

Supplementary Information

Cleaning mutualisms: potential effects on fish community structure and herbivory rates

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Table 1 Basic ecological information of recorded fish species. Species are organized by mean density from most to least common, with their family, trophic role (from FishBase), mean density across all study reefs, proportion of study reefs occupied (out of 25), and the proportion of all cleaner interactions associated with that species.

Fish Species	Family	Trophic Role	Mean Density (fish/m²)	Proportion of Reefs Occupied	Proportion of Cleaner Interactions
<i>Ctenochaetus striatus</i>	Acanthuridae	Herbivore/ Detritivore	0.2269	1	0.3208
<i>Chlorurus spilurus</i>	Labridae	Herbivore/ Detritivore	0.1307	1	0.0166
<i>Zebrasoma scopas</i>	Acanthuridae	Herbivore/ Detritivore	0.1157	1	0.2120
<i>Thalassoma hardwicke</i>	Labridae	Invertivore	0.1112	1	0.0096
<i>Chromis margaritifer</i>	Pomacentridae	Planktivore	0.1053	0.76	0.0157
<i>Stegastes nigricans</i>	Pomacentridae	Herbivore/ Detritivore	0.0756	0.88	0.0494
<i>Abudefduf sexfasciatus</i>	Pomacentridae	Planktivore	0.0730	0.44	0.0586
<i>Scarus psittacus</i>	Labridae	Herbivore/ Detritivore	0.0626	1	0.0446

<i>Acanthurus nigrofuscus</i>	Acanthuridae	Herbivore/ Detritivore	0.0461	0.88	0.0087
<i>Pseudocheilinus hexataenia</i>	Labridae	Invertivore	0.0401	1	0
<i>Paracirrhites arcatus</i>	Cirrhitidae	Piscivore	0.0337	0.84	0
<i>Centropyge flavissima</i>	Pomacanthidae	Herbivore/ Detritivore	0.0327	0.88	0.0004
<i>Halichoeres hortulanus</i>	Labridae	Invertivore	0.0212	0.92	0.0009
<i>Labroides dimidiatus</i>	Labridae	Invertivore	0.0208	0.52	0.0306
<i>Dascyllus flavicaudus</i>	Pomacentridae	Planktivore	0.0206	0.24	0.0481
<i>Canthigaster solandri</i>	Tetraodontidae	Omnivore	0.0202	0.80	0.0026
<i>Pomacentrus pavo</i>	Pomacentridae	Planktivore	0.0166	0.20	0
<i>Cirripectes variolosus</i>	Blenniidae	Herbivore/ Detritivore	0.0163	0.60	0
<i>Neoniphon sammara</i>	Holocentridae	Piscivore	0.0163	0.36	0.0004
<i>Stethojulis bandanensis</i>	Labridae	Invertivore	0.0144	0.68	0
<i>Chrysiptera brownriggii</i>	Pomacentridae	Omnivore	0.0144	0.40	0
<i>Heniochus chrysostomus</i>	Chaetodontidae	Corallivore	0.0138	0.60	0.0166
<i>Gomphosus varius</i>	Labridae	Invertivore	0.0129	0.64	0
<i>Gnathodentex aureolineatus</i>	Lethrinidae	Piscivore	0.0129	0.36	0
<i>Chaetodon ornatissimus</i>	Chaetodontidae	Corallivore	0.0121	0.76	0.0420
<i>Thalassoma amblycephalum</i>	Labridae	Planktivore	0.0113	0.12	0
<i>Cephalopholis argus</i>	Serranidae	Piscivore	0.0108	0.80	0.0013

