Northeast Forest Fire Protection Compact Stress-testing Project

Atlantics Canada Fire History Working Paper 1919-2011

Revised Draft
April 18, 2012
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Highlights

1. For this region, we rely on a historical record, from 1919 (New Brunswick), 1930 (Nova Scotia) and 1944 (Newfoundland) to 2011. Most of the fire in the Atlantics occurs in Newfoundland, principally in Labrador. From 1944 to 2011, 3.25 million ha burned in the Atlantics, 86% in Newfoundland. For comparison, this roughly equals all the forest area of Massachusetts plus New Hampshire.
2. Decadal averages for the region as a whole peaked in the 1960s, at 97,000 ha per year. For the 2000s ending in 2011, the decadal average was only 26,000 ha, or 1/4 as much.
3. Regional area burned in 2011 was the lowest recorded since 1944.
4. Over this period, Newfoundland has shown a modest decline in area burned, but not in number of fires. Volatility is very high – in every decade there occurs one fire that is one standard deviation larger than the mean. Newfoundland's experience in this period displays clear extreme value tendencies.
5. Area burned has declined significantly in Nova Scotia and New Brunswick. On an annual basis, these provinces do not display extreme value tendencies at all, but for one extreme event in each province (1976 and 1986, respectively). These extreme years prevent any meaningful analysis in terms of return periods. The odds of such extremes recurring cannot be measured statistically, as so many factors have changed since then.
6. A tendency for severe fire years to occur together in this region has moderated since the 1960s. But on occasion, bad Quebec fire years occur together with bad Newfoundland years.

7. Because of its milder fire experience, there has been less detailed research on weather-fire interactions in this region than in the rest of the Boreal Shield.

8. Analysis of individual fire data for Newfoundland in selected years indicates clear differences in fire size distributions over time and across regions.

9. Based on individual fire data, fires greater than 1 acre, 1987-2009, we can see that:

    a. The fire season has become shorter.

    b. Largest fires occur in the longest fire seasons.

    c. Nova Scotia has experienced a fire exceeding 500 ha more than once per decade since 1987. The size reached by the largest fire is not decreasing.

    d. The lowest quintile of fires, 400 ha and smaller, accounts for 69% of area burned, but the all-time record fire burned 10% of the entire area burned over the period.

10. We were unable to locate long-term weather data to see if any interesting associations with weather conditions would be found.

Introduction

This note summarizes key Provincial data on forest fire history of the Atlantic Provinces since the early twentieth century. It supplies further analysis for the period since 1970. We omit Prince Edward Island as it is not a Compact member. This region accounts for less than 2% of average annual area burned in Canada.[1] Compared to the previous version of this paper, new data has been received in a number of areas.

We reach back into history for several reasons. First, it is useful to see whether major fire years are synchronous or not, and if so to associate those with weather conditions to the extent we can. Second, the history can yield clues to important associations with weather that might not be evident from a short period of records. Analyzing this kind of information is subject to the usual caveats; especially for the older data, completeness and accuracy of coverage cannot always be assured. For example, it is easy to find in the literature widely differing estimates of the area for the same fire! Even today it is believed that not all wildfires make it into the statistical reporting system.[2] Most importantly we must take care in making casual extrapolations to the future. Ultimately we hope to analyze circumstances surrounding the very largest fires in the region, and hope to use the annual fire occurrence data to identify years when those occurred.

As a policy matter, the number of acres burned annually may not be a sensible way to discuss policy. A year is an arbitrary unit of time. Would it make more sense to think in terms of area burned per decade or even longer, given resource and property values involved? Also, in this research we are searching for general empirical regularities to the extent they can be observed, but our purpose is not to develop methods for prediction.

We have been able to locate history for all 3 provinces on area burned and fire numbers since 1944 for Newfoundland, 1930 for Nova Scotia, and 1919 for New Brunswick. We notice differences between Provincial and Canadian Forest Service data since 1970, and have chosen to use the Provincial data here. The data are in a table at the end of this Working Paper. Comparisons of fire history during the early 20th century when the Northeast experienced extreme fire years will have to await further primary research, outside scope of this project. Still, information from 1944 yields interesting contrasts. We have obtained individual fire data for a sample of years from Newfoundland, for 1982-2011 for New Brunswick, and for 1987-2010 for Nova Scotia. These are presented at the end of this paper. For valuable history of past fires and control programs, see Alexander (2010) and Pyne (2007).

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[1] National data, CIFFC, 2011. We would like to acknowledge helpful assistance from Ed Swift of the Canada Forest Service, and members of the Natural Resources Departments who provided official data.

[2] Papers by Wein and Moore (1977 and 1979) supply full details on these issues.

Occasionally in these analyses we present equations for the fitted lines; these are descriptive only and do not imply that we have found the "best fit". Further, they have no predictive implications.

This paper is organized as follows: first are two summaries of regional trends, one beginning with our earliest data, then a section exploring 1970 to the present in a bit more depth.

A. Regional Fire History, 1919-2011

Valuable papers by Wein and Moore (1977 and 1979) give fire history in considerable detail for New Brunswick for 1920-1975, and Nova Scotia 1915-1975, including discussions on causes and fire rotation periods. They supply valuable discussion as well on limitations of historical data. While they included extensive tables of derived data on an annual basis, along with charts, they did not publish the raw data on area burned and number of fires.

To date, we have been able to locate fire history data for:

Newfoundland	1944-2010
Nova Scotia	1930-2011
New Brunswick	1919-2100

The area burned according to this dataset is heavily concentrated in Newfoundland (mostly Labrador), which is also highly volatile, as is Quebec. Since 1944, Newfoundland has accounted for anywhere from 1% to more than 90% of the area burned in the region. On occasion, peaks in area burned do coincide over this period. For comparisons we first look at trends since 1944, the first year for which we have 3 provinces of data (Figs. 1 and 2).

Figure 1

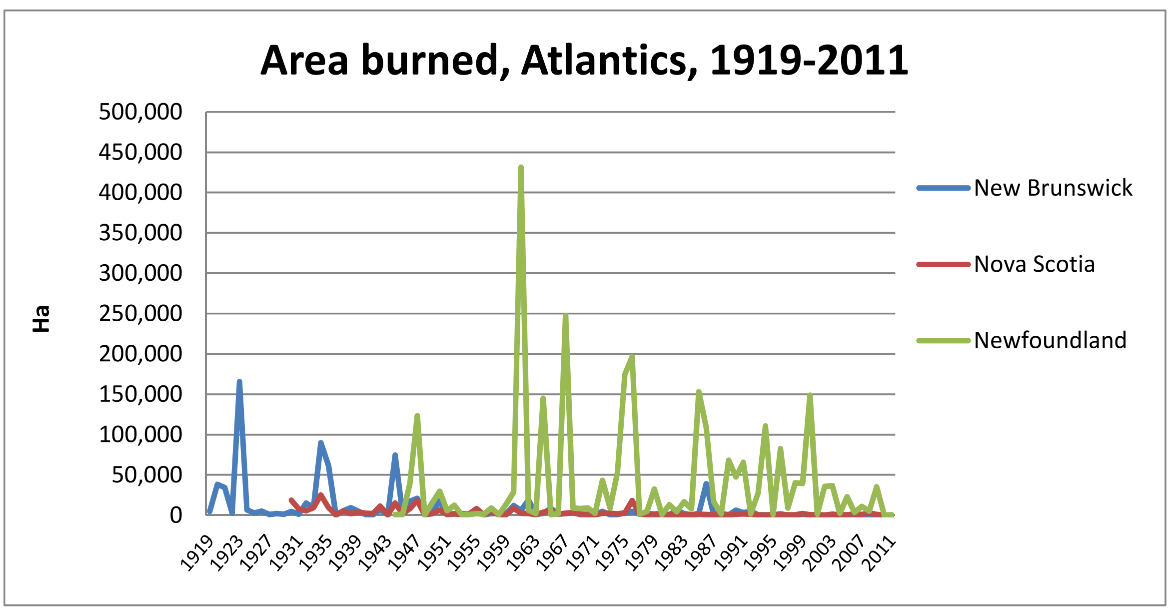
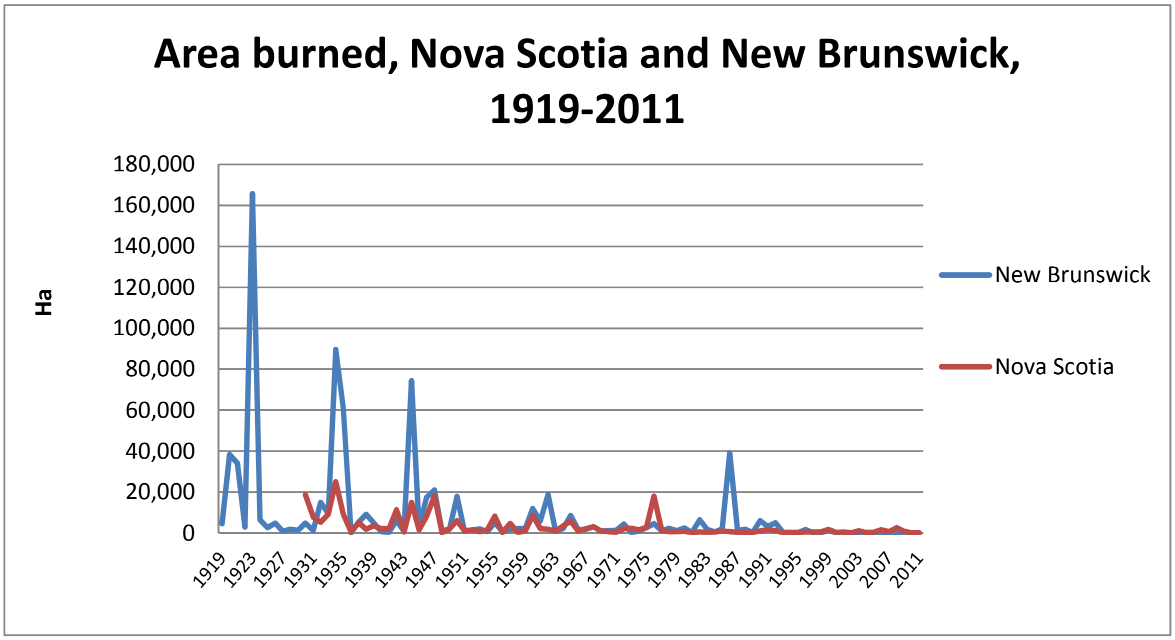


Figure 2



From 1944 to 2011, a total of 3.2 MM ha were burned – roughly the size of all southern New England. Reported fire numbers show a striking humped pattern, due entirely to the fire numbers in New Brunswick and Nova Scotia (Figs. 3 and 4).

Figure 3

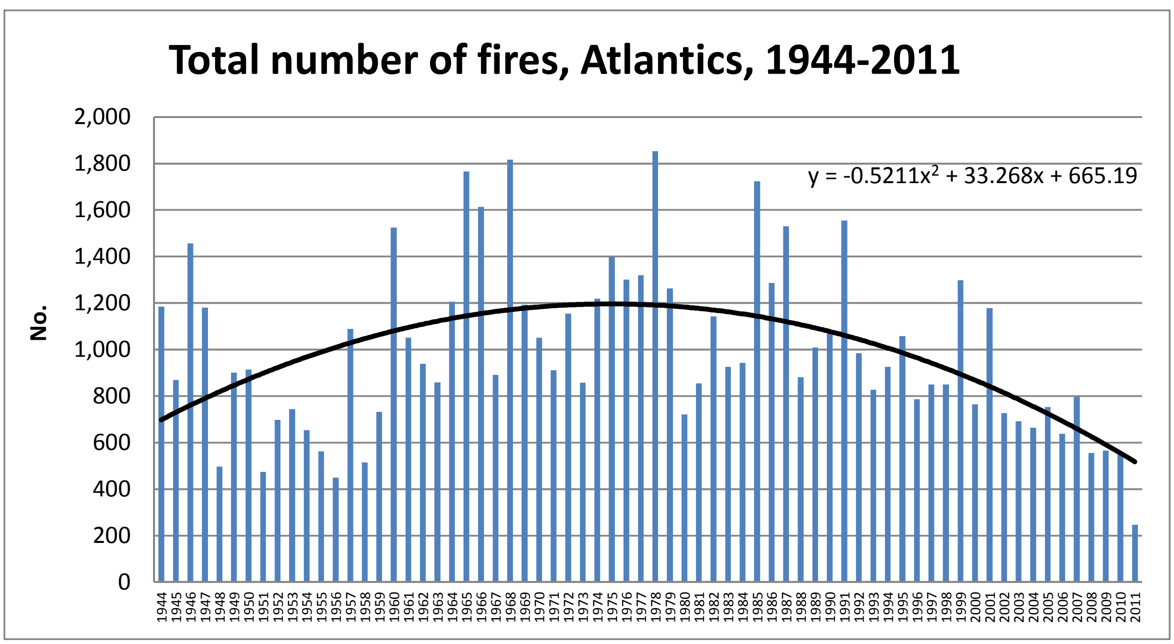
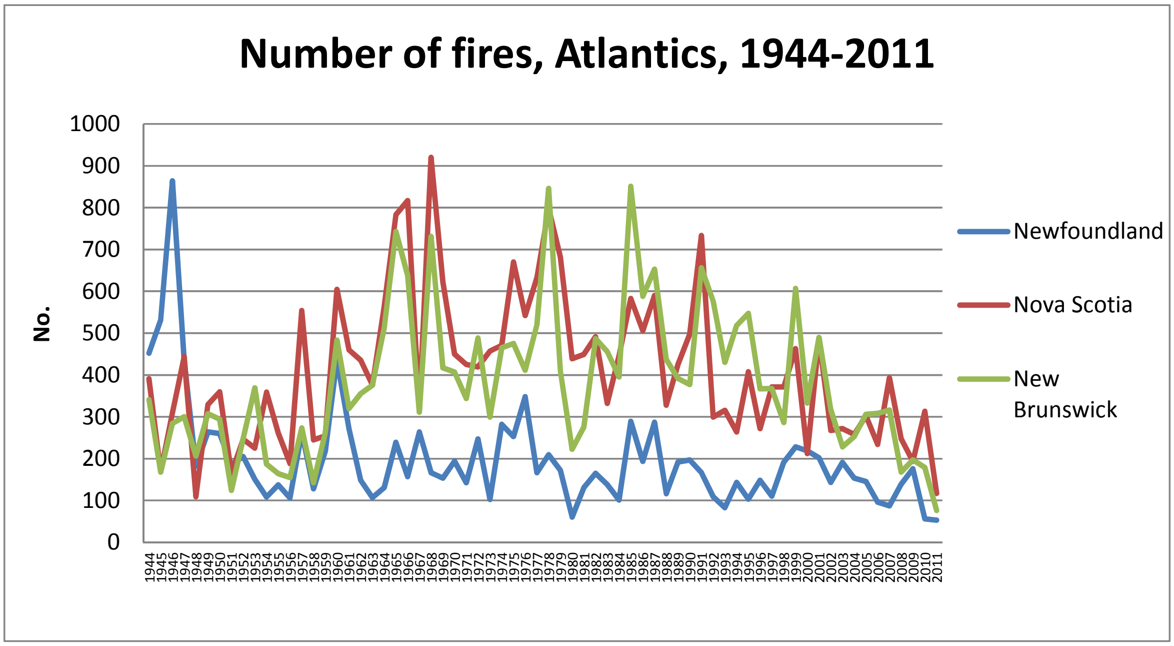


Figure 4



The decadal averages smooth out the volatility somewhat, placing the geography and time history in perspective (Fig. 5, Table 1). Newfoundland's peak in the 1960s is a significant exception to the regional trend of decline in fire. Valuable context for these trends can be found in Wallennius (2011).

Figure 5

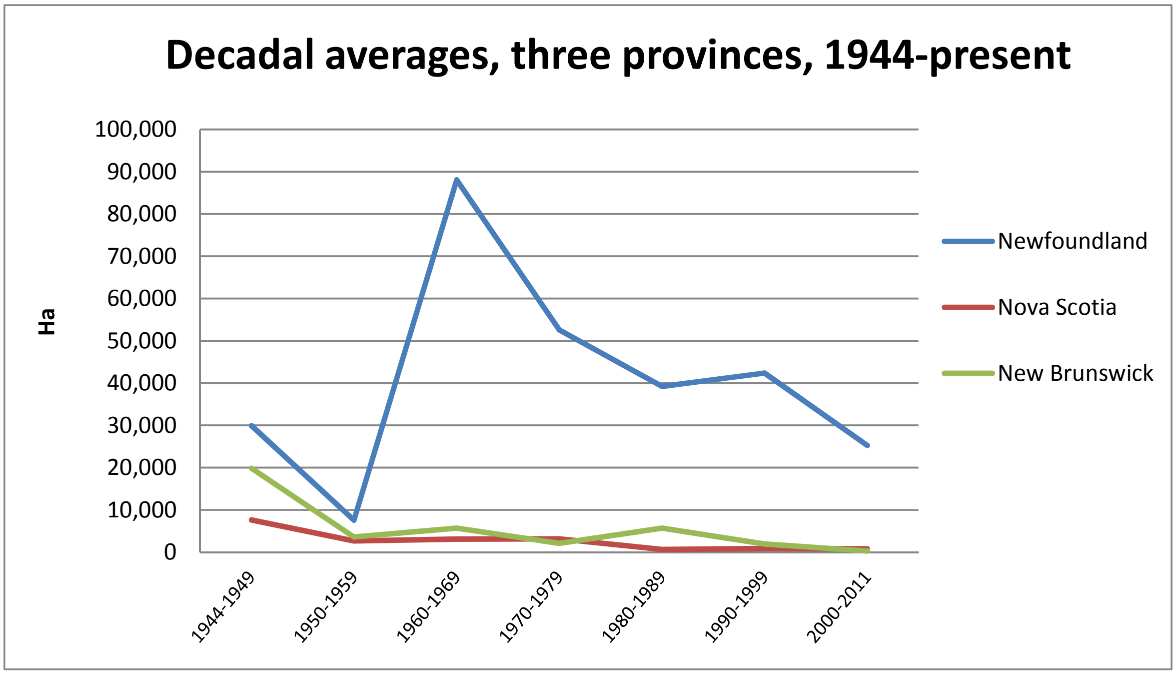


Table 1. Decadal averages for area burned, 1940's-2011

	Newfoundland	Nova Scotia	New Brunswick	Atlantics
1944-1949	29,905	7,583	19,843	57,332
1950-1959	7,579	2,636	3,585	13,800
1960-1969	88,075	3,107	5,702	96,884
1970-1979	52,610	3,139	2,068	57,816
1980-1989	39,198	627	5,678	45,503
1990-1999	42,387	867	1,939	45,193
2000-2011	25,241	801	271	26,312
Full Period	**41,496**	**2,369**	**4,657**	**48,522**

Average fire sizes since 1944 varied as well. Overall there is a slight rising trend in Newfoundland (Fig. 6). In comparison, except for their unusual outbreaks of 1976 and 1986, the trend was downward in Nova Scotia and New Brunswick through the 1960s (Fig. 7). In both cases, outlier fire years (1976 for Nova Scotia, 1986 for New Brunswick) were dramatic. The average sizes for those years were 10.7 times the post-1970 mean for Nova Scotia, and 13.7 times for New Brunswick.

