

Wave-sheltered embayments are recruitment hotspots for tropical fishes on temperate reefs

H. J. Beck*, D. A. Feary, Y. Nakamura, D. J. Booth

*Corresponding author: hbeck84@gmail.com

Marine Ecology Progress Series 546: 197–212 (2016)

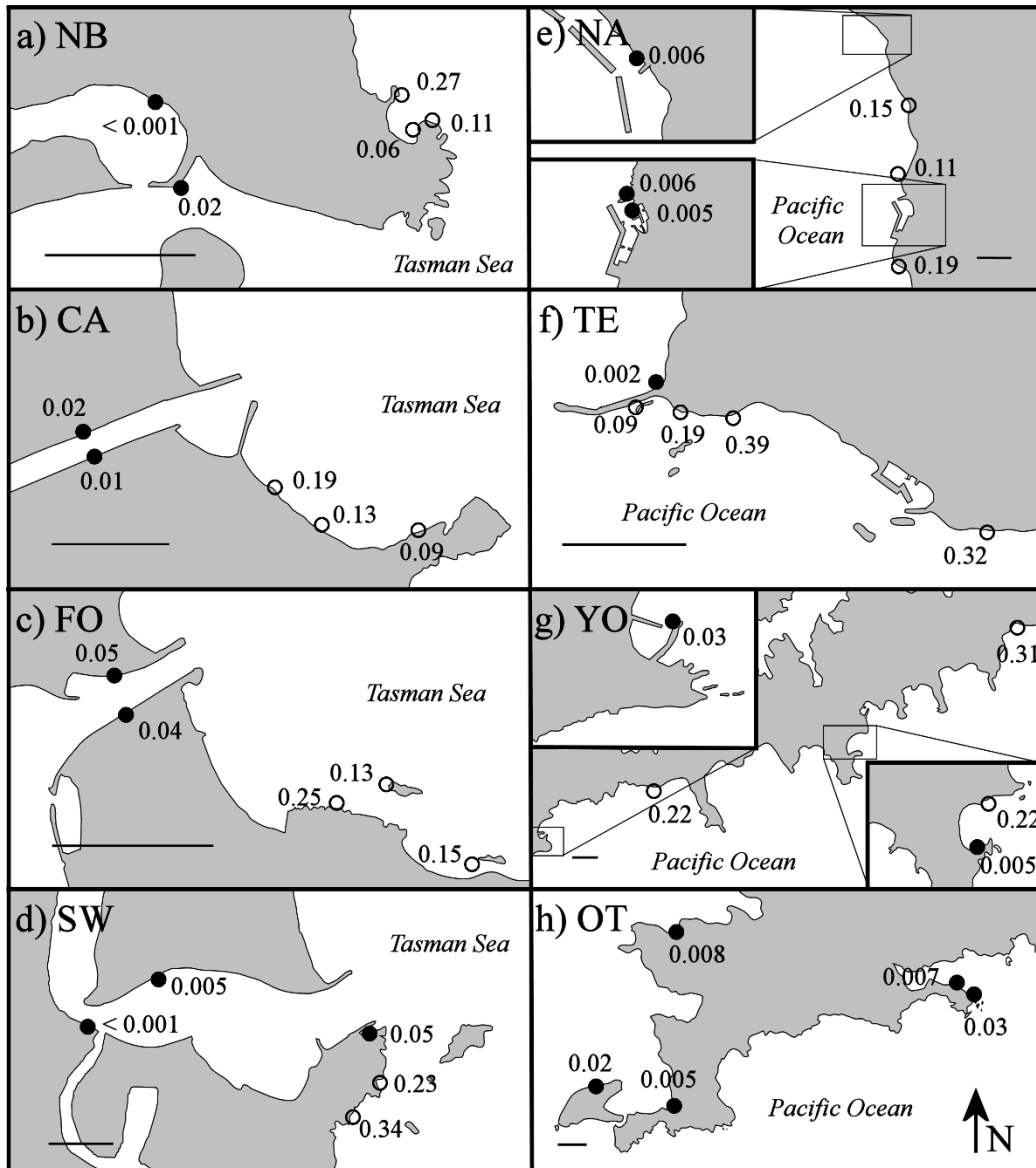


Figure S1. Wave-exposure index values for embayed (closed circles) and exposed (open circles) reefs surveyed within southeastern Australia [a-d)] and western Japan [e-h)]. Wave exposure indices out of a maximum exposure value of 1, respectively. Embayed and exposed sites had index values < 0.4 (i.e. 15% of exposure), respectively. Index values were constructed with 7.5° spacing around the midpoint of survey sites to a maximum of 650 km, the minimum fetch distance for fully developed seas to form. CA = Camden Haven, FO = Forster, NA = Nahara, NB = Nambucca, OT = Otsuki, SW = Swansea, TE = Tei, YO = Yokonami. Scale bar = 500m.

