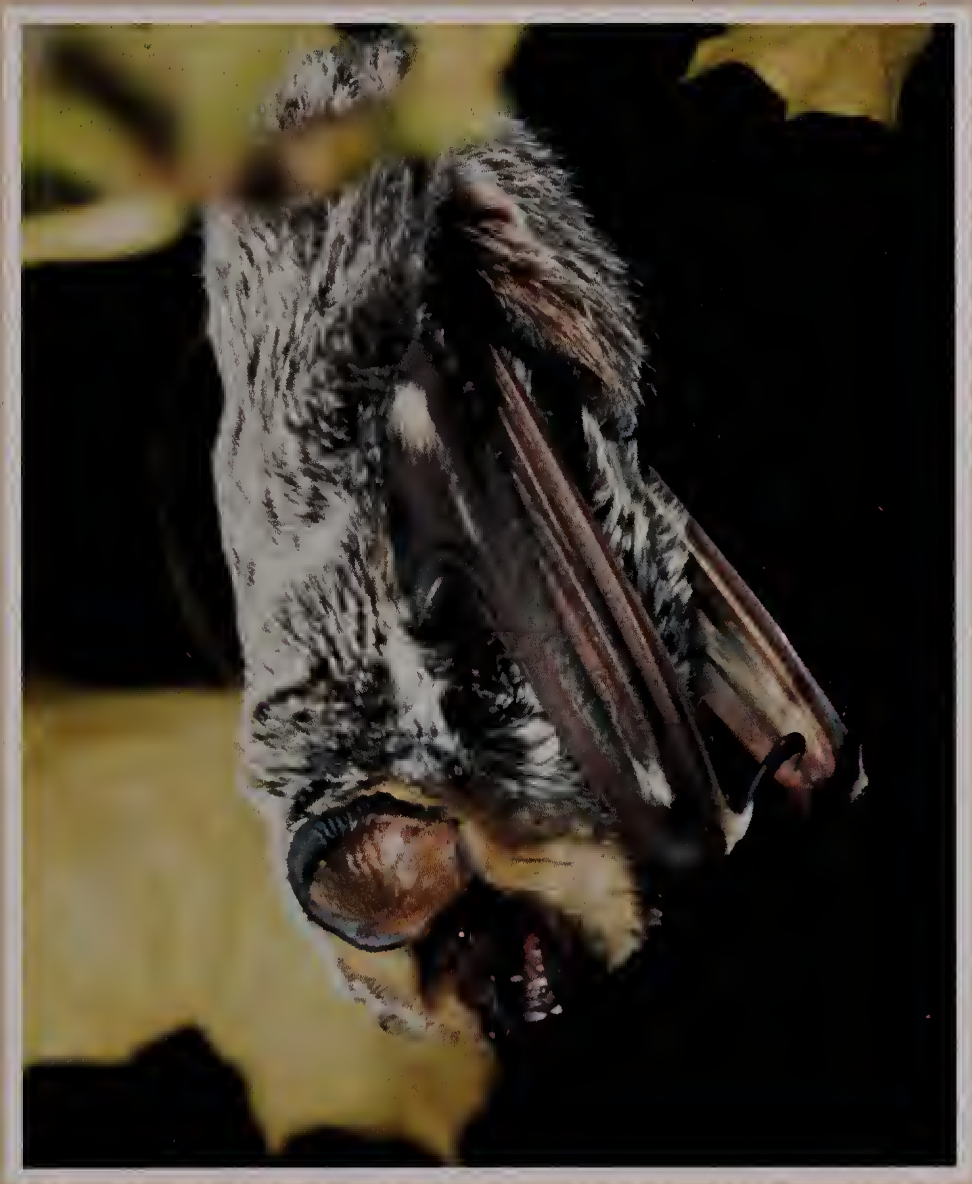
PROCEEDINGS

of the

Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA

Volume 46 | 2011 | Part 2



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Manuscripts should be submitted electronically to the editor (**nsis@dal.ca** and **oceans2@ns.sympatico.ca**). Membership of the NSIS is open to all those interested in Science and subscription details can be found on the Nova Scotian Institute of Science website **http://www.chebucto.ns.ca/Science/NSIS.** Members of the NSIS are not required to pay page charges but others are currently charged $25 per page to help defray the cost of publication **http://www.chebucto.ns.ca/Science/NSIS/index-new.html**

This journal is abstracted in:

Biological Abstracts
BIOSIS Previews
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Zoological Record
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Cover: A Hoary Bat *Lasiurus cinereus*, one of three bat species recorded inland and at offshore locations in Nova Scotia (see Lucas and Hebda, this issue pp. 117-138) and which are vulnerable to injury by wind turbines. Bat species that hibernate in Nova Scotia are also threatened by the white nose syndrome (see editorial pp 111-114).

Cover photo: Brock Fenton. **Back cover photos:** P.G. Wells and Brock Fenton.

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Proceedings of the Nova Scotian Institute of Science (2011)
Volume 46, Part 2, pp. 111-114

EDITORIAL

Celebrating 150 years of the NSIS and Maritime Science: Reflecting on the Society's Role, and Identifying Future Roles and Challenges

The Nova Scotian Institute of Science (NSIS) celebrates its 150th Anniversary in 2012. It was founded in Halifax in May, 1862, originating from the Halifax Mechanics' Institute (1831–1860) and the Halifax Literacy and Scientific Society (1839–1862). It was originally called the Nova Scotian Institute of Natural Science, as early areas of interest were geology, minerals, botany, zoology, meteorology and physical geography, and the economic potential of natural resources. The Institute received its first grant from the Nova Scotia Legislature in 1867; it was incorporated in the Province by an Act of the Legislature in 1890 and the Revised Statutes of Nova Scotia in 1967.

The NSIS is the oldest, continuous scientific organization and one of the oldest learned societies in Canada. As such, it has been a focal point for the important role and contributions of science in the Maritime Provinces and Atlantic Canada from just before Confederation (1867) to the present day. The Maritimes and Nova Scotia in particular, with many universities and research institutes, have produced a plethora of prominent scientists and key discoveries. These range from Abraham Gesner, inventor of kerosene, to fundamental discoveries in marine ecology and oceanography (with key marine science laboratories in Halifax, Dartmouth and St. Andrews, NB), to the most recent recognition of Willard S. Boyle who shared the 2009 Nobel Prize in Physics for his work developing the sensor widely used in digital cameras. The Institute played a key role in the establishment of the Provincial Natural History Museum in Halifax. As well, Nova Scotia is the home to the Pugwash Conferences, a meeting place of the world's most prominent scientists.

Being 150 years old is a major achievement. The organization has been a stimulus and focal point for scientific progress, reporting and communication in the Maritime Provinces. The Proceedings have been published from the beginning, with many distinguished contributors writing on a wide spectrum of topics. Each year the NSIS organizes a lecture series that includes topics of current interest. Over the years, hundreds of monthly lectures have been given, communicating scientific research and achievements to members and to the broader community. The lectures are often published in the Proceedings.

In this issue we include a paper on bats which have been in the news lately for two reasons. Firstly, large numbers of migrating bats are killed each year by wind turbines, but recent research has shown that deaths can be reduced by 50-75% if the turbines are shut down at low wind speeds when they generate very little electricity. The second concern about bats is occurrence of a new fungal disease called 'white-nose syndrome' which seems to have spread from Europe to the USA, where it was first recorded in 2006. Since then, the disease has been reported in many states and has spread to at least four Canadian provinces. Mortality rates for the disease often exceed 90% for bat species that hibernate in caves during winter. In addition to bat-to-bat infection, the disease is being spread from cave to cave inadvertently by cavers and geocaching enthusiasts. The concern about bat populations is so serious that COSEWIC (Committee on the Status of Endangered Wildlife in Canada) has called for special reports on three bat species. The paper in this issue is a significant contribution to our understanding of bat biology in Nova Scotia.

The year 2012 has many local and global anniversaries with a science theme, and this gives us pause for thought. Locally, the Bedford Institute of Oceanography in Dartmouth, NS, is 50 years old and is planning a book detailing its various achievements in ocean science during the period 1962-2012. Rachel Carson's Silent Spring, published in 1962 to alert the world to the perils of toxic chemicals, galvanized a generation of environmentalists and concerned scientists; Carson emphasized the wide spread use and impacts of pesticides, and referred to aquatic studies on salmon and DDT conducted in New Brunswick in the 1950s by Maritime scientists. This influential book is still a best seller and will undoubtedly be celebrated widely in 2012. As well, the active American Scientific Research Society, Sigma Xi, is celebrating its 125th anniversary, with an emphasis on how science serves society and the role of team science in the 21st century. As a local aside, the ocean liner *Titanic*, a marvel of nautical engineering but a 20th Century example of technological hubris, hit an iceberg and sank in 1912, a fact hard to forget if you live in Halifax and visit the Maritime Museum! The liner resting at the bottom of the NW Atlantic has been studied by local scientists in recent years. These are but a few of the current science-related anniversaries; the reader probably knows of many more. Clearly, 2012 is a year to celebrate science!

Today, NSIS serves Nova Scotia and the Maritime region of Canada by:

- Providing a forum for scientists and those interested in science to learn about and discuss scientific matters, through a monthly public lecture and discussion series, its journal (The Proceedings of the NSIS), and its website;
- Drawing attention to issues of societal concern that intersect the natural and social sciences, such as education, environmental and natural resource policies, and ethics;
- Promoting research and education in science by running a Mentorship Program, conducting an annual Scientific Writing Competition for university students, and supporting Regional Science Fairs;
- Presenting current and historical material of Canadian scientific importance to the public on its website, www.chebucto.ns.ca/science/nsis; and
- Housing the NSIS virtual Hall of Fame for men and women who have contributed significantly to the scientific activity of Nova Scotia, Canada, and the world beyond our borders (see website).

Noting this, what should the NSIS anniversary mean to members of the Society and to the interested public? Celebrating NSIS in 2012 and the achievements of science in Nova Scotia and the Maritimes brings attention to:

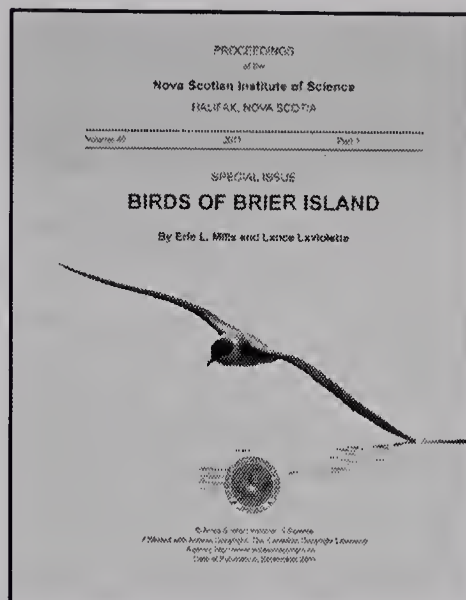
- the pivotal role of the natural and social sciences and researchers in Canada's history and development as a nation;
- the cornerstone role of science in Canada's future prosperity in an ecologically and economically sustainable world; and
- the contributions of regional scientific societies in Canada to communicating science to the broader interested public and to encouraging careers in science in Canada.

In addition, 2012 provides an opportunity to celebrate Maritime science and the scientific enterprise as a whole, in all of its dimensions and with all of its societal benefits. We can contemplate future challenges where all branches of science play a pivotal role in our society. It is an opportunity for NSIS to enlarge and broaden its membership, to distribute its Proceedings more widely in digital and paper formats, and to reinvigorate its website. 2012 is a time to defend the importance of science in all of our institutions, especially in the Public Service, during a time of economic downturns and debt-related cutbacks. It is a time to strengthen linkages with other scientific organizations, such as the Royal Society of Canada and specialized professional groups, and to collaborate with the scientific activities of citizen-driven, non-governmental organizations. It is a time to sponsor forward-looking seminars and workshops so that science and science education are strong players in our future Maritime economy and culture. Clearly the NSIS and its members have a key role to play now and over the next 150 years!

Peter G. Wells, Editor
David H. S. Richardson, Associate Editor

Proceedings of the Nova Scotian Institute of Science (2011)
Volume 46, Part 2, pp. 115

ERRATA



Eric L. Mills and Lance Laviolette. 2011. The Birds of Brier Island, Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 46 (1) (Special Issue), 107 pp.

Inside Cover: COVER PHOTO: Dr. Richard Stern, Kentville.

p. 3. line 4 of first paragraph: "(1981)" should read "(1981a, b)".

p. 10, first line. Add "Research" before "Station".

p. 16, lines 28-29 should read "Merritt Fernald, the Harvard botanist, also visited the area, landing at Sandy Cove on Digby Neck …"

p. 48. Figure 22 should be captioned "Moulting adult Little Stint …"

p. 87. The last sentence should read "McLaren (in press) mentions that this in some ways resembled the non-migratory California subspecies *A. b. canescens*, but adds (*in litt.*) that it may have been within the range of variation of the migratory subspecies *A. b. belli*."

p. 101. McLaren 1981 should be re-numbered 1981a. Add to the reference list: "McLaren, I.A. 1981b. The incidence of vagrant landbirds on Nova Scotian islands. *The Auk* 98 (2): 243-257.

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LASIURINE BATS IN NOVA SCOTIA

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Three lasiurine bat species, *Lasionycteris noctivagans* (Silver-haired Bat), *Lasiurus cinereus* (Hoary Bat), and *Lasiurus borealis* (Red Bat), have been recorded in inland, coastal, and offshore locations as of Nova Scotia. Although these records occurred over a century, 70% are from the mid-1990s or later, largely because of research in mainland Nova Scotia, and increased interest on Sable Island. The 65 records presented here include 11, 25, and 29 for Silver-haired, Hoary, and Red bats, respectively, of which 31 are previously unpublished. Seventy-seven percent of records are from August through November, the autumn migration period for lasiurine bats. These observations suggest that most autumn occurrences of these species in Nova Scotia are not extralimital, but are part of normal migratory patterns in the province.

INTRODUCTION

Seven vespertilionid species are recorded for Nova Scotia (Broders et al. 2003, Rockwell 2005, Scott & Hebda 2004). The province is thought to be at or beyond the northern range limit for 5 of the 7 species, including the 3 species of North American lasiurine bats, *Lasionycteris noctivagans* (Le Conte) Silver-haired Bat, *Lasiurus cinereus* (Palisot de Beauvois) Hoary Bat, and *Lasiurus borealis* (Müller) Red Bat (Broders et al. 2003, van Zyll de Jong 1985). In June-August 2003, during a province-wide survey, Rockwell (2005) recorded >10,000 identifiable echolocation sequences, of which only 0.4% were from lasiurine bats. Broders et al. (2003) suggest that the lack of detection of these species in mid-summer in the forested areas of Kejimkujik National Park and during September (migration period) at islands in southwestern Nova Scotia, demonstrates that there are no significant populations of lasiurine bats in Nova Scotia. They conclude that records for these species, including a Red Bat breeding record from Yarmouth County, are likely extralimital. Extensive monitoring programs continued since 2003 in mainland Nova Scotia during summer, and to a lesser extent in autumn, appears to support this conclusion. Of the thousands of echolocation records collected, very few lasiurine bats were recorded (pers. comm. H. Broders, 2011).

Lasiurine bats are highly migratory, some moving south hundreds of kilometres during autumn (Cryan 2003, van Zyll de Jong 1985). Silver-haired, Hoary, and Red bats are generally solitary, but during migration may form flocks of >100 individuals (Carter 1950, Miller 1897). Fenton (1983) notes that the rearing of young in midsummer is followed by mating season and migration, a period during which bats of temperate areas become vagrants; this can result in bats turning up in unexpected locations such as ships at sea and far offshore islands.

We first review prior distributional and migratory knowledge of lasiurine bats found in Nova Scotia in the context of their biology in North America. We then provide data on new records in Nova Scotia and discuss this in terms of the underlying ecology of the three species.

Silver-haired Bat

The Silver-haired Bat (mean weight 11 g, wingspan 27-31 cm; van Zyll de Jong 1985) ranges from southeastern Alaska and much of Canada, with a maximum latitude of 61°07'N (Cryan 2003, Hall 1981), and extends south to northern Mexico (Cryan 2003). This species is relatively scarce in eastern Canada, but fairly common across central North America (Hall 1981, Peterson 1966). Over most of its range, both sexes fly south between middle of August and early October. Records along northern parts of the Atlantic Coast in autumn indicate that some Silver-haired Bats may migrate along coastlines (Cryan 2003). Banfield (1974) notes that Silver-haired Bats have "been observed migrating in flocks, far at sea, off the east coast of the United States, and have been blown as far as Bermuda in autumn storms". This species apparently has well-developed homing instinct (Nowak 1994). In the eastern USA they winter mainly at mid latitudes, approximately south of Michigan and east of the Mississippi River (Cryan 2003, van Zyll de Jong 1985). Van Zyll de Jong (1985) states that they have been captured flying at temperatures below freezing (-2°C) and will hibernate north approximately to the -6.7°C mean daily minimum January isotherm. Cryan (2003) notes occasional reports of Silver-haired Bats hibernating in caves, mines and trees. Previous winter records for Canada are known from southern Ontario, southwestern British Columbia, and mainland Nova Scotia (Moseley 2007a, Moseley 2007b, Peterson 1966, van Zyll de Jong 1985), and include 1 bat found clinging to a stone pillar on December 16, 1959, in Rondeau Provincial Park, Ontario.

Hoary Bat

The Hoary Bat (mean weight 27.6 g, wingspan 34-41 cm; van Zyll de Jong 1985) has the most extensive range of any New World bat, extending from Canada south to Chile and Argentina (Cryan 2003). It occurs throughout most of North America south of the tree line (Cryan 2003, van Zyll de Jong 1985). Monitoring with bat detectors has established that this species is widely distributed in Canada and is common in many areas, although the species is seldom sighted. Individuals have been recorded far beyond areas that are considered suitable habitat (van Zyll de Jong 1985), as far north as Bear Island, at the northwest end of Hudson Bay and more than 500 miles above the treeline (Hitchcock 1943). Records indicate coastward movement during late summer (Cryan 2003). Fall migration takes place from mid-August to October, and most are thought to winter in southern USA and Mexico. There are few records for November-February north of Georgia and South Carolina in the east (van Zyll de Jong 1985), however several records for Connecticut, New York, Indiana, and Michigan suggest that some may winter farther north (van Zyll de Jong 1985). This species migrates some of the longest distances of any bat (Tuttle 1995). Strays have been reported from Iceland and Bermuda (Allen 1939, Hayman 1959, van Gelder & Wingate 1961), and some have landed on ships at sea. Hoary Bats are thought to be rare in Nova Scotia (Broders et al. 2003, Scott & Hebda 2004). However, based on echolocation recordings collected in 2003, Rockwell (2005) suggests that they are more common in summer than direct observations indicate.

Red Bat

The Red Bat (mean weight 12.5 g, wingspan 28-33 cm; van Zyll de Jong 1985) occurs throughout much of eastern North America, generally east of the continental divide in southern Canada from the Maritimes to Saskatchewan, south to northeastern Mexico (Cryan 2003, Hall 1981, van Zyll de Jong 1985). The northernmost record is at 57°15'N (Hall 1981). Fall migration begins in late August and September and continues into October. Movements during autumn are oriented east and south (Cryan 2003). The relatively high densities after June along the Atlantic Coast (north of New York City) may indicate coastal migration during autumn (Cryan 2003). They winter generally south of latitude 40°N (van Zyll de Jong 1985), throughout southeastern USA and into northeastern Mexico. Cryan (2003) notes that winter concentrations are highest in coastal Atlantic and Gulf of Mexico regions. Known to survive temperatures as low as -5°C, this species responds to sub-freezing temperatures by increasing metabolism just enough to keep its body temperature above the critical lower limit (van Zyll de Jong 1985). They are strong flyers with propensity to wander, sometimes landing on ships at sea or oceanic islands, especially Bermuda (Findley & Jones 1964, van Gelder & Wingate 1961). Most oceanic records are from late August and September (van Zyll de Jong 1985). In Nova Scotia, Red Bats are rare but probably widespread, and a confirmed breeding there in 2001 was a first for Atlantic Canada (Broders et al. 2003). Three of the 4 previously published extralimital or extraseasonal records for Nova Scotia have been from vessels off the southwest coast of the province (Brown 1953, Norton 1930, Peterson 1970).

METHODS

We reviewed published records, fluid-preserved carcasses, skins, photographs, and reliable sight records (based on details provided and/or known experience of the observer), and solicited information from birders. Although bats represented by sight records were not captured and examined, in Red Bats sex could be determined because of the marked colour difference between the males and females of this species. Locations of occurrences are categorized as inland, coastal, coastal island, Sable Island, and vessel. Sable Island (44°N, 60°W), the most offshore of Nova Scotia's islands, is approximately 160 km southeast of Canso, Nova Scotia, the nearest landfall. The island is roughly 45 km in length with a maximum width of 1.5 km, and surface area of 3200 ha, 30% of which is vegetated. However, except for a solitary 50 cm high Scots Pine *Pinus sylvestris* Linnaeus, the island is treeless (Catling et al. 1984) and does not offer suitable foraging and roosting habitat for lasiurine bats.

