Cross-Shelf Differences in the Response of Herbivorous Fish Assemblages to Severe Environmental Disturbances

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Supplementary materials

Table S1 Fish traits assigned to surveyed species. Trait classification based on published literature (Green and Bellwood 2009 [1]; Mouillot et al. 2013 [2]; Froese and Pauly 2018 [3]). Schooling trait categories abbreviated as follows: Small groups (SmallG); medium groups (MedG); large groups (LargeG).

Species	Maximum body-size (TL; cm)	Diet	Mobility	Activity	Social grouping	Position
Acanthurus blochii	51-60	Grazer/detritivore	Mobile within reef	Diurnal	SmallG	Benthic
Acanthurus dussumieri	51-60	Grazer/detritivore	Sedentary	Nocturnal	MedG	Bentho-pelagic
Acanthurus grammoptilus	31-40	Grazer/detritivore	Mobile within reef	Diurnal	SmallG	Bentho-pelagic
Acanthurus lineatus	31-40	Grazer/detritivore	Territorial	Diurnal	Solitary	Bentho-pelagic
Acanthurus nigricans	21-30	Grazer/detritivore	Sedentary	Diurnal	SmallG	Benthic
Acanthurus nigricauda	31-40	Grazer/detritivore	Mobile within reef	Diurnal	SmallG	Benthic
Acanthurus nigrofuscus	21-30	Grazer/detritivore	Sedentary	Diurnal	SmallG	Benthic
Acanthurus olivaceus	31-40	Grazer/detritivore	Mobile within reef	Diurnal	SmallG	Benthic
Acanthurus triostegus	21-30	Grazer/detritivore	Sedentary	Diurnal	Solitary	Bentho-pelagic
Acanthurus xanthopterus	61-70	Grazer/detritivore	Mobile within reef	Diurnal	MedG	Benthic
Bolbometopon muricatum	≥100	Excavator	Mobile across reefs	Diurnal	MedG	Benthic
Calotomus carolinus	51-60	Browser	Mobile within reef	Nocturnal	LargeG	Bentho-pelagic
Cetoscarus ocellatus	71-80	Excavator	Mobile within reef	Diurnal	SmallG	Benthic
Chlorurus japanensis	31-40	Excavator	Mobile within reef	Diurnal	SmallG	Benthic
Chlorurus microrhinos	61-70	Excavator	Mobile within reef	Diurnal	SmallG	Benthic
Chlorurus spilurus	31-40	Excavator	Mobile within reef	Diurnal	SmallG	Benthic
Ctenochaetus binotatus	21-30	Detritivore	Sedentary	Diurnal	Solitary	Benthic
Ctenochaetus striatus	21-30	Detritivore	Sedentary	Diurnal	MedG	Benthic
Hipposcarus longiceps	51-60	Scraper	Mobile within reef	Diurnal	MedG	Benthic
Kyphosus cinerascens	41-50	Browser	Mobile across reefs	Diurnal	MedG	Bentho-pelagic
Kyphosus vaigiensis	61-70	Browser	Mobile across reefs	Diurnal	MedG	Bentho-pelagic
Lo vulpinus	21-30	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic
Naso annulatus	≥100	Grazer/Planktivore	Sedentary	Nocturnal	Pairing	Pelagic
Naso brachycentron	≥100	Browser	Sedentary	Nocturnal	Pairing	Bentho-pelagic
Naso brevirostris	41-50	Grazer/Planktivore	Mobile across reefs	Diurnal	LargeG	Bentho-pelagic
Naso lituratus	51-60	Browser	Mobile within reef	Diurnal	SmallG	Benthic
Naso tonganus	61-70	Browser	Mobile within reef	Diurnal	SmallG	Benthic
Naso unicornis	71-80	Browser	Mobile within reef	Diurnal	SmallG	Benthic
Naso vlamingii	51-60	Grazer/Planktivore	Mobile across reefs	Diurnal	SmallG	Bentho-pelagic
Platax sp	61-70	Browser	Mobile across reefs	Diurnal	MedG	Bentho-pelagic
Scarus altipinnis	51-60	Scraper	Mobile within reef	Diurnal	LargeG	Benthic
Scarus chameleon	31-40	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus dimidiatus	31-40	Scraper	Mobile within reef	Diurnal	SmallG	Benthic
Scarus flavipectoralis	31-40	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus forsteni	51-60	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus frenatus	41-50	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus ghobban	71-80	Scraper	Mobile within reef	Diurnal	SmallG	Benthic
Scarus globiceps	41-50	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus niger	31-40	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus oviceps	31-40	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Scarus psittacus	31-40	Scraper	Mobile within reef	Diurnal	MedG	Benthic
Scarus rivulatus	31-40	Scraper	Mobile within reef	Diurnal	MedG	Benthic
Scarus rubroviolaceus	61-70	Scraper	Mobile within reef	Nocturnal	MedG	Bentho-pelagic

