forests

The Cumulative effects of forest disturbance and climate variability on streamflow in the Deadman River Watershed

Supplementary Materials

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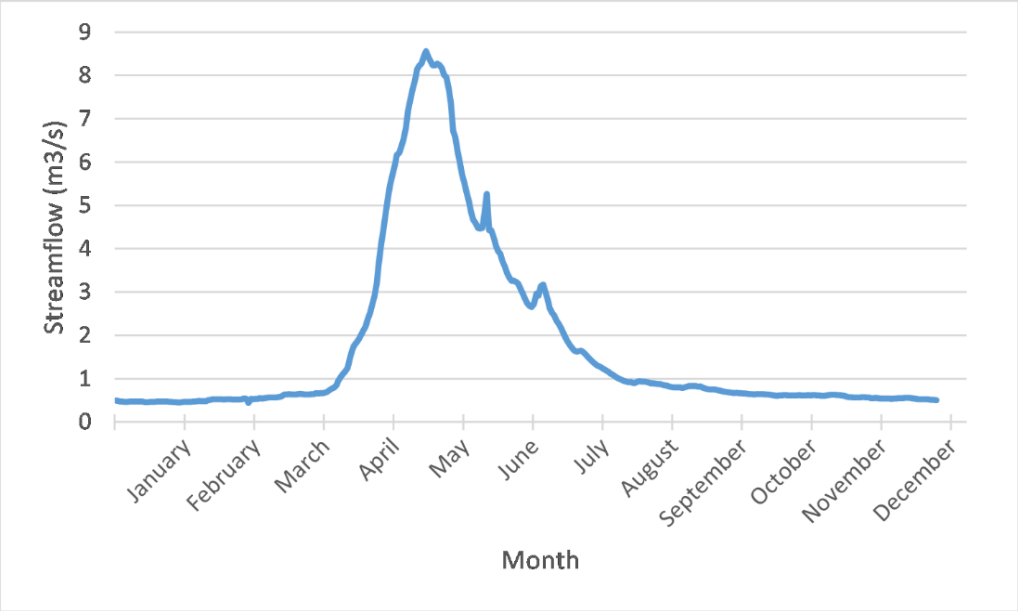
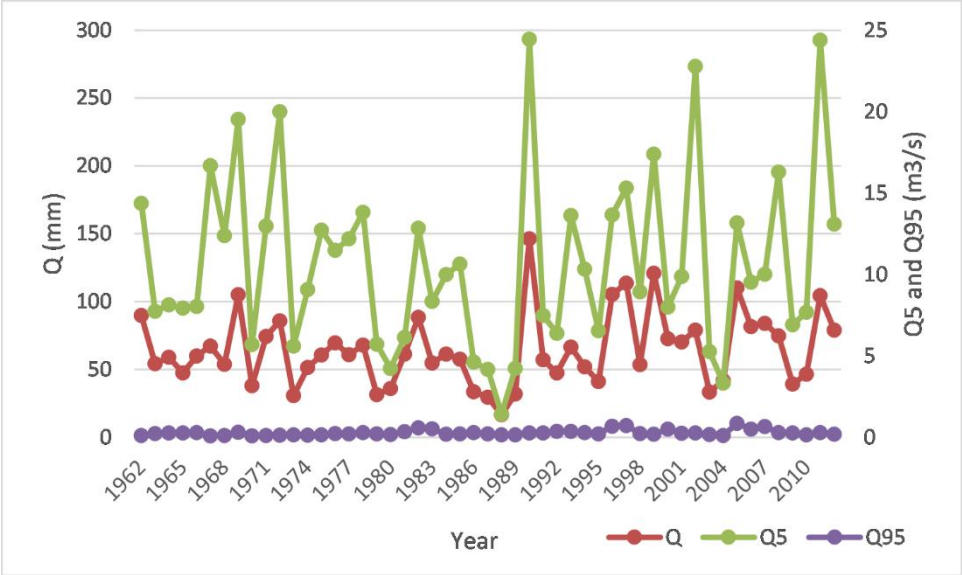


Figure S1: Hydrograph at hydrometric station 08LF027 showing daily flow (m3/s) averaged by day of the year from 1962 to 2012 from January 1 to December 31.



