The following supplement accompanies the article

Direct and indirect effects of invasive lionfish on coral-reef cleaning mutualists

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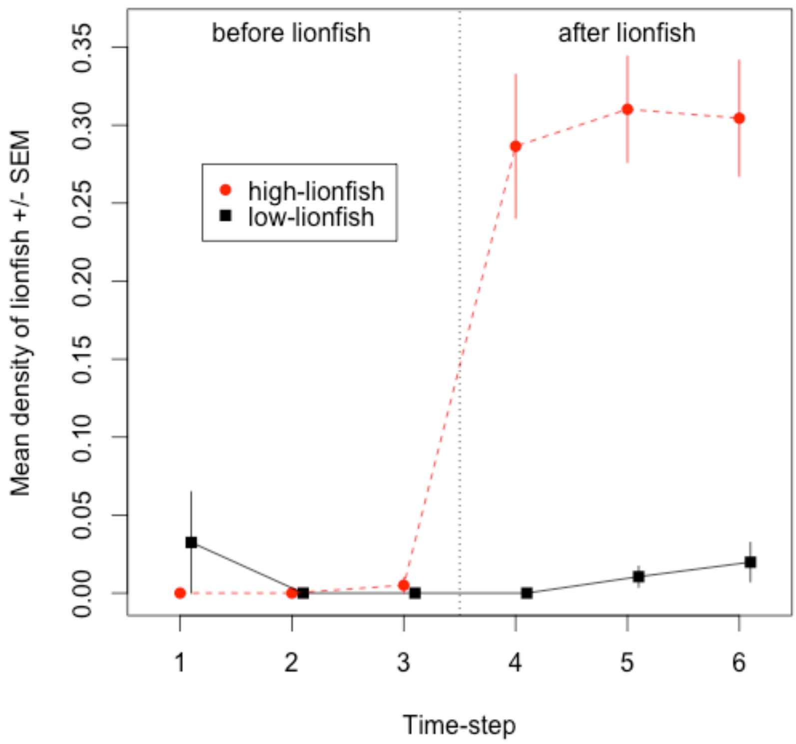

Fig. S1. Density of lionfish at experimental reefs. Dots represent means and error bars are SEM. Impact reefs with "high-lionfish" densities: n = 6; and control reefs with "low-lionfish" densities: n = 6.

Table S1. Potential client species that were surveyed during the study. Residency was based on the relative size of each species' typical home range over the course of a day on patch reefs in Rock Sound, Eleuthera, the Bahamas: resident = one patch reef (tens to hundreds of square meters) vs. transient = many patch reefs (>thousands of square meters).

Species Name	**Common Name**	**Residency**
Acanthurus bahianus	Ocean Surgeonfish	resident
Acanthurus chirurgus	Doctorfish	resident
Acanthurus coeruleus	Blue Tang	resident
Bodianus rufus	Spanish Hogfish	resident
Calamus calamus	Saucereye Porgy	resident
Cephalopholis cruentata	Graysby	resident
Chaetodon capistratus	Foureye Butterflyfish	resident
Diodon hystrix	Porcupinefish	resident
Epinephelus striatus	Nassau Grouper	resident
Gymnothorax funebris	Green Moray	resident
Gymnothorax moringa	Spotted Moray	resident
Haemulon album	Margate	resident
Haemulon aurolineatum	Tomtate	resident
Haemulon flavolineatum	French Grunt	resident
Haemulon melanurum	Cottonwick	resident
Haemulon plumierii	White Grunt	resident
Haemulon sciurus	Bluestripe Grunt	resident
Halichoeres bivittatus	Slippery Dick	resident
Halichoeres garnoti	Yellowhead Wrasse	resident
Halichoeres radiatus	Puddingwife	resident
Holocentrus adscensionis	Squirrelfish	resident
Holacanthus ciliaris	Queen Angelfish	resident
Holocentrus rufus	Longspine Squirrelfish	resident
Lutjanus griseus	Grey Snapper	resident
Lutjanus synagris	Lane Snapper	resident
Mycteroperca bonaci	Black Grouper	resident
Pomacanthus arcatus	Grey Angelfish	resident
Pomacanthus paru	French Angelfish	resident
Sargocentron coruscum	Reef Squirrelfish	resident
Sparisoma aurofrenatum	Redband Parrotfish	resident
Sparisoma radians	Bucktooth Parrotfish	resident
Sparisoma viride	Stoplight Parrotfish	resident
Stegastes leucostictus	Beaugregory	resident
Thalassoma bifasciatum	Bluehead Wrasse	resident
Urobatus jamaicensis	Yellow Stingray	resident
Caranx ruber	Bar Jack	transient
Canthidermis sufflamen	Ocean Triggerfish	transient
Chaetodipterus faber	Atlantic Spadefish	transient
Dasyatis americana	Southern Stingray	transient
Echeneis naucrates	Sharksucker	transient
Ginglymostoma cirratum	Nurse Shark	transient
Lutjanus analis	Mutton Snapper	transient
Ocyurus chrysurus	Yellowtail snapper	transient
Scomberomorus regalis	Cero	transient
Sphyraena barracuda	Great Barracuda	transient

