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

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PREFACE

On 6-10 December 1999, the Department of Fisheries and Oceans, in collaboration with the Prince Edward Island Department of Technology and Environment, sponsored a scientific workshop to examine the impacts of land use practices on aquatic resources of Prince Edward Island. The meeting was held in Charlottetown, and was chaired by André Ducharme. This workshop was prompted by widespread concern about the effects of sedimentation, livestock access to watercourses, toxic chemicals, and anthropogenic nutrient releases on freshwater and estuarine systems of Prince Edward Island. It heard 16 presentations by biologists, toxicologists, enforcement officials, resource managers, and soil and water specialists.

The findings of the workshop were recorded in a Habitat Status Report (DFO 2000). Workshop objectives, agenda, participant list, and summaries of oral discussion were presented by Cairns (2000).

The 11 papers and five abstracts or extended abstracts in this report represent the scientific proceedings of the workshop. All papers were peer-reviewed by two or more referees. The editor thanks Bob Bancroft, Rod Bradford, Daniel Caissie, Simon Courtenay, Cindy Crane, Ted Currie, Todd Dupuis, Richard Gallant, Ron Gray, Daryl Guignion, Andrea Locke, Rosie MacFarlane, Linda MacLean, John MacMillan, Darren MacPherson, Dave Moore, Kelly Munkittrick, Clair Murphy, Dacia Omilusik, Bruce Raymond, Bruce Smith, and Erin Swansburg for providing referee reports.

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Land use and aquatic resources of Prince Edward Island streams and estuaries: an introduction

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ABSTRACT

Prince Edward Islanders' long-standing preoccupation with land issues has been increasingly directed toward questions of land use impacts on aquatic environments. PEI's geological history provides it with a heavily indented coast, short rivers, and few natural ponds. The original Acadian forest, dominated by sugar maple, beech, and yellow birch, was cleared or cut over by European settlers and by 1900 only 30.9% of the province was forested. In the 20th century some farmland was allowed to revert to forest and in 1990 49% of the province was forested. PEI's agricultural economy continues to be based on a mix of livestock and crops. Land planted in potatoes increased from 26,000 ha in 1986 to 45,000 ha in 1998. About 18-20% of the province's land mass is in potato rotation. Most farmland on PEI is classified as having severe to high risk of erosion, and the increasing cultivation of potatoes exacerbates this risk. Soft-shelled clams, quahogs, and oysters harvested from PEI bays and estuaries fetched reported values of $1.6 to $7.2 million in 1981-1998. Mussels are cultivated on longlines suspended in deeper bays and estuaries. Sales were valued at $15.1 million in 1998. Due to its insular status PEI has a depauperate freshwater fish fauna. Only three species have purely freshwater distributions, and these may have been introduced. The chief commercial finfish of bays and estuaries are eels, gaspereau (consisting of alewife and blueback herring), silversides, and smelts. The main recreational species are brook trout which are widespread, and Atlantic salmon which have disappeared from most systems, but which persist in a limited number of rivers due to natural reproduction and stocking.

INTRODUCTION

Prince Edward Islanders have been preoccupied with questions of land since the beginning of British settlement. Islanders' interest in (some would say obsession with) land may be due to its scarcity (PEI is the most densely populated province in Canada), to the status of agriculture as an economic mainstay, and to a troubled early history in which orderly settlement was impeded by a system of absentee land tenure.

In the last part of the twentieth century, concerns about land on PEI have led to two Royal Commissions and a major Round Table study (Anon. 1973, Boylan 1990, Anon. 1997). Increasingly, land controversies revolve around environmental issues, especially the relation between land use practices and aquatic environments.

A simple example will underline the connection between land use and watercourses on PEI. In 1994, Marchbanks Pond on the Wilmot River in west-central Prince Edward Island was drained in order to allow the removal of silt that had accumulated in it. The pondbed yielded no fewer than 4,150 truckloads of earth, with a total volume of approximately 57,000 m^3 (S. Hill, pers. comm.). Marchbanks is a small pond that receives water from a stream only about 10 km long. The quantity of silt it had gathered is testament to the massive transfer of topsoil, and many other materials, from the terrestrial environment to the aquatic environment of Prince Edward Island.

The Round Table report spawned a series of pubic hearings, action committees, and task forces to deal with its recommendations, and also to respond to urgent issues (such as a spate of fish kills in summer 1999). These fora, like their predecessors, receive input from scientific witnesses but their orientation is to recommend or create public policy, not to critically examine the physical, chemical, and biological processes by which land use practices effect change on aquatic environments.

The series of papers in this volume provides that scientific scrutiny. They will focus on four avenues by which land use practices may affect aquatic resources, q.v. sedimentation, toxic chemicals, cattle access, and estuarine eutrophication.

This Introduction provides background material in the form of a brief history of land use on Prince Edward Island, and a summary of freshwater and estuarine fisheries resources.

Pp. 1-13 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

A BRIEF HISTORY OF LAND USE ON PRINCE EDWARD ISLAND

Prince Edward Island is underlain by sandstone and siltstone bedrock formed from the erosion of the early Appalachian Mountains (van de Poll 1983, DeGrace 1999). This sedimentary bedrock is overlain by glacial till which shares the bedrock's characteristic red colour, which is caused by a layer of hematite dust that sticks to each particle. What is now Prince Edward Island was a peninsula after the last ice age, but fluctuations in sea level and rebound from glacial depression gave PEI insular status about 5,000 years ago.

The rising sea level in relation to the land also drowned the valleys of PEI's short rivers. This produced a deeply incised coast with broad tidal estuaries and many bays. In many river systems the estuaries are larger than the rivers themselves. Because of its base of soft sedimentary rock, PEI has few natural lakes. This underlying geology also permits abundant groundwater seepages, which serve to maintain flow and dampen temperature fluctuations (Smith 1966).

At the time of European contact, most of Prince Edward Island was covered by a forest dominated by sugar maple, beech, and yellow birch, with some stands of spruce and fir, especially in coastal and poorly drained areas (Clark 1959, McAskill 1987). The economy of native people at the time was based on hunting and gathering, and had little effect on land cover. European settlement began with French colonists early in the 18th century (Clark 1959). Most farms were along coastlines or estuaries, and salt marsh and sand dunes were exploited for livestock forage. After the British acquired official control in 1763, settlement and land clearing increased, with the biggest waves of arrivals occurring in the first half of the 19th century. These settlers operated mixed farms, raising cattle, sheep, pigs, and a variety of cereal crops and potatoes. Land clearing continued, and by 1900, only 30.9% of the province remained forested (Anon. 1997). The land that retained forest cover was much affected by wood harvest for shipbuilding, local construction, and firewood.

In the early part of the 20th century the province's population shrank due to declining economic opportunities, and much farmland was abandoned. Most of this land reverted to single-species stands of white spruce. In 1990 (the most recent year for which accurate data are available) 49% of PEI was forested. The forest resource is approximately evenly split between hardwoods and softwoods (Anon. 1997). Prince Edward Island has no virgin forest and all forested land has been subject to at least some degree of harvest. During the 1990s there has been an upturn in forest harvesting due to high lumber prices, and also because of pressure to clear woodland 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 by the Forestry Division of the PEI government to be unsustainable (Table 1; Anon. 1997).

PEI's agricultural economy continues to be based on a mix of livestock (mostly dairy and beef cattle and pigs) and crop (cereals, potatoes) production. However the number of farms and farmers has decreased markedly. The number of farms peaked at about 14,000 at the turn of the century, fell to 3,154 in 1981 and continues to decline (there were 2,217 in 1996, Table 1) (Clark 1959, Anon. 1997). With the decreasing number of farms there has been a major increase in farm size. In parallel, there has been an increasing trend for land to be farmed by those who do not own it.

From 1880 to 1950, PEI farmers planted from 13,000 to 22,000 ha of potatoes annually (Clark 1959). In the 1980s, potato acreage began a steep increase, rising from 25,851 ha in 1986 to about 45,730 ha in 1998 (Table 1, Fig. 1). Cash receipts from potatoes are now roughly half of all farm revenues on PEI (Table 1, Fig. 1). According to PEI Department of Agriculture and Forestry analyses of satellite images recorded in 1996-1998 (Anon. 1999a), between 103,000 and 115,000 ha of PEI is currently in potato rotation. This constitutes about 18-20% of PEI's land mass. Of the land in potato production, between 55 and 62% is planted in potatoes every three years, and between 36% and 43.5% grows potatoes every two years. Between 1.5 and 2% of potato land is planted in potatoes three years in a row (Anon. 1999a).

Eighty-one percent of cultivated land on Prince Edward Island is considered by Agriculture and Agri-foods Canada to be at high to severe risk of water erosion, and PEI is the only province in Canada where the water erosion risk increased between 1981 and 1991 (Anon. 1997). This trend is due to the increase in potato acreage. Of all major crops grown on PEI, potatoes are the most environmentally intrusive for the following reasons:

a) Potato production removes large quantities of organic matter from the soil. In 1998, the mean potato yield from PEI fields was 29 t/ha (Anon. 1999b). In contrast, typical hay and grain yields are 5 and 3 t/ha, respectively.

b) Potato cultivation involves leaving soil bare for extended periods, leading to high erosion risk. Traditionally, land is plowed the fall before potato planting, and fields lie bare after the crop is harvested. Some farmers are adopting alternate methods that reduce erosion risk, but potato cultivation still entails more erosion potential than other crops.

c) Potatoes attract a wide variety of pests, which are typically controlled by intensive pesticide applications.

Washburn and Gillis (1992) estimated a mean soil loss for potato land in the Dunk-Wilmot area of 10 t/ha/year, assuming that 70% of the land was in a three year potato rotation with the remainder in a two year rotation.

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, probably due to the conversion of some cattle operations to potato farms (Table 1, Fig. 1).

Prince Edward Island's population in 1999 was 138,000. With a land area of 5,660 km^2, PEI has a population density of 24.4 persons km^{-2}, the highest of any Canadian province. The national population density is 3.1 persons km^{-2} and the second most densely populated province is Nova Scotia with 16.9 persons km^{-2} (figures from Statistics Canada web site, 2000).

MOLLUSCS AND THEIR FISHERIES

Prince Edward Island's broad estuaries and shallow bays provide habitat for several bivalve shellfish of economic importance. The southern Gulf of St. Lawrence, termed the "Acadian Pocket," has summer water temperatures which often rise to the low 20°s C in sheltered inshore areas. This provides summer thermal conditions which are not encountered elsewhere in eastern North America north of the middle of the US Eastern Seaboard. The following account of bivalve shellfish is summarized from Jenkins et al. (1997).

Soft-shelled clams are harvested in bays and estuaries at low tide with hand tools. Reported harvests in 1981-1998 declined irregularly, and ranged from 159 to 407 t (Table 2, Fig. 2). Reported landed value during this period ranged from $173,000-$788,000. Quahogs are harvested from muddy bottoms in grounds which are covered by 0 to 0.75 m of water at low tide. The main method is hand picking by combing through the mud surface with gloved hands. Reported quahog landings were between 29 and 622 t in 1981-1998, with landed values of $200,000-$1,983,000 (Table 2, Fig. 2). Prince Edward Island also has a bar clam industry which typically harvests 200-800 t annually. Bar clams typically occupy sandy bottoms fronting on open salt water, so they occupy only the outer portions of estuaries.

The oldest commercial bivalve fishery on PEI is for the oyster, which was intensively harvested in 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, which may be enhanced by cooperative or government efforts, and culture on private leaseholds. There are also efforts to raise oysters in racks held off-bottom in shallow water. Some of the most important grounds are contaminated by coliform pollution, which has given rise to the widespread practice of "relaying" contaminated oysters in clean water until they are safe for human consumption.

Market demand, and therefore price, of oysters varies greatly with shell shape. The highest grades generally come from firm bottom while those grown on soft mud earn low grades and low prices.

Reported oyster production varied from 870 to 1,974 t between 1981 and 1998 (Table 2, Fig. 2). Reported landed values in the same period ranged from $1,016,000 to $4,447,000.

Summed reported harvests of soft-shelled clams, quahogs, and oysters were 1,677 to 2,897 t in 1981-1998, with reported landed values from $1,687,000 to $7,218,000 (Table 2, Fig. 3).

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 which 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 12,461 t in 1998, with a landed value of $15,110,000 (Table 2).

FINFISH AND THEIR FISHERIES

The formation of the Northumberland Strait about 5,000 years ago posed a barrier to the colonization of mammals and freshwater fish to Prince Edward Island. PEI's mammalian fauna is depauperate in comparison with that of mainland provinces (Cameron 1958), and its list of fishes is similarly short (Anon. 2000a). At present, about 21 fish species spawn in PEI rivers and estuaries (or spend most of their lives there, in the case of the American eel) (Table 3). This includes introductions such as brown and rainbow trout and arctic char. The native spawning population included approximately 15 species. However, the species list is dominated by diadromous forms which are adapted to salt water and therefore could readily invade PEI from neighbouring provinces. The only purely freshwater fish found on PEI are the northern red-bellied dace, the golden shiner, and the slimy sculpin. All of these have very restricted ranges on PEI and may have been introduced. It is therefore possible that the indigenous fauna of PEI includes no purely freshwater fish.

The following accounts are summarized from Cairns (1997a). Eels are found in bays, estuaries, coastal ponds, rivers, and freshwater ponds on PEI. Muddy bottoms are favoured, although in streams stony substrates may be used. The commercial fishery is restricted to tidal waters, where eels are captured by fyke nets and by night-time spearing under generator-powered lights, a practice known as flambeauing. Reported landings in fisheries for eels and other diadromous species are notoriously unreliable. However, the sharp decline in reported landings, from 150-250 t in the early

1980s to a few tens of tons in the late 1990s (Table 2, Fig. 4), accords with reports from industry observers. The gaspereau fishery of PEI targets two species, the alewife and the blueback herring, both of which spawn in rivers during springtime runs. These fish are caught in trap nets in rivers, by beach seines in rivers and at the outlets of creeks emptying into the Gulf of St. Lawrence, and in gillnets set in open water. Official landings figures do not properly capture gaspereau catches because the dominant market is for lobster bait. Nevertheless it is clear that catches are in the range of hundreds of tons or more. Silversides inhabit coastal waters, tidal creeks, and coastal ponds, and are subject to a fall fishery on PEI, which accounts for about two thirds of world landings of this species. Reported catches are highly variable, and have ranged up to 543 t with a landed value of $207,621. Smelts, like gaspereau, enter rivers in spring to spawn. They are taken in gillnets and traps in fall and traps through winter ice. Reported landings ranged from 85 to 704 t in 1981-1998, with reported landed values of $77,238 to $681,564.

The main recreational fisheries on PEI are for brook trout and Atlantic salmon. Brook trout exist in self-sustaining populations in most PEI watercourses, but self-sustaining runs of salmon have disappeared from most streams in the period since European settlement. Remnant natural salmon runs persist in a some streams, and runs are supported by stocking in several of the larger rivers, notably the Morell, Mill, Trout (Coleman), Dunk, West, and Valleyfield. The number of brook trout licences issued has declined since the 1980s (Table 4, Fig. 5). Salmon licence sales increased sharply in the late 1980s after the implementation of a stocking system based on semi-natural rearing, which boosted returns (Davidson and Bielak 1993). Salmon returns have declined in the 1990s, and so have licence sales (Table 4, Fig. 5; Cairns 1997b).

In 1994, anglers spent an estimated $4.6 million for goods and services directly attributed to recreational fishing on PEI (Table 4, Fig. 3). Total expenditures, partly or completely attributable to angling activities, were $7.0 million (Cairns 1996).

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Table 1
Selected forestry and agricultural statistics for Prince Edward Island.
Data from Anon. 1996, 1999b, and Anon. 2000b.

Year	Forest production (m^3)	Number of farms	Cattle on farms	Potatoes planted (ha)	Potato cash receipts	Total farm cash receipts (000)
1981		3,154		25,851		
1982			102,000			
1983			101,000			
1984			101,000			
1985			100,000	28,733		
1986		2,833	100,500	25,989		186,970
1987	499,000		99,000	27,114		215,097
1988	510,000		99,000	27,519		208,614
1989	451,000		98,000	27,519		257,650
1990	442,000		97,000	30,351	114,238	252,953
1991	411,000	2,361	95,000	31,485	96,573	243,232
1992	465,000		94,500	34,398	72,839	227,066
1993	490,000		94,000	35,208	97,996	238,821
1994	596,000		93,500	38,445	163,704	307,455
1995	643,000		94,000	43,706	149,741	311,616
1996	599,000	2,217	94,600	44,515	137,544	289,144
1997	616,000		94,000	45,325	128,843	274,125
1998	635,000		95,000	45,325	172,177	312,937
1999	853,000			45,730	194,818	345,918

Table 2

Reported landings and landed values of clams, quahaugs, oysters, mussels, and estuarine finfish on Prince Edward Island. Data from Annual Reports of the PEI Departments of Fisheries and Tourism and Agriculture, Fisheries and Forestry, and Cairns 1997a.

Year	Molluscs												Finfish							
	Soft-shelled clams		Quahaugs		Oysters		Total, s-s clams, oysters, and quahaugs		Mussels		Bar clams		Eels		Gaspereau		Silversides		Smelts	
	t	Landed value	t	Landed value	t	Landed value	t	Landed value	t	Landed value	t	Landed value	t	Landed value	t	Landed value	t	Landed value	t	Landed value
1981	332	209,000	303	200,000	1,218	1,426,000	1,854	1,835,000	47	51,000	218	96,000	220		259		33		324	
1982	279	203,000	528	466,000	870	1,016,000	1,677	1,685,000	69	107,000	311	144,000	168		133		63		299	
1983	262	173,000	507	615,000	1,104	1,290,000	1,873	2,078,000	162	233,000	429	189,000	151		36		108		262	
1984	279	277,000	444	588,000	1,535	2,031,000	2,259	2,896,000	259	407,000	742	327,000	165		88		131	30,694	244	131,848
1985	389	472,000	622	823,000	1,544	2,042,000	2,555	3,337,000	464	562,000	636	280,000	140	255,056	238		48	13,018	118	681,564
1986	391	474,000	29	409,000	1,681	2,409,000	2,100	3,292,000	1,218	1,330,000	404	178,000	226	558,249	464	103,146	76	18,553	704	114,813
1987	407	674,000	561	1,112,000	1,346	2,226,000	2,314	4,012,000	1,035	1,712,000	456	261,000	150	466,745	364	104,398	137	37,573	150	172,599
1988	215	380,000	479	845,000	1,461	2,899,000	2,155	4,124,000	1,441	2,333,000	420	277,000	125	351,287	234	69,011	80	22,710	219	90,968
1989	176	311,000	596	1,533,000	1,891	3,753,000	2,664	5,597,000	2,443	4,309,000	427	377,000	77	212,446	132	42,986	33	10,864	104	77,238
1990													124	390,258	83	26,620	82	27,068	85	145,075
1991													129	435,501	87	28,427	118	51,820	158	153,523
1992	256	464,000	559	803,000	1,177	2,062,000	1,992	3,329,000	4,178	4,959,000	805	554,000	54	183,809	317	92,608	46	17,539	193	212,597
1993	224	479,000	523	810,000	1,205	2,227,000	1,953	3,516,000	4,788	4,972,000	677	731,000	74	246,170	200	68,878	83	29,088	180	373,609
1994	292	705,000	468	1,108,000	1,553	3,263,000	2,313	5,076,000	5,948	6,321,000	719	552,000	46	220,056	115	36,149	543	207,621	255	355,995
1995	163	342,000	470	1,196,000	1,793	3,070,000	2,426	4,608,000	7,470	8,596,000	281	223,000	33	194,706	42	13,925	179	71,832	270	97,428
1996	159	301,000	561	1,322,000	1,676	2,945,000	2,397	4,568,000	8,819	10,693,000	333	275,000	11	73,661	53	22,724	151		98	
1997	339	747,000	584	1,685,000	1,429	3,181,000	2,351	5,613,000	9,976	12,096,000	670	644,000	46	257,000	107	43,000	238	103,000	158	251,000
1998	321	788,000	602	1,983,000	1,974	4,447,000	2,897	7,218,000	12,461	15,110,000	268	251,000	34	146,000	52	34,000	232	102,000	261	378,000

Table 3

Fresh and brackish water fish on Prince Edward Island. Data from Anon. 2000a, Cairns 1997a, S. Hill unpubl., and Cairns unpubl.

Species	Scientific Name	Spawns on PEI		Fishery	Comments
		At present	At time of European settlement		
Sea lamprey	*Petromyzon marinus*	No	No evidence	No	Juvenile lamprey have been found attached to salmon in PEI
Atlantic sturgeon	*Acipenser oxyrinchus*	No	Possible	Occasional bycatch in open water commercial fisheries	There are early reports of sturgeon in rivers and bays (Walsh 1984)
Blueback herring	*Alosa aestivalis*	Yes	Probable	Commercial	Fished commercially as "gaspereau." Confirmed for only few rivers; probably present in many rivers.
Alewife	*Alosa pseudoharengus*	Yes	Yes	Commercial	Fished commercially as "gaspereau." Widespread in rivers and estuaries.
American shad	*Alosa sapidissima*	No	Possible	Occasional bycatch in open water commercial fisheries	There are historical records of shad in rivers.
Rainbow trout	*Oncorhynchus mykiss*	Yes	No	Recreational	Introduced, present in a number of watercourses
Atlantic salmon	*Salmo salar*	Yes	Yes	Recreational	Originally widespread, stocking maintains populations in a few large rivers, remnant populations persist in a number of rivers.
Brown trout	*Salmo trutta*	Probable	No	May be bycatch in rec. fishery	Present in a few rivers, possibly strays from introduced populations in Nova Scotia
Arctic char	*Salvelinus alpinus*	Yes	No	May be bycatch in rec. fishery	Present in West River from aquaculture escapees
Brook trout	*Salvelinus fontinalis*	Yes	Yes	Recreational	Widespread in streams and estuaries
Rainbow smelt	*Osmerus mordax*	Yes	Yes	Commercial, some recreational	Widespread in streams and estuaries
Northern redbelly dace	*Phoxinus eos*	Yes	?	No	Known only from the Morell R. See Woronecki 1969. Not known if indigenous or introduced.
Golden shiner	*Notemigonus crysoleucas*	Yes	No	Some taken for bait	Present in some ponds in east Queens Co. Introduced.
American eel	*Anguilla rostrata*	No	No	Commercial, some recreational	Widespread in rivers, ponds, and estuaries. Spawns in the Sargasso Sea.
Banded killifish	*Fundulus diaphanus*	Yes	Probable	No	Widespread in lower rivers and coastal ponds
Mummichog	*Fundulus heteroclitus*	Yes	Probable	No	Widespread in brackish and salt waters
Atlantic tomcod	*Microgadus tomcod*	Yes	Yes	Bycatch in commercial smelt fishery	Widespread in estuaries
Fourspine stickleback	*Apeltes quadracus*	Yes	Probable	No	Known from only a few sites, but data very poor
Threespine stickleback	*Gesterosteus aculeatus*	Yes	Yes	Bycatch in silverside fishery	Widespread in fresh, brackish, and salt habitats
Blackspotted stickleback	*Gasterostaus wheatlandi*	Probable	Probable	No	Probably exists, data very poor
Ninespine stickleback	*Pungitius pungitius*	Yes	Probable	No	Present in at least some rivers
White perch	*Morone americana*	Yes	Probable	Recreational	Present in many rivers, coastal ponds, and estuaries
Striped bass	*Morone saxatilis*	Possible	Possible	Recreational	Taken in small numbers during spawning season, but it is not known whether these fish are local spawners.
Slimy sculpin	*Cottus cognatus*	Possible	Unknown	No	Known only from a fish kill in Big Pierre Jacques River. Not known if populations recovered after the kill. Not known if species is indigenous or introduced. See Currie and McAskill 1994.
Atlantic Silverside	*Menidia menidia*	Yes	Probable	Commercial	Present in many coastal ponds and bays
Brown bullhead	*Ictalurus nebulosus*	Possible	No	None	Appeared in Trout River, Tyne Valley, in 1999. Thought to be deliberately introduced.
No. spawning species confirmed or probable[a]		21	15		

[a]Totals include American eel and slimy sculpin

Table 4
Licences issued to recreational anglers on PEI, and expenditures by anglers that are attributable to recreational fishing.

Year	Trout[a]							Atlantic salmon[a]	Major purchases and direct expenditures attributable to recreational fishing on PEI	
	Regular season, fee required			Courtesy resident	Farmer/ fisher	Non-resident day	Winter			
	Resident	Non-resident	Total						Value	Source
1948	3,068	783	3,851							
1949	3,552	907	4,459							
1950	3,746	1,165	4,911							
1951	4,251	1,086	5,337							
1952	4,952	1,158	6,110							
1953	5,467	1,159	6,626							
1954	5,222	1,209	6,431							
1955	5,291	1,238	6,529							
1956	5,298	1,371	6,669							
1957	4,989	1,596	6,585							
1958	6,884	1,941	8,825							
1959	7,265	1,965	9,230							
1960	6,987	1,705	8,692							
1961	6,370	1,704	8,074							
1962	7,681	1,834	9,515							
1963	6,882	1,953	8,835							
1964	7,127	1,912	9,039							
1965	7,738	1,927	9,665							
1966	8,374	2,063	10,437							
1967	7,046	2,079	9,125							
1968	8,607	2,592	11,199							
1969	9,195	2,733	11,928							
1970	9,067	2,917	11,984							
1971	9,368	2,919	12,287							
1972	8,518	2,793	11,311							
1973	9,911	2,777	12,688	1,286						
1974	9,777	3,069	12,846	1,170						
1975	10,860	2,169	13,029	1,446					$1,699,396	Anon. 1978
1976	11,887	2,155	14,042	1,442						
1977	11,205	1,994	13,199	1,401						
1978	11,168	1,899	13,067	1,391						
1979	12,951	2,074	15,025	1,559						
1980	11,641	1,538	13,179	1,675					$2,389,100	Smith and Brickley 1985
1981	11,722	1,517	13,239	1,629						
1982	11,929	1,619	13,548	1,718						
1983	12,164	1,505	13,669	1,761				321		
1984	11,103	1,372	12,475	1,648				68		
1985	10,740	1,341	12,081	1,649				117	$3,725,358	Anon. 1988
1986	10,619	1,547	12,166	1,642				279		
1987	9,667	1,272	10,939	1,638				461		
1988	9,177	1,410	10,587	1,667				719		
1989	9,804	1,427	11,231	1,650				649		
1990	9,726	1,361	11,087	1,582				793	$4,030,207	Anon. 1994
1991	9,648	1,154	10,802	1,665				716		
1992	8,524	1,016	9,540	1,026			195	928		
1993	8,439	988	9,427	1,499			233	829		
1994	8,627	967	9,594	1,450			233	587	$4,622,833	Cairns 1996
1995	9,392	1,028	10,420	1,566	1,513		229	633		
1996	9,338	871	10,209	1,633	1,608	230	291	697		
1997	7,975	811	8,786	1,438	1,596	261	213	616		
1998	6,608	724	7,332	999	1,463	204		520		
1999	6,905	650	7,555	1,067	1,237	189		450		

[a]From PEI Fish and Wildlife Division files

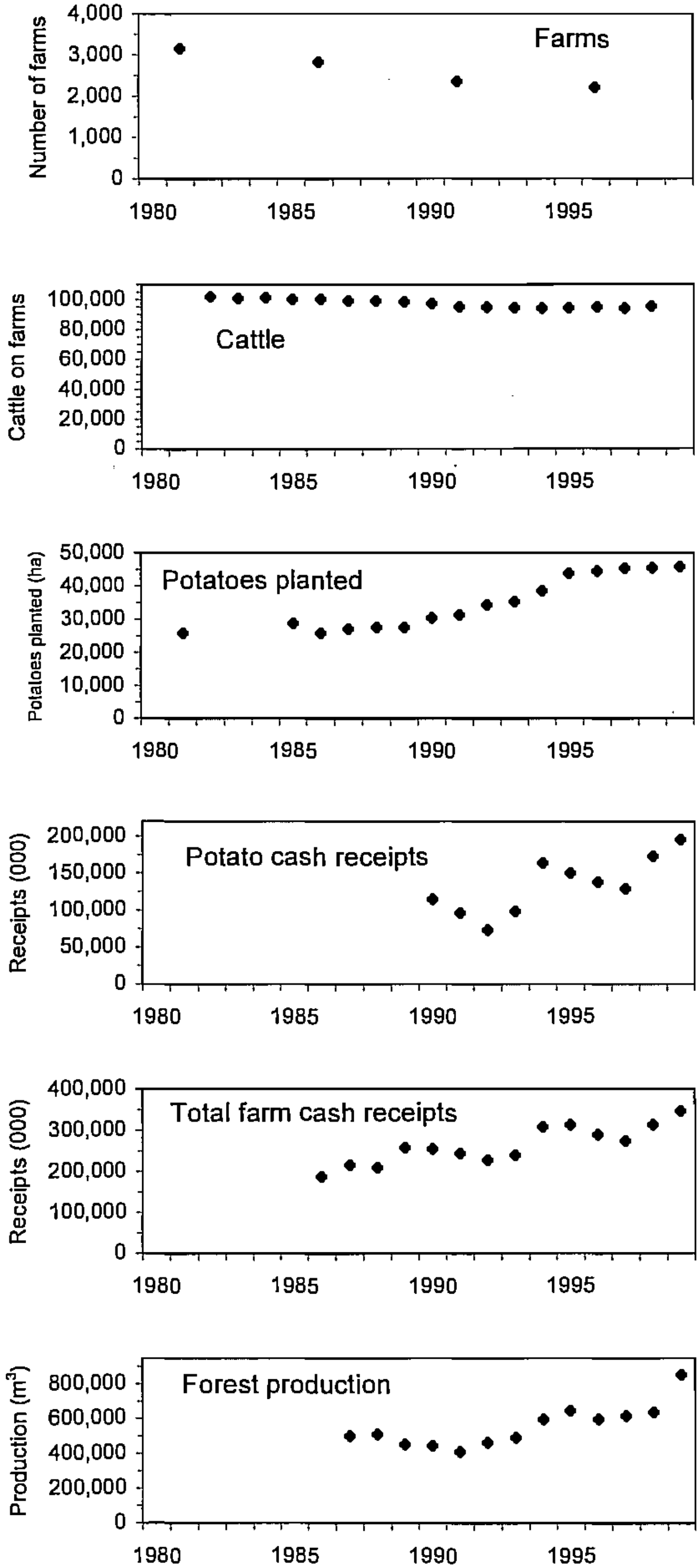

Fig. 1
Selected agricultural and forestry statistics for Prince Edward Island. See Table 1 for sources.

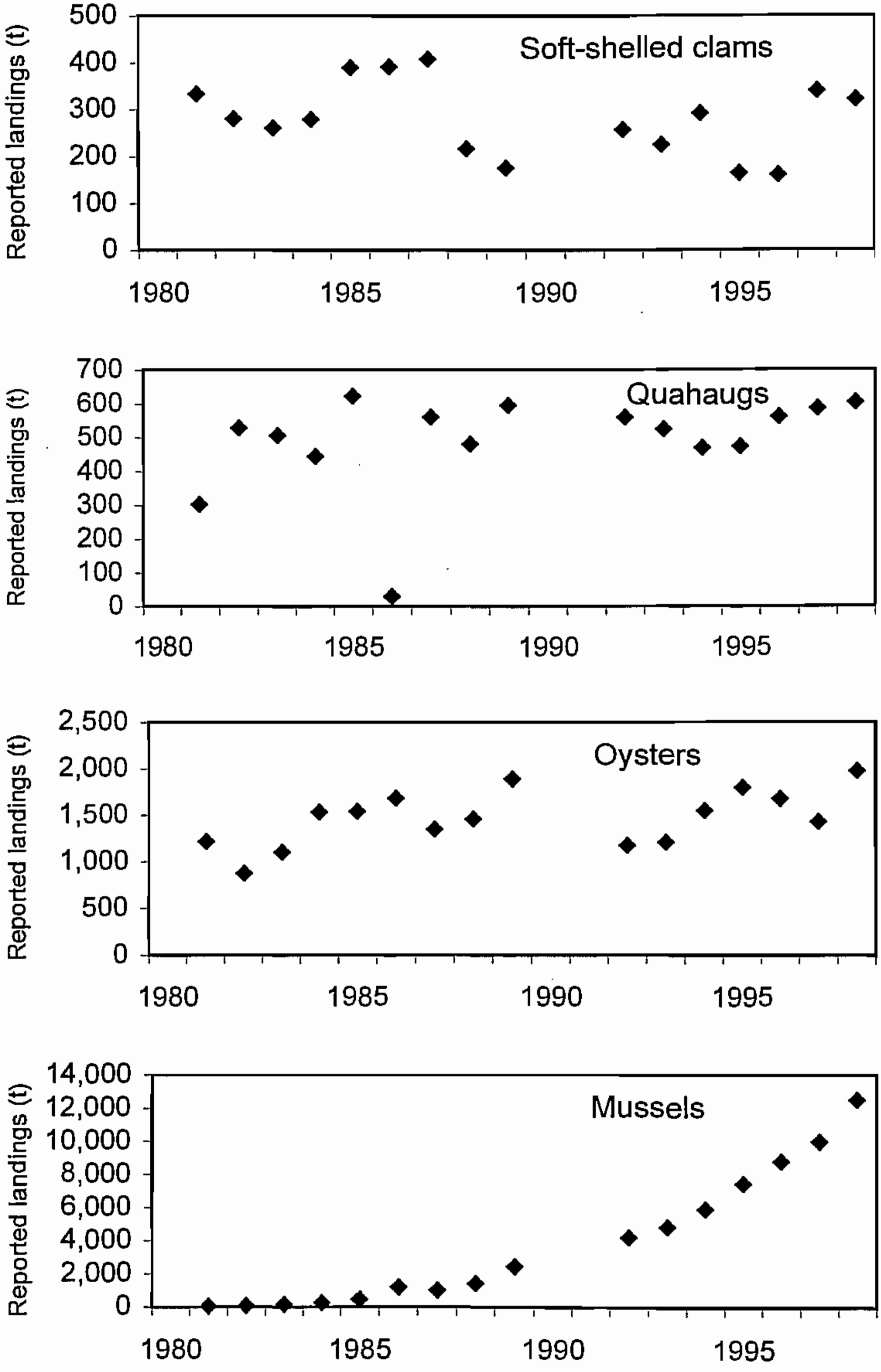

Fig. 2

Reported landings of soft-shelled clams, quahaugs, oysters, and mussels on Prince Edward Island.

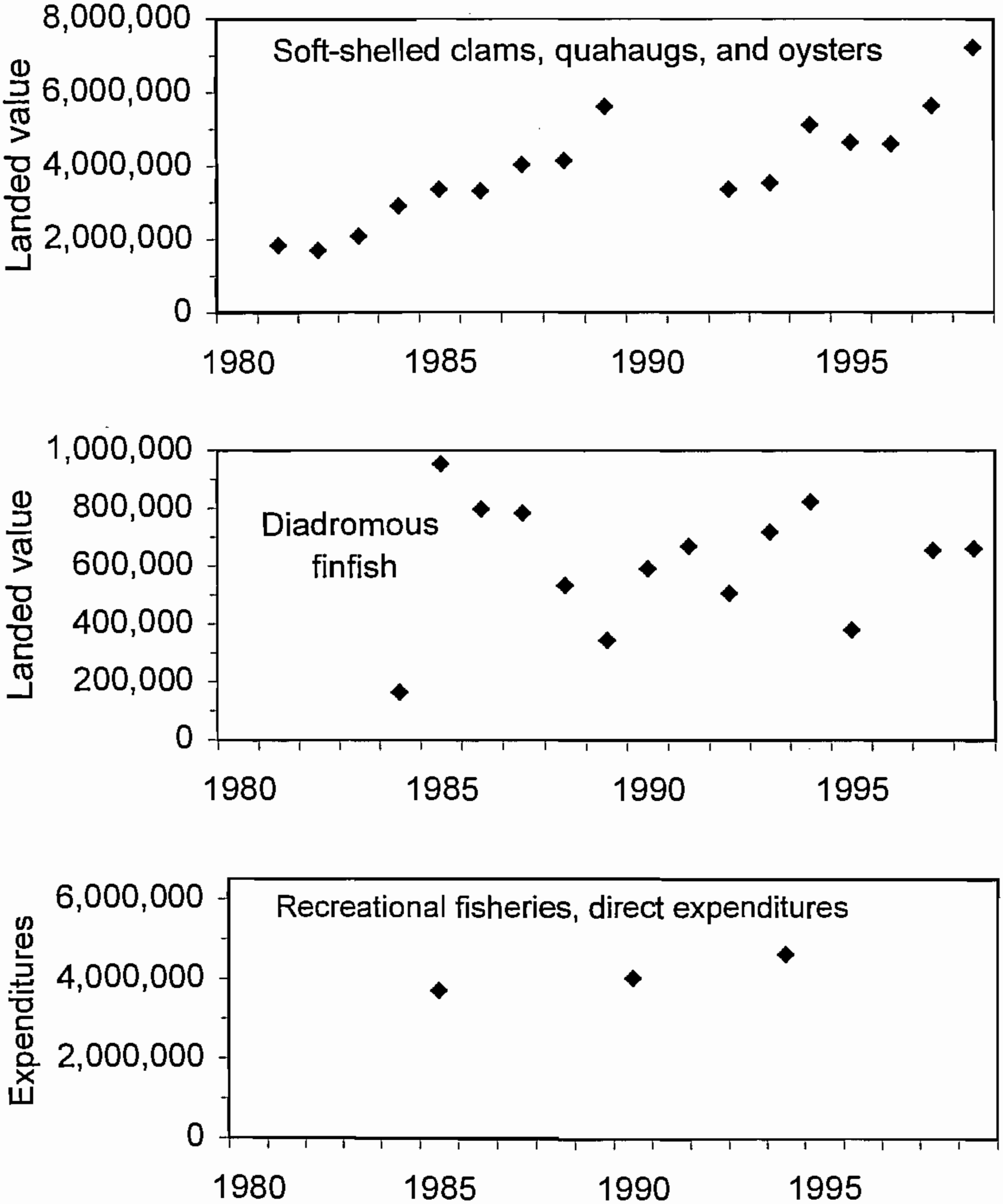

Fig. 3
Value of reported landings of soft-shelled clams, quahaugs, oysters, and diadromous finfish, and expenditures directly attributable to recreational angling on PEI.

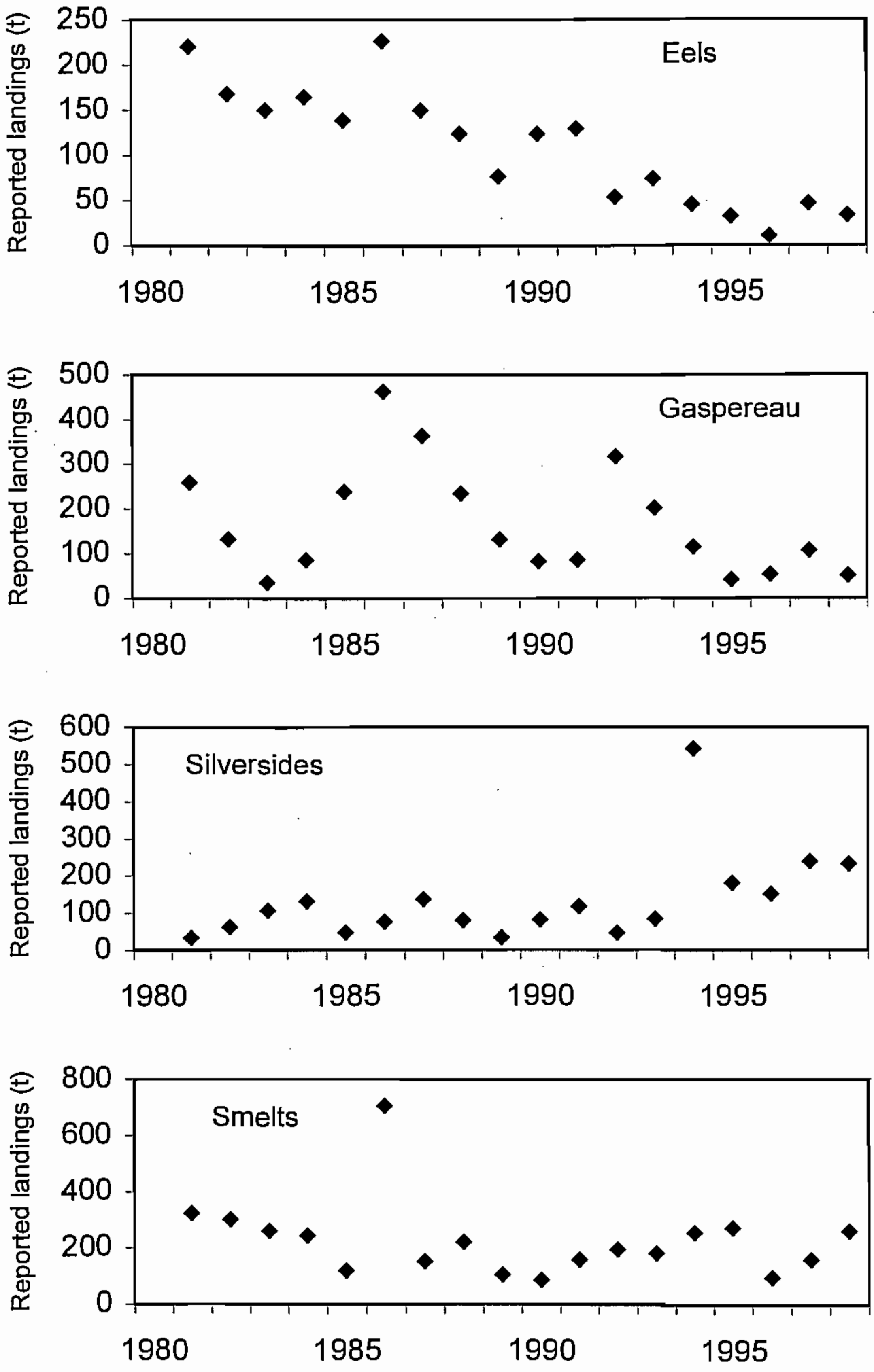

Fig. 4
Reported landings of eels, gaspereau, silversides, and smelts on PEI.

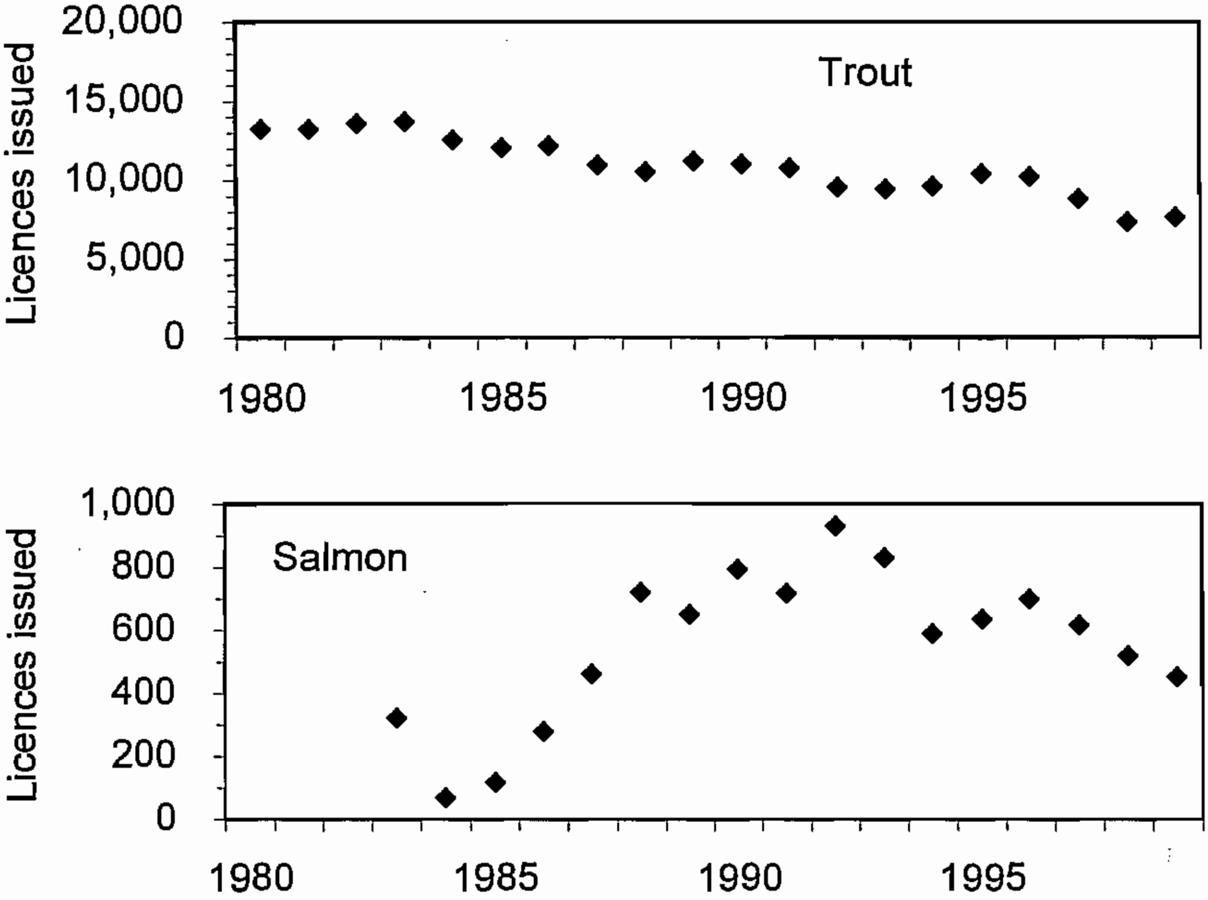

Fig. 5
Number of regular-season, fee-required, trout licences and number of salmon licences issued on PEI, 1980-1999. Data from PEI Fish and Wildlife Division.

Acts, regulations, and policies pertaining to protection of aquatic environments on Prince Edward Island

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ABSTRACT

The governments of Canada and of Prince Edward Island have Acts, Regulations, and Policies which protect aquatic organisms and their habitats. Environment Canada administers Section 36 of the federal Fisheries Act, which prohibits the release of deleterious substances into water frequented by fish. The Department of Fisheries and Oceans administers other sections of the Act, including Sections 20 and 22 which require provision for fish passage and adequate water flow for fish, and Section 35 which prohibits the harmful alteration, disruption, or destruction of fish habitat. The Prince Edward Island Environmental Protection Act prohibits alteration of watercourses without a permit, and protects riparian habitat through stream-side buffer zones. Other provincial legislation which protects aquatic environments includes the Natural Areas Protection Act, under which parcels of land are designated for protection against development, the Planning Act, which has been used to declare a 60 m wide conservation zone along the Morell River, and the Pesticides Control Act, which regulates pesticide sale, transport, use, and disposal.

INTRODUCTION

Governments possess a number of tools to assist, promote and compel industry and citizens to conduct themselves in a manner which protects environmental resources. These tools include educational materials, funding, technical assistance, research, and finally, legislation and regulations. Under the Constitution Act, the government of Canada has exclusive legislative authority to manage and regulate Canada's sea coast and inland fisheries. The Fisheries Act, first passed by Parliament in 1868, is the federal statute promulgated pursuant to this constitutional authority. Under a Memorandum of Understanding, environmental protection sections of the Fisheries Act are co-managed by Environment Canada (EC) and the Department of Fisheries and Oceans (DFO). EC deals with introduction of pollutants into waters frequented by fish (Section 36), while DFO has responsibility for administration and enforcement of the provisions dealing with physical alteration of fish habitat (Section 35). These two sections provide Canada's strongest tool for discharging the federal constitutional responsibility for protection of fishery resources.

Because of their jurisdiction over natural resources, provincial governments also have major responsibilities in conservation of aquatic environments. The government of Prince Edward Island has enacted several statutes which protect watercourses, wetlands, and associated habitats. The lead agency in this field is the Prince Edward Island Department of Fisheries, Aquaculture and Environment (FAE).

This paper describes the regulatory mandates of EC, DFO, and the government of Prince Edward Island with respect to protection of aquatic environments on PEI.

ENVIRONMENT CANADA

Pollution prevention

Section 36(3) of the Fisheries Act of Canada states:

> Subject to subsection (4), no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water.

Pp. 14-19 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

The Fisheries Act provides definitions will help clarify this provision:

Person - a human being, a body corporate (company) or a government department.

Fish - includes (a) parts of fish, (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals (Section 2).

Water frequented by fish - Canadian fisheries waters (Section 34(1)).

Canadian fisheries waters - all waters in the fishing zones of Canada, all waters in the territorial sea of Canada and all internal waters of Canada (Section 2).

Deleterious substance - any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water . . . (Section 34(1)).

Deposit - any discharging, spraying, releasing, spilling, leaking, seeping, pouring, emitting, emptying, throwing, dumping or placing (Section 34(1)).

In the landmark case R. vs MacMillan Bloedel Alberni Ltd., the Supreme Court of Canada ruled that "What is being defined is the substance that is added to the water, rather than the water after the addition of the substance.... Once it is determined that (the substance) is a deleterious substance and that it has been deposited, the offence is complete without ascertaining whether the water itself was thereby rendered deleterious."

Water frequented by fish means water which, at some time, has fish in it. Again in R. vs MacMillan Bloedel, the Supreme Court ruled that "This section (of the Fisheries Act) does not speak of "water in which there are fish" but of "water frequented by fish". To restrict the word "water" to the few cubic feet into which the (substance) was poured would be to disregard the fact that both fish and water move."

In administering the Fisheries Act, Environment Canada's enforcement officers, designated by the Minister to be "Inspectors," have certain authorities which allow them to enter, at any reasonable time, any place where they have reasonable grounds to believe that any work or undertaking resulting or likely to result in the deposit of a deleterious substance into water frequented by fish, is occurring.

While an inspector is conducting an inspection, the owner or person in charge of any place, and any person found there is obliged by the Fisheries Act to give the Inspector all reasonable assistance, and must furnish the Inspector with information the Inspector requires (Section 39(10)).

It is an offence under the Fisheries Act to obstruct or hinder a Fisheries Officer, or to make a false or misleading statement to an Inspector who is carrying out duties under the Act.

Recent court cases involving accidental releases of deleterious substances into water frequented by fish have resulted in fines in the order of $25,000 to $50,000. Courts are significantly harder on offenders who deliberately deposit or knowingly neglect to prevent deposits. See Sections 78, 78.1, 78.2, and 78.3 of the Fisheries Act.

Employees of corporations that violate the Fisheries Act are also subject to prosecution as individuals:

> Where a corporation commits an offence under this Act, any officer, director or agent of the corporation who directed, authorized, assented to, acquiesced in or participated in the commission of the offence is a party to and guilty of the offence and is liable on conviction to the punishment provided for the offence, whether or not the corporation has been prosecuted (Section 78.2).

Due diligence

What can a person do to avoid being prosecuted under Section 36(3) of the Fisheries Act? The short answer is to exercise "due diligence." Section 78.6 of the Fisheries Act protects a person from being convicted under the Act if the person establishes that he or she exercised all due diligence to prevent the commission of the offence. Paraphrasing from Black's Law Dictionary, due diligence is a measure of prudence or care which you would ordinarily expect from a reasonable person under the circumstances. In other words, if it is reasonable to anticipate an event, and you have the power or authority to prevent the event, you must act, or you will not have exercised all due diligence. If you prevent the offence you can't be prosecuted, but if despite all your efforts, the offence still occurred, you may be able to defend against a prosecution. If you have been warned by an Inspector that you are in danger of violating the law, or that you are violating the law, and you do not do everything in your power to stop or prevent the offence, you will be unlikely to be able to successfully argue a due diligence defence.

What sort of evidence is accepted by the courts as valid due diligence? In the case of R. v. Bata Industries Ltd. (1992, Unreported), Judge Ormston of the Ontario Provincial Court sets out a useful checklist:

> I ask myself the following questions in assessing the defence of due diligence:
>
> (a) Did the Board of Directors establish a pollution prevention "system?" Was there supervision or inspection? Was there improvement in business

methods? Did he exhort those he controlled or influenced?

(b) Did each Director ensure that the Corporate officers have been instructed to set up with a system sufficient within the terms and practices of its industry of ensuring compliance with environmental laws, to ensure that the officers report back periodically to the Board of the operations of the system, and to ensure that the officers are instructed to report any substantial non-compliance to the Board in a timely manner?

(c) The Directors are responsible for reviewing the environmental compliance reports provided by the officers of the corporation but are justified in placing reasonable reliance on reports provided to them by corporate officers, consultants, counsel or other informed parties.

(d) The Directors should substantiate that the officers are promptly addressing environmental concerns brought to their attention by government agencies or other concerned parties including shareholders.

(e) The Directors should be aware of the standards of their industry and other industries which deal with similar environmental pollutants or risks.

(f) The Directors should immediately and personally react when they receive notice that the system has failed.

Application to land use and livestock management

Substances of concern under Section 36(3) of the Fisheries Act include, but are not limited to, pesticides, other toxins, petroleum products, silt, livestock faeces, land runoff contaminated with livestock faeces, and chemical treatments used on livestock.

Livestock wastes present three hazards to fish:

First, animal faeces contain and develop high levels of ammonia and nitrites. These materials have a direct and immediate deleterious effect on fish. In recent tests of cattle faeces in Environment Canada laboratories, rainbow trout exposed to faeces all died within one hour.

Second, decomposing animal waste consumes large quantities of oxygen. This is referred to as Biochemical Oxygen Demand or BOD. Other substances having a high BOD include milk, blood and many industrial effluents like vegetable processing waste.

Finally, livestock waste contains high concentrations of faecal coliform bacteria. Most faecal bacteria do not pose a direct hazard to fish or the environment. Nevertheless, if we return to the definition of "deleterious substance" above, we are reminded that it also includes any substance which if added to water is likely to render fish that frequent that water deleterious to use by humans. International conventions oblige Canada to test waters from which shellfish are harvested to ensure that they are relatively free of faecal coliform bacteria. The deposit of livestock waste into fishery waters is often the only identifiable cause of closures of shellfish harvesting areas. This problem is increasing; in the Atlantic Region in 1998, 29% of all areas tested were deemed to be unsafe for shellfish harvesting and therefore closed to the shellfishery.

The final issue covered by Section 36(3) is the deposit of chemicals into water frequented by fish. The chemicals may be fuels, paints, wood preservatives, pesticides, fertilizers, and any other substance which meets the criteria for deleteriousness. Any deleterious substance which finds its way into water frequented by fish occasions an offence, even if the amount of substance deposited is very small. Examples of deposits which constitute offences include:

The overturning of a pesticide sprayer due to improperly maintained ditches, with resulting pesticide deposition in the stream.

The leaking of diesel fuel into a stream caused by inadequate maintenance, inadequate dikes, or careless operation of storage tanks.

Cleaning of contaminated equipment in streams.

Runoff of silt and pesticides into streams due to poor farm management practices.

DEPARTMENT OF FISHERIES AND OCEANS

The Department of Fisheries and Oceans administers the habitat protection provisions of the Fisheries Act.

Fish passage and water flow

Fish passage and water flow for living and spawning are protected by the following sections of the Act:

> Every obstruction across or in any stream where the Minister determines it to be necessary for the public interest that a fish-pass should exist shall be provided by the owner or occupier with a durable and efficient fish-way or canal around the obstruction, which shall be maintained in good and effective condition by the owner or occupier . . . (Section 20(1)).
>
> The owner or occupier of any obstruction shall make such provisions as the Minister determines to be necessary for the free passage of both ascending and descending migratory fish during the period of construction thereof (Section 22(2)).
>
> The owner or occupier of any obstruction shall permit the escape into the river-bed below the

obstruction such quantity of water, at all times, as will, in the opinion of the Minister, be sufficient for the safety of fish and for the flooding of the spawning grounds to such depth as will, in the opinion of the Minister, be necessary for the safety of the ova deposited thereon (Section 22(3)).

Every water intake, ditch, channel or canal in Canada constructed or adapted for conducting water from any Canadian fisheries waters for irrigating, manufacturing, power generation, domestic or other purposes shall, if the Minister deems it necessary in the public interest, be provided at its entrance or intake with a fish guard or a screen, covering or netting so fixed as to prevent the passage of fish from any Canadian fisheries waters into the water intake, ditch, channel or canal (Section 30(1)).

Habitat destruction

Fish habitat is defined as "Spawning grounds, and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes" (Section 34(1)).

Habitat is protected by Section 35:

No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat (Section 35(1)).

No person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or regulations made by the Governor in Council under this Act.

A key concept in the enforcement of habitat protection is Habitat Alteration, Disruption or Destruction (HADD). HADD means any change in fish habitat that reduces its capacity to support one or more life processes of fish. The three elements of HADD are defined as follows:

Harmful alteration - Any change to fish habitat that indefinitely reduces its capacity to support one or more life processes of fish but does not completely eliminate the habitat.

Disruption - Any change to fish habitat occurring for a limited period which reduces its capacity to support one or more life processes of fish.

Destruction - any permanent change of fish habitat which completely eliminates its capacity to support one or more life processes of fish.

Fish habitat policy

In 1986 the Department of Fisheries and Oceans adopted a "Policy for the management of Fish Habitats." The policy is national in scope and applies to habitats that directly or indirectly support fish stocks that sustain commercial, recreational, or native fishing activities. The Policy covers fresh water, estuarine, and marine habitats.

The Policy's overall objective is to "increase the natural productive capacity of habitat for the nation's fisheries resources, to benefit present and future generations." This means that DFO works toward a net gain in habitat production capacity.

The Policy has three goals, which are intended to lead to the overall objective of a net gain.

The first goal is "to maintain the current productive capacity of the fish habitat supporting Canada's fisheries resources, such that fish suitable for human consumption may be produced." The guiding principle here is "no net loss," which means that habitat losses are to be balanced by habitat gains on a project-by project basis.

The second goal is to "Rehabilitate the productive capacity of fish habitat in selected areas where economic or social benefits can be achieved through the fisheries resources."

The third goal is to "improve and create fish habitat in selected areas where the production of fisheries resources can be increased for the social or economic benefit of Canadians."

GOVERNMENT OF PRINCE EDWARD ISLAND

The government of Prince Edward Island protects aquatic environments chiefly through four Acts.

Environmental Protection Act

Several sections of the Environmental Protection Act specifically protect watercourses, while other sections protect them indirectly.

The Act defines watercourse as "the full length and width, including the sediment bed, bank and shore, of any stream, spring, creek, brook, river, lake, pond, bay, estuary or coastal water body or any part thereof, whether the same contains water or not" (Section 1(s)).

The key sections in the Environmental Protection Act that protect watercourses are as follows:

No person shall, without a permit from the Minister, alter a watercourse, or wetland, or any part thereof, or water flow therein of the land within 10 metres of the watercourse boundary or wetland boundary, in any manner . . . (Section 10).

Alteration under Section 10 includes such activities as dam construction, irrigation, excavating, culvert installation, infilling and operating machinery on the streambed.

FAE in cooperation with DFO has prepared a booklet of guidelines to help proponents comply with the Act as they work in and close to watercourses. Pamphlets on erosion control and irrigation are also available. There is also a Department Policy concerning water extraction for irrigation.

Watercourse and wetland buffer zone protection has been added under section 11 of the Act. Landlocked ponds, perimeter coastline, and drainage ditches are excluded from buffer zone provisions.

The buffer zone provisions deal with three areas of land use:

1) Agricultural crops. A buffer zone 10 m wide is required for agricultural crops. Planting of crops is prohibited in this zone, with some exceptions for forage crops. Where row crops are planted in a field with rows running up and down the slope, row crops cannot be planted in a headland adjacent to the buffer zone. In cases where agricultural land within 50 m of a buffer zone has a slope of 5% or more, fall tillage of vegetated cover crops is prohibited, and winter cover crops or hay or straw mulching is required on barren soil. Alternatively, a 20 m buffer zone can be maintained.

2) Intensive livestock operations. Intensive livestock operations occur where animals are kept in a confined area at high density and where feed and water are delivered to the animals. New intensive livestock operations cannot be constructed within 90 m of a watercourse. For existing operations, buffer zones of 20 to 30 m are required, depending on slope. Farmers are required to control runoff of livestock wastes to watercourses and wetlands.

3) Forested riparian zones. These zones are 20-30 m wide, depending on the slope. Forested riparian zones cannot be converted to any use other than forest production. Wood harvest within the zones must be by selective cutting, and heavy equipment cannot be operated within 10 m of the stream.

Section 9(1) requires that a person initiating any undertaking that may cause a release of a contaminant into the environment, threaten any rare or endangered feature of the environment, have a significant effect on the environment or be a cause for public concern must obtain approval from the Minister. Depending on the nature of the undertaking, an environmental impact assessment may be required.

Section 7.1 gives the Minister the power to issue orders to persons and corporations when he or she believes that there is a potential for an environmental damage. For example the Minister may order a farmer to carry out specific activities to prevent the release of a contaminant into a watercourse from a manure storage system.

Section 24 makes it illegal for anyone to litter into or upon any water.

Sections 20 and 21 make it illegal to discharge a contaminant into the environment. Failure to report a discharge of a contaminant is also an offence. Contaminants are broadly defined in the Act and include any substance that may adversely affect the environment or human health.

Penalties for violation of the Environmental Protection Act range from $200 to $10,000 for an individual and $1,000 to $50,000 for a corporation. The sentence can also include restitution and up to 90 days imprisonment. There is a two-year limitation on action.

FAE has developed an enforcement policy to assist officers in making decisions. It emphasizes fairness, consistency and the ability to be firm.

<u>Natural Areas Protection Act</u>
This Act gives the Minister of Fisheries, Aquaculture and Environment the power to designate parcels of land as Natural Areas. Such areas may be provincial crown land, land which the Province purchases or leases, or privately owned land. In the latter case, the land is protected by a restrictive covenant. Restrictions imposed on Natural Areas vary. Limited harvest activities such as berry-picking, hunting, and maple syrup harvest may be permitted, but activities that would change the essential character of the ecosystem (e.g. clear-cutting) are not.

The maximum fine for violation of the Natural Areas Protection Act is a fine of $1000 plus restitution. Every day is a separate offence and there is a two-year limitation of action.

<u>Planning Act</u>
The Planning Act gives the Lieutenant Governor in Council the authority to issue regulations that designate parcels of land as conservation zones or environmentally sensitive areas.

Conservation Zone Regulations have been issued to protect a 60 m buffer strip along the Morell River from development and tree cutting. The Morell is the only watercourse on PEI that currently has such protection.

<u>Pesticides Control Act</u>
This Act, administered by the Department of Agriculture and Forestry, contains a broad range of provisions covering the sale, transport, storage, use, and disposal of pesticides. Release of pesticides into water bodies is specifically prohibited:

> No person shall apply, deposit, add, emit, discharge, or cause or permit the application, deposit, addition, emission, or discharge of a pesticide or any substance or thing containing a pesticide into, upon, or over an open body of water unless he holds a license or permit in accordance with the regulations authorizing him to so act

(Section 7).

Under regulations made pursuant to the Act, it is an offence to fill, discharge or flush out pesticide sprayers within 25 meters of the edge of any open body of water. It is also an offence to bring pesticide containers within 25 meters of the water's edge unless they are in a separate enclosed spill-proof container securely affixed to the vehicle.

The maximum fine is $1000 and up to three months in jail.

SOURCES

The Fisheries Act is available for download at http://canada.justice.gc.ca/FTP/EN/Laws/Chap/F/F-14.txt.

Acts of the Province of Prince Edward Island are available for download at http://www.gov.pe.ca/law/statutes/index.php3.

Soil conservation in Prince Edward Island potato land

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EXTENDED ABSTRACT

Erosion is a natural phenomenon. When forested lands are cleared for agriculture, erosion rates may increase greatly from natural background levels. Excessive soil erosion from farmland is considered a problem because it may harm receiving watercourses, and because soil loss, especially loss of topsoil, impairs agricultural production.

Prince Edward Island commonly experiences intense rainfall events during the cropping season and repeated freeze-thaw cycles during winter, both of which increase risk of water erosion. PEI also has moderately windy conditions, which create risk of wind erosion especially on fields that are left bare over the winter or which have little shelter from hedges or woodlands.

Potatoes are PEI's main agricultural commodity. Potatoes are commonly grown on fine sandy loams, which have a high erosion potential. These soils are naturally low in organic matter and can be easily compacted by heavy equipment if worked under wet conditions. If not properly managed, these soils can experience reduced water infiltration rates which lead to increased water run-off and accelerated soil erosion.

Annual potato plantings on PEI were in the range of 45,000 ha in the late 1990s. Based on satellite imagery, the total land base in potato rotation, over a three year period from 1996 to 1998, was between 103,000 and 115,000 ha. Of this total, between 55% and 62% of the land base had a potato crop once in the three years, between 36% and 43.5% of the land base had two potato crops in the three years, and between 1.5% and 2% of the land base produced a potato crop three years in a row.

Potato producers have a number of measures at their disposal to reduce erosional soil loss. Adequate crop rotation is the cornerstone of any good soil conservation plan. By rotating the potato crop with well managed cereals and/or forages, producers can maintain higher soil organic matter levels which result in improved aggregate stability and soil structure. This leads to soils with a greater ability to resist both water and wind erosion.

Traditionally, producers prepare their land for potato planting by moldboard plowing in the fall, followed by discing and harrowing in the spring. Some producers have reduced erosion levels within this tillage system by leaving hollows with permanent grass, and grassed headlands at the lower ends of fields. Some producers have switched to spring plowing. Because the soil retains vegetative cover, erosion during the winter prior to planting is reduced to very low levels.

Approximately 10% of the PEI potato crop is grown under a system known as residue management. The objective of residue management is to leave the maximum amount of plant residue from the previous crop on the soil surface after each stage of cultivation. In the traditional fall plow/spring disc and harrow system, residue levels are typically less than 3% after potatoes have been planted. Producers who follow recommended residue management practices obtain up to 30% cover. In rainfall simulation tests conducted after planting but prior to row cultivation, soil losses averaged nine times less on residue managed land than on conventionally tilled land. Increased crop residues improve moisture holding capacity, which can translate into better yields. In a five-year comparative study, residue managed strips produced 7% higher yields than those which were subject to conventional tillage.

Cover crops are an effective means of reducing erosion in the winter following potato harvest, provided that the cover crop is established by the end of September. At the present time cover crops are used on about 1,600 ha of PEI potato land.

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The majority (70%) of the PEI potato harvest occurs after the end of September. Hay or straw mulching provides similar erosion control to cover crops following late harvest of potatoes. Mulching involves the spreading of round bales of hay or straw with a commercially available bale buster. Rainfall simulation tests showed runoff rates that were 13 times lower and erosion rates that were 40 times lower on mulched land as compared to land left bare after potato harvest. In the late 1990s, PEI potato producers were mulching about 3,200 ha annually.

Strip cropping involves cultivation in strips across the slope, with alternate strips of potatoes and other crops. Producers who grow potatoes in a three year rotation with grain and forage have reduced their erosion potential by 75% with strip cropping as compared with farming up and down the slope with the same rotation. In 1998 potato produces were strip cropping about 3,500 ha of land on PEI.

When slopes are excessively long or steep, terraces can be used to control erosion. These are commonly combined with strip cropping. In 1998, PEI potato producers were farming about 3,400 ha of land upon which terraces had been constructed over the previous 10 years.

Grassed waterways are natural or excavated channels that reduce erosion by transporting water at non-erosive velocities. In 1998, 10.4 km of grassed waterways were constructed by PEI potato producers. Hedgerows protect fields from wind erosion. In 1998, about 27 km of hedgerows were planted by PEI farmers.

Soil conservation techniques such as those described above have become much more widely used on PEI in recent years. However, not all potato land is cultivated with such techniques, and soil loss remains a serious agricultural and environmental problem on PEI. Many potato producers have actively promoted sound soil conservation practices through personal contacts with other producers. They have also been active in promoting and implementing Environmental Farm Plans and Best Management Practices, which recognize erosion as a risk, and specify means to reduce that risk. The potato industry realizes that its own long-term production potential, and continued access to many agricultural markets, will depend on being good stewards of the soil resource.

Physical watercourse enhancement on Prince Edward Island: history, methods, and effects on stream habitat

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ABSTRACT

Streams on Prince Edward Island have been the subject of enhancement for over 25 years. Enhancement efforts have been driven by concerns about salmonid populations, particularly of brook trout (*Salvelinus fontinalis*), Prince Edward Island's primary sportfish. A perceived decline in brook trout numbers is blamed on the degradation of stream habitat, brought about by changes in land use following European settlement - primarily land clearing, road and dam construction, and a shift towards large-scale potato cultivation. Enhancement work has expanded from small beginnings and in 1999 involved 37 community groups assisted by federal and provincial funding agencies. Physical enhancement techniques have evolved from the "steam clearing" of the past to include the installation of instream structures and sediment retention and removal. Provision of fish passage is also a major component of many stream habitat improvement projects. Quantitative assessment of the effectiveness of stream enhancement techniques is limited. Stream enhancement is not carried out in isolation, and is now considered to be a component of watershed management. Although the level of awareness regarding land use issues has increased dramatically, stream habitat quality continues to suffer as a result of poor land use practices. Sediment is the major pollutant in PEI streams and the sources of this contaminant must be controlled before stream enhancement can fully succeed.

INTRODUCTION

The state of our environment is a reflection of past and current human activities. On Prince Edward Island, the network of small streams, long winding estuaries, and coastal bays is showing the effects of decades of high-impact land use practices. Early settlers carved out roads, built bridges and causeways, constructed dams, and transformed the land from forest to field; in doing so, they began the process of stream habitat degradation.

Today, soil erosion is recognized as PEI's number one environmental problem (Anon. 1987). The podzol soils underlain with permo-carboniferous red sandstone (MacDougall et al. 1988) are easily eroded by wind and water. Sediment enters watercourses in massive quantities from a number of sources, including agricultural, forestry, and highway activities, as well as commercial/industrial development. Annual soil erosion rates of 25 tonnes/ha are common on agricultural land in row crop production, although rates as high as 750 tonnes/ha/yr have been recorded (Anon. 1997). Sediments entering surface waters can drastically alter the habitats required for vertebrate and invertebrate life processes. Nutrient-laden water entering watercourses from agricultural areas can lead to over-enrichment of shallow ponds and estuaries, and the resulting degraded water quality may be toxic to fish (Raymond et al. 2002). Pesticide-laden water entering streams has been blamed for numerous fish kills in recent years, with eight such kills recorded in 1999 (Mutch et al. 2002). Many streams also have obstacles to fish migration due to dams or improperly installed culverts. These barriers can prevent the upstream movement of fish species within the river system.

A concern for the state of stream habitat, in particular for PEI's primary sport fish, brook trout (*Salvelinus fontinalis*), has prompted many community groups to undertake stream enhancement projects. This paper examines the history of stream enhancement on PEI, the evolution in techniques used, and the relative success of stream enhancement projects to date.

HISTORY OF STREAM ENHANCEMENT ON PEI

The first concerted efforts towards steam enhancement on Prince Edward Island began in the 1970s. The

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provincial government employed crews to undertake "stream clearing" on a number of streams throughout the province, but government quickly recognized that it did not have the resources to meet the demands. Hence community groups came into the picture to provide local leadership and coordination. By 1999, stream enhancement had expanded to the point where 37 community groups carried out stream enhancement projects on 51 streams. In the 1980s, financial assistance was provided to community groups by the provincial Department of Environmental Resources through the Island Conservation Assistance Program. In 1992, the Canada-Prince Edward Island Sustainable Development Agreement provided funding and technical assistance through the Watershed Improvement/ Recreational Fisheries Development Program. The termination of this initiative was followed by the creation of the provincially-sponsored Wildlife Habitat Improvement Program. In 1998, the newly created Prince Edward Island Wildlife Conservation Fund began allocating monies collected from a levy on hunting, trapping, and angling licences to wildlife enhancement activities, including stream enhancement projects. Labour continues to be supported by federal and provincial employment programs, but monies are now available to top up wages, purchase materials and equipment, and pay expenses such as mileage.

GETTING TO THE ROOT OF THE PROBLEM

Watercourse enhancement on Prince Edward Island has traditionally involved work on the uplands to address the sources of the problems, as well as instream work. Community groups have worked closely with provincial departments to address land use problems affecting streams. Over the years, various federal and provincial incentive programs have been available for landowners to adopt sustainable farming practices and manage woodlots. Healthy riparian zones are crucial to the protection and enhancement of watercourses and the benefits of forested buffers to stream habitat are well documented (Welsch 1991). Riparian zones become degraded when landowners remove native vegetation in favour of agricultural crops, or allow livestock free access to the stream for watering (Duffy 2002). Community groups have assisted landowners by planting native vegetation in riparian zones and hedgerows and fencing livestock from streams. Various species of trees have been planted in riparian zones to increase diversity and to replace short-lived species with longer-lived shade trees. Road construction and maintenance have been a major source of sediment to streams, and continued pressure from community groups has frequently led to improvements in highway practices.

There appears to be an increasing level of awareness in Provincial departments about how their activities affect the environment. In 1999, the Departments of Agriculture and Forestry and Technology and Environment jointly established the Agriculture and Environment Resource Conservation Program. Financial incentives are available to help farmers adopt sustainable farming practices. The Department of Transportation and Public Works has created an environmental management division which has increased the awareness of the need for proper sediment control during road construction and maintenance.

INSTREAM ENHANCEMENT METHODS

The main techniques used in stream enhancement on PEI are summarized below. Morell River Management Co-op (1994) provides detailed methodologies for most techniques.

Selective debris removal

Communities beginning the process of stream restoration are often faced with silt-laden streams that are congested with alders and deadfall. Forest and land clearing activities in the past have resulted in a riparian zone devoid of long-lived shade trees. Alders grow large and eventually fall into the stream, ultimately widening the stream as the channel erodes the bank. The removal of excess vegetation, both living and dead, in a heavily congested stream is a first step. In the past, stream enhancement meant "stream clearing" and some over-enthusiastic efforts resulted in too much vegetation being removed. More care is now taken when working in streams with forested riparian zones (Morell River Management Co-op 1994). Fish habitat in streams with numerous beaver dams can become seriously degraded. In such streams, spawning and holding areas become infilled with sediment, and water quality can become unsuitable for salmonids as water temperature increases and dissolved oxygen decreases. Removing beaver dams, particularly inactive dams, restores water flow, gradually restores stream habitat, and removes blockages to migration.

Sediment retention and removal

Removing alders and debris accelerates stream flow and leads to the scouring of the channel. As a result, large quantities of sediment previously held in place move downstream. This can damage habitat, including ponds and estuaries, so various techniques have been employed to manage the mobilized sediment. Prior to restoration work, particularly in watersheds with intensive agricultural activity, it has been beneficial to excavate a sediment trap, either in the stream (Hansen 1973, Morell River Management Co-op 1994, Waters 1995) or next to the channel in a by-pass sediment pond. Large excavators have been used to dig these basins, which are periodically cleaned as they become infilled.

A useful technique for consolidating sediment and restoring stream meander is the installation of brush mats (Grand River Conservation Authority N.D., Hunt 1993, Morell River Management Co-op 1994). Bundles of brush or trees are anchored to the stream bottom, usually on the inside of turns of a river bank bend where sediment is naturally deposited. In heavily silted streams, brush mats can fill up within a few months. Often, crews must expand the brush mat the following year to enable the mats to keep functioning. The change in the stream after brush mat installation can be dramatic. As the mat captures sediment, it narrows the channel, thus increasing water depth on the turns. Young-of-the-year brook trout are also attracted to the slow water under the brush mat and can be seen using these areas for cover (pers. obs.).

Construction of instream structures

After the initial work has been done, or in streams not heavily congested with alders or deadfall, other techniques are employed to restore stream meander, provide holding areas, or to increase cover for fish. Considerable planning is required before installing wooden or rock structures, such as digger logs, deflectors, or cover logs in streams. Measurements of average stream width are taken to determine the natural stream meander (5-7 times the stream width). Digger logs are installed to scour pools and restore riffle/pool/run sequences (Hunt 1993, Morell River Management Co-op 1994). Deflectors are used in bigger streams to scour pools to provide holding areas (Giles and Summers 1996, Hunt 1993, Morell River Management Co-op 1994). Cover logs, either whole or half logs, are installed parallel to the current and increase cover available for fish.

Provision of fish passage

Fish passage may be impeded by impassable dams or hanging culverts. These blockages are particularly harmful when they are located at the head of tide and prevent upstream movement of fish to the entire river system. Blockages in middle and upper reaches can also be detrimental to brook trout by preventing access to preferred spawning areas in small, headwater streams with groundwater discharge. Community groups have worked with private landowners and government agencies, particularly the Department of Transportation and Public Works, to address fish passage obstructions. Culverts can block migration if there is a vertical drop of water at the downstream end ("hanging culvert"). Culverts can also present a water velocity barrier inside the structure. The best way to remedy improperly installed culverts is to remove the obstruction and replace it with a structure at stream level. When removal is not an option, the most successful technique is to create a series of rock dams which raise the water level and allow fish into the culvert (Newbury and Gaboury 1993). The number of rock dams needed depends on the vertical drop and the slope of the stream. The problem with an impassable artificial dam is harder to address. Some community groups have been able to garner permission to remove old dam structures.

Small, head water streams are preferred spawning areas for brook trout, but they are also areas favoured by beavers for the construction of dams. Community groups involved in stream enhancement are becoming increasingly sensitive to the needs of other wildlife species within the watershed. The value of beavers in creating wetlands is well recognized, and beavers are encouraged to establish colonies in some stream reaches. However, it is important to ensure that trout have access to critical spawning areas. Community volunteers closely monitor these sites in autumn, and if necessary and if authorization is obtained, beavers and their dams are removed.

EVALUATION AND MONITORING

Cairns (2002) measured density of brook trout in two sets of Prince Edward Island streams before and after enhancement, but density differences were not statistically significant. No other attempts have been made to quantify effects of stream enhancement work on Prince Edward Island. A cursory assessment has shown increased percentages of gravel/cobble substrate and increased stream depths following enhancement. The rapid rate of infilling of brush mats and sediment traps is testimony to their effectiveness in consolidating sediment. Bottom substrate downstream from a sediment trap improves noticeably following its installation. There is a need for additional data collection which would allow us to measure the effectiveness of the enhancement techniques used.

