes a special case study by reason of its geography and particularly its physical definition as an island. Physically, Prince Edward Island is a province that is well delineated by the sea surrounding it and with a relatively homogeneous terrestrial environment throughout. As a sub-national island jurisdiction, the provincial government is vested with authority and some autonomy from the national government in the crafting of its laws that respond to the special and particular needs and demands of its island environment. The Prince Edward Island Development Plan of 1969, for example, has set the pace for the process of provincial state building and has led to greater empowerment of provincial authorities, reducing federal intervention in decision-making (Bickerton, 1998).

This contribution is divided in three sections. The first reviews the state of the environment on PEI. The second scans some comparable environmental practices by various sub-national island jurisdictions, teasing out some of those policies which PEI appears to be in a position to consider and perhaps benefit from. The third and final section draws up a summative 'environmental score card' for PEI and reaffirms the opportunities that islandness could provide towards sounder environmental management for the island province.

The Prince Edward Island Scenario

Biological Resources

Demographics is a key factor in the growth of economies. An inevitable effect of population growth is the exploitation of natural resources. By 1900, approximately 70% of the original forest on Prince Edward Island had been cleared for agriculture and human settlement. The remaining forests have become fragmented and unable to carry out forest ecological processes at previous levels (MacQuarrie and Lacroix, 2003). Due to vigorous reforestation efforts in recent years, 'forested' areas — which include plantations and abandoned agricultural lands — have increased to almost 50% of the total area, with 23% descended from pre-colonial forests of black spruce and hardwood species. Fragmented habitats support sparse but stable wildlife populations such as amphibians (Silva *et al.*, 2003) and small mammals (Silva, 2001). Even in 'protected' habitats such as the Prince Edward Island National Park the same low populations have been observed, taking note that it is the most environmentally degraded in the whole national park system in Canada subsequent to development for tourism. To conserve interior forest habitats on the Island, especially within the remnant hardwood old-growth Acadian forests, buffer zones of no less than 120 metres to an ideal 160 metres from the forest edge have been proposed (MacQuarrie and Lacroix, 2003). Wetlands on Prince Edward Island have witnessed large scale peat moss harvesting and infilling in recent decades. The restoration of important wetland habitats is in progress and is another effective management tool to support such breeding waterfowls as the green-winged teal, *Anas crecca*, and the American black duck, *A. rubripes* (Stevens *et al.*, 2003). This presents a clear indication of the intimate connectivity of ecological components, whether going up or down the food chain.

The stability of ecosystems is built upon a cohesive yet dynamic interaction of biological components occupying different niches, performing different ecological functions. The introduction of foreign or alien species which oftentimes turn into weedy, nuisance or invasive species can easily upset the equilibrium. This is so because most of these exotic species do not participate in the natural check and balance, or predator-prey relationships so well entrenched among local, well established species. While invasive entities may compete and threaten native species possibly causing extinctions, they are not to be blamed entirely for such disturbances. Land clearances and hunting have resulted in the local extirpation of a number of island birds and mammals. Anthropogenic impacts also account for Island plant species being classified as threatened or endangered: for example, the Gulf of Saint Lawrence aster, *Symphiotrichum laurentianum*.

While both terrestrial and aquatic environments on Prince Edward Island have been impacted by the introduction of exotic plant and animal species to a certain extent, nowhere is the effect more profound than in the marine environment because of the serious economic implications such introductions have on the local shellfish industry. There are currently nine exotic marine species that have become established in the Gulf of Saint Lawrence during the past decade. Eight of these species occur in the estuaries of Prince Edward Island, including four species of tunicates or sea squirts, one species of green seaweed and a species of estuarine crab (Locke *et al.*, 2007). The protected estuaries around Prince Edward Island with their calm waters are particularly suitable for culturing blue mussels (*Mytilus edulis*) and eastern oysters (*Crassostrea virginica*). Primarily because of the scarcity of natural hard surfaces in the waters around Prince Edward Island on which these shellfish can attach, fishermen have devised alternative culture methods using suspended devices or mussel socks to increase productivity. Suspended cultures also yield cleaner and healthier organisms kept away from bottom sediments and contaminants and which have better access to suspended food particles. Unfortunately, these socks also represent extensive surface areas of artificial substrates on which exotic species like the clubbed tunicates (*Styela clava*) and the green seaweed (*Codium fragile* subspecies *tomentosoides*, or commonly known as the oyster thief) can colonize. Mussel socks are deemed ideal substrates for these exotic species because they are replaced regularly and as such, kept relatively free of substrate competitors (Locke *et al.*, 2007). Constant replacement of mussel socks as dictated by periodic harvests of mussels becomes conducive for opportunistic larval settlement behaviour of invasive species.

The greatest ecological and economic impact on mussel culture is brought about by tunicates. These are sessile, colonial marine animals which attach to artificial and natural surfaces like buoys, harbour pilings, ship hulls and aquaculture structures. Because of their sessile or attached nature, food particles are filtered from the surrounding water column by means of an extensive internal water circulation system. On Prince Edward Island, four species of infesting tunicates have been identified since 1998. One species, the clubbed tunicate, *Styela clava*, has been identified as a significant fouling species that can potentially compromise the local mussel industry (LeBlanc *et al.*, 2007). The deleterious effects of infesting tunicates on mussel socks can be seen in the interference of mussel spat settlement and the seed collection process. The extra weight and volume of mussel socks as a consequence of infestation, and the use of corrosive lime powder as a control agent, increase harvesting costs and compromise worker health and safety. Damage to socks, breakdown of harvesting equipment and extra waste also lead to increased disposal costs. As more expenses are incurred, the profit margin decreases.

