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Effect of the removal of cleaner fish on the abundance and species composition of reef fish

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Abstract The ecological significance of cleaner fish on coral reefs was investigated. I removed all cleaner fish, *Labroides dimidiatus*, from eight small reefs, measured the subsequent effect on the abundance and species composition of all reef fish after 3 and 6 months, and compared it with eight control reefs with cleaner fish. The removal of cleaner fish had no detectable effect on the total abundance of fish on reefs and the total number of fish species at both times. Multivariate analysis by non-metric multidimensional scaling and ANOSIM pairwise tests based on 191 fish species revealed no effect of cleaners on the community structure of fish. Similar results were obtained using principal components analysis on subsets of the data using the 33 most common fish species and the 15 most abundant species (≥5 individuals per reef) with both log10 $(x + 1)$ transformed data and with fish numbers standardized for abundance. This study demonstrates that the removal of cleaner fish for 6 months did not result in fish suffering increased mortality nor in fish leaving reefs to seek cleaning elsewhere.

Key words Cleaner fish · *Labroides dimidiatus* · Coral reef fish abundance · Fish behavior · Cleaning symbiosis

Introduction

Cleaning symbioses, behavioral interactions between cleaner organisms and their clients, occur in terrestrial and aquatic environments. Cleaners include crustaceans, fish, and birds that clean vertebrate clients ranging from reptiles to mammals (see Poulin and Grutter 1996 for list of associations). Whether associations such as these are mutualistic requires information on the costs and benefits to both participants (Cushman and Beattie 1991). Many studies have investigated fish cleaning interactions, in which cleaner fish remove ectoparasites and other materials from client fish body surfaces, yet the significance of cleaning to the client is not clear (see reviews by Losey 1987; Poulin and Grutter 1996). Two hypotheses have been suggested to explain client cleaning behavior. One is that fish seek cleaners to receive rewarding tactile stimuli (Losey and Margules 1974; Losey 1979) and the other is that clients seek cleaners for ectoparasite removal resulting in a mutualistic association (Trivers 1971; Poulin and Vickery 1995).

There is no doubt that cleaner fish benefit from the association which provides the cleaner with a reliable food supply (Youngbluth 1968; Grutter 1996a, 1997 a,b). Whether clients benefit from cleaning is uncertain. A test of whether fish benefit from cleaning is to remove all cleaner fish and monitor the subsequent effect on client fish. The prediction is that the absence of cleaner fish will result in an increase in parasite infections, higher mortality, and/or that fish will emigrate to seek cleaning elsewhere.

Four removal experiments, involving the removal of all cleaner fish from reefs, have been made to test the effect of cleaner fish on client fish abundance. Only one study has demonstrated an effect on the abundance of reef fish (Limbaugh 1961). In this "modest field experiment" (p. 49) in the Bahamas all "known cleaning organisms" (p. 49) were removed from two reefs and after "a few days the number of fish was drastically reduced; within two weeks almost all except territorial fish had disappeared" (p. 49).

In contrast, the other three more quantitative removal experiments found no evidence of an effect of cleaner fish on the distribution of client fish (Youngbluth 1968; Gorlick et al. 1987; Grutter 1996b). In Hawaii, Youngbluth (1968) found that "the density of fish did not appear to be changed" (p. 924) when he removed all cleaner fish, *Labroides phthirophagus*, from a reef. In a more quantitative study at Enewetak Atoll (Marshall

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Islands), Gorlick et al. (1987) counted the number of each species per reef and found no differences in the number of fish on reefs where all the cleaner fish, *L. dimidiatus*, were removed, although they did find larger parasites on reefs without cleaners. At Lizard Island, Great Barrier Reef, Australia, Grutter (1996b) found that the abundance of the damsel fish *Pomacentrus moluccensis* was not affected by the removal of all *L. dimidiatus* from several reefs. In a similar study Losey (1972) removed most cleaner fish from a reef and found an increase in cleaning behavior by the remaining cleaners and changes in the behavior and distribution of the client fish. No changes in parasite abundance were detected.

Grutter (1996b) also found that cleaner fish had no effect on the abundance and size of ectoparasites on *P. moluccensis*. A possible explanation given was that *P. moluccensis* has no parasitic gnathiids which are the preferred food of *L. dimidiatus* (Grutter 1996a, 1997 a, b). Traditional cleaner fish removal experiments using parasitological data focused on sedentary fish species that remain on experimental reefs. Most fish that have gnathiids are relatively large species (≥50 mm, Grutter 1994, 1995; Grutter unpublished work) that are more likely to move between reefs. An alternative approach would be to examine all fish species, including those with gnathiids, and to monitor their abundance on reefs with and without cleaner fish.

