

Research Article

Corallivory and algal dynamics on some coral reefs in the Persian Gulf

Javid Kavousi^{1*}, Parviz Tavakoli-Kolour² and Sanaz Hazraty-Kari²

¹University in Brest, CNRS, IRD, Ifremer, LEMAR, F-29280 Plouzane, France

²Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, Sesoko 3422, Okinawa 905-0227, Japan

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*Corresponding author: Javid Kavousi, University in Brest, CNRS, IRD, Ifremer, LEMAR, F-29280 Plouzane, France, E-mail: javid.kavousi@gmail.com

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Abstract

Macroalgae are a sign of degradation of coral reefs. Distribution of macroalgae on reefs is moderated by grazers including fish and sea urchins. However, several fish species including certain parrotfishes graze on live coral tissues, at times causing profound damage. In this paper, the potential role of macroalgae in suppressing parrotfish predation on *Porites* corals, the dominant coral genus in Qeshm Island, is investigated at three research sites at Qeshm Island in the Persian Gulf between April and July 2014 and 2015. Macroalgae, which were abundant in April, decreased significantly in frequency in July, while at the same time, the percentage of *Porites* colonies, the frequency of fish bite marks on *Porites* colonies, and the overall area of live coral tissue, which was grazed by parrotfishes increased dramatically, all of which were only negligible in April (with certain exceptions). Nevertheless, no changes were observed in parrotfish abundance. Despite partially supportive statistical data, because of the observed exceptions, this phenomenon is more likely to be due to other factors, in particular the increased nutritional values of the corals in July in comparison to April. However, to understand the cause(s) and mechanisms involved in this annual phenomenon, more investigations seem necessary.

Introduction

Macroalgae including fleshy and filamentous algae have been considered serious threats to coral reefs [1,2]. Both filamentous algae [3] and macroalgae have negative effects on scleractinian corals, resulting in reef decline through coral-algae shifts, which change scleractinian coral-dominated reefs into macroalgae-dominated reefs [1,2,4]. Macroalgae diminish coral reefs by decreasing coral larval settlement, survival, growth rate, fecundity, resilience and recovery, and by causing bleaching and coral mortality [1,5]. Macroalgae on coral reefs are moderated by several factors such as physicochemical -e.g. temperature [6] -, geomorphological -e.g. substrate characteristic [7]- or biological -e.g. herbivores [8]-factors. The most important macroalgae-moderators, however, are herbivores, including sea urchin and fish [8,9]. In spite of this, corallivorous fishes are a threat to coral reefs themselves [10,11]. These fishes reduce coral abundance, diversity and colony size [11], coral expansion and spread, resistance to other stressors and resilience [12] and also increase coral mortality [13].

Although the role of herbivorous fishes in moderating macroalgal assemblies as well as the impact of corallivorous fishes on coral reefs is well documented, there is limited information on the effects of macroalgae on fish corallivory. It was it discerned that under experimental conditions, macroalgae can provide protection for juvenile corals against parrotfishes [14], which are among the most important coral predators preferring massive *Porites* corals on many reefs [12] and references therein). Moreover, field studies mainly focus on interactions among algae, fishes and juvenile corals (e.g. [15]. Hoey & Bellwood [16] showed that highly dense macroalgae could repel given fish species including parrotfishes from some reefs. This study implies that if there are any coral colonies among those macroalgal assemblages, they could be sheltered from fish corallivory, this hypothesis still needs to be tested directly.

In this study, field data is gathered to test if macroalgae are involved in moderating parrotfish predations of massive *Porites* colonies at Qeshm Island, the Persian Gulf. Several parameters,

including the percentage of coral colonies, the number of fish bites and the area of *Porites* spp. surface grazed by fishes in correlation to macroalgal cover were analyzed at the three designated research sites during April and July 2014 and 2015 to assess this hypothesis.