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14 **Figure S2**: Annual mean (Q) in mm, low (Q95) and high (Q5) flows (m3/s) in the Deadman River
15 watershed from Environment Canada Station ID 08LF027 standardized by area (mm).

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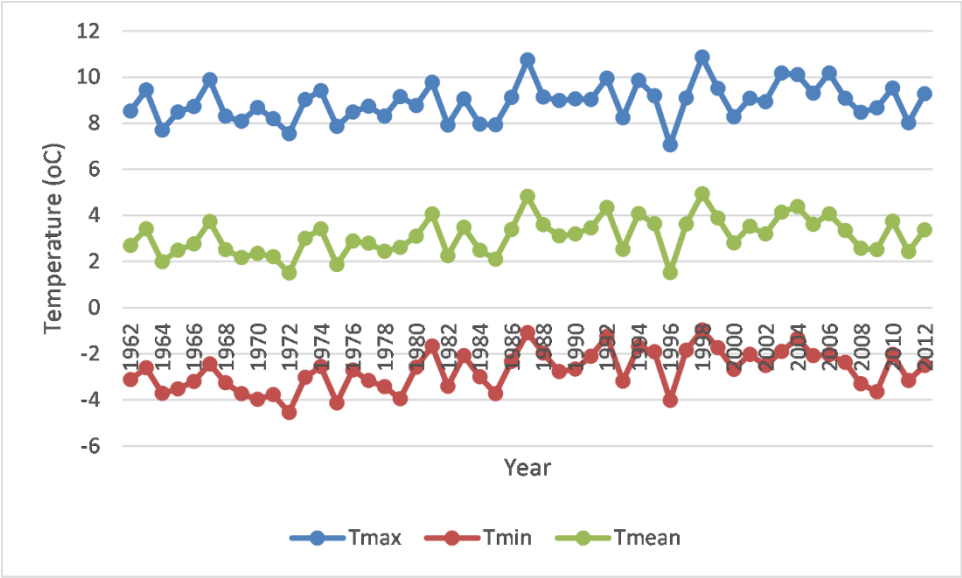

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18 **Figure S3**: Annual Temperature timeseries in the Deadman River watershed from Climate BC, where
19 Tmean is the annual daily average temperature, Tmax is the maximum daily temperature per year
20 and Tmin is the minimum daily temperature per year averaged across the watershed (°C).

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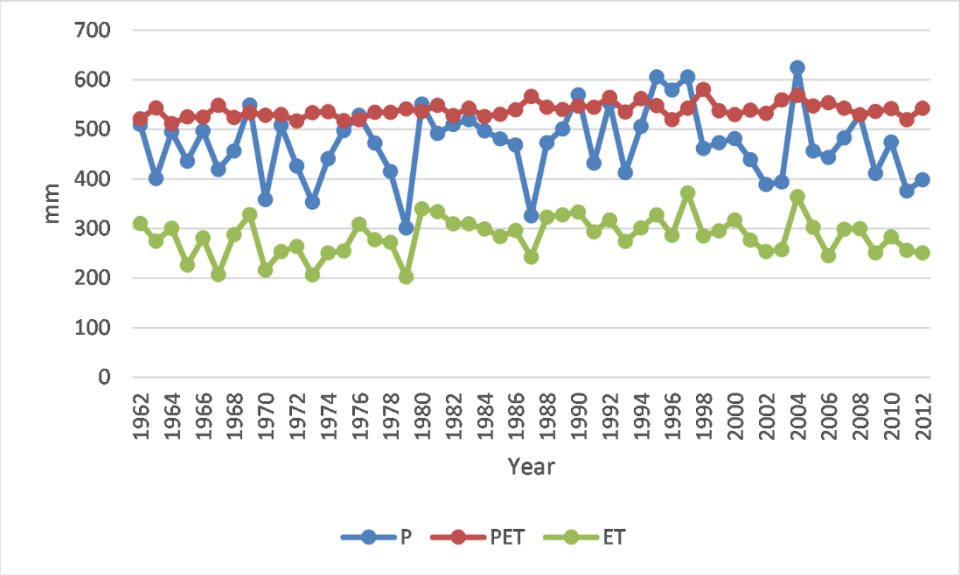

Figure S4: Annual timeseries in the Deadman River watershed, where Precipitation (P) is from Climate BC, potential evapotranspiration (PET) is calculated using the Hargreaves equation and evapotranspiration (ET) using Zhang's equation, all in mm.

