Fisheries and Oceans / Pêches et Océans
Gulf Region

DFO Maritimes Regional
Habitat Status Report 2000/1E

Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island

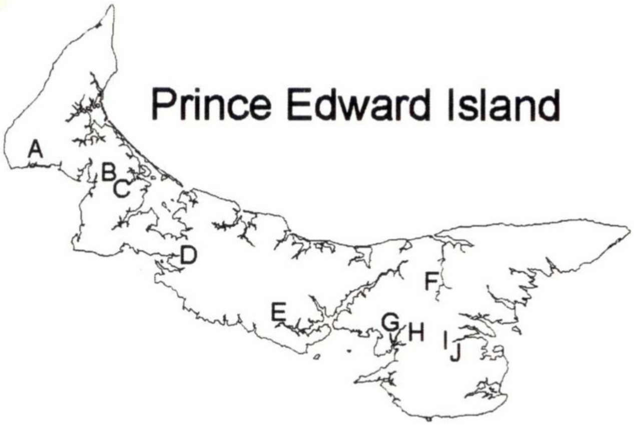
Background

Prince Edward Island (PEI) is Canada's smallest province. Because of its narrow shape and moderate relief, rivers are short and free of natural barriers. The lower portions of most rivers were flooded by rising waters following the Pleistocene, producing broad estuaries, many of which flow into wide shallow bays. These conditions are conducive to production of shellfish and anadromous fishes, and early European settlers reported an abundance of such species, including mussels, clams, oysters, smelts, gaspereau, trout, and salmon.

PEI was almost entirely forested at the time of European contact. Land clearance for agriculture began in the 18th century and continued with greater intensity in the 19th. By 1900, forests covered only 31% of PEI's surface. Early in the 20th century many fields were abandoned and allowed to revert to forest. In 1990, 49% of the province was forested. There is roughly an even split between hardwoods, found mostly on land that was never cultivated, and softwoods, which grow chiefly on former farmland.

PEI is Canada's most densely populated province, and the intensity of human activity juxtaposed with streams and estuaries of high production potential has led to resource conflicts. The red colour of most PEI rivers following rainfalls is a highly visible symbol of the interaction between land use and aquatic resources. Land use impacts on aquatic resources have a high profile on PEI, and the main areas of concern among resource managers and the public are impacts of sediments, toxic chemicals, and cattle access to streams on freshwater and estuarine resources, and the consequences of nutrient inputs to estuarine biota.

The following terms are used in this report:
Watercourse - includes streams, ponds, and estuaries.
Aquatic - refers to fresh, brackish, and salt water.



A-Little Pierre Jacques River, B-Enmore River, C-Ellerslie Brook, D-Wilmot River, E-West River, F-Morell River, G-Seal River, H-Vernon River, I-Montague River, J-Valleyfield River.

Summary

- Agricultural land use practices contribute major inputs of sediments, pesticides, animal wastes, and nutrients to PEI streams and estuaries. Road construction and maintenance, forestry operations, and sites undergoing landscape changes also contribute sediments to watercourses.

- Sedimentation negatively impacts salmonid populations on PEI, particularly those of Atlantic salmon.

- Fish kills associated with potato pesticides cause locally intense mortality in streams. Eight such kills occurred in 1999.

- Sedimentation due to land use practices negatively impacts production of oysters. Sediment deposition does not have known effects on other estuarine bivalves.

- Livestock in unfenced streams contribute faecal coliform bacteria to watercourses. Many shellfish grounds that are adjacent to

farmland are closed to direct harvest due to coliform contamination, but the origin of the contamination has not been established.

- Concentrations of nitrogen and phosphorus, which are major promoters of aquatic plant growth, have risen substantially in PEI estuaries since the 1960s. Anoxic events, due to the proliferation and subsequent death of sea lettuce, are becoming more widespread in PEI estuaries.

- Chlorophyll levels in estuaries are closely related to the amount of farmland in the adjacent watershed. Nutrients of land use origin appear to be a major contributor to the growth of phytoplankton consumed by cultured mussels.

- Land use techniques that minimize inputs to watercourses are becoming more widespread on PEI. However, the practices of many land users remain unchanged, and recent expansions of potato acreage and the conversion of woodland to cropland have increased the potential for inputs to watercourses. Except in rare cases, federal and provincial legislation that protects fish and their habitats has not been used to limit land use inputs into PEI watercourses.

- A coordinated research program on land use effects on aquatic resources of PEI streams and estuaries is required to monitor, model, and quantify impacts, to establish benchmarks for enforcement, and to guide mitigation and rehabilitation efforts.

- A broadly based consensus among community, industry, and government is required to achieve an effective program to reduce land use inputs that harm PEI's aquatic resources.

Introduction

Owing to scientific and public concerns about the effects of land use practices on fisheries resources of the rivers and estuaries of Prince Edward Island, Science Branch of the Department of Fisheries and Oceans and the PEI Department of Technology and Environment convened a meeting to review scientific data related to these issues. The meeting was held in Charlottetown on 6-10 December 1999.

The meeting panel consisted of 34 invited specialists in fisheries biology, shellfish biology, estuarine ecology, hydrology, toxicology, soil engineering, enforcement, and natural resource management. Panel membership included the majority of scientists who have conducted research in PEI streams and estuaries in recent years. The meeting was open to the public and non-panel attendees participated in the deliberations.

The meeting examined the effects of sedimentation, toxic chemicals, livestock and their wastes, and nutrient inputs on fish, shellfish and their habitats in PEI through the following questions:

- What is the nature and extent of physical, chemical, and biological alterations of PEI watercourses due to land use practices?
- What effects do these alterations and inputs have on fisheries resources in watercourses?
- What is the relative importance of these alterations and inputs in adversely affecting the fisheries resources?
- What research is needed to understand impacts and to identify appropriate remedial measures?
- What measures could be adopted to reduce negative impacts of land use practices on PEI fisheries resources?

Land use patterns

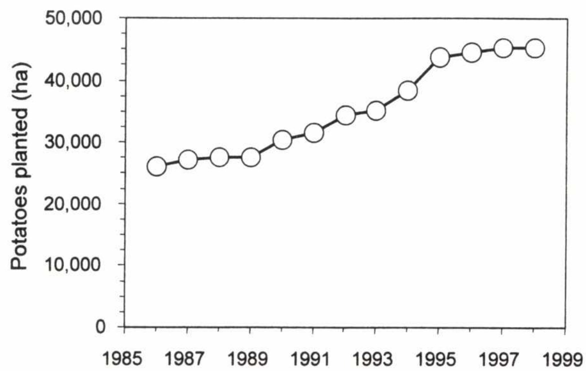
Prince Edward Island's total land area is 5,660 km^2. The population in 1999 was 138,000, or 24.3 persons/km^2, the highest population density of any province and much higher than the overall Canadian density of 3.1 persons/km^2.