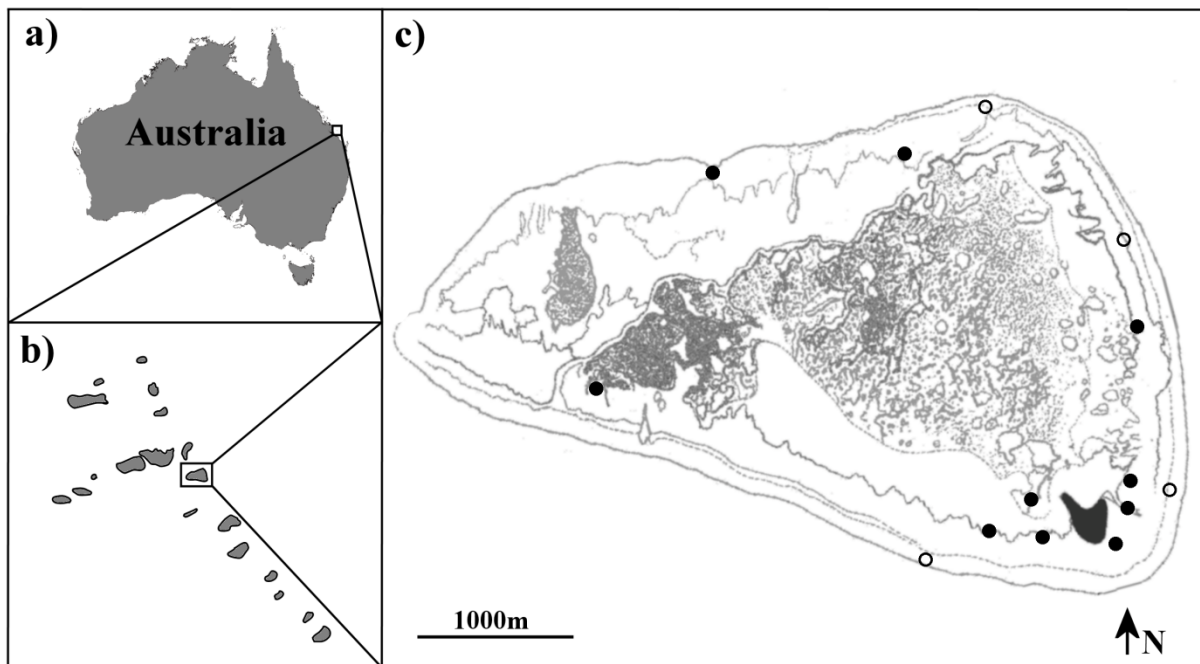


Figure S2. Location of survey sites in One Tree Island (OTI), Great Barrier Reef. OTI is located off the coast of Queensland, Australia in the southern Capricorn-Bunker Group of the Great Barrier Reef [insets a) and b)]. To determine habitat associations within their natal, historic range, recruit and early juvenile tropical fishes were surveyed in sheltered (closed circles) and exposed (open circles) reef sites of OTI. Exposed sites were those on the windward side of the island, positioned on the reef flat and reef edge (i.e. spur-and-groove); sites were on the eastern and southern aspects of the reef, which are exposed to the predominant southerly swell direction. Sheltered sites were those on the reef flat and reef edge on the leeward side of the island, as well as back reef sites protected from swell by the reef crest. In total, nine and 23 half-hour GPS-tracked roaming surveys were conducted in exposed and sheltered reef sites. Note: Surveys were conducted at the same site during 2011 and 2012. In some cases replicate surveys were conducted ~100m of each other, so not all survey sites were marked here.

Table S1. Species, primary trophic guild and country tropical reef fishes were detected. Species classified as tropical according to IUCN Red List, Froese and Pauly (2015) and/or Kuitert 2003. Trophic guilds allocated from references below. A = Southeastern Australia; J = Western Japan. Where known, dietary preferences were assigned for recruits/juveniles (R), as well as for vagrant fishes (V).

Tropical Fishes detected	Dietary classification	Region	Documented diets
F. Acanthuridae			
<i>Acanthurus dussumieri</i>	Herbivore	A, J	Grazer/detritivore, algae in temperate reefs (R; V) ^{1,2}
<i>Acanthurus lineatus</i>	Herbivore	A, J	Algal turfs ^{3,4}
<i>Acanthurus mata</i>	Herbivore	A	Juveniles feed on benthic algae, adults on zooplankton (R) ⁵
<i>Acanthurus nigrofuscus</i>	Herbivore	A, J	Algal turfs ^{1,4}
<i>Acanthurus olivaceus</i>	Detritivore	A, J	Organic detritivore with some algae and sediment ³
<i>Acanthurus triostegus</i>	Herbivore	A, J	Algal turfs (R; V) ⁴
<i>Ctenochaetus binotatus</i>	Detritivore	A, J	Organic detritivore with some algae and sediment ⁶
<i>Ctenochaetus striatus</i>	Detritivore	J	Organic detritivore with some algae and sediment ⁷
<i>Naso unicornis</i>	Herbivore	A, J	Macroscopic algae, mainly larger brown algae ^{3,4}
F. Balistidae			
<i>Sufflamen chrysopterus</i>	Benthivore	A	Benthic invertebrates ⁷
F. Chaetodontidae			
<i>Chaetodon auriga</i>	Benthivore	A, J	Benthic invertebrates, including polychaetes, sea anemones and algae ⁸
<i>Chaetodon auripes</i>	Benthivore	J	Benthic invertebrates ⁹
<i>Chaetodon citrinellus</i>	Benthivore	A	Facultative corallivore, algae, polychaetes, and benthic invertebrates ¹⁰
<i>Chaetodon flavirostris</i>	Benthivore	A	Facultative coralivore, benthic invertebrates and microalgae ^{11,12}
<i>Chaetodon guentheri</i>	Omnivore	A	Omnivore (occasionally zooplankton) ¹³
<i>Chaetodon kleinii</i>	Benthivore	A	Facultative corallivore and hydroids (occasionally zooplankton) ^{13,14}
<i>Chaetodon melannotus</i>	Corallivore	J	Obligate corallivore (hard and soft corals) ¹⁵
<i>Chaetodon plebeius</i>	Corallivore	J	Obligate corallivore (Pocillopora) ¹⁵
<i>Chaetodon selene</i>	Omnivore	J	Omnivore ¹³
<i>Chaetodon speculum</i>	Corallivore	J	Obligate corallivore (many corals) ¹⁶
<i>Chaetodon trifasciatus</i>	Corallivore	J	Obligate corallivore (many corals) ¹⁷
<i>Chaetodon vagabundus</i>	Omnivore	A, J	Anemones, coral polyps, polychaete worms and algae ¹⁸
<i>Heniochus acuminatus</i>	Planktivore	A	Zooplankton, supplemented with benthic invertebrates ¹⁹
F. Gobiesocidae			
<i>Diademichthys lineatus</i>	Benthivore	J	Pedicellariae and sphaeridia of host urchins and copepods (R) ²⁰
F. Labridae			
<i>Anampses caeruleopunctatus</i>	Benthivore	A, J	Small benthic crustaceans and polychaetes (R) ²¹
<i>Anampses melanurus</i>	Benthivore	J	Small crustaceans, molluscs and polychaetes ²²
<i>Anampses meleagrides</i>	Benthivore	J	Benthic invertebrates ²³