CONCLUSIONS

Stream enhancement has come a long way from the rip-and-tear approach used over 20 years ago. Community groups now see the big picture and carry out stream enhancement as one part of holistic watershed management. It is increasingly obvious that landowners and government agencies must assume greater responsibility for water quality and stream habitat. The transport of sediment to watercourses must be controlled or stream enhancement efforts will not have a great impact. Education and mitigation are not always sufficient to address major land use problems. Federal and provincial government agencies have been reluctant to enforce legislation which protects fish and fish habitat. Enhancement of stream habitat will only be achieved if all of the players - community groups, landowners, and provincial and federal government agencies - make the environment a priority and allocate resources to it.

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Substrate composition in the Morell River and other Maritime Province rivers: implications for Atlantic salmon fry emergence

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ABSTRACT

Fine sediments in streams and rivers have potential impacts on aquatic resources, and especially on the emergence of salmonid fry. On Prince Edward Island, there is large scale movement of sediments into streams due to the nature of the soil and the intensity of land use, particularly by the agriculture industry. We compared the size distribution of substrate particles in the Morell River, Prince Edward Island, with those of the Point Wolfe River and Catamaran Brook, New Brunswick. Percentage of Fines (particles <2 mm) in the substrates of these rivers varied between 5% to 46%, with the highest values in the Morell River. In the two New Brunswick rivers, Fines were ≤15% of substrates. Based on literature data, concentration of Fines below 15% should not significantly reduce emergence success. In the Morell River percentage of Fines varied between 18% and 46%. Literature findings suggest that sites with high percentage of fines (Old Cardigan Road, 36%; Kennys Bridge, 46%) are likely to have substantial impairment of emergence success.

INTRODUCTION

The impact of sediment input into streams and rivers has been the object of increasing concern and investigation in recent years (Anderson et al. 1996, Newcombe and Jensen 1996, Birtwell 1999). Sediment movement into Prince Edward Island streams is a matter of particular concern because the soil is highly erodable, and because of the intensity of land use for farming and other purposes. Atlantic salmon prefer a substrate type with low concentrations of fine sediments. For example, Bourgeois et al. (1996) found that juvenile salmon preferred gravel and cobble ranging between 64-512 mm, and were infrequently observed in substrates where bottom particles were less than 10-20 mm in size.

When fine sediments reach streams or rivers, adverse biological consequences are often observed (see reviews by Cordone and Kelly 1961 and Waters 1995). A number of laboratory and field experiments have been carried out on the effects of fine sediments on salmonids (Everest et al. 1987). These have shown a negative relation between the percentage of Fines (<2 mm) and the survival/emergence of salmonids and macroinvertebrates. Studies have shown that the accumulation of fine sediments in rivers is often the result of human activities such as logging practices, road construction, agriculture, and mining (Lisle 1989, Cunjak 1995). Fine sediments can also accumulate in pools (Lisle and Hilton 1992). Sediment loading in rivers is typically a function of geomorphology, hydrology, stream gradient, and channel morphology.

Peterson (1978) and Peterson and Metcalfe (1981) demonstrated through laboratory experiments that fine sediments inhibited the emergence of salmon fry in the Maritime Provinces. These authors noted that a reduction in emergence was usually observed when fine sediments were in the range of 15% to 30%, and that when Fines exceeded 50% emergence rapidly approached zero. These studies also showed that effects of fine sediments on young Atlantic salmon were present from the egg stage until emergence was completed. Peterson and Metcalfe (1981) observed that substrate comprising more than 20% of fine sediments was often associated with low concentrations of dissolved oxygen in substrate water. This may lead to constraints on intake of oxygen by the eggs. In addition to physiological effects, accumulations of Fines can physically preclude fry emergence from the substrate.

It has been shown that the permeability and availability of interstitial pores, as measured by the Freddle Index, are important factors in egg survival and fry emergence (Lotspeich and Everest 1981). In the Miramichi River, the

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percentage of emergence has been estimated at 68-100% (St-Hiliaire et al. 1997).

The objective of the present study is to compare substrate composition in the Morell River, Prince Edward Island (PEI) with those of Point Wolfe River and Catamaran Brook, New Brunswick (NB).

METHODS

Site location

The Morell River is located in eastern Prince Edward Island, and drains into the Gulf of St. Lawrence. The Morell is PEI's most important salmon river (Cairns et al. 2000). Three sites were sampled: Kennys Bridge (46°17'48"N, 62°44'52"W), Old Cardigan Road (46°16'25"N, 62°43'36"W), and Cranes (46°18'28"N, 62°41'28"W (Fig. 1)). Three samples were collected at each sites. Samples were taken at the head of riffles where Atlantic salmons typically spawn. At each site, the distance between the sampling point and the river bank was measured. In the Morell River, samples were also taken near the sites used during an egg incubation study (Cunjak et al. 2002).

The Point Wolfe River drains into the inner Bay of Fundy in Fundy National Park. Rivers in this area formerly had substantial salmon populations, but runs have declined severely in recent years (Marshall et al. 1999). Three sites were sampled: Wood Dam (45°35'53"N, 65°09'12"W), Key Hold (45°35'28"N, 65°06'47"W), and Bennett Brook (45°35'16"N, 65°05'05"W). Seven samples were taken on the Point Wolfe River. Samples were taken at the head of riffles. Distance from the river bank at each site was measured. The Catamaran Brook is a tributary of the Little Southwest Miramichi River in central NB. The Miramichi River is eastern North America's most important salmon river (Anon. 2000). The sampling site was 1.2 km from the mouth of the brook at 46°52'27"N, 66°07'06"W. At this site, three transects, spaced at 10 m apart, were sampled from a relatively homogeneous section of the brook. At each transect, samples were taken at approximately 25%, 50% and 75% of the stream width, to show if substrate composition changed with position with respect to centre of the stream.

Sampling method

The substrate was sampled using a McNeil sampler (McNeil 1964, Wesche et al. 1989). Our sampler consisted of a tapered steel cylinder 45 cm long and 20 cm in diameter. At the bottom of the cylinder three sieves were mounted 4 cm apart. The mesh sizes of the top, middle, and bottom sieves were 1 cm x 2 cm, 3 mm x 3 mm, and 80 µm (similar to a plankton net), respectively. These meshes serve to retain the particles in the substrate samples, while allowing water to escape.

At each site, the McNeil sampler was used to remove two to three scoops of material from the top 20-25 cm of the streambed. Each sample covered an area of about 0.5 m^2. An initial field sieving was carried out at each site to sort larger substrate material using 31.5 mm, 45 mm and 100 mm sieves. Material retained in each sieve was weighed on site using a balance with a precision of 20 g. The remaining sediments (<31.5 mm) was then transferred to a plastic bag including some water to be further analyzed in the laboratory. In the laboratory, the <31.5 mm sample was dried and sieved to establish the particle size distribution. The following sieve sizes were used to analyze the substrate; 16 mm, 8 mm, 4 mm, 2 mm, 1 mm, 500 µm, 250 µm, 125 µm, 63 µm, 38 µm and less than 38 µm. Grain size distribution was divided into three categories: Large Gravel (≥31.5mm), Gravel (2-31.4 mm), and Fines (< 2mm).

RESULTS

A total of 74.2 kg of substrate samples was analyzed from the Morell River (Table 1). Sample sizes for the three sites were similar (23.1 kg at Kennys Bridge, 24.4 kg at Old Cardigan Road, 26.7 kg at Cranes). Most of the substrate material consisted of Gravel, which represented more than 50% of the material collected at Old Cardigan Road and Cranes. The Large Gravel component (11.9-28.5%) was more variable among sites than the Gravel component. Fines varied among sites, with the highest percentage at Kennys Bridge where the mean value was 45.9%. The Old Cardigan Road site was 35.6% Fines and the Cranes site was 18.4% Fines. The Fines component at Kennys Bridge was 2.5 times higher than that at Cranes.

Within-site variability, as reflected by coefficients of variation (CV), was greatest at Kennys, where the CV for Large Gravel was 1.29 (Table 1). Large Gravel was also the most variable component at the other sites. The Old Cardigan Road site showed intermediate variability with a coefficient of variation of 0.15 for Gravel and of 0.04 for Fines. The site at Cranes showed the least variability among samples with CVs of 0.14, 0.08 and 0.02 for Large Gravel, Gravel and Fines respectively.

Grain sizes on the Morell River were bimodally distributed (Fig. 2). The site at Kennys Bridge showed a large quantity of material in the range of 0.125 mm to 1 mm. This material can be classified as Very Fine Sand to Coarse Sand based on the Wentworth Scale (Gordon et al. 1992, Table 2). The highest percentage of material at Kennys was in the Medium Sand component, which was the material retained in the 0.25 mm sieve (i.e. particles between 0.25 mm to 0.5 mm). The Kennys Bridge sample showed 37% of the material in this range, while Old Cardigan Road showed 15% and 25% respectively. At Old Cardigan Road, the quantity of Fines was less than at Kennys Bridge but a bimodal distribution was still evident (Fig. 2b). At Old Cardigan Road, the bulk of the fine material was in the range of 0.125 mm to 1 mm, with the highest percentage value between 0.25 mm and 0.5 mm or within the Medium Sand component.

Cranes showed fewer Fines and therefore the Medium Sand component did not stand out from other fine components (Fig. 2c). The distribution of the larger material, i.e. Large Gravel, was observed to be similar for each sample at Crane.

Substrate analysis was based on >100 kg of material from each site at Point Wolfe, and on 30-35 kg of sample for Catamaran sites. Substrate particles on the Morell River were generally much smaller than those of the Point Wolfe River and Catamaran Brook (Table 3). Morell River sites contained 11.9-28.5% Large Gravel, whereas Point Wolfe River and Catamaran Brook samples were 51-60% and 35-40% Large Gravel, respectively. The Gravel component was similar in Catamaran Brook (48-50%) and the Morell River (42-53%). Fines were least frequent in Point Wolfe River (5%). In Catamaran Brook Fines were 13-15% of substrates. Morell River had the highest percentage of Fines, with high variation among sites (range 18% at Cranes to 46% at Kennys Bridge).

In Point Wolfe River, the CV for Fines was 0.28-0.29, except for the site at the old logging dam which showed a value of 0.76 (Table 3). In Catamaran Brook, CVs were $\leq$ 0.28 for Large Gravel and $\leq$ 0.15 for Gravel. The variability in the Fines was between 0.15 to 0.30. The Morell River showed the highest coefficient of variation for Large Gravel at 1.29. The CV of the Gravel component was 0.15 or less. The Morell River had the highest percentage of Fines and the lowest coefficient of variation among Fines. Values ranged from 0.02 to 0.32.

Particle size distributions at Point Wolfe River and at Catamaran Brook were similar. The size distribution for Site A at Catamaran (Fig. 3) is representative of all sites in the two NB rivers. Percent composition peaked in the Large Gravel range. An increasing percentage was observed between the 37.5 mm sieve and the 8 mm sieve, where a second peak formed (Fig. 3). This was followed by a gradual decline in percentage for finer materials.

Fines decreased from Kennys Bridge to Cranes, with the site at Old Cardigan Road showing intermediate values (Fig. 4a). The Large Gravel component showed a contrasting trend, with an increase from Kennys Bridge to Cranes. Point Wolfe River and Catamaran Brook showed consistent results in all components (Figs. 4b and 4c). This consistency was especially evident in the Fine component at both sites, although these rivers showed different levels of Fines.

DISCUSSION AND CONCLUSIONS

The effects of fine sediments on stream ecosystems include the reduction of primary production, reduction of intragravel oxygen, damage to fish respiratory systems, and reduction in hatching success (Cordone and Kelly 1961, Waters 1995). Sediments can be suspended in water or deposited on the substrate. The present study deals with the fine sediments within the substrate and their potential impact on the emergence success of Atlantic salmon.

Everest et al. (1987) and Peterson and Metcalfe (1981) found that when the Fines were less than 10-15%, emergence success was over 80%. Based on this finding, Fines in the Point Wolfe River (6%) and in Catamaran Brook (13-15%) are unlikely to impair emergence success.

At high concentrations of Fines, substrate permeability is markedly reduced, which constricts the flow of oxygen-bearing water to eggs (Peterson 1978). When Fines exceed 15%, emergence success decreases, and when Fines are over 30%, emergence decreases very rapidly (Everest et al. 1987; Peterson and Metcalfe 1981). In substrates with 30-40% Fines, emergence success was 10-40%, and in substrates of >40% Fines, emergence success was 5-20% (Everest et al. 1987). The site at Cranes on the Morell River, with 18% Fines, is near the threshold where the literature indicates that fine sediments begin to have detrimental effects. Fines exceeded 35% at Old Cardigan Road and at Kennys Bridge. Based on literature relations, emergence success at these sites is likely <30%.

Cunjak et al. (2002) investigated the relation between survival of brook trout and Atlantic salmon eggs placed in incubation baskets in the Morell River, and fine sediment accumulation in the baskets. Emergence survival was highly variable among sites. Emergence survival was weakly related to sediment accumulation in baskets for brook trout, but not for salmon.

In the Morell River, where fine sediments were abundant, the size distribution became increasingly bi-modal for values below 32 mm (Fig. 2). At Kennys Bridge, which had the highest percentage of Fines, a peak in the distribution was observed at the Medium Sand component (0.25 mm to 0.5 mm; Fig. 2a). These results contrasted with those of Pointe Wolfe River and Catamaran Brook where anthropogenic influences are smaller. In these NB rivers the particle size distribution followed a decreasing trend from a peak value at Medium Gravel (8 mm to 16 mm) to smaller particles, as illustrated in Catamaran Brook site A (Fig. 3). In the Morell River, the peak at the medium sand particle size may be due to sediment originating from agriculture or other land use practices, rather than from natural erosion processes.

In conclusion, the percentage of Fines in the studied rivers varied between 5% to 45%, with the highest values observed in the Morell River (PEI). The low percentage of fines in New Brunswick study sites (≤15%) suggest that fines would not impair emergence of salmon fry. On PEI, percent fines were much higher (18-46%), and fine sediments are likely to cause moderate to severe reductions in emergence success, based on literature data. These results are based on a modest number of samples from three rivers. A much greater sampling effort is required to fully characterize substrate particle size distributions in rivers in the Maritime Provinces. Nevertheless, our limited results are consistent with the expectation, based on land use practices, that fine sediments are more prevalent in PEI stream bottoms than in those of the nearby mainland.

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Table 1.
Substrate composition at different sites in the Morell River (PEI). Particle size distribution: Large Gravel ≥ 31.5 mm; Gravel 2-31.4 mm; and Fines < 2 mm.

	Kennys Bridge			
Particle sizes	Large Gravel (%)	Gravel (%)	Fines (%)	Total Weight (kg)
Kennys Bridge A	1.9	40.4	57.7	3.4
Kennys Bridge B	4.2	44.9	50.9	4.7
Kennys Bridge C	29.5	41.3	29.2	15.0
Mean	11.9	42.2	45.9	
Std	15.3	2.3	14.9	
CV	1.29	0.05	0.32	
Total weight				23.1 kg

	Old Cardigan Road			
Particle sizes	Large Gravel (%)	Gravel (%)	Fines (%)	Total Weight (kg)
Old Cardigan Road A	3.3	60.1	36.6	6.0
Old Cardigan Road B	18.2	47.8	34.0	4.2
Old Cardigan Road C	17.7	46.0	36.3	14.2
Mean	13.1	51.3	35.6	
Std	8.5	7.7	1.4	
CV	0.65	0.15	0.04	
Total weight				24.4 kg

	Cranes			
Particle sizes	Large Gravel (%)	Gravel (%)	Fines (%)	Total Weight (kg)
Cranes A	24.1	57.6	18.3	6.2
Cranes B	31.2	50.0	18.8	4.2
Cranes C	30.2	51.8	18.0	16.3
Mean	28.5	53.1	18.4	
Std	3.9	4.0	0.4	
CV	0.14	0.08	0.02	
Total weight				26.7 kg

Table 2.
Particle size distribution following the Wentworth Scale (from Gordon et al. 1992). Phi scale is equal to the negative logarithm (in base 2) of the particle size in mm.

Substrate classes	mm	ϕ
Very large boulder	2048-4096	-11 to –12
Large boulder	1024-2048	-10 to -11
Medium boulder	512-1024	-9 to -10
Small boulder	256-512	-8 to -9
Large cobble	128-256	-7 to -8
Small cobble	64-128	-6 to -7
Very coarse gravel	32-64	-5 to -6
Coarse gravel	16-32	-4 to -5
Medium gravel	8-16	-3 to -4
Fine gravel	4-8	-2 to -3
Very fine gravel	2-4	-1 to -2
Very coarse sand	1-2	-1 to 0
Coarse sand	0.5-1	0 to 1
Medium sand	0.25-0.5	1 to 2
Fine sand	0.125-0.25	2 to 3
Very fine sand	0.0625-0.125	3 to 4
Coarse silt	0.0312-0.0625	4 to 5
Medium silt	0.0156-0.0625	5 to 6
Fine silt	0.0078-0.0156	6 to 7
Very fine silt	0.0039-0.0078	7 to 8
Coarse clay	0.0020-0.0039	8 to 9
Medium clay	0.0010-0.0020	9 to 10
Fine clay	0.0005-0.0010	10 to 11
Very fine clay	0.00024-0.0005	11 to 12

Table 3.
Substrate composition in percentage at different sites in the Maritime provinces (Morell River, PEI; Point Wolfe River, NB and Catamaran Brook, NB). Values in parentheses represent the coefficient of variation. Particle size distribution: Large Gravel $\geq$ 31.5 mm; Gravel 2-31.4 mm; and Fines < 2 mm.

Location	% Large gravel	% Gravel	% Fines	Total weight (kg)	Sample size
Point Wolfe R. at old dam	50.8 (0.33)	44.7 (0.32)	4.5 (0.76)	111.2	7
Point Wolfe R. at Key Hold	52.6 (0.20)	42.3 (0.22)	5.1 (0.28)	107.0	7
Point Wolfe R. at Bennett Bk	59.2 (0.14)	35.3 (0.21)	5.5 (0.29)	100.0	7
Catamaran Brook A	34.8 (0.25)	50.2 (0.15)	15.0 (0.15)	34.5	5
Catamaran Brook B	37.0 (0.28)	50.3 (0.14)	12.7 (0.30)	33.3	5
Catamaran Brook C	39.7 (0.20)	47.7 (0.13)	12.6 (0.17)	30.3	5
Morell R. at Kennys Bridge	11.9 (1.29)	42.2 (0.05)	45.9 (0.32)	23.1	3
Morell R. at Cardigan Rd	13.1 (0.65)	51.3 (0.15)	35.6 (0.04)	24.4	3
Morell R. at Cranes	28.5 (0.14)	53.1 (0.08)	18.4 (0.02)	26.7	3

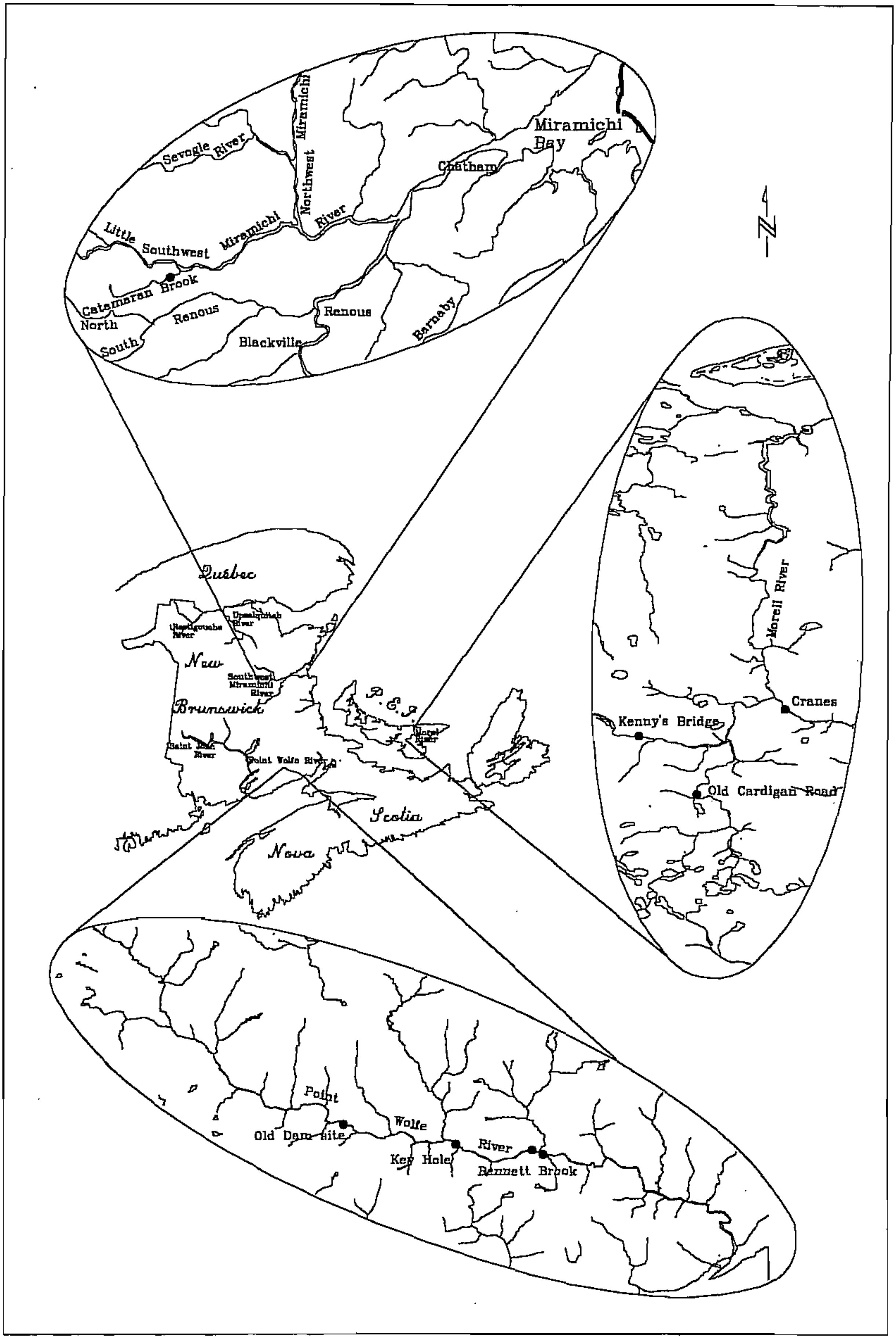

Figure 1. Map of substrate composition sampling sites in the Maritime Provinces.

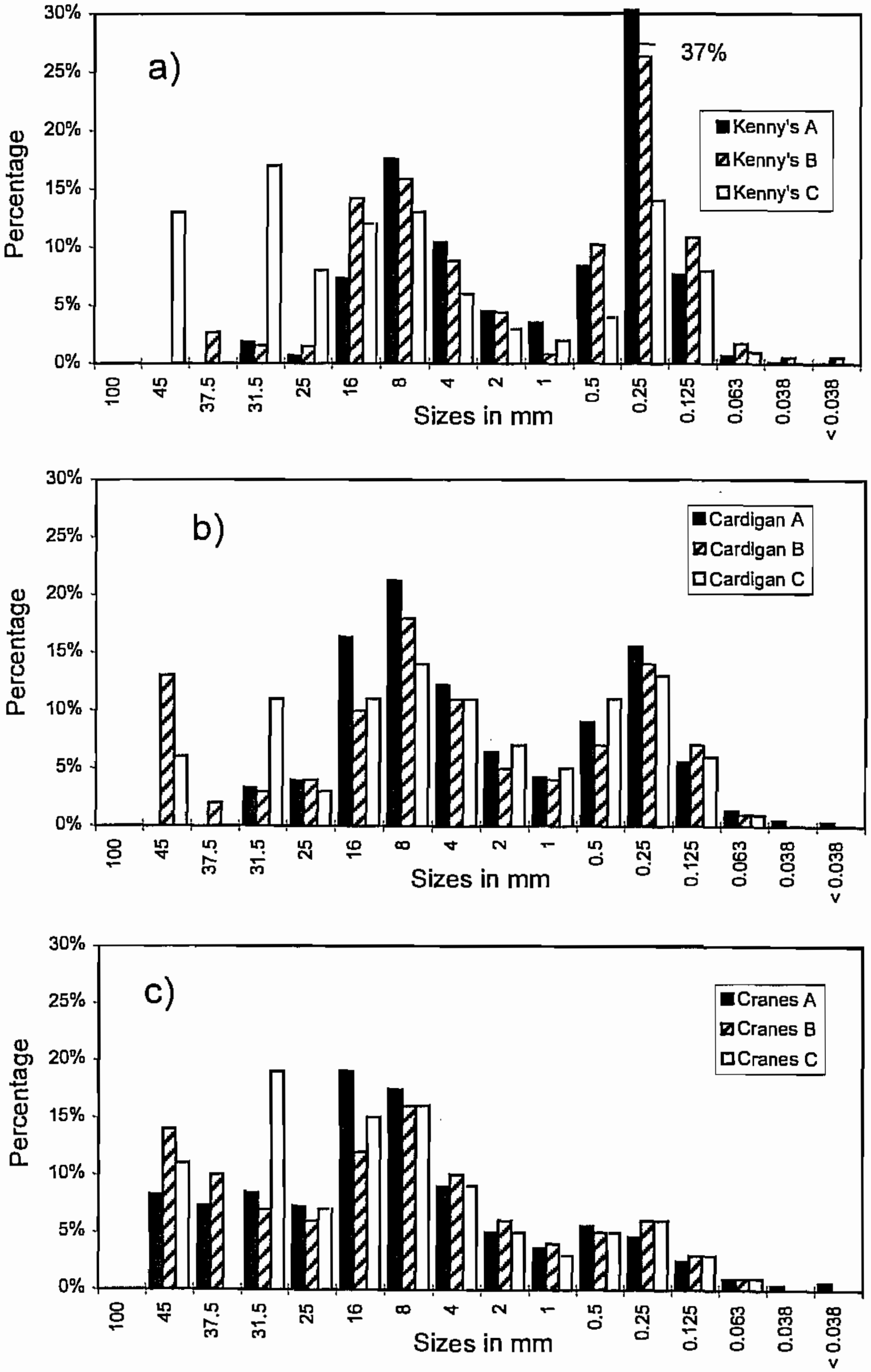

Fig. 2. Particle size distribution for sites in the Morell River (PEI) : a) Kenny's Bridge; b) Old Cardigan Road; c) Cranes.

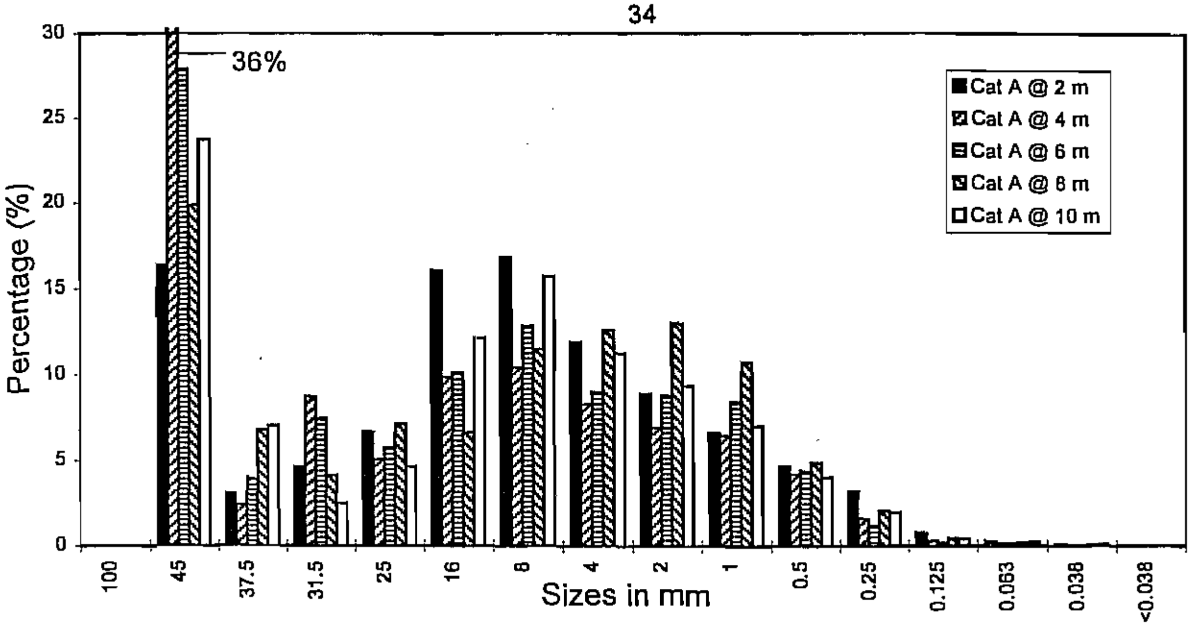

Fig. 3. Particle size distribution for site A at Catamaran Brook

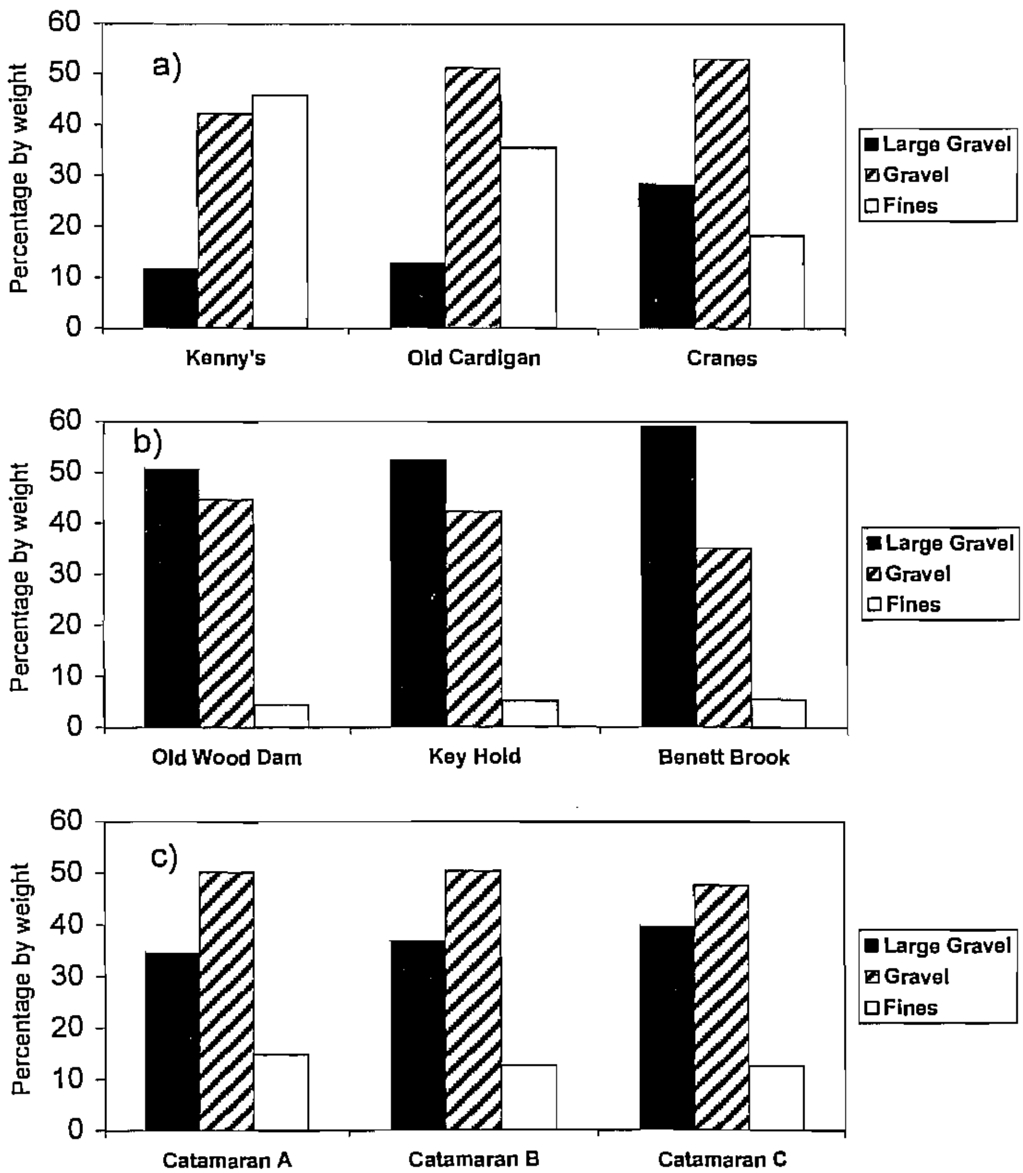

Fig 4. Substrate composition for three sites in the Maritime provinces:
a) Morell River PEI; b) Point Wolfe River NB; c) Catamaran Brook NB.

Substrate sedimentation and salmonid densities in Prince Edward Island streams

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ABSTRACT

This paper is based on densities of brook trout and juvenile Atlantic salmon estimated from electrofishing surveys in Prince Edward Island. Mean densities were 17.4 brook trout and 13.0 Atlantic salmon 100 m^{-2} in the Morell River. Brook trout densities averaged 49.1 100 m^{-2} in the Little Pierre Jacques, Enmore, Ellerslie, Seal, and Vernon Rivers, and 47.5 100 m^{-2} for the province overall. Salmon were rare or absent in most rivers other than the Morell. No significant correlations were found between densities of brook trout and of Atlantic salmon, and the proportion of bottom covered by fine particles or the proportion of bottom which included fine particles. Anecdotal reports indicate that salmonids may be absent in stream reaches with very high sediment loadings but electrofishing surveys did not cover such habitats. Summed densities of brook trout and Atlantic salmon on PEI (57.5 100 m^{-2}) were similar to those measured in New Brunswick and Nova Scotia (54.3 100 m^{-2}), where sedimentation is less intense. Given Prince Edward Island's relatively high soil fertility, short rivers, and paucity of non-salmonid fishes, trout and salmon densities prior to European settlement were probably higher than those of New Brunswick and Nova Scotia. The fact that present salmonid densities on Prince Edward appear to not substantially exceed those of neighbouring provinces may be due to land-use effects.

INTRODUCTION

Soil erosion is widely recognized as Prince Edward Island's most important environmental problem (Anon. 1987). PEI is Canada's most densely populated province, and about half of the province's surface is deforested, and used primarily for agricultural production (Cairns 2002). The most important crop is the potato. Potato acreage has increased substantially in recent years, and current cultivation practices often leave the soil bare for extended periods of time. This leads to significant soil erosion, with subsequent sediment inputs to streams and rivers. Forestry and road construction have also been important sources of anthropogenic sediments in PEI watercourses.

The principal species of freshwater fish on Prince Edward Island are brook trout, which is widespread throughout the province, and Atlantic salmon, which has become greatly reduced since the time of European contact. At the present time salmon populations are largely supported through stocking of smolts reared in semi-natural ponds. The largest salmon runs occur in the Morell River (Cairns 1997). Smaller numbers of salmon return to the Mill, Trout (Coleman), Dunk, West, Montague, Valleyfield, and other rivers. Recreational fisheries for trout and salmon are important economically, and generate expenditures of about $7 million annually (Cairns 1996).

Numerous investigations have underlined the importance of unsilted habitats for both trout and salmon (Waters 1995, Anderson et al. 1996, Birtwell 1999). Gravel substrates provide habitat for redds, in which eggs are oxygenated by water flowing through interstitial spaces. Stony bottoms shelter fry and parr from predators, and provide habitat for stream insects which salmonids eat.

This paper takes an empirical approach to the relation between stream sedimentation and trout and salmon populations on Prince Edward Island. It asks two questions: a) Are trout and salmon population densities related to the proportion of stream bottom that is covered by fine particles?, and b) how do trout and salmon populations on Prince Edward Island compare with those of mainland Maritime Provinces rivers, which are less subject to sediment input? These questions are addressed through datasets of freshwater fish densities obtained through electrofishing in Prince Edward Island, New Brunswick, and Nova Scotia.

METHODS

Data on fish densities on Prince Edward Island were obtained from published and unpublished sources, and from electrofishing conducted under DFO assessment programs and the federal-provincial Watershed/ Improvement Recreational Fisheries Development

Pp. 35-81 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

Program (WI/RF). Data sources and collaborating agencies are listed in Table 1. Locations of electrofishing sites are given in Figs. 1-2 and Appendix 1.

Data obtained from DFO assessment programs in the Morell River and the WI/RF sites (Little Pierre Jacques, Enmore, Ellerslie, Seal, and Vernon Rivers) were used to examine the relation between habitat and fish densities. These rivers were not stocked during the study years, except for salmon released as 2+ smolts during spring in the Morell. Temperatures at study sites were generally moderate (Appendix 2). Only 6 temperatures > 20° were recorded, and the maximum temperature was 22.7°C.

Electrofishing at these sites was conducted using a generator- or battery-powered Smith-Root electrofisher. In multi-sweep electrofishing, the site was blocked at its upstream and downstream ends by barrier nets. A crew typically consisted of a shocker, a dipnetter, and two members who deployed a lip seine immediately downstream from the shocker. Sweeping direction was from downstream to upstream to prevent the turbidity raised by the crew from reducing the visibility of stunned fish. All fish caught were recorded by species, number, and length.

The number of sweeps was usually 3; less frequently 4, 5, or 6. The population of each species in the site was estimated by the method of Zippin (1958). Where this method failed because of non-decrease of successive catches, populations were assumed to be two times the number caught (Jones and Stockwell 1995).

Fishing methods in single-sweep sessions were similar to those of multi-sweep sessions, except that no barrier nets were used. Populations of single-sweep sites were estimated from the mean proportion of first sweep catches divided by total Zippin estimates for sites where several sweeps were conducted (0.532).

Detailed habitat measurements were taken at Morell and WI/RF sites, usually immediately after the electrofishing session. Measurements were taken at cross-stream transects separated by 4 m intervals, starting at the downstream end. The last transect was the upstream boundary of the site.

Measurements were made at each transect as follows. The width of undercut habitat at either end of the transect was measured with a metre stick. The number of metres of stream width with canopy vegetation directly overhead and with overhanging vegetation directly overhead was visually estimated. Vegetation with foliage higher than 3 m was considered canopy and vegetation less than 3 m high was considered overhanging. Crews also visually estimated the number of metres of stream bottom covered by aquatic macrophytes and by instream debris suitable for fish cover.

At 1 m intervals along each transect, starting from the left side of the stream (looking upstream), crews measured water depth with a metre stick and recorded the substrate type. Substrates were visually classified by particle size as follows:

Fines - ≤0.5 cm (pea size or less)
Gravel - 0.6 - 10.2 cm (pea size to fist size)
Cobble - 10.3 - 30.5 cm (larger than fist size to head size)
Boulder - > 30.6 cm (larger than head size)
Hardpan - Exposed bedrock

Current was measured by timing the downstream movement of a stick set floating on the water.

Brook trout and Atlantic salmon were classified into age groups on the basis of length. For brook trout, splitpoints between ages 0+ and 1+, between 1+ and 2+, between 2+ and 3+, between 3+ and 4+, between 4+ and 5+, and between 5+ and older were 10.95, 17.95, 29.75, 38.95, 46.35, and 51.45 cm, respectively (Dupuis et al. 1991). For Atlantic salmon, splitpoints between ages 0+ and 1+ and older were taken from frequency distributions of fish measured during this study.

Fish weights were estimated from lengths by the formula weight = a*length^b, where weight is in g and length is in cm. Coefficients are as follows:

	Brook trout	Atlantic salmon	American eel	Alewife	Rainbow smelt	Mean
a	0.00848	0.0120	0.000491	0.00536	0.00301	0.00587
b	3.120	3.030	3.322	3.274	3.301	3.210

Brook trout coefficients are from Dupuis et al. (1991) and salmon coefficients are from juvenile salmon measured in the Morell in 1984-1985 by R. Gray and K. Davidson (unpubl.). Eel, alewife, and smelt coefficients are from Cairns unpubl. For other species, weights were estimated from the mean of coefficients given above.

RESULTS

Mean proportions of sites covered by canopy, overhanging vegetation, aquatic vegetation, and instream cover were 0.299, 0.222, 0.103, and 0.089, respectively (Table 2) (raw data in Appendix 2). Proportion of stream banks with undercuts deeper than 10 cm was 0.185. The commonest substrate type was fines, which covered 0.269 of Morell sites and 0.350 of WI/RF sites. The proportion of bottom covered by fines, either alone or mixed with other particle sizes, was 0.412 for the Morell and 0.650 for WI/RF sites.

Brook trout were present at nearly all sites, but salmon were regularly encountered only in the Morell (see Appendix 3 for raw data). Mean densities in the Morell were 17.4 (SD 9.5) brook trout and 13.0 (SD 9.1) Atlantic salmon 100 m^{-2} (n=102) (Tables 3 and 4). Densities at WI/RF sites averaged 49.1 brook trout and 0.9 Atlantic salmon 100 m^{-2} (n=136). Densities varied irregularly with time (Fig. 3). The overall mean density for all sites measured since 1975 was 47.5 brook trout and 7.6 Atlantic salmon 100 m^{-2}, for a total of 57.5 fish 100 m^{-2} (n=303) (Table 4).

Length frequencies of brook trout were multi-modal, and ranged up to 52 cm (Figs. 4-7). Lengths of 0+ and 1++ Atlantic salmon were distinctly separate in July, but overlapped thereafter (Fig. 5). Length frequency troughs for salmon, used as splitpoints to estimate ages from lengths, were 8 cm in May-June, 9 cm in July, 10 cm in August, 11 cm in September, and 11.5 cm in October-December.

Densities of brook trout did not show significant correlations with proportion of bottom covered by fines or by substrates including fines, for either the Morell or WI/RF sites (Fig. 8). Atlantic salmon densities in the Morell were also uncorrelated with the proportion of the bottom covered by fines, or by substrates that included fines. A multiple linear regression between the habitat parameters listed in Table 2 and brook trout densities yielded the following equation: Trout 100 m^{-2} = *31.1*-*37.4**proportion fines+*39.7**proportion any fines+3.51 *undercut banks-*32.0**prop. canopy+*52.5* prop. overhanging vegetation-*52.5**proportion aquatic vegetation-27.1*proportion instream cover. Coefficients that are significant at P=0.05 are italicized. A multiple regression of habitat parameters vs. salmon density in the Morell River was not significant overall (P>0.05) and produced no significant coefficients (P>0.05).

In summer 1994, floating logs were placed as instream cover in the Enmore River downstream from Route 2. Mean estimated brook trout densities were 16.1 (SD 7.0) 100 m^{-2} prior to log placement and 13.4 (SD 11.1) 100 m^{-2} after log placement (F=0.51, P=.0.48, df=1,22; anova) (Fig. 3). In summer 1995, the base of an old dam, located on the Seal River just above Route 3, was removed to allow fish passage in this stream. A silt trap was dug just below the dam site to catch sediment released during construction work. Brook trout densities in the Seal River prior and post-dam removal did not differ significantly (54.9 (SD 34.6) 100 m^{-2} before dam removal; 33.9 (SD 30.7) 100 m^{-2} after removal; F=1.2, P=.28, df=1,18; anova).

Mean densities of 0+ brook trout ranged from 7.9 100 m^{-2} on the Morell to 68.4 100 m^{-2} on the Vernon (Table 5). In both brook trout and Atlantic salmon, densities of 0+ fish were much higher than those of older year classes. Brook trout contributed the bulk of biomass density in the Morell and all WI/RF rivers. Summed mean biomass was 770 g 100 m^{-2} in the Morell and 842 g 100 m^{-2} in WI/RF rivers (Table 5).

DISCUSSION

Fish density vs. proportion fines

This study found no significant correlations between fish density and the proportion of the substrate covered, or partly covered, by fine sediments, either for brook trout or for Atlantic salmon. All salmon and the majority of trout enumerated in these surveys are juveniles. These results suggest that fine sediment disposition does not negatively affect the juvenile stages of these species on Prince Edward Island during the summer period.

Some cautions are in order due to limitations of the data set. Habitat classification was by visual estimate, and crews varied among sites and among years. This means that classifications are less reliable than those obtained by sampling and sieving (e.g. Caissie and Arseneau 2002). Electrofishing sites were typically 20 m or more long, and contained a variety of substrates, usually including at least a small area of clean stony bottom. Because fish densities were calculated for the full site, fine-scale analysis of habitat preference is not possible. Fish densities obtained by electrofishing are inherently variable; hence moderate differences in means are difficult to detect (e.g. 25 electrofishing sessions are required to detect a 20% difference in means, Paller 1995).

Comparisons with mainland data

The mean density of brook trout and Atlantic salmon combined was 30.4 100 m^{-2} in the Morell and 50.2 100 m^{-2} in WI/RF sites (Table 4). Most densities measured in other PEI rivers were higher than these, and the overall mean provincial density was 57.5 100 m^{-2}. This overall density was comprised mainly of brook trout (47.5 trout 100 m^{-2}, 7.6 salmon 100 m^{-2}).

Summed brook trout and Atlantic salmon densities from a collation of New Brunswick and Nova Scotia data were similar to the total for Prince Edward Island (54.3 100 m^{-2}, Table 6). The species breakdown for the mainland provinces (8.0 brook trout and 46.3 Atlantic salmon 100 m^{-2}) was virtually a mirror image of that of Prince Edward Island. However, the preponderance of salmon in mainland surveys may be due to more intense sampling of rivers where salmon are important.

It must be noted that mean population densities cannot be calculated for any Maritime province in a statistically robust way. Electrofishing sites are often selected because a river is known to be important for salmonids, and exact placements are typically chosen because of accessibility.

Nevertheless, the similarity between PEI and other Maritime trout+salmon figures (Tables 4 and 6) suggests that PEI salmonid populations are not lower than, or at least not greatly lower than, those of the adjacent mainland. However, there are reasons to believe that salmonid densities on PEI ought to be higher than those of other Maritime Provinces. PEI's soils are fertile relative to those of its mainland neighbours and its waters are generally more eutrophic than those of the other Maritime Provinces (Smith 1966). Higher nutrient inputs are associated with increased salmonid productivity (Perrin et al. 1987, McInerney 1989). PEI also has short rivers which are free of natural waterfalls. This means that anadromy, which is often associated with higher growth rates in brook trout (Ryther 1997), was available to nearly all PEI salmonids in pre-European times. PEI also has fewer fish species than New Brunswick and Nova Scotia, and has only three purely freshwater species, all of which have very small distributions (Anon. 2000). This means that PEI brook trout and Atlantic salmon have less competition in fresh water than do trout and salmon in the other Maritime provinces.

Given these advantages, salmonid densities in PEI streams in the period before European settlement were probably substantially greater than those of the other Maritime Provinces. Salmonid habitats in New Brunswick and Nova Scotia have been altered by human activities, but changes are not as far-reaching as those on PEI because the mainland provinces have lower human population densities and a lower proportion of land cleared for agriculture. The fact that salmonid densities on PEI are roughly similar to, instead of greater than, those of adjacent mainland provinces may be due to land-use effects, including stream sedimentation.

<u>Streambed sedimentation and salmonid populations</u>

An abundance of literature demonstrates that both suspended and deposited sediments can have negative impacts on fresh water fish (Anderson et al. 1996). Sedimentation has been reported to affect all life stages, including egg incubation, yolk-sac fry, emerging fry, and juveniles in summer and winter. Deposited sediment may reduce production of invertebrates used by salmonids for food, infill interstitial spaces used by juveniles as cover, and infill pools used by adults as cover. Because such effects are both severe and widespread, sedimentation is considered the number one pollutant in fresh waters of the United States (Waters 1995).

The lack of significant correlation between brook trout and Atlantic salmon densities and proportions of fines suggests that juvenile salmonids can successfully use habitat with substantial streambed sedimentation. However, some PEI rivers have much greater loadings than the Morell and WI/RF streams. The Wilmot River drains an intensively cultivated area in west-central PEI. Some parts of this river are completely blanketed by fine sediments, and salmonid fishes are rare or absent in these reaches (S. MacNeill, pers. comm.).

One historical and one recent study have examined the relation between summer juvenile brook trout densities and sedimentation on PEI. Standing crops of 0+ brook trout in the Ellerslie River dropped significantly after a siltation event that covered most of the stream bottom, and then recovered in the following year (Saunders and Smith 1965). MacNeill and Curry (2002a) examined brook trout densities in relation to substrate type in the Wilmot and West Rivers. These authors found a significant negative correlation between densities of 0+ trout and the proportion of the bottom covered by fines.

This study addressed only sediment effects on juvenile densities in summer. Sediment impacts on other life stages may be greater. Both brook trout and Atlantic salmon rely on water flowing through their redds to incubate their eggs. Brook trout commonly spawn in spring seeps, where upwelling groundwater forces its way through the redd, even if sediment occupies the inter-gravel spaces (Cunjak et al. 2002, MacNeill and Curry 2002b). Atlantic salmon do not target spring seeps for spawning in PEI, and instead spawn in streams at the heads of riffles. The ability of brook trout to reduce the negative impact of sedimentation by spawning in seeps may be a major reason that their populations are much higher than those of salmon on PEI.

For trout, the degree of reproductive impairment may depend on the proportion of spawning fish that have the opportunity to spawn in groundwater seepages. This has not been measured on a province-wide basis. Moreover, water quality parameters critical to egg and fry survival (dissolved oxygen, gas supersaturation) have been measured in only a few groundwater seepages, so the proportion of seepages on PEI that provide water that is suitable for salmonid reproduction is unknown.

The mean proportion of fines at electrofishing sites on the Morell is 0.27 (SD 0.22), and the mean proportion of the bottom covered by substrate types that include fines is 0.42 (SD 0.27) (Table 2). Corresponding means for WI/RF sites are 0.35 (SD 0.31) and 0.63 (SD 0.30), respectively. This suggests that the Morell has a lower silt load than most other PEI rivers. If so, head-of-riffle habitats on most PEI rivers may typically have too many fines to support successful salmon reproduction. The Morell has a low proportion of substrate fines in comparison with other PEI rivers, but its proportion of substrate fines is higher than those of mainland rivers examined by Caissie and Arseneau (2002).

Winter habitat use by juvenile salmonids has not been investigated on PEI. However, studies elsewhere have underlined the importance of rocky bottoms for wintering (Cunjak 1996). Such substrates offer cover from predators and lower water velocities, which reduce maintenance metabolic costs. Spaces under boulders and large cobbles may be particularly important for larger juveniles. Given the high portion of PEI streambeds that are covered by fine sediments, it is possible that lack of adequate cover negatively affects overwinter survival of juvenile brook trout and Atlantic salmon on PEI.

No data on habitat selection by adult brook trout and Atlantic salmon on PEI are available. However, casual observations on PEI and literature elsewhere indicate that large brook trout use cover in the form of instream debris, undercut banks, or pools. It is likely that pool habitat is particularly important in winter, because only pools may have adequate depth to avoid risk of water freezing to the bottom. Adult salmon use pools for cover. Large-scale sediment input into PEI streams has resulted in infilling of many pools.

Sediment probably reduces available habitat for adult trout because of pool infilling, but the extent to which trout can compensate for this by choosing other types of cover is unknown. Adult salmon appear to be obligate users of pools while in rivers. Therefore the infilling of pool habitat on PEI has substantially reduced the habitat available to this life stage.

The impact of an environmental factor such as sedimentation depends on its cumulative effect across all life stages. Density-dependent population regulation is well known among juvenile salmonids (Grant and Kramer 1990), so reduced production of emerging fry does not necessarily lead to reduced production of adults. Sediments probably reduce brook trout reproductive success on PEI, but the extent of this reduction is unknown because some spawners avoid negative effects by spawning in groundwater seeps. For Atlantic salmon, the high levels of sediment in most PEI streams are probably sufficient to reduce or eliminate successful reproduction. Salmon were formerly present in most, if not all, PEI streams, but runs have disappeared in all but a small number of systems (Dunfield 1985, Cairns 1997). Salmon have been stocked in many systems but only in the Morell, where sediment levels appear to be lower than most streams, has stocking led to the re-establishment of substantial wild production.

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Table 1
Sources of Prince Edward Island electrofishing data.

River	Site	Year	Source
Morell		1975	Ducharme 1977
Morell		1984-1985	R. Gray and K. Davidson, DFO files; Cairns et al. 1995
Morell	Old Cardigan III, Smiths Spring	1994	R. Cunjak, DFO files
Morell	All others	1994-2001	Cairns et al. 1995, 1996; Cairns 1997; DFO files
Mill		1984-1985	R. Gray and K. Davidson, DFO files
Little Pierre Jacques		1993-1995	O'Leary Wildlife Federation, WI/RF[a]
Enmore		1993-1995	O'Leary Wildlife Federation, WI/RF
Ellerslie		1993-1995	O'Leary Wildlife Federation, WI/RF
Ellerslie	Hayes Brook	1947-1959	Saunders and Smith 1955, 1962
Ellerslie	Main stem	1949-1958	Saunders 1960
Trout River (Coleman)	Bannys Hole	1993	O'Leary Wildlife Federation, WI/RF
Dunk	Lower Dunk	1973-1974	Johnston and Cheverie 1980
Seal River (Orwell Bay)		1993-1995	Montague Watershed Co-op, WI/RF
Vernon River		1993-1995	Montague Watershed Co-op, WI/RF
Orwell River		1993-1994	A. MacLennan, PEI Fish & Wildlife Division files
Belle River		1993	PEI Fish & Wildlife Division files
Montague River		1987-1990	Montague Watershed Project, Anon. 1991a,b
Valleyfield River		1979	A. Smith, PEI Fish & Wildlife Division files
Bristol Creek		1994	R. Cunjak, DFO files
North Lake Creek	Head of tide	1990	A. MacLennan, PEI Fish & Wildlife Division files
North Lake Creek	Other sites	1994	R. Cunjak, DFO files

[a]Watershed Improvement/Recreational Fisheries Development Program

Table 2
Habitat characteristics of electrofishing sites on the Morell, Little Pierre Jacques, Enmore, Ellerslie, Trout, Seal, and Vernon Rivers.

Site	N		Mean depth (cm)	Maximum depth (cm)	Current (m/s)	Proportion of banks with undercut >10 cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegeation	Proportion of bottom covered by instream cover	Proportion of bottom covered by															
											Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/Cobble	Gravel/boulder	Gravel/hardpan	Cobble boulder	Cobble/hardpan	Boulder/hardpan
Morell River																										
Rowells Riffle	9	Maan	34.5	153.7	0.39	0.253	0.101	0.159	0.525	0.121	0.145	0.197	0.103	0.084	0.049	0.318	0.045	0.007	0.000	0.000	0.149	0.007	0.012	0.012	0.021	0.004
		SD	4.4	287.8	0.06	0.201	0.049	0.061	0.178	0.177	0.027	0.049	0.118	0.065	0.044	0.175	0.047	0.017	0.000	0.000	0.067	0.009	0.016	0.012	0.025	0.008
Mooneys Bridge	5	Mean	30.4	50.3	0.53	0.211	0.237	0.107	0.067	0.043	0.147	0.297	0.142	0.191	0.049	0.002	0.117	0.033	0.000	0.000	0.288	0.000	0.000	0.013	0.006	0.000
		SD	3.7	4.4	0.10	0.144	0.053	0.036	0.022	0.024	0.055	0.102	0.054	0.057	0.029	0.004	0.053	0.045	0.000	0.000	0.100	0.000	0.000	0.029	0.014	0.000
Grants	4	Mean	36.4	63.3	0.44	0.236	0.157	0.347	0.267	0.101	0.294	0.324	0.048	0.047	0.000	0.563	0.028	0.002	0.000	0.000	0.013	0.000	0.000	0.000	0.004	0.000
		SD	8.1	14.0	0.16	0.189	0.118	0.071	0.251	0.033	0.047	0.051	0.073	0.035	0.000	0.051	0.019	0.004	0.000	0.000	0.021	0.000	0.000	0.000	0.005	0.000
Forks	9	Mean	28.3	47.4	0.50	0.460	0.109	0.354	0.592	0.204	0.279	0.438	0.091	0.057	0.016	0.253	0.117	0.036	0.002	0.005	0.109	0.001	0.006	0.002	0.005	0.001
		Mean	6.5	7.7	0.09	0.120	0.133	0.073	0.135	0.125	0.045	0.086	0.059	0.044	0.017	0.168	0.053	0.055	0.006	0.009	0.076	0.003	0.012	0.004	0.007	0.003
Above Landing Pool	4	SD	31.5	54.9	0.43	0.069	0.077	0.225	0.462	0.067	0.445	0.625	0.317	0.006	0.000	0.019	0.180	0.000	0.000	0.000	0.033	0.000	0.000	0.000	0.000	0.000
		Mean	1.5	2.3	0.03	0.070	0.058	0.027	0.296	0.069	0.043	0.073	0.055	0.004	0.000	0.027	0.030	0.000	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000
Leards Bridge	9	SD	27.2	97.9	0.48	0.156	0.180	0.198	0.002	0.021	0.051	0.119	0.259	0.213	0.035	0.040	0.067	0.002	0.000	0.000	0.265	0.000	0.010	0.026	0.012	0.000
		Mean	2.3	7.6	0.12	0.040	0.077	0.096	0.007	0.014	0.059	0.125	0.216	0.110	0.067	0.035	0.073	0.005	0.000	0.000	0.075	0.000	0.016	0.053	0.021	0.000
Kennys Hole	9	SD	23.5	62.9	0.73	0.272	0.332	0.334	0.086	0.167	0.157	0.326	0.234	0.126	0.057	0.118	0.149	0.013	0.002	0.004	0.074	0.004	0.024	0.002	0.013	0.000
		Mean	2.0	6.9	0.18	0.129	0.155	0.112	0.064	0.072	0.046	0.135	0.195	0.062	0.039	0.067	0.093	0.017	0.006	0.009	0.058	0.012	0.065	0.006	0.028	0.000
Upper Kennys	4	Mean	30.8	60.8	0.31	0.069	0.120	0.165	0.216	0.021	0.822	0.996	0.004	0.000	0.000	0.000	0.174	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		SD	3.0	1.2	0.09	0.070	0.121	0.077	0.107	0.015	0.230	0.009	0.009	0.000	0.000	0.000	0.229	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mooney Tracks	4	Mean	12.8	33.3	0.40	0.338	0.657	0.375	0.003	0.069	0.019	0.076	0.700	0.038	0.000	0.000	0.056	0.000	0.000	0.000	0.187	0.000	0.000	0.000	0.000	0.000
		SD	1.7	4.5	0.24	0.046	0.136	0.082	0.005	0.040	0.024	0.089	0.227	0.075	0.000	0.000	0.072	0.000	0.000	0.000	0.145	0.000	0.000	0.000	0.000	0.000
Gill Road	4	Mean	25.1	43.1	0.24	0.361	0.046	0.234	0.325	0.047	0.619	0.900	0.100	0.000	0.000	0.000	0.281	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		SD	4.0	6.1	0.01	0.116	0.034	0.121	0.150	0.032	0.095	0.141	0.141	0.000	0.000	0.000	0.184	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Oates	2	Mean	41.1	95.0	0.10	0.111	0.000	0.271	0.052	0.270	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Mean	0.0	0.0	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Old Cardigan III	4	SD	31.8	82.3	0.28	0.472	0.431	0.515	0.035	0.162	0.177	0.321	0.365	0.142	0.061	0.016	0.045	0.017	0.082	0.000	0.094	0.000	0.000	0.000	0.000	0.000
		Mean	0.7	3.7	0.10	0.072	0.248	0.138	0.037	0.061	0.060	0.148	0.179	0.139	0.044	0.021	0.031	0.034	0.134	0.000	0.135	0.000	0.000	0.000	0.000	0.000
Lower Cranes	4	SD	29.9	58.8	0.35	0.417	0.326	0.380	0.068	0.132	0.311	0.436	0.297	0.004	0.029	0.209	0.122	0.000	0.004	0.000	0.020	0.004	0.000	0.000	0.000	0.000
		Mean	1.9	3.4	0.05	0.096	0.041	0.161	0.012	0.088	0.039	0.077	0.034	0.008	0.026	0.009	0.066	0.000	0.008	0.000	0.025	0.008	0.000	0.000	0.000	0.000
Cranes	9	SD	29.8	64.0	0.43	0.019	0.180	0.301	0.053	0.120	0.276	0.404	0.160	0.123	0.016	0.086	0.118	0.009	0.001	0.000	0.181	0.000	0.002	0.007	0.004	0.000
		Mean	2.6	4.1	0.28	0.030	0.108	0.082	0.031	0.073	0.064	0.056	0.090	0.107	0.020	0.052	0.078	0.016	0.004	0.000	0.097	0.000	0.007	0.017	0.007	0.000
Everglades	4	Mean	24.9	37.8	0.30	0.075	0.180	0.356	0.503	0.032	0.181	0.464	0.373	0.005	0.000	0.106	0.282	0.000	0.000	0.000	0.047	0.000	0.005	0.000	0.000	0.000
		SD	3.1	3.1	0.13	0.065	0.042	0.135	0.085	0.009	0.086	0.258	0.259	0.009	0.000	0.107	0.204	0.000	0.000	0.000	0.094	0.000	0.011	0.000	0.000	0.000
Martinvale	4	Mean	25.1	46.1	0.27	0.014	0.050	0.132	0.433	0.082	0.326	0.713	0.247	0.000	0.000	0.000	0.381	0.005	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000
		SD	2.4	4.7	0.11	0.028	0.016	0.083	0.169	0.036	0.078	0.242	0.227	0.000	0.000	0.000	0.320	0.011	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000
All sites	88	Mean	28.6	70.4	0.43	0.226	0.199	0.274	0.239	0.106	0.269	0.412	0.206	0.083	0.025	0.125	0.128	0.010	0.004	0.001	0.116	0.001	0.006	0.006	0.006	0.001
		SD	6.3	93.5	0.18	0.182	0.175	0.133	0.249	0.101	0.224	0.271	0.202	0.096	0.038	0.166	0.137	0.025	0.030	0.004	0.115	0.006	0.023	0.020	0.015	0.003

Table 2 (continued)

Site	N		Mean depth (cm)	Maximum depth (cm)	Current (m/s)	Proportion of banks with undercut >10 cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegeation	Proportion of bottom covered by instream cover	Proportion of bottom covered by															
											Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/Cobble	Gravel/boulder	Gravel/hardpan	Cobble boulder	Cobble/hardpan	Boulder/hardpan
Little Pierre Jacques River																										
1	7	Mean	29.3	53.0	0.50	0.107	0.876	0.099	0.016	0.125	0.325	0.743	0.131	0.099	0.000	0.000	0.358	0.059	0.000	0.000	0.028	0.000	0.000	0.000	0.000	0.000
		SD	4.7	4.5	0.57	0.140	0.056	0.041	0.017	0.057	0.075	0.177	0.112	0.082	0.000	0.000	0.172	0.066	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000
2	7	Mean	29.1	64.0	0.37	0.111	0.507	0.154	0.047	0.097	0.154	0.552	0.287	0.105	0.000	0.010	0.368	0.030	0.000	0.000	0.047	0.000	0.000	0.000	0.000	0.000
		SD	2.7	5.2	0.11	0.072	0.062	0.049	0.035	0.016	0.071	0.306	0.234	0.091	0.000	0.016	0.240	0.079	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000
3	7	Mean	18.9	55.0	0.29	0.188	0.609	0.091	0.009	0.063	0.260	0.604	0.253	0.092	0.000	0.000	0.319	0.025	0.000	0.000	0.051	0.000	0.000	0.000	0.000	0.000
		SD	3.0	4.3	0.14	0.130	0.069	0.041	0.006	0.016	0.334	0.271	0.150	0.099	0.000	0.000	0.243	0.056	0.000	0.000	0.066	0.000	0.000	0.000	0.000	0.000
4	7	Mean	23.5	44.4	0.19	0.098	0.763	0.047	0.001	0.066	0.702	0.926	0.060	0.003	0.000	0.010	0.210	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		SD	4.5	8.4	0.09	0.080	0.124	0.032	0.001	0.020	0.285	0.145	0.118	0.009	0.000	0.027	0.167	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
All sites	28	Mean	25.2	54.1	0.34	0.126	0.689	0.098	0.018	0.088	0.360	0.706	0.183	0.075	0.000	0.005	0.314	0.032	0.000	0.000	0.031	0.000	0.000	0.000	0.000	0.000
		SD	5.7	9.0	0.31	0.109	0.164	0.055	0.026	0.040	0.299	0.266	0.179	0.086	0.000	0.016	0.207	0.059	0.000	0.000	0.047	0.000	0.000	0.000	0.000	0.000
Enmore River																										
1	8	Mean	11.5	20.4	0.53	0.075	0.255	0.110	0.023	0.053	0.020	0.201	0.044	0.097	0.000	0.301	0.172	0.010	0.000	0.000	0.333	0.000	0.000	0.000	0.024	0.000
		SD	4.7	5.9	0.18	0.090	0.172	0.059	0.018	0.036	0.022	0.201	0.060	0.116	0.000	0.150	0.201	0.027	0.000	0.000	0.290	0.000	0.000	0.000	0.068	0.000
2	8	Mean	15.3	26.3	0.37	0.097	0.374	0.074	0.025	0.031	0.105	0.428	0.173	0.073	0.000	0.192	0.323	0.000	0.000	0.000	0.123	0.000	0.011	0.000	0.000	0.000
		SD	6.5	9.4	0.17	0.083	0.180	0.044	0.024	0.018	0.066	0.253	0.142	0.057	0.000	0.118	0.225	0.000	0.000	0.000	0.112	0.000	0.030	0.000	0.000	0.000
3	8	Mean	38.0	67.1	0.10	0.049	0.049	0.132	0.024	0.059	0.957	0.994	0.006	0.000	0.000	0.000	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		SD	9.3	16.1	0.09	0.137	0.067	0.059	0.016	0.010	0.090	0.018	0.018	0.000	0.000	0.000	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	8	Mean	37.4	70.9	0.09	0.069	0.081	0.131	0.106	0.082	0.779	0.961	0.000	0.019	0.000	0.000	0.105	0.078	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000
		SD	5.8	9.0	0.04	0.040	0.077	0.035	0.046	0.055	0.082	0.073	0.000	0.027	0.000	0.000	0.106	0.100	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.000
All sites	32	Mean	25.5	46.2	0.28	0.072	0.190	0.112	0.045	0.056	0.465	0.646	0.056	0.047	0.000	0.123	0.159	0.022	0.000	0.000	0.119	0.000	0.003	0.000	0.006	0.000
		SD	14.0	25.5	0.23	0.091	0.186	0.053	0.045	0.038	0.421	0.381	0.102	0.074	0.000	0.160	0.190	0.059	0.000	0.000	0.201	0.000	0.015	0.000	0.034	0.000
Ellerslie River																										
1	7	Mean	13.9	51.1	0.24	0.056	0.698	0.040	0.045	0.051	0.147	0.498	0.077	0.118	0.000	0.161	0.334	0.017	0.000	0.000	0.146	0.000	0.000	0.000	0.000	0.000
		SD	1.2	5.3	0.06	0.079	0.057	0.025	0.033	0.009	0.093	0.222	0.074	0.167	0.000	0.068	0.238	0.031	0.000	0.000	0.096	0.000	0.000	0.000	0.000	0.000
2	7	Mean	36.0	69.1	0.07	0.048	0.305	0.222	0.016	0.096	0.404	0.648	0.063	0.139	0.000	0.071	0.204	0.036	0.000	0.004	0.079	0.000	0.000	0.000	0.000	0.000
		SD	5.1	7.5	0.03	0.081	0.133	0.160	0.043	0.051	0.120	0.207	0.119	0.125	0.000	0.147	0.152	0.060	0.000	0.011	0.112	0.000	0.000	0.000	0.000	0.000
3	7	Mean	26.9	42.9	0.14	0.087	0.364	0.358	0.011	0.077	0.358	0.628	0.083	0.079	0.000	0.178	0.257	0.012	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000
		SD	2.2	3.9	0.06	0.084	0.045	0.192	0.016	0.026	0.145	0.115	0.111	0.086	0.000	0.092	0.135	0.021	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000
4	7	Mean	19.5	34.7	0.14	0.000	0.842	0.077	0.011	0.065	0.194	0.467	0.087	0.134	0.000	0.131	0.233	0.037	0.000	0.004	0.181	0.000	0.000	0.000	0.000	0.000
		SD	2.0	5.3	0.09	0.000	0.046	0.071	0.009	0.024	0.117	0.106	0.118	0.131	0.000	0.129	0.156	0.040	0.000	0.011	0.128	0.000	0.000	0.000	0.000	0.000
All sites	28	Mean	24.1	49.5	0.15	0.048	0.552	0.174	0.021	0.072	0.276	0.560	0.078	0.117	0.000	0.135	0.257	0.025	0.000	0.002	0.110	0.000	0.000	0.000	0.000	0.000
		SD	8.9	14.0	0.08	0.074	0.241	0.178	0.031	0.034	0.158	0.180	0.101	0.125	0.000	0.115	0.172	0.040	0.000	0.007	0.114	0.000	0.000	0.000	0.000	0.000

Table 2 (continued)

Site	N		Mean depth (cm)	Maximum depth (cm)	Current (m/s)	Proportion of banks with undercut >10 cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegeation	Proportion of bottom covered by instream cover	Proportion of bottom covered by: Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/Cobble	Gravel/boulder	Gravel/hardpan	Cobble boulder	Cobble/hardpan	Boulder/hardpan
Trout River (Coleman)																										
Bannys Hole	33	Mean	33.0	56.0	0.26	0.100	0.000	0.254	0.000	0.116	0.351	0.825	0.018	0.123	0.000	0.000	0.316	0.158	0.000	0.000	0.035	0.000	0.000	0.000	0.000	0.000
		SD																								
Seal River																										
1	5	Mean	16.5	29.8	0.51	0.080	0.254	0.411	0.108	0.060	0.056	0.360	0.585	0.000	0.000	0.000	0.289	0.014	0.000	0.000	0.055	0.000	0.000	0.000	0.000	0.000
		SD	3.7	9.3	0.22	0.130	0.183	0.254	0.087	0.031	0.053	0.123	0.094	0.000	0.000	0.000	0.092	0.032	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000
2	5	Mean	49.4	63.6	0.11	0.880	0.198	0.228	0.000	0.122	0.900	1.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		SD	7.3	8.9	0.04	0.110	0.287	0.143	0.000	0.149	0.224	0.000	0.000	0.000	0.000	0.000	0.224	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	5	Mean	13.4	22.1	0.31	0.420	0.048	0.137	0.002	0.095	0.197	0.640	0.267	0.038	0.000	0.000	0.435	0.008	0.000	0.000	0.047	0.000	0.000	0.000	0.008	0.000
		SD	3.2	4.2	0.13	0.084	0.063	0.029	0.005	0.115	0.044	0.278	0.217	0.067	0.000	0.000	0.272	0.017	0.000	0.000	0.070	0.000	0.000	0.000	0.017	0.000
4	6	Mean	24.2	33.5	0.16	0.283	0.141	0.261	0.000	0.176	0.353	0.793	0.126	0.052	0.010	0.000	0.371	0.069	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000
		SD	6.2	6.9	0.08	0.160	0.110	0.196	0.000	0.089	0.142	0.170	0.075	0.081	0.024	0.000	0.192	0.107	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000
All sites	21	Mean	25.8	37.1	0.29	0.410	0.159	0.260	0.026	0.116	0.376	0.703	0.239	0.024	0.003	0.000	0.302	0.025	0.000	0.000	0.030	0.000	0.000	0.000	0.002	0.000
		SD	15.0	17.2	0.21	0.318	0.181	0.191	0.061	0.106	0.344	0.284	0.247	0.056	0.013	0.000	0.228	0.063	0.000	0.000	0.053	0.000	0.000	0.000	0.008	0.000
Vernon River																										
1	5	Mean	20.7	49.2	0.78	0.283	0.212	0.438	0.006	0.019	0.000	0.000	0.333	0.324	0.000	0.000	0.000	0.000	0.000	0.000	0.344	0.000	0.000	0.000	0.000	0.000
		SD	1.3	5.0	0.11	0.046	0.306	0.182	0.013	0.014	0.000	0.000	0.378	0.335	0.000	0.000	0.000	0.000	0.000	0.000	0.244	0.000	0.000	0.000	0.000	0.000
2	6	Mean	44.2	68.4	0.19	0.203	0.013	0.162	0.007	0.028	0.317	0.777	0.206	0.000	0.000	0.000	0.460	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000
		SD	5.6	6.0	0.09	0.101	0.032	0.067	0.011	0.010	0.149	0.151	0.160	0.000	0.000	0.000	0.132	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000
3	6	Mean	19.8	35.3	0.30	0.219	0.221	0.627	0.000	0.111	0.224	0.481	0.183	0.069	0.014	0.147	0.185	0.071	0.000	0.000	0.098	0.000	0.000	0.000	0.007	0.000
		SD	2.4	1.0	0.13	0.123	0.205	0.097	0.000	0.070	0.102	0.118	0.026	0.078	0.022	0.197	0.150	0.051	0.000	0.000	0.067	0.000	0.000	0.000	0.017	0.000
4	6	Mean	26.2	57.3	0.33	0.236	0.022	0.164	0.127	0.148	0.384	0.752	0.181	0.012	0.006	0.044	0.368	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000
		SD	2.8	4.2	0.17	0.034	0.042	0.112	0.110	0.038	0.046	0.205	0.206	0.018	0.015	0.068	0.186	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000
All sites	23	Mean	28.0	52.7	0.42	0.233	0.113	0.344	0.036	0.079	0.242	0.524	0.221	0.092	0.005	0.050	0.264	0.019	0.000	0.000	0.104	0.000	0.001	0.000	0.002	0.000
		SD	10.7	13.2	0.27	0.085	0.194	0.232	0.077	0.068	0.168	0.335	0.213	0.196	0.014	0.117	0.219	0.040	0.000	0.000	0.174	0.000	0.007	0.000	0.009	0.000
All non-Morell sites	133	Mean	25.7	48.3	0.28	0.160	0.352	0.186	0.029	0.080	0.350	0.630	0.144	0.072	0.001	0.068	0.254	0.026	0.000	0.000	0.081	0.000	0.001	0.000	0.002	0.000
		SD	11.1	17.8	0.24	0.194	0.304	0.175	0.050	0.061	0.307	0.302	0.183	0.118	0.008	0.120	0.206	0.054	0.000	0.003	0.140	0.000	0.008	0.000	0.017	0.000
All sites	209	Mean	26.8	52.8	0.32	0.185	0.299	0.222	0.103	0.089	0.325	0.554	0.173	0.073	0.009	0.092	0.209	0.018	0.002	0.001	0.089	0.001	0.003	0.002	0.004	0.000
		SD	9.8	19.0	0.22	0.194	0.275	0.168	0.179	0.080	0.285	0.313	0.197	0.111	0.026	0.145	0.195	0.044	0.020	0.004	0.132	0.003	0.016	0.013	0.017	0.001

Table 3
Mean densities of brook trout and Atlantic salmon at electrofishing sites on Prince Edward Island.