Material and methods

This study was done at the southeast of Qeshm Island ($26^{\circ}45'N$, $55^{\circ}49'E$), situated in the Persian Gulf. Coral reefs in this place are located near-shore, and are mainly less than 6 m deep dominated by massive *Porites* spp. for $89\% \pm 12.2\%$ (of live coral cover \pm standard deviation) [17]. Three sites, namely 1, 2 and 3 were chosen at the two ends as well as the middle of the reef site (Figure 1). Surveys of fish and benthic assemblages were performed in the middle of April, and then again in early July of 2014 and 2015. This time the scale was chosen based on our annual qualitative monitoring method launched in 2009, which includes the month in which grazed corals were abundant (i.e. July) as well as a short period before that when they were scarce (i.e. April).

To estimate benthic communities including grazed *Porites* and algal cover, five $30m^{-1}$ Line-Intercept transects were established at each site in each month. The only exception was site 3 in July 2014 with only 4 transects due to an unexpected event. We differentiate among Macroalgal (MA) cover, Filamentous Algal (FA) cover, and algal (MA + FA) cover. The number of fishes and *Porites* colonies grazed by fishes was counted in five $30*1m^{-2}$ -belt transects for each site. Since the fish bites on the colonies belonged to parrotfishes, we only show the data for this fish. Furthermore, $400cm^{-2}$ -photo-

quadrates were taken at $1m^{-1}$ intervals along each $30m^{-1}$ -transect to assess the frequency and extent of damage from parrotfish bite marks on *Porites* colonies between April and July. To this end, fish bites of parrotfishes were categorized into spot bites (i.e. individual, superficial bites) and focused bites (i.e. repeated overlapping deep bites resulting in extensive live tissue removal) [18]. The number of spot fish bites and the area of both spot and focused bites on *Porites* surfaces were counted and estimated using the software CPCe [19].

From April 2015, we calculated the number of bites of *S. persicus* on both *Porites* corals and algae min^{-1} [20], in three month intervals.

As the data sets did not meet the assumptions of parametric tests, and transformations did not work, the non-parametric Kruskal-Wallis test was applied to compare each factor among the sites in each month. Also, the Mann-Whitney U test was utilized for pairwise comparisons. We used the Holm-Bonferroni method (Holm 1979) to correct the p values to test the respective significant differences in each site between the months. The Significance level, was set at 0.05. Either the Pearson correlation test (when data sets were normally distributed) or the Spearman rho test was used to investigate the relationships between each type of algal groups (MA, FA or AL cover) and other factors. Statistical analyses were performed using SPSS (ver. 22) [21].