<i>Sargocentron caudimaculatum</i>	Holocentridae	Piscivore	0.0104	0.64	0.0026
<i>Cheilodipterus artus</i>	Apogonidae	Piscivore	0.0096	0.04	0
<i>Balistapus undulatus</i>	Balistidae	Piscivore	0.0095	0.60	0
<i>Myripristis murdjan</i>	Holocentridae	Piscivore	0.0091	0.12	0.0017
<i>Dascyllus trimaculatus</i>	Pomacentridae	Planktivore	0.0091	0.12	0.0127
<i>Parupeneus multifasciatus</i>	Mullidae	Invertivore	0.0081	0.60	0.0210
<i>Chaetodon vagabundus</i>	Chaetodontidae	Corallivore	0.0079	0.52	0.0048
<i>Lutjanus fulvus</i>	Lutjanidae	Piscivore	0.0072	0.56	0.0004
<i>Labroides bicolor</i>	Labridae	Invertivore	0.0062	0.44	0.0052
<i>Chaetodon lunula</i>	Chaetodontidae	Corallivore	0.0059	0.28	0.0083
<i>Chaetodon citrinellus</i>	Chaetodontidae	Corallivore	0.0059	0.32	0.0013
<i>Halichoeres trimaculatus</i>	Labridae	Invertivore	0.0057	0.40	0
<i>Melichthys vidua</i>	Balistidae	Omnivore	0.0057	0.44	0.0013
<i>Chromis viridis</i>	Pomacentridae	Planktivore	0.0047	0.04	0.0004
<i>Cheilinus trilobatus</i>	Labridae	Invertivore	0.0047	0.52	0.0013
<i>Ecsenius midas</i>	Blenniidae	Planktivore	0.0047	0.08	0
<i>Chaetodon reticulatus</i>	Chaetodontidae	Corallivore	0.0045	0.40	0.0223
<i>Canthigaster bennetti</i>	Tetraodontidae	Omnivore	0.0043	0.20	0.0017
<i>Thalassoma quinquevittatum</i>	Labridae	Invertivore	0.0040	0.20	0
<i>Mulloidichthys flavolineatus</i>	Mullidae	Invertivore	0.0036	0.40	0.0009
<i>Monotaxis grandoculis</i>	Lethrinidae	Piscivore	0.0034	0.36	0

<i>Plagiotremus tapeinosoma</i>	Blenniidae	Piscivore	0.0032	0.24	0.0004
<i>Zanclus cornutus</i>	Zanclidae	Invertivore	0.0028	0.48	0
<i>Acanthurus triostegus</i>	Acanthuridae	Herbivore/ Detritivore	0.0025	0.20	0.0057
<i>Forcipiger longirostris</i>	Chaetodontidae	Corallivore	0.0023	0.32	0.0004
<i>Chaetodon auriga</i>	Chaetodontidae	Corallivore	0.0023	0.28	0.0031
<i>Parupeneus cyclostomus</i>	Mullidae	Invertivore	0.0023	0.24	0.0013
<i>Acanthurus lineatus</i>	Acanthuridae	Herbivore/ Detritivore	0.0023	0.08	0
<i>Epibulus insidiator</i>	Labridae	Piscivore	0.0021	0.32	0.0009
<i>Plectroglyphidodon lacrymatus</i>	Pomacentridae	Omnivore	0.0019	0.12	0
<i>Pristiapogon fraenatus</i>	Apogonidae	Invertivore	0.0019	0.08	0
<i>Ctenochaetus binotatus</i>	Acanthuridae	Herbivore/ Detritivore	0.0019	0.16	0.0013
<i>Chaetodon ephippium</i>	Chaetodontidae	Corallivore	0.0019	0.16	0
<i>Sargocentron microstoma</i>	Holocentridae	Piscivore	0.0019	0.16	0
<i>Diodon hystrix</i>	Diodontidae	Invertivore	0.0019	0.12	0.0087
<i>Corythoichthys flavofasciatus</i>	Syngnathidae	Invertivore	0.0017	0.24	0
<i>Chaetodon lunulatus</i>	Chaetodontidae	Corallivore	0.0015	0.08	0.0022
<i>Parapercis millepunctata</i>	Parapercidae	Piscivore	0.0015	0.20	0
<i>Sufflamen bursa</i>	Balistidae	Omnivore	0.0015	0.20	0