River	Site	Dates	N	Density (fish 100 m^{-2})					
				Brook trout		Atlantic salmon		Sum	
				Mean	SD	Mean	SD	Mean	SD
Morell	Indian Bridge	Sep 1975	1	5.10		0.60		5.70	
Morell	Rowells Riffle	Aug-Oct 1985-2001	10	15.72	11.91	8.18	4.80	23.90	11.01
Morell	Mooneys Bridge	Aug-Sep1985-2001	7	5.82	0.69	5.30	5.62	11.11	5.74
Morell	Grants	Aug-Nov 1995-1997	4	8.49	1.64	7.57	2.68	16.06	3.65
Morell	Forks	Jul-Oct 1984-2001	10	9.48	4.97	29.13	12.89	38.61	14.83
Morell	Above Landing Pool	Aug-Nov 1995-1997	4	5.98	3.85	8.98	3.54	14.97	6.98
Morell	Lower Leards	23 Aug 1985	1	5.42		14.33		19.75	
Morell	Leards Bridge	Jul-Oct 1984-2001	11	2.91	2.90	31.97	8.56	34.88	8.85
Morell	Kennys Hole	Jul-Oct 1984-2001	11	35.86	13.49	38.34	45.82	74.20	51.41
Morell	Upper Kennys	Aug-Nov 1995-1997	4	30.72	13.41	7.56	5.43	38.29	14.66
Morell	Mooney Tracks	Aug-Nov 1995-1997	4	21.07	11.50	27.06	12.83	48.12	19.32
Morell	Gill Road	Aug-Nov 1995-1997	4	50.67	12.60	2.95	4.49	53.62	13.67
Morell	Oates	Aug-Nov 1995	2	13.28	9.39	4.80	1.57	18.08	10.96
Morell	Old Cardigan III	May-Nov 1994-1997	5	18.64	16.81	20.13	16.84	38.77	30.63
Morell	Smiths Spring	May 1994	1	34.86		1.36		36.22	
Morell	Lower Cranes	Aug-Nov 1995-1997	4	16.01	4.74	12.87	4.24	28.89	7.91
Morell	Cranes	Jul-Oct 1984-2001	11	33.25	32.17	19.47	9.96	52.72	40.51
Morell	Everglades	Aug-Nov 1995-1997	4	6.37	4.51	4.42	3.41	10.79	7.10
Morell	Martinvale	Aug-Nov 1995-1997	4	10.42	7.50	2.64	2.76	13.07	8.41
Morell	Mean, all sites	May-Nov 1984-2001	102	17.37	9.51	13.03	9.09	30.41	15.98
Mill	Upper stretch	Sep 1984	1	25.34		43.00		68.34	
Mill	Second stretch	Sep 1984	1	34.20		76.90		111.10	
Mill	Third stretch	Sep 1984	1	22.13		57.90		80.03	
Mill	Upper stretch	Aug 1985	1	53.73		47.50		101.23	
Mill	Second stretch	Aug 1985	1	33.25		92.70		125.95	
Mill	Third stretch	Aug 1985	1	50.64		46.60		97.24	
Mill	Fourth stretch	Aug 1985	1	55.34		32.90		88.24	
Mill	Fifth stretch	Aug 1985	1	24.61		52.30		76.91	
Mill	Mean	Aug-Sep 1984-1985	8	37.41	13.80	56.23	19.51	93.63	19.10
Little Pierre Jacques	1	Jun-Oct 1993-1995	7	32.94	18.32	1.78	1.47	34.72	18.97
Little Pierre Jacques	2	Jun-Oct 1993-1995	7	62.43	41.40	0.62	1.06	63.05	41.92
Little Pierre Jacques	3	Jun-Oct 1993-1995	7	33.06	15.23	0.73	1.36	33.79	16.42
Little Pierre Jacques	4	Jun-Oct 1993-1995	7	30.73	17.29	0.00	0.00	30.73	17.29
Little Pierre Jacques	Mean, all sites	Jun-Oct 1993-1995	28	39.79	23.06	0.78	0.97	40.57	23.65
Enmore	1	Jun-Oct 1993-1995	8	12.32	9.28	7.51	13.30	19.83	17.16
Enmore	2	Jun-Oct 1993-1995	8	12.18	7.00	4.65	5.48	16.83	9.59
Enmore	3	Jun-Oct 1993-1995	8	13.12	8.18	0.00	0.00	13.12	8.18
Enmore	4	Jun-Oct 1993-1995	8	25.73	9.73	0.26	0.74	25.99	9.60
Enmore	Mean, all sites	Jun-Oct 1993-1995	32	15.84	8.55	3.10	4.88	18.94	11.13
Ellerslie	1	Jun-Oct 1993-1995	7	32.87	5.14	0.00	0.00	32.87	5.14
Ellerslie	2	Jun-Oct 1993-1995	7	41.96	7.51	0.00	0.00	41.96	7.51
Ellerslie	3	Jun-Oct 1993-1995	7	74.99	19.72	0.00	0.00	74.99	19.72
Ellerslie	4	Jun-Oct 1993-1995	7	19.93	10.64	0.27	0.72	20.21	10.49
Ellerslie	Mean, all sites	Jun-Oct 1993-1995	28	42.44	10.75	0.07	0.18	42.51	10.71
Ellerslie	Hayes Brook	Aug-Sep 1947-1959	8	164.68	36.35	0.00	0.00	164.68	36.35
Ellerslie	Entire stream	1949-1958	10			61.81	60.02		
Trout (Coleman)	Bannys Hole	2 Oct 1993	1	51.04		28.87		79.91	
Dunk	Lower Dunk	1973	Many	5.95					
Dunk	Lower Dunk	1974	Many	24.07					
Dunk	All years	1973-1974		15.01	12.81				

Table 3 (continued)

River	Site	Dates	N	Density (fish 100 m^{-2})					
				Brook trout		Atlantic salmon		Sum	
				Mean	SD	Mean	SD	Mean	SD
Seal	1	May-Oct 1993-1995	6	76.62	45.84	0.00	0.00	76.62	45.84
Seal	2	May-Oct 1993-1995	6	57.01	47.77	0.00	0.00	57.01	47.77
Seal	3	May-Oct 1993-1995	6	52.34	23.80	0.00	0.00	52.34	23.80
Seal	4	May-Oct 1993-1995	6	22.77	15.07	0.00	0.00	22.77	15.07
Seal	Mean, all sites	May-Oct 1993-1995	24	52.19	33.12	0.00	0.00	52.19	33.12
Vernon	1	Jun-Oct 1993-1995	6	110.06	81.77	1.56	1.92	111.62	81.52
Vernon	2	Jun-Oct 1993-1995	6	73.22	30.94	0.61	0.95	73.83	31.18
Vernon	3	Jun-Oct 1993-1995	6	67.70	26.98	0.00	0.00	67.70	26.98
Vernon	4	Jun-Oct 1993-1995	6	129.64	22.62	0.32	0.79	129.97	22.87
Vernon	Mean, all sites	Jun-Oct 1993-1995	24	95.16	40.58	0.62	0.91	95.78	40.64
Orwell	MacPhails	Jul 1993	1	85.90		0.00		85.90	
Orwell	MacPhails	Jul 1994	1	61.78		0.00		61.78	
Orwell	Mean, all sites	Jul 1993-1994	2	73.84	17.06	0.00	0.00	73.84	17.06
Belle	Above bridge	22/Jul/1993	1	157.72		0.00		157.72	
Belle	Bridge at Martha Maine's	28/Jun/1994	1	131.60		0.00		131.60	
Belle	Mean, all sites	Jun-Jul 1993-1994	2	144.66	18.47	0.00	0.00	144.66	18.47
Montague	B	13/Jul/1988	1	55.00		0.00			
Montague	B	10/Jul/1989	1	30.80		0.00			
Montague	B	20/Jul/1990	1	31.90		0.00			
Montague	B, mean	Jul 1988-1990	3	39.23	13.67	0.00	0.00	39.23	13.67
Montague	C	1/Jul/1987	1	119.20		0.00			
Montague	C	14/Jul/1988	1	131.80		0.00			
Montague	C	26/Jul/1989	1	50.30		0.00			
Montague	C	19/Jul/1990	1	93.40		0.00			
Montague	C, mean	Jul 1987-1990	4	98.68	35.99	0.00	0.00	98.68	35.99
Montague	D1	8/Jul/1987	1	17.60		0.00			
Montague	D1	12/Jul/1988	1	75.30		0.00			
Montague	D1	27/Jun/1989	1	32.00		0.00			
Montague	D1	10/Jul/1990	1	26.20		0.00			
Montague	D1, mean	Jul 1987-1990	4	37.78	25.71	0.00	0.00	37.78	25.71
Montague	D2	22/Jun/1988	1	17.30		0.00			
Montague	D2	30/Jun/1989	1	37.50		0.00			
Montague	D2	12/Jul/1990	1	71.80		0.00			
Montague	D2, mean	Jun-Jul 1988-1990	3	42.20	27.55	0.00	0.00	42.20	27.55
Montague	E	6/Jul/1988	1	29.20		0.00			
Montague	E	17/Jul/1989	1	42.20		0.00			
Montague	E	13/Jul/1990	1	23.00		0.00			
Montague	E, mean	Jul 1988-1990	3	31.47	9.80	0.00	0.00	31.47	9.80
Montague	F	7/Jun/1987	1	29.90		0.00			
Montague	F	13/Jul/1988	1	68.40		0.00			
Montague	F	20/Jul/1989	1	66.60		0.00			
Montague	F	16/Jul/1990	1	61.20		0.00			
Montague	F, mean	Jun-Jul 1987-1990	4	56.53	18.01	0.00	0.00	56.53	18.01
Montague	G	2/Jul/1987	1	102.10		0.00			
Montague	G	19/Jul/1988	1	182.00		0.00			
Montague	G	19/Jul/1989	1	116.40		0.00			
Montague	G	18/Jul/1990	1	146.20		0.00			
Montague	G, mean	Jul 1987-1990	4	136.68	35.36	0.00	0.00	136.68	35.36

Table 3 (continued)

River	Site	Dates	N	Density (fish 100 m^{-2})					
				Brook trout		Atlantic salmon		Sum	
				Mean	SD	Mean	SD	Mean	SD
Montague	JOH 1	1/Jun/1989	1	25.50		0.00			
Montague	JOH 1	1/Jul/1989	1	42.60		0.00			
Montague	JOH 1	1/Aug/1989	1	52.30		0.00			
Montague	JOH 1	1/Jul/1990	1	152.80		0.00			
Montague	JOH 1	1/Aug/1990	1	84.20		0.00			
Montague	JOH 1, mean	Jun-Aug 1989-1990	5	71.48	50.23	0.00	0.00	71.48	50.23
Montague	JOH 2	1/Jun/1989	1	51.50		0.00			
Montague	JOH 2	1/Jul/1989	1	52.10		0.00			
Montague	JOH 2	1/Aug/1989	1	103.30		0.00			
Montague	JOH 2	1/Jul/1990	1	74.00		0.00			
Montague	JOH 2	1/Aug/1990	1	88.20		0.00			
Montague	JOH 2, mean	Jun-Aug 1989-1990	5	73.82	22.62	0.00	0.00	73.82	22.62
Montague	JOH 3	1/Jun/1989	1	27.40		0.00			
Montague	JOH 3	1/Jul/1989	1	45.80		0.00			
Montague	JOH 3	1/Aug/1989	1	62.70		0.00			
Montague	JOH 3	1/Jul/1990	1	63.20		0.00			
Montague	JOH 3	1/Aug/1990	1	88.60		0.00			
Montague	JOH 3, mean	Jun-Aug 1989-1990	5	57.54	22.75	0.00	0.00	57.54	22.75
Montague	JOH 4	1/Jun/1989	1	23.00		0.00			
Montague	JOH 4	1/Jul/1989	1	54.00		0.00			
Montague	JOH 4	1/Aug/1989	1	68.20		0.00			
Montague	JOH 4	1/Jul/1990	1	102.40		0.00			
Montague	JOH 4	1/Aug/1990	1	49.20		0.00			
Montague	JOH 4, mean	Jun-Aug 1989-1990	5	59.36	29.09	0.00	0.00	59.36	29.09
Montague	Mean, all sites	Jun-Aug 1987-1990	45	65.96	38.88	0.00	0.00	65.96	38.88
Valleyfield	Below G. Nickerson's	1979	1	19.40		0.00		19.40	
Valleyfield	Below Heatherdale Mill	19/Jul/1979	1	37.56		0.00		37.56	
Valleyfield	Mean, all sites	1979	2	28.48	12.84	0.00	0.00	28.48	12.84
Bristol Creek	Forestry road	25/May/1994	1	23.15		7.97		31.12	
Bristol Creek	Spring	25/May/1994	1	0.00		0.00		0.00	
Bristol Creek	Mean, all sites	25/May/1994	2	11.58	16.37	0.00	0.00	11.58	16.37
North Lake Creek	Head of tide	7/Aug/1990	1	35.25		10.59		45.84	
North Lake Creek	Below Dixon's Pond	24/May/1994	1	18.28		1.65		19.93	
North Lake Creek	Fountainload Spring	24/May/1994	1	12.45		0.00		12.45	
North Lake Creek	Mean, all sites	May-Aug 1990-1994	3	21.99	11.84	4.08	5.70	26.07	17.52

Table 4
Summary of mean densities of brook trout and Atlantic salmon at electrofishing sites on Prince Edward Island, 1973-2001.

River	Dates	N	Density (fish 100 m^{-2})					
			Brook trout		Atlantic salmon		Sum	
			Mean	SD	Mean	SD	Mean	SD
Morell	May-Nov 1984-2001	102	17.4	9.5	13.0	9.1	30.4	16.0
Mill	Aug-Sep 1984-1985	8	37.4	13.8	56.2	19.5	93.6	19.1
Little Pierre Jacques	Jun-Oct 1993-1995	28	39.8	23.1	0.8	1.0	40.6	23.6
Enmore	Jun-Oct 1993-1995	32	15.8	8.5	3.1	4.9	18.9	11.1
Ellerslie	Jun-Oct 1993-1995	28	42.4	10.8	0.1	0.2	42.5	10.7
Trout (Coleman)	2 Oct 1993	1	51.0		28.9		79.9	
Dunk	1973-1974	Many	15.0	12.8				
Seal	May-Oct 1993-1995	24	52.2	33.1	0.0	0.0	52.2	33.1
Vernon	Jun-Oct 1993-1995	24	95.2	40.6	0.6	0.9	95.8	40.6
Orwell	Jul 1993-1994	2	73.8	17.1	0.0	0.0	73.8	17.1
Belle	Jun-Jul 1993-1994	2	144.7	18.5	0.0	0.0	144.7	18.5
Montague	Jun-Aug 1987-1990	45	66.0	38.9	0.0	0.0	66.0	38.9
Valleyfield	1979	2	28.5	12.8	0.0	0.0	28.5	12.8
Bristol Creek	25/May/1994	2	11.6	16.4	0.0	0.0	11.6	16.4
North Lake Creek	May-Aug 1990-1994	3	22.0	11.8	4.1	5.7	26.1	17.5
All WI/RF sites		136	49.1		0.9		50.0	
All sites		303	47.5		7.6		57.5	

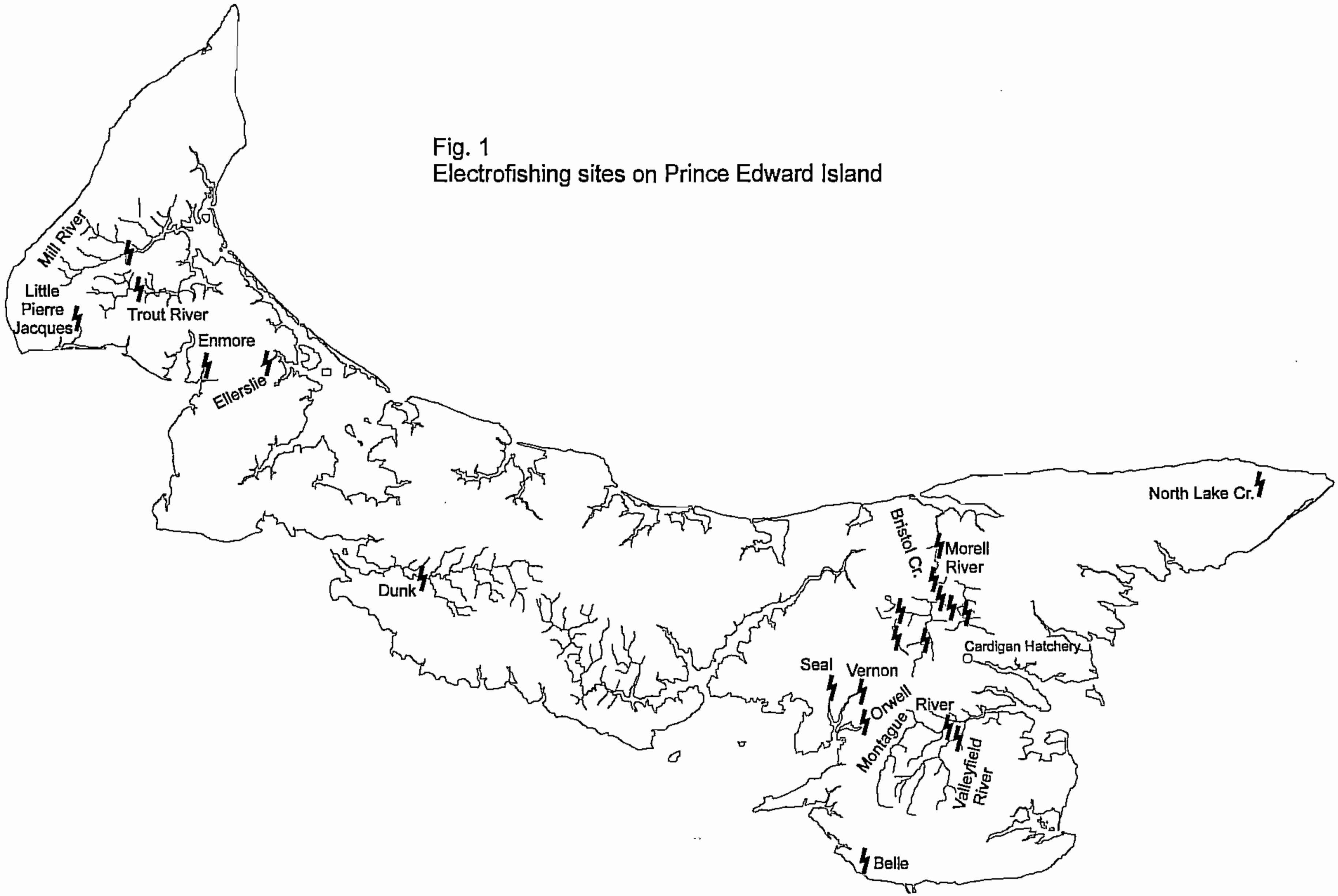
Table 5
Summary of densities of brook trout and Atlantic salmon by age and biomass density by species of fish at electrofishing sites on the Morell, Little Pierre Jacques, Enmore, Ellerslie, Trout, Seal, and Vernon Rivers.

River	N	Density (fish 100 m^{-2})							Biomass (g 100 m^{-2})					
		Brook trout					Atlantic salmon		Brook trout	Atlantic salmon	Three-spined stickle-back	American eel	Other	Total
		0+	1+	2+	3+	4++	0+	1++						
Morell	106	7.9	5.9	2.5	0.3	0.1	11.4	6.0	524	204.6	4.0	33.7	4.0	770
Little Pierre Jacques	28	18.4	19.4	2.0	0.0	0.0	0.3	0.5	802	8.2	1.4	0.0	0.5	812
Enmore	32	7.5	5.8	2.4	0.1	0.0	2.1	1.0	504	19.8	5.5	0.0	0.7	530
Ellerslie	28	22.3	17.8	2.2	0.1	0.1	0.1	0.0	945	0.1	3.6	0.0	0.2	949
Trout (Coleman)	1	22.7	24.3	3.0	0.5	0.5	26.8	2.1	1,660	138.5	25.2	0.0	0.0	1,824
Seal	24	36.5	14.3	1.4	0.0	0.0	0.0	0.0	679	0.0	10.1	0.0	8.1	697
Vernon	24	68.4	24.0	2.6	0.1	0.1	0.4	0.3	1,176	5.1	25.1	0.0	14.3	1,220
All WI/RF sites	27	30.6	16.3	2.1	0.1	0.0	0.6	0.4	821	6.6	9.1	0.0	4.8	842
All sites	243	26.2	15.9	2.3	0.1	0.1	5.9	1.4	899	53.7	10.7	4.8	4.0	972

Table 6
Mean densities of brook trout and Atlantic salmon from electrofishing surveys in New Brunswick and Nova Scotia.

River	Years	N	Fish 100 m^{-2}			Source
			Brook trout	Atlantic salmon	Sum	
Restigouche	1991-1996	72		78.7		A. Locke unpubl.
Jacquet	Aug 1984	15	9.2	7.7	16.9	Ritchie 1989
Nepisiguit	1991-1996			33.3		A. Locke unpubl.
Miramichi	1991-1996	240		116.7		D. Moore and G. Chaput unpubl.
Margaree	1957-1987	178	18.3	75.0	93.3	Chaput and Claytor 1989
St. Marys River	1969-1975	37	1.4	28.2	29.6	Gray et al. 1978
West R., Sheet Harbour	1966-1977	32	0.4	16.0	16.3	Gray et al. 1978
LaHave	1976-1977	16	0.6	14.0	14.6	Gray et al. 1978
Shubenacadie	1969-1977	12	21.8	35.3	57.1	Gray et al. 1978
Stewiacke	1984-1988	229	11.8	62.1	73.9	Amiro et al. 1989
Maccan	1966-1977	10	0.4	57.7	58.1	Gray et al. 1978
Saint John	1991-1996	259		31.3		L. Marshall and R. Jones unpubl.
Mean			8.0	46.3	54.3	
N.B. rivers, "Elson's norm"				67.0		Elson 1967

Fig. 1
Electrofishing sites on Prince Edward Island



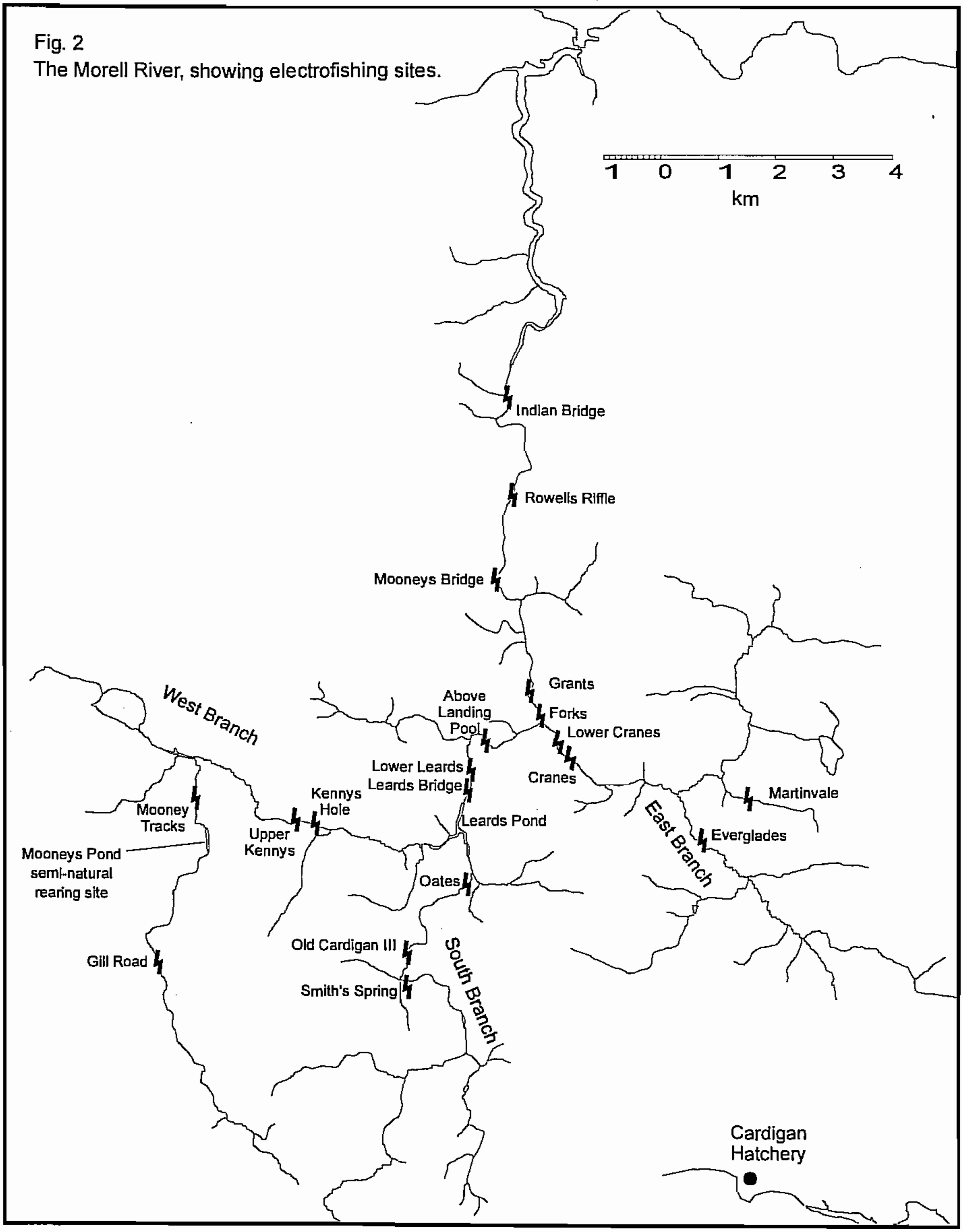


Fig. 2
The Morell River, showing electrofishing sites.

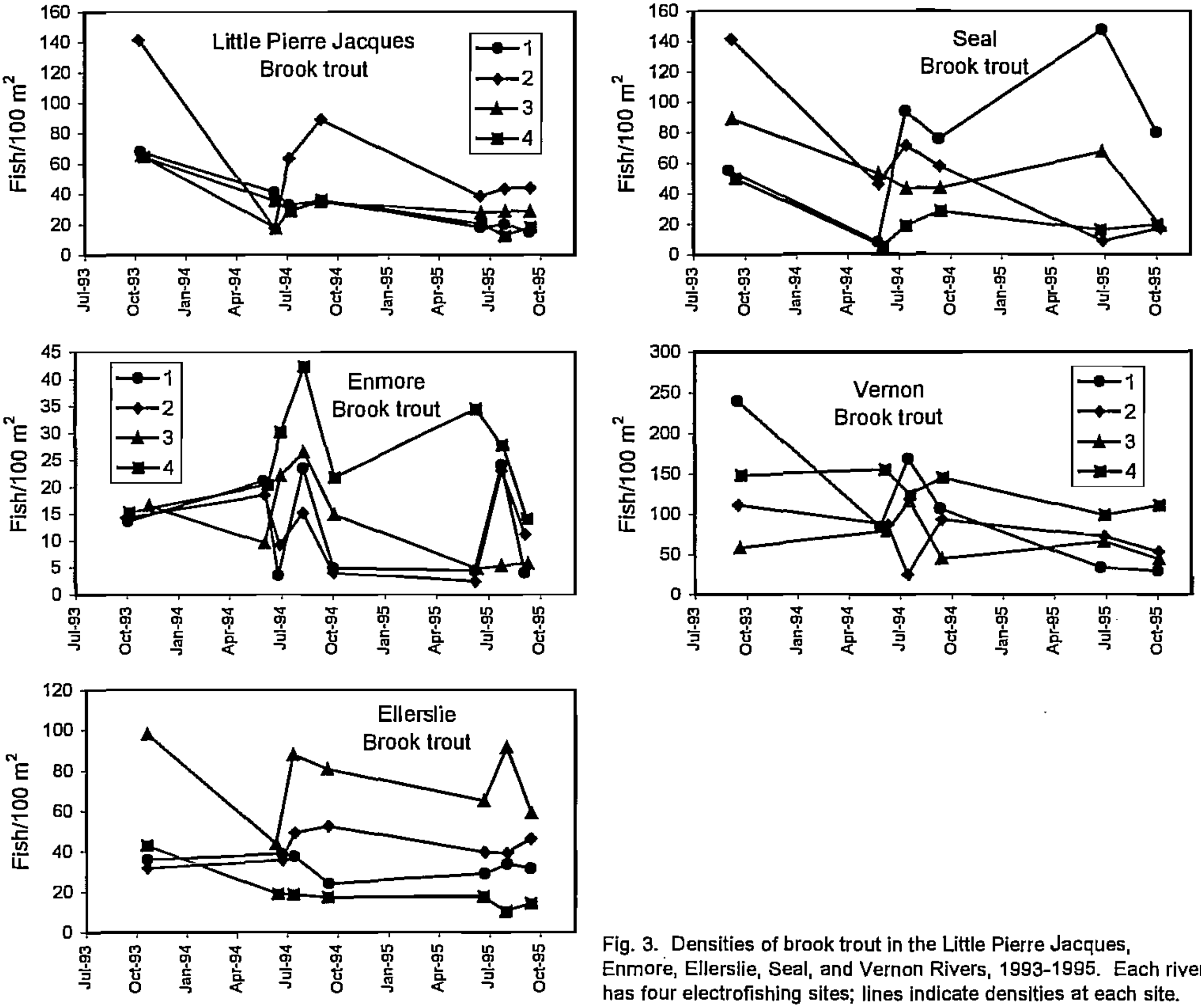


Fig. 3. Densities of brook trout in the Little Pierre Jacques, Enmore, Ellerslie, Seal, and Vernon Rivers, 1993-1995. Each river has four electrofishing sites; lines indicate densities at each site.

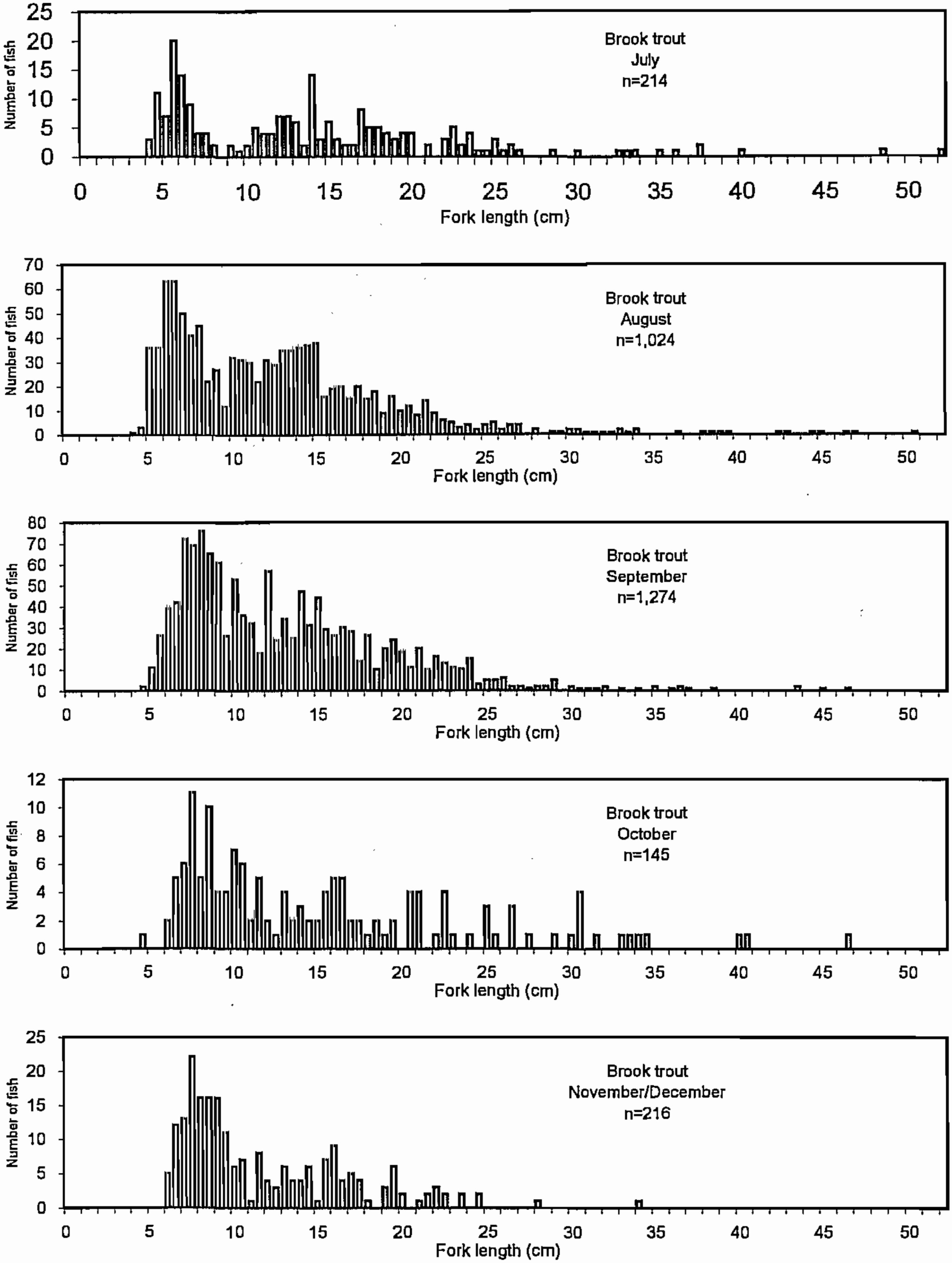


Fig. 4
Length frequencies of brook trout electrofished on the Morell River, 1984-2001.

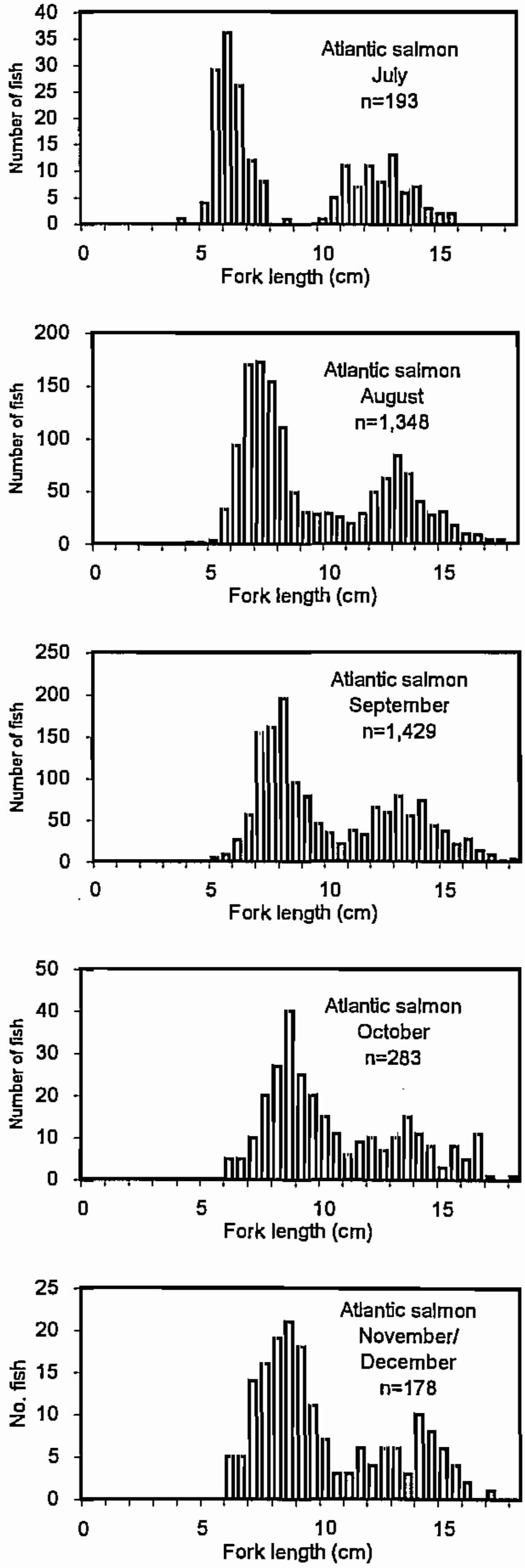


Fig. 5
Length frequencies of juvenile Atlantic salmon electrofished on the Morell River, 1984-2001.

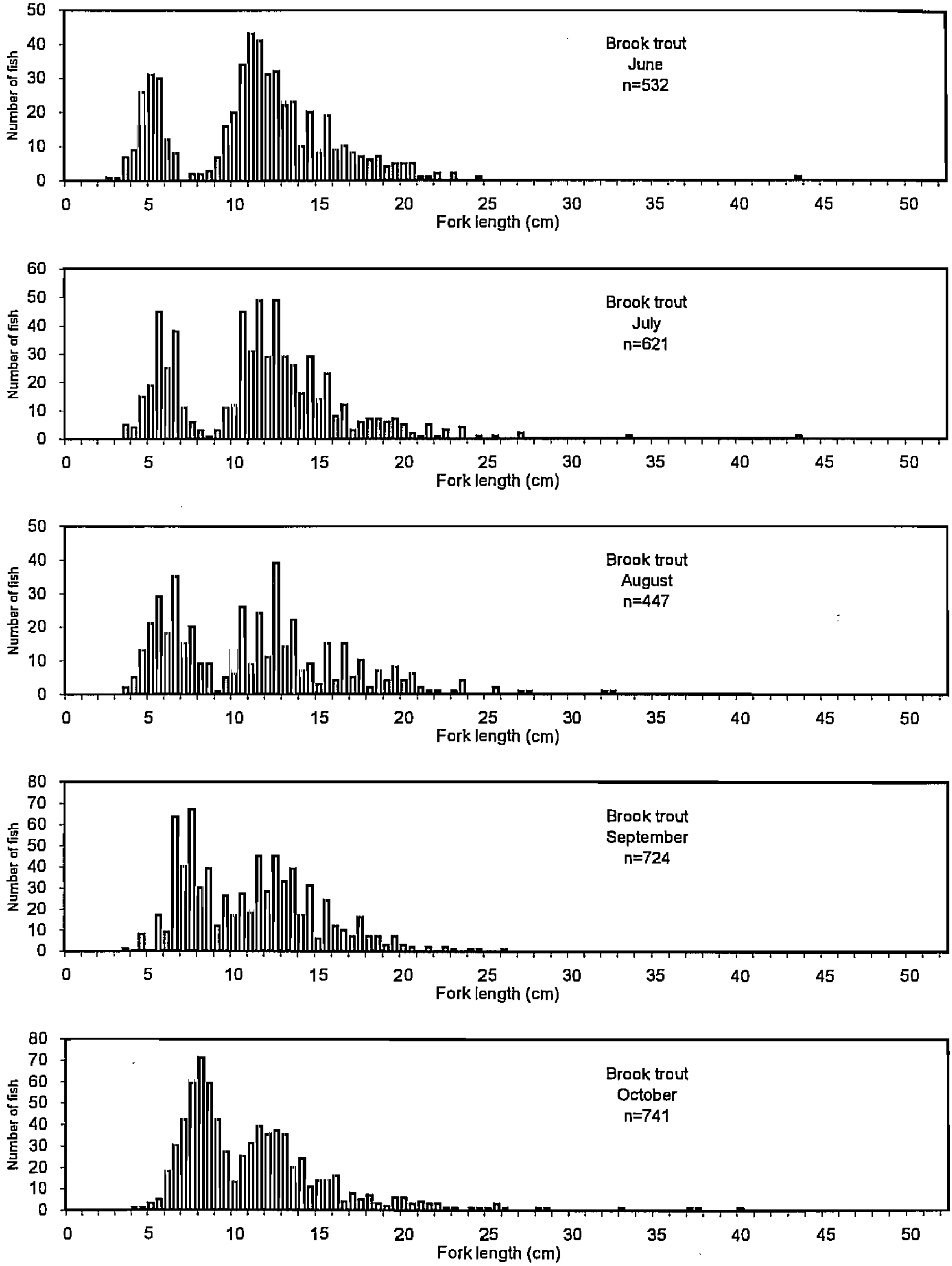


Fig. 6
Length frequencies of brook trout electrofished on the Little Pierre Jacques, Enmore, and Ellerslie Rivers, 1993-1995.

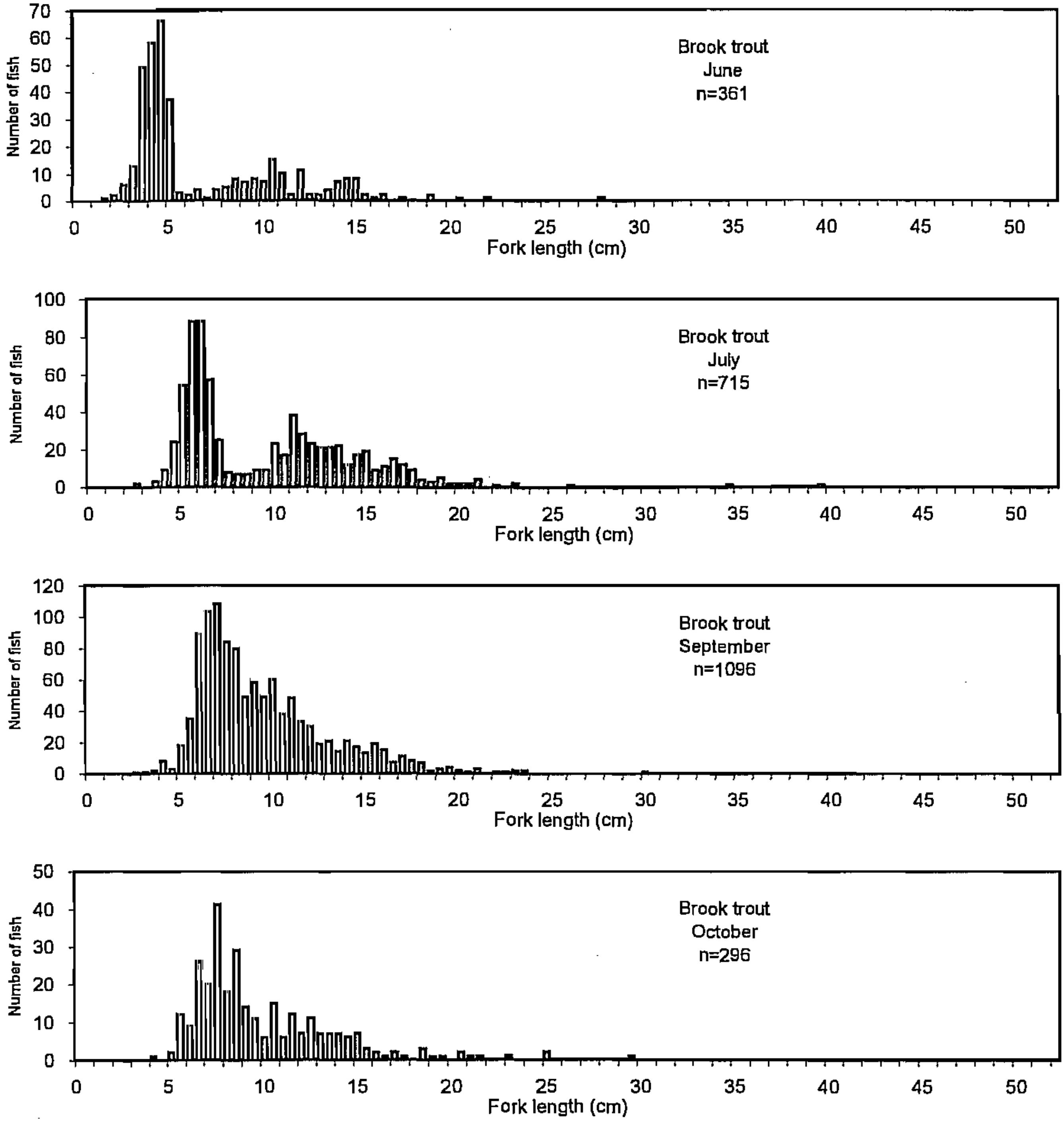


Fig. 7
Length frequencies of brook trout electrofished on the Seal and Vernon Rivers, 1993-1995.

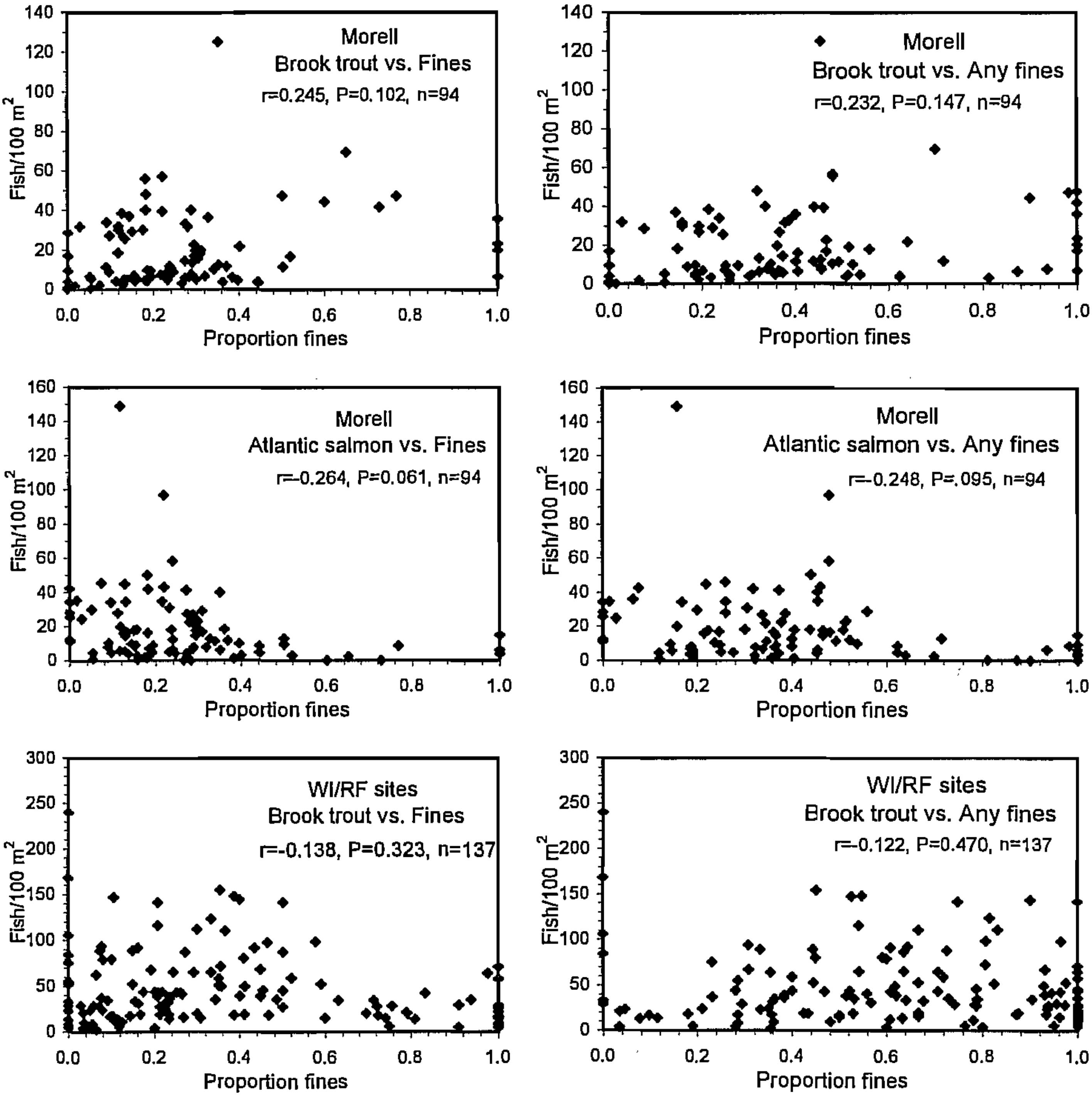


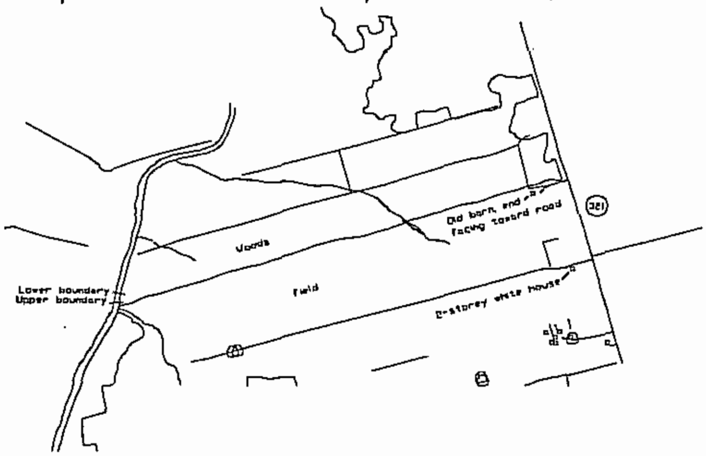
Fig. 8
Relation between densities of brook trout and Atlantic salmon and proportion of bottom covered in fines, on substrate types that include fines, in the Morell River and at WI/RF sites in the Little Pierre Jacques, Enmore, Ellerslie, Seal, and Vernon Rivers. P values are Bonferroni corrected.

Appendix 1.
Locations of electrofishing sites on the Morell, Mill, Little Pierre Jacques, Enmore, Ellerslie, Seal, and Vernon Rivers. All site lengths are measured along the mid-line of the stream, following all bends in the stream.

<u>Morell River</u>

Indian Bridge
The site is downstream from the bridge. Further details are unavailable (Ducharme 1977, L.J.A. Ducharme pers. comm.).

Rowells Riffle
This site is located on the Main Branch midway between Mooney's Bridge and Indian Bridge. The reference point for the upper boundary is an old barbed wire fence which follows the line between the field and woods, marked below, to the edge of the river. The old fence line meets the river at an old stump, which still has barbed wire attached. The upper boundary is 5.9 m downstream from this stump. The site is 21.3 m long. Access permission is required from Donald Rowell, the landowner.

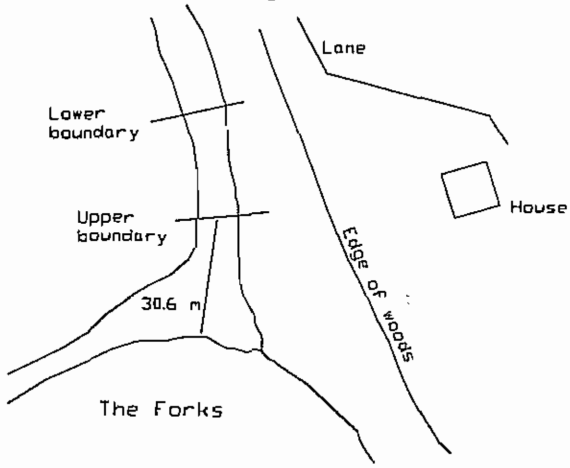


Mooneys Bridge
This site is located on the Main Branch just above Mooney's Road, an unnumbered seasonal road that runs west from the Bangor Road (Route 321). The site is located just south (upstream) from a washed-out bridge. In 1994, a stream deflector structure made of logs was installed on the east side of the river at the location of the old bridge pier. The lower barrier is located 11.2 m upstream from the point where this log structure meets the bank. The lower barrier is also located 19.2 m upstream from the point where this structure extends the greatest distance into the river. The site is 30.2 m long.

In 1975, Mooneys Bridge site was located downstream from the bridge. Further details are unavailable (Ducharme 1977, L.J.A. Ducharme pers. comm).

Grants
This site is located upstream from Grants Bridge, where the main branch of the Morell crosses Route 320. There are three landmarks to locate the lower boundary: a) The lower boundary is adjacent to the third utility pole along a laneway east of the river. The pole adjacent to the road counts as the first. The pole is marked P92 34-5. b) The lower boundary is adjacent to twin white birch trees which are located about halfway up the river bank. c) The lower boundary is 57 m upstream from the point where the river substantially changes in width (wide downstream, narrow upstream). The site is 30 m long.

Forks
This site is located just downstream from the confluence of the East and West Branches. The upper boundary is located 30.6 m downstream from the upstream bank of the pool formed at the confluence of the streams (see diagram). The site is 25.5 m long.



Above Landing Pool
This site is located between the confluence of the East and West Branches, and Leards Bridge. Upstream from the confluence, the West Branch runs straight for about a kilometer, and then takes a right-angle bend towards the northwest. The lower boundary is approximately 95 m upstream from this bend. The lower boundary is located at a marker indicating transect 27 of a stream survey. There is a tall spruce tree at this point, on the north side of the river. The lower boundary is 5.3 m downstream from an 8 m high white birch tree, which is the only white birch on the north bank of the river. The site is 30 m long. It is most easily accessed by a trail that runs from the road between Leards Pond and Riverton, to the river.

Leards Bridge
This site is located on the West Branch of the Morell at a washed-out bridge, just below Leards Pond. Distances are measured from a concrete abutment on the east side which formerly supported the bridge. The upper boundary is 9.7 m upstream from the upstream edge of the concrete abutment. The downstream boundary is 10.0 m downstream from the downstream edge of the concrete abutment. The site is 30.2 m long.

Kennys Hole
This site is located on the West Branch of the Morell at Kennys Road, an unnumbered road that runs between the crook in Route 22 at St. Theresa and the Peakes Road (Route 320). The site is downstream (east) of the road. The upper boundary runs across the stream at the lower edge of a small rock barrier. The distance between the north end of the upper boundary and the south edge of the road culvert is 10.6 m. The site is 42.4 m long.

Upper Kennys
The downstream boundary of this site is 10.1 m upstream from the north edge of the culvert on the west (upstream) side of Kennys Bridge. This distance is measured parallel to the bank. The site is 30 m long.

Mooney Tracks
This site is at the old railway bridge (now a trail), which is just downstream from Mooneys Pond. The upper boundary is 1 m downstream from the outer wing of the bridge's concrete abutment. The site is 30.6 m long.

Gill Road
This site is located on the stream that flows into Mooneys Pond. The first side road that meets Route 320, south of Route 22, is Route 214. The next side road to the south is unnumbered. This is a traveled road west of Route 320, and a dirt track to the east of it. The site is upstream from the point where the stream crosses the dirt track. The downstream boundary of the site is 49 m, straight-line distance, upstream from the culvert. The site is 30 m long.

Oates
This site is located on the South Branch of the Morell, just before it empties into Leards Pond. It is most easily accessed by a canoe launched from Leards Dam. Bear left when the pond forks, and continue until the pond narrows into a stream. The first tributary flows in from the east. Bear right to avoid this tributary. The next tributary also flows in from the east. The upstream boundary of the site is 29 m downstream from the confluence of the South Branch and this second tributary. The site is 30.7 m long.

Old Cardigan III
The South Branch of the Morell River crosses the Old Cardigan Road, which runs between Head of Cardigan and St. Theresa, three times. This site is just downstream (northeast) of the most downstream of the three crossings. The upper boundary is 7 m downstream from the main carrying beam of the bridge. The site is 29 m long.

Smiths Spring
This site is located on the loop of the South Branch of the Morell River that crosses to the southwest side of the Old Cardigan Road, and then crosses back to the northeast side. The site is approximately 200 m upstream from the most downstream of the three crossings of the Old Cardigan Road. There is a spring in the woods on the southwest side of the river, with a short (approximately 100 m) run to the river. The site consists of the spring and the first 35 m of the run to the river.

Lower Cranes
This site is located between the confluence of the West and East Branches of the Morell, and Cranes Bridge. The upper boundary is 217 m downstream from the edge of the pavement at Cranes Bridge. The upper boundary is 13 m upstream from the tip of a promontory on the west side of the stream. This point is covered with alders and marshy vegetation. The site is 30 m long.

Cranes
This site is located where the East Branch crosses Rte. 355, the first road above the Forks between the East and West Branches. The site is upstream (south) of the bridge. The west end of the lower boundary is 4.9 m upstream from the timbered wall of the bridge on the west side. The east end of the lower boundary is 2.3 m upstream from the timbered wall of the bridge on the east side. The upstream boundary is 5.2 m downstream from the sill of the old Crane's dam. The site is 41.1 m long.

Everglades
The upper boundary is 31.7 m downstream from the concrete wall of the Ducks Unlimited dam. The site is 35 m long.

Martinvale
This site is located on the East Branch, downstream from Route 321. The upper boundary is 13.4 m downstream from the culvert. The site is 31.6 m long.

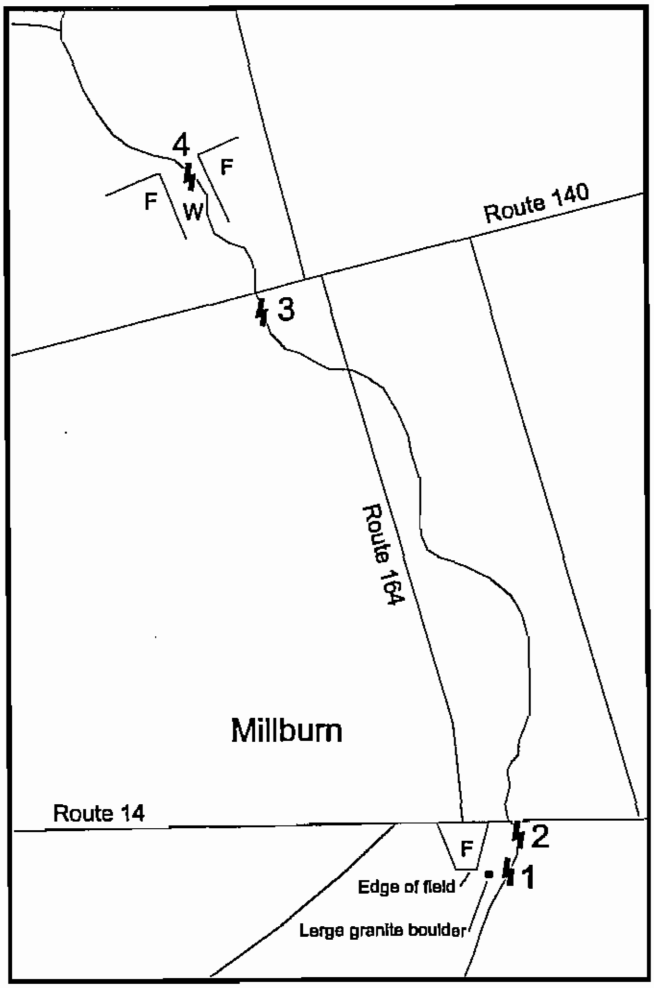
<u>Mill River</u>
Upper Stretch
The upper boundary of this site is just below the first islet downstream from the Duvar crossroad (Rte 148), which is the first bridge upstream from Bloomfield Provincial Park. The site is about 120 m downstream from the crossing.

Third Stretch
This site is just above the plunge pool of a former mill dam between Bloomfield Park and the Duvar crossroad.

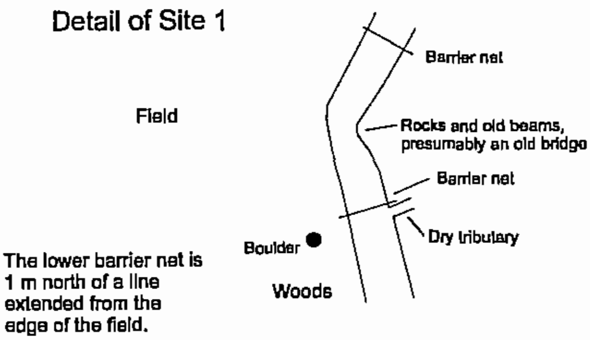
Fifth Stretch
Just above old water meter station in Bloomfield Provincial Park.

<u>Trout River</u> (Coleman)
Bannys Hole
This site is on the Trout River upstream from the Western Road (Route 2). Access is by a lane on Route 14, 1.25 km west of Route 2. The lower boundary is a farm bridge. The site is 35.7 m long.

<u>Little Pierre Jacques</u>
See map for overview.



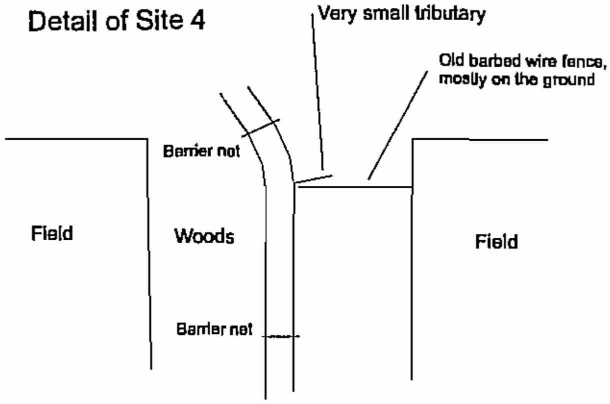
Site 1
This site is located below the bridge on Route 1. See map below. The site is 34.8 m long.



Site 2
The upper boundary of this site is 21.0 m downstream from the bridge on Route 14. The site is 29.2 m long.

Site 3
The upper boundary of this site is 14.7 m downstream from the lip of the culvert on Route 140.
The site is 25.2 m long.

Site 4
This site is located upstream from Route 140. The upstream boundary is 10.9 m upstream from the old barbed wire fence. See map below. The site is 25.7 m long.



Enmore River
Site 1
This site is accessed from a trail that leads off an unnumbered road that is south of and parallel to the Enmore River. The trail entrance is 1.1 km west of the Western Road (Route 2). The trail entrance is 15 m east of a large elm and 17 east of a culvert over a small stream that is a tributary of the Enmore. The upstream boundary of the site is 44 m downstream from the confluence of this small tributary with the Enmore. The site is 27.7 m long.

Site 2
This site is accessed by the same trail noted for Site 1. The downstream boundary of the site is 11 m upstream from the confluence of the small tributary with the Enmore. The site is 31.7 m long.

Site 3
This site is downstream from the point where the Enmore crosses under the Western Road. The upstream boundary is 10.3 m upstream from an old barbed wire fence that runs to the stream on the west side. The upstream boundary is also 13.5 m upstream from a large semi-dead elm with a large burl on the trunk, 15 m above the ground. The site is 32 m long.

Site 4
The lower boundary of this site is 25.0 m upstream from the overhead edge of the bridge across the Western Road. The site is 28.9 m long.

Ellerslie River
Site 1
This site is downstream from the confluence with Hayes Brook. The upper boundary is 20.5 m downstream from the upstream edge of Hayes Brook at the point where it empties into the Ellerslie. The lower boundary is 20 m upstream from a large boulder, 1 m in diameter, that lies

partially exposed on the north side of the stream. The site is 30.5 m long.

Site 2
The lower boundary of this site is 70 m upstream from the upstream edge of Hayes Brook at the point where it empties into the Ellerslie. There is a small island in the river. On the north side of this island, there are railway sleepers set in the streambed to assist in fish passage. The downstream boundary is 1.8 m upstream from the upstream end of this series of sleepers. A log is embedded across the streambed between the south side of the island and the mainland. The downstream boundary is 2.3 m upstream from this log. The site is 30 m long.

Site 3
The lower boundary of this site is 38.3 m upstream from the overhead arch of the old railway bridge that crosses Ellerslie River. The lower boundary is also 8.2 m upstream from old concrete stairsteps in the river. The upstream boundary is 0.6 m downstream from a large concrete slab in the river. The site is 30.5 m long.

Site 4
This site is upstream from the old railroad bridge. The lower boundary is 7.6 m upstream from a granite boulder of dimensions 50 cm x 65 cm, which is located in the middle of the stream. The upper boundary is directly opposite a 1 1/2 storey white house. The site is 28.5 m long.

<u>Seal River</u>
Site 1
The upstream boundary of this site is 9.7 m downstream from the lower edge of the culvert through which the Seal River passes under the Georgetown Road, Route 3. The site is 15.6 m long.

Site 2
The site is 15.0 m long.

Site 3
The site is 13.6 m long.

Site 4
The site is 14.3 m long.

<u>Vernon River</u>
Site 1
This site is downstream from Route 24.

Site 2
There is a small tributary which enters the Vernon from the south between Route 24 and the old railway bridge. This tributary crosses the Glencoe Road, Route 212. The site is downstream from the tributary. There is a field west of this tributary and south of the Vernon. A strip of woods lies between the field and the Vernon. Starting at the west end of the field, the field edge runs east, then north, and then east again. A line projected north from the field edge that runs north-south will meet the river. This is the location of the site's upper boundary. The lower boundary is 39 m upstream from some heavy beams which appear to be the remains of an old bridge.

Site 3
The reference point for this site is the tributary mentioned in Site 2 above. The lower boundary is 12.5 m upstream from the upstream edge of this tributary at the point where it enters the Vernon. The site is 16 m long.

Site 4
The upper boundary of this site is 26 m downstream from the centre pier of the old railway bridge. The site is 20.4 m long.

Appendix 2

Habitat characteristics of electrofishing sites on the Morell, Little Pierre Jacques, Enmore, Ellerslie, Trout, Seal, and Vernon Rivers.

															Proportion of bottom covered by															
Site	Habitat survey date	Water temperature	Length (m)	Mean width (m)	Mean depth (cm)	Maximum depth (cm)	Area (m^2)	Volume (m^3)	Current (m/s)	Proportion of banks with undercut > 10cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegetation	Proportion of bottom covered by instream cover	Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/cobble	Gravel/boulder	Gravel/hardpan	Cobble/boulder	Cobble/hardpan	Boulder/hardpan
Morell River																														
Indian Bridge	12 Sep 75	16	30.5	11.6			353.8																							
Mooneys Bridge	11 Sep 75	14.8	32.0	11.9			380.8																							
Grants	10 Sep 75	14.2	24.6	14.1			346.9																							
Forks	9 Sep 75	16	26.1	12.7			331.5																							
Leards Bridge	8 Sep 75	15	38.7	8.7			336.7																							
Forks	11 Sep 84	15					363.3																							
Leards Bridge	23 Aug 84	21					304.9																							
Kennys Hole	22 Aug 84	21					335.5																							
Cranes	30 Aug 84	NA					400.0																							
Rowells Riffle	5 Sep 85	NA					183.1																							
Mooneys Bridge	28 Aug 85	NA					374.0																							
Lower Leards	23 Aug 85	18.5					347.3																							
Leards Bridge	22 Aug 85	NA					541.2																							
Kennys Hole	21 Aug 85	21					466.0																							
Cranes	27 Aug 85	NA					400.0																							
Old Cardigan III	24 May 94	NA					264.0																							
Smiths Spring	24 May 94	NA	35.0				138.3																							
Rowells Riffle	7 Sep 94	15	21.3	15.2	32.9	56	307.1	10,088	0.404	0.00	0.12	0.09	0.60	0.58	0.184	0.184	0.146	0.194	0.010	0.262	0.000	0.000	0.000	0.000	0.184	0.000	0.010	0.000	0.010	0.000
Mooneys Bridge	6 Sep 95	15	30.2	11.1	23.9	43	293.3	7,001	0.503	0.00	0.33	0.05	0.03	0.01	0.054	0.118	0.226	0.097	0.000	0.000	0.065	0.000	0.000	0.000	0.462	0.000	0.000	0.065	0.032	0.000
Forks	1 Sep 94	15	25.5	15.4	21.5	38	369.9	7,960	0.558	0.25	0.02	0.25	0.45	0.51	0.271	0.373	0.203	0.076	0.000	0.237	0.065	0.000	0.000	0.017	0.059	0.000	0.034	0.000	0.017	0.000
Leards Bridge	24 Aug 94	18	30.2	7.2	28.9	108	200.2	5,788	0.447	0.11	0.15	0.23	0.00	0.01	0.000	0.000	0.277	0.323	0.015	0.031	0.000	0.000	0.000	0.000	0.308	0.000	0.000	0.046	0.000	0.000
Kennys Hole	23 Aug 94	16	42.2	4.7	23.6	67	188.1	4,444	0.655	0.17	0.26	0.18	0.07	0.06	0.118	0.157	0.157	0.157	0.020	0.235	0.020	0.000	0.000	0.020	0.000	0.000	0.196	0.000	0.078	0.000
Cranes	25 Aug 94	13	41.1	8.6	27.8	62	347.2	9,657	0.561	0.00	0.12	0.25	0.09	0.04	0.351	0.454	0.216	0.082	0.041	0.072	0.103	0.000	0.000	0.000	0.103	0.000	0.021	0.010	0.021	0.000
Rowells Riffle	4 Aug 95	NA	21.3	15.5	32.9	57	311.7	10,242	0.400	0.21	0.19	0.21	0.24	0.00	0.143	0.143	0.057	0.029	0.029	0.524	0.000	0.000	0.000	0.000	0.114	0.019	0.019	0.000	0.048	0.019
Grants	8 Aug 95	NA	30.0	12.7	36.1	61	343.7	12,396	0.545	0.06	0.03	0.38	0.10	0.15	0.231	0.250	0.037	0.065	0.000	0.630	0.019	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.009	0.000
Forks	31 Jul 95	NA	25.5	15.2	34.2	51	380.4	13,022	0.578	0.44	0.00	0.44	0.49	0.17	0.302	0.405	0.112	0.043	0.009	0.302	0.103	0.000	0.000	0.000	0.121	0.000	0.000	0.009	0.000	0.000
Above Landing Pool	8 Aug 95	NA	30.0	13.9	33.7	58	398.2	13,438	0.411	0.00	0.03	0.19	0.30	0.06	0.395	0.538	0.303	0.008	0.000	0.059	0.143	0.000	0.000	0.000	0.092	0.000	0.000	0.000	0.000	0.000
Leards Bridge	27 Jul 95	NA	30.2	7.7	31.0	110	204.1	6,324	0.526	0.11	0.07	0.32	0.00	0.01	0.016	0.063	0.063	0.286	0.206	0.000	0.032	0.016	0.000	0.000	0.222	0.000	0.000	0.159	0.000	0.000
Kennys Hole	24 Jul 95	NA	42.4	5.1	25.2	56	195.9	4,939	NA	0.46	0.12	0.52	0.01	0.10	0.148	0.222	0.204	0.204	0.130	0.074	0.037	0.019	0.019	0.000	0.111	0.037	0.000	0.019	0.000	0.000
Upper Kennys	10 Aug 95	NA	30.0	6.8	27.7	60	196.5	5,432	0.280	0.06	0.00	0.23	0.15	0.02	0.768	0.982	0.018	0.000	0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mooney Tracks	15 Aug 95	19	30.6	5.0	11.7	31	138.1	1,621	0.191	0.28	0.46	0.46	0.00	0.04	0.000	0.075	0.750	0.000	0.000	0.000	0.075	0.000	0.000	0.000	0.175	0.000	0.000	0.000	0.000	0.000
Gill Road	16 Aug 95	20	30.0	2.9	26.1	45	81.7	2,128	0.244	0.22	0.00	0.41	0.32	0.06	0.650	0.700	0.300	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Oates	22 Aug 95	NA	30.7	8.9	41.1	95	255.5	10,502	0.099	0.11	0.00	0.27	0.05	0.27	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Old Cardigan III	10 Aug 95	NA	29.0	5.5	32.9	81	152.6	5,020	0.178	0.44	0.09	0.67	0.09	0.25	0.182	0.318	0.455	0.045	0.068	0.023	0.068	0.068	0.000	0.000	0.091	0.000	0.000	0.000	0.000	0.000
Lower Cranes	9 Aug 95	NA	30.0	7.2	30.3	60	197.3	5,983	0.316	0.33	0.33	0.51	0.08	0.09	0.288	0.322	0.322	0.017	0.068	0.220	0.034	0.000	0.000	0.000	0.051	0.000	0.000	0.000	0.000	0.000
Cranes	27 Jul 95	NA	41.1	9.0	30.0	65	331.6	9,949	0.237	0.04	0.10	0.47	0.08	0.06	0.326	0.400	0.221	0.116	0.053	0.063	0.074	0.000	0.000	0.000	0.095	0.000	0.000	0.053	0.000	0.000
Everglades	7 Aug 95	NA	35.0	5.2	28.6	38	164.8	4,714	0.223	0.05	0.12	0.45	0.39	0.04	0.128	0.191	0.553	0.000	0.000	0.234	0.064	0.000	0.000	0.000	0.000	0.000	0.021	0.000	0.000	0.000
Martinvale	8 Aug 95	NA	31.6	5.6	25.3	46	149.4	3,783	0.153	0.00	0.04	0.12	0.36	0.03	0.383	0.404	0.574	0.000	0.000	0.000	0.000	0.021	0.000	0.000	0.021	0.000	0.000	0.000	0.000	0.000
Rowells Riffle	31 Oct 95	8	21.3	15.6	38.4	64	309.7	11,905	0.438	0.64	0.16	0.28	0.34	0.11	0.152	0.248	0.010	0.038	0.000	0.524	0.095	0.000	0.000	0.000	0.162	0.000	0.000	0.019	0.000	0.000
Grants	3 Nov 95	5	30.0	13.3	36.9	86	370.0	13,665	0.263	0.22	0.18	0.37	0.09	0.10	0.319	0.363	0.000	0.044	0.000	0.549	0.035	0.009	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000
Forks	31 Oct 95	8	25.5	15.8	29.8	48	373.5	11,122	0.317	0.56	0.21	0.40	0.42	0.23	0.215	0.455	0.099	0.017	0.008	0.140	0.215	0.008	0.017	0.000	0.264	0.008	0.000	0.008	0.000	0.000
Above Landing Pool	2 Nov 95	6	30.0	15.0	30.8	58	434.6	13,388	0.411	0.17	0.16	0.22	0.13	0.17	0.500	0.715	0.246	0.000	0.000	0.000	0.215	0.000	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.000
Leards Bridge	25 Oct 95	NA	30.2	7.4	30.1	100	203.8	6,137	0.368	0.11	0.26	0.30	0.00	0.04	0.000	0.000	0.164	0.361	0.049	0.049	0.000	0.000	0.000	0.000	0.377	0.000	0.000	0.000	0.000	0.000
Kennys Hole	26 Oct 95	6	42.4	5.0	21.9	57	202.2	4,419	0.532	0.42	0.50	0.50	0.01	0.24	0.132	0.245	0.302	0.151	0.019	0.170	0.113	0.000	0.000	0.000	0.113	0.000	0.000	0.000	0.000	0.000
Upper Kennys	1 Nov 95	5	30.0	6.6	35.0	62	190.2	6,651	0.405	0.17	0.03	0.12	0.14	0.01	0.519	1.000	0.000	0.000	0.000	0.000	0.481	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 2 (continued)

Site	Habitat survey date	Water temperature	Length (m)	Mean width (m)	Mean depth (cm)	Maximum depth (cm)	Area (m^2)	Volume (m^3)	Current (m/s)	Proportion of banks with undercut > 10cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegetation	Proportion of bottom covered by instream cover	Proportion of bottom covered by: Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/cobble	Gravel/boulder	Gravel/hardpan	Cobble/boulder	Cobble/hardpan	Boulder/hardpan
Morell River																														
Mooney Tracks	1 Nov 95	6	30.6	5.1	12.4	31	138.7	1,721	0.660	0.39	0.71	0.43	0.00	0.12	0.050	0.200	0.425	0.150	0.000	0.000	0.150	0.000	0.000	0.000	0.225	0.000	0.000	0.000	0.000	0.000
Gill Road	6 Nov 95	5	30.0	3.0	30.1	51	81.5	2,454	NA	0.50	0.06	0.17	0.15	0.06	0.727	1.000	0.000	0.000	0.000	0.000	0.273	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Oates	22 Aug 95	NA	30.7	8.9	41.1	95	255.5	10,502	0.099	0.11	0.00	0.27	0.05	0.27	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Old Cardigan III	1 Nov 95	6	29.0	5.4	31.7	85	148.9	4,720	0.367	0.56	0.45	0.47	0.01	0.12	0.095	0.167	0.214	0.262	0.071	0.000	0.046	0.000	0.024	0.000	0.286	0.000	0.000	0.000	0.000	0.000
Lower Cranes	2 Nov 95	4	30.0	7.7	32.4	63	210.3	6,811	0.385	0.56	0.27	0.53	0.05	0.26	0.369	0.492	0.246	0.000	0.015	0.200	0.108	0.000	0.015	0.000	0.031	0.015	0.000	0.000	0.000	0.000
Cranes	24 Oct 95	7	41.1	9.0	32.1	67	341.4	10,947	0.266	0.08	0.23	0.38	0.06	0.24	0.297	0.515	0.129	0.129	0.000	0.119	0.218	0.000	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000
Everglades	2 Nov 95	4	35.0	5.9	26.3	42	193.8	5,090	0.455	0.15	0.20	0.20	0.58	0.03	0.245	0.453	0.302	0.019	0.000	0.038	0.208	0.000	0.000	0.000	0.189	0.000	0.000	0.000	0.000	0.000
Martinvale	3 Nov 95	6	31.6	6.2	26.9	48	191.8	5,153	0.372	0.06	0.04	0.06	0.26	0.10	0.400	0.640	0.220	0.000	0.000	0.000	0.240	0.000	0.000	0.000	0.140	0.000	0.000	0.000	0.000	0.000
Rowells Riffle	4 Sep 96	NA	21.3	15.9	39.5	65	333.3	13,174	NA	0.43	0.13	0.13	0.65	0.11	0.150	0.187	0.383	0.000	0.037	0.393	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grants	21 Aug 96	NA	30.0	15.8	26.5	46	465.5	12,321	NA	0.50	0.31	0.40	0.63	0.09	0.287	0.338	0.154	0.000	0.000	0.507	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Forks	21 Aug 96	NA	25.5	15.9	26.3	46	404.6	10,631	NA	0.50	0.29	0.40	0.67	0.09	0.287	0.344	0.139	0.000	0.000	0.516	0.057	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Above Landing Pool	30 Aug 96	NA	30.0	14.2	30.6	53	377.7	11,572	0.455	0.06	0.08	0.25	0.71	0.02	0.443	0.623	0.361	0.008	0.000	0.008	0.160	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Leards Bridge	19 Aug 96	NA	30.2	8.7	25.9	100	234.3	6,059	NA	0.17	0.26	0.32	0.00	0.01	0.000	0.014	0.781	0.041	0.041	0.014	0.014	0.000	0.000	0.000	0.110	0.000	0.000	0.000	0.000	0.000
Kennys Hole	14 Aug 96	NA	38.5	5.5	25.1	76	201.3	5,050	NA	0.41	0.34	0.26	0.02	0.14	0.091	0.236	0.636	0.000	0.018	0.109	0.145	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Upper Kennys	19 Aug 96	NA	30.0	6.2	30.6	62	178.3	5,454	NA	0.06	0.23	0.23	0.37	0.01	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mooney Tracks	22 Aug 96	NA	30.8	4.7	11.7	31	130.0	1,521	NA	0.33	0.75	0.33	0.00	0.03	0.027	0.027	0.973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gill Road	28 Aug 96	NA	30.0	2.8	20.7	36	79.5	1,646	NA	0.33	0.05	0.14	0.30	0.00	0.500	1.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Old Cardigan III	15 Aug 96	NA	29.0	5.8	31.2	86	161.2	5,022	0.215	0.50	0.49	0.57	0.03	0.17	0.191	0.277	0.574	0.000	0.106	0.043	0.064	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lower Cranes	29 Aug 96	NA	30.0	7.1	28.4	56	193.3	5,490	NA	0.39	0.35	0.24	0.07	0.09	0.293	0.466	0.310	0.000	0.017	0.207	0.172	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cranes	20 Aug 97	NA	41.1	8.6	29.7	61	350.3	10,400	NA	0.00	0.30	0.34	0.03	0.01	0.236	0.438	0.348	0.067	0.000	0.067	0.202	0.000	0.000	0.000	0.079	0.000	0.000	0.000	0.000	0.000
Everglades	28 Aug 96	NA	35.0	6.0	22.1	36	194.3	4,287	NA	0.00	0.20	0.29	0.55	0.03	0.264	0.811	0.038	0.000	0.000	0.151	0.547	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Martinvale	26 Aug 96	NA	31.6	4.9	21.7	40	154.2	3,340	NA	0.00	0.04	0.10	0.45	0.09	0.282	0.872	0.128	0.000	0.000	0.000	0.590	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rowells Riffle	8 Sep 97	12.8	21.3	15.6	39.8	62	241.7	9,628	0.400	0.42	0.06	0.22	0.29	0.11	0.156	0.300	0.011	0.022	0.000	0.478	0.144	0.000	0.000	0.000	0.167	0.000	0.000	0.022	0.000	0.000
Grants	4 Sep 97	12.8	30.0	14.2	46.2	80	402.8	18,628	0.522	0.17	0.11	0.24	0.25	0.07	0.339	0.347	0.000	0.081	0.000	0.565	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000
Forks	4 Sep 97	NA	25.5	16.0	42.8	65	171.7	7,347	0.444	0.64	0.34	0.42	0.46	0.10	0.231	0.306	0.000	0.009	0.000	0.509	0.074	0.000	0.000	0.000	0.176	0.000	0.000	0.000	0.000	0.000
Above Landing Pool.	30 Aug 96	NA	30.0	14.2	30.6	53	377.7	11,572	0.455	0.06	0.06	0.25	0.71	0.02	0.443	0.623	0.361	0.008	0.000	0.008	0.160	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Leards Bridge	17 Sep 97	NA	30.2	8.8	27.7	100	235.4	6,517	0.353	0.24	0.29	0.06	0.02	0.03	0.000	0.000	0.386	0.314	0.000	0.029	0.000	0.000	0.000	0.000	0.243	0.000	0.000	0.029	0.000	0.000
Kennys Hole	28 Aug 97	18.1	42.4	5.2	25.7	70	219.6	5,646	0.545	0.17	0.64	0.35	0.09	0.11	0.125	0.214	0.446	0.161	0.107	0.071	0.089	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Upper Kennys	10 Sep 97	15.8	30.0	6.5	30.1	60	183.2	5,521	0.231	0.00	0.22	0.08	0.20	0.04	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mooney Tracks	4 Sep 97	15.1	30.8	5.2	15.3	40	141.9	2,178	0.343	0.35	0.71	0.28	0.01	0.08	0.000	0.000	0.651	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.349	0.000	0.000	0.000	0.000	0.000
Gill Road	25 Aug 97	14.1	30.0	2.8	23.7	41	76.5	1,811	0.233	0.39	0.08	0.21	0.52	0.07	0.600	0.900	0.100	0.000	0.000	0.000	0.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Old Cardigan III	16 Sep 97	13.8	29.0	5.7	31.7	78	161.3	5,105	0.375	0.39	0.69	0.35	0.01	0.11	0.239	0.522	0.217	0.261	0.000	0.000	0.000	0.000	0.283	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lower Cranes	29 Aug 96	NA	30.0	7.1	28.4	56	193.3	5,490	NA	0.39	0.35	0.24	0.07	0.09	0.293	0.466	0.310	0.000	0.017	0.207	0.172	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cranes	24 Sep 97	NA	41.1	9.5	35.6	73	382.7	13,624	0.226	0.04	0.40	0.24	0.05	0.12	0.129	0.366	0.079	0.396	0.000	0.030	0.238	0.000	0.000	0.000	0.129	0.000	0.000	0.000	0.000	0.000
Everglades	26 Aug 97	22.7	35.0	5.0	22.8	35	163.4	3,728	0.231	0.10	0.20	0.48	0.50	0.02	0.089	0.400	0.600	0.000	0.000	0.000	0.311	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Martinvale	26 Aug 97	19	31.6	5.6	26.4	51	148.1	3,915	0.286	0.00	0.07	0.25	0.66	0.11	0.239	0.935	0.065	0.000	0.000	0.000	0.696	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rowells Riffle	16 Sep 98	NA	21.9	15.3	30.1	50	310.3	9,353	0.319	0.14	0.06	0.13	0.65	0.06	0.117	0.146	0.039	0.097	0.097	0.223	0.029	0.000	0.000	0.000	0.233	0.019	0.049	0.029	0.068	0.000
Mooneys Bridge	9 Sep 98	NA	29.5	12.7	33.5	55	348.1	11,650	0.626	0.22	0.21	0.11	0.07	0.03	0.156	0.321	0.110	0.220	0.073	0.000	0.156	0.009	0.000	0.000	0.275	0.000	0.000	0.000	0.000	0.000
Forks	28 Sep 98	NA	25.5	15.6	26.4	48	371.0	9,796	0.535	0.50	0.02	0.33	0.72	0.19	0.298	0.512	0.058	0.058	0.041	0.165	0.165	0.025	0.000	0.025	0.124	0.000	0.017	0.000	0.017	0.008
Leards Bridge	17 Aug 98	NA	30.2	6.5	26.0	91	178.9	4,856	0.504	0.17	0.14	0.15	0.00	0.03	0.074	0.259	0.111	0.167	0.000	0.056	0.185	0.000	0.000	0.000	0.315	0.000	0.037	0.000	0.056	0.000
Kennys Hole	24 Aug 98	NA	42.4	4.8	24.5	63	195.2	4,783	0.869	0.25	0.29	0.32	0.10	0.24	0.180	0.480	0.100	0.080	0.060	0.140	0.280	0.020	0.000	0.000	0.080	0.000	0.020	0.000	0.040	0.000
Cranes	21 Aug 98	NA	40.1	8.8	28.3	62	305.6	8,647	NA	0.00	0.14	0.30	0.02	0.18	0.278	0.378	0.111	0.044	0.011	0.133	0.067	0.022	0.011	0.000	0.322	0.000	0.000	0.000	0.000	0.000
Rowells Riffle	21 Sep 99	13.1	22.0	15.5	30.2	57	310.0	9,365	0.332	0.14	0.06	0.12	0.67	0.04	0.173	0.192	0.163	0.125	0.115	0.202	0.019	0.000	0.000	0.000	0.135	0.010	0.010	0.019	0.029	0.000
Mooneys Bridge	20 Sep 99	12.8	29.5	13.1	31.9	52	361.9	11,561	0.370	0.17	0.20	0.12	0.07	0.05	0.179	0.357	0.152	0.198	0.063	0.009	0.170	0.009	0.000	0.000	0.223	0.000	0.000	0.000	0.000	0.000
Forks	15 Sep 99	17.7	25.7	15.7	25.0	48	390.8	9,753	NA	0.44	0.02	0.23	0.69	0.16	0.361	0.508	0.057	0.098	0.041	0.213	0.107	0.041	0.000	0.000	0.082	0.000	0.000	0.000	0.000	0.000
Leards Bridge	13 Sep 99	19.7	30.4	6.5	25.6	91	174.6	4,476	NA	0.17	0.12	0.10	0.00	0.02	0.130	0.259	0.185	0.148	0.000	0.093	0.130	0.000	0.000	0.000	0.241	0.000	0.037	0.000	0.037	0.000
Kennys Hole	10 Sep 99	17.2	42.7	4.5	23.5	59	181.2	4,263	NA	0.08	0.23	0.29	0.13	0.15	0.220	0.480	0.120	0.100	0.060	0.140	0.180	0.040	0.000	0.020	0.120	0.000	0.000	0.000	0.000	0.000
Cranes	14 Sep 99	14.5	40.2	8.6	29.6	61	342.2	10,116	NA	0.00	0.12	0.26	0.00	0.15	0.286	0.337	0.173	0.102	0.020	0.143	0.051	0.000	0.000	0.000	0.224	0.000	0.000	0.000	0.000	0.000

