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Impact of Holocene climate variability on Arctic vegetation

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ABSTRACT

This paper summarizes current knowledge about the postglacial history of the vegetation of the Canadian Arctic Archipelago (CAA) and Greenland. Available pollen data were used to understand the initial migration of taxa across the Arctic, how the plant biodiversity responded to Holocene climate variability, and how past climate variability affected primary production of the vegetation. Current evidence suggests that most of the flora arrived in the area during the Holocene from Europe or refugia south or west of the region immediately after local deglaciation, indicating rapid dispersal of propagules to the region from distant sources. There is some evidence of shrub species arriving later in Greenland, but it is not clear if this is dispersal limited or a response to past climates. Subsequent climate variability had little effect on biodiversity across the CAA, with some evidence of local extinctions in areas of Greenland in the late Holocene. The most significant impact of climate changes is on vegetation density and/or plant production.

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1. Introduction

An interest in predicting the impact of global warming on Arctic ecosystems has led to considerable research using many approaches. Plant physiological studies have long been popular in Arctic regions, as this is a clear example of an area where temperature stress is important, although other environmental factors also affect plant growth, reproduction, and survival (Crawford, 1989). Population and community level studies, for example from the ITEX project, have attempted to estimate how the current warming is affecting the vegetation (e.g., Elmendorf et al., 2012). Remote sensing is used to document larger scale changes in plant production (Epstein et al., 2013), and models of the vegetation can summarize our understanding of Arctic vegetation response to climate variability (e.g., Epstein et al., 2000). Among the many conclusions of the above studies is the importance of scale, in that short-term transient changes cannot be used to predict longer-term development of terrestrial plant communities, and that considerable spatial variability is present, especially from the Low to the High Arctic. The current warming is affecting the Low Arctic more than the High Arctic and changes differ depending on plant functional type (Elmendorf et al., 2012). Although there are occasional exceptions (e.g., from Svalbard, Prach et al., 2010), these inferences are based on data from the past ~20–30 years.

Studies of the past can contribute to this research effort. Based on a diverse set of information, including ice cores, fossil records, and isotopic or sediment analyses from across the Canadian Arctic Archipelago (CAA) and Greenland, it has been demonstrated that the early or mid-Holocene was warmer than the 20th century, although the timing of maximum warmth differed from place to place (Bradley, 1990; Gajewski and Atkinson, 2003; Kaufman et al., 2004; Gajewski, 2015). Understanding how the vegetation responded to this early- to mid-Holocene warming may lend insight into what may happen in the future.

In this paper, I review paleoecological evidence to understand how climate changes of the Holocene affected the Arctic vegetation. Available pollen diagrams from across the Canadian Arctic Archipelago and Greenland (Table 1; Fig. 1) are synthesized to show the postglacial vegetation succession across the region. This paper will focus on three questions:

1. What was the nature of the initial migration of taxa across the Arctic? Is there evidence of migration lag of the various plants as the Innuition, Laurentide and Greenland Ice Sheets retreated and newly uncovered land was made available for colonization? Where did the plants come from?
2. How did the plant biodiversity respond to Holocene climate variability? What were regional differences in the vegetation through time?

Table 1
Pollen diagrams used in this study.

No	Site name	Region	Longitude (dd)	Latitude (dd)	Altitude (m)	Basal date (ka)	Reference
1	MS7411	W Arctic	−124.27	71.75	30	11.3	Gajewski et al. (2000)
2	Muskox	W Arctic	−122.67	71.78	305	12.5	Gajewski et al. (2000)
3	MS7415	W Arctic	−120.22	73.53	120	11.8	Gajewski et al. (2000)
4	MS7412	W Arctic	−119.83	72.37	220	10.1	Gajewski et al. (2000)
5	KR02	W Arctic	−113.78	71.34	229	9.7	Peros and Gajewski (2008)
6	MB01	W Arctic	−112.08	69.81	290	2.3	Peros and Gajewski (2009)
7	BC01	W Arctic	−111.92	75.18	225	12.9	Peros et al. (2010)
8	PWWL	Cent Arct	−98.48	73.58	110	7.3	Gajewski and Frappier (2001)
9	RS29	Cent Arct	−95.28	73.13	180	11.3	Gajewski (1995)
10	RS36	Cent Arct	−95.07	72.58	160	13.0	Gajewski (1995)
11	JR01	Cent Arct	−95.07	69.90	120	7.1	Zabenskie and Gajewski (2007)
12	SL06	Cent Arct	−91.89	68.59	243	2.7	Peros and Gajewski (2009)
13	FishLake	Cent Arct	−85.22	73.03	91	16.3	Short et al. (1994)
14	PatriciaBay	E Arctic	−68.50	70.47	11	7.1	Short et al. (1985)
15	Iglutalik	E Arctic	−66.08	66.13	90	9.9	Short et al. (1985)
16	Robinson	E Arctic	−64.27	63.40	170	11.8	Miller et al. (1999)
17	Donard	E Arctic	−61.78	66.67	460	15.1	Miller et al. (2005)
18	Dyer	E Arctic	−61.42	66.63	306	9.5	Miller et al. (2005)
19	Jake	E Arctic	−65.17	63.67	300	9.6	Miller et al. (2005)
20	Fog	E Arctic	−63.25	67.18	460	9.0	Fréchette et al. (2008a)
21	Sermiut A	E Arctic	−51.13	69.20	10	3.7	Fredskild (1967)
22	Lake31	E Arctic	−50.47	67.05	115	5.7	Eisner et al. (1995)
23	BairdInlet	N Greenl	−76.78	78.50	295	10.0	Hyvärinen (1985)
24	Qeqertat	N Greenl	−66.65	77.50	22	7.6	Fredskild (1985a)
25	Lange Sø	N Greenl	−58.60	75.37	15	9.5	Fredskild (1985a)
26	Klare Sø	N Greenl	−30.57	82.17	45	7.7	Fredskild (1973)
27	Peters Bugt Sø	E Greenl	−20.05	75.32	16	15.2	Bjorck and Persson (1981)
28	Bramgass Sø	E Greenl	−28.03	70.52	200	7.6	Funder (1978)
29	Potomogeton Sø	E Greenl	−27.73	70.95	58	7.0	Funder (1978)
30	PG1214	E Greenl	−21.54	70.60	40	10.0	Wagner and Melles (2001)
31	PG1205	E Greenl	−22.47	72.72	110	10.0	Wagner et al. (2000)
32	Terte Lake A	S Greenl	−51.92	64.47	61	10.0	Fredskild (1983)
33	Sardlup Qaqa	S Greenl	−51.68	64.40	140	10.0	Fredskild (1983)
34	Johs Iversen Sø	S Greenl	−50.00	64.40	100	9.6	Fredskild (1983)
35	Nigerdleq	S Greenl	−49.33	62.07	92	10.8	Kelly and Funder (1974)
36	Karra	S Greenl	−50.58	64.77	265	9.8	Fredskild (1983)
37	ComarumSø	S Greenl	−45.53	61.13	125	9.5	Fredskild (1973)
38	Spongilla Sø	S Greenl	−44.35	59.97	6	10.4	Fredskild (1973)
39	Kloft Sø	S Greenl	−44.23	60.05	60	9.6	Fredskild (1973)