RESULTS

Review of documents and specimens resulted in 65 records (11 Silver-haired, 25 Hoary, and 29 Red bats) in Nova Scotia (Figs 1, 2, and 3, and Tables 1, 2, 3, and 4). Of these, 16 are represented by

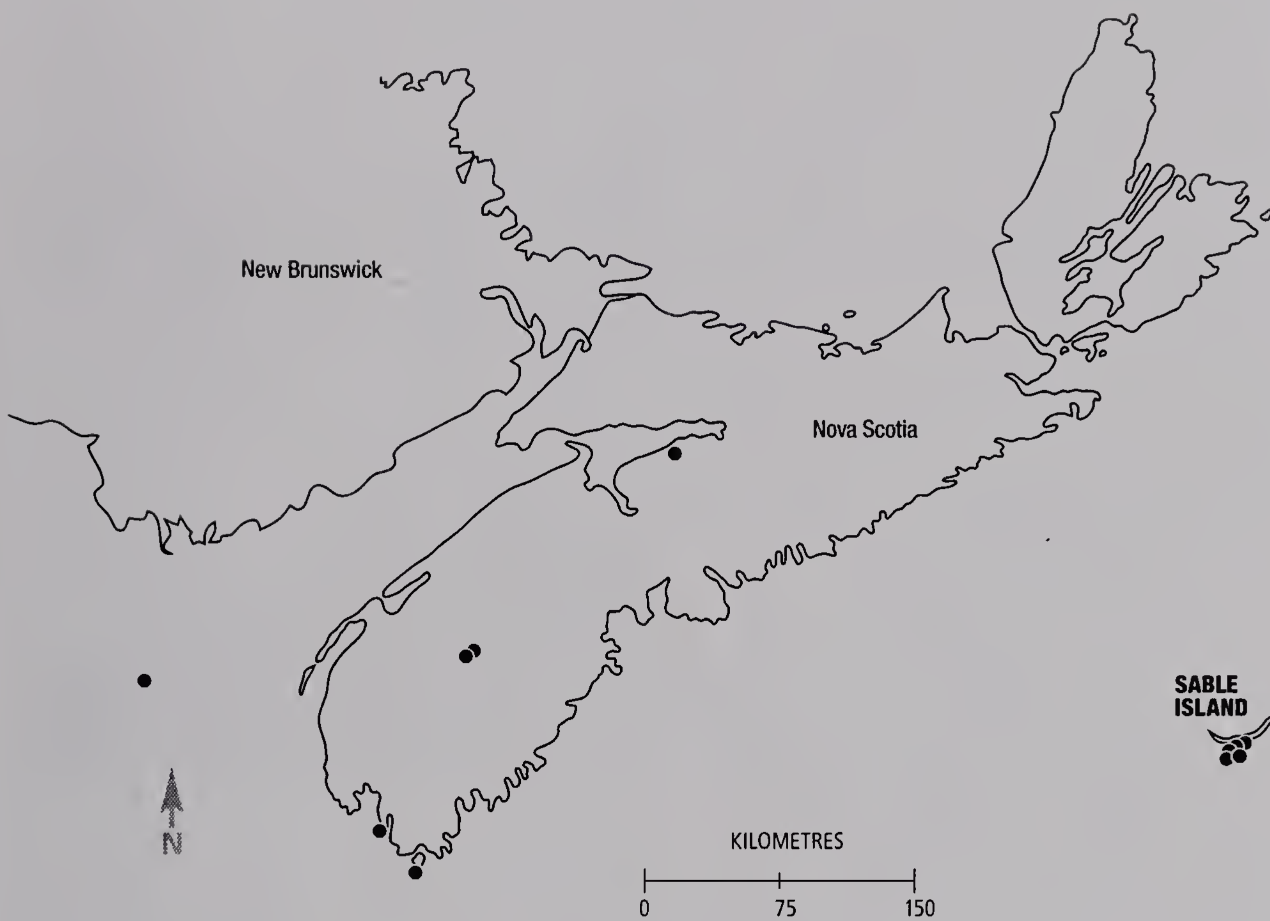

Fig 1 Silver-haired Bat records.

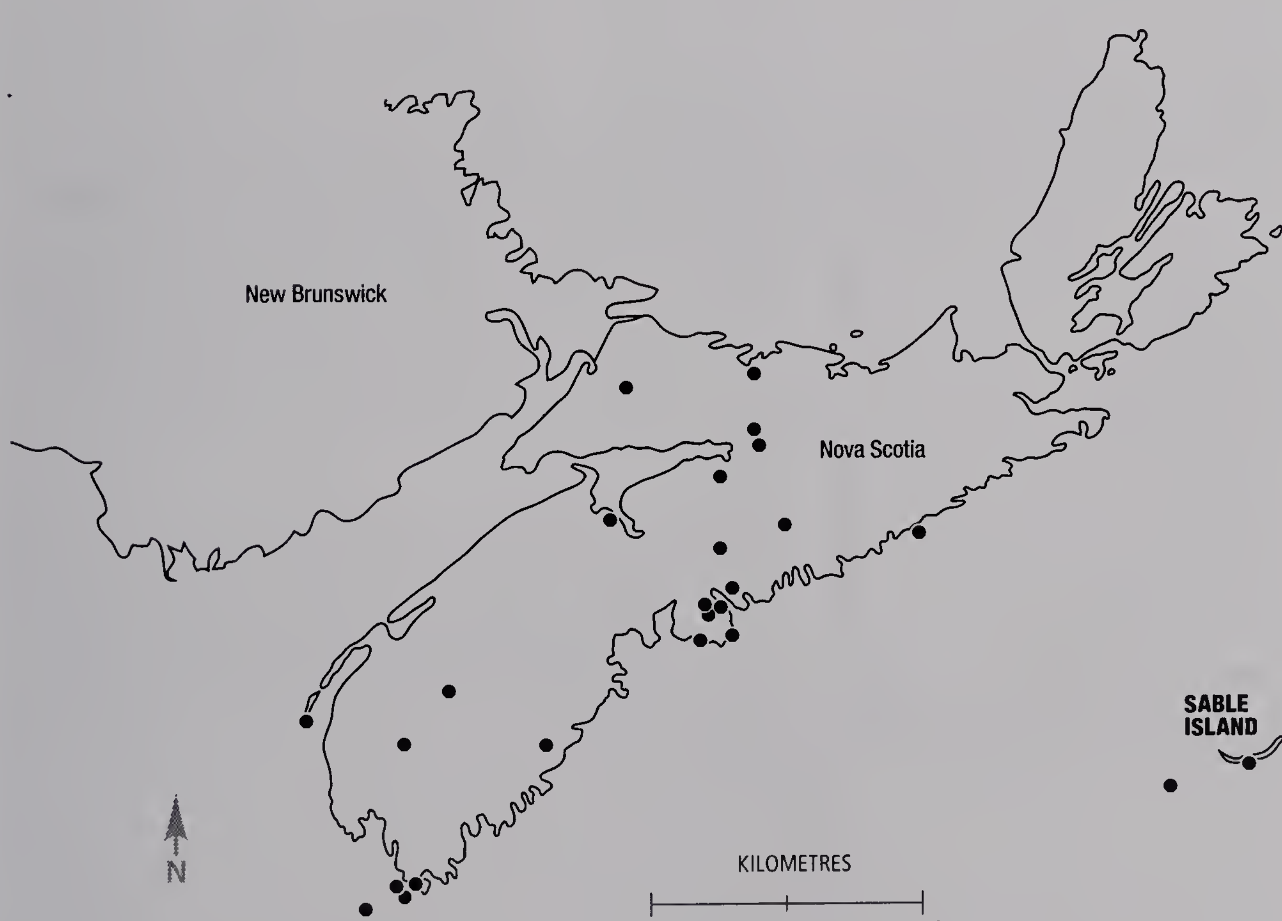

Fig 2 Hoary Bat records.

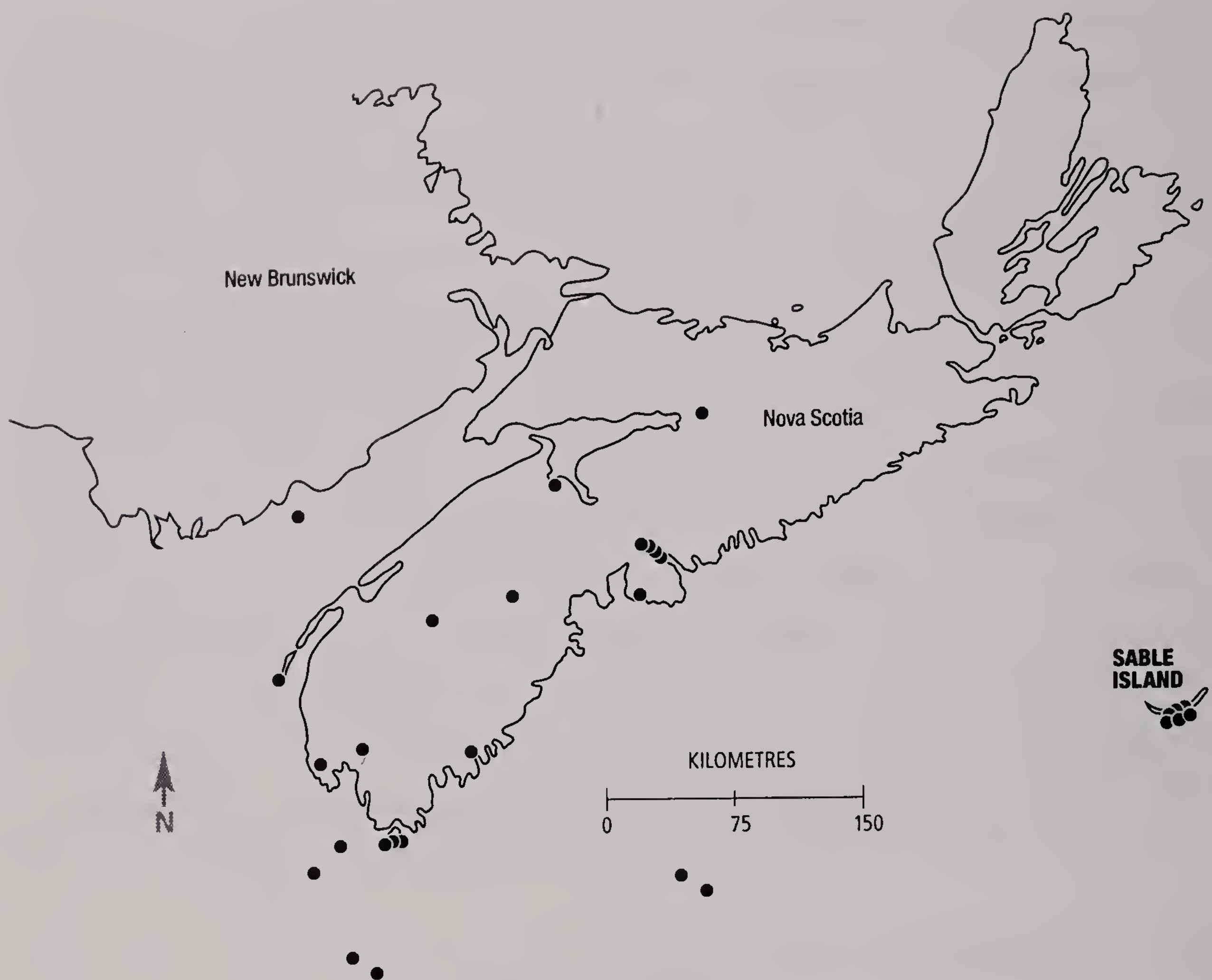

Fig 3 Red Bat records.

Table 1 Summary of records of tree bats in Nova Scotia

	Silver-haired	Hoary	Red	Total
Total records	11	25	29	65
Published	2	20	12	34
Unpublished	9	5	17	31
Record Type				
Specimen	2	7	7	16
Photo	6	2	7	15
Sight	3	5	10	18
Echolocation		11	4	15
Not recorded			1	1
Total individuals	**12**	**29[1]**	**34[1]**	**75**

[1] Includes echolocation records as one bat each

Table 2 Silver-haired Bat records for Nova Scotia

Number	Sex	Date	Location	Record	Reference/Observer
1	F	1950 Jul 10	Kejimkujik National Park	NSM 971.335.034, study skin	Bleakney 1965
1		1974 Jun 2	Kejimkujik National Park	Sight record	R. Burrows
1		1983 Aug 19	Yarmouth-Bar Harbour ferry, on rigging, daylight, 2:00 pm [1]	Sight record	A. Hebda
1		1996 Feb 14	Tennycape Mine, live, hibernating in shot-hole [2]	Sight record	Moseley 2007a,b
1	M	1999 May-Jun	SI [3], found in lumber pile	NSM 78021 photo	S. Miller
1		2002 Sep 14	SI, resting in Stevenson screen, morning, flew off	NSM 78022 photo	Z. Lucas
1	F	2004 Sep 5	Bon Portage Island, found alive, tested for rabies, negative	NSM 78023 photo	S. Boates
1	M	2005 Oct 26	SI, resting in Stevenson screen, night, released	NSM 78024 photo	Z. Lucas
2	M	2005 Dec 29	SI, live, grounded, morning, died in captivity	NSM 75899 & 75900, dry whole specimens & photos	Z. Lucas
1	M	2007 Sep 13	SI, entered building through open door, midnight, released	NSM 78025 photo	Z. Lucas
1		2010 May 2	Vessel, Lobster Bay, 6 km offshore	Photo (NS MCRD[4])	B. MacKenzie

[1] Remained on rigging until the ferry reached Bar Harbor, then flew away.
[2] This record of Silver-haired Bat is extremely north for hibernation, and should be considered a winter extralimital record.
[3] SI = Sable Island
[4] Nova Scotia Mammal Collection Record Database

Table 3 Hoary Bat records for Nova Scotia

Number	Sex	Date	Location	Record [1]	Reference/Observer
1		Before 1864	Sambro	Sight record	Gilpin 1867
1		Before 1864	Halifax harbour (taken from the foretopsail of a brigantine)	Sight record	Gilpin 1867
1	M	1909 Nov 9	City of Halifax	NSM 917.031.001, study skin	Bleakney 1965
1	M	1917 Oct 22	City of Dartmouth	NSM 917.030.001, study skin	Bleakney 1965
1	M	1971 Sep 2	Seal Island	NSM 971.329.001, study skin, skull	Maunder 1988
1	M	1980 Nov 2	City of Halifax	NSM 980.300.001, study skin, skull	Maunder 1988
1	F	1985 Oct 12	Bon Portage Island	Photo & MA3019	Maunder 1988
1		1987-1990 late Jul-Aug	Harbour Island	Sight record	M. O'Brien
2		1996 Aug 27	Bon Portage Island, night, full moon through thin overcast	Sight record	Scott & Hebda 2004
1	M	1996 Nov 11	Elmsdale, Hants County	NSM 75897, dry whole specimen	A. Hebda
1	M	1996 Dec 17	Duncan's Cove	NSM 10732, study skin	not recorded
4		1999 Aug 27	Bon Portage Island, night, full moon through fog	Sight record	Scott & Hebda 2004
		2001 Sep 5	Near river, Kejimkujik National Park, river site	Echolocation (2) [2]	Broders et al. 2003
		2001 Sep 11	Brier Island, coastal meadow	Echolocation (2)	Broders et al. 2003
		2003 Jun 16	Kings County, field	Echolocation (1)	Rockwell 2005
		2003 Jul 4	Queens County, river site	Echolocation (1)	Rockwell 2005
		2003 Aug 1	Truro area, Colchester County, clearing	Echolocation (4)	Rockwell 2005
		2003 Aug 1	Truro area, Colchester County, trail site	Echolocation (2)	Rockwell 2005
		2003 Aug 2	Cumberland County, river site	Echolocation (1)	Rockwell 2005
		2003 Aug 5	Tusket River System, Yarmouth County, river site	Echolocation (18)	Rockwell 2005
		2003 Aug 25	Halifax County, field	Echolocation (1)	Rockwell 2005
		2003 Aug 26	Waughs River, Tatamagouche, Colchester County, river site	Echolocation (6)	Rockwell 2005

Table 3 *Continued*

Number	Sex	Date	Location	Record [1]	Reference/Observer
		2003 Oct 8	Near entrance, Hayes Cave, Hants County	Echolocation (1)	Garroway 2004
1	M	2005 Nov 16	SI, live, grounded, morning, euthanized & tested, negative	NSM 78029 photo	Z. Lucas
1		2010 Sep 22	Vessel, Maersk Challenger, south of SI [3]	Photo (NS MCRD)	L. Williams

[1] A Hoary Bat on Sable Island reported in Rockwell 2005 is an error.
[2] Number of echolocation sequences recorded. Number of individuals represented by multiple echolocation recordings is unknown.
[3] First seen on board while the vessel was stationed at the RGIII platform (50 km west of Sable Island), and remained on the vessel for 6 days.

Table 4 Red Bat records for Nova Scotia

Number	Sex	Date	Location	Record	Reference/Observer
1	M	Between 1873-1899	Near the City of Halifax	NSM 973.331.001, Study skin, skull	Scott & Hebda 2004
1		1929 Aug 17	Vessel, 210 km southwest of Cape Sable NS, 42°, 66°	Not recorded	Norton 1930
1	F	1952 Oct 7	Vessel, 240 km south-southeast of Liverpool	Study skin No.1533 (Brown's collection)	Brown 1953
1	F	1969 mid-Oct	Vessel, 145 km south of Yarmouth, 42°30', 66°10'	ROM 57256, specimen	Peterson 1970
1	M	1976 Jul 21	SI, live & captured	NSM 976.032.000, study skin	Scott & Hebda 2004
1		1977 Oct 19	Kejimkujik National Park, daylight feeding, 3:30 pm	Sight record	P. Hope
1	M	1981 Jul	Vessel, between Digby NS & St John NB, live on deck	NSM 78030 photos	R. Swain
1	F	1983 Oct 8	Bon Portage Island	MA1848 (Acadia U), wet specimen	Maunder 1988
1	M	1995 autumn	Bon Portage Island, resting in a tree along path	Sight record	J. Czapalay
1	F	1998 Oct 12	City of Halifax, near harbour	NSM 75898 dry specimen & photos	Scott & Hebda 2004
1	M	1998 Oct 24	Vessel, 80 km off Pubnico	Sight record	E. d'Entremont
2		1999 Aug 27	Bon Portage Island, night, full moon through fog	Sight record	F. Scott
3	M	1999 Sep 27	Vessel, 240 km south of NS, live on deck, flew off	Sight record	USS Harry S Truman
1	F	1999 Nov 6	West Dover, daylight feeding, 4:00 pm	Sight record & photo (NS MCRD)	C. Majka
1	M	1999 Nov 20	Hemlock Ravine	Sight record	D. Kaufman
1	M	1999 Dec 6	Sable River, daylight travel, 4:00 pm	Sight record	D. Young
1	F	2001 Aug 4	In a horse-chestnut tree at Sand Beach, Yarmouth [1]	Photo (NS MCRD)	Broders et al. 2003
1		2001 Oct 26	Seal Island, feeding over pond during daylight	Sight record	B. Maybank
1	M	2002 Oct 8	SI, feeding around Station buildings, mid-day	NSM 78026 photo	Z. Lucas
1	M	2003 Jun 5	Vessel CERES container ship [2]	NSM 75096, wet specimen	D. Eddy
		2003 Jun 16	Queens County, field, <15 km from coast	Echolocation (1)	Rockwell 2005

Table 4 *Continued*

Number	Sex	Date	Location	Record	Reference/Observer
		2003 Aug 1	Colchester County, river site <15 km from coast	Echolocation (1)	Rockwell 2005
		2003 Aug 3	Lunenburg County, lake site <15 km from coast	Echolocation (1)	Rockwell 2005
		2003 Aug 4	Yarmouth County, field, <15 km from coast	Echolocation (1)	Rockwell 2005
2	M	2005 Oct 31	SI, feeding around Station buildings, early evening	Sight record	Z. Lucas
1	M	2005 Nov 15	SI, live, on ground in sparse leaf litter, mid-day, released [3]	NSM 78027 photo	Z. Lucas
1	M	2008 Nov 4	Brier Island, sleeping in tree, 11:30 am	NSM 78028 photo	J. Swift
2	M	2010 Sep 25	SI, feeding around Station buildings, early evening	NSM 78151 photo	Z. Lucas
1	M	2010 Oct 20	SI, daylight feeding around Station buildings, late afternoon	Sight record	Z. Lucas

[1] First confirmation of breeding for Nova Scotia. A female with four young were observed/photographed.
[2] The vessel had come from Europe and the bat was found when the vessel docked in Halifax.
[3] Possibly was one of the bats seen on Oct 31 at the Station.

specimens (including 12 at the Nova Scotia Museum of Natural History, Halifax; 2 at Acadia University, Wolfville; 1 at the Royal Ontario Museum, Toronto); 15 by photos; and 15 by echolocation recordings (Broders et al. 2003, Garroway 2004, Rockwell 2005). The remaining 18 are considered to be reliable sight records and/or reports. The earliest are of 2 Hoary Bats, 1 found in Halifax and 1 in Sambro some time before 1864 (Gilpin 1867), but 49% of records are from 2001 or later, due largely to research in mainland Nova Scotia (e.g., Broders et al. 2003, Garroway 2004, Rockwell 2005), and increased interest on Sable Island. Of 31 previously unpublished records, 11, all since 1999, are from Sable Island.

Month was recorded for 61 records (Table 5), and of these, 47 are from August through November, the autumn migration period for lasiurine bats. Only 9 were in summer (June-July) and 4 in winter (December-February). Of the 47 autumn records, 24 were coastal and 16 offshore, on Sable Island or at sea (Table 5). By species, 7 of 11 Silver-haired Bats, and 13 of 27 Red Bats, were recorded offshore compared with only 2 of 25 Hoary Bats. Of the 40 individual lasiurine bats for which sex was recorded, 31 were male (5 of 7 Silver-haired Bats, 7 of 8 Hoary Bats, and 19 of 25 Red Bats).

Sable Island Records

Useful information on Sable Island occurrences of lasiurine bats is more comprehensive than for other published records for Nova Scotia, and details provide additional insight into their behaviour. On the morning of September 14, 2002, a Silver-haired Bat was found in the Stevenson screen (a wooden box with louvered sides, approximately one meter above the ground, containing thermometers) at the Sable Island Station. The bat appeared to be sunning itself, with head and back exposed, as it rested on a slat in the east-facing (sunny side) of the screen. Later when that side fell into shade, the bat moved into the sunshine on the south side of the screen. The bat was gone by early evening and not seen there again. Occasionally, during the next few weeks, a solitary bat flew around the buildings at dusk but was not identified. On October 8, 2002, in late afternoon, a male Red Bat was seen flying, and apparently feeding, around buildings at the station. This bat was observed for about 30 minutes before it flew out of sight towards the freshwater ponds.

Table 5 Location and month of tree bat records in Nova Scotia.

a. Silver-haired Bat

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Feb	total
Inland		1	1						1	3
Coastal										0
Coastal Is					1					1
Sable Is		1			2	1		1		5
Vessel	1			1						2
total	**1**	**2**	**1**	**1**	**3**	**1**		**1**	**1**	**11**

b. Hoary Bat

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Feb	total
Inland				3	1	1	1			6
Coastal		1	1	3		1	2	1		9
Coastal Is				3	2	1				6
Sable Is							1			1
Vessel					1					1
total		**1**	**1**	**9**	**4**	**3**	**4**	**1**		**23**

Table 5 *Continued*

c. Red Bat

	May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Feb**	**total**
Inland						1				1
Coastal [1]		1		3		1	2	1		8
Coastal Is				1	1	2	1			5
Sable Is			1		1	3	1			6
Vessel		1	1	1	1	3				7
total		**2**	**2**	**5**	**3**	**10**	**4**	**1**		**27**

[1] Does not include the single breeding record of July-August 2001.

