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EFFECT OF CLIMATE CHANGE ON ABOVE-GROUND DECAY HAZARD FOR WOOD PRODUCTS ACCORDING TO THE SCHEFFER INDEX

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Summary

The Scheffer Index for wood decay potential above ground provides guidance in planning design and treatment strategies to ensure the durability of wood products. Work to improve its predictive capability was sidetracked by finding values calculated from recent climate data were higher than those from the literature; presumably a result of climate change, whether directional or cyclical. This led to development of an updated North American decay hazard map for comparison to a map created using published Scheffer Index data. We found considerable expansion of the moderate decay hazard zone, particularly in the interior wet belt of British Columbia, at the southern edge of boreal forest and around the Gulf of St. Lawrence. This has practical implications for the durability of wood in service. It may also affect decay of woody debris and standing dead trees such as those killed by the mountain pine beetle.

1. Introduction

The Scheffer Index (Scheffer 1971) has proved to be a reasonably useful tool for predicting the effect of continent-wide variations in climate on the potential for wood to decay above ground. Using basic climate data of monthly temperature and rainfall, Ted Scheffer developed an equation that gave a relative ranking of the time wood spends warm enough and wet enough for decay to begin and progress.

$$\text{Climate Index} = \sum_{Jan}^{Dec} \frac{(T-2)(D-3)}{16.7}$$

Where T is the mean monthly temperature in Celsius, D is the mean number of days in the month with 0.25 mm or more of precipitation and $\sum_{\text{Jan}}^{\text{Dec}}$ is the sum for the year of the products for each month. This was an empirical formula designed to give numbers in the range around 0 to 100 and adjusted such that the driest regions of the arid southwestern United States of America (USA) had an index of zero. The index thus ranged from 0.0 in Las Vegas, Nevada to 137.5 in West Palm Beach Florida. It was calibrated based on relative rates of decay in natural exposure tests in

Wisconsin, Oregon and Mississippi. Scheffer (1971) suggested dividing the USA into three zones: low hazard less than 35, moderate hazard 35 to 65, high hazard over 65; and presented a map of these hazard zones.

The general acceptance of this index can be judged by the number of papers that have built on it or applied it to other parts of the world (DeGroot 1982; Setliff 1986; Preston et al. 1996; Hasegawa 2001; Foliente et al. 2002; Van Acker 2003; Grinda and Carey 2004; Francis and Norton 2006). DeGroot and Esenther (1982), based on experience with decay in houses, proposed moving the boundary of the high hazard zone from 65 to 70. Setliff (1986) adopted this modification and developed an above ground wood decay hazard map for Canada.

In the early 1990s, a combination of the Scheffer and Setliff maps, assembled by Forintek, was unfortunately adopted by a supplier of northern pine shakes to indicate regions of the continent (unshaded zones) where preservative treatment was not required (Fig. 1). The original development in the late 1980s of the untreated pine shake industry was largely based on anecdotal reports of good performance from older buildings in the Prairies of the USA and Canada. This industry completely collapsed after untreated pine shakes suffered from decay after as little as 4 years in the Edmonton area (Dept. of Alberta Municipal Affairs 2006). This paper provides evidence for climate change as one of the factors contributing to these events.