Results

Fish dynamics

There were only two species of parrotfishes present at

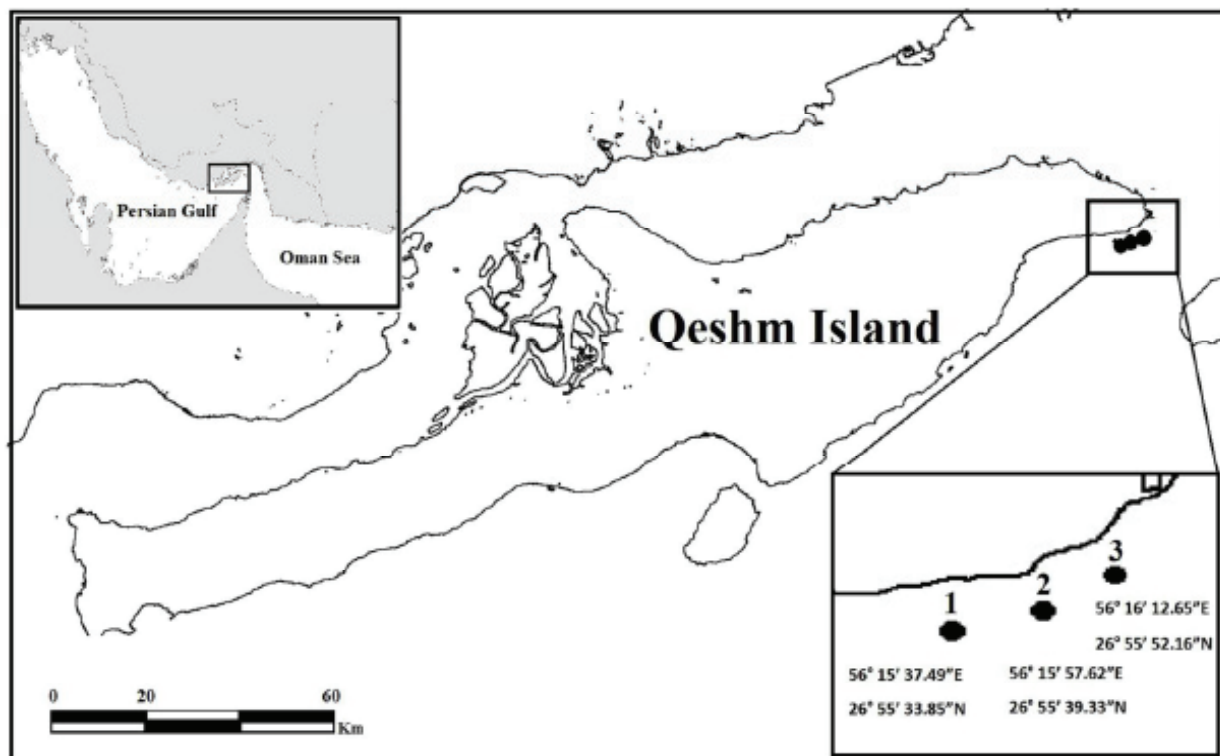


Figure 1: Map of Qeshm Island and the examined research sites in this study.

the studied sites viz. *Scarus ghobban* and *S. persicus*. The abundance of *S. ghobban* was extremely low at all three study sites in both sampling years (in average $0.2-0.6$ individual transect⁻¹). However, *S. persicus* was abundant in all the sites. In 2014, none of the fish species (Figure 2A,B) or size classes (not shown) showed any significant differences in number between the sampling months at each individual site. In 2015, both species showed significantly higher abundance in Site A in April (Figure 2C,D). Both fish species, size class 20 cm showed significantly higher abundance in April 2015 than in July. However, no difference was recorded for other size classes.

Benthic dynamics

In 2014, AL, MA and FA cover showed a significant decline in all sites in July compared to April, except AL and FA cover for site B (Figure 3A-C). In 2015, AL and FA did not differ significantly in site A; however, MA cover in Site A and AL, MA and FA cover in the other two sites significantly declined in July (Figure 4A-C). On the other hand, the other factors significantly increased in July compared to April in all sites in 2014 (Figure 3D-F) and in sites B and C in 2015 (Figure 4D-F). However, the percentage of live coral grazed and the number of spot fish bite marks m⁻² were higher in April at site A in 2015.

Correlational analyses between algal cover (including AL, MA and FA cover) and fish grazing related factors (including the percentage of *Porites* colonies, the frequency of fish bite marks on *Porites* colonies, and the overall area of live coral tissue,

which was grazed by parrotfishes) at site level in 2014 and 2015 did not show significant relations (Tables 1,2). At transect level, however, there were significant negative relationships between MA and other factors in both years, except between MA and the frequency of fish bite marks in 2015 (Tables 1,2). Such correlational tests when considering sites and transects showed non-significant relationships between either AL cover and fish grazing related factors or FA cover and fish grazing related factors.

Discussion

The results of this study invoke the question whether marine algae protected *Porites* colonies from parrotfishes in Qeshm Island. The results in both sampling years, 2014 and 2015, mainly showed increased fish grazing on *Porites* corals when the coverage of algae decreased. However, the correlational tests represented mixed results. The non-significant relationships at the site level in both years suggest that there was not enough evidence to confirm this hypothesis. On the other hand, correlational data, when considering transects, support the role of MA (but not FA or both MA and FA combined) in reducing the impacts of parrotfish grazing on the corals. This is backed by previous observations at the same sites. In September 2009, although macroalgae completely disappeared, short filamentous algae prevailed. Simultaneously, severe fish biting on more than 80% of the *Porites* colonies could be observed [17].