In 2005, all 3 lasiurine species were seen on the island. On the evening of October 25 2005, Hurricane Wilma passed 100 km south of Sable. During the afternoon and evening, winds gusted to 115 km/hr from the southeast, and backing to the east and northeast as the hurricane passed. The first bats were sighted a few days after the hurricane, and 1 to 5 individuals were seen feeding around station buildings every evening until mid-November. On one occasion 2 were identified as male Red Bats. During this same period several grounded bats were recovered. On October 26, 1 wet Silver-haired Bat was found in the Stevenson screen at the station during a night of heavy rain and temperatures of 10.4°C to 15.3°C. The bat was held indoors overnight, and flew off when released the following day. On November 15, a male Red Bat was captured at mid-day when it flew up from leaf litter roughly 2 km west of the station. It flew off when released after being photographed. The temperature during the previous night was 7.6°C to 12.8°C, and 10.0°C when the bat was captured and released. The single Hoary Bat from Sable was found on November 16, wet and torpid on open ground at the side of a cement walkway at the station. Overnight temperatures were 5.7°C to 8.4°C, and 7.1°C to 8.4°C in the morning when the bat was found. It was taken indoors and within a few hours, presumably after warming up, the bat became active. It was held for three weeks and fed an artificial diet. In captivity the bat was active and capable of flight, and ate regularly. The bat was returned to the mainland where it was weighed (27.6 g), euthanized and tested for rabies (negative). Two wet and grounded adult Silver-haired Bats were found at the Station on December 29. Overnight temperatures were 1.5°C to 4.5°C, and 3.0°C to 4.5°C during the morning when the bats were found clinging to a cement foundation. They were returned to the mainland and held for four weeks but died in captivity.

During September 2010, 1 to 2 bats were occasionally seen feeding around station buildings after dark. They were identified as Red Bats on September 25 when two males were captured after they hit a window and dropped to the ground. The bats were 'in a clinch' when they hit the glass, and may have been fighting over a prey item. One was held briefly for a photograph, and then released. On October 20, a single male Red Bat was feeding near a station building during late afternoon.

DISCUSSION

Normal Coastal Migration

Although it is well known that lasiurine bats migrate, the timing of these movements in North America is poorly understood (Cryan 2003, Nowak 1994). Cryan (2003) and Findley and Jones (1964) used museum records to examine seasonal movements and distributions of tree bats. Cryan (2003) found that records for each species occur beyond the usual summer range during late summer and early autumn. This expansion may be the result of mating activity or population increase after birth and nursing of young, or it may be associated with exploratory migration (Cryan 2003). Cryan (2003) also found that these 3 species occur along northern coastlines more in autumn than in spring. He suggested that this is associated with coastal navigation augmented by exploratory migration and increase in population size.

Some bats may travel with migratory birds, or use the same migratory routes along the Atlantic seaboard as do many birds (Bleakney 1965, Maunder 1988). Numerous observations, beginning in the late 1800s, of bats in late summer and autumn flying near, and/or landing on, vessels at sea, flying towards land from offshore, and flying along coastlines, have been recorded for southwest Nova Scotia through to the northeast USA (Allen 1939, Bleakney 1965, Brown 1953, Carter 1950, Griffin 1940, Mackiewicz & Backus 1956, Miller 1897, Norton 1930, Peterson 1970, Thomas 1921). The number reported ranges from a single bat to hundreds, and in many instances the species were identified as Silver-haired, Hoary, and Red bats. Bleakney (1965) reports information from Brier Island fishermen and suggests that their observations may reflect an autumn migration of bats out of Nova Scotia. Bleakney writes "Digby Neck, Long Island and Brier Island form a long narrow peninsula opposite the coast of Maine. It is known that many Nova Scotia landbirds funnel to the tip of this peninsula in late summer and gather in flocks on Brier Island where they apparently await favourable weather before making the crossing to the United States mainland." Further, Broders et al. (2003) note that if there are any lasiurine bats moving through Nova Scotia in autumn, the northeast-southwest orientation of the province might guide bat migration towards southwest Nova Scotia, resulting in a concentration of bats passing through coastal islands in that region. This is supported by the autumn lasiurine bat records for Nova Scotia reviewed here, mostly from coastal and offshore locations. There may be some bias towards a higher number of records in these locations because bats might be more readily sighted in relatively open coastal and offshore areas. Nevertheless, these observations suggest that most of these lasiurine bats are not extralimital. However, some, like the "Wilma" bats on Sable Island, could have been displaced by weather from southern parts of the species' range.

We suggest that the tendency of lasiurine bats to move northwards through the continent during spring migration, and coastward then southward in autumn is likely based on temperature and food availability. During autumn, inland areas cool more rapidly than coastal areas. Thus bats moving towards the coast would be moving into warmer areas where flying insect prey is available later into the season, and also where milder temperatures may reduce energy requirements for normal activities such as arousal, feeding, and seasonal movements.

In Hoary Bat populations there is some segregation of sexes during summer, with males occurring primarily in mountainous regions of western North America, and females in eastern areas, although scattered records of male Hoary Bats in more eastern areas during summer may be young-of-the-year (Cryan 2003, Findley & Jones 1964) and some adult males may also occur in the east. Cryan (2003) suggests that the high proportion of male Red Bat records in northern regions during late autumn and winter indicates that males may not migrate as far south as females. This is consistent with the Nova Scotia observations presented here in which males predominate in all 3 species.

Offshore Occurrences

Van Gelder and Wingate (1961) note a consistent correlation between the occurrences of waves of bats and waves of birds in Bermuda during the fall migration season, with the largest influxes from September to late November. They suggested that both bats and birds are strays wind-drifted off the American coast while migrating. Hayman (1959) notes that 2 separate Hoary Bats found in Iceland in October may also have been blown off course by a storm (suggested by the occurrence of storm-blown North American birds in Iceland), and that in at least 1 case, this was supported by weather patterns. Maunder (1988) notes that migratory lasiurine bats in Atlantic Canada may simply be fall wanderers, but it seems more likely that at least some of the northeastern records, especially those recorded after mid-September, are the result of "drift migration". McLaren (1981) suggests that "drift migration" is responsible for unusual autumn records of birds in eastern Canada and the New England States, and describes "an extraordinary convergence of air masses and wind streamlines" in the Nova Scotia region during both spring and autumn landbird migrations. He also notes that during early autumn winds from the mid-western to southeastern USA, converge on Nova Scotia and continue on out to sea. McLaren et al. (2006) examined the occurrence of avian transatlantic vagrants from eastern North America and the meteorological systems associated with species composition and distribution. Their analyses supported earlier suggestions that many vagrant North American landbirds occurring in Britain and Ireland in autumn are likely displaced downwind across the North Atlantic after becoming entrained in strong southwest winds in warm sectors ahead of cold fronts along the eastern seaboard of North America.

Migratory lasiurine bats found in offshore areas of Nova Scotia may be individuals caught up in the same weather patterns. Of the 47 lasiurine bats recorded in Nova Scotia during August through November, 24 occurred along the mainland coast and on coastal islands, and 16 occurred on vessels and at Sable Island. The latter may have been individuals displaced beyond what is likely a normal coastal migration route along the Atlantic coast of Nova Scotia and northeastern USA.

Since the 1970s, there have been occasional sightings of bats on Sable Island. The first confirmed lasiurine bat record for the island was a Red Bat from 1976. Subsequently several live individuals were dislodged from piles of lumber during spring maintenance activities, and some were seen feeding around the Station buildings during late afternoon or dusk in autumn, however most were not identified (e.g., 4 individuals feeding near the Station after dusk between October 30 and November 8, 2006). No additional records were kept until autumn 2002 when a Red Bat and a Silver-haired Bat were photographed at the Sable Station.

During autumn 2005, there was an increase in bat sightings following Hurricane Wilma. This coincided with the appearance of large numbers of rare or extraseasonal birds in the wake of the hurricane that generated a great deal of interest in Atlantic Canada (McLaren & Mills 2006). Species sighted on the mainland and on Sable Island included *Sterna caspia* (Caspian Tern), *S. maxima* (Royal Tern), *S. sandvicensis* (Sandwich Tern) and *S. forsteri* (Forster's Tern), and *Coccyzus americanus* (Yellow-billed Cuckoo). On Sable, as in mainland

Nova Scotia and Cape Breton, extralimital or extraseasonal sightings of birds are sometimes attributed to the high winds of gales, tropical storms and hurricanes, although McLaren (1981) notes that the role of weather in displacing landbird migrants is generally through geostrophic wind patterns rather than through storms. It is possible that the weather systems that brought the many southern and/or migratory birds to Sable Island in autumn 2005 also brought the lasiurine bats. Thus while lasiurine bats found along the coast of mainland Nova Scotia and on coastal islands would be within a normal migratory corridor for these species, bats on Sable Island, and sighted well offshore flying or resting on vessels, are likely animals displaced by weather, including strong offshore winds. This may be an important factor in the much lower occurrence of Hoary Bats found offshore. Hoary Bats are more than twice the size of Silver-haired Bats and Red Bats, and thus probably stronger fliers, less prone to being blown offshore, or more likely get back on course after being displaced. However, 6 of the 12 individual Silver-haired Bats were found on Sable Island. They are the smallest of the lasiurine bat species, and may be more vulnerable displacement by strong winds.

CONCLUSIONS

Although no comprehensive surveys for lasiurine bats have been conducted in Nova Scotia, extensive echolocation surveys have suggested that there are no significant populations of these species in the Province. While the records considered here are largely from incidental observations, the seasonality of these records suggests that most occurrences of these species in Nova Scotia are likely not extralimital. Instead they may be part of normal migratory movements toward coastal areas and then southward to overwintering areas. The lasiurine bats involved in these movements may comprise animals migrating coastward from other regions in eastern Canada and/or individuals from small breeding populations in Nova Scotia.

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CAN WE STOP THE ATLANTIC LOBSTER FISHERY GOING THE WAY OF NEWFOUNDLAND'S ATLANTIC COD? A PERSPECTIVE

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ABSTRACT

The cod and lobster fisheries of Atlantic Canada are managed in very different ways. Regulatory policy for Atlantic cod has traditionally been based on population or biomass measurements, something that has never been done for the management of Atlantic Canada's lobster. While these traditional methods differ, an alternate logical or analytic approach to management is perhaps one way that sound and rational fisheries can be managed. The recommendations that follow derive from asking: can we learn analytic lessons from the collapse of Atlantic cod that might allow us to avoid a similar collapse in Atlantic lobster? A landings-per-unit-of-effort (LPUE) index could be constructed for the lobster industry that would provide a continuous trend over time. This trend would form an effective feedback model; a declining trend over time would indicate the goal of sustainability was in jeopardy, whereas a level or increasing trend over time would indicate that the industry was maintaining its sustainability. Crucially, an LPUE index should only be used as an argument *a posteriori* involving feedback in the form of trends. This index should never be used as an argument *a priori* to estimate lobster abundance or lobster biomass.

INTRODUCTION

The Newfoundland fishery for Atlantic cod (*Gadus morhua* Linnaeus 1758) was once the largest and most productive cod fishery in the world (McGrath, 1911; Thompson, 1943). In the early 1990s, this fishery suffered a major collapse that has become one of the world's most prominent case studies of failure in fisheries management (Charles, 1997). This paper attempts to answer the question: can we learn lessons from the collapse of Newfoundland's Atlantic cod that can be used to avoid a similar collapse in Atlantic Canada's lobster (*Homarus americanus* H. Milne-Edwards, 1837) fishery? Newfoundland is not the only jurisdiction that has suffered a shortage of cod. For example, Britain ten years ago had an annual demand for cod of 170,000 metric tonnes (MT), well above the British fishing fleet's EU quota for North Sea cod which in 2002 was just under 34,000 MT. By contrast, over the same period Iceland and Norway both had cod fisheries that were in excellent condition with 'fishing quotas of both countries fluctuating only slightly from year to year, around an average of 190,000 MT'(Globefish, 2003).

Can we learn lessons from Iceland's successful management of it's cod fishery, lessons that can be applied to Atlantic Canada's lobster fishery? Perhaps if we make a comparative study of successful (Iceland and Norway) and unsuccessful (Canada and Britain) cod fisheries, we might gain some insight as to how lobster fisheries could be better managed? This would doubtless be of interest but it is not the approach taken in this discussion paper. Here, I do not look for factual answers based on a comparative analysis; rather, I look for analytic answers based on a logical analysis. Analytic answers are of particular interest since they apply to the sound and rational management of fisheries world-wide. Similar analytic methods could be used for management of Canada's, Iceland's, Britain's and Norway's cod fisheries and for the Atlantic Canada lobster fishery.

1. Traditional differences between the management of cod and lobster

The applied science of managing Atlantic Canada's ground fish stocks has traditionally involved the use of catch limits based on population abundance, often in the form of biomass measurements. Biomass measurements, however, have never been part of Atlantic Canada's lobster management plans. Perhaps it is just because these plans have not involved biomass based advice such as: 'The maximum sustainable yield (MSY) of lobster in LFA 33 is 2 thousand MT', that lobster stocks have not yet 'gone the way of the cod'. To understand why biomass based advice has been so devastating for ground fish stocks, we need to understand why a decision cannot be derived solely from facts or data. Nobody knows how many lobsters are on the sea bottom but, even if that were known, a management decision should not be obtained from this information. Decisions still have to be taken. A failure to understand this fact would mean that the mistakes made with the management of the Newfoundland cod would be repeated in the management of Atlantic lobster.

2. How are management decisions to be based on scientific fact?

Regulatory management policies for a fishery are made by a collection of people - the decision makers. In the management of an Atlantic lobster fishery, these decision makers are members of a Lobster Advisory Committee together with the Regional Director General of Canada's Department of Fisheries and Oceans (DFO). No one claims that laws enacted by the decision makers of a parliament are derived from data; why should the policies for fisheries management be any different? That is not to say that scientific advice based on scientific fact is not one of the important inputs the decision makers seek in order to help them construct the policies needed to manage a fishery. But the connection between decision and fact must be a sound one. An example of the sound managerial use of scientific fact is to be found in the logical analysis of engineering.

The engineer makes decisions all the time and this is done by trial and error; that is, a decision is taken (trial) and factual feedback is obtained by 'seeing what happens' (error elimination). We can represent a fishery version of this engineering decision making by the analytic problem solving schemata provided by the philosopher of science, Karl Popper (1979), as:

$$P_1 \rightarrow TD \rightarrow EE \rightarrow P_2 \rightarrow TD \rightarrow EE \ldots etc. \qquad (1)$$

where P_1 = the initial problems including the goal to be pursued (How do we obtain a sustainable fishery? How do we obtain further employment for our fish processors?); TD = tentative decision, a tentative policy that reflects the chosen goal; EE = error elimination, objective feedback by which the effectiveness of the policy is assessed; and P_2 = the new problems and consequences that arise as the result of the decision taken.

3. How are management decisions to be guided by universal laws?

Under an analytic or logical view of the scientific enterprise, the laws, models, or theories of fisheries science apply world-wide and involve a falsifiable view of science (Corkett, 2009). A neoclassical view of bioeconomics meets this logical requirement. Rights-based models, for example, do not describe an actual world occupied by fallible people such as you and me, but describe a situation logic animated by 'agents' or 'actors', players whose rationality gives the model its great flexibility. It is this flexibility or simplicity that allows a rights-based model to explain the prejudicial nature of derby fishing - the rush for the fish. Just as the laws of physics apply universally (i.e. apply world-wide) and set limits on what can be accomplished by the engineer (i.e. show what cannot be done), the logical models of fisheries economics give negative advice that universally explains (in this case, explains for both cod and lobster harvesting) what cannot be accomplished by regulatory policy. For example:

> One cannot obtain a sustainable cod and lobster fishery (goal) while at the same time providing unlimited jobs for cod and lobster fishermen (social objective).
>
> One cannot obtain unlimited jobs for cod and lobster fishermen (goal) without using tax payer's money (concomitant effect).
>
> One cannot obtain a sustainable cod and lobster fishery (goal) without controlling the prejudicial behavior of cod and lobster fishing derbies (unintended consequence).
>
> One cannot control cod and lobster fishing derbies (goal) without assigning property rights (for example, by the use of Individual Transferable Quotas [ITQs]).

The point is not that these examples are necessarily true or particularly good, and I am certainly not advocating the adoption of ITQs for the lobster fishery. The important point is that the examples illustrate how, as in the physical sciences, universal advice in the social sciences takes the analytic form of a politically neutral negative argument: If you choose to accept goal or objective A, you cannot at the same time achieve goal or objective B.

If you wish to achieve goal A, you have to control unintended consequence B; or you cannot achieve goal A without also controlling concomitant effect B.

From a logical point of view, a fisheries economic tradition (such as the use of ITQs in managing Iceland's cod fishery) involves negative apolitical advice, advice that explains what you should not do. Limitations on and the potential consequences of options are presented to the decision makers by fishery economists, but the decisions are not derived from the science. The decisions and the responsibility that goes with these decisions remain entirely in the hands of the decision makers.

4. Rational management of a lobster fishery

Decisions for the rational and sound management of any lobster fishery require the institutional and structural support of a dual modeled system, comprised of two parts:

(i) a universal model of fishery economics that provides an understanding of the prejudicial nature of derby fishing (see section 3). This model is applicable to all fisheries (thus applying to both cod and lobster) and provides politically neutral, negative scientific advice of the form: 'You cannot have a sustainable cod or lobster fishery (goal) unless you control fishing effort and overcapacity (concomitant effects)'.

(ii) a feedback model of the lobster fishery in question that informs us of the effectiveness of the regulatory policies put in place by the decision makers (see section 2). Feedback is used to assess the effectiveness of the chosen policy in meeting the goal of a sustainable fishery. The feedback model applies only to the lobster fishery in question (i.e. it is not universal).

5. Where does biomass modeling go so wrong?

The scientists at Canada's DFO sometimes complain that the politicians do not listen to their advice, and indeed there is some truth to this. But from a logical point of view, it is not at all surprising that DFO advice is not necessarily adhered to; since this advice itself is not politically neutral, there is no reason why other policy or political considerations should not override it. Why should the decision makers not strive to reduce unemployment (goal) by favoring a total allowable catch (TAC) of, say, 30 million MT instead of 20 million MT? Or why should they not strive to raise the standard of decision making by applying the precautionary principle and setting a TAC of, say, 10 million MT or should it be 5 million MT?

Unlike the feedback model (1, above) where the empirical evidence provides feedback after the decision has been taken (a type of argument referred to as *a posteriori*), DFO fisheries scientists collect data that is used to form biomass models, that in turn provide advice for the decision to be taken (a type of argument referred to as *a priori*), as:

database → biomass model → prediction → decision (2)

Clearly, if there are uncertainties in data quality and quantity, the scientific advice will be uncertain – a situation sometimes crudely summarized as: 'Garbage in: garbage out'. The prediction or advice derived from schema (2) above deploys an argument *a priori* and is referred to as political advice since, unlike economic advice (see section 3), it is not neutral in policy terms. It describes a political or policy decision to be taken. For example: 'The TAC should be 20 MT' or 'The MSY is 30 million MT'. The reason why an *a priori* argument is so damaging is that it sets the emphasis in decision making in entirely the wrong direction. Instead of understanding that all decisions have to be taken, we are now led to believe that decisions can be reduced to facts. Better decisions require better facts; find the 'better facts' and we have the 'better decisions'. Instead, it is a matter of elementary logic that decisions together with goals (such as sustainability) and standards (such as the precautionary principle) cannot be produced from, or be reduced to, facts or data. Decisions, goals and standards reflect the values of the proponents and form part of the problem situation requiring solution (P_1, P_2... in [1] of section 2). Solutions require ingenious and creative policies, not accurate or 'certain' measurements of biomass! From an ethical perspective, the hope of the fisheries scientist that the establishment of norms such as sustainability can be based on an *a priori* argument results in a monism of scientific ethics (Corkett, 2005). An example of a fisheries monism would be the widespread use of reference points in a naïve attempt to guide the development of a sustainable fishery (Beddington *et al*., 2007, their figure 1).

CONCLUDING COMMENTS

The management decisions of Atlantic Canada's commercial ground fisheries have been based on predictions derived from data-based models that combine within themselves the features of the dual model system advocated in section 4 (above). Unlike this dual system, the data-based models used by Canada's DFO (i) are derived from data and so are not universal (they cannot possibly apply to both cod and lobster); (ii) are models of fish populations and not fishing behavior and so provide no understanding of the prejudicial nature of derby fishing; and (iii) advise the decision makers what to do by describing a policy to be adopted, rather than by taking a politically neutral position that sets limits to what can be done.

The ITQs were introduced into Iceland's cod fishery in 1984 (Einarsson, 2001). It is very easy to find objections to the ITQ system. For example, detractors point out that the smaller fishing boats are bought out, resulting in the larger boat owners and processors owning much of the available quota. If the goal is to maintain high employment for fishermen and processors, then one should never even consider introducing a management system involving quota ownership. If the goal, however, is to establish and maintain a sustainable fishery, the wisdom of involving market forces in both reducing and controlling overcapacity will be appreciated. The supporters of the ITQ system point out that, under this system of economic benefit, vessel owners have an incentive to buy out one another, a form of fleet downsizing that, contrary to the usual practice, reduces fishing overcapacity without involving government money. Iceland's successful management of its cod fishery, using rights-based models in the form of ITQs, is an example of a management tradition and regime that has effectively controlled its effort levels and overcapacity. It will come as no surprise that similarly, a sustainable lobster fishery has to contain its effort and fishing capacity as advocated in the universal scientific advice of section 4 (i), as: 'One cannot have a sustainable cod or lobster fishery (goal) unless you control fishing effort and overcapacity (concomitant effects)'.

RECOMMENDATIONS

Our ability to maintain a sustainable lobster fishery into the distant future depends on learning from those mistakes of method that have allowed the development of a gross overcapacity in our cod fisheries (Charles 1997). The basic mistake in managing Atlantic groundfish has been the use of biomass based advice to tell the decision makers which policy should be adopted (see [2] section 5), rather than using a feedback model to assess if the policy decided upon has in fact enabled the fishery to meet the stated goal being pursued (see [1] section 2).