The introduction of exotic species to a new habitat also serves to alter community trophic dynamics. On Prince Edward Island, the introduction and proliferation of the European green crab, *Carcinus maenas*, has drastically changed predator-prey relations. The green crab consumes a native moonsnail species, *Astyris lunata*, which is the predator of the clubbed tunicate, *Styela clava*. The clubbed tunicate attaches itself to the mussel socks and onto oyster shells, effectively impeding water circulation that is critical for the nutrition of filter feeders like the blue mussels and eastern oysters. On the other hand, the green seaweed or oyster thief attaches itself onto the outer surfaces of oyster and mussel shells, growing into massive clumps which are eventually carried away by water currents, bringing along or 'stealing' the shellfish to which it is attached. In both cases, shellfish harvest is marked by high mortality, stunted animal growth and biomass loss translated into lower financial returns. While the proliferation of invasive species in aquaculture sites results in increased costs, there are no known health issues for shellfish consumers.

The success of invasive marine species on Prince Edward Island, particularly tunicates, has been partially explained using the fluctuating resources availability model by Locke *et al.* (2007). According to these authors, the rate of invasiveness is tightly associated with pulses of resources introduced into the aquatic ecosystem, principally the high, fluctuating nutrient levels which favour the reproduction and survival of many species, including non-indigenous ones. High nutrient levels have been attributed to the intense development of agriculture where fertilizer run-offs occur and intensive aquaculture where excess, unconsumed animal feeds contribute to eutrophic conditions in the water. High human population also contributes to increased nutrient levels from the release of domestic sewage, wastewater, and other polluting agents.

Recent research efforts have been directed towards finding mitigating measures to combat invasive species. LeBlanc *et al.* (2007) tested different anti-fouling treatments to get rid of clubbed tunicates infesting blue mussels. Methods such as 40-hour air exposure and 5% acetic acid immersion have been tested with satisfactory results. A 74% weight reduction of mussel sock weight correlated with high tunicate mortality after 2-minute immersion in 5% acetic acid seems to do the job, especially when the use of acetic acid has been found not to affect the long term health of the cultured organisms. However, research is going on to explore more cost-effective and environmentally friendly mitigating measures using the tools of molecular biology and natural products chemistry.

Agricultural Practices

Prince Edward Island accounts for about 25% of total Canadian potato production. Approximately 40% of the agricultural land base on the province is devoted to the production of potato on a rotation basis (Carter and Sanderson, 2001), making it the single most important agricultural commodity on Prince Edward Island. As a matter of fact, the province prides itself as the largest producer of premium potatoes in Canada.

The unique reddish, fine, sandy loam soil on Prince Edward Island is said to be particularly suitable for the farming of potatoes. This particular soil type is however vulnerable to erosion in the spring and during the potato growing season (Holmstrom *et al.*, 2006). In addition, current potato farming practices present various problems of which soil erosion and contamination from pesticide and fertilizer use are the more widely publicized.

Soils on Prince Edward Island are easily eroded, and this is exacerbated by the methods of potato production currently employed. In addition, gently sloping island topography, strong maritime winds, seasonal water run-offs, poor soil management and peculiar physico-chemical soil characteristics all join forces in destabilizing soil structure. Soil erosion has impacts on the environment, primarily through the loss of valuable, nutrient-rich topsoil. Secondary effects include decreased soil moisture retention, unwanted infilling and enrichment of bodies of water, decreased soil microbial diversity, and even the rise of respiratory illnesses among humans.

Farming practices clearly influence soil erosion rates. In a comparative soil erosion study, Edwards *et al.* (1998) documented varying rates of soil loss in fields planted with forages (0.4 ton/hectare), grains (1.6 tons/hectare) and potatoes (13.3 tons/hectare). Rates also show an increasing trend depending on farming practices used. For example, 20 tons of soil/hectare is lost from potato fields untilled over the winter season, increasing to 36 tons per hectare when autumn soil ploughing is practiced.

To help address the problem of soil erosion, composting and mulching have been tested for their ability to reduce the rate of soil loss, especially on those lands used for potato production (Edwards *et al.*, 2000). Culled potatoes and remnants from mechanized potato harvesting represent a composting resource on a commercial scale. However, composting alone showed no ameliorating effect to farm soil loss. Mulch from straw waste product represents a cost effective means of utilizing residues against soil erosion, reducing loss by almost 50%. A combined composting and mulching system also enriches soil water content by 6-7%.

An alternative soil conservation measure to control erosion is conservation tillage, a process involving minimal soil cultivation. When tillage is reduced, stubbles or plant residues are not completely incorporated and most, if not all, is left on top of the soil instead of being ploughed back into the soil. Weeds often proliferate and heavier herbicide use results. Conservation tillage serves to increase the soil water content through soil compaction at 10-30 cm soil depth, well above the level considered detrimental to root growth (Carter *et al.*, 2005). In general, conservation tillage may translate into lower producer input costs but may also impact negatively on potato crop performance (Holmstrom *et al.*, 2006). For potato farms, conservation tillage is desirable in order to maintain soil cover during the cool winter months and to decrease the depth and intensity of tillage (Carter *et al.*, 2007).

The continued expansion of potato acreage on Prince Edward Island has caused more extensive agricultural land clearing, and subsequently, increased soil erosion rates (Edwards *et al.*, 2000). More intensive potato farming has resulted in more physical degradation of the soil that is subjected to heavy tillage and traffic associated with farm mechanization. Rising to the challenge, various PEI provincial governments have to date convened no less than three Round Tables on Resource Land Use and Stewardship, the latest in 1996 specifically to address the various problems besetting the province's primary agricultural industry (Jatoe *et al.*, 2007). The committee submitted some 260 recommendations, of which the following were taken up: (1) a mandatory crop rotation formula for potato-based farming systems; (2) prohibition of row crop production on land with slopes above 9%; (3) implementation of an integrated pest management program using environmentally friendly methods; and (4) the establishment of the Environmental Farm Plan project. The committee also recommended that a 30 metre buffer zone be established between any waterway and a row crop cultivated land; legislation provided for a 10 metre buffer zone only.