Figure 6

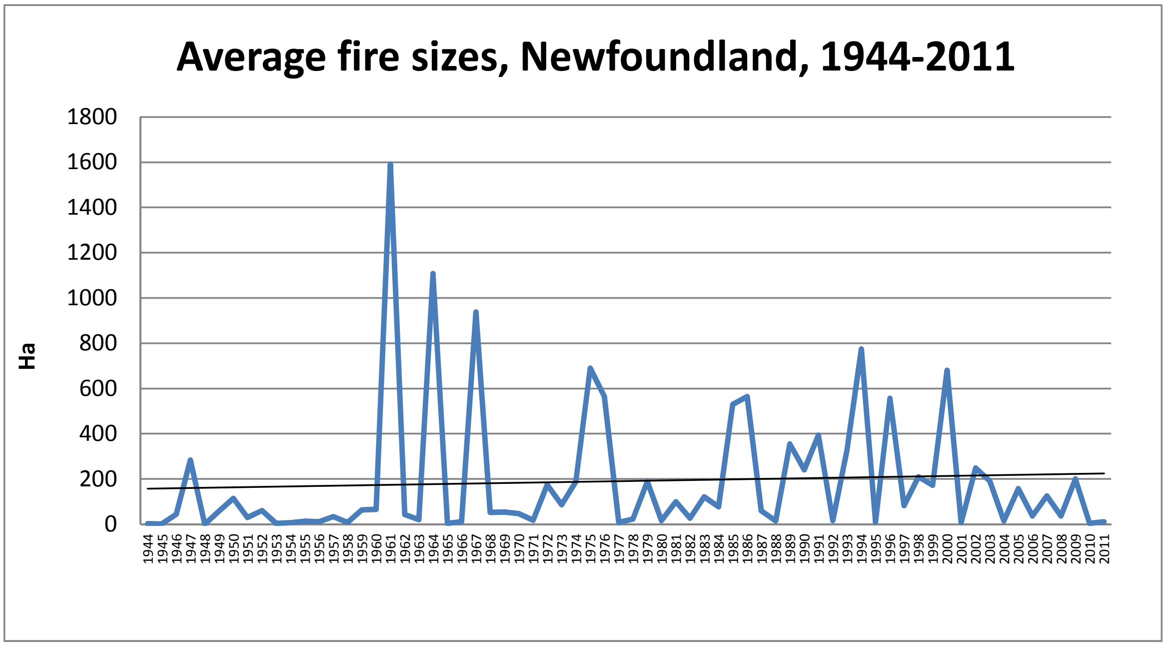
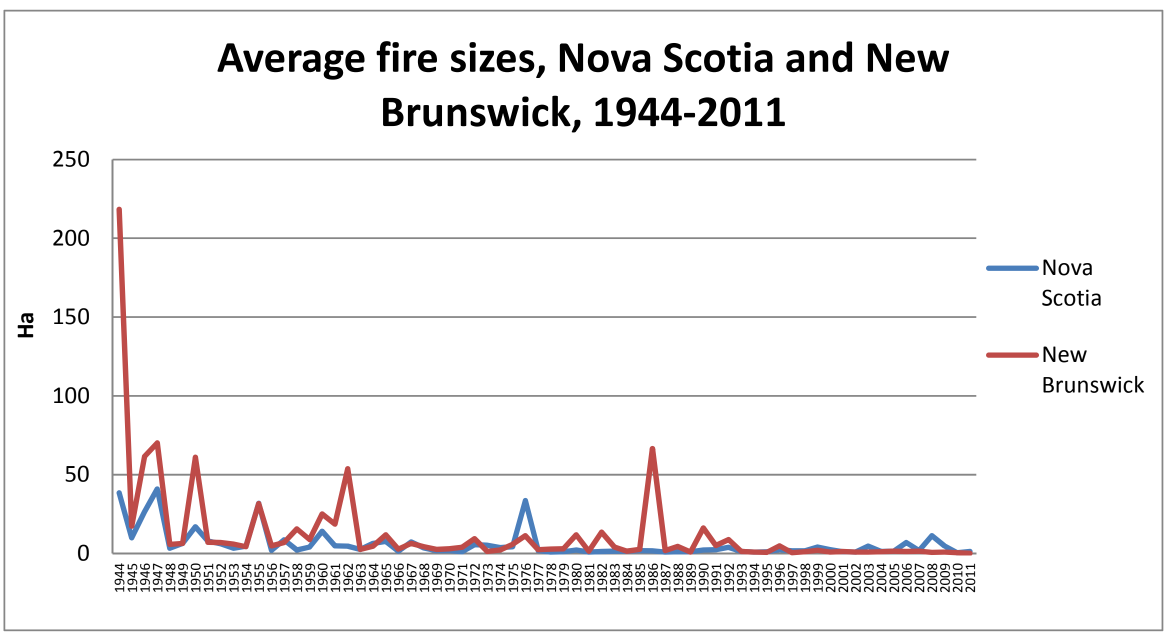


Figure 7



B. Regional Fire History 1970-2011

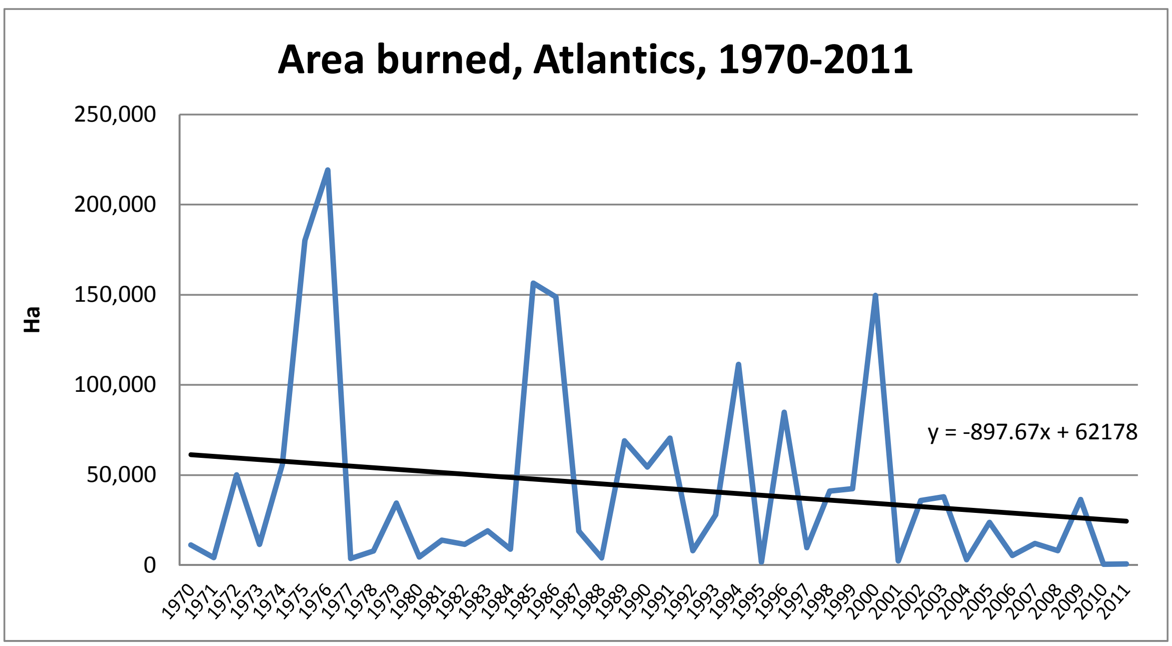
Here, we focus in more detail on the post 1970 period. By this time fire protection services had largely reached their current state of equipment and methods, and other social and economic changes tending to reduce ignitions had largely run their course.

B.1. Area Burned

Total area burned in this region trended downward from 1970-2010 on a fairly volatile trend line (Fig. 8). Newfoundland[3] accounts for by far the bulk of the total, and also most of the volatility. Speaking very roughly on the basis of decadal averages, from the 1970s, Newfoundland area burned fell by half, Nova Scotia by two-thirds, and New Brunswick by almost 90% (Table 1). Eight of the ten lowest years after 1970 occurred during the 2000s. Area burned region-wide in 2011 reached its lowest level since 1944.

Over this period, cumulative total area burned was 1.8 million ha, 91% of which occurred in Newfoundland. The Newfoundland Boreal ecoregion sees a long-term average of .13% of area burned annually, while Atlantic Maritimes sees .35% (Federal, Provincial and Territorial Governments of Canada 2010).

Figure 8



[3] In this paper, we will refer to Newfoundland and Labrador as "Newfoundland" unless it is necessary to distinguish regions within the Province.

Another way to view the region's fire history is to tabulate the fire years by levels of annual area burned (Table 2). The five heaviest years accounted for 77% of the area burned over this period. *One-fourth of the area burned occurred in only three of the years.*

Table 2. Area burned by size class of fire year, Atlantics

1,000 ha	No. Years	Hectares
0-50	29	451,969
51-100	6	384,891
101-150	3	409,721
151-200	2	336,426
201-250	1	218,620
Total	**41**	**1,801,627**

The volatility in area burned can be viewed in terms of departures from averages (Fig. 9; Table 3), or as standard deviations (Table and Fig. 8 below). In either case, it is clear that on average, an extreme regional fire year occurs in every decade. Six years exceeded 100,000 ha; in five of these years, area burned exceeded one standard deviation from the mean. Insurers often think in terms of the ratio between the extreme event and the mean. For the period since 1970, these ratios have been extremely high, due in part to the individual years of 1876 and 1986. Further data on variability are in Appendix Table 3.

With highly skewed distributions, SD's often exceed the means, as is the case here. In such cases, using the SD to characterize occurrence of low fire years is not useful. Here, we show the size of the tenth lowest years, which roughly is the cut point for the bottom quartile. The low years are a small percentage of the long-term averages.

Figure 9

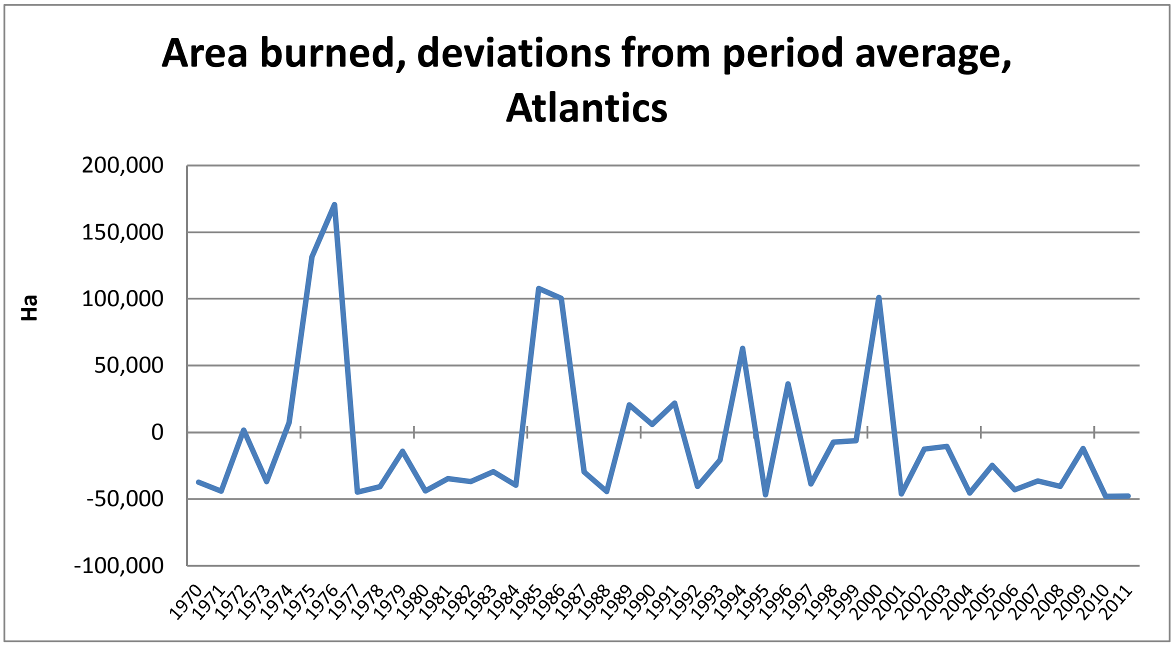


Table 3. Descriptive statistics on variability, 1970-2011

	Newfoundland	Nova Scotia	New Brunswick	Atlantics
Averages	40,103	1,361	2,441	43,905
SD	51,476	2,777	6,106	54,850
CV	1.28	2.04	2.50	1.25
Maximum	431,378	25,095	165,759	439,567
Max vs mean	10.8	18.4	67.9	10.0
Bottom quartile	3436	440	307	5435
Bottom quarter vs mean	0.09	0.32	0.13	0.12

Most of the volatility and total acreage burned, occurred in Newfoundland, so we will present that data separately. A declining area burned trend does not obscure the fact that as recently as 2000, a very large fire year occurred (Fig. 10). In six years, area burned exceeded one standard deviation from the mean (Fig. 11).

Figure 10

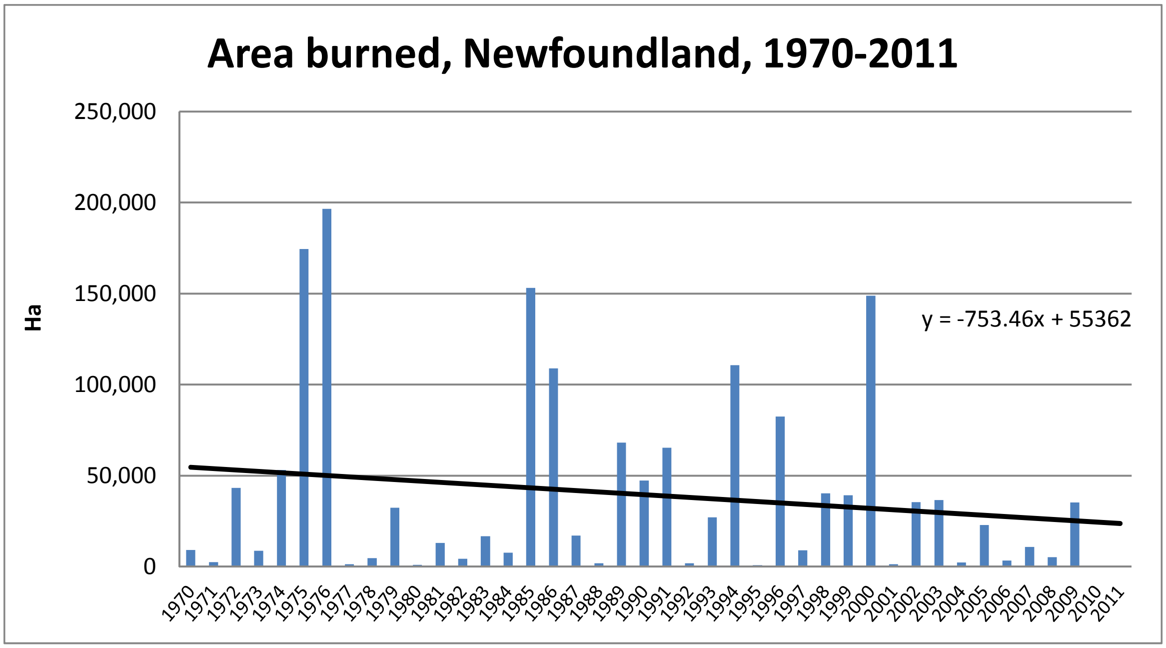
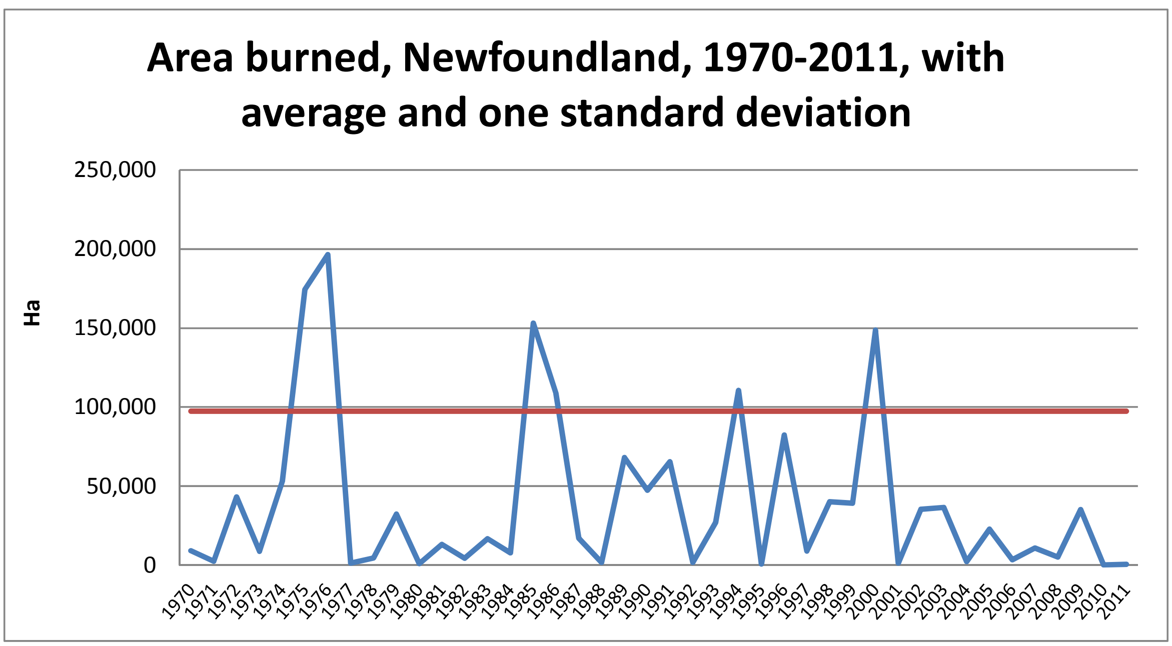


Figure 11



Nova Scotia had its peak fire year since 1930 in 1934, when 25,000 ha burned over in 690 fires. A 1942 moderate fire year mirrored experience elsewhere in the region, while the regional outbreak was manifested here in 1947 with the Trafalgar Bay fire reaching 10,000 ha. At 25,000 acres, this fire alone would rank among the very largest region-wide for that year. From 1950 to 1970, the extreme years were 1955 and 1960, but over that period area burned exceeded 5,000 ha in four years – on average, a bit more than once a decade. While the chart is fairly jagged, recorded fire numbers rose to a broad plateau that then stayed volatile but at a roughly constant level until beginning a slow decline after the late 1980s.

Newfoundland experienced its peak area burned in 1961. Since then, in 8 years area burned exceeded 100,000 ha. The recent decade, however, has been very quiet. Interestingly, a fire peak occurred in 1947; it would be interesting to see if this relates to a regional weather system or is mere coincidence. Fire numbers have been on a gently descending trend.

We would love to have some brief note on what took place in Nfld in 1961--

The 1976 Trafalgar Fire in Nova Scotia matched an extreme year in Newfoundland as well (Fig. 9), while the extraordinary fires of 1986 stand out regionally (would like further info on those fires)

Extreme fire years occasionally coincide across these provinces, notably:

1934, Nova Scotia and Newfoundland

1947, all 3 provinces

Great 1960s drought, several provinces had extreme years, notably Newfoundland in 1961.