Lobster management has a long history of effort control; in Canada, some regulatory measures, such as fishing seasons and size limits, have been in place for more than eighty years (FRCC, 2007). The health of this industry has been monitored traditionally through the use of landings. This method, however, needs structural improvement in the form of a more effective feedback model (see section 2). For example, beginning in the mid-1970s, annual landings in the Atlantic region underwent a sustained increase from about 15,000 MT to a peak of 48,000 MT in 1991 (FRCC, 2007). Did the increased landings indicate increases in lobster abundance or was it a reflection of increased effort levels or was it a bit of both? Only a LPUE index (also called a catch-per-unit-of-effort [CPUE]) can answer this kind of question.

A LPUE index should be constructed for the lobster industry, hence providing a continuous trend over time. This trend would form an effective feedback model; a declining trend over time would indicate the goal of sustainability was in jeopardy, whereas a level or increasing trend over time would indicate that the industry was maintaining its sustainability.

More importantly, if it is determined that new regulatory policies are required to reduce effort levels and avoid overcapacity, a failure of the LPUE index to increase over time would indicate that the regulations were not effective; additional and more effective regulations would be needed.

Crucially, a LPUE index is only to be used as an argument *a posteriori* involving feedback in the form of trends. This index should never be used as an argument *a priori* to estimate lobster abundance or lobster biomass. Every care must be taken not to repeat the mistakes made by Canada's DFO in managing the stocks of Atlantic groundfish, methodological mistakes that many hold responsible for the collapse of the Newfoundland Atlantic cod stock by the 1990's, with its severe economic, ecological and social impacts.

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LATE BLOOMING OF PLANTS FROM NORTHERN NOVA SCOTIA: RESPONSES TO A MILD FALL AND WINTER*

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ABSTRACT

Over 1400 flowering records of 135 species were recorded from over 125 visits to more than 20 sites in Antigonish County, Nova Scotia from November 2005 to January 2006, when the growing season is normally over. The species identified were primarily herbaceous dicots; however, there were four species of woody plants (*Cornus sericea, Spiraea latifolia, Symphoricarpos albus* and *Salix* sp.) and one monocot (*Allium schoenoprasum*). The number of species flowering declined linearly as fall progressed, as did the amount of flowering for each species. Nevertheless, over 40 species were still in flower in early December, and over 20 species flowered in January. The final flowering date was 21 January, when ten species were found. This work builds on a previous study in 2001, when 93 species were recorded in flower during November-December. In addition to the 30% increase in recorded species in 2005, almost 50% of the species found in 2005 were not recorded in 2001. This study provides an expanded baseline against which changes in flowering phenology can be evaluated with respect to subsequent regional climate change.

Key Words: Antigonish, flowering, Nova Scotia, phenology, climate change

And through this distemperature we see the seasons alter:
hoary-headed frosts fall in the fresh lap of the crimson rose.
– *A Midsummer Night's Dream, W. Shakespeare*

INTRODUCTION

There is a general consensus that climate warming has occurred on a global scale, and that mean air temperature has increased 0.5-0.6°C during the twentieth century (e.g., Houghton et al. 2001, Menzel et al. 2005, McCarty 2001, Schlelp et al. 2009, Walther et al. 1995a,b,c). In

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many parts of the world the impact or 'fingerprint' of global warming has been recorded in diverse biological systems (IPPC 2007, see Core Writing Team et al. 2007). These biological responses include the timing of bird and insect migrations, amphibian breeding, and various phenomena associated with plant phenology, e.g., changes in timing of leaf bud burst or leaf colour or the timing of flowering (Hughes 2000, Parmesan 2007, Root et al. 2003, Walther 2002, 2004, Walther et al. 2001, 2005a).

Changes in colonization patterns along environmental gradients have been a useful fingerprint of climate change (e.g. Walther et al. 2005b). Changes in the timing of flowering, especially earlier spring flowering, have also been a key indicator (e.g., Abu-Asab et al. 2001, Fitter & Fitter 2002, Gu et al. 2008, Houle 2007, Miller-Rushing & Primack 2008, Thórhallsdóttir 1998). Menzel (2002) argues that aspects of plant phenology are important biological indicators of climate change and form an excellent proxy for temperature.

Published studies take several approaches to examining phenological responses to climate. Most studies are observational and look for correlated changes in plant and animal behaviour with changing environment (e.g., Menzel & Fabian 1999); relatively fewer are experimental and manipulate climate in the field to examine responses of individual species (e.g., Dunne et al. 2003, Post et al. 2008). Some studies use remote sensing of vegetation to quantify phenological changes as a result of climate forcing (Badeck et al. 2005, White et al. 2005).

Although prolongation of the growing season in the fall has been reported, this extension is considered much less significant than early spring growth and flowering (Hovenden et al. 2008, Menzel 2003, Menzel & Fabian 1999, Menzel et al. 2001, Walther 2002, Thakur et al. 2008). The emphasis on the spring arises primarily because climate change is thought to have its greatest impact on winter and spring temperatures, and because fall responses reflect factors in addition to temperature to a greater extent than do spring responses (Sparks & Menzel 2002; Walther 2003). In addition, Schaber & Badeck (2005) and Menzel (2003) report little or no change in the timing of fall leaf colouration, while the growing season was extended by 10 days as a consequence of earlier springs. In Europe and North America, climate warming in the late twentieth century has advanced spring phenology by 1.2-3.8 days/decade, whereas changes in the fall are on the order of 0.3-1.6 days/decade (Menzel 2002, Menzel et al. 2001).

The smaller apparent changes in fall have resulted in much less research emphasis on impacts of changing climate on fall events. For species with indeterminate flowering, such as many ruderal annuals that flower until they are killed by frost, an extension of the flowering season in fall could lead to important increases in reproductive success, if pollinating insects are still active or species are self pollinating. Extensions of the fall growing season may be particularly important in the Canadian Maritime Provinces, where extended warm periods may follow intermittent frosts. Post et al. (2008) argue that changes in the entire life history of species in response to climate change, including reproduction, should be examined in an integrative way. Consequently, there is a need for more empirical data on fall phenomena associated with plant phenology and how this might be affected by climate change.

There is no long-term database of systematically collected observations on fall flowering in Nova Scotia. There is, however, an excellent provincial flora (Roland & Smith 1969, revised by Zinck 1998) with generalized accounts of flowering times for each species, largely based on observations during the 1940s to the1960s. In addition, there are extensive herbarium holdings at Acadia University (ACAD), Nova Scotia Museum (NSPM), Nova Scotia Agricultural College (NSAC) and St. Francis Xavier University (STFX) that reflect both historical and more recent collections. Despite their limitations, regional herbaria provide a useful background against which changes in flowering phenology can be evaluated (e.g., Lavoie & Lachance 2006, Miller-Rushing et al. 2006).

During the course of a particularly warm fall in 2001, robust flowering was apparent in the local flora at the beginning of November. The identity and persistence of plants in flower were recorded at a number of local sites to the end of flowering in mid-December (Taylor & Garbary 2003). These observations provided the latest reported flowering times in Nova Scotia for virtually all the species identified, and extended the limit of flowering by an average of 45 days. The fall of 2005 was another exceptionally warm season, highlighted by the absence of frost during September and October and conspicuously robust flowering of wild plants. A second survey of late-fall flowering times in Antigonish County, from November 2005 to January 2006, was therefore undertaken to compare against the 2001 survey. Specifically, our objectives were (1) to compare late flowering phenology in 2005 with those reported in the flora of Nova Scotia (Roland 1998) and herbarium records in the largest provincial herbarium (ACAD);

(2) to compare late-fall flowering in 2001 and 2005 to determine if the flowering season had lengthened or the flowering species had changed over the four-year period; and (3) to determine whether differences in flowering phenology between 2001 and 2005 were congruent with evidence of local climate change in the fall since the 1950s.

MATERIALS AND METHODS

To assess the prevalence of late fall flowering, 21 sites in Antigonish County, Nova Scotia, were visited two or more times at approximately 10-day intervals beginning 1 November 2005, until flowering ceased

Table 1 Primary collecting sites in Antigonish Town and County and the habitats examined regularly from November 2005 to January 2006. Sites visited in at least two, ten-day periods.

Site name and coordinates	Habitats
Hawthorne Street (45°37.5'N, 62°00.0'W)	backyards, old field, lawns, garden plots; ~0.5 km walk
St. Andrews Street (45°37.0'N, 61°58.5'W)	waste ground and soil banks surrounding building lot with unfinished house foundation; 100 m walk
Williams Point (45°37.2'N, 61°57.5'W)	waste ground and streamside; ditches and garden plots along 3 km drive
Lower West River Road (45°36.1'N, 62°00.2'W)	ditches, roadside banks and fields along 5 km road
South Side Harbour Road (45°37.7'N, 61°53.8'W)	ditches and roadside fields and garden plots along 10 km drive
Pomquet Harbour (45°38.8'N, 61°50.1'W)	fields, ditches, roadside, salt marsh; 5 km drive with several stops
Arisaig Provincial Park (45°45.3'N, 62°10.0'W)	roadside, ditches and regenerating boreal forest; 0.25 km walk
'Liquor Lane' and StFX Campus (45°37.0'N, 61°59.5'W)	flower beds, grassy banks, waste ground, margins of conifer stand; ~1 km walk
Kells Construction, Antigonish Municipal Facility (45°37.6'N, 61°59.5'W)	waste ground, river bank, construction waste piles, soil mounds; ~1 km walk
Antigonish Landing (45°38.0'N, 61°57.7'W)	waste ground, soil banks, margins of marshy areas, field; ~ 0.5 km walk
Tera Tory Drive (45°39.6'N, 61°54.7'W)	roadside, ditches, lawns, garden plots; 2 km drive

Table 1 *Continued*

Site name and coordinates	Habitats
Seabright Road (45°40.2'N, 61°57.6)	roadside and ditches, corn field, waste ground around barn construction site, margins of boreal forest; 2 km drive
Beech Hill Road (45°36.9'N, 61°58.3'W)	waste ground, muddy banks, gravel surfaces; 5 km drive
Whidden's Camp Ground (45°37.3'N, 61°59.9'W)	grass field and stream banks; waste ground at margin of parking lots; 0.5 km walk
Mount Cameron (45°37.8'N, 61°58.5'W)	grassy banks, old field, gravel surfaces, garden plots, soil mounds and around housing construction sites; 0.5 km walk
Main Street, opposite Hospital (45°37.7'N, 61°58.8'W)	large building lot consisting of waste ground and fine gravel with numerous soil mounds and bare banks; 0.25 km walk
Archibalds Point Road (45°40.8'N, 61°54.6'W)	roadside and ditches, garden plots, margin of boreal forest, disturbed ground at building site; 1 km drive
Antigonish Mall (45°37.1'N, 61°58.9'W)	waste ground and soil heaps beside parking lot, farmer's field, 0.5 km walk
Adam Street (45°37.5'N, 61°58.7'W)	waste ground around commercial buildings and industrial sites, small garden plot; 0.5 km walk

in late January (Table 1). The 31st of December and January were assigned to the final period in each month (i.e., they were 11 days long). A number of additional sites were visited once, for a total of over 125 site-time combinations. All sites were located within 30 km of the Town of Antigonish. Except for occasional forays inland to St. Andrews (45°32.8'N, 61°53.5'W) and Glen Alpine (45°28.8'N, 62°00.6'W), all sites were within 5 km of salt water. Latitude and longitude for each site were determined with a hand-held global positioning unit (Garmin GPS 12, Garmin Corp., Olathe, Kansas) or calculated from the Nova Scotia Atlas (Anonymous 2001) with values rounded to the nearest 0.1'. All sites were at low elevation, mostly < 20 m and all < 75 m above sea level. Although some sites were revisited within the same 10-day period, only new-found species for that collection period were counted as additions to the list, regardless of the number of visits. Some sites were visited only once or a few times during the study because of logistic constraints or the occurrence of only a few species in flower. At each site, a complete list of species in bloom was made during a 15-120 min excursion with one or two observers.

At least one specimen of each species was collected and preserved. Vouchers were deposited in STFX. Nomenclature and species authorities follow Roland (1998) and are given in Appendix 1.

The number of days that flowering was lengthened was calculated with reference to the latest flowering period cited by Roland (1998), with the last day of the cited month being scored as within the flowering period. Furthermore, herbarium records at ACAD, NSAC and NSPM were examined, and the latest flowering time among these specimens was used as the reference point for counting flowering extension when this was later than that from Roland (see Appendix 1). Records in the three herbaria were examined for the Taylor & Garbary (2003) study; only records in ACAD (the largest regional herbarium, Holmgren and Holmgren 1998) were re-evaluated for the current study. Plants were considered in blossom if a single flower was present in which the petals retained their natural colour and the pistils or stamens remained intact. Typically, multiple plants, each with multiple flowers, were present at a given site. Inconspicuous flowers (e.g. *Chenopodium album*) were dissected under a stereomicroscope to ensure that appropriate organs were present before including the species in the list of actively flowering species. When flowering apparently ended in 2005 for a given species earlier than in 2001, this was recorded as a number of negative days in the calculation of the overall average for the study (see Appendix 1). This mitigated potential exaggeration of flowering extension times in 2005 relative to 2001.

To determine if late flowering was consistent with evidence of climate change, climate data from two weather stations in Antigonish County, at Collegeville (45°28'N, 62°1'W, 1950-2005) and South Side Harbour (45°37'N, 61°54'W, 1997-2005) were obtained by downloading data from the National Climate Data and Information Archive of Environment Canada (http://climate.weatheroffice.ec.gc.ca). South Side Harbour is close to Antigonish Harbour and 7 km from the Town of Antigonish; Collegeville is 25 km inland. Only the Collegeville station has sufficient data to have established 30-year climate normals (1971-2000). Antigonish County falls into plant hardiness zone 5B of Agriculture Canada (http://sis.agr.gc.ca/cansis/nsdb/climate/ hardiness/intro.html), in which harsh winters kill non-hardy species (see Davis & Browne 1997 for regional climate summary).

The relationship between numbers of species in flower during each ten-day period and weather variables during the fall and early winter of 2005-2006 was explored using linear correlations. Mean maximum, minimum and overall mean temperatures were computed for each 10-day period from Environment Canada data at Collegeville. In addition, heat units (with units of degree-days) were calculated as the sum of the daily, above-zero maxima for each period; cold units were calculated similarly as the sum of all daily minima below zero. Linear regression was also used to model the decline in number of species flowering over time, as this facilitated comparisons with the 2001 study.

RESULTS

Weather in fall 2005.

Temperatures in fall are typically warmer at South Side Harbour, along the coast, than at Collegeville, which lies inland. Frosts arrive later and are less severe near the coast as well (Table 2). Temperatures throughout the fall and early winter of 2005 were conspicuously warmer than usual. At Collegeville, mean temperatures remained 1-3°C warmer than the 30-year normal from September to December (Table 2). The bigger difference, however, is in the much lower frequency and severity of frost in 2005. In 2005 there were only 3 days of frost at Collegeville in October 2005, and 14 in November, compared with 14 and 23 in the 30-year Normals (Table 2). Frosts were less frequent nearer the coast, where most flowering observations were made. The temperature difference between 2005 and previous years is less obvious in December, but even in this month the daytime high was above zero on 15 days at Collegeville. A 16-cm snowfall on 10 December would have insulated low-lying plants from the most severe cold. Even in January, the coldest month of the year, the mean maximum temperature was above zero in 2006.

There is no consistent difference among most temperature statistics between 2001 and 2005; the earlier year was warmer in some months and by some measures, the later year by other measures or in other months. The number of frost days, however, was consistently less in 2005 than in 2001 at both South Side Harbour and Collegeville weather stations (Table 2).

Fall climate warming in northern Nova Scotia.

In addition to the specific temperature indicators in Table 2, we also examined changes in numbers of frost days between 1950 and 2005 using the Collegeville data set (Figure 1). While these data show major fluctuations on a year to year basis, there is no apparent trend in the five-year running average until the mid 1990s, after which there is a strong decline. This decline is more apparent in the data from 1997-2005 from South Side Harbour (Figure 2) where there is an almost continuous decline in number of frost days from 8 days to 1 day, and a major increase in days to first frost after 1 September from 33 to 61 days. The reduction in early fall frosts may be a key factor in the persistence of flowering after 1 November.

Table 2 Climate data for an inland site (Collegeville) and a coastal site (South Side Harbour) in Antigonish County during 2001 and 2005, and 30-year climate normals for Collegeville, 1971-2000. Climate normals not yet established for South Side Harbour. Some data missing for South Side Harbour in 2005-2006; bracketed numbers allow possibility that these were frost days.

Month	Temperature (°C) and Frost Days	South Side Harbour		Collegeville		Collegeville Climate Normals
		2005-2006	2001-2022	2001-2002	2005-2006	1971-2000
Sept	Mean maximum	21.5	22.8	22.8	21.0	18.8
	Mean	16.1	16.7	15.6	15.8	13.5
	Mean minimum	10.7	10.5	9.1	10.6	7.8
	Extreme minimum	3.4	0.5	-2.0	2.0	-
	Frost days	0	0	2	0	4.9
Oct	Mean maximum	14.7	17.2	16.1	14.5	13.0
	Mean	10.5	11.1	10.1	9.9	8.0
	Mean minimum	6.4	5.0	3.9	5.2	3.3
	Extreme minimum	-1.4	-1.8	-4.0	-3.0	-
	Frost days	1	4	5	3	13.8
Nov	Mean maximum	10.0	8.7	8.8	10.0	6.9
	Mean	5.6	4.6	4.3	5.4	2.9
	Mean minimum	1.3	0.4	0.3	0.7	-0.9
	Extreme minimum	-6.7	-6.5	-9.0	-7	-
	Frost days	12	17	15	12	22.6
Dec	Mean maximum	1.8	3.6	-0.5	2.2	1.0
	Mean	-2	0.6	-0.5	-1.2	-3.1
	Mean minimum	-5.9	-2.6	-3.5	-4.7	-7.5
	Extreme minimum	-15.1	-9.25	-10.0	-17.5	-
	Frost days	23 (25)	25	27	25	29.6
Jan	Mean maximum	3.5	-1.1	-2.2	2.4	-1.5
	Mean	-0.2	-4.8	-7.1	-0.7	-6.6
	Mean minimum	-3.9	-8.6	-12.0	-3.8	-11.6
	Extreme minimum	-10.6	-17.2	-22.0	-10.0	-
	Frost days	17 (20)	30	31	23	28.8

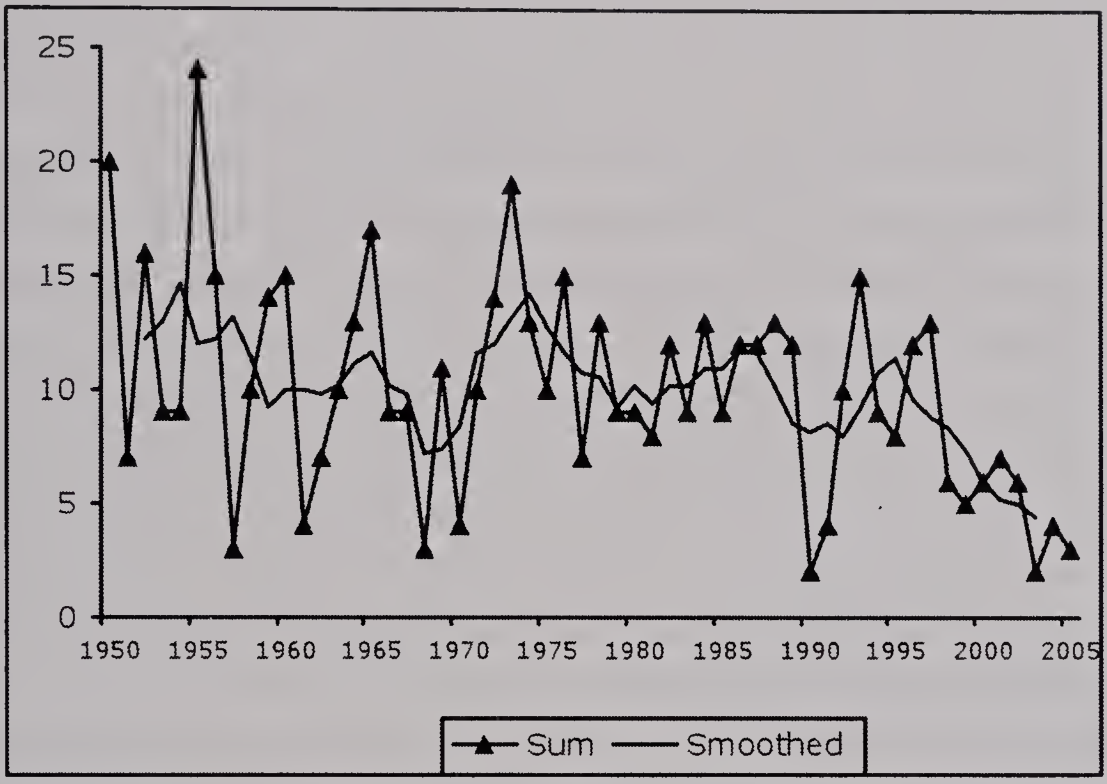

Fig 1 Days of frost, September and October combined, with five year smoothed line based on data from Collegeville.