Table S2. Akaike's Information Criterion (AIC) and p-values from likelihood-ratio tests (LRT and LRT p) used to determine whether or not to include a random effect, an auto-correlation term, and non-homogenous variance structures in the linear mixed effects models. Models were created with the *nlme* package in *R*. Model components: F = full fixed effects structure (*treatment, period, treatment*period*), R = random effect for *reef*, C = AR1 temporal autocorrelation structure for *time-step* nested in *reef*, and V = weighted term for variance to differ among *reef*. Likelihood-ratio tests comparing the full fixed effects model (F) to the model including a random effect for *reef* (F + R) incorporated an adjustment to the p-value to compensate for testing-on-the-boundary. The best-fitting model is indicated in **bold**. When the best-fitting model did not have an autocorrelation term, I chose to use model 3 (F + R + C) to account for non-independence due to repeated measures at reefs.

Response variable (units)	Model No.	Model components	d.f.	AIC	Model Comparison	LRT	LRT p
Density of cleaner goby (ind. m^{-2})	1	F	5	-96.093			
	2	F + R	6	-105.094	1 v 2	11.001	0.001
	3	F + R + C	7	-106.252	2 v 3	3.157	0.076
	4	**F + R + C + V**	**18**	**-105.261**	**3 v 4**	**21.010**	**0.033**
Change in mean total length (cm) of cleaner goby	1	F	5	11.602			
	2	F + R	6	4.153	1 v 2	9.448	0.002
	3	**F + R + C**	**7**	**0.031**	**2 v 3**	**6.123**	**0.013**
	4	F + R + C + V	18	14.391	3 v 4	7.640	0.745
Density of non-goby cleaners (ind. m^{-2})	1	F	5	-11.809			
	2	F + R	6	-53.427	1 v 2	43.617	<.0001
	3	**F + R + C**	**7**	**-56.192**	**2 v 3**	**4.765**	**0.029**
	4	F + R + C + V	18	-47.960	3 v 4	13.769	0.246
Density of juvenile bluehead wrasse (ind. m^{-2})* ^	1	F	5	-116.911			
	2	**F + R**	**6**	**-169.709**	**1 v 2**	**54.798**	**<.0001**
	3	F + R + C	7	-169.393	2 v 3	1.684	0.194
Density of banded coral shrimp (ind. m^{-2}) ^	1	F	5	-107.753			
	2	F + R	6	-147.851	1 v 2	42.097	<.0001
	3	**F + R + C**	**7**	**-153.716**	**2 v 3**	**7.865**	**0.005**
Density of obligate cleaner shrimps (ind. m^{-2}) ^	1	F	5	-80.067			
	2	F + R	6	-98.923	1 v 2	20.856	<.0001
	3	**F + R + C**	**7**	**-103.799**	**2 v 3**	**6.876**	**0.009**
Log(Density of resident clients (ind. m^{-2}))	1	F	5	148.050			
	2	F + R	6	99.712	1 v 2	50.338	<.0001
	3	F + R + C	7	94.502	2 v 3	7.210	0.007
	4	**F + R + C + V**	**18**	**40.768**	**3 v 4**	**75.734**	**<.0001**
Density of transient clients (ind. m^{-2})	1	F	5	-72.710			
	2	F + R	6	-73.207	1 v 2	2.497	0.114
	3	F + R + C	7	-77.020	2 v 3	5.813	0.016
	4	**F + R + C + V**	**18**	**-134.434**	**3 v 4**	**79.415**	**<.0001**