Despite the increasing evidence that cleaner fish have no effect on the abundance of client fish and the fact that Limbaugh (1961) admitted his "experiment was a gross one and not well controlled", statements implying that cleaner fish are vital to the health of reef fishes are continually found in the literature (e.g., Paxton and Eschmeyer 1994). The number of removal experiments relative to the number of cleaner fish and client species (see references in Losey 1987; Poulin and Grutter 1996) is low. Furthermore, the range of methods in these studies is wide, varying from qualitative to progressively more quantitative estimates of client abundance. Only Gorlick et al. (1987) and Grutter (1996b) used replicate reefs in their experiments, and of these only the former included all client fish species in their study. Most importantly, there is spatial variation in the diet of cleaner fish (Youngbluth 1968; Hobson 1971; Grutter 1997 a; Chikasue 1990; G.S. Losey personal communication) and in the parasite loads of its clients (Hobson 1971; Losey 1974; Grutter 1994). Such variation may affect the interactions between cleaner fish and client resulting in spatial variation in the associations between cleaner and clients (Grutter 1997 a). To resolve these problems, more quantitative removal experiments are needed involving different client species.

The highest recorded rates of parasite removal in a cleaner fish are found at Lizard Island where *L. dimidiatus* feeds on 1200 parasites per day (mainly parasitic gnathiid isopod larvae) (Grutter 1996a). The high predation rate relative to the number of gnathiids on fish and their infection rate indicate that *L. dimidiatus* have an effect on the abundance of gnathiids on fish (Grutter 1996a). The likelihood of detecting an effect of cleaner fish on fish at this location is therefore high.

The removal experiment conducted by Grutter (1996b) focused on the effect of cleaner fish on the abundance of one fish species and its parasites. In this study, conducted at the same time and sites as Grutter (1996b), I examined the effect of *L. dimidiatus* on the abundance of all reef fish species found on several reefs. All cleaner fish were removed from reefs at Lizard Island and fish abundance estimated at three different times and compared to control reefs with cleaner fish. The parameters I tested were (1) total number of fish species per reef, (2) total number of fish per reef, and (3) number of fish per species per reef.

Methods

The study was done on 16 reefs at Lizard Island (see Grutter 1996b for map and detailed reef descriptions and criteria used in the selection of sites). Six of the reefs (3 removal and 3 control) were situated at one site (Casuarina Beach) and ten (5 removal and 5 control) were situated at another site (Lagoon). Reefs were at a depth of 2–7.3 m and 5.8–26.5 m from the nearest reef separated by an open sandy bottom. Areas of control and removal reefs were 102 ± 25 (SE) and 74 ± 13 m^2 respectively. Treatments at each site were determined haphazardly.

The duration of the experiment was based on the recruitment patterns of *L. dimidiatus*. Recruitment of juveniles onto reefs is seasonal and occurs mainly during the austral summer, with the least recruitment occurring in April to October (A. Green, personal communication). Therefore I did the experiment during April to October 1993. All fish collections and counts were made by scuba diving.

Removal of *Labroides dimidiatus*

I removed all *L. dimidiatus* from eight reefs during 24–29 April 1993; the eight other reefs were used as controls (see Grutter 1996b for number removed/remaining per reef). Between two and eight *L. dimidiatus* were removed from removal reefs. Control reefs were also disturbed by searching for and counting *L. dimidiatus*. Controls had between three and six *L. dimidiatus* per reef. Reefs were subsequently checked at intervals of several days during a period of 2 weeks; however no additional *L. dimidiatus* were found. I surveyed reefs again for *L. dimidiatus* in May, July, and October 1993. Any *L. dimidiatus* on removal reefs were removed. On 23 May 1993, I found one *L. dimidiatus* juvenile on a removal reef which I removed; on 20–21 July 1993, five juveniles were found and also removed; on the final survey (21–25 October 1993), six more *L. dimidiatus* juveniles were found and removed (see Grutter 1996b for the number of *L.dimidiatus* present or removed per reef, whether they were adults or juvenile, and their standard lengths).

