The following supplements accompany the article

Highly localized replenishment of coral reef fish populations near nursery habitats

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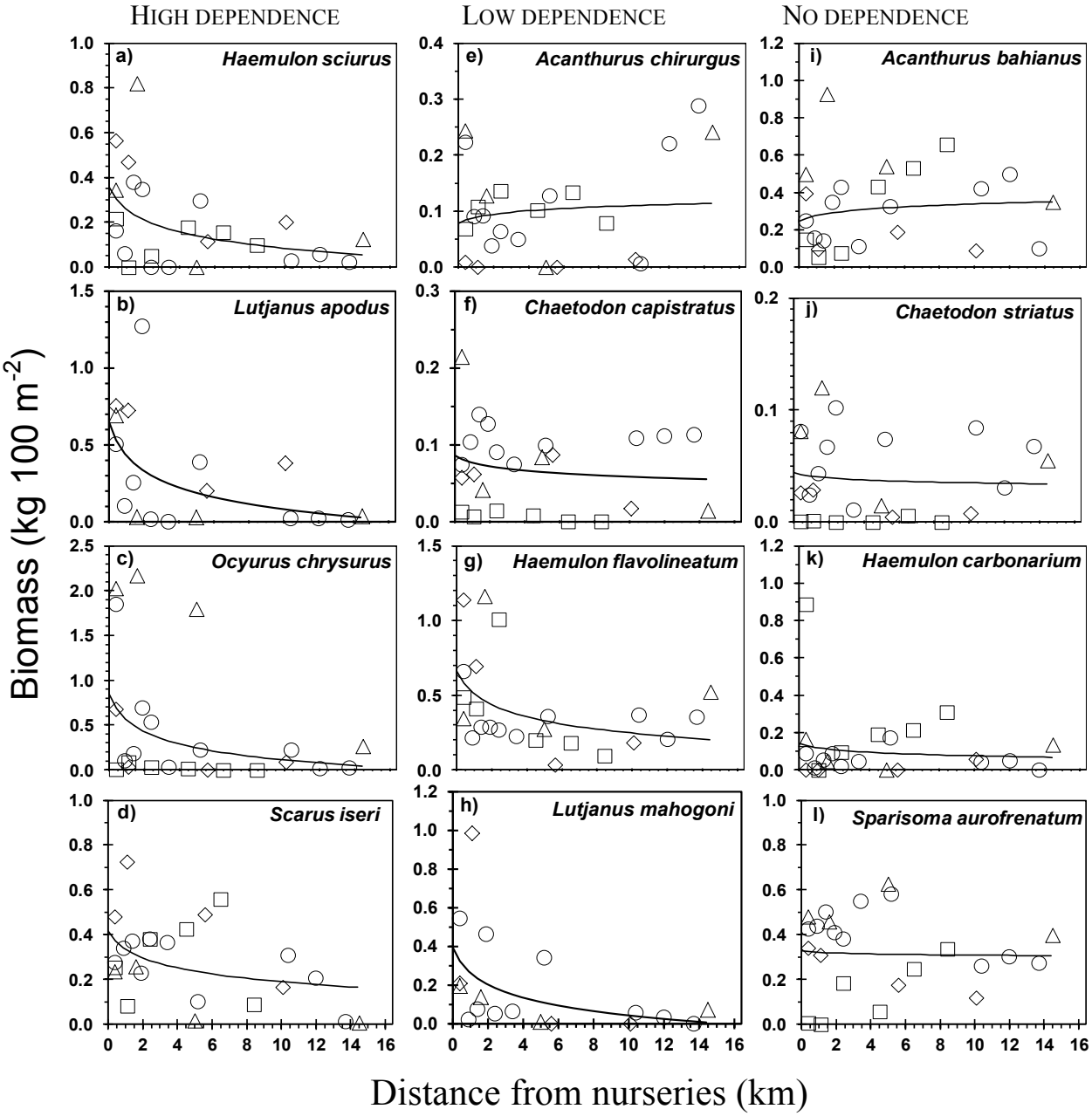
Supplement 1. Example of calculation of reef shelf surface area close to nurseries using Google Earth. The white rectangle shows a reef shelf area 1.2 km in length, located at the mouth of the Spanish Water Bay that harbours the nursery habitats. We measured mean shelf width at several points (white arrows as an example) along the 1.2 km distance (# measurements depending on shelf heterogeneity). We calculated shelf area as 1.2 km × mean shelf width. We did this procedure for the reef shelf directly up-current and directly down-current of the bay mouth, and summed the two areas for total shelf area close to nurseries.

