The net exchange of methane with high Arctic landscapes during the summer growing season

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Supporting Information

TABLES

Table S1 Meteorological and soil measurements collected by sensors mounted on the eddy covariance towers at the desert and wetland sites.

Meteorological measurements	
Air temperature	HMP45C212 temp./humidity probes inside radiation shields
Air pressure	Licor LI-7500 CO_2/H_2O gas analyzer
Wind speed and direction	Campbell Scientific CSAT3 sonic anemometers
Net, photosynthetically active radiation	Kipp & Zonen net and PAR radiometers
Precipitation	TE525 Tipping Bucket rain gauge
Soil measurements	
Soil temperature	CS107B soil temperature probes
Soil moisture	CS616-L soil water content reflectometers
Soil heat flux at 5 cm depth	CSHFT3 soil heat flux plates

Notes:1. All soil sensors were buried at 5cm depth within 1m of each tower; 2. Precipitation was only periodically monitored during the study period because of high spatial variability and rare measureable events.

Table S2 Spearman rank correlation matrix of daily mean environmental parameters and mean CH_4 fluxes from desert chambers (A.) and wetland chambers (B.) during the 2008-12 growing seasons. Bold indicates statistical significance at α=0.05.

A. Desert chambers		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.CH_4 NEE	1											-
2.Air pressure	-0.16	1										-
3.Air temperature	-0.02	0.02	1									-
4.Water vapour flux	0.07	-0.02	-0.20	1								-
5.Air density	-0.03	**0.48**	**-0.78**	0.02	1							-
6.Soil thaw depth	-0.01	-0.32	0.00	**0.46**	-0.29	1						-
7.Net radiation	-0.13	-0.04	0.06	-0.16	0.02	**-0.43**	1					-
8.PAR	-0.28	-0.07	0.20	-0.27	-0.08	**-0.46**	**0.93**	1				-
9.Soil heat flux (5 cm)	-0.14	-0.24	**0.37**	-0.20	**-0.34**	-0.09	**0.65**	**0.71**	1			-
10.Soil moisture	-0.20	0.06	-0.02	-0.27	0.07	**-0.43**	**0.40**	**0.39**	**0.35**	1		-
11.Soil temperature	0.01	0.13	**0.84**	-0.26	**-0.50**	**-0.36**	0.21	**0.38**	**0.41**	0.16	1	-
B. Wetland chambers												
1.CH_4 NEE	1											-
2.Air pressure	-0.26	1										-
3.Air temperature	0.08	-0.33	1									-
4.Water vapour flux	0.36	-0.01	0.13	1								-
5.Air density	-0.12	**0.69**	**-0.88**	0.01	1							-
6.Soil thaw depth	**0.51**	**-0.48**	-0.04	**0.53**	-0.11	1						-
7.Net radiation	**-0.53**	0.27	**0.54**	**-0.38**	-0.37	**-0.61**	1					-
8.PAR	**-0.52**	0.29	**0.53**	-0.41	-0.35	**-0.66**	**0.99**	1				-
9.Soil heat flux (5 cm)	**-0.52**	0.32	0.38	**-0.52**	-0.16	**-0.58**	**0.80**	**0.81**	1			-
10.Soil moisture	0.34	0.25	0.06	-0.04	0.05	0.21	0.17	0.14	-0.03	1		-
11.Soil temperature	0.22	0.06	**0.47**	-0.20	-0.35	-0.23	**0.51**	**0.49**	0.31	**0.66**	1	-
12.Stream discharge	**0.72**	-0.20	0.05	**0.53**	-0.04	**0.77**	**-0.43**	**-0.47**	**-0.51**	**0.50**	0.23	1

Table S3 Spearman rank correlation matrix of environmental factors and mean EC CH_4 fluxes from wetland LI-7700 measurements during the 2012 growing season. Bold indicates statistical significance at α=0.05.

