International Journal of Wildland Fire **28**, 160–166
doi:10.1071/WF18124_AC

Supplementary material

Post-fire invasion in Torres del Paine Biosphere Reserve: the role of seed tolerance to heat

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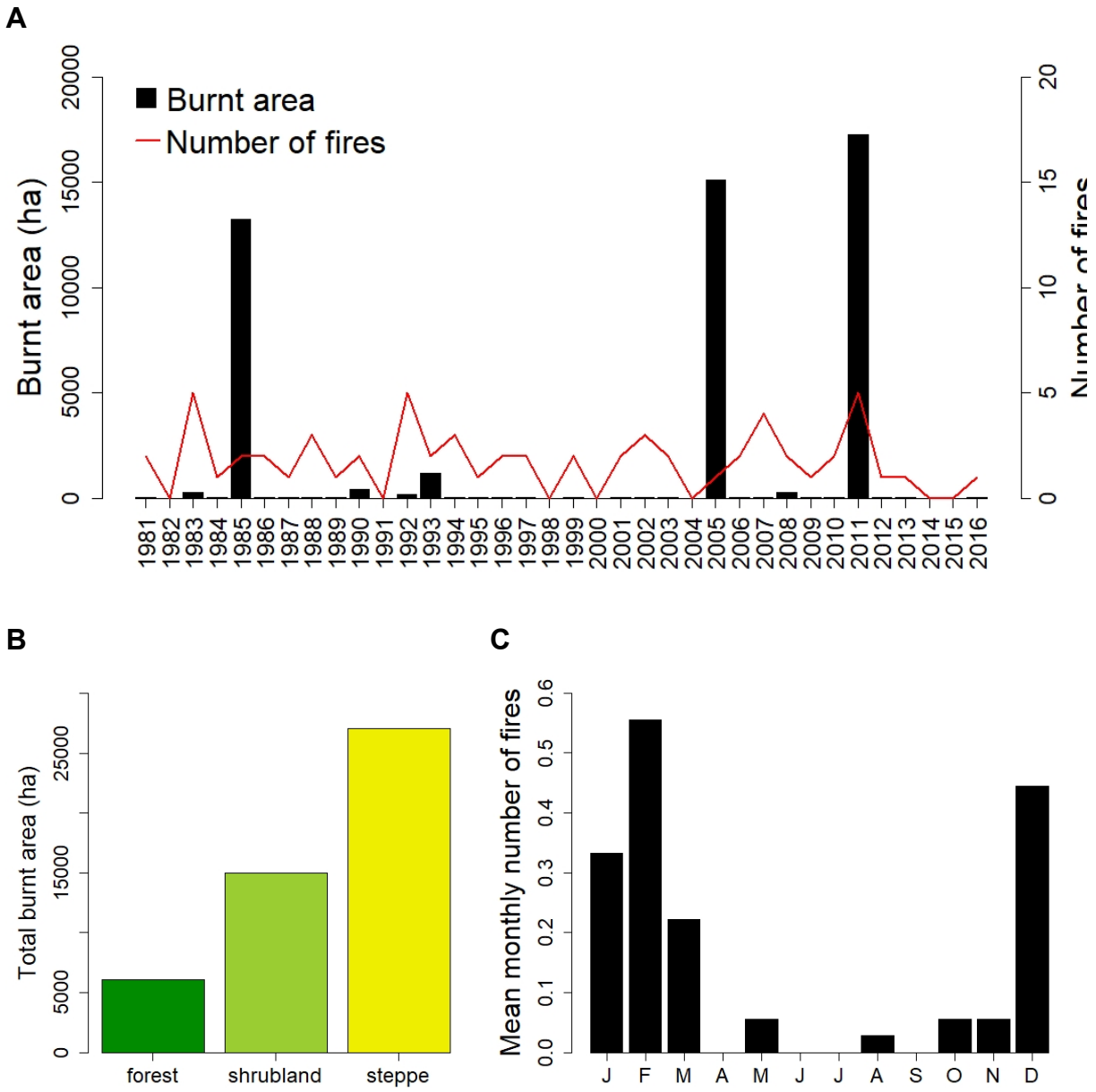

Fig S1. Fire history (A), vegetation-types historically affected by fires (B) and fire seasonality (C) in Torres del Paine N. P. Data for the 1981 – 2016 period. Data provided by the National Forestry Service, CONAF.