Scarus schlegeli	31-40	Scraper	Mobile within reef	Diurnal	MedG	Benthic
Scarus sp	41-50	Scraper	Mobile within reef	Diurnal	SmallG	Benthic
Scarus spinus	21-30	Scraper	Mobile within reef	Diurnal	Solitary	Benthic
Siganus argenteus	31-40	Grazer/detritivore	Sedentary	Nocturnal	Solitary	Bentho-pelagic
Siganus canaliculatus	31-40	Browser	Sedentary	Nocturnal	Solitary	Bentho-pelagic
Siganus coralinus	31-40	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic
Siganus doliatus	31-40	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic
Siganus puellus	31-40	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic
Siganus punctatus	31-40	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic
Siganus sp	31-40	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic
Siganus spinus	21-30	Grazer/detritivore	Mobile across reefs	Diurnal	LargeG	Benthic
Zebrasoma scopas	41-50	Grazer/detritivore	Mobile within reef	Diurnal	SmallG	Benthic
Zebrasoma velifer	41-50	Grazer/detritivore	Mobile within reef	Diurnal	Pairing	Benthic

Table S2 Two-way nested PERMANOVA pairwise comparisons with Monte Carlo sampling estimates of taxonomic composition of herbivorous fish among shelf position and between years. Comparisons based on Bray-Curtis similarities of fourth root transformed data (shelf position and year, fixed factors; site random factor nested in shelf position; 9999 iterations). Herbivorous fish species consistently contributing to average similarity within assemblages across the shelf (grey boxes) in each year are listed (one-way SIMPER; sim/SD, dissim/SD > 2). Multivariate dispersion analysis (MVDISP) results shown with an index of multivariate dispersion (IMD).

	Inner	Mid	Outer
Inner	Av. sim: 2008/9: **63%**; 2016: **52%** PERMANOVA: **P=0.03** (comparison between years) IMD**:** 2008/9: **0.65**; 2016: **1.07** SIM/SD ≥2: 2008/9: ***Scarus rivulatus, Siganus doliatus, Acanthurus blochii, Scarus ghobban*** 2016: ***Scarus rivulatus***	Av. disssim: 2008/9: **66%**; 2016: **84%**	Av. disssim: 2008/9: **81%**; 2016: **97%**
Mid	IMD: 2008/9: **0.06**; 2016: **0.25** 2008/9: P: **0.0002 (MC)**; 2016: **0.002 (perm)**	Av. sim: 2008/9: **62%**; 2016: **44%** PERMANOVA: **P(MC)=0.14** (comparison between years) IMD: 2008/9: **0.71**; 2016: **1.35** SIM/SD ≥2: 2008/9: ***Zebrasoma scopas, Ctenochaetus striatus, Scarus frenatus, Acanthurus nigrofuscus, Naso unicornis, Siganus coralinus, Scarus niger, Chlorurus spilurus*** 2016: ***Acanthurus nigrofuscus***	Av. disssim: 2008/9: **62%**; 2016: **71%**
Outer	IMD: 2008/9: **-0.44** ; 2016: **-0.18**	IMD: 2008/9: **0.42**; 2016: **0.49**	Av. sim: 2008/9: **69%**; 2016: **57%**

	2008/9: P: **0.0001 (MC)**; 2016: **0.0001 (MC)**	2008/9: P: **0.0002 (MC)**; 2016: **0.002 (perm)**	PERMANOVA: **P=0.03** (comparison between years) IMD: 2008/9: **0.38**; 2016: **0.89** SIM/SD ≥2: 2008/9: ***Naso tonganus, Naso unicornis, Acanthurus lineatus, Chlorurus microrhinos, Ctenochaetus striatus, Acanthurus nigricans, Naso lituratus, Acanthurus triostegus*** 2016: ***Acanthurus lineatus, Ctenochaetus striatus***

Table S3 Pairwise comparisons (with lower and upper 95% confidence intervals: CI) of linear mixed effects models of variation in cross-shelf benthic composition and herbivorous fish assemblage structure in 2008/9 and 2016.