Fish abundance estimates

I estimated the number of each fish species by slowly swimming around each reef and counting each individual. Abundant species were counted one species at a time, while less abundant species were counted two to five at a time per swim around the reef. Two replicate counts were made, one after the other, and the mean of these counts was used in the analyses. However, I used the highest count for species with low abundance (≤5 individuals per reef) or for species that only appeared for a short time in schools. Small cryptic species such as most blennies or gobies were not counted. Counts

were made on 12 reefs (6 removal, 6 control). Fish on the remaining 4 reefs were not counted as these had a relatively large surface area, mainly due to their greater height and variable habitat structure, which made counting of fish too time consuming and inaccurate. On these larger reefs, only the identity of each fish species was recorded to obtain the total number of species present. Counts were made at intervals of about 3 months (13–23 April 1993, 18–23 July 1993, and 13–17 October 1993), with the first counts being made prior to the removal of *L. dimidiatus*. The duration of counts was typically about 2 h per reef.

Statistical analyses

To test for differences in the number of species and total number of fish per reef over time and between treatments, I used a multivariate repeated-measures analysis with treatment as a between-subjects factor and time as a within-subjects factor. Several multivariate analyses using different transformations were used to examine the patterns of abundance of fish per species per reef among times and between treatments. Similar patterns found using a range of multivariate methods are likely representative and also qualitative evidence that the results are robust (Jackson 1993).

The multivariate analogue of analysis of variance, analysis of similarity (ANOSIM), which uses non-parametric permutation/randomization methods on the similarity matrix produced by a cluster analysis (Clarke and Green 1988), was used to test for differences in the community structure of fish between treatments. Since ANOSIM cannot test whether treatments differed over time (the equivalent of the interaction term treatment × time in analysis of variance) (Clarke 1993), I tested treatments at each time separately. The cluster analysis was done on a Bray-Curtis similarity matrix using $\log10(x + 1)$ transformed data. The Bray-Curtis similarity index was selected because it does not treat "joint absences", which were abundant in the data, as similar (Clarke and Warwick 1994). Non-metric multidimensional scaling (MDS) analysis was used to ordinate the results of the cluster analysis.

Several principal components analyses (PCA) were done on a subset of the data. As rare species can have a distorting effect on PCA ordination (Clarke and Warwick 1994), the number of variables (species) in the PCAs was reduced by selecting the most common species (species found in April on 7 or more of the 12 reefs). Because changes of abundance in species with low abundance (≤ 5) can exert a strong effect on PCA, PCAs were repeated using the most abundant (≥ 5 individuals per reef) species. PCA's were performed on $\log10(x+1)$ transformed data and on standardized data. The transformation was selected to down-weight the importance of very abundant species allowing less dominant species to also contribute to the patterns (Clarke and Warwick 1994). Standardizing data, which removes abundance effects and thus is sensitive to changes in the abundance of rare species, was done by setting the maximum value for each species at all times to equal 100% (i.e. each value was divided by the maximum value and multiplied by 100). The statistical package S.A.S. was used for the PCAs and repeated-measures analyses while "Primer 4.0 Beta" (Plymouth Marine Laboratory) was used in the ANOSIM and MDS analyses.