Appendix 2 (continued)

Site	Habitat survey date	Water temperature	Length (m)	Mean width (m)	Mean depth (cm)	Maximum depth (cm)	Area (m^2)	Volume (m^3)	Current (m/s)	Proportion of banks with undercut > 10cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegetation	Proportion of bottom covered by instream cover	Proportion of bottom covered by: Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/cobble	Gravel/boulder	Gravel/hardpan	Cobble/boulder	Cobble/hardpan	Boulder/hardpan
Morell River																														
Rowells Riffle	14 Sep 00	15	21.8	15.2	28.8	51	307.6	8,845	0.494	0.14	0.06	0.11	0.66	0.04	0.096	0.192	0.048	0.144	0.087	0.260	0.048	0.048	0.000	0.000	0.144	0.000	0.019	0.000	0.038	0.019
Mooneys Bridge	13 Sep 00	13.3	30.4	12.6	31.2	51	343.0	10,694	0.576	0.28	0.21	0.09	0.08	0.08	0.156	0.321	0.083	0.248	0.064	0.000	0.055	0.110	0.000	0.000	0.248	0.000	0.000	0.000	0.000	0.000
Forks	12 Sep 00	14.4	25.6	15.2	24.2	41	367.0	8,877	0.546	0.31	0.04	0.36	0.76	0.20	0.239	0.479	0.103	0.128	0.017	0.197	0.077	0.162	0.000	0.000	0.068	0.000	0.000	0.000	0.009	0.000
Leards Bridge	30 Aug 00	17.4	30.3	6.7	24.3	90	182.6	4,444	0.674	0.17	0.16	0.14	0.00	0.03	0.127	0.218	0.182	0.145	0.000	0.091	0.091	0.000	0.000	0.000	0.291	0.000	0.018	0.000	0.018	0.000
Kennys Hole	29 Aug 00	14.6	42.5	4.7	19.4	62	195.3	3,797	0.984	0.25	0.30	0.29	0.15	0.23	0.180	0.440	0.040	0.180	0.080	0.120	0.220	0.040	0.000	0.000	0.140	0.000	0.000	0.000	0.000	0.000
Cranes	11 Sep 00	13	40.0	8.6	26.9	65	302.4	8,131	0.862	0.00	0.13	0.26	0.08	0.16	0.273	0.386	0.080	0.068	0.000	0.148	0.068	0.045	0.000	0.000	0.307	0.000	0.000	0.000	0.011	0.000
Rowells Riffle	19 Sep 01	13.1	22.0	15.0	38.0	921	306.2	11,642	0.305	0.14	0.07	0.14	0.62	0.05	0.136	0.184	0.068	0.107	0.068	0.000	0.029	0.019	0.000	0.000	0.204	0.019	0.000	0.019	0.000	0.000
Mooneys Bridge	18 Sep 01	15	31.0	12.5	31.4	51	342.7	10,759	0.573	0.39	0.24	0.15	0.08	0.07	0.193	0.387	0.138	0.193	0.046	0.000	0.138	0.037	0.000	0.000	0.229	0.000	0.000	0.000	0.000	0.000
Forks	17 Sep 01	15	26.0	15.4	24.7	43	367.0	9,079	0.531	0.50	0.03	0.35	0.67	0.17	0.308	0.558	0.050	0.083	0.025	0.000	0.167	0.083	0.000	0.000	0.083	0.000	0.000	0.000	0.000	0.000
Leards Bridge	12 Sep 01	18	31.0	6.4	25.2	91	175.6	4,423		0.17	0.16	0.16	0.00	0.00	0.111	0.259	0.185	0.130	0.000	0.000	0.148	0.000	0.000	0.000	0.278	0.000	0.000	0.000	0.000	0.000
Kennys Hole	11 Sep 01	17.7	43.0	4.7	22.4	57	189.3	4,244	0.817	0.25	0.30	0.30	0.19	0.23	0.220	0.480	0.100	0.100	0.040	0.000	0.260	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000
Cranes	12 Sep 01	16	42.0	13.2	28.5	60	564.6	16,092		0.00	0.08	0.21	0.08	0.12	0.309	0.361	0.082	0.124	0.021	0.000	0.041	0.010	0.000	0.000	0.258	0.000	0.000	0.000	0.000	0.000
Little Pierre Jacques River																														
1	12 Oct 93	6	34.8	3.6	26.8	51	125.0	3,350	0.232	0.15	0.82	0.14	0.00	0.05	0.448	0.931	0.034	0.034	0.000	0.000	0.345	0.138	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	8 Oct 93	10	29.2	3.4	28.2	60	93.0	2,624	0.339	0.11	0.40	0.25	0.00	0.13	0.208	0.750	0.000	0.125	0.000	0.000	0.333	0.208	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.000
3	14 Oct 93	5	25.2	4.7	19.8	50	114.3	2,269	0.358	0.19	0.50	0.18	0.01	0.04	0.242	0.636	0.303	0.061	0.000	0.000	0.242	0.152	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	19 Oct 93	7	25.7	5.6	23.4	55	144.1	3,378	0.108	0.00	0.81	0.09	0.00	0.08	0.976	1.000	0.000	0.000	0.000	0.000	0.000	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	14 Jun 94	13	34.0	4.1	36.7	59	135.4	4,974	0.347	0.40	0.81	0.07	0.03	0.17	0.265	0.559	0.206	0.206	0.000	0.000	0.176	0.118	0.000	0.000	0.029	0.000	0.000	0.000	0.000	0.000
2	15 Jun 94	14	29.2	3.9	33.7	73	110.8	3,738	0.519	0.17	0.54	0.16	0.10	0.09	0.097	0.097	0.645	0.194	0.000	0.000	0.000	0.000	0.000	0.000	0.065	0.000	0.000	0.000	0.000	0.000
3	16 Jun 94	13	27.1	5.8	20.8	60	157.0	3,268	0.371	0.44	0.63	0.11	0.02	0.07	0.143	0.357	0.357	0.167	0.000	0.000	0.190	0.024	0.000	0.000	0.119	0.000	0.000	0.000	0.000	0.000
4	16 Jun 94	13	27.4	5.9	30.6	55	161.4	4,941	0.221	0.06	0.61	0.09	0.00	0.08	0.714	0.905	0.071	0.024	0.000	0.000	0.167	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	11 Jul 94	14	34.0	4.0	34.4	54	134.8	4,631	0.305	0.10	0.83	0.10	0.05	0.16	0.226	0.677	0.065	0.194	0.000	0.000	0.323	0.129	0.000	0.000	0.065	0.000	0.000	0.000	0.000	0.000
2	12 Jul 94	15	29.2	4.0	30.0	68	114.5	3,435	0.400	0.11	0.52	0.15	0.08	0.09	0.065	0.355	0.387	0.194	0.000	0.032	0.290	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000
3	13 Jul 94	14	27.1	4.8	18.6	60	125.6	2,335	0.385	0.25	0.66	0.07	0.00	0.08	0.059	0.294	0.353	0.206	0.000	0.000	0.235	0.000	0.000	0.000	0.147	0.000	0.000	0.000	0.000	0.000
4	14 Jul 94	14	27.4	5.4	24.9	41	145.5	3,617	0.217	0.13	0.89	0.02	0.00	0.09	0.757	0.973	0.027	0.000	0.000	0.000	0.162	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	7 Sep 84	11	34.0	3.8	25.1	57	124.7	3,133	0.198	0.05	0.87	0.03	0.00	0.19	0.344	0.531	0.313	0.156	0.000	0.000	0.156	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	6 Sep 94	12	29.2	3.7	28.2	61	103.7	2,922	0.232	0.22	0.48	0.16	0.03	0.08	0.074	0.333	0.444	0.185	0.000	0.000	0.259	0.000	0.000	0.000	0.037	0.000	0.000	0.000	0.000	0.000
3	7 Sep 94	11	27.1	4.7	15.2	54	122.5	1,856	0.000	0.06	0.69	0.09	0.01	0.08	0.091	0.364	0.424	0.212	0.000	0.000	0.273	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	9 Sep 94	12	27.4	4.9	21.6	35	133.3	2,903	0.175	0.06	0.81	0.06	0.00	0.09	0.938	1.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	28 Jun 95	12	34.0	3.8	30.2	52	128.4	3,881	0.309	0.05	0.94	0.09	0.01	0.09	0.387	0.871	0.097	0.032	0.000	0.000	0.484	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	27 Jun 95	11	29.2	3.7	30.6	86	106.2	3,266	0.376	0.11	0.59	0.10	0.05	0.10	0.207	0.621	0.241	0.034	0.000	0.034	0.414	0.000	0.000	0.000	0.069	0.000	0.000	0.000	0.000	0.000
3	29 Jun 95	14	27.1	4.7	18.2	58	125.5	2,278	0.399	0.13	0.58	0.09	0.01	0.06	0.212	0.788	0.121	0.000	0.000	0.000	0.576	0.000	0.000	0.000	0.091	0.000	0.000	0.000	0.000	0.000
4	30 Jun 95	14	27.4	4.9	26.2	41	132.1	3,459	0.095	0.13	0.85	0.02	0.00	0.04	0.697	1.000	0.000	0.000	0.000	0.000	0.303	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	10 Aug 95	17	34.0	3.4	24.0	45	115.5	2,768	0.286	0.00	0.93	0.10	0.01	0.06	0.300	0.667	0.200	0.033	0.000	0.000	0.367	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000
2	10 Aug 95	15	29.2	3.3	25.5	61	91.6	2,332	0.460	0.06	0.55	0.12	0.06	0.10	0.208	0.708	0.292	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	11 Aug 95	16	27.4	4.6	23.6	52	128.5	3,060	0.298	0.19	0.54	0.09	0.01	0.06	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	11 Aug 95	15	27.4	4.0	15.9	48	106.4	1,695	0.333	0.25	0.89	0.02	0.00	0.05	0.107	0.607	0.321	0.000	0.000	0.071	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	25 Sep 95	8	34.0	3.4	28.2	53	115.2	3,248	1.769	0.00	0.93	0.16	0.00	0.14	0.308	0.962	0.000	0.038	0.000	0.000	0.654	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	28 Sep 95	10	29.2	3.3	27.0	59	92.6	2,510	0.233	0.00	0.47	0.13	0.01	0.10	0.217	1.000	0.000	0.000	0.000	0.000	0.783	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	28 Sep 95	10	27.1	4.0	15.7	51	104.1	1,632	0.205	0.08	0.66	0.03	0.00	0.08	0.071	0.786	0.214	0.000	0.000	0.000	0.714	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	27 Sep 95	10	27.4	4.3	21.8	36	117.9	2,573	NA	0.06	0.88	0.02	0.00	0.08	0.724	1.000	0.000	0.000	0.000	0.000	0.276	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Enmore River																														
1	4 Oct 93	10	27.7	3.6	13.6	24	98.1	1,336	0.636	0.19	0.20	0.20	0.01	0.13	0.000	0.077	0.000	0.038	0.000	0.577	0.000	0.077	0.000	0.000	0.115	0.000	0.000	0.000	0.192	0.000
2	1 Oct 93	11	31.7	4.5	15.0	25	143.7	2,151	0.339	0.17	0.42	0.16	0.03	0.01	0.114	0.114	0.429	0.143	0.000	0.200	0.000	0.000	0.000	0.000	0.029	0.000	0.086	0.000	0.000	0.000
3	12 Nov 93	5	32.0	4.0	55.5	99	129.8	7,208	0.228	0.39	0.02	0.22	0.03	0.05	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	6 Oct 93	9	28.9	4.0	50.2	79	115.2	5,785	0.127	0.06	0.03	0.13	0.17	0.22	0.742	1.000	0.000	0.000	0.000	0.000	0.000	0.258	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 2 (continued)

Site	Habitat survey date	Water temperature	Length (m)	Mean width (m)	Mean depth (cm)	Maximum depth (cm)	Area (m^2)	Volume (m^3)	Current (m/s)	Proportion of banks with undercut > 10cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegetation	Proportion of bottom covered by instream cover	Proportion of bottom covered by															
															Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/cobble	Gravel/boulder	Gravel/hardpan	Cobble/boulder	Cobble/hardpan	Boulder/hardpan
Enmore River																														
1	6 Jun 94	18	28.5	3.8	18.4	28	106.3	1,953	0.713	0.17	0.09	0.06	0.03	0.03	0.034	0.034	0.034	0.069	0.000	0.069	0.000	0.000	0.000	0.000	0.793	0.000	0.000	0.000	0.000	0.000
2	8 Jun 94	13	32.0	4.9	28.3	44	157.0	4,448	0.582	0.22	0.24	0.04	0.02	0.03	0.103	0.179	0.333	0.154	0.000	0.103	0.077	0.000	0.000	0.000	0.231	0.000	0.000	0.000	0.000	0.000
3	9 Jun 94	14	32.6	4.3	47.8	84	141.2	6,744	0.221	0.00	0.00	0.06	0.02	0.05	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	13 Jun 94	18	28.0	3.4	38.2	76	96.0	3,664	0.117	0.13	0.04	0.15	0.05	0.05	0.792	1.000	0.000	0.000	0.000	0.000	0.000	0.208	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	3 Jul 94	20	28.5	4.1	10.8	21	115.4	1,246	0.600	0.06	0.09	0.05	0.03	0.03	0.033	0.033	0.000	0.067	0.000	0.200	0.000	0.000	0.000	0.000	0.700	0.000	0.000	0.000	0.000	0.000
2	5 Jul 94	19	32.0	4.6	15.6	27	148.6	2,312	0.320	0.11	0.25	0.04	0.02	0.03	0.056	0.361	0.139	0.111	0.000	0.111	0.306	0.000	0.000	0.000	0.278	0.000	0.000	0.000	0.000	0.000
3	6 Jul 94	20	32.6	3.6	39.6	65	118.9	4,706	0.069	0.00	0.00	0.10	0.03	0.05	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	7 Jul 94	20	28.0	3.3	34.7	83	92.0	3,191	0.106	0.06	0.04	0.16	0.10	0.05	0.909	0.955	0.000	0.045	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	15 Aug 94	18	28.5	3.2	6.5	13	89.3	580	0.329	0.00	0.12	0.17	0.02	0.05	0.000	0.045	0.000	0.091	0.000	0.409	0.045	0.000	0.000	0.000	0.455	0.000	0.000	0.000	0.000	0.000
2	15 Aug 94	19	32.0	2.2	7.1	15	80.0	566	0.150	0.00	0.09	0.05	0.08	0.00	0.179	0.500	0.107	0.071	0.000	0.107	0.321	0.000	0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.000
3	16 Aug 94	18	32.6	3.0	33.9	55	98.8	3,346	0.039	0.00	0.00	0.10	0.05	0.05	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	17 Aug 94	19	28.0	3.0	31.3	55	84.0	2,627	0.016	0.06	0.05	0.12	0.18	0.05	0.833	0.944	0.000	0.056	0.000	0.000	0.056	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	11 Oct 94	7	28.5	3.0	6.9	14	83.2	574	0.373	0.00	0.18	0.07	0.00	0.04	0.000	0.190	0.048	0.381	0.000	0.333	0.190	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000
2	11 Oct 94	7	32.0	3.9	13.0	22	127.0	1,651	0.203	0.06	0.31	0.05	0.00	0.06	0.200	0.800	0.100	0.033	0.000	0.067	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	12 Oct 94	7	32.6	3.1	33.1	53	102.5	3,395	0.033	0.00	0.00	0.08	0.00	0.07	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	12 Oct 94	7	28.0	2.8	32.5	71	78.0	2,537	0.122	0.13	0.00	0.19	0.08	0.06	0.789	1.000	0.000	0.000	0.000	0.000	0.158	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	22 Jun 95	19	28.5	3.3	11.3	23	91.0	1,027	0.475	0.00	0.40	0.08	0.04	0.02	0.000	0.280	0.120	0.040	0.000	0.240	0.280	0.000	0.000	0.000	0.320	0.000	0.000	0.000	0.000	0.000
2	22 Jun 95	20	32.0	3.9	13.8	28	127.2	1,752	0.427	0.06	0.54	0.08	0.02	0.04	0.065	0.355	0.194	0.032	0.000	0.355	0.290	0.000	0.000	0.000	0.085	0.000	0.000	0.000	0.000	0.000
3	26 Jun 95	21	32.6	3.2	34.9	64	106.4	3,718	0.070	0.00	0.08	0.15	0.02	0.06	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	23 Jun 95	19	28.0	3.1	38.1	66	85.8	3,269	0.041	0.06	0.12	0.09	0.09	0.08	0.632	0.789	0.000	0.053	0.000	0.000	0.158	0.000	0.000	0.000	0.158	0.000	0.000	0.000	0.000	0.000
1	7 Aug 95	18	28.5	2.8	7.3	14	75.5	551	0.313	0.00	0.43	0.10	0.05	0.04	0.050	0.350	0.150	0.050	0.000	0.300	0.300	0.000	0.000	0.000	0.150	0.000	0.000	0.000	0.000	0.000
2	7 Aug 95	18	32.0	3.3	10.0	16	107.4	1,070	0.320	0.00	0.61	0.12	0.02	0.04	0.000	0.333	0.083	0.042	0.000	0.375	0.333	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000
3	8 Aug 95	17	32.6	2.9	30.4	59	94.0	2,854	0.025	0.00	0.09	0.18	0.02	0.07	0.909	1.000	0.000	0.000	0.000	0.000	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	9 Aug 95	19	28.0	3.0	37.5	69	84.4	3,165	0.086	0.00	0.13	0.09	0.09	0.07	0.722	1.000	0.000	0.000	0.000	0.000	0.278	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	19 Sep 95	12	28.0	3.7	17.4	26	102.6	1,789	0.800	0.19	0.53	0.16	0.00	0.08	0.040	0.600	0.000	0.040	0.000	0.280	0.560	0.000	0.000	0.000	0.080	0.000	0.000	0.000	0.000	0.000
2	19 Sep 95	13	32.0	4.3	19.8	33	140.4	2,777	0.640	0.17	0.53	0.05	0.01	0.02	0.125	0.781	0.000	0.000	0.000	0.219	0.656	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	28 Sep 95	9	32.0	2.7	28.6	58	87.8	2,511	NA	0.00	0.19	0.19	0.02	0.07	0.750	0.950	0.050	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	22 Sep 95	14	28.0	3.3	36.4	68	93.2	3,391	0.069	0.06	0.24	0.12	0.10	0.06	0.810	1.000	0.000	0.000	0.000	0.000	0.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ellerslie River																														
1	27 Jun 94	5	30.5	5.6	15.4	56	172.4	2,660	0.220	0.17	0.62	0.08	0.07	0.05	0.292	0.708	0.000	0.000	0.000	0.250	0.417	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000
2	21 Oct 93	5	30.0	4.9	43.5	84	145.8	6,340	NA	0.22	0.20	0.51	0.00	0.11	0.143	0.286	0.321	0.000	0.000	0.071	0.143	0.000	0.000	0.000	0.321	0.000	0.000	0.000	0.000	0.000
3	20 Oct 93	8	30.0	3.4	26.3	49	100.2	2,640	0.199	0.22	0.29	0.53	0.02	0.06	0.154	0.641	0.000	0.000	0.000	0.179	0.487	0.000	0.000	0.000	0.179	0.000	0.000	0.000	0.000	0.000
4	20 Oct 93	8	28.2	4.2	18.9	45	116.9	2,207	0.129	0.00	0.79	0.12	0.01	0.04	0.400	0.514	0.000	0.086	0.000	0.400	0.057	0.029	0.000	0.029	0.000	0.000	0.000	0.000	0.000	0.000
1	27 Jun 94	19	30.5	5.6	15.4	56	172.4	2,680	0.220	0.17	0.62	0.08	0.07	0.05	0.234	0.383	0.128	0.149	0.000	0.170	0.106	0.043	0.000	0.000	0.170	0.000	0.000	0.000	0.000	0.000
2	28 Jun 94	21	30.0	4.7	36.4	71	140.6	5,115	0.081	0.06	0.22	0.11	0.00	0.08	0.486	0.730	0.000	0.189	0.000	0.027	0.081	0.162	0.000	0.000	0.054	0.000	0.000	0.000	0.000	0.000
3	17 Jun 94	18	30.0	3.4	29.8	46	99.7	2,987	0.192	0.06	0.35	0.32	0.01	0.10	0.200	0.400	0.320	0.200	0.000	0.080	0.160	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	20 Jun 94	17	28.5	4.4	23.6	38	124.0	2,932	0.306	0.00	0.82	0.22	0.01	0.07	0.212	0.424	0.121	0.152	0.000	0.091	0.152	0.061	0.000	0.000	0.212	0.000	0.000	0.000	0.000	0.000
1	20 Jul 94	18	30.5	4.9	14.5	47	152.4	2,215	0.173	0.06	0.71	0.02	0.08	0.07	0.077	0.231	0.026	0.258	0.000	0.231	0.077	0.077	0.000	0.000	0.256	0.000	0.000	0.000	0.000	0.000
2	22 Jul 94	20	30.0	4.4	37.1	68	131.5	4,873	0.058	0.00	0.26	0.18	0.00	0.08	0.412	0.818	0.029	0.324	0.000	0.000	0.147	0.059	0.000	0.000	0.029	0.000	0.000	0.000	0.000	0.000
3	18 Jul 94	19	30.0	3.1	25.0	40	90.1	2,248	0.138	0.11	0.36	0.10	0.00	0.10	0.500	0.727	0.045	0.182	0.000	0.045	0.182	0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	19 Jul 94	17	28.5	3.9	18.1	31	109.8	1,987	0.090	0.00	0.81	0.04	0.03	0.11	0.233	0.433	0.133	0.233	0.000	0.100	0.100	0.100	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000
1	22 Sep 94	9	30.5	5.0	12.6	42	154.3	1,945	0.338	0.00	0.70	0.02	0.00	0.06	0.079	0.211	0.105	0.421	0.000	0.132	0.132	0.000	0.000	0.000	0.132	0.000	0.000	0.000	0.000	0.000
2	21 Sep 94	9	30.0	3.3	26.5	59	120.0	3,178	0.080	0.00	0.14	0.00	0.11	0.00	0.485	0.667	0.000	0.273	0.000	0.000	0.182	0.000	0.000	0.000	0.081	0.000	0.000	0.000	0.000	0.000
3	19 Sep 94	9	30.0	3.0	25.5	38	86.7	2,207	0.088	0.17	0.37	0.09	0.04	0.11	0.409	0.591	0.091	0.091	0.000	0.227	0.182	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	20 Sep 94	8	28.5	4.1	20.3	35	113.6	2,310	0.058	0.00	0.81	0.05	0.00	0.08	0.100	0.500	0.033	0.367	0.000	0.033	0.333	0.067	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000
1	5 Jul 95	16	30.5	4.8	13.0	54	149.7	1,950	0.227	0.00	0.77	0.03	0.04	0.04	0.029	0.743	0.200	0.000	0.000	0.057	0.714	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	5 Jul 95	16	30.0	3.9	34.7	87	117.7	4,079	0.039	0.00	0.45	0.24	0.00	0.16	0.448	0.931	0.000	0.069	0.000	0.000	0.483	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	4 Jul 95	17	30.5	3.2	24.8	45	99.1	2,453	0.082	0.00	0.37	0.50	0.00	0.07	0.292	0.708	0.000	0.000	0.000	0.250	0.417	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000
4	4 Jul 95	17	30.0	3.7	18.3	32	110.9	2,024	0.106	0.00	0.88	0.04	0.01	0.05	0.143	0.286	0.321	0.000	0.000	0.071	0.143	0.000	0.000	0.000	0.321	0.000	0.000	0.000	0.000	0.000

Appendix 2 (continued)

Site	Habitat survey date	Water temperature	Length (m)	Mean width (m)	Mean depth (cm)	Maximum depth (cm)	Area (m²)	Volume (m³)	Current (m/s)	Proportion of banks with undercut > 10cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegetation	Proportion of bottom covered by instream cover	Proportion of bottom covered by: Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/cobble	Gravel/boulder	Gravel/hardpan	Cobble/boulder	Cobble/hardpan	Boulder/hardpan
Ellerslie River																														
1	15 Aug 95	14	30.5	4.9	13.3	54	153.1	2,041	0.308	0.00	0.74	0.03	0.04	0.04	0.154	0.641	0.000	0.000	0.000	0.179	0.487	0.000	0.000	0.000	0.179	0.000	0.000	0.000	0.000	0.000
2	15 Aug 95	15	30.0	4.5	38.1	68	138.2	5,271	0.133	0.06	0.39	0.21	0.00	0.13	0.400	0.514	0.000	0.086	0.000	0.400	0.057	0.029	0.000	0.029	0.000	0.000	0.000	0.000	0.000	0.000
3	14 Aug 95	15	30.0	3.1	30.0	42	90.2	2,710	0.216	0.06	0.34	0.47	0.00	0.07	0.435	0.609	0.087	0.000	0.000	0.304	0.174	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	13 Aug 95	16	28.5	3.5	18.7	30	100.0	1,866	0.189	0.00	0.88	0.04	0.01	0.05	0.037	0.481	0.000	0.000	0.000	0.185	0.444	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.000
1	27 Sep 95	11	30.5	4.7	13.0	49	147.0	1,915	0.175	0.00	0.72	0.04	0.01	0.05	0.162	0.568	0.081	0.000	0.000	0.108	0.405	0.000	0.000	0.000	0.243	0.000	0.000	0.000	0.000	0.000
2	26 Sep 95	11	30.0	4.3	35.8	67	127.8	4,574	0.048	0.00	0.48	0.29	0.00	0.11	0.455	0.788	0.091	0.030	0.000	0.000	0.333	0.000	0.000	0.000	0.091	0.000	0.000	0.000	0.000	0.000
3	29 Sep 95	11	30.0	3.5	26.9	40	102.9	2,770	0.100	0.00	0.45	0.49	0.00	0.04	0.520	0.720	0.040	0.080	0.000	0.160	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	29 Sep 95	11	28.5	3.6	18.7	32	105.2	1,963	0.070	0.00	0.91	0.03	0.00	0.06	0.233	0.633	0.000	0.100	0.000	0.033	0.400	0.000	0.000	0.000	0.233	0.000	0.000	0.000	0.000	0.000
Trout River (Coleman)																														
Bannys Hole	2 Oct 93	11	35.7	6.3	33.0	56	225.6	7,454	0.255	0.10	0.00	0.25	0.00	0.12	0.351	0.825	0.018	0.123	0.000	0.000	0.316	0.158	0.000	0.000	0.035	0.000	0.000	0.000	0.000	0.000
Seal River																														
1	3 Sep 93	12	15.6	3.2	15.7	24	50.3	825	0.743	0.00	0.23	0.21	0.16	0.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	7 Sep 93	19	15.5	3.1	47.0	54	47.7	2,907	0.148	0.80	0.00	0.24	0.00	0.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	9 Sep 93	12	13.4	5.8	15.5	26	77.3	1,065	0.437	0.40	0.00	0.14	0.00	0.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4	14 Sep 93	15	14.0	3.3	21.6	30	47.8	1,035	NA	0.00	0.00	0.00	0.00	0.00	0.357	0.929	0.071	0.000	0.000	0.000	0.357	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	30 May 94	11	15.6	3.5	16.6	30	49.8	825	0.743	0.00	0.23	0.21	0.16	0.06	0.000	0.286	0.643	0.000	0.000	0.000	0.214	0.071	0.000	0.000	0.071	0.000	0.000	0.000	0.000	0.000
2	31 May 94	14	15.0	3.5	55.4	72	52.5	2,907	0.148	0.80	0.00	0.24	0.00	0.10	0.500	1.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	1 Jun 94	NA	13.6	5.7	13.3	27	80.1	1,065	0.437	0.40	0.00	0.14	0.00	0.02	0.148	0.444	0.519	0.037	0.000	0.000	0.296	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	8 Jun 94	11	14.3	4.1	30.8	41	58.9	1,813	NA	0.40	0.23	0.34	0.00	0.20	0.118	0.765	0.235	0.000	0.000	0.000	0.647	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	20 Jul 94	17	15.6	3.4	15.1	22	48.6	733	0.743	0.00	0.24	0.22	0.17	0.07	0.077	0.308	0.692	0.000	0.000	0.000	0.231	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	21 Jul 94	14	15.0	3.5	54.5	63	52.5	2,859	0.148	0.80	0.00	0.24	0.00	0.10	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	21 Jul 94	15	13.9	5.7	13.4	22	81.6	1,097	0.437	0.50	0.00	0.14	0.00	0.02	0.259	0.963	0.037	0.000	0.000	0.000	0.704	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	20 Jul 94	NA	14.3	3.6	16.8	26	51.7	869	NA	0.40	0.18	0.39	0.00	0.23	0.467	0.933	0.067	0.000	0.000	0.000	0.467	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	19 Sep 94	8	15.6	3.2	11.0	19	45.6	501	0.446	0.00	0.28	0.26	0.18	0.07	0.000	0.231	0.615	0.000	0.000	0.000	0.231	0.000	0.000	0.000	0.154	0.000	0.000	0.000	0.000	0.000
2	20 Sep 94	8	15.0	3.3	50.6	70	48.0	2,427	0.067	1.00	0.00	0.06	0.00	0.00	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	20 Sep 94	11	13.6	5.5	14.0	21	76.5	1,071	0.133	0.30	0.04	0.09	0.00	0.28	0.217	0.609	0.391	0.000	0.000	0.000	0.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	21 Sep 94	8	14.3	3.7	19.2	27	54.6	1,048	0.080	0.30	0.21	0.41	0.00	0.24	0.500	0.938	0.063	0.000	0.000	0.000	0.438	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	9 Jul 95	NA	15.1	4.4	19.6	40	65.8	1,289	0.378	0.30	0.00	0.74	0.00	0.01	0.105	0.526	0.474	0.000	0.000	0.000	0.421	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	11 Jul 95	12	15.4	3.8	49.3	64	58.4	2,880	0.125	1.00	0.36	0.16	0.00	0.03	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	11 Jul 95	13	13.7	5.6	8.8	16	78.6	690	0.274	0.50	0.04	0.14	0.00	0.02	0.192	0.308	0.346	0.154	0.000	0.000	0.077	0.038	0.000	0.000	0.154	0.000	0.000	0.000	0.038	0.000
4	7 Jul 95	14	15.4	3.8	24.4	35	58.5	1,428	0.241	0.20	0.00	0.40	0.00	0.20	0.267	0.667	0.200	0.133	0.000	0.000	0.200	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	17 Oct 95	8	15.9	4.5	20.3	38	69.5	1,408	0.245	0.10	0.52	0.63	0.03	0.09	0.100	0.450	0.500	0.000	0.000	0.000	0.350	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000
2	23 Oct 95	0	8.0	3.3	37.1	49	50.9	1,887	0.070	0.80	0.63	0.45	0.00	0.38	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	23 Oct 95	8	15.3	5.5	17.7	25	84.4	1,494	0.255	0.40	0.15	0.17	0.01	0.14	0.167	0.875	0.042	0.000	0.000	0.000	0.708	0.000	0.000	0.000	0.083	0.000	0.000	0.000	0.000	0.000
4	17 Oct 95	9	15.0	3.9	32.3	42	58.1	1,876	0.172	0.40	0.23	0.02	0.00	0.19	0.412	0.529	0.118	0.176	0.059	0.000	0.118	0.000	0.000	0.000	0.118	0.000	0.000	0.000	0.000	0.000
Vernon River																														
1	2 Jun 94	17.5	16.6	5.5	22.0	53	91.7	2,017	0.976	0.25	0.00	0.60	0.00	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	16 Sep 93	14	16.2	6.6	40.8	65	106.5	4,346	0.312	0.08	0.00	0.08	0.00	0.03	0.300	0.667	0.333	0.000	0.000	0.000	0.367	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	20 Sep 93	10.5	16.0	4.5	22.8	35	72.4	1,651	0.131	0.20	0.00	0.64	0.00	0.18	0.350	0.400	0.150	0.000	0.000	0.400	0.000	0.050	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000
4	21 Sep 93	12	20.4	5.5	23.8	55	113.9	2,712	0.588	0.25	0.03	0.26	0.29	0.18	0.387	0.548	0.290	0.000	0.000	0.129	0.161	0.000	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000
1	2 Jun 94	14	16.6	5.5	22.0	53	91.7	2,017	0.976	0.25	0.00	0.60	0.00	0.01	0.000	0.000	0.967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.000	0.000	0.000	0.000
2	15 Jun 94	15	15.5	7.0	46.6	71	108.5	5,058	NA	0.20	0.00	0.08	0.00	0.03	0.273	0.636	0.364	0.000	0.000	0.000	0.364	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	14 Jun 94	15	17.1	4.8	21.0	36	79.9	1,680	0.398	0.33	0.24	0.67	0.00	0.07	0.080	0.600	0.200	0.000	0.000	0.040	0.440	0.080	0.000	0.000	0.160	0.000	0.000	0.000	0.000	0.000
4	10 Jun 94	14	19.1	5.7	29.7	64	108.7	3,223	NA	0.17	0.00	0.06	0.04	0.13	0.355	0.452	0.548	0.000	0.000	0.000	0.097	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	22 Jul 94	18	16.6	5.1	19.0	46	80.9	1,537	0.722	0.25	0.00	0.52	0.00	0.02	0.000	0.000	0.071	0.679	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000
2	22 Jul 94	19	15.5	6.7	37.8	65	103.8	3,929	NA	0.20	0.00	0.22	0.00	0.03	0.226	0.935	0.065	0.000	0.000	0.000	0.710	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	25 Jul 94	0	19.0	4.6	18.0	34	75.8	1,364	NA	0.25	0.26	0.56	0.00	0.07	0.208	0.542	0.208	0.208	0.042	0.000	0.208	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	26 Jul 94	20	19.1	5.0	24.1	52	95.1	2,294	NA	0.25	0.00	0.08	0.04	0.15	0.333	0.815	0.111	0.037	0.037	0.000	0.481	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 2 (continued)

															Proportion of bottom covered by															
Site	Habitat survey date	Water temperature	Length (m)	Mean width (m)	Mean depth (cm)	Maximum depth (cm)	Area (m^2)	Volume (m^3)	Current (m/s)	Proportion of banks with undercut > 10cm	Proportion of site covered by canopy	Proportion of site covered by overhanging vegetation	Proportion of bottom covered by aquatic vegetation	Proportion of bottom covered by instream cover	Fines	Fines, pure or mixed	Gravel	Cobble	Boulder	Hardpan	Fines/gravel	Fines/cobble	Fines/boulder	Fines/hardpan	Gravel/cobble	Gravel/boulder	Gravel/hardpan	Cobble/boulder	Cobble/hardpan	Boulder/hardpan
Vernon River																														
1	19 Sep 94	12	16.6	5.1	19.8	46	80.9	1,598	0.755	0.25	0.00	0.52	0.00	0.02	0.000	0.000	0.071	0.679	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000
2	22 Sep 94	9	15.5	6.9	39.5	60	104.8	4,138	0.100	0.10	0.00	0.19	0.00	0.03	0.161	0.645	0.355	0.000	0.000	0.000	0.484	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	22 Sep 94	12	17.1	4.5	16.0	35	74.3	1,185	0.200	0.00	0.27	0.61	0.00	0.07	0.174	0.522	0.174	0.087	0.043	0.000	0.217	0.130	0.000	0.000	0.174	0.000	0.000	0.000	0.000	0.000
4	23 Sep 94	10	19.1	5.4	23.3	56	102.9	2,392	0.200	0.25	0.00	0.07	0.04	0.15	0.400	0.900	0.100	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	6 Jul 95	16	17.0	5.7	21.1	56	97.1	2,052	0.773	0.33	0.40	0.42	0.00	0.01	0.000	0.000	0.161	0.226	0.000	0.000	0.000	0.000	0.000	0.000	0.613	0.000	0.000	0.000	0.000	0.000
2	12 Jul 95	14	16.0	7.0	50.3	75	111.2	5,594	0.184	0.30	0.00	0.16	0.02	0.01	0.355	0.806	0.097	0.000	0.000	0.000	0.452	0.000	0.000	0.000	0.097	0.000	0.000	0.000	0.000	0.000
3	12 Jul 95	19	16.0	5.2	20.8	37	82.8	1,720	0.372	0.20	0.00	0.50	0.00	0.06	0.333	0.542	0.208	0.042	0.000	0.042	0.167	0.042	0.000	0.000	0.125	0.000	0.000	0.000	0.042	0.000
4	13 Jul 95	NA	20.0	5.5	27.9	57	111.0	3,092	0.260	0.25	0.00	0.32	0.12	0.09	0.464	0.964	0.036	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	18 Oct 95	8	17.0	5.1	21.6	45	85.0	1,855	0.680	0.33	0.67	0.13	0.03	0.04	0.000	0.000	0.393	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.000	0.000	0.000	0.000	0.000
2	19 Oct 95	9	16.3	7.0	50.3	75	112.3	5,655	0.150	0.33	0.08	0.24	0.02	0.04	0.590	0.974	0.026	0.000	0.000	0.000	0.385	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	20 Oct 95	8	18.4	4.7	20.1	35	81.9	1,645	0.409	0.33	0.55	0.78	0.00	0.22	0.200	0.280	0.160	0.080	0.000	0.400	0.080	0.000	0.000	0.000	0.080	0.000	0.000	0.000	0.000	0.000
4	20 Oct 95	9	20.0	5.6	28.6	81	112.4	3,218	0.274	0.25	0.10	0.19	0.23	0.20	0.367	0.833	0.000	0.033	0.000	0.133	0.467	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 3

Counts of fish captured by electrofishing in the Morell, Little Pierre Jacques, Enmore, Ellerslie, Trout, Seal, and Vernon Rivers, by species and sweep number, 1975-2001.

Site	Electro-fishing date	Number of sweeps	Brook trout				Atlantic salmon				Rainbow trout				9-spined stickle.				3-spined stickle.				American eel				Red-bellied dace				Banded killifish				Alewife				Rainbow smelt				Brown trout			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Morell River																																														
Indian Bridge	12 Sep 75	4	12	2	1	5	2	0	0	0	0	0	0	0	3	3	1	6	0	0	0	0	19	19	15	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mooneys Bridge	11 Sep 75	5	13	6	4	1	1	3	1	0	0	0	0	0	4	3	3	1	0	0	0	0	11	4	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grants	10 Sep 75	5	13	8	3	2	7	2	3	0	0	0	0	0	11	6	3	7	0	0	0	0	4	8	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forks	9 Sep 75	5	16	13	10	2	13	5	0	1	0	0	0	0	5	1	0	1	0	0	0	0	14	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leards Bridge	8 Sep 75	5	5	4	4	0	3	5	2	1	0	0	0	0	0	0	0	2	0	0	0	0	20	10	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forks	11 Sep 84	4	5	3	5	2	25	22	10	1	0	0	0	0	0	0	0	0	0	0	0	0	8	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leards Bridge[a]	23 Aug 84	5	0	0	0	0	36	13	4	6	0	0	0	0	6	10	5	2	0	0	0	0	33	10	4	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kennys Hole[b]	22 Aug 84	5	7	7	6	1	4	1	2	1	0	0	0	0	1	3	2	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cranes[c]	30 Aug 84	6	7	7	4	3	16	9	2	0	0	0	0	0	6	3	0	0	0	0	0	0	33	7	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rowells Riffle[d]	5 Sep 85	5	12	3	4	2	10	5	3	4	0	0	0	0	0	1	0	0	0	0	0	0	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mooneys Bridge	28 Aug 85	4	16	1	1	2	6	6	8	2	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower Leards[e]	23 Aug 85	5	2	2	4	1	10	6	14	4	0	0	0	0	0	0	1	2	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leards Bridge[f]	22 Aug 85	5	9	5	2	3	27	29	23	12	0	0	0	0	0	5	0	0	0	0	0	0	42	21	20	15	0	0	0	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Kennys Hole[g]	21 Aug 85	4	68	39	13	21	4	5	1	1	0	0	0	0	6	17	3	7	0	0	0	0	6	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cranes[h]	27 Aug 85	5	17	9	10	7	11	2	4	1	0	0	0	0	1	1	0	0	0	0	0	0	6	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Old Cardigan III	24 May 94	1	22	NA	NA	NA	10	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smiths Spring	24 May 94	3	31	11	4	NA	0	0	1	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rowells Riffle	7 Sep 94	4	21	7	2	0	9	5	4	1	0	0	0	0	16	16	6	5	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mooneys Bridge	6 Sep 94	4	6	2	4	1	5	4	3	0	0	0	0	0	9	9	3	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forks	1 Sep 94	4	12	13	7	5	37	30	24	14	0	0	0	0	6	2	2	6	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leards Bridge	24 Aug 94	4	0	0	0	0	19	12	7	5	0	0	0	0	7	2	2	2	1	0	0	1	9	4	1	1	1	0	0	0	1	1	0	1	0	0	4	0	0	0	0	0	0	0	0	0
Kennys Hole	23 Aug 94	3	32	18	5	NA	77	60	39	NA	0	0	0	NA	14	20	27	NA	0	0	0	NA	2	3	2	NA	8	4	6	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Cranes	30 Aug 94	4	28	15	16	24	35	23	20	15	0	0	0	0	23	16	8	9	1	0	3	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rowells Riffle	27 Dec 94	1	7	NA	NA	NA	5	NA	NA	NA	0	NA	NA	NA	5	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Mooneys Bridge	23 Dec 94	1	1	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Forks	20 Dec 94	1	11	NA	NA	NA	8	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Leards Bridge	16 Dec 94	1	4	NA	NA	NA	13	NA	NA	NA	0	NA	NA	NA	16	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Kennys Hole	15 Dec 94	1	30	NA	NA	NA	20	NA	NA	NA	0	NA	NA	NA	13	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Cranes	16 Dec 94	1	23	NA	NA	NA	11	NA	NA	NA	0	NA	NA	NA	9	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Rowells Riffle	4 Aug 95	3	40	35	13	NA	21	8	1	NA	0	0	0	NA	2	5	5	NA	0	0	0	NA	4	0	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Grants	8 Aug 95	1	17	NA	NA	NA	9	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Forks	31 Jul 95	4	40	12	5	2	37	20	7	2	0	0	0	0	0	1	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Above Landing Pool	8 Aug 95	1	10	NA	NA	NA	21	NA	NA	NA	0	NA	NA	NA	6	NA	NA	NA	0	NA	NA	NA	3	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Leards Bridge	26 Jul 95	3	2	0	1	NA	22	17	10	NA	0	0	0	NA	1	4	2	NA	0	0	0	NA	2	4	2	NA	1	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Kennys Hole	24 Jul 95	3	24	14	8	NA	16	8	5	NA	0	0	0	NA	5	1	2	NA	0	0	0	NA	7	1	0	NA	8	6	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Upper Kennys	10 Aug 95	1	49	NA	NA	NA	9	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	13	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Mooney Tracks	15 Aug 95	1	21	NA	NA	NA	31	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Gill Road	11 Aug 95	1	30	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Oates	22 Aug 95	1	27	NA	NA	NA	8	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Old Cardigan III	10 Aug 95	1	39	NA	NA	NA	34	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Lower Cranes	9 Aug 95	1	14	NA	NA	NA	8	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Cranes	27 Jul 95	4	51	31	11	13	22	9	8	1	1	0	0	0	1	2	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Everglades	7 Aug 95	1	2	NA	NA	NA	5	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Martinvale	8 Aug 95	1	5	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	24	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Rowells Riffle	31 Oct 95	3	12	5	3	NA	16	7	3	NA	0	0	0	NA	1	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Grants	3 Nov 95	1	13	NA	NA	NA	15	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Forks	27 Oct 95	3	15	7	3	NA	63	33	16	NA	0	0	0	NA	0	0	2	NA	0	0	0	NA	0	0	0	NA	1	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Above Landing Pool	2 Nov 95	1	27	NA	NA	NA	30	NA	NA	NA	0	NA	NA	NA	6	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Leards Bridge	25 Oct 95	3	0	1	0	NA	30	17	9	NA	0	0	0	NA	0	1	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Kennys Hole	26 Oct 95	3	30	13	5	NA	20	9	3	NA	0	0	0	NA	2	2	0	NA	0	0	0	NA	0	0	0	NA	11	4	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA

Appendix 3 (continued)

Site	Electro-fishing date	Number of sweeps	Brook trout				Atlantic salmon				Rainbow trout				9-spined stickle.				3-spined stickle.				American eel				Red-bellied dace				Banded killifish				Alewife				Rainbow smelt				Brown trout			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Morell River																																																			
Upper Kennys	1 Nov 95	1	17	NA	NA	NA	3	NA	NA	NA	0	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	13	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Mooney Tracks	1 Nov 95	1	5	NA	NA	NA	22	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Gill Road	6 Nov 95	1	18	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Oates	7 Nov 95	1	9	NA	NA	NA	5	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Old Cardigan III	1 Nov 95	1	7	NA	NA	NA	27	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Lower Cranes	2 Nov 95	1	13	NA	NA	NA	13	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Cranes	24 Oct 95	3	26	15	10	NA	31	18	12	NA	0	0	0	NA	5	3	2	NA	0	0	0	NA	0	0	0	NA	3	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Everglades	2 Nov 95	1	9	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	7	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Martinvale	3 Nov 95	1	22	NA	NA	NA	3	NA	NA	NA	0	NA	NA	NA	10	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	22	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Rowells Riffle	4 Sep 96	3	8	5	2	NA	13	8	3	NA	0	0	0	NA	4	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Grants	21 Aug 96	1	19	NA	NA	NA	16	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Forks	21 Aug 96	3	18	6	4	NA	44	25	9	NA	0	0	0	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Above Landing Pool	30 Aug 96	1	8	NA	NA	NA	9	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Leards Bridge	19 Aug 96	3	0	0	0	NA	36	20	11	NA	0	0	0	NA	0	1	0	NA	0	0	0	NA	1	1	0	NA	1	0	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Kennys Hole	14 Aug 96	3	32	19	8	NA	16	5	0	NA	0	0	0	NA	1	1	0	NA	0	0	0	NA	0	0	1	NA	5	0	7	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Upper Kennys	19 Aug 96	1	22	NA	NA	NA	14	NA	NA	NA	0	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	7	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Mooney Tracks	22 Aug 96	1	22	NA	NA	NA	17	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Gill Road	28 Aug 96	1	20	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Old Cardigan III	15 Aug 96	1	8	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Lower Cranes	29 Aug 96	1	23	NA	NA	NA	15	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Cranes	20 Aug 96	3	24	10	4	NA	34	16	7	NA	0	0	0	NA	6	3	0	NA	0	0	0	NA	0	0	0	NA	2	0	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Everglades	28 Aug 96	1	3	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	2	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Martinvale	26 Aug 96	1	5	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	3	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	13	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Rowells Riffle	8 Sep 97	3	5	4	0	NA	30	10	3	NA	0	0	0	NA	7	3	4	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Grants	4 Sep 97	1	22	NA	NA	NA	24	NA	NA	NA	0	NA	NA	NA	4	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Forks	4 Sep 97	3	7	1	0	NA	29	13	6	NA	0	0	0	NA	2	1	0	NA	0	0	0	NA	0	0	0	NA	3	0	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Above Landing Pool	7 Sep 97	1	7	NA	NA	NA	17	NA	NA	NA	0	NA	NA	NA	7	NA	NA	NA	0	NA	NA	NA	3	NA	NA	NA	2	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Leards Bridge	7 Sep 97	3	18	4	0	NA	40	18	6	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	3	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Kennys Hole	28 Aug 97	3	47	23	8	NA	24	7	3	NA	0	0	0	NA	0	2	1	NA	0	0	0	NA	0	0	0	NA	4	2	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Upper Kennys	10 Sep 97	3	41	15	6	NA	6	1	0	NA	0	0	0	NA	443	0	0	NA	0	1	0	NA	1	0	0	NA	0	2	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Mooney Tracks	4 Sep 97	3	13	7	2	NA	13	3	0	NA	0	0	0	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	2	1	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Gill Road	25 Aug 97	1	18	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	160	NA	NA	NA	1	NA	NA	NA	0	NA	NA	NA	3	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Old Cardigan III	15 Sep 97	3	12	3	1	NA	10	4	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Lower Cranes	10 Sep 97	1	17	NA	NA	NA	18	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Cranes	24 Sep 97	3	55	31	8	NA	31	17	4	NA	0	0	0	NA	52	0	0	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Everglades	26 Aug 97	1	10	NA	NA	NA	7	NA	NA	NA	0	NA	NA	NA	8	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	7	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Martinvale	26 Aug 97	1	8	NA	NA	NA	5	NA	NA	NA	0	NA	NA	NA	16	NA	NA	NA	0	NA	NA	NA	1	NA	NA	NA	20	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA	0	NA	NA	NA
Rowells Riffle	16 Sep 98	3	36	9	8	NA	6	3	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Mooneys Bridge	11 Sep 98	4	2	4	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forks	28 Aug 98	3	10	3	3	NA	35	24	10	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	2	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Leards Bridge	17 Aug 98	3	1	2	0	NA	24	17	12	NA	0	0	0	NA	14	1	1	NA	1	0	0	NA	4	6	5	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Kennys Hole	11 Aug 98	3	16	6	13	NA	5	4	7	NA	1	0	0	NA	1	0	0	NA	1	1	0	NA	3	2	3	NA	2	3	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Cranes	21 Aug 98	3	18	14	11	NA	25	16	10	NA	0	0	0	NA	4	3	2	NA	0	0	0	NA	3	0	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Rowells Riffle[1]	21 Sep 99	4	65	21	5	2	5	1	0	0	0	0	0	0																																
Mooneys Bridge[1]	20 Sep 99	3	4	4	2	NA	4	1	0	NA	0	0	0	NA																																
Forks[1]	15 Sep 99	4	4	5	2	1	31	15	11	8	0	0	0	0																																
Leards Bridge[1]	13 Sep 99	4	8	1	0	0	29	19	6	3	0	0	0	0																																
Kennys Hole[1]	10 Sep 99	3	48	12	8	NA	46	17	9	NA	0	0	0	NA																																
Cranes[1]	14 Sep 99	4	52	39	23	7	35	24	15	6	0	0	0	0																																
Rowells Riffle[1]	14 Sep 00	3	41	22	10	NA	4	3	2	NA	0	0	0	NA																																
Mooneys Bridge[1]	13 Sep 00	3	11	8	1	NA	4	1	2	NA	0	0	0	NA																																
Forks[1]	12 Sep 00	3	25	11	2	NA	105	58	24	NA	0	0	0	NA																																
Leards Bridge[1]	30 Aug 00	3	3	0	0	NA	45	22	8	NA	0	0	0	NA																																
Kennys Hole[1]	29 Aug 00	3	39	22	8	NA	54	24	11	NA	0	0	0	NA																																
Cranes[1]	11 Sep 00	3	65	20	10	NA	45	13	14	NA	0	0	0	NA																																

Appendix 3 (continued)

Site	Electro-fishing date	Number of sweeps	Brook trout				Atlantic salmon				Rainbow trout				9-spined stickle.				3-spined stickle.				American eel				Red-bellied dace				Banded killifish				Alewife				Rainbow smelt				Brown trout			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Morell River																																																			
Rowells Riffle	19 Sep 01	3	11	5	0	NA	8	3	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	1	2	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Mooneys Bridge	18 Sep 01	3	13	4	3	NA	7	9	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Forks	17 Sep 01	3	30	21	6	NA	60	25	12	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Leards Bridge	12 Sep 01	3	4	3	0	NA	19	12	7	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	4	4	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Kennys Hole	11 Sep 01	3	44	23	17	NA	65	42	27	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	2	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Cranes	12 Sep 01	3	63	21	16	NA	52	29	6	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	6	2	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Little Pierre Jacques River																																																			
1	12 Oct 93	4	33	17	8	12	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8 Oct 93	4	74	26	15	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	14 Oct 93	4	28	11	13	8	2	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	19 Oct 93	4	45	14	19	6	0	0	0	0	0	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	14 Jun 94	4	29	13	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	15 Jun 94	3	7	6	2	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	18 Jun 94	3	18	6	2	NA	0	0	0	NA	0	0	0	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	16 Jun 94	4	27	13	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	11 Jul 94	4	28	7	6	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	12 Jul 94	4	22	13	14	8	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	13 Jul 94	4	17	10	5	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	14 Jul 94	4	26	11	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	7 Sep 94	4	30	12	2	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8 Sep 94	4	34	32	9	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7 Sep 94	3	21	16	2	NA	0	0	0	NA	0	0	0	NA	0	4	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	9 Sep 94	3	24	18	2	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	28 Jun 95	3	19	3	1	NA	1	1	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	27 Jun 95	4	21	11	5	2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	29 Jun 95	4	15	15	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	30 Jun 95	4	16	6	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	10 Aug 95	3	11	9	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	10 Aug 95	4	26	8	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	11 Aug 95	4	13	7	7	3	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	11 Aug 95	3	4	5	1	NA	0	0	0	NA	0	0	0	NA	2	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	25 Sep 95	4	12	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	26 Sep 95	4	25	11	3	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	26 Sep 95	3	21	7	1	NA	0	0	0	NA	0	0	0	NA	0	2	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	27 Sep 95	3	16	4	1	NA	0	0	0	NA	0	0	0	NA	0	2	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Enmore River																																																			
1	4 Oct 93	4	6	2	4	0	25	8	3	2	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1 Oct 93	4	8	5	4	1	13	4	2	2	0	0	0	0	14	11	8	9	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	12 Nov 93	4	5	4	5	1	0	0	0	0	0	0	0	0	1	8	0	0	8	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	6 Oct 93	4	6	7	3	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	6 Jun 94	4	4	4	3	2	6	2	1	0	0	0	0	0	5	4	4	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8 Jun 94	4	3	4	3	2	4	1	1	0	0	0	0	0	8	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	9 Jun 94	3	5	5	1	NA	0	0	0	NA	0	0	0	NA	4	4	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	13 Jun 94	4	10	7	2	0	0	1	0	0	0	0	0	0	5	1	3	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3 Jul 94	3	3	1	0	NA	2	1	1	NA	0	0	0	NA	4	6	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	5 Jul 94	3	9	3	1	NA	5	2	0	NA	0	0	0	NA	7	1	1	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	6 Jul 94	3	14	8	2	NA	0	0	0	NA	0	0	0	NA	6	0	0	NA	1	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	7 Jul 94	3	20	5	2	NA	0	0	0	NA	0	0	0	NA	17	7	0	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	15 Aug 94	3	13	6	1	NA	0	1	1	NA	0	0	0	NA	0	3	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	15 Aug 94	4	9	1	2	0	2	0	2	0	0	0	0	0	3	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	16 Aug 94	3	16	8	1	NA	0	0	0	NA	0	0	0	NA	7	1	1	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	17 Aug 94	4	18	11	4	1	0	0	0	0	0	0	0	0	2	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Site	Electro-fishing date	Number of sweeps	Brook trout				Atlantic salmon				Rainbow trout				9-spined stickle.				3-spined stickle.				American eel				Red-bellied dace				Banded killifish				Alewife				Rainbow smelt				Brown trout			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Enmore River																																														
1	11 Oct 94	3	2	0	0	NA	1	0	0	NA	0	0	0	NA	2	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	11 Oct 94	3	4	1	0	NA	0	2	0	NA	0	0	0	NA	2	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	12 Oct 94	3	11	4	0	NA	0	0	0	NA	0	0	0	NA	1	4	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	12 Oct 94	3	10	5	1	NA	0	0	0	NA	0	0	0	NA	1	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	22 Jun 95	3	2	0	0	NA	0	0	0	NA	0	0	0	NA	2	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	22 Jun 95	3	2	1	0	NA	0	0	0	NA	0	0	0	NA	7	1	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	26 Jun 95	3	4	1	0	NA	0	0	0	NA	0	0	0	NA	1	2	1	NA	4	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	23 Jun 95	4	20	4	4	1	0	0	0	0	0	0	0	0	1	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	7 Aug 95	3	15	2	1	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	7 Aug 95	4	10	7	3	2	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8 Aug 95	3	4	1	0	NA	0	0	0	NA	0	0	0	NA	2	0	0	NA	1	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	9 Aug 95	4	13	4	3	2	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	19 Sep 95	3	3	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	19 Sep 95	3	10	4	1	NA	0	0	0	NA	0	0	0	NA	0	1	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	25 Sep 95	3	4	1	0	NA	0	0	0	NA	0	0	0	NA	14	6	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	22 Sep 95	3	7	4	1	NA	0	0	0	NA	0	0	0	NA	3	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Ellerslie River																																														
1	21 Oct 93	4	39	10	6	5	0	0	0	0	0	0	0	0	3	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	21 Oct 93	4	12	4	6	6	0	0	0	0	0	0	0	0	8	6	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	21 Oct 93	4	43	27	15	5	0	0	0	0	0	0	0	0	3	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	21 Oct 93	4	15	13	5	6	0	0	0	0	0	0	0	0	15	13	12	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	27 Jun 94	4	30	17	10	4	0	0	0	0	0	0	0	0	3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	28 Jun 94	3	26	17	3	NA	0	0	0	NA	0	0	0	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	17 Jun 94	4	19	13	5	3	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	20 Jun 94	4	12	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	20 Jul 94	4	32	14	7	2	0	0	0	0	0	0	0	0	2	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	22 Jul 94	4	34	24	4	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	16 Jul 94	4	46	16	10	4	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	19 Jul 94	3	12	5	2	NA	0	0	0	NA	0	0	0	NA	0	3	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	22 Sep 94	4	21	9	5	1	0	0	0	0	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	21 Sep 94	4	36	16	6	3	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	19 Sep 94	4	43	22	3	1	0	0	0	0	0	0	0	0	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	20 Sep 94	3	13	5	1	NA	0	0	0	NA	0	0	0	NA	1	2	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	5 Jul 95	4	31	7	3	2	0	0	0	0	0	0	0	0	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5 Jul 95	4	27	11	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4 Jul 95	4	33	17	6	3	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3 Jul 95	3	14	4	1	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	15 Aug 95	4	37	10	3	1	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	15 Aug 95	4	36	10	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	14 Aug 95	4	36	23	10	6	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	13 Aug 95	3	7	3	0	NA	0	0	0	NA	0	0	0	NA	2	0	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	27 Sep 95	4	28	12	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	28 Sep 95	4	35	13	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	29 Sep 95	4	35	18	4	2	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	28 Sep 95	3	9	4	1	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Trout River (Coleman)																																														
Bannys Hole	2 Oct 93	4	48	26	17	10	11	15	11	4	0	0	0	0	39	12	3	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seal River																																														
1	3 Sep 93	4	16	8	2	1	0	0	0	0	0	0	0	0	4	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	7 Sep 93	4	28	22	9	3	0	0	0	0	0	0	1	0	14	11	5	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	9 Sep 93	4	33	16	13	2	0	0	0	0	0	0	0	0	10	7	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	14 Sep 93	4	6	6	2	3	0	0	0	0	0	0	0	0	8	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Site	Electro-fishing date	Number of sweeps	Brook trout				Atlantic salmon				Rainbow trout				9-spined stickle.				3-spined stickle.				American eel				Red-bellied dace				Banded killifish				Alewife				Rainbow smelt				Brown trout			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Seal River																																														
1	30 May 94	3	2	0	0	NA	0	0	0	NA	0	0	0	NA	0	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	31 May 94	3	12	6	3	NA	0	0	0	NA	2	2	3	NA	5	2	2	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	1 Jun 94	3	13	7	7	NA	0	0	0	NA	1	0	0	NA	0	0	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	8 Jun 94	3	2	1	0	NA	0	0	0	NA	0	0	0	NA	1	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	20 Jul 94	4	23	9	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	21 Jul 94	3	25	8	3	NA	0	0	0	NA	0	0	0	NA	0	2	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	21 Jul 94	3	17	6	5	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	20 Jul 94	3	4	3	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	19 Sep 94	3	12	8	5	NA	0	0	0	NA	0	0	0	NA	1	0	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	20 Sep 94	3	19	7	1	NA	0	0	0	NA	1	0	0	NA	3	6	4	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	20 Sep 94	3	15	9	4	NA	0	0	0	NA	1	0	0	NA	5	11	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	21 Sep 94	3	6	4	2	NA	0	0	0	NA	0	0	0	NA	3	3	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	11 Jul 95	3	54	22	12	NA	0	0	0	NA	0	0	0	NA	0	0	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	11 Jul 95	3	4	1	0	NA	0	0	0	NA	0	0	0	NA	2	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	11 Jul 95	3	14	9	8	NA	0	0	0	NA	0	0	0	NA	2	4	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	7 Jul 95	3	6	3	0	NA	0	0	0	NA	0	0	0	NA	1	1	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	17 Oct 95	3	32	16	4	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	23 Oct 95	3	5	2	1	NA	0	0	0	NA	0	0	0	NA	3	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	23 Oct 95	3	9	5	1	NA	0	0	0	NA	0	0	0	NA	4	2	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	17 Oct 95	3	7	4	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
Vernon River																																														
1	15 Sep 93	4	121	52	30	8	1	0	0	0	1	7	2	0	97	72	48	22	11	16	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	16 Sep 93	3	76	23	13	NA	1	0	0	NA	0	3	0	NA	230	0	0	NA	4	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	20 Sep 93	3	27	13	1	NA	0	0	0	NA	0	1	0	NA	21	25	11	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	1	0	NA
4	21 Sep 93	4	85	40	23	10	0	0	0	0	0	0	0	0	68	26	27	15	3	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2 Jun 94	4	27	12	15	7	0	0	0	0	2	1	0	0	12	6	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0
2	15 Jun 94	4	48	24	12	5	0	0	0	0	0	0	0	0	7	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	14 Jun 94	3	19	14	9	NA	0	0	0	NA	0	0	0	NA	6	4	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	10 Jun 94	3	77	39	24	NA	0	0	0	NA	0	0	0	NA	12	7	4	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	22 Jul 94	3	25	19	7	NA	0	0	0	NA	0	0	0	NA	4	1	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	22 Jul 94	3	14	6	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	25 Jul 94	4	40	18	15	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	26 Jul 94	3	73	28	10	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	19 Sep 94	3	44	22	10	NA	0	1	0	NA	0	2	0	NA	41	10	8	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	22 Sep 94	3	44	24	13	NA	0	0	0	NA	2	1	0	NA	0	0	0	NA	23	18	10	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	22 Sep 94	3	15	7	5	NA	0	0	0	NA	0	0	0	NA	11	4	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	23 Sep 94	3	73	35	20	NA	0	0	1	NA	0	0	0	NA	11	9	4	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	6 Jul 95	3	16	8	4	NA	0	0	0	NA	0	0	0	NA	6	4	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	12 Jul 95	3	14	12	14	NA	0	0	0	NA	0	0	0	NA	2	1	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	12 Jul 95	3	24	14	7	NA	0	0	0	NA	0	0	0	NA	5	4	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	13 Jul 95	3	47	27	15	NA	0	0	0	NA	0	0	0	NA	9	4	3	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
1	18 Oct 95	3	10	7	3	NA	2	0	0	NA	0	0	0	NA	6	4	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
2	19 Oct 95	3	21	13	9	NA	0	1	0	NA	0	0	0	NA	3	2	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
3	20 Oct 95	3	15	9	5	NA	0	0	0	NA	0	0	0	NA	3	1	1	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA
4	20 Oct 95	3	80	26	12	NA	0	0	0	NA	0	0	0	NA	9	5	2	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA	0	0	0	NA

[a] 1 salmon, 2 3-spined sticklebacks, and 2 American eels were captured on the 5th sweep.

[b] 2 brook trout and 3 red-bellied dace were capured in the 5th sweep.

[c] 3 brook trout and 1 Atlantic salmon ware capture in the 5th sweeep. 3 brook trout and 3 Atlantic salmon were captured in the 6th sweep.

[d] 1 brook trout was captured in the 5th sweep.

[e] 1 brook trout, 2 Atlantic salmon, and 2 3-spined were captured in the 5th sweep.

[f] 3 brook trout, 3 Atlantic salmon, 9 American eels, and 1 red-bellied dace were captured in tha 5th sweep.

[g] 7 3-spined sticklebacks were captured in the 5th sweep.

[h] 2 brook trout were captured in the 5th sweep.

[i] Non-salmonids were not recorded.