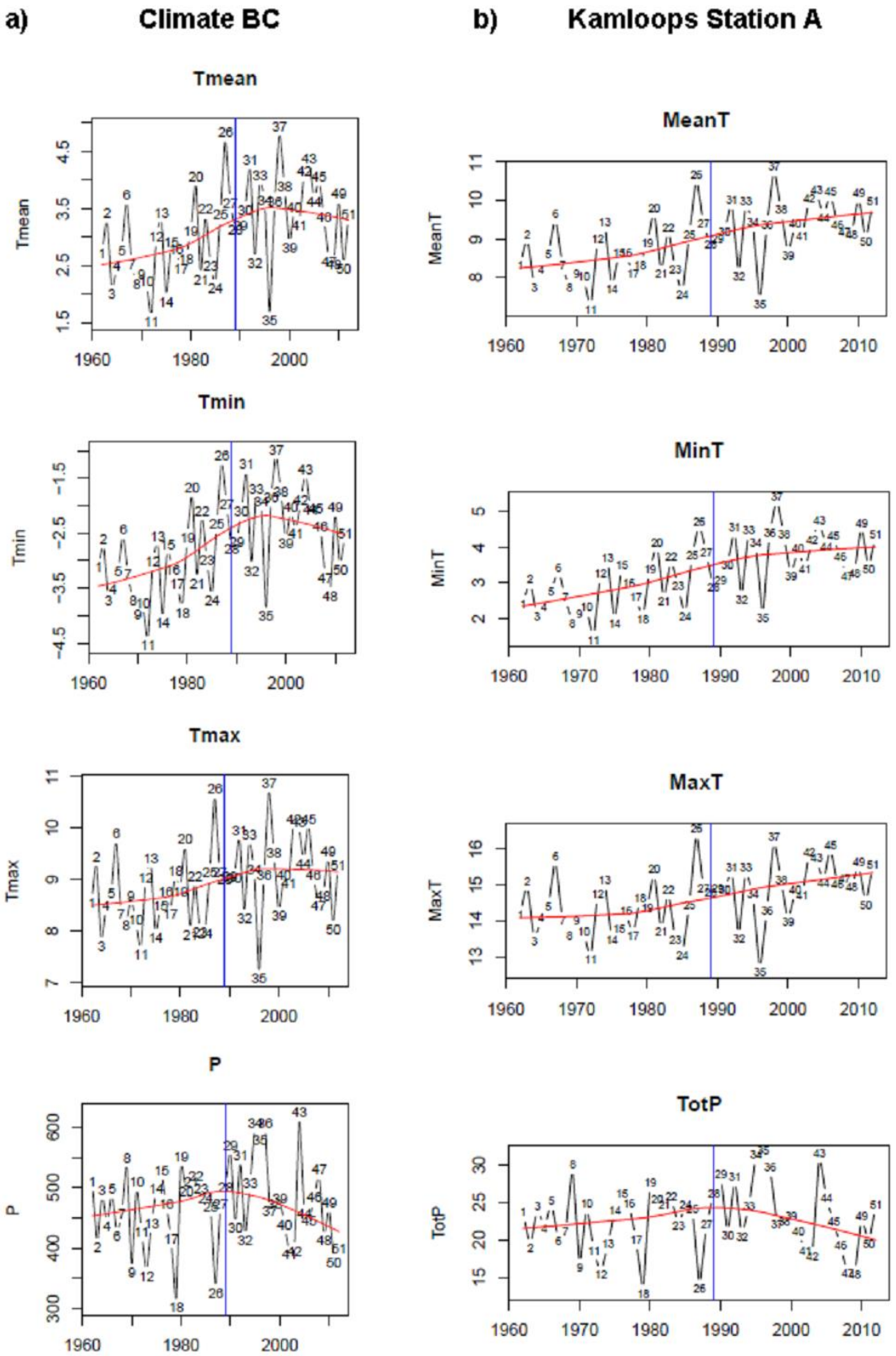

Figure S5: Annual average temperature (Tmean/meanT), minimum daily temperature (Tmin/minT), maximum daily temperature (Tmax/maxT) and annual precipitation (P/TotP) from the Climate BC watershed average (a) and the Kamloops A climate station (b).

Table S1: Kendall tau tests between the hydrological variable and climate variable by season in the Deadman River watershed. Bold values indicate statistical significant at the level of 0.05.

Season		**T_{max}**	**T_{min}**	**T_{mean}**	**P**
Annual					
$Q_{5\%}$	P	**0.008**	**0.023**	**0.012**	0.280
$Q_{95\%}$	P	0.664	0.402	0.819	0.118
Spring					
$Q_{5\%}$	P	**0.008**	**0.011**	**0.007**	0.482
$Q_{95\%}$	P	0.123	0.105	**0.099**	0.201
Summer					
$Q_{5\%}$	P	0.142	0.421	0.170	0.807
$Q_{95\%}$	P	0.167	**0.013**	0.931	**0.040**
Winter					
$Q_{5\%}$	P	**0.037**	**0.027**	**0.024**	0.381
$Q_{95\%}$	P	0.782	0.931	0.837	0.559
Winter and Spring					
$Q_{5\%}$	P	0.130	0.788	0.398	**0.003**
$Q_{95\%}$	P	0.103	0.112	0.082	0.393

Note: P: Precipitation. T_{min}, T_{max}, and T_{mean} are minimum, maximum, and mean annual temperatures. Spring: March to May; Summer: June to September; Winter: October to February. Winter and spring denotes the winter in the antecedent year and spring in the current year.

Table S2: Canonical correlation analysis between hydrological variables and the set of climate variables in the Deadman River watershed.