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
EC measurements	**1. CH_4 NEE**	1													
	2. Momentum flux	**0.35**	1												
	3. Sensible heat flux	0.09	**0.32**	1											
	4. Latent energy flux	0.22	**0.40**	**0.59**	1										
	5. CO_2 flux	**-0.71**	-0.01	0.19	0.03	1									
	6. Water vapour flux	0.21	**0.39**	**0.59**	**1.00**	0.03	1								
	7. Friction velocity	**0.36**	**0.99**	**0.30**	**0.39**	0.00	**0.39**	1							
Other measurements	**8. Net radiation**	**-0.38**	0.20	**0.73**	**0.49**	**0.60**	**0.49**	0.18	1						
	9. PAR	0.00	0.26	**0.79**	**0.74**	0.14	**0.74**	0.24	**0.80**	1					
	10. Soil heat flux (5cm)	0.03	-0.11	0.11	0.25	-0.04	0.25	-0.15	**0.29**	**0.33**	1				
	11. Soil moisture	0.09	**0.46**	**0.37**	**0.38**	**0.31**	**0.37**	**0.52**	0.26	0.21	**-0.48**	1			
	12. Soil temperature	**0.65**	0.18	0.15	**0.53**	**-0.58**	**0.53**	0.17	-0.22	**0.28**	0.09	0.12	1		
	13. Air pressure	**-0.36**	-0.19	**0.35**	0.05	**0.39**	0.06	-0.22	**0.54**	**0.44**	**0.47**	-0.26	-0.21	1	
	14. Air temperature	**0.49**	0.25	0.18	**0.70**	**-0.43**	**0.70**	0.27	-0.03	**0.45**	0.17	**0.29**	**0.82**	-0.27	1

Table S4 Parabolic model estimates for Equation (1).

R	Rsqr	Adj Rsqr	SE Est.	F	p
0.8181	0.6694	0.6185	0.5405	13.2	<0.01

	Coefficient	SE	t	p
b0	23.36	10.60	2.20	0.04
b1	-0.54	0.11	-4.98	<0.01
b2	-5.41	2.68	-2.01	0.05
b3	-0.08	0.04	-2.20	0.04
b4	0.33	0.17	1.96	0.06

Table S5 Summary table of site mean methane fluxes (F_{CH4}) measured in high-, low- and subarctic tundra (as defined by *AMAP*, 1998) for some portion of the northern growing season (May-October). Fluxes organized by chamber and eddy covariance measurements and by terrestrial sites predominantly emitting or consuming CH_4. All fluxes in mg CH_4 m^{-2} d^{-1}.

Location	Lat Lon	LANDSCAPE / METHOD				Reference
		Emission Sites		Consumption Sites		
		Chambers	Eddy Cov.	Chambers	Eddy Cov.	
<u>High Arctic</u>						
Ellesmere I., CA	81°49' -71° 20'	0.2	1.3	-1.4		*This study*
Ellesmere I., CA	77-82° -63-75			-0.9 – -0.3		*1-2*
Zackenberg, GL	74°28' -20° 34'	71 – 202	40 – 90	-0.3		*3-8*
Northern RU	72-73° 140-143°	0.1 – 78				*9*
<u>Low Arctic</u>						
Lena Delta, RU	72°22' 126° 30'	16 – 55	19 – 30			*10-13*
Tiski, RU	71°30' 130° 00'	23				*14*
Barrow, US	71°17' -156° 41'	23 – 52	32			*15-18*
Alaska, US	68-71° -148-158°	49 – 5				*19,20*
Toolik, US	68°38' -149° 38'	5 – 78				*21-26*
Yamal, RU	68°08' 71° 42'	58				*27*
Northern RU	67-77° 40-179°	27		-0.5		*11*
Vorkuta, RU	67°20' 63° 44'	5-83				*28,29*
Daring Lake, CA	64°52' -111° 35'	62				*30*
Bethel, US	60°45' -161° 45'	96	20			*31,32*
Churchill, CA	58°45' -94° 09'	54				*33*
Skan Bay, US	53° 39' -167° 04'			-3		*34*
<u>Sub Arctic</u>						
Indigirka, RU	70°49' 147° 29'	103	63			*35,36*
Cherskii, RU	69°36' 161° 20'	165-281		-1		*14,37,38*
Kaamanen, FI	69°08' 27° 16'	68	29			*39,40*
Stordalen, SE	68°21' 19° 02'	10-203	28-38	-1		*41-47*
Schefferville, CA	54°47' -66° 49'	30		-3		*48,49*
James Bay, CA	51°31' -80° 27'	16-52				*33,50*