In 1990, the latest year for which figures are available, 49% of PEI was forested. There is no virgin forest on PEI and all woodland has been subject to some degree of harvest. During the 1990s there was an upturn in forest harvesting due to high lumber prices, and also because of woodland clearances for potato and blueberry production. Harvest of wood products increased from 411,000 m^3 in 1991 to 643,000 m^3 in 1995, a level that is considered unsustainable by the Forestry Division of the PEI Department of Agriculture and Forestry.

Since the 19th century, PEI's agricultural economy has been based on a mixture of livestock (mostly dairy and beef cattle and pigs) and crop (potatoes, cereals, forage) production. The number of farms has decreased markedly since its peak of about 14,000 in 1900. Farm numbers fell to 3,154 in 1981 and to 2,217 in 1996. With this decrease, there have been major increases in farm size and the farming of leased land.

Potatoes are commonly grown in alternation with other crops, a practice known as crop rotation. Between 103,000 and 115,000 ha of PEI is currently in potato rotation. This constitutes about 18-20% of PEI's total land area. Of the land in potato rotation, 55-62% is planted in potatoes once every three years, 36-44% once every two years, and 1.5-2% is in potatoes three years in a row. The area planted in potatoes increased from 28,733 ha in 1985 to 45,325 ha in 1998.

Potatoes



Eighty-one percent of cultivated land on PEI is considered by Agriculture and Agri-foods Canada to be at high to severe risk of water-borne soil erosion, and PEI is the only province in Canada where water erosion risk increased between 1981 and 1991. This trend is due to the increase in potato acreage. Of all major crops grown on PEI, potatoes are the most environmentally intrusive because a) potato cultivation removes large quantities of organic matter from the soil, b) traditional cultivation methods leave the soil bare and at high erosion risk for extended periods, and c) potatoes attract a wide variety of pests which are typically controlled by intensive pesticide applications.

No reliable assessments of total soil loss from PEI farms are available. However, typical losses from potato fields which are cultivated by traditional methods are estimated to be in the range of 10-20 tonnes/ha/yr (1-2 kg/m^2/yr). Losses may exceed 100 tonnes/ha/yr (10 kg/m^2 /yr) in localized and exceptional circumstances. It is estimated that some form of effective erosion control is currently applied to about 40% of potato land.

In contrast to the expanding potato industry, the livestock sector has been relatively stable in recent years. Cattle numbers have dipped slightly since the 1980s.

Fisheries and aquaculture

Prince Edward Island is Canada's leading fishing province in terms of landings as a percentage of provincial Gross Domestic Product. Fisheries dependent on freshwater and estuarine habitats employ a substantial proportion of fishers on PEI and have high cultural and economic significance. The importance of estuarine fisheries is commonly expressed in terms of officially reported landed values. Industry observers and biologists associated with this sector commonly report that official statistics substantially underestimate actual landings and landed values of estuarine shellfish and finfish fisheries.

Finfish fisheries

At present, about 20 finfish species spawn in PEI rivers and estuaries. The American eel, which spawns in the southern North Atlantic Ocean, is also a common inhabitant of PEI watercourses. Most fish which currently inhabit PEI are indigenous. Most prominent of the nonindigenous species is the rainbow trout which has established populations in a number of rivers. PEI has only three fish species which are restricted to freshwater; all of these have very small distributions on PEI. The diversity of fish species in PEI fresh waters is much lower than that of neighbouring Maritime Provinces.

Reported eel landings declined sharply from 150-250 t in the 1980s to 11 t in 1996, which parallels declining trends elsewhere in the Gulf of St. Lawrence - St. Lawrence River system. Over the same period, annual reported catches of gaspereau fluctuated widely from less than 100 t to more than 400 t. Similarly, reported landings for smelt varied from less than 100 t to over 300t.

PEI's fishery for Atlantic silversides, which inhabit coastal waters and tidal creeks, accounts for about two thirds of the world landings of this species. Reported silverside landings have varied considerably, up to over 500 t and a landed value of over $200,000.

The main recreational fisheries on PEI are for brook trout and Atlantic salmon. Brook trout exist in self-sustaining populations in most PEI watercourses. Early accounts indicated that Atlantic salmon were widespread and abundant on PEI, but self-sustaining runs have disappeared from most streams. Salmon runs are maintained by stocking in several of the larger rivers, notably the Morell. The number of brook trout licenses issued declined from 14,868 in 1980 to 12,072 in 1996. Salmon license sales dropped from 793 in 1990 to 520 in 1998. Direct expenditures due to salmonid angling on PEI in 1994 were estimated to be $4.6 million; the sum of direct and indirect expenditures was estimated to be $7 million.

Shellfish fisheries

Soft-shelled clams are harvested in bays and estuaries, primarily at low tide with hand tools. Reported soft-shelled clam harvests in 1981-1996 declined irregularly, and ranged from 159 to 407 tonnes/yr. Reported landed values during this period ranged from $173,000-$705,000. Most quahaugs are hand-picked at low tide from sub-tidal waters. Reported quahaug landings were generally in the range of 500 - 700 tonnes/yr in 1981-1996. Reported landed values were between $200,000 and $1.5 million.

Oysters have been subject to intensive commercial harvest on PEI since the 19th century. In 1915, a disease known as Malpeque Disease appeared and eventually destroyed most oyster beds in the province. A disease-resistant strain emerged and eventually re-populated the lost beds. At present the oyster industry is a mix of fisheries on open grounds and culture on private leaseholds. There are also efforts to raise oysters in racks held off-bottom in shallow water. Some of the more important grounds are contaminated by faecal coliform pollution, which has given rise to the widespread practice of "relaying" contaminated oysters in clean water until they are safe for human consumption (depuration). Reported oyster production in 1981-1996 varied from 870 to 1891 tonnes/yr, with values of $1 million to $3.8 million.

In the 1970s and 1980s methods were developed for the cultivation of blue mussels which were suited to the province's seasonally ice-covered waters. Naturally spawned spat are captured on collectors, and later transferred to "socks" suspended from longlines that are sunk below ice level in winter. The mussel industry needs adequate water depth (at least 4 m), and most production occurs in bays and estuaries in the central and eastern parts of PEI where depths tend to be greater. Mussel production has increased dramatically since the inception of the industry, rising to 8,819 t in 1996, with a harvested value of $10.7 million.