Appendix 4

Densities (fish $100m^{-2}$) of fish at electrofishing sites in the Morell, Little Pierre Jacques, Enmore, Ellerslie, Trout, Seal, and Vernon Rivers

Site	Date	Brook trout	Atlantic salmon	Rainbow trout	3-spined stickleback	9-spined stickleback	American eel	Red-bellied dace	Banded killifish	Alewife	Rainbow smelt	Brown trout
Morell River												
Indian Bridge	12 Sep 75	5.10	0.60	0.00	6.60	0.00	33.80	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	11 Sep 75	6.50	1.50	0.00	3.50	0.00	5.30	0.00	0.00	0.00	0.00	0.00
Grants	10 Sep 75	8.80	3.80	0.00	9.30	0.00	6.60	0.00	0.00	0.00	0.00	0.00
Forks	9 Sep 75	14.20	5.90	0.00	2.40	0.00	6.20	0.00	0.00	0.00	0.00	0.00
Leards Bridge	8 Sep 75	5.50	5.10	0.00	1.20	0.00	14.80	0.00	0.00	0.00	0.00	0.00
Forks	11 Sep 84	7.80	17.27	0.00	0.00	0.00	3.34	0.00	0.55	0.00	0.00	0.00
Leards Bridge	23 Aug 84	0.00	20.03	0.00	10.08	0.00	16.91	0.00	0.66	0.00	0.00	0.00
Kennys Hole	22 Aug 84	8.15	2.53	0.00	2.00	0.00	1.19	3.58	0.00	0.00	0.00	0.00
Cranes	30 Aug 84	9.31	7.96	0.00	2.52	0.00	11.77	0.00	0.00	0.00	0.00	0.00
Rowells Riffle	5 Sep 85	12.64	12.91	0.00	0.67	0.00	4.06	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	28 Aug 85	5.41	11.31	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00
Lower Leards	23 Aug 85	5.42	14.33	0.00	1.73	0.00	2.30	0.00	0.00	0.00	0.00	0.00
Leards Bridge	22 Aug 85	5.01	20.70	0.00	0.98	0.00	23.82	0.00	1.53	0.00	0.00	0.00
Kennys Hole	21 Aug 85	34.84	2.72	0.00	17.06	0.00	1.73	0.00	0.86	0.00	0.00	0.00
Cranes	27 Aug 85	13.26	4.59	0.00	0.50	0.00	2.78	0.00	0.00	0.00	0.00	0.00
Old Cardigan III	24 May 94	16.67	7.58									
Smiths Spring	24 May 94	34.86	1.36									
Rowells Riffle	7 Sep 94	9.83	6.88	0.00	17.22	0.00	1.64	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	6 Sep 94	5.45	4.53	0.00	8.25	1.36	0.00	0.00	0.00	0.00	0.00	0.00
Forks	1 Sep 94	14.33	41.15	0.00	8.65	0.00	0.81	0.00	0.00	0.00	0.00	0.00
Leards Bridge	24 Aug 94	0.00	25.47	0.00	7.55	2.00	7.74	1.00	3.61	0.00	0.00	0.00
Kennys Hole	23 Aug 94	32.01	148.98	0.00	64.86	0.00	7.44	24.22	0.00	0.00	0.00	0.00
Cranes	30 Aug 94	125.11	40.01	0.00	20.86	2.88	0.58	1.15	0.00	0.00	0.00	0.00
Rowells Riffle	27 Dec 94	4.30	3.07	0.00	3.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	23 Dec 94	0.64	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	20 Dec 94	5.61	4.08	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leards Bridge	16 Dec 94	3.77	12.25	0.00	15.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kennys Hole	15 Dec 94	30.07	20.05	0.00	13.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	16 Dec 94	12.49	5.97	0.00	4.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rowells Riffle	4 Aug 95	37.08	9.86	0.00	7.70	0.00	1.67	0.00	0.00	0.00	0.00	0.00
Grants	8 Aug 95	9.32	4.94	0.00	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00
Forks	31 Jul 95	15.74	17.94	0.00	0.32	0.00	0.83	0.00	0.00	0.00	0.00	0.00
Above Landing Pool	8 Aug 95	4.73	9.94	0.00	2.84	0.00	1.42	0.00	0.00	0.00	0.00	0.00
Leards Bridge	26 Jul 95	1.86	35.50	0.00	6.86	0.00	7.84	1.07	0.00	0.00	0.00	0.00
Kennys Hole	24 Jul 95	29.12	17.70	0.00	8.17	0.00	4.09	9.81	0.00	0.00	0.00	0.00
Upper Kennys	10 Aug 95	47.02	8.64	0.00	1.92	0.00	0.00	12.48	0.00	0.00	0.00	0.00
Mooney Tracks	15 Aug 95	28.67	42.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gill Road	11 Aug 95	69.23	2.31	0.00	9.23	0.00	0.00	4.62	0.00	0.00	0.00	0.00
Oates	22 Aug 95	19.93	5.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old Cardigan III	10 Aug 95	48.17	42.00	0.00	0.00	0.00	0.00	0.00	0.00	2.47	0.00	0.00
Lower Cranes	9 Aug 95	13.38	7.65	0.00	1.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	27 Jul 95	36.00	12.74	0.60	3.02	0.00	0.60	0.60	0.00	0.00	0.00	0.00
Everglades	7 Aug 95	2.29	5.72	0.00	1.14	0.00	0.00	2.29	0.00	0.00	0.00	0.00
Marlinvale	8 Aug 95	6.31	1.26	0.00	0.00	0.00	0.00	30.28	0.00	0.00	0.00	0.00
Rowells Riffle	31 Oct 95	7.26	9.14	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grants	3 Nov 95	6.62	7.64	0.00	0.51	0.00	0.00	0.51	0.00	0.00	0.00	0.00
Forks	27 Oct 95	7.38	34.68	0.00	1.07	0.00	0.00	0.58	0.00	0.00	0.00	0.00
Above Landing Pool	2 Nov 95	11.71	13.02	0.00	2.60	0.00	0.87	0.43	0.00	0.00	0.00	0.00
Leards Bridge	25 Oct 95	0.98	34.25	0.00	1.96	0.00	0.00	0.00	0.98	0.00	0.00	0.00
Kennys Hole	26 Oct 95	25.58	16.97	0.00	2.16	0.00	0.00	7.51	0.00	0.00	0.00	0.00
Upper Kennys	1 Nov 95	16.85	2.97	0.00	3.97	0.00	0.00	12.89	0.00	0.00	0.00	0.00
Mooney Tracks	1 Nov 95	6.80	29.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gill Road	6 Nov 95	41.65	0.00	0.00	4.63	0.00	0.00	4.63	0.00	0.00	0.00	0.00
Oates	7 Nov 95	6.64	3.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old Cardigan III	1 Nov 95	8.86	34.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Cranes	2 Nov 95	11.65	11.65	0.00	0.90	0.00	0.00	0.90	0.00	0.00	0.00	0.00
Cranes	24 Oct 95	19.42	23.31	0.00	5.86	0.00	0.00	1.18	0.00	0.00	0.00	0.00
Everglades	2 Nov 95	8.76	3.89	0.00	3.89	0.00	0.00	6.81	0.00	0.00	0.00	0.00
Marlinvale	3 Nov 95	21.63	2.95	0.00	9.83	0.00	0.00	21.63	0.00	0.00	0.00	0.00

Appendix 4 (continued)

Site	Date	Brook trout	Atlantic salmon	Rainbow trout	3-spined stickleback	9-spined stickleback	American eel	Reb-bellied dace	Banded killifish	Alewife	Rainbow smelt	Brown trout
Morell River												
Rowells Riffle	4 Sep 96	5.27	8.31	0.00	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grants	21 Aug 96	7.70	6.48	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	21 Aug 96	7.54	21.69	0.00	0.49	0.00	0.00	0.49	0.00	0.00	0.00	0.00
Above Landing Pool	30 Aug 96	3.99	4.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leards Bridge	19 Aug 96	0.00	34.43	0.00	0.85	0.00	0.93	1.71	0.00	0.00	0.00	0.00
Kennys Hole	14 Aug 96	34.13	10.53	0.00	1.08	0.00	0.99	6.96	0.00	0.00	0.00	0.00
Upper Kennys	19 Aug 96	23.26	14.80	0.00	4.23	0.00	1.06	7.40	0.00	0.00	0.00	0.00
Mooney Tracks	22 Aug 96	31.91	24.66	0.00	0.00	0.00	0.00	5.80	0.00	0.00	0.00	0.00
Gill Road	28 Aug 96	47.42	9.48	0.00	2.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old Cardigan III	15 Aug 96	9.36	4.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Cranes	29 Aug 96	22.44	14.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	20 Aug 96	11.66	18.00	0.00	2.63	0.00	0.00	1.08	0.00	0.00	0.00	0.00
Everglades	28 Aug 96	2.91	0.00	0.00	0.00	0.00	1.94	0.97	0.00	0.00	0.00	0.00
Martinvale	26 Aug 96	6.11	0.00	0.00	3.67	0.00	0.00	15.89	0.00	0.00	0.00	0.00
Rowells Riffle	8 Sep 97	3.95	18.41	0.00	11.58	0.83	0.00	0.00	0.00	0.00	0.00	0.00
Grants	4 Sep 97	10.30	11.23	0.00	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	4 Sep 97	4.67	30.82	0.00	1.79	0.00	0.00	6.99	0.00	0.00	0.00	0.00
Above Landing Pool	7 Sep 97	3.49	8.49	0.00	3.49	0.00	1.50	1.00	0.00	0.00	0.00	0.00
Leards Bridge	7 Sep 97	9.39	28.01	0.00	0.00	0.85	2.55	0.00	0.00	0.00	0.00	0.00
Kennys Hole	28 Aug 97	38.68	16.06	0.00	2.73	0.00	0.00	3.64	0.00	0.00	0.00	0.00
Upper Kennys	10 Sep 97	35.76	3.83	0.00	18.26	1.09	1.09	2.18	0.00	0.00	0.00	0.00
Mooney Tracks	4 Sep 97	16.89	11.33	0.00	1.41	0.00	0.00	4.12	0.00	0.00	0.00	0.00
Gill Road	25 Aug 97	44.38	0.00	0.00	394.46	2.47	0.00	7.40	0.00	0.00	0.00	0.00
Old Cardigan III	15 Sep 97	10.13	12.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Cranes	10 Sep 97	16.58	17.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	24 Sep 97	26.75	14.65	0.00	7.05	0.00	0.00	0.52	0.00	0.00	0.00	0.00
Everglades	26 Aug 97	11.54	8.07	0.00	9.23	0.00	0.00	8.07	0.00	0.00	0.00	0.00
Martinvale	26 Aug 97	7.64	6.37	0.00	20.37	0.00	1.27	25.46	0.00	0.00	0.00	0.00
Rowells Riffle	16 Sep 98	18.33	5.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	11 Sep 98	6.04	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	28 Aug 98	4.90	22.67	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00
Leards Bridge	17 Aug 98	2.12	45.83	0.00	8.98	1.12	16.77	0.00	0.00	0.00	0.00	0.00
Kennys Hole	11 Aug 98	55.87	16.39	1.02	1.02	1.12	8.20	3.40	0.00	0.00	0.00	0.00
Cranes	21 Aug 98	31.65	22.38	0.00	5.89	0.00	3.93	0.00	0.00	0.00	0.00	0.00
Rowells Riffle	21 Sep 99	30.25	1.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	20 Sep 99	4.61	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	15 Sep 99	3.78	18.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leards Bridge	13 Sep 99	5.16	34.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kennys Hole	10 Sep 99	39.32	42.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	14 Sep 99	39.99	26.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rowells Riffle	14 Sep 00	27.21	4.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	13 Sep 00	6.35	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	12 Sep 00	10.79	58.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leards Bridge	30 Aug 00	3.29	44.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kennys Hole	29 Aug 00	39.74	50.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	11 Sep 00	33.02	27.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rowells Riffle	19 Sep 01	5.33	4.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mooneys Bridge	18 Sep 01	6.34	8.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forks	17 Sep 01	17.86	28.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leards Bridge	12 Sep 01	4.20	28.04	0.00	0.00	0.00	4.96	0.00	0.00	0.00	0.00	0.00
Kennys Hole	11 Sep 01	57.02	96.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cranes	12 Sep 01	19.64	16.54	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.00	0.00

Appendix 4 (continued)

Site	Date	Brook trout	Atlantic salmon	Rainbow trout	3-spined stickleback	9-spined stickleback	American eel	Reb-bellied dace	Banded killifish	Alewife	Rainbow smelt	Brown trout
Little Pierre Jacques River												
1	12 Oct 93	68.02	3.20	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	8 Oct 93	141.50	2.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	14 Oct 93	65.47	3.50	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	19 Oct 93	64.55	0.00	0.00	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	14 Jun 94	41.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	15 Jun 94	17.11	0.00	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	18 Jun 94	17.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	16 Jun 94	35.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	11 Jul 94	32.84	1.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	12 Jul 94	63.45	0.00	0.00	3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	13 Jul 94	29.17	1.59	0.00	1.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	14 Jul 94	28.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	7 Sep 94	35.50	3.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	8 Sep 94	88.97	0.00	0.00	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	7 Sep 94	34.93	0.00	0.00	6.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	9 Sep 94	35.95	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	28 Jun 95	18.04	1.70	0.00	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	27 Jun 95	38.72	0.00	0.00	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	29 Jun 95	27.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	30 Jun 95	20.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	10 Aug 95	20.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10 Aug 95	43.39	2.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11 Aug 95	28.70	0.00	0.00	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	11 Aug 95	12.48	0.00	0.00	3.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	25 Sep 95	14.97	1.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	26 Sep 95	43.87	0.00	0.00	2.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	26 Sep 95	28.43	0.00	0.00	3.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	27 Sep 95	18.09	0.00	0.00	3.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enmore River												
1	4 Oct 93	13.55	39.55	0.00	4.08	2.04	0.00	0.00	0.00	0.00	0.00	0.00
2	1 Oct 93	14.27	15.31	0.00	58.54	2.78	0.00	0.00	0.00	0.00	0.00	0.00
3	12 Nov 93	16.51	0.00	0.00	7.90	8.53	0.00	0.00	0.00	0.00	0.00	0.00
4	6 Oct 93	15.24	0.00	0.00	6.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	6 Jun 94	21.00	8.57	0.00	64.93	1.88	0.00	0.00	0.00	0.00	0.00	0.00
2	8 Jun 94	18.42	3.93	0.00	9.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	9 Jun 94	9.48	0.00	0.00	6.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	13 Jun 94	20.36	2.08	0.00	30.13	2.08	0.00	0.00	0.00	0.00	0.00	0.00
1	3 Jul 94	3.50	5.07	0.00	13.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5 Jul 94	9.08	4.79	0.00	6.20	1.35	0.00	0.00	0.00	0.00	0.00	0.00
3	6 Jul 94	21.99	0.00	0.00	10.10	1.83	0.00	0.00	0.00	0.00	0.00	0.00
4	7 Jul 94	30.08	0.00	0.00	26.52	2.17	0.00	0.00	0.00	0.00	0.00	0.00
1	15 Aug 94	23.37	4.48	0.00	6.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	15 Aug 94	15.15	10.00	0.00	26.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	16 Aug 94	26.39	0.00	0.00	9.33	2.02	0.00	0.00	0.00	0.00	0.00	0.00
4	17 Aug 94	42.20	0.00	0.00	11.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	11 Oct 94	4.81	2.40	0.00	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11 Oct 94	3.96	3.15	0.00	3.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	12 Oct 94	14.82	0.00	0.00	11.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	12 Oct 94	21.69	0.00	0.00	2.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	22 Jun 95	4.39	0.00	0.00	3.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	22 Jun 95	2.42	0.00	0.00	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	26 Jun 95	4.72	0.00	0.00	11.27	4.73	0.00	0.00	0.00	0.00	0.00	0.00
4	23 Jun 95	34.48	0.00	0.00	7.74	2.33	0.00	0.00	0.00	0.00	0.00	0.00
1	7 Aug 95	24.02	0.00	0.00	2.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	7 Aug 95	23.02	0.00	0.00	3.72	2.29	0.00	0.00	0.00	0.00	0.00	0.00
3	8 Aug 95	5.35	0.00	0.00	4.25	2.32	0.00	0.00	0.00	0.00	0.00	0.00
4	9 Aug 95	27.75	0.00	0.00	8.57	2.37	0.00	0.00	0.00	0.00	0.00	0.00
1	19 Sep 95	3.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	19 Sep 95	11.15	0.00	0.00	1.42	1.42	0.00	0.00	0.00	0.00	0.00	0.00
3	25 Sep 95	5.73	0.00	0.00	24.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	22 Sep 95	14.02	0.00	0.00	4.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 4 (continued)

Site	Date	Brook trout	Atlantic salmon	Rainbow trout	3-spined stickleback	9-spined stickleback	American eel	Reb-bellied dace	Banded killifish	Alewife	Rainbow smelt	Brown trout
Ellerslie River												
1	21 Oct 93	36.06	0.00	0.00	11.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	21 Oct 93	31.75	0.00	0.00	14.55	1.37	0.00	0.00	0.00	0.00	0.00	0.00
3	21 Oct 93	98.08	0.00	0.00	10.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	21 Oct 93	43.04	0.00	0.00	62.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	27 Jun 94	38.68	0.00	0.00	6.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	28 Jun 94	35.63	0.00	0.00	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	17 Jun 94	43.81	0.00	0.00	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	20 Jun 94	18.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	20 Jul 94	37.41	0.00	0.00	6.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	22 Jul 94	49.12	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	18 Jul 94	87.66	0.00	0.00	6.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	19 Jul 94	18.59	0.00	0.00	5.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	22 Sep 94	24.15	0.00	0.00	7.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	21 Sep 94	52.57	0.00	0.00	6.67	1.67	0.00	0.00	0.00	0.00	0.00	0.00
3	19 Sep 94	80.58	0.00	0.00	4.95	1.42	0.00	0.00	0.00	0.00	0.00	0.00
4	20 Sep 94	17.28	0.00	0.00	3.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	5 Jul 95	29.06	0.00	0.00	4.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5 Jul 95	39.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	4 Jul 95	64.81	0.00	0.00	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	3 Jul 95	17.49	0.00	0.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	15 Aug 95	33.54	0.00	0.00	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	15 Aug 95	38.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	14 Aug 95	91.30	0.00	0.00	6.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	13 Aug 95	10.18	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	27 Sep 95	31.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	28 Sep 95	46.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	29 Sep 95	58.68	0.00	0.00	3.89	1.94	0.00	0.00	0.00	0.00	0.00	0.00
4	28 Sep 95	14.03	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trout River (Coleman)												
Bannys Hole	2 Oct 93	51.04	28.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seal River												
1	3 Sep 93	55.02	0.00	0.00	24.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	7 Sep 93	141.52	0.00	4.20	124.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	9 Sep 93	88.81	0.00	0.00	25.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	14 Sep 93	49.71	0.00	0.00	30.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	30 May 94	8.03	0.00	0.00	4.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	31 May 94	45.76	0.00	26.69	21.68	3.81	0.00	0.00	0.00	0.00	0.00	0.00
3	1 Jun 94	52.73	0.00	2.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	8 Jun 94	5.22	0.00	0.00	3.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	20 Jul 94	93.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	21 Jul 94	71.36	0.00	0.00	11.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	21 Jul 94	43.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	20 Jul 94	18.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	19 Sep 94	75.43	0.00	0.00	8.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	20 Sep 94	57.71	0.00	4.17	54.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	20 Sep 94	43.19	0.00	2.62	44.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	21 Sep 94	27.78	0.00	0.00	17.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 4 (continued)

Site	Date	Brook trout	Atlantic salmon	Rainbow trout	3-spined stickleback	9-spined stickleback	American eel	Reb-bellied dace	Banded killifish	Alewife	Rainbow smelt	Brown trout
Seal River												
1	11 Jul 95	147.54	0.00	0.00	6.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11 Jul 95	8.61	0.00	0.00	6.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11 Jul 95	67.24	0.00	0.00	18.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	7 Jul 95	15.79	0.00	0.00	10.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	17 Oct 95	79.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	23 Oct 95	17.11	0.00	0.00	7.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	23 Oct 95	19.02	0.00	0.00	9.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	17 Oct 95	19.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vernon River												
1	15 Sep 93	239.90	2.18	14.95	315.16	75.49	0.00	0.00	0.00	0.00	0.00	0.00
2	16 Sep 93	111.22	1.88	5.63	431.92	7.51	0.00	0.00	0.00	0.00	0.00	0.00
3	20 Sep 93	58.49	0.00	2.76	143.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	21 Sep 93	148.01	0.00	0.00	138.40	9.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2 Jun 94	84.29	0.00	3.28	30.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	15 Jun 94	86.83	0.00	0.00	8.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	14 Jun 94	79.04	0.00	0.00	24.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	10 Jun 94	154.23	0.00	0.00	26.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	22 Jul 94	168.31	0.00	0.00	6.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	22 Jul 94	24.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	25 Jul 94	115.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	26 Jul 94	123.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	19 Sep 94	105.78	2.47	4.94	77.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	22 Sep 94	92.14	0.00	2.93	0.00	70.38	0.00	0.00	0.00	0.00	0.00	0.00
3	22 Sep 94	43.90	0.00	0.00	24.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	23 Sep 94	143.95	1.94	0.00	31.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	6 Jul 95	32.97	0.00	0.00	20.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	12 Jul 95	71.94	0.00	0.00	8.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	12 Jul 95	65.11	0.00	0.00	11.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	13 Jul 95	98.02	0.00	0.00	17.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	18 Oct 95	29.11	4.71	0.00	17.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	19 Oct 95	52.74	1.78	0.00	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	20 Oct 95	44.07	0.00	0.00	7.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	20 Oct 95	110.41	0.00	0.00	16.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 5
Density of brook trout and Atlantic salmon by age and biomass density by species of fish at electrofishing sites on the Morell, Little Pierre Jacques, Enmore, Ellerslie, Trout, Seal, and Vernon Rivers.

Site	Date	Density (fish 100 m^{-2})							Biomass (g 100 m^{-2})					
		Brook trout					Atlantic salmon		Brook trout	Atlantic salmon	Three-spined stickle-back	American eel	Other	Total
		0+	1+	2+	3+	4++	0+	1++						
Morell River														
Forks	11 Sep 84	2.60	4.16	1.04	0.00	0.00	10.13	7.15	140	371	0	0	0	510
Leards Bridge	23 Aug 84	0.00	0.00	0.00	0.00	0.00	17.03	3.00	0	220	0	0	0	220
Kennys Hole	22 Aug 84	3.19	4.61	0.35	0.00	0.00	0.00	2.53	182	151	0	0	0	333
Cranes	30 Aug 84	1.72	5.86	1.72	0.00	0.00	6.67	1.28	317	78	0	0	0	395
Rowells Riffle	5 Sep 85	0.00	0.00	0.00	0.00	0.00	9.39	3.52	0	248	0	0	0	248
Mooneys Bridge	28 Aug 85	0.00	0.00	0.00	0.00	0.00	7.20	4.11	0	116	0	0	0	116
Lower Leards	23 Aug 85	0.00	0.00	0.00	0.00	0.00	10.35	3.98	0	149	0	0	0	149
Leards Bridge	22 Aug 85	0.00	0.00	0.00	0.00	0.00	11.01	9.69	0	313	0	0	0	313
Kennys Hole	21 Aug 85	0.00	0.00	0.00	0.00	0.00	0.00	2.72	0	89	0	0	0	89
Cranes	27 Aug 85	0.00	0.00	0.00	0.00	0.00	2.55	2.04	0	80	0	0	0	80
Old Cardigan III	24 May 94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0
Smiths Spring	24 May 94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0
Rowells Riffle	7 Sep 94	7.54	2.29	0.00	0.00	0.00	1.09	5.79	139	233	6	406	0	784
Mooneys Bridge	6 Sep 94	4.19	1.26	0.00	0.00	0.00	1.89	2.64	41	77	3	0	1	122
Forks	1 Sep 94	8.91	5.04	0.39	0.00	0.00	27.83	13.33	171	383	2	111	0	667
Leards Bridge	24 Aug 94	0.00	0.00	0.00	0.00	0.00	20.74	4.74	0	187	3	88	13	291
Kennys Hole	23 Aug 94	15.72	7.57	7.57	1.16	0.00	116.81	32.17	1,716	804	15	30	7	2,571
Cranes	30 Aug 94	45.22	48.24	21.10	4.52	6.03	37.85	2.15	2,678	135	11	127	2	2,954
Rowells Riffle	27 Dec 94	3.07	1.23	0.00	0.00	0.00	0.00	3.07	29	68	2	0	0	98
Mooneys Bridge	23 Dec 94	0.64	0.00	0.00	0.00	0.00	0.00	1.29	3	23	0	0	0	26
Forks	20 Dec 94	2.04	3.57	0.00	0.00	0.00	3.57	0.51	65	23	1	0	0	89
Leards Bridge	16 Dec 94	2.83	0.00	0.00	0.94	0.00	9.42	2.83	262	75	8	0	0	345
Kennys Hole	15 Dec 94	28.07	2.00	0.00	0.00	0.00	20.05	0.00	101	53	5	0	0	159
Cranes	16 Dec 94	11.95	0.00	0.54	0.00	0.00	5.97	0.00	113	22	3	0	0	138
Rowells Riffle	4 Aug 95	28.66	6.74	1.69	0.00	0.00	8.55	1.32	430	91	6	40	0	568
Grants	8 Aug 95	2.19	2.74	4.39	0.00	0.00	2.19	2.74	364	43	0	4	0	411
Forks	31 Jul 95	5.60	9.34	0.80	0.00	0.00	14.13	3.81	443	168	0	144	0	754
Above Landing Pool	8 Aug 95	0.47	4.26	0.00	0.00	0.00	9.00	0.95	76	32	1	139	0	248
Leards Bridge	26 Jul 95	1.86	0.00	0.00	0.00	0.00	30.43	5.07	4	158	3	125	1	291
Kennys Hole	24 Jul 95	17.73	3.80	5.70	1.90	0.00	0.00	17.70	1,458	317	4	112	6	1,897
Upper Kennys	10 Aug 95	23.99	22.07	0.96	0.00	0.00	0.00	8.64	529	115	0	0	10	655
Mooney Tracks	15 Aug 95	13.65	9.56	5.46	0.00	0.00	23.21	19.11	539	290	0	0	0	830
Gill Road	11 Aug 95	48.46	18.46	2.31	0.00	0.00	0.00	2.31	631	82	1	0	2	716
Oates	22 Aug 95	0.74	11.81	6.64	0.74	0.00	1.48	4.43	790	67	0	0	0	857
Old Cardigan III	10 Aug 95	30.88	13.59	3.71	0.00	0.00	12.35	29.64	612	407	0	0	7	1,025
Lower Cranes	9 Aug 95	4.78	2.87	4.78	0.96	0.00	1.91	5.73	696	78	0	0	0	774
Cranes	27 Jul 95	11.31	10.97	11.31	1.71	0.69	7.33	5.42	3,799	126	2	168	99	4,194
Everglades	7 Aug 95	0.00	0.00	2.29	0.00	0.00	0.00	5.72	129	107	0	0	1	238
Martinvale	8 Aug 95	2.52	2.52	1.26	0.00	0.00	0.00	1.26	136	19	0	0	15	170
Rowells Riffle	31 Oct 95	3.99	2.90	0.36	0.00	0.00	7.03	2.11	145	169	1	0	0	315
Grants	3 Nov 95	2.55	1.53	2.55	0.00	0.00	4.59	3.06	207	90	0	0	0	298
Forks	27 Oct 95	2.95	3.25	1.18	0.00	0.00	27.25	7.43	264	429	1	0	0	694
Above Landing Pool	2 Nov 95	5.21	6.07	0.43	0.00	0.00	11.28	1.74	166	81	1	88	0	337
Leards Bridge	25 Oct 95	0.00	0.00	0.00	0.00	0.98	19.57	14.68	421	791	1	0	1	1,214
Kennys Hole	26 Oct 95	12.79	4.26	5.33	3.20	0.00	6.89	10.07	2,426	347	2	0	8	2,782
Upper Kennys	1 Nov 95	13.88	2.97	0.00	0.00	0.00	1.98	0.99	61	24	2	0	7	93
Mooney Tracks	1 Nov 95	2.72	4.08	0.00	0.00	0.00	27.20	2.72	64	170	0	0	0	234
Gill Road	6 Nov 95	25.45	13.88	2.31	0.00	0.00	0.00	0.00	509	0	1	0	3	514
Oates	7 Nov 95	2.95	2.95	0.74	0.00	0.00	2.95	0.74	93	32	0	0	0	125
Old Cardigan III	1 Nov 95	0.00	6.33	2.53	0.00	0.00	13.93	20.25	349	396	0	0	0	744
Lower Cranes	2 Nov 95	0.90	6.28	4.48	0.00	0.00	8.96	2.69	433	83	0	0	0	517
Cranes	24 Oct 95	6.85	4.95	5.33	1.52	0.76	14.90	8.41	1,797	270	2	0	2	2,070
Everglades	2 Nov 95	1.95	3.89	2.92	0.00	0.00	0.97	2.92	260	73	2	0	4	339
Martinvale	3 Nov 95	9.83	6.88	4.92	0.00	0.00	0.00	2.95	410	63	4	0	15	492
Rowells Riffle	4 Sep 96	2.81	2.46	0.00	0.00	0.00	8.31	0.00	95	94	1	0	0	190
Grants	21 Aug 96	5.27	1.62	0.81	0.00	0.00	6.48	0.00	88	42	0	0	0	130
Forks	21 Aug 96	4.31	1.88	1.35	0.00	0.00	21.69	0.00	241	275	0	0	0	516

Appendix 5 (continued)

Site	Date	Density (fish 100 m^{-2})							Biomass (g 100 m^{-2})					
		Brook trout					Atlantic salmon		Brook trout	Atlantic salmon	Three-spined stickle-back	American eel	Other	Total
		0+	1+	2+	3+	4++	0+	1++						
Morell River														
Above Landing Pool	30 Aug 96	0.00	3.49	0.50	0.00	0.00	4.49	0.00	103	20	0	0	0	123
Leards Bridge	19 Aug 96	0.00	0.00	0.00	0.00	0.00	34.43	0.00	0	253	0	41	2	295
Kennys Hole	14 Aug 96	17.93	11.57	4.05	0.58	0.00	10.53	0.00	1,281	269	0	3	4	1,558
Upper Kennys	19 Aug 96	13.75	8.46	1.06	0.00	0.00	14.80	0.00	237	101	2	34	3	377
Mooney Tracks	22 Aug 96	17.41	14.51	0.00	0.00	0.00	24.66	0.00	321	139	0	0	3	462
Gill Road	28 Aug 96	4.74	40.31	2.37	0.00	0.00	9.48	0.00	693	72	0	0	0	765
Old Cardigan III	15 Aug 96	5.85	3.51	0.00	0.00	0.00	4.68	0.00	62	26	0	0	0	88
Lower Cranes	29 Aug 96	4.88	10.73	5.85	0.98	0.00	14.63	0.00	814	100	0	0	0	913
Cranes	20 Aug 96	5.50	2.91	2.91	0.32	0.00	18.00	0.00	1,439	256	2	0	1	1,697
Everglades	28 Aug 96	0.00	0.97	1.94	0.00	0.00	0.00	0.00	136	0	0	205	0	342
Martinvale	26 Aug 96	0.00	3.67	2.44	0.00	0.00	0.00	0.00	154	0	1	0	11	165
Rowells Riffle	8 Sep 97	1.75	2.19	0.00	0.00	0.00	9.85	8.56	89	404	8	0	1	502
Grants	4 Sep 97	6.55	2.34	1.40	0.00	0.00	7.96	3.28	151	94	1	0	0	246
Forks	4 Sep 97	1.17	1.75	1.75	0.00	0.00	21.83	8.99	231	409	2	0	3	645
Above Landing Pool	7 Sep 97	0.50	3.00	0.00	0.00	0.00	7.99	0.50	61	33	1	147	1	244
Leards Bridge	7 Sep 97	6.40	2.99	0.00	0.00	0.00	16.26	11.75	147	478	0	257	0	883
Kennys Hole	28 Aug 97	20.33	10.91	4.46	1.98	0.99	8.98	7.09	2,878	237	1	0	3	3,118
Upper Kennys	10 Sep 97	23.65	10.96	1.15	0.00	0.00	2.74	1.09	541	41	136	282	2	1,001
Mooney Tracks	4 Sep 97	12.28	3.84	0.77	0.00	0.00	9.92	1.42	201	94	1	0	4	300
Gill Road	25 Aug 97	17.26	19.72	7.40	0.00	0.00	0.00	0.00	705	0	135	0	7	847
Old Cardigan III	15 Sep 97	5.70	4.43	0.00	0.00	0.00	10.06	2.16	154	117	0	0	0	271
Lower Cranes	10 Sep 97	4.88	5.85	5.85	0.00	0.00	13.66	3.90	425	114	0	0	0	540
Cranes	24 Sep 97	15.94	5.98	3.13	1.14	0.57	10.14	4.51	1,911	172	17	0	0	2,101
Everglades	26 Aug 97	9.23	2.31	0.00	0.00	0.00	1.15	6.92	65	100	5	0	4	173
Martinvale	26 Aug 97	2.55	3.82	1.27	0.00	0.00	1.27	5.09	149	102	7	6	20	284
Rowells Riffle	16 Sep 98	6.23	9.69	2.42	0.00	0.00	0.94	4.71	595	118	0	0	0	713
Mooneys Bridge	11 Sep 98	3.63	1.81	0.60	0.00	0.00	0.00	0.57	62	11	0	0	0	73
Forks	28 Aug 98	1.53	3.37	0.00	0.00	0.00	10.51	12.16	105	430	0	219	0	754
Leards Bridge	17 Aug 98	0.00	2.12	0.00	0.00	0.00	39.77	6.05	76	266	7	32	0	381
Kennys Hole	11 Aug 98	28.73	12.77	14.37	0.00	0.00	7.17	9.22	719	122	1	39	151	1,031
Cranes	21 Aug 98	19.30	6.95	4.63	0.77	0.00	14.04	8.34	619	228	4	204	0	1,055
Rowells Riffle	21 Sep 99	19.52	7.48	3.25	0.00	0.00	0.32	1.61	874	80	0	0	0	954
Mooneys Bridge	20 Sep 99	4.15	0.46	0.00	0.00	0.00	1.39	0.00	15	9	0	0	0	24
Forks	15 Sep 99	0.63	2.52	0.63	0.00	0.00	6.36	11.85	109	401	0	0	0	509
Leards Bridge	13 Sep 99	1.72	3.44	0.00	0.00	0.00	17.56	16.95	146	812	0	0	0	958
Kennys Hole	10 Sep 99	14.46	18.50	6.36	0.00	0.00	14.92	28.05	1,491	870	0	0	0	2,361
Cranes	14 Sep 99	12.56	10.91	13.88	2.31	0.33	20.09	6.70	3,238	282	0	0	0	3,520
Rowells Riffle	14 Sep 00	19.75	5.22	2.24	0.00	0.00	3.56	1.02	553	36	0	0	0	589
Mooneys Bridge	13 Sep 00	4.44	1.59	0.32	0.00	0.00	2.38	0.40	108	23	0	0	0	131
Forks	12 Sep 00	3.97	5.96	0.85	0.00	0.00	40.96	17.07	307	484	0	0	0	791
Leards Bridge	30 Aug 00	1.10	0.00	2.19	0.00	0.00	34.72	10.18	93	560	0	0	0	653
Kennys Hole	29 Aug 00	18.43	16.13	4.03	1.15	0.00	13.52	36.61	1,237	965	0	0	0	2,202
Cranes	11 Sep 00	11.47	7.65	12.86	0.70	0.35	15.85	11.32	2,881	332	0	0	0	3,214
Rowells Riffle	19 Sep 01	4.00	1.33	0.00	0.00	0.00	2.40	1.71	72	109	0	202	0	383
Mooneys Bridge	18 Sep 01	4.12	1.27	0.95	0.00	0.00	5.66	3.30	141	108	0	0	0	249
Forks	17 Sep 01	13.79	3.76	0.31	0.00	0.00	25.89	2.98	225	252	0	0	0	477
Leards Bridge	12 Sep 01	2.40	1.20	0.60	0.00	0.00	16.23	11.80	162	414	0	57	0	633
Kennys Hole	11 Sep 01	6.11	33.94	16.97	0.00	0.00	36.81	59.91	2,423	1,405	0	12	0	3,840
Cranes	12 Sep 01	1.18	7.86	10.02	0.59	0.00	10.26	6.27	1,712	320	0	249	0	2,280
Little Pierre Jacques River														
1	12 Oct 93	34.98	28.18	4.86	0.00	0.00	0.00	3.20	1,152	42	2	0	0	1,196
2	8 Oct 93	67.92	57.73	15.85	0.00	0.00	0.00	2.15	4,053	22	0	0	0	4,076
3	14 Oct 93	50.19	15.28	0.00	0.00	0.00	3.50	0.00	607	23	3	0	0	633
4	19 Oct 93	36.12	28.43	0.00	0.00	0.00	0.00	0.00	883	0	5	0	0	888
1	14 Jun 94	14.74	24.06	2.33	0.00	0.00	0.00	0.00	875	0	0	0	0	875
2	15 Jun 94	7.98	9.12	0.00	0.00	0.00	0.00	0.00	233	0	0	0	13	247
3	18 Jun 94	14.55	2.65	0.00	0.00	0.00	0.00	0.00	146	0	0	0	0	147
4	16 Jun 94	12.80	21.56	0.67	0.00	0.00	0.00	0.00	806	0	0	0	0	806

Appendix 5 (continued)

Site	Date	Density (fish 100 m^{-2})							Biomass (g 100 m^{-2})					
		Brook trout					Atlantic salmon		Brook trout	Atlantic salmon	Three-spined stickle-back	American eel	Other	Total
		0+	1+	2+	3+	4++	0+	1++						
Little Pierre Jacques River														
1	11 Jul 94	8.40	20.62	3.82	0.00	0.00	0.00	1.85	841	19	0	0	0	860
2	12 Jul 94	25.38	34.81	3.46	0.00	0.00	0.00	0.00	1,117	0	4	0	0	1,120
3	13 Jul 94	18.87	8.58	1.72	0.00	0.00	0.00	1.59	475	18	1	0	0	494
4	14 Jul 94	11.18	17.47	0.00	0.00	0.00	0.00	0.00	558	0	0	0	0	558
1	7 Sep 94	12.10	20.17	3.23	0.00	0.00	2.96	0.99	991	41	0	0	0	1,033
2	8 Sep 94	35.80	53.16	0.00	0.00	0.00	0.00	0.00	1,562	0	3	0	0	1,565
3	7 Sep 94	25.97	8.96	0.00	0.00	0.00	0.00	0.00	300	0	1	0	0	301
4	9 Sep 94	22.06	13.89	0.00	0.00	0.00	0.00	0.00	425	0	1	0	0	425
1	28 Jun 95	2.35	14.90	0.78	0.00	0.00	0.00	1.70	526	43	1	0	0	570
2	27 Jun 95	8.93	28.80	2.98	0.00	0.00	0.00	0.00	1,076	0	6	0	0	1,082
3	29 Jun 95	21.70	5.84	0.00	0.00	0.00	0.00	0.00	205	0	0	0	0	205
4	30 Jun 95	4.70	15.68	0.00	0.00	0.00	0.00	0.00	553	0	0	0	0	553
1	10 Aug 95	3.83	13.39	2.87	0.00	0.00	0.00	0.00	512	0	0	0	0	512
2	10 Aug 95	6.67	31.15	5.56	0.00	0.00	2.18	0.00	1,513	4	0	0	0	1,517
3	11 Aug 95	14.35	12.44	1.91	0.00	0.00	0.00	0.00	494	0	4	0	0	499
4	11 Aug 95	6.24	4.99	1.25	0.00	0.00	0.00	0.00	211	0	3	0	0	214
1	25 Sep 95	2.64	11.45	0.88	0.00	0.00	0.00	1.74	433	17	0	0	0	450
2	26 Sep 95	15.35	27.42	1.10	0.00	0.00	0.00	0.00	1,177	0	3	0	0	1,180
3	26 Sep 95	19.61	7.84	0.98	0.00	0.00	0.00	0.00	394	0	1	0	0	395
4	27 Sep 95	10.34	6.89	0.86	0.00	0.00	0.00	0.00	344	0	1	0	0	344
Enmore River														
1	4 Oct 93	13.55	0.00	0.00	0.00	0.00	38.51	1.04	53	150	1	0	1	205
2	1 Oct 93	12.68	1.59	0.00	0.00	0.00	13.85	1.46	83	92	16	0	1	193
3	12 Nov 93	2.20	12.11	2.20	0.00	0.00	0.00	0.00	565	0	5	0	8	578
4	6 Oct 93	5.71	5.71	3.81	0.00	0.00	0.00	0.00	830	0	3	0	0	834
1	6 Jun 94	17.77	3.23	0.00	0.00	0.00	0.00	8.57	67	79	17	0	2	165
2	8 Jun 94	12.28	3.07	3.07	0.00	0.00	0.00	3.93	177	39	10	0	0	226
3	9 Jun 94	3.45	4.31	1.72	0.00	0.00	0.00	0.00	288	0	3	0	0	291
4	13 Jun 94	6.43	11.79	2.14	0.00	0.00	0.00	2.08	623	13	8	0	1	645
1	3 Jul 94	3.50	0.00	0.00	0.00	0.00	0.00	5.07	5	51	7	0	0	64
2	5 Jul 94	6.99	1.40	0.00	0.70	0.00	0.00	4.79	390	69	4	0	0	463
3	6 Jul 94	0.92	16.50	4.58	0.00	0.00	0.00	0.00	1,130	0	2	0	2	1,134
4	7 Jul 94	2.23	17.82	10.03	0.00	0.00	0.00	0.00	1,750	0	21	0	0	1,771
1	15 Aug 94	23.37	0.00	0.00	0.00	0.00	4.48	0.00	26	23	2	0	0	52
2	15 Aug 94	15.15	0.00	0.00	0.00	0.00	5.00	5.00	31	65	10	0	0	106
3	16 Aug 94	2.11	22.17	2.11	0.00	0.00	0.00	0.00	834	0	8	0	1	843
4	17 Aug 94	4.96	17.38	17.38	2.48	0.00	0.00	0.00	3,778	0	7	0	0	3,785
1	11 Oct 94	4.81	0.00	0.00	0.00	0.00	2.40	0.00	3	22	1	0	0	26
2	11 Oct 94	3.96	0.00	0.00	0.00	0.00	1.57	1.57	20	30	2	0	0	53
3	12 Oct 94	3.95	10.87	0.00	0.00	0.00	0.00	0.00	329	0	2	0	0	331
4	12 Oct 94	5.42	9.49	6.78	0.00	0.00	0.00	0.00	1,028	0	3	0	0	1,031
1	22 Jun 95	4.39	0.00	0.00	0.00	0.00	0.00	0.00	2	0	4	0	0	6
2	22 Jun 95	1.61	0.00	0.81	0.00	0.00	0.00	0.00	74	0	7	0	0	81
3	28 Jun 95	1.89	1.89	0.94	0.00	0.00	0.00	0.00	165	0	5	0	4	173
4	23 Jun 95	7.13	17.83	9.51	0.00	0.00	0.00	0.00	1,572	0	5	0	2	1,580
1	7 Aug 95	24.02	0.00	0.00	0.00	0.00	0.00	0.00	40	0	2	0	0	41
2	7 Aug 95	23.02	0.00	0.00	0.00	0.00	0.00	0.00	38	0	1	0	0	39
3	8 Aug 95	3.21	0.00	2.14	0.00	0.00	0.00	0.00	349	0	2	0	1	352
4	9 Aug 95	6.31	15.14	6.31	0.00	0.00	0.00	0.00	1,179	0	2	0	1	1,182
1	19 Sep 95	3.94	0.00	0.00	0.00	0.00	0.00	0.00	10	0	0	0	0	10
2	19 Sep 95	9.66	0.74	0.74	0.00	0.00	0.00	0.00	104	0	0	0	0	105
3	25 Sep 95	1.15	4.58	0.00	0.00	0.00	0.00	0.00	160	0	9	0	0	169
4	22 Sep 95	3.51	8.18	2.34	0.00	0.00	0.00	0.00	429	0	3	0	0	432
Ellerslie River														
1	21 Oct 93	19.83	15.62	0.60	0.00	0.00	0.00	0.00	604	0	4	0	0	608
2	21 Oct 93	10.21	13.61	5.67	2.27	0.00	0.00	0.00	1,679	0	16	0	1	1,697
3	21 Oct 93	57.76	37.05	3.27	0.00	0.00	0.00	0.00	1,528	0	4	0	0	1,532
4	21 Oct 93	36.42	6.62	0.00	0.00	0.00	0.00	0.00	283	0	34	0	0	317
1	27 Jun 94	27.27	11.41	0.00	0.00	0.00	0.00	0.00	341	0	4	0	0	345
2	28 Jun 94	12.39	16.27	6.20	0.00	0.77	0.00	0.00	2,037	0	0	0	0	2,037
3	17 Jun 94	19.72	23.00	1.10	0.00	0.00	0.00	0.00	866	0	2	0	0	868
4	20 Jun 94	13.99	4.94	0.00	0.00	0.00	0.00	0.00	207	0	0	0	0	207
1	20 Jul 94	23.80	13.60	0.00	0.00	0.00	0.00	0.00	397	0	3	0	0	400
2	22 Jul 94	12.47	28.07	7.80	0.00	0.78	0.00	0.00	2,655	0	1	0	0	2,656
3	18 Jul 94	35.76	47.29	4.61	0.00	0.00	0.00	0.00	1,947	0	4	0	0	1,951
4	19 Jul 94	12.72	5.87	0.00	0.00	0.00	0.00	0.00	217	0	3	0	0	219
1	22 Sep 94	13.42	10.06	0.67	0.00	0.00	0.00	0.00	346	0	2	0	0	348
2	21 Sep 94	14.65	29.30	8.62	0.00	0.00	0.00	0.00	1,992	0	2	0	1	1,995
3	19 Sep 94	39.70	36.20	4.67	0.00	0.00	0.00	0.00	1,812	0	4	0	3	1,818
4	20 Sep 94	10.01	7.28	0.00	0.00	0.00	0.00	0.00	272	0	2	0	0	274

Appendix 5 (continued)

Site	Date	Density (fish 100 m^{-2})							Biomass (g 100 m^{-2})					
		Brook trout					Atlantic salmon		Brook trout	Atlantic salmon	Three-spined stickle-back	American eel	Other	Total
		0+	1+	2+	3+	4++	0+	1++						
Ellerslie River														
1	5 Jul 95	17.57	10.14	1.35	0.00	0.00	0.00	0.00	487	0	2	0	0	489
2	5 Jul 95	18.51	19.39	1.76	0.00	0.00	0.00	0.00	886	0	0	0	0	886
3	4 Jul 95	26.56	34.00	4.25	0.00	0.00	0.00	0.00	1,621	0	4	0	0	1,625
4	3 Jul 95	14.73	2.76	0.00	0.00	0.00	0.00	0.00	127	0	1	0	0	127
1	15 Aug 95	21.71	10.52	1.32	0.00	0.00	0.00	0.00	528	0	1	0	0	530
2	15 Aug 95	22.80	13.98	2.21	0.00	0.00	0.00	0.00	834	0	0	0	0	834
3	14 Aug 95	42.61	45.04	3.65	0.00	0.00	0.00	0.00	2,037	0	6	0	0	2,043
4	13 Aug 95	8.15	2.04	0.00	0.00	0.00	0.00	0.00	63	0	1	0	0	64
1	27 Sep 95	18.72	11.09	1.39	0.00	0.00	0.00	0.00	497	0	0	0	0	497
2	28 Sep 95	24.23	20.19	1.62	0.00	0.00	0.00	0.00	922	0	0	0	0	922
3	29 Sep 95	34.81	21.88	1.99	0.00	0.00	0.00	0.00	1,185	0	0	0	0	1,186
4	28 Sep 95	13.03	1.00	0.00	0.00	0.00	1.90	0.00	104	2	0	0	0	106
Trout River (Coleman)														
Bannys Hole	2 Oct 93	22.74	24.25	3.03	0.51	0.51	26.76	2.11	1,660	138	25	0	0	1,824
Seal River														
1	3 Sep 93	55.02	0.00	0.00	0.00	0.00	0.00	0.00	212	0	3	0	0	215
2	7 Sep 93	63.91	70.76	6.85	0.00	0.00	0.00	0.00	2,768	0	110	0	33	2,911
3	9 Sep 93	83.26	5.55	0.00	0.00	0.00	0.00	0.00	406	0	10	0	0	416
4	14 Sep 93	40.94	8.77	0.00	0.00	0.00	0.00	0.00	308	0	16	0	0	325
1	30 May 94	8.03	0.00	0.00	0.00	0.00	0.00	0.00	1	0	4	0	0	5
2	31 May 94	23.97	19.61	2.18	0.00	0.00	0.00	0.00	1,035	0	21	0	74	1,130
3	1 Jun 94	50.78	1.95	0.00	0.00	0.00	0.00	0.00	105	0	1	0	5	111
4	8 Jun 94	1.74	3.48	0.00	0.00	0.00	0.00	0.00	138	0	0	0	0	138
1	20 Jul 94	93.81	0.00	0.00	0.00	0.00	0.00	0.00	213	0	0	0	0	213
2	21 Jul 94	7.93	53.52	9.91	0.00	0.00	0.00	0.00	2,809	0	8	0	0	2,817
3	21 Jul 94	38.77	4.31	0.00	0.00	0.00	0.00	0.00	185	0	0	0	0	185
4	20 Jul 94	9.29	9.29	0.00	0.00	0.00	0.00	0.00	314	0	0	0	0	314
1	19 Sep 94	72.41	3.02	0.00	0.00	0.00	0.00	0.00	375	0	2	0	0	377
2	20 Sep 94	10.69	42.75	4.27	0.00	0.00	0.00	0.00	1,951	0	25	0	27	2,003
3	20 Sep 94	38.56	4.63	0.00	0.00	0.00	0.00	0.00	236	0	7	0	56	299
4	21 Sep 94	16.21	11.58	0.00	0.00	0.00	0.00	0.00	363	0	1	0	0	363
1	11 Jul 95	88.86	55.33	3.35	0.00	0.00	0.00	0.00	2,052	0	3	0	0	2,054
2	11 Jul 95	1.72	5.17	1.72	0.00	0.00	0.00	0.00	354	0	2	0	0	356
3	11 Jul 95	60.73	6.51	0.00	0.00	0.00	0.00	0.00	159	0	9	0	0	168
4	7 Jul 95	10.53	5.26	0.00	0.00	0.00	0.00	0.00	300	0	3	0	0	303
1	17 Oct 95	70.67	9.22	0.00	0.00	0.00	0.00	0.00	717	0	0	0	0	717
2	23 Oct 95	4.28	6.42	6.42	0.00	0.00	0.00	0.00	708	0	13	0	0	721
3	23 Oct 95	13.95	5.07	0.00	0.00	0.00	0.00	0.00	191	0	5	0	0	196
4	17 Oct 95	8.89	10.66	0.00	0.00	0.00	0.00	0.00	388	0	0	0	0	388
Vernon River														
1	15 Sep 93	217.16	21.60	1.14	0.00	0.00	2.18	0.00	2,412	6	156	0	113	2,686
2	16 Sep 93	64.54	39.72	6.95	0.00	0.00	0.00	1.88	2,153	26	108	0	9	2,295
3	20 Sep 93	44.23	14.27	0.00	0.00	0.00	0.00	0.00	549	0	37	0	22	607
4	21 Sep 93	102.11	42.15	3.75	0.00	0.00	0.00	0.00	1,955	0	65	0	7	2,027
1	2 Jun 94	63.56	19.35	1.38	0.00	0.00	0.00	0.00	698	0	36	0	147	880
2	15 Jun 94	62.44	20.49	3.90	0.00	0.00	0.00	0.00	1,224	0	4	0	0	1,228
3	14 Jun 94	67.75	11.29	0.00	0.00	0.00	0.00	0.00	317	0	9	0	0	325
4	10 Jun 94	141.01	13.22	0.00	0.00	0.00	0.00	0.00	812	0	18	0	0	630
1	22 Jul 94	141.90	26.40	0.00	0.00	0.00	0.00	0.00	402	14	4	0	0	420
2	22 Jul 94	18.07	4.25	2.13	0.00	0.00	0.00	0.00	435	0	0	0	0	435
3	25 Jul 94	48.83	57.07	10.24	0.00	1.46	0.00	0.00	3,977	0	0	0	0	3,977
4	26 Jul 94	76.62	43.30	2.22	1.11	0.00	0.00	0.00	2,513	0	0	0	0	2,513
1	19 Sep 94	86.30	16.70	2.78	0.00	0.00	2.47	0.00	1,114	7	32	0	11	1,164
2	22 Sep 94	50.05	35.26	5.69	1.14	0.00	0.00	0.00	1,851	0	0	0	35	1,887
3	22 Sep 94	35.77	8.13	0.00	0.00	0.00	0.00	0.00	319	0	29	0	0	348
4	23 Sep 94	107.96	33.74	2.25	0.00	0.00	1.94	0.00	1,463	4	12	0	0	1,479
1	6 Jul 95	22.37	10.60	0.00	0.00	0.00	0.00	0.00	251	0	11	0	0	262
2	12 Jul 95	28.78	37.77	5.40	0.00	0.00	0.00	0.00	877	0	5	0	0	881
3	12 Jul 95	52.09	13.02	0.00	0.00	0.00	0.00	0.00	365	0	6	0	0	371
4	13 Jul 95	53.96	41.85	2.20	0.00	0.00	0.00	0.00	1,284	0	38	0	0	1,322
1	18 Oct 95	18.92	10.19	0.00	0.00	0.00	2.35	2.35	297	35	10	0	0	343
2	19 Oct 95	23.30	17.17	12.26	0.00	0.00	0.00	1.78	1,887	30	6	0	0	1,723
3	20 Oct 95	38.47	7.60	0.00	0.00	0.00	0.00	0.00	305	0	4	0	0	309
4	20 Oct 95	79.53	30.88	0.00	0.00	0.00	0.00	0.00	1,156	0	12	0	0	1,168

Survival of eggs and alevins of Atlantic salmon and brook trout in relation to fine sediment deposition

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ABSTRACT

This study tests the hypothesis that salmonid egg/alevin survival in the wild is related to the amount of fine sediment deposited in redds from erosion within the catchment. Survival to pre-hatch and survival to emergence were estimated for Atlantic salmon (*Salmo salar*) and for brook trout (*Salvelinus fontinalis*) at 10 sites in the Morell River in Prince Edward Island, Canada, where there is intensive agriculture activity and consequent sediment inputs to river channels. Fertilized eggs from local wild stocks were placed in incubation baskets with substrate particles between 2 and 50 mm diameter and set (in triplicate) in the streambed in known spawning locations. In mid-winter (January), one basket was removed from each site to estimate pre-hatch survival and fine sediment accumulation. Pre-hatch survival ranged from 63% to 99% for Atlantic salmon and from 39% to 95% for trout. Highest trout survival occurred in the site with greatest groundwater discharge (flux). In the spring, emergence traps were attached to remaining baskets, and monitored daily. Fine sediment accumulation was high in all baskets compared with similar incubation experiments in non-agricultural catchments. Survival to emergence varied widely between baskets and among sites for brook trout (0 – 85%) and for salmon (0 – 56%) with a mean emergence survival for both species of <15%. Accumulated sediment weight was not significantly correlated with survival to pre-emergence or to survival to emergence in salmon, in trout, and in trout and salmon combined. Groundwater flux, stream habitat and trap design may have influenced pre-emergence and emergence success.

INTRODUCTION

Sediment is the number one pollutant in streams in North America (Waters 1995). Fishes are very susceptible to negative impacts generated from sediment input to streams. This impact is mostly the result of increased turbidity and suspended sediments (Redding et al. 1987, Barrett et al. 1992, but see Johnson and Hines 1999) that can act directly to reduce production and habitat complexity (Saunders and Smith 1965, Hartman and Scrivener 1990, Waters 1995, Cunjak 1996, Wohl and Carline 1996) and invertebrate (prey) abundance (Campbell and Doeg 1989, O'Connor and Lake 1994). Sedimentation is especially problematic for egg/alevin survival (Chapman 1988, Sowden and Power 1985) of autumn spawning species such as Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*) because this life-stage is protracted over winter and eggs/alevins are unable to avoid high sediment concentrations due to lack of mobility in the redd.

Atlantic salmon and brook trout are native to streams of Prince Edward Island (PEI), Canada, and both are important species to the recreational fishery. Agriculture is the most important industry in PEI and about 18-20% of the province's land area is in potato rotation (Cairns 2002). Sediment in streams on PEI originates from a variety of sources including erosion from agricultural activity, unpaved roads, forestry activity, and residential and commercial development. One estimate of sediment deposition indicated an average soil loss of 10 and 14 tonnes per hectare per year from the agricultural lands in the Wilmot/Dunk and Montague/Valleyfield River catchments in PEI (Washburn and Gillis 1992). In recent years, pesticide runoff from agricultural land has been implicated in several fish kills in PEI streams (Mutch et al. 2002). The direct (lethal) results of pesticide

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contamination are often evident and well publicized, but the damage to fish caused by sedimentation is less obvious.

Given these circumstances, the present study was designed as a first step to address the hypothesis that salmonid eggs/alevins are negatively affected by sedimentation in PEI streams. Specifically, we predicted that survival to the eyed-stage (egg) and to emergence (alevin) would be negatively related to the amount of fine sediment (<2 mm particle size) accumulating in redds. In order to simulate in-redd conditions, incubation baskets with emergence traps (modified from those developed by Bardonnet and Gaudin 1990) were tested for their potential to monitor survival in relation to sediment loading in the Morell River, PEI. One advantage of this technique is that survival of a known number of individuals can be accurately determined. Further, measuring the amount of particles within each basket permits assessment of the relation between survival and fine sediment accumulation.

METHODS

Study area

The Morell River, a fourth-order river system (170 km^2 drainage area) in northeastern PEI, was chosen for the field research. The Morell has naturally spawning, anadromous populations of both brook trout and Atlantic salmon and is the most important river on PEI for recreational fishing (Cairns 1996). Approximately 40% of the catchment area is cleared.

Survival to pre-hatch (eyed stage), and survival to emergence, were estimated separately for brook trout and Atlantic salmon at 10 sites (Fig. 1). For Atlantic salmon, five sites for planting of egg-baskets were selected where salmon were known to have spawned in previous years. In October/November 1996 (this study) recently dug redds were identified at each of the chosen sites. Typically, study sites were in runs or in the lower ends of a pool, near the riffle crest, where substrate was a mixture of sand/gravel/cobble. Site S1 was located in the West Branch approximately 100 m downstream from the outflow of Leards Pond (Fig. 1). Sites S2 and S3 were located in the South Branch within 0.5 km of one another. Numerous road crossings and agricultural land-use potentially affect these sites. Site S3 is immediately downstream of an in-channel sediment collection pit built in 1996 and was chosen for comparison with site S2, where no such sediment mitigation measures have been constructed. Site S4 is located on the East Branch approximately 1 km upstream of its junction with the mainstem. This sub-basin is considered to have the least land-use activity within the Morell catchment (D. Guignion, personal observation). Site S5 is located on the West Branch 3 km upstream from the junction with the South Branch (Fig. 1). Fine sediment accumulation in the stream is most pronounced here of all the sites, presumably from the intensive agricultural activity in this sub-basin. Based on local knowledge and an initial visual assessment of substrate composition, fine sediment loading to sites was predicted to be S4<S1<S3<S2<S5 (lowest to highest).

For brook trout, five sites for planting of egg-baskets were selected (Fig. 1) in areas where brook trout have been seen spawning, including the year of this research (1996). Unlike the situation for Atlantic salmon, trout egg-baskets were planted in proximity to localized groundwater discharges ('spring seeps') reflecting this species' preference for such zones for spawning and egg incubation (Curry and Noakes 1995, Curry et al. 1995). Groundwater discharge zones were visibly identifiable. Substrate in all sites was typically sand/gravel. Site T1 was located in the mainstem approximately 100 m upstream from the head of tide and near mid-channel. Site T2 was located in the source (pool and channel) of a first-order spring-fed tributary (<500 m from site T1, Fig. 1) where groundwater was discharging. Site T3 was located in the South Branch 1 km upstream from the junction with the West Branch (Fig. 1). Site T4 was located in the East Branch within 50 m of the salmon site (S4). Site T5 was located in the West Branch 100 m upstream from salmon site S5. Fine sediment loading to trout incubation sites was predicted to be T2<T4<T3<T1<T5 (lowest to highest).

Procedures

All spawning of Atlantic salmon and brook trout, and egg enumeration was done at the Cardigan Salmonid Enhancement Centre in Cardigan, PEI (Fig. 1). On 6 November 1996, a pair of wild salmon (male grilse and multi-sea-winter female) captured at the Morell River fish-trap earlier that year was spawned. Eggs were immediately water-hardened for 3 h and immersed in a topical disinfectant (iodine solution) for 10 min. Individual lots of 100 eggs were counted and immersed in separate, covered, glass jars for transport to sites. In addition to the eggs destined for incubation baskets, 6,796 eggs were retained in the hatchery in egg trays to serve as controls to monitor fertilization success and egg survival under 'optimal' conditions. At the study site, jars were allowed to temperature-acclimate in the stream while the incubation site was prepared (1 h). Three excavation pits approximately 40 cm wide x 70 cm long x 30 cm deep were dug, in mid-channel at salmon sites; and in the influence of groundwater discharge at trout sites. Baskets were placed 1-2 m apart from one another.

Incubation baskets were cylindrical in shape (as described in Bardonnet and Gaudin 1990), constructed of black ABS pipe-fitting caps (12.4 cm diameter) for the top and bottom of the basket. Black Nytex screening (2 mm mesh openings), bonded along the seam with plastic cement, made up the 40 m long cylinders. The top screw cap was also fitted with a smaller (5 cm diameter), threaded, plastic neck (8 cm long) and cap for eventual attachment of the emergence basket. Emergence baskets (traps) were similar to the incubation baskets, with the same materials, but slightly smaller (20 cm long cylinders, 12 cm diameter). Emergence trap caps had a threaded female insert for attachment to the incubation basket. When attached, the traps rested entirely within the stream column, or partly out of the water depending on water level.

After pits were dug, sand, gravel, and small cobble from the streambed were sieved to remove all fines <2 mm. The sieved material was placed in the incubation basket to ¼ volume. With the basket immersed in the stream, approximately 1/3 of the eggs were carefully poured into basket. More sieved substrate was placed in the basket followed by more eggs, and so on until all 100 eggs were inserted and covered by a final layer of particles. The incubation basket was then capped and placed within the pit, facing downstream and inclined approximately 20° such that the top-cap was at the streambed. The basket was covered with the remainder of sieved substrate such that only that portion of the top-cap with the emergence trap fitting was exposed on the streambed. All 15 baskets (5 sites, 3 baskets per site) were planted the same day, within 12 h of spawning. Water temperatures at the sites ranged between 3.4°C and 4.7°C at the time of egg planting.

On 8 November 1996, two brook trout of wild, anadromous Morell River stock (captured earlier that summer) were spawned (a 49.5 cm female and a 48.5 cm male). As a control for monitoring egg survival, 2,754 eggs from this pairing were retained in the hatchery, in egg trays. The procedure for planting of trout egg baskets was similar to the protocol used for Atlantic salmon. All 15 baskets (5 sites) were planted the same day, within 12 h of spawning. Water temperature at the sites ranged between 6.9°C and 7.4°C, reflecting the groundwater influence at brook trout sites.

Removal of a single incubation basket was carried out on 9-10 January, 1997, to assess pre-hatch survival ('eyed' stage). The middle basket in each triplet set (per site) was removed; the same protocol was used for all Atlantic salmon and brook trout egg baskets. First, all substrate particles covering the baskets were carefully cleared aside to expose approximately half the basket. With a single, quick motion, the basket was lifted from the stream and immediately placed in a bucket to capture any fines draining from the basket. The individual buckets (with baskets) were then transported to the laboratory the same day for assessment of egg survival.

In the laboratory, contents of the bucket and basket were emptied and rinsed into a large tub for sorting eggs from sediments. Eggs were enumerated and separated into two categories: live eggs (yellow/orange, often with evidence of eyed alevin inside), and dead eggs (white, opaque). In the case of brook trout eggs at sites T2 and T4, the first yolk-sac fry were already present; hence, these stages were separately enumerated. No sac fry were found in Atlantic salmon egg baskets. Fungus was occasionally found on dead eggs; in those circumstances when a group of dead eggs was covered in fungus, separation and enumeration was done under a light microscope.

All sediment was sieved and sorted to remove particles >2 mm diameter (as these could not have entered through the mesh openings). The remaining sediment and water was placed in labeled, plastic bags and frozen for future drying and particle size analysis. In the laboratory, fine sediments (<2 mm) accumulating in the incubation baskets were oven dried (60°C) for 24 – 48 h and then sorted, by sieving, into the following fractions: 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm, and silt (<0.063 mm). Each fraction was then weighed (±0.001g).

Emergence traps were attached to the pair of remaining egg baskets at each site in order to capture emergent fry. In the case of brook trout baskets at sites T2 and T4, emergence traps were put in the stream on 10 January 1999. The remainder of the emergence traps were attached to incubation baskets in early February (brook trout sites) or late April (Atlantic salmon sites). Emergence traps were checked 2-3 times per week. Fry were enumerated and time of day and basket identification noted. A sub-sample of Atlantic salmon fry in emergence traps were measured (fork length (FL), mm) to determine if the incubation environment differentially affected early growth among sites. Following the peak of emergence at any site, baskets were removed following two consecutive checks with no fry captured.

Groundwater measurements were made with mini-piezometers (Lee and Cherry 1978) on 25 February 1997. Hydraulic head is a measure of pressure head; conductivity is an indicator of substrate permeability; and flux reflects the amount of groundwater discharging per unit are per unit time ($cm^3/cm^2/s$). Mean groundwater flux measured in brook trout redds in lake and stream habitats in central Ontario were typically >1 X 10^{-3} cm/s (Curry and Devito 1996).

Statistics
Survival (S, %) to pre-hatch (or emergence) was calculated as:

$$S = [n / (i - m)] \cdot 100$$

where n = number of live eggs (or emergent fry) enumerated upon retrieval of basket; i = initial number of eggs placed in basket (=100); m = percentage of dead eggs in hatchery control group.

Analysis of variance (ANOVA) was used to compare sizes of emergent Atlantic salmon fry from the three study sites where sufficient numbers permitted testing. Regression analysis was used to test for relations between sediment accumulation and survival to emergence.

RESULTS AND DISCUSSION

<u>Survival to pre-hatch (eyed stage)</u>
For Atlantic salmon, egg survival for the control group (held in hatchery trays) was high, at both pre-hatch (98.6%) and pre-emergence (97.7%). Survival of brook

trout eggs in the hatchery was relatively poor. By 6 January 1997 (just prior to removal of first baskets from stream sites), 678 of the initial 2,754 trout eggs died or failed to develop because of non-fertilization. This represented a survival of 75.4%, within the expected range for brook trout according to a local hatchery manager (M. Hambrook, Miramichi Fish Hatchery, NB, personal communication). Subsequent mortality of trout eggs in the control group was negligible (1.3% egg mortality between 6 January and 9 March). These survival values, 75.4% and 74.1%, were used as a correction for estimating egg survival to pre-hatch and emergence, respectively

For Atlantic salmon eggs in the stream sites, survival to pre-hatch was generally high with four of five sites having survival >80% (Table 1). Both sites on the South Branch (sites S2 and S3) had near 100% survival. Pre-hatch survival at site S5 was low (62.9%). Incubation basket experiments (n=10) in Catamaran Brook, New Brunswick (Miramichi basin) in 1998/99 yielded similar results with a mean pre-hatch survival of 91.5% (range = 75% - 95%, J. Flanagan, Biology Department, University of New Brunswick, Fredericton, NB, unpublished data).

Brook trout survival to pre-hatch was markedly lower than that of Atlantic salmon (Table 1). For four of five sites, brook trout egg to pre-hatch survival was <70%. Only the spring-fed tributary (site T2), where groundwater discharge (flux) was highest (Table 2) showed a high survival (95.0%).

Survival to emergence

The number of fry captured in emergence traps varied greatly between the two traps at each site as well as among sites (Figs. 2 and 3). Survival to emergence was generally low for both species. For Atlantic salmon, the best survival to emergence was found in the two baskets at site S3 with survival estimates of 56% and 27% (Fig. 2). This is the site where an in-stream sediment collection pit was excavated in the summer of 1996. Such measures have been successful in other salmonid streams in North America (Hansen et al. 1983, Alexander and Hansen 1988) where sediment loading reduced salmonid production. Such stream enhancement measures may offer a temporary solution to sediment problems in PEI streams and should be considered where conditions are suitable.

Emergence survival in all Atlantic salmon baskets in the other four sites was <26% (Fig. 2). Both baskets at site S2 had zero emergence despite being located <1 km upstream of site 3 where highest emergence survival was recorded. Zero emergence was also recorded from single baskets at sites S1 and S4. Emergence survival for salmon in the Morell River sites ranged from 0% - 56%, a marked decline from the high survivals measured at the pre-hatch stage. By comparison, mean emergence survival estimated for four sites (13 baskets) in Catamaran Brook, NB, in 1998/99 was 61.5% (range = 21% - 83%; J. Flanagan, unpublished data).

For brook trout, emergence survival ranged from 0% to 85%. The best single basket survival was found at site T2; no other basket had an emergence survival >30%. Both baskets at site T3 and one basket at site T1 yielded no emergent trout fry (Fig. 3).

Fine sediments were often found in the emergence traps when checking for alevins. This sediment seemed to originate from *within* the incubation basket, suggesting a large amount of fines accumulated in the incubation basket, some of which then 'leaked' into the emergence trap. Indeed, upon emptying these baskets, an abundance of fine sediment was noted extending well into the throat of the emergence channel. Therefore, it is possible that some of the alevins that hatched in the incubation basket may have been precluded from emerging due to a 'plug' of sediment between the basket and emergence trap. This may explain the occurrence of alevins, many with depleted yolk sacs, within incubation baskets when these were retrieved at the end of the experiment (Table 3). However, even when accounting for these individuals as an estimate of alevin survival, emergence success was still quite low for both brook trout and for Atlantic salmon in the Morell River sites (Figs. 2, 3).

It is difficult to establish the precise timing of emergence of brook trout because so few alevins actually emerged from the baskets (Table 3). Based on results from sites T1, T2 and T4 where emergent fry were captured, the period of emergence was earliest (February/March) in site T2 (the spring-fed tributary) and latest (late April) in the lower mainstem reach (site T1) of the Morell River (Table 3), reflecting the thermal regimes in these sites. Atlantic salmon emergence was later than for trout as is typical where these two species coexist (Randall 1982). Salmon emergence generally started in May, with peaks in early June (Table 3). Whether emergence timing from baskets was representative of the timing from natural redds was not investigated here. However, in parts of the Miramichi River system, NB, emergence into traps was coincident with emergence as inferred from drift patterns in the stream (Cunjak, unpublished data; Johnston 1997).

Emergent fry of Atlantic salmon were measured between 1 June and 12 June 1997 (Table 4) from sites S1, S3 and S5 (where numbers were sufficient). Mean size was greatest at site S3 (29.28 mm ± 0.79) where emergence survival was highest (Fig. 2); the smallest fry were found at site S1 (28.06 mm ± 0.83). Size of emergent fry differed significantly among sites ($F = 12.03$, $p < 0.001$). Emergent brook trout fry were not measured.

Sediment Accumulation in Baskets

Atlantic salmon baskets accumulated 62.3 - 200.5 g dry weight of fines after two months in the stream (Table 5). Accumulations in brook trout baskets were much higher (206.5 - 958.2 g). No significant correlations were found between survival to pre-emergence and sediment accumulation for salmon (r=-0.41, P>0.5), for trout (r=0.08, P>05), and for salmon and trout combined (r=-0.53, P>0.5) (Fig. 4).

In the case of brook trout, groundwater flowage may have mitigated the effects of heavy sediment loads. Site T2 showed the highest sediment accumulation and the highest pre-emergence survival. This site had a groundwater flux that was much higher than that of any other site (Table 2).

After seven months in the streams, the accumulated fine sediments in Atlantic salmon incubation baskets increased four-fold from the levels after two months. Highest accumulations were measured at site S5, moderate accumulations at sites S2 and S3, and least fines measured at sites S1 and S4. A similar pattern in the percentage of fines was found by Caissie and Arseneau (2002) who found fines to make up 46%, 36% and 18% of streambed particle composition at sites S5, S2, and S4, respectively. These results suggest that the accumulations measured in baskets in the present study reflect local substrate characteristics.

For Atlantic salmon sites, after seven months, the mean fine sediment accumulation in baskets was 636.3 g (Table 5). In Catamaran Brook, mean fine sediment accumulation in baskets (n = 4) was only 126.7 g (range = 102 – 190 g) after five months in the water (J. Flanagan, unpublished data). These accumulations are similar to those found in the Morell River sites after two months.

Unlike the marked sediment increase measured in Atlantic salmon baskets between two and seven months, the situation for brook trout baskets was striking for the lack of change of accumulated sediments between November and May. Except for site T3 where a 757 g increase was realized, the trout sites had a sediment accumulation change of <50 g between the two dates. However, total sediment loading was still very high (Table 5). Possibly, incubation baskets at brook trout sites became saturated with fine sediments. The 6-7 month sediment accumulation was much higher in brook trout baskets than in salmon baskets (Table 5), similar to the situation measured after two months.

The positioning of salmon redds near mid-channel in relatively fast flows, and where hydraulics would reduce deposition of fines (i.e. near riffle crests), could partly explain the lower accumulation of fines relative to brook trout egg incubation sites. The relatively low accumulation of fines at site T2 was likely related to these same habitat characteristics because this site was located in mid-channel where streamflow was moderate to high, depending on river stage. Such habitat-specific effects on localized sedimentation partly explain why the predicted sediment-loading pattern in brook trout sites was not realized. For example, site T1 accumulated fewer fines than predicted and site T4 received far more than expected despite a low accumulation in the salmon baskets nearby (S4, Table 5).

No significant correlations were found between survival to emergence and sediment accumulation for salmon (r=0.24, P>0.5), for trout (r=-0.41, P>05), and for salmon and trout combined (r=-0.15, P>0.5) (Fig. 5).

The initially high pre-hatch survival advantage of Atlantic salmon (relative to brook trout, Table 1) was nullified by the time of emergence despite the lower sediment loading in salmon baskets (Table 5). The highest mean salmon fry survival (41%) was found at site S3 (Fig. 2) where accumulated sediment was 712 g, above the average for salmon sites but well below that measured in trout baskets (Table 5). One of the lowest sediment accumulations was found at site S4 (281.2 g) and yet survival to emergence was only 1% (Fig. 2). By contrast, brook trout survival to emergence (Fig. 3) was highest at site T2 (mean = 49%) and site T4 (mean = 17%) where mean sediment accumulations were 950 g and 1427 g, respectively (Table 5). Groundwater flux, however, was highest at these two sites (Table 2) and may have contributed to alevin survival. Future studies of alevin survival should test the hypotheses that 1) Atlantic salmon alevins in streams like the Morell River may be more sensitive than brook trout alevins to fine sediment loading, and 2) groundwater discharge lessens the impact of fine sediment loading (perhaps by providing sufficient aeration to offset the potential impact).

The present study has demonstrated the utility of the egg basket technique for investigating effects of sediments on salmonid reproductive success. However, some points need further attention before it can be established that fine sediment loading in PEI streams affects survival of salmonid eggs and alevins. Subsequent experiments should incorporate larger sample sizes. Daily monitoring of alevin survival is recommended to preclude potential biases due to undetected escapes of alevins, or deaths and degeneration, or return travel to the incubation baskets. Finally, various designs of the basket and emergence trap need to be developed and tested so that the equipment can match as closely as possible the natural conditions in the study streams. Because of the large amount of fines accumulating in our study sites, a larger diameter emergence channel may have permitted more alevins to reach the emergence trap instead of being trapped inside by sediment plugs.

In conclusion, the present study has established the potential utility of incubation-emergence baskets for assessing egg and alevin survival of salmonids in eastern Canadian streams. The study also demonstrated that survival to emergence was very low for brook trout and Atlantic salmon in the Morell River sites, and that fine sediment accumulation was high. More research is needed to determine the relation between sediment accumulation and survival in Atlantic salmon and brook trout. The study generated several hypotheses for future work, notably that groundwater discharge moderates the negative effects of sediment loading in trout redds and that habitat hydraulics can reduce deposition of fines in Atlantic salmon redds. Although statistical significance is lacking, our data are consistent with the notion that sedimentation pits increase alevin survival by reducing the amount of fines settling in incubation areas. However, the most effective measure to improve salmonid survival would be to stop, or at least reduce, sediment loading at its source.

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Table 1
Survival (%) to pre-hatch of eggs of Atlantic salmon and brook trout in incubation baskets in 5 salmon sites and 5 trout sites in the Morell River, PEI. Percentages are based on single basket retrieval per site.

Species	Site 1	Site 2	Site 3	Site 4	Site 5
Atlantic salmon (S)	82.2	99.0	97.4	89.3	62.9
Brook trout (T)	60.0	95.0	45.3	38.7	69.3

Table 2
Characteristics of groundwater discharge zones at brook trout study sites, Morell River, PEI.

Site	Hydraulic head (cm)	Hydraulic conductivity (cm/s)	Groundwater flux (cm/s)
T2	3	0.0127	7.6×10^{-3}
T3	3.1	0.0011	0.7×10^{-4}
T4	3	0.0019	1.2×10^{-4}
T5	0.1	0.0117	0.2×10^{-4}

Table 3
Timing of emergence of Atlantic salmon and brook trout incubating in baskets in the Morell River, PEI, in 1997. n = number of alevins emerging from both baskets per site.

Species	Site	n	Emergence period	Peak of emergence	Alevins remaining in baskets
Atlantic salmon	S1	12	May 21 – June 10	9 June	4
	S2	0	–	–	2
	S3	81	1 – 19 June	11 – 14 June	2
	S4	2	30 April	30 April	53
	S5	28	13 May – June 10	10 June	15
Brook trout	T1	8	26-30 April	26 April	16
	T2	72	8 February – 31 March	14-21 March	0
	T3	0	–	–	11
	T4	25	14 March – 13 April	26-31 March	4
	T5	1	7 May	7 May	32

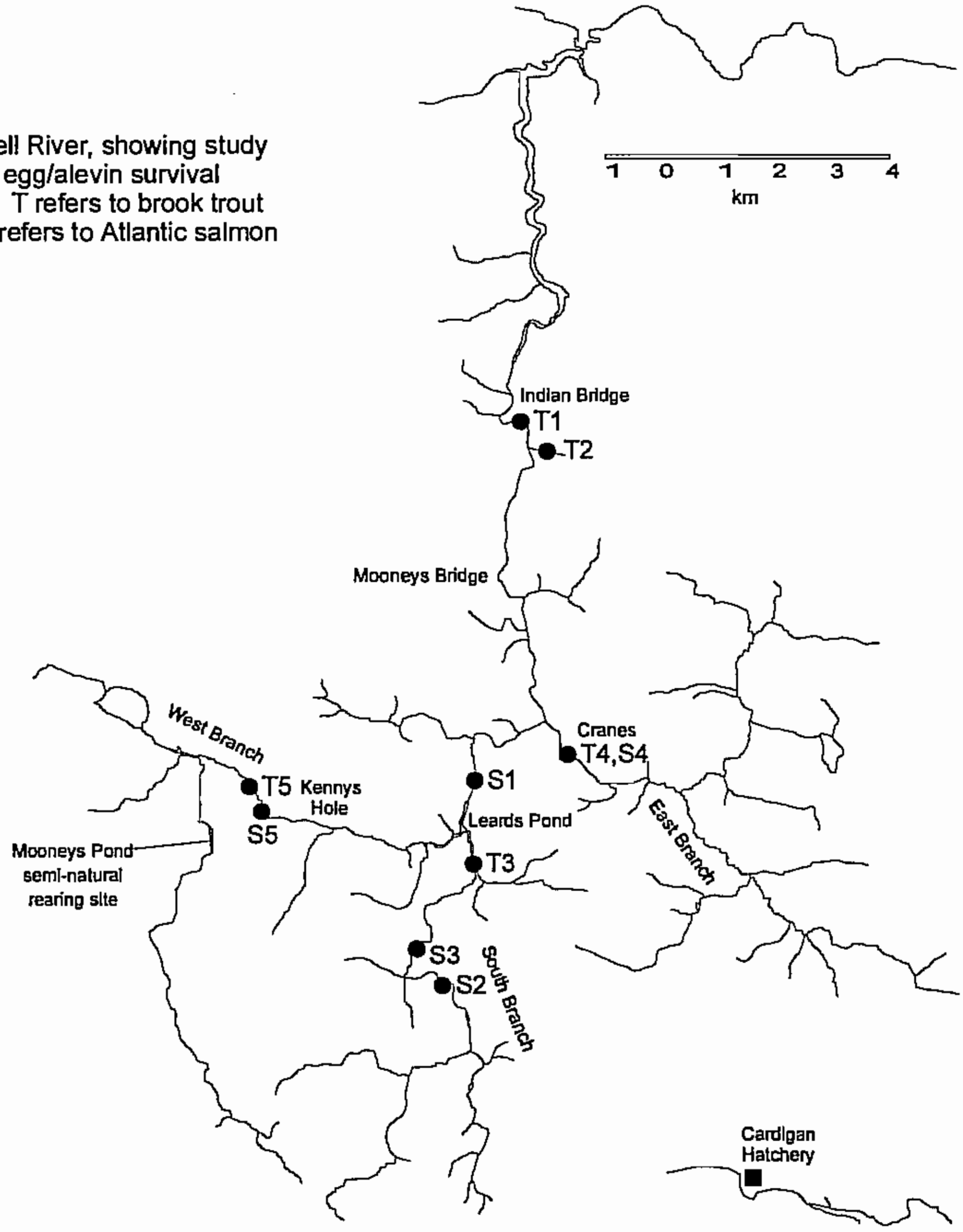
Table 4
Sizes (FL, mm) of Atlantic salmon fry captured in emergence traps from three sites in the Morell River, PEI, 1-12 June, 1997. n = pooled sample from two traps; SD = standard deviation.

Site	n	Mean FL ± SD	Range (mm)
S1	12	28.06 ± 0.83	26.35 – 29.50
S3	24	29.28 ± 0.79	27.50 – 30.45
S5	14	28.39 ± 0.67	27.05 – 29.40

Table 5
Accumulated fine sediments (<2mm diameter) in the incubation baskets of brook trout and Atlantic salmon between November 1996 and January 1997 (2 months), or between November 1996 and May/June 1997 (6-7 months) in various locations in the Morell River, PEI. Values are the dry weights (g) of all particle size fractions, as measured for a single basket per site (pre-hatch) or the mean weights of two baskets per site (emergence).

Species	Period	Site 1	Site 2	Site 3	Site 4	Site 5	Mean
Atlantic salmon (S)	Pre-hatch (2 months)	62.3	164.2	96.6	133.1	200.5	131.4
	Emergence (6-7 months)	206.5	808.4	712.6	281.2	958.2	636.3
Brook trout (T)	Pre-hatch (2 months)	531.8	948.5	468.2	1461.3	1000.5	882.1
	Emergence (6-7 months)	502.1	950.4	1224.8	1427.0	954.0	1011.7

Fig. 1
Map of Morell River, showing study sites for the egg/alevin survival experiment. T refers to brook trout sites and S refers to Atlantic salmon sites.



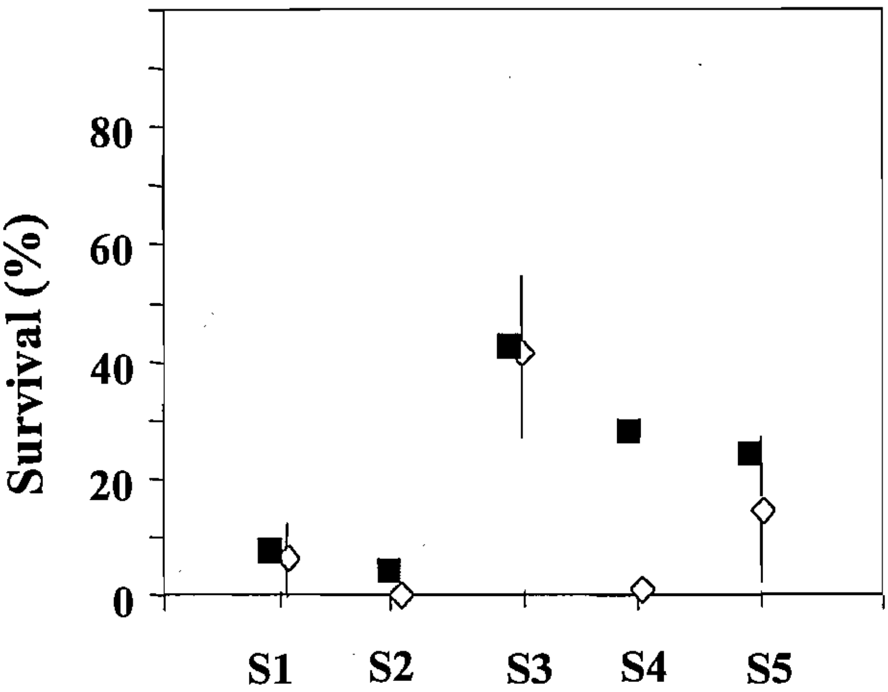


Fig. 2
Mean survival to emergence (diamonds) from incubation baskets for Atlantic salmon in different sites in the Morell River, PEI. Vertical bars represent range of survival estimates for individual baskets. Solid squares represent estimated survival by including alevins trapped in baskets but not found in traps at end of experiment.

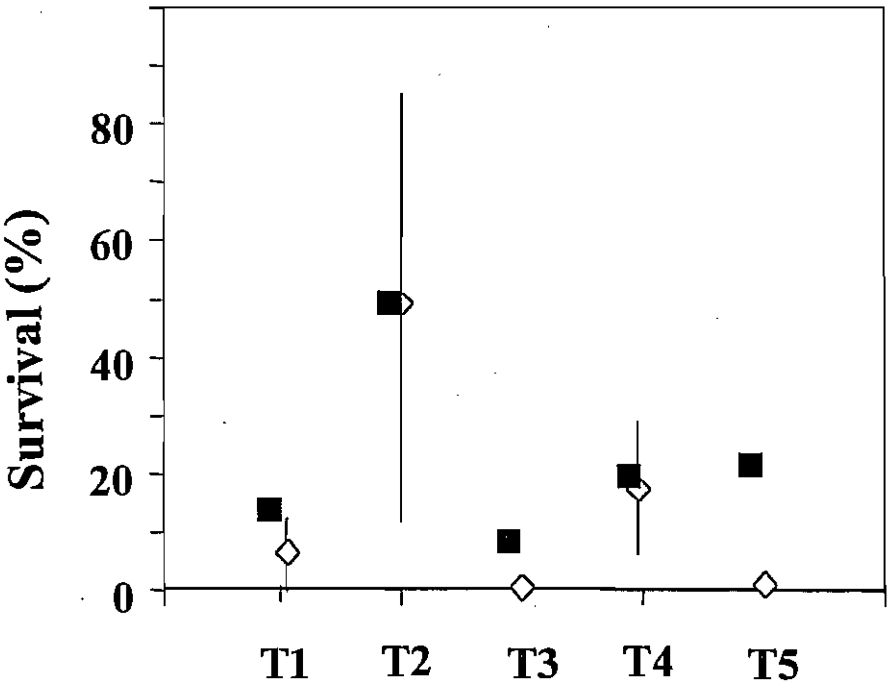


Fig. 3
Mean survival to emergence (diamonds) from incubation baskets for brook trout in different sites in the Morell River, PEI. Vertical bars represent range of survival estimates for individual baskets. Solid squares represent estimated survival by including alevins trapped in baskets but not found in traps at end of experiment.

