Tropical herbivores provide resilience to a climate mediated phase-shift on temperate reefs

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Supplementary materials:

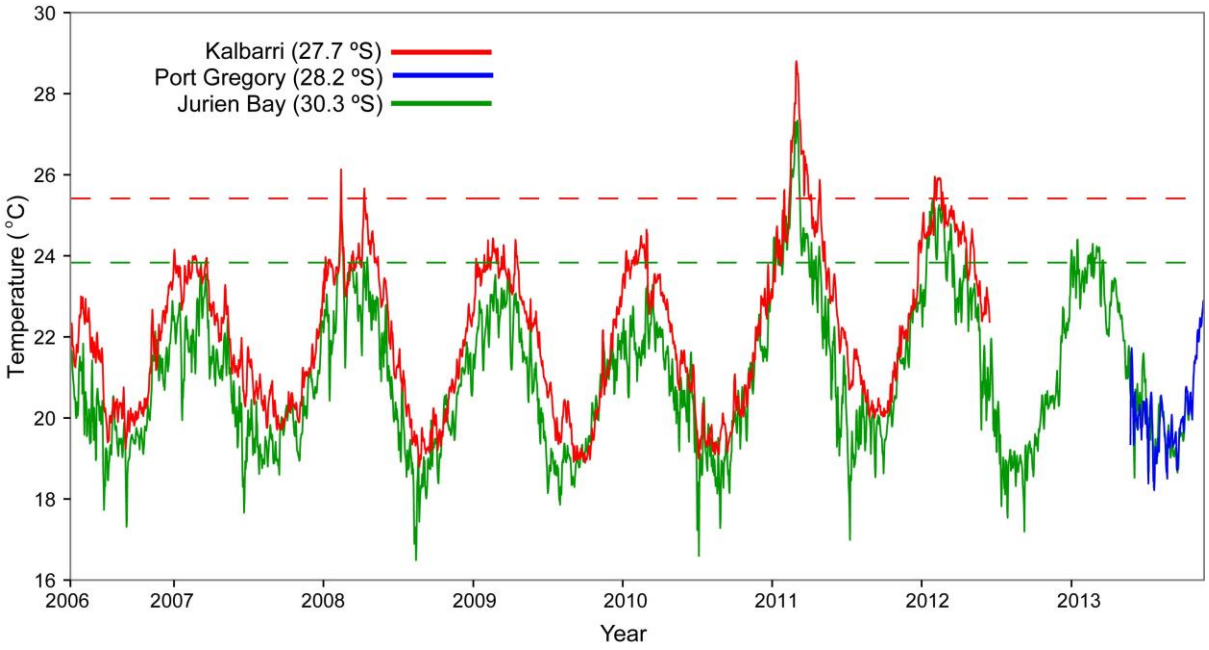

Figure S1. Time series illustrating mean daily water temperatures on reefs from 2006 November 2013, when the herbivory experiments were conducted. Time series clearly indicates the anomalous temperatures during the 2011 marine heatwave. Colours represent the different locations where temperatures were recorded. Dashed lines illustrate average maximum annual temperature in each location (averaged from 2006 to 2013). Port Gregory temperatures closely correspond to temperatures in Jurien Bay and Kalbarri in particular, due to their close geographical proximity and the highly structured latitudinal gradient in temperature along the coast (Smale & Wernberg 2009). Daily temperatures were calculated from hourly temperature measurements recorded 5 cm above the reef (8 – 12m depth) at 3 reefs within each location using 'TidbiT' loggers (Smale & Wernberg 2009) (Onset Stowaway logger, model TBI32-05+37, accuracy ±0.2°C). Port Gregory time series began recording in May 2013. Kalbarri time series was not available between June 2012 and November 2013.