The Prince Edward Island Agricultural Crop Rotations Act (ACR) was enacted in 2002 as a result of the recommendation of the Round Table on Resource Land Use and Stewardship committee. It provided for one particular crop no more than once in three years. The 3-year crop rotation scheme is grounded in many scientific studies including the choice of suitable crops with which potato rotates. Crop rotation has inherent benefits not readily observed, such as the maintenance of soil structure and organic matter, reduction of soil erosion and a decrease in plant diseases caused by soil-borne pathogenic agents (Carter *et al.*, 2003). Without rotation, susceptible crops can build up the population of soil pathogens which, in turn, can decrease crop yield.

A more frequent and faster cropping scheme for potatoes is obviously favoured by farmers to maximize farm revenue. But apparently this comes with high costs in terms of crop yield quality, and indirectly, high environmental costs. In the past, farmers used a variety of rotations stretching from 4 to 9 years, with a 7-year rotation cycle being common. A comparison of the effects between two-year and three-year crop rotations was made by Carter and Sanderson (2001) who found many beneficial effects in the three-year scheme. Using the two-year rotation, potato tuber harvest showed an increase in the proportion of unmarketable tuber sizes, and the harvested tubers exhibited an increased severity of diseases such as rots caused by the pathogenic fungus *Rhizoctonia*. No such post-harvest effects were observed in potatoes planted using a three-year rotation formula. In addition, farms using the three-year rotations showed improved soil structure and healthy organic matter profiles at the surface.

An experiment was conducted to determine compatible rotation crops with potatoes. Carter *et al.* (2003) compared the effects of the Italian ryegrass, *Lolium multiflorum* and the red clover, *Trifolium pratense* as potential crops in two-year rotations with potatoes. They found mixed effects where potato tuber yield was highest when planted with ryegrass in soils that are nitrogen limited. With red clover, lower potato tuber yield was found with the least occurrence of tuber-borne diseases but with high populations of pathogenic soil nematodes. Soil nitrogen profile was enhanced by red clover which is a nitrogen-fixing species. Taking into consideration the benefits and limitations set by each of these tested rotation crops, Carter *et al.* (2003) recommended a three-year rotation utilizing the ryegrass, red clover and potato to maximize potato yield and at the same time maintain farm soil quality.

Notwithstanding the potato farming schemes that serve to maximize farm yield, the problem of soil erosion still needs to be addressed. While three-year rotations have produced more desirable potato crops and some supplemental income from forage crops used in the rotation schemes, the prospects of decreasing soil fertility are growing realities for the farmer. The combined effects of strong seasonal winds and the lack of natural topographic barriers that fend off these winds contribute significantly to soil erosion in Prince Edward Island farms. Most of the farm soil is eroded during the potato phase of the three-year rotation (Kachanoski and Carter, 1999), partly because of the decreased ability of the potato root system to bind the upper soil layers compared to the greater restraining ability shown by the fibrous root systems of grasses. In addition, forage crops have a greater degree and duration of vegetation cover and can therefore maintain the physical qualities of the soil better than potato plants. Potato plants are usually planted in rows thereby exposing the bare surface soil between rows. In planting forages, bare soil surfaces are kept to a minimum.

Rotating potatoes with crops capable of nitrogen fixation serves to enrich the soil and enhance potato crop yield to a certain extent. Free nitrogen available in the air needs to be converted into nitrogenous compounds such as nitrates, nitrites and ammonia before they can be useful for plants. Most leguminous species harbour beneficial nitrogen-fixing bacteria in their roots for this purpose. Myrold and Huss-Danell (2003) documented enhanced soil nitrogen and nitrogen availability in Swedish forest plots planted with nitrogen-fixing species such as the lupine, *Lupinus nootkatensis* and the gray alder, *Alnus incana*. However, soil restoration in high latitudes such as Prince Edward Island employing nitrogen-fixing species might be a slow process owing to their short growing seasons.

An approach to boost soil nitrate profile in Prince Edward Island was tested by Sanderson and Macleod (1994) using the common lupine, *Lupinus albus*. These plants bear colourful flowers in the spring and are found on the banks of most ditches throughout the province. It was found that late incorporated lupines resulted in higher potato yields, while an early fall incorporation translated into a significant fall in nitrogen mineralization and winter leaching. With lupines being nitrogen-fixing species, carbon and nitrogen levels, particularly ammonium, are expectedly higher in soils around the lupine root zones, and this is accompanied by higher and more active soil bacterial and mycorrhizal populations beneficial to adjacent plants (Halvorson *et al.*, 1991). Furthermore, lupines can also enhance phosphorus availability in the soil (Redel *et al.*, 2007). When grown in phosphorus deficient soils, the proteoid roots of lupines secrete chelating acids which are precursors of phosphatase production. Aside from triggering phosphatase production, other phosphorus-mobilizing root exudates such as carboxylates, protons and phenolics are released from the roots of lupines (Kania *et al.*, 2003). Lupins also exhibit a special adaptability for both calcareous and acidic soils (Neumann and Römheld, 1999).

To augment the low nitrogen supply in the soil, farmers apply inorganic fertilizers. In Prince Edward Island, high levels of nitrates in groundwater as well as in waterways are more strongly correlated with the use of such inorganic fertilizers, than with manure inputs to the soil (Benson *et al.*, 2007).