Total value of fisheries

Reported landed values of commercial estuarine species and recreational angling expenditures sum to more than $20 million annually on PEI, of which roughly half is due to mussel culture. As noted above, landed value figures may be underreported. Total economic activity generated by freshwater and estuarine fish and shellfish is much greater than landed values due to economic multipliers.

Regulatory environment

Federal and provincial governments have a number of tools to assist, promote and enforce the protection of fish, shellfish, and their habitats. These include educational materials, funding, technical assistance, research, and legislation.

Under the *Constitution Act*, the federal government has legislative authority to manage and regulate Canada's sea coast and inland fisheries. The Supreme Court of Canada has recognized the joint authorities of federal and provincial governments to regulate protection of the environment.

The federal government uses the *Fisheries Act* to exercise its mandate to protect fish and fish habitat. The environmental protection sections of the *Fisheries Act* are co-administered by the Department of Fisheries and Oceans and Environment Canada. The Department of Fisheries and Oceans administers the habitat protection provisions of the *Fisheries Act.* Section 35, the most frequently applied of these provisions, forbids the harmful alteration, disruption and destruction of fish habitat. Environment Canada administers Section 36 of the *Act*, which forbids the deposition of deleterious substances into water frequented by fish. Deleterious substances include those that are harmful to fish, fish habitat, or which impair the use of fish by people (fish includes shellfish).

The federal government, through Environment Canada, also administers the *Pest Control Products Act* and the *Canadian Environmental Protection Act*.

The government of PEI discharges its environmental protection mandate through several pieces of legislation, including the *Environmental Protection Act*, the *Natural Areas Protection Act*, the *Wildlife Conservation Act*, the *Recreational Development Act*, the *Planning Act*, and the *Pesticide Control Act*.

On PEI, federal and provincial authorities jointly regulate works in or near streams through a single referral and permitting process administered by the Province under authority of its *Environmental Protection Act*. Similar co-management processes are used in New Brunswick and Nova Scotia.

Sedimentation

Transport and deposition

The amount of sediment carried into PEI streams and estuaries since European settlement has not been systematically measured. Soil loss from agricultural fields, itself poorly known, does not directly reflect influx into watercourses because not all soil eroded from fields reaches waterways. In the estuary of the Wilmot River, core samples and examination of historic charts indicate that 2-5 m of sediment were deposited between 1765 and 1841. Subsequent sediment deposition infilled channels and further decreased water depths across the estuary. PEI was a major shipbuilding centre in the 19th century. Many of the waterways where ocean-going vessels were once launched now have insufficient water to float a canoe at low tide.

Substrate composition data are available for a few PEI rivers. Fine sediments composed a mean of 28-33% of the bottom of sites on the Morell River, which is the most important angling stream on PEI. Fine sediments measured at 20 sites on five other rivers covered a mean of 35% of the bottom. Fines mixed with other substrate types covered means of 42% and 63% of the bottom of Morell and non-Morell rivers, respectively.

River	Measurement type*	Percent fines		
		Mean	SD	Sites
Morell, PEI	Bottom grab	33.3	14.2	9
Morell, PEI	Visual, pure fines	28.1	23.7	14
Morell, PEI	Visual, mixed fines	42.1	28.7	14
Non-Morell rivers, PEI	Visual, pure fines	35.0	30.7	20
Non-Morell rivers, PEI	Visual, mixed fines	63.0	30.2	20
Pt.Wolfe R., NB	Bottom grab	5.0	0.5	1
Catamaran Brook, NB	Bottom grab	13.4	1.4	1

*In bottom grab measurements, particle-size composition was determined by sieving. In visual measurements, particle sizes at the surface of the streambed were determined visually at grid points. Pure fines is a bottom type in which only fine sediments were found. Mixed fines is a bottom type which contained fines and another particle size (e.g. fines/gravel, fines/cobble).

Bottom grab samples, but not visual observations, indicate the infilling of substrate gravels by fine sediments. However the bottom grab samples were not representative of rivers as a whole because they were obtained at the heads of riffles where high water velocity may tend to wash fine particles out of the substrate. No measurements are available from intensively farmed areas without vegetated streamside buffer zones. Anecdotal reports from panel members and observers indicate that stream bottoms in such areas may be covered by dune-like deposits of fine sediment, with a complete absence of gravel or larger particles.

The limited quantitative data available on sediment deposition in streams are supplemented by visual observations by panel members during many thousands of hours of field work in streams in PEI and in the neighbouring provinces of Nova Scotia and New Brunswick. These observations indicate that stream sedimentation affects virtually all watercourses in PEI, and that the proportion of bottom covered by fine sediments is typically much higher on PEI than in neighbouring provinces.

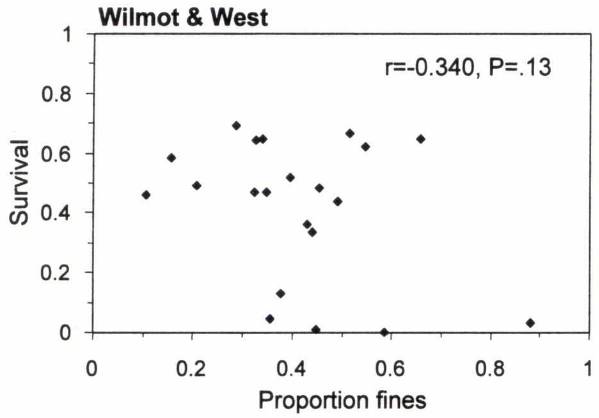
Suspended sediment in PEI watercourses is readily visible because the water acquires the red colour of the soil. Most rivers, especially those in heavily farmed areas, turn red during and after rainfalls. Concentrations of suspended sediments during rainfalls may exceed 20,000 mg/L.

Quantitative data on the sources of sediment input are lacking. However, visual observations by panel members indicate that agriculture (especially potato cultivation), forestry operations, road construction and maintenance, and landscape changes due to urban and commercial development are the main origins of sediments.