Tropical Fishes detected	Dietary classification	Region	Documented diets
<i>Cirrhilabrus temminckii</i>	Planktivore	J	Zooplankton ²⁴
<i>Coris gaimard</i>	Benthivore	J	Benthic molluscs, crabs, tunicates and foraminiferans ²⁵
<i>Gomphosus varius</i>	Benthivore	J	Benthic crustaceans, sometimes small fishes, brittle stars, and molluscs ¹¹
<i>Halichoeres margaritaceus</i>	Benthivore	J	Benthic crustaceans, molluscs, polychaetes, forams, fishes and eggs ⁸
<i>Hologymnosus annulatus</i>	Benthivore	J	Crustaceans (R) ²⁶
<i>Labroides dimidiatus</i>	Parasite cleaner	A, J	Ectoparasites and fish mucus (V) ^{27,28}
<i>Pseudocheilinus hexataenia</i>	Benthivore	J	Crustaceans ⁸
<i>Stethojulis bandanensis</i>	Benthivore	A, J	Crustaceans and benthic invertebrates ²¹
<i>Stethojulis strigiventer</i>	Benthivore	J	Benthic invertebrates, including copepods ²⁹
<i>Thalassoma hardwicke</i>	Benthivore	J	Benthic and planktonic crustaceans, fish eggs, small fishes and foraminiferans ^{30,31}
<i>Thalassoma janseni</i>	Benthivore	A	Benthic invertebrates ³⁰
F. Lutjanidae			
<i>Lutjanus argentimaculatus</i>	Piscivore	A	Fish and pelagic invertebrates ³²
<i>Lutjanus russellii</i>	Piscivore	A	Fish and pelagic invertebrates ^{32,33}
F. Ostraciidae			
<i>Ostracion cubicus</i>	Benthivore	A, J	Benthic invertebrates, including molluscs, sponges, polychaetes and crustaceans ³⁴
F. Pomacentridae			
<i>Abudefduf bengalensis</i>	Omnivore	A	Crabs, gastropods, benthic algae and zooplankton ³⁴
<i>Abudefduf sexfasciatus</i>	Planktivore	A, J	Zooplankton and algae ³⁴
<i>Abudefduf sordidus</i>	Omnivore	A	Algae, crustaceans and other benthic invertebrates ³⁴
<i>Abudefduf vaigiensis</i>	Planktivore	A, J	Zooplankton (R; V), supplemented with invertebrates and algae ^{34,35}
<i>Abudefduf whiteleyi</i>	Planktivore	A	Zooplankton ³⁴
<i>Amphiprion clarkii</i>	Planktivore	J	Zooplankton ³⁴
<i>Chromis fumea</i>	Planktivore	A	Zooplankton ³⁴
<i>Chromis margaritifer</i>	Planktivore	A, J	Zooplankton ³⁴
<i>Chromis weberi</i>	Planktivore	J	Zooplankton ³⁴
<i>Chrysiptera starcki</i>	Omnivore	J	Zooplankton and algae ³⁴
<i>Chrysiptera unimaculata</i>	Herbivore	J	Algae ³⁰
<i>Dascyllus reticulatus</i>	Omnivore	J	Zooplankton and algae ³⁴
<i>Dascyllus trimaculatus</i>	Omnivore	J	Zooplankton, copepods and algae ³⁶
<i>Plectroglyphidodon leucozonus</i>	Herbivore	A, J	Benthic algae ³⁰
<i>Pomacentrus coelestis</i>	Planktivore	A, J	Primarily zooplankton, sometimes algae ³⁶
<i>Pomacentrus nagasakiensis</i>	Planktivore	A, J	Primarily zooplankton, sometimes algae ³⁴

Tropical Fishes detected	Dietary classification	Region	Documented diets
<i>Pomachromis richardsoni</i>	Benthivore	J	Zoobenthos ³⁰
F. Scaridae			
<i>Scarus forsteni</i>	Herbivore	J	Benthic algae ³⁸
F. Scorpaenidae			
<i>Pterois volitans</i>	Piscivore	J	Small fishes, shrimps and crabs ³⁴
F. Serranidae			
<i>Cephalopholis argus</i>	Piscivore	A	Fishes ³⁹
<i>Diploprion bifasciatum</i>	Piscivore	A	Fishes ³⁴
<i>Grammistes sexlineatus</i>	Piscivore	A	Fishes ³⁴
<i>Pseudanthias squamipinnis</i>	Planktivore	J	Zooplankton ⁴⁰
F. Tetraodontidae			
<i>Canthigaster rivulata</i>	Omnivore	J	Uncertain - assumed similar to <i>Canthigaster valentini</i>
<i>Canthigaster valentini</i>	Omnivore	J	Benthic algae, bryozoans, polychaetes, echinoderms, molluscs ³⁴
F. Zanclidae			
<i>Zanclus cornutus</i>	Benthivore	A, J	Benthic invertebrates, including sponges ^{40, 41}