Chemicals in the Environment

Nitrates present an environmental problem in Prince Edward Island because of intensive agricultural land use, a sloping topography that has the propensity to cause run-offs, and a porous soil top layer coupled with a high water table that is readily recharged. Benson *et al.* (2007) estimate that 20,000 to 25,000 rural private water wells serve about half the total population of the province, with the rest getting water from urban groundwater wells through centralized water supply systems. A chemical analysis of these wells suggests that the nitrate levels in 80% of the wells exceed background levels expected from unimpacted watersheds (that is, less than 3mg/l); while 4.5% of wells had nitrate concentrations in excess of the 10mg/l commonly associated with human health risks (Benson *et al.*, 2006: 422). Waterways that receive nitrate run-offs courtesy of nearby sloping fields manifest significant ecological changes in the form of massive blooms of rapidly growing seaweeds, as recently documented in a majority of estuaries around the province.

The intensification of potato farming has also seen an increase in the use of pesticides. About 90% of the pesticides sold in Prince Edward Island are used in potato farms. Of the pesticides applied on potato farms, 80-90% are fungicides such as chlorothalonil (White *et al.*, 2006). While only 9% of pesticides used throughout Canada are fungicides, the remarkably high fungicide use in the province is attributed to the monoculture of potatoes which are usually heavily affected by fungal pathogens. Fungicide and insecticide residues are mostly air-borne and may present human health risks, aside from the potential harm to exposed wildlife. In a study conducted by Yao *et al.* (2006), highest levels of air-borne pesticides were recorded in the Kensington region in Prince Edward Island, where potato farming is most intensive. Some domestic wells close to potato and blueberry fields, as well as PEI rivers and streams that have been tested for pesticide residues, have been found to be contaminated by combinations of commonly-used pesticides (Somers *et al.*, 1999). Potential impacts of insecticide contamination of rivers on the island's marine lobster fishery are under study (Fairchild *et al.*, 2006).

Episodes of massive fish kills have been documented in many estuaries and rivers in Prince Edward Island. The first documented case took place in 1994, and except for one year, fish kills have occurred every year since then. The latest fish kill case reported to this author occurred in July 2007. From a single episode in 1994, up to nine fish kills have been recorded in 2002 alone, the highest number in recorded history. Fish kills are sometimes attributed to anoxic water conditions resulting from intensive fertilizer application followed by rainfall. In this scenario, discharges of industrial and agricultural wastes or residues combined with soil nutrients leached into a body of water essentially cause a phytoplankton or seaweed bloom. This bloom uses up dissolved oxygen supply in the water column as a result of increased respiratory activities, thereby depriving animals of oxygen. There may also be some ichthyotoxic effects of pesticide residues. In the case of Prince Edward Island, fish kills coincided with pesticide application on nearby farms following heavy rainstorms (Edwards *et al.*, 2000). One of the most lethal pesticides found in water samples taken during or just after most of the fish kills in Prince Edward Island has been azinphos-methyl (Wagner *et al.*, 2002). Pesticides like azinphos-methyl are particularly lethal because of their high solubility in water and consequently their high toxicity to fish and other aquatic organisms.

To help address the problems of waterway contamination by fertilizer and pesticide residues as well as soil erosion, the Round Table on Resource Land Use and Stewardship committee recommended the ban of row crop production on steep farm slopes (more than 9% slope), the provision of farm buffer zones and the adoption of the integrated pest management or IPM program (Jatoe *et al.*, 2007). The slope requirement became effective in 2003 and was meant to cut down on rainwater run-offs that may carry harmful chemical residues to the rivers and estuaries. A buffer zone law provided for a 10 metre free space between a waterway and the edge of row crop cultivated land (but not a 30 metre buffer zone as recommended).

The adoption of integrated pest management programs on farms in Prince Edward Island forms part of the recommendations of the Round Table on Resource Land Use and Stewardship committee to reduce the use of synthetic fertilizers and pesticides on agricultural farms. These environmentally friendly methods include pest control using biological agents, that is, identifying and matching natural prey and predators or the development of disease-resistant crop strains. In addition, enhancement of soil fertility using natural materials can include making use of green crop manure such as nitrogen-fixing species, agricultural crop residues as mulch materials and the application of animal manure. It was recommended that various integrated pest management schemes be rated on certain criteria, and those farmers who effectively apply these farm strategies be eligible for financial assistance.

Waste Management

As PEI modernized in the latter half of the 20th century, the ever increasing solid waste load in island communities with fixed land areas saw a temporary solution in poorly designed, environmentally unsound landfills. Soon, these landfills from the 1980s were filling to near capacity, and new solutions had to be found. Laws meant to reduce solid waste were passed, such as the ban on canned carbonated drinks enacted more than 20 years ago. Government is under increasing pressure from consumers and corporations to revoke the "can ban"; but, so far, PEI remains unique in North America in requiring such beverages to be sold exclusively in refillable bottles (CBC News, 2007).

The provincial government of Prince Edward Island established the Island Waste Management Corporation (IWMC) in 2002 to standardize collection and disposal of waste and to implement its Waste Watch program. The IWMC is a provincial Crown corporation supported through provincial property taxes. The Waste Watch program is a mandatory, island-wide initiative characterized by a three-stream waste separation management system, namely compost, recyclables and waste (non-recyclables and non-compost). To help support operating costs, IWMC sells compost to garden supply distribution chains and recyclables to recycling firms in central Canada and northeastern United States.