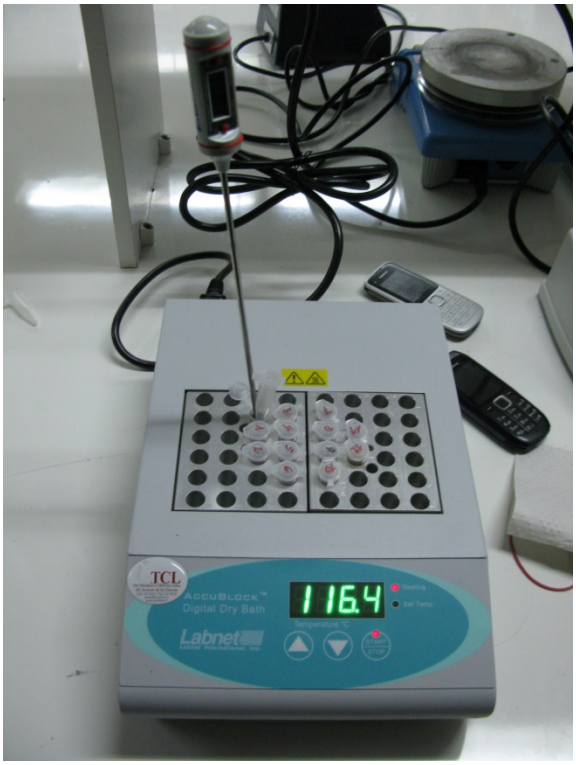

Fig. S2. Heat treatment application in digital dry bath (Accu BlockTM, Labnet International Inc, New Jersey, USA). The temperature was controlled by the microprocessor of the dry bath (0.3°C of accuracy) and checked with a digital thermometer introduced in one of the wells within the block chamber.

Table S1. Full results of the GLMM analyses conducted to compare germination percentage of seeds subjected to each heat treatment with that of the control seeds. Parameter estimation was fitted by maximum likelihood using the Laplace approximation. The significance of the fixed effect (i.e., heat treatment) was evaluated by means of the likelihood ratio test (using a Chi-square distribution) and the Wald Z test (after testing for overdispersion). Comparisons were conducted only for treatments where at least one seed germinated.

						Likelihood ratio test			***Overdispersion test***		***Wald Z test***			
Source of variation	***df***	***AIC***	***BIC***	***logLik***	***deviance***	χ^2	***df***	***P***	***Ratio***	***P(χ^2)***	***Estimate***	***SE***	***Z***	***P***
Armeria maritima														
Null	2	154.63	161.23	-75.316	150.63									
+ T60°C5min	3	156.26	166.16	-75.132	150.26	0.37	1	0.544	1.00	0.498	0.277	0.452	0.61	0.540
Null	2	117.58	124.18	-56.79	113.58									
+ T90°C10min	3	98.186	108.08	-46.093	92.186	21.39	1	<0.001	1.01	0.459	-6.428	1.073	-5.99	<0.001
Embothrium coccimeum														
Null	2	193.25	199.73	-94.628	189.25									
+ T60°C5min	3	192.19	201.9	-93.093	186.19	3.07	1	0.080	1.02	0.425	-0.646	0.374	-1.73	0.084
Mulguraea tridens														
Null	2	254.35	260.95	-125.17	250.35									
+ T60°C5min	3	255.04	264.95	-124.52	249.04	1.31	1	0.253	0.97	0.591	-0.490	0.406	-1.21	0.228
Osmorhiza chilensis														
Null	2	150.76	157.78	-73.382	146.76									
+ T60°C5min	3	150.83	161.35	-72.415	144.83	1.94	1	0.164	0.91	0.846	0.825	0.589	1.40	0.161
Senecio patagonicus														
Null	2	118.78	125.32	-57.39	114.78									