<i>Acanthurus nigricauda</i>	Acanthuridae	Herbivore/ Detritivore	0.0015	0.16	0
<i>Ostracion meleagris</i>	Ostraciidae	Invertivore	0.0013	0.28	0.0009
<i>Dascyllus aruanus</i>	Pomacentridae	Planktivore	0.0011	0.08	0
<i>Neocirrhites armatus</i>	Cirrhitidae	Piscivore	0.0008	0.08	0
<i>Pterois volitans</i>	Scorpaenidae	Piscivore	0.0008	0.08	0
<i>Halichoeres ornatissimus</i>	Labridae	Invertivore	0.0006	0.12	0
<i>Chromis iomelas</i>	Pomacentridae	Planktivore	0.0006	0.04	0
<i>Scarus frenatus</i>	Labridae	Herbivore/ Detritivore	0.0006	0.08	0
<i>Cheilinus chlorurus</i>	Labridae	Invertivore	0.0004	0.04	0.0013
<i>Sargocentron spiniferum</i>	Holocentridae	Piscivore	0.0004	0.04	0
<i>Rhinecanthus aculeatus</i>	Balistidae	Omnivore	0.0004	0.08	0
<i>Sargocentron praslin</i>	Holocentridae	Piscivore	0.0004	0.04	0
<i>Exallias brevis</i>	Blenniidae	Corallivore	0.0004	0.04	0
<i>Halichoeres marginatus</i>	Labridae	Invertivore	0.0002	0.04	0
<i>Coris gaimard</i>	Labridae	Invertivore	0.0002	0.04	0
<i>Coris aygula</i>	Labridae	Invertivore	0.0002	0.04	0
<i>Grammistes sexlineatus</i>	Serranidae	Piscivore	0.0002	0.04	0
<i>Anampses caeruleopunctatus</i>	Labridae	Invertivore	0.0002	0.04	0
<i>Plectroglyphidodon johnstonianus</i>	Pomacentridae	Herbivore/ Detritivore	0.0002	0.04	0
<i>Novaculichthys taeniourus</i>	Labridae	Invertivore	0.0002	0.04	0

<i>Lutjanus gibbus</i>	Lutjanidae	Piscivore	0.0002	0.04	0
<i>Synodus binotatus</i>	Synodontidae	Piscivore	0.0002	0.04	0
<i>Leptoscarus vaigiensis</i>	Labridae	Herbivore/ Detritivore	0.0002	0.04	0
<i>Canthigaster valentini</i>	Tetraodontidae	Omnivore	0.0002	0.04	0.0013
<i>Plectroglyphidodon dickii</i>	Pomacentridae	Omnivore	0.0002	0.04	0
<i>Arothron hispidus</i>	Tetraodontidae	Omnivore	0.0002	0.04	0
<i>Aulostomus chinensis</i>	Aulostomidae	Piscivore	0.0002	0.04	0

Table 2 Herbivory assays modeling summary. An ANOVA table detailing the results of two linear mixed effects models. The full model examines the main effects and interactions between algal species, cleaner presence, and time, as well as reef area, macroalgae coverage, and *Asparagopsis taxiformis* coverage as covariates. The simplified model examines only the main effects and interactions between algal species, cleaner presence, and time.