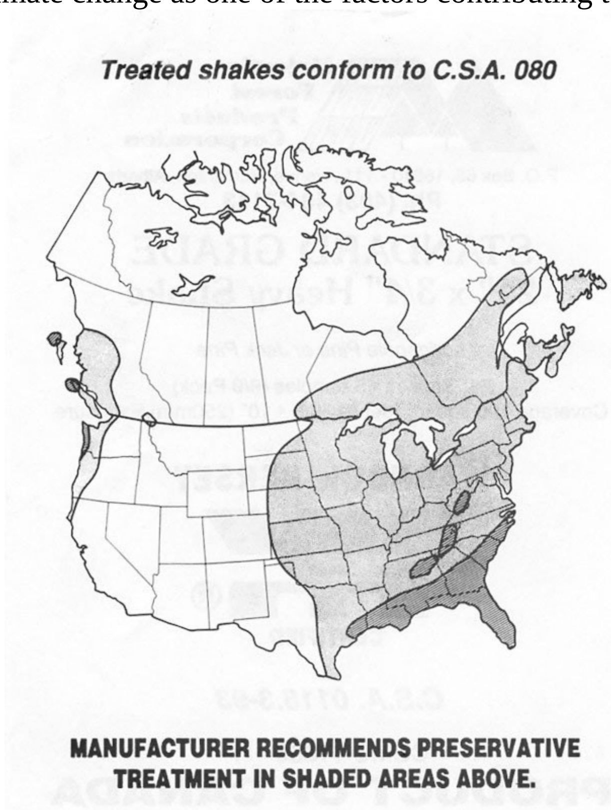

Figure 1. Label from bundle of untreated pine shakes

It has long been recognized that while being the best we have, the Scheffer Index is by no means perfect. DeGroot (1982) stated "the incidence of wood decay above ground in residential construction is not linearly distributed with the Scheffer Index at the upper limits of the index". Foliente et al. (2002) added a drying component to the equation using Vapour Pressure Deficit but this research group since changed focus to simply modeling time of wetting (Leicester, personal communication). Francis and Norton (2006) found the Scheffer Index correlated better with decay rates when data from one hot dry site was excluded from statistical analysis.

The possibility of improving the predictive capability of Scheffer Index for above ground decay in North America was considered, however the objective of this work was diverted by some unexpected findings using the original equations. Preliminary testing of a spreadsheet to calculate Scheffer Index values from climate data for a few Canadian and US cities gave numbers that were different from those published by Scheffer (1971) and Setliff (1986). Double-checking the calculations revealed no errors and cross checking the equations used revealed no discrepancies. At that point it was realized that the major difference was in the data. Climate normals are based on 30-year climate data. The new spreadsheet used data from 1971 to 2000, Setliff (1986) would have used data from 1951 to 1980 and Scheffer (1971) would likely have used data from 1941 to 1970. Examination of the raw data showed the increases in the Scheffer Index in certain locations were due to increases in temperature and rainfall in the recent data compared to the older data sets. These changes in climate data are consistent with the scientific consensus that the global climate is changing (Intergovernmental Panel on Climate Change 2007). It is recognized that the greatest impact will be in countries that extend further from the equator, such as Canada (Cohen 1997). Hansen et al. (1998) have suggested that western North America is one region where the effects of climate change should be noticeable by the general population. The decision was therefore taken to develop a new map for North America based on the latest climate data using the original Scheffer equation and compare it to a map based on the values calculated by Scheffer (1971) and Setliff (1986).

2. Materials and Methods

Climate data for 1971 to 2000 for the USA were obtained from the National Aeronautical and Atmospheric Administration (NOAA). Comparable climate data for Canada were downloaded from the website of Environment Canada (2007a), but mean number of days in the month with precipitation over 0.20 mm, instead of 0.25 mm was used for the calculation for all Canadian locations since this was the threshold used for the Canadian data (Note: according to Environment Canada, this would also have been the threshold in the data used by Setliff 1986 and the major differences in values were found in Canada). Both of these are regarded as "trace" values for precipitation and days with between 0.20 and 0.25 mm of rain are extremely rare. Mexico was not included in the map since no official meteorological website was found for climate data when the work was started.

An Excel spreadsheet was created to accept these climate data and calculate the Scheffer Index according to the above formula. Maps were created using GIS software, mainly based on latitude, longitude with the Scheffer Index of each location. One map was created using the data published by Scheffer (1971) and Setliff (1986). The second map was created using results calculated using the original Scheffer equation with the recent climate data. However, more data points were added especially in areas where boundaries between zones were difficult to draw with the available data points.