1-Lamb et al., 2011
2-Stewart et al., 2012
3-Christensen et al., 2000
4-Mastepanov et al., 2008
5-Ström et al., 2012
6-Joabsson and Christensen, 2001
7-Tagesson et al., 2012
8-Friborg et al., 2000
9-Christensen et al., 1995
10-Kutzbach et al., 2004
11-Sachs et al., 2008
12-Sachs et al., 2010
13-Wille et all, 2008
14-Nakano et al., 2000
15-Lara et al., 2012
16-Rhew et al., 2007
17-Sturtevant et al., 2012
18-von Fischer et al., 2010
19-Morrissey and Livingston, 1992
20-Sebacher et al., 1986
21-King et al., 1998
22-Moosavi & Crill, 1998
23-Schimel, 1995
24-Torn and Chapin, 1993
25-Verville et al, 1998
26-Oberbauer et al., 1998
27-Heyer et al., 2002
28-Berestovakaya et al., 2005
29-Heikkinen et al., 2002a
30-Wilson & Humphreys, 2012
31-Bartlett et al., 1992
32-Fan et al., 1992
33-Roulet et al., 1994
34-Whalen & Reeburgh, 1990
35-Parmentier et al., 2011
36-van Huissteden et al., 2005
37-Merbold et al., 2009
38-Corradi et al., 2005
39-Hargreaves et al., 2001
40-Heikkinen et al., 2002b
41-Friborg et al., 1997
42-Jackowicz-Korczynski et al., 2010
43-Oquist and Svensson, 2002
44-Ström et al., 2007
45-Svensson and Rosswell, 1984
46-Svensson et al., 1999
47-Christensen et al., 1997
48-Bubier, 1995
49-Adamsen & King, 1993
50-Moore et al., 1994

Table S6 Concentrations (±1SD) of several chemicals downstream through the Skeleton Creek wetland complex. All chemicals are reported in μmol L^{-1}.

	Location	Dissolved CH_4	Dissovled CO_2	$Water_T$	NO_3^-:NH_4^+	DIN:TDN	DOC	PN	Ca^{2+}
←Downstream	**PF-1**	0.00±0.00	40±1	4±1	205	1.0	67	0.08	3.1
	PF-2	0.00±0.01	45±9	11±2	-	-	-	-	-
	Skeleton	0.18±0.22	23±9	12±3	0.14±0.20	0.03±0.02	425±100	0.05±0.02	1.4±0.5
	Pond 11	0.04±0.02	25±8	14±2	0.20±0.66	0.03±0.02	389±13	0.04±0.02	2.2±0.6
	Stream-1	0.03±0.02	106±35	12±2	-	-	-	-	-
	Stream-2	0.00±0.00	69±21	12±2	-	-	-	-	-
	Wet-In	0.01±0.01	80±41	9±2	0.11±0.14	0.04±0.03	471±48	0.03±0.04	3.0±0.5
	Wet-Out	0.00±0.01	77±24	9±2	0.07±0.13	0.04±0.02	524±47	0.05±0.05	3.0±0.5

$Water_T$: water temperature; NO_3: dissolved nitrate; NH_4: dissolved ammonium; DIN: dissolved inorganic nitrogen; TDN: total dissolved nitrogen; DOC: dissolved organic carbon; PN: particle-bound nitrogen; Ca^{2+}: dissolved calcium