Supplement 2. General linear mixed-effects models for reef fish density and biomass as a function of distance to nursery (*dist*), nursery dependence class (*dep*: high, low, none), coral cover (*corcv*, %) and coral height (*corh*, m). All models include the species/island nested random effect. We calculated the median of density and biomass over transects per site as the response variables, as well as the median values for the coral variables. Included for each model is maximum log-likelihood (*LL*), number of parameters (*k*), change in Akaike's information criterion corrected for small samples relative to the top-ranked model (ΔAIC_c), their weights ($wAIC_c$), the marginal R^2 of each resampled GLMM (R_m) as a measure of the variance explained by the fixed terms, and the conditional R^2 of each resampled GLMM (R_c) as a measure of the variance explained by both the fixed effects and the random factors (Nakagawa & Schielzeth 2013).

Model	*k*	*LL*	ΔAIC_c	$wAIC_c$	R_m	R_c
(*i*) density						
~*dist+dep+corcv+corh+dist×dep*	11	–312.875	0	0.720	6.4	72.4
~*dist+dep+corh+dist×dep*	10	–312.543	2.662	0.190	5.9	72.0
~*dist+dep+dist×dep*	9	–312.714	4.785	0.066	5.6	71.9
~*dist+dep+corcv+dist×dep*	10	–315.680	6.774	0.024	5.6	71.8
~*dist+corcv+corh*	7	–330.175	34.284	< 0.001	3.8	65.1
~*dist+corh*	6	–329.650	36.439	< 0.001	3.3	64.7
~*dist+dep+corcv+corh*	9	–330.199	38.266	< 0.001	3.4	68.9
~*dist*	5	–329.727	38.274	< 0.001	3.0	64.6
~*dist+corcv*	6	–332.645	40.268	< 0.001	3.0	64.5
~*dist+dep+corh*	8	–329.674	40.421	< 0.001	3.0	68.6
~*dist+dep*	7	–329.751	42.256	< 0.001	2.7	68.5
~*dist+dep+corcv*	8	–332.669	44.249	< 0.001	2.7	68.4
~*corcv+corh*	6	–345.838	68.948	< 0.001	0.6	61.5
~1 (intercept-only)	4	–344.017	70.047	< 0.001	–	61.1
~*corh*	5	–345.409	71.202	< 0.001	0.1	61.0
~*corcv*	5	–346.574	71.381	< 0.001	0.1	61.1
~*dep+corcv+corh*	8	–345.866	72.931	< 0.001	0.6	65.7
~*dep*	6	–344.045	74.030	< 0.001	0.1	65.3
~*dep+corh*	7	–345.437	75.184	< 0.001	0.1	65.3
~*dep+corcv*	7	–346.602	75.364	< 0.001	0.1	65.4
(*ii*) biomass						
~*dist+dep+corh+dist×dep*	10	–319.397	0	0.610	8.6	64.2
~*dist+dep+corcv+corh+dist×dep*	11	–321.899	1.775	0.251	8.6	64.1
~*dist+dep+corcv+dist×dep*	10	–322.071	3.190	0.124	8.3	63.5
~*dist+dep+dist×dep*	9	–322.242	7.474	0.015	7.7	63.2
~*dist+corh*	6	–337.045	35.732	< 0.001	5.1	56.2
~*dist+corcv+corh*	7	–339.475	37.459	< 0.001	5.1	56.0
~*dist+corcv*	6	–339.425	38.321	< 0.001	4.7	55.3
~*dist+dep+corh*	8	–337.529	39.713	< 0.001	4.7	59.9
~*dist+dep+corcv+corh*	9	–339.959	41.440	< 0.001	4.7	59.7
~*dist*	5	–339.424	42.131	< 0.001	4.1	55.1
~*dist+dep+corcv*	8	–339.908	42.303	< 0.001	4.4	59.1
~*dist+dep*	7	–339.907	46.113	< 0.001	3.8	58.9
~*corh*	5	–355.592	76.052	< 0.001	0.4	51.3
~*corcv*	5	–357.000	76.703	< 0.001	0.3	50.8
~1 (intercept-only)	4	–355.279	76.985	< 0.001	–	50.8
~*corcv+corh*	6	–358.023	77.876	< 0.001	0.4	51.1
~*dep+corh*	7	–356.075	80.033	< 0.001	0.4	55.4
~*dep+corcv*	7	–357.483	80.685	< 0.001	0.3	55.0
~*dep*	6	–355.762	80.967	< 0.001	0.1	55.0
~*dep+corcv+corh*	8	–358.505	81.858	< 0.001	0.4	55.3