The initial five years of implementation of the Waste Watch program witnessed an annual diversion of waste from landfill at the rate of 64% representing over 380,000 tons of resources diverted, 155,000 tons of which represent organic material processed into Category A compost. As a result, all 14 unlined community dumps on the Island have been closed, and the province was placed in the forefront among Canadian provinces as a leader in at-source separation and diversion of wastes from landfill. This success is also attributed to the small geography and the low population of the province.

Energy Resources and Supply

The abundant national supply of fossil fuels and hydroelectric power, supplemented by some nuclear energy, has fulfilled most of the energy requirements in Canada for the last century. However, due to the growing awareness of the negative consequences of fossil fuel production and consumption on the environment such as climate change and air pollution, along with a generalized aversion to nuclear energy, consumers have demanded 'green energy' in an attempt to control some of the negative impacts that burning of fossil fuels brings. While our dependence on fossil fuels will likely remain in the coming decades, recent efforts to tap renewable energy have grown and signal a shift towards alternative, more environmentally friendly energy resources.

By virtue of its geological structure, low elevation, and short rivers, Prince Edward Island cannot claim to have hydrocarbon or hydroelectric resources like those found in other Canadian provinces. With no proven coal, petroleum or natural gas reserves available locally, fully 80% of total energy consumed in PEI comes from imported petroleum products (PEI Dept. of Environment & Energy, 2004). Transportation, mechanized agriculture and the fishery rely exclusively upon gasoline and diesel fuel while most thermal applications such as heating of homes and commercial buildings, as well as powering of industrial operations, burn imported light and heavy oil or propane (*ibid.*: 2). A further 6-7% of the total energy supply is derived from burning locally produced biomass (cordwood, sawmill residue, and municipal garbage) to produce heat or steam.

Bulk electricity accounts for the remaining 13% of the energy supply, almost all of which is imported from New Brunswick via underwater cable across the Northumberland Strait (*ibid.*). The public electrical utility, which has a monopoly on distribution in PEI, is a relatively autonomous sub-unit of a multinational energy corporation headquartered elsewhere in Canada. The utility purchases high-voltage electricity on the eastern North American market from a variety of sources, including coal and oil-fired thermal plants, nuclear facilities and hydroelectric dams, viewing its role to distribute reliable, low cost electricity to island rate-payers for a profit, subject to annual regulatory approval. The local utility takes pride in the quality of its service on PEI. Without infusion of public funds to shift market forces, there is little or no incentive under this arrangement to reduce energy consumption or absorb the variability and high start-up costs of alternative systems such as wind energy.

The regulation of electricity rates and petroleum pricing within Prince Edward Island falls under the jurisdiction of the Island Regulatory and Appeals Commission. IRAC was established in 1991 as an independent quasi-judicial tribunal and regulatory agency operating "at arms-length from the provincial government." In particular, the Commission administers the Petroleum Products Act of the province that sets forth the requirements for the licensing of petroleum outlets in the province and the "determination of just and reasonable wholesale and retail prices" of different petroleum products. Aside from petroleum pricing, the Commission regulates the automobile insurance industry, water and wastewater utilities, and hears appeals relating to land use, property and revenue tax, and unsightly premises (www.irac.pe.ca/aboutirac/). PEI remains one of the few provinces with such a regulatory environment for the energy sector.

Energy Sources for the Future

Owing to the increasing demand for energy and the search for more environmentally friendly technologies, public attention has shifted to 'green energy' or renewable energy sources that impose the least burden on the environment while tapping indigenous resources. While Prince Edward Island lacks the more traditional energy resources used extensively today, it can very well compensate by tapping resources that are endowed by nature, specifically through its topography, geography and agriculture. In doing so, a burgeoning alternative energy sector generates employment, and income spent on energy stays within the province (ACOA, 1989). With a staggering $440 million annual imported energy bill, the search for alternative local sources becomes crucial to a province like Prince Edward Island which is not traditionally considered well-to-do.

The wind-swept northern coasts of Prince Edward Island provide an opportunity to harness what may be the province's greatest natural energy resource. In 1980, the federal government built the national wind test facility, the Atlantic Wind Test Site, in North Cape at the northwestern tip of the island. This led to the establishment of the Atlantic Wind Test Site Incorporated, a subsidiary of the PEI Renewable Energy Corporation, with 75% federal and 25% provincial funding (Atlantic Wind Test Site, 1992). Today, the North Cape wind farm produces 13.5 megawatts, contributing 5% of the province's electricity supply and which in turn is made available to the consuming public through the local utilities provider.

Another wind farm facility is the Eastern Kings wind farm which is one of the largest capital projects in the history of Prince Edward Island. Located at the extreme northeast tip of Kings County overlooking the Gulf of Saint Lawrence, its ten turbines collectively produce 30 megawatts, or 7.5% of the electricity needs of the province, enough to power 12,000 homes and cut 75,000 tons of greenhouse gases every year, the equivalent of removing 16,000 vehicles off the road. Dubbed as the first V-90 wind farm in Canada, Eastern Kings began commercial operations in early 2007. V-90 refers to the Vestas V-90 turbines which are the largest in North America.

The federal government in collaboration with the Prince Edward Island government established the $4.5 million Wind Energy Institute of Canada in Tignish with the mandate to conduct research, testing, innovation, technical consultation, training and public education on wind energy as well as developing services and products for the worldwide market (www.weican.ca). A Canadian government program that promotes the generation of electricity from wind power to combat greenhouse gases from the burning of fossil fuels is the Wind Power Production Incentive. This program subsidizes the excess cost of generation from wind power for the first ten years of a project.