Table S1: Mean biomass (± SE) changes of fish species between 2006 and 2013 across six sites in Port Gregory. Species are listed in order of their mean biomass change from largest increase to largest decrease. Colour coding represents trophic classifications (Froese and Pauly 2014). Climatic affinities based on observed fish distributions along Western Australian coast (Langlois *et al.* 2012, Bennett and Harvey unpubl. data)

Species	**Trophic group**	**Climatic affinity**	**2006 biomass (g 100m^{-2})**	**2013 biomass (g 100m^{-2})**
Scarus spp	grazer	tropical	226.84 ± 77.33	1660.58 ± 199.01
Siganus fuscescens	browser	tropical	130.62 ± 80.65	806.36 ± 330.83
Choerodon rubescens	carnivore	sub-tropical	0 ± 0	206.71 ± 75.53
Seriola hippos	carnivore	temperate	0 ± 0	206.09 ± 206.09
Parma occidentalis	grazer	sub-tropical	35.84 ± 12.15	187.66 ± 21.91
Abudefduf bengalensis	omnivore	tropical	0 ± 0	142.95 ± 33.22
Kyphosus cornelii	grazer	temperate	880.4 ± 611.2	982.95 ± 186.21
Glaucosoma hebraicum	carnivore	temperate	28.09 ± 28.09	123.74 ± 87.24
Pomacentrus milleri	planktivore	tropical	0.56 ± 0.42	86.67 ± 14.15
Plectorhinchus schotaf	carnivore	tropical	0 ± 0	78.97 ± 66.8
Coris auricularis	carnivore	temperate	0.32 ± 0.32	79.02 ± 22.62
Pseudocaranx spp	planktivore	ambiguous	0 ± 0	69.04 ± 49.21
Cheilodactylus rubrolabiatus	carnivore	temperate	3.96 ± 3.96	62.30 ± 22.41
Parupeneus spilurus	detritivore	tropical	0 ± 0	40.77 ± 17.19
Acanthurus grammoptilus	grazer	tropical	0 ± 0	39.07 ± 11.19
Lutjanus carponotatus	carnivore	tropical	0 ± 0	29.94 ± 11.92
Plectropomus maculatus	carnivore	tropical	0 ± 0	12.86 ± 12.86
Anampses geographicus	carnivore	sub-tropical	0 ± 0	10.76 ± 5.90
Thalassoma lunare	carnivore	tropical	0 ± 0	10.31 ± 5.42
Platax batavianus	omnivore	tropical	0 ± 0	9.27 ± 9.27
Plectropomus leopardus	carnivore	tropical	26.74 ± 26.74	35.65 ± 18.06
Lutjanus quinquelineatus	carnivore	tropical	0 ± 0	8.54 ± 8.54
Heniochus acuminatus	planktivore	tropical	0 ± 0	6.43 ± 2.49
Abudefduf vaigiensis	planktivore	tropical	0 ± 0	5.43 ± 5.43
Lutjanus lemniscatus	carnivore	tropical	0 ± 0	4.73 ± 4.73
Parma mccullochi	grazer	temperate	12.92 ± 7.42	17.48 ± 6.10
Caesio cuning	planktivore	tropical	0 ± 0	4.02 ± 4.02
Bodianus frenchii	carnivore	temperate	0 ± 0	3.97 ± 3.97
Abudefduf sexfasciatus	planktivore	tropical	0 ± 0	3.74 ± 2.37
Thalassoma spp	carnivore	ambiguous	0 ± 0	3.42 ± 3.42
Epinephelides armatus	carnivore	temperate	0 ± 0	3.241 ± 3.24
Scorpaena gasta	carnivore	tropical	0 ± 0	2.98 ± 2.98
Psammoperca waigiensis	carnivore	ambiguous	0 ± 0	2.74 ± 2.74
Scorpis georgiana	omnivore	temperate	0 ± 0	2.40 ± 2.40
Thalassoma septemfasciatum	carnivore	sub-tropical	0 ± 0	2.29 ± 2.1
Lutjanus fulviflamma	carnivore	tropical	0 ± 0	2.14 ± 2.14