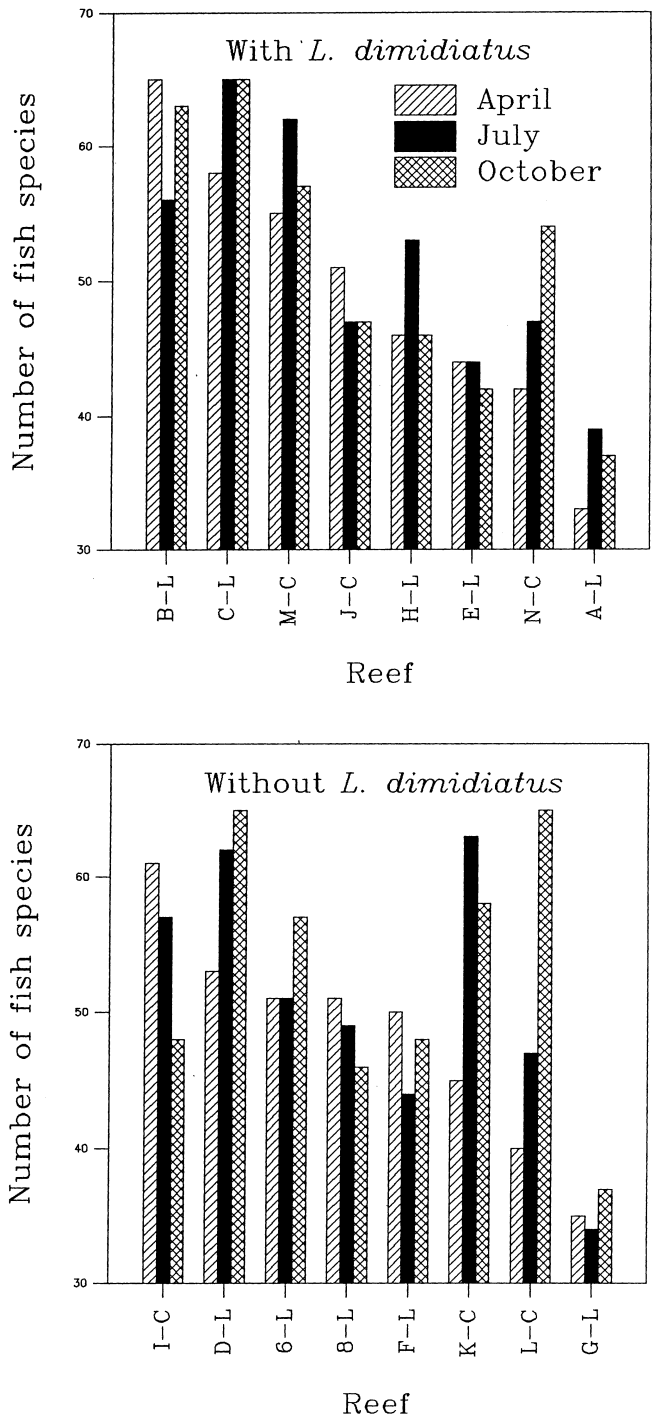

Fig. 1 Total number of fish species per reef on reefs with and without *Labroides dimidiatus* (*L* Lagoon site, *C* Casuarina Beach site). See Grutter 1996b for map of sites

Results

The total number of species per reef was not significantly different among times (Multivariate repeated measures analysis: Pillai's trace = 0.156, F = 1.206, df = 2, 13, P = 0.331) (Fig. 1). The interaction term (time × treatment) was also not significant (Pillai's trace = 0.036, F = 0.242, df = 2, 13, P = 0.789) which indicates that the changes over time did not differ among treatments (Fig. 1).

The total number of fish per reef differed among times (multivariate repeated measures analysis: Pillai's trace = 0.786, F = 16.495, df = 2, 9, P = 0.001). This was mainly due to a decrease in fish abundance between April and October (Fig. 2). The interaction term (time × treatment) was not significant (Pillai's trace = 0.068, F = 0.328, df = 2, 9, P = 0.728) which indicates that the changes over time did not differ among treatments. This analysis, repeated without apogonids and pempherids (species which often school and are found in