Supplement 3. Adult fish biomass on reefs as a function of isolation from nursery habitats for species with (a–d) high dependence on nursery habitats, (e–h) low dependence on nursery habitats, and (i–l) no dependence on nursery habitats. Symbols represent data from Aruba (triangles), Bermuda (squares), Curaçao (circles), and Grand Cayman (diamonds). Logarithmic regression lines are fitted to the combined island data as an indication of the pattern at species level, independent of locality.



Supplement 4. Correlation coefficients (*r*) of Pearson product-moment correlations (for Gaussian data) or Spearman's rank correlation (for non-Gaussian data) between total abundance of juvenile fishes in mangrove (Mg) or seagrass (Sg) habitats and adult fish densities / total abundance ('population') on adjacent coral reefs (CR), up to distances of 1.2 or 5.2 km away from nearest nursery habitat, respectively. Numbers in bold indicate highest coefficient for the respective species–distance combination across the Mg, Sg, and Mg + Sg correlations. Nursery dependence: of the 17 Caribbean species identified as nursery species (Nagelkerken et al. 2000), we selected 4 species with high and 4 species with low dependence on nursery habitats (Nagelkerken et al. 2002); in addition, we selected 4 species with no dependence on nursery habitats (Nagelkerken & van der Velde 2002).

Species	Nursery dependence	Habitat	CR density 1.2 km	CR population 1.2 km	CR density 5.2 km	CR population 5.2 km
			r	*r*	*r*	*r*
Haemulon sciurus (bluestriped grunt)	High	Mg	**0.98**	**0.89**	0.71	**0.89**
Lutjanus apodus (schoolmaster snapper)	High	Mg	**0.93**	**0.89**	**0.86**	**0.89**
Ocyurus chrysurus (yellowtail snapper)	High	Mg	0.15	0.09	-0.03	-0.15
Scarus iseri (striped parrotfish)	High	Mg	**0.10**	**0.50**	**0.10**	**0.30**
Acanthurus chirurgus (doctorfish)	Low	Mg	-0.55	**0.20**	-0.55	-0.26
Chaetodon capistratus (foureye butterflyfish)	Low	Mg	-0.54	0.26	-0.31	0.26
Haemulon flavolineatum (French grunt)	Low	Mg	0.04	**0.60**	**0.35**	**0.63**
Lutjanus mahogoni (mahogany snapper)	Low	Mg	-0.26	-0.14	-0.26	-0.14
Acanthurus bahianus (ocean surgeonfish)	None	Mg	**0.75**	**0.75**	**0.55**	**0.81**
Chaetodon striatus (banded butterflyfish)	None	Mg	**0.73**	0.35	**0.73**	0.71
Haemulon carbonarium (Caesar grunt)	None	Mg	**0.66**	**0.66**	**0.66**	**0.66**
Sparisoma aurofrenatum (redband parrotfish)	None	Mg	-0.35	0.00	-0.71	-0.71