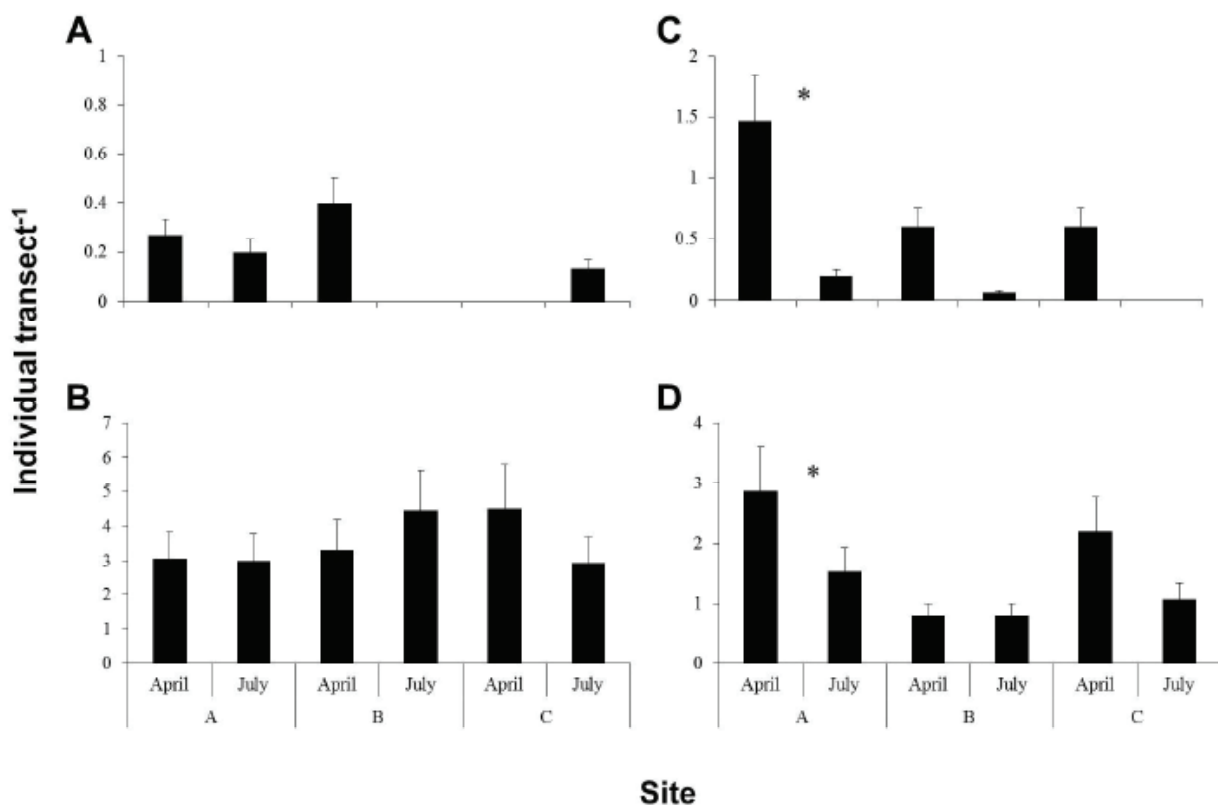


Figure 2: Parrotfish abundance at the studied sites. Abundance of **A)** *Scarus ghobban* and **B)** *S. persicus* in 2014 and **C)** *Scarus ghobban* and **D)** *S. persicus* in 2015. Asterisk show significant differences between sampling months.

Previously, it was found that experimental removal of algae from around the juvenile corals could increase parrotfish predations of those corals [14]. It was suggested that coral camouflaging and creating microhabitats with lower graze rates were two mechanisms by which algae could protect juvenile corals against parrotfishes [14]. However, none of these appeals to the present study because the massive *Porites* colonies in this work, which in some cases were 2–3 m in size, could not be sheltered from fish predation by either camouflage or microhabitats. Thus, we have to consider other mechanisms before entertaining the idea whether macroalgae prevented fish predation of *Porites* corals at Qeshm Island.