Set number	Climate variables	Hydrological Variables ($Q_{5\%}$,$Q_{95\%}$)	
		Canonical R	p
Set 1	(P,T_{min},T_{max},T_{mean})	0.46	0.019
Set 2	(P,T_{min},T_{mean})	0.39	0.023
Set 3	(P,T_{max},T_{mean})	0.38	0.023
Set 4	(P,T_{min},T_{max})	0.38	0.024
Set 5	(P_S,T_{minS},T_{maxS},T_{meanS})	0.50	0.022
Set 6	(P_S,T_{minS},T_{meanS})	0.42	0.035
Set 7	(P_S,T_{maxS},T_{meanS})	0.42	0.035
Set 8	(P_S,T_{minS},T_{maxS})	0.42	0.036
Set 9	(P_{SU},T_{minSU},T_{maxSU},T_{meanSU})	0.52	0.038
Set 10	(P_{SU},T_{minSU},T_{meanSU})	0.52	0.014
Set 11	(P_{SU},T_{maxSU},T_{meanSU})	0.52	0.015
Set 12	(P_{SU},T_{minSU},T_{maxSU})	0.52	0.014
Set 13	(P_W,T_{minW},T_{maxW},T_{meanW})	0.33	0.404
Set 14	(P_W,T_{minW},T_{meaW})	0.32	0.237
Set 15	(P_W,T_{maxW},T_{meaW})	0.32	0.233
Set 16	(P_W,T_{minW},T_{maxW})	0.32	0.236
Set 17	(P,T_{minS},T_{maxS},T_{meanS})	0.50	0.027
Set 18	(P,T_{minS},T_{meanS})	0.42	0.041
Set 19	(P,T_{maxS},T_{meanS})	0.42	0.042
Set 20	(P,T_{minS},T_{maxS})	0.42	0.043
Set 21	(P,T_{minSU},T_{maxSU},T_{meanSU})	0.50	0.057
Set 22	(P,T_{minSU},T_{meanSU})	0.50	0.023
Set 23	(P,T_{maxSU},T_{meanSU})	0.49	0.024
Set 24	(P,T_{minSU},T_{maxSU})	0.50	0.023
Set 25	(P_{ws}, T_{max}, T_{min})	0.55	<0.001
Set 26	(P_{ws}, T_{max}, T_{min}, T_{mean})	0.59	<0.001
Set 27	(P_{ws}, T_{maxS}, T_{min}, T_{meanS})	0.52	0.002
Set 28	**(P_{ws}, T_{max}, T_{minSU}, T_{mean})**	**0.63**	**<0.001**
Set 29	(P_{ws}, T_{maxS}, T_{minSU}, T_{mean})	0.60	<0.002
Set 30	(P_{ws}, T_{maxS}, T_{minSU}, T_{meanW})	0.61	<0.001