Full Model Results (All Covariates)						
	Sum Sq	Mean Sq	Num DF	Den DF	F	P
Algal Species	92.93	92.93	1	23	112.58	2.5×10^{-10}
Cleaner Presence	1.76	1.76	1	20	2.14	0.16
Time	25.36	25.36	1	346	30.72	5.9×10^{-8}
Reef Area	0.03	0.03	1	20	0.04	0.85
Macroalgae	0.01	0.01	1	20	0.01	0.92
<i>Asparagopsis taxiformis</i>	0.38	0.38	1	20	0.46	0.50
Algal Species X Cleaner Presence	1.03	1.03	1	23	1.24	0.28
Algal Species X Time	20.64	20.64	1	346	25.01	9.1×10^{-7}
Cleaner Presence X Time	0.14	0.14	1	346	0.17	0.68
Algal Species X Cleaner Presence X Time	0.31	0.31	1	346	0.38	0.54
Simplified Model Results (Algal Species, Cleaner Presence, & Time Only)						
	Sum Sq	Mean Sq	Num DF	Den DF	F	P
Algal Species	92.93	92.93	1	23	112.58	2.5×10^{-10}
Cleaner Presence	2.28	2.28	1	23	2.77	0.11
Time	25.36	25.36	1	346	30.72	5.9×10^{-8}
Algal Species X Cleaner Presence	1.03	1.03	1	23	1.24	0.28
Algal Species X Time	20.64	20.64	1	346	25.01	9.1×10^{-7}
Cleaner Presence X Time	0.14	0.14	1	346	0.17	0.68
Algal Species X Cleaner Presence X Time	0.31	0.31	1	346	0.38	0.54

Table 3 Feeding activities of different fish species in the herbivory assay videos. A summary of the feeding activities of different fish species that took bites on the deployed algae during the herbivory assays. Cameras were deployed for one hour, on 17 of the 25 study reefs

	<i>Asparagopsis taxiformis</i>		<i>Sargassum pacificum</i>	
Fish Species	Total Bites	Number of reefs on which feeding was observed	Total Bites	Number of reefs on which feeding was observed
<i>Ctenochaetus striatus</i>	14	3	17	4
<i>Acanthurus nigrofusus</i>	12	1	22	1
<i>Zebrasoma scopas</i>	9	1	3	2
<i>Centropyge flavissima</i>	3	1	1	1
<i>Melichthys vidua</i>	4	1	0	0
<i>Balistapus undulatus</i>	3	1	0	0
<i>Chlorurus spilurus</i>	0	0	13	2
<i>Ctenochaetus binotatus</i>	0	0	1	1

Table 4 Behavioral dynamics of *L. dimidiatus* client species. A summary of cleaner-client interactions for the twelve most common client species, which comprised 89% of all observed interactions. Cleans, cheats, and chases are the total number of all interactions observed on reefs with cleaners. Positivity is $\log_{10}(\text{cleans} / (\text{cheats} + \text{chases}))$, and the difference in density (fish/m²) is the mean density on the reefs with cleaners present minus the mean density on reefs with cleaners absent.

Client Species	Trophic Role	Cleans	Cheats	Chases	Total	Positivity	Difference in Density
<i>Ctenochaetus striatus</i>	Herbivore/ Detritivore	89	125	520	734	-0.860	-0.025
<i>Zebrasoma scopas</i>	Herbivore/ Detritivore	119	40	326	485	-0.488	0.078
<i>Abudefduf sexfasciatus</i>	Planktivore	3	17	114	134	-1.640	-0.079
<i>Stegastes nigricans</i>	Herbivore/ Detritivore	75	13	25	113	0.295	0.049
<i>Dascyllus flavicaudus</i>	Planktivore	92	13	5	110	0.709	0.020
<i>Scarus psittacus</i>	Herbivore/ Detritivore	9	9	84	102	-1.014	-0.023
<i>Chaetodon ornatissimus</i>	Corallivore	45	13	38	96	-0.054	-0.0003
<i>Chaetodon reticulatus</i>	Corallivore	30	7	14	51	0.155	0.002
<i>Parupeneus multifasciatus</i>	Invertivore	18	4	26	48	-0.222	0.018
<i>Chlorurus spilurus</i>	Herbivore/ Detritivore	6	5	27	38	-0.727	0.052
<i>Heniochus chrysostomus</i>	Corallivore	7	7	24	38	-0.646	0.007

