Photophysiological responses of canopy-forming kelp species to short-term acute warming

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Supplementary Material

Table S1. Pulse Amplitude Modulation (PAM) photosynthetic parameters and definitions used in this study. Extracted from: Burdett et al (2012).

Parameter	Definition
F_o	Minimum fluorescence (quasi-dark acclimated)
F_m	Maximum fluorescence (quasi-dark acclimated)
F'	Fluorescence under actinic light
F_v	Variable fluorescence (quasi-dark acclimated); ($F_m - F_o$)
F_v'	Variable fluorescence yield under actinic light; ($F_m' - F_o'$)
F_q'	Fluorescence quenched; ($F_m - F'$)
F_q'/F_m'	Effective photochemical efficiency or quantum yield of PSII under actinic light; ($F_m - F'$)/ F_m'
F_v/F_m	Maximum photochemical efficiency or quantum yield of PSII (quasi-dark acclimated); ($F_m - F_o$)/ F_m
E_k	Minimum saturating intensity (µmol photons m^{-2} s^{-1}); calculated using non-linear least squares regression following Jassby & Platt 1976)
α	Initial photosynthetic rate – calculated from the slope of the light dependent part of a Rapid Light Curve; calculated using non-linear least squares regression following Jassby & Platt 1976)
$r\text{ETR}_{max}$	Maximum relative electron transport rate (µmol electrons m^{-2} s^{-1}); $E_k*\alpha$
NPQ	Quasi non-photochemical quenching; ($F_m - F_m'$)/ F_m'
qN	Non-photochemical quenching; (F_v'/F_m')
qP	Photochemical quenching; (F_q'/F_v')

Table S2. The effect of temperature treatment, tank and experimental day on alpha (α) and rETR$_{max}$ as determined by RM ANOVA for *Laminaria digitata* and *Laminaria hyperborea* for both basal and distal blade tissue. P-values shown in bold are significant (at P<0.05); pairwise tests (SNK) were conducted as necessary. 'Spp' = species (LD: *Laminaria digitata*, LH: *Laminaria hyperborea*), 'Var' = response variable, 'Sect' = section, 'Res' = residual. Degrees of freedom (*df*) associated with each factor are shown in squared brackets.

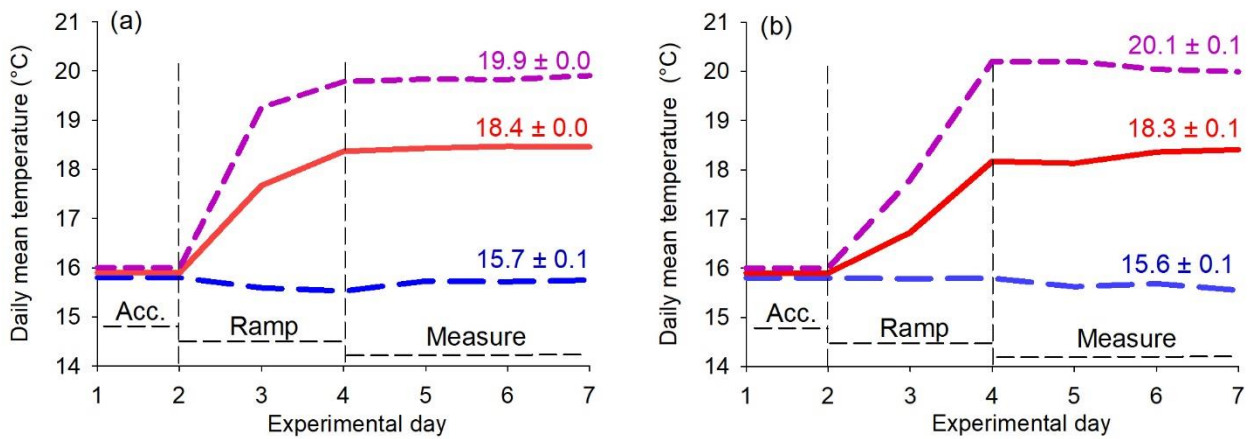| Spp	Var	Sect	Temp [2]			Tank (Temp) [9]	Day [1]			Temp x Day [2]			Res [9]
			MS	F	P	MS	MS	F	P	MS	F	P	MS
LD	α	Basal	4.9×10^{-4}	1.71	0.234	2.8×10^{-4}	1.9×10^{-3}	15.83	**0.003**	5.9×10^{-5}	0.49	0.628	1.2×10^{-4}
		Distal	5.1×10^{-4}	2.96	0.103	1.7×10^{-4}	2.6×10^{-4}	1.70	0.224	9.1×10^{-5}	0.59	0.573	1.5×10^{-4}
	rETR$_{max}$	Basal	53.31	1.04	0.391	51.00	419.70	14.38	**0.004**	12.33	0.42	0.668	29.17
		Distal	91.33	1.48	0.277	61.37	44.35	2.26	0.167	57.45	2.93	0.105	19.60
	Pairwise tests: α Basal; Day: 1>2 rETR$_{max}$ Basal; Day: 1<2													
LH	α	Basal	3.9×10^{-4}	1.34	0.308	2.8×10^{-4}	1.1×10^{-4}	0.58	0.464	3.2×10^{-6}	0.01	0.984	2.3×10^{-4}
		Distal	4.4×10^{-4}	0.95	0.421	4.6×10^{-4}	1.6×10^{-4}	0.23	0.643	9.6×10^{-5}	0.13	0.872	6.9×10^{-4}
	rETR$_{max}$	Basal	54.15	0.82	0.468	65.50	13.08	0.79	0.396	2.44	0.14	0.864	16.47
		Distal	272.40	3.18	0.090	85.51	571.02	41.62	**0.001**	41.48	3.02	0.099	13.71
	Pairwise tests: rETR$_{max}$ Distal; Day: 1>2													