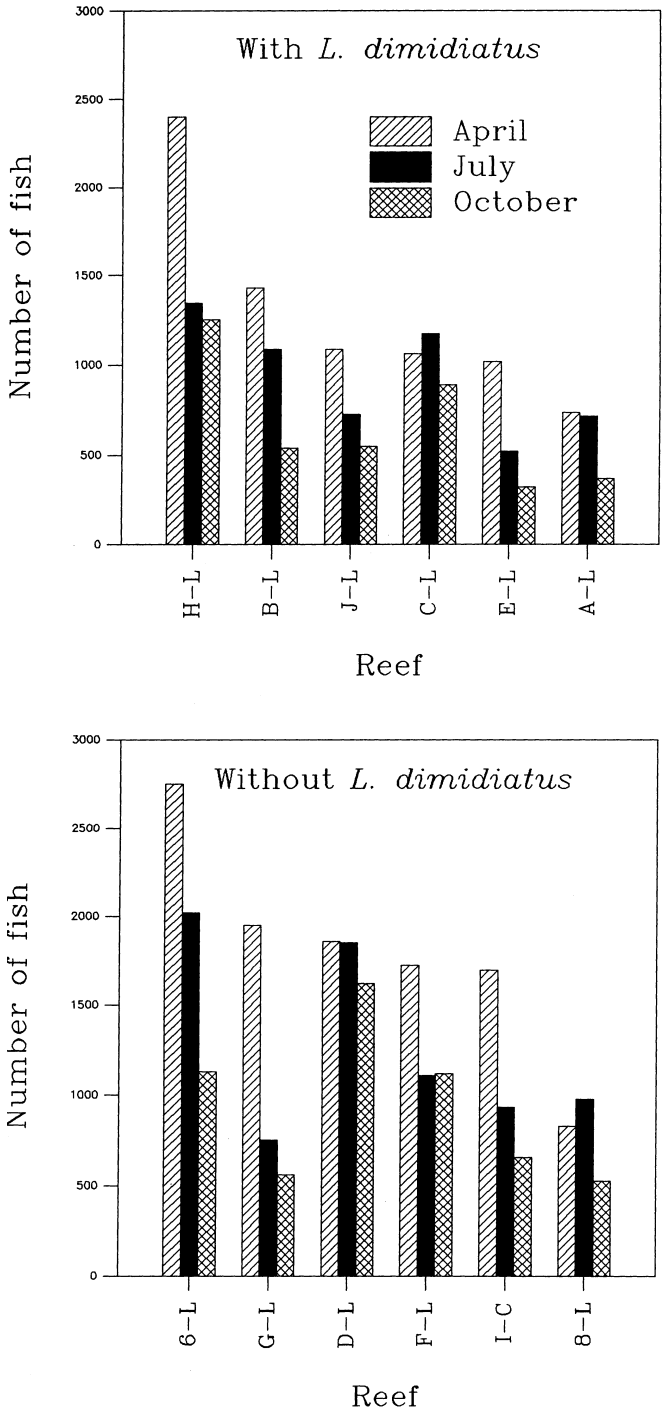

Fig. 2 Total number of fish per reef on reefs with and without *Labroides dimidiatus*. Reefs are labeled as in Fig. 1

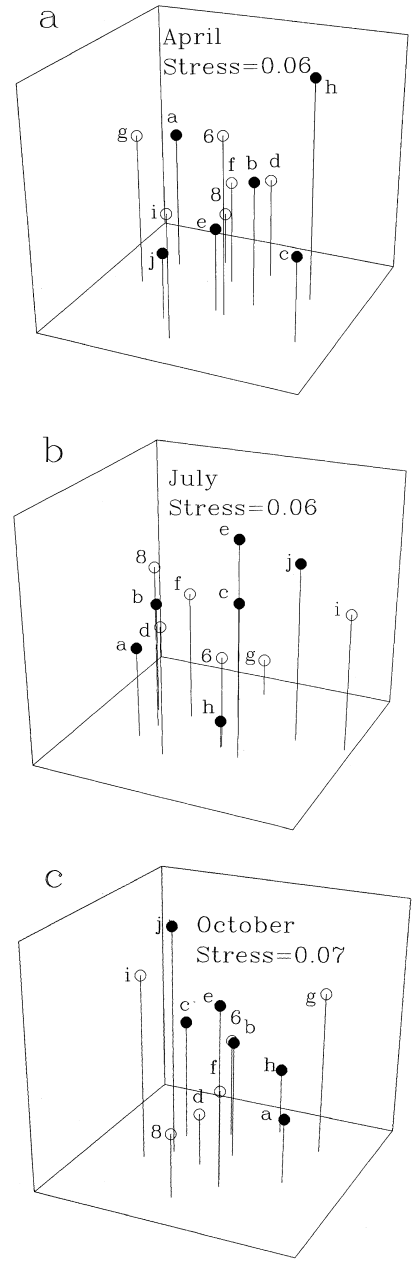

Fig. 3a–c Ordination of non-metric multidimensional scaling analysis. *Open circles* represent reefs without *L. dimidiatus* while *filled circles* represent reefs with *L. dimidiatus*

large numbers, i.e., 200–1350 fish per reef, and are therefore difficult to quantify accurately), produced similar results (time: Pillai's trace = 0.511, $F = 4.698$, $df = 2, 9$, $P = 0.040$; time × treatment: Pillai's trace = 0.003, $F = 0.012$, $df = 2, 9$, $P = 0.988$).

A total of 191 species were counted on all 16 reefs combined (see Appendix A for species list and species used in the following analyses). Principal component analysis (PCA) on the 33 most common species revealed that most reefs at different times tended to cluster together although in general there was much overlap. There were some changes in the fish community of each reef over time, however, there was no apparent effect of the removal of cleaner fish on the number of fish per species per reef, either when data were $\log10(x + 1)$ transformed or standardized for abundance. PCAs on the 15 most abundant species also showed no detectable effect of the removal of cleaner fish on the number of fish per species.