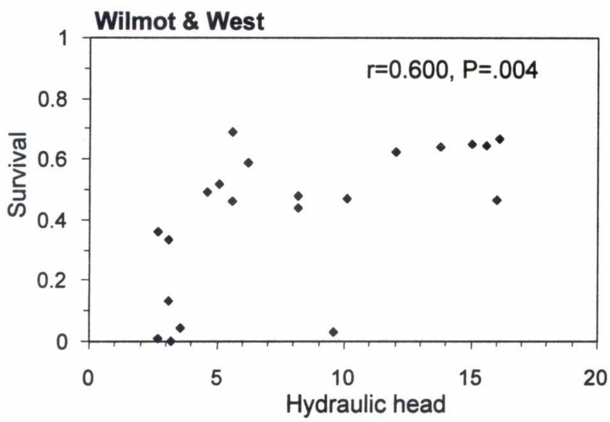
Effects on finfish

An abundance of international literature demonstrates that suspended and deposited sediments negatively affect all life stages of stream salmonids. Major effects of suspended sediments include impairment of feeding and gill function. Major effects of deposited sediments include decreases in reproductive success due to the prevention of oxygenation of incubating eggs, entombment of hatched alevins, reduced production of invertebrate food, infilling of interstitial spaces used by juveniles as cover, and infilling of pools used by adults as cover.

The main salmonid species on PEI are brook trout and Atlantic salmon. In the Wilmot and West rivers, survival to emergence of brook trout eggs/alevins was not significantly correlated with the proportion of fines within the redd.



Brook trout on PEI commonly spawn in groundwater upwellings (springs) in the bottom of streams. In such sites, upwelling water percolates through the redd, even if the redd contains a high proportion of fines that prevent the influx of stream water. In the Wilmot and West rivers, survival to emergence was positively correlated with hydraulic head, a measure of the strength of upwelling.

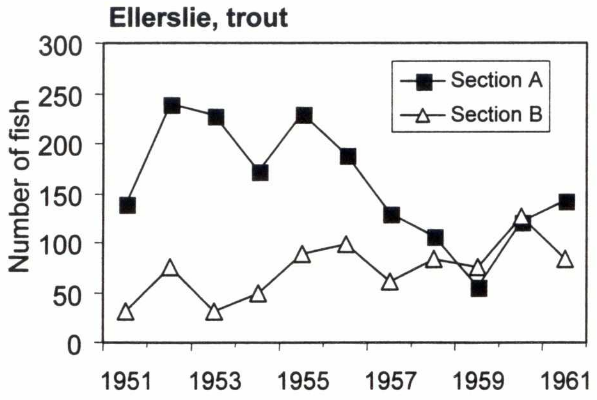


Brook trout eggs incubated in screened baskets in the Morell streambed accumulated large quantities of fine sediment (mean 1,012 g per 5.3 L basket). Mean survival to emergence was 14%, and survival to emergence was not significantly correlated with amount of accumulated fine sediment. Instead, survival to emergence appeared to be related to presence of groundwater seepages.

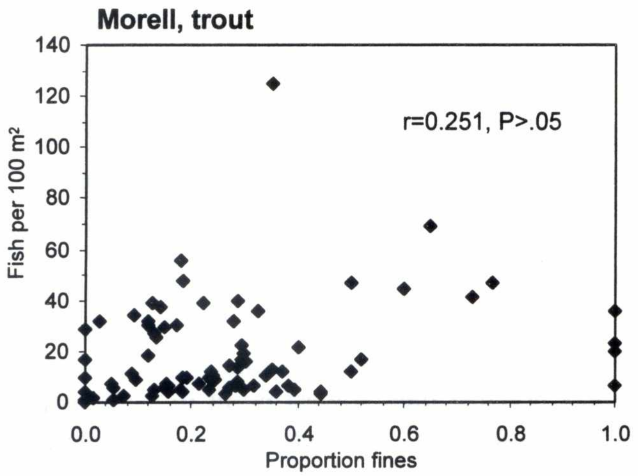
These results and studies conducted elsewhere suggest that brook trout use spring seepages to reduce egg mortality caused by poor oxygenation in sedimented sites. However, observations in the West and Wilmot indicate that areas of groundwater seepages were insufficient to accommodate all spawners, forcing some to spawn in heavily sedimented areas. Moreover, fish that spawned in sites with relatively low proportions of fines were not assured of good reproductive success because winter freshets sometimes deposited thick layers of sediment over sites which had been sediment-free during the fall spawning period.

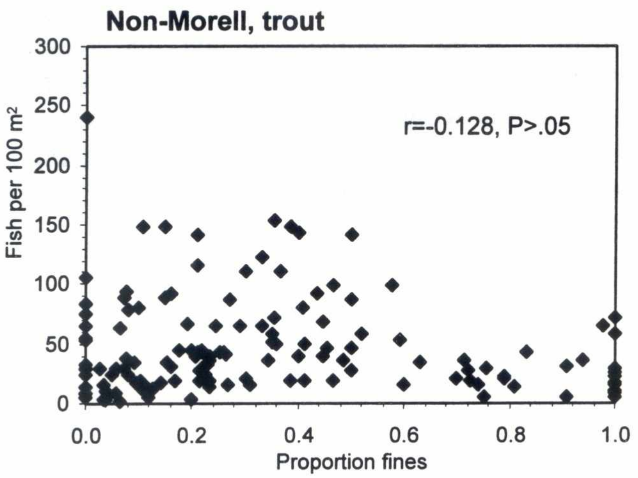
The degree to which sedimentation impairs brook trout reproduction on PEI cannot be accurately estimated in the absence of province-wide data on the availability of instream groundwater seeps. Province-wide data on groundwater qualities critical to egg and fry survival (dissolved oxygen, gas supersaturation) are also unavailable.

Several historical and current studies of the relation between sedimentation and densities of juvenile brook trout during summer are available. In Ellerslie Brook, numbers of brook trout declined from 1955 through 1959 in a reach (Section A) which was subject to unusually heavy sediment deposition in this period. Trout numbers reached their lowest point in 1959 after sediment from road maintenance work covered the streambed, and then improved the following year after freshets removed much of the sediment. Trout numbers in another reach (Section B), whose bottom sediments were decreasing following the conversion of cultivated land to pasture, showed a generally increasing trend during the time series.



Densities of juvenile brook trout were measured by electrofishing in the Morell River, and in five other rivers in PEI. Densities were not significantly correlated with the proportion of bottom covered by fines in either the Morell or non-Morell rivers.





In the Wilmot and West rivers, density of 0+ juveniles was significantly higher in low-sediment sites than in high sediment sites (2.59 and 2.03 fish/m^3 in low and high sediment sites, respectively; t=2.6, P=.01, df=70).