FIGURES

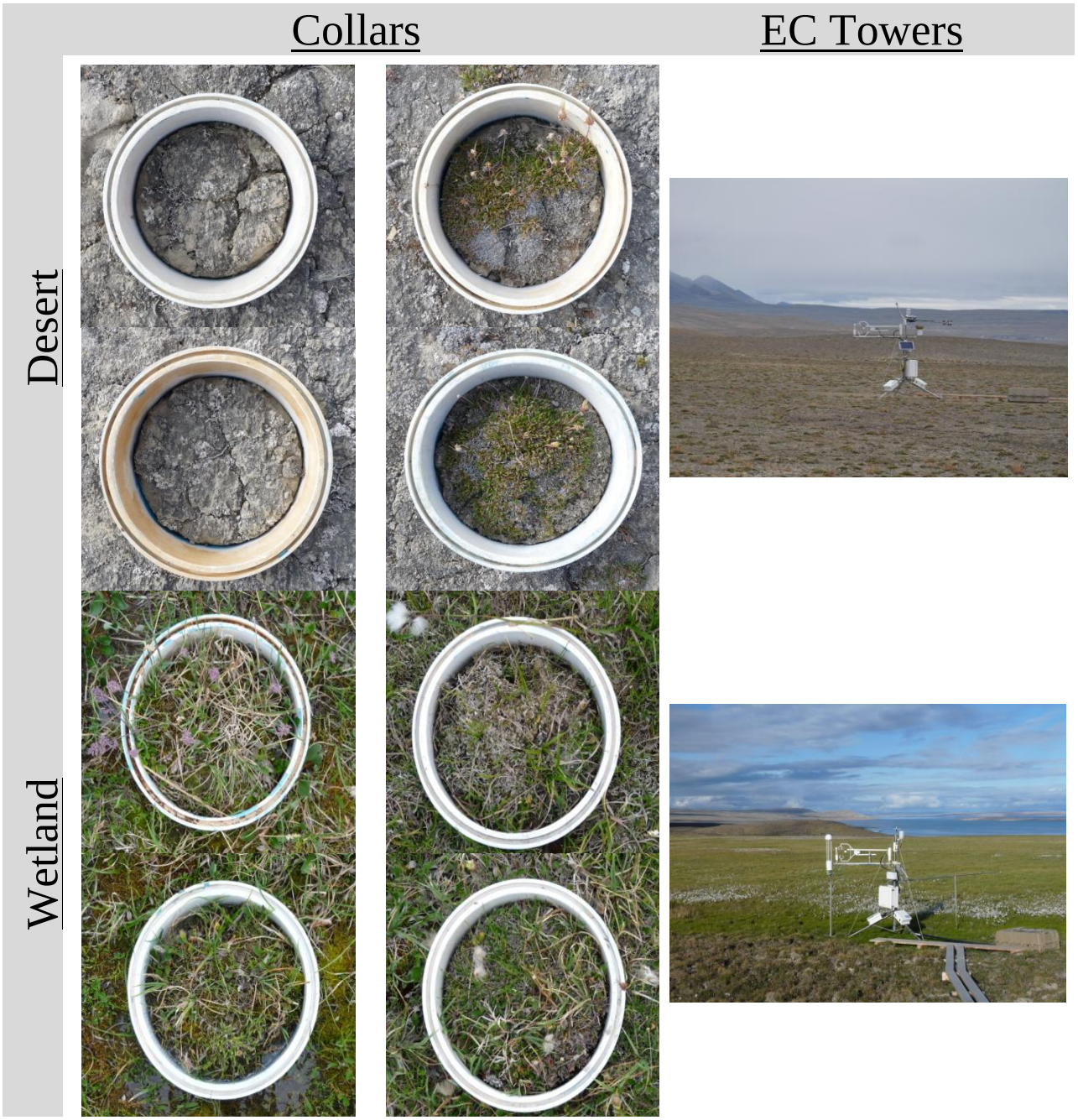

Figure S1 Photos of all chambers and enclosed vegetation, and EC towers and footprints at the desert and wetland sites. Photos taken during the growing season (*photos by C. Emmerton*).