1. Green AL, Bellwood DR (2009) Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region. IUCN, Gland, Switzerland.
2. Basford AJ, Feary DA, Truong G, Steinberg PD, Marzinelli E, Vergés A (2015) Feeding habits of range-shifting herbivores: tropical surgeonfishes in a temperate environment. Mar. Freshwater. Res. doi: 10.1071/MF14208
3. Choat, JH, Clements KD, Robbins WD (2002) The trophic status of herbivorous fishes on coral reefs. 1. Dietary analyses. Mar. Biol. 140:613-623.
4. Choat JH, Robbins WD, Clements KD (2004) The trophic status of herbivorous fishes on coral reefs. Mar. Biol. 145:445-454.
5. Randall JE (2001) Surgeonfishes of the world. Mutual Publishing and Bishop Museum Press, Honolulu, Hawaii, USA.
6. Randall JE, Clements KD (2001) Second revision of the surgeonfish genus *Ctenochaetus* (Perciformes: Acanthuridae), with descriptions of two new species. Indo-Pacific Fishes 32:33.
7. Ishihara M, Kuwamura T (1996) Bigamy or monogamy with maternal egg care in the triggerfish, *Sufflamen chrysopterus*. Ichthyol. Res. 43(3):307-313.
8. Myers RF (1991) Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia. Coral Graphics, Barrigada, Guam.
9. Myers R, Pratchett M (2010) *Chaetodon auripes*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)

10. Myers R, Pratchett M (2010) *Chaetodon citrinellus*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)
11. Randall JE, Allen GR, Steene RC (1997) *Fishes of the Great Barrier Reef and Coral Sea*. University of Hawaii Press, Honolulu, Hawaii, USA.
12. Carassou L, Kulbicki M, Nicola TJ, Polunin, NV (2008) Assessment of fish trophic status and relationships by stable isotope data in the coral reef lagoon of New Caledonia, southwest Pacific. *Aquat. Living Resour.* 21(1):1-12.
13. Cole AJ, Pratchett MS (2013) Diversity in diet and feeding behaviour of butterflyfishes; reliance on reef corals versus reef habitats. In: Pratchett MS, Berumen ML, Kapoor BG (eds) *Biology of Butterflyfishes*, CRC Press, Florida, USA, p 107-140.
14. Rocha LA, Pyle R, Myers R, Craig MT, Pratchett M (2010) *Chaetodon kleinii*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)
15. Pratchett MS (2005) Dietary overlap among coral-feeding butterflyfishes (Chaetodontidae) at Lizard Island, northern Great Barrier Reef. *Mar. Biol.* 148:373-382.
16. Allen G, Myers R (2010) *Chaetodon speculum*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)
17. Pyle R, Rocha LA, Craig MT, Pratchett M (2010) *Chaetodon trifasciatus*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)
18. Myers R, Pratchett M (2010) *Chaetodon vagabundus*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)
19. Rocha LA, Pyle R, Craig MT, Pratchett M, Carpenter KE (2010) *Heniochus acuminatus*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed Aug 2015)
20. Sakashita H (1992) Sexual dimorphism and food habits of the clingfish, *Diademichthys lineatus*, and its dependence on host sea urchin. *Environ. Biol. Fish.* 34(1):95-101.
21. Lieske E, Myers RF (1994) *Coral reef fishes. Indo-Pacific and Caribbean including the Red Sea*. Harper Collins Publishers, New York, USA.
22. Cabanban AS, Sadovy YJ (2010) *Anampses melanurus*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 Aug 2015)
23. Masuda H, Allen GR (1993) *Meeresfische der Welt - Groß-Indopazifische Region*. Tetra Verlag, Herrenteich, Melle, Germany.
24. Randall JE (1992) A review of the labrid fishes of the genus *Cirrhilabrus* from Japan, Taiwan and the Mariana Islands, with descriptions of two new species. *Micronesica* 25(1):99-121.
25. Pollard D, Liu M (2010) *Coris gaimard*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (accessed 31 August 2015)
26. Randall JE (2005) *Reef and Shore Fishes of the South Pacific. New Caledonia to Tahiti and the Pitcairn Islands*. University of Hawaii Press, Honolulu, Hawaii, USA.
27. Potts G (1973) The ethology of *Labroides dimidiatus* (Cuv. & Val.) (Labridae, Pisces) on Aldabra. *Anim. Behav.* 21:250-291.