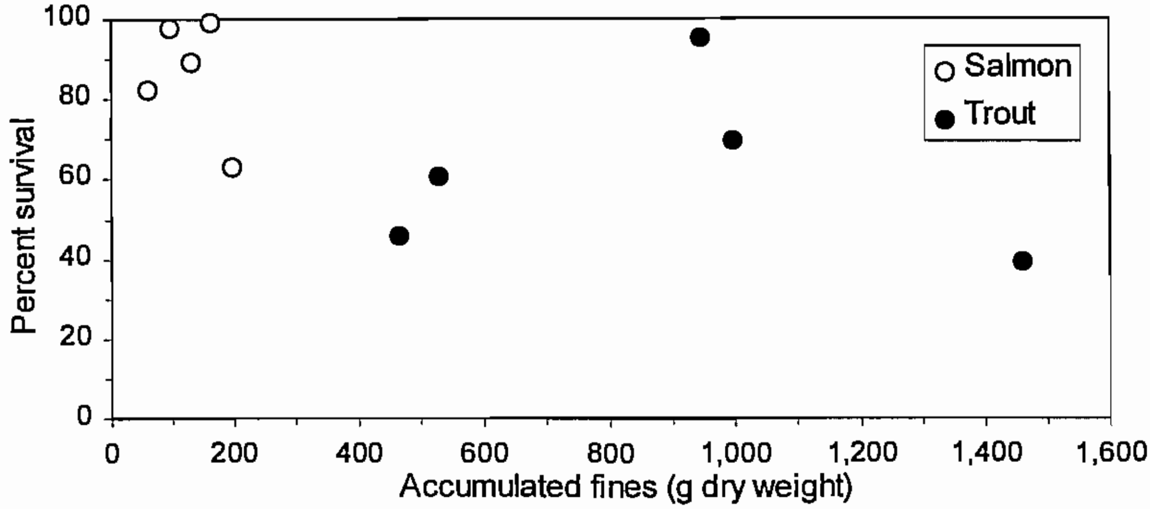


Fig. 4
Percent survival to pre-emergence of Atlantic salmon and brook trout in incubation baskets in the Morell River vs. fine sediment accumulation in the baskets.

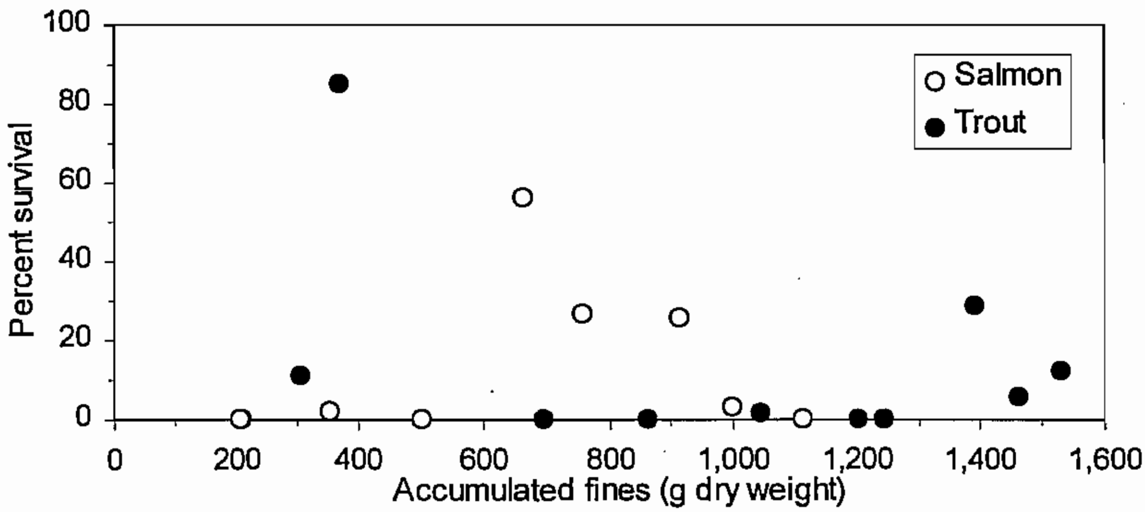


Fig. 5
Percent survival to emergence of Atlantic salmon and brook trout in incubation baskets in the Morell River vs. fine sediment accumulation in the baskets.

Sediment effects on brook trout survival to emergence in Prince Edward Island streams

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Brook trout (*Salvelinus fontinalis*) embryo and alevin survival were examined within cohorts in streams affected by differing sediment loads. We observed 88% survival to the egg-eyed stage. Percent composition of redd fines < 2 mm increased from 29 $\pm$ 9 to 43 $\pm$ 19 between the egg-eyed stage. Alevin emergence and survival were significantly reduced by the accumulation of sediments. Groundwater flux through redds and survival to emergence (STE) were significantly different between sites with heavy silt impacts and those without, but the difference in the percent composition of fines was not. STE was positively related to the flux of water through the redd and negatively related to the percent composition of fines. The best-fit equation was: STE = 7.189 * flux (cm/s) + (-0.473 * fines + 0.5) ($r^2 = 0.46$, $p_{flux} = 0.005$, $p_{fines}=0.06$, $p_{intercept} < 0.001$, n = 21). A fungicide (Metalaxyl), insecticide (Methamidophos) and herbicide (Metribuzin) were detected in the ground water discharging through redds. Early development of embryos was unaffected by the accumulation of fine sediment and most mortality occurred at the later stages of development within the chorion in what appeared to be a function of oxygen deprivation within redds. Brook trout seem to alter their reproductive strategies in PEI streams to suit conditions and the variation in reproductive behaviour appears to be an adaptation to high sediment loads. This study demonstrates the need to study multiple life history stages and spatial scales to explain variability among populations.

This abstract is from:

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Sediment effects on juvenile brook trout abundance in Prince Edward Island streams

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Agriculture dominates the landscape of Prince Edward Island (PEI) where >80% of some watersheds exist in a potato crop rotation. The consequences for aquatic ecosystems include inputs of sediment and agricultural chemicals. In four PEI streams, brook trout (*Salvelinus fontinalis*) abundance of young-of-the-year (YOY) were examined within cohorts in streams affected by differing sediment loads. The stream with the greatest measurement of substrate fines and suspended sediment concentrations (Wilmot C) had a significantly lower density of YOY brook trout ($0.28 \pm 0.11/m^2$) than the other monitored streams. Conversely, Wilmot A had significantly higher measurements of sediment levels than Ross's Brook, but YOY densities were similar ($0.69 \pm 0.15/m^2$ and $0.64 \pm 0.16/m^2$, respectively). The comparison of measured stream habitat variables with YOY brook trout abundance, demonstrated a negative correlation between the proportion of substrate fines and YOY densities, but the linkages were weak and unclear ($p = 0.034$, $r^2 = 0.06$, $n = 71$).

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Pesticide monitoring and fish kill investigations on Prince Edward Island, 1994-1999

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ABSTRACT

Twelve fish kills suspected to have been caused by agricultural pesticides occurred on Prince Edward Island in 1995-1999. Pesticide risk and impact for Prince Edward Island fish populations were evaluated by measuring pesticide concentrations in water and in sediments. Samples were obtained through a monitoring program, and from fish kill investigations launched as soon as possible after kills. In the monitoring program, pesticides were detected 11 times in 21 sediment samples and 169 times in 60 water samples. Fish kill investigations yielded four pesticide detections in stream and pond water samples, nine detections in water from puddles and gullies, and five detections in sediment, soil, and vegetation. Pesticide concentrations from both the monitoring program and from fish kill investigations were generally well below published lethal concentrations. In the case of fish kill investigations, the lack of samples with lethal concentrations of pesticides can be attributed to the lag between the kill event and sampling. Together, monitoring programs and fish kill investigations help increase understanding of pesticide risks to fish on Prince Edward Island. However, neither approach can be expected to fully elucidate the process by which pesticides enter water and kill fish.

INTRODUCTION

Fish kills that are thought to be related to agricultural pesticides have occurred sporadically on Prince Edward Island (PEI) for decades. However, since 1994 the frequency of these incidents has increased. Between 1994 and 1998, four fish kills of suspected pesticide origin occurred. All of these kills occurred in western PEI. In 1999, eight fish kills of suspected pesticide origin were reported; all of these were in central and eastern PEI.

Between 1989 and 1995, planted potato acreage on PEI increased from 27,500 ha to 43,700 ha, and then levelled off at about 45,700 ha (Anon. 1999). Two factors that have allowed this dramatic increase in acreage are a move to a shorter crop rotation, and the use of additional lands that were not previously in potato production. Current methods of potato production on PEI are heavily dependent on pesticides, with up to 15 applications per growing season.

In response to the fish kills in 1994, 1995 and 1996, a surface water pesticide monitoring program was initiated in 1996 (Savard et al. 1999). Kills in these years were all in western PEI, and sampling was conducted in the river systems that had experienced the kills. The intent of this program was to determine whether pesticides were entering surface water systems in sufficient concentrations to present an acute risk to fish. Concurrent with the monitoring program, fish kills were investigated by collecting samples of water, sediment, and fish as soon as possible after the kill.

This paper compares pesticide concentrations measured in the surface water monitoring program with those found in water and sediment during fish kill investigations, and it relates both data sets to potential impacts to aquatic systems.

METHODS

Surface water monitoring program

This program operated in the Big Pierre Jacques River, Long Creek (a tributary of the Mill River), and Huntley River, western PEI (Fig. 1). These streams drain watersheds of 2,100, 900, and 2,000 ha, respectively. The portion of western Prince County where these streams are located sustains fairly intensive agricultural production. Forest covers 38-40% of the Big Pierre Jacques watershed and 15% of the Long Creek watershed (Savard et al. 1999). In 1995-1997, potato fields constituted 20-32% of the Big Pierre Jacques watershed and 20-40% of the Long Creek watershed (Savard et al. 1999).

Sampling design of the surface water pesticide monitoring program changed each year to target limited resources on sampling that had the greatest potential to

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show adverse pesticide concentrations. During the initial year of the program (1996), water and sediment samples were collected at six locations on the Big Pierre Jacques and Long Creek systems, which had experienced fish kills in previous years (Figs. 1 and 2). In 1997, the number of sampling locations was reduced to three (BPJ2, BPJ4 and LC2) to allow more intensive sampling at each site. In 1996 and 1997, single grab samples of water and sediment were collected during each sampling session. Sampling was conducted in both dry and wet-weather conditions.

In 1998 and 1999, dry-weather and sediment sampling was discontinued to allow more water samples to be collected during storm events. Sampling was initiated when there was visible evidence in rivers of soil washoff from agricultural fields. Efforts were made to obtain samples shortly after an event started, and then again at approximately two and six hours after initiation of washoff. Following a fish kill on the Huntley River in August 1998, the monitoring program was expanded to include this site (Figs. 1 and 2).

Water samples were collected by hand in laboratory-cleaned and treated 4 L amber glass bottles. Sediment samples were collected at natural deposition sites in the streams with stainless steel spoons and placed in 500 ml wide-mouth glass jars. The spoons and glass jars were also laboratory-cleaned and solvent rinsed. After collection was complete, samples were transported to the PEI Government's Environmental Services Lab (ESL) in Charlottetown, PEI, where water samples were maintained at 4°C, and sediment samples were frozen and maintained at -40°C. Samples were transported to Environment Canada's Environmental Conservation Branch (ECB) Lab in Moncton, New Brunswick, where they were kept under similar conditions prior to being analyzed.

In 1998 and 1999, water samples were preserved with the addition of 100 ml of laboratory grade methylene chloride. In these years, analytical accuracy was evaluated by adding known quantities of product to samples (spiking). Recovery rates of added products were subsequently measured in the lab. Spike solutions were prepared by the ECB lab.

When the samples arrived at the ESL lab, 100 μL of the spiking solution was added to the spike samples and shaken, prior to being preserved with methylene chloride. In other cases, spiking took place in the lab, just prior to the analysis. Concentrations in unspiked blanks were also measured.

Water samples were extracted with hexane and detections were performed with an electron capture detector (ECD) and gas chromatogram - mass spectrometric detector (GC-MSD). Sediment samples were extracted with a combination of acetone and hexane, and analyzed by GC-MSD. The time between collection and analyses at the ECB lab ranged from two weeks to nine months. Additional details of the analytical procedures can be found in Savard et al. (1999).

Fish kill investigations

The unpredictable nature of fish kills limits the amount of control that can be exercised over sampling locations, timing and procedures. With many fish kills, there is a substantial delay between the time when a rainfall event initiates pesticide washoff into a stream, and when the resulting impacts on fish are noticed and reported. This delay ranged from two hours to as much as a week in the fish kill investigations that have been conducted on PEI since 1994. Because of the short length of PEI streams and the speed with which surface water moves through these systems, pesticides may be flushed from the stream water by the time sampling can be initiated. As a result, sampling locations for water vary and are prioritized based on the circumstances of each incident. A preference list for water sampling locations, and the advantages and disadvantages of each, is given in Table 1.

Water samples included those that were collected from the streams and those that were collected from puddles between the suspected source(s) and the stream after the storm event had concluded. Many of the pesticides commonly used on PEI readily bind to soil and sediment. Three types of sediment/soil samples were taken: sediment collected from stream beds, sediment collected under puddles where the standing water samples were collected, and soil that was collected from the suspected source field.

Sample handling during fish kill investigations was similar to that described for the pesticide monitoring program. Water samples were collected in laboratory cleaned and solvent rinsed, 1-L amber bottles, while sediment samples were collected in clean glass jars.

After collection, samples were placed in coolers where possible, and were transported to the ESL lab for temporary storage under appropriate conditions (dark storage at 4°C for water, and -40°C for sediment samples). Additional preservation techniques (other than proper storage and having the samples analyzed as soon as possible) could not be employed after sample collection because it was not known at that point what type of analysis would be required.

As part of the investigations, potato producers within the watershed were contacted and asked to provide information on pesticide applications that had occurred in the previous two weeks. A list of products that were used was compiled. Several laboratories were contracted to assay pesticides in samples that were obtained during fish kill investigations since 1994. These include the ECB lab in Moncton, N.B, the Research and Productivity (RPC) lab in Fredericton, N.B., Ricerca Labs in Painesville, Ohio, and the Atlantic Veterinary College

(AVC) lab in Charlottetown, PEI. It is beyond the scope of this paper to describe all of the methodologies that were used in analyzing the samples from the various fish kills. All the labs that were contracted have conducted pesticide analyses for a number of years and all have internal quality control procedures. In general, one or more extraction procedures were employed, depending on the amount of sample available and the types of pesticides reportedly used in the watershed. Pesticide scans were then conducted to identify which pesticides were present, and targeted analyses followed to quantify the concentrations of those pesticides present in the sample.

RESULTS

Surface water monitoring program:

1996

There were two sampling events in 1996, one in dry weather and one in wet weather. Six locations were sampled in the Big Pierre Jacques and in Long Creek (Fig. 2) for a total of 12 samples. Previous rainfall to the dry-weather sampling event amounted to 10.8 mm and occurred three days prior to the sample collection A total of 14.8 mm of rain fell on the day of the wet weather sampling.

The water samples were analyzed for seven parameters (Table 2). Only one of the 42 analyses (2.4%) produced a detection; chlorothalonil was found in a sample from LC2 at a concentration of 78.254 ng/L. This detection was from a wet-weather sample.

The sediment samples were analyzed for nine parameters (Table 2). Seven detections were reported from the 54 analyses (13%). Chlorothalonil was found in three samples, and alpha- and beta-endosulfan were detected in two samples. The maximum concentrations were 55.82 ng/g for chlorothalonil, 6.84 ng/g for alpha-endosulfan and 17.19 ng/g for beta-endosulfan. Four of the detections occurred in the Long Creek system and three were detected in the Big Pierre Jacques. All of the sediment detections came from dry-weather sampling. Two of the 12 sediment samples had three pesticide residues detected.

1997

There were one dry-weather and two wet-weather sampling events in 1997. The closest previous rainfall was five days prior to the dry-weather sampling event, when 1.2 mm of rain was recorded. On the two wet-weather sampling events, 44.1 mm and 22.9 mm of precipitation were recorded.

Nine water samples were collected in the three sampling events and a total of 57 analyses (18 dry and 39 wet) was performed (Table 3). Seven different pesticides were present in the 18 detections (31.6%) that were reported. Four detections were reported from dry-weather samples (22.2%) and 14 were reported in wet-weather samples (35.9%). Chlorothalonil and its metabolites were found on eight occasions. The maximum concentration of the parent product in five detections was 1340 ng/L, while the metabolite SDS2 was found three times with a maximum concentration of 98 ng/L. Metalaxyl and metribuzin were found in each of the three samples analyzed for these products with maximum concentrations of 65.8 and 206 ng/L, respectively. Dimethoate was found in three of six samples (maximum concentration 33.4 ng/L), and azinphos methyl was found in one of three samples at 109.2 ng/L. Nine of the detections occurred at Long Creek and nine occurred at Big Pierre Jacques. One of the wet-weather water samples had a total of seven detections, while two other samples had four and three detections, respectively.

The nine sediment samples were analyzed for 10 different parameters (90 analyses) (Table 3). Only two products were found in a total of four detections (4.4%). Linuron was found in one dry weather sample at a concentration of 55.1 ng/g, and chlorothalonil was found in three of nine samples (one dry-weather and two wet-weather samples), with a maximum concentration of 19.3 ng/g. All four of the sediment detections were from samples collected in the Big Pierre Jacques.

1998

There were three sampling events in 1998 (Table 4) All were conducted under wet-weather conditions, with 12 mm (21 July), 38 mm (12 August) and 21 mm (4 September) of precipitation falling on the days on which samples were collected. A total of 32 samples was collected from the three river systems. The samples were analyzed for 18 pesticides for a total of 576 analyses.

Samples were analyzed in January/February 1999, approximately 6-7 months after collection. Recovery rates of product from spiked samples were low in many cases (Table 5). This suggests that concentrations measured in the lab may not reliably reflect actual concentrations in the field. Hence results from 1998 are used in a qualitative fashion (presence / absence).

There was a total of 111 (19.3%) detections. Metalaxyl and metribuzin were most frequently detected, with 32 (100%) and 28 (87.5%) detections, respectively. Dimethoate and chlorothalonil followed, with 14 (43.7%) and 13 (40.6%) detections, respectively. Azinphos methyl was present in 8 samples (25%), and alpha- and beta-endosulfan were detected in five samples (15.6%) each. Cypermethrin was found in three samples (9.3%), and phorate, fonofos and disulfoton were found in only one sample (3.1%). All of the samples collected in 1998 contained at least one pesticide. Fifteen of the samples (46.8%) had four or more pesticides present, with one sample containing eight pesticide residues.

1999

Because of a relatively dry summer in western Prince Edward Island, there were only two sampling events in

1999 (Table 6). Seven samples were collected, and precipitation records indicate that 32 mm (11 July) and 36 mm (17 September) of rainfall fell on the two sampling days. Twenty-three pesticide analyses were conducted in 1999. Interferences were reported with some of the analyses, so in total, there were 154 analytical results. Sampling was limited to Long Creek and Huntley River. Nine pesticides were found in a total of 43 detections (27.9%). Three products, chlorothalonil, metribuzin and metalaxyl, were found in all seven samples (100%). The maximum concentrations were 0.997 ng/L, 0.206 ng/L and 0.014 ng/L for the three products, respectively. Azinphos methyl and atrazine had six detections each (85.7%) and maximum concentrations of 0.073 ng/L and 0.015 ng/L, respectively. Carbofuran was detected five times (71.4%; maximum concentration of 0.063 ng/L). Alpha-endosulfan was detected three times (42.9%), but the beta-isomer was detected only once (14.3%). Maximum concentrations were 0.021 and 0.020 ng/L. Dimethoate was present in one sample (14.3%; maximum concentration 0.066 ng/L). Of the seven samples, one had five pesticide residues, five samples contained six pesticide residues, and one sample had eight pesticides present.

Analysis of spiked samples indicated low recovery rates for phosmet (Table 7). This might have been due to degradation of the product in water, to the lengthy period between collection and analysis, or to problems with extraction or analysis. All other products showed high recovery rates.

Fish kill investigations

Fig. 1 shows the location of fish kills recorded in provincial government files and known or suspected to have been caused by agricultural pesticides on PEI between 1966 and 2000. Further details of kills are presented in Appendix A. This list may not be comprehensive. A kill, detected in the Desable River on 25 August 1969, was reported in a local newspaper but does not appear in provincial records (Anon. 1969).

There were 12 kills in the study period (1995-1999), but analytical data are lacking for three of these because of delays between the time of the kills and the time they were reported. In one other case sediment analyses were conducted, but no water samples were analyzed.

The analytical results from the fish kill investigations are presented in Tables 8-16. Four pesticides were detected in stream and pond water samples. Azinphos methyl was found three times in stream and pond water samples, with concentrations ranging from 0.34 to 3.2 ppb. Carbofuran was found twice, with concentrations of 0.32 and 0.60 ppb. Chlorothalonil (4.0 ppb), alpha-endosulfan (0.20 ppb), and beta-endosulfan (0.2 ppb) were each found once.

A total of nine pesticides was detected in water standing in puddles or gullies. Azinphos methyl was found in standing water samples from five different fish kills, with the maximum concentration detected being 261 ppb. Endosulfan (range 0.19-75 ppb), and carbofuran (range 2.54-39 ppb) were found in three investigations each. Dithiocarbamates (20 and 26 ppb), chlorothalonil (0.2, 113.5 ppb) and metribuzin (0.3-0.55, 1.30 ppb) were each detected in standing water samples collected during two fish kill investigations. Metobromuron and metalaxyl were detected in one sample each, but the values were not quantified by the lab.

Five pesticides were detected in sediment, soil, and vegetation samples. Azinphos methyl was detected in such samples from six fish kills, with concentrations ranging from 0.51 to 910 ppb. Dithiocarbamates were found at five kills (200-2,540 ppb), endosulfan was found at four kills (28-884 ppb), and carbofuran and chlorothalonil were each found at three kill sites (0.29-78 ppb and 12-6,220 ppb), respectively.

DISCUSSION

Surface water monitoring - detections in sediment

Sediment samples were collected during the first two years of the four-year surface water monitoring program. Twenty-one sediment samples were collected, with 11 pesticide detections being reported. Fig. 3 indicates that there were no pesticide detections in 15 (71%) of the samples. Three samples (14%) contained one pesticide detection, while one sample (5%) had two, and two samples (10%) had three pesticides detected. Three pesticides (chlorothalonil, endosulfan and linuron) accounted for the eleven detections. The maximum concentrations were 55, 24 and 55 ng/g, respectively. It is difficult to interpret the results from the sediment sampling in terms of impacts on fish health because there are no guidelines or toxicity values for concentrations of pesticides bound to sediment. During runoff events when the streams carry high loads of suspended sediment, sediment passes through the gills of the fish, but the actual exposure to the pesticides is not known.

Surface water monitoring - detections in water

A total of 60 water samples was collected over the four-year monitoring program, with 169 pesticide detections being reported. Fig. 4 presents the frequency of the number of detections per sample. Pesticide residues were detected in 76.7% of the samples that were analyzed. Almost half of the samples (46.7%) contained three or more pesticide residues, and approximately one-quarter of the samples (23.3%) had five or more pesticides present. Two of the samples (3.3%) that were collected contained eight pesticide residues.

Twelve pesticides accounted for the 169 detections. The eight most frequently detected pesticides are shown in Fig. 5. Metalaxyl was detected in 100%, and metribuzin was present in 90% of the 42 samples that were analyzed for these two parameters. Atrazine (86%) and carbofuran (71%) were detected in over 70% of the samples, but only seven samples were analyzed for these products. Chlorothalonil was analyzed throughout the four-year program and was detected in 25 of the 60 analyses (42%).

Fig. 6 compares maximum concentrations detected in water samples to Freshwater Aquatic Life Guidelines (FWALG) (CCME 1999), and to 96 hr LC_{50} concentrations (EPB 1999, Extoxnet). All maximum concentrations were below LC_{50} values. The two products that were closest to the LC_{50} values were azinphos methyl and chlorothalonil, by factors of 27 x and 57 x, respectively. One pesticide was detected in excess of FWALG values. Chlorothalonil was detected in one sample at a concentration of 1340 ng/L, compared to its FWALG value of 180 ng/L. The mean (118.7 ng/L) and the median (0.826 ng/L) concentrations for all chlorothalonil detections were below the FWALG. Metribuzin was the next closest to its aquatic life guideline, with a maximum concentration of one fifth the FWALG.

<u>Fish kill investigations</u>

Maximum concentrations detected in sediment analyses from fish kills are compared to the maximum sediment concentrations detected during the surface water monitoring program in Fig. 7. Chlorothalonil was found at a slightly higher maximum concentration in the surface water monitoring program (55 ng/g) than during the fish kill investigations (50 ng/g). In the case of azinphos methyl and endosulfan, all maximum concentrations from the fish kill investigations exceeded maximum concentrations from the surface water monitoring program.

<u>Conclusions</u>

This paper compares ongoing surface water monitoring to fish kill investigations as approaches to the evaluation of pesticide risks to fish. Samples obtained from the monitoring program contained pesticide concentrations that were generally well below lethal limits, even when the samples are taken when concentrations are likely to be highest (i.e. during heavy rain). Likewise, samples taken from fish kill investigations were generally well below published lethal limits. This means that we do not have direct evidence that pesticides were responsible for the fish kills reported in recent years. However, the circumstantial evidence that pesticides were responsible for these kills is compelling. There are hundreds and ponds and streams on PEI that contain fish. If summer fish kills are commonly caused by low oxygen conditions, excessive heat, or other non-pesticide problems, kills should occur in a wide variety of circumstances, both agricultural and non-agricultural, and in dry and rainy conditions. The fact that the recent rash of fish kills occurred in cultivated watersheds subject to pesticide application, and after rainfalls, points to pesticide-bearing agricultural run-off as the cause of the kills.

The most likely explanation for the general lack of lethal pesticide levels in our samples is that pesticide-induced kills occur when pesticide concentrations briefly rise to highly toxic levels, and then rapidly subside due to flushing and dilution. Such events are not common, and require particular circumstances of pesticide application, rainfall patterns, and run-off routes to occur. Regular monitoring programs are unlikely to detect these peaks in pesticide concentration because they occur infrequently. Fish kill investigations are unlikely to detect them because concentrations will have diminished by the time researchers arrive on the scene.

Alternative, or perhaps supplementary, explanations of our results include the following: a) The cumulative effect of exposure to multiple pesticides might render normally sublethal concentrations lethal, especially if the fish are stressed by high temperature, low oxygen, or other factors. b) It is possible that brook trout have different sensitivities to pesticides than rainbow trout, which are the basis of toxicity guidelines. c) There are no guidelines or limits for lethal concentrations of pesticides bound to sediments. Streams that receive run-off from farm fields on PEI commonly have high loadings of suspended sediments after rainfalls. Pesticides bound to these sediments could be the agents of mortality. d) Pesticide concentrations measured in some samples may be inaccurate due to delays in analysis or other problems.

Both surface water monitoring and fish kill investigations have a role in bringing about an understanding of pesticide risk to fish. Ongoing monitoring establishes the broad patterns of pesticide entry into aquatic systems, and fish kill investigations help determine the particular circumstances in which pesticide concentrations become high enough to be lethal. However, neither approach can be expected to fully elucidate the process by which pesticides enter water and kill fish.

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Table **1**

Selection criteria for sites for sampling pesticide concentrations after fish kills.

Sampling location	Conditions	Advantages / Disadvantages
Stream water	Generally collected if within 12 - 24 hours of the rainfall event	Provides best evidence for drawing conclusion about impacts on aquatic species, but likelihood of getting detections deceases quickly with time after rainfall event
Pond water	Collected if within a day or two of rainfall event	Increases the retention time for the pesticide in the system, but is counter-balanced by dilution effects.
Standing water between suspect field and stream	Collected if standing water is still present	Provides an indication of which pesticides were leaving the field and what their concentrations were towards the end of the event. It is not known to what degree this concentration would be diluted when entering the stream.
Standing water in the suspect field	Usually collected if the standing water is still present	Verifies which pesticides were available for movement from the field and at what concentrations. Dilution factors are not known.

Table 2
Chemical concentrations in Big Pierre Jacques River (BPJ) and Long Creek (LC), Prince Edward Island, measured in the 1996 surface water monitoring program. Concentrations are in ng/L (water samples) and in ng/g (sediment samples).

Date	Wea-ther	Location	Sample type	Analysis date	alpha - Endosulfa	beta - Endosulfan	Dimethoate	Chlorothalonil	SDS 47524	SDS 19221	SDS 1	SDS 2
21 Aug	dry	LC1	water	13/5/97	–[a]	–	–	<4.346[b]	–	–	<3.193	<2.040
21 Aug	dry	LC2	water	13/5/97	–	–	–	<1.346	–	–	<3.425	<8.225
21 Aug	dry	BPJ1	water	13/5/97	–	–	–	<2.064	–	–	<2.850	<2.265
21 Aug	dry	BPJ2	water	13/5/97	–	–	–	<2.132	–	–	<2.944	<2.340
21 Aug	dry	BPJ3	water	13/5/97	–	–	–	<2.080	–	–	<2.872	<2.283
21 Aug	dry	BPJ4	water	13/5/97	–	–	–	<2.090	–	–	<2.885	<2.293
21 Aug	dry	LC1	sed.	13/2/97	**4.989**[c]	**15.37**	<4.417	**3.106**	<2.725	<1.490	–	–
21 Aug	dry	LC2	sed.	13/2/97	<0.922	<1.02	<5.977	**55.82**	<3.688	<1.045	–	–
21 Aug	dry	BPJ1	sed.	13/2/97	**6.841**	**17.19**	<7.858	**7.23**	<2.893	<1.373	–	–
21 Aug	dry	BPJ2	sed.	13/2/97	<0.763	<0.843	<4.948	<0.700	<1.822	<0.865	–	–
21 Aug	dry	BPJ3	sed.	13/2/97	<0.733	<0.810	<4.75	<0.516	<1.045	<0.830	–	–
21 Aug	dry	BPJ4	sed.	13/2/97	<0.743	<0.821	<4.817	<0.523	<1.059	<0.842	–	–
14 Sep	wet	LC1	water	6/2/97	–	–	<5.236	<0.418	<0.650	<0.451	–	–
14 Sep	wet	LC2	water	6/2/97	–	–	<5.260	**78.254**	<0.653	<0.453	–	–
14 Sep	wet	BPJ1	water	6/2/97	–	–	<4.875	<0.389	<0.605	<0.420	–	–
14 Sep	wet	BPJ2	water	6/2/97	–	–	<4.967	<0.396	<0.617	<0.428	–	–
14 Sep	wet	BPJ3	water	6/2/97	–	–	<3.232	<0.354	<0.525	<0.382	–	–
14 Sep	wet	BPJ4	water	6/2/97	–	–	<3.531/ <3.549	<0.386/ <0.388	<0.574/ <0.577	<0.417/ <0.419	–	–
14 Sep	wet	LC1	sed.	13/2/97	–	–	–	<0.154	–	–	<0.160	<0.156
14 Sep	wet	LC2	sed.	13/2/97	–	–	–	<0.146	–	–	<0.189	<0.144
14 Sep	wet	BPJ1	sed.	13/2/97	–	–	–	<0.207	–	–	<0.269	<0.204
14 Sep	wet	BPJ2	sed.	13/2/97	–	–	–	<0.132	–	–	<0.171	<0.130
14 Sep	wet	BPJ3	sed.	13/2/97	–	–	–	<0.140	–	–	<0.155	<0.141
14 Sep	wet	BPJ4	sed.	13/2/97	–	–	–	<0.147/ <0.145	–	–	<0.163/ <0.161	<0.148/ <0.146

[a]Not analyzed
[b]Cells with < symbol are below stated detection limit
[c]Detections are bolded

Table 3
Chemical concentrations in Big Pierre Jacques River (BPJ) and Long Creek (LC), Prince Edward Island, measured in the 1997 surface water monitoring program. Concentrations are in ng/L (water samples) and in ng/g (sediment samples).

Date	Weather	Location	Sample type	Analysis date	Azinphos Methyl	Linuron	Metalaxyl	Metribuzin	Disulfoton	Dimethoate	Phorate	Fonofos
25 July	dry	LC2	water	16/9/97	--[a]	--	--	--	--	<4.3[b]	--	--
25 July	dry	BPJ2	water	16/9/97	--	--	--	--	--	<4.8	--	--
25 July	dry	BPJ4	water	16/9/97	--	--	--	--	--	<4.8	--	--
25 July	dry	LC2	sed.	30/4/98	<4.2	<8.7	<3.8	<2.1	<1.8	<1.9	<2.9	<2.9
25 July	dry	BPJ2	sed.	30/4/98	<4.2	**55.1**[c]	<3.8	<2.1	<1.8	<1.9	<2.9	<3
25 July	dry	BPJ4	sed.	30/4/98	<4.4/<4.6	<9.3/<9.7	<4 /<4.2	<2.2/<2.3	<1.9/<2	<2/<2.1	<3/<3.2	<3.1/<3.2
3 Sep	wet	LC2	water	19&23/9/97	**109.2**	<6.3	**36.1**	**206**	<0.6	**33.4**	--	--
3 Sep	wet	BPJ2	water	19&23/9/97	<4.2	<6.2	**65.8**	**52.2**	<0.6	**23.9**	--	--
3 Sep	wet	BPJ4	water	19&23/9/97	<4.3	<6.3	**47.3**	**35.4**	<0.6	**23.6**	--	--
3 Sep	wet	LC2	sed.	30/4/98	<4.3	<9.1	<3.9	<2.2	<1.9	<2.0	<3.0	<3.1
3 Sep	wet	BPJ4	sed.	30/4/98	<3.3	<7.0	<3.0	<1.7	<1.5	<1.5	<2.3	<2.3
3 Sep	wet	BPJ2	sed.	30/4/98	<4.7	<9.8	<4.2	<2.3	<2.0	<2.2	<3.2	<3.3
20 Sep	wet	LC2	water		--	--	--	--	--	--	--	--
20 Sep	wet	BPJ2	water		--	--	--	--	--	--	--	--
20 Sep	wet	BPJ4	water		--	--	--	--	--	--	--	--
20 Sep	wet	LC2	sed.	30/4/98	<5.6	<11.7	<5.1	<2.8	<2.4	<2.6	<3.8	<3.9
20 Sep	wet	BPJ2	sed.	30/4/98	<4.2	<8.7	<3.8	<2.1	<1.8	<1.9	<2.9	<2.9
20 Sep	wet	BPJ4	sed.	30/4/98	<3.5	<7.4	<3.2	<1.7	<1.5	<1.6	<2.4	<2.5

Table 3 (con't)

Date	Wea-ther	Location	Sample Type	Analysis date	Chlorothalonil (Ricerca Inc.)	Chlorothalonil	SDS 1	SDS 2	alpha - Endosulfan	beta - Endosulfan	Meth-amidophos
25 July	dry	LC2	water	16/9/97	--	**0.7**/<3.564	<1.430	**1.499**	<2.308	<1.001	--
25 July	dry	BPJ2	water	16/9/97	--	**1.8**/<1.407	<1.594	<1.671	<2.573	<1.115	--
25 July	dry	BPJ4	water	16/9/97	--	**2.2**/<1.407	<1.594	<1.671	<2.573	<1.115	--
25 July	dry	LC2	sed.	30/4/98	--	<0.8	--	--	--	--	<6.8
25 July	dry	BPJ2	sed.	30/4/98	--	**19.3**	--	--	--	--	<6.9
25 July	dry	BPJ4	sed.	30/4/98	--	<0.9/<0.9	--	--	--	--	<7.2/<7.6
3 Sep	wet	LC2	water	19&23/9/97	**1340**	**311.3**	<39	**98**	<7	<6	--
3 Sep	wet	BPJ2	water	19&23/9/97	<200	<5	<23	**26**	<4	<4	--
3 Sep	wet	BPJ4	water	19&23/9/97	<200	<5	<16	<14	<3	<2	--
3 Sep	wet	LC2	sed.	30/4/98	--	<0.9	--	--	--	--	<7.1
3 Sep	wet	BPJ4	sed.	30/4/98	--	<0.7	--	--	--	--	<5.5
3 Sep	wet	BPJ2	sed.	30/4/98	--	**1.4**	--	--	--	--	<7.6
20 Sep	wet	LC2	water	11/97	<200	--	--	--	--	--	--
20 Sep	wet	BPJ2	water	11/97	<200	--	--	--	--	--	--
20 Sep	wet	BPJ4	water	11/97	<200	--	--	--	--	--	--
20 Sep	wet	LC2	sed.	30/4/98	--	<1.1	--	--	--	--	<9.1
20 Sep	wet	BPJ2	sed.	30/4/98	--	**1.2**	--	--	--	--	<6.8
20 Sep	wet	BPJ4	sed.	30/4/98	--	<0.7	--	--	--	--	<5.8

[a]Not analyzed
[b]Cells with < symbol are below stated detection limit
[c]Detections are bolded

Table 4
Chemical concentrations in Big Pierre Jacques River (BPJ), Long Creek (LC), and Huntley River (HR), Prince Edward Island, measured in the 1998 surface water monitoring program. Samples were collected from water during wet weather. Concentrations are in ng/L.

Date	Location	Methimidiphos	Carbofuran	Phorate	Dimethoate	Atrazine	Fonofos	Diazinon	Disulfoton	Chlorothalonil	Pirimicarb	Metribuzin
21 July	LC2 - 1	–[a]	–	<0.012[b]	<0.005	–	<0.001	<0.004	**2.419**[c]	<0.002	–	<0.004
21 July	LC2 - 2	–	–	<0.082	<0.016	–	<0.001	<0.012	<0.082	<0.003	–	<0.006
21 July	BPJ2 - 1	–	–	<0.068	<0.013	–	<0.001	<0.010	<0.068	<0.003	–	**0.040**
21 July	BPJ2 - 2	–	–	<0.021	<0.006	–	<0.001	<0.006	<0.029	<0.003	–	**0.029**
21 July	BPJ4 - 1	–	–	<0.082	<0.016	–	<0.001	<0.012	<0.082	<0.003	–	**0.026**
21 July	BPJ4 - 2	–	–	<0.076	<0.015	–	<0.001	<0.011	<0.076	<0.003	–	**0.031**
12 Aug	LC2 -1	–	–	<0.021	**0.025**	–	<0.001	<0.006	<0.028	**0.165**	–	**0.049**
12 Aug	LC2 -2	–	–	<0.020	<0.005	–	<0.001	<0.005	<0.023	**0.115**	–	**0.051**
12 Aug	LC2 -3	–	–	<0.014	<0.005	–	<0.001	<0.005	<0.008	**0.036**	–	**0.075**
12 Aug	BPJ2 - 1	–	–	<0.020	**0.254**	–	<0.001	<0.006	<0.027	**0.006**	–	**0.053**
12 Aug	BPJ2 - 2	–	–	<0.087	**0.067**	–	<0.015	<0.027	<0.177	**0.032**	–	**0.056**
12 Aug	BPJ2 - 3	–	–	<0.013	**0.039**	–	<0.001	<0.005	<0.007	<0.002	–	**0.047**
12 Aug	BPJ4 - 1	–	–	<0.021	<0.005	–	<0.001	<0.006	<0.027	<0.003	–	**0.034**
12 Aug	BPJ4 - 2	–	–	<0.017	<0.004	–	<0.001	<0.004	<0.019	<0.002	–	**0.024**
12 Aug	BPJ4 - 3	–	–	<0.012	<0.005	–	<0.001	<0.005	<0.007	<0.002	–	**0.034**
12 Aug	HR1 - 1	–	–	<0.021	**1.098**	–	<0.001	<0.005	<0.024	**0.014**	–	**0.029**
12 Aug	HR1 - 2	–	–	<0.016	**0.350**	–	<0.001	<0.005	<0.007	<0.002	–	**0.652**
12 Aug	HR1 - 3	–	–	<0.013	**0.246**	–	<0.001	<0.005	<0.008	<0.002	–	**2.621**
4 Sep	LC2 - 1	–	–	<0.013	<0.005	–	**0.012**	<0.005	<0.007	**0.025**	–	**0.005**
4 Sep	LC2 - 2	–	–	<0.012	<0.005	–	<0.001	<0.004	<0.006	**0.013**	–	<0.004
4 Sep	LC2 - 3	–	–	<0.012	<0.004	–	<0.001	<0.004	<0.007	**0.011**	–	<0.004
4 Sep	BPJ2 - 1	–	–	<0.015	**0.045**	–	<0.001	<0.005	<0.010	**0.005**	–	**0.055**
4 Sep	BPJ2 - 2	–	–	<0.011	**0.019**	–	<0.000	<0.004	<0.006	<0.002	–	**0.026**
4 Sep	BPJ2 - 3	–	–	<0.013	**0.044**	–	<0.001	<0.005	<0.007	**0.033**	–	**0.027**
4 Sep	BPJ4 - 1	–	–	<0.013	**0.070**	–	<0.001	<0.005	<0.007	**0.015**	–	**0.024**
4 Sep	BPJ4 - 2	–	–	<0.012	**0.009**	–	<0.001	<0.004	<0.006	**0.003**	–	**0.019**
4 Sep	BPJ4 - 3	–	–	<0.012	<0.005	–	<0.001	<0.004	<0.007	<0.002	–	**0.016**
4 Sep	HR1 - 1	–	–	<0.013	<0.005	–	<0.001	<0.004	<0.008	<0.002	–	**0.027**
4 Sep	HR1 - 2	–	–	**0.147**	**0.956**	–	<0.001	<0.005	<0.007	<0.002	–	**0.053**
4 Sep	HR1 - 3	–	–	<0.012	<0.005	–	<0.001	<0.004	<0.006	<0.002	–	**0.019**
4 Sep	HR3 - 1	–	–	<0.048	**0.252**	–	<0.001	<0.004	<0.006	<0.002	–	**0.024**
4 Sep	HR4 - 1	–	–	<0.012	<0.005	–	<0.001	<0.004	<0.008	<0.002	–	**0.014**

Table 4 (con't)

Date	Location	Metalaxyl	Linuron	Malathion	Chlor-pyriphos	a-Endosulfan	b-Endosulfan	Phosmet	Meth-oxychlor	Azinphos-methyl	Per-methrin	Cyper-methrin	Delta-methrin
21July	LC2 - 1	**0.036**	IN[d]	<0.004	<0.004	<0.010	<0.032	<0.007	<0.006	<0.068	<0.030	<0.051	<0.101
21July	LC2 - 2	**0.019**	IN	<0.007	<0.010	<0.018	<0.023	<0.006	<0.005	<0.065	<0.044	<0.094	<0.082
21July	BPJ2 - 1	**0.085**	IN	<0.007	<0.008	<0.015	<0.019	<0.005	<0.004	<0.054	<0.036	<0.078	<0.068
21July	BPJ2 - 2	**0.064**	IN	<0.006	<0.006	<0.012	<0.013	<0.004	<0.003	<0.032	<0.037	<0.078	<0.070
21July	BPJ4 - 1	**0.070**	IN	<0.008	<0.010	<0.018	<0.023	<0.006	<0.005	<0.065	<0.044	<0.094	<0.082
21July	BPJ4 - 2	**0.074**	IN	<0.008	<0.009	<0.017	<0.021	<0.005	<0.004	<0.060	<0.041	<0.087	<0.076
12 Aug	LC2 -1	**0.032**	IN	<0.006	<0.006	<0.012	<0.013	<0.004	<0.003	**0.153**	<0.038	<0.079	<0.070
12 Aug	LC2 -2	**0.024**	IN	<0.005	<0.005	<0.010	<0.012	<0.003	<0.002	**0.066**	<0.028	<0.069	<0.065
12 Aug	LC2 -3	**0.034**	IN	<0.005	<0.005	<0.011	<0.013	<0.003	<0.003	**0.072**	<0.031	<0.068	<0.081
12 Aug	BPJ2 - 1	**0.088**	IN	<0.005	<0.005	<0.011	<0.013	<0.003	<0.003	<0.030	<0.035	<0.074	<0.066
12 Aug	BPJ2 - 2	**0.079**	IN	<0.037	<0.034	<0.005	<0.011	<0.020	<0.015	<0.001	<4.824	<0.101	<0.127
12 Aug	BPJ2 - 3	**0.078**	IN	<0.005	<0.005	<0.011	<0.012	<0.003	<0.003	<0.029	<0.030	<0.065	<0.078
12 Aug	BPJ4 - 1	**0.081**	IN	<0.006	<0.006	<0.012	<0.013	<0.003	<0.003	<0.032	<0.037	<0.077	<0.068
12 Aug	BPJ4 - 2	**0.058**	IN	<0.004	<0.004	<0.009	<0.010	<0.003	<0.002	<0.024	<0.024	<0.059	<0.055
12 Aug	BPJ4 - 3	**0.077**	IN	<0.004	<0.004	<0.010	<0.012	<0.003	<0.003	<0.028	<0.028	<0.062	<0.074
12 Aug	HR1 - 1	**0.020**	IN	<0.005	<0.005	**0.102**	**0.102**	<0.003	<0.003	**0.202**	<0.030	<0.073	<0.069
12 Aug	HR1 - 2	**0.025**	IN	<0.005	<0.004	**0.068**	**0.062**	<0.003	<0.003	**0.113**	<0.029	<0.064	<0.077
12 Aug	HR1 - 3	**0.024**	IN	<0.005	<0.004	**0.047**	**0.039**	<0.004	<0.003	**0.094**	<0.032	<0.068	<0.076
4 Sep	LC2 - 1	**0.012**	IN	<0.005	<0.004	<0.011	<0.015	<0.007	<0.006	<0.029	<0.029	<0.075	<0.076
4 Sep	LC2 - 2	**0.011**	IN	<0.005	<0.004	<0.011	<0.015	<0.008	<0.007	<0.073	<0.036	<0.081	<0.078
4 Sep	LC2 - 3	**0.006**	IN	<0.004	<0.004	<0.011	<0.029	<0.007	<0.006	<0.057	<0.026	<0.065	<0.073
4 Sep	BPJ2 - 1	**0.065**	IN	<0.005	<0.005	<0.013	<0.016	<0.004	<0.003	<0.037	<0.037	<0.077	<0.086
4 Sep	BPJ2 - 2	**0.051**	IN	<0.004	<0.004	<0.010	<0.026	<0.006	<0.005	<0.052	<0.024	<0.060	<0.067
4 Sep	BPJ2 - 3	**0.052**	IN	<0.005	<0.005	<0.013	<0.017	<0.009	<0.008	<0.084	<0.041	<0.093	<0.089
4 Sep	BPJ4 - 1	**0.050**	IN	<0.005	<0.005	<0.011	<0.015	<0.007	<0.006	<0.030	<0.030	<0.078	<0.079
4 Sep	BPJ4 - 2	**0.032**	IN	<0.004	<0.004	<0.011	<0.028	<0.006	<0.006	<0.056	<0.025	<0.063	<0.071
4 Sep	BPJ4 - 3	**0.028**	IN	<0.004	<0.004	<0.011	<0.029	<0.007	<0.006	<0.058	<0.026	<0.066	<0.074
4 Sep	HR1 - 1	**0.014**	IN	<0.004	<0.004	<0.011	<0.013	<0.003	<0.003	<0.031	<0.031	<0.065	<0.073
4 Sep	HR1 - 2	**0.024**	IN	<0.005	<0.005	**0.205**	**0.466**	<0.009	<0.008	**1.116**	<0.040	**3.558**	<0.089
4 Sep	HR1 - 3	**0.011**	IN	<0.005	<0.004	<0.011	<0.015	<0.008	<0.007	<0.075	<0.036	**0.093**	<0.080
4 Sep	HR3 - 1	**0.012**	IN	<0.004	<0.004	**0.025**	**0.059**	<0.006	<0.005	**0.138**	<0.026	**0.269**	<0.067
4 Sep	HR4 - 1	**0.010**	IN	<0.004	<0.004	<0.010	<0.013	<0.003	<0.003	<0.030	<0.030	<0.063	<0.070

[a]Not analyzed
[b]Cells with < symbol are below stated detection limit
[c]Detections are bolded
[d]Interference

Table 5
Recovery rates of pesticides in blank (no product added) and spiked (measured product added) samples from the 1998 surface water monitoring program in the Big Pierre Jacques River, Long Creek and Huntley River, Prince Edward Island. Samples were taken at various dates in July and August.

Sample	Methimidiphos	Carbofuran	Phorate	Dimethoate	Atrazine	Fonofos	Diazinon	Disulfoton	Chlorothalonil	Pirimicarb	Metribuzin
Blank	–[a]	–	<0.090	<0.018	–	<0.001	<0.013	<0.090	<0.003	–	<0.010
Spike	–	–	0.0%	0.0%	–	19.0%	0.0%	0.0%	12.0%	–	0.0%
Spike	–	–	95.0%	30.0%	–	32.0%	14.0%	296.0%	24.0%	–	15.0%
Spike	–	–	0.0%	142.0%	–	102.0%	109.0%	0.0%	113.0%	–	126.0%
Spike	–	–	132.0%	104.0%	–	133.0%	110.0%	3054.0%	94.0%	–	112.0%

Table 5 (con't)

Location	Metalaxyl	Linuron	Malathion	Chlorpyriphos	a-Endosulfan	b-Endosulfan	Phosmet	Methoxychlor	Azinphos-methyl	Permethrin	Cypermethrin	Deltamethrin
Blank	<0.017	IN[b]	<0.009	<0.011	<0.020	<0.025	<0.006	<.005	<0.072	<0.063	<0.091	<0.114
Spike	0.0%	IN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Spike	34.0%	IN	18.0%	26.0%	0.0%	0.0%	27.0%	26.0%	0.0%	0.0%	0.0%	0.0%
Spike	192.0%	IN	103.0%	111.0%	113.0%	123.0%	120.0%	114.0%	136.0%	91.0%	0.0%	0.0%
Spike	147.0%	IN	90.0%	103.0%	103.0%	116.0%	136.0%	134.0%	143.0%	138.0%	120.0%	0.0%

[a]Not analyzed
[b]Interference

Table 6
Chemical concentrations in Long Creek (LC) and Huntley River (HR), Prince Edward Island, measured in the 1999 surface water monitoring program. Samples were collected from water during wet weather. Concentrations are in ng/L.

Date	Location	Methimidiphos	Carbofuran	Phorate	Dimethoate	Atrazine	Fonofos	Diazinon	Disulfoton	Chlorothalonil	Pirimicarb	Metribuzin
11 July	LC2 - 1	<0.024[a]	**0.029**[b]	<0.001	<0.004	**0.003**	<0.001	<0.002	<0.001	**0.001**	<0.000	**0.018**
11 July	LC2 - 2	<0.024	**0.060**	<0.001	<0.004	**0.001**	<0.001	<0.002	<0.001	**0.008**	<0.000	**0.206**
11 July	LC2 - 3	<0.025	**0.063**	<0.001	<0.004	**0.002**	<0.001	<0.002	<0.001	**0.028**	<0.000	**0.152**
11 July	HR3 - 1	<0.024	**0.020**	<0.001	<0.004	**0.014**	<0.001	<0.002	<0.001	**0.002**	<0.000	**0.048**
17 Sep	HR3 - 1	IN[c]	<0.003	<0.004	<0.002	**0.009**	<0.006	<0.009	<0.001	**0.952**	<0.002	**0.023**
17 Sep	HR2 - 1	IN	<0.003	<0.004	<0.002	**0.015**	<0.006	<0.009	<0.001	**0.997**	<0.002	**0.018**
17 Sep	LC2 - 1	IN	**0.035**	<0.003	**0.066**	<0.002	<0.006	<0.009	<0.001	**0.383**	<0.002	**0.149**

Table 6 (con't)

Date	Location	Metal-axyl	Linuron	Mala-thion	Chlor-pyriphos	alpha-Endosulfan	beta-Endosulfan	Phosmet	Meth-oxychlor	Azinphos-methyl	Per-methrin	Cyper-methrin	Delta-methrin
11 July	LC2 - 1	**0.006**	IN	<0.002	<0.001	**0.014**	<0.004	<0.004	<0.001	<0.012	<0.024	<0.023	-0.046
11 July	LC2 - 2	**0.005**	IN	<0.002	<0.001	<0.002	0.004	<0.004	<0.001	**0.034**	<0.024	<0.023	-0.046
11 July	LC2 - 3	**0.005**	IN	<0.002	<0.001	<0.002	<0.004	<0.004	<0.001	**0.055**	<0.024	<0.023	-0.046
11 July	HR3 - 1	**0.005**	IN	<0.002	<0.001	<0.002	<0.004	<0.004	<0.001	**0.059**	<0.024	<0.023	-0.046
17 Sep	HR3 - 1	**0.014**	<0.003	<0.005	<0.003	<0.013	<0.010	<0.001	<0.004	**0.073**	<0.004	<0.046	-0.008
17 Sep	HR2 - 1	**0.008**	<0.003	<0.005	<0.003	**0.020**	<0.010	<0.001	<0.004	**0.023**	<0.004	<0.046	-0.008
17 Sep	LC2 - 1	**0.008**	<0.003	<0.005	<0.003	**0.021**	**0.020**	<0.001	<0.004	**0.010**	<0.004	<0.046	-0.008

[a]Cells with < symbol are below stated detection limit
[c]Detections are bolded
[d]Interference

Table 7
Recovery rates of pesticides in spiked (measured product added) samples from the 1999 surface water monitoring program.

Date	Time of spiking[a]	Methi-midiphos	Carbo-furan	Phorate	Di-methoate	Atrazine	Fonofos	Di-azinon	Di-sulfoton	Chloro-thalonil	Pirimi-carb	Metri-buzin
11 July	Analysis	0%	110%	95%	79%	95%	92%	91%	81%	91%	93%	89%
11 July	Collection	3%	NA	98%	99%	89%	89%	86%	70%	87%	91%	73%
17 Sep	Collection	0.0%	NA	94.0%	96.8%	93.9%	94.4%	93.9%	80.6%	72.2%	102.7%	109.9%
17 Sep	Analysis	0.7%	80.8%	85.3%	73.3%	96.5%	93.7%	95.6%	86.7%	113.9%	99.9%	100.5%

Table 7 (con't)

Date	Location	Metalaxyl	Linuron	Mala-thion	Chlor-pyriphos	alpha-Endosulfan	beta-Endosulfan	Phosmet	Meth-oxychlor	Azinphos-methyl	Per-methrin	Cyper-methrin	Delta-methrin
11 July	Analysis	94%	96%	94%	87%	95%	97%	80%	100%	113%	86%	96%	107%
11 July	Collection	91%	111%	86%	84%	77%	83%	13%	107%	144%	95%	138%	131%
17 Sep	Collection	95.4%	143.8%	91.1%	92.9%	83.1%	88.0%	1.1%	98.9%	141.0%	88.5%	100.2%	86.6%
17 Sep	Analysis[a]	100.0%	179.6%	95.1%	97.3%	97.6%	97.1%	106.0%	119.1%	103.2%	84.5%	68.0%	66.3%

[a]Collection spikes were added in the ESL lab with several hours of field collection. Analysis spikes were added just prior to laboratory analysis.

Table 8
Results of pesticide analysis from the Valleyfield River fish kill, July 1999.

Sample type	Date sampled	Pesticide	Concentration (ppb)
Pond water	11 Jul	None detected	-
Standing water	12 Jul	Azinphos methyl	15.4
Potato foliage	12 Jul	Azinphos methyl	(523 μg/m^2)
Sediment	12 Jul	Azinphos methyl	160
		Dithiocarbamates	633
Standing water	12 Jul	Azinphos methyl	10.8
		Alpha-endosulfan	0.19
		Beta-endosulfan	0.26
		Metobromuron	0.4*
Sediment	12 Jul	Azinphos methyl	37
		Chlorothalonil	12
		Dithiocarbamates	230

*Estimated concentration

Table 9
Results of pesticide analysis from the Souris River fish kill, July 1999.

Sample type	Pesticide	Concentration (ppb)
Sediment from stream bottom	Alpha-endosulfan	7.3
	Beta-endosulfan	7.2
Soil, bottom of potato field	Alpha-endosulfan	266
	Beta-endosulfan	216
	Dithiocarbamates	600
Vegetation in potato field	Alpha-endosulfan	(0.253 μg/m^2)
	Beta-endosulfan	(1.04 μg/m^2)

Table 10
Results of pesticide analysis from the Tryon River fish kill, July 1999.

Sample type	Date sampled	Pesticide	Concentration (ppb)
Water	19 Jul	Azinphos methyl	2.31
		Carbofuran	0.32
Water	20 Jul	Azinphos methyl	0.52
		Carbofuran	18.5
		Dithiocarbamates	20
Sediment	20 Jul	Carbofuran	5.26
		Dithiocarbamates	Trace
Water	20 Jul	None Detected	-
Sediment	20 Jul	None Detected	-
Sediment	20 Jul	Azinphos methyl	55.3
		Dithiocarbamate	1200
Sediment	20 Jul	Dithiocarbamates	130
Water	22 Jul	Azinphos methyl	5.43
		Dithiocarbamates	Trace

Notes:
Dithiocarbamates reported as mancozeb
Dithiocarbamates in sediment - Trace - LOQ = 100 ppb, LOD = 30 ppb
Dithiocarbamates in water - Trace - LOQ = 6 ppb, LOD = 2 ppb

Table 11
Results of pesticide analysis from the Westmoreland River fish kill, July 1999.

Sample type	Date sampled	Pesticide	Concentration (ppb)
Standing water	20 Jul	Carbofuran	2.54
		Chlorothalonil	113.5
		Dithiocarbamate	26
		Alpha-endosulfan	0.517
		Beta-endosulfan	1.04
		Metribuzin	0.300 to 0.554*
		Endosulfan Sulfate	**
Sediment	20 Jul	Chlorothalonil	1643
		Dithiocarbamates	Trace
Standing water	20 Jul	Carbofuran	5.78
		Chlorothalonil	66.9
		Beta-endosulfan	1
Soil	20 Jul	Carbofuran	78
		Chlorothalonil	6220
		Dithiocarbamates	890
		Alpha-endosulfan	152
		Beta-endosulfan	165
Sediment	20 Jul	Dithiocarbamates	140
Sediment	22 Jul	Azinphos methyl	409

Notes
* - Estimated concentration range
** - Detected but not quantified
Dithiocarbamates reported as mancozeb
Dithiocarbamates in sediment - Trace - LOQ = 100 ppb, LOD = 30 ppb
Dithiocarbamates in water - Trace - LOQ = 6 ppb, LOD = 2 ppb

Table 12
Results of pesticide analysis from the Orwell River fish kill, 29 July 1999.

Sample type	Pesticide	Concentration (ppb)
Water	Alpha-endosulfan	0.15
	Beta-endosulfan	0.2
	Azinphos methyl	0.34
Sediment	Alpha-endosulfan	14.0
	Beta-endosulfan	28.0
	Azinphos methyl	57.0
	Dithiocarbamate residues	2540

Table 13
Results of pesticide analysis from the Trout River, Tyne Valley, August 1999.

Sample type	Pesticide	Concentration (ppb)
Standing water between potato drills	Azinphos methyl	42.4
	Metribuzin	1.3
	Chlorothalonil	0.2
	Metalaxyl component	Present

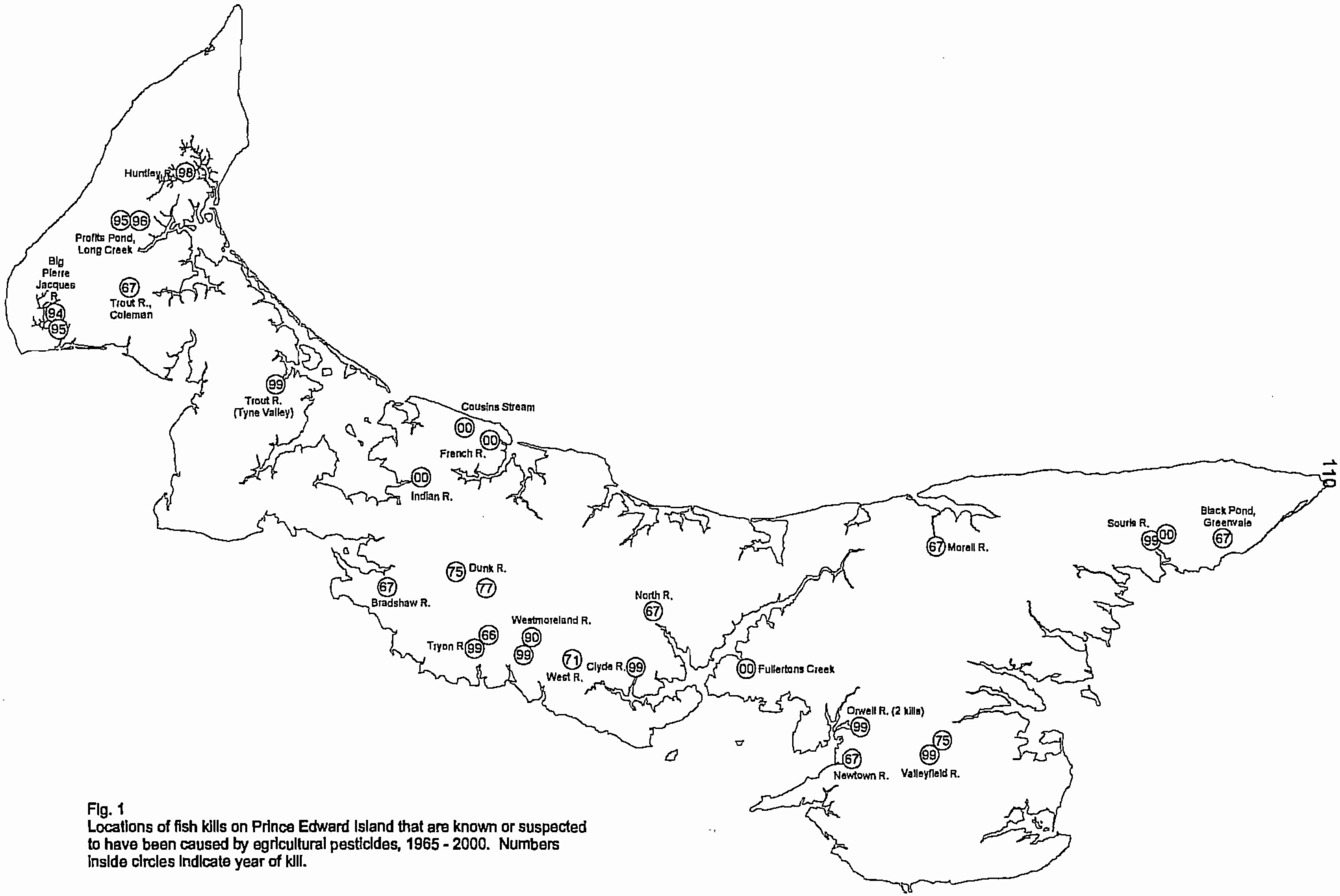

Fig. 1
Locations of fish kills on Prince Edward Island that are known or suspected to have been caused by agricultural pesticides, 1965 - 2000. Numbers inside circles indicate year of kill.

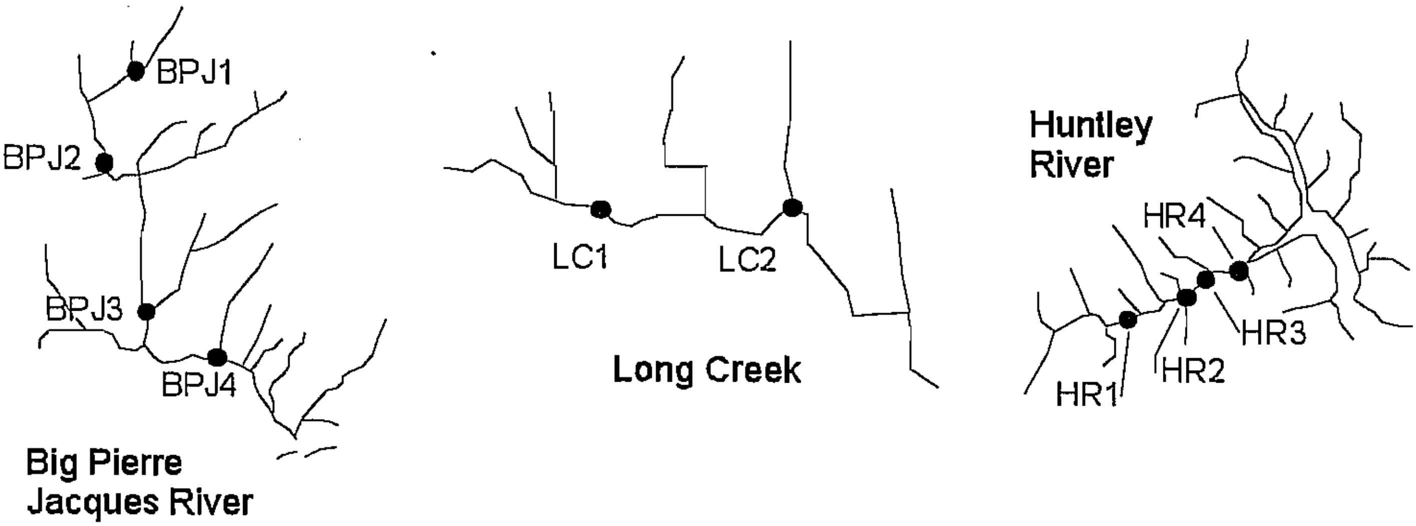

Fig. 2
Location of sampling points within study sites.

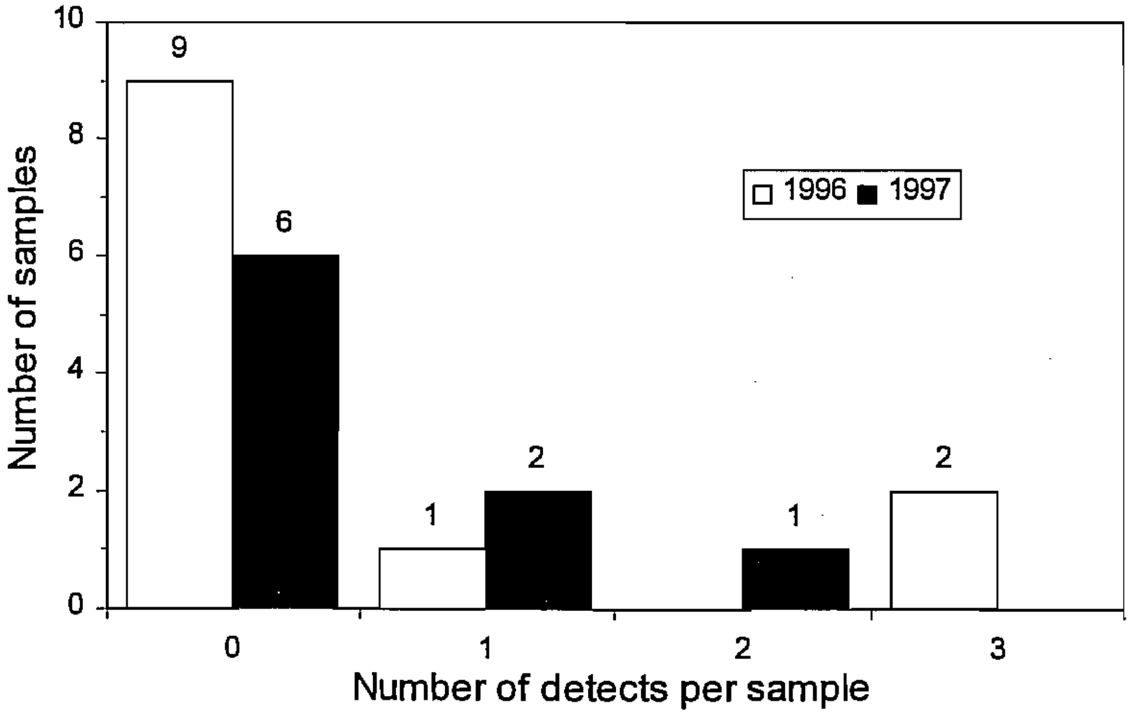

Fig. 3
Detection frequency of pesticides detected in sediment samples from the monitoring program.

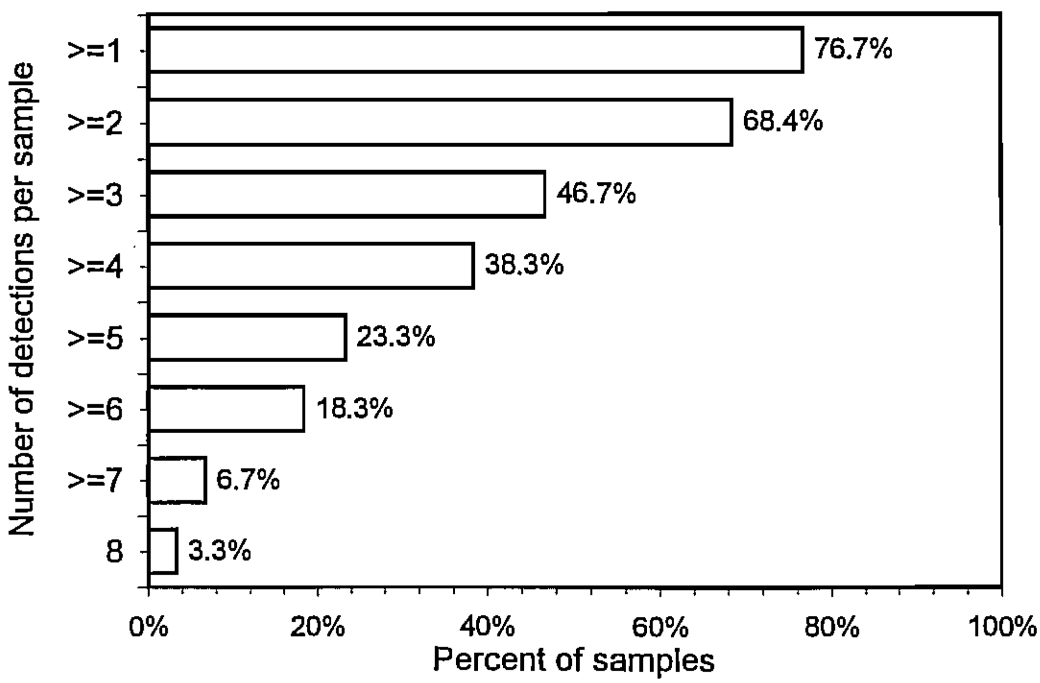

Fig. 4

Frequency of pesticide detections per water sample in the monitoring program, 1996-1999.

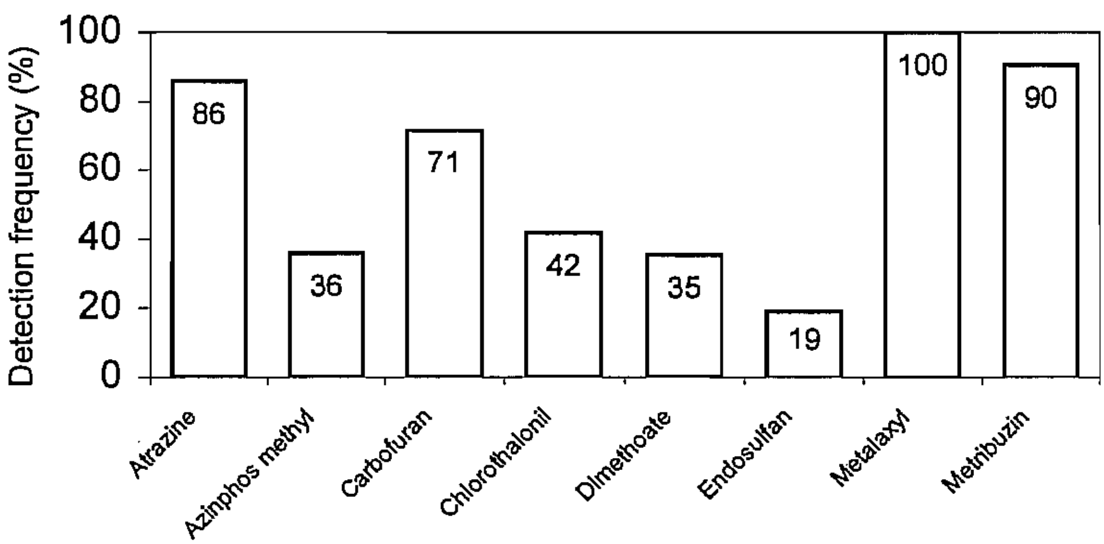

Fig. 5

Frequency of detection of the 8 pesticides most commonly found in water samples from the monitoring program, 1996-1999.

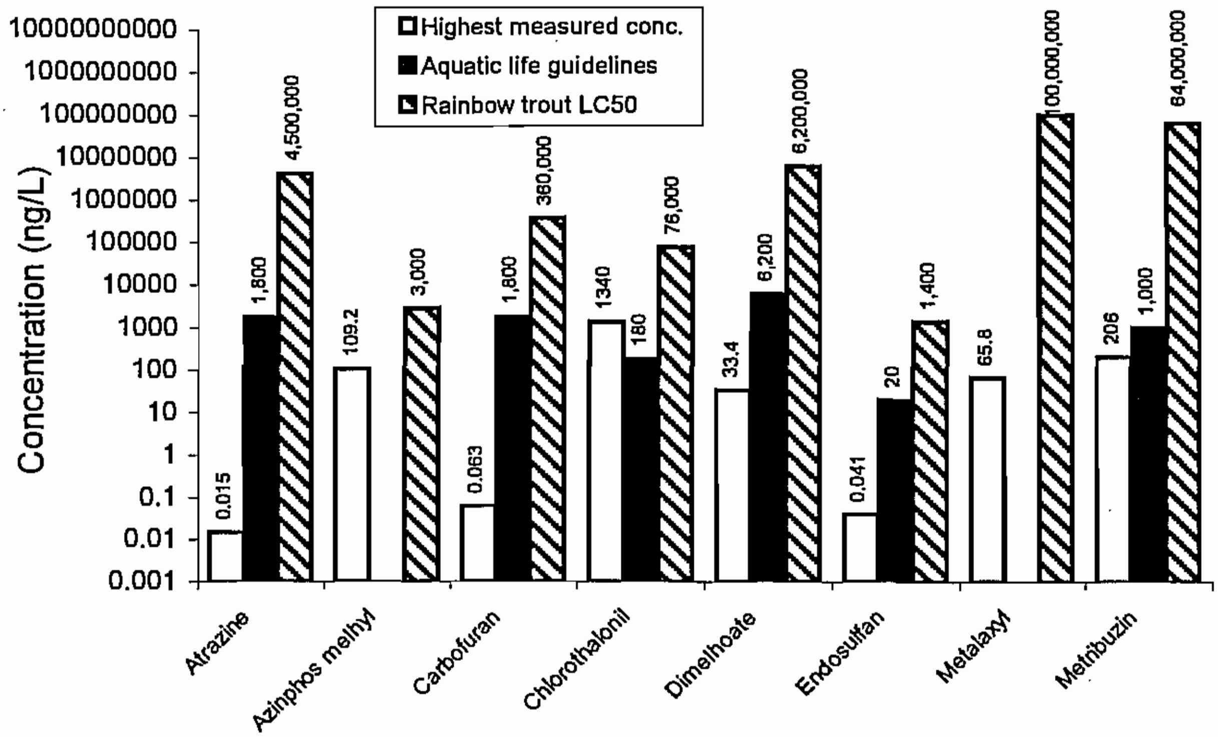

Fig. 6

Comparison between the maximum concentrations detected in the monitoring program and the Freshwater Aquatic Life Guidelines and rainbow trout LC50 values.

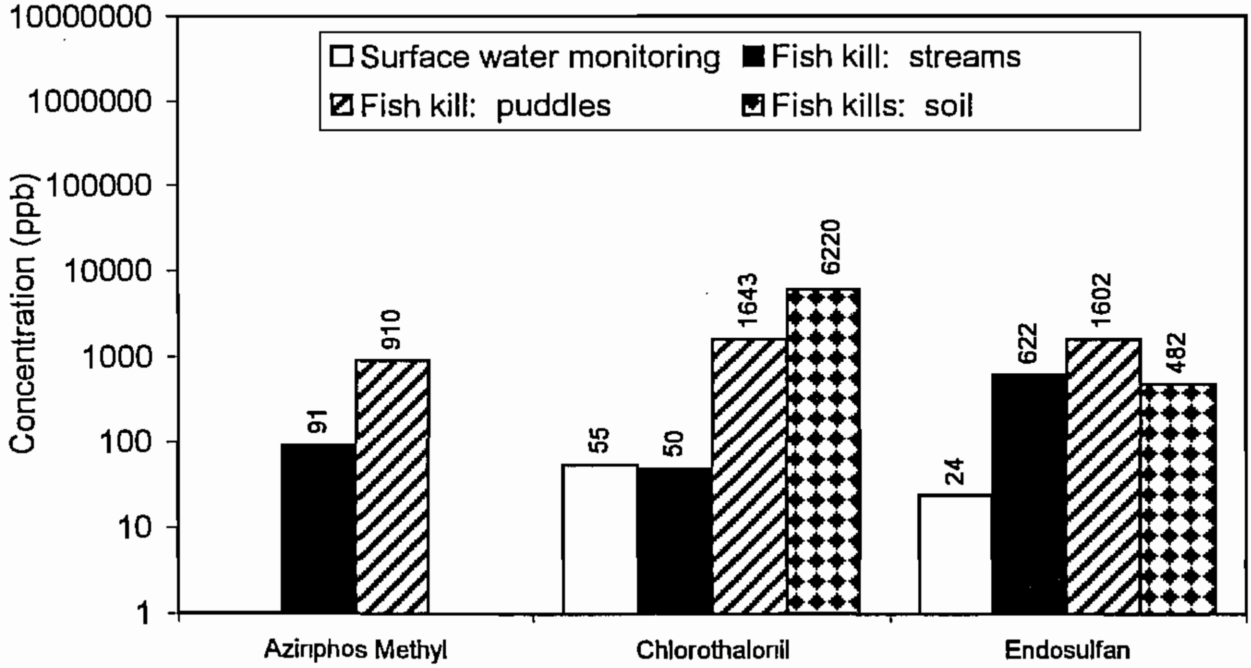

Fig. 7

Maximum pesticide concentrations measured in water in the monitoring program and in water and soil in fish kill investigations. A concentration shown as 0 means that the product was not detected.