Species	Trophic group	Climatic affinity	2006 biomass (g 100m^{-2})	2013 biomass (g 100m^{-2})
Epinephelus rivulatus	carnivore	tropical	0 ± 0	1.48 ± 1.48
Pomacanthus sexstriatus	omnivore	tropical	0 ± 0	1.19 ± 1.19
Elagatis bipinnulata	planktivore	tropical	0 ± 0	0.55 ± 0.55
Austrolabrus maculatus	carnivore	temperate	0 ± 0	0.50 ± 0.50
Labroides dimidiatus	carnivore	tropical	0 ± 0	0.24 ± 0.11
Amphiprion clarkii	omnivore	tropical	0 ± 0	0.07 ± 0.07
Ophthalmolepis lineolatus	carnivore	temperate	0 ± 0	<0.01
Omegophora cyanopunctata	carnivore	ambiguous	0 ± 0	<0.01
Labracinus lineatus	carnivore	sub-tropical	0 ± 0	<0.01
Chelmonops curiosus	carnivore	temperate	0 ± 0	<0.01
Platax teira	omnivore	tropical	0 ± 0	<0.01
Labridae spp	omnivore	ambiguous	0 ± 0	<0.01
Pomacentrus coelestis	planktivore	tropical	0 ± 0	<0.01
Neopomacentrus azysron	planktivore	tropical	0 ± 0	<0.01
Alepes sp	planktivore	tropical	0 ± 0	<0.01
Pseudolabrus biserialis	carnivore	temperate	0.69 ± 0.69	0 ± 0
Scorpis aequipinnis	planktivore	temperate	3.93 ± 3.93	0 ± 0
Plectorhinchus flavomaculatus	carnivore	sub-tropical	36.66 ± 18.44	32.46 ± 14.96
Diagramma labiosum	carnivore	temperate	56.10 ± 56.10	50.74 ± 50.74
Olisthops cyanomelas	browser	temperate	5.49 ± 3.85	0 ± 0
Notolabrus parilus	carnivore	temperate	48.47 ± 17.21	4.48 ± 3.64
Dactylophora nigricans	carnivore	temperate	48.49 ± 48.49	0 ± 0
Kyphosus spp	browser	temperate and tropical	11287.26 ± 8398.89	10048.18 ± 4567.71

Table S2: Results of repeated measures ANOVA, comparing the biomass removal rates of kelp patches, *Ecklonia radiata,* among sites and times.

Between subjects					
Source of variation	Df	Sum Sq	Mean Sq	F value	P
Site	1	35600	35600	3.614	0.13
Residuals	4	39407	9852		
Within subjects					
Source of variation	Df	Sum Sq	Mean Sq	F value	P
Time	2	545575	272788	77.77	5.73E-06
Site:Time	2	69151	34576	9.857	0.00694

Table S3: Results of repeated measures ANOVA, comparing the biomass removal rates of solitary kelps, *Ecklonia radiata,* among sites and times.

Between subjects					
Source of variation	Df	Sum Sq	Mean Sq	F value	P
Site	1	8611	8611	0.329	0.573
Residuals	18	471108	26173		
Within subjects					
Source of variation	Df	Sum Sq	Mean Sq	F value	P
Time	1	1687932	1687932	112.108	3.68E-09
Site:Time	1	75767	75767	5.032	0.0377

Table S4: Mean MaxN and maximum observed MaxN of herbivorous fishes from the 35 replicate filming periods throughout the feeding experiment.

Family	**Species**	**Mean ± SE (N = 35)**	**MaxN**
Kyphosidae	*Kyphosus bigibbus*	27 ± 8.88	156
	Kyphosus cornelii	5.83 ± 2.39	74
	Kyphosus sydneyanus	1.63 ± 0.63	15
	Kyphosus gladius	0.43 ± 0.22	3
Siganidae	*Siganus fuscescens*	18.31 ± 5.23	112
Labridae	*Scarus ghobban*	1.94 ± 0.22	5
	Scarus schlegeli	0.43 ± 0.15	3
	Scarus prasiognathos	0.08 ± 0.05	1
	Anampses geographicus	0.26 ± 0.07	2
	Chlorurus microrhinos	0.08 ± 0.04	1
Acanthuridae	*Acanthurus grammoptilus*	0.057 ± 0.05	2
	Naso unicornis	0.03 ± 0.03	1
Pomacentridae	*Abudefduf bengalensis*	0.91 ± 0.43	11
	Parma occidentalis	0.62 ± 0.14	2
	Pomacentrus milleri	0.06 ± 0.04	1

Literature cited:

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Langlois, T.J., Radford, B.T., Van Niel, K.P., Meeuwig, J.J., Pearce, A.F., Rousseaux, C.S. *et al.* (2012). Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography*, 21, 886-897.

2.

Smale, D.A. & Wernberg, T. (2009). Satellite-derived SST data as a proxy for water temperature in nearshore benthic ecology. *Marine Ecology Progress Series*, 387, 27-37.