28. Luiz OJ, Madin EMP, Madin JS, Baird AH, Grutter AS (*In press*) Interactions between tropical and temperate reef fishes in a biogeographic transition zone: implications for range shifts of a specialist species. *Front. Ecol. Environ.*
29. Shibuno T, Nakamura Y, Horinouchi M, Sano M (2008). Habitat use patterns of fishes across the mangrove-seagrass-coral reef seascape at Ishigaki Island, southern Japan. *Ichthyol. Res.* 55(3):218-237.
30. Sano M, Shimizu M, Nose Y (1984) Food habits of teleostean reef fishes in Okinawa Island, southern Japan. University of Tokyo Press, Tokyo, Japan.
31. Shima J, Osenberg C (2003) Cryptic density dependence: effects of covariation between density and site quality in reef fish. *Ecology* 84:46-52.
32. Salini JP, Blaber SJM, Brewer DT (1994) Diets of trawled predatory fish of the Gulf of Carpentaria, Australia, with particular reference to predation on prawns. *Aust. J. Mar. Freshwat. Res.* 45(3):397-411.
33. Kulbicki M, Bozec YM, Labrosse P, Letourneur Y, Mou-Tham G, Wantiez L (2005) Diet composition of carnivorous fishes from coral reef lagoons of New Caledonia. *Aquat. Living Resour.* 18:231-250.
34. Froese R, Pauly D (2015) Fishbase. www.fishbase.org (accessed 31 Aug 2015)
35. Beck, HJ (2014) Tropical fish recruitment success varies among temperate reefs, potentially impacting their range expansion. PhD dissertation, University of Technology Sydney, Sydney, Australia
36. Allen GR (1991) Damsel fishes of the world. Mergus Publishers, Melle, Germany.
37. Hobson ES, Chess JR (1978) Trophic relationships among fishes and plankton in the lagoon at Enewetak Atoll, Marshall Islands. *Fish. Bull.* 76(1):133-153.
38. Bellwood DR, Choat JH (1990) A functional analysis of grazing in parrotfishes (family Scaridae): the ecological implications. *Environ. Biol. Fish.*, 28(1-4):189-214.
39. Bagnis R, Mazellier P, Bennett J, Christian E (1972) Fishes of Polynesia. Les Editions du Pacifique, Tahiti, France.
40. Anderson C, Hafiz A (1987) Common reef fishes of the Maldives. Part 1. Novelty Press, Republic of Maldives.
41. Kuitert RH (1993) Coastal fishes of south-eastern Australia. University of Hawaii Press, Honolulu, USA.

Table S2. Mean (SD) areas (m²) surveyed during replicate surveys of embayed and exposed habitats of a) southeastern (SE) Australia and b) western (W) Japan. n = number of replicate half-hour timed swim surveys, following Beck et al. (2014). Note: replicate surveys averaged across two years in SE Australia and one year in W Japan.

Location	Habitat	n	Mean (SE) area m²
a) SE Australia			
Nambucca	Embayed	5	505.33 (100.08)
	Exposed	6	925.38 (666.75)
Camden Haven	Embayed	4	1714 (596.04)
	Exposed	6	1378.03 (482.69)
Forster	Embayed	4	1190.25 (446.26)
	Exposed	6	1428.59 (504.71)
Swansea	Embayed	4	1008.21 (491.67)
	Exposed	6	1208.03 (220.96)
b) W Japan			
Nahara	Embayed	3	707.64 (55.61)
	Exposed	3	1170.54 (182.72)
Tei	Embayed	2	778.88 (7.34)
	Exposed	3	915.14 (32.07)
Otsuki	Embayed	2	719.25 (223.12)
	Exposed	3	778.65 (6.02)
Yokonami	Embayed	3	629.98 (84.13)
	Exposed	2	1044.32 (67.38)

Table S3. PERMANOVA comparison of trophic guilds and species of importance between habitats (H; embayed and exposed), countries (C; Australia and Japan) and locations (L; n = 4 in SE Australia, n = 3 in W Japan). Bold denotes a significant result (i.e. $p < 0.05$). * indicates species converted to presence/absence prior to analysis due to non-homogenous density data (i.e. PERMDISP, $p < 0.05$). Data for all trophic groups and species pooled across survey years in SE Australia ($p > 0.25$ for all listed trophic groups and species). A = Australia only, as was only observed there.

Parameter	Effects of variable			Other variable's p -values			
	<i>Pseudo-F</i>	d.f.	p	C	L(C)	C x H	H x L(C)
Trophic guilds							
Planktivores	11.55	1, 42	0.02	0.12	0.20	0.63	0.09
Herbivores	38.99	1, 42	0.002	0.77	0.01	0.02	0.41
Benthivores	53.59	1, 42	0.001	1.28	0.05	0.05	0.54
Omnivores	16.16	1, 42	0.01	0.94	0.26	0.04	0.26
Species							
<i>A. vaigiensis</i>	8.49	1, 42	0.03	0.15	0.15	0.32	0.06
<i>A. bengalensis</i> * ^A	22.22	1, 32	0.02	-	0.47	-	0.22
<i>A. sexfasciatus</i> *	18.17	1, 42	0.008	1	0.10	0.98	0.09
<i>P. coelestis</i>	10.08	1, 42	0.03	0.03	0.43	0.08	0.07
<i>A. dussumieri</i> *	7.66	1, 42	0.04	0.09	0.001	0.12	0.05
<i>A. nigrofuscus</i> *	10.50	1, 42	0.002	0.09	0.17	0.83	0.36
<i>A. triostegus</i> ^A	16.76	1, 32	0.02	-	0.02	-	0.29
<i>L. dimidiatus</i> *	8.43	1, 42	0.04	0.28	0.36	0.74	0.11
<i>C. auriga</i> *	41.40	1, 42	0.002	0.09	0.44	0.09	0.45

Table S4. Results of Distance Based Linear Modelling of biophysical variables within temperate reefs on assemblages of dietary generalist [a) Southeastern Australia and b) western Japan] and specialist [a) W Japan only] tropical fishes.