Appendix A
Fish kills on Prince Edward Island, 1966-1999, that are known or suspected to have been caused by agricultural pesticides.
Data from Prince Edward Island Department of Fisheries, Aquaculture, and Environment files.

Year	Date	System	Location	Number of dead fish reported	Circumstances
1966	6 Aug	Tryon R.	East Arm	>400	Partially full can of dithane (mancozeb) found within 2 m of stream
1967	28 Jun	Trout R., Coleman	O'Leary sewage lagoon to estuary		
1967	July	Black Pond, Greenvale (Kings Co.)	Stream leading into pond		
1967	4 Aug	North R.	Above Milton Bridge		Traces of endrin found in water and fish tissue
1967	~15 Aug	Newtown R.			
1967	29 Aug	Bradshaw R.	Including Afflecks Pond	100s	
1967	Aug	Morell R.			
1971	19 Jun	West R.	Kill originated in Howells Brook, kill extended over 16 km		Endrin found in water and fish samples
1975	14 Aug	Valleyfield R.			Traces of endrin found in water
1975	28 or 29 Aug	Dunk R.	North Brook	1034	Endosulfan spill (see Johnston and Cheverie 1980)
1977	28 Jun	Dunk R.	near Shamrock	Almost 1000; no live fish found in a 2 km stretch of stream	A pit 20 m from the stream had empty premerge (3 DinitroAmine) containers, and there was a channel between the pit and the watercourse
1990		Westmoreland R.		200-300	Kill occurred below a field to which thiodan had been applied 8 h prior to a downpour
1994	26/27 Jul	Big Pierre Jacques R.		>2000. All fish dead on a 7 km stretch of river	
1994		Westmoreland R.			
1995	21/22 Jul	Big Pierre Jacques R.		>2000. All fish dead on a 10 km stretch of river	
1995	25 Jul	Mill R.	Long Creek, Profits Pond	All fish killed from the point of entry to the estuary (about 4 km). Kill included 35,000 salmon parr in a semi-natural rearing pond.	A spayer loaded with Dithane (Mancozeb) overturned and the pesticide ran into the watercourse
1996	20 Jul	Mill R.	Long Creek, Profits Pond	All salmon parr in a semi-natural rearing pond were killed	
1998	23 Jul	Huntley R.	From estuary to 3.5 km upstream		Heavy rainfall prior to kill

Appendix A (con't)

Year	Date	System	Location	Number of dead fish reported	Circumstances
1999	11 Jul	Valleyfield R.	Heatherdale to the confluence with the Montague R.	2506	Heavy rain prior to the kill.
1999	12 Jul	Orwell R.	Dead fish found at Rte 24 crossing	50	No potato fields in the immediate area. A heavy rainfall occurred 2 days before the kill was reported.
1999	14 Jul	Souris R.	Below the Manning Rd.	250-300 dead fish found over 1 km of stream	Heavy rainfalls occurred prior to the kill.
1999	19 Jul	Tryon R.	Lords Pond and upstream	Fish killed along a 4 km stretch of stream. About 1350 collected	Heavy rainfalls on the day and on the day before the kill was reported. Temperature and dissolved oxygen levels were normal.
1999	20 Jul	Westmoreland R.	Between Rte. 233 and Crapaud; downstream from Crapaud	Fish killed along about 2.5 km of stream	Heavy rainfalls before the kill was reported. Temperature and dissolved oxygen levels were normal.
1999	21 Jul	Clyde R.	Above Rte 247	10+	
1999	29 Jul	Orwell R.	South Branch	50+	Temperature and dissolved oxygen were normal. Heavy rainfall 3 days before the kill was reported.
1999	13 Aug	Trout R., Tyne Valley	West Branch	200-300 dead fish found over a 3 km stretch of river	Heavy rainfalls occurred prior to the kill. There was a potato field ajacent to the kill area. This field has poor drainage and is rated as unsuitable for cereal and potato production.

Potential endocrine disruption in freshwater systems near agricultural areas on Prince Edward Island

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EXTENDED ABSTRACT

A pilot study was undertaken in the summer of 1998 to assess whether sediments and freshwater in agricultural areas on Prince Edward Island had the potential to induce endocrine disrupting effects.

The field component of the study involved caging rainbow trout (*Oncorhynchus mykiss*) in eight Prince Edward Island streams draining areas of low, medium, and high agricultural intensity for 21 or 42 days, from mid-July to mid-September. There were three exposures periods during the most active pesticide spray period: Group I (weeks of July 13 - August 3), Group II (weeks of July 27 - September 7) and Group III (weeks of August 24 - September 14). Each of the 18 caging locations was assigned a relative risk ranking based on the assumed potential to receive agricultural run-off. Both male and female fish were analyzed for levels of circulating testosterone (Fig. 1). Although some sites showed significantly increased and decreased levels of the steroid hormone, there was no clear relation between testosterone levels and agricultural activity. The blood samples were also analyzed for vitellogenin concentrations to determine if vitellogenin induction had occurred. However, incorrect handling procedures at the time of sample collection may have produced unreliable data.

Wild fish were also collected from various rivers across PEI to determine the incidence of intersex and to determine their circulating levels of testosterone. There was no evidence of intersex in any of the gonads and there were no significant differences in circulating testosterone levels between fish collected from high intensity sites compared with those from lower intensity agricultural areas.

Laboratory studies were undertaken in which Japanese medaka (*Oryzias latipes*) embryos were exposed to sediments collected from each of the caging sites. Mortality and failure to inflate a swim bladder was higher in eggs and larvae exposed to sediments from high intensity sites compared with low intensity sites (Fig. 2). Larvae exposed to high risk sediment also took longer to hatch than those exposed to low risk sediment (Fig. 3).

While the observed effects in the caged fish component could not be positively attributed to endocrine disruption, the results of the study provided support to undertake additional research activities on PEI in the summer of 1999. Eight sites were selected (six in intensive agricultural areas and two in a less intensively farmed area). At each site, a suite of bioassays was undertaken including the measurement of endocrine responses in caged fish and screening of semi-permeable membrane device extracts for endocrine responses. At three sites, composite whole water samples were collected and water samples were also collected on XAD resin for pesticide and nonylphenol analyses.

Pp. 116-118 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

The chemical analyses will provide an indication of exposure levels within each watershed, facilitating comparison of the results of the other assays and aiding in the overall assessment of causative agents of any observed effects.

This Extended Abstract is based on:

Gray, M.A., K.L. Teather, J. Sherry, M. MacMaster, M. Hewitt, and R.E. Mroz. 2000. Endocrine disrupting potential in freshwater ecosystems near agricultural areas on Prince Edward Island. Environment Canada Surveillance Report EPS-5-AR-99-6.

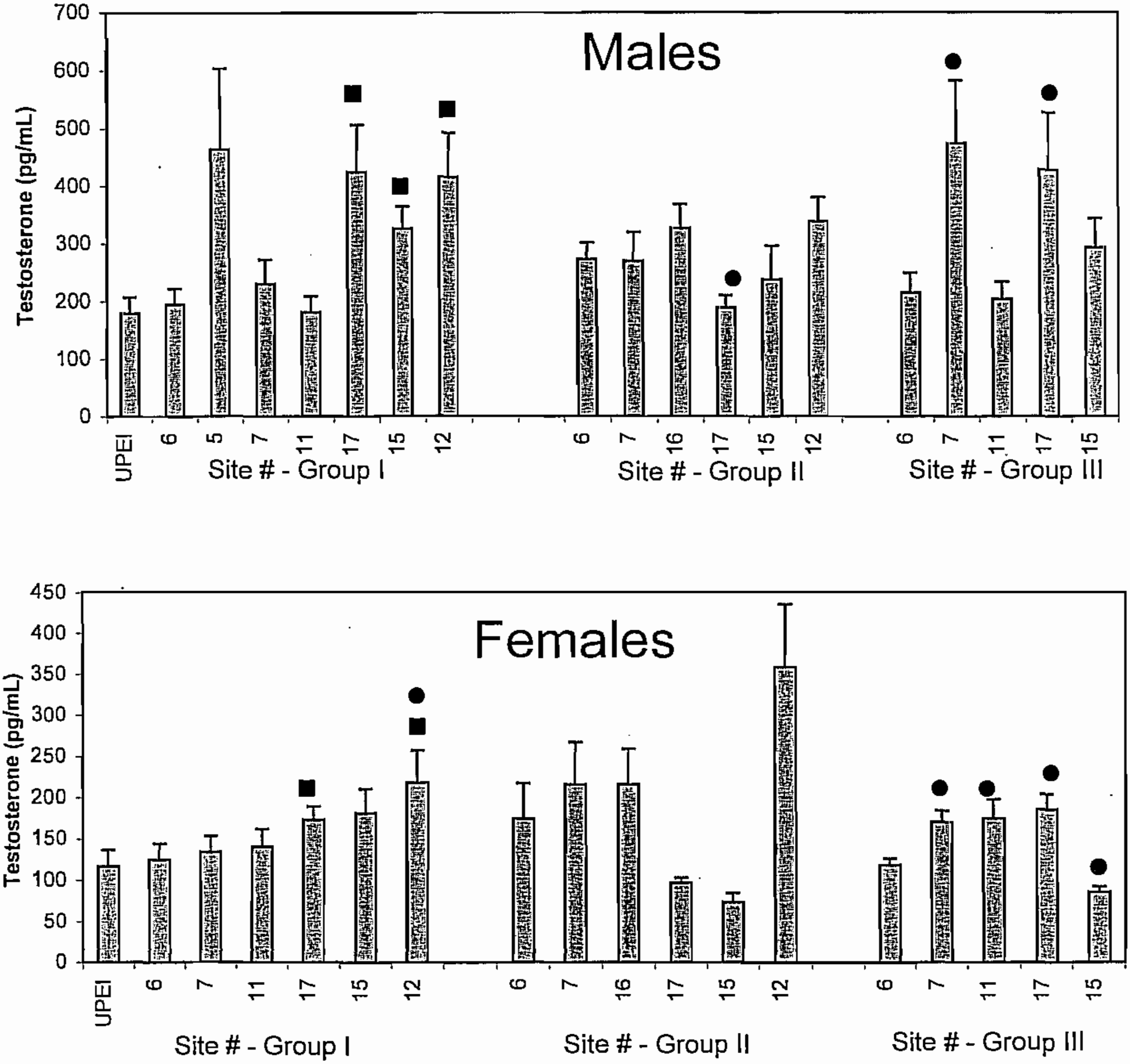

Fig. 1

Mean testosterone concentrations (±SE) in rainbow trout from the three exposure periods (Groups I, II & III). The upper panel indicates concentrations in males and the lower panel indicates concentrations in females. Sites are listed in increasing presumed risk to agricultural run-off exposure. Circles indicate a significant difference from the lowest risk site (Site 6) within each group. Squares indicate a significant difference from UPEI fish (Group I only). ($P<0.05$).

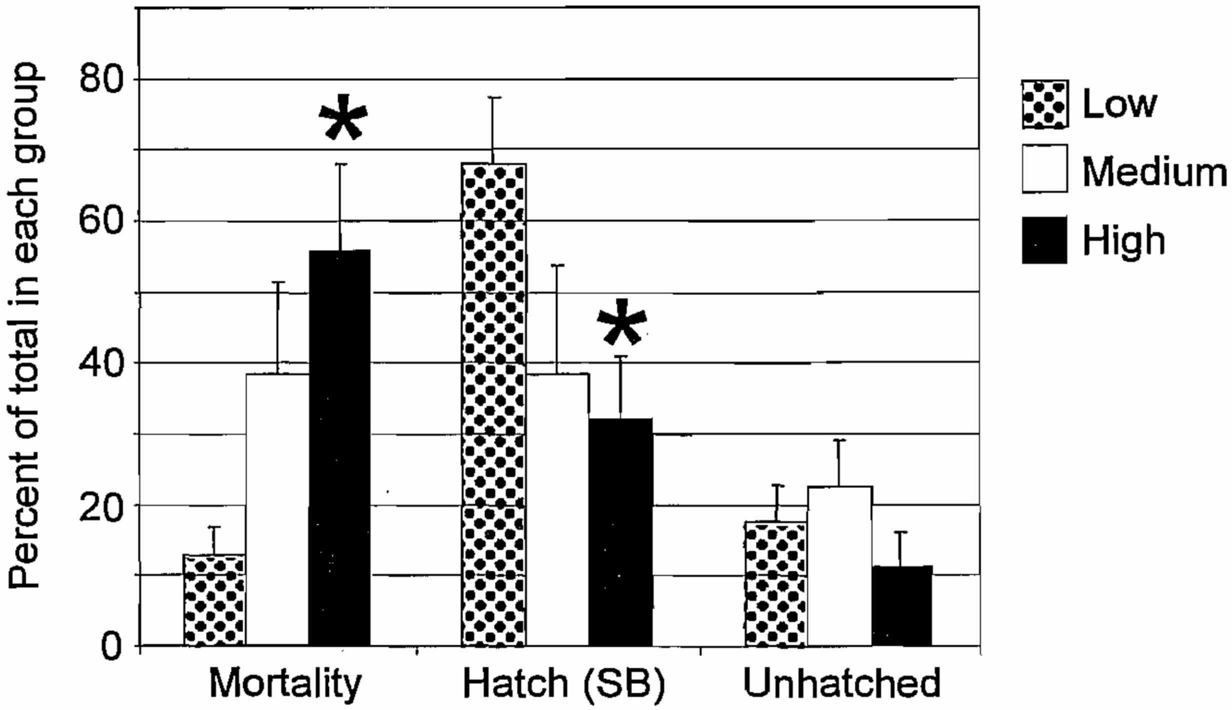

Fig. 2
Mean percent mortality, swim bladder inflation and unhatched larvae (±SE) for medaka embryos exposed to sediments collected from rainbow trout caging sites grouped into low, medium and high risk groups. The asterisk indicates a significant ranking difference from the lowest risk group (P<0.05).

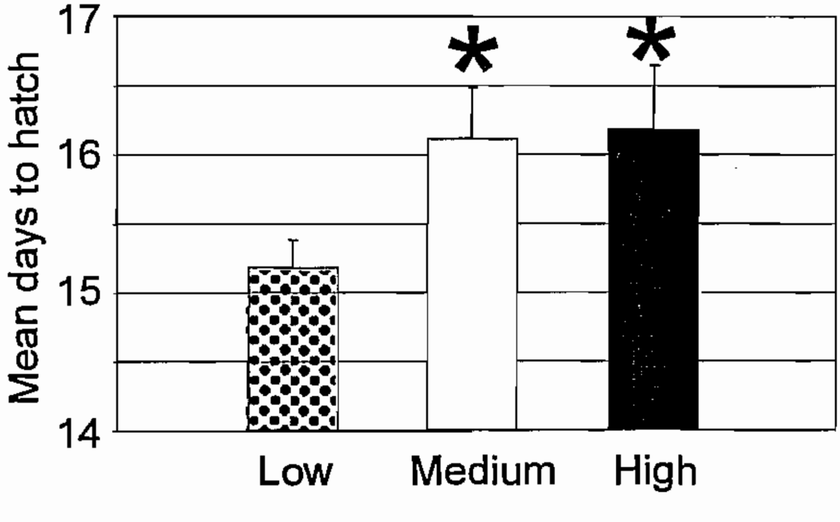

Fig. 3
Mean days to hatch (±SE) for medaka embryos exposed to sediments collected from rainbow trout caging sites grouped into low, medium and high risk groups. The asterisk indicates a significant ranking difference from the lowest risk group (P<0.05).

Livestock access to watercourses: issues and solutions

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ABSTRACT

Livestock on PEI have traditionally accessed watercourses for drinking water and marshes for grazing. Access by livestock to these habitats can lead to bacterial and chemical contamination and physical damage. In 1991, the Eastem Habitat Joint Venture and the Prince Edward Island Soil and Crop Improvement Association, in partnership with other organizations, initiated a fencing program to prevent livestock access to wetlands and watercourses. The program provides financial and technical support to farmers, and has resulted in the restriction of about 10,000 cattle from watercourses by more than 75 km of fencing.

INTRODUCTION

Prince Edward Island is Canada's smallest province, consisting of 567,000 ha of which 90% is privately owned. The province's coastline is dotted with productive coastal marshes and indented with bays and estuaries that reach into the interior of the land. Fresh water wetlands, beaver ponds and streams are located throughout the province. About half the upland is forested and most of the remainder is under agricultural production.

The farmland-forest mosaic that characterizes PEI provides abundant habitat for many wildlife species, but agriculture also produces negative effects. PEI has a significant livestock industry; there are approximately 95,000 cattle on PEI of which about 20,000 are located on feedlots. Traditionally on PEI, streams are used as watering sources for livestock, and stock may also be allowed access to marshlands for grazing.

Livestock in streams and wetlands may cause environmental damage, and the main concems have to do with water quality changes induced by manure, and physical damage caused by trampling. Water quality may be degraded by contamination from faecal coliform bacteria (Gabor et al. 2001, Adams 2002). Estuarine eutrophication is caused by excessive nutrient supply (Meeuwig 2002, Raymond 2002); nutrients leached from manure deposited in and near streams may contribute to this. Manure may also release ammonia or nitrates which are lethal to fish if concentrations are sufficiently high (Aggett et al. 2002). The sharp hooves of cattle break down streambank vegetation and the banks themselves, leading to steam widening and increased erosion (Trimble 1994, Laubel et al. 1999). Cattle walking in streams increases turbidity and causes sediment to re-suspend.

The PEI Wetland Stewardship Program aims to conserve wetlands in PEI's agricultural landscape through cooperation with farmers and agricultural agencies. Much of this work focuses on reducing livestock impacts to watercourses. The program is sponsored by Eastem Habitat Joint Venture (EHVJ) in partnership with the PEI Soil and Crop Improvement Association (PEISCIA), Wildlife Habitat Canada, Ducks Unlimited Canada, the Canadian Wildlife Service, federal and state govemments of the United States, Ducks Unlimited Inc., and the Province of Prince Edward Island.

PROGRAM DESCRIPTION

Prior to 1991, there was little organized effort on PEI to protect wildlife habitat in streams and wetlands by fencing livestock. Livestock commonly had unhindered access to watercourses, and little had changed in this regard since the beginning of European settlement. EHJV wanted to develop a program to prevent livestock access to streams and wetlands while providing an altemative method for watering livestock.

At the time EHJV was considering a livestock fencing program, the PEISCIA was looking at a similar program. The EHJV's motivation was environmental, while the PEISCIA was motivated by a desire to improve pasture management. Because the organizations shared a common goal, they put together a cooperative demonstration program. Since 1991 EHJV and the PEISCIA have cooperated annually on an assistance program which covers at least 50% of the cost of projects. The program requires farmers to sign agreements to keep fencing in place for 15 years.

In 1999, the program was funded through the Agriculture and Environmental Resource Conservation Program

Pp. 119-120 in D.K. Caims (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

(AERC), and delivered by the PEISCIA. This has proved to be an arrangement with many advantages. EHJV is able to dedicate funds where most needed and the PEISCIA is able to continue its important work in soil and water conservation. The PEISCIA is also invaluable in their ability to promote the program. EHJV is aware of the environmental costs of livestock access to wetlands and can point out the damage to sensitive riparian zones and marshlands, but it is not in a position to make an argument on the agricultural costs. The PEISCIA can effectively do this.

Through this program EHJV has participated in approximately 180 projects on livestock farms across PEI. This translates to approximately 10,000 cattle fenced, more than 75 km of fencing erected and more than 550 ha of wetlands and riparian habitat directly protected. Provision of alternate watering systems, such as gravity-fed lines or nose-powered pumps, is an important part of the program. As farmers have become more aware of the consequences of livestock access to watercourses, many have voluntarily fenced without financial assistance. Hence the total amount of stream protected by new fencing is greater than that indicated by the Stewardship Program statistics noted above.

DISCUSSION AND CONCLUSIONS

The number of livestock that presently have access to watercourses on PEI is unknown. To determine this requires data on the number of farms allowing access and the mean number of animals per farm. This information is currently unavailable. In addition, PEI does not have a comprehensive stream inventory, so that the length of fenced watercourses cannot be compared with total watercourse..

Should legislation be used to force farmers to fence livestock out of streams? In exceptional cases this may be appropriate, and enforcement is possible under the federal Fisheries Act (see Aggett et al. 2002). However, the Wetland Stewardship Program has demonstrated the advantages of a stewardship approach. Stewardship allows for flexibility and can be applied to many diverse situations whereas application of laws and regulations tends to hamper the innovation required to solve problems.

Fencing livestock from wetlands and streams can be promoted by appealing to the business interest of farmers. Allowing livestock to water in streams which receive manure inputs has implications for animal health (Willms et al. 1999). The advantages of fencing to profitability of fencing need to be articulated as farming is a business and farmers need to make a profit.

The following steps would further advance livestock exclusion from watercourses on PEI:

1. The gathering of reliable statistics on the length of watercourses with livestock fencing, the length with livestock but no fencing, and the length without livestock in adjacent fields. Such data would assist in evaluating progress and creating targets.
2. Assessment on a watershed basis of the extent of damage and contamination to watercourses and riparian areas due to livestock access.
3. Research on the effects of exclusion from watercourses on livestock health and production.
4. Continuation of incentive programs.
5. In exceptional cases, enforcement of the federal Fisheries Act.

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Concentrations of faecal coliform bacteria in Prince Edward Island headwater streams: an interim report

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ABSTRACT

This project measured faecal coliform (FC) levels in headwater streams of Prince Edward Island in July-November 1998 and May-October 1999. Potential FC bacteria contributors at study sites included cattle, sheep, geese, and humans. Water and sediment (1998 only) samples were taken upstream and downstream of potential FC contributors. There was a significant positive correlation between wet-days (sample days with > 10 mm of rain) and FC concentrations in water, suggesting that runoff or resuspension contributes to increased FC levels. All the cattle and sheep access sites showed a significant increase of FC downstream from the livestock. The site with a forested buffer zone which had cattle fenced out of the stream showed no difference in FC concentrations between upstream and downstream sampling points. The waterfowl site, consisting of a stream that runs through two ponds, provided evidence that high numbers of geese (mean = 83) had a significant effect on FC concentrations. Results from this site also suggested that ponds can act as filters or buffers for FC concentrations. Water samples from the stream exiting the upper pond showed significantly lower FC concentrations than water samples taken upstream of the pond. Additional sites were sampled in the 1999 field season. The two 1999 cattle access sites showed significant increases in FC concentrations at downstream sampling sites, and the 1999 cattle fenced site showed no change in bacteria levels between upstream and downstream points. A site added in the 1999 field season provided a reference on what levels of FC to expect naturally since the stream occurred primarily in a forested area without other influences (geometric mean = 11 MPN/100 ml). Several upstream locations in which there was no agricultural or anthropogenic activity also showed low FC levels.

PREFACE

This paper presents the results of a Canadian Rural Partnership pilot project. Other funding contributors included Environment Canada's Science Horizons Program and Science Linkages Program, EcoAction 2000, Human Resource Development Canada's Youth Employment Strategy, the Bedeque Bay Environmental Management Association (BBEMA), the Southeast Environmental Association (SEA) and the PEI Department of Technology and Environment (now the Department of Fisheries, Aquaculture, and Environment).

The project was guided by a Steering Committee representing the following organizations: Bedeque Bay Environmental Management Association, Southeast Environmental Association, PEI Department of Technology and Environment, PEI Department of Agriculture and Forestry, PEI Department of Fisheries and Tourism, Environment Canada, Department of Fisheries and Oceans, PEI Cattlemen's Association, PEI Federation of Agriculture, PEI Shellfishers' Association and the PEI Aquaculture Alliance.

INTRODUCTION

Water quality can be degraded by a variety of contaminants. On Prince Edward Island, pollutants of concern include sediments, nutrients, pesticides and faecal coliform bacteria (FC). Faecal coliform bacteria are used as an indicator, accepted on a world-wide basis, to assess potential impacts of faecal contamination from humans, livestock, birds and other warm-blooded animals.

Faecal coliform occur in the intestines of all warm-blooded animals. They are excreted in the faeces of these organisms and therefore their presence in water

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indicates faecal contamination. Thus the occurrence of faecal coliform bacteria in water indicates a risk that pathogens (e.g. salmonella) that occur in the digestive tract of warm-blooded animals could also be present.

Faecal coliform bacteria are used internationally as an indicator of water quality. The mean level of FC permissible for primary contact (bathing, swimming, etc.) is 200 MPN/100 ml with no samples exceeding 400 MPN/100 ml (at least five samples in a 30 day period) (Health and Welfare Canada 1992). MPN stands for most probable number of FC when using the laboratory method of multiple tube fermentation (Neter 1970, Eaton et al. 1995).

Contributors of FC bacteria to waterways include outflows of sewage treatment plants, improper septic sewage systems, wild animals (e.g. geese), and domestic livestock. This project examined the FC contributions of non-point source pollution from agricultural areas, specifically livestock with access to streams, and also contributions from waterfowl.

Non-point source pollution from sources such as run-off from agricultural or urban land is a major source of FC. The origin of this type of pollution is generally more difficult to identify than the origin of pollution that comes from point sources such as sewage outfalls. Runoff from agricultural land may drain grazed pastures and manured fields and can contain FC bacteria. It has been shown that soils in pasture land contain higher concentrations of FC bacteria than soils in forests or soils in cornfields (Faust 1982). The bacteria can occur at depths as great as 7 cm below the soil surface (Faust 1982). Faecal coliforms can persist in faeces even when the faeces is completely dry (Thelin and Gifford 1983). These authors showed that a 30-day-old cow paddy, when rained upon, can produce runoff with a concentration of FC bacteria up to 40000 MPN/100 ml. It is therefore not surprising that streams in agricultural lands have been shown to have higher concentrations of FC than streams in pristine lands (Doran and Linn 1979, Niemi and Niemi 1991).

Agriculture is an important economic contributor to Prince Edward Island. The sale of farm products in PEI in 1997 was $273,328,000 (PEI Department of Agriculture and Forestry 1998). Because 265,226 ha of PEI's land is used in agricultural production, including 11,826 ha in improved pasture (PEI Department of Agriculture and Forestry 1999), it is important that watercourses in these areas be examined for concentrations of FC. Where FC levels are shown to be above acceptable limits, measures can be taken to reduce them. Water quality is important in the agricultural industry for irrigation and livestock watering.

Water quality is critically important in the molluscan shellfish industry. Bivalve molluscs are filter feeders and when grown in polluted areas may ingest pathogens from the water. If these shellfish are consumed raw or partially cooked, consumers may become ill. Contaminated shellfish can result in a loss of harvest opportunity to shellfishers. The classification of shellfish harvest areas is based on a mean or median no greater than 14MPN/100 ml of water with no more than 10% of the samples taken greater than 43MPN/100 ml.

The shellfish industry is also important to the economy of PEI, and the province is recognized as a world leader in high quality mussels, oysters and clams. In 1997, the value of PEI aquaculture was approximately $27 million (Paul Neima, pers. comm. 1998). Since 1940, the number of shellfish closures in the Maritimes has been increasing (Menon 1988). Presently, there are 83 closures around PEI with the three largest closure areas being Charlottetown Harbour, Bedeque Bay and the Dunk River watershed (Thompson 1998). A closure is defined as an area which does not meet the water quality standards and therefore shellfish grown there cannot be consumed directly. Shellfishing may still continue but the shellfish have to be placed in clean water for a period of time to remove any accumulated toxins. A reduction in the size and number of closures is important to the continued success of this industry. Therefore, work needs to be done to reduce the levels of FC bacteria in PEI's waterways and coastal areas.

<u>Purpose</u>

The purpose of this study is to examine FC concentrations in PEI streams with potential non-point source pollution. Collection occurred mainly in the Bedeque Bay and Cardigan Bay watersheds. Faecal coliform concentrations were measured upstream and downstream at sites where potential contributors were readily identified.

Two important recommendations resulting from the PEI Round Table on Resource Landuse and Stewardship were the implementation of buffer zones along streams and rivers (Recommendation 10), and the restriction of access of all forms of livestock from waterways (Recommendation 16) (MacDonald 1997). This study will provide information necessary for addressing Recommendation 16. This project is a response to a request by The Standing Committee on Agriculture, Forestry and Environment (1998) to conduct PEI-specific research under the direction of a committee utilizing members from both the farming and shellfish industries.

<u>Objectives</u>

In June 1998 a Steering Committee was organized to determine the objectives, methodology and funding for the study. The Committee set the following objectives:

1. To monitor FC concentrations in streams subjected to non-point source pollution,

2. To compare FC concentrations associated with various types of land use activity,
3. To remediate sites that show a significant increase in FC bacteria downstream,
4. To assess the effectiveness of remediation,
5. To educate landowners and the general public about FC contributions resulting from non-point source pollution and how these contributions affect water quality, and
6. To educate landowners and the general public about remediation techniques.

Historical Review

Thompson (1998) reviewed FC bacteria data collected in PEI streams as far back as 1977. One study compared the Greek River, Montague River and Wheatley River. It was found that the Wheatley River contained a greater number of livestock in its watershed and showed the highest geometric mean for FC (497 MPN/100 ml) (Machell et al. 1981). Data collected on 15 PEI streams between 1991 and 1997 showed the Clyde River, an agricultural watershed with cattle access, to have the highest FC levels (Thompson 1998).

The present study commenced following a similar study conducted by Uhlman (1998). Uhlman's study examined the three main rivers of the Bedeque Bay watershed but chiefly focused on three cattle access sites on the Dunk River. Water and sediment samples were taken upstream and downstream of cattle access at each site. Samples were collected on both wet-days and dry-days (>10 mm and <10 mm of rain respectively) (Uhlman 1998). He found that one third of cattle access sites showed a significant increase in FC downstream of the cattle. He also found that after rain events FC levels increased in the water indicating the effect of runoff or resuspension from bottom sediments. The means at the three study sites were all above 200 MPN/100 ml of water (Uhlman 1998).

METHODS

Study sites

Study sites were chosen from the Bedeque Bay, Cardigan Bay, and Murray River watersheds (Fig. 1). A reconnaissance of prospective sites was carried out with the assistance of Ronda Bellefontaine of the PEI Cattlemen's Association and Crystal MacDonald of the PEI Federation of Agriculture. Sites were chosen to represent a variety of potential FC contributors including a partially forested site intended to reflect background levels of FC bacteria. An ideal site would have only one potential contributor for faecal contamination. While there were a number of prospective sites available, it was often difficult to isolate discrete upstream and downstream sampling points.

A total of ten sites was chosen. Seven sites included a sampling station upstream from a potential FC source and a sampling station downstream from the source. Six of these had livestock access to the stream and one had livestock fenced from the stream. The partially forested site (C2) had one sampling station. The waterfowl site (C3), a protected sanctuary, included three sampling stations (upstream of the upper pond, between the upper pond and the lower pond, and downstream of the lower pond). One site where both cattle and sheep had access (B5) had two streams on the same pasture. Both streams were sampled downstream of potential contributors but upstream samples could not be taken because the springs originated in the pastures where livestock had access.

Potential FC contributors on the various sites included cattle (both dairy and beef), sheep and waterfowl. For a description of the sites see Table 1.

In 1999 five additional sites, including a site from the St. Peter's Bay watershed and one from the Wood Islands watershed, were sampled. These additional sites provided more data on different types of sites. Another branch of the Greek River was added because it was determined that the branch sampled in 1998 was not completely forested and thus contained various unknown potential contributors. The new branch was completely forested (C2B) and thus the only contributions of FC would arise from wild animals. At site C3, the waterfowl sanctuary, it was noted in 1998 that a separate stream flowed into the lower pond, possibly contributing to FC levels leaving that pond, and therefore it should be sampled (C3R). Two additional cattle access sites were added. One site (C6) had cattle accessing the length of the stream in the pasture while the other (C7) had cattle accessing at only one point (point access), approximately 10 m of stream length. A site with a forested riparian buffer zone and where the cattle were fenced out of the stream was also added (W1).

Landowner Contact

Contact was made with landowners prior to sampling. Permission to sample and information regarding number of livestock and relevant farm practices were obtained during a preliminary interview with each landowner.

Sample Collection

Sampling was conducted from 28 July to 5 November, 1998 and from 18 May to 19 October, 1999. Sites were sampled at least weekly during this period. Sampling days took place during rain events (wet-day >10 mm of rain) if a rain event occurred during the week. If no rain event occurred during the week, sampling was conducted on a dry-day (< 10 mm of rain). When possible, all sites were sampled on the same day.

Water samples were collected in sterile bottles and were taken by hand or using a sampling stick at a depth of 0-20 cm depending on the depth of the stream. Sediment samples (collected in 1998 only) were taken using sterile, stainless steel tablespoons and placed in sterile Whirlpak bags. Approximately 100 g of sediment were taken per sample from the top layer (5 cm) of the stream bed. Sediment samples were taken in the first year to establish the relationship between FC in the water and FC in the sediment. Once this correlation was established, water samples were sufficient to determine bacterial inputs to the streams. All samples were placed in a cooler with ice packs and/or crushed ice until analysis.

Rain gauges were placed near sample sites in both watersheds. Rain gauges were placed near sampling stations B4D, C1U, C4U on 28 August 1998 and later near stations B1U and C3D. In 1999 additional rain gauges were installed at sites C5U, C6U, C7U, and W1U. Gauges were emptied prior to a rainfall event and checked during sampling. A wet-day was represented by a rainfall of >10 mm within 24 hours of sampling. This amount was chosen for consistency with Uhlman (1998). Environment Canada rainfall records were also examined. These records were used only to compare monthly rainfall between 1998 and 1999. The rainfall amounts were measured at the Environment Canada stations nearest to the sampling sites in the study and recorded as rain that had fallen between 19:00 the day before sampling and 07:00 the day of sampling.

Other information noted included the presence or absence of cattle on the sample day and the air temperature.

Bacteriological Analysis
Laboratory analysis was usually conducted within 6 hours of sampling. When laboratory assistance was not immediately available, the samples were stored at 4°C and analyzed within 24 hours. Samples were analyzed using the A1 multiple tube fermentation technique which provides a most probable number (MPN) of FC (Neter 1970, Eaton et al. 1995). Dilutions up to 1000-fold were made when necessary to ensure the results were within the analytical range. For statistical analysis, any sample exceeding the detection limit was represented as the minimum of that range and any sample below the detection limit is represented as the maximum of that range.

Statistical Analysis
Descriptive statistics were developed for each sampling station for both sampling years. These statistics include: geometric mean - the antilogarithm of the arithmetic mean of the logarithms of the data (Zar 1996), the minimum and maximum concentration and the percentage of samples exceeding water quality standards.

Statistical analyses were performed with Systat version 7.0. (SPSS 1997). Concentrations of FC were log transformed for all analyses. Paired t-tests were used to test whether there was a significant increase in FC concentration downstream of potential sources at each site. These tests were conducted using data that were weighted for watershed area and log-transformed (Equation 1). As stream flow was not measured, FC loads could not be calculated directly. As a surrogate, concentration data were weighted by watershed area upstream of the sampling station as stream flow is closely linked to watershed area. Data for statistical analysis were weighted for watershed area so that dilution effects due to the size of the stream (amount of water) could be taken into account, thus allowing intersite comparisons. Also, because downstream sampling stations include the length of the stream between the upstream location and the downstream location, this variable needed to be factored in when comparing FC concentrations between the two. Watershed area was obtained by measuring the size of the watershed upstream of each sampling location using MapInfo Professional on the PEI government's Geographic Information System.

Weighted Data = $\log_{10}$[FC (MPN/100 ml) x watershed area (km^2)] [Equation 1]

Pearson correlations were used to examine relationships between FC concentrations in water with those in sediments for the 1998 sampling season. ANOVA was used to test for differences between FC concentrations on dry and wet days. Pearson correlation was used to determine relationships between rainfall amount and concentrations of FC in both water and sediment.

ANOVA was used to test whether there was any overall difference in FC levels between the two field seasons.

Because data were collected over two years, results were calculated for each year separately. However, for sites sampled in both years, the data were also pooled into one data set and analyzed.

RESULTS

Descriptive statistics for both field seasons are shown in Tables 2 and 3. The station showing the highest concentrations of FC in water was B1D which is downstream of cattle access. The station with the lowest geometric mean was C2B (a stream occurring in a forested area) sampled only during the 1999 field season (Table 2). Station B4D showed the largest geometric mean for sediments with the lowest being at station C3M (Table 3). Sediment geometric means for FC were on average 49 times greater than water geometric means. Sediment samples were taken only during the first year of sampling. The geometric means, and the maximums and minimums, for both water and sediment, should be viewed with caution since numbers with a greater than or less than sign were simply represented as that number for all calculations.

Overall FC levels did not differ significantly between the 1998 and 1999 field seasons (P=0.982).

1998 Field Season

Upstream concentrations of FC in water and sediment were compared with downstream concentrations at most sites in the 1998 field season (Figs. 2-5). Sites with no upstream samples available are represented as downstream of the contributor. Reference sites are represented as upstream samples only. P-values are shown (Table 4) for tests conducted with data weighted for watershed area. Figures represent actual field data.

Three sites which showed significant increases in FC concentrations downstream had direct cattle access: B1, B4, and C1 with P-values of 0.000, 0.004, and 0.000 respectively (Figs. 2-3, Table 4). The waterfowl site (C3) had three sampling locations (upstream of upper pond, downstream of upper pond, and downstream of lower pond). It showed a significant decrease in the concentration of FC in the water between the upstream and downstream of the upper pond where there were fewer geese (P=0.001) and then a significant increase between the downstream of the upper pond and downstream of the lower pond where there were many geese (P=0.000) (Fig. 2). The waterfowl site also had another input (separate stream) into the lower pond that was not measured in 1998 so the data must be interpreted with caution.

For wet-day data only sites B1 (P=0.021), C1 (P=0.015) and C3 (lower pond) (P=0.005) showed significant increases in FC between upstream and downstream stations. For dry-day data only sites B1 (P=0.000), B4 (P=0.013) and C3 (lower pond) (P=0.007) showed significant differences (Table 4).

Sites which showed no significant differences in FC downstream were the sheep access site (C4), two cattle access sites (B3 and C5), and the cattle fenced site (B2) (Figs. 2-3).

Upstream and downstream concentrations of FC in sediment were also compared (Table 4, Figs. 4-5). Sites B1, B4 and C3 (lower pond) showed significant increases in FC downstream (P=0.000, P=0.000, and P=0.002, respectively). When using wet-day data, site B4 and site C3 (lower pond) showed significant increases in FC (P=0.021 and P=0.019 respectively). When using dry-day data both B1 and B4 showed significant increases of FC in sediment (P=0.000 and P=0.008 respectively) (Table 4).

Sites showing no significant differences in FC concentrations in sediment included two cattle access sites (B3 and C5), the sheep access site (C4), the cattle fenced site (B2) and the waterfowl site (C3) (first pond) (Figs. 4-5).

The concentration of FC in water was positively correlated with the concentration of FC in sediment (r = 0.620) (Fig. 6). The correlations were found to be stronger in separate comparisons of dry-day data (r = 0.688) and wet-day data (r = 0.639).

The concentration of FC in water was significantly greater on wet-days than on dry-days (P=0.000) (Fig. 7); however the same was not true for FC in sediment (P=0.916). No significant correlations were observed between the amount of rainfall and the concentration of FC in either water or sediment (r = 0.423 and 0.038 respectively); however, peak concentrations of FC in water appeared to occur during storm events.

1999 Field Season

In the 1999 field season two new cattle access sites and one cattle fenced site were added, creating a total of 7 cattle access sites, one sheep access site, and two cattle fenced sites. All of the access sites showed significant bacterial increases in water downstream of the livestock (Table 5, Figs. 8-9). Of the two cattle fenced sites, one showed a significant increase in bacteria (B2, P=0.048) while the other showed no change (W1, P=0.709).

When looking at wet-day data, sites B1 (P=0.000), B4 (P=0.006), and C1 (P=0.001) showed significant increases in bacteria downstream. When looking at dry-day data, sites B1, B3, B4, C1, C5 and C7 also showed significant differences (Table 5).

At the waterfowl site, an additional Input (Sturgeon River) into the lower pond was sampled in 1999. This input was combined with the input from the upper pond and compared with FC levels downstream of the lower pond. There was a significant increase in FC downstream of the lower pond but no change in bacteria concentration between upstream and downstream of the upper pond (Table 5).

Overall the concentration of FC was significantly greater on wet-days than on dry-days (P=0.001) (Fig. 10) as also observed in the 1998 field season. However, no correlation was observed between amount of rainfall and FC concentration (correlation coefficient = 0.232).

1998 and 1999 Field Seasons Combined

Data from the sites that were sampled in both field seasons were processed as one data set for various statistical tests allowing for greater statistical power. Before data were combined, both field seasons were examined to determine whether there were any differences between the two years with regards to weather and FC levels in the streams. Environment Canada weather data indicated that May and June of 1999 were drier than 1998, however sampling did not commence in 1998 until mid-July. July, August and

September of 1999 were wetter than 1998, however the days targeted as wet-sample days in 1998 and 1999 were not significantly different in amount of rainfall when using the rain gauge data at the sites. Overall (all sites and sample days combined) the level of FC in the streams was not significantly different between 1998 and 1999. Although annual differences may help explain differences in FC levels at certain sites it does not have to be taken into account when examining all the data combined.

When data from both years are combined, all five cattle access sites as well as the sheep access site showed a significant increase in FC levels downstream. The cattle fenced site showed no change in FC concentration (Figs. 11-12 and Table 6).

Data were also combined for wet-day versus dry-day analysis. Wet-days were found to have significantly greater concentrations of FC in the water than dry-days (P=0.000).

FC Concentrations at the Sites

Although significant increases were shown to occur at all livestock access sites using the combined data, the magnitude of these differences are not always large. Table 7 shows the differences in FC concentration between upstream and downstream at each of the sites for 1998, 1999 and for the two years combined. The four sites showing the largest actual increases in FC are B1, B3, B4 and C7. These sites all had cattle access to the streams with B1 and B4 having large numbers of cattle (105 and 200 respectively) and B3 and C7 having low numbers of cattle (10 and 15 respectively). Sites showing small increases using both years were the cattle fenced site (B2), the sheep access site (C4) and two cattle access sites (C1 and C5) having low numbers of cattle (15 and 19 respectively). Sites sampled only in 1999 showing large increases were two cattle access sites (C6 and C7) with low numbers of cattle (16 and 15 respectively). The lower pond of the waterfowl site (C3) showed a small increase in FC.

DISCUSSION

Faecal coliform concentrations in streams of this study often exceeded the recommended primary contact levels. It has been shown that when the concentration of FC in water exceeds 200 MPN/100 ml the occurrence of salmonella (a harmful bacteria) is greatly increased (Van Donsel and Geldreich 1971).

Analysis performed on Uhlman's (1998) data and this study showed a strong positive correlation between FC in water and FC in sediment (FC concentrations in sediment being 1-2 orders of magnitude greater than FC concentrations in water). Van Donsel and Geldreich (1971) also indicated a strong positive relationship between FC in water and FC in sediment.

The concentration of FC in water was significantly greater on wet-days than on dry-days for both years which accords with the findings of Cooper and Knight (1989), Niemi and Niemi (1991) and Uhlman (1998). This result suggests that runoff and/or resuspension contributes to increased concentration of FC in the streams and eventually in the estuaries. There was no correlation, however, between rainfall amounts and FC concentration in either year.

Waterfowl 1998 and 1999

Site C3, the waterfowl site, included two ponds separating C3U (upstream of upper pond) from C3M (stream connecting upper and lower ponds) and C3M from C3D (downstream of lower pond). Sampling station C3M had the lowest mean concentration of FC for this site in both field seasons. Few waterfowl were noted at this upper pond in either year. Sampling station C3U had a higher concentration than C3M which may be due to the pond acting as a buffer. FC are more prominent in flowing waters than in ponds (Niemi and Niemi 1991), suggesting that ponds might act as buffers that filter out FC (Uhlman 1998). The FC concentration at sampling station C3D was significantly greater than C3M in both 1998 and 1999 even though a pond also separated these two stations. This lower pond consistently had high numbers of waterfowl (mean 83) as opposed to the upper pond (mean 6) which could account for the increased levels of FC. In the 1998 field season it was not possible to conclude that the geese in the lower pond were solely responsible for the increased downstream concentration of FC as another stream enters the second pond which was not sampled in 1998. In the 1999 field season this stream (C3R) was sampled. Data from C3R was combined with data from C3M to be considered the overall input upstream of the lower pond. A significant increase downstream of the lower pond (C3D) was shown, indicating the waterfowl in the pond to be the FC contributor.

Cattle and Sheep Access 1998 Field Season

Three out of five sites with cattle access showed a significant increase in FC in water downstream. When examining dry-day data, two of these sites showed an increase in FC, suggesting that levels are increased when runoff has not occurred. These two cattle access sites had high numbers of cattle in their pasture. The third site had a low number of cattle but it also had a sewage system without a proper tile drain, allowing the runoff to reach the stream. This site also had a steep, eroded streambank that the cows used and therefore, when the cows defecated on this bank the faeces would be easily washed into the stream during a rainfall event.

The two cattle access sites that showed no change in FC concentration downstream both had < 20 animals on streams in fairly large watersheds (Table 1). These low numbers of livestock did not have a measured effect on bacterial concentrations in 1998, however they did show significant increases in 1999. This difference may be due to the number of samples taken in 1998 versus 1999. About twice as many samples were taken in 1999, thus increasing statistical power.

Two streams, not included in the upstream versus downstream analysis (B5AD and B5BD) because upstream samples were not possible to collect, show high levels of FC in both water and sediment downstream of cattle and sheep access on dry days. Both of these streams begin in the pasture and therefore no clean upstream samples could be taken. The cattle used the small stream (B5AD) for watering as indicated by the many hoof prints and cow paddies observed in and near the stream.

The sheep site showed no significant difference in FC in either the water (P=0.067) or the sediment. Sheep require much less water per day (5-18 L/head) than beef or dairy cattle (22-75 L/head and 38-100 L/head respectively) (Anderson 1982). However sheep faeces contains 70 times the FC bacteria found in cattle faeces (Geldreich 1977).

The one site which contained cattle but in which the cattle had no direct access (were fenced about 5 m from the stream with a forested buffer zone) showed no difference between upstream and downstream samples. The cattle drank from springs and dugouts starting in the pasture that rarely reached the main stream in the 1998 field season. The cattle were absent from this pasture for some of the sampling season; they were moved often and may have been in the pasture for only a few days at a time. However, early samples taken when cows had been in the pasture for weeks still showed no difference in FC concentration between upstream and downstream.

<u>Cattle and Sheep Access 1999 Field Season</u>

All seven cattle access sites and the sheep access site showed significant increases in FC downstream. One of the two cattle fenced sites also showed a significant increase downstream. This site contained springs which the cows drank from (noted in 1998) but never appeared to reach the stream in that year. In 1999 the farmer had these springs dug out and they were observed to flow to the stream on occasion which could account for the increase in bacteria in the second year. One of the cattle access sites was a point access. Some literature suggests point access as a form of remediation. In the present study, the point access site showed a significant increase in FC (measuring immediately downstream of where the cows have access) with only 15 cows using the pasture. At the access point, the streambank was devoid of vegetation and the stream was heavily trampled and widened. Further downstream, the cows were fenced out of the stream with no access. If this site is monitored in a subsequent year, the measurements could be taken further downstream (at the end of the pasture) to determine whether the remaining portion of the pasture influences stream FC levels.

Approximately twice as many samples were taken in the 1999 sampling season because sampling commenced earlier in the year (May as opposed to July in 1998). The increase in the number of samples in 1999 allows for greater statistical power which could account for the two cattle and one sheep access site showing a significant increase in bacteria in the 1999 field season but not in the 1998 field season.

<u>1998 and 1999 Field Seasons Combined</u>

All five cattle access sites and the sheep access site showed significant increases in FC downstream. The cattle fenced site did not show any change downstream. Results from the data collected on dry-days provides a strong argument that cattle and sheep with access to streams contribute to the FC concentration regardless of runoff contributions. This increase in FC levels can be a result of direct deposit or stirring of sediments on these dry-days. The number of samples combined over the two years allows for ample statistical power and therefore sites which were showing close to a significant increase in FC in 1998 with few samples now showed a strong significant increase in bacteria. Although all livestock access sites studied indicated significant increases in bacteria, not all of these increases were large. For example site C5 had a geometric mean of 22 MPN/100 ml upstream and 39 MPN/100 ml downstream (2 years combined data). Even though a significant increase in bacteria was found, this site is not contributing greatly to the FC level. Site B1, however, went from a geometric mean of 35 MPN/100 ml upstream to 8353 MPN/100 ml downstream (2 years combined data). This site is contributing a great amount to the FC level in the stream.

<u>Conclusion</u>

This study indicates that runoff from pasture land, direct cattle and sheep access, and concentrations of wildlife cause increased FC levels in streams. It is not known to what extent individual sites affect water quality in shellfishing areas because most of the sites studied were great distances from these areas. However, water quality in the streams themselves is of concern for primary contact and livestock watering.

The magnitude of the difference in FC levels between upstream and downstream at each site varies. Some sites are not contributing greatly to the overall FC concentration in the stream. Each site is unique and therefore other variables could be measured to allow for better understanding of why some sites are contributing high levels of FC while others are not (for example: stream size and length in pasture, stream flow, stream temperature, stream bottom type, pasture size, slope, behaviour of herd, etc.). Measuring these variables is beyond the scope of this project but other projects may be able to test the effects of these variables on FC concentrations.

Recommendations

1. *Sampling should continue*, especially at the remediated sites. Post-remediation data are important to determine whether the remediation is indeed decreasing the FC inputs into the stream.

2. *Bacterial genotyping should be investigated as a tool to identify specific types of FC bacteria and link them to specific sources.*

3. *Additional livestock access sites should be examined for remediation.* Other forms of alternate watering could be investigated. For example, allowing livestock limited or controlled access without allowing them to actually walk and linger in the stream. Point access (where the livestock are restricted from most of the stream but are permitted to drink at specific points) has been suggested by some people, however this study indicates that it does not reduce FC inputs. Providing a limited or controlled access (where livestock are restricted from walking or standing in the stream but are permitted to drink at certain points) could be examined to determine if it is a suitable alternative to fencing livestock completely from the stream.

4. *A watershed study should be conducted for a complete river and estuary.* Water samples could be collected at various intervals along a river and its tributaries to measure the effects of all potential contributors. The use of bacterial genotyping would also be beneficial to distinguish between the various FC contributors. The dilution factor could be observed to detect whether FC contributors at the head of the river are affecting FC concentrations in the estuary. Once contributors that are increasing the FC concentrations by large amounts are identified they could be remediated.

REMEDIATION

Literature Review

A remediation technique used to decrease the amount of FC that reaches the stream is vegetated filter strips (VFS). Grass filter strips have been shown to trap some FC in runoff (Coyne et al. 1995, Doyle et al. 1977, Schellinger and Clausen 1992, Chaubey et al. 1994). However, in most cases the FC reduction was not significant enough to bring levels below primary contact guidelines. Forested buffer strips have been shown to reduce FC bacteria significantly (Doyle et al. 1977 as cited in Lammers-Helps and Robinson 1991). The forested buffer in the study was 30.5 m in width but the FCs were not reduced significantly past 3.8 m. More research needs to be conducted on the use of VFS in the removal of FC bacteria. All of these studies were different in methodology, using various types of manure (poultry, swine and dairy) with various types of filter strips, and application of manure and rain simulation. All studies show, however, that vegetated filter strips reduce bacteria to some degree. Therefore, the use of VFS in pastures may potentially reduce FC levels enough to make a difference in the estuaries.

The effectiveness of VFS would be greatly increased if cattle are kept off the strips. Fencing cattle out of streams has not only been shown to improve water quality (Larsen et al. 1994), it is also beneficial to herd health (EHJV 1991, Thomas 1994). A study in Alberta showed that cattle drinking from dugouts lost weight while cattle drinking from fresh water in troughs gained (Thomas 1994). Farmers in PEI who have fenced their cattle out of streams state that their cows seem cleaner and healthier with fewer colds, mastitis and foot rot (EHJV 1991). Recommended guidelines, based on a study which states that dairy cow drinking water should not exceed 50 MPN/100 ml for coliform bacteria, suggest that livestock water should be of good quality and tested for pathogens on a regular basis (CCME 1995).

If cattle are fenced out of streams then an alternate watering source must be provided. Alternate watering sources include nose pumps, gravity flow water reservoirs, windmills, solar pumps and pipeline systems (Williamson 1996). Water bowls can also be used if the operation is small in scale and the pasture is in close proximity to a well.

Providing shaded areas away from the stream is another option that should be investigated. If livestock linger near streams for the shade that trees provide, then other places for shade such as the inclusion of more trees within the pasture or artificial roofed structures could be established.

Present Study

The two cattle access sites that showed significant increases in FC downstream in the 1998 field season were examined for remediation possibilities. Both landowners agreed to complete an Environmental Farm Plan (EFP) and an EFP action plan to assess their farm practices and determine what they could do to improve conditions to decrease their farm's input of FC into the streams. After consideration of a variety of remediation possibilities it was determined that the following remediation plans would be most beneficial and practical. Although, the remediation was completed, it has not yet been determined if it is reducing the FC contributions in the streams at these sites.

Site B1

This site consisted of a pasture bisected by a stream. It had been partially fenced in 1998 but cattle were still able to access the stream for drinking water (the only available source of water). Because the stream is small it was not recommended that it be used as the source of water for gravity flow pumps. Instead, a well was drilled which provided water to different stations in the pasture. The water tanks were placed on concrete slabs to prevent the area around the trough from becoming muddy. The stream was fenced completely and a cattle crossing (culvert with path) was constructed so that the cattle could graze on both sides of the stream. Instead of keeping the area as one pasture it has now been fenced into four sections so that rotational grazing can be utilized.

Site B4
This site had many factors to consider when remediating. First, there were two barns - one beef and one dairy. The beef barn was approximately 100 m from the stream and the cattle had access to the stream. The dairy barn was located behind this barn and these cows also had access to the stream. The dairy cow pasture was located on both sides of the stream and thus the cows had to cross the stream in order to reach all available areas. There was already a well, however the water pump had to be upgraded. The landowner decided to improve his pasture management by strip grazing. This practice would complement his strip cropping fields as they would also be grazed. Water lines were placed in the ground to 12 different areas of the pasture. The farmer purchased two stock tanks which he can move to the different locations in the pasture. A stream crossing was also discussed since his pasture crossed the stream in two locations, however, this was decided against and the pasture on the other side of the stream will not be used for grazing.

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Table 1. Description of sites used in the study (1998 and 1999).

Site	Watershed	River	Site Type	Maximum number of animals	Access	Watershed size of upstream sample location (km^2)	Watershed size of downstream sample location (km^2)
B1	Bedeque Bay	Dunk	Cattle	105	All animals	0.19	0.51
B2	Bedeque Bay	Dunk	Cattle	110	No	16.63	16.67
B3	Bedeque Bay	Dunk	Cattle /Horses	10 / 2	All animals	6.45	6.77
B4	Bedeque Bay	Dunk	Cows	200	35 animals	1.41	1.90
B5A	Bedeque Bay	Dunk	Cattle/ Sheep	53/47	All animals	n/a	0.10
B5B	Bedeque Bay	Dunk	Cattle/ Sheep	53/47	All animals	n/a	0.28
C1	Murray Hbr	Fox	Cattle/ Human	15	All animals	6.93	6.97
C2	Murray Hbr	Greek	Partially forested	n/a	n/a	3.00	n/a
C2B	Murray Hbr	Greek	Completely forested	n/a	n/a	0.90	n/a
C3 (upper pond)	Cardigan Bay	Sturgeon	Geese/ Ducks	70	Yes	6.50	7.10
C3 (lower pond)	Cardigan Bay	Sturgeon	Geese/ Ducks	300	Yes	16.27	17.30
C4	Cardigan Bay	Montague	Sheep	144	All animals (not at same time)	7.94	8.29
C5	Cardigan Bay	Brudenell	Cattle	19	All animals	23.19	25.52
C6	Cardigan Bay	Montague	Cattle	16	All animals	5.40	5.47
C7	St. Peter's Bay	Morell	Cattle	15	All animals	10.83	10.93
W1	Wood Islands	MacPherson's Creek	Cattle	50	No	4.53	4.63

Table 2. Geometric means of FC concentrations (MPN/100 mL) in water for each sampling location (1998, 1999 and 1998-99 combined data).

	1998		1999		1998-1999			
Site	N	Geo. mean	N	Geo. mean	N	Geo. mean	Minimum	Maximum
B1U	17	29	23	39	40	35	<2	540
B1D	10	2170	23	15010	33	8353	200	>1600000
B2U	13	664	21	452	34	524	33	16000
B2D	13	414	21	626	34	534	33	>16000
B3U	13	1712	23	1138	36	1319	2	160000
B3D	13	2748	23	1980	36	2229	<20	160000
B4U	13	1447	23	628	36	849	<20	>16000
B4D	13	4988	23	7292	36	6358	130	160000
B5AD	12	1959	22	2019	34	1997	11	24000
B5BD	6	2967	13	4666	19	4045	140	54000
C1U	13	74	25	24	38	35	<2	>1600
C1D	13	388	25	132	38	191	13	>16000
C1S	n/a	n/a	14	23	n/a	n/a	<2	>1600
C2	13	36	24	42	37	40	2	>1600
C2B	n/a	n/a	25	11	n/a	n/a	<2	920
C3U	13	458	19	168	32	218	2	>16000
C3M	13	22	24	87	37	53	<2	1600
C3D	13	246	23	202	36	217	7	5400
C3R	n/a	n/a	23	54	n/a	n/a	2	920
C4U	13	136	24	141	37	142	4	1700
C4D	13	261	25	236	38	233	7.8	16000
C5U	13	28	24	19	37	22	<2	540
C5D	13	27	24	47	37	39	<2	>1600
C6U	n/a	n/a	21	360	n/a	n/a	20	>16000
C6D	n/a	n/a	21	850	n/a	n/a	45	45000
C7U	n/a	n/a	20	206	n/a	n/a	18	1600
C7D	n/a	n/a	20	1033	n/a	n/a	22	78000
W1U	n/a	n/a	20	95	n/a	n/a	4.5	1600
W1D	n/a	n/a	20	100	n/a	n/a	4	1600

Table 3. Geometric means of FC concentrations (MPN/100 g) in sediment for each sampling location (1998 data).

Site	N	Geometric mean	Minimum	Maximum
B1U	16	1475	36	160000
B1D	9	282009	20000	>1600000
B2U	13	9092	1100	17000
B2D	13	5292	1700	35000
B3U	13	34805	1400	170000
B3D	13	47615	<2000	350000
B4U	13	20951	1300	>160000
B4D	12	305873	13000	9200000
B5AD	12	56468	13000	1600000
B5BD	6	137285	22000	1600000
C1U	0	n/a	n/a	n/a
C1D	13	39619	13000	240000
C2	13	4582	330	95000
C3U	13	1689	110	17000
C3M	13	901	<200	5400
C3D	13	2991	<200	13000
C4U	13	4873	110	24000
C4D	13	8319	1300	35000
C5U	13	1105	200	5400
C5D	13	918	130	16000

Table 4. T-test probabilities comparing FC concentrations downstream vs. upstream at each site using weighted, log-transformed data (1998 field season).

			Water						Sediment					
Site	Animals	Access	All	n	Wet	n	Dry	n	All	n	Wet	n	Dry	n
B1	70 cattle	Y	***0.000**	13	***0.021**	6	***0.000**	7	***0.000**	9	0.187	2	***0.000**	7
B2	68 cattle	N	0.113	13	0.814	6	0.069	7	0.067	13	0.684	6	0.054	7
B3	8 cattle, 2 horses	Y	0.101	13	0.150	6	0.455	7	0.240	13	0.759	6	0.231	7
B4	53 cattle	Y	***0.004**	13	0.079	6	***0.013**	7	***0.000**	12	*** 0.021**	5	***0.008**	7
C1	11 cattle	Y	***0.000**	10	***0.001**	2	0.061	7	n/a	n/a	n/a	6	n/a	n/a
C3** upper pond	70 waterfowl	Y	***0.001**	13	***0.015**	6	***0.043**	7	0.267	13	0.147	6	0.856	7
C3** lower pond	300 waterfowl	Y	***0.000**	13	***0.005**	6	***0.007**	7	***0.002**	13	***0.019**	6	0.053	7
C4	144 sheep	Y	0.067	13	0.287	6	0.160	7	0.121	13	0.875	6	0.065	7
C5	19 cattle	Y	0.871	13	0.670	6	0.939	7	0.859	13	0.509	6	0.214	7

*Bolded numbers indicate significant differences (p<=0.05)

**C3 had an additional input into the second pond. Results for 1998 data should therefore be interpreted with caution.

Table 5. T-test probabilities comparing FC concentrations downstream vs. upstream at each site using weighted, transformed data (1999 field season).

Site	Livestock	Access	All	n	Wet	n	Dry	n
B1	105 cows	Y	***0.000**	23	***0.000**	7	***0.000**	15
B2	50 cows	N**	***0.048**	21	0.189	7	0.157	14
B3	10 cows, 2 horses	Y	***0.007**	23	0.434	7	***0.010**	16
B4	40 cows	Y	***0.000**	23	***0.006**	7	***0.000**	15
C1	15 cows	Y	***0.000**	25	***0.001**	8	***0.000**	17
C3 upper pond	30 waterfowl	Y	0.330	20	0.577	7	0.435	13
C3 lower pond	120 waterfowl	Y	***0.021**	23	0.079	9	0.180	14
C4	100 sheep	Y	***0.047**	24	0.098	9	0.177	15
C5	16 cows	Y	***0.001**	24	0.206	7	***0.002**	17
C6	16 cows***	Y	***0.023**	21	0.072	8	0.197	13
C7	15 cows	Y	***0.003**	20	0.087	8	***0.02**	12
W1	50 cows	N	0.709	20	0.724	7	0.421	13

*Bolded numbers indicate significance (p<=0.05)

**Cows drank from a dugout spring that sometimes flowed into the stream

***51 calves were observed on one day

Table 6. T-test probabilities comparing FC concentrations upstream vs. downstream using weighted, transformed data (combined 1998-99 field seasons).

Site	All	n	Wet	n	Dry	n
B1	***0.000**	33	***0.000**	9	***0.000**	24
B2	0.888	34	0.382	13	0.500	21
B3	***0.001**	36	0.089	13	***0.009**	23
B4	***0.000**	36	***0.000**	14	***0.000**	22
C1	***0.000**	38	***0.000**	14	***0.000**	24
C4	***0.006**	37	0.060	15	***0.049**	22
C5	***0.005**	37	0.210	13	***0.013**	24

*Bolded numbers indicate significance (p<=0.05)

Table 7. Differences in FC concentration between upstream and downstream at each site.

Site	1998 increase (MPN/100 ml)	1999 increase (MPN/100 ml)	1998-1999 combined increase (MPN/100 ml)
B1	2141	14971	8318
B2	-250	174	10
B3	1036	842	910
B4	3541	6664	5509
C1	314	108	156
C3 (upper pond)	-436	-81	-165
C3 (lower pond)	n/a	134	n/a
C4	125	95	91
C5	-1	28	17
C6	n/a	490	n/a
C7	n/a	827	n/a
W1	n/a	5	n/a

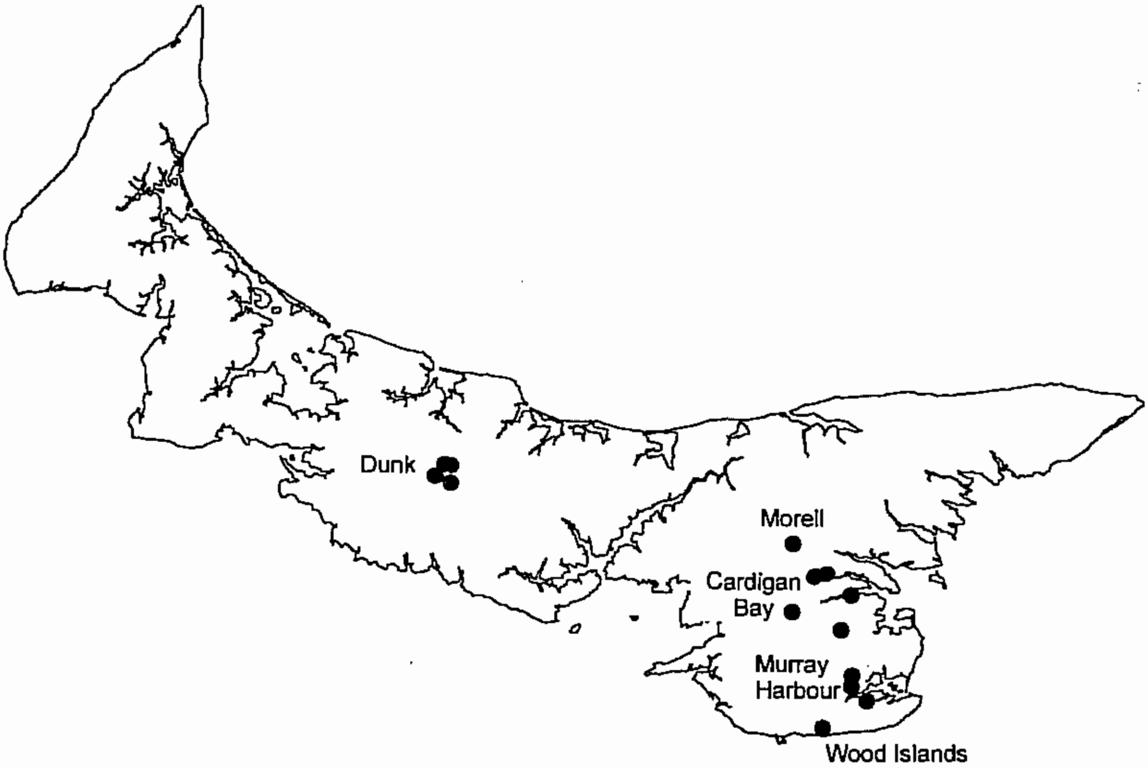

Fig. 1.
Prince Edward Island, showing study sites

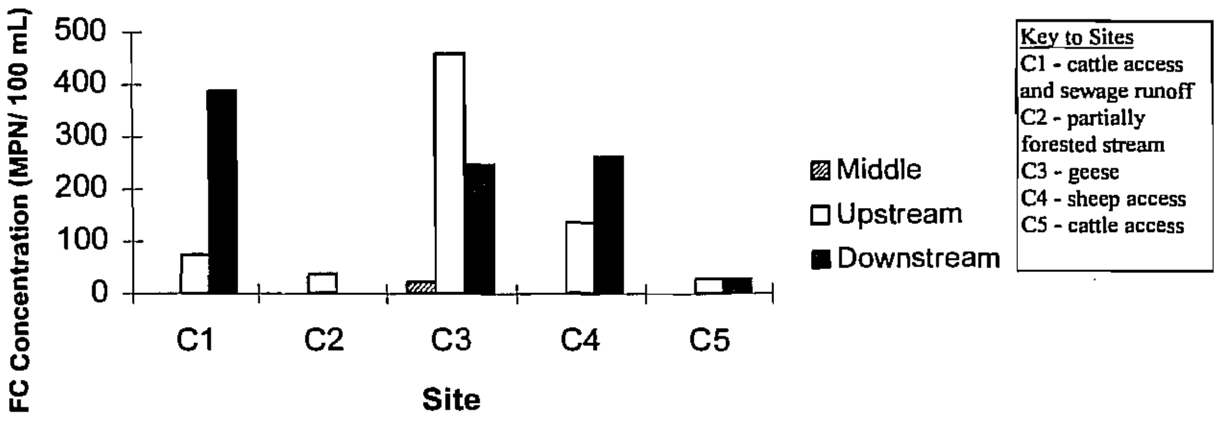

Fig. 2.
Geometric mean concentration of faecal coliform (FC) in water upstream and downstream at each site in the Cardigan Bay watershed, 1998.

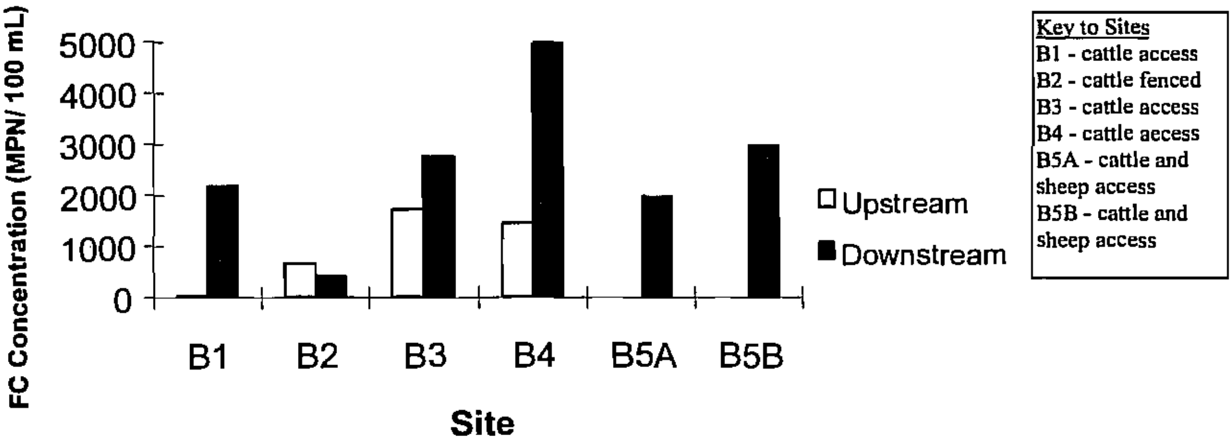

Fig. 3.
Geometric mean concentration of faecal coliform (FC) in water upstream and downstream at each site in the Bedeque Bay watershed, 1998.

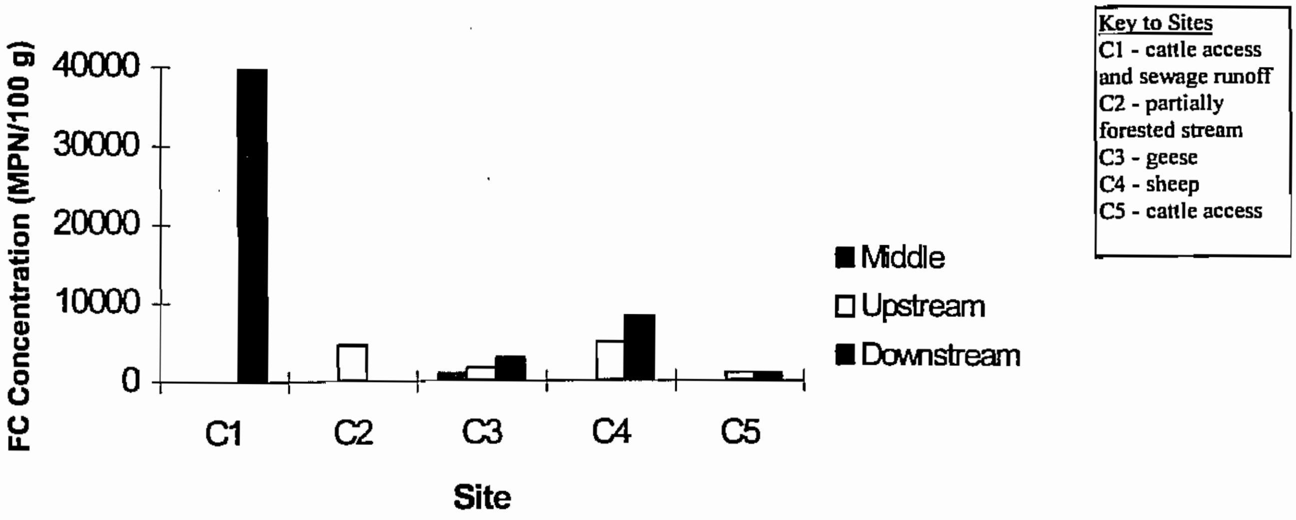

Fig. 4.
Geometric mean concentration of FC in sediment upstream and downstream at each site in the Cardigan Bay watershed, 1998.

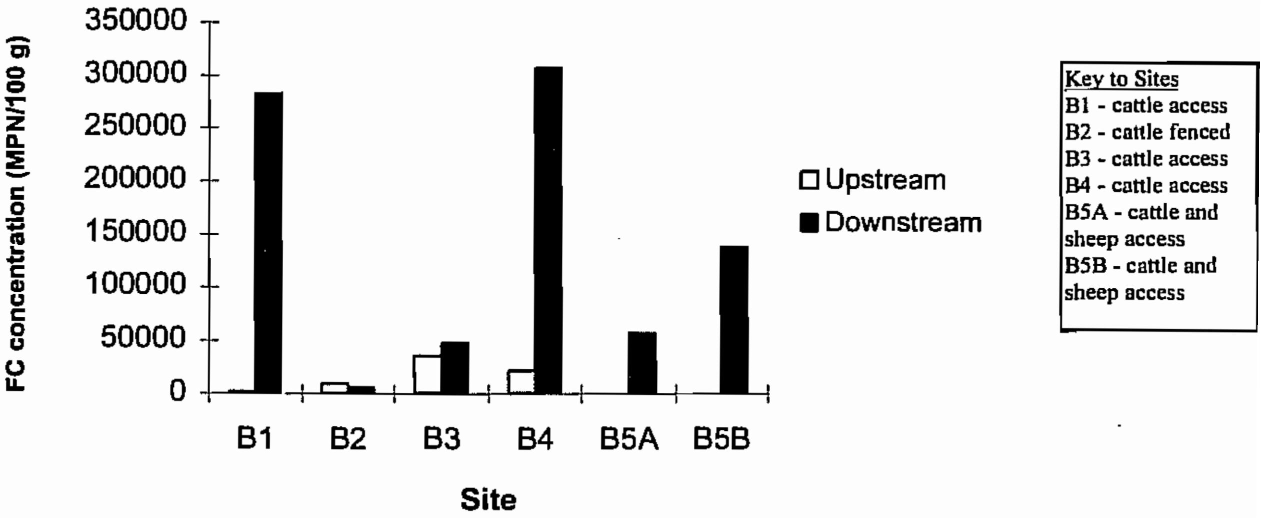

Fig. 5.
Geometric mean concentration of FC in sediment upstream and downstream at each site in the Bedeque Bay watershed, 1998.

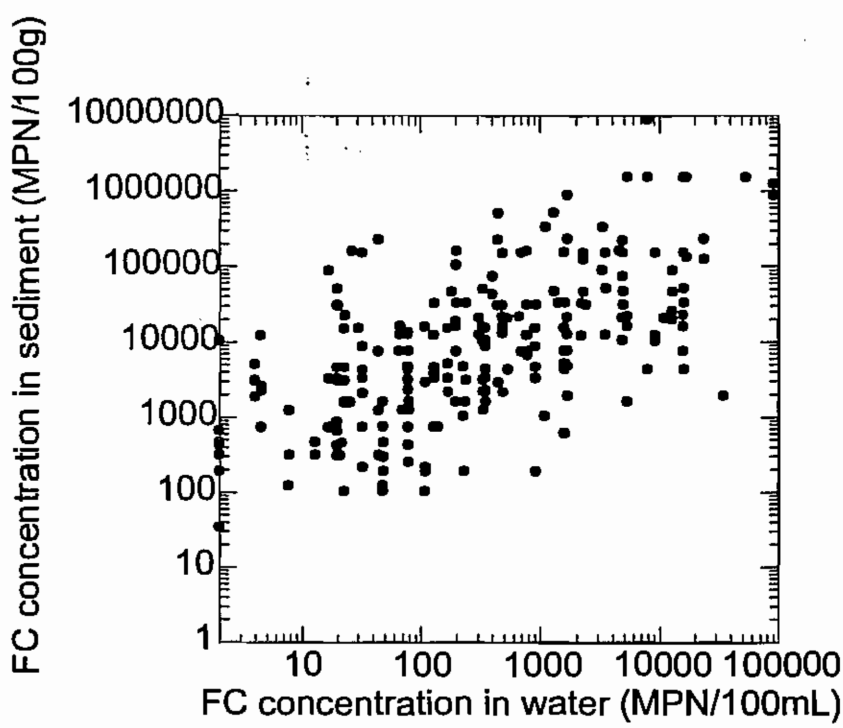

Fig. 6.
Relation between concentration of FC in water with concentration of FC in sediment. Pearson correlation coefficient = 0.620. Concentration in sediment is 1-2 orders of magnitude greater than concentration in water.

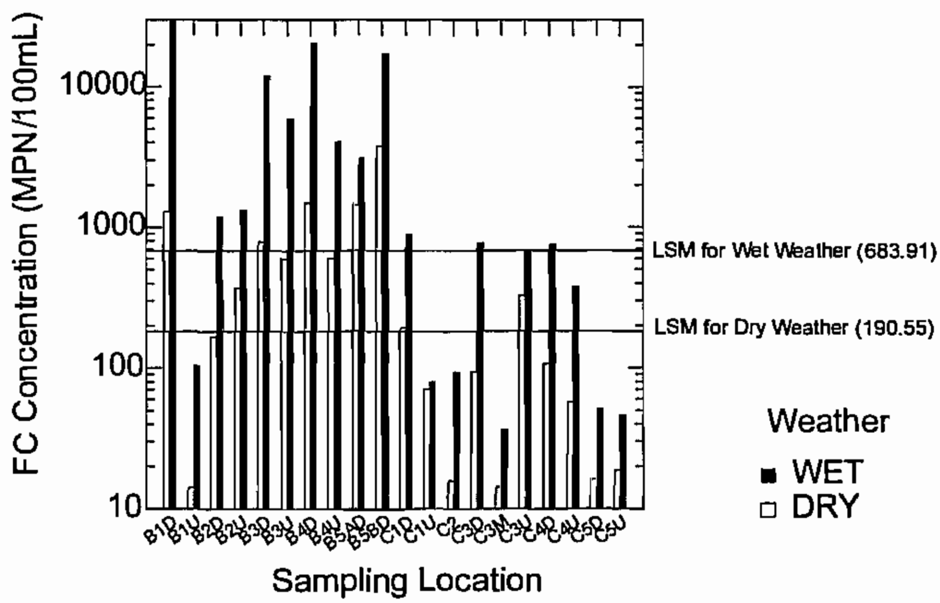

Fig. 7.
Geometric mean concentrations of faecal coliform (FC) in water for wet-days versus dry-days at each sampling location. Least square means (LSM) are indicated.