3. Results and Discussion

The North American decay hazard map based on the data from Scheffer (1971) and Setliff's (1986) calculations (Fig. 2) was drawn using the boundaries between zones as they were on the original maps. High decay hazard zones were confined to the southeastern USA, a few locations in the Appalachians, the Washington coast and a few hypermaritime locations in British Columbia. The moderate decay hazard zone covered many of the major population centers of the eastern USA and Canada plus coastal British Columbia, the Puget Sound and coastal Oregon. As with all human-designated climate boundaries, these should not be considered as hard lines and the values for individual cities are more useful than the zone allocation.

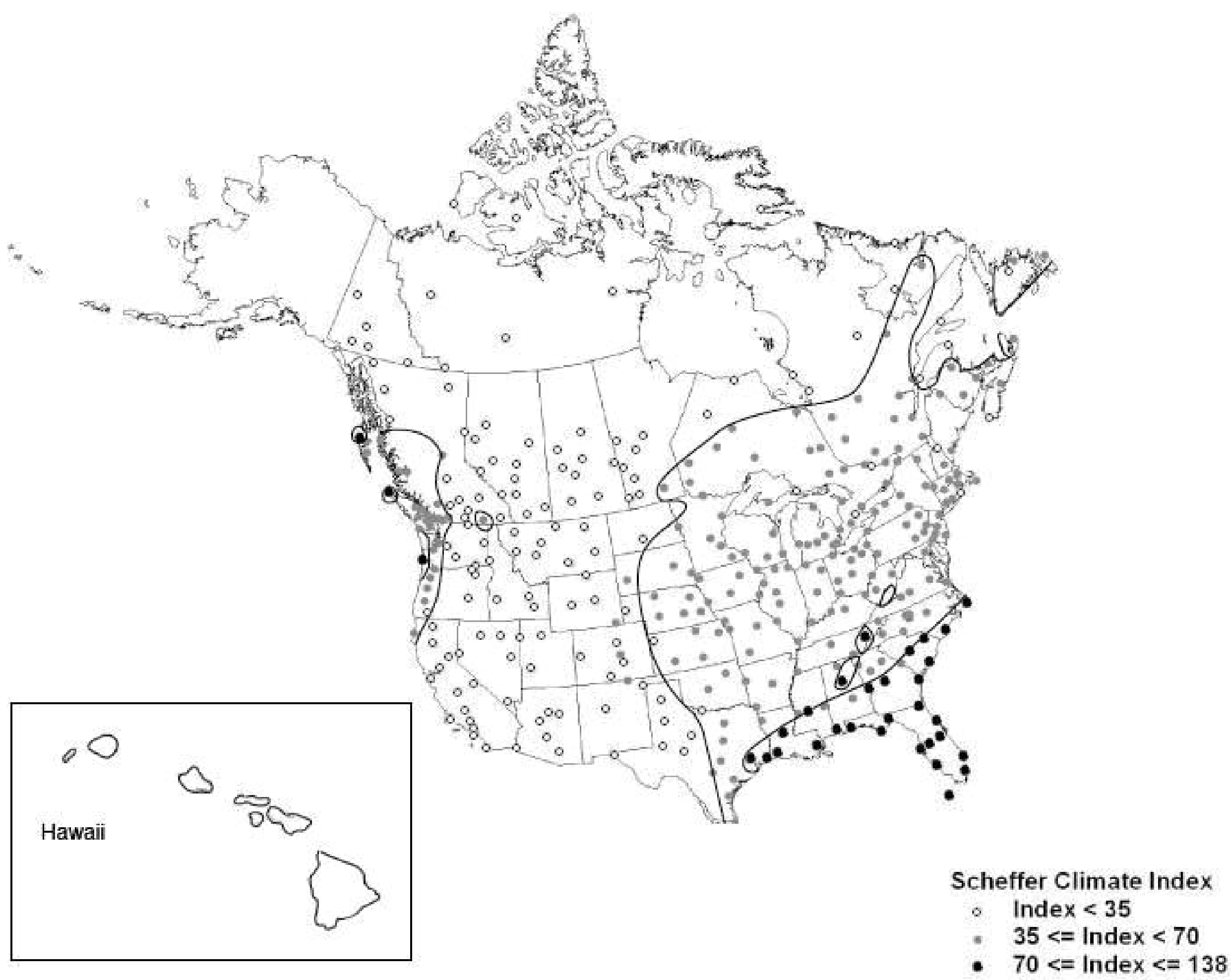

Figure 2. *Above ground decay hazard map for North America based on published Scheffer Index values.*

The map based on climate data from 1970 to 2000 (Fig. 3) shows a number of important differences from the earlier map. Note that data points have been added for Alaska (Table 2). Some of the differences are due to the larger number of data points used and the consequent ability to draw more accurate boundaries. Other differences are due to increases in rainfall and temperature. In some locations the Scheffer Index has increased by as much as 10 units (Table 1-2).