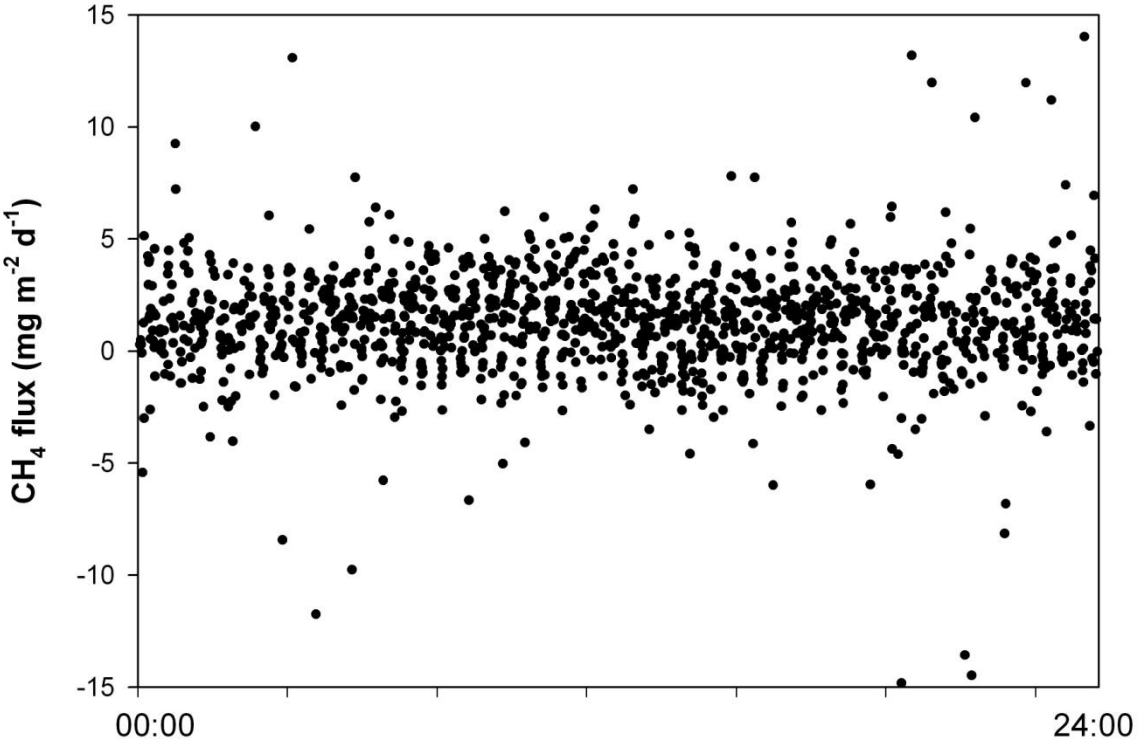

Figure S2 Diurnal organization of all half-hourly CH_4 fluxes for the 2012 growing season at the wetland as measured by the EC tower.

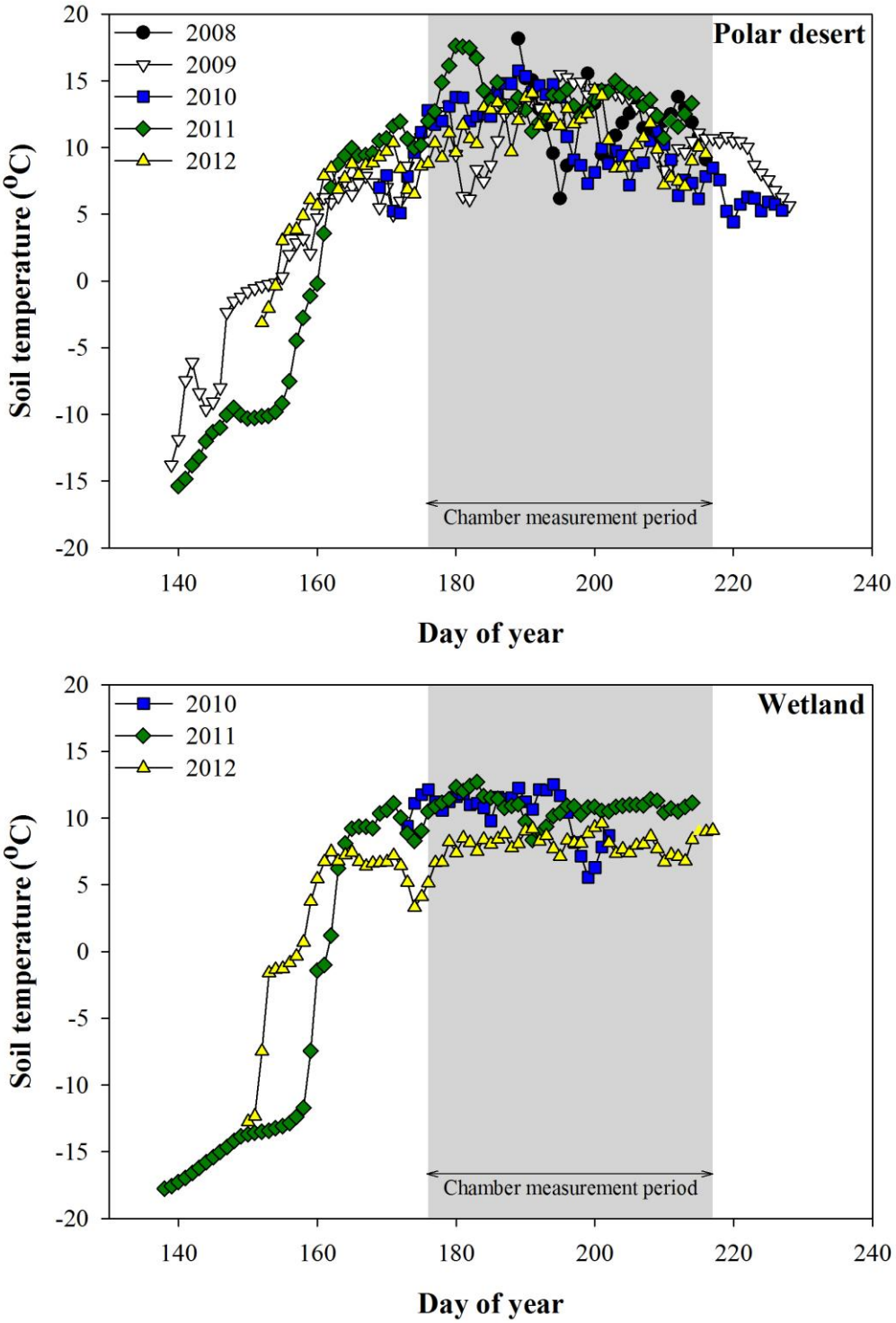

Figure S3 Soil temperatures at 5 cm depth during the growing seasons of 2008 to 2012 at the desert (upper) and wetland (lower) eddy covariance flux towers.