Haemulon sciurus (bluestriped grunt)	High	Sg	0.71	**0.89**	**0.75**	0.19
Lutjanus apodus (schoolmaster snapper)	High	Sg	0.26	0.45	0.26	0.45
Ocyurus chrysurus (yellowtail snapper)	High	Sg	**0.79**	**0.82**	**0.68**	**0.75**
Scarus iseri (striped parrotfish)	High	Sg	-0.06	0.35	-0.06	0.06
Acanthurus chirurgus (doctorfish)	Low	Sg	-0.63	0.00	-0.60	-0.46
Chaetodon capistratus (foureye butterflyfish)	Low	Sg	**0.38**	**0.45**	**0.54**	**0.45**
Haemulon flavolineatum (French grunt)	Low	Sg	-0.14	0.39	-0.14	0.07
Lutjanus mahogoni (mahogany snapper)	Low	Sg	**0.06**	-0.02	-0.36	-0.34
Acanthurus bahianus (ocean surgeonfish)	None	Sg	0.56	0.68	0.36	0.71
Chaetodon striatus (banded butterflyfish)	None	Sg	0.67	**0.85**	0.67	**0.78**
Haemulon carbonarium (Caesar grunt)	None	Sg	0.62	0.61	0.62	0.61
Sparisoma aurofrenatum (redband parrotfish)	None	Sg	-0.06	**0.46**	-0.32	-0.20
Haemulon sciurus (bluestriped grunt)	High	Mg + Sg	0.64	0.86	0.68	0.79
Lutjanus apodus (schoolmaster snapper)	High	Mg + Sg	0.32	0.52	0.32	0.52
Ocyurus chrysurus (yellowtail snapper)	High	Mg + Sg	**0.79**	**0.82**	**0.68**	**0.75**
Scarus iseri (striped parrotfish)	High	Mg + Sg	-0.06	0.35	-0.06	0.06
Acanthurus chirurgus (doctorfish)	Low	Mg + Sg	-0.63	0.00	-0.59	-0.46
Chaetodon capistratus (foureye butterflyfish)	Low	Mg + Sg	0.11	0.36	0.32	0.36
Haemulon flavolineatum (French grunt)	Low	Mg + Sg	-0.14	0.39	-0.14	0.07
Lutjanus mahogoni (mahogany snapper)	Low	Mg + Sg	**0.06**	-0.02	-0.36	-0.33
Acanthurus bahianus (ocean surgeonfish)	None	Mg + Sg	0.56	0.68	0.36	0.71
Chaetodon striatus (banded butterflyfish)	None	Mg + Sg	0.67	**0.85**	0.67	**0.78**
Haemulon carbonarium (Caesar grunt)	None	Mg + Sg	0.62	0.61	0.62	0.61
Sparisoma aurofrenatum (redband parrotfish)	None	Mg + Sg	-0.06	**0.46**	-0.32	-0.20

Supplement 5. Correlation coefficients (*r*) of Pearson product-moment correlations (for Gaussian data) or Spearman's rank correlation (for non-Gaussian data) between total nursery habitat surface area (Mg vs Sg vs Mg + Sg) and adult fish densities / total abundance ('population') on adjacent coral reefs (CR), up to distances of 1.2 or 5.2 km away from nearest nursery habitat, respectively. Mg = mangroves; Sg = seagrasses; Mg + Sg = both habitats combined. Numbers in bold indicate highest coefficient for the respective species–distance combination across the Mg, Sg, and Mg + Sg correlations.