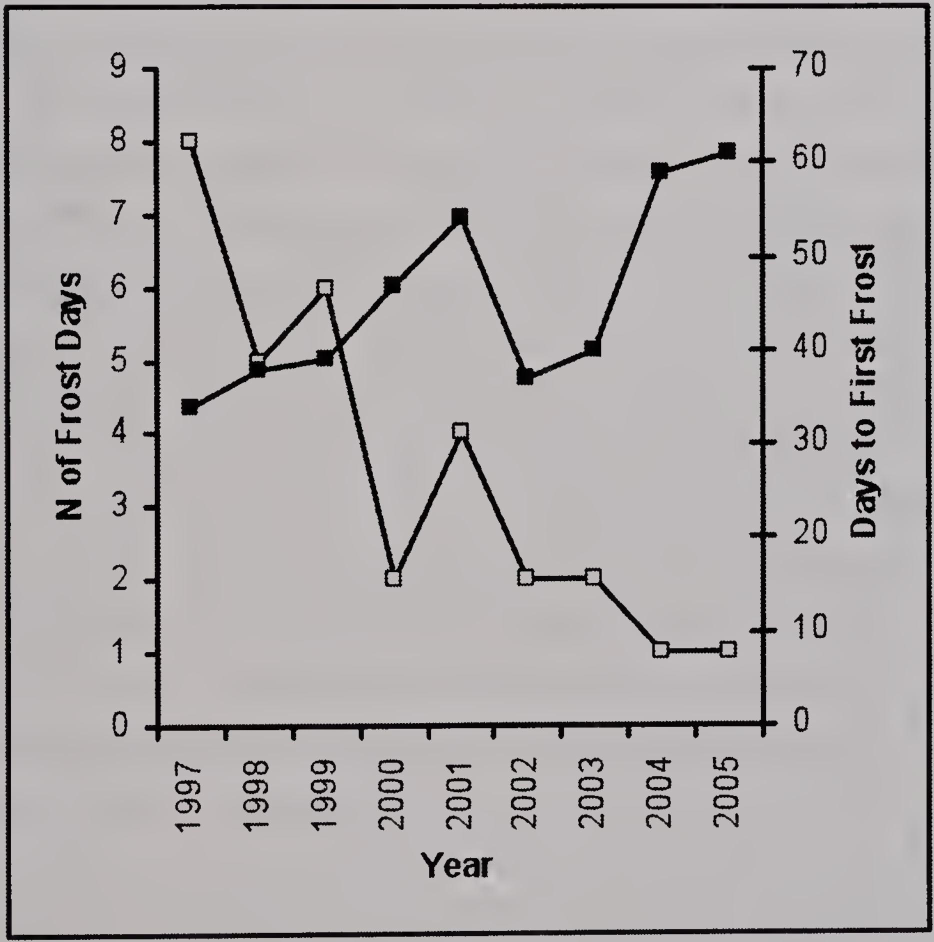

Fig 2 Number of frost days September and October combined (open squares) and days to first frost after 1 September (filled squares) based on data from South Side Harbour.

Plants in flower.

Over 1400 site-time observations of flowering were made during the 113 days of this research (Appendix 2). The field observations produced a tally of 136 species from the 21 sites that were regularly visited and 20 or more additional sites that were visited once or a few times (Appendix 2). Limited destructive sampling of plants for identification and preparation of vouchers necessitated continual exploration of new sites. Most of the sites represented similar habitats: waste ground, roadside ditches, lawns, garden plots and agricultural fields (Table 1). Most sites were highly disturbed, many with less than 50% cover of vegetation, used for agriculture or industry (e.g., building sites, soil dump sites, parking lots, ditches), and were characterized by pioneer successional communities in which the bulk of the plants in flower were herbaceous, weedy species. Although various wetlands and forest communities were explored, these were typically devoid of plants in flower. Exceptions were open spaces in mixed conifer forest at Arisaig with *Solidago bicolor*, a streamside *Alnus* thicket near Monastery with *Solidago flexicaulis*, and a salt marsh at Monks Head (Pomquet Harbour) with *Solidago sempervirens* and *Sueda maritima*.

Unlike the survey in 2001, the list of flowering species in 2005 includes woody plants for the first time. Three of the four species observed are shrubs that normally bloom in summer: *Spiraea latifolia, Cornus sericea* and *Symphoricarpos albus*. The fourth species, *Salix* sp. (probably pussy willow, *S. discolor* or *S. pellita*) ordinarily blooms in April or May. All of these species were found at either more than one site or during more than one ten-day period (Appendix 2), suggesting that this late fall flowering was more than a rare and isolated event.

In early and mid-November, 20-30 species were found in flower at most sites, with a maximum of 34. By the end of November, flowering was conspicuously reduced, with an average of 13 species per site and a maximum of 23 species. In early December there was a slight further reduction to an average of 12 species per site and a maximum of 19. Middle and late December showed a mean of 4 species per site with a maximum of 6 species. Snow cover and low temperatures produced a limited window for collecting in mid-December and precluded visiting large numbers of sites. About half of the sites visited in late December had no species flowering and several still had extensive snow cover.

A total of 22 species remained in bloom in the last third of December (Figure 3); indeed 15 observations were made of 12 species from four sites on December 30, when air temperature reached 14°C. These records varied from the occurrence of a single blossom on a population of dozens of individuals (*Ranunculus repens*), to abundant blossoms on many highly frost-compromised (i.e. wilted) plants (*Raphanus raphanistrum*), to healthy plants with large numbers of buds and blossoms (e.g., *Polygonum arenastrum* and *Stellaria media*). *Taraxacum officinale* was present at three of the four sites visited, albeit with only one or two flowering individuals per site. All of these species, except *Salix* sp. and *Ranunculus repens* had been in bloom in every ten-day period since the beginning of November.

There was little change in the flowering species between the end of December and records from January. Most species flowered in two of the three time intervals. No species was lost, and there was a single record of *Epigea repens* added in mid-January. Even the final collection day for the study (21 January) yielded twelve records of eight species of herbaceous plants from seven sites, with two further records of *Salix*.

Our observations in 2001 and 2005 (Appendix 1) extend the known flowering periods of plants in Nova Scotia by 70 days. The observations in 2001 for some species are later than those collected here, but usually within the same ten-day period. The late January collections (see Garbary & Taylor 2007 for details of these collections) provide the latest flowering records in the province.

The change in number of species in flower over consecutive 10-day periods from 1 November clearly follows a two-phase pattern (Figure 3). Over the first five periods, from 1 November to 20 December, the number of species in flower declines regularly, to a minimum of 12 during the 11-20 December period. Over the last five periods, from 11 Dec to 21 January, the number of species in flower remains low (< 25) and more or less constant. The fifth period is a transition from the first phase to the second. The decline in species flowering over the first five periods can be well described by a simple linear regression:

Number of species = 140.9 - 25.3 * (Time Period)
($R^2 = 0.99, n = 5, p = 0.0017$)

In contrast, the change in species flowering over the last 5 periods has no significant correlation with time, and in fact $r = 0$. Hence, rather than the flowering period ending abruptly at the first deep frost, successive bouts of cold weather removed progressively more species from the

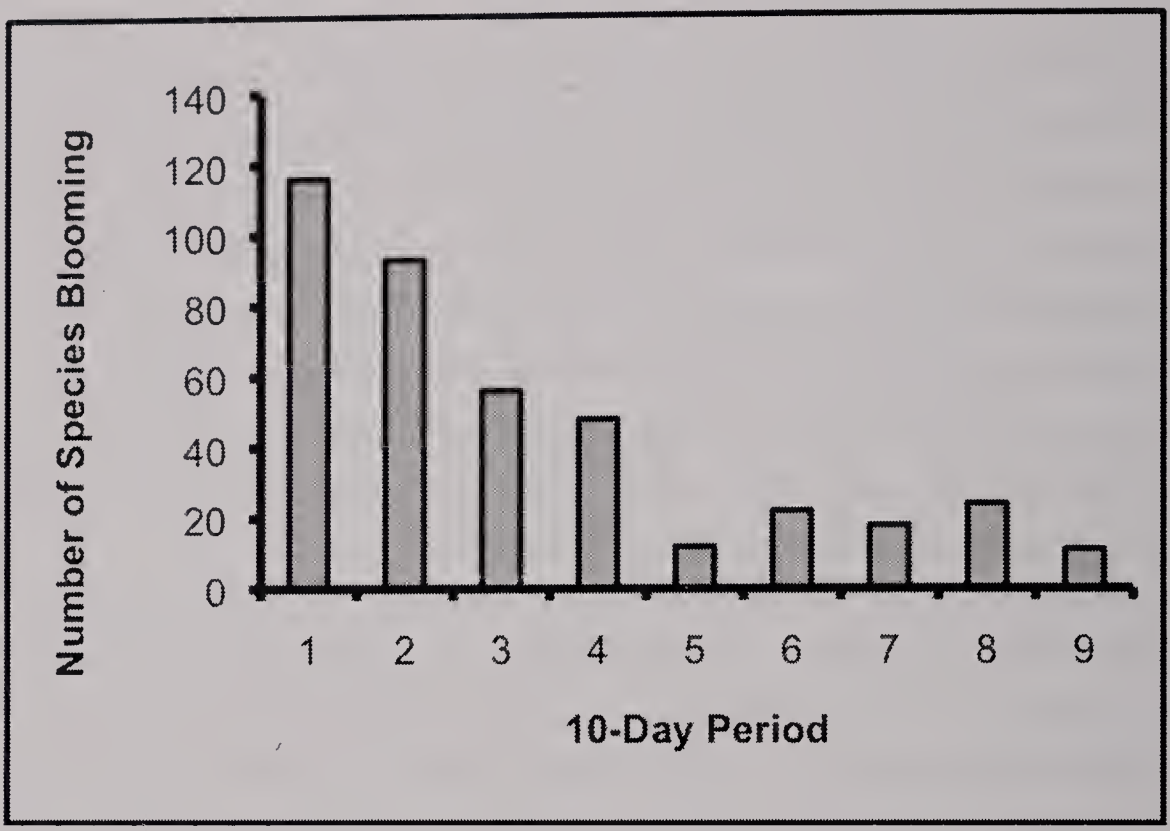

Fig 3 Number of species of plants recorded in bloom in Antigonish County, Nova Scotia during 10-day periods from 1 November 2005 to 21 January 2006. Periods 1-3 cover November, 3-6 cover December and 7-9 cover January.

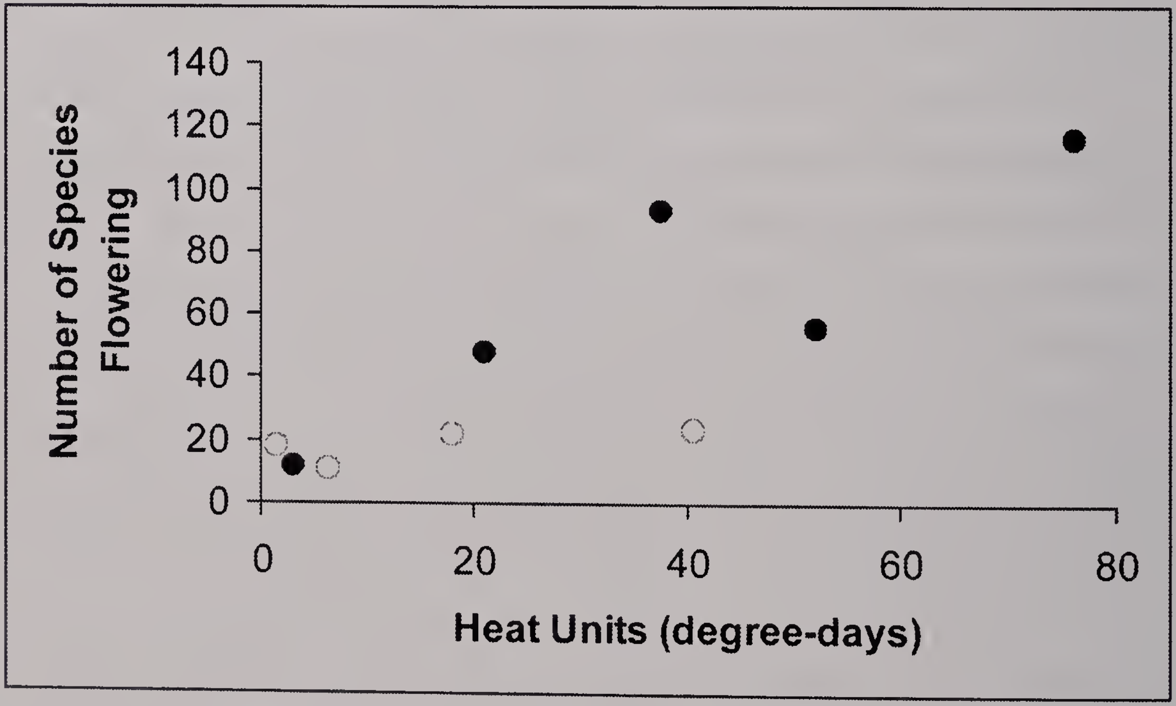

Fig 4 Relationship between number of species of plants in flower from 1 November 2005 to 21 January 2006 and cumulative heat units in each 10-day period. Dark circles represent data from 1 November to 20 December, when the number of species declined linearly. Open circles are data from 21 December to 21 January, when the number of species in flower was approximately constant.

flowering pool. The final group of species, those that persisted until mid-January, were evidently able to prolong their growing season even further because of the continued mild weather and their ability to suffer frosts that were fatal to less resistant species.

Over the entire nine periods, the number of species in flower is more or less equally correlated with mean maximum, mean minimum and daily mean temperatures and cumulative heat units in each period ($r = 0.82$ to 0.84, $n = 9$). Only cold units are a relatively poor predictor of number of species ($r = 0.73$). Nevertheless, the response in number of species flowering to temperature during the last four 10-day periods appears to be weaker than that during the first five periods (Figure 4). This is probably so because after 20 December there were only a few species available to reflower when the weather turned warmer again at the end of the month, the others having entered dormancy or succumbed to frost. Therefore above-zero temperatures were less effective in encouraging flowering late in the season than earlier.

In the 2001 study, flowering ended in the fifth 10-day period, between 11 and 20 December. Over those five periods however, the rate of decline in 2005 appears remarkably similar to that in 2001. A direct comparison between the two equations is not possible, however, because of the greater number of species collected in 2005. To correct for this disparity, the 2001 and 2005 regressions were both recomputed in terms of percentages of the total number of species found in bloom that year. The slope of the line in 2005 (-18.7 ± 1.7 % period^{-1}) is not significantly different ($t = 1.59$, $p > 0.10$) from the slope of the line in 2001 ($-17.4 \pm 1.0\%$ period^{-1}). Hence, the identical ecological process of sequential removal of progressively more frost-resistant species appears to have been active in both years.

DISCUSSION

This study and the previous one (Taylor & Garbary 2003) were initiated because of the high diversity of plants in flower and the robustness of flowering in early November of 2005 (and 2001). This pattern was highly unusual for northern Nova Scotia, where frosts in September and October typically terminate flowering of all but the most robust species. While some of our records are based on a single plant with a single inflorescence (e.g., *Hieracium aurantiacum* on 15 November), many of our records, even those in January, are based on multiple specimens, from multiple times and multiple sites (Appendix 2 and Garbary & Taylor 2007).

This study of late flowering phenology in a local area of Nova Scotia provides an empirical approach to documenting biological responses to changes in weather patterns, if not the impact of climate change. Our use of herbarium records to establish baseline flowering phenologies is consistent with previous work in northeastern North America by Miller-Rushing et al. (2006) and Primack et al. (2004), although these studies used estimates of peak flowering times rather than latest flowering times. Our use of herbarium specimens and the regional flora (Roland 1998) as starting points against which to gauge our observations assumes that prior observations and collections were made throughout the flowering period. We have mitigated this potential source of error by assuming that the last day of the month cited by Roland (1998), or the latest herbarium specimen in ACAD or NSAC, was the end of the flowering period; this minimizes our estimate of the flowering period extension. Furthermore, our primary reference herbarium, ACAD, is in a warmer plant hardiness zone than Antigonish (5B rather than 5A), and plants from the Annapolis Valley might be assumed to have a later flowering period than those from Antigonish County do. Many of the collections of roadside flowers and ruderals in ACAD, NSAC and STFX are student collections made as part of course assignments, and therefore many specimens would likely have been collected later in the autumn, toward the end of flowering periods when some collectors were attempting to meet course requirements. This background, combined with over 20 years experience on the local flora by DJG and BRT, gives us confidence in our conclusion that 2001 and 2005 represent major anomalies in flowering phenology for the Antigonish area, and these events were associated with an apparent fall warming trend in the area (Table 2).

Our results complement and extend the previous study by Taylor & Garbary (2003) that showed a 45 day average extension of known flowering durations for Nova Scotia during 2001. The current study suggested a further 25 day extension in mean flowering duration for the 135 documented species. We conclude that persistent flowering beyond the normal growing season is a reliable integrator of weather phenomena associated with a warming climate (i.e., higher mean temperatures, later frost, less frequent and less severe cold periods), and therefore fall-flowering surveys can be a useful instrument to document and detect climate change. Table 2 shows that 2001 and 2005 were consistently warmer than climate normals based on a variety of metrics. Furthermore, we documented an apparent change in temperature since the mid 1990s as shown by a reduction of frost occurrences in northern Nova Scotia (Figures 1-2). Whether these are part of an ongoing trend remains to be established, but they are consistent with predictions of global climate change (e.g., Walther et al. 2005).

While our systematic observations were carried out only in 2001 and 2005, casual observations in all other years since 2001 did not show the diversity of species in flower or robustness of flowering after 1 Nov that we observed during the study years. In 2009 and 2010 for example, typical frosts occurred in October and casual observation of several sites by one of us (DJG) revealed fewer than ten species in flower at any site in Antigonish County during November. Our analysis of climate data for the region (Table 2) shows that the fall and early winter seasons of 2001 and 2005 were particularly mild, and supports our conclusion that late flowering is a response to milder temperatures.

It is remarkable that the rate of disappearance of flowering species, expressed as a percentage of the total, through the first five 10-day periods should follow the same linear trajectory in 2005 as in 2001, especially given that the 2005 survey includes many new species. This pattern has been interpreted previously as successive cold snaps acting as environmental sieves, separating groups of species according to increasing frost tolerance (Taylor & Garbary 2003). The reappearance of the same pattern in 2005 as in 2001 suggests that most ruderal species are differentiated along this niche axis. As well, the apparent generality of the pattern suggests that deviations from the expected sequence may be used as an indicator of climate change. Such a deviation was observed in the current study, when the final, most persistent group of species, rather than succumbing to deep cold as winter approached, instead persisted well into January along with the unseasonable warmth.

The majority of studies on changes in phenology in relation to climate warming refer to the advancement of flowering or other phenomena in the spring, and much smaller effects during the fall (e.g., Cleland et al. 2007, Fitter & Fitter 2002, Gu et al. 2008, Menzel et al. 2006, and references therein). Hence the apparent 45-day prolongation of flowering reported by Taylor & Garbary (2003), and the further 25-day apparent prolongation reported here (Appendix 1) would seem counter to generalized responses in the literature. It may be that later flowering is more difficult to document as it requires multiple visits to many sites as was done here and in Taylor & Garbary (2003).

The 135 species recorded in this study represent about 10% of the total vascular flora of Nova Scotia. However, the dicotyledenous flora of Nova Scotia consists of about 970 species. Based on distributions reported in Roland (1998) and additions in Garbary & Deveau (2007) and Taylor et al. (2008), only about 75% of this diversity may be represented in Antigonish County, a small area with low habitat and climatic diversity (Davis & Browne 1997). Hence, the species we observed flowering during November-January comprise ~20% of the local diversity of dicots. This total qualifies the late flowering assemblage as a significant component of the angiosperm flora, and highlights the phenological changes that can arise from even slight changes in temperature. The capacity of so many species to extend or recommence flowering in warm fall weather raises the prospect of even greater blooming for longer periods with climate change that includes further warming during the late autumn and early winter. It remains to be determined if viable seeds can be produced by these late fall flowering species, especially those that require insect pollination.

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Appendix 1 Combined list of species from 2001 and 2005 that were observed flowering in Antigonish County after November 1st. The date given under latest herbarium record indicates the latest flowering specimens found in one of the following herbaria - ACAD, NSAC or NSPM. Flowering extension (days) indicates the number of additional flowering days in Antigonish County compared with the latest times given in Roland (1998) or a previous herbarium collection. Symbols are as follows: Question marks indicate missing data; #-Species found in 2001 study but not in the fall of 2005; *-earliest flowering times for two pussy willow species; ^-interpreted as late second flowering rather than early flowering – see text.