An opportunity for the general public to get involved with 'green energy' initiatives in the province came in the form of PEI Energy Savings Bonds. Offered exclusively to Islanders at the start of 2007 through different credit unions province-wide, these financial instruments present a potentially lucrative form of investment while fostering heightened awareness and appreciation of the province's on-going alternative energy programs. These bonds are invested in the province's Eastern Kings wind farm with guaranteed long-term financial returns. In effect, the bonds confer partial 'ownership' of the Eastern Kings wind farm. Issued by the PEI Renewable Energy Corporation, the bonds are guaranteed by the provincial government. Bonds were available for a minimum purchase of $500 to a maximum of $10,000 per year with a guaranteed 5% annual interest rate return for five years, generating $4.7 million in investments during the first three months of public offering.

A potential off-shoot of the wind energy conversion technology being put in place in the province is the use of hydrogen technologies. A technical group was convened in 2003 to explore composite wind-hydrogen applications for alternative energy generation (Prince Edward Island Wind-Hydrogen Symposium, 2003). The group specifically seeks to determine the feasibility of a viable hydrogen storage and conversion system for the province. Using energy generated from wind turbines to split hydrogen atoms from water molecules, hydrogen atoms can then be used to power fuel cells. These cells will then form the backbone of so-called hydrogen powered villages which are considered 100% pollution free (Woodard, 2006).

Fuel from biomass represents another potential source of alternative energy, given the agricultural economy obtaining on the island. As a matter of fact, about 6.3% of the energy needs of the province have been supplied from either prime or residual biomass (so called 'biofuels') like cord wood, municipal wastes or wood chips since 1988 (ACOA, 1989). White spruce on Prince Edward Island has recently been tapped for fuel, but this comes with some environmental trade-offs, since the harvesting of these fuel trees for making wood chips depletes soil nutrient pools through leaching action (Mahendrappa *et al.*, 2006). Large-scale removal of trees essentially increases soil temperature which in turn leads to an increase in the decomposition rate on the forest floor. Notwithstanding these impacts on the environment, wood biomass for fuel from whole tree chipping in the province still represents an alternative energy source of considerable economic potential. However, in other provinces where pulp mills operate, wood chips are obtainable as waste by-products.

A formula was employed by Gingerich and Hendrickson (1993) to calculate energy return on investment (EROI) by determining the ratio of energy gained from a particular resource relative to the energy invested to achieve that gain. They showed convincingly an EROI of 26.7:1 for whole tree chipping activities in Prince Edward Island, with the energy investments mainly derived from the transport of chips to the burning facilities taking into consideration the distance and load size. In comparison, coal-fired power generation is shown to have an EROI of between 5 and 10:1, while nuclear power is calculated to have an EROI of no greater than 5:1. Petroleum products generally have EROIs between 10:1 and 20:1, except in cases such as Canada's tar sands where the energy spent on extraction reduces the return to 3-5:1. Plant based fuel oils have EROI's in the range of 3-10:1, outperforming corn ethanol (1.3:1) and hydrogen (0.2:1).

The introduction of environmentally friendly vehicle models in recent years has spurred the need for ethanol in the international market. In Canada, ethanol is blended with gasoline at concentrations of 5-10% for use in cars without costly engine or carburetor modification. Blended gasoline can reduce carbon monoxide emissions by up to 30%. In Prince Edward Island, there has been exploratory talk about putting up facilities that can produce ethanol from locally grown sugar beets (Woodard, 2006).

In 2004, Prince Edward Island introduced its first Renewable Energy Act which called for producing 15% of the province's electricity from on-Island renewable resources by 2010, among other provisions. Having achieved this target in early 2007, three years ahead of schedule, the province has dubbed itself "Canada's green province." A program called "30/16" unveiled at that time by the Binns government sought to generate 30% of the province's total energy requirements from local, renewable resources by 2016. The success of this program will hinge on further developing various green initiatives such as wind energy, biofuels as well as solar energy. Other emerging energy options include tidal energy, heat pumps and hydrogen fuel cells.

Biodiversity

Biodiversity in Prince Edward Island is not particularly remarkable, owing to historical deforestation and extensive human development: after all, PEI has the highest average provincial population density of 24 persons per km^2, as well as the most paved roads per km^2 of any province in Canada. Only a few species have gained the attention of conservationists and eco-tourists. Two of these are the piping plover, *Charadrius melodus*, which breeds in the heavily impacted and disturbed near-shore environments on the province's north coast; and the Gulf of Saint Lawrence aster, *Symphiotrichum laurentianum*, an endemic species that used to be widespread in Atlantic Canada but is now limited to a few pockets of wetland habitats. The programs of the Prince Edward Island National Park have highlighted the precarious status of these and other threatened species, and raised awareness among the general public. The active lobbying of local nature conservation groups has also served to showcase the value of species and habitat diversity.

One exception to the generally low level of biodiversity on the island is Malpeque Bay, which is a globally important feeding area for North America's migratory waterfowl and the only Ramsar Convention site in eastern Canada. It is also important to note that historically, the Southern Gulf of St Lawrence in which the island is nestled has been identified as one of the more biologically productive marine areas of Canada (Loutfi, 1973) and is also relatively more biodiverse than outer coastal waters (Novaczek and McLachlan, 1989).

Comparisons With Other Sub-National Island Jurisdictions

The physical geography of island environments, such as that of the Hawaiian archipelago and the Chatham Islands, has favoured the development and evolution of a rich, endemic biota, especially on those islands that are far from continental influences. The unique biota can become the basis of a successful ecotourism industry. However, because of the high endemism and relative isolation of these places, they are also particularly vulnerable to the threat of non-native species when these are introduced through human activity, and are the sites of the majority of the world's species extinctions. Both the Hawaiian archipelago and the Chatham Islands, for example, report a growing number of introduced species each year, both in their terrestrial and aquatic environments. These species cause often irreversible ecological impacts that can translate into significant economic losses in the long term.