Panel members and observers reported that the dune-like sediment deposits found in some stream reaches in heavily farmed areas are devoid of fish or nearly so. No quantitative electrofishing data are available from such habitats.

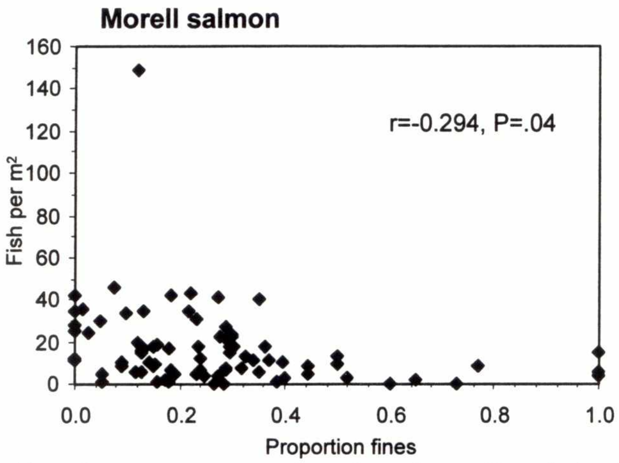
Juvenile brook trout are much less active during winter and have a strong need for cover. No data have been collected on PEI to determine if infilling of streambed particles by fine sediments limits overwinter survival.

Adult brook trout use pools for cover in both summer and winter. Sedimentation has infilled many pools in PEI streams. It has not been determined if brook trout are able to avoid negative effects due to loss of pool habitat by using alternate types of cover.

Atlantic salmon on PEI generally spawn at the crests above riffles, as they do elsewhere. Unlike brook trout, they do not preferentially use groundwater seepages for spawning sites. Grab samples taken at riffle crests on the Morell River contained a mean of 33.3% fine sediment (see Transport and deposition section above).

Atlantic salmon eggs placed in incubation baskets in the Morell had a mean survival to emergence of 12.6%. Mean fine sediment accumulation was 636 g per basket, but there was no significant correlation between survival to emergence and sediment deposition. Survival to emergence of salmon eggs placed in similar baskets in Catamaran Brook, New Brunswick, was 61.5%. Those baskets accumulated a mean load of 127 g of fine sediments.

Densities of juvenile Atlantic salmon in the Morell River were negatively correlated with the proportion of fine sediments on the stream bottom. However this does not necessarily mean that sediment depresses salmon populations because juvenile salmon prefer sites with rapidly flowing water which tends to remove fine sediments.



Like brook trout, wintering juvenile Atlantic salmon require cover to protect them during this period of low activity. Older parr need the larger cavities that occur underneath large cobble or boulders. The effects on juvenile Atlantic salmon of infilling of such habitats by sediment have not been investigated on PEI. Adult Atlantic salmon require pools as both summer and winter habitat, and being larger than adult brook trout are probably less able than brook trout to use alternative cover if pools are filled in by sedimentation.

Investigation of land use effects on Atlantic salmon is problematic because most PEI streams no longer have any salmon to study. Smolts raised in semi-natural conditions have been stocked for many years in streams which supported large salmon runs during the early stages of European colonization. These programs have failed to re-establish substantial natural production in any river except the Morell, where there is modest production of juveniles. The limited available data on land use effects are from this stream.

Effects on shellfish

Oyster spat prefer to settle on firm substrates, and they suffer low settlement success on soft bottoms. Oysters tend to sink into soft substrates, and the animals grow elongated shells to retain access to the water column. This shell shape reduces the commercial value of oysters. Because of the infilling of estuaries by soft sediments, the oyster industry in cooperation with governments operates large-scale and costly programs to bring old shell to the surface to provide a suitable substrate for oyster culture. Such efforts would not be necessary if estuaries were not extensively infilled by sediments.

Soft-shelled clams and quahaugs live in sedimented bottoms and the effects of sediment deposition on these species are not well understood. Mussels are grown off-bottom in relatively deep water and mussel cultivation does not appear to be negatively affected by sediment deposition at the present time. However, suspended sediment increases the cost of processing mussels because sediments must be removed prior to marketing.

Control of sediment input

Soil erosion cannot be entirely stopped but a number of practices are being promoted that reduce flux of sediments to watercourses. Measures pertaining to agriculture (particularly potato cultivation) include three-year crop rotations, spring ploughing, cross-slope cultivation, grassed waterways, terrace construction, strip cropping, residue management, fall mulching, planting of winter cover, and hedgerow planting. Improved forestry and highway construction and maintenance practices can also substantially reduce sediment inputs to watercourses. Riparian buffer zones reduce sediment input from both agricultural and forestry sources.

Toxic chemicals

Effects of pesticides

There were 12 fish kills on PEI in 1994-1999 which were known or suspected to have been caused by pesticides. Eight of these occurred in 1999, including a large kill on the Valleyfield River, a major angling stream. It is not clear whether or not the high number of reported kills in 1999 was a random aberration. Typically, kills occurred after a heavy rainfall, with complete mortality occurring in a zone downstream from a point that received run-off from a potato field. It is not known to what extent aquatic life outside the kill zone is harmed by sublethal effects due to direct toxicity or to endocrine disruption.

Kills were normally signaled when dead fish were seen by anglers, conservation officers, or passersby. Hence it is possible that other kills, especially small ones, may have occurred that were not reported to investigators.

Pesticide effects on aquatic life on PEI have been investigated by monitoring pesticide concentrations in streams in a potato growing area, and by measuring pesticide concentrations in water after fish kills.

There were 169 pesticide detections in the 60 water samples obtained during the monitoring program in 1996-1999. About 75% of the samples contained one or more pesticide detections. Twelve pesticides were detected, including metalaxyl (found in 42 of 42 samples), metribuzin (38 of 42 samples), atrazine (6 of 7 samples), carbofuran (5 of 7 samples), and endosulfan (8 of 42 samples). Only one pesticide (chlorothalonil, 1.34 ppb) was found to be in excess of the Fresh Water Aquatic Life Guideline (FWALG) value for that pesticide (0.18 ppb). All of the pesticide detections were well below their respective 96 h LC50 values for rainbow trout (LC50 is the pesticide concentration that kills 50% of the sample after 96 hours of exposure).

Samples collected at fish kill sites in 1999 showed pesticide concentrations that were higher than those of the monitoring program. Azinphos methyl was found in stream water at one site at concentrations equal to the LC50 value for rainbow trout. Concentrations of two other pesticides (chlorothalonil and endosulfan) in stream water exceeded their respective FWALG values. Concentrations of azinphos methyl, chlorothalonil, and endosulfan sampled from puddles located above the streams were found to exceed LC50 values.