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
Achillea millefolium L.	Sep	2 Dec '05	14 Dec	12 Jan	29
Allium schoenoprasum L.	July	1 Aug '57	-	2 Dec	124
Ambrosia artemisiifolia L.	Sep	16 Nov '06	-	23 Nov	7
Anaphalis margaritaceae (L.) Benth. & Hook.	Sep	18 Oct '81	5 Dec	6 Nov	-29
Anthemis tinctoria L.	Sep	3 Aug '51	-	2 Dec	122
Arctium minus (Hill.) Bernh.	Sep	15 Nov '94	-	13 Nov	0
Aster ciliolatus Lindl.	Sep	14 Aug '68	12 Dec	2 Dec	-10
A. cordifolius L.	Oct	18 Oct '79	12 Dec	22 Nov	-20
A. lateriflorus (L.) Britton	Sep	28 Oct '87	10 Dec	3 Dec	-7
A. novae-angliae L.	Oct	16 Nov '05	-	1 Nov	-
A. novi-belgii L.	Sep	2 Dec '05	10 Dec	3 Dec	-7
A. puniceus L.	Sep	7 Oct '30	11 Nov	3 Dec	22
A. umbellatus P. Mill.	Sep	9 Sep '54	-	6 Nov	36
#*Bellis perennis* L.	Sep	6 July '50	16 Nov	-	47
Berteroa incana (L.) DC	Sep	1 Oct '41	-	1 Nov	31
Bidens connata Muhl.	Sep	6 Sep '52	-	7 Nov	38
#*Bidens frondosa* L.	Sep	29 Sep '41	7 Nov	-	37
Brassica nigra (L.) W.J.D. Koch	Oct	11 Nov '69	10 Nov	2 Nov	-8
#*B. rapa* L.	Oct	27 Sep '91	12 Dec	-	-
Campanula rapunculoides L.	Aug	20 Sep '79	7 Nov	3 Nov	-4
Capsella bursa-pastoris (L.) Medik.	Nov	2 Dec '05	14 Dec	14 Jan	31
Cardamine pensylvanica Muhl. ex Willd.	Aug	11 Sep '49	15 Dec	21 Jan	37
Centaurea nigra L.	Sep	20 Nov '94	17 Nov	15 Nov	-2
Cerastium vulgatum L.	?	12 Dec '06	15 Nov	21 Jan	44
Chenopodium album L.	?	14 Oct '79	17 Nov	1 Dec	14
C. glaucum L.	Oct	-	-	22 Nov	22
Chaenorrhinum minus (L.) Lange	Aug	4 Sep '48	15 Nov	15 Nov	0
Chrysanthemum leucanthemum L.	July	18 Sep '83	26 Nov	22 Nov	-4
Cichorium intybus L.	Aug	15 Oct '90	-	12 Nov	28
Cirsium arvense (L.) Scop.	Aug	9 Oct '30	-	18 Nov	39
C. palustre (L.) Scop.	July	9 Aug '45	-	6 Nov	90
C. vulgare (Savi) Tenore	Sept	1 Oct '32	-	7 Nov	36
#*Conioselinum chinense* (L.) Britton, Sterns & Poggenb.	Sep	17 Sep '55	11 Nov	-	-

Appendix 1 *Continued*

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
Cornus sericea L.	June	4 Sep '25	-	22 Nov	80
Coronilla varia L.	July	13 Sep '90	-	12 Nov	50
#*Dianthus armeria* L.	July	1 Oct '67	19 Nov	-	-
Daucus carota L.	Sep	2 Dec '05	20 Nov	2 Dec	0
Echinocystis lobata (Michx.) T. & G.	Oct	30 Sep '90	-	12 Nov	12
Echium vulgare L.	Sep	18 Aug '55	-	2 Nov	33
Epigaea repens L.	May	7 Nov '98	-	14 Jan	68
Erigeron annuus (L.) Pers.	Sep	1 Oct '45	16 Nov	24 Nov	8
E. philadelphicus L.	Aug	14 June '51	-	2 Nov	64
E. strigosus Muhl. Ex Willd.	Sep	16 Nov '06	8 Dec	6 Nov	-32
Erucastrum gallicum (Willd.) O.E. Schulz	Oct	18 Sep '54	12 Dec	3 Dec	-9
Erysimum cheiranthoides L.	Sep	16 Nov '06	15 Dec	14 Jan	30
Euphorbia helioscopia L.	Sep	7 Jan '02	14 Dec	21 Jan	17
Euphrasia officinalis L.	Sep	10 Oct '30	10 Nov	24 Nov	14
Euthamnia graminifolia (L.) Nutt.	Sep	17 Oct '17	22 Nov	1 Nov	-21
Fragaria vesca L.	June	27 July '46	-	1 Nov	63
F. virginiana Duchesne	May	5 Sep '86	27 Nov	15 Nov	-12
Fumaria officinalis L.	Aug	6 Sep '54	-	14 Jan	131
Galeopsis tetrahit L.	Sep	10 Oct '69	14 Dec	3 Dec	-11
Galium mollugo L.	Aug	23 Aug '52	-	1 Dec	93
Glechoma hederacea L.	Summer	1 Aug '62	-	2 Nov	64
Hesperis matronalis L.	July	25 Sep '63	17 Nov	22 Nov	5
Hieracium aurantiacum L.	Aug	18 Oct '79	-	15 Nov	27
H. floribundum Wimm. & Grab	July	3 Dec-06	24 Nov	-	-
H. lachenalii C. Gmelin.	Aug	16 Nov '05	-	3 Dec	17
H. paniculatum L.	Sept	17 Sep '45	-	15 Nov	46
H. piloselloides Vill.	July	29 Aug '62	-	6 Nov	69
Hypericum perforatum L.	Aug	12 Nov '79	5 Nov	7 Nov	-5
#*Lamium amplexicaule* L.	Nov	18 Sep '79	8 Dec	-	-
Lathyrus pratensis L.	July	15 Aug ' 66	-	2 Nov	79
Leontodon autumnalis L.	Oct	3 Dec '05	16-Dec	30 Dec	14
Lepidium campestre (L.) R. Br.	Sep	3 Sep '69	6-Dec	18 Dec	12
L. virginicum L.	Sep	2 Dec '06	5-Dec	15 Nov	-20
Linaria vulgaris Mill.	Aug	18 Nov 1869	5-Dec	28 Nov	-7
Lupinus polyphyllus Lindl.	July	20 Sep '79	-	11 Nov	53
Malva moschata L.	July	3 Dec '05	-	1 Dec	-2
M. neglecta Wallr.	Oct	2 Dec '05	14-Dec	14 Nov	-30
#*M. rotundifolia* L.	?	18 Oct '92	10-Nov	-	-
Matricaria maritima L.	Aug	2 Dec '05	15-Dec	13 Jan	29
M. matricarioides (Less.) Porter	Nov	16 Nov '06	14-Dec	14 Jan	31
Medicago lupulina L.	Sep	7 Oct '87	12-Dec	9 Nov	-33
M. sativa L.	Aug	16 Nov '05	-	1 Nov	-15

Appendix 1 *Continued*

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
Melilotus alba Desr.	Aug	9 Nov '79	20-Nov	2 Dec	12
M. officinalis (L.) Lam.	Aug	19 Sep '71	11-Nov	14 Nov	3
Myosotis laxa Lehm.	July	10 Oct '30	-	12 Nov	33
M. scorpioides L.	July	13 Oct '30	-	6 Nov	24
Oenothera biennis L.	Oct	16 Oct '15	24-Nov	24 Nov	0
O. perennis L.	Sep	6 Sep '38	10-Nov	-	-
Oxalis dillenii Jacq.	?	6 Sep '29		4 Nov	60
Pastinaca sativa L.	July	5 Sep '62	5-Dec	2 Dec	-3
Physalis heterophylla Nees	Aug	25 Oct '49	-	12 Nov	18
Plantago lanceolata L.	Oct	11 Nov '79	11-Nov	13 Nov	2
Polygonum arenastrum Jord. ex Boreau	?	24 Oct '23	12-Dec	30 Dec	18
P. aviculare L.	Nov	-	-	19 Nov	-11
P. convolvulus L.	Nov	16 Oct '44	24-Nov	15 Nov	-9
P. cuspidatum Sieb. & Zucc.	Sep	6 Oct '78	-	1 Nov	26
P. hydropiper L.	?	11 Nov '05	-	12 Nov	1
P. lapathifolium L.	?	31 Aug '55	-	5 Nov	67
P. pensylvanicum L.	?	17 Sep '13	-	9 Nov	54
P. persicaria L.	Oct	10 Dec '25	25 Nov	15 Nov	-10
P. sagittatum L.	Oct	10 Oct '17	10 Nov	9 Nov	-1
Potentilla argentea L.	Aug	20 Nov '37	5 Dec	18 Nov	-17
P. canadensis L.	June	27 July '55	24 Nov	-	-
#*P. intermedia* L.	July	21 July '62	18 Nov	-	-
P. norvegica L.	July	4 Sep '53	-	2 Dec	90
P. simplex Michx.	July	19 Sep '83	-	13 Nov	56
Potentilla recta L.	July	28 Oct '51	16 Nov	-	-
Prunella vulgaris L.	Summer	10 Oct '83	-	15 Nov	36
Ranunculus acris L.	Aug	1 Oct '78	-	6 Nov	36
R. repens L.	Sep	4 Dec '05	25 Nov	30 Dec	26
Raphanus raphanistrum L.	Oct	2 Dec '05	20 Nov	30 Dec	28
Rubus ideaus L.	July	6 Nov '94	-	6 Nov	0
Rudbeckia laciniata L.	Aug	20 July '87	-	23 Nov	85
Rumex longifolius Alph. de Candolle	Oct	20 Oct '30	16 Nov	15 Nov	-1
#*R. obtusifolius* L.	Sep	20 Oct '30	10 Nov	-	-
Salix discolor Muhl.	*Feb-May	-	-	24 Nov	68
S. pellita Andersson	*May-June	-	-	24 Nov	157
Senecio jacobaea L.	Sep	7 Oct '73	9 Dec	24 Nov	-15
S. vulgaris L.	Nov	1 Nov '12	15 Dec	30 Dec	15
Silene latifolia Poir.	Sep	16 Nov '05	7 Nov	18 Nov	11
Sinapis alba L.	Aug	30 July '71	14 Dec	3 Dec	-9
S. arvensis L.	Oct	-	-	15 Nov	15
Sisymbrium officinale (L.) . Scop	Oct	2 Dec '05	-	15 Nov	-17
#*Solanum dulcamara* L.	Sep	23 Sep '90	17 Nov	-	-
Solidago bicolor L.	Sep	16 Nov '06	-	2 Dec	16

Appendix 1 *Continued*

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
S. canadensis L.	Aug	2 Dec '05	5 Dec	3 Dec	-2
S. flexicaulis L.	Sep	25 Sep '63	-	12 Nov	43
S. puberula Nutt.	Sep	15 Nov '94	10 Nov	-	-
S. rugosa P. Mill.	Sep	16 Nov '05	29 Nov	1 Nov	-28
S. sempervirens L.	Sep	2 Dec '05	18 Nov	.13 Nov	-5
Sonchus arvensis L.	Sep	22 Oct '70	22 Nov	3 Dec	11
S. asper L.	Oct	18 Oct '79	9 Nov	3 Dec	25
S. oleraceus L.	Oct	3 Dec '05	15 Nov	6 Nov	-9
Spergula arvensis L.	Oct	28 Oct '87	12 Dec	14 Jan	33
Spergularia marina (L.) Griseb.	Sep	5 Oct '28	12 Dec	30 Dec	18
Spiraea latifolia (Ait.) Borkh.	Aug	5 Oct '01	-	15 Nov	41
Stellaria graminea L.	Oct	16 Sep '60	-	24 Nov	24
S. media (L.) Cirillo	Nov	11 Sep '52	12 Dec	21 Jan	40
Sueda maritima (L.) Dumort.)	Sep	3 Oct '80	-	3 Nov	31
Symphoricarpos albus (L.) Blake	?	15 July '55	-	22 Nov	131
Tanacetum vulgare L.	Aug	5 Nov '12	12 Dec	3 Dec	-9
Taraxacum officinale (L.) Weber	June	23 Sep '95	15 Dec	21 Jan	37
Thlaspi arvense L.	Sep	29 Aug '36	12 Dec	21 Jan	40
#Thymus serpyllum L.	Aug	4 Sep '64	15 Nov	-	-
Tragopogon pratensis L.	Aug	2 Dec '05	7 Dec	1 Dec	-6
#Trifolium hybridum L.	?	10 Sep '25	5 Nov	-	93
Trifolium pratense L.	Sep	16 Nov '05	12 Dec	3 Dec	-9
T. repens L.	?	20 Oct '30	18 Nov	18 Nov	0
Verbascum thapsus L.	Sep	16 Nov '05	-	3 Dec	17
Veronica agrestis L.	Sep	14 July '48	-	29 Nov	60
V. longifolia L.	Aug	2 Sep '48	-	23 Nov	83
V. officinalis L.	Aug	20 Nov '94	-	3 Dec	13
V. persica Poir.	Sep	7 Sep '51	28 Nov	21 Jan	54
Vicia cracca L	Aug	16 Nov '05	27 Nov	3 Dec	6
V. sepium L.	July	26 June '00	-	1 Nov	94
V. villosa L.	Sep	12 Oct '27	-	3 Nov	22
#Viola cucullata Aiton	July	14 Sep '51	10 Nov	-	-
V. tricolor L.	Nov	13 Oct '44	5 Dec	21 Jan	47

Appendix 2 List of species and numbers occurring at collection sites from November 2005 to January 2006 in Antigonish County. Values indicate the number of different sites where each species was found in flower during that ten-day period. No species were found in flower following January 21st.

Species	Nov 1-10	Nov 11-20	Nov 21-30	Dec 1-10	Dec 11-20	Dec 21-31	Jan 1-10	Jan 11-20	Jan 21
Achillea millefolium	16	15	12	7	1	2	2	1	-
Allium schoenoprasum	1	1	-	1	-	-	-	-	-
Ambrosia artemisiifolia	-	3	1	-	-	-	-	-	-
Anaphalis margaritacea	2	-	-	-	-	-	-	-	-
Anthemis tinctoria	-	1	1	1	-	-	-	-	-
Arctium minus	1	1	-	-	-	-	-	-	-
Aster ciliolatus	2	3	3	2	-	-	-	-	-
A. cordifolius	6	2	1	-	-	-	-	-	-
A. lateriflorus	2	2	2	2	-	-	-	-	-
A. novae-angliae	3	-	-	-	-	-	-	-	-
A. novi-belgii	10	14	10	6	-	-	-	-	-
A. puniceus	5	1	-	-	-	-	-	-	-
A. umbellatus	1	-	-	-	-	-	-	-	-
Berteroa incana	1	-	-	-	-	-	-	-	-
Bidens connata	1	-	-	-	-	-	-	-	-
Brassica nigra	1	-	-	-	-	-	-	-	-
Campanula rapunculoides	3	-	-	-	-	-	-	-	-
Capsella bursa-pastoris	5	9	12	8	2	6	4	8	1
Cardamine pensylvanica	1	1	1	1	1	1	1	1	1
Centaurea nigra	5	3	-	-	-	-	-	-	-
Cerastium vulgatum	2	12	7	7	-	2	2	3	1
Chenopodium album	4	6	2	1	-	-	-	-	-
C. glaucum	1	1	1	-	-	-	-	-	-
Chenorrhinum minus	-	1	-	-	-	-	-	-	-
Chrysanthemum leucanthemum	4	4	1	-	-	-	-	-	-
Cichorium intybus	-	1	-	-	-	-	-	-	-
Cirsium arvense	3	3	-	-	-	-	-	-	-
C. palustre	2	-	-	-	-	-	-	-	-
C. vulgare	1	-	-	-	-	-	-	-	-
Cornus sericea	2	1	1	-	-	-	-	-	-
Coronilla varia	1	1	-	-	-	-	-	-	-
Daucus carota	21	18	10	2	-	-	-	-	-
Echinocystis lobata	3	1	-	-	-	-	-	-	-
Echium vulgare	2	-	-	-	-	-	-	-	-
Epigaea repens	-	-	-	-	-	-	-	1	-
Erigeron annuus	15	12	6	-	-	-	-	-	-
E. philadelphicus	2	-	-	-	-	-	-	-	-
E. strigosus	1	-	-	-	-	-	-	-	-
Erucastrum gallicum	1	1	1	1	-	-	-	-	-
Erysimum cheiranthoides	5	9	10	6	-	4	-	2	-
Euphorbia helioscopia	2	3	4	4	1	1	1	1	1
Euphrasia officinalis	3	3	2	-	-	-	-	-	-
Euthamnia graminifolia	1	-	-	-	-	-	-	-	-

Appendix 2 *Continued*

Species	Nov 1-10	Nov 11-20	Nov 21-30	Dec 1-10	Dec 11-20	Dec 21-31	Jan 1-10	Jan 11-20	Jan 21
Fragaria vesca	1	-	-	-	-	-	-	-	-
F. virginiana	3	1	-	-	-	-	-	-	-
Fumaria officinalis	2	2	3	3	-	1	1	1	-
Galeopsis tetrahit	3	3	3	4	-	-	-	-	-
Galium mollugo	1	3	2	-	-	-	-	-	-
Glechoma hederacea	1	-	-	-	-	-	-	-	-
Hesperis matronalis	1	1	1	-	-	-	-	-	-
Hieracium aurantiacum	-	1	-	-	-	-	-	-	-
H. lachenalii	3	1	-	1	-	-	-	-	-
H. paniculatum	1	1	-	-	-	-	-	-	-
H. piloselloides	1	-	-	-	-	-	-	-	-
Hypericum perforatum	3	-	-	-	-	-	-	-	-
Lathyrus pratensis	1	-	-	-	-	-	-	-	-
Leontodon autumnalis	12	20	18	13	-	5	2	-	-
Lepidium campestre	2	2	4	3	1	-	-	1	-
L. virginicum	1	2	-	-	-	-	-	-	-
Linaria vulgaris	14	16	1	-	-	-	-	-	-
Lupinus polyphyllus	2	1	-	-	-	-	-	-	-
Malva moschata	1	1	2	1	-	-	-	-	-
M. neglecta	-	1	-	-	-	-	-	-	-
Matricaria maritima	10	7	8	4	1	1	1	2	-
M. matricarioides	2	6	4	4	1	2	2	2	-
Medicago lupulina	9	2	-	-	-	-	-	-	-
M. sativa	1	-	-	-	-	-	-	-	-
Melilotus alba	14	9	3	1	-	-	-	-	-
M. officinalis	3	1	-	-	-	-	-	-	-
Myosotis laxa	3	1	-	-	-	-	-	-	-
M. scorpioides	1	-	-	-	-	-	-	-	-
Oenothera biennis	15	13	4	-	-	-	-	-	-
Oxalis dillenii	1	-	-	-	-	-	-	-	-
Pastinaca sativa	3	8	5	2	-	-	-	-	-
Physalis heterophylla	-	1	-	-	-	-	-	-	-
Plantago lanceolata	3	1	-	-	-	-	-	-	-
Polygonum arenastrum	3	3	1	4	-	1	-	1	-
P. aviculare	-	1	-	-	-	-	-	-	-
P. convolvulus	3	2	-	-	-	-	-	-	-
P. cuspidatum	1	-	-	-	-	-	-	-	-
P. hydropiper	1	1	-	-	-	-	-	-	-
P. lapathifolium	2	-	-	-	-	-	-	-	-
P. pensylvanicum	1	-	-	-	-	-	-	-	-
P. persicaria	7	7	-	-	-	-	-	-	-
P. sagittatum	3	-	-	-	-	-	-	-	-
Potentilla argentea	2	2	-	-	-	-	-	-	-
P. norvegica	-	-	-	1	-	-	-	-	-
P. simplex	1	2	-	-	-	-	-	-	-
Prunella vulgaris	6	3	-	-	-	-	-	-	-
Ranunculus acris	5	-	-	-	-	-	-	-	-
R. repens	2	7	-	1	-	1	-	-	-
Raphanus raphanistrum	5	9	10	5	-	3	2	1	-

Appendix 2 *Continued*

Species	Nov 1-10	Nov 11-20	Nov 21-30	Dec 1-10	Dec 11-20	Dec 21-31	Jan 1-10	Jan 11-20	Jan 21
Rubus ideaus	1	-	-	-	-	-	-	-	-
Rudbeckia laciniata	1	1	2	-	-	-	-	-	-
Rumex longifolius	2	2	-	-	-	-	-	-	-
Salix discolor	-	-	1	1	-	1	1	1	1
S. pellita	-	-	1	1	-	1	-	1	1
Senecio jacobaea	9	10	2	-	-	-	-	-	
S. vulgaris	9	7	11	8	1	3	1	1	-
Silene latifolia	-	1	-	-	-	-	-	-	-
S. vulgaris	1	-	-	-	-	-	-	-	-
Sinapis alba	1	1	-	1	-	-	-	-	-
S. arvensis	1	3	2	4	-	-	-	-	-
Sisymbrium officinale	-	1	-	-	-	-	-	-	-
Solidago bicolor	2	1	-	-	-	-	-	-	-
S. canadensis	20	14	12	8	-	-	-	-	-
S. flexicaulis	-	1	-	-	-	-	-	-	-
S. puberula	1	-	-	-	-	-	-	-	-
S. rugosa	3	-	-	-	-	-	-	-	-
S. sempervirens	1	1	-	-	-	-	-	-	-
Sonchus arvensis	13	21	6	2	-	-	-	-	-
S. asper	1	-	-	-	-	-	-	-	-
S. oleraceus	3	-	-	-	-	-	-	-	-
Spergula arvensis	3	2	2	3	-	1	1	1	-
Spergularia marina	1	-	-	1	-	2	-	1	-
Spiraea latifolia	2	2	-	-	-	-	-	-	-
Stellaria graminea	1	3	1	1	-	-	-	-	-
S. media	5	1	4	5	1	2	3	4	2
Suaeda maritima	1	-	-	-	-	-	-	-	-
Symphoricarpos albus	1	2	1	-	-	-	-	-	-
Tanacetum vulgare	3	2	2	3	-	-	-	-	-
Taraxacum officinale	13	16	14	11	1	5	5	7	1
Thlaspi arvense	-	3	2	2	1	1	3	2	1
Tragopogon pratensis	21	5	3	1	-	-	-	-	-
Trifolium pratense	10	14	8	3	-	-	-	-	-
T. repens	13	7	-	-	-	-	-	-	-
Verbascum thapsus	2	1	-	1	-	-	-	-	-
Veronica agrestis	-	1	1	-	-	-	-	-	-
V. longifolia	-	1	1	-	-	-	-	-	-
V. officinalis	4	-	-	2	-	-	-	-	-
V. persica	-	-	-	-	-	-	-	1	1
Vicia cracca	3	6	2	1	-	-	-	-	-
V. sepium	1	-	-	-	-	-	-	-	-
V. villosa	1	-	-	-	-	-	-	-	-
Viola tricolor	2	2	3	4	2	2	2	2	1
Number of records	458	408	236	161	14	48	34	46	11
Number of sites	21	21	18	14	3	16	10	18	7

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THE CRYSTAL STRUCTURE AND QUANTUM MECHANICAL TREATMENT OF THE ANTI-CANCER AGENT FLAVOPIRIDOL (HYDROCHLORIDE) AND THE CHROMONE ALKALOID ROHITUKINE

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ABSTRACT

The characterisation of the solid-state crystal structure of the hydrochloric acid salt of anti-cancer agent *Flavopiridol* (*i.e.*, (–)-2-(2-chlorophenyl)-5,7-dihydroxy-8-[(3*S*,4*R*)-3-hydroxy-1-methyl-4-piperidinyl]-4*H*-1-benzopyran-4-one) is described. The title compound forms meta-stable X-ray quality crystals by slow evaporation of solutions of the material in aqueous methanol. The crystalline unit cell contains two organic cations, two formal chloride counterions and two molecules of methanol, one of which is replaced in 20% occupancy by a water molecule. The crystal form is of space group *P*1 with cell parameters a = 7.2014(10) Å, b = 12.0094(9) Å, c = 12.6581(14) Å, α = 89.146(4)°, β = 89.788(6)° and γ = 82.180(4)°. The unit cell volume is 1084.4(2)$Å^3$. The general structural features of individual (gas-phase) molecules of protonated Flavopiridol and the naturally occurring 2-methyl-[4*H*]-chromen-4-one analogue *Rohitukine* have been calculated by application of Density Functional Theory (DFT) at the B3LYP/6-31G* level of sophistication. These results are compared to the reported solid-state data of these two biologically relevant flavanoids.