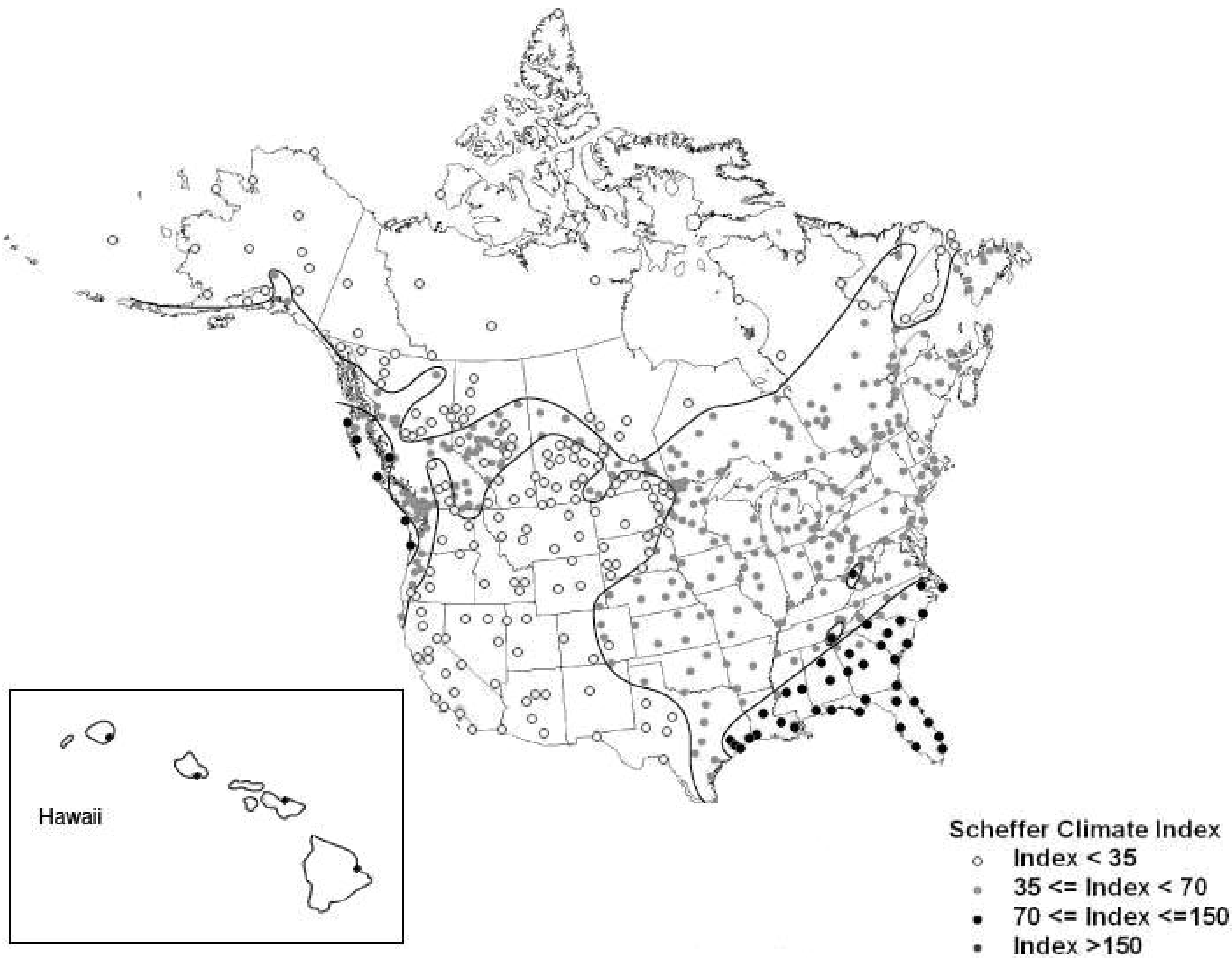

Figure 3. *Above ground decay hazard map for North America based on calculation of the Scheffer Index using recent climate data.*