+ T60°C5min	3	115.31	125.12	-54.657	109.31	5.47	1	0.019	0.94	0.703	-1.782	0.731	-2.44	0.015
Dactylis glomerata														
Null	2	252.15	258.7	-124.08	248.15									
+ T60°C5min	3	253.83	263.65	-123.92	247.83	0.32	1	0.571	1.01	0.461	0.184	0.320	0.57	0.566
Null	2	215.79	222.35	-105.89	211.79									
+ T90°C5min	3	212.89	222.74	-103.44	206.89	4.90	1	0.027	1.01	0.462	-0.929	0.375	-2.48	0.013
Null	2	227.9	234.47	-111.95	223.9									
+ T90°C10min	3	227.96	237.83	-110.98	221.96	1.93	1	0.164	0.98	0.580	-0.598	0.408	-1.47	0.142
Holcus lanatus														
Null	2	230.24	236.76	-113.12	226.24									
+ T60°C5min	3	232.22	241.99	-113.11	226.22	0.03	1	0.872	1.02	0.426	0.052	0.323	0.16	0.872
Null	2	223.86	230.4	-109.93	219.86									
+ T90°C5min	3	224.96	234.77	-109.48	218.96	0.90	1	0.342	1.02	0.426	0.315	0.332	0.95	0.343
Null	2	222.32	228.8	-109.16	218.32									
+ T90°C10min	3	224.06	233.79	-109.03	218.06	0.26	1	0.613	1.00	0.468	0.178	0.351	0.51	0.612
Null	2	253.53	260.04	-124.77	249.53									
+ T120°C5min	3	249.62	259.38	-121.81	243.62	5.91	1	0.015	0.98	0.576	-1.168	0.407	-2.87	0.004
Rumex acetosella														
Null	2	219.91	226.53	-107.96	215.91									
+ T60°C5min	3	221.05	230.98	-107.53	215.05	0.86	1	0.353	0.93	0.751	-0.521	0.556	-0.94	0.349
Null	2	157.44	164	-76.719	153.44									
+ T90°C5min	3	145.94	155.79	-69.969	139.94	13.5	1	<0.001	0.82	0.971	-4.581	0.859	-5.33	<0.001
Null	2	170.97	177.55	-83.486	166.97									
+ T90°C10min	3	161.99	171.85	-77.994	155.99	10.99	1	<0.001	0.77	0.992	-4.259	0.948	-4.49	<0.001

Table S2. Full results of the GLMM analyses conducted to compare viability percentage of seeds subjected to each heat treatment with that of the control seeds. Parameter estimation was fitted by maximum likelihood using the Laplace approximation. The significance of the fixed effect (i.e., heat treatment) was evaluated by means of the likelihood ratio test (using a Chi-square distribution) and the Wald Z test (after testing for overdispersion). Comparisons were conducted only for treatments where at least one seed germinated.

						Likelihood ratio test			***Overdispersion test***		***Wald Z test***			
Source of variation	***df***	***AIC***	***BIC***	***logLik***	***deviance***	χ^2	***df***	***P***	***Ratio***	***P(χ^2)***	***Estimate***	***SE***	***Z***	***P***
Armeria maritima														
Null	2	150.69	157.29	-73.347	146.69									
+ T60°C5min	3	152	161.9	-73	146	0.69	1	0.405	1.01	0.464	0.383	0.452	0.85	0.397
Null	2	117.58	124.18	-56.79	113.58									
+ T90°C5min	3	98.186	108.08	-46.093	92.186	21.39	1	<0.001	1.01	0.459	-0.648	1.073	-5.99	<0.001
Null	2	161.66	168.26	-78.832	157.66									
+ T90°C10min	3	142.75	152.64	-68.373	136.75	20.92	1	<0.001	1.02	0.427	-4.258	0.468	-9.10	<0.001
Null	2	123.63	130.24	-59.815	119.63									
+ T120°C5min	3	106.58	116.49	-50.288	100.58	19.05	1	<0.001	0.97	0.622	-5.777	0.838	-6.90	<0.001
Embothrium coccimeum														
Null	2	178.67	185.14	-87.335	174.67									
+ T60°C5min	3	179.03	188.74	-86.517	173.03	1.64	1	0.201	1.02	0.425	-0.495	0.391	-1.27	0.205
Null	2	114.901	121.38	-55.45	110.901									
+ T90°C10min	3	92.369	102.09	-43.184	86.369	24.53	1	<0.001	1.02	0.425	-6.371	1.049	-6.08	<0.001
Mulguraea tridens														
Null	2	254.35	260.95	-125.17	250.35									
+ T60°C5min	3	255.04	264.95	-124.52	249.04	1.309	1	0.253	0.97	0.591	-0.490	0.406	-1.21	0.228
Osmorhiza chilensis														