INTRODUCTION

Flavanoids are a class of natural products that are widely distributed in the biosphere, particularly in the plant kingdom (Harborne & Mabry, 1982), as primarily secondary metabolites. Many flavanoids are, not surprisingly, biologically active and hence have been the subject of intense scrutiny by natural products chemists and the pharmaceutical industry (Eisnor et al., 2006; Joule et al., 1995). These investigations

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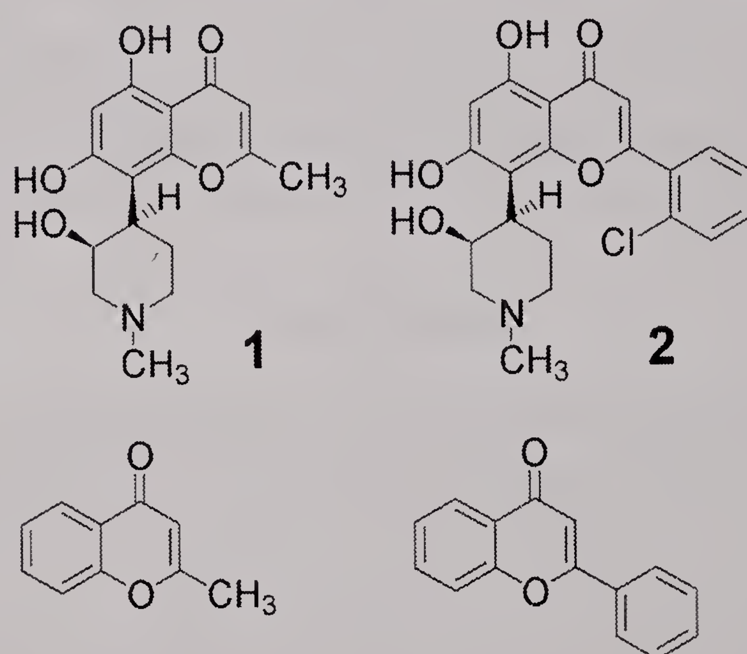
have led to the identification of a vast number of potential new sources of phytochemicals that have been used or are under development as both nutraceuticals and/or chemotherapy agents. In addition, novel structural motifs derived from natural products often serve as starting points or "leads" for compounds that are investigated for their clinical potential. Many years ago, the flavanoid compound dubbed *Rohitukine* (**1**: Scheme 1), which contains a 2-methyl-[4*H*]-chromen-4-one frag-



Scheme 1 Schematic representations of *Rohitukine* (**1**) and *Flavopiridol* (**2**). Below these pictorials are the parent structures of 2-methyl-[4*H*]-chromen-4-one and flavone: left and right, respectively.

ment, was isolated (Harmon et al., 1979) from the Asian plant *Amoora rohituka* (Syn. *Aphanamixis polystachya*) (meliaceae). This alkaloid incorporates both the aforementioned chromone skeleton, a common organic motif (Joule et al., 1995), and an unusual modified piperidinyl ring system. Rohitukine itself displays a range of biological activities including its ability to modulate immune response systems and act as an anti-inflammatory agent (Naik et al., 1998; Sedlacek et al., 1996). However, it is most noteworthy for its potent anti-cancer potential. Large quantities of **1** can be obtained from *Dysoxylum binectariferum* (Yang et al., 2004; Mohanakumara et al., 2010), which is currently the primary natural source of this chromone, although two species of *Schumanniophyton* also produce **1** (Houghton, 2002; Houghton & Hairong, 1987; Houghton & Woldemariam, 1993). Chemical modification of the basic structure of **1** has led to the synthesis of a more biologically active flavone (Harborne & Mabry, 1982) derivative given the name *Flavopiridol* (**2**: 2-[2-chlorophenyl]-5,7-dihydroxy-

8-[{3*S*,4*R*}-3-hydroxy-1-methyl-4-piperidinyl]-4*H*-1-benzopyran-4-one: Scheme 1). This compound has already entered Phase III clinical trials for applications against a number of classes of cancer including breast, colon and lung cancers, leukaemia and cancers of the head and neck (Billard et al., 2003; Carlson et al., 1996; Fischer & Lane, 2000; Kitada et al., 2000; Lin & Porcu, 2004; Patel et al., 1998; Wu et al., 2002). The mode(s) of action of **2** have been identified as primarily due to the ability of the compound to act as a selective kinase inhibitor and thus it represents the first such inhibitor to enter clinical trials (Bishop et al., 2001; Byrd et al., 1998; Carlson et al., 1996; Fabbro et al., 2002; Filigueira et al., 1996 & 2002; Huwe et al., 2003; Kitada et al., 2000; König et al., 1997; Kryŝtof & Strnad, 2003; Noble et al., 2004; Patel et al., 1998; Pepper et al., 2003; Sedlacek, 2001; Sedlacek et al., 1996; Senderowicz et al., 1999; Senderowicz & Sausville, 2000; Takada & Aggarwal, 2004; Wang & Ren, 2010). A brief report of the characterisation of **1**, *via* single crystal X-ray diffraction methods, has been previously reported (Yang et al., 2003) but details of the structure (bond lengths, bond angles, *etc.*) were not disclosed. Flavopiridol has not been investigated in this way. Neither **1** nor **2** have been structurally examined from a theoretical perspective by quantum mechanical methods. In this report, dedicated to the 150th anniversary of the *Nova Scotian Institute of Science*, we disclose the characterisation of the hydrochloric acid salt of **2** by X-ray diffraction methods and compare the solid-state structures of both **1** and **2** to those obtained by examining the molecules *via* quantum mechanical methods, specifically employing Density Functional Theory (DFT) at the B3LYP/6-31G* level of theory (Goodman, 1998; Koch & Holthausen, 2002; Sholl & Steckel, 2009).

METHODS

Flavopiridol hydrochloric acid salt (*i.e.*, *Alvocidib*) was kindly supplied to the authors by Sanofi-Aventis, Inc. **Caution!** Flavopiridol is a potent biologically active agent and therefore should only be handled by qualified personnel using strict laboratory safety protocols. Crystals of the material were obtained by dissolving approximately 25 mg of the compound in methanol (~10 mL) and then allowing the resulting solution, contained in a small vial, to slowly evaporate under ambient conditions. Yellow rectangular shaped crystals were obtained after a period of about 7 days. These meta-stable crystals remain intact for a period of about 6 weeks before returning to a powder form of (presumably) solvent-free material.

X-ray diffraction data was collected at –100°C on a Nonius Kappa CCD diffractometer, using the COLLECT program (Nonius, 1998). Cell refinement and data reductions used the programs DENZO and SCALEPACK (Otwinowski & Minor, 1997). SIR97 (Altomare et al., 1999) was used to solve the structure and SHELXL97 (Sheldrick, 2008) was used to refine the structure. ORTEP-3 for Windows (Farrugia, 1997) was used for molecular graphics (Figure 1) and PLATON (Spek, 2001) was used to prepare material for publication. H atoms were placed in calculated positions with U_{iso} constrained to be 1.2 times U_{eq} of the carrier atom for all hydrogen atoms. The structure solution has two cations and two chloride ions in the asymmetric unit. In addition, there are two solvent methanol molecules in the asymmetric unit, one with disorder. Twenty percent of one methanol is replaced by a water molecule. Modelling the disorder proved to be difficult because of the strong coupling between the occupancy factors and the thermal factors. In the end, the occupancy of water was set at 0.20 and the methanol at 0.80 to stabilize the refinement. The only B ALERT is for possible higher symmetry. This test does not consider the disordered atoms. Since one methanol is disordered with a water molecule and the other is not, higher symmetry is not possible. Crystallographic data (excluding structure factors) have been deposited in the *Cambridge Crystallographic Data Centre* as Supplementary publication No. CCDC 832180. Copies of these data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, U.K. (fax: +44 1223 336 033; e-mail: deposit@ccdc.cam.ac.uk).

Density Functional Theory was used for the quantum mechanical calculations employing the B3LYP/6-31G* level of theory (Becke, 1993; Lee et al., 1988); these data were obtained by using the SPARTAN 10.0 (Spartan, 2010) suite of programs. These calculations included neutral **1** and the cationic *N*-protonated form of Flavopiridol (*i.e.*, [**2+H**]$^+$). Zero point energy calculations were performed on the idealised structures to ensure that the data reflect true minima along the potential energy surface and hence no negative IR or Raman frequencies were calculated. Details of these data (including .mol files) are available from the authors on request.

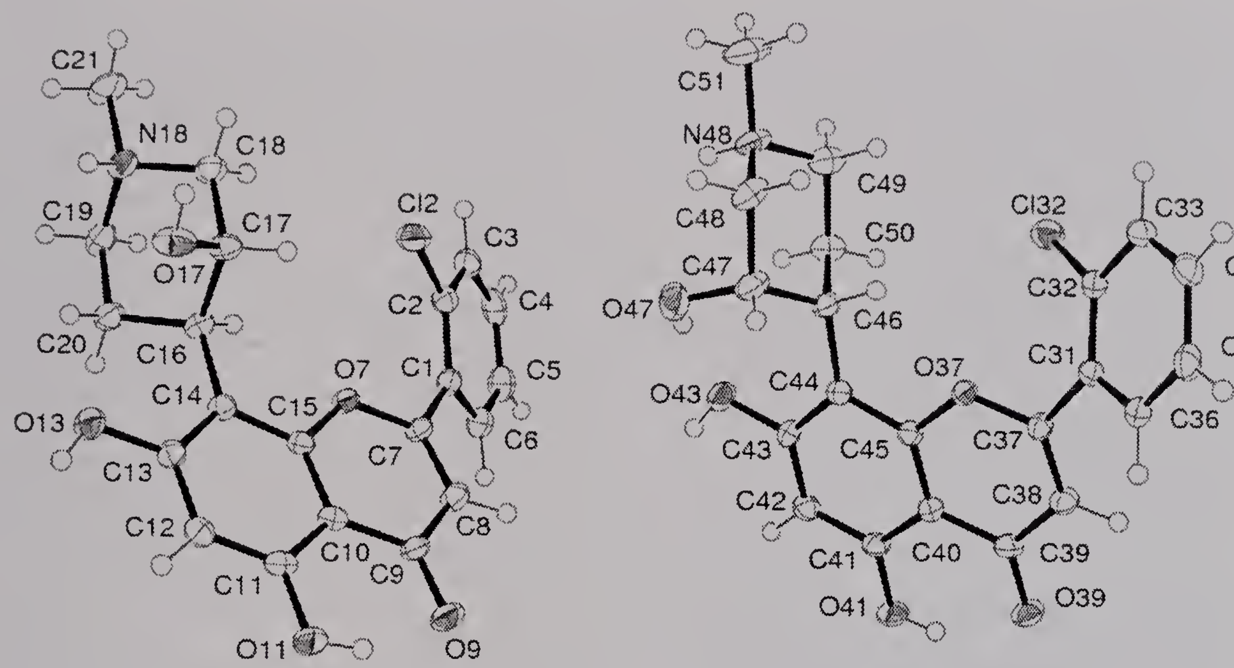


Fig 1 ORTEP representation of the two independent cations of [**2**+H] found in the unit cell; cation A (left) and cation B (right).

RESULTS AND DISCUSSION

The general crystal data parameters for the HCl salt of **2** (*i.e*., [**2**+H]Cl) can be found in Table 1. A list of selected bond lengths, bond and torsion angles for [**2**+H]Cl, in addition to the computationally derived gas phase values of both **1** and cationic [**2**+H]$^+$, are displayed in Table 2. Molecular representations (ORTEP) of the two independent [2+H] cations found within the unit cell are shown in Figure 1. In many respects, the solid-state structure of the cation of **2** is very similar to that described for other structurally characterised flavones with quite typical bond lengths and angles, specifically with respect to the benzopyrone and aromatic ring systems (Allen et al., 1987). 5-Hydroxyflavones, such as the title material, typically display intra-molecular *H*-bonding between the H atom on ring position-5 and the carbonyl O-atom (Chou et al., 2002; Krishnaiah et al., 2005; Parvez et al., 2001; Shoja 1989, 1990; Watson et al., 1991) and this certainly appears to be evident here (O9H•••O = 1.856Å). The benzopyrone ring is essentially planar with a torsion angle of less than 3°, similar to other flavones that have been previously reported (*e.g*., Krishnaiah et al., 2005) and this also appears to be the case for Rohitukine (Yang et al., 2003). For simplicity, direct comparisons will be noted for unit cell Molecule A only. Details of Molecule B can be found in the appropriate .cif file and/or details noted in Table 2. The overall crystal motif reveals considerable

Table 1 General crystal data for compound $(2{+}HCl)_2{\bullet}(MeOH)_{1.80}{\bullet}(H_2O)_{0.20}$

Parameter:	$\mathbf{(2{+}HCl)_2{\bullet}(MeOH)_{1.80}{\bullet}(H_2O)_{0.20}}$
Formula	$C_{43.80}H_{49.60}N_2O_{12}Cl_4$
fw	937.85
Crystal size (mm)	0.25 × 0.20 × 0.13
a (Å)	7.2014(10)
b (Å)	12.0094(9)
c (Å)	12.6581(14)
α (°)	89.146(4)
β (°)	89.788(6)
γ (°)	82.180(4)
V (Å^3)	1084.4(2)
D_{calc} (g/cm^3)	1.436
Crystal system; space group	Triclinic; P1
Z	1
F(000)	490.4
T (K)	173(2)
Absorption coefficient (mm^{-1})	0.339
2θ range (°)	2.86 – 27.63
Limiting indices	$-9 \le h \le +9$; $-15 \le k \le +15$; $-16 \le l \le +16$
Reflections collected	15962
Reflections unique	8544 [R(int) = 0.0414]
Reflections I > 2σ(I)	8544
Restraints / Parameters	3 / 571
GOF on F^2	1.055
Final R indices I > 2σ(I)	$R_1 = 0.0422$; $wR_2 = 0.0911$
R indices (all data)	$R_1 = 0.0522$; $wR_2 = 0.0987$
$\varrho_{min,max}$ (e·Å^3)	0.269, –0.284
Abs. Structure Parameter	–0.01(4)
λ (Å)	0.71073 Mo Kα

Table 2 Selected bond lengths (Å), bond and torsion angles (°) measured for $[2{+}HCl]_2{\bullet}(MeOH)_{1.80}{\bullet}(H_2O)_{0.20}$ and calculated (DFT: B3LYP/6-31G*) for **1** and $[\mathbf{2}{+}H]^+$. Estimated standard deviations are shown in parentheses.

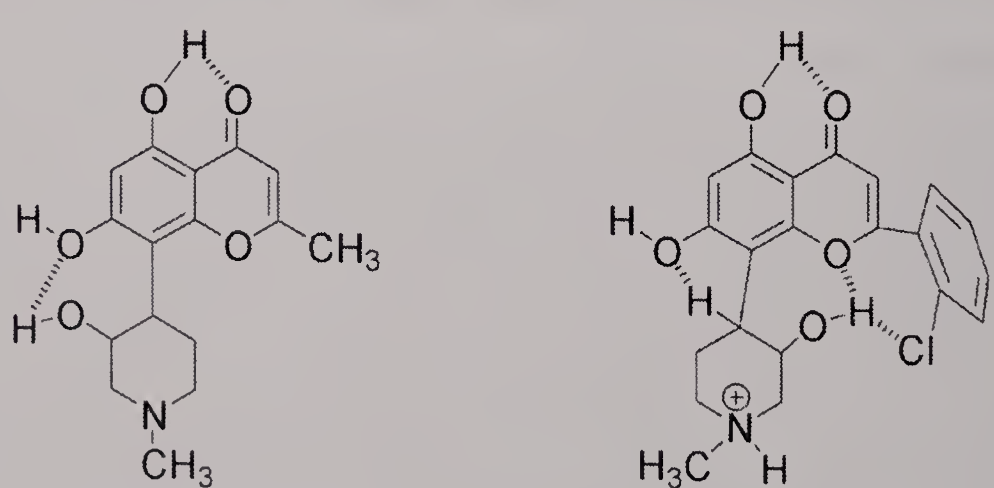
Value	1 (calc.)	[2+H]$^+$.(calc.)	[2+H]Cl•(observed)[a]
C=O (Å)	1.251	1.243	1.263(4); 1.269(3)
C=C (Å)	1.351	1.346	1.343(4); 1.358(4)
$C_{aromatic}$-OH (Å)	1.339; 1.359	1.330; 1.363	1.360(3); 1.364(4) 1.358(3); 1.368(3)
C-Cl (Å)	n/a	1.761	1.737(3); 1.741(3)
C=C-CH_3 (°)	126.2	n/a	n/a
C=C-C_{phenyl} (°)	n/a	124.84	125.4(3); 125.6(3)
C-CH-CH-OH (°)	56.13	-77.10	-66.4(3); -63.6(4)
C=C-C-CCl (°)	n/a	106.42	-143.0(3); 141.3(3)

[a] Entries for Molecule A (see text) are listed first.

intermolecular *H*-bonding aspects, specifically the 7-OH group with a formal chloride anion (O13H•••Cl = 2.23Å). The N-H functionality is also in close proximity to one of the lattice methanol O atoms (N18H•••O = 1.96Å). The chlorophenyl group is oriented out of the plane of the benzopyrone ring by about 41°; a property which decreases the contact distance between the Cl atom and the H on piperidinyl ring position 3' (C17H•••Cl = 2.86Å). Other flavones (Hall et al., 2001; Waller et al., 2005), including 2'-substituted examples, also display such large angles (Chou et al., 2002; Shoja, 1989; Ting et al., 1972) and indeed a value of 62° has been reported for 6-hydroxy-2',3'-dimethoxyflavone (Wallet et al., 1993).

Flavopiridol hydrochloride obviously demonstrates considerable inter- and intra-molecular *H*-bonding, as detailed above, in the solid-state. The obvious low volatility of this salt negates one's ability to also examine this material in the gas-phase to evaluate any *H*-bonding facets. However, the examination of compounds from a theoretical perspective allows one to probe the structural aspects of such species in the hypothetical gas-phase (*i.e.*, a single isolated molecule). Of the plethora of computational methods that can be used in this regard, Density Functional Theory (DFT) has become a widely employed and powerful tool to examine molecules and molecular fragments from a theoretical point of view in the gas-phase, solution and indeed even in network solids (Goodman, 1998; Koch & Holthausen, 2002; Sholl

& Steckel, 2009). An examination of both **1** and [**2**+H]$^+$ was therefore carried out using DFT to examine the overall structural properties and attempt to draw some conclusions about possible gas-phase structures of these two species. Selected calculated bond lengths and bond and torsion angles can be found in Table 2. As expected (Chojnacka et al., 2011), the DFT calculations do closely parallel the solid-state structures of the two materials. As details of the bond lengths and angles for the crystalline state of **1** do not appear in the literature (Yang et al., 2003), a comparison of calculated **1** to that of [**2**+H]$^+$ depicts a reasonable structural similarity between the two species (Table 2). As inter-molecular *H*-bonding cannot be involved here, this restricts the attractive forces to those of an intra-molecular nature. A skeletal diagram indicating the calculated *H*-bonding aspects (dashed line 'bonds') is shown in Scheme 2. The calculated Flavopiridol cation displays lesser rotation of the aromatic group with respect to that of the benzopyrone ring (calc. 106°; found 141°) and this serves to facilitate *H*-bonding between the 3'-OH (piperdinyl) group and the chlorine atom (calc. O17H•••Cl = 2.65Å). Obviously, this latter result causes considerable rotation of the piperdinyl ring and this again strengthens intra-molecular *H*-bonding, in this case between the same –OH and the benzopyrone ether O atom (O17H•••O7 = 2.05Å). These latter aspects do not appear for **1** but instead strong interactions between the piperonyl OH and the benzopyrone 7'-OH position is observed (O17H•••O = 1.88Å: Table 2; Scheme 2). Not surprisingly, both calculated structures include close contacts between the H atom on ring position-5 and the



[1]   [2+H]$^+$

Scheme 2 Schematic representation of the H-bonds (dashed lines) calculated for gas-phase 1 and the Flavopiridol cation ([2+H]$^+$). In both cases, stereochemical bond descriptors have been removed for clarity.

carbonyl O-atom although a slight over estimation of this strength is noted (calc. O11H•••O9 = 1.69Å for **1** and 1.70Å for [**2**+H]$^+$). The C=O (**1**: 1.25Å; **2**: 1.24Å) and C-Cl bonds ([**2**+H]$^+$) are well-estimated in both cases (**2**: C-Cl = 1.76Å). The calculated UV-Visible absorptions are also estimated with fair accuracy for both **1** (λ_{max} [calc.]: 241 nm; λ_{max}: [observed]: 252 nm) and [**2**+H]Cl (λ_{max} [calc.]: 247 nm; λ_{max}: [observed: aqueous]: 269 nm), despite the molecular rearrangements noted above for gas-phase calculations (Sedlacek et al., 1996; Tang et al., 2004; Yang et al., 2009).

CONCLUSIONS

The solid-state crystal structure of Flavopiridol hydrochloride, in the form of meta-stable crystals containing both methanol and water molecules, has been detailed. This compound has features similar to other related flavanoids that have been characterised in the solid-state such as Rohitukine. This latter material and the cationic component of the title compound have been further examined from a theoretical perspective by Density Functional Theory and these results suggest a modified pattern of *H*-bonding for individual gas-phase molecules.

Acknowledgements The author is indebted to *Ryerson University* for support of this work. Additional funding for the author has been provided by NSERC (Canada) in the form of a Discovery Grant. Prof. D.-M. Ren (*Shandong University*) is thanked for providing a reprint of his publication. Prof. Daniel A. Foucher (*Ryerson University*) is acknowledged for his critical review of this manuscript, as well as anonymous journal referees.

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Proceedings of the Nova Scotian Institute of Science (2011)
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REPORTS FROM THE NSIS COUNCIL NOVA SCOTIAN INSTITUTE OF SCIENCE

REPORT OF THE PRESIDENT, 2010 TO 2011

The Nova Scotian Institute of Science serves Nova Scotia and the greater Atlantic region of Canada by:

- Providing a forum for scientists and those interested in science to learn about and discuss scientific matters, through a monthly public lecture and discussion series,
- Publishing its journal (The Proceedings of the Nova Scotian Institute of Science) which has appeared regularly since 1863,
- Drawing attention to issues of societal concern that intersect the natural and social sciences, such as education, environmental and natural resource policies, and ethics via the NSIS website,
- Promoting research and education in science by awards made to students at each of the Regional Science Fairs in Nova Scotia,
- Supporting a number of undergraduate conferences organized by the Atlantic Provinces Council on the Sciences (APICS) by providing prizes for winning presentations,
- Conducting an annual Scientific Writing Competition for university students,
- Presenting current and historical material of Canadian scientific importance to the public on its website: http://www.chebucto.ns.ca/Science/NSIS/index.html, and
- Maintaining a library in collaboration with Dalhousie University and the Nova Scotian Institute of Science 'Virtual Hall of Fame' which honours men and women who have contributed significantly to the scientific activity in Nova Scotia.