Species	Nursery dependence	Habitat	CR density 1.2 km	CR population 1.2 km	CR density 5.2 km	CR population 5.2 km
			r	*r*	*r*	*r*
Haemulon sciurus (bluestriped grunt)	High	Mg	0.43	0.43	0.46	0.46
Lutjanus apodus (schoolmaster snapper)	High	Mg	0.18	0.36	0.18	0.18
Ocyurus chrysurus (yellowtail snapper)	High	Mg	**0.74**	**0.75**	**0.82**	**0.82**
Scarus iseri (striped parrotfish)	High	Mg	-0.31	0.14	-0.31	-0.31
Acanthurus chirurgus (doctorfish)	Low	Mg	-0.31	-0.04	-0.38	-0.38
Chaetodon capistratus (foureye butterflyfish)	Low	Mg	-0.43	0.07	-0.36	-0.36
Haemulon flavolineatum (French grunt)	Low	Mg	0.00	0.50	0.21	0.21
Lutjanus mahogoni (mahogany snapper)	Low	Mg	**0.96**	0.86	0.55	0.55
Acanthurus bahianus (ocean surgeonfish)	None	Mg	**0.61**	0.57	0.39	0.39
Chaetodon striatus (banded butterflyfish)	None	Mg	**0.75**	0.66	**0.49**	0.49
Haemulon carbonarium (Caesar grunt)	None	Mg	**0.65**	0.68	**0.61**	0.61
Sparisoma aurofrenatum (redband parrotfish)	None	Mg	-0.20	0.37	-0.43	-0.43
Haemulon sciurus (bluestriped grunt)	High	Sg	**0.71**	**0.93**	**0.64**	0.64
Lutjanus apodus (schoolmaster snapper)	High	Sg	**0.75**	**0.86**	**0.75**	0.75
Ocyurus chrysurus (yellowtail snapper)	High	Sg	0.58	0.64	0.54	0.54
Scarus iseri (striped parrotfish)	High	Sg	**0.20**	**0.60**	**0.20**	0.20
Acanthurus chirurgus (doctorfish)	Low	Sg	-0.50	**0.29**	-0.40	-0.40
Chaetodon capistratus (foureye butterflyfish)	Low	Sg	0.00	0.64	-0.07	-0.07
Haemulon flavolineatum (French grunt)	Low	Sg	**0.36**	**0.79**	**0.46**	0.46
Lutjanus mahogoni (mahogany snapper)	Low	Sg	0.76	**0.89**	**0.82**	0.82
Acanthurus bahianus (ocean surgeonfish)	None	Sg	**0.59**	**0.71**	**0.43**	**0.43**
Chaetodon striatus (banded butterflyfish)	None	Sg	0.64	**0.89**	0.29	0.29
Haemulon carbonarium (Caesar grunt)	None	Sg	0.55	**0.79**	0.49	0.49
Sparisoma aurofrenatum (redband parrotfish)	None	Sg	**0.31**	**0.77**	**0.14**	0.14
Haemulon sciurus (bluestriped grunt)	High	Mg + Sg	**0.71**	**0.93**	**0.64**	**0.79**
Lutjanus apodus (schoolmaster snapper)	High	Mg + Sg	**0.75**	**0.86**	**0.75**	**0.86**
Ocyurus chrysurus (yellowtail snapper)	High	Mg + Sg	0.58	0.64	0.54	0.68
Scarus iseri (striped parrotfish)	High	Mg + Sg	**0.20**	**0.60**	**0.20**	**0.49**
Acanthurus chirurgus (doctorfish)	Low	Mg + Sg	-0.51	**0.29**	-0.40	-0.21
Chaetodon capistratus (foureye butterflyfish)	Low	Mg + Sg	0.00	**0.64**	-0.07	**0.64**
Haemulon flavolineatum (French grunt)	Low	Mg + Sg	**0.36**	**0.79**	**0.46**	**0.64**
Lutjanus mahogoni (mahogany snapper)	Low	Mg + Sg	0.76	**0.89**	**0.82**	**0.89**
Acanthurus bahianus (ocean surgeonfish)	None	Mg + Sg	**0.60**	**0.71**	**0.43**	**0.79**
Chaetodon striatus (banded butterflyfish)	None	Mg + Sg	0.64	**0.89**	0.29	**0.77**
Haemulon carbonarium (Caesar grunt)	None	Mg + Sg	0.55	**0.79**	0.49	**0.82**
Sparisoma aurofrenatum (redband parrotfish)	None	Mg + Sg	**0.31**	**0.77**	**0.14**	**0.37**

LITERATURE CITED IN SUPPLEMENT

Nagelkerken I, van der Velde G (2002) Do non-estuarine mangroves harbour higher densities of juvenile fish than adjacent shallow-water and coral reef habitats in Curaçao (Netherlands Antilles)? Mar Ecol Prog Ser 245:191−204

Nagelkerken I, van der Velde G, Gorissen MW, Meijer GJ, van't Hof T, den Hartog C (2000) Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. Estuar Coast Shelf Sci 51:31−44

Nagelkerken I, Roberts CM, van der Velde G, Dorenbosch M, van Riel MC, Cocheret de la Morinière E, Nienhuis PH (2002) How important are mangroves and seagrass beds for coral-reef fish? The nursery hypothesis tested on an island scale. Mar Ecol Prog Ser 244:299−305

Nakagawa S, Schielzeth H (2013) A general and simple method for obtaining R^2 from generalized linear mixed-effects models. Meth Ecol Evol 4:133-142