Table 1. *Scheffer Index values based on recent climate data compared to literature values for Canada.*

Sites	Recent	Literature	Sites	Recent	Literature
Alberta			**Nova Scotia**		
Banff	35	28.4	Halifax Airport	42	38.0
Calgary	32	28.4	Sydney	43	42.3
Edmonton	35	32.5	Yarmouth	37	32.0
Lethbridge	27	24.4	**Ontario**		
Medicine Hat	29	24.1	Kingston	43	39.4
British Columbia			London	48	44.0
Cape Scott	86	79.7	North Bay	44	42.3
Castlegar	44	34.6	Ottawa	48	41.2
Fort Nelson	35	31.3	Sault Ste Marie	39	34.8
Kelowna	36	27.6	Sudbury	40	37.9
Ocean Falls	72	63.3	Thunder Bay	37	35.5
Osoyoos West	31	19.2	Toronto Airport	44	37.1
Prince George	39	35.0	Windsor	51	45.3
Prince Rupert	63	55.9	**Prince Edward Island**		
Vancouver Airport	50	45.6	Charlottetown	44	41.1
Victoria	42	40.9	**Quebec**		
Manitoba			Chicoutimi	52	52.2
Brandon	32	24.5	Gaspe	36	25.7
Grand Rapids	32	27.4	Montreal Airport	48	48.9
Swan River	37	27.5	Quebec City	50	48.2
The Pas	32	29.0	Rimouski	47	34.1
Winnipeg Airport	37	34.9	Schefferville	28	
New Brunswick			Sherbrooke	50	47.8
Fredericton	44	42.6	Val d'Or	43	40.7
Moncton	45	40.4	**Saskatchewan**		
Newfoundland and Labrador			La Ronge	36	32.3
Churchill Falls	35	34.4	Prince Albert	34	28.8
Gander Airport	47	43.1	Regina	33	28.3
St. John's	42	40.6	Saskatoon	30	26.9
Northwest Territories			Swift Current	31	26.1
Fort Liard	26	23.1	**Yukon**		
Sachs Harbor	3	1.9	Dawson	28	19.4
Yellowknife	18	15.5	Haines Junction	30	10.5
Nunavut			Watson Lake	23	27.2
Alert	1	0.6	Whitehorse		18.6
Baker Lake	9	7.7			
Iqaluit		8			

Table 2. *Scheffer Index values based on recent climate data compared to literature values for USA.*