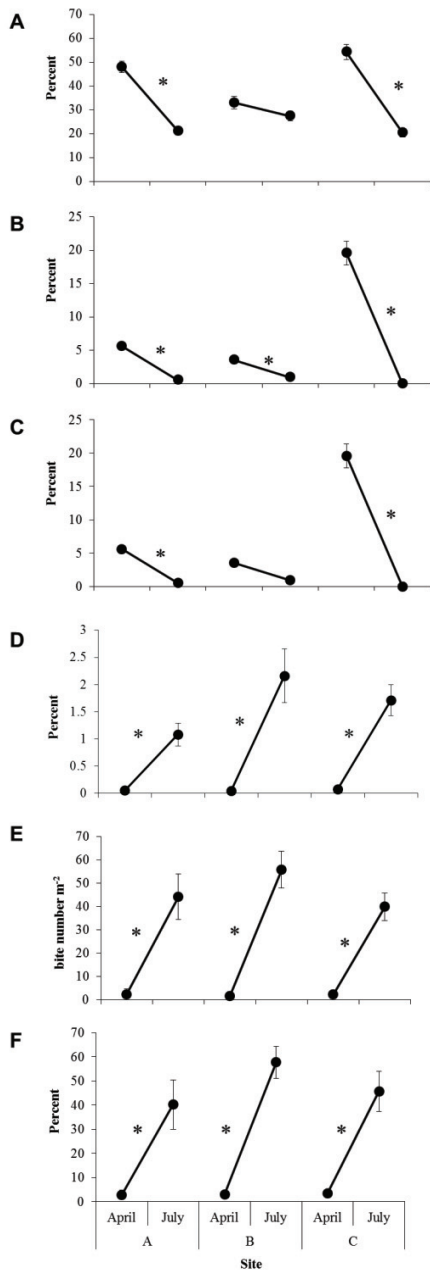


Figure 3: A) Algal cover (combined macroalgae (MA) and filamentous (FL) algae) B) MA cover C) FA cover D) live coral tissue grazed by parrotfish E) number of spot fish bite marks m² of live coral surface area F) percent *Porites* colonies with fish bite marks d) in April and July 2014 at three research sites. Error bars show standard errors. Asterisk show significant differences between sampling months.

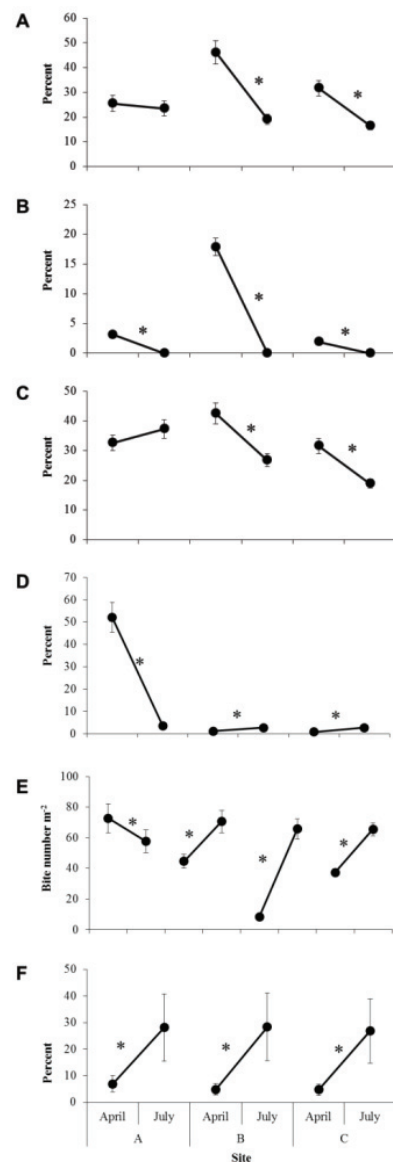


Figure 4: A) Algal cover (combined macroalgae (MA) and filamentous (FL) algae) B) MA cover C) FA cover D) live coral tissue grazed by parrotfish E) number of spot fish bite marks m² of live coral surface area F) percent *Porites* colonies with fish bite marks in April and July 2015 at three research sites. Error bars show standard errors. Asterisk show significant differences between sampling months.