						Likelihood ratio test			Overdispersion test		Wald Z test			
Source of variation	***df***	***AIC***	***BIC***	***logLik***	***deviance***	χ^2	***df***	***P***	***Ratio***	$P(\chi^2)$	***Estimate***	***SE***	***Z***	***P***
Null	2	312.45	319.46	-154.22	308.45									
+ T60°C5min	3	305.44	315.95	-149.72	299.44	9.01	1	0.003	0.99	0.512	1.322	0.337	3.92	<0.001
Senecio patagonicus														
Null	2	118.78	125.32	-57.39	114.78									
+ T60°C5min	3	115.31	125.12	-54.657	109.31	5.47	1	0.019	0.94	0.703	-1.782	0.731	-2.44	0.015
Dactylis glomerata														
Null	2	254.9	261.45	-125.45	250.9									
+ T60°C5min	3	256.09	265.91	-125.05	250.09	0.81	1	0.368	1.02	0.426	0.275	0.302	0.91	0.364
Null	2	215.79	222.35	-105.89	211.79									
+ T90°C5min	3	212.89	222.74	-103.44	206.89	4.90	1	0.027	1.01	0.462	-0.929	0.375	-2.48	0.013
Null	2	234.58	241.16	-115.29	230.58									
+ T90°C10min	3	235.57	245.43	-114.78	229.57	1.01	1	0.315	0.98	0.579	-0.416	0.402	-1.04	0.300
Null	2	179.36	185.95	-87.68	175.36									
+ T120°C5min	3	173.13	183.01	-83.566	167.13	8.23	1	0.004	0.90	0.842	-2.047	0.603	-3.39	0.001
Holcus lanatus														
Null	2	228.28	234.79	-112.14	224.28									
+ T60°C5min	3	230.28	240.05	-112.14	224.28	0	1	0.999	1.01	0.445	0.001	0.333	0.00	0.999
Null	2	221.65	228.19	-108.82	217.65									
+ T90°C5min	3	223.03	232.84	-108.51	217.03	0.62	1	0.431	1.02	0.426	0.262	0.333	0.79	0.431
Null	2	220.19	226.68	-108.1	216.19									
+ T90°C10min	3	222.07	231.8	-108.04	216.07	0.12	1	0.728	1.00	0.486	0.126	0.361	0.35	0.727
Null	2	251.65	258.15	-123.82	247.65									
+ T120°C5min	3	247.51	257.26	-120.75	241.51	6.14	1	0.013	0.97	0.584	-1.226	0.417	-2.94	0.003

						Likelihood ratio test			*Overdispersion test*		*Wald Z test*			
Source of variation	***df***	***AIC***	***BIC***	***logLik***	***deviance***	χ^2	***df***	***P***	***Ratio***	***P(χ^2)***	***Estimate***	***SE***	***Z***	***P***
Rumex acetosella														
Null	2	219.91	226.53	-107.96	215.91									
+ T60°C5min	3	221.05	230.98	-107.53	215.05	0.86	1	0.353	0.93	0.751	-0.521	0.556	-0.94	0.349
Null	2	172.18	178.75	-84.091	168.18									
+ T90°C5min	3	158.25	168.1	-76.125	152.25	15.93	1	<0.001	0.94	0.714	-4.035	0.646	-6.25	<0.001
Null	2	208	214.58	-102	204									
+ T90°C10min	3	196.53	206.4	-95.265	190.53	13.47	1	<0.001	0.94	0.732	-3.061	0.555	-5.51	<0.001
Null	2	137.24	143.85	-66.618	133.24									
+ T120°C5min	3	121.89	131.81	-57.945	115.89	17.35	1	<0.001	0.94	0.731	-5.688	0.981	5.80	<0.001

Table S3. Full results of the GLMM analyses conducted to compare germination probability during the stratification period among treatments (control *vs*. 60°C 5 min) and species origin (native *vs*. exotics). Parameter estimation was fitted by maximum likelihood using the Laplace approximation. The significance of the fixed effects was evaluated by means of the likelihood ratio test (using a Chi-square distribution) and the Wald Z test (after testing for overdispersion).