Samples of spring water seeping through brook trout redds in spring 1997 (prior to any pesticide applications for that year) contained methamidophos, metribuzin, and metalaxyl. Concentrations of metribuzin and metalaxyl were well below guidelines, but the concentration of methamidophos (60 ng/L) was 263 times higher than the reported lethal level for aquatic crustaceans.

Effects of endocrine disrupting compounds

There has been increased concern over the release of endocrine disrupting compounds into the environment. Agricultural activities are a potential source of these compounds, and PEI is a potentially susceptible area considering that most cleared land in the province is used for agriculture.

Rainbow trout held in stream cages in PEI showed significant changes in circulating testosterone, but there was no clear pattern of change in relation to assumed risk of pesticide exposure. Japanese medaka embryos exposed to sediments from cage sites in intensively farmed areas showed higher mortality and longer hatching times than those exposed to sediments from less intensively farmed areas. Further studies are required to determine if the observed changes are due to endocrine disruptors, and if so, to identify the source of these compounds.

Effects of livestock access to streams

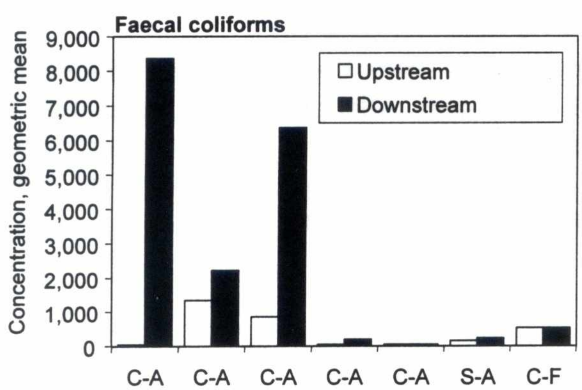
International literature indicates that cattle and other livestock which have access to streams harm salmonid populations by breaking down bank structure, by trampling gravel and other large particles into the streambed, by increasing suspended sediment loads, and by introducing manure and its toxic leachates into watercourses.

Panel members have commonly observed the physical effects noted above in PEI streams to which livestock have access. It is likely that the negative effects measured elsewhere also occur in PEI streams with livestock access. However, no scientific studies have been conducted on PEI to measure such effects.

Since 1991, a government-NGO stewardship program has assisted farmers in fencing cattle from watercourses and providing alternative ways to water livestock. As of fall 1999, 180 projects have been completed. This program in collaboration with livestock operators has put approximately 10,000 cattle behind 75 km of fencing which protects more than 500 ha of riparian land. Since no survey of livestock access to PEI streams has been conducted, the amount of stream length that continues to be accessible to livestock is unknown.

Livestock faeces contains faecal coliform bacteria, as do the faeces of other warm-blooded animals. These bacteria are commonly used as indicators of the possible presence of pathogenic microorganisms. Mean permissible concentrations of faecal coliforms for direct human contact and for shellfish harvesting are 200 and 14 organisms/100 mL, respectively.

Geometric mean faecal coliform concentrations were significantly higher downstream than upstream of five sites where cattle had access and one site where sheep had access (t-tests, all P values ≤ 0.006). Concentrations upstream and downstream of a site where cattle were fenced from the stream were not significantly different.

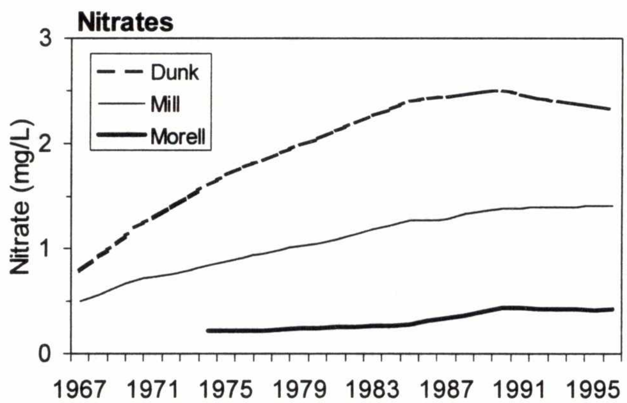


(C-A means accessible by cattle, S-A means accessible by sheep, C-F means fenced against cattle).

More than 80 sites in PEI are closed to direct harvest of bivalve shellfish because of excessive faecal coliform concentrations. Some of these grounds are adjacent to agricultural areas that have no municipal sewage outfalls and no substantial concentrations of wildlife. This suggests that livestock wastes may be the source of the contamination. However, the contribution of livestock waste to faecal coliform levels in closed shellfish areas has not been measured.

Effects of nutrients on estuaries

Plant growth in estuaries depends on the presence of nitrogen and phosphorus. Concentrations of nitrogen in PEI estuaries have risen substantially since the 1960s, although there has been a leveling-off or decrease in the 1990s. Concentrations of phosphorus have also risen.



Nitrogen concentrations of 0.3-0.5 mg/L and phosphorus concentrations of 0.035 mg/L are considered to be the threshold for eutrophic conditions in estuaries. Ten of 20 estuaries sampled in 1998-1999 had mean nitrogen concentrations exceeding 0.5 mg/L.

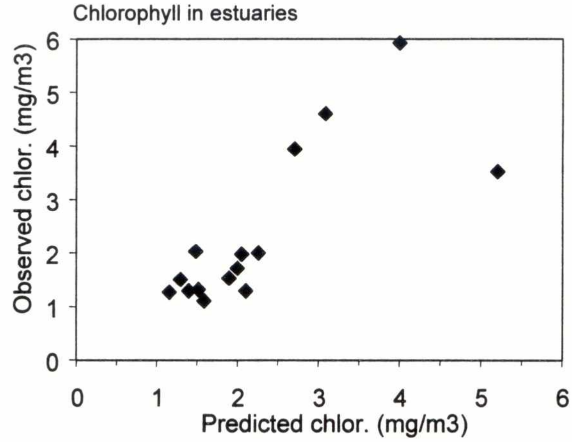
The macrophytic alga sea lettuce grows in bays and estuaries around PEI. Highly luxuriant growth may lead to anoxic conditions when dense layers of vegetation rot, robbing the water of its oxygen. During anoxic events, the water typically turns milky and visibility drops to near nil. Most fish are able to swim away from the anoxic zone but bivalve shellfish are unable to move and hence die. Anoxic events usually occur in July and August, and occasionally September.