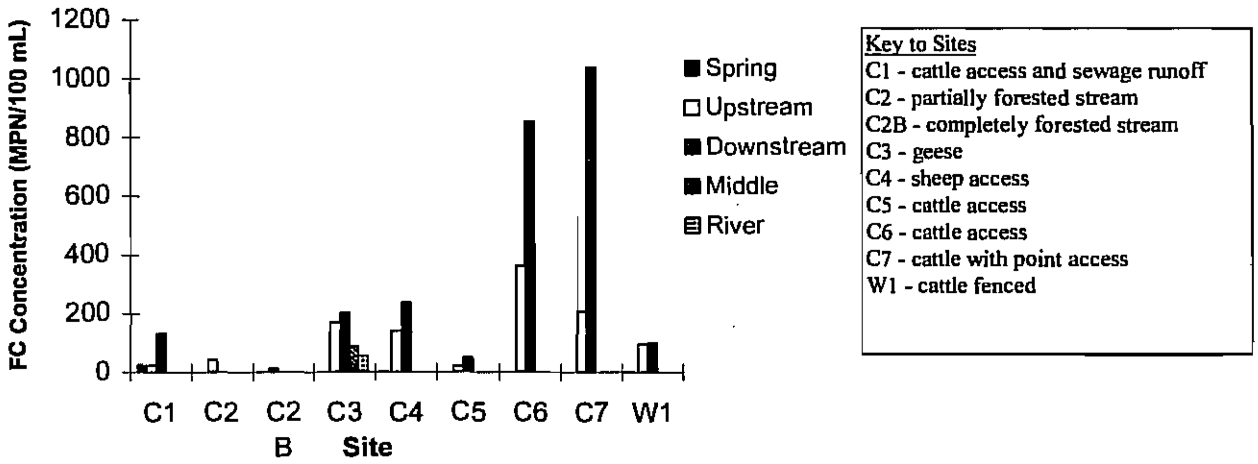

Fig. 8.
Geometric mean concentrations of faecal coliform (FC) in water at various positions within each site in the Cardigan Bay, Wood Islands and St. Peter's Bay watersheds, 1999.

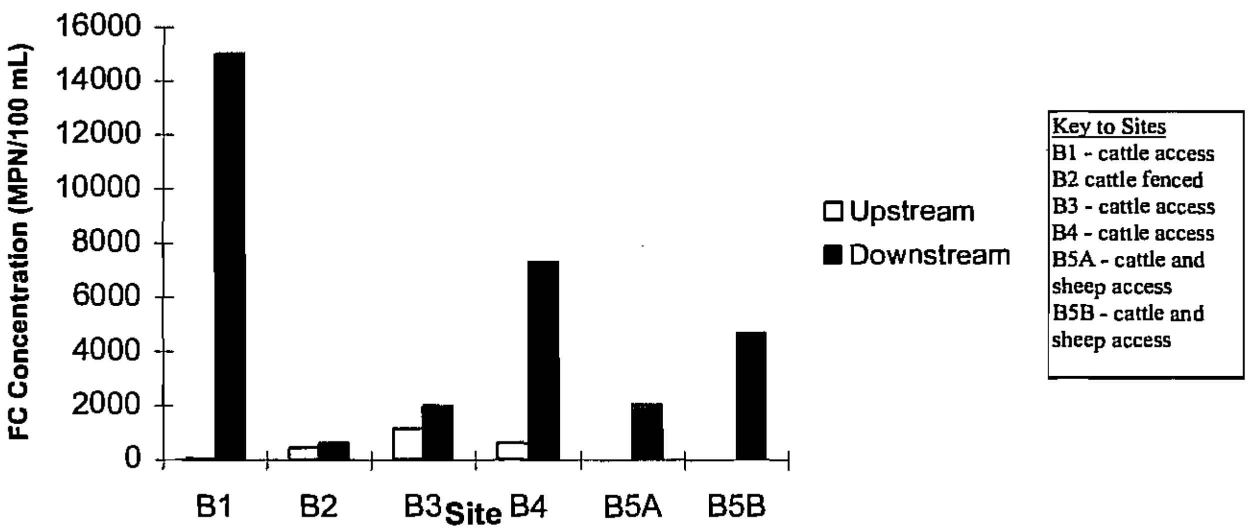

Fig. 9.
Geometric mean concentration of faecal coliform (FC) in water upstream and downstream at each site in the Bedeque Bay watershed, 1999.

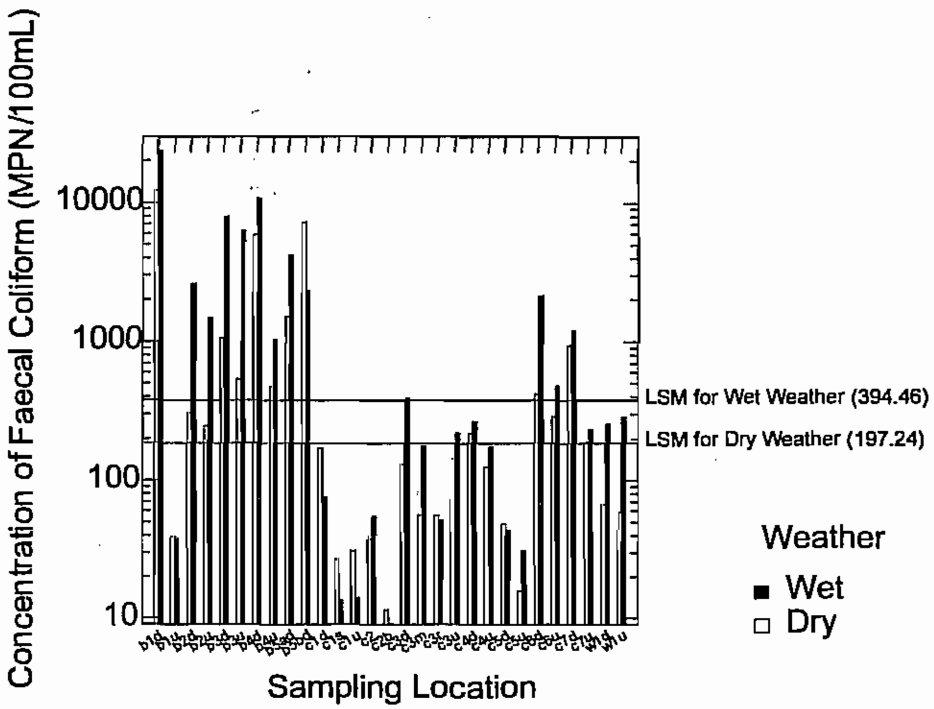

Fig. 10.
Geometric mean concentrations of faecal colifrom in water for wet-days versus dry-days at each sampling location in 1999. Least square means (LSM) are indicated.

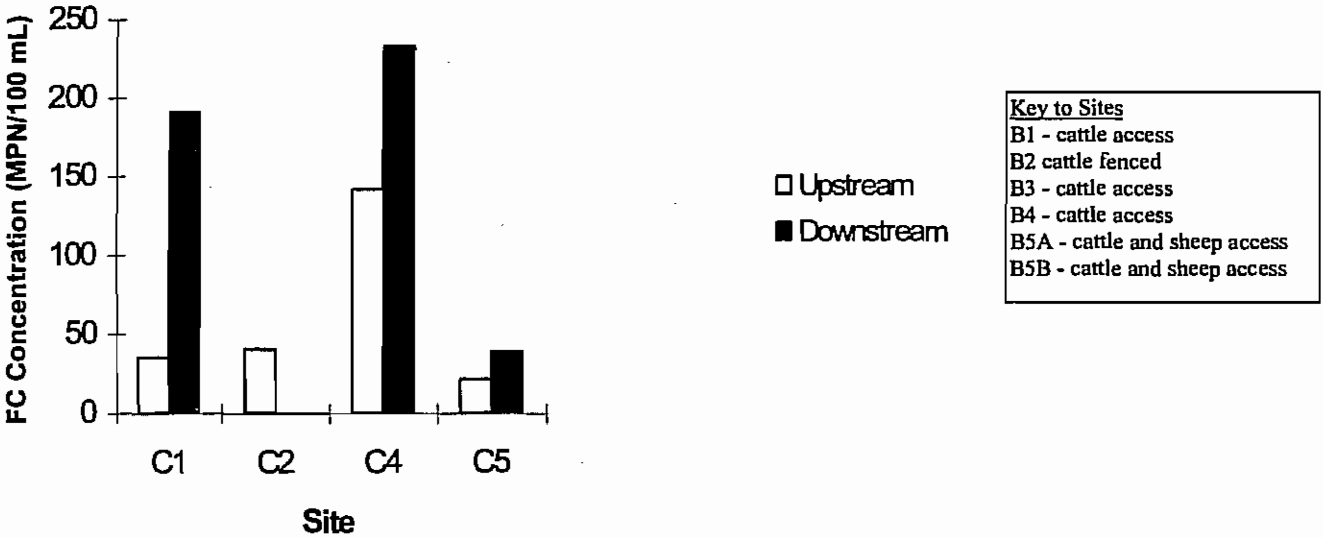

Fig. 11.
Geometric mean concentration of faecal coliform (FC) at each site in the Cardigan Bay watershed, 1998 and 1999 field seasons combined.

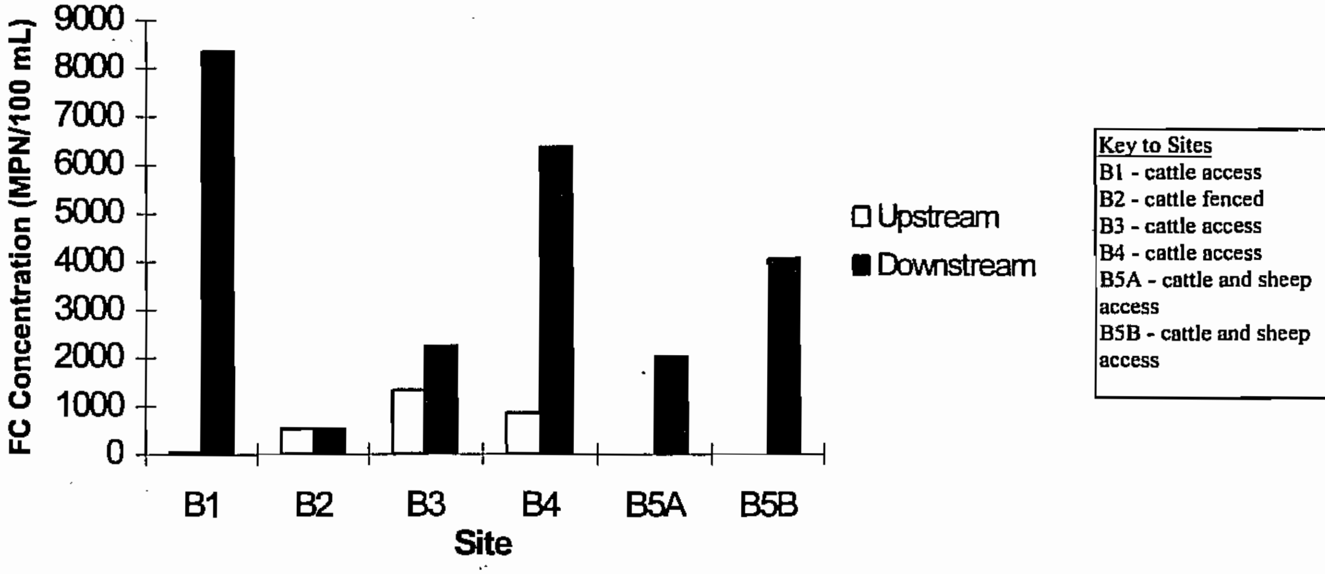

Fig. 12.
Geometric mean concentration of faecal coliform (FC) at each site in the Bedeque Bay watershed, 1998 and 1999 field seasons combined.

Nutrient and chlorophyll trends in Prince Edward Island estuaries

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ABSTRACT

Eutrophication is a common phenomenon in the estuaries and coastal bays of Prince Edward Island. In recent years sea lettuce (*Ulva lactuca*) blooms have become more frequent, and dense mats of this plant may raft on the shoreline, causing odor problems, or decompose in the water, causing anoxic conditions. The re-construction of several causeways on PEI to allow greater water passage has remediated anoxic conditions at those sites. Most of the remaining sites with anoxic conditions are found on the north shore, where tidal amplitude is weaker than on the south shore. Concentrations of total nitrogen, nitrates, and phosphorus have increased in PEI estuaries since the 1970s. The rank-order of concentration of these nutrients corresponds with the proportion of the watershed which is used for agriculture. Nutrient and chlorophyll concentrations were highly variable among sites and these concentrations did not differ significantly between sites with and without anoxic events.

INTRODUCTION

Eutrophication of coastal waters is recognized as a growing problem in many areas of the world (Nixon 1990). On Prince Edward Island, eutrophic conditions commonly exist in many of the broad estuaries and shallow bays which incise the province's coastline. Public interest in estuarine water quality has been prompted by cases of excessive growth of macrophytic algae which often accumulate on shorelines, creating odor problems as they rot.

Meeuwig (1998, 1999) and Meeuwig et al. (1998) showed that phytoplancton densities in PEI estuaries, as measured by chlorophyll a concentrations, are positively related to the proportion of the watershed which is cultivated for agriculture. Meeuwig (1998) found that both long-term and recent land use changes have resulted in significant water quality deterioration in the Mill River. Somers et. al. (1999) determined that phosphorus concentrations in the Mill, West and Montague River estuaries have increased over the last thirty years. Nitrogen loading to the Mill, Dunk and Morell River estuaries, based on measurements made in fresh water, have more than doubled over the last twenty to thirty years (Meeuwig 1998, Somers et al. 1999).

This paper reviews the history and symptoms of water quality problems in PEI estuaries in the context of available qualitative and quantitative data.

METHODS

Estuarine water quality in PEI has been monitored through a variety of programs operated by the Prince Edward Island Department of Fisheries, Aquaculture and Environment and its predecessors (Department of Technology and Environment, Department of Environmental Resources, Department of the Environment, Department of Community and Cultural Affairs, Department of Community Affairs, Environmental Control Commission, Department of Environment and Tourism), and Environment Canada (see Somers et al. 1999 for details). Systematic data collection began with the establishment of the International Hydrologic Decade (IHD) in the mid 1960s. As Canada's contribution to the IHD, the National Water Quality network (1965-1974) saw four stations established on PEI. By the early to mid-1970s the original IHD network evolved into the National Water Quality Monitoring Program, which added new stations on an issue-driven basis. At the height of activity, 22 sites were in operation, representing the major river basins on PEI. In 1978 the network was reduced to three sites on PEI, and continued operation under the Atlantic Region Overview/LRTAP Network (1978-1991). Two of these stations, Carruthers Brook on the Mill River system and the Dunk River, had been continuously monitored since the IHD program was initiated in 1965, and the third station on the Morell had been established in 1974.

In 1991, the Canada/PEI Water Quality Monitoring Agreement expanded sampling sites in an integrated approach to the collection and assessment of surface

Pp. 142-153 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

water and groundwater data. In 1995, this agreement and others were replaced by the Canada PEI Water Annex; however the programs differed only in their administrative framework. Estuaries were monitored under the IHD program, but subsequent monitoring was completed by the province alone until 1991. With the establishment of the Canada/PEI Water Quality Monitoring Agreement, three estuaries (Mill, West and Montague Rivers) were monitored at upper, mid and lower locations approximately 6-8 times per year.

In 1998, the PEI Estuary Survey was initiated by the province with the objective of providing long-term information on the nutrient and chlorophyll status of twenty-one bays and estuaries at the typical time for anoxic events, i.e. summer. These estuaries are sampled at upper, mid and lower locations during the first two weeks of August of each year.

Ideally, to examine long-term nutrient and chlorophyll trends in PEI estuaries, one would simply look to the results of historic sampling programs. However, there are methodological problems for some parameters. In the 1970s, total kjeldahl nitrogen was measured, but the current methodology is total nitrogen measurement. As the relationship between results obtained by the two methods is unknown, the two time frames of nitrogen data cannot be directly compared. However, there are freshwater data that use the same total nitrogen method over a long-term period.

For nitrate, many of the available estuarine reports for the period before 1992 show values below the detection limit, thus providing no information on trends. However, once again, there are freshwater data that can be utilized to provide insight into the loading of nutrients to estuaries. For the PEI Estuary Survey, only data from 2000-2001 are useable due to a change in analyis methods.

For total phosphorus in estuaries, the same methodology was used over a long time frame and thus results give a valid reflection of long-term trends. Freshwater phosphorus data are based on reliable laboratory methods, but the sampling regime probably prevents the use of the freshwater data to determine loading to the estuaries. This is due to the tendency of phosphorus to be closely associated with sediment in water. Sampling in the historical and most of the recent monitoring programs has been conducted on a regular basis. This sampling regime does not attempt to capture the effects of high sediment runoff during significant precipitation or thaw events. As a result, the freshwater phosphorus data may severely underestimate the actual phosphorus loading to the estuary.

Chlorophyll concentrations prior to 1987 are unreliable, and despite careful reexamination, appear not to be correctable due to insufficient calibration information. Therefore, only data from 1988 and subsequently can be utilized.

Nitrogen:phosphorus ratios were calculated by the Redfield method, which standardizes N and P concentrations by atomic mass:

$$N{:}P \text{ ratio} = (TN/14) / (TP/1000/30.97),$$

where TN is total nitrogen in mg/l and TP is total phosphorus in µg/l.

Differences in nutrient and chlorophyll concentrations were tested with mixed model Anovas, using anoxia status as a fixed variable and estuary as a random variable. Variables were log-transformed to reduce non-normality.

RESULTS

History and symptoms of estuarine eutrophication on PEI

The most striking symptoms of severe eutrophication in PEI estuaries are intense blooms of sea lettuce (*Ulva lactuca*) and anoxic events. Neither phenomenon has been systematically monitored in PEI estuaries. However, anecdotal reports and observations made in the course of other duties permit a qualitative account of patterns.

Fig. 1 indicates locations of reported anoxic events. Excessive concentrations of sea lettuce and anoxic events were infrequent 20-30 years ago. In the past several years, such events have been common and anoxic conditions have occurred in areas where such conditions had not previously been reported.

Excessive sea lettuce populations typically occur at freshwater entry points to the estuary. These populations generally occur in shallow and sheltered waters. Plant material commonly fills the water column over broad areas at such sites. Water column concentrations of chlorophyll can be very high prior to an anoxic event, and dissolved oxygen is likely to exhibit supersaturation during the strong growth phase of the sea lettuce and phytoplankton. As the sea lettuce dies off, oxygen levels diminish. Anoxic conditions result when oxygen levels fall to zero. Even when the sea lettuce is growing, the algal mats can be so thick that the water under the top layers may become devoid of oxygen. Anoxic events usually occur during July and August but on occasion, can occur during September.

During anoxic conditions, the water typically turns whitish, sometimes with greyish or lime green tints. These colours are apparently due to algal or bacterial growth (P. Lane and Associates 1991). At this time, water clarity is very low and visibility is reduced to centimetres. The strongest smells associated with anoxic events normally occur when the estuary is white. Odor levels may become so severe that people living close to the site may be prompted to leave. During these events, any benthic shellfish in the area die. Fish that are caught with no escape routes also die. After the anoxic - whitish phase of the event, water colour turns very dark green during the initial recovery.

Dead sea lettuce often accumulates in large windrows on windward shores. In sufficient amounts, the beached sea lettuce also produces obnoxious smells.

Excessive algal growth is a rate process where the primary productivity of an area is determined by the rate at which nutrients are introduced to the system and the rate by which they are removed. Traditionally, this is viewed in the estuarine environment in terms of freshwater or other land inputs and their residence time in the estuary. On PEI, there are problems with both nutrient supply and nutrient removal. Enrichment from agricultural and other sources is common. In some systems, bridges and natural features such as barrier beaches restrict nutrient removal via natural tidal flushing.

Causeway construction was common on PEI in the 1950s as a way of reducing costs of river crossings. In some cases, the causeways were constructed with openings of sufficient size to allow unhampered tidal flow. In general, this was more by luck than by planning as the risks to water quality were not realized at the time. In some structures such as the North River causeway, the intent was to create a fresh water lake.

Since the 1980s, several causeways that cross estuaries where anoxic events were reported have been rebuilt to allow for adequate tidal flushing. These include structures at the West River, North River, Cardigan River, and, most recently, the Vernon River. Marked improvements in the West and North Rivers have been both seen and measured. While not measured, improvements in the Cardigan River were readily observed. The Kildare River is an example of an estuary with trophic status problems that, while it has a causeway bridge structure, the problem was identified to be a long naturally restricting sand channel mouth to the estuary. Although a new larger structure has been installed and local residents believe there are notable improvements, these have not been demonstrated by monitoring.

Causeways with inadequate water passage account for only a small proportion of anoxic conditions in PEI estuaries. Most estuaries with anoxic conditions do not have bridges or causeways that restrict water flow. The majority of anoxic sites are on the north shore of PEI. Water residence time on the north shore tends to be longer than on the south shore because tidal amplitude is smaller on the north shore (Table 1). There are also more barrier beaches across mouths of north shore estuaries, but only in the case of the Kildare River is this known to be restricting the tide sufficiently to promote anoxic events.

The recent re-construction of the Vernon River causeway is the last water quality remediation that can be made from improvements in water passage. The other cause of eutrophication is nutrient input, and little progress has been made in this area. Non-point source pollution is generally difficult to control, regardless of the pollutant. The Barbara Weit River is the only estuary where point sources of nutrients were a significant part of the problem and is the only estuary where nutrient remediation has resulted in demonstrable improvements to estuarine conditions. However, even at this location, the estuary has only been improved from hypertrophic to eutrophic.

<u>Nutrient and chlorophyll concentrations</u>

Long-term freshwater concentrations of nitrate and total nitrogen were highest in the Dunk River, lower in Carruthers Brook (a main tributary to the Mill River Estuary), and lowest in the Morell River (Figs. 2 and 3). This rank order parallels the rank order of the percentage of the watershed cleared for agriculture (Dunk highest, followed by Carruthers and Morell). Over the time-series, concentrations at each site have retained their relative position but have all increased. Nitrate concentrations recorded on the Dunk River leveled off during the late 1980s, but concentrations of total nitrogen continued to climb. Seasonally, nitrate and total nitrogen tend to peak in winter, and generally decline in the course of the year (Figs. 4 and 5). Carruthers Brook, however, showed concentration troughs in early summer.

Mean total nitrogen concentrations in 21 estuaries in summer 2000-2001 were between 0.1 and 0.7 mg/l (Fig. 6). Mean total nitrogen concentrations in estuaries with no anoxia (mean=0.246 mg/l, SD=0.203, N=177) did not differ significantly from those with periodic anoxia (mean=0.452, SD=0.307, N=78) (F=0.945, P=0.346; Table 2). All estuaries with recent anoxic events are on the north shore, where tidal range is small.

Long-term total phosphorus concentrations are available from three estuaries in the current Annex monitoring program (Fig. 7). Overall, they indicate a general increase from approximately 0.025 mg/l in the mid 1970s to current conditions of approximately 0.050 mg/l. Seasonally, total phosphorus tends to peak in late summer and early fall (Fig. 8).

Mean total phosphorus in estuaries during summer 1998-2001 ranged from 0.04 to 0.11 mg/l (Fig. 9). Mean phosphorus concentrations in estuaries with no anoxia (mean=0.060 mg/l, SD=0.041, N=344) were similar to those with periodic anoxia (mean=0.067, SD=0.043, N=155) (F=0.335, P=0.568; Table 2).

Nutrient ratios have been utilized to examine the role of nutrients in limiting primary productivity. For the twenty-one estuaries examined in summers 2000-2001, the ratio of total nitrogen to total phosphorus (Redfield method) ranged from ~5 to ~38 (Fig. 10). Mean nitrogen: phosphorus ratios in estuaries with no anoxia (mean=10.848, SD=9.127, N=177) did not differ significantly from those with periodic anoxia (mean=21.243, SD=31.051, N=78 (F=0.108, P=0.747; Table 2).

Reliable chlorophyll data, available only since 1992, show no consistent trends (Fig. 11). The low values in 1992 are likely an artifact of sampling date; samples were taken in the winter when chlorophyll is ordinarily low (Fig. 12). Measured concentrations peaked in summer in the Mill and West Rivers, but in fall in the Montague River. Fall algal blooms have previously been recorded in the Boughton and Cardigan Rivers (P. Lane and Associates, 1991). It must be noted that data are unavailable during the time that the spring bloom would be expected.

Chlorophyll concentrations varied widely among sites (Fig. 13). Mean chlorophyll concentration in sites without reported anoxia was 9.277 µg/l (SD=8.651, N=346) and 15.754 µg/l (SD=12.036, N=155) for estuaries with periodic anoxia (F=2.019, P=0.177). The four sites with the highest mean chlorophyll concentrations were on the north shore.

DISCUSSION

With estuarine total phosphorus and freshwater nitrogen concentrations increasing over the last 20-30 years in those systems that have long-term data sets, it is not surprising that a number of PEI estuaries exhibit eutrophic symptoms and in some cases completely anoxic conditions. Since it is not known when the present increases will end, it is possible that more estuaries may experience problems and those already showing symptoms may do so more frequently.

Meeuwig et al. (1998) examined herbivory by cultured mussels, turbidity, and water residence time as factors which reduced chlorophyll levels predicted from regression equations based on land use and estuary morphology. Mussel herbivory and turbidity were found to play an important role in reducing chlorophyll levels. Although water residence time varied widely (3 to 356 days) within the 15 estuaries in their data set, Meeuwig et al. (1998) found that residence time had little influence on estuarine trophic status. In contrast, the present study has reported that eutrophic problems were greatly reduced in several PEI estuaries after bridge reconstruction opened water passage and reduced water residence time.

Values of 0.3 to 0.63 mg/l of total nitrogen are considered to cause eutrophic conditions in estuaries (MacNeil and Frank 1991). Nine of the 21 sites sampled during the summers of 2000 and 2001 showed mean total nitrogen concentrations greater than 0.3 mg/l, and one of these sites had a mean concentration that exceeded 0.63 mg/l.

Values of total estuarine phosphorus exceeding 0.035 mg/l are considered to indicate eutrophic conditions (Meeuwig 1998). All PEI estuaries sampled in 1998-2001 had mean concentrations above this level. However, most of these estuaries do not suffer from anoxic events and are not considered to be eutrophic. This lack of concordance suggests that phosphorus levels do not control eutrophication and anoxia in PEI estuaries.

Chlorophyll concentrations exceeding 20 µg/l are considered to indicate eutrophic conditions (Brylinsky 1998). In the 1998-2001 data set, no sites had mean concentrations above this level. Fourteen of the sites, including all six sites with reported anoxia, exhibited concentrations on particular days that exceeded 20 µg/l.

Both phytoplancton and macrophytes contribute to primary productivity in estuaries. Phytoplancton productivity is reflected in concentrations of chlorophyll in the water column. Productivity stemming from sea lettuce and other macrophytes in PEI estuaries appears to be substantial, but this productivity is not currently measured. Hence water column chlorophyll concentrations provide only a partial picture of primary productivity in PEI estuaries.

It is not clear why some south shore estuaries have been better able to withstand high total nitrogen concentrations than north shore estuaries. If this is simply due to a shorter residence time, then total nitrogen concentration should be lower. Further examination of freshwater loading, turbidity, bivalve herbivory, and residence time may offer additional insight into the factors which control eutrophic status in PEI estuaries.

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Table 1
Tidal ranges of the north and south shores of Prince Edward Island.
Data are from Fisheries and Oceans Canada 1999.

Shore	Reference port	Tide range (m)	
		Mean tide	Large tide
North	Rustico	0.7	1.1
South	Charlottetown	1.8	2.9

Table 2
Measurements of nitrogen, phosphorus, nitrogen:phosphorus ratios, and chlorophyll in bays and estuaries where anoxic events have and have not been reported.

	Sites with no anoxia			Sites with periodic anoxia			F[a]	P[a]
	Mean	SD	N	Mean	SD	N		
Total nitrogen (mg/l)	0.246	0.203	177	0.452	0.307	78	0.945	0.346
Total phosphorus (mg/l)	0.060	0.041	344	0.067	0.043	155	0.335	0.568
Nitrogen:Phosphus ratio[b]	10.848	9.127	177	21.244	31.052	78	0.108	0.747
Chlorophyll (u/l)	9.277	8.651	346	15.754	12.036	155	2.019	0.177

[a]Mixed-model Anova test of difference between means. Categories are locations, and no anoxia/periodic anoxia. Data are log-transformed. F and P values are for the category no anoxia/periodic anoxia.

[b]Calculated by the Redfield method (see text)

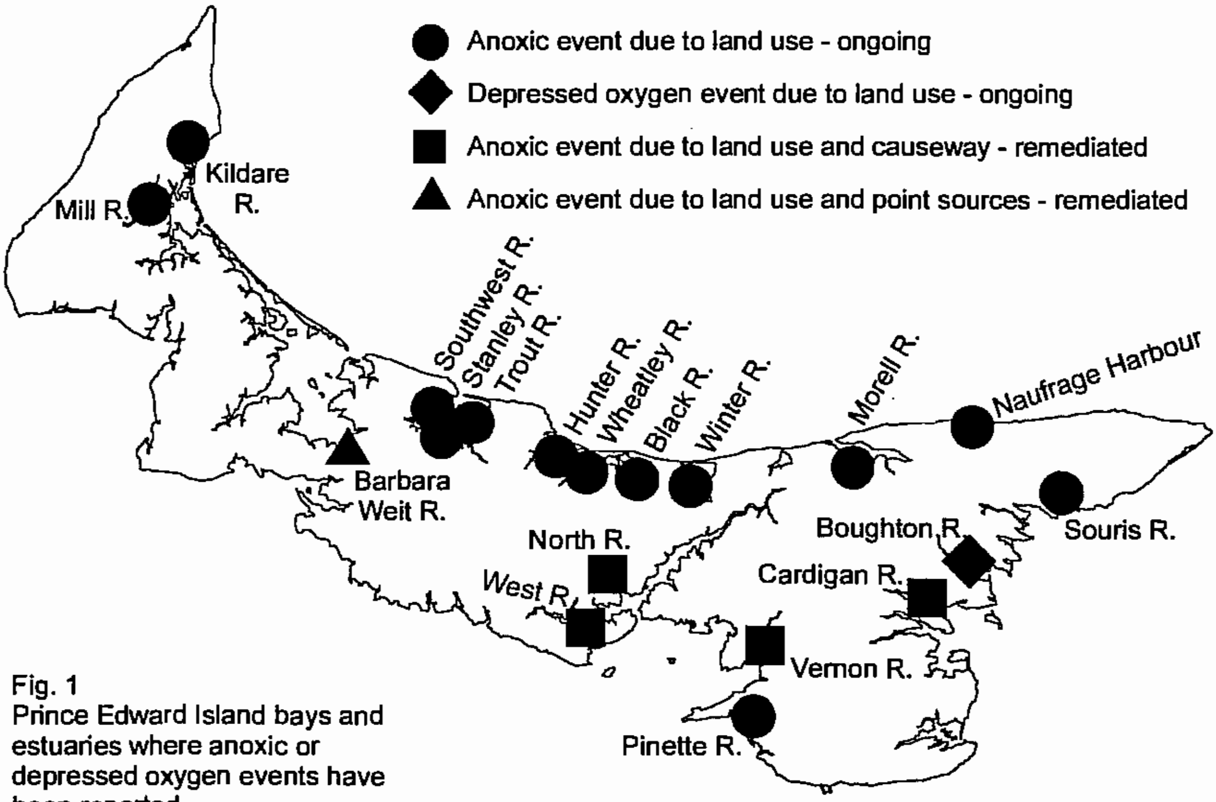

Fig. 1
Prince Edward Island bays and estuaries where anoxic or depressed oxygen events have been reported.

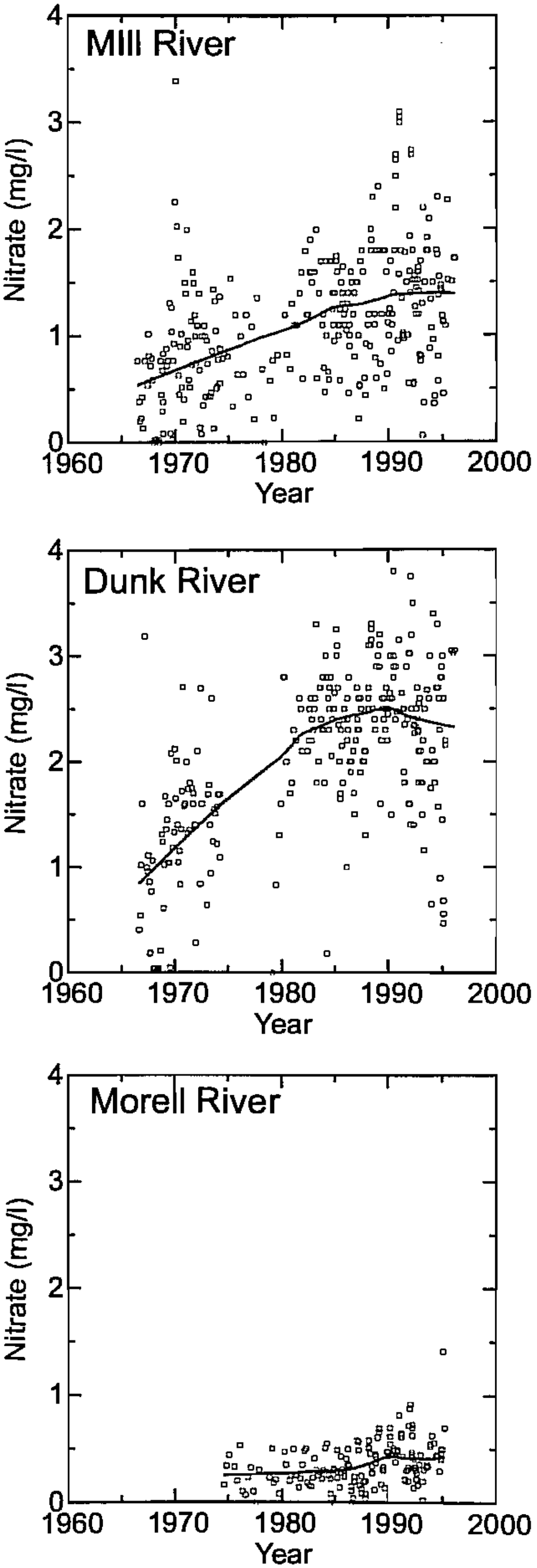

Fig. 2
Nitrate concentrations in the Mill, Dunk, and Morell Rivers. Lines indicate lowess-smoothed mean concentrations.

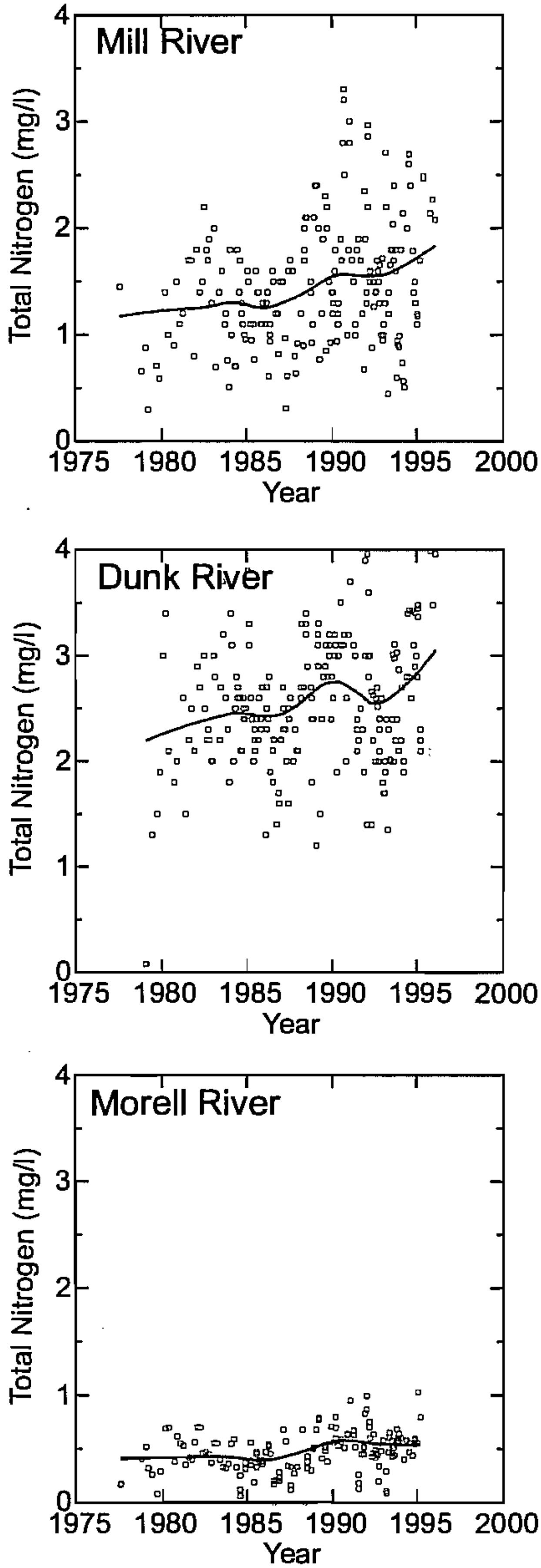

Fig. 3
Total nitrogen concentrations in the Mill, Dunk, and Morell Rivers. Lines indicate lowess-smoothed mean concentrations.

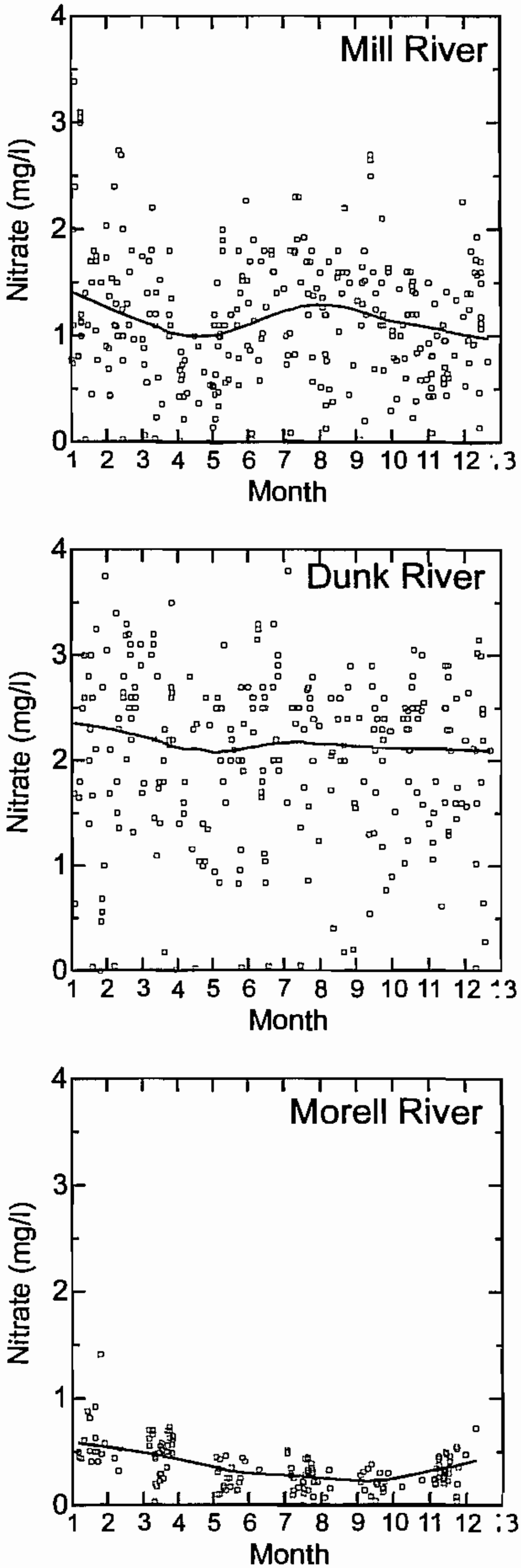

Fig. 4
Seasonal concentrations of nitrates in the Mill, Dunk, and Morell Rivers. Lines indicate lowess-smoothed mean concentrations.

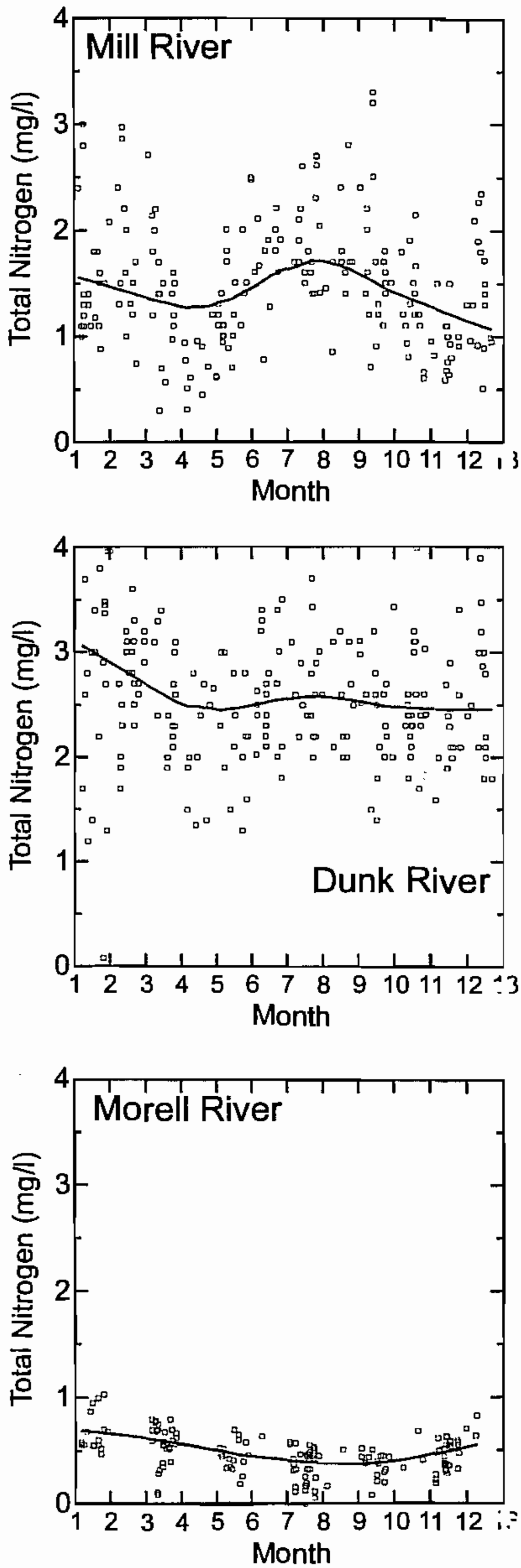

Fig. 5
Seasonal concentrations of total nitrogen in the Mill, Dunk, and Morell Rivers. Lines indicate lowess-smoothed mean concentrations.

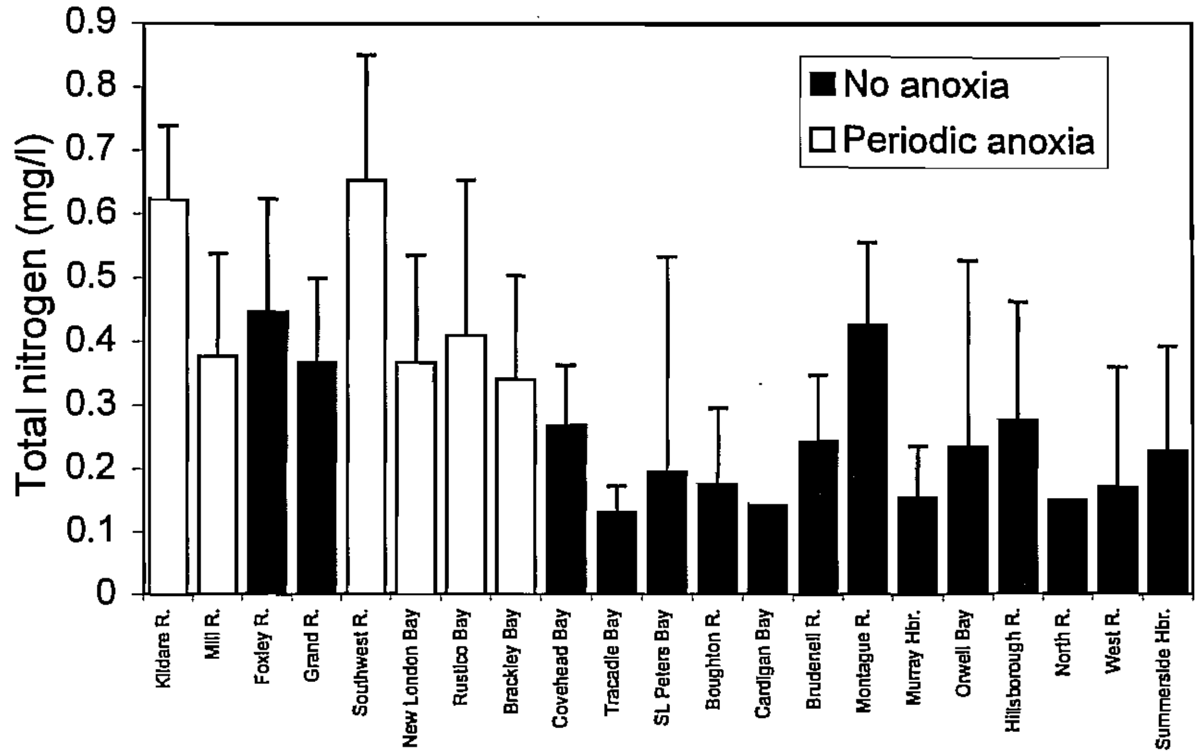

Fig. 6
Mean nitrogen concentrations in PEI bays and estuaries in July 2000 and July-August 2001. Black bars indicate sites where anoxia has not been reported. Open bars represent sites where anoxia has been reported. Error bars indicate mean+SD.

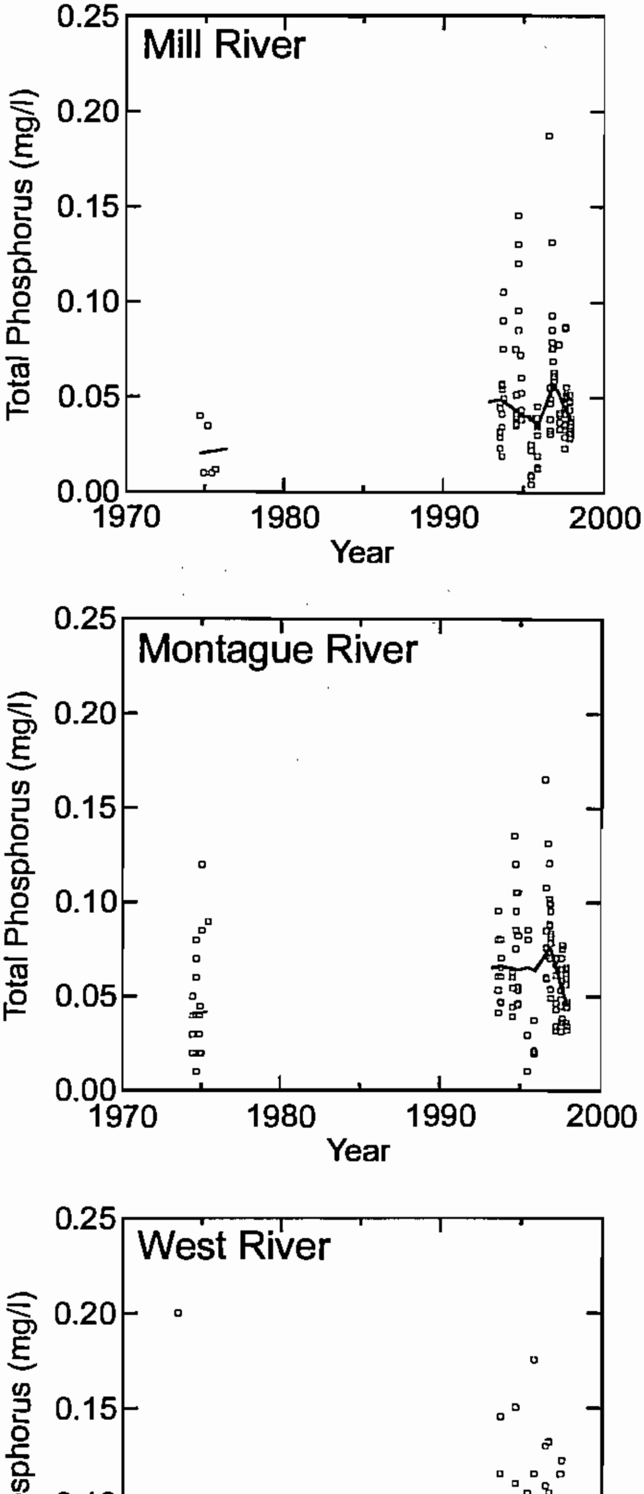

Fig. 7
Total phosphorus concentrations in the Mill, Montague, and West Rivers. Lines indicate lowess-smoothed mean concentrations.

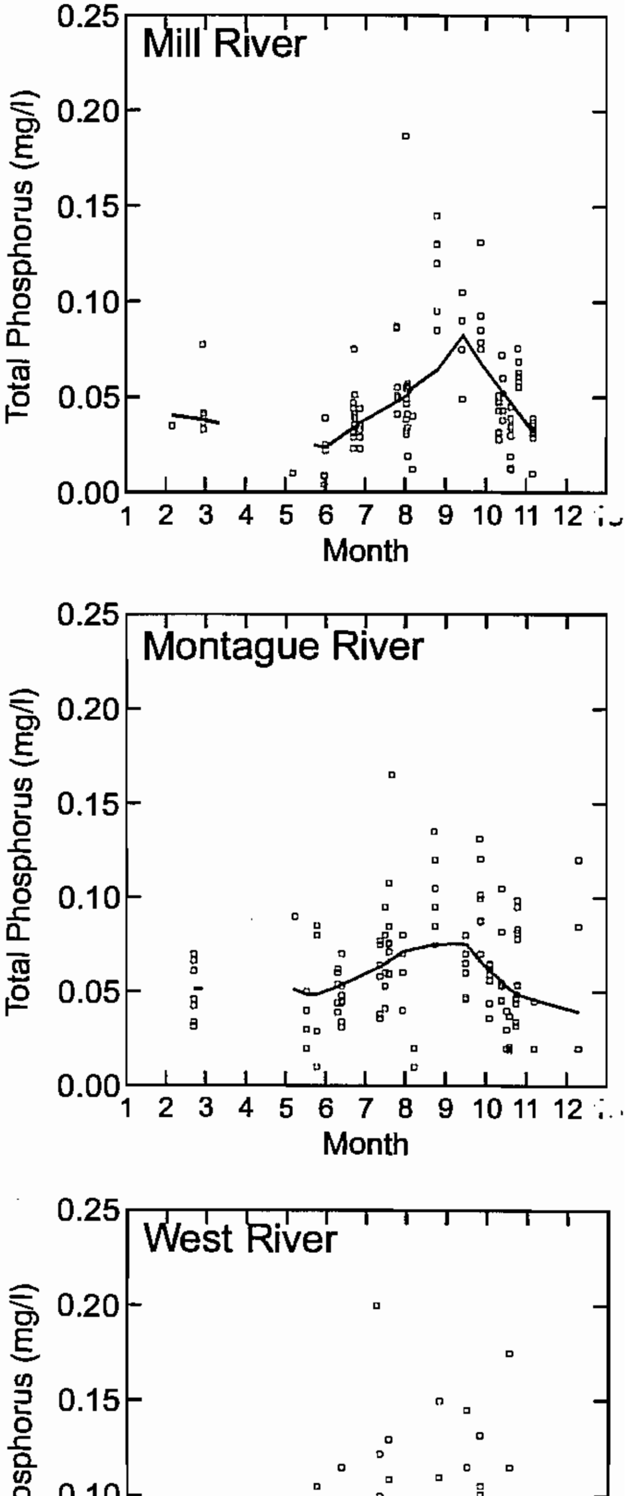

Fig. 8
Seasonal concentrations of total phosphorus in the Mill, Montague, and West Rivers. Lines indicate lowess-smoothed mean concentrations.

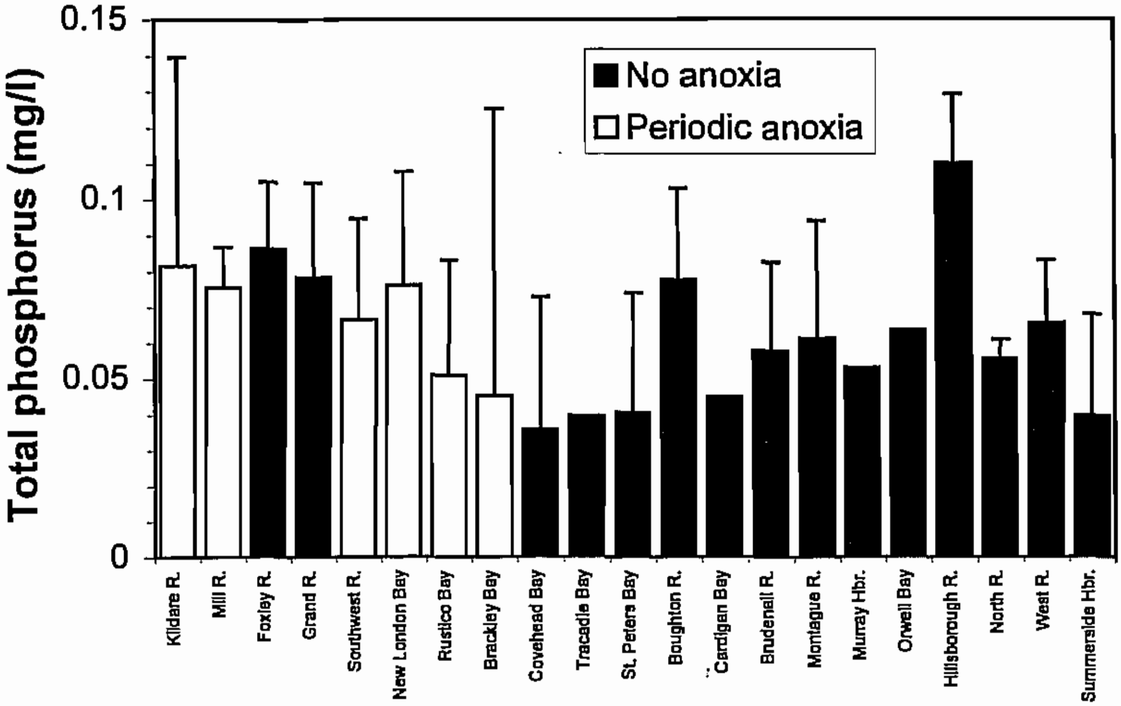

Fig. 9
Mean phosphorus concentrations in PEI bays and estuaries, July-August 1998-2001. Black bars indicate sites where anoxia has not been reported. Open bars represent sites where anoxia has been reported. Error bars indicate mean+SD.

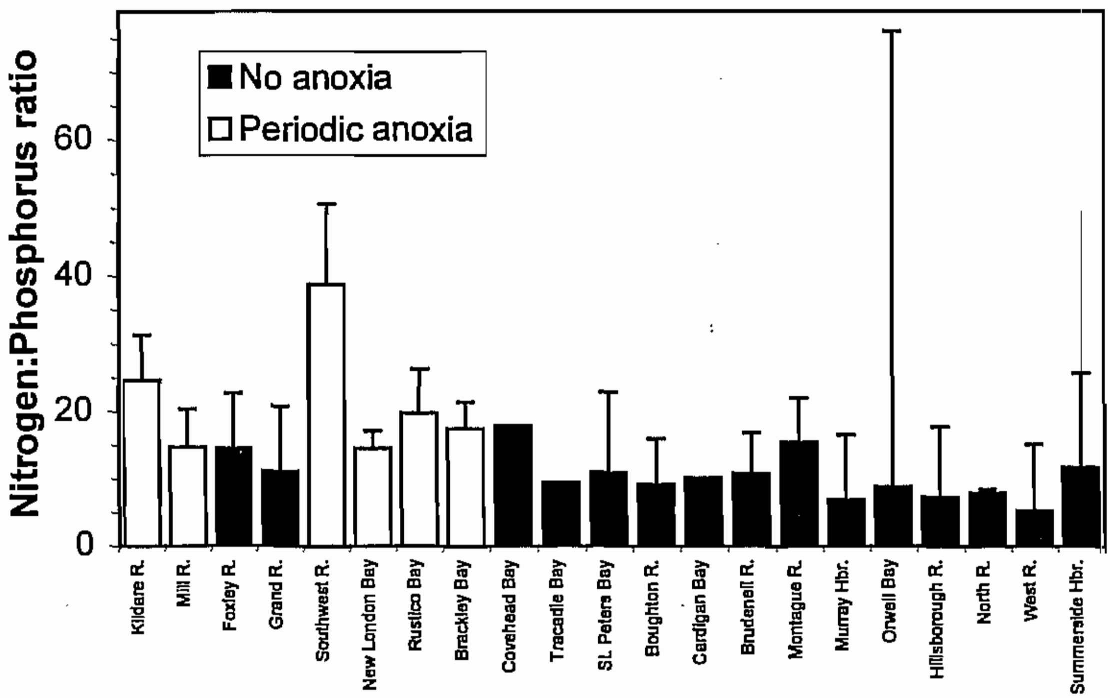

Fig. 10
Mean ratio of nitrogen:phosphorus concentrations in PEI bays and estuaries, July 2000 and July-August 2001. Black bars indicate sites where anoxia has not been reported. Open bars represent sites where anoxia has been reported. Error bars indicate mean+SD. N:P ratios calculated by the Redfield method (see text).

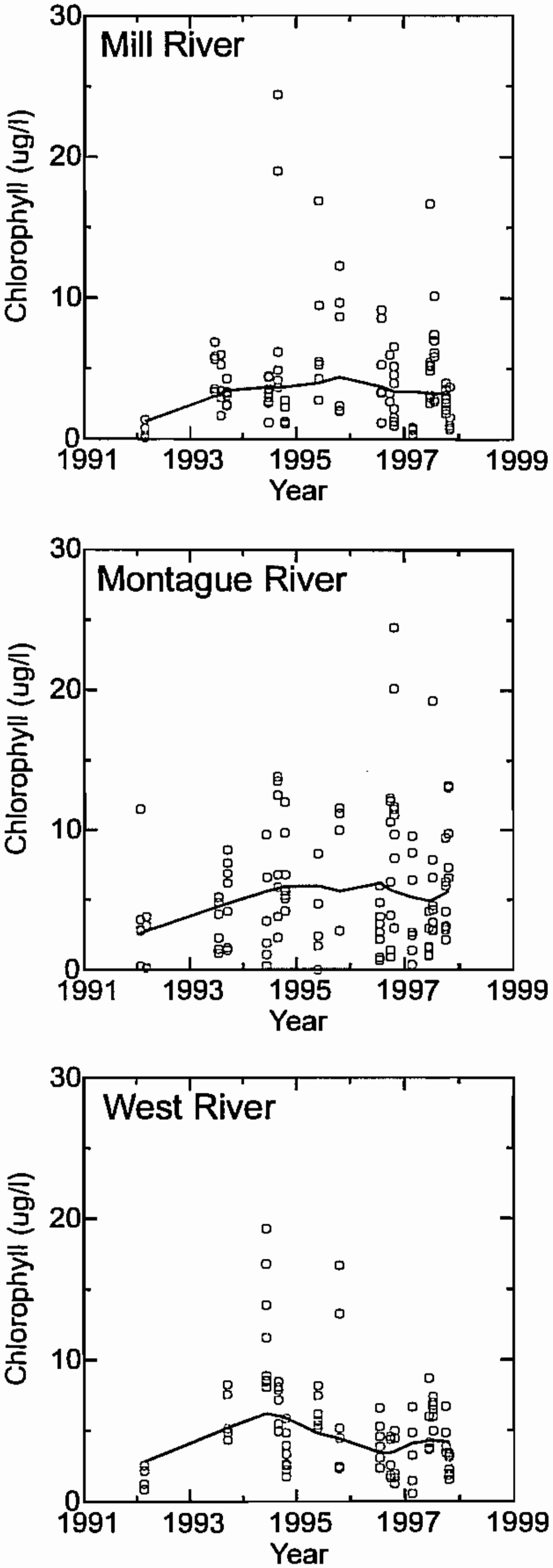

Fig. 11
Chlorophyll concentrations in the Mill, Montague, and West Rivers. Lines indicate lowess-smoothed mean concentrations. Note that 1992 sampling was conducted in winter when concentrations are generally low.

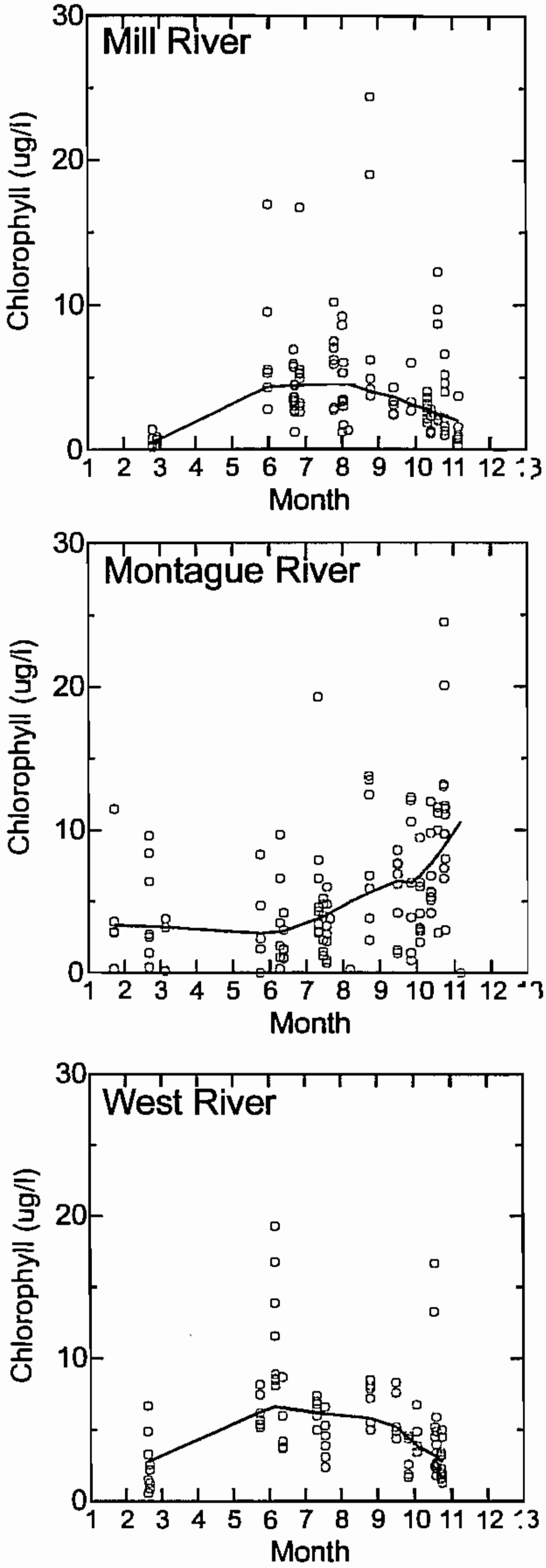

Fig. 12
Seasonal concentrations of chlorophyll in the Mill, Montague, and West Rivers. Lines indicate lowess-smoothed mean concentrations.

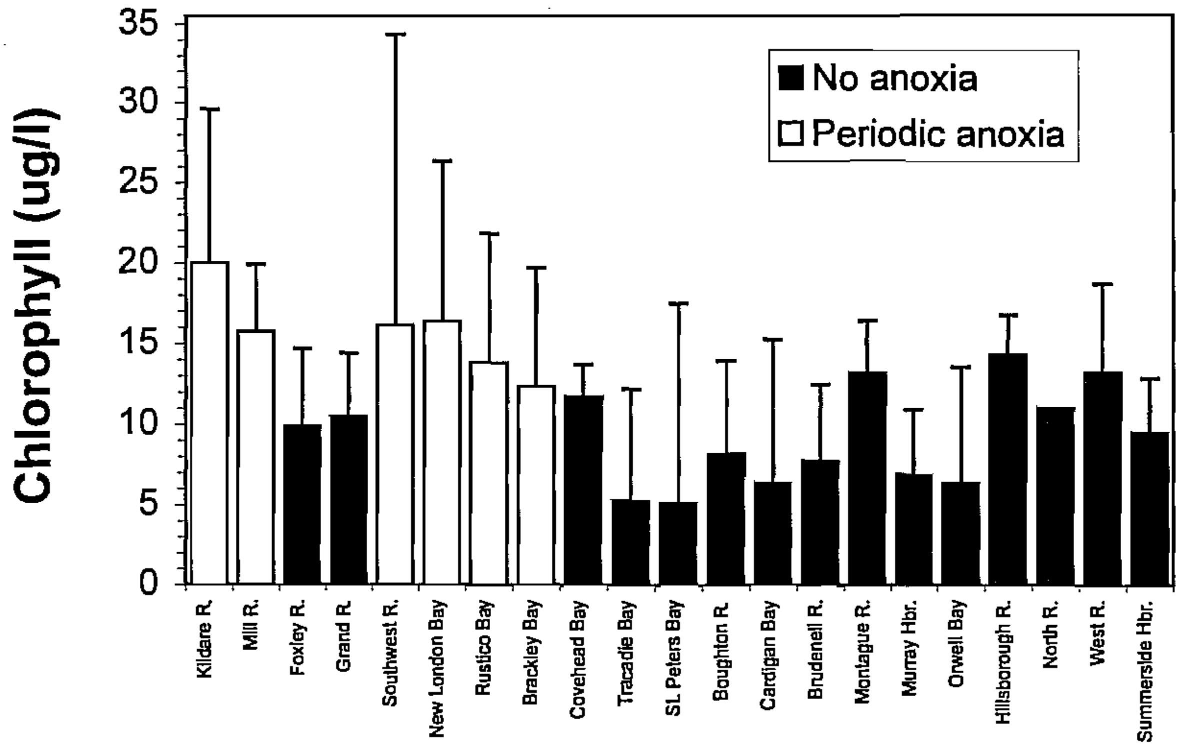

Fig. 13
Mean chlorophyll concentrations in PEI bays and estuaries, July-August 1998-2001. Black bars indicate sites where anoxia has not been reported. Open bars represent sites where anoxia has been reported. Error bars indicate mean+SD.

Predicting eutrophication in Prince Edward Island estuaries from land use patterns

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ABSTRACT

This abstract is based on Meeuwig et al. (1998) and Meeuwig (1999).

Managing land use in the context of impacts on aquatic systems requires a means to predict or estimate the nature and magnitude of such impacts. In lakes, regression models have been commonly used to estimate nutrient levels or trophic status from physical parameters or nutrient loadings (e.g. Dillon and Rigler 1975, Field et al. 1996). In coastal waters, models that predict eutrophication status have traditionally used complex numerical simulations that require large volumes of oceanographic data. They are also site specific and tend to be expensive, limiting the extent of their use. Although eutrophication is a widespread problem in many coastal areas of the world, the empirical regression-based approach has been little used in estuaries and other coastal waters.

Phytoplancton biomass (as indicated by chlorophyll a, chl), total phosphorus (TP), total nitrogen (TN), estuary morphometry and land use characteristics were measured and compiled for 15 estuaries on Prince Edward Island. Field work was done in 1996. A regression model predicting chl as a function of estuary volume and area of agriculture accounted for 68% of the variance in chl. Regression models accounted for 72% of the variance in TN and 66% of the variance in TP. The estuary models based on land use and total nutrients estimated chl levels that were one to two orders of magnitude lower than those predicted by empirical models for lakes. A mass balance approach was used to examine the possible roles of flushing, herbivory, and turbidity in producing this low yield. Residence time (an indicator of flushing rate) had little influence on the models. In the six estuaries with mussel aquaculture, 45% to 88% of the chl deficit could be accounted for by herbivory. In the remaining nine estuaries, turbidity accounted for 35% to 75% of the chl deficit. Considering both herbivory and turbidity, the mass balance analysis accounted for a mean of 68% of the chl deficit for the 15 estuaries.

The mass balance analysis suggests that chl:nutrient relations can be generalized across fresh water and estuarine systems provided that herbivory and turbidity are taken into consideration. On PEI, the relation between estuarine chl and land use is sufficiently clear that environmental managers can predict the effects of changing land use on estuary water quality with a known level of error.

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P. 154 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

The potential role of bivalve shellfish in mitigating negative impacts of land use on estuaries

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ABSTRACT

Water filtration by bivalve molluscs often has extensive effects on nutrient, turbidity, phytoplancton, and sediment dynamics in estuaries and bays. On Prince Edward Island, landings of wild bivalves were relatively stable during the 1990s, but landings of cultured bivalves (particularly mussels) grew sharply. This suggests that total bivalve filtering capacity in PEI bays and estuaries has increased. During the 1990s, increased acreage was devoted to potato production, which is a potential source of sediment and nutrients to coastal waters. Mussels and other bivalves absorb more material than they release, and the harvest of mature animals may remove substantial amounts of nitrogen and carbon from nutrient-rich systems. Sedimentation rates under mussel lines have been measured to be two-three times higher than nearby control areas. However, overall sedimentation rates in systems that contain mussel culture operations may be lower than systems without mussel culture, because mussels remove large quantities of particulate matter. Bivalve culture operations provide substrates that increase biomass and diversity of a variety of epifaunal animals, but they may also depress biomass and diversity in the endobenthos. No studies are yet available that examine the effects of culture operations on overall biodiversity and abundance across the benthic and pelagic zones.

INTRODUCTION

The potential role of bivalve shellfish in improving or restoring estuarine water quality has received much recent attention. Bivalve filter-feeders remove particulate matter from the water column, extract foodstuffs for their own use, and release unused material as biodeposits. Bivalve water filtration is an important mechanism of nutrient cycling, and may exert significant control over water turbidity, phytoplancton standing crops, and sediment dynamics (Dahlback and Gunnarsson 1981, Dame and Dankers 1988, Meeuwig et al. 1998).

Oyster and clam populations have declined along much of the east coast of North America, leading to a decrease of bivalve filtering activity. At the same time, nutrient inputs from terrestrial sources have increased, which has encouraged excessive plant production and water quality problems (Nixon 1990). In Prince Edward Island, bays and estuaries commonly exhibit excessive summer plant growth, which sometimes leads to anoxic conditions (Raymond et al. 2002). Prince Edward Island also has substantial shellfish production, both natural and cultured. This paper examines the potential role of bivalve shellfish in mitigating the estuarine water quality problems of the sort that are experienced in Prince Edward Island.

RESOURCE STATUS

The biomass of bivalves in PEI waters is not known. However, landing statistics can be used to infer biomass trends. In 1990-2000, landings of wild estuarine molluscs, mainly clams and oysters, have been relatively stable at about 2,700 t (Fig. 1). Landings of wild fisheries are often strongly influenced by market conditions, regulations, and alternate fishing opportunities. During the same period aquaculture production, primarily that of mussels, increased six-fold from about 3,000 t to about 18,000 t. This major increase in bivalve aquaculture production on PEI strongly suggests that bivalve filtering capacity is presently much higher than it was in the 1980s. This increase is not evenly distributed across PEI, because the mussel aquaculture industry requires bays and estuaries with relatively deep water, which tend to be more common in the northern and eastern parts of the province.

Agriculture, particularly potato cultivation, may impact water quality in estuaries and bays through transport of nutrients and sediments. Planted potato acreage on PEI climbed from 30,351 ha in 1990 to 45,730 ha in 1999 (Cairns 2002). Soil loss from potato production is poorly known, but land in potato rotation has been estimated to lose about 10 t $ha^{-1}yr^{-1}$ (Cairns 2002). Synthetic fertilizers are typically applied at rates of 1.1 to 1.6 t ha^{-1} yr^{-1} on PEI agricultural land (Meeuwig et al. 1998). Other land use activities, including road construction and maintenance, forestry operations, tourism development, and conversion of land for industrial and commercial use, may also lead to releases of materials to estuaries and bays.

Pp. 155-157 in D.K. Cairns (ed.). 2002. Effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2408.

FILTRATION

The filtration rate of oysters and mussels depends on their size, water temperature, and food quality and quantity. Mussel filtration rates can range from 0.03 to 0.4 $m^3g^{-1}d^{-1}$ (dry weight of mussels) (Vahl 1973). The Murray River estuary has a volume of about 356,000,000 m^3, and an estimated mussel biomass of 96,300,000 g (dry weight). The total volume of this estuary could be filtered by mussels in nine to 123 days given Vahl's (1973) high and low rates, respectively. This situation is common in most of the systems with intensive mussel culture.

The overall uptake by mussels is greater than their release. Dame and Dankers (1988) showed that a mussel bed has an uptake of total seston (mean of 2.58 g $m^{-2}h^{-1}$), total organic carbon (TOC) (mean of 0.62 g $m^{-2}h^{-1}$) and nitrate and nitrite (mean of 0.03 g $m^{-2}h^{-1}$), while releasing lower amounts of phosphate (average of 0.06 g $m^{-2}h^{-1}$) and ammonia (average of 0.06 g $m^{-2}h^{-1}$). Similar findings have been reported for oysters (Dame et al. 1984). Overall, bivalve beds are considered to play a retention role for nitrogen. This role is even more important when bivalve crops are rotated at regular intervals such as in aquaculture situations. The removal of older mature animals and their replacement with young animals in full growth increases the potential for reducing nitrogen and carbon from nutrient-rich systems. Rice (1999) estimated that for each kilogram of bivalve meat harvested, 16.8 g of nitrogen was removed from the estuary. This is an important function in a system that receives excessive nutrients from land use.

Bivalves are used in shrimp culture areas to clean effluent waters before they are released to estuaries. Jones and Preston (1999) have shown that oysters were able to remove up to 49% of suspended solids, 58% of the bacterial counts, 80% of total nitrogen and 67% of total phosphorus from the effluent waters of an Australian shrimp farm. Similar approaches have been tested in Sweden by increasing mussel biomass (enhancement and aquaculture) to improve oxygen conditions in fjords. This work was prompted by major ecological and economical impacts resulting from temporary anoxia due to low water exchange and eutrophication, mainly associated with nutrient enrichment from fish farming (Haamer 1998).

SEDIMENTATION

Bivalve populations affect sedimentation processes. Increased sedimentation rates and changes in sediment composition are often associated with molluscan aquaculture, and more so with suspended operations compared to bottom culture. Biodeposits from bivalves are considered to play an important role in nitrogen remineralization and therefore contribute to phytoplancton production or turnover. Smaal and Zurburg (1997) showed that pelagic primary production is not enough to sustain the cultured biomass of mussels and oysters in Marennes-Oleron Bay in France. They therefore suggested that benthic primary production, which is stimulated by biodeposition, is a major contribution of food for these culture operations.

Sedimentation rates under mussel farms have been estimated to be three times greater than those from control sites (Dahlback and Gunnarsson 1981). These estimates, however, are generally taken within the same area and do not take into consideration the effect of mussel farms on overall reduction of particles from the entire system. Grant et al. (1995) concluded that, although sedimentation rates at a mussel farm in Nova Scotia were double those of a reference site, the impact on the benthos appeared to be minor. They also suggested that the impacts were more associated with mussel fall-off than the result of biodeposits. Similar conclusions were drawn by Buschmann et al. (1996) in their review of environmental effects of mussel aquaculture in Chile.

Meeuwig et al. (1998) concluded that the two main factors affecting phytoplancton production in 15 PEI estuaries were herbivory and turbidity. They suggested that in estuaries with mussel farms, herbivory affected phytoplancton production, while turbidity was the main effect in estuaries without mussel farming. This suggests that reduction of turbidity and sedimentation due to mussel aquaculture may enhance primary production both in the water column and in the benthos. In addition, supporting structures for aquaculture may play an important role in reducing turbidity by acting as passive filters or sediment traps. Sediments caught on mussel lines or in oyster bags can represent a substantial proportion of the total weight of these infrastructures.

EPIFAUNA AND ASSOCIATED COMMUNITIES

Bivalve reefs and culture operations provide a base for the establishment of a variety of epifaunal species, mainly sponges, ascidians and polychaetes. These animals increase biodiversity in estuarine systems and may play an important role in nutrient and oxygen flux within a system. Mazouni et al. (1998) showed that the retention efficiency of epifauna is generally higher than for the main molluscan species. Polychaetes are considered to play an important role in phosphorus flux.

Increases in epifaunal diversity and abundance may benefit fish species that prey on these species. Bivalve reefs and aquaculture systems may therefore play an important role in food production for commercially and recreationally important fish species, in addition to improving their habitat.

While culture operations may benefit the epifaunal community, they can also have negative effects on the endobenthos. Grant et al. (1995) found that the abundance of endobenthic fauna under mussel lines was significantly lower throughout the year, and biodiversity was also lower during fall, winter, and spring. I have located no studies that examine the effects of molluscan aquaculture on biodiversity and abundance from an entire ecosystem perspective (both pelagic and benthic communities). Until such studies are completed, no conclusions can be drawn regarding the overall effects of bivalve culture on habitat modification, biodiversity and abundance within bay and estuarine systems.

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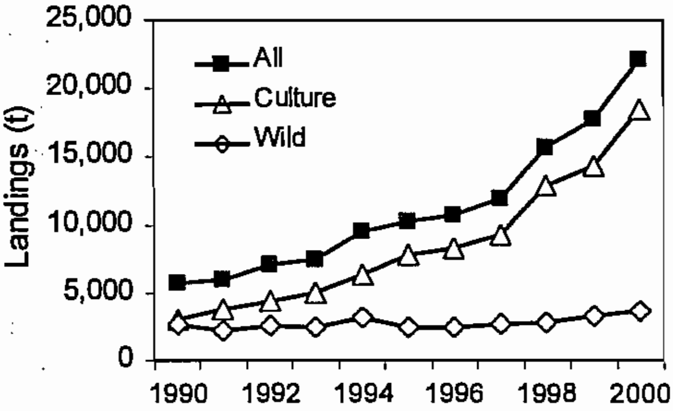

Fig 1.
Reported landings of wild and cultured clams, mussels and oysters on Prince Edward Island from 1989 to 1997.