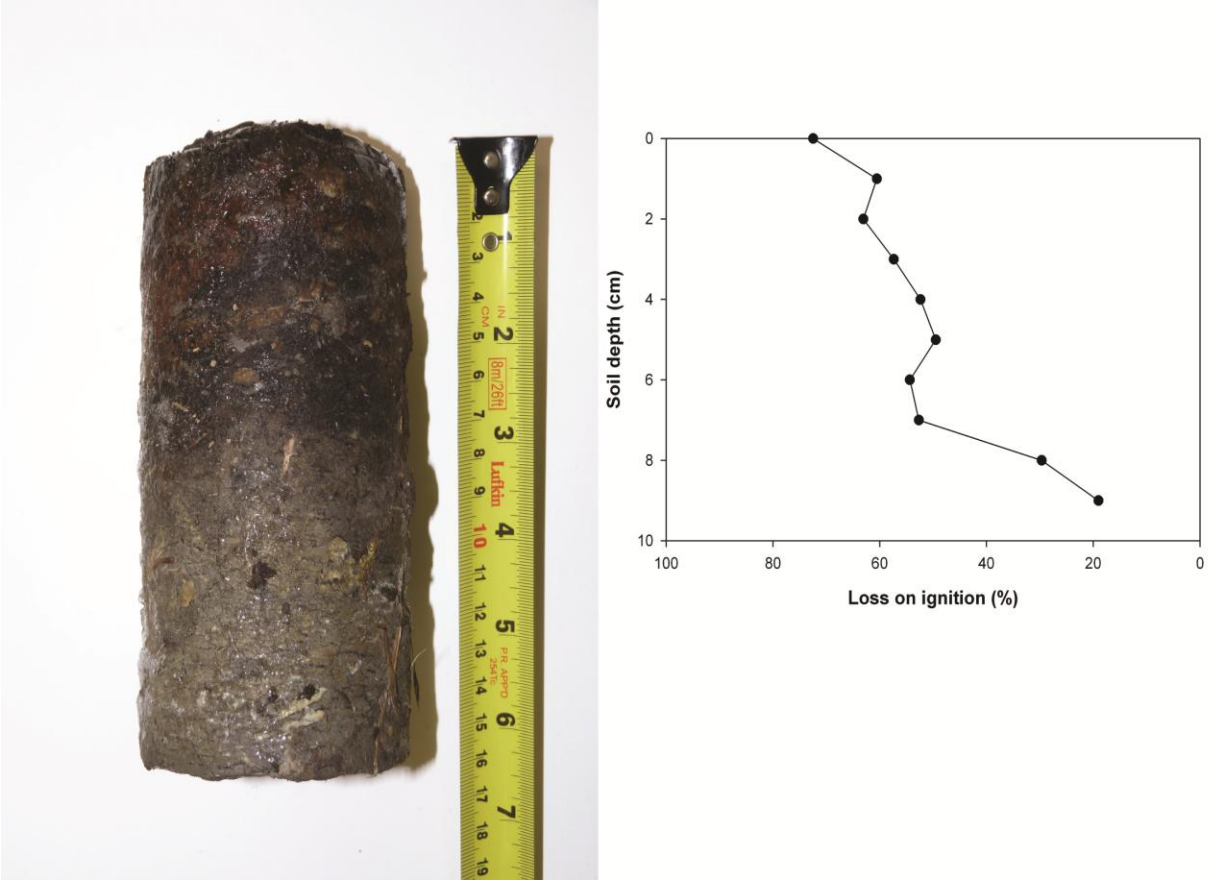

Figure S4 Photograph of a soil core extracted from the approximate middle of the wetland in May 2011 during frozen conditions (left panel). Graph of loss of ignition values (550°C) by depth for 0.5 cm portions of the wetland core (right panel) (*photo by C. Emmerton*).

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