Most of the anoxias have been on the north shore of PEI, where tidal flushing is weak due to the low tidal amplitude (mean 0.7 m on the north shore, mean 1.8 m on the south shore). (Anoxic conditions associated with water-flow restraints due to causeways are not considered here).

Locations of anoxic events

No long-term records are available of anoxic events in PEI estuaries. However, observations by panel members indicate that such events have increased greatly in frequency over the past several decades, and that anoxic events have recently occurred in areas where such events were unknown in the past or occurred very rarely.

Chlorophyll concentrations in 15 PEI estuaries were related to concentrations of both total nitrogen (r^2 = 0.72) and total phosphorus (r^2 = 0.65). Chlorophyll concentrations were also related to land use practices in the adjoining watershed. An equation in which estuary volume and area of the watershed under agriculture were independent variables predicted chlorophyll concentrations with an r^2 of 0.68.



Cultured mussels are important herbivores in PEI estuaries. Nitrogen and phosphorus of agricultural origin appear to be major contributors to the growth of mussel food. Hence current agricultural practices may contribute substantially to the success of the cultured mussel industry.

Overall impacts on aquatic biota

Finfish
Brook trout and Atlantic salmon, the main recreational fish in PEI streams, experience sedimentation, pesticides, and livestock and their wastes in their habitats. The extensive literature on sediment effects on salmonids indicates that negative effects are pervasive and often severe. Currently available data for PEI are limited and cover only some life stages and ecological situations.

Mean densities (fish/100 m^2) of summed juvenile brook trout and Atlantic salmon measured in rivers for which more than 10 density estimates are available are roughly similar in New Brunswick/Nova Scotia and PEI.

River	Trout	Salmon	Sum
New Brunswick/Nova Scotia			
Restigouche		78.7	78.7
Jacquet	9.2	7.7	16.9
Miramichi		116.7	116.7
Margaree	18.3	75.0	93.3
St. Marys River	1.4	28.2	29.6
West R., Sheet Harbour	0.4	16.0	16.3
LaHave	0.6	14.0	14.6
Shubenacadie	21.8	35.3	57.1
Stewiacke	11.8	62.1	73.9
Maccan	0.4	57.7	58.1
Saint John		31.3	31.3
Mean	8.0	47.5	53.3
Prince Edward Island			
Morell	17.5	12.1	29.5
Little Pierre Jacques	39.8	0.8	40.6
Enmore	15.7	3.3	18.9
Ellerslie	42.4	0.1	42.5
Seal	56.2	0.5	56.7
Vernon	90.8	1.4	92.2
Montague	66.0	0.0	66.0
Mean	46.9	2.6	49.5

In comparison with New Brunswick and Nova Scotia, PEI has greater natural soil fertility (which is associated in the literature with higher salmonid densities), lower diversity of freshwater fish species (which means less competition), and widespread spring seepages that limit summer temperature extremes and maintain flow in dry periods. These are important habitat advantages, and suggest that, in the absence of land use and other anthropogenic influences, densities of stream salmonids would be higher on PEI than they are in New Brunswick and Nova Scotia.

There are four types of information upon which to base an overall assessment of the impact of land use practices on PEI salmonids:
a) Data gathered on PEI. Such data have small sample sizes and limited temporal scope.
b) Direct observations by panel members and others. Such observations are based on large amounts of field experience and go back several decades, but they are not quantitative.
c) Comparisons with salmonid densities in New Brunswick and Nova Scotia.
d) The international literature on land use effects on salmonids.

These information sources, when viewed as a whole, indicate that past and present land use practices have had and continue to have a substantial negative effect on salmonid populations in PEI. These effects are most heavily felt on Atlantic salmon. Despite intensive stocking programs, this species has not re-established substantial natural production in any PEI river except the Morell. The most likely explanation for the failure of Atlantic salmon to re-colonize rivers in which they were formerly abundant is that land use practices, particularly those resulting in sediment deposition, have rendered the habitat unsuitable for this species.

Shellfish

Habitats used by shellfish in PEI estuaries are altered by inputs of sediment, faecal coliforms, and nutrients. Sediment deposition chiefly affects oysters, because soft sedimented bottoms cause slow growth and misshapen shells which reduce market value.

Many shellfish grounds on PEI are closed to direct harvest due to faecal coliforms. Livestock wastes produce high faecal coliform counts in streams to which livestock have access, but the effect of livestock inputs on faecal coliform concentrations in estuaries has not been determined.

Nitrogen and phosphorus of land use origin promote growth of phytoplankton in estuaries and bays, which benefits cultured mussels. Nutrients of land use origin also promote excessive growth of sea lettuce, which leads in some cases to anoxic conditions that kill local shellfish beds.

Ranking of impacts

Available data are insufficient to quantify the effects of inputs from land use practices on the aquatic resources of PEI. For this reason a formal ranking of the relative importance of the various effects is not possible at this time.

Impacts of land use on aquatic resources depend on land use patterns in local watersheds. These patterns vary considerably. Hence the relative importance of the various impacts is likely to be heterogeneous across the province.

Mitigation

Reduction of soil loss from potato cultivation can be achieved by three year crop rotations, cross-slope plowing, strip cropping, terracing, fall mulching, and other techniques. Integrated application of these and other erosion control techniques substantially reduces soil loss from fields and sediment input into watercourses. Expert advice on conservation-based soil management is available to growers through programs sponsored by the PEI government.

Recent pesticide-induced fish kills on PEI are associated with run-off from potato fields after rainfalls. Because erosion control techniques for potato cultivation are designed to minimize rapid surface run-off, these techniques also reduce risk of fish kills by pesticides.

Negative effects of livestock access to streams can be reduced by fencing. Unfenced streams are commonly used as a water source for livestock. There are a variety of means by which livestock can be watered without allowing them direct access to the stream.

There are broadly based efforts involving government and agricultural and conservation non-governmental organizations (NGOs) to induce land users to adopt practices that will reduce inputs into watercourses. Due at least in part to these campaigns, there has been a gradual expansion of conservation-based farming practices, including erosion prevention techniques in potato cultivation and stream fencing by livestock operators. However, there are still numerous land users whose practices remain unchanged.

Conservation NGOs have made major efforts to reduce effects of sediment inputs and improve salmonid habitats through instream techniques including sediment traps, digger logs, and angled gabions. No province-wide data on the physical and biological effects of such interventions are available. However, on the basis of their experience in PEI streams, panel members felt that improvements brought about by these efforts are very small in relation to continued sediment inputs due to land use practices.