Factor	Pseudo-F	P	Proportion (%)
a) SE Australia - Trophic generalists			
Wave exposure	16.41	0.001	30.17
Predator density	10.63	0.001	21.86
Distance from river mouth	9.12	0.002	19.35
Invertebrate cover (other than coral)	5.18	0.002	12.00
Foliose algal cover	4.94	0.003	11.51
Latitude	3.07	0.02	7.47
SD water temperature	3.02	0.04	7.35
Sand	2.59	0.04	6.37
Encrusting algal cover	2.15	0.07	5.35
Average water temperature	2.06	0.08	5.14
Minimum water temperature	1.73	0.13	4.35
Reef rugosity	1.10	0.31	2.83
Bare rock	1.00	0.38	2.57
Rubble	0.84	0.49	2.16
Turfing algal cover	0.58	0.73	1.51
b) W Japan - Trophic generalists			
Wave exposure	3.74	0.0002	16.44
Latitude	3.01	0.001	13.67
Branching coral cover	2.52	0.005	11.71
Sand	1.93	0.03	9.23
Encrusting algal cover	1.37	0.18	6.71
Live coral cover	1.36	0.19	6.69
Plate coral cover	1.22	0.27	6.02
Invertebrate cover (other than coral)	1.18	0.29	5.83
Coral rubble	1.15	0.32	5.71
Reef rugosity	1.08	0.39	5.38
Distance from river mouth	0.94	0.51	4.72
Encrusting coral cover	0.92	0.51	4.60
Bare rock	0.75	0.68	3.31
Foliose algae cover	0.62	0.83	3.16
Predator density	0.62	0.83	3.16
Turfing algae cover	0.48	0.92	2.49
c) W Japan - Trophic specialists			
Branching coral cover	12.63	0.001	39.93
Live coral cover	6.83	0.01	26.44
Plate coral cover	5.48	0.01	22.38
Encrusting algal cover	5.36	0.01	22.02
Wave exposure	3.73	0.04	16.41
Turfing algae cover	3.04	0.05	13.80
Invertebrate cover (other than coral)	1.54	0.22	7.52
Latitude	1.04	0.38	5.17
Encrusting coral cover	0.71	0.49	3.60
Foliose algae cover	0.65	0.53	3.30
Reef rugosity	0.45	0.63	2.33
Bare rock	0.43	0.93	2.21
Predator density	0.39	0.71	2.01
Sand	0.34	0.71	1.74
Distance from river mouth	0.14	0.88	0.73
Coral rubble	0.14	0.88	0.72

Table S5. Ranked best solutions from Distance-based Linear Modelling (DistLM) of environmental factors (within 2 AICc values from the best overall model), which explained variance in vagrant tropical fish assemblages throughout southeastern (SE) Australia (a) and western (W) Japan (b and c). Bold values denote the top model - the lowest AICc and the least number of variables within 2 AICc units of the overall best model. AT = average water temperature, SDT = standard deviation of water temperature, MT = minimum water temperature, PD = predator density, WE = wave exposure, LA = latitude, DM = distance to nearest river mouth, FA = foliose algae, BC = branching coral, PC = plate coral, RU = rugosity, EA = encrusting algae, INV = invertebrates (other than coral), C = live coral, EC = encrusting coral, BR = bare rock and R = rubble. Note: no specialists were observed in SE Australia.

AICc	R ²	RSS	No. Variables	Selections
a) SE Australia - generalists				
293.46	0.51	42687	5	PD, WE, LA, DM, FA
293.50	0.48	45804	4	PD, WE, LA, FA
294.06	0.43	49608	3	PD, WE, LA
294.25	0.50	43541	5	AT, PD, WE, DM, FA
294.27	0.47	46702	4	PD, WE, LA, DM
294.30	0.54	40488	6	AT, PD, WE, LA, DM, FA
294.37	0.50	43671	5	AT, PD, WE, LA, FA
294.42	0.46	46880	4	SDT, PD, WE, LA
294.45	0.46	46915	4	WE, LA, DM, FA
294.45	0.46	46915	4	AT, PD, WE, FA
294.55	0.50	43871	5	PD, WE, LA, R
294.57	0.50	43892	5	SDT, PD, WE, LA, FA
294.60	0.53	40801	6	PD, WE, DM, R, FA
294.69	0.50	44021	5	PD, WE, LA, INV, FA
294.83	0.50	44176	5	SDT, PD, WE, LA, DM
294.84	0.42	50580	3	WE, LA, FA
294.89	0.53	41091	6	SDT, PD, WE, LA, DM, FA
294.93	0.49	44290	5	MT, PD, WE, LA, FA
294.94	0.53	41142	6	MT, PD, WE, LA, DM, FA
294.95	0.49	44317	5	PD, WE, LA, BR, FA
294.98	0.46	47531	4	AT, PD, WE, LA
295.01	0.49	44379	5	MT, PD, WE, DM, FA
295.01	0.53	41219	6	PD, WE, LA, DM, BR, FA
295.04	0.53	41249	6	PD, WE, LA, DM, INV, FA
295.09	0.45	47669	4	PD, WE, LA, INV
295.14	0.42	50960	3	PD, WE, FA
295.15	0.45	47739	4	PD, WE, LA, R
295.21	0.49	44601	5	AT, PD, WE, LA, DM
295.22	0.53	41440	6	PD, WE, LA, DM, FA, EA
295.25	0.49	44645	5	AT, SDT, PD, WE, LA
295.27	0.49	44665	5	PD, WE, DM, FA, EA
295.30	0.45	47920	4	MT, PD, WE, FA
295.30	0.41	51170	3	AT, PD, WE
295.33	0.45	47958	4	AT, WE, DM, FA
295.34	0.45	47968	4	PD, WE, LA, BR
295.35	0.52	41566	6	PD, RU, WE, LA, DM, FA
295.35	0.52	41574	6	AT, SDT, PD, WE, LA, FA