There were no significant differences between treatments in the community structure of fish in April (prior to removal of cleaner fish) (ANOSIM: $R = -0.111$,

P = 0.868, 462 permutations), June (ANOSIM: R = −0.178, P = 0.961, 462 permutations), and October (ANOSIM: R = −0.059, P = 0.677, 462 permutations). The maximum possible number of permutations (462), however, is lower than the recommended 1000 (Manly 1991) needed to reduce the variance around significance levels and therefore the ANOSIMs must be interpreted cautiously. The stress values for all MDS analyses were 0.06–0.07 (Fig. 3a–c) which indicates a good ordination with no real prospect of misinformation (Clarke and Warwick 1994). MDS ordination plots, which varied over time but did not form two clusters representing treatments, indicate that although fish assemblages on reefs varied over time, the removal of cleaner fish had no detectable effect on these assemblages (Fig. 3a–c).

Discussion

The removal of cleaner fish from reefs had no detectable effect on fish abundance or species composition. This indicates that client fish did not suffer increased mortality in the absence of cleaners and/or fish did not leave reefs to seek cleaning elsewhere. The findings agree with all other similar quantitative cleaner fish removal experiments (Youngbluth 1968; Gorlick et al. 1987; Grutter 1996b).

L. dimidiatus daily ingests large numbers of gnathiid isopods (Grutter 1996a), parasites which when in high numbers have been known to cause the death of captive fishes (Paperna and Por 1977). In addition, it has been suggested that cleaning may promote the health of injured fish (Foster 1985). Increased mortality rates would lend support to the hypothesis that the ultimate cause of client cleaning behavior is ectoparasite removal. The lack of an effect of cleaner fish on client abundance shows that fish did not suffer increased disease leading to increased mortality rates.

Many Great Barrier Reef fish species move between reefs (e.g., Brothers et al. 1983; Lassig 1983; Sweatman 1985; Caley 1993; Williams 1991; Williams et al. 1994). Therefore, some client species have the ability to move between reefs to seek cleaners. During the present study, relatively large fish species (e.g., acanthurids, lutjanids, lethrinids, some labrids, and adult scarids) were occasionally observed to move between experimental reefs. Although relatively smaller fish species were not observed moving between reefs in this study, other studies show that some small fish such as *Chromis atripectoralis* (Williams et al. 1994) and *Epibulus insidiator* (Robertson and Foster 1982) move between reefs. Variation due to fish movements may therefore have masked any effect of cleaners on fish abundance.

Brief absences by fish making quick visits to neighboring reefs to get cleaned, and which may not have been detected by the fish censuses, are unlikely in most species. Cleaning is generally not completed in a single cleaning bout. Instead, fish are cleaned several times a day (some as much as 144 times a day) for a few seconds only (Grutter 1995). Many visits to other reefs would therefore be needed to duplicate normal cleaning rates of fish. Such visits would likely have been detected in this study. Furthermore, the risk of predation while making numerous trips across open areas is probably high cancelling any benefit gained from cleaning.

Decisions in animals are made by balancing the costs and benefits of an action (McFarland 1993). A decision by a fish to migrate to a reef with cleaners would suggest that fish may benefit from such an action. The lack of evidence of such migration suggests that potential costs associated with such a behavior (e.g., increased predation risk, loss of territory, and energy output) may be too high or that conversely, no benefits may be involved.

The absence of an effect of cleaner fish on client fish is supported by parasitological evidence collected at the same time and location which showed that the damsel fish *Pomacentrus moluccensis* did not suffer increased parasite levels nor have larger parasites in the absence of cleaner fish (Grutter 1996b). The parasites that make up most of the diet of cleaner fish, gnathiid isopods (Grutter 1996a, in press a,b), are not found on *P. moluccensis*. Grutter (1996b) proposed that no effect of cleaning on *P. moluccensis* was detected because they had no gnathiids. The present study, however, which included client species with gnathiids (i.e., usually larger, more mobile species, Grutter 1994, 1995, Grutter Unpublished Work) indicates that fish with gnathiids also do not appear to be affected by cleaner fish. This is in contrast to the finding that larger fish with more parasites and more gnathiids (Grutter 1994, Grutter Unpublished Work) seek cleaners more often and spend more time being cleaned (Grutter 1995).