Federal and provincial legislation prohibits the degradation of fish habitat through physical alteration or the introduction of harmful substances. There has been little enforcement of this legislation with respect to the introduction of sediment, pesticides, and animal wastes into PEI watercourses.

Conclusions

- Land use practices since the beginning of European settlement have contributed very large quantities of sediment to PEI streams and estuaries, greatly altering these habitats.
- Agriculture, forestry, roads, and commercial development continue to contribute large quantities of sediment to PEI streams and estuaries.
- Streams flowing through potato growing areas commonly contain a variety of pesticides in low concentrations. Occasional high concentrations produce fish kills. There were eight pesticide-related kills in 1999.
- Land use practices exert a substantial negative effect on salmonids, particularly on Atlantic salmon, which have been extirpated from most PEI streams and which are reduced to remnant populations in all others (except those which are artificially stocked).
- Estuarine sedimentation due to land use practices reduces the productivity of oyster beds and increases production costs.
- Nutrients of land use origin appear to be a major contributor to the growth of phytoplankton eaten by cultured mussels.
- Streams to which livestock have access often have high concentrations of faecal coliform

bacteria and many shellfish grounds that are adjacent to farmland are closed due to coliform contamination. However the source of contamination in such areas has not been established.

- Inputs of sediment, pesticides, and animal wastes into streams can be substantially reduced by adopting conservation-based cultivation practices and by fencing livestock from streams.
- Federal and provincial legislation contains far-reaching powers to protect fish and fish habitat but there is little enforcement of these provisions with respect to inputs of sediment, pesticides, animal waste, and nutrients.
- Use of conservation-based land use practices is expanding, but there are also trends (increases in potato acreage, conversion of forest to cropland) which tend to increase inputs into watercourses.

Recommendations

- PEI-specific data on land use impacts on aquatic resources are very limited. To evaluate land use impacts where current understanding is insufficient and to guide mitigative efforts and rehabilitation of PEI's freshwater and estuarine fisheries resources, an integrated, coordinated, and long-term research program is required.

- Research should be directed towards:
  - monitoring the inputs of sediment, toxic chemicals, animal wastes including bacteria, and nutrients into PEI watercourses,
  - quantifying and modeling effects of these inputs on fish, shellfish, and their habitats,
  - establishing benchmarks to support enforcement of legislation, and
  - evaluating existing and devising new mitigative measures.

- Implementation of an effective program to mitigate the harmful effects of land use practices on PEI fisheries resources requires a broad consensus and buy-in by government agencies, community members and industry.

For more information:

Contact: David Cairns
Science Branch
Dept. of Fisheries and Oceans
P.O. Box 1236
Charlottetown, PEI
C1A 7M8

Tel: (902) 566-7825
Fax: (902) 566-7948
E-Mail:
cairnsd@dfo-mpo.gc.ca

References

Adams, J.D. Concentrations of faecal coliform bacteria in headwater streams in the Bedeque Bay and Cardigan Bay watersheds. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Aggett, D., G. MacDougall, and L. Murphy. Acts, regulations, and policies pertaining to protection of aquatic environments on Prince Edward Island. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Anon. 1999 Measuring our progress: soil conservation efforts of P.E.I. potato producers in the late 1990's. Video produced by the PEI Soil and Crop Improvement Association and the PEI Department of Agriculture and Forestry.

Cairns, D.K. Land use and aquatic resources of Prince Edward Island streams and estuaries - an introduction. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Cairns, D.K. Substrate sedimentation and salmonid densities in Prince Edward Island streams. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Caissie, D., and E. Arseneau. Substrate composition in the Morell River and other Maritime Province rivers: potential implications for Atlantic salmon fry emergence. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Cunjak, R.A., D.L. Guignion, R.E. MacFarlane, and R. Angus. Survival of eggs and alevins of wild brook trout and Atlantic salmon in relation to fine sediment deposition. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.) (abstract).

Duffy, T.J. Livestock access to watercourses: issues and solutions. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Gray, M.A., K.L. Teather, J. Sherry, M. McMaster, and R.E. Mroz. Endocrine disrupting potential in freshwater ecosystems near agricultural areas on Prince Edward Island. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Landry, T. The potential role of bivalve shellfish in mitigating negative impacts of land use on estuaries. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

MacFarlane, R.E., B.M. Smith, and T.D. Dupuis. Physical watercourse enhancement on PEI: methods, extent, and effects on habitats and biota. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

MacNeill, S., and R.A. Curry. Abundance of juvenile brook trout and sediment in Prince Edward Island streams. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.) (abstract).

MacNeill, S., and R.A. Curry. Brook trout survival to emergence in relation to sediment in Prince Edward Island streams. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.) (abstract).

Meeuwig, J. Predicting estuarine eutrophication in Prince Edward Island from land use patterns. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.) (abstract).

Meeuwig, J.J. 1999. Predicting coastal eutrophication from land-use: an empirical approach to small non-stratified estuaries. Mar. Ecol. Prog. Ser. 176:231-241.

Meeuwig, J.J., J.B. Rasmussen, and R.H. Peters. 1998. Turbid waters and clarifying mussels: their moderation of empirical chl:nutrient relations in estuaries in Prince Edward Island, Canada. Mar. Ecol. Prog. Ser. 139-150.

Mutch, J.P., M. Savard, G. Julien, B. MacLean, B.G. Raymond, and J.A. Doull. Pesticides in water and sediment: monitoring vs. fish kill investigations on Prince Edward Island. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

P. Lane and Associates Ltd. 1991. Sedimentation study of the Wilmot River estuary. Report on Project E-174 submitted to Environment Canada and the PEI Department of the Environment, Charlottetown.

Raymond, B.G. Nutrient and chlorophyll trends in PEI estuaries. In D.K. Cairns (ed.). Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.).

Saunders, J.W., and M.W. Smith. 1965. Changes in a stream population of trout associated with increased silt. J. Fish. Res. Board Can. 22:395-404.

Waters, T.F. 1995. Sediment in streams: sources, biological effects and control. Amer. Fish. Soc. Monogr. No. 7.

This report is available from the:

Maritimes Provinces
Regional Advisory Process
Department of Fisheries and Oceans
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2
Phone number: 902-426-7070
e-mail address: MyraV@mar.dfo-mpo.gc.ca

La version française est disponible à l'adresse ci-dessus.

Correct citation for this publication

DFO. 2000. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. DFO Maritimes, Regional Habitat Status Report 2000/1E.