Response variable (units)	Model No.	Model components	d.f.	AIC	Model Comparison	LRT	LRT p
Density of yellowtail snapper (ind. m^{-2})	1	F	5	-60.459			
	2	**F + R**	**6**	**-73.802**	**1 v 2**	**15.343**	**<.0001**
	3	F + R + C	7	-72.173	2 v 3	0.372	0.542
Log(Density of prey-sized fishes (ind. m^{-2}))* "	**1**	**F**	**5**	**118.618**			
	2	F + R	6	120.618	1 v 2	0.000	1.000
	3	F + R + C	7	122.578	2 v 3	0.040	0.842
	4	F + R + C + V	18	135.282	3 v 4	9.296	0.595

* A model without an autocorrelation term was best-fitting. However, I chose to use model 3 (F + R + C) to account for temporal non-independence.
^ A model with non-homogenous variance structures by reef could not be created for this response variable.
" All prey-sized fishes (≤10 cm total length), excluding *Haemulon* spp., which outnumbered other prey by an order of magnitude at some reefs.

Table S3. Results from linear mixed effects (LME) models to test for effects of *treatment* (control vs. impact), *period* (before vs. after), and the *treatment*period* interaction on the response variables. LME models were fit by restricted maximum likelihood with p-values for fixed effects based on t-tests, using the *nlme* package in *R*. Significant p-values ($p < 0.05$) are indicated in bold. The indicator for all models (i.e., the group to which all categorical statistical comparisons are made) is After-Impact reefs. Where $\mu\{\text{response} \mid treatment, period\} = \beta_0 + \beta_1{*}treatment + \beta_2{*}period + \beta_3{*}treatment{*}period$, and *treatment* = 1 if control and 0 if impact, and *period* = 1 if before and 0 if after, $\boldsymbol{\beta_0}$ equals the mean response on After-Impact reefs. Also, $\boldsymbol{\beta_1}$ equals the difference in mean response between After-Control and After-Impact reefs, $\boldsymbol{\beta_2}$ equals the difference in mean response between Before-Impact and After-Impact reefs, and $(\boldsymbol{\beta_1} + \boldsymbol{\beta_2} + \boldsymbol{\beta_3})$ equals the difference in mean response between Before-Control and After-Impact reefs. $\boldsymbol{\beta_3}$ equals the difference between After-Control and After-Impact reefs, after accounting for the difference between Before-Control and Before-Impact reefs, i.e., how much more different the control and impact reefs were from each other after the addition of lionfish, given how different they were before the addition of lionfish.

Response variable (units)	Fixed Effects	Estimate (β_x)	Std. Error	d.f.	*t* value	*p*-value
Density of cleaner goby (ind. m^{-2})	Intercept	β_0 = 0.281	0.036	69	7.736	**<0.001**
	Treatment	β_1 = -0.001	0.052	10	-0.028	0.978
	Period	β_2 = 0.098	0.027	69	3.586	**0.001**
	Treatment x Period	β_3 = 0.033	0.041	69	0.806	0.423
Change in mean total length (cm) of cleaner goby	Intercept	0.711	0.096	57	7.434	**<0.001**
	Treatment	-0.042	0.136	10	-0.313	0.761
	Period	-0.331	0.082	57	-4.052	**<0.001**
	Treatment x Period	0.035	0.116	57	0.300	0.765
Density of non-goby cleaners (ind. m^{-2})	Intercept	0.230	0.072	58	3.206	**0.002**
	Treatment	0.140	0.101	10	1.378	0.198
	Period	0.037	0.046	58	0.789	0.434
	Treatment x Period	-0.121	0.066	58	-1.836	0.071