Sites	Recent	Literature	Sites	Recent	Literature
Alabama			**Montana**		
Birmingham	73	72.2	Billings Airport	33	29.0
Mobile	94	99.2	Great Falls	28	28.5
Montgomery	72	69.2	Helena	27	24.6
Alaska			Missoula Airport	31	26.9
Anchorage	24		**Nebraska**		
Barrow	2		Lincoln	44	48.6
Fairbanks	26		Norfolk	39	38.1
Juneau	52		North Platte	38	35.1
Nome	18		Omaha Airport	47	47.3
Valdez	40		**Nevada**		
Arizona			Las Vegas	1	0.0
Flagstaff	25	19.2	Reno	4	2.5
Phoenix	9	6.7	**New Hampshire**		
Tucson	26	27.2	Atlantic City Airport	45	44.3
Arkansas			**New Jersey**		
Fort Smith	56	52.3	Newark	56	53.1
Little Rock	61	56.7	**New Mexico**		
Texarkana	60	58.6	Albuquerque	27	24.7
California			Raton	36	34.9
Bakersfield	8	9.2	**New York**		
Long Beach	9	3.8	Albany	48	46.0
Los Angeles	9	8.0	Buffalo	52	44.5
Sacramento	17	15.8	New York Airport	53	
San Diego	13	13.6	Rochester	51	44.8
San Francisco	22	19.4	Syracuse	55	52.1
Colorado			**North Carolina**		
Colorado Springs	41	35.3	Cape Hatteras	78	79.5
Denver	36	33.3	Charlotte	67	64.1
Pueblo	31	30.5	Raleigh	60	65.6
Connecticut			Wilmington 7 N	75	79.6
Hartford	51	48.8	**North Dakota**		
New Haven		48.1	Bismarck	31	33.0
Delaware			Fargo	35	35.2
Wilmington	52	51.2	**Ohio**		
Florida			Akron	53	
Daytona Beach	102	101.9	Cincinnati	57	60.4
Jacksonville	97	101.0	Cleveland	54	47.3
Key West	106	111.0	Columbus Airport	59	54.7
Miami	150	131.3	Dayton	53	51.5
Pensacola	83	87.2	**Oklahoma**		
Tampa	96	104.0	Oklahoma City	44	41.0
West Palm Beach	142	137.5	Tulsa	51	48.4
Georgia			**Oregon**		
Athens	65	67.9	Astoria	70	71.1
Atlanta	71	66.7	Eugene	41	41.4
Augusta	70	65.0	Portland	52	50.2

Macon	70	77.5	Salem	44	46.7
Savannah	84	82.5	**Dependencies**		
Hawaii			Guam	355	
Hilo	311		Majuro, Marshall Island	342	
Honolulu	79		Pago Pago, Amer Samoa	323	
Kahului	83		San Juan, Puerto Rico	237	
Lihue	221		**Pennsylvania**		
Idaho			Allentown	41	52.5
Boise Airport	15	16.7	Philadelphia	47	49.8
Lewiston	30	24.8	Pittsburgh	48	50.4
Pocatello	17	14.3	**Rhode Island**		
Illinois			Providence	39	48.0
Chicago Airport	47	45.5	**South Carolina**		
Peoria	48	42.7	Charleston Airport	82	83.1
Rockford	45	42.9	**South Dakota**		
Springfield	48	47.7	Rapid City Airport	36	35.7
Indiana			Sioux Falls	39	37.2
Fort Wayne	50	46.0	**Tennessee**		
Indianapolis Airport	54	46.7	Chattanooga	70	67.3
South Bend	51	43.9	Knoxville Airport	68	71.7
Iowa			Memphis	62	55.3
Des Moines	50	44.8	Nashville	63	63.8
Sioux City	39	43.2	**Texas**		
Waterloo	44	35.0	Abilene	34	31.1
Kansas			Amarillo	35	33.5
Dodge City	39	39.7	Austin	55	46.6
Topeka	50	48.4	Brownsville	50	43.0
Wichita	45	44.7	Corpus Christi	51	43.9
Kentucky			Dallas-Love Field	44	38.6
Lexington	60	57.9	Houston Airport	77	76.5
Louisville	62	53.5	Port Arthur	81	76.5
Paducah	51		San Antonio	52	43.4
Louisiana			**Utah**		
Lake Charles	80	79.0	Milford	17	7.1
New Orleans Airport	95		Salt Lake City	26	19.8
New Orleans	106	103.5	**Vermont**		
Shreveport	64	56.6	Burlington	55	49.4
Maine			Norfolk	65	66.3
Portland	41	36.0	**Virginia**		
Maryland			Richmond	59	61.7
Baltimore	53	50.6	**Washington**		
Massachusetts			Olympia	44	49.4
Boston	48	51.2	Quillayute	70	
Worcester	42	44.3	Seattle Airport	50	49.7
Michigan			Spokane	21	19.9
Detroit	49	46.2	Yakima	7	8.2
Flint	44	39.5	**West Virginia**		
Grand Rapids	44	38.5	Charleston	71	69.0
Lansing	44	40.9	Huntington Tri	65	60.5
Minnesota			**Wisconsin**		