AICc	R ²	RSS	No. Variables	Selections
295.36	0.45	47989	4	PD, WE, DM, FA
295.40	0.49	44811	5	SDT, PD, WE, LA, R
295.41	0.52	41633	6	PD, WE, LA, DM, TA, FA
295.41	0.45	48056	4	MT, PD, WE, LA
295.42	0.49	44831	5	AT, WE, LA, DM, FA
295.43	0.49	44842	5	PD, WE, LA, FA, EA
295.44	0.49	44852	5	PD, WE, LA, DM, R
295.46	0.45	48113	4	AT, PD, WE, DM
b) W Japan - generalists				
157.24	0.16	30036	1	WE
157.80	0.24	27064	2	WE, LA
157.93	0.14	31032	1	LA
158.08	0.24	27430	2	LA, BC
158.40	0.12	31738	1	BC
158.43	0.22	27882	2	WE, PC
158.45	0.22	27913	2	LA, C
158.51	0.22	27986	2	WE, EA
158.57	0.22	28073	2	WE, INV
158.61	0.22	28127	2	WE, RU
158.62	0.22	28134	2	WE, BC
158.62	0.22	28137	2	WE, R
158.65	0.22	28185	2	LA, EA
158.71	0.22	28260	2	WE, C
158.80	0.22	28387	2	WE, BR
158.83	0.21	28426	2	R, PC
158.83	0.21	28426	2	WE, S
158.98	0.09	32628	1	S
159.11	0.19	28805	2	WE, FA
159.12	0.19	28823	2	LA, S
159.23	0.19	28962	2	WE, EC
159.24	0.19	28979	2	WE, DM
c) W Japan - specialists				
128.16	0.61	5964	3	C, BC, EC
128.27	0.67	4845	4	BR, C, BC, PC
129.03	0.66	5025	4	INV, C, BC, PC
129.15	0.53	6915	2	S, BC
129.17	0.59	5974	3	S, INV, BC
129.17	0.66	5058	4	S, C, BC, PC
129.25	0.71	4197	5	BR, INV, BC, EC, PC
129.33	0.65	5096	4	RU, C, BC, PC
129.41	0.71	4228	5	BR, INV, C, BC, PC
129.65	0.58	6114	3	S, BC, PC
129.71	0.65	5189	4	BR, BC, PC
129.93	0.71	4335	5	BR, C, BC, EC, PC
129.94	0.64	5246	4	C, BC, EC, PC
129.98	0.64	5258	4	PD, C, BC, PC
130.01	0.70	4352	5	RU, INV, C, BC, PC
130.01	0.57	6220	3	S, EA, BC

	AICc	R ²	RSS	No. Variables	Selections
130.03		0.64	5270	4	S, INV, BC, PC
130.11		0.51	7240	2	BC, PC
130.13		0.70	4376	5	S, INV, C, BC, PC
130.13		0.57	6255	3	LA, S, BC

Table S6. Mean (SE) piscivore densities within embayed and protected reef habitats within a) SE Australia and b) W Japan. * denotes significant difference in densities between habitats (PERMANOVA; $p < 0.05$).

Species	Common name	Embayed reef Mean (SE)	Exposed reef Mean (SE)
a) SE Australia			
<i>Acanthopagrus australis</i>	Yellowfin Bream	45.64 (7.82)*	4.91 (1.65)
<i>Argyrosomus japonicas</i>	Jewfish	0.32 (0.33)	0.00
<i>Brachaelurus waddi</i>	Blind shark	0.00	0.03 (0.03)
<i>Dinolestes lewini</i>	Longfin Pike	2.12 (1.55)	1.20 (0.60)
<i>Epinephelus coioides</i>	Estuary cod	0.24 (0.14)	0.00
<i>Epinephelus daemeli</i>	Black cod	0.16 (0.17)	0.03 (0.03)
<i>Gymnothorax prasinus</i>	Green Moray	0.23 (0.24)	0.00
<i>Lutjanus argentimaculatus</i>	Mangrove Jack	0.12 (0.13)	0.00
<i>Lutjanus russellii</i>	Moses' snapper	4.88 (2.11)	1.71 (1.71)
<i>Platycephalus bassensis</i>	Sand flathead	2.67 (2.37)	0.03 (0.03)
<i>Platycephalus fuscus</i>	Dusky flathead	0.80 (0.53)	0.09 (0.09)
<i>Sepia plangon</i>	Mourning cuttlefish	0.20 (0.21)	0.00
<i>Sepia sp.</i>	Unidentified cuttlefish	0.00	0.09 (0.09)
	Total	57.54 (8.69)*	8.09 (2.28)
b) W Japan			
<i>Acanthopagrus schlegelii</i>	Japanese black porgy	0.13 (0.13)	0.44 (0.25)
<i>Apogon sp.</i>	Unidentified cardinal fish	19.29 (9.88)	4.16 (4.16)
<i>Gymnothorax sp.</i>	Unidentified morey eel	0.13 (0.13)	0.00
<i>Lethrinus genivattatus</i>	Thread-finned emperor	0.15 (0.15)	0.00
<i>Lethrinus nebulosus</i>	Spangled emperor	0.12 (0.12)	0.56 (0.56)
<i>Lutjanus russellii</i>	Moses' snapper	0.13 (0.13)	0.00
<i>Lutjanus stellatus</i>	Star snapper	0.23 (0.15)	0.10 (0.10)
<i>Plectropomus leopardus</i>	Coral trout	0.10 (0.10)	0.00
<i>Pterois volitans</i>	Red lionfish	0.10 (0.10)	0.00
<i>Scolopsis affinis</i>	Monocole bream	0.15 (0.15)	0.35 (0.35)
<i>Sphyaena japonica</i>	Japanese barracuda	2.52 (2.52)	1.76 (1.76)
<i>Synodus ulae</i>	Red lizard fish	0.61 (0.47)	0.07 (0.07)
	Total	25.49 (9.10)	5.63 (3.13)

Table S7. Mean (SE) densities, overall densities and species richness of adult tropical fishes in embayed and exposed temperate reefs of SE Australia (A) and W Japan (J). Data combined amongst countries (for species observed in both), survey years (SE Australia only) and locations. Adults identified by length categories provided by Booth et al. (2010). Bold species denote those only found in embayed reefs. * Indicates a significant difference in densities between exposed and embayed habitats (i.e. $p < 0.05$), as determined by T-test.