Extremes of 1976 and 896 – Newfoundland also experienced highs those years.

Since then, as often as not Newfoundland extreme years do not match high years for the other two.

Overall, though, there is little correlation between fires in Newfoundland and New Brunswick / Nova Scotia. In the past, there has been noticeable correlation between New Brunswick and Nova Scotia (Figs. 12a, 12b). For these two provinces, the correlation coefficients (R2) were:

1930-2011	.65
1944-2011	.57
1970-2011	.07

The decline in correlation was not only due to the extreme years of 1986 and 1976, but persists when those years are removed. Since 1970, then, there has been little correspondence between severe fire years in these 2 provinces.

Figure 12a

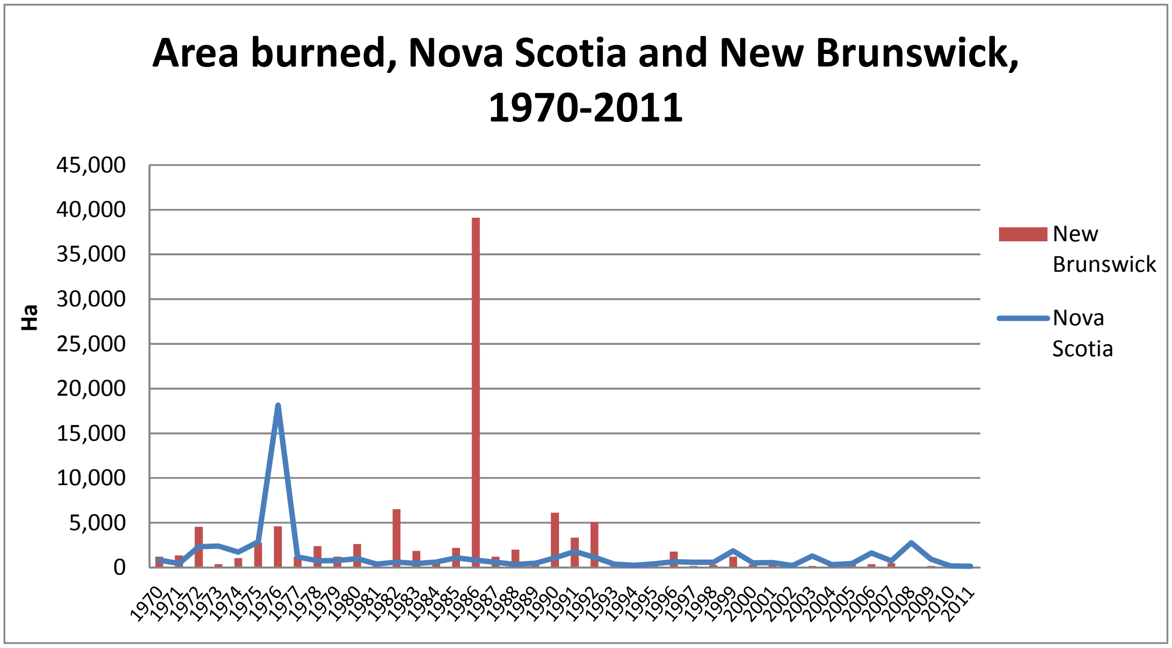
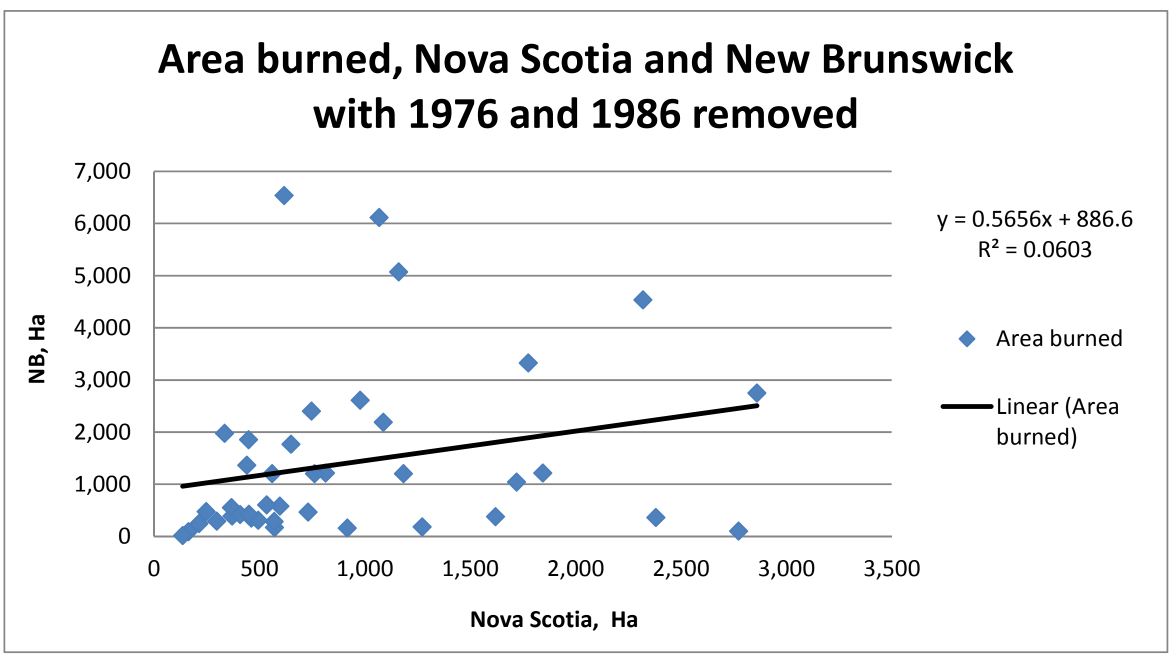


Figure 12b



Interesting Question: Was there any relation between fire numbers / area burned and spruce budworm defoliation or mortality? Pursue…

Also, seek details on the 1976 Nova Scotia and 1986 NB fire years… what happened? Weather? Outbreak of many fires, or a few very large ones?

B. 2. Number of Fires 1970-2011

Regional fire numbers reported over this period followed a slightly humped path with a slow decline after the mid-1980s (Fig. 13). Apart from 2 or 3 high years in the mid-1970s, fire numbers in Newfoundland have shown hardly a trend at all, while they have fallen noticeably in Nova Scotia and New Brunswick, though on a volatile path (Fig. 14).

Figure 13

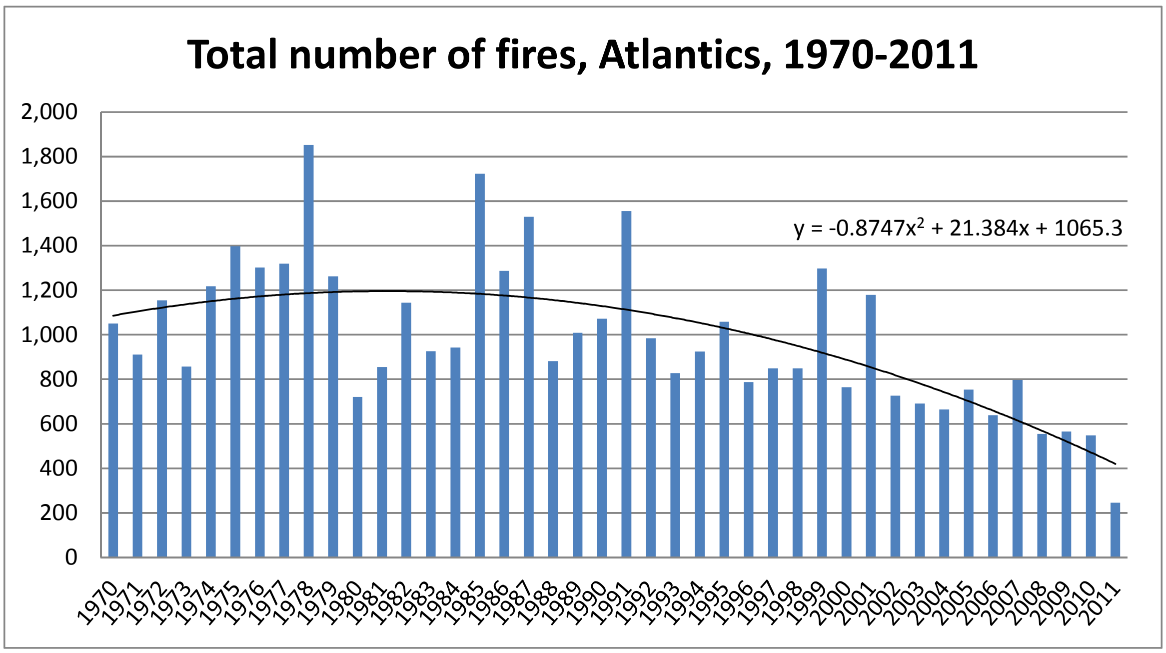
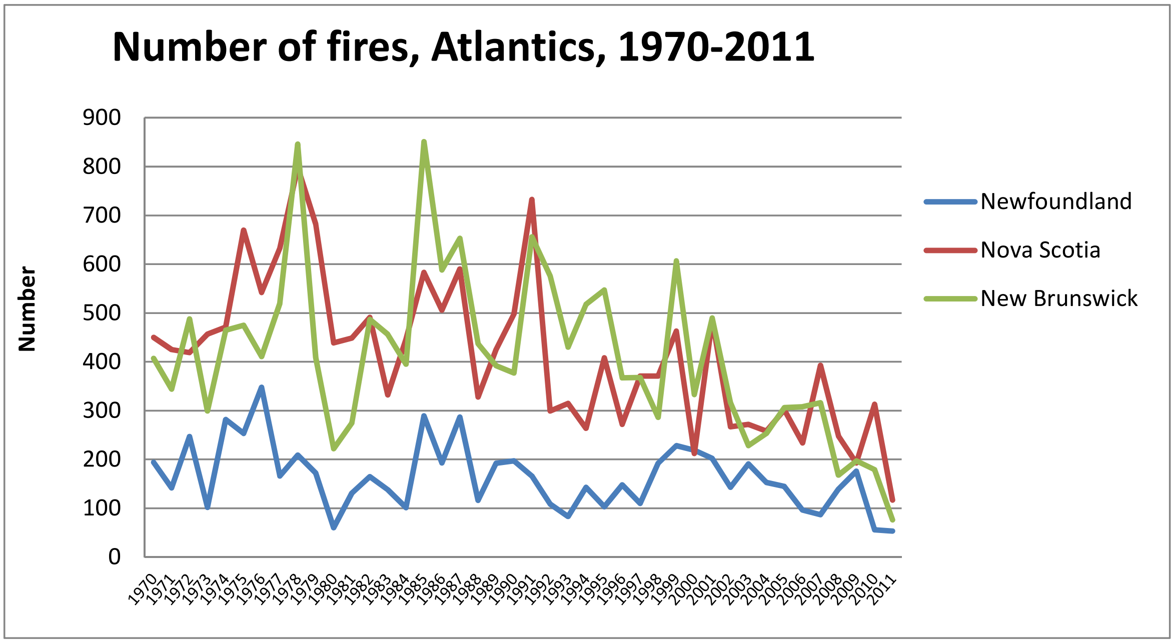
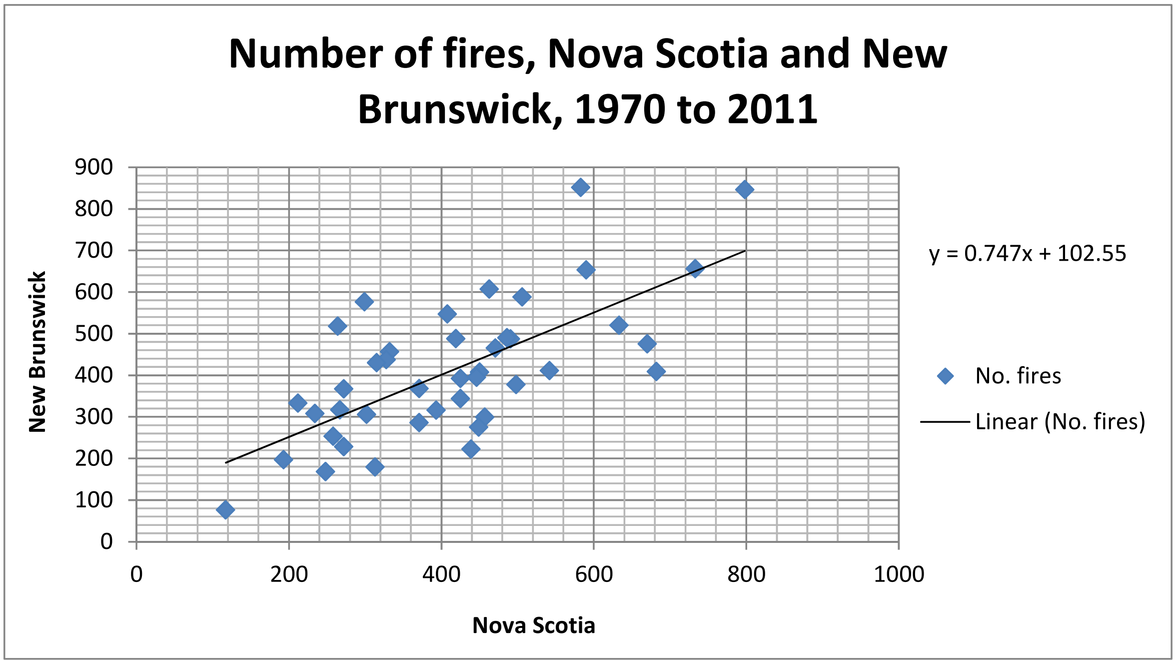


Figure 14



Fire numbers in Nova Scotia and New Brunswick have been correlated over this period – The correlation is .69 (Fig. 15). But there has been no noticeable correlation between Newfoundland and the Nova Scotia and New Brunswick, nor between Newfoundland and Quebec.

Figure 15



B. 3. Size of Fires

Newfoundland has fewer fires but much larger ones. In fact, most of the volatility in Newfoundland area burned comes from variability in size of fires and not in their numbers (Fig. 10).

Period averages, 1970-2011:

Newfoundland	203.2
Nova Scotia	3.1 (2.4)
New Brunswick	4.9 (3.5)

(In parenthesis: the average after dropping the single outlier. 1976 in Nova Scotia, 1986 in New Brunswick).

Within the Atlantics, fire size trends varied between Newfoundland versus Nova Scotia / New Brunswick. In Newfoundland, following a burst of large ones in the 1960s, sizes fluctuated, following no clear trend. The trend since 1944 is actually up, but probably not statistically significant. Since the 1970s there is no noticeable trend. In contrast, in Nova Scotia and New Brunswick, average sizes fell considerably after the 1940s. In both cases, outlier fire years (1976 for Nova Scotia, 1986 for New Brunswick) were dramatic. The worst years for those years were 10.7 times the post-1970 mean for Nova Scotia, and

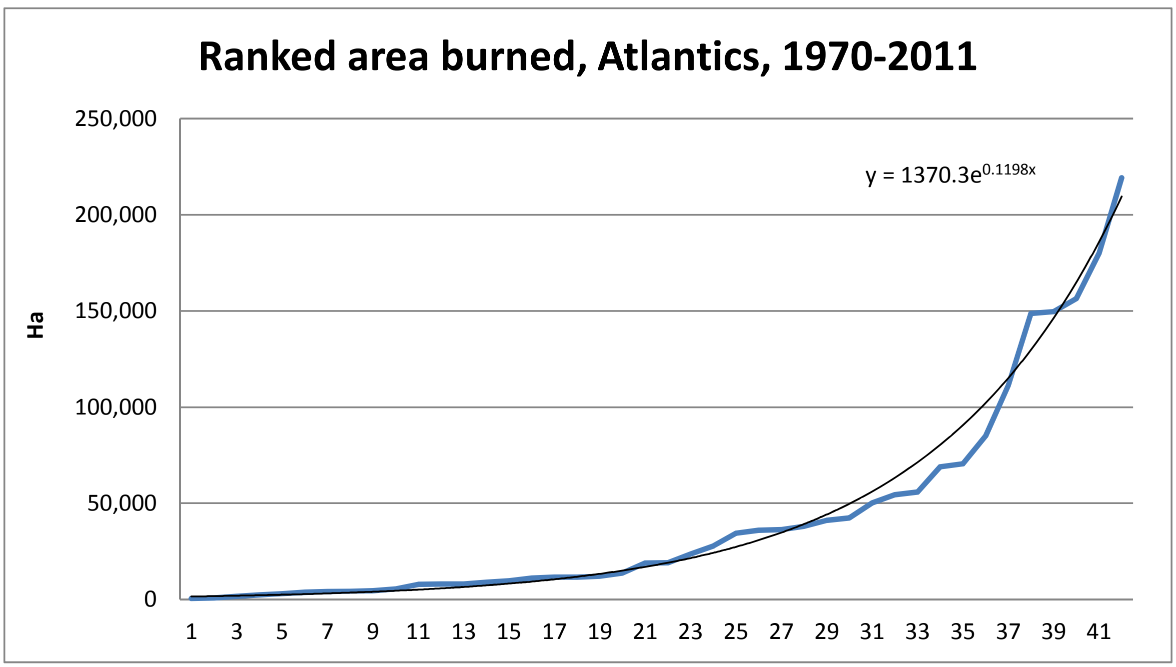
13.7 times for New Brunswick. Dropping the peak years for Nova Scotia and New Brunswick notably reduces average fire sizes, as we notice above.