Note: P: Precipitation. T_{min}, T_{max}, and T_{mean} are minimum, maximum, and mean temperatures. Spring: March to May; Summer: June to September; Winter: October to February. The subscript S, SU, W denote to Spring, Summer, and Winter, respectively. The subscript WS denotes the winter in the antecedent year and spring in the current year.

Table S3 Selected paired climate variables and hydrological variables in the Deadman River watershed paired-year analysis.

Year	Pairs	$Q_{5\%}$	$Q_{95\%}$	P_{WS}	T_{max}	T_{mean}	T_{minSU}	Periods
1964	1	8.14	0.27	216.32	7.70	1.99	4.03	Reference
2001	1	10.80	0.26	220.66	9.08	3.52	5.14	Disturbance
1980	2	4.24	0.17	246.23	8.76	3.09	4.71	Reference
1994	2	10.32	0.30	248.66	9.86	4.08	5.83	Disturbance
1963	3	7.74	0.24	269.22	9.44	3.41	5.21	Reference
2013	3	15.70	0.39	265.56	9.83	3.79	6.21	Disturbance
1981	4	6.14	0.35	286.66	9.77	4.06	5.15	Reference
1999	4	17.39	0.19	287.33	9.51	3.88	4.83	Disturbance
1984	5	10.00	0.20	293.55	7.96	2.49	4.57	Reference
2002	5	11.24	0.20	298.67	8.93	3.20	5.06	Disturbance
1966	6	8.03	0.30	302.12	8.72	2.76	4.29	Reference
1993	6	13.63	0.37	301.67	8.24	2.53	4.83	Disturbance
1976	7	11.48	0.23	349.67	8.49	2.89	4.26	Reference
2011	7	24.39	0.30	340.67	8.02	2.43	4.67	Disturbance
1968	8	12.38	0.11	381.76	8.31	2.52	4.44	Reference
1996	8	13.66	0.68	385.89	7.06	1.52	4.94	Disturbance
1983	9	8.34	0.52	326.13	9.05	3.48	4.76	Reference
2009	9	6.92	0.27	325.77	8.67	2.51	5.38	Disturbance
1987	10	4.18	0.21	257.45	10.75	4.83	5.70	Reference
2004	10	3.34	0.12	258.67	10.10	4.38	6.17	Disturbance

Note: P: Precipitation. T_{min}, T_{max}, and T_{mean} are minimum, maximum, and mean temperatures. Spring: March to May; Summer: June to September; Winter: October to February. The subscript S, SU, W denote to Spring, Summer, and Winter, respectively. The subscript WS denotes the winter in the antecedent year and spring in the current year.

Table S4: Trend analysis for Kamloops A station data for seasonal and annual variables over the reference and disturbance periods, where P: Precipitation. T_{min}, T_{max}, and T_{mean} are minimum, maximum, and mean temperatures. Spring: March to May; Summer: June to September; Winter: October to February. P-values in bold indicate a significance level of 0.05.