Response variable (units)	**Fixed Effects**	**Estimate (β_x)**	**Std. Error**	**d.f.**	***t* value**	***p*-value**
Density of juvenile bluehead wrasse (ind. m^{-2})	Intercept	0.101	0.035	58	2.886	**0.006**
	Treatment	0.073	0.050	10	1.478	0.170
	Period	0.044	0.018	58	2.522	**0.015**
	Treatment x Period	-0.053	0.025	58	-2.151	**0.036**
Density of banded coral shrimp (ind. m^{-2})	Intercept	0.082	0.035	58	2.367	**0.021**
	Treatment	-0.023	0.049	10	-0.475	0.645
	Period	-0.010	0.023	58	-0.430	0.669
	Treatment x Period	0.026	0.033	58	0.779	0.439
Density of obligate cleaner shrimps (ind. m^{-2})	Intercept	0.078	0.041	58	1.909	0.061
	Treatment	0.023	0.058	10	0.397	0.699
	Period	-0.016	0.034	58	-0.477	0.635
	Treatment x Period	-0.051	0.048	58	-1.062	0.293
log(Density of resident clients (ind. m^{-2}))*	Intercept	0.813	0.214	58	3.801	**<0.001**
	Treatment	0.157	0.310	10	0.505	0.624
	Period	0.002	0.021	58	0.080	0.937
	Treatment x Period	-0.116	0.067	58	-1.725	0.090
Density of transient clients (ind. m^{-2})	Intercept	0.015	0.009	58	1.725	0.090
	Treatment	0.074	0.024	10	3.025	**0.013**
	Period	0.013	0.012	58	1.118	0.268
	Treatment x Period	-0.065	0.031	58	-2.073	**0.043**
Density of yellowtail snapper (ind. m^{-2})	Intercept	0.007	0.043	58	0.160	0.873
	Treatment	0.133	0.061	10	2.200	**0.052**
	Period	0.008	0.035	58	0.241	0.810
	Treatment x Period	-0.095	0.050	58	-1.922	0.060
log(Density of prey-sized fishes** (ind. m^{-2}))*	Intercept	0.705	0.118	58	5.951	**<0.001**
	Treatment	0.541	0.168	10	3.227	**0.009**
	Period	0.132	0.166	58	0.793	0.431
	Treatment x Period	-0.633	0.235	58	-2.693	**0.009**

*These are the untransformed estimates for the model. Transformed estimates = $e^{\beta x}$.

**All prey-sized fishes (≤10 cm total length), excluding *Haemulon* spp., which outnumbered other prey by an order of magnitude at some reefs.

Table S4. Results from permutation-based multivariate analyses of variance (PERMANOVA) to test for effects of *treatment* (control vs. impact), *period* (before vs. after), and the *treatment*period* interaction on the multivariate response variables (communities). Species abundance data were log-transformed to reduce the influence of the most abundant species, and PERMANOVA used Bray-Curtis distance and 999 permutations constrained within reef. Analyses were done in the *vegan* package in R.

Community	**Fixed Effects**	**df**	**Sum of Squares**	**Mean Squared Error**	***F***	**R^2**	***p*-value**
Non-goby cleaners	Treatment	1	0.300	0.300	1.890	0.027	0.050
	Period	1	0.198	0.198	1.252	0.018	0.037
	Treatment x Period	1	0.099	0.099	0.624	0.009	0.278
	Residuals	67	10.617	0.158		0.947	
	Total	70	11.213			1.000	
Resident clients	Treatment	1	0.469	0.469	2.764	0.039	0.387
	Period	1	0.110	0.110	0.647	0.009	0.016
	Treatment x Period	1	-0.016	-0.016	-0.094	-0.001	0.993
	Residuals	68	11.548	0.170		0.953	
	Total	71	12.111			1.000	
Transient clients	Treatment	1	0.707	0.707	1.955	0.046	0.054
	Period	1	0.675	0.675	1.867	0.044	0.016
	Treatment x Period	1	0.386	0.386	1.067	0.025	0.297
	Residuals	38	13.745	0.362		0.886	
	Total	41	15.513			1.000	