The 2010-2011 year has proved successful with 21 new members joining the Nova Scotian Institute of Science, the publication of two issues of Volume 45 of the Proceedings, and the enthusiastic response of members and the public to our lecture series. The lecture program was organized by Ron MacKay with the help of John Rutherford and Angelica Silva. Most of the lectures were held at the Nova Scotia Museum of Natural History and the Institute is indebted to the Museum for its continued support. We acknowledge the monthly assistance of David Christianson, the Museum's Manager of Collections. From thirty to fifty members attended each lecture. There was an annual round table held in January, and the NSIS also co-sponsored the Seventh Annual Sable Island Update, which was held at Saint Mary's University and attended by some 200 people. The programme of NSIS lectures was as follows:

Monday 4th October 2010
Dr. Brendan Murphy, Earth Sciences Department, St. Francis Xavier University, **"Mountains: Past, Present and Future"**, 7:30 pm Nova Scotia Museum of Natural History.

Monday 1st November 2010
Dr. Mike C. James, Department of Biology, Dalhousie University/ Aquatic Species at Risk, Fisheries and Oceans Canada, **"The Leather-back Turtle: Atlantic Canada's Giant Jellyfish Predator"**, 7:30 pm Nova Scotia Museum of Natural History.

Monday 6th December 2010
Timothy Frasier and Brenna McLeod, Department of Biology, Saint Mary's University. **"Using Genetics to Learn about the History of Arctic Whales"** 7:30 pm Nova Scotia Museum of Natural History.

Monday 10th January 2011
Panel discussion **"How Reliable is Science Anyway?" : The Problem of Decision-making in the Context of Scientific Uncertainty.** Panellists: Dr. Lisa Gannett, Department of Philosophy, St. Mary's University; Dr. Bill Freedman, Department of Biology, Dalhousie University; Dr. Tony Charles, Department of Environmental Studies, Saint Mary's University. 7:30 pm Scotiabank Conference Theatre, Sobey Building, St. Mary's University.

Monday 7th February 2011
Drs. Jerry Singleton, Melanie Keats, Laurene Rehman and David Westwood of the School of Health and Human Performance, Dalhousie University, in collaboration with Halifax Public Libraries, **"Be a Good Sport: Fun for Everyone Across the Life Course"**, 7:00pm Keshen Goodman Public Library.

Monday 7th March 2011
Drs. Jonathan Fowler and Tanya Peckmann Department of Anthropology, Saint Mary's University. **"Facial Reconstruction: an Acadian Child from the 18th Century"**, 7:30 pm Nova Scotia Museum of Natural History.

Monday 4th April 2011
Dr. Cathy Conrad, Department of Geography, Saint Mary's University. **"Citizen Science: How the Public Can Engage in Scientific Inquiry"**, 7:30 pm Nova Scotia Museum of Natural History.

Monday 2nd May 2011
NSIS Annual Dinner and AGM (Dalhousie Faculty Club). After dinner speaker Dr. Jeanette Janssen, Department of Mathematics and Statistics, Dalhousie University. **"Using Mathematics to Model the World Wide Web"**.

Two issues of the Proceedings were published in 2010, the first was one devoted to Scatarie Island, NS, and the second was a regular issue. Feedback to these issues has been very positive. The editor, Peter Wells, plans to produce two issues of the Proceedings during 2011 calendar year. The Institute is indebted to the Editor and to the members of the Editorial Board for their services. We also thank the Nova Scotia Department of Tourism and Heritage for a grant to assist with the cost of publishing the Proceedings. Finally, the Institute has printed a further 100 copies of the first edition of *The Flora of Nova Scotia* which is used by students in courses on plant identification at Nova Scotian Universities.

Dalhousie University which houses the NSIS library has digitized the Proceedings of the NSIS from 1863-1934 and we hope will make more recent volumes available by 2012. Further details can be found at: http://dalspace.library.dal.ca/dspace/handle/10222/11192.

A Science Writing Competition was organized again this year by Robert Cook. This year we initiated a Video category, but unfortunately after some initial enthusiasm, no video entries were sent in. However, there were submissions in the Writing category and we extend congratulations to the winners in the 2011 NSIS Student Science Writing Competition who were presented with certificates at the April meeting of the NSIS:

Mr. Scott G. Harroun of Saint Mary's University is the Winner of the Writing Award for his paper "Application of Surface Enhanced Raman Spectroscopy for the Determination of Chemical Composition of Paint Samples from the Historic Charles Morris Building in Halifax, Nova Scotia".

And

Ms. Carol Anne Black of Dalhousie University, an Honourable Mention award for her paper "Turbidity Currents: Nova Scotia's African Heritage"

A NSIS committee has been established, chaired by Michelle Paon, which is working on special events for the 150th Anniversary. One of the regular monthly lectures for the forthcoming year, 2012, will be on the history of gold exploration in Nova Scotia and will be held at the Art Gallery of Nova Scotia in association with their special exhibition 'The Golden Touch': Art and Gold in Nova Scotia.

We have submitted proposals to Canada Post for a special stamp to celebrate this event. In addition, the Dalhousie University School for Resource and Environmental Studies (SRES) with support from the NSIS, applied to organize the 2012 Killam Lecture Series at Dalhousie University. This was approved and will be part of the celebrations for our anniversary. It will involve a series of leading science speakers. We are also collaborating with the Bedford Institute of Oceanography which celebrates its 50th anniversary in 2012. We applied to the Donner Canadian Foundation in 2010 for funds to assist with NSIS activities associated with our 150th anniversary but were unfortunately not successful.

In other activities, the Institute has again provided financial support to the ten Regional Science Fairs in Nova Scotia. Various members of the NSIS Council acted as judges at these fairs and selected projects for the NSIS awards.

In conclusion, members of the Institute are undoubtedly aware that the NSIS mission of presenting and promoting science, especially research, can only be achieved by continued activity on the part of members by serving on Council and by taking part in other activities of the Institute. As with all similar volunteer organizations, there is a need for younger members to become active as older members retire.

The Institute has a long and proud history and will celebrate 150 years of promoting science to Nova Scotians in 2012. Few other Canadian organizations can boast this track record.

Finally, I thank all members of Council for their diligence and hard work during the past year.

Respectfully submitted,
David H.S. Richardson
May 2nd 2011

LIBRARIAN'S REPORT 2010/2011

Prepared for AGM May 2, 2011

There are currently one hundred and seventy-nine NSIS exchange partners. Four institutions, Linda Hall Library, Kansas City; Polska Akademia Nauk, Poland; Societe Geologique de Normandie et des Amis du Museum du Havre, France; VNIRO Library, USSR cancelled their exchange program with us over the past year. The number of institutional members has decreased by two and is now at twenty-four. Public Archives of Nova Scotia & Blacker Wood Library, Montreal cancelled their membership in 2011. Invoices were sent out in February 2011 for institutional memberships and to date we have received payment for nineteen renewals.

Volume 45, parts 1 and 2 of the ***Proceedings of the Nova Scotian Institute of Science*** were both published in 2010. Both issues were sent to exchange partners and institutional members in one mailing to save on the cost of postage. The NSIS president, David Richardson, was able to use the St. Mary's University mail room service which offered reasonable rates for overseas postage.

Sales of past volumes of the ***Proceedings*** during 2010/2011 generated $930.50 in revenue. (See Appendix A (attached) for details.) There are 126 copies of the ***Flora of Nova Scotia*** by A.E. Roland on hand @ $35.00 each.

The Librarian submitted the required forms to Access Copyright for the 2010 repertoire payment to publishers. A cheque in the amount of $431.54 was received.

During the summer of 2010 volumes 13 (1910-1914) – v.18 (1930-1934) of the ***Proceedings of the Nova Scotian Institute of Science*** were digitized and made available online through a digital initiative in the Dalhousie University Libraries. These volumes were deposited in DalSpace and can be viewed at http://www.library.dal.ca/collections/digitalcollections/nsis. At the March 4, 2011, meeting Council approved a request from the Librarian for funding for the digitization of v. 19 (1934-1938) – v. 25 (1958-1962) of the ***Proceedings of the Nova Scotian Institute of Science***. This will complete the first 100 years of the journal. A launch of the digitized version of the ***Proceedings*** is being planned for January 2012, as part of the 150th NSIS anniversary celebration. At the April 4th meeting of Council, a cheque for $2,205.00

was received by the Librarian to fund a four week position to complete this digitization. A further proposal is being prepared to estimate the cost of finishing the digitization of the ***Proceedings*** for v. 26-present.

At the Council meeting of April 4th, 2011, a motion was passed that the price for copies of the ***Flora*** would be reduced by 10% if ten or more copies were purchased for a class and picked up from the Librarian's office (Regular price for a single copy is $35.00; bulk buy discount price is $31.50 per copy).

Dalhousie University has been assigned a new postal code. This means a change to the NSIS mailing address, effective immediately. The new mailing address is:

Nova Scotian Institute of Science
c/o Killam Library Reference & Research Services Office
1459 Oxford Street
Dalhousie University, Halifax, NS Canada
B3H 4R2

Publications continue to be received regularly from our 179 active exchange partners and this material is added on an ongoing basis to the collection. I would like to thank Carol Richardson and the Serials Department staff in the Killam Library who ensure that the NSIS Library operations continue to function smoothly.

Respectfully submitted,
Sharon Longard
NSIS Librarian
April 12, 2011

LIBRARIAN'S REPORT
Appendix A

Date	Monies Received	# Sold	Institution	COST	Paid
June 2010	Flora of NS	1	Meade Victoria Humble	$35.00	$35.00
June 2010	Flora of NS	1	Emma Morgan-Thorp	$35.00	$35.00
June 2010	Flora of NS	20	Phil Schappert Biology 2601 class	$700.00	$700.00
September 2010	v.29 pg. 1-131	1	Matteo Carbona	$14.50	$14.50 (7.50+7.00 S/H)
November 2010	v. 45, pt. 1, 2010	12	Nova Scotia Environment	$96.00	$96.00
December 2010	v.36, pt. 2, 1986	1	N. S. Environment Library	$10.00	$10.00 (7.50+2.50 S/H)
December 2010	v.34, pt. ¾, 1984	1	Sherman Jackson	$10.00	$10.00
January 2011	v.34, pt. ¾	1	Peter Wells	$10.00	$10.00
February 1, 2011	v.27 suppl. 3, 1975	3	David Bethoney	$20.00	$20.00 (3 x $5.00 + $5.00 S/H)
Total				**$930.50**	**$930.50**

Sales of Proceedings June 2010 – February 2011

EDITOR'S REPORT

NSIS ANNUAL GENERAL MEETING
MAY 2ND, 2011

Status of the Proceedings of the NSIS

PNSIS Volume 45 (Parts1 and 2) was successfully completed over the past calendar year. Over the same period, we have strengthened the Editorial Board, prepared guidelines for manuscript flow, and communicated with the new Editorial Board regarding the Journal and Board members responsibilities. We hope the Board will support the Proceedings by actively soliciting papers and being involved in the review process more directly. As well, we are supported at Dalhousie University by two staff members (Sarah Stevenson, Gail LeBlanc) for journal layout and production, crucial roles for the Journal's success. We have an excellent and enthusiastic team to run the Proceedings.

So far in 2011, two scientific papers and two student papers have been submitted to Volume 46(2), and a full manuscript has been submitted for a special issue Volume 46(1) by Dr. Eric Mills. An internal list of prospective papers and editorials is guiding our activities on the Proceedings, especially as we move towards the 150th Anniversary year, 2012. As we progress through this year, the Proceedings will be redesigned with a new cover and layout, and options considered for making the Proceedings available in both print and electronic formats.

Papers and editorials are requested from all members of the NSIS. Supported by the website, the Proceedings are the visible, written voice piece for the Society as well as for science in all of its dimensions in Nova Scotia and the Maritime Provinces. We hope to keep attracting papers highlighting the advances of science by practitioners in the Region, as well as articles on the history of science and its current role in furthering the welfare of Maritime society, from health to economy to environment. This is your journal; please contribute to it and help us continually improve it's content, distribution and use so that it serves the Society, the Region and Canada with excellence, far into the future.

Submitted:
Peter G. Wells, Dalhousie University (Editor)

TREASURER'S REPORT

NOVA SCOTIAN INSTITUTE OF SCIENCE
MARCH 31, 2011

ASSETS:		
Bank Account	5,674.44	
Investments	63,068.14	
TOTAL ASSETS		**68,742.58**
LIABILITIES AND NET WORTH:		
Accounts Payable		
Science Fair	100.00	
		100.00
NET WORTH		**68,642.58**
TOTAL LIABILITIES AND NET WORTH		**68,742.58**

INVESTMENTS:	
Renaissance High Interest Savings Account	11,268.14
CIBC Investment	
Certificate A @5.05% (due Jun 2011)	11,500.00
CIBC Investment	
Certificate A @5.20% (due Oct. 2012)	20,000.00
National Bank of Canada	
Certificate A@2.900% (due May 2013)	10,300.00
Montreal Trust Company	
Certificate A@3.250 % (dueJuly15 2015)	10,000.00
TOTAL INVESTMENTS	**63,068.14**

Finances

The net worth of the Institute is $68,642.58 For this year, revenue included a grant of $1000.00 from the Nova Scotia Department of Tourism and Culture. The Institute also received $431.54 from ACCESS copyright for publication royalties. A donation of $500.00 was received from the Situating Science Cluster (SSC); this is being held for a future video award.

REVENUE AND EXPENDITURES FOR 2010-2011

REVENUE		
Membership Dues		
Individuals	$2,480.00	
Institutions	469.83	
AGM (2010)	1,482.00	
Donations/Grant	1535.00	
Sales/Page charges		
Proceedings	409.50	
Other-Flora	770.00	
Income/Royalties		
Investment Income	2,458.01	
Access Copyright Royalty	431.54	
Bank Interest	0.91	
		$10,036.79
EXPENDITURES		
Advertisement/Promotion	$542.36	
AGM (2010)	1,557.17	
Office supplies	27.49	
Rent	56.50	
Postage	1,738.21	
Donations/Prizes	1,750.00	
Honoraria	200.00	
Proceedings Costs	3,814.86	
Flora Costs	1,897.50	
		$11,584.09

Net income: (Loss) ($1,547.30)

Expenditures for donations and prizes totalled $1750.00. This included $100.00 donations to each of 10 regional Science Fairs in Nova Scotia, and two writing competition awards, one each of $500.00 for graduate and $250.00 for undergraduate.

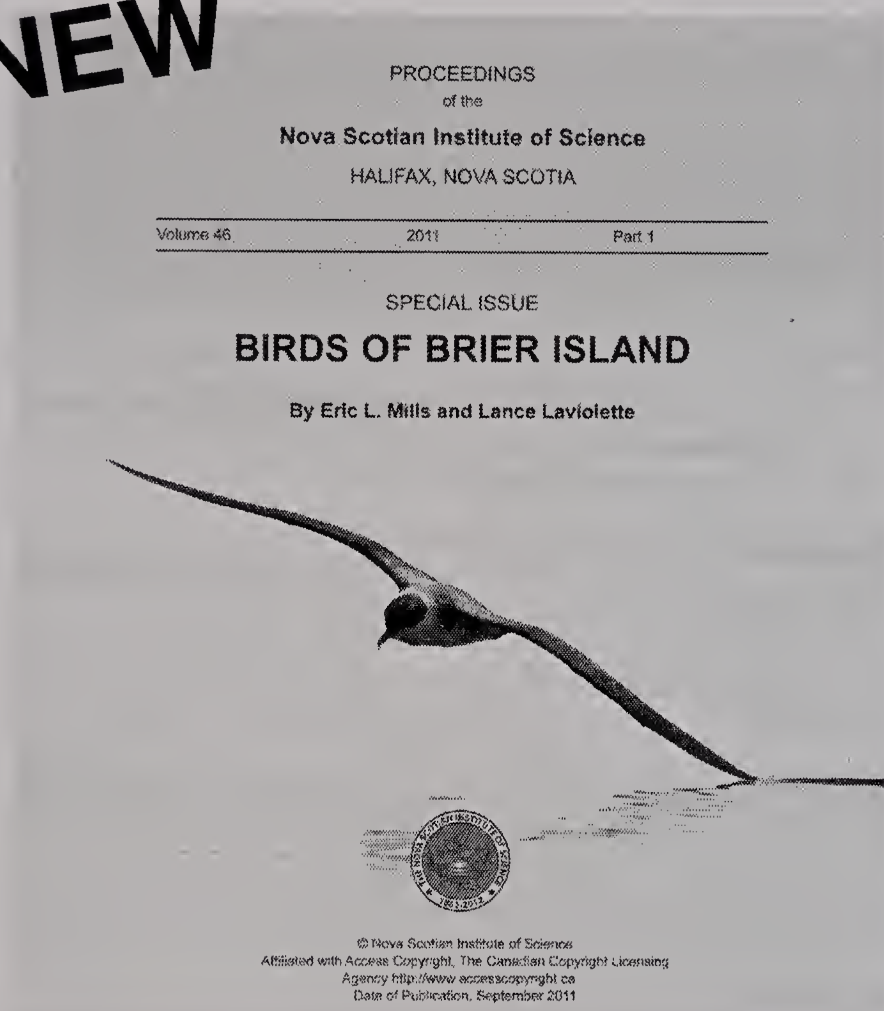
Membership

The Institute has 106 individual members including 6 life members and 3 student members. This year there were 21 new members. Dues from individual members amounted to $2,480.00 and from institutional members $469.83.

Respectfully submitted to the AGM
May 2, 2011
Elaine D. McCulloch
Treasurer

BIRDS OF BRIER ISLAND

NEW


PROCEEDINGS
of the
Nova Scotian Institute of Science
HALIFAX, NOVA SCOTIA

Volume 46 2011 Part 1

SPECIAL ISSUE
BIRDS OF BRIER ISLAND
By Eric L. Mills and Lance Laviolette

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Date of Publication, September 2011

Cover photo: Great Shearwater by Richard Stern

Birds of Brier Island by Eric L. Mills & Lance Laviolette. Sept. 2011; gives a fascinating overview of the visiting and nesting birds that have travelled through Nova Scotia's Bay of Fundy region and made a stopover on Brier Island. 107pp, ill. 8.5 x 11 in; softcover. Published as a special issue — Vol. 46, Part 1, of the Proceedings of the Nova Scotian Institute of Science.

Price: CDN$25.00 + postage and handling.

2011 postage & handling charges per copy (CDN dollars) : Within Canada: add $5.00 US orders: add $8.00.

If you wish to purchase multiple copies, please contact Carol Richardson (clrichar@dal.ca) about the cost of postage and handling.

To avoid postage fees, copies of the book can also be purchased in person at the Killam Library Research Services office, 3rd floor, Killam Library, 6225 University Ave., Halifax, Nova Scotia.

See next page for Order Form.

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Email address: ____________________________________

Please make cheque payable to: Nova Scotian Institute of Science

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Nova Scotian Institute of Science
c/o Killam Library, Dalhousie University, 6225 University Avenue
P. O. Box 15000, Halifax, Nova Scotia, Canada B3H 4R2

PLEASE PHOTOCOPY & FILL OUT AND FORWARD TO ADDRESS ABOVE.

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Les auteurs peuvent soumettre leur manuscrit en anglais ou en français et doivent l'envoyer au rédacteur en chef par courriel (nsis@dal.ca et oceans2@ns.sympatico.ca). Le titre du manuscrit doit être suivi des noms de tous les auteurs, leurs adresses respectives et leurs adresses de courriel. Un résumé doit suivre qui comptera au plus 200 mots. Si approprié, il doit y avoir des sections tel que l'introduction, les méthodes, les résultats, la discussion, les conclusions et les références bibliographiques. L'orthographe doit suivre *Le Grand Robert*, et il est recommandé de se servir du Système international d'unités. Des frais de 25,00$ par page sont présentement imposés, à moins que tous les auteurs sont membres du Nova Scotian Institute of Science. (Les frais d'adhésion pour membres réguliers sont 25,00$ par an, et pour étudiants sont 10,00$ par an.) Des tableaux, des illustrations et des photos en noir et blanc peuvent être inclus et seront reproduits sans frais supplémentaires. Au format copie papier du journal, les coûts de reproduction en couleurs seront aux frais des auteurs, et seront environ 500$ par planche qui peut être une seule photo ou un collage. Chaque tableau ou illustration doit porter un titre et une légende auto-explicative.

Veuillez consulter des exemplaires du Journal pour vérifier le format du manuscrit. Chaque page doit être numérotée. Les références bibliographiques doivent être en ordre alphabétique et doivent montrer le nom complet de la revue, et si approprié, les numéros des revues, comme les exemples suivants:

Nielsen, K.J., & France, D.F. (1995) The influence of adult conspecifics and shore level on recruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine Biology and Ecology* 188 (1):89-98.

Cushing, D. & Walsh, J. (1976) The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975) Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

Communication personnelle: Smith A.J. (2001, pers. comm.) in text.

Document sur un site web: Auteur (l'année de publication) titre, URL et la date de consultation.

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INSTRUCTIONS TO AUTHORS

Papers may be submitted in either English or French and should be sent electronically to the Editor at (nsis@dal.ca and oceans2@ns.sympatico.ca). The title should be followed by names, addresses and e-mails of all authors. An abstract of up to 200 words should follow. As appropriate, sections devoted to introduction, methods, results, discussion, conclusions and references should be included. Canadian spelling and SI units should be used wherever possible. There is currently a page charge of $25 per page but this will not be levied if all authors are NSIS members (Membership costs $25 per year for regular members and $10 year for students.) Tables, figures and black and white photographs may be included and will be published without an extra charge. Publication of colour figures in any hard copy of the journal will incur a charge that must be borne by the author and will likely be in the range of $500 per plate which may be a single photo or a collage. All tables and illustrations should have a title and a self-explanatory legend.

Refer to back issues of the Journal for general layout of a paper. Pages should be numbered. References should be in alphabetical order and give the full title of the journal and issue numbers where appropriate, thus:

Nielsen, K.J., & France, D.F. (1995) The influence of adult conspecifics and shore level on recruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine Biology and Ecology* 188 (1):89-98.

Cushing, D. & Walsh J. (1976) The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975) Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

Personal Communication: Smith A.J. (2001, pers. comm.) in text.

Website Citation: Author (year) title, URL and date accessed.

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