Food provision is a challenge for many islands, especially those that are separated by great distances from the closest mainland. In many islands, the costs of importation can drive up the prices of food items. On many islands therefore, agricultural prosperity, oftentimes based on single crops, plays a crucial role in their economic survival.

Tasmania and Prince Edward Island share many similar agronomic methods when it comes to potatoes. To help control soil erosion, Tasmanian farmers broadcast cereal seeds a few days before potato harvests. These seeds are then covered by soil during the lifting operation of potato tubers. Corsica prides itself with its almost pesticide-free farms that supply France with about 98% of its citrus fruit requirement. Because of the long history of citrus growing in Corsica and the biological consequences of monoculture, farms are said to be aging and face the risk of desertification.

Taiwan is one of the most agriculturally self-sufficient island nations in the world. Fruits and vegetables from Taiwan are produced for both domestic and export markets. Lately, some farms have transformed themselves into demonstration showcases for tourists in what the government terms as 'agricultural tourism.' This is reminiscent of agricultural fairs and farmers' markets in Prince Edward Island that have begun to gain popularity each summer. Working farms have also made it into the list of tourist facilities in Prince Edward Island.

Unlike PEI, with its abundant ground water lens, isolated and tiny islands in the middle of the ocean often have serious problems with potable water supplies. Places like the Cocos-Keeling Islands and the Cook Islands are too small in land area to have a reliable groundwater source for potable water, and hence rely almost exclusively on rain water. This problem is compounded on islands whose soil and rocks are highly permeable and show poor water-holding capabilities, like those in Bermuda. The absence of freshwater streams and lakes in many small islands compounds the problem. Bermuda used to import potable water from the North American mainland up until the 1960s when desalination plants were set up. Today, there are reverse osmosis plants in Bermuda with the outlying catchment areas designed for the extraction of non-potable water. In the Balearic Islands, water extraction activities using windmills have at one time threatened to deplete subsoil water. An extreme situation is that of the densely populated island state of Singapore which imports a large portion of its potable water supply from neighbouring Malaysia. Singapore has contracted to purchase water from Malaysia up until 2030, as provided in bilateral treaties that are negotiated periodically.

Among the resources that affect human lives profoundly in so many islands, energy supply is crucial. In this post Industrial Revolution era marked by the great dependence on fossil fuels and the gradual reawakening to the horrifying consequences of such dependence, humans are faced with the dilemma of tapping alternative energy sources. Clearly, the trophy belongs to those who can survive and detach themselves from dependence on fossil fuels. While this may not be possible altogether, the safest route would be a diversification of energy sources.

Such a diversification can be seen today in islands that are sub-national jurisdictions of wealthier countries. In the Canary Islands (Spain) today, 99.4% of the energy comes from petroleum, with a target reduction to 78% by 2011. Because of the favourable trade winds off the northwestern coast of Africa, more than 500 wind turbines have been deployed since 1995, generating a total of 147 megawatts of electricity. To tap solar energy in its subtropical location, more than 51,000 solar panels have been installed for water heating. To further secure its energy supply, natural gas plants are planned using imported materials.

Tasmania (Australia) has traditionally tapped its rivers and lakes for electricity until dry conditions set in and put some of its hydroelectric facilities on hold. The Bell Bay power station that is powered by oil serves as a supplemental source for power. However, two great breakthroughs were scored when the Tasmania Natural Gas project led to the establishment of the Basslink, the giant undersea natural gas pipeline crossing the Bass Strait from the Australian mainland to Tasmania. The wind regimes off Tasmania are also favourable for the establishment of wind farms. The Woolworth wind farm, the largest in Australia, had a 65 megawatt initial generating capacity that was doubled in 2007. Hydro Tasmania, the principal electricity provider, operates 27 hydropower stations and 50 large dams. It established joint ventures with private foreign entities like Roaring 40s, which is a company doing business throughout Asia, under whose umbrella various wind energy management and technical consultations are made possible (www.roaring40s.com.au). Tasmania supplies an impressive 60% of the total Australian renewable energy pool, although the Australian mainland relies heavily on coal-fired plants for its energy needs.

The Greek offshore islands show an extremely high potential for alternative energy development in the Mediterranean. Their highly diversified battery of energy sources include 63 thermal generating units, 50 wind parks generating a total of 120 megawatts of electricity, 300 kilowatts from photovoltaic power systems, another 300 kilowatts from a small hydroelectric unit and a biogas-burning unit in Crete generating 166 kilowatts. These various power generating systems provide fuel as well as electricity for the desalination plants.

In the Caribbean basin, the diversity of renewable energy sources in Guadeloupe (France) — such as wind, geothermal, hydraulic and solar — serves as a model for tropical islands. The agricultural economy on the island contributes to power generation with the use of bagasse, the sugar cane residue that is burned in electricity generating stations, although this is today considered polluting technology. Nevertheless, renewable energy sources contribute an impressive 25% of Guadeloupe's energy requirement.

The virtually inexhaustible solar energy is being increasingly tapped by islands in tropical latitudes whose geographical location provides nearly year-round insolation. Solar power is being tapped in the Galápagos Islands (Ecuador), with the goal of eliminating fossil fuel dependence by 2012. In the Cocos-Keeling Islands (Australia), photo-voltaic solar panels are mainly used to supply energy for lighting needs. Solar power is being tapped in various stages in the Madeira Islands (Portugal) and the Lakshadweep Islands (India), among others. Although not a beneficiary of tropical insolation, PEI now has the largest array of photo-voltaic panels in Canada on a building owned by the federal government.