<i>Chromis margaritifer</i>	Planktivore	26	4	6	36	0.415	0.098
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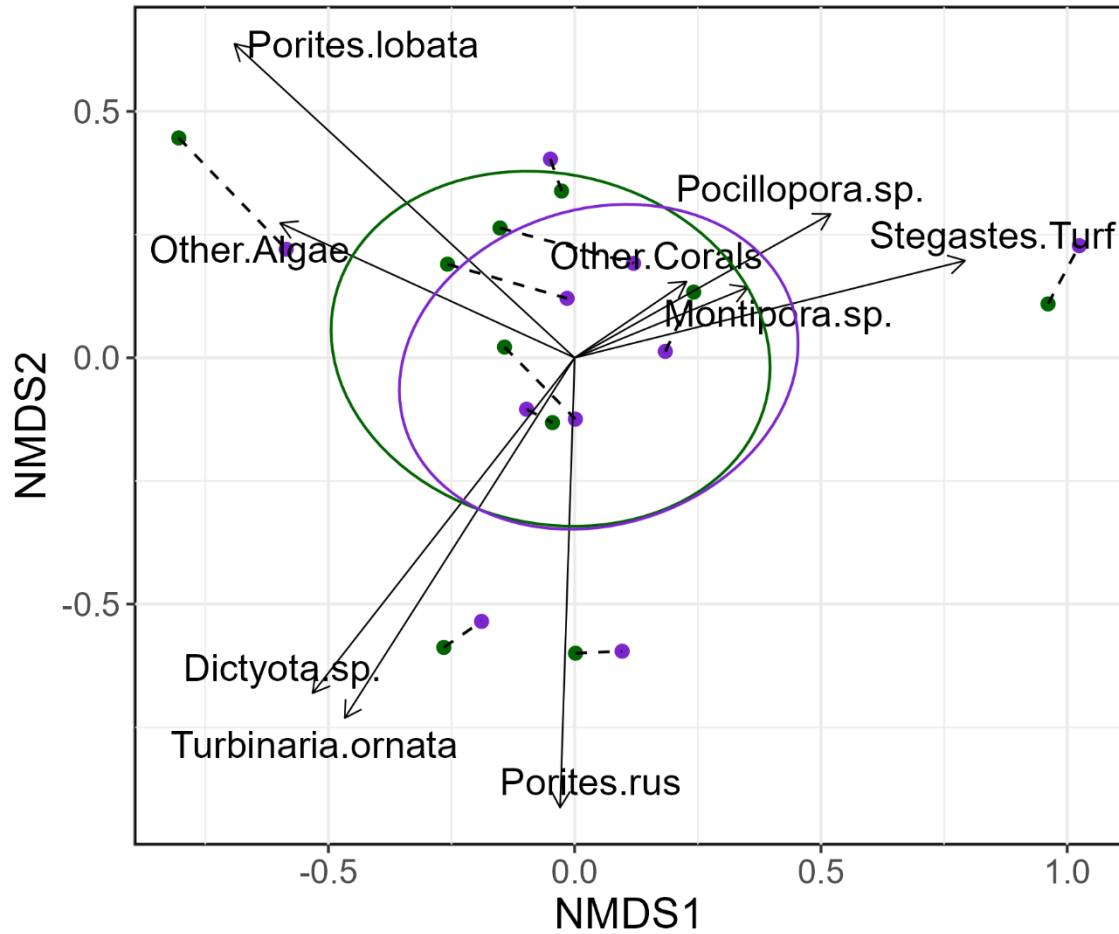


Figure 1. Consistency in coral and algal community assessments. A non-metric multidimensional scaling biplot comparing the relative abundance of different coral and algal substrates for ten randomly selected study reefs. The video was assessed two different times (green versus purple points) to evaluate the consistency with which substrates were quantified. Ellipses are the 95% confidence intervals for each group, and dashed lines connect the two assessments for each reef. The proximity of these pairs indicates relatively little disparity between the two sets of observations. NMDS and permutational multivariate analysis of variance (PERMANOVA) also indicate the two assessments were similar and not significantly different ($F_{1,18}=0.17$, $P=0.97$).