Species	Exposed	Protected
F. Acanthuridae		
<i>Acanthurus dussumieri</i> ^{A,J}	0.67(0.30)	1.38(0.39)
<i>Acanthurus nigrofuscus</i> ^{A,J}	0.0(0.0)	0.46(0.24)*
<i>Ctenochaetus striatus</i> ^J	0.0(0.0)	0.11(0.11)
<i>Naso unicornis</i> ^J	0.11(0.11)	0.0(0.0)
F. Blenniidae		
<i>Meiacanthus kamoharui</i> ^J	0.0(0.0)	1.26(0.52)*
F. Centropyge		
<i>Centropyge tibicen</i> ^J	0.0(0.0)	0.89(0.55)
<i>Centropyge vrolikii</i> ^J	0.0(0.0)	0.38(0.38)
F. Chaetodontidae		
<i>Chaetodon auriga</i> ^{A,J}	0.0(0.0)	0.33(0.31)
<i>Chaetodon auripes</i> ^{A,J}	11.93(1.73)	21.88(4.73)*
<i>Chaetodon flavirostris</i> ^A	0.0(0.0)	0.27(0.18)
<i>Chaetodon melannotus</i> ^J	0.0(0.0)	0.13(0.13)
<i>Chaetodon septentrionalis</i> ^J	0.0(0.0)	0.11(0.11)
<i>Chaetodon speculum</i> ^J	0.0(0.0)	0.11(0.11)
<i>Chaetodon vagabundus</i> ^J	0.0(0.0)	0.12(0.12)
F. Cheilodactylidae		
<i>Goniistius zonatus</i> ^J	1.04(0.35)	1.11(0.49)
F. Diagramma		
<i>Diagramma pictum pictum</i> ^J	0.32(0.23)	0.11(0.11)
F. Diodontidae		
<i>Diodon holocanthus</i> ^J	0.0(0.0)	0.11(0.11)
F. Gobiesocidae		
<i>Diademichthys lineatus</i> ^J	0.0(0.0)	0.09(0.09)
F. Labridae		
<i>Anampses caeruleopunctatus</i> ^{A,J}	0.03(0.03)	0.09(0.09)
<i>Anampses melanochir</i> ^J	0.11(0.11)	0.00(0.00)
<i>Anampses melanurus</i> ^J	0.0(0.0)	0.25(0.17)
<i>Anampses meleagrides</i> ^J	0.0(0.0)	0.21(0.21)
<i>Cirrhilabrus cyanopleura</i> ^J	0.0(0.0)	0.13(0.13)
<i>Cirrhilabrus temminckii</i> ^J	0.0(0.0)	0.25(0.25)
<i>Gomphogus varius</i> ^J	1.58(0.81)	0.97(0.38)
<i>Halichoeres melanochir</i> ^J	0.11(0.11)	0.12(0.12)
<i>Labroides dimidiatus</i> ^J	0.41(0.22)	0.08(0.05)
F. Lethrinidae		
<i>Lethrinus genivatatus</i> ^J	0.0(0.0)	0.13(0.13)
<i>Lethrinus nebulosus</i> ^J	0.08(0.08)	0.57(0.47)
F. Lutjanidae		
<i>Lutjanus argentimaculatus</i> ^A	0.0(0.0)	0.33(0.19)
<i>Lutjanus russeli</i> ^{A,J}	0.09(0.05)	0.59(0.29)*

Species	Exposed	Protected
<i>Lutjanus stellatus</i> ^J	0.23(0.15)	0.11(0.11)
F. Ostraciidae		
<i>Lactoria fornasini</i> ^J	0.0(0.0)	0.11(0.11)
F. Pomacanthidae		
<i>Chaetodontoplus septentrionalis</i> ^J	0.0(0.0)	0.19(0.13)
F. Pomacentridae		
<i>Abudefduf bengalensis</i> ^{A, J}	0.18(0.13)	3.07(0.73)*
<i>Abudefduf sexfasciatus</i> ^J	0.0(0.0)	2.82(2.53)
<i>Abudefduf vaigiensis</i> ^{A, J}	3.84(1.60)	4.68(1.30)
<i>Abudefduf whitleyi</i> ^A	0.1(0.1)	0.0(0.0)
<i>Amphiprion clarkii</i> ^J	0.80(0.35)	2.47(0.94)
<i>Chromis weberi</i> ^J	0.0(0.0)	0.29(0.29)
<i>Chromis leucura</i> ^J	0.0(0.0)	0.66(0.52)
<i>Chrysiptera unimaculata</i> ^J	0.0(0.0)	0.53(0.30)*
<i>Dascyllus trimaculatus</i> ^J	0.0(0.0)	2.53(1.94)
<i>Plectroglyphidodon leucozonus</i> ^A	1.16(0.9)	0.0(0.0)
F. Serranidae		
<i>Plectropomus leopardus</i> ^J	0.0(0.0)	0.09(0.09)
F. Tetraodontiform		
<i>Canthigaster rivulata</i> ^J	0.21(0.14)	0.00(0.00)
Mean overall density (individuals/1000m²)	15.00(4.06)	27.19(5.28)*
Mean overall richness (species/1000m²)	1.95(0.49)	4.46(0.71)*