Season	Period	Value	T_{min}	T_{max}	T_{mean}	P
Annual	Disturbance	Average	3.84	14.96	9.42	23.34
		Tau	0.05	0.18	0.10	-0.26
		p-value	0.77	0.25	0.54	0.08
	Reference	Average	**2.84**	14.29	8.58	22.22
		Tau	**0.28**	0.11	0.18	0.10
		p-value	**0.04**	0.44	0.19	0.45
Spring	Disturbance	Average	3.48	16.25	9.89	18.60
		Tau	-0.05	-0.14	-0.11	0.01
		p-value	0.75	0.37	0.49	0.98
	Reference	Average	**2.64**	**15.78**	**9.24**	15.09
		Tau	**0.45**	**0.31**	**0.39**	0.26
		p-value	**0.00**	**0.02**	**0.00**	0.06
Summer	Disturbance	Average	13.20	27.53	20.40	**30.90**
		Tau	0.03	0.25	0.18	**-0.35**
		p-value	0.85	0.10	0.24	**0.02**
	Reference	Average	**12.31**	27.02	19.69	28.10
		Tau	**0.44**	0.08	0.24	0.11
		p-value	**0.00**	0.58	0.08	0.43
Autumn	Disturbance	Average	3.81	14.29	9.07	24.23
		Tau	0.25	0.24	0.26	-0.07
		p-value	0.11	0.11	0.09	0.67
	Reference	Average	3.11	13.69	8.42	21.80
		Tau	0.01	-0.09	-0.02	0.06
		p-value	0.95	0.51	0.87	0.66
Winter	Disturbance	Average	-5.08	1.78	-1.66	20.14
		Tau	0.04	0.02	0.06	-0.10
		p-value	0.79	0.94	0.73	0.53
	Reference	Average	-6.68	0.66	-3.02	**23.89**
		Tau	0.15	0.08	0.12	**-0.35**
		p-value	0.26	0.57	0.38	**0.01**

Table S5: Trend analysis for ClimateBC data for seasonal and annual variables over the reference and disturbance periods, where P: Precipitation (mm/month). T_{min}, T_{max}, and T_{mean} are minimum, maximum, and mean temperatures. Spring: March to May; Summer: June to September; Winter: October to February. P-values in bold indicate a significance level of 0.05.

Season	Period	Value	T_{min}	T_{max}	T_{mean}	P
Annual	Disturbance	Average	-2.31	9.17	3.43	482.59
		Tau	-0.19	0.02	-0.06	-0.25
		p-value	0.11	0.91	0.69	0.21
	Reference	Average	-3.06	8.71	2.83	460.16
		Tau	0.20	0.10	0.15	0.09
		p-value	0.53	0.48	0.30	0.14
Spring	Disturbance	Average	-2.79	9.42	3.31	36.15
		Tau	-0.14	-0.17	-0.14	0.05
		p-value	0.78	0.28	0.37	0.37
	Reference	Average	**-3.44**	9.13	2.84	**30.69**
		Tau	**0.29**	0.13	0.26	**0.30**
		p-value	**0.03**	0.36	0.06	**0.04**
Summer	Disturbance	Average	6.16	20.13	13.15	51.00
		Tau	-0.17	0.13	0.01	-0.14
		p-value	0.37	0.40	0.96	0.28
	Reference	Average	5.52	19.88	12.70	47.06
		Tau	0.23	0.03	0.09	0.15
		p-value	0.30	0.83	0.50	0.10
Autumn	Disturbance	Average	-1.98	8.74	3.38	38.48
		Tau	-0.13	0.06	0.05	-0.19
		p-value	0.24	0.74	0.78	0.40
	Reference	Average	-2.27	8.47	3.10	36.47
		Tau	0.00	-0.03	0.00	0.00
		p-value	1.00	0.83	1.00	1.00
Winter	Disturbance	Average	-10.61	-1.61	-6.11	35.25
		Tau	-0.11	-0.08	-0.11	0.13
		p-value	0.40	0.61	0.50	0.50
	Reference	Average	-12.03	-2.62	-7.32	39.17
		Tau	0.08	0.07	0.06	-0.23
		p-value	0.10	0.65	0.68	0.59