Various "nearshore" islands, like Jeju (South Korea), Zanzibar (Tanzania), Tasmania and Prince Edward Island, are linked to energy sources based on the mainland by means of submarine cables or pipelines. However, cables such as these can also facilitate the export of island-generated electricity where access to the national grid can be obtained. However, while precautionary measures are in place for the safe and efficient transmission of energy and materials through these undersea links, an element of risk associated with navigational traffic, storms, seismic shocks, and accidental leaks is unavoidable.

Tidal power represents another potential energy resource. The island of Guernsey (Great Britain) is the site of a big tidal power generating station which has been proposed to run a desalination plant on the island and eventually replace its existing oil power station. Guernsey is a net exporter of energy within Europe, partly because of low local demand. The same surplus situation is true with the province of Newfoundland and Labrador which exports 70% of the electricity it generates from hydropower, sourced mainly in the Churchill region in Labrador, to Quebec, under an agreement signed in 1969 and which expires in 2041.

Conclusions

From the foregoing, it can be said that Prince Edward Island, in comparison to many sub-national island jurisdictions, has been largely blessed with abundant natural resources set within an environment that has the theoretical capability to cope with human needs, now and into the near future. The carrying capacity of the natural environment of PEI has never been determined, but Monette *et al.* (2003) have calculated the average ecological footprint of Prince Edward Island at 8.98 hectares per person in 1999, far above the 1.7 hectares per person globally available and the highest among Canadian provinces and territories. Energy consumption (4.29 hectares per person) accounted for almost half of its total ecological footprint. Together, energy and food consumption (the latter being 3.49 hectares per person) constituted 87% of the average Islander's ecological footprint. If current trends are maintained, an increase to 10.8 hectares per person is projected by the year 2020. Any effort to reduce this significant ecological footprint must therefore be directed towards some immediate and drastic lifestyle changes and decisions, particularly energy and food consumption patterns and food procurement policies: more than half of the fruit and vegetables currently sold on PEI are imported from California. Current levels of exploitation are deepening problems of soil erosion, declining fish stocks, and deteriorating water quality. Current consumption levels are only possible thanks to the historically low human population that is inching up very slowly. The current levels of human population are largely dictated by such factors as economic development, seasonality of employment, and migration flows.

Historical records reveal that many of the economic activities on Prince Edward Island have an intimate relationship with the environment, often with long-term, negative impacts for the resources within the environment. The cycle between the land and the sea, for example, must be considered in the pursuit of livelihood and economic well-being (Paterson, 2000). Traditional use of discarded lobster carcasses and mussel shells for farm soil enhancement is illustrative of this intimate relationship, which today is replaced by cheaper oil-based fertilizers. The cycle between the land and the sea is thereby broken, and the addition of a new element will have its impacts and environmental costs. To further elaborate on this point, one can look at the evolution of factory-style dairy, pig and potato operations due to improved mechanization and the economic imperative of economies of scale. Clearly, these industrial monocultures show little or no continuity with the past paradigm of 'economies of scope': small, diverse, family farms with their woodlots and, if coastal, complimentary fishing activities.

In Prince Edward Island, introduced marine species have caused economic losses mainly in the aquaculture industry. Control and eradication measures are the result of concerted efforts among various stakeholders: aquaculturists, government agencies and academics. Since these invasive species are likely to impact on tourism in one way or another, the tourism sector should be involved in control, eradication and mitigation efforts.

Consistent with global trends, the provincial government of Prince Edward Island has, for the past 15 years or so, started addressing environmental practices that have impacted on the small, fragile island environment and the various resources therein. Clearly, improving environmental legislation in Prince Edward Island is consistent with national goals for a better and sustainable environment for all. The province has become widely recognized for its leadership on a broad range of environmental initiatives, particularly renewable energy resources. It is however imperative that similar leadership be demonstrated in other areas of provincial environmental policy.

The province cannot rest on its laurels or allow any gains to erode away through complacency, inaction and conservatism. The provincial government would do well to continue to wield strong and sustained political intent in pushing the environmental agenda and upholding these good practices for the benefit of residents and the environment. There must be a well-defined balance between exploitation and management, between development and conservation. Laws governing biological and environmental resources must be reviewed periodically to make sure they stay relevant with the needs and values of Islanders as well as with the sustainability of the resources and the realities of emerging technologies.

Compared to many similar sub-national island jurisdictions around the world, some of which were cited above, Prince Edward Island comes out as a potential role model in specific areas of environmental governance, particularly with its success in renewal energy resources and solid waste reduction. A concerted effort towards the promotion of alternative energy sources must also be accompanied by more vigorous initiatives for transportation, industrial and home energy efficiencies coupled with environmental conservation education among the citizens. Bearing in mind the particular vulnerability of islands to sea level rise triggered by climate change, social and economic policy formulation must be geared towards more sustainable transportation (bus systems, carpooling, bike trails), land use (organic farming) and resource consumption patterns (compact fluorescent bulbs, low-flow shower heads) that reduce carbon dioxide releases. A well-informed, environmentally pro-active citizenry and a crop of legislators with commonsensical environmental conscience would help preserve the gains of sound environmental policies, and will spell the difference between the failure and success of any environmental protection agenda. There will always be room for improvement and for further learning from the experiences of other islands.

With their typically more limited land areas and smaller populations, many islands have every incentive to avoid practices that damage their environments, or which are relatively expensive because of diseconomies of scale. When such islands — like PEI — also happen to be jurisdictions, and therefore have some home-based capacity to govern themselves, then they are in a position to propose and advance policies and regulations that are intended to preserve habitats, mitigate unsustainable practices, and work towards a harmonization of economic development goals with those of habitat conservation and widespread species health.

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