Response	Contrast	Contrast estimate	Lower CI	Upper CI	Test stat	*P*
Total hard coral cover (%)	Inner: 2008/9 vs 2016	-23.75	-29.80	-17.70	-7.77	<0.0001
	Mid: 2008/9 vs 2016	-42.20	-48.40	-36.01	-13.49	<0.0001
	Outer: 2008/9 vs 2016	-48.24	-54.29	-42.19	-15.79	<0.0001
Total macroalgal cover (%)	Inner: 2008/9 vs 2016	21.06	13.01	29.11	5.18	<0.0001
	Mid: 2008/9 vs 2016	-0.28	-1.40	0.85	-0.48	0.63
	Outer: 2008/9 vs 2016	-0.39	-1.06	0.28	-1.16	0.25
Shannon diversity (H)	2008/9 vs 2016	-0.43	-0.58	-0.27	-5.48	<0.0001
	Inner vs Mid	0.59	0.31	0.87	4.88	<0.0001
	Inner vs Outer	-0.19	-0.50	0.12	-1.45	0.32
	Outer vs Mid	-0.78	-1.06	-0.50	-6.46	<0.0001
Functional richness	2008/9 vs 2016	-0.16	-0.20	-0.13	-9.54	<0.0001
	Inner vs Mid	0.07	0.02	0.12	3.07	0.01
	Inner vs Outer	-0.004	-0.05	0.06	0.17	0.98
	Outer vs Mid	-0.06	-0.11	-0.01	-2.99	0.01
	Inner: 2008/9 vs 2016	0.09	0.09	0.23	4.32	<0.0001

Functional specialisation	Mid: 2008/9 vs 2016	-0.07	-0.11	-0.03	-3.35	0.001
	Outer: 2008/9 vs 2016	-0.02	-0.45	0.01	-1.54	0.13
Functional originality	Inner: 2008/9 vs 2016	-0.24	-0.37	-0.11	-3.72	0.0004
	Mid: 2008/9 vs 2016	-0.04	-0.14	0.06	-0.85	0.40
	Outer: 2008/9 vs 2016	0.01	-0.19	0.21	0.14	0.89
Total herbivores (log kg ha^{-1})	Inner: 2008/9 vs 2016	0.13	-0.20	0.47	0.79	0.43
	Mid: 2008/9 vs 2016	0.4	0.16	0.64	3.33	0.001
	Outer: 2008/9 vs 2016	0.84	0.51	1.17	4.98	<0.0001
Macroalgal browsers (kg ha^{-1})	2008/9 vs 2016	-114.28	-158.35	-70.22	-5.16	<0.0001
	Inner vs Mid	60.07	-18.71	138.85	1.74	0.17
	Inner vs Outer	1153.00	811.56	1494.44	7.71	<0.0001
	Outer vs Mid	1092.93	746.38	1439.48	7.20	<0.0001
Croppers (kg ha^{-1})	Inner: 2008/9 vs 2016	-37.65	-113.58	38.29	-0.99	0.33
	Mid: 2008/9 vs 2016	280.67	111.87	449.46	3.31	0.001
	Outer: 2008/9 vs 2016	538.67	348.90	728.433	5.65	<0.0001
Scrapers (kg ha^{-1})	2008/9 vs 2016	-43.94	-72.51	-15.38	-3.06	0.002
	Inner vs Mid	60.10	12.19	108.01	2.84	0.01
	Inner vs Outer	-275.64	-36.56	587.84	2.00	0.09
	Outer vs Mid	215.54	-99.38	530.46	1.55	0.24
Detrital feeders (kg ha^{-1})	Inner: 2008/9 vs 2016	0.42	-0.19	1.03	1.37	0.18
	Mid: 2008/9 vs 2016	171.76	94.92	248.60	4.45	<0.0001
	Outer: 2008/9 vs 2016	157.50	82.89	232.11	4.20	<0.0001
Excavators (kg ha^{-1})	2008/9 vs 2016	-8.39	-17.54	0.76	-1.82	0.07
	Inner vs Mid	87.64	38.89	136.40	4.17	<0.0001
	Inner vs Outer	108.85	61.87	155.84	5.37	<0.0001
	Outer vs Mid	21.21	-46.07	88.50	0.73	0.74

Supplemental information references

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