Increase in adult parrotfish number in July rather than in April

It is shown that increase in the abundance of adult corallivore fishes usually leads to higher grazing on corals [12, 22,23]. In the present study, the unusual increases in fish bite marks on coral colonies and the number of grazed colonies at site A in April 2015 compared to July could be due to the significantly higher abundance of adult fishes of both species. On the other hand, in neither July 2014 nor July 2015, did fish abundance show changes compared to April. Therefore, we cannot relate the observed phenomenon to parrotfish abundance.

Declining food resources increased corallivory

Parrotfishes are essential to some coral reefs because they feed on macroalgae [10,11]. Bellwood & Choat [24] showed

that the majority of *Scarus* species in the Great Barrier Reefs consume epilithic algae. Carpenter, et al. [25] also reported that *Scarus* spp. in the Persian Gulf were mainly grazers on shallow benthic algae. However, neither the study by Carpenter, et al. [25] nor any other study presents any information on the diet of *S. persicus*. In spite of this, field observations confirm that this species seems to be a scraper (i.e. it takes a piece of substratum and its accompanying algae in each bite [26] and eats filamentous algae (P. Tavakoli-Kolour, pers. obsv). In September 2009, although macroalgae completely disappeared, short filamentous algae prevailed. Simultaneously, severe fish biting on more than 80% of the *Porites* colonies could be observed [17]. Filamentous algae are favorable food sources for herbivorous fish [28], and are more desirable, palatable and digestible than fleshy algae [27-29]. Therefore, high corallivory rates in September, when filamentous algae were abundant at the research locations, cannot be attributed to scarcity of food.

Macroalgae prevented parrotfish grazing on *Porites* corals

It has been proven that herbivorous coral reef fishes avoid dense macroalgae patches and prefer places with lower macroalgae [16]. Thus, if there are coral colonies among such dense macroalgae, they are most likely naturally protected from fish corallivory. In this study, there was no change in parrotfish distribution at any site between April and July, which suggests that macroalgae did not repel fish from the reefs. The increased

Table 1: Correlational analyses between algal cover (including AL, MA and FA cover) and fish grazing related factors (including CCG= the overall area of live coral tissue which was grazed by parrotfishes, FBN= the frequency of fish bite marks on *Porites* colonies, and PCG= the percentage of *Porites* colonies grazed by parrotfishes,) at site and transect levels in 2014. Significant results are shown in bold.

Sites				
		CCG	FBN	PCG
AL	Pearson Correlation	-0.744	-0.798	-0.796
	Sig. (2-tailed)	0.90	0.057	0.058
	N	6	6	6
MA	Spearman's rho	-0.600	-0.600	-0.657
	Sig. (2-tailed)	0.208	0.208	0.156
	N	6	6	6
FA	Pearson Correlation	-0.699	-0.760	-0.759
	Sig. (2-tailed)	0.122	0.080	0.080
	N	6	6	6
Transects				
		CCG	FBN	PCG
AL	Spearman's rho	-0.313	-0.318	-0.361
	Sig. (2-tailed)	0.098	0.093	0.054
	N	29	29	29
MA	Spearman's rho	-0.438	-0.463	-0.454
	Sig. (2-tailed)	0.018	0.011	0.013
	N	29	29	29
FA	Spearman's rho	-0.245	-0.267	-0.334
	Sig. (2-tailed)	0.200	0.161	0.076
	N	29	29	29

Table 2: Correlational analyses between algal cover (including AL, MA and FA cover) and fish grazing related factors (including CCG= the overall area of live coral tissue which was grazed by parrotfishes, FBN= the frequency of fish bite marks on *Porites* colonies, and PCG= the percentage of *Porites* colonies grazed by parrotfishes,) at site and transect levels in 2015. Significant results are shown in bold.

Sites				
		CCG	FBN	PCG
AL	Pearson Correlation	0.029	-0.314	-0.314
	Sig. (2-tailed)	0.957	0.544	0.544
	N	6	6	6
MA	Spearman's rho	-0.314	-0.086	-0.657
	Sig. (2-tailed)	0.544	0.872	0.156
	N	6	6	6
FA	Pearson Correlation	0.029	-0.314	-0.314
	Sig. (2-tailed)	0.957	0.544	0.544
	N	6	6	6
Transects				
		CCG	FBN	PCG
AL	Spearman's rho	0.139	0.255	-0.151
	Sig. (2-tailed)	0.464	0.174	0.425
	N	30	30	30
MA	Spearman's rho	-0.365	-0.127	-0.624
	Sig. (2-tailed)	0.047	0.505	0.000
	N	30	30	30
FA	Spearman's rho	0.200	0.270	-0.016
	Sig. (2-tailed)	0.290	0.149	0.934
	N	30	30	30

fish abundance at site A in April 2015 backs this hypothesis. Thus, the low fish bite rates in April must be attributed to other factors. For example, macroalgal cover might prevent fish from grazing on corals through other mechanisms, most likely producing chemicals, which are reported to exist in macroalgae [30]. Recently, it has been shown that both coral larvae and juvenile fishes of different species avoid waters with water soluble chemicals produced by macroalgae [31]. However, the mixed statistical results and low macroalgal cover at two sites in April in each year (~5%) bring up two other hypotheses that may be involved in the findings of this study.

Increased water temperature increased corallivory

Previous studies show that changes in water temperature can change the food intake rate [32-34]. Some studies show that increases in water temperature increase metabolism and nutrient requirement rate among fishes [34-37]. Water temperature obviously increases in the Persian Gulf in summer, which could explain the potential increase in graze rate by the fishes, which, however, did not happen. Indeed, there was a significant increase in the number of fish bite min⁻¹ (only on algae) in February 2016, when it was cold. Despite this, even if there was an increase in fish grazing rates due to elevated temperatures, the reason(s) why there was a shift from the main food source of *S. persicus* (whatever kind it is) to corals may not be explained by increased seawater temperature.



Enhanced nutrient contents of *Porites* corals increased corallivory

Parrotfishes selectively graze on nutrient-rich foods [38–40]. Rotjan & Lewis [41–45] showed that parrotfishes selectively graze on high reproductive polyps within a single colony known to have higher nutritional values than non-reproductive polyps. Unfortunately there is no information on reproduction of *Porites* spp. (the focus of this study) in Qeshm Island. However, coral eggs were taken with a Neuston net on the 20th of August 2009 and also on the 21st of August 2011 somewhere between southeast of Qeshm Island (our studied site) and northwest of Larak Island (H. Rezai, personal communication). Personal observations at two other Iranian Islands (Kish and Larak Islands) suggest June and August as the peak months of spawning [42]. As no study has specifically monitored reproduction of *Porites* spp. in Qeshm Island, we cannot be certain about the exact month in which the highest proportion of colonies with mature oocytes peaked. Therefore, it is difficult to relate the increased corallivory to coral reproduction. However, the observed coral spawning in August makes it likely that *Porites* colonies were rich in nutrients in June/July and attracted parrotfishes.

This study brings up the hypothesis of the naturally protective role of macroalgae of adult corals against parrotfishes. This ecological process is an annual phenomenon happening among the southeastern reefs of Qeshm Island sometime in June, July or September of every year. Although there is some supporting data, this phenomenon is more likely to be related to enhanced corals' nutrition (or another factor), in particular, to the fact that the macroalgal cover was not dense enough to hide or somehow impact large coral colonies (~5% at sites A and B in April 2014, and 5% at sites A and C in April 2015). Therefore, the increased impacts of parrotfishes on *Porites* colonies while macroalgal cover decreased at Qeshm Island may be coincidental.

The coral colonies grazed by parrotfishes in September 2009 were found to have fully healed by November of the same year [17]; however, in our most recent study in August 2014, partial coral mortality due to fish biting was also observed, and in 2015, the grazed colonies were observed even in October. Therefore, healing is not always an option. To better understand this phenomenon, further investigation in particular at other reef sites is deemed necessary.

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