C. Variability: Ranked Data, Return Periods, and Seasons

C.1. Ranked Data

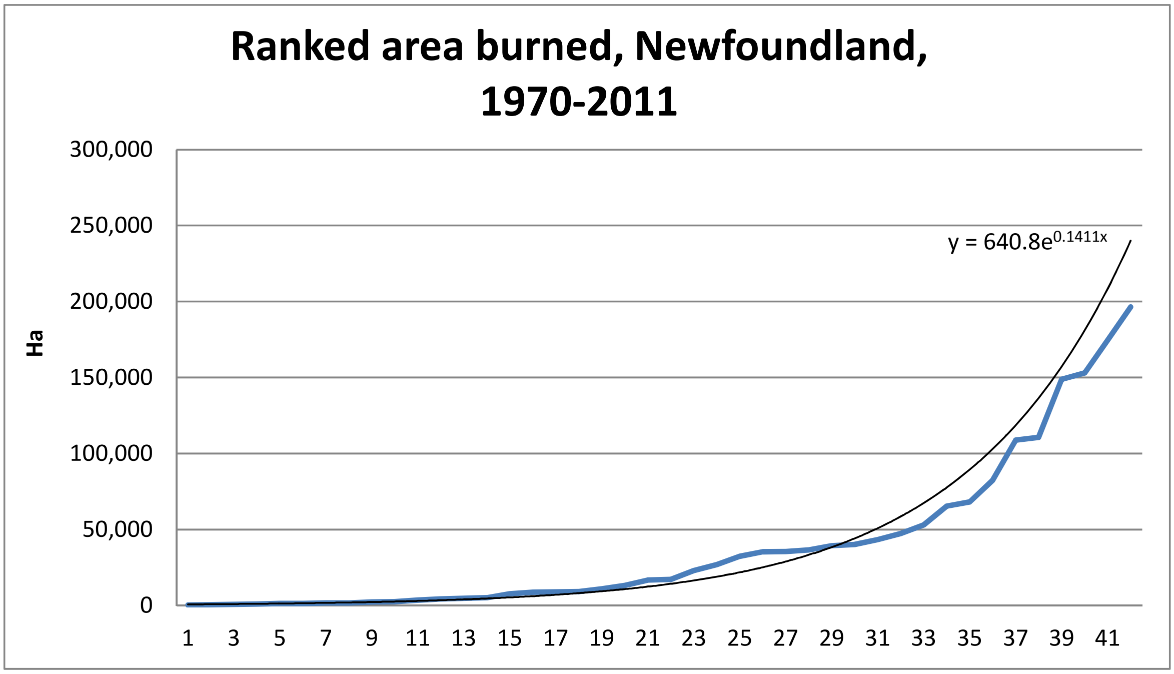
A simple form of extreme value analysis is to rank the fire years from low to high and see what form the display takes[4]. Ideally, this analysis would be done with individual fires as well, and below we show some examples (Figs. 16 and 17). The summary for the three jurisdictions shows a moderate level of extreme value behavior: successively large fire years are usually significantly larger than the next lower ones. Of the dozen largest burn years, half exceeded the next largest by 19% or more. In practical terms this means that there is no reason why the next record year could not exceed the current record year (1976) by 20%. This is common for weather-related phenomena.

Figure 16



[4] Background on these issues can be found in Cui and Pereira (2008), Homes, et. al (2007), and Lin and Rinaldi (2009). A modern classic is Taleb (2011).

Figure 17



In contrast to Newfoundland, Nova Scotia and New Brunswick display very flat distributions of annual area burned, with the important exceptions of their singular extreme fire years (1976 and 1986). It is important to understand what was exceptional about those extreme years, and also to obtain a longer fire history, especially for New Brunswick. Were the circumstances in those extreme years such that we can be sure they will never happen again?

In New Brunswick, 1986 was an extreme year (Fig. 18). As described by Tim Greer, of New Brunswick Department of Natural Resources (pers. comm.):

The New Brunswick situation in 1986 was as follows;

- In 1986 we experienced 109 fire starts between the 13th and the 17th of May
- 4 fires were 100-1,000 ha
- 3 fires were 1,000-10,000 ha
- The largest was 23,165 ha
- After the 17th of May we had less than a dozen fires provincially that burned less than a dozen acres
- Several districts didn't have one single fire after the 17th of May

- It wasn't a bad fire "year" at all – it all happened over 4-5 days in May

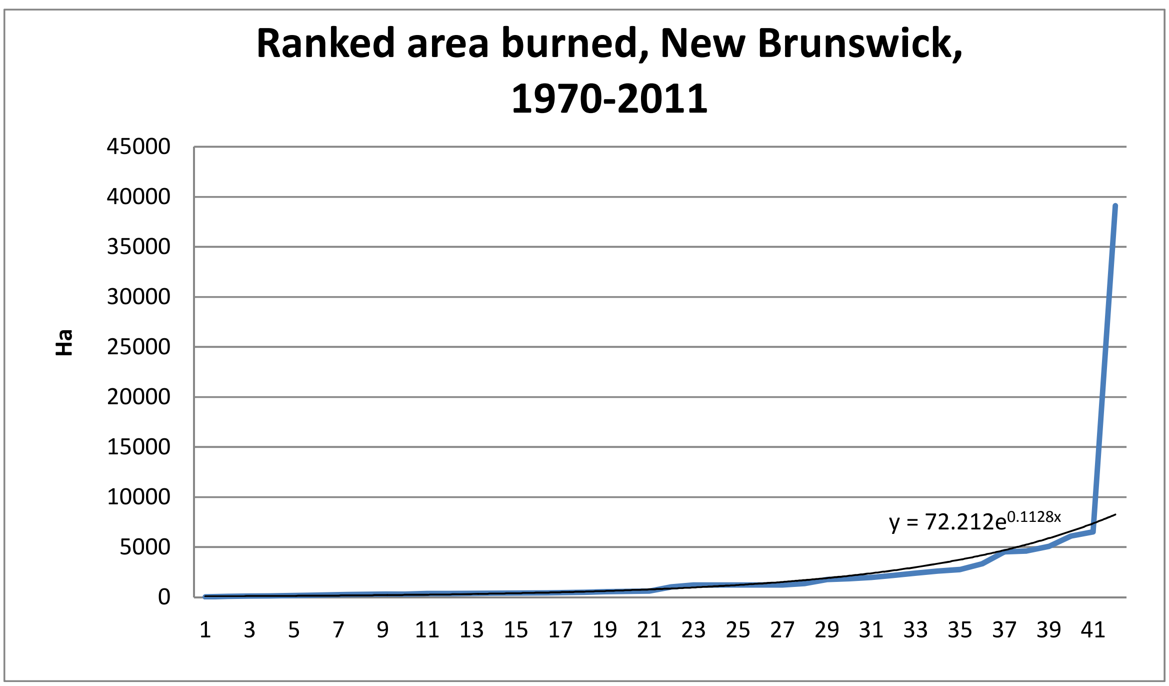
There was nothing unusual about the spring of 1986. Weather records indicated a normal spring, cold one day, warm the next. One thing that stood out to me was the fact the two weeks preceding the fires it was abnormally windy. Then, starting around the 8th it got warm and dry for a few days, but nothing unexpected for May. Then on the 13th to the 15th it was warm, low RH and windy. Many residents were conducting their spring cleaning up / burning and the next thing you know the whole province was on fire.

Today, fires wouldn't be detected any faster and we have much less human resources on staff so suppression wouldn't be any quicker. But we are better trained especially in the area of fire behavior and pre suppression planning.

If we had the same thing happen in 2012 we would be unable to handle this on our own, only we would see it coming sooner. With 25 RAWS stations, conditions can be monitored real-time, and predictions developed. Air observation and waterbombing capability enables water to be delivered promptly if needed. Resources would have to come from other agencies to help manage and suppress these fires. Based on forecasting, this can be requested in advance of need.

Most importantly, rules on open burning and compliance have improved dramatically, so there would be far fewer ignitions of this type if weather of this kind happens again.

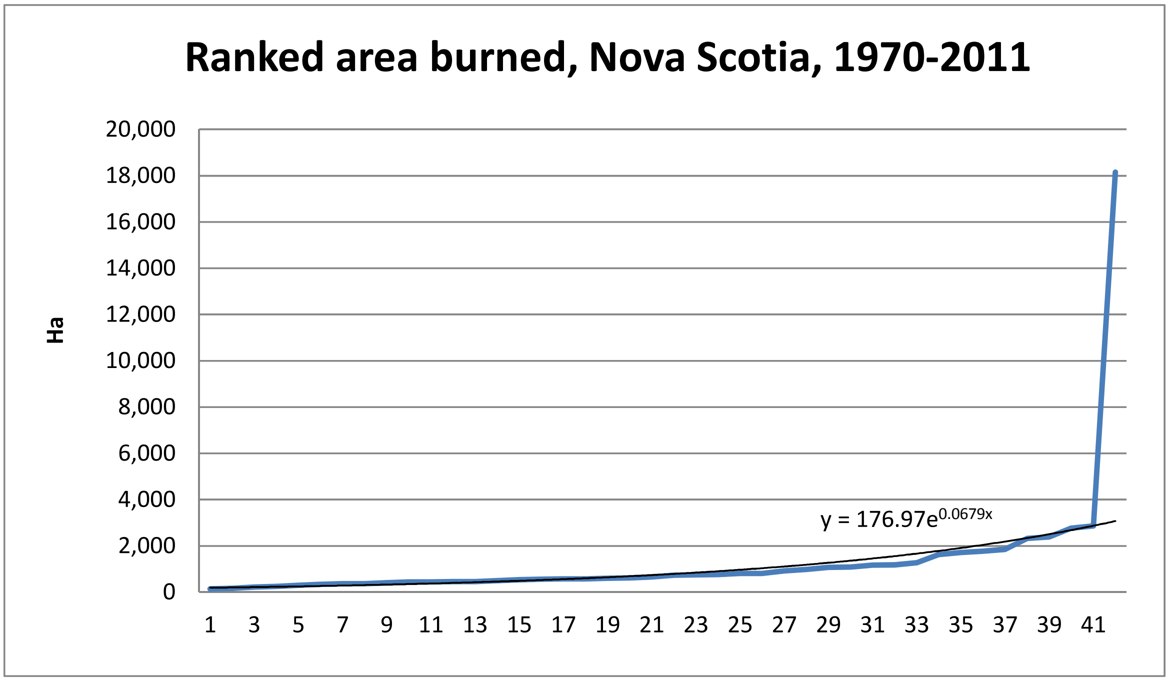
Figure 18



The ranked data shows dramatically the unusual fire year of 1976 in Nova Scotia (Fig. 19).

Could we get a similar summary for 1976 fire year in NS?

Figure 19



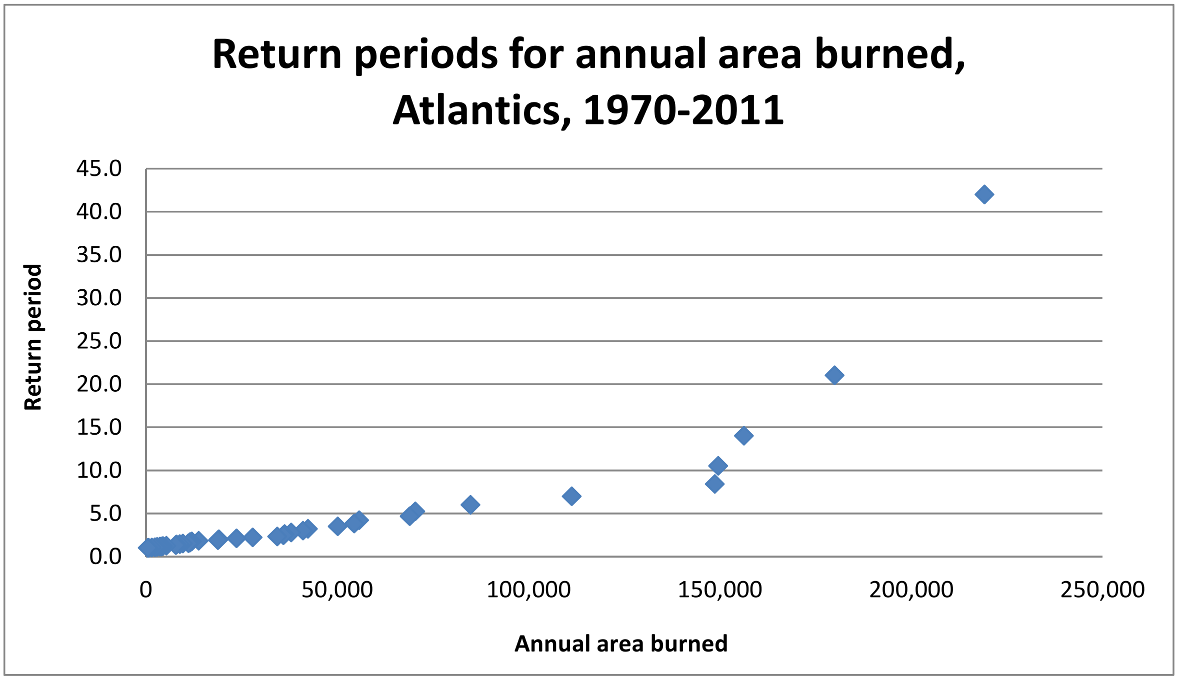
C. 2. Return Periods

Following common practice in analyzing flood peaks, we can analyze the annual area burned estimates to gain a sense of the return period of different levels of annual burning. It is common to plan flood control works to withstand a given extreme projected flood based on a historical record. Usually flood control works are designed to withstand a 100 year flood. When a shorter record is available, engineers use statistical methods to extrapolate a design flood. This can be done for fire years (Fig. 19 a-d). These charts show one statistical fit to the data; others might be considered. These are only to illustrate a general point for now, not to propose a final conclusion concerning functional form.

Fig. 20a implies that region-wide, a fire season of 225,000 acres would recur once every 40 years. For a 20-year return period the amount would be 180,000 acres.

Below, we analyze such a list, 1987-2010, for Nova Scotia.

Figure 20a



Newfoundland's post 1970 fire history generates a fairly smooth exponential curve. The form shown that roughly 170,000 acres in area burned will recur every 20 years. For a 40 year return period, the area would be 200,000 acres. We hesitate to even show the Nova Scotia and New Brunswick charts, but they do illustrate the extreme discontinuity in the data due to a single extreme fire year in each province.

Figure 20b

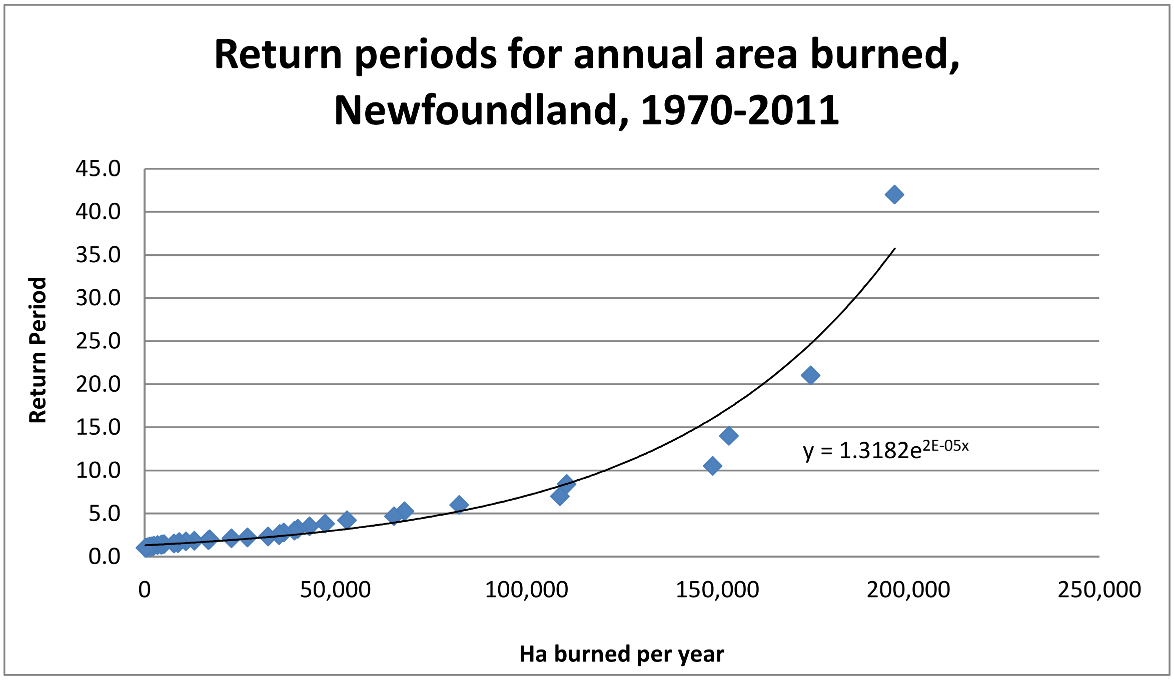


Figure 20c

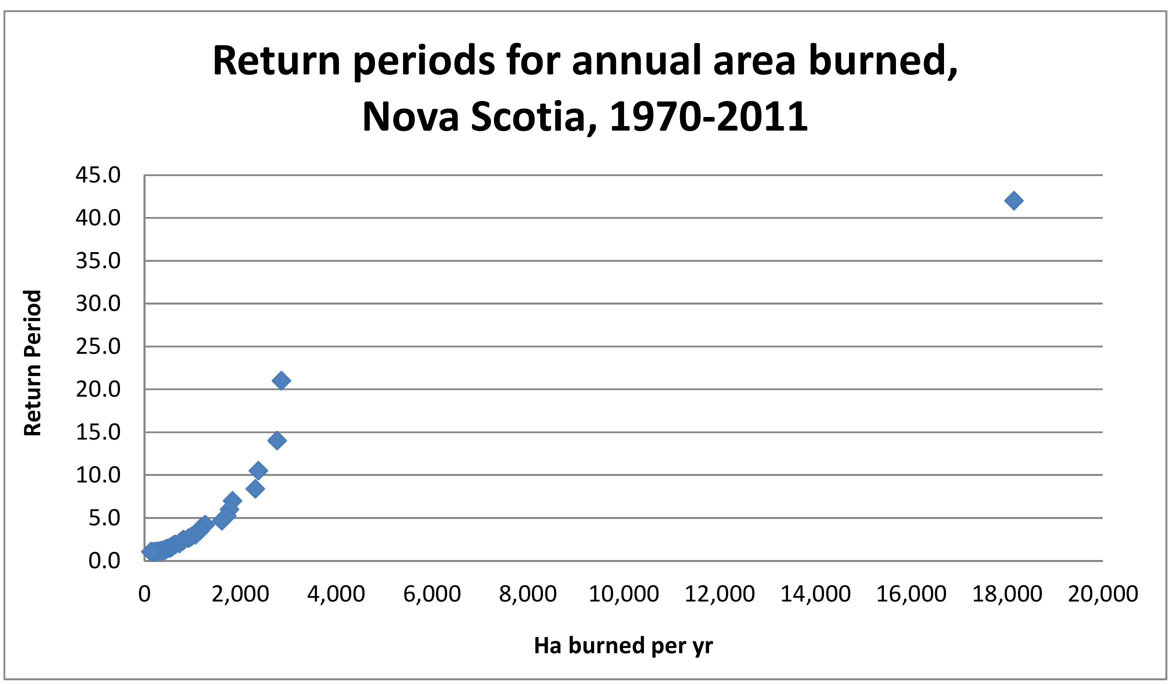
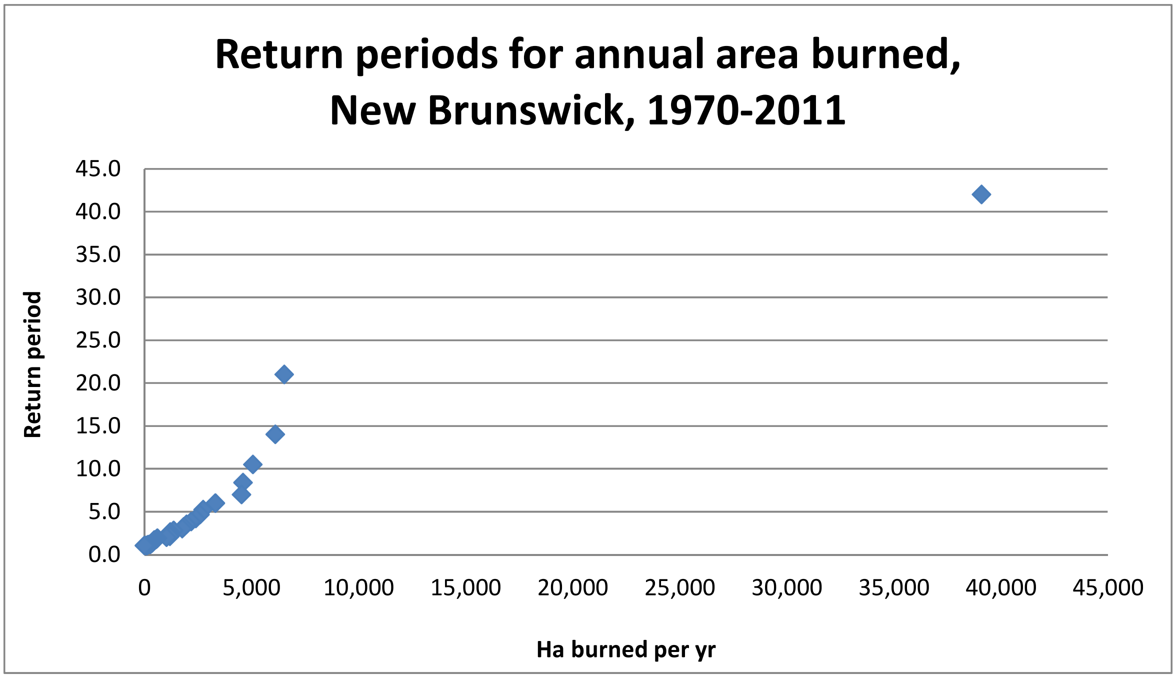


Figure 20d



From this data we would have difficulty deriving any meaningful return period analysis until more can be learned about the circumstances surrounding those extreme fires. Drawing conclusions in New Brunswick and Nova Scotia regarding return periods is basically a matter of whether you believe the extreme fire years of 1976 and 1986 were anomalies that will never occur again, or whether you believe otherwise. These, it appears, qualify as true Black Swan events; for such events statistics and averages can provide little guidance.