Duluth Airport	39	37.0	Green Bay	41	37.3
Minneapolis-St. Paul	45	41.7	Madison	44	39.5
Rochester	42	43.2	Milwaukee	44	35.6
Mississippi			**Wyoming**		
Jackson	70	79.9	Casper	26	22.0
Meridian	72	65.2	Cheyenne	36	34.9
Vicksburg	57	67.0	Lander	18	14.3
Missouri					
Kansas City	57	51.3			
St. Louis Airport	54	49.8			
Springfield	53	51.2			

The high decay hazard zone in the south-eastern USA has expanded a little and there are a few more high hazard locations on the coast of British Columbia. The major difference is in the moderate zone. In the central USA, it has expanded slightly into the Texas panhandle and Colorado. In Quebec, the Atlantic Provinces of Canada and in New England, it has expanded to reduce the area of low hazard around the Gulf of St. Lawrence. This would be consistent with a warming trend in the Gulf waters from 1947 to 1999 (Fisheries and Oceans Canada 2000).

In Western Canada, the moderate hazard zone now stretches in a continuous arc from coastal BC, through the BC interior wet belt, at the southern edge of the boreal forest from the Yellowhead pass in the Rocky Mountains, through Northern Alberta, including Edmonton, and central Saskatchewan to southern Manitoba. The position of this arc seems to relate partly to penetration of maritime air through the Rockies and the Alberta storm track (Nkemdirin and Weber 1999). It can also be seen in maps of annual total precipitation for Alberta (Alberta Dept. of Agriculture, Food and Rural Development 2006). However, at least the BC end of this arc has also experience significant increases in temperature (Environment Canada 2007b). Examination of the raw data confirmed the increases in Scheffer Index values found here were partly due to increases in temperature and partly to increases in rainfall amount and number of events as found by Akinremi and McGinn (2001).

The effects of climate change on Forestry have been extensively studied since the mid 1980s (Wheaton et al. 1987; Freer-Smith et al. 2007). The effects on forest products have not. This work may also have implications for decay of coarse woody debris in northern forests (Moore et al. 1999) and standing dead trees such as those killed by the mountain pine beetle (Byrne et al. 2006). It also appears related to the causes of increased foliar disease of pines in parts of British Columbia (Woods et al. 2005).

Whether the Scheffer Index values calculated here for the 1971 to 2000 period will be valid for the next decades can not be determined with any degree of certainty. The increases in the Scheffer Index may be due to directional climate change but, they may also be caused by an upswing in cyclical temperature change in the North Pacific (Mantua et al. 1997), termed the Pacific Decadal Oscillation (PDO). The PDO index was in negative territory between the early 1940s and the late 1970s which spans the time period from which both Scheffer (1971) and Setliff (1986) drew their data. This shifted to a positive trend from the mid 1970s to the late

1990s (Mantua et al. 1997). Warm periods in the PDO are strongly correlated with warmer winter temperatures over western Canada (Mantua et al. 1997; Goshit and Malanson 2008) and weakly correlated with lower winter precipitation in the Northern Prairies and western boreal forest (Goshit and Malanson 2008). It may therefore be prudent to review the Scheffer Index every ten years.

The concept of designation of climate zones with specific requirements for durability protection measures is now making its way into treatment standards and building codes. The American Wood Preservers' Association (2006) standards have been converted to a Use Category System where different levels of preservative treatment are specified for different decay hazards. The latest edition of the National Building Code of Canada (National Research Council 2005) has a requirement for a capillary break behind cladding in areas with a Moisture Index greater than 1.0 according to Canada's National Research Council Institute for Research in Construction (Cornick and Dalgleish 2003). The increases in Scheffer Index values for parts of North America suggest measures to mitigate decay of wood outdoors above ground should be intensified.

4. Conclusions

Climate change has increased the decay hazard for wood products used above ground in parts of North America. The most substantial changes are in Canada from the interior wet belt of British Columbia, at the southern edge of the boreal forest and around the Gulf of St. Lawrence.

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