Grutter (1996b) discussed several factors which may or may not have contributed to finding no effect of cleaners on clients and which may also apply to this study. Some removal reefs were colonized by juvenile *L. dimidiatus* (see Grutter 1996b for sizes). Juvenile cleaner fish, however, have relatively few parasites in their diet and smaller home ranges compared to adults (A.S. Grutter, personal observations). Their impact on clients is therefore probably minor. It did not appear that other cleaners replaced *L. dimidiatus*. Only two instances of juvenile labrids' cleaning behavior were observed during the numerous hours spent counting fish. Cleaner shrimp, although present on some of the reefs did not appear to increase their cleaning rates in the absence of clearer fish and were only occasionally observed cleaning large mobile fish species (Grutter 1996b).

Other removal studies were for 2 years (Gorlick et al. 1987), 7 months (Losey 1972), 1 month (Youngbluth 1968), and 2 weeks (Limbaugh 1961). Of these only the longest study detected an effect of cleaning on the size of parasites (Gorlick et al. 1987). This raises the question of whether the duration of this experiment was too short to detect an effect of cleaners. The cumulative amount of cleaning some species would receive in 6 months is relatively high (e.g., 30,000 estimated cleaning inspections for the rabbitfish *Siganus doliatus*, Grutter 1995). The

large amount of cleaning over the course of the experiment suggests that the duration of the experiment was adequate. Furthermore, the study was logistically constrained to the winter months to avoid the high summer recruitment rates of juvenile *L. dimidiatus* (A. Green, personal communication). Parasite abundance, however, can vary temporally (Kennedy 1975; Grutter 1994) and cleaner fish may only have a detectable effect on parasites at certain times of the year when infections are high.

An alternate means of quantifying the effect of cleaners on fish by using estimates of parasite removal and infection rates shows that *L. dimidiatus* may suppress the gnathiid numbers on the mobile wrasse *Hemigymnus melapterus* and other fish species (Grutter 1996a). It is difficult to envisage why clients with more parasites seek cleaners more often (Grutter 1995) and in the process have many parasites (gnathiids) removed if cleaning did not evolve for ectoparasite removal. Possibly, fish have some resistance to parasites which affords them some protection in the absence of cleaner. Or, the effects of cleaning may be so subtle that they can only be detected over the lifetime of fish. The Hawaiian cleaner fish *L. phthirophagus* appears to have parasitized the client's response to tactile stimuli (Losey and Margules 1974; Losey 1979). The role of tactile stimuli in other cleaning interactions has not been investigated. Parasites as the proximate cause of cleaning is currently being tested which will help resolve the significance of cleaning to the client.

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Appendix 1 Identity of 191 fish species recorded on the 16 reefs involved in the experiment. *One of 15 fish species or **one of 33 fish species used in PCA analyses. MDS analyses used all species except those labeled*** (the latter were only present on reefs K,L,M,N where fish were not counted, just identified)