D. 3. Fires by Season

Shifts in the time pattern of large fires were summarized in the Large Fires Study (Krezek-Hanes, et al. 2011) (Fig. 21). This report analyzed all documented fires larger than two square kilometers.

Figure 21

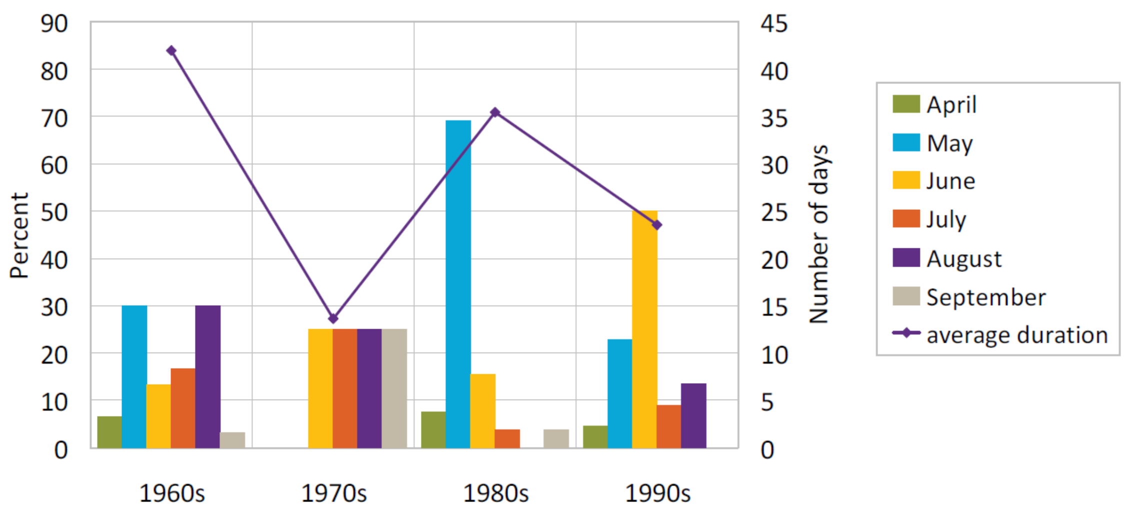


Figure 37. Proportion of large fires that occur each month in the Atlantic Maritime and the average duration of the active fire season (purple line), 1960s-1990s.
Monthly numbers are the percentage of the total number of fires that occurred during the month.
Source: data are from the large fire database

Source: Krezek-Hanes, p. 42.

According to the Canada Large Fires study, the fire season in the Newfoundland land Boreal ecoregion is very short, only 35 days, and the Atlantic Maritimes is very similar. But this is not what these charts based on individual fire data suggest.[5] Our dataset includes only 1999, 2000, and 2009 at present, but these illustrate the diversity in patterns across regions, years, and months (Fig. 22). Nova Scotia experience, 1987-2009 (Fig. 23) shows similarly how managers have to cope with a "moving fire season."

[5] It could be that, without mentioning it, they mean "fire season" to include only the periods when the Large fires occurred.

Figure 22a

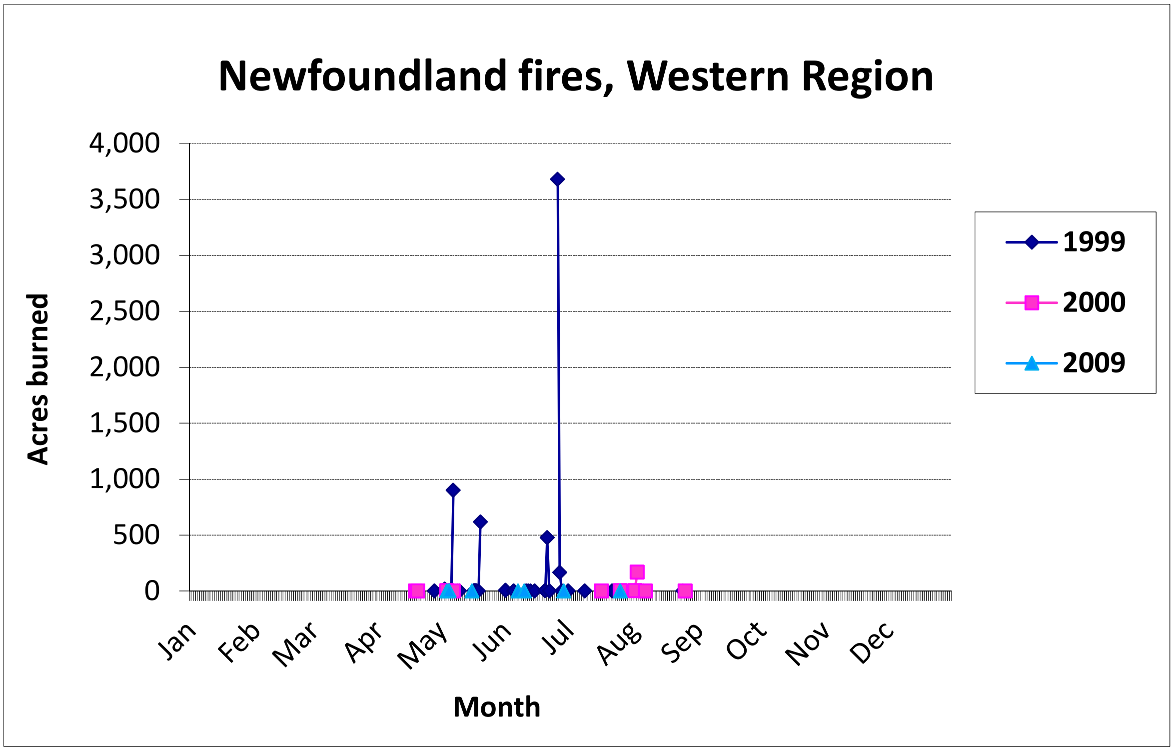


Figure 22b

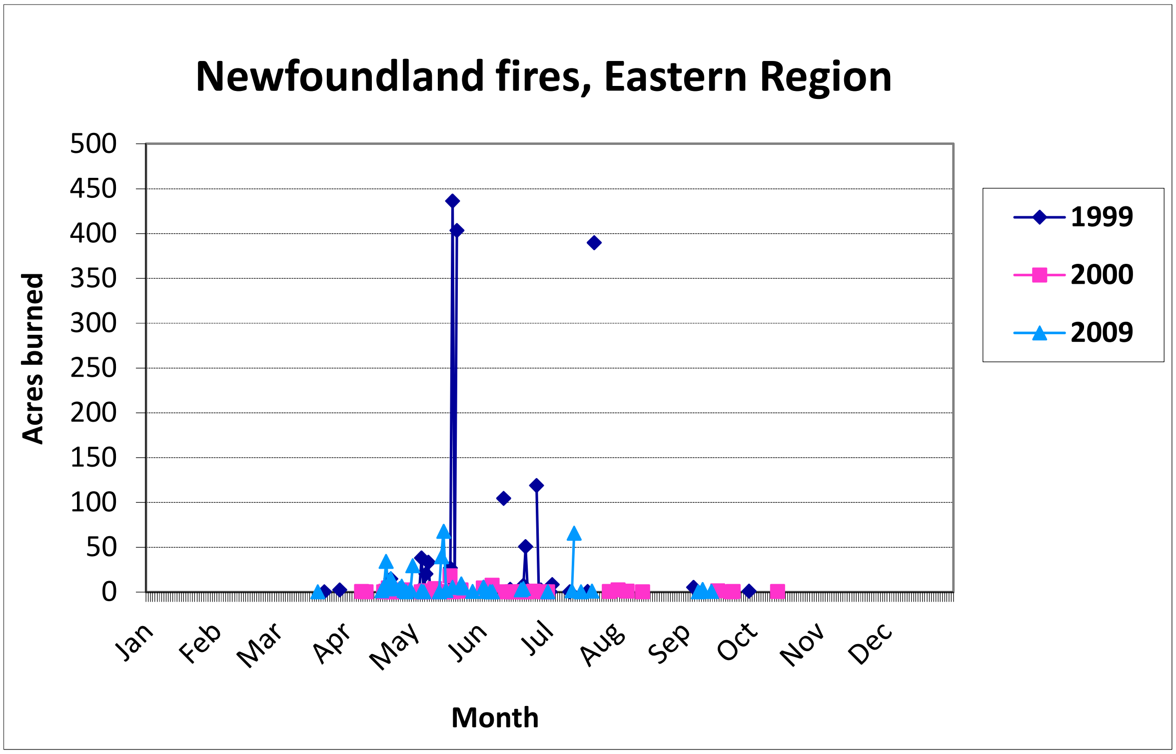

Newfoundland fires, Eastern Region
500
450
400
350
300
250
200
150
100
50
0
Acres burned
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
1999
2000
2009

Figure 22c

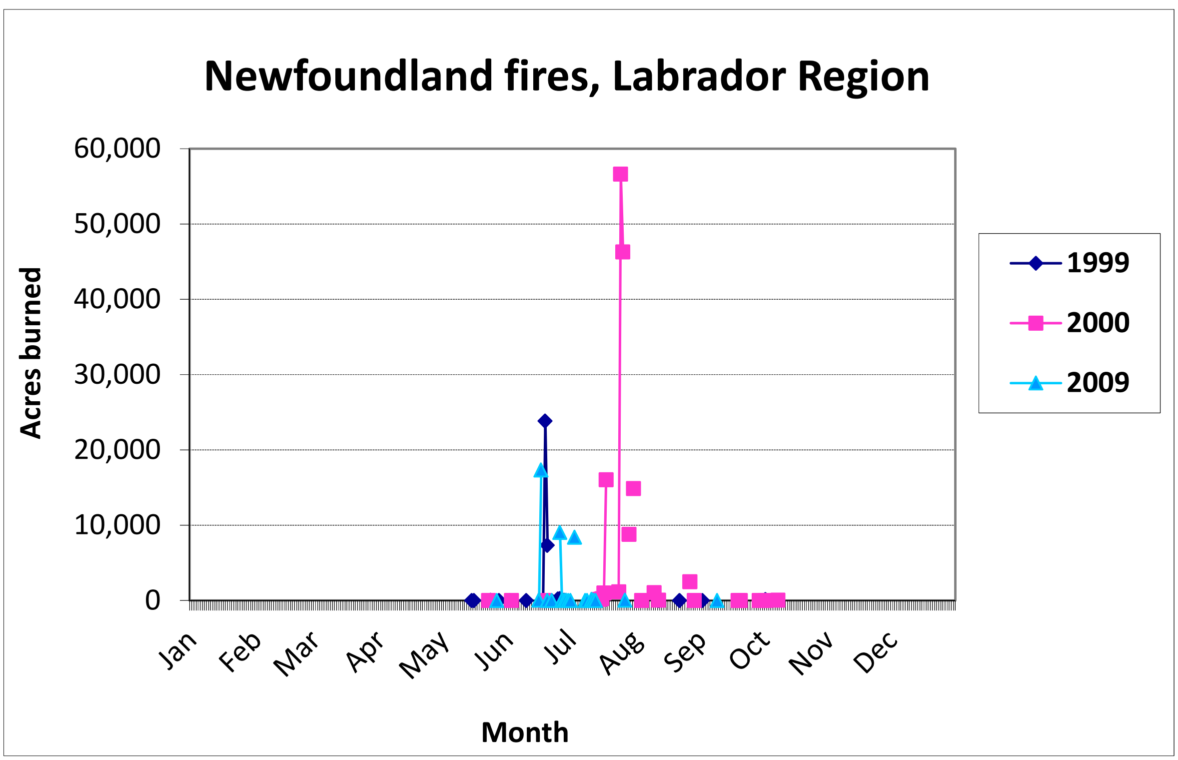
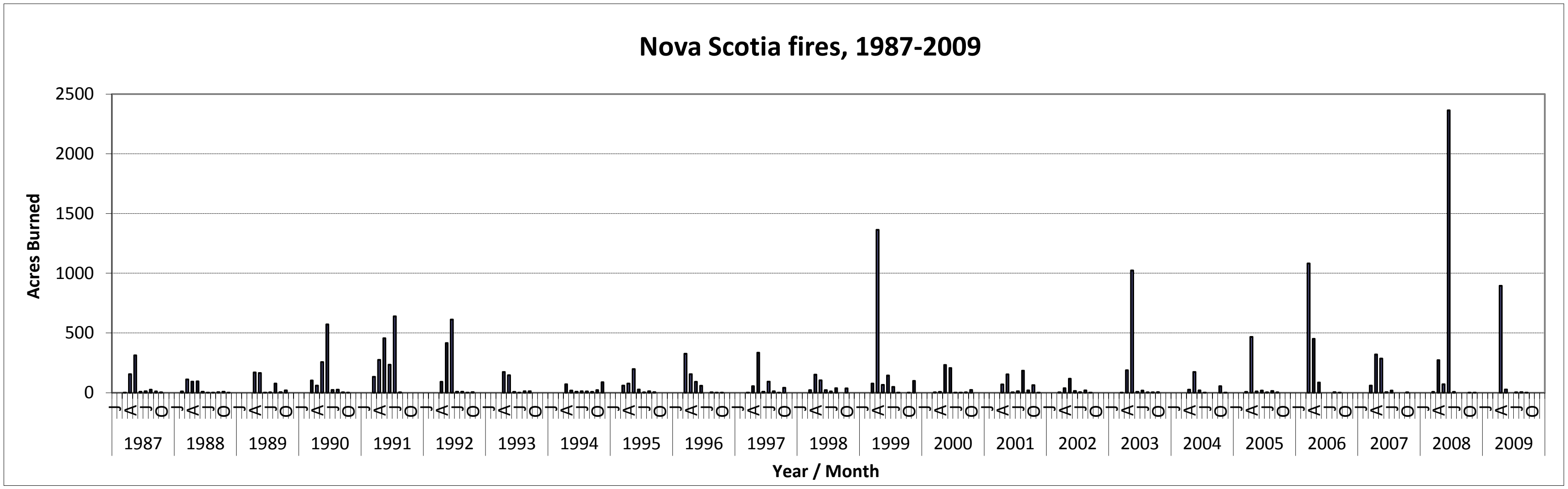

Newfoundland fires, Labrador Region
60,000
50,000
40,000
30,000
20,000
10,000
0
Acres burned
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
1999
2000
2009

Figure 23


Nova Scotia fires, 1987-2009
Acres Burned
2500
2000
1500
1000
500
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year / Month

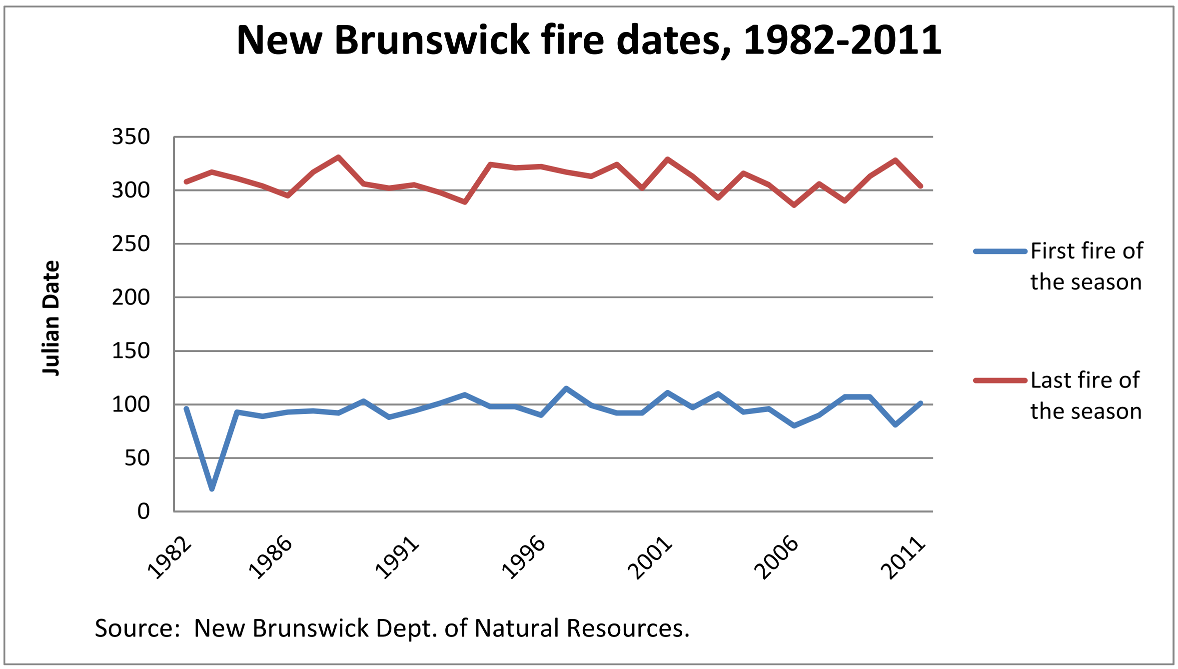
D. Individual Fire Data

We have differing samples of individual fire and related data for each of the provinces. Each enables us to see different things of interest.

D.1. Individual Fires: New Brunswick 1982-2011

Fire data for 1982 to 2011 were supplied by Tim Greer of the DNR.[6] Looking at the first and last fires of each year, there is essentially no trend, either in the dates of the start and end of the season, nor in the length of the season (Fig. 24).

Figure 24



The fire numbers by size classification show that the smallest fires show the largest declines since 1982 (Fig. 25). We plot the largest, class 1 and 2, separately due to scaling. Since 1992 there has been no fire larger than 1000 ha, and after 1999, only one that has exceeded 100 acres.