Fig. S1. Daily mean water temperature during the experiment on (a) *Laminaria digitata* and (b) *Laminaria hyperborea*. Each experiment comprised a 2 day acclimatisation ('Acc.') period at ambient temperature, followed by a 2-day 'ramping up' period whereby temperatures were steadily elevated to pre-determined treatment levels and, finally, a 3-day simulated heat spike event during which measurements were taken. The first experiment commenced on 13/07/2017 and the second on 21/07/2017.

Fig. S2. Mean values of alpha (α) of *L. digitata* (panels a,c) and *L. hyperborea* (panels b,d) at the distal and basal sections of blade tissue under each temperature treatment on days 1 and 2 of the simulated warming event, as measured via PAM fluorometry. Data presented as mean±SE (n=4 individual aquaria per treatment).
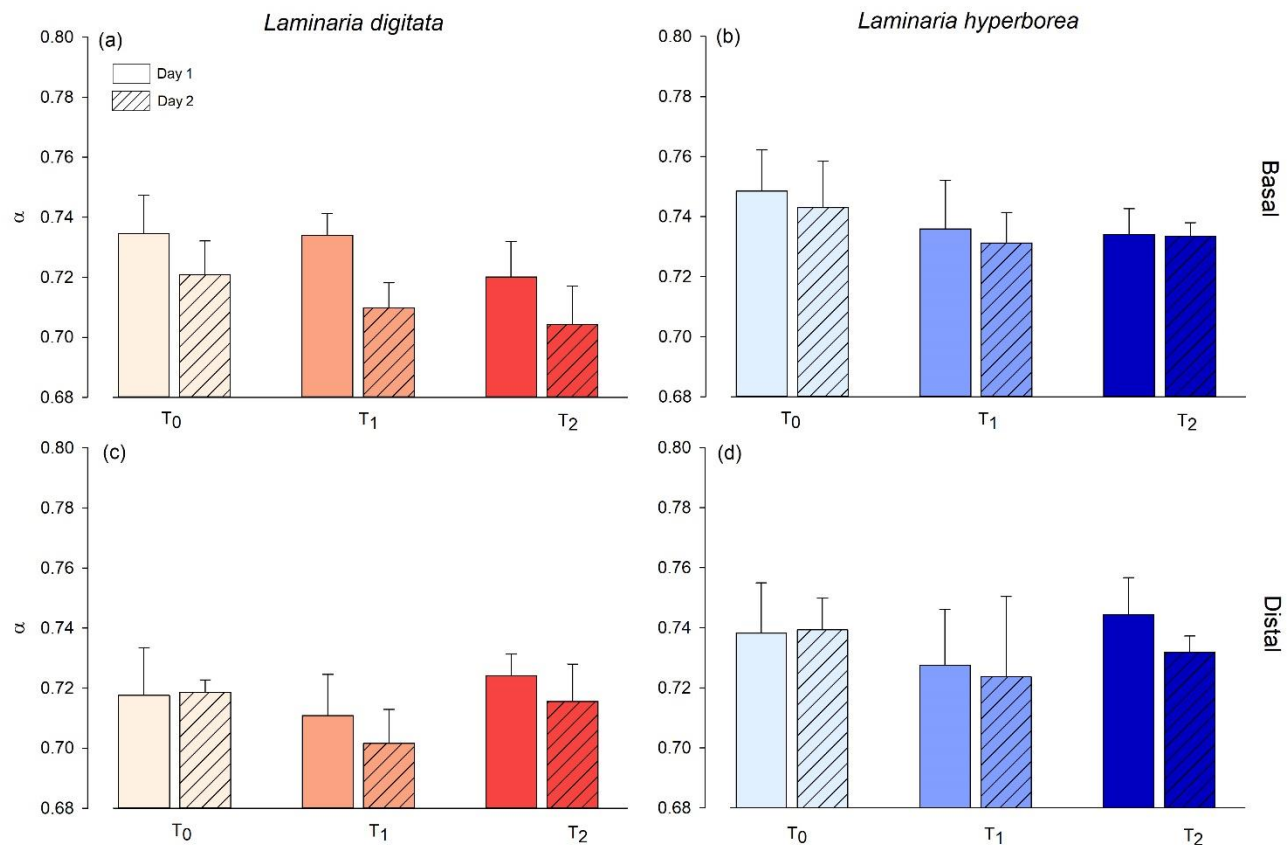
Fig. S3. Mean values of rETR$_{max}$ of *L. digitata* (panels a,c) and *L. hyperborea* (panels b,d) at the distal and basal sections of blade tissue under each temperature treatment on days 1 and 2 of the simulated warming event, as measured via PAM fluorometry. Data presented as mean±SE (n=4 individual aquaria per treatment).