						Likelihood ratio test			***Overdispersion test***		***Wald Z test***			
Source of variation	***df***	***AIC***	***BIC***	***logLik***	***deviance***	χ^2	***df***	***P***	***Ratio***	***P(χ^2)***	***Estimate***	***SE***	***Z***	***P***
Null	2	1082.1	1092.0	-539.05	1078.1						1.004	0.540	1.86	0.063
+ Treatment (T)	3	1082.3	1097.1	-538.15	1076.3	1.81	1	0.178	0.76	1.000	-0.119	0.767	-0.16	0.876
+ Origin (O)	4	1067.1	1086.8	-529.53	1059.1	17.23	1	<0.001			-1.627	0.705	-2.31	0.021
+ T × O	5	1068.0	1092.6	-528.99	1058.0	1.09	1	0.297			-1.044	0.995	-1.05	0.294

Table S4. Full results of the GLMM analyses conducted to compare (for each species) the germination probability during the stratification period of seeds exposed to 60°C 5min with that of the control seeds. Parameter estimation was fitted by maximum likelihood using the Laplace approximation. The significance of the fixed effects was evaluated by means of the likelihood ratio test (using a Chi-square distribution) and the Wald Z test (after testing for overdispersion). Comparisons were conducted only for treatments where at least one seed germinated.

						Likelihood ratio test			*Overdispersion test*		*Wald Z test*			
Source of variation	***df***	***AIC***	***BIC***	***logLik***	***deviance***	χ^2	***df***	***P***	***Ratio***	$P(\chi^2)$	***Estimate***	***SE***	***Z***	***P***
Armeria marítima														
Null	2	167.0	173.4	-81.51	163.0									
+ T60°C5min	3	160.3	169.8	-77.14	154.3	8.74	1	0.003	0.90	0.817	-3.287	0.906	-3.63	<0.001
Mulguraea tridens														
Null	2	189.0	194.8	-92.78	184.96									
+ T60°C5min	3	190.8	199.5	-92.39	184.78	0.18	1	0.673	0.67	0.592	-0.205	0.481	-0.43	0.670
Senecio patagonicus														
Null	2	199.7	206.1	-97.86	195.7									
+ T60°C5min	3	199.5	209.0	-96.76	193.5	2.19	1	0.139	1.01	0.422	-0.521	0.354	-1.47	0.140
Dactylis glomerata														
Null	2	85.6	89.9	-40.79	81.6									
+ T60°C5min	3	87.6	94.1	-40.79	81.6	0.00	1	0.998	0.90	0.700	0.002	0.748	0.003	0.998
Holcus lanatus														
Null	2	121.9	127.8	-58.97	117.9									
+ T60°C5min	3	123.9	132.7	-58.93	117.9	0.08	1	0.780	0.98	0.542	0.145	0.523	0.28	0.781
Rumex acetosella														
Null	2	216.9	222.9	-106.43	212.86									
+ T60°C5min	3	215.6	224.7	-104.79	209.58	3.27	1	0.070	1.02	0.417	-0.623	0.327	-1.91	0.057

Table S5. Comparison of functional traits contributing to postfire persistence among native and exotic plant species from the *Mulguraea tridens* scrubland, a vegetation-type within the Patagonian steppe of the Torres del Paine National Park. Data were obtained from Vidal et al. (2015)*.

			Chi-squared contingency table test	
	Natives	**Exotics**	χ^2	***P***
Postfire resprouting				
no	2 (14%)	5 (21%)		
yes	12 (86%)	19 (79%)	0.005	0.945
total	14 (100%)	24 (100%)		
Below-ground bud bank				
no	13 (50%)	20 (48%)		
yes	13 (50%)	22 (52%)	0	1
total	26 (100%)	42 (100%)		
Dispersal distance				
short	16 (62%)	27 (64%)		
long	10 (38%)	15 (36%)	0	1
total	26 (100%)	42 (100%)		

* Vidal, O, Ramírez, C, Latorre, J, Henríquez, JM, San Martín, C (2015) Matorral de "Mata Negra" (*Mulguraea tridens* [Lag.] N. O'Learly & P. Peralta): Una asociación vegetal amenazada por incendios en el Parque Nacional Torres del Paine, Chile. *Anales del Instituto de la Patagonia* **43**, 45-59.