[6] This information was provided in summarized form, we do not have the individual fire database itself.

Figure 25a

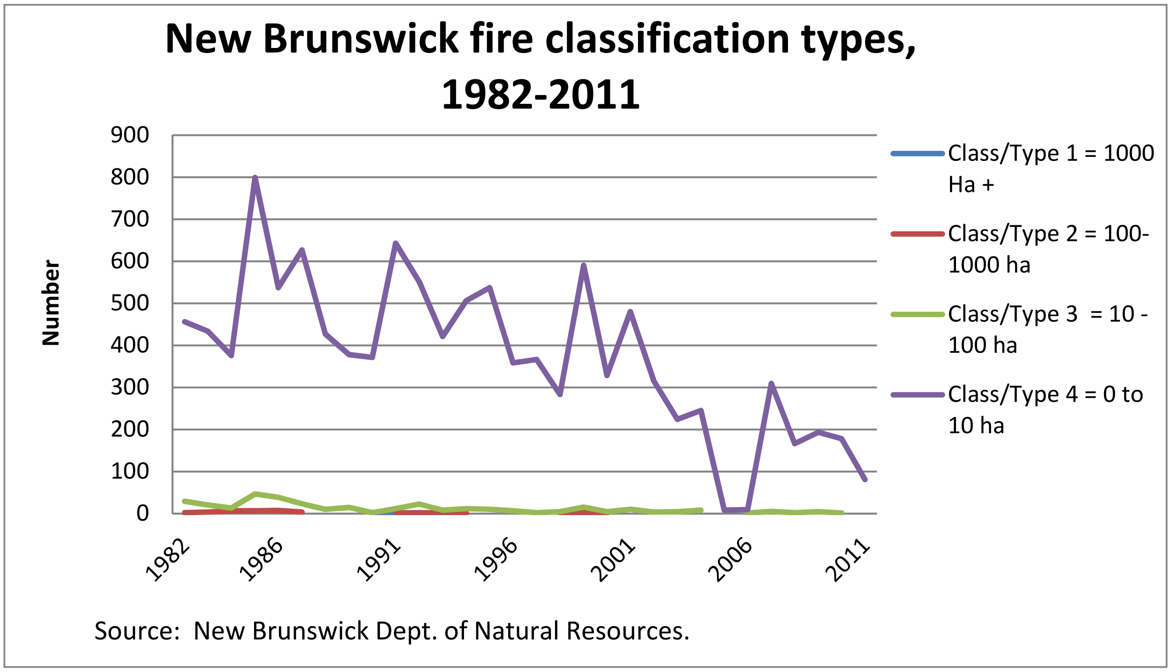
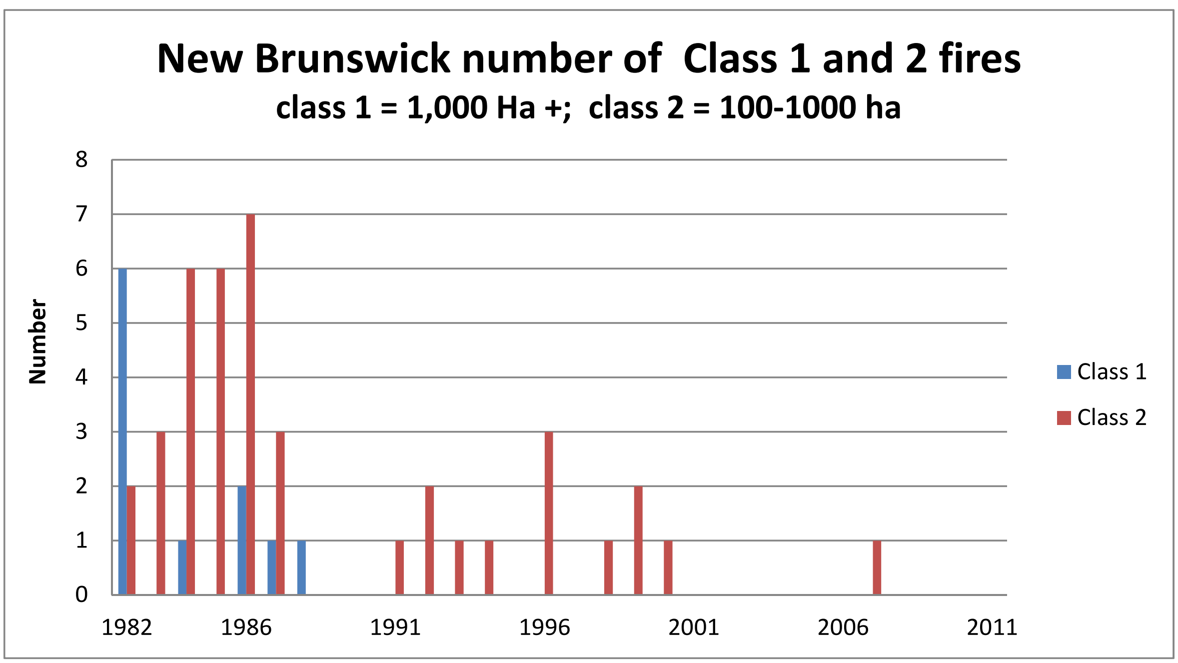


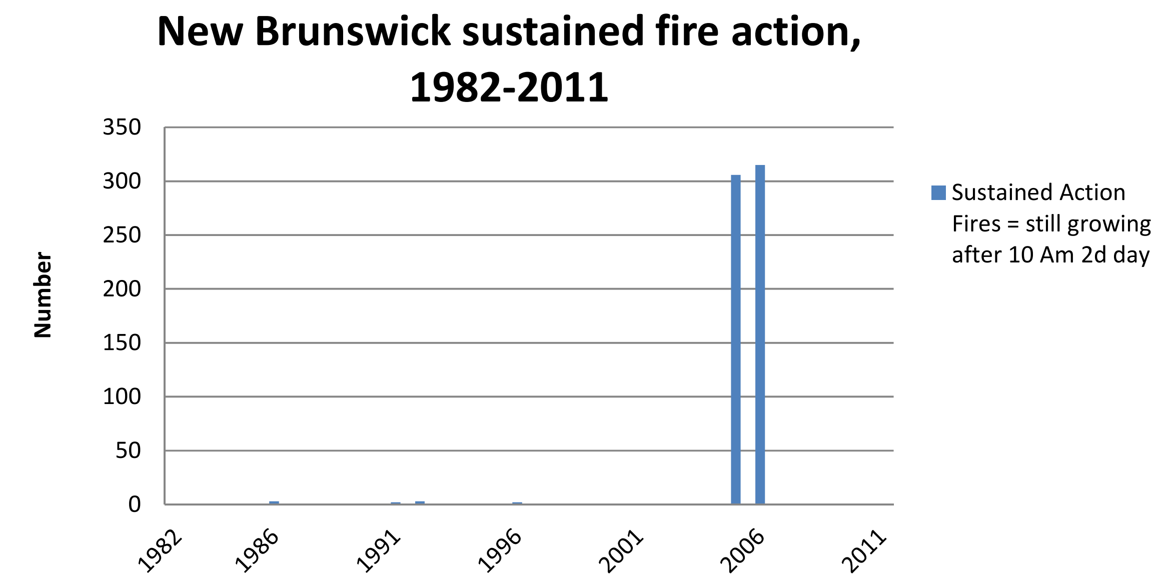
Figure 25b



Several measures of pressure on resources and significance of impact are provided in this dataset. Fig. 26 shows the number of Sustained Action fires, those which are still growing in size on 10:00 am of their second day. Few fire years experience more than 1 or 2 of these, but in 2005 and 2006 they were numerous. Days with multiple starts and large fires have also declined (Fig. 27). But it continues to be necessary to occasionally evacuate nearby residents due to fires (Fig. 28).

(A typo in the data? If not, any brief note on what happened in those years?)

Figure 26



Source: New Brunswick Dept. of Natural Resources.

Figure 27

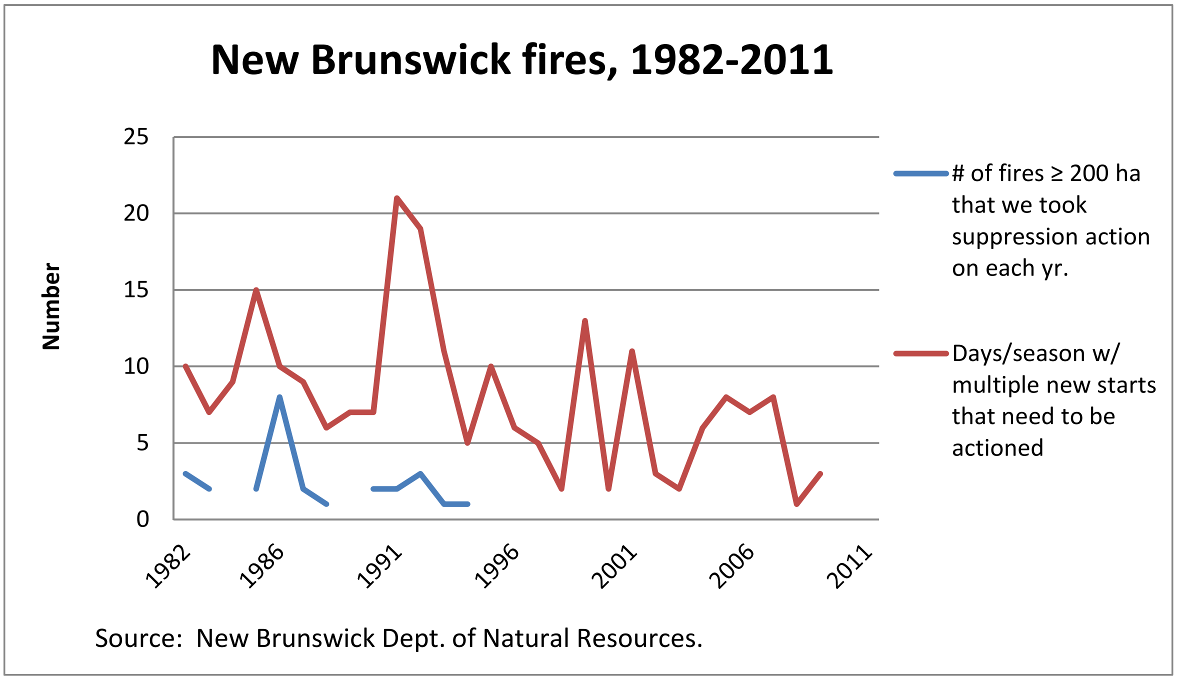
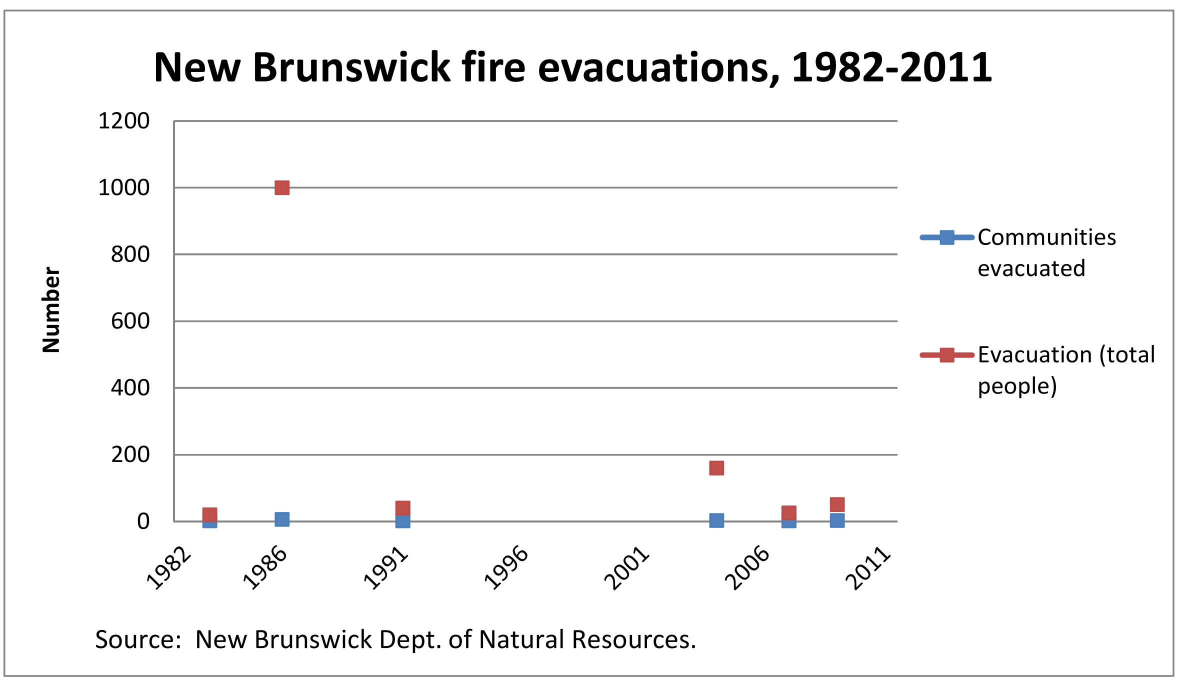
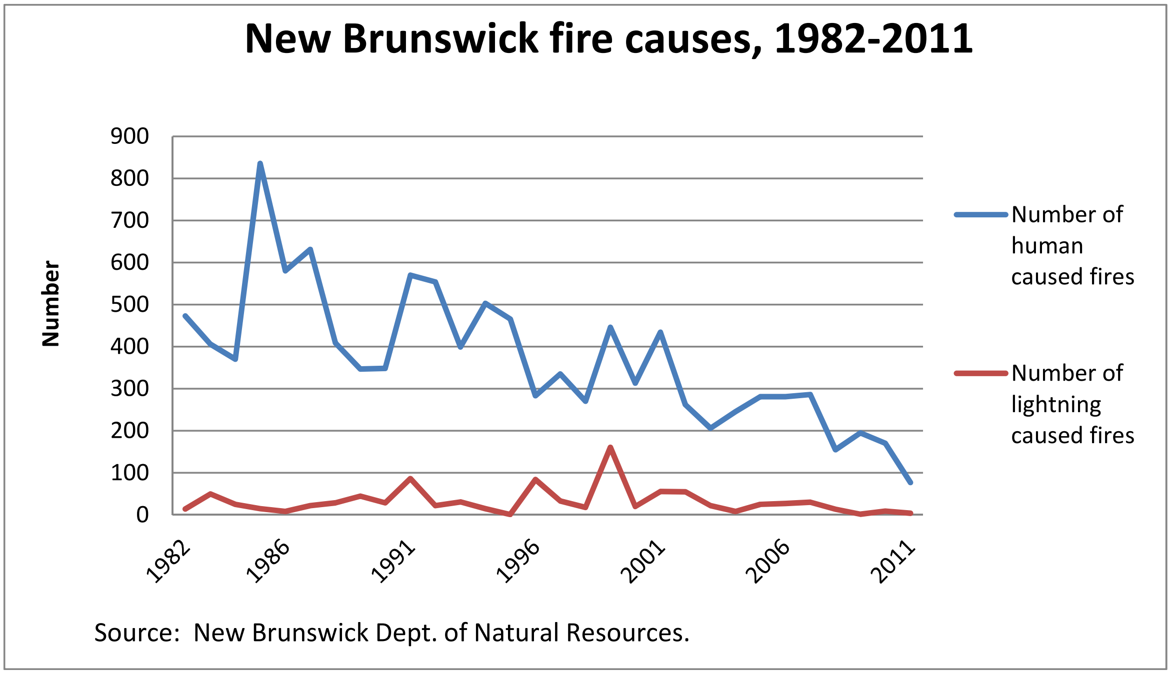


Figure 28



Social changes and prevention programs are steadily reducing the human caused fires in New Brunswick (Fig. 29). Since a peak in the late 1990s, lightning fires have been less frequent as well. Interestingly, the 1986 fire outbreak did not result from a record large number of fires – the peak was the previous year. The large number of lightning fires noted in 1989 were not accompanied by a difficult fire year – due to weather and prompt suppression action, the total area burned that year was very low.

Figure 29



D. 2. Individual Fires: Newfoundland

We have individual fire data for Newfoundland for 3 years, 1999, 2000, and 2009. It is interesting to place the ranked fire size data for each year on a chart for the same region to show how variable the patterns of fire occurrence can be (Figs. 30a-c). Usually, but not always, the largest fires are in Labrador; and fires are smaller and more numerous in eastern Newfoundland. Note that the log scales flatten the appearance of the comparisons.

Figure 30a

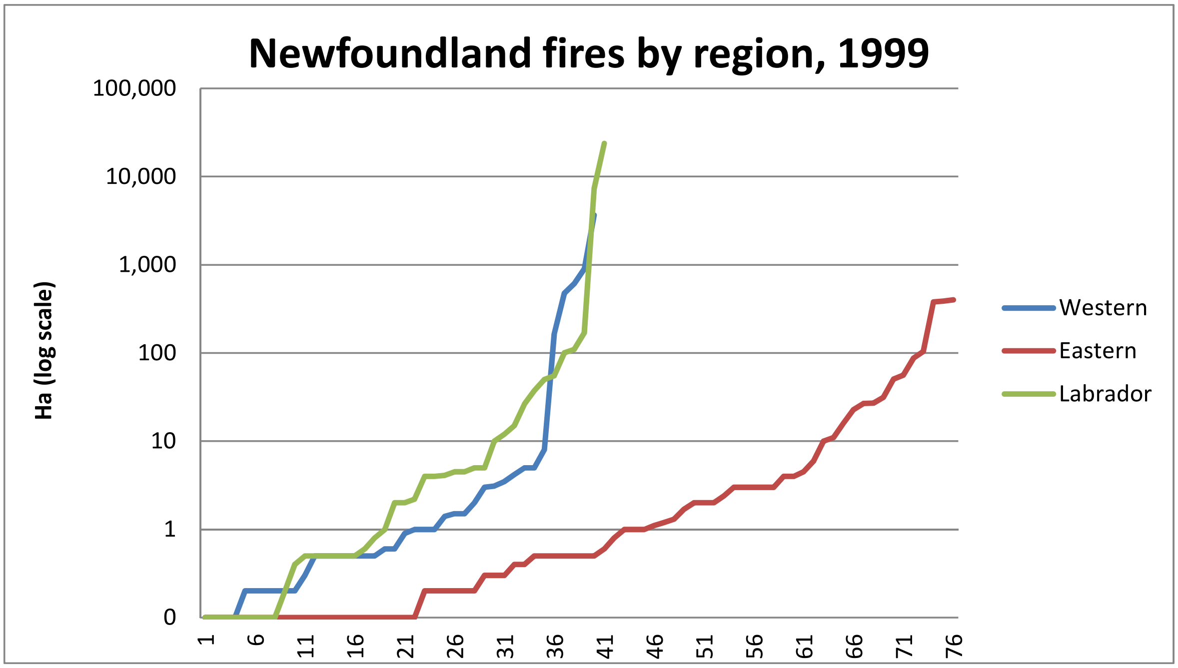


Figure 30b

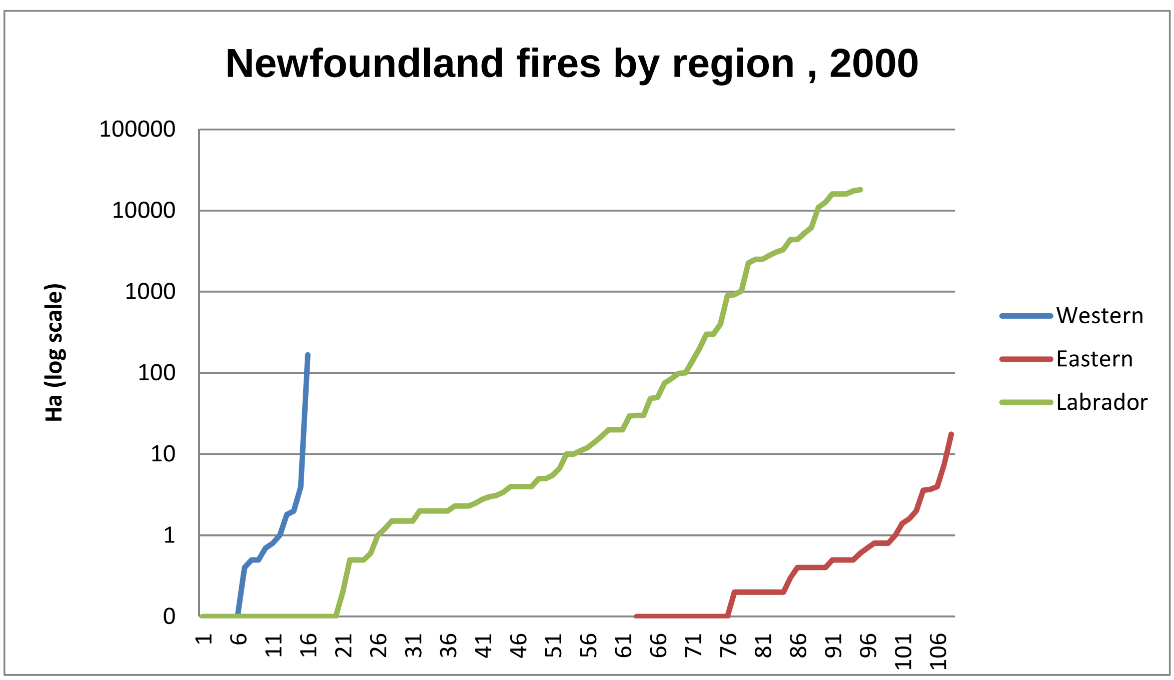
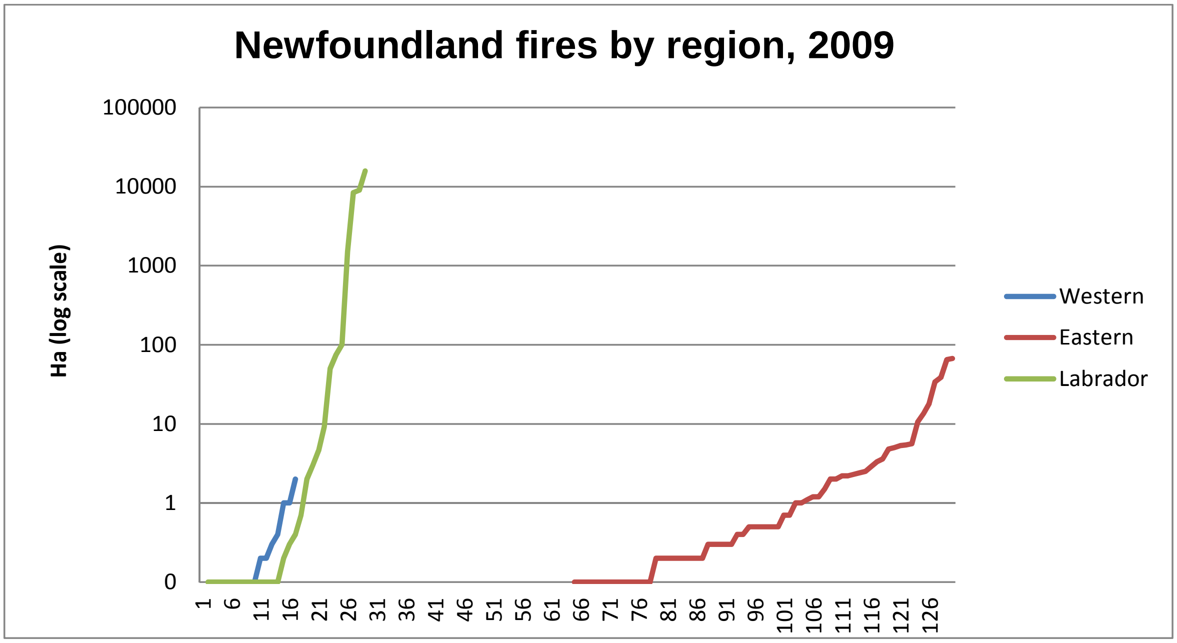


Figure 30c



D. 3. Individual Fire Analysis: Nova Scotia 1987-2011

From the Department of Natural Resources we received a detailed database of fires from 1987 to 2009. Here we analyze this data in a number of ways, for purposes of sketching fire seasons we use all fires larger than 1 acre (0.4 ha), and later for more detailed exploration we use fires of the larger sizes. Over this period, 6 fires exceeding 500 acres occurred, with the extreme fire for the period in 2008 (Fig. 31).

We used the data base to examine the “fires season” based on dates of occurrence of fires larger than one acre. In contrast to other areas we have examined, this shows a shorter fire season on average (Fig. 32). But the opening and ending dates are highly variable (Table 4), so just knowing this may not be very useful in practice.

Figure 31

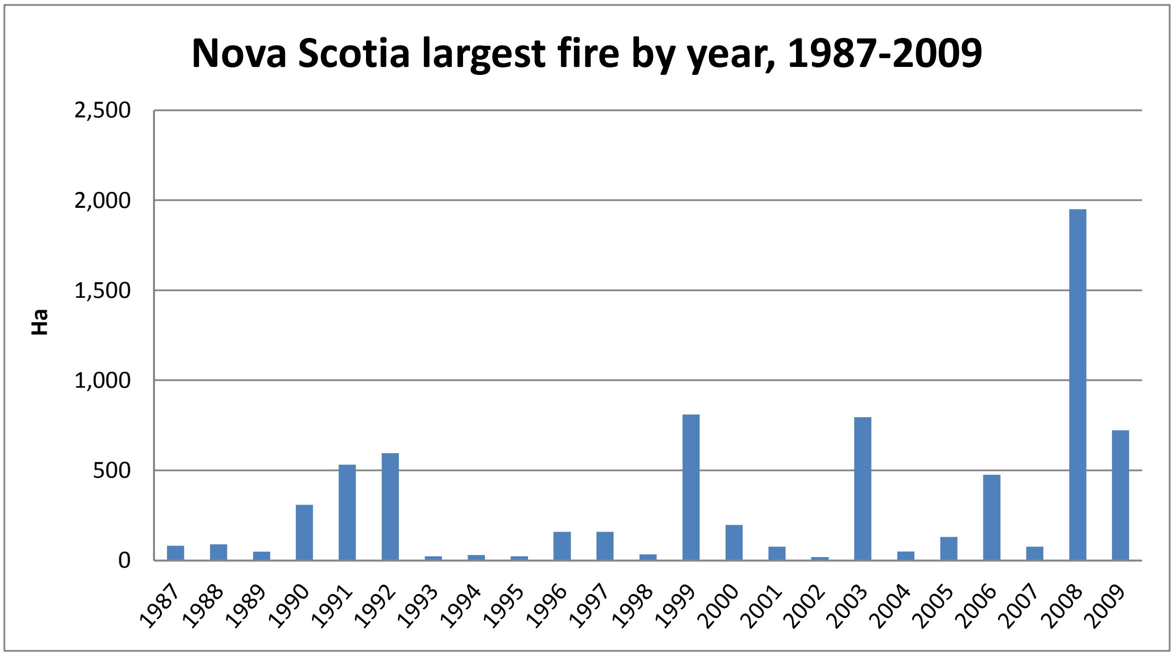


Figure 32

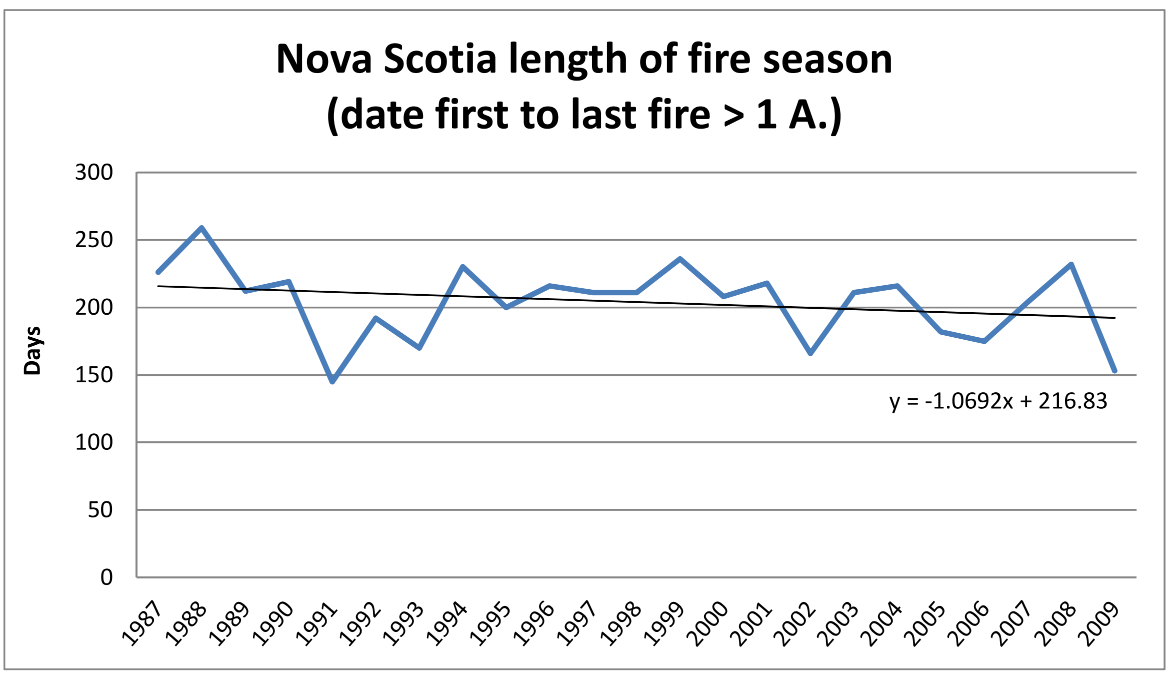


Table 4. Nova Scotia Fire Sizes and Seasons, 1987-2009

	Largest Fire	Smallest Fire	Number of Fires	Julian Dates Earliest	Latest	Fire Season Length
1987	80.92	0.4	182	31841	32067	226
1988	90.4	0.4	132	32201	32460	259
1989	48.5	0.4	172	32600	32812	212
1990	308	0.4	169	32944	33163	219
1991	532.4	0.4	295	33314	33459	145
1992	594.89	0.4	102	33702	33894	192
1993	22.4	0.4	124	34067	34237	170
1994	30	0.4	93	34426	34656	230
1995	22.1	0.4	158	34772	34972	200
1996	158	0.4	146	35144	35360	216
1997	157.6	0.4	124	35517	35728	211
1998	33	0.4	132	35884	36095	211
1999	810	0.4	171	36238	36474	236
2000	197	0.4	64	36609	36817	208
2001	76.8	0.4	148	36982	37200	218
2002	17.1	0.4	85	37341	37507	166
2003	795	0.4	110	37694	37905	211
2004	50	0.4	108	38087	38303	216
2005	130	1	122	38438	38620	182
2006	475	1	110	38802	38977	175
2007	76	1	181	39168	39372	204
2008	1950	1	115	39534	39766	232
2009	722	1	63	39912	40065	153
	Total		**3,106**			

In analyzing the fire size distribution, we first divide into quintiles (Table 5). While this is often preferable in analyses like this, it leaves a hole in the distribution and displays such skewness that it conceals a great deal. Hence, we adopt a non-uniform set of bins to more clearly depict the data (Table 6). On this basis, much of the area burned occurs in small fires, although the single large 2008 fire took 10% of the entire acreage burned over this entire period. Fully 99% of all the fires were 80 ha or less in size.

Table 5. Nova Scotia fire size distribution, quintiles, 1987-2009

Quintile	Area Burned	Percent
400	12,839	69%
800	3,119	17%
1200	810	4%
1600	0	0%
2000	1,950	10%
Total	**18,718**	

Table 6. Nova Scotia fire size distribution, alternate size classes, 1987-2009

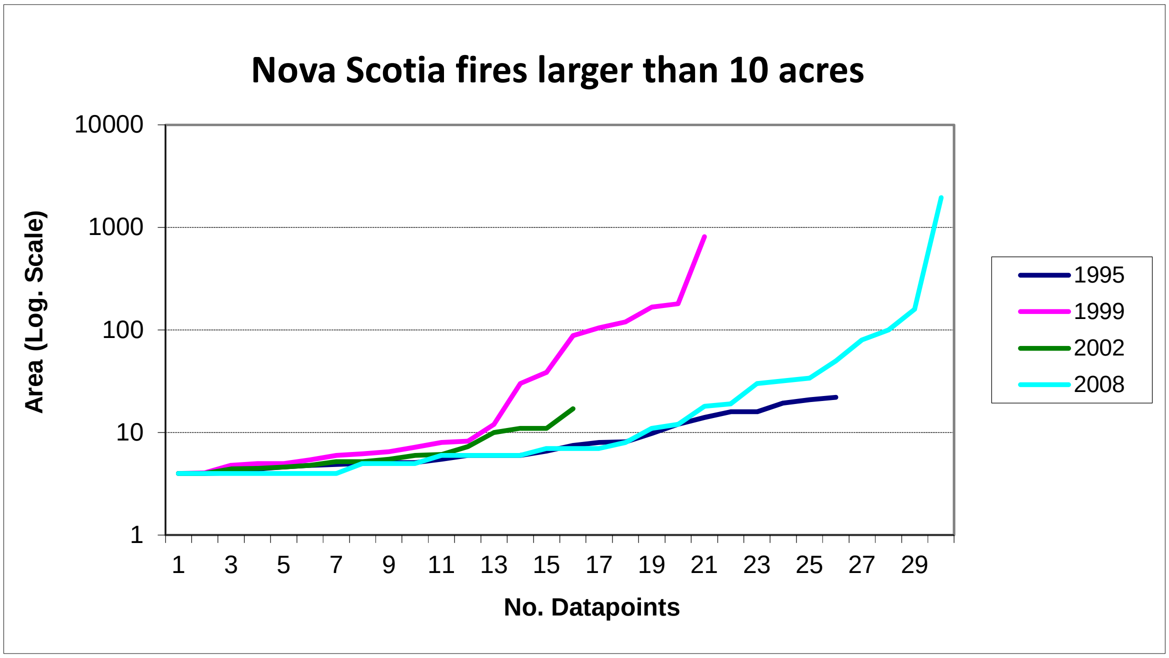
Bin	Frequency	Cumulative %	Bin	Frequency	Cumulative %
10	2906	93.56%	10	2906	93.56%
40	153	98.49%	40	153	98.49%
80	16	99.00%	80	16	99.00%
120	10	99.32%	120	10	99.32%
160	5	99.48%	More	7	99.55%
200	5	99.65%	160	5	99.71%
240	1	99.68%	200	5	99.87%
260	1	99.71%	240	1	99.90%
280	0	99.71%	260	1	99.94%
320	1	99.74%	320	1	99.97%
400	1	99.77%	400	1	100.00%
More	7	100.00%	280	0	100.00%

Another way to look at the role of extreme fires is to compare the heavy burn years and light burn years. The year with the smallest top-ranking fire over this period –17 ha – occurred in 2002, which also had a record short fire season. The next smallest top-ranking fire was in 1995, at 22 ha. The record individual fire, in 2008, consumed a large fraction of total area burned that year, at almost 2000 ha. The second largest fire in this period was in 1999, at 810 ha. These were also the 2 longest fire seasons since 1998.[7] So, how did the fire size distributions compare across these years? Fig. 33 shows that the sizes of the smaller fires, just above the 10 ha threshold, are almost identical across the years. In 1995, there were more fires but no large ones.

[7] Hmmmm maybe there's a connection here we ought to explore further. Fire managers know this already, but do the rest of us?

For the two years with the largest fires, 199 actually had fewer fires above 10 ha than did 1995, but its fires were much larger. In 2008, a small number of very large fires made all the difference between it and 1995.

Figure 33
(Note that the log scale flattens the appearance of the size distributions)



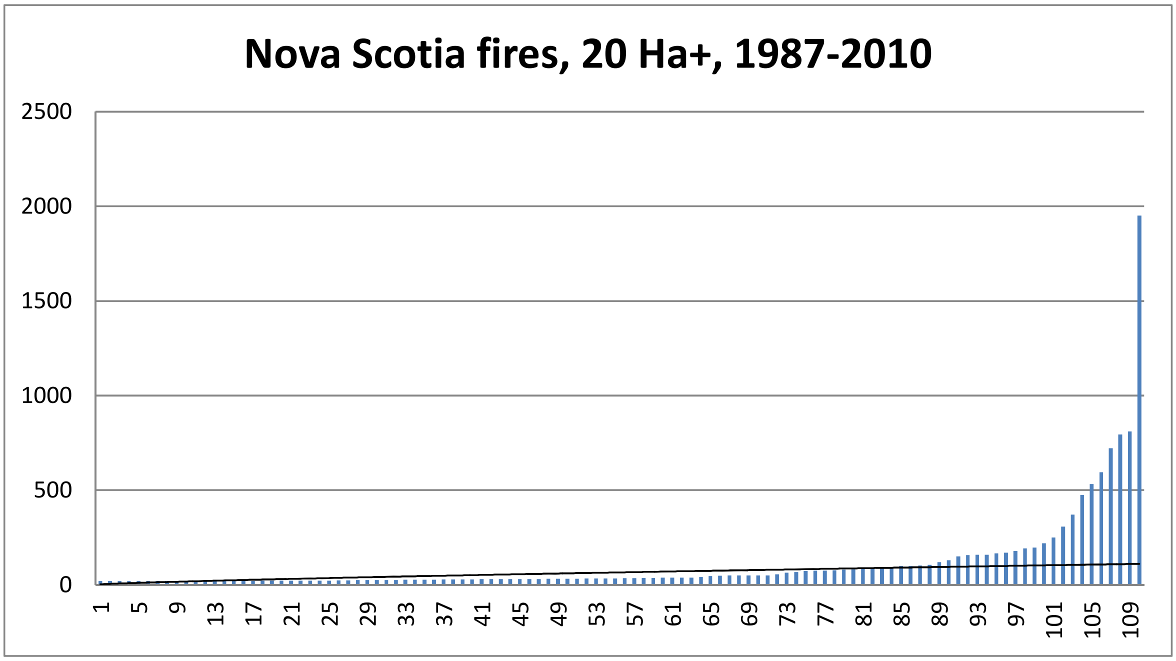
Ranking and Extreme Values for Individual Fires

Nova Scotia is a land of countless small fires and just a few really large ones. It has been noted repeatedly as a region of low fire activity, but this is the general picture and not a complete one. Even when the dataset is trimmed down to just the fires above 20 hectares, some 200 fires, the ranked distribution has a very long lower branch of fires of roughly the same size (Fig. 34). The extreme fires, say the top 10 or 20, really are very different in character, perhaps in the fuel types where they occur, the nature of the ignitions, or in the unusual weather conditions that accompany them.