Abudebduf bengalensis
*Acanthochromis polyacanthus***
Acanthuridae sp. a
*Acanthurus nigricauda***
Acanthurus nigrofuscus
Acanthurus xanthopterus
*Amblyglyphidodon curacao***
Amblyglyphidodon leucogaster
Amblygobius rainfordi
Amphiprion akindynos
Amphiprion chrysopterus
Amphiprion clarkii
Anampses neoguinaicus
*Anyperodon leucogrammicus****
Apogon bandanensis
*Apogon compressus***
*Apogon cyanosoma***
Apogon doerderleini
Apogon exostigma
*Apogon fragilis***
Apogon leptacanthus
Apogon or Rhabdamia gragilis
Apogon sangiensis
Apogonidae sp. a
Apogonidae sp. b
Apogonidae sp. c
Archamia fucata
*Assesor macneilli**
*Balistapus undulatus****
*Bodianus axillaris****
Caesio caerulaurea
Caesio cuning
Canthigaster valentini
*Centropyge vroliki****
Cephalopholis boenak
*Cephalopholis cyanostigma***
Chaetodon aureofasciatus
*Chaetodon auriga***
Chaetodon baronessa
Chaetodon ephippium
*Chaetodon melannotus****
Chaetodon plebeius
Chaetodon rainfordi
Chaetodon trifascialis
Chaetodon ulietensis
Chaetodon vagabundis
Cheilinus chlorourus
*Cheilinus diagrammus****
Cheilinus fasciatus
Cheilinus trilobatus
*Cheilio inermis****
Cheilodipterus artus
Cheilodipterus macrodon
*Cheilodipterus quinquelineatus***
Chelmon rostratus
*Choerodon anchorago****
Choerodon fasciatus
Choerodon schoenleinii
Chromis atripectoralis
Chromis sp. a
Chromis ternatensis
*Chromis viridis***
Chrysiptera cyanea
Chrysiptera flavipinnis
*Chrysiptera rollandi***
*Chrysiptera talboti****
Cirripectes spp.
*Coris schroederi***
Ctenochaetus binotatus
*Ctenochaetus striatus***
Dascyatus kuhlii
Dascyllus aruanus
Dascyllus reticulatus
Diagramma pictum
Dischistodus melanotus
*Dischistodus perspicillatus***
Ecsenius bicolor
Epibulus insidiator
Epinephelus ongus
Gobidae sp. a
Gobidae spp.
Gymnocranius sp.
*Halichoeres melanurus***
Halichoeres trimaculatus
*Hemigymnus fasciatus***
Hemigymnus melapterus
Labridae sp. a
Labridae sp. b
Labridae sp. c
Labridae sp. d
Lethrinus atkinsoni
Lethrinus harak
Lethrinus nebulosus
Lethrinus spp.
Lutjanus bohar
*Lutjanus carponotatus***
Lutjanus fulviflamma
Lutjanus fulvus
Lutjanus gibbus
Lutjanus kasmira
*Lutjanus quinquelineatus****
Lutjanus russeli
Meiacanthus sp.***
Monacanthidae sp.***
*Monotaxis grandoculis***
Mulloides flavolineatus
Myripristis adusta
Myripristis berndti
Myripristis spp.
Naso sp.
Naso unicornis
Neoglyphidodon melas
Neoglyphidodon nigroris
Neoniphon sammara
*Neopomacentrus azysron***
Neopomacentrus bankieri
*Neopomacentrus cyanomos***
Ostracion cubicus
Parupeneus barberinus
Parupeneus multifasciatus
Pempherididae sp.
Pempheris oualensis
*Plagiotremus rhinorhynchos****
Plagiotremus tapeinosoma
Platax pinnatus
Plectorhincus celebicus
*Plectroglyphidodon dickii****
Plectroglyphidodon lacrymatus
Plectropomus leopardus
*Plectrorhinchus gibbosus****
Pomacanthus sexstriatus
Pomacentridae sp. a**
Pomacentridae sp. b
Pomacentridae sp. c
Pomacentridae sp. d
Pomacentridae sp. e
Pomacentridae sp. f
Pomacentridae sp. g
*Pomacentrus adelus***
*Pomacentrus amboinensis***
Pomacentrus australis
Pomacentrus bankanensis
Pomacentrus brachialis
Pomacentrus chrysurus
Pomacentrus coelestis
*Pomacentrus grammorhynchus***
Pomacentrus lepidogenys
*Pomacentrus moluccensis***
*Pomacentrus nagasakiensis***
*Pomacentrus pavo***
Pomacentrus vaiuli
Pomacentrus wardi
Premnas biaculatus
Priacanthus hamnur
Pseudocheilinus hexataenia
*Pseudochromis fuscus***
Pterocaesio marri
Pterocaesio trilineata
*Pterois volitans****
Sargocentrum spiniferum
Scaridae sp. a
Scaridae sp. b
Scaridae sp. c
Scaridae sp. d
Scaridae sp. e
Scaridae sp. f***
Scarus dimidiatus
Scarus flavipectoralis
Scarus ghobbhan
Scarus niger
Scarus psittacus
Scarus rivulatus
Scarus schlegeli
*Scarus sordidus***
*Scolopsis bilineatus***
Scolopsis monogramma
Siganus corallinus
*Siganus doliatus***
Siganus lineatus
Siganus punctatissimus
Siganus punctatus
Sphyraena sp.
*Stegastes apicalis****
Stegastes nigricans
Stethojulis sp.***
Stethojulis strigiventer
Synodus sp.
*Thalassoma ampblycephalum****
*Thalassoma harwicke****
*Thalassoma lunare***
Zebrasoma scopas
*Zebrasoma veