

Experimental demonstration of no effect by the cleaner wrasse *Labroides dimidiatus* (Cuvier and Valenciennes) on the host fish *Pomacentrus moluccensis* (Bleeker)

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Abstract

To date, the benefits of cleaner fish to host fish have not been clearly identified. This study investigates the effect of the cleaner wrasse *Labroides dimidiatus* (Cuvier and Valenciennes) on the host damselfish *Pomacentrus moluccensis* (Bleeker) by excluding all cleaner fish from 8 reefs for 6 months at Lizard Island, Great Barrier Reef. The subsequent effect of cleaner removal on parasites (total number, number per category of parasite, and size of parasite) and host abundance was estimated and compared to control reefs where *L. dimidiatus* were not removed. Parasite loads of *P. moluccensis* were low (usually 0–3 per fish) on all reefs after the experiment, and were dominated by small copepod larvae (260–1370 μm). The removal of *L. dimidiatus* had no detectable effect on the mean number of parasites per host, either across all parasite taxa combined or by each parasite taxon individually. Nor did I detect a difference in the mean size of the most abundant copepod species. There was, however, a significant difference in the mean number of parasites (combining all species) per fish among reefs irrespective of the presence of *L. dimidiatus*. This difference was not correlated with *P. moluccensis* abundance. The abundance of *P. moluccensis* declined during the experiment (7–33%) but the decline did not differ among reefs with and without *L. dimidiatus*. This result suggests that *P. moluccensis* did not leave reefs and seek cleaning elsewhere, nor did this host suffer increased mortality in the absence of *L. dimidiatus*. The absence of any detectable effect of *L. dimidiatus* on the parasites of *P. moluccensis* is compatible with the selective feeding habits of *L. dimidiatus*. It is likely that factors other than ectoparasite removal motivate *P. moluccensis* to seek cleaning.

Keywords: Cleaning symbiosis; Coral reef fish; Ectoparasites; Fish behavior; Great Barrier Reef; *Labroides dimidiatus*

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1. Introduction

The ecological significance of cleaning behavior in the marine environment is still poorly understood, despite many studies (see review by Losey, 1987). Although there is no doubt that cleaner fish benefit from cleaning, which provides them with food (Randall, 1958; Youngbluth, 1968; Gorlick, 1980), the benefit of cleaning for host fish remains unresolved (Youngbluth, 1968; Losey, 1972; Gorlick et al., 1987). Recent work has shown that individuals of some diurnal species spend a significant proportion of their time being cleaned (up to 32 min per day and 144 visits) (Grutter, 1995a). Thus, it appears that cleaning is important, but as yet there is little evidence which suggests a particular benefit to the host.

In considering the ecological effects that drive cleaning interactions, ultimate and proximate causation must be separated (Gorlick et al., 1987; Losey, 1987, 1993). Ultimate causation or adaptive value refers to factors which result in the evolution of the association, such as increased reproductive success as a result of ectoparasite removal by cleaner fish, proximate causation refers to factors that maintain the behavior, such as the attraction of fish to cleaners (Gorlick et al., 1987). An obvious candidate for the ultimate cause of cleaning in fish is ectoparasite removal. A direct experimental test of this ultimate cause would be to remove all cleaners and measure any subsequent effects on parasites and hosts (Losey, 1972, 1987). These effects can be measured as variation in parasite infection, changes in host condition and or abundance, or by an increase in cleaning by other organisms (Losey, 1972, 1987).

This experiment has been done several times with different results. Only one experiment has shown that the removal of cleaners results in increased infection or emigration of host fish (Limbaugh, 1961). Limbaugh's study, conducted in the Bahamas, removed 'all the known cleaning organisms (p. 49)' but no quantitative data and controls were used. Youngbluth (1968) found no increase in infection of host fish nor change in density of fish when he removed all cleaner fish, *Labroides phthirophagus* from a reef in Hawaii. However only 'approximations of numbers of parasites (p. 916)' were used and fish abundance was not directly quantified. A more quantitative study by Losey (1972), at the same sites used by Youngbluth (1968), found no increase in parasite abundance nor changes in fish abundance in the absence of cleaner fish.

In a detailed quantitative removal study, Gorlick et al. (1987) found that the number of parasites was not affected but that parasites were larger in the absence of cleaner fish. This study was made at Enewetak Atoll and involved the cleaner fish *Labroides dimidiatus* (Cuvier and Valenciennes) and one host fish species (*Pomacentrus vaiuli*) which had only a single parasite species. This was the first quantitative demonstration of an effect of cleaner fish on an ectoparasite. Whether hosts benefitted as a result of the decrease in parasite size could not be determined (Gorlick et al., 1987).

A different approach to this problem was taken by Grutter (1996). Estimates of the rate at which cleaner fish remove parasites (mainly gnathiid isopod larvae) from fish were compared to the standing crop and infection rate of gnathiids on fish. The study found that *L. dimidiatus* may suppress the abundance of gnathiids

on the fish species *Hemigymnus melapterus* (Bloch 1791) (Labridae). However, the long term effect of cleaning on gnathiid abundance was not determined.

Examination of the diet of a cleaner fish provides information on the potential effect its feeding habits may have on hosts. The numbers of parasites in the diet of *L. dimidiatus* at Lizard Island (Grutter, 1996) were much higher than in Japan (Chikasue, 1990), Enewetak Atoll (Losey, pers. comm.), and at Heron Island (Grutter, 1995b). Guts of cleaner fish at Heron Island contain more mucus and non-parasitic copepods than at Lizard Island (Grutter, 1995b). These patterns suggest that *L. dimidiatus* may be targeting parasites more at Lizard Island. *Labroides dimidiatus* at Lizard Island also feed selectively among species of parasites (Grutter, 1995b) and therefore may influence the species composition of their prey. The only quantitative *L. dimidiatus* removal experiment to date (Gorlick et al., 1987) was made in an area where cleaner fish have few parasites in their diet (Losey, pers. comm.) and which at times eat zooplankton (Losey, 1979). It also involved a host fish which only had one parasite species. A study on reefs where ectoparasites comprise a larger fraction of the cleaner fish diet and host fish have a range of parasites provides a more appropriate ecological setting to examine the effect of cleaner fish on hosts.

The aim of this study was to evaluate experimentally the influence of *L. dimidiatus* on the parasites and abundance of the host fish *P. moluccensis* (Bleeker). This host species was selected to test this hypothesis because it is abundant and ubiquitous on isolated reefs at Lizard Island, Great Barrier Reef (14° 40' S, 145° 26' E). It also has sedentary habits and so is unlikely to move between reefs. Out of 700 individually marked *P. moluccensis* which were recaptured 2–4 times per year for 6 yr, only two were found to move more than 10 m (Mapstone, 1988). In addition, their home ranges are small, $\gg 2$ m maximum radius (B. Mapstone, unpubl. data).

Over a 6-month period at Lizard Island, the cumulative amount of cleaning that individual *P. moluccensis* receive is likely to be substantial. On average, each individual *P. moluccensis* was inspected by *L. dimidiatus* 0.89 (\pm SE 0.25) times every 30 min and for 1.5 (\pm SE 0.27) sec every 30 min (Grutter, 1995a). Thus, over the entire 6 months, an individual fish would have been inspected by *L. dimidiatus* about 4000 times or for about 108 min. *Labroides dimidiatus* at Lizard Island feed on parasitic caligid copepod larvae, which are found on *P. moluccensis*. *Pomacentrus moluccensis* at this site also has several other species of parasites. This range of parasites is ideal for testing whether *L. dimidiatus* has an effect on the species composition of parasites. Thus, this study is the first quantitative cleaner-removal experiment in an area which has a high rate of parasite feeding by cleaner fish (Grutter, 1996).

2. Materials and methods

The experiment was conducted at Lizard Island in lagoonal habitats with sandy bottoms which reduced the likelihood of movement of fish between reefs. Ten of the reefs (5 removal, 5 control) were situated at one site (Lagoon) and six (3

removal, 3 control) were situated at another site (Casuarina Beach) (Fig. 1). Reef treatments at each site were determined haphazardly. The reefs at the Lagoon site were at a depth of 2.0–7.3 m and were 8.0–26.5 m from the nearest reef (except for two control reefs which were 5.8 m apart). Reefs at the Casuarina Beach site were at a depth of 5.2–7.3 m and were 9.2–15.6 m from the nearest reef. The mean area of control reefs was $102 \text{ m}^2 \pm \text{SE } 25$ and the mean area of removal reefs was $74 \pm \text{SE } 13$ (Table 1) (Projected areas of reefs were estimated using aerial photos and the software Framegrabber 3.2 and Image 1.4.).

The appropriate reefs and fish species for the removal experiment were selected in a pilot study (January 1993). A survey of 40 sites at Lizard Island was made to select reefs which had *L. dimidiatus* yet were sufficiently isolated from other reefs that movement of *L. dimidiatus* among reefs was unlikely. To select a fish species

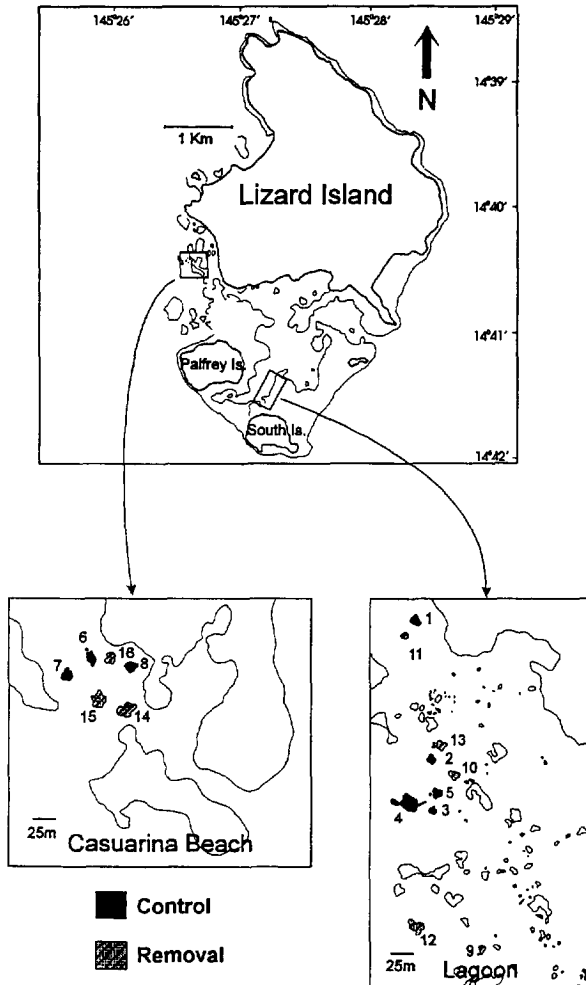


Fig. 1. Map of Lizard Island showing the locations of eight control and eight cleaner-removal reefs.

Table 1

The number of *L. dimidiatus* (adults/juveniles) per reef on the 4 months (1993) sampled

Reef	Treatment Area (m ²)	April 24–29	May 21–23	July 18–23	Oct. 13–25	
1	C	72	3/0	NA	2/2	2/2
2	C	47	3/0	NA	3/0	3/0
3	C	31	2/4	NA	2/3	2/4
4	C	245	3/0	NA	3/2	3/2
5	C	124	2/2	NA	2/2	2/1
6	C	40	3/1	NA	3/3	3/0
7*	C	115	3/3	NA	3/2	3/2
8*	C	146	3/3	NA	3/1	3/1
9	R	52	-2/2	-0/1	0/0	-0/1
10	R	29	-2/3	0/0	0/0	-0/1
11	R	41	-2/0	0/0	-0/1	-0/2
12	R	125	-2/1	0/0	-0/1	-0/1
13	R	76	-2/1	0/0	-0/1	0/0
14*	R	52	-3/5	0/0	0/0	0/0
15*	R	125	-3/5	0/0	-0/2	-0/1
16	R	91	-2/4	0/0	0/0	0/0

* *P. moluccensis* not censused. C = Control, R = Removal. (-) indicates *L. dimidiatus* removed. NA = Not available. Adults were ≥ 50 mm.

that was relatively abundant and present on all selected reefs, the abundance of 13 relatively common and abundant fish species was quantified. *Pomacentrus moluccensis* was selected as an abundant and ubiquitous species on which a variety of parasites were found.

Recruitment of *L. dimidiatus* juveniles onto reefs at Lizard Island is seasonal and occurs largely during the austral summer, with much less recruitment during April to October (A. Green, pers. comm.). Similar patterns of recruitment also occur in *P. moluccensis* (B. Kerrigan, pers. comm.). The experiment was therefore conducted during April to October to reduce the likelihood of *L. dimidiatus* recruiting onto cleaner-removal reefs and to reduce variation due to recruitment of juvenile *P. moluccensis*. All *L. dimidiatus* were removed (see section 2.1. Removal of *L. dimidiatus*) from eight reefs in April 1993. Eight control reefs were similarly disturbed by the process of searching for and counting *L. dimidiatus*. Reefs were surveyed for *L. dimidiatus* in May, July, and October 1993 and any new *L. dimidiatus* on removal reefs were removed. The abundance of *P. moluccensis* was estimated (see section 2.3. Fish abundance estimates) in April, prior to *L. dimidiatus* removals, and repeated in July and at the end of the experiment in October. *Pomacentrus moluccensis* for parasite analysis were randomly selected on removal and control reefs and collected in October after their final abundance was estimated.

2.1. Removal of *Labroides dimidiatus*

All *L. dimidiatus* were removed from eight reefs during 24–29 April 1993; another eight reefs were used as undisturbed controls. Reef treatments at each site were determined randomly. Subsequent checks, made at intervals of several

days for a period of 2 wk, revealed no additional *L. dimidiatus*. The number of *L. dimidiatus* removed per reef ranged from 2–8 individuals 27–67 mm in standard length (SL) (Table 1). Control reefs had between 3 and 6 *L. dimidiatus* per reef. During a survey on 23 May, 1993, one *L. dimidiatus* juvenile (about 23 mm in SL) was found on a removal reef and removed; on 20–21 July, 1993, five *L. dimidiatus* juveniles (14, 16, 19, 22, and 42 mm in SL) were found on removal reefs and also removed. On the final survey (21–25 October, 1993), 6 additional *L. dimidiatus* (1.1, 1.3, 2.3, 3.9, 4.9, 4.9 mm in SL) were found on removal reefs and also removed (Table 1).

2.2. Collection of parasites

Pomacentrus moluccensis ($n = 10\text{--}13$ per reef) were collected at the end of the experiment on 19–30 October 1993 with a net, fixed in 10% formalin, and their parasites quantified by scanning the fish under a microscope ($35\times$) following Grutter (1994). Parasites were measured using an eyepiece micrometer and identified to lowest taxonomic grouping (usually family).

2.3. Fish abundance estimates

The total number of *P. moluccensis* per reef was estimated by slowly swimming around each reef and counting each individual. Two replicate counts were made, one after the other, and the mean used in the analyses. Counts were made on 12 reefs (6 removal, 6 control) (Table 1). Fish on the remaining four reefs (Table 1) were not counted as these reefs had a relatively large surface area, mainly due to their greater height and variable habitat structure, which made counting of *P. moluccensis* too time-consuming and inaccurate. Counts were made at intervals of about 3 months (13–23 April, 1993, 18–23 July, 1993, and 13–17 October, 1993).

2.4. Statistical analyses

Differences in the number of parasites (species combined) per host between treatments (removal and control) and among reefs were tested using a nested analysis of variance (ANOVA) with reefs (random) nested in treatments, and reefs used to test the main treatment effect. Thus, reefs were used as replicates. The number of parasites per host in each category of parasite, combined across reefs, was tested for differences between treatments using a multivariate analysis of variance (MANOVA). Data were $\ln(x + 1)$ transformed to satisfy the assumptions of homogeneity of variance in the ANOVAs and MANOVA.

The size frequency distribution of an unknown species of caligiform copepod (sp. a) (combined among reefs) was tested for differences between treatments using chi-square analysis of homogeneity. To determine whether there was sufficient power to detect the same difference in size of parasites that Gorlick et al. (1987) found for treatment reefs ($21\% \pm \text{SD } 2.19$), a randomization test was conducted. The sample sizes in this simulation were the number of caligiform

copepods per treatment. Sixty 'controls' were drawn at random (with replacement) from the population of the copepod. To obtain estimates of 'removal' sizes, 77 samples were drawn similarly and multiplied by the proportional difference in size that Gorlick et al. (1987) found. The size frequencies per size class were then calculated for 'controls' and 'removal' and a chi-square analysis with Yate's correction performed. The simulation was run for 4000 iterations.

To test for differences in the abundance of *P. moluccensis* over time and between treatments, a multivariate repeated-measures analysis was used with treatment as a between-subjects factor and time as a within-subjects factor. To evaluate possible relationships between reef area, parasite abundance and density, *P. moluccensis* abundance and density, and *L. dimidiatus* abundance and density, correlation coefficients for several combinations of these variables were calculated.

3. Results

Pomacentrus moluccensis abundance per reef declined significantly over the 6-month duration of the study (Pillai's Trace = 0.768, $F = 14.919$, $df = 2, 9$, $p = 0.001$) (Fig. 2); however, the interaction term (time \times treatment) was not significant (Pillai's Trace = 0.065, $F = 0.314$, $df = 2, 9$, $p < 0.738$) which indicates that the decline did not differ among treatments. Although the number of *P. moluccensis* increased on some reefs between April and July, the lowest numbers were found in October (Fig. 2).

Taxonomically, diverse parasites occurred on *P. moluccensis* and all were relatively small (Table 2). The gill copepod, *Hatschekia crenulatus*, was represented by females (some with eggs) and was the only adult copepod found. All other copepods were larval stages and could therefore not be identified: caligiform Copepoda sp. a (1st copepodids to 1st–3rd chalimus stages), Copepoda sp. b (late chalimus stage of Pennellidae?), and Copepoda sp. c (1st copepodid of Hatschekidae?) (G. Boxshall, pers. comm.). The remaining parasites consisted of gill and skin cysts, turbellaria, *Transversotrema licinum* (Digenea), other Digenea, platyhelminths, and other unidentified parasites (Table 2).

At the end of the 6-month manipulation of *L. dimidiatus* presence/absence, the total number of all species of parasites combined per *P. moluccensis* was relatively low, usually 0–3 parasites per fish, and no differences between treatments were detected ($F < 0.01$, $df = 1, 14$, $p = 0.952$) (Fig. 3). However, there was a significant difference in the total number of parasites per fish among reefs irrespective of the presence of *L. dimidiatus* ($F = 2.22$, $df = 14, 148$, $p < 0.001$) (Fig. 3). This was due mainly to reefs 12 and 13, which had about one third as many parasites as the other reefs. I detected no difference between treatments in the species composition of parasites (MANOVA Pillai's Trace = 0.073, $F = 1.088$, $df = 11, 152$, $p = 0.374$) (Fig. 4). Although copepod sp. b and other digenea were only found on reefs without *L. dimidiatus*, their abundance was extremely low and probably reflected sampling effort (i.e. low statistical power to detect such a difference).

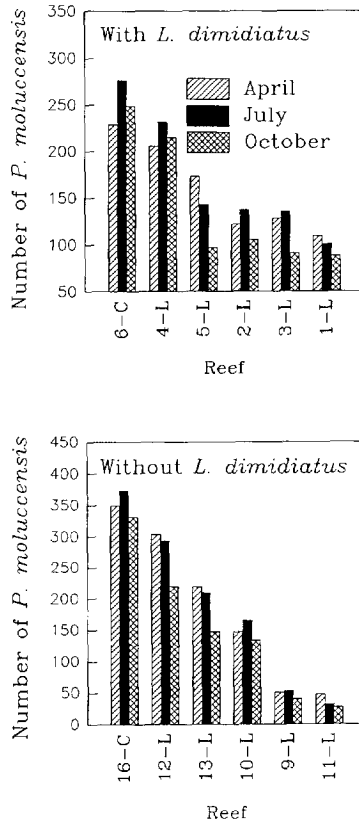


Fig. 2. The abundance of *P. moluccensis* on reefs with and without *L. dimidiatus*. Note: *L. dimidiatus* were removed from reefs after fish counts in April. L = Reefs located in the Lagoon. C = Reefs located at Casuarina Beach.

Table 2
The ectoparasites of *P. moluccensis* and their size ranges

Parasite	Size (μm)	Parasite	Size (μm)
Copepoda		Digenea	
<i>Hatschekia crenulatus</i>	890–940	<i>Transversotrema licinum</i>	1000–1170
Sp. a larvae (caligiform)	260–1370	Other Digenea	860–1000
Sp. b larvae (Pennellidae?)	370–540	Platyhelminthes	260–460
Sp. c larvae (Hatschekidae?)	370–830	Gill cysts	260–310
Turbellaria	90–710	Skin cysts	1140–1660
Other	170–1000		

Bold headings are broad descriptions of parasites.

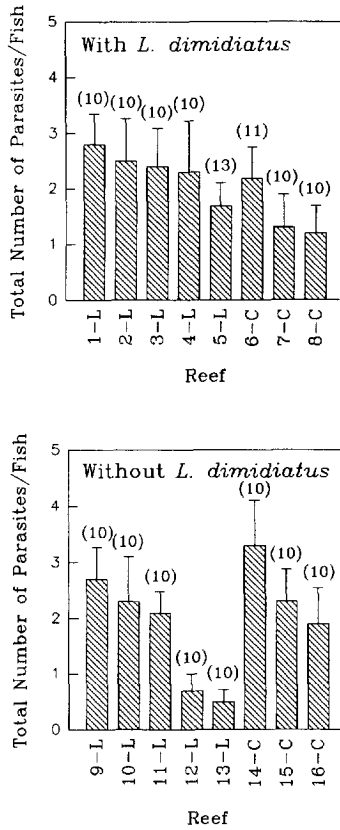


Fig. 3. The mean number of ectoparasites per host (SE), all species combined, on *P. moluccensis* across reefs with and without *L. dimidiatus* at the end of the experiment. L = Reefs located in the Lagoon. C = Reefs located at Casuarina Beach.

The size frequency distribution of the most abundant copepod, caligiform Copepoda sp. a, also did not differ between removal and control treatments ($\chi^2 = 2.35$, $df = 4$, $p = 0.672$; Two-sample Kolmogorov-Smirnov test = 0.08, $p = 1.0$) (Fig. 5). A randomization test revealed that the power to detect the same difference in size that Gorlick et al. (1987) found among treatments was 98%. Excellent power reflected the large effect size (21%) that Gorlick et al. (1987) detected.

The number of parasites per fish was not significantly correlated with *P. moluccensis* abundance ($r = 0.33$, $n = 12$, $p = 0.30$), *P. moluccensis* density, reef area, and *L. dimidiatus* density (all $p > 0.20$), and abundance per reef ($r = 0.454$, $n = 16$, $p = 0.08$). Furthermore, *P. moluccensis* abundance per reef and *L. dimidiatus* abundance per reef were not significantly correlated with reef area (all $p > 0.20$).

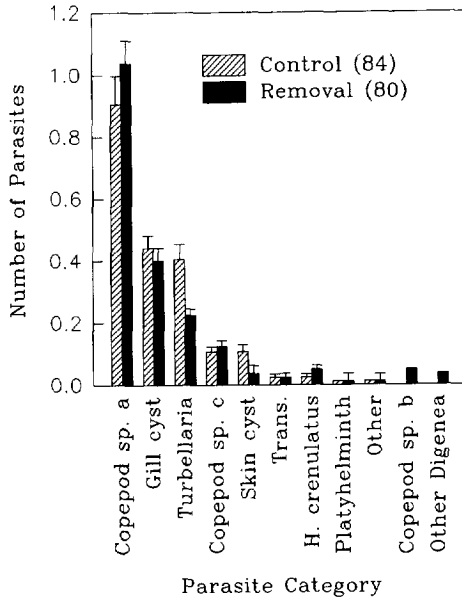


Fig. 4. The mean number of parasites per host (SE) of each category of parasite on *P. moluccensis* averaged across all reefs with (control) and without (removal) *L. dimidiatus* at the end of the experiment. Trans = *Transversotrema licinum*.

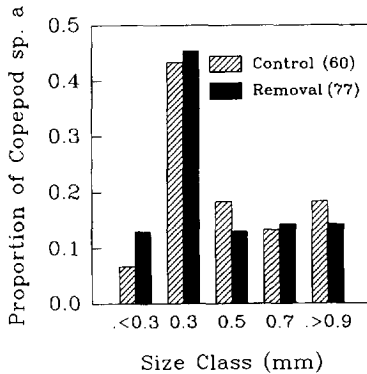


Fig. 5. The proportion of Copepoda sp. a per size class of copepod on *P. moluccensis* combined across reefs with (control) and without (removal) *L. dimidiatus* at the end of the experiment. Size classes are: <0.30 mm, 0.30–0.49 mm, 0.50–0.69 mm, 0.70–0.89 mm, and >0.90 mm. Sample size of copepods is in brackets.

4. Discussion

Despite the large proportion of parasites in the diet of *L. dimidiatus* at Lizard Island (Grutter, 1995b), and the high rates at which this cleaner removes parasites (Grutter, 1996), the cleaner-removal experiment did not provide any conclusive evidence of a *L. dimidiatus* cleaning effect on *P. moluccensis*. I could not detect differences in the total number and species composition of parasites nor in the abundance of *P. moluccensis* among treatments. These results are similar to all other quantitative cleaner-removal experiments (Youngbluth, 1968; Losey, 1972; Gorlick et al., 1987). There was also no evidence of an effect on the size frequency distribution of the most abundant copepod species. This result is in contrast to the study of Gorlick et al. (1987) which found larger parasites in the absence of *L. dimidiatus*.

It is unlikely that the absence of a significant effect of *L. dimidiatus* on parasites is due to sampling technique or lack of power to detect differences. The variation associated with the number of parasites was relatively low. Biologically meaningful differences in the number and species composition of parasites on several fish species have been detected between Lizard Island and Heron Island with sample sizes of 5 to 9 (Grutter, 1994), which are about 10 times lower than the sample size of this study (80–84). Furthermore, a randomization test revealed that there was sufficient power to detect the same difference in parasite size among reefs with and without *L. dimidiatus* that Gorlick et al. (1987) found.

The significant difference in total number of parasites (species combined) among reefs within a treatment level did not appear to be driven by the number of hosts per reef because there was no correlation between the number of parasites per fish and the abundance of *P. moluccensis*.

Labroides dimidiatus also had no detectable effect on the abundance of *P. moluccensis*, which showed an overall decline between April and October. The changes in abundance of *P. moluccensis* were the same on the control and removal reefs, which indicates that *P. moluccensis* did not leave reefs to seek cleaning elsewhere. The role of cleaning in promoting the healing of injured fish has been suggested (Foster, 1985); however, there was no evidence of increased mortality in the absence of *L. dimidiatus*. Youngbluth (1968), Losey (1972), and Gorlick et al. (1987) also found no changes in host fish density after the removal of cleaner fish from reefs. This is in contrast to Limbaugh's (1961) qualitative study which suggested that host fish emigrated from reefs after the removal of cleaners.

Although some removal reefs were colonized by a few *L. dimidiatus* during the experiment, these were all juveniles most of which were relatively small (see methods). Small *L. dimidiatus* have fewer parasites in their diet compared to larger individuals (Grutter, unpubl. data). Juvenile *L. dimidiatus* also have relatively smaller home ranges than adults (pers. obs.). As a result, any potential impact of juvenile cleaner fish on parasite and fish abundance is likely to be relatively minor compared to that of adults.

There was no evidence that other cleaners replaced the role of *L. dimidiatus* on cleaner-removal reefs. Although a single juvenile *Thalassoma lunare* and a

juvenile *Bodianus axillaris* were observed picking at fish on reefs without cleaner fish, the inspection was brief and was followed by benthic feeding behavior. No other cleaning events by fish were observed during approximately 100 h spent on all reefs counting fish. Cleaner shrimp were found on half of the control and removal reefs but there was no evidence that their cleaning rates increased in the absence of *L. dimidiatus*. Cleaner shrimps also spend less time than cleaner fish inspecting client fish (pers. obs.). Furthermore, the only fish species observed being cleaned by cleaner shrimp were large mobile species (e.g. *Pomacanthus sexstriatus*, *Diagramma pictum*, *Plectorhinchus celebicus*, *Plectropomus leopardus*). *Pomacentrus moluccensis* was never observed being cleaned by cleaner shrimp. Therefore, it is unlikely that other cleaner species influenced the parasites or abundance of *P. moluccensis* on reefs without cleaner fish.

Other studies have excluded all cleaner fish for 2 wk (Limbaugh, 1961), 1 month (Youngbluth, 1968), 7 months (Losey, 1972), and 2 yr (Gorlick et al., 1987). It is interesting to note that, of these, the longest removal study had a significant effect of cleaning on parasites (Gorlick et al., 1987). Thus, it may be argued that a longer removal experiment may have produced an effect in this study. However, *L. dimidiatus* recruited onto reefs even during the presumed non-recruitment winter season. As recruitment rates are even higher during the summer, it was only logistically feasible to keep reefs clear of *L. dimidiatus* for 6 months during the winter. Most importantly, individual *P. moluccensis* are cleaned daily (Grutter, 1995a). Thus, the cumulative amount of cleaning they would receive in 6 months would be substantial (see section 1. Introduction).

This outcome raises the question of why hosts retain the motivation to seek cleaning if *L. dimidiatus* has no substantial effect on their parasites. There is strong evidence that the proximate cause of host cleaning behavior is the tactile stimuli that hosts receive from cleaner fish during cleaning interactions (Losey, 1971, 1977; Losey and Margules, 1974). There are two possible ways that such a mechanism for cooperation could have developed (Losey, 1987). The first is as a result of a positive survival value of cleaning and the second is that cleaner fish may have taken advantage of an existing tactile reward system in hosts (Losey, 1987).

The lack of an effect of *L. dimidiatus* on the parasites of *P. moluccensis* may be influenced by the diet selectivity of *L. dimidiatus* (Grutter, 1995b). *Labroides dimidiatus* on the Great Barrier Reef selectively feed on large gnathiids (Grutter, 1995b) while *P. moluccensis* have relatively small parasites and no gnathiids. Therefore, *P. moluccensis* probably does not represent an attractive food source for *L. dimidiatus*. This conclusion implies that species which have more attractive parasites may be more affected by cleaner fish.

Fish species with gnathiids (Grutter, 1994) are generally mobile species and therefore not amenable to traditional removal experiments which require the containment of fish to particular reefs. New approaches are needed to test the effect of cleaner fish on these mobile hosts. One such study, which examined the rates of parasite removal and infection, suggests that *L. dimidiatus* may suppress the abundance of gnathiids on the mobile fish species *Hemigymnus melapterus*

(Grutter, 1996). More information is needed on the effect of gnathiids on hosts to determine whether hosts benefit from their removal.

This study, and three others using quantitative experimental evidence (Youngbluth, 1968; Losey, 1972; Gorlick et al., 1987), suggest that host fish do not benefit detectably from cleaning. The number of studies is relatively low compared to the large number of cleaner fish and host species (see references in Losey, 1987). More studies examining the potential benefits of cleaning for hosts are needed in order to determine whether the patterns found to date hold for other cleaners and different host fish.

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