The largest fire of this period occurred in 2008.

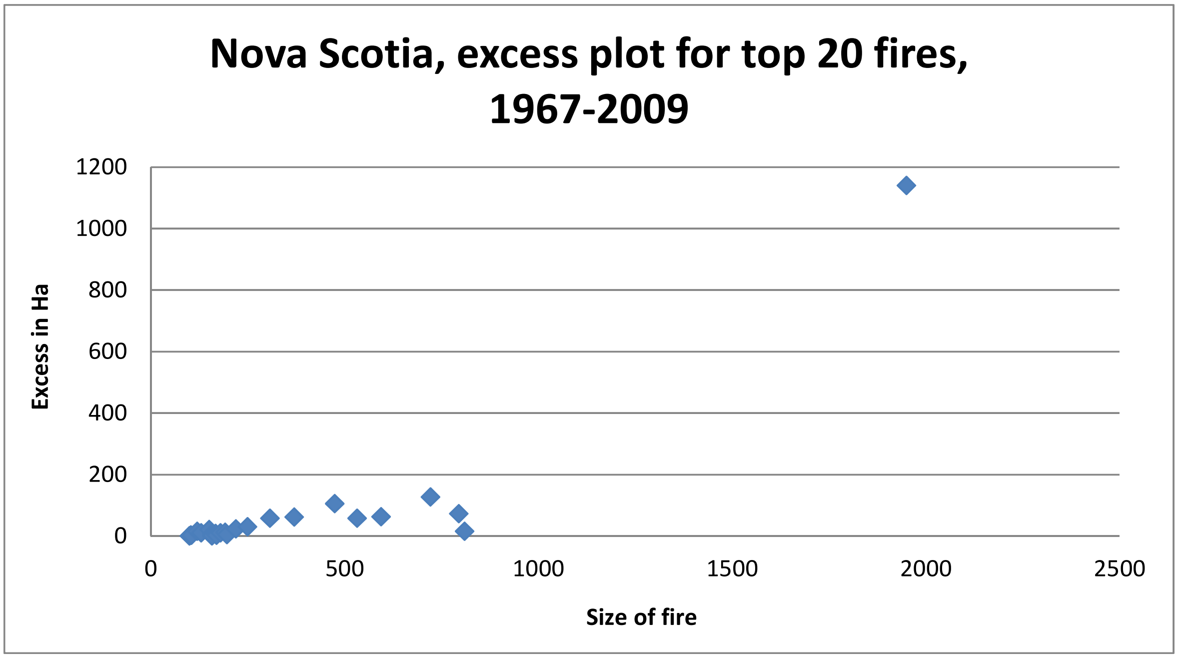
(Friends; can you give us some details, on say, the top 5 fires, in these terms?)

Figure 34



Statisticians often use an “excess plot” as diagnostic for “thick-tailed” distributions. In this case, the excess plot is ill-behaved. It rises for a time, suggesting a thick tail, then declines, but then the true extreme occurs (2008) and falls far outside the rest of the points (Fig. 35).

Figure 35



Analysts often use standard deviations as measures of variability. In this case, the SD is a multiple of the mean, which is normal with distributions that are highly skewed and highly peaked. In such cases, SDs do not have quite the same interpretation as in normal distributions, but for descriptive purposes we use them here. In securities markets analysts speak of an "X-standard deviation event" as a way of describing extreme price movements. In the case of the Nova Scotia fires above 1 ha, 24 fires exceeded 2 SDs from the mean. The extreme fire was 323 times the size of them mean, and even the second largest fire was 132 times the mean (Table 7).

Table 7. Nova Scotia fires 1967-2009: Descriptive statistics, Stats for all fires > 1 ha

Standard deviation	48.2	
Mean	6.0	91
Median	1.0	
Extreme over mean	323.1	
Second highest/mean	1234	
Mean plus 1 SD	54.3	
Mean plus 2 SD	102.5	24 fires exceeded 2 SD from mean
If 15 times mean is “catastrophe,” then they has 25 “catastrophes.”		
	Need to use some threshold	
	But, 91 ha = 227.5 acres, which is a bit of land!	

All of this is descriptive and backward-looking. It shows the risk of relying on averages and medians when working with highly skewed fire size distributions, and when it is the occasional large ones that are of most concern. It is clear that the fire protection system is sized for and capable of holding most of the fires to small sizes. But on average, about once a decade in Nova Scotia, a fire escapes control to exceed 500 ha. Maintaining the mix of capabilities and training for these occasional events is the management issue.

E. Fire Occurrence and Weather

Analyzing secular changes in relationships between weather and fire necessarily relies on annual estimates of both factors, as calendar dates for refined kinds of data are not available for long historic periods. Assessment of broad factors influencing fire regimes is thus fairly rough, and is not conducted in the same way as fire weather assessment for day by day fire management. The perceptions of relationships and demands for precision are quite different in the two fields.

An analysis of drought regime shifts (Federal, Provincial and Territorial Governments of Canada 2010, p. 97) showed that the July Drought Code decreased substantially in much of Newfoundland and all of Labrador from 1901-2001, as well as in the tip of the Gaspe and central highlands of Nova Scotia. In southern Newfoundland and most of New Brunswick, the Drought Code declined moderately.

A quick review of recent publications on this topic leads to a number of results, summarized briefly here:

1. Teleconnections with conditions in the Gulf of Alaska, and Pacific, and North Atlantic appear to influence drought, and hence, fire occurrence.
2. Temperature, through its role in drying fuels, is a key variable and has been generally increasing in our region.
3. Growing season and ice-free seasons are rising, and hence, very likely, length of fire seasons.
4. Growing season rainfall has been rising slightly, but the frequency of rainfall within the year is more important for fire incidence than the total amount.
5. Low snow winters and early springs can accelerate fire seasons by opening growing seasons with low soil moisture reserves.
6. Considerable work has been done on regional weather systems in their influences on fire. An excellent review, still understandable through the technical meteorology jargon, is Fauria and Johnson (2008).

Drought history in eastern Canada has been intensively studied. Work by Girardin and collaborators (2004, 2006, 2011) **– Lloyd – All 3? This is the only Girardin mention)** have developed multi-century reconstructions. Unfortunately, most of the work does not cover the Atlantic Provinces. Work is underway to develop nationwide long-term weather reconstructions (McKenney, et. al 2011). We have inquired to see if we can use that data. Long-term analyses of windiness and humidity, surely key factors, are not known to be available. Further, fire danger rating data incorporating such information is not electronically available for long time periods, though it can often be recovered for limited periods of days or weeks to study individual incidents.

References

Alexander, M. E. 2010. Lest we forget: Canada's major wildland fire disasters of the past, 1825-1938. *In*, Wade, D. D, and Robinson, M. (eds). Proceedings of 3rd Fire Behavior and Fuels Conference, 25-29 October 2010, Spokane, WA. Birmingham, AL: International Association of Wildland Fire. 21 p.

Canadian Interagency Forest Fire Centre (CIFFC). 2011. Canada report 2010. 15 pp.

Cui, W., and A. H. Perera. 2008. What do we know about forest fire size distribution, and why is this knowledge useful for forest management? *International Journal of Wildland Fire*, 17:234-244.

Federal, Provincial and Territorial Governments of Canada. 2010. Canadian biodiversity: ecosystem status and trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 142 p. http://www.biodivcanada.ca/default.asp?lang=En&n=83A35E06-1

Macias-Fauria, M., and E. A. Johnson. 2008. Climate and wildfires in the North American boreal forest. *Philosophical Transactions of the Royal Society B Biology Sciences,* 363(1501):2317-2329.

Girardin, M. P., J. Tardif, M. D. Flannigan, B. M. Wotton, and Y. Bergeron. 2004. Trends and periodicities in the Canadian Drought Code and their relationships with atmospheric circulation for the southern Canadian boreal forest. *Canadian Journal of Forest Research*, 34:103-119.

Girardin, M. P., J. Tardif, M. D. Flannigan, and Y. Bergeron. 2006. Synoptic scale atmospheric circulation and boreal Canada summer drought variability of the past three centuries. *Journal of Climate,* 19:1922-1947.

Girardin, M. P., P. Y. Bernier, and S. Gauthier, S. 2011. Increasing potential NEP of eastern boreal North American forests constrained by decreasing wildfire activity. *Ecosphere - A journal of the Ecological Society of America*, 2:art25.

Holmes, T. P., R. J. Huggett, Jr., and A. J. Westerling. 2008. Statistical analysis of large wildfires. Ch. 4, *In*, Holmes, T. P., J. P. Prestemon, and K. L. Abt (eds). The Economics of Forest Disturbances. New York: Springer. 422 p.

Krezek-Hanes, C. C., F. Ahern, A. Cantin, and M. D. Flannigan. 2011. Trends in large fires in Canada, 1959-2007. Canadian Biodiversity: Ecosystem Status and Trends 2010. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta, and Canadian Councils of Resource Ministers, Ottawa, Ontario. Technical Thematic Report No. 6.

http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-0 (esp. pp. 11 ff on Boreal Shield).

Lin, J., and S. Rinaldi. 2009. A derivation of the statistical characteristics of forest fires. *Ecological Modelling*, 220(7):898-903.

McKenney, D. W., M. F. Hutchinson, P. Papadopol, K. Lawrence, J. Pedlar, K. Campbell, E, Milewska, R. F. Hopkinson, D. Price, and T. Owen. 2011. Customized spatial climate models for North America. *American Meteorological Society* (early online release), doi: 10.1175/2011BAMS3132.1.

Pyne, S. J. 2007. Awful splendour: A fire history of Canada. Vancouver: UBC Press. 549 pp.

Taleb, N. N. 2010. The black swan: The impact of the highly improbable. 2nd ed. New York: Random House. 444 pp.

Wallennius, T. 2011. Major decline in fires in coniferous forests – reconstructing the phenomenon and seeking the cause. *Silva Fennica* 45(1):139-155.

Wein, R. W., and J. M. Moore. 1977. Fire history and rotations in the New Brunswick Acadian Forest. *Canadian Journal of Forest Research,* 7:285-294.

Wein, R. W., and J. M. Moore. 1979. Fire history and recent fire rotation periods in the Nova Scotia Acadian Forest. *Canadian Journal of Forest Research*, 9:166-178.

Appendix Tables

Appendix Table 1. Atlantics region long-term history, annual data

Year	Nova Scotia (1930)		Newfoundland (1944)		New Brunswick (1919)		**Atlantics (1944)**	
	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires
1919					4,677	409		
1920					38,359	312		
1921					34,189	495		
1922					2,984	113		
1923					165,759	264		
1924					6,545	241		
1925					2,762	103		
1926					4,997	65		
1927					981	77		
1928					1,979	107		
1929					1,366	162		
1930	18,700	509			4,871	312		
1931	7,953	263			1,437	203		
1932	5,372	335			14,990	268		
1933	9,170	470			9,578	455		
1934	25,095	690			89,708	235		
1935	9,439	415			61,250	363		
1936	620	146			208	102		
1937	5,277	404			5,368	328		
1938	2,013	183			9,215	167		
1939	3,577	442			5,142	256		
1940	2,274	251			812	220		
1941	2,198	153			476	147		
1942	11,384	292			6,124	252		
1943	583	101			926	181		
1944	15,060	391	945	452	74,500	341	90,506	1,184
1945	1,676	169	876	532	2,914	168	5,466	869
1946	8,134	309	38,946	864	17,476	284	64,556	1,457
1947	18,190	444	123,422	436	21,032	300	162,644	1,180
1948	370	109	65	182	1,170	206	1,604	497
1949	2,067	329	15,179	264	1,968	307	19,214	900
1950	6,098	360	29,667	260	17,975	294	53,740	914
1951	1,288	165	5,525	185	876	124	7,689	474
1952	1,511	246	12,445	205	1,721	247	15,676	698
1953	767	225	557	150	2,191	369	3,515	744
1954	1,698	359	744	108	810	187	3,252	654
1955	8,286	261	1,898	137	5,175	164	15,358	562
1956	371	188	1,178	106	738	155	2,287	449
1957	4,772	554	8,859	262	1,886	273	15,517	1,089
1958	522	245	1,059	128	2,210	142	3,791	515
1959	1,043	254	13,860	217	2,271	261	17,173	732
1960	8,569	605	28,638	437	12,107	483	49,313	1,525
1961	2,226	460	431,378	271	5,963	320	439,567	1,051
1962	2,029	435	6,311	148	19,053	355	27,393	938
1963	930	376	2,103	107	966	376	4,000	859
1964	3,538	562	145,026	131	2,335	512	150,899	1,205

Appendix Table 1. Atlantics region long-term history, annual data (cont.)

Year	Nova Scotia Area Burned (Ha)	Nova Scotia No. Fires	Newfoundland Area Burned (Ha)	Newfoundland No. Fires	New Brunswick Area Burned (Ha)	New Brunswick No. Fires	**Atlantics (1944)** Area Burned (Ha)	**Atlantics (1944)** No. Fires
1965	6,019	783	876	239	8,714	743	15,608	1,765
1966	1,138	817	1,730	157	1,709	639	4,578	1,613
1967	2,335	317	247,756	264	1,979	311	252,070	892
1968	3,148	920	8,773	166	3,130	731	15,051	1,817
1969	1,138	623	8,159	153	1,062	417	10,359	1,193
1970	815	450	9,130	194	1,210	407	11,155	1,051
1971	440	425	2,470	142	1,365	344	4,275	911
1972	2,320	419	43,283	247	4,536	488	50,139	1,154
1973	2,382	457	8,784	102	360	299	11,526	858
1974	1,721	471	53,050	282	1,041	465	55,812	1,218
1975	2,861	670	174,476	253	2,745	475	180,082	1,398
1976	18,153	542	196,468	348	4,616	411	219,237	1,301
1977	1,184	633	1,337	166	1,204	520	3,725	1,319
1978	748	798	4,681	209	2,399	846	7,828	1,853
1979	762	682	32,418	172	1,202	409	34,382	1,263
1980	979	439	954	60	2,610	222	4,543	721
1981	370	449	13,087	131	390	275	13,847	855
1982	617	491	4,392	165	6,537	487	11,546	1,143
1983	449	332	16,792	138	1,851	456	19,092	926
1984	598	446	7,743	101	580	395	8,921	942
1985	1,089	583	153,115	289	2,185	851	156,389	1,723
1986	814	506	108,831	193	39,099	588	148,744	1,287
1987	560	590	17,129	287	1,199	653	18,888	1,530
1988	334	328	1,780	116	1,976	437	4,090	881
1989	462	425	68,156	192	348	392	68,966	1,009
1990	1,068	498	47,317	197	6,113	377	54,498	1,072
1991	1,776	733	65,374	166	3,325	656	70,475	1,555
1992	1,161	299	1,814	109	5,071	576	8,046	984
1993	368	315	26,998	83	551	430	27,917	828
1994	247	264	110,629	143	472	518	111,348	925
1995	409	408	794	103	415	547	1,618	1,058
1996	651	272	82,448	148	1,769	367	84,868	787
1997	572	371	8,981	110	172	368	9,725	849
1998	571	371	40,226	192	284	286	41,081	849
1999	1,846	463	39,292	228	1,213	607	42,351	1,298
2000	494	212	148,820	219	307	333	149,621	764
2001	535	486	1,275	202	604	490	2,414	1,178
2002	214	267	35,484	143	246	317	35,944	727
2003	1,272	272	36,533	191	183	228	37,988	691
2004	298	258	2,361	153	289	253	2,948	664
2005	450	302	22,834	145	421	306	23,705	753
2006	1,621	234	3,436	96	378	308	5,435	638
2007	732	393	10,892	87	463	316	12,087	796
2008	2,775	248	5,140	139	102	168	8,017	555
2009	917	193	35,268	176	156	197	36,341	566
2010	163	313	251	56	90	179	504	548
2011	136	117	594	53	11	76	741	246

Sources: Used Provincial data sources. Except Newfoundland 1970-2010. which used CFS.

Appendix Table 2. Atlantics region long-term history comparison, averages by decades

Decade	Nova Scotia (1930)		Newfoundland (1944)		New Brunswick (1919)		**Atlantics (1944)**	
	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires
1901-1910								
1911-1920					21,518	361		
1921-1930					22,643	194		
1931-1940	7,079	360			19,771	260		
1941-1950	6,576	266	29,871	427	14,456	248	56,819	1,000
1951-1960	2,883	310	7,476	194	2,999	241	13,357	744
1961-1970	2,332	574	86,124	183	4,612	481	93,068	1,238
1971-1980	3,155	554	51,792	198	2,208	448	57,155	1,200
1981-1990	636	465	43,834	181	6,028	491	50,498	1,137
1991-2000	809	371	52,538	150	1,358	469	54,705	990
2001-2011	828	280	14,006	131	268	258	15,102	669

Appendix Table 3. Atlantics region long-term history comparison: Descriptive statistics and extremes analysis

Year	Nova Scotia (1930)		Newfoundland (1944)		New Brunswick (1919)		**Atlantics (1944)**	
	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires	Area Burned (Ha)	No. Fires
1944-2011								
Maximum 1944-present	18,190	920	431,378	864	74,500	851	439,567	1,853
Mean	2,369	415	41,496	201	4,657	387	48,522	1,003
Median	1,068	393	10,892	166	1,709	367	15,676	925
SD same	3,720	173	71,696	123	10,660	166	74,130	344
Ave + 1 SD	6,089	588	113,192	324	15,316	554	122,652	1,348
Ave + 2 SD	9,808	760	184,888	447	25,976	720	196,782	1,692
Ratios:								
Max /mean	7.7	2.2	10.4	4.3	16.0	2.2	9.1	1.8
Mean/Median	2.2	1.1	3.8	1.2	2.7	1.1	3.1	1.1
CV	1.57	0.42	1.73	0.61	2.29	0.43	1.53	0.34
1970-2011								
Maximum 1970-2011	18,153	798	196,468	348	39,099	851	219,237	1,853
Mean	1,361	422	40,103	168	2,441	421	43,905	1,010
Median	732	425	17,129	165	1,041	407	19,092	926
SD same	2,743	146	50,844	65	6,031	158	54,177	312
Ave + 1 SD	4,104	568	90,947	233	8,472	578	98,083	1,323
Ave + 2 SD	6,846	713	141,791	297	14,504	736	152,260	1,635
Ratios:								
Max./ mean	13.3	1.9	4.9	2.1	16.0	2.0	5.0	1.8
Mean/median	1.9	1.0	2.3	1.0	2.3	1.0	2.3	1.1
CV	2.02	0.34	1.27	0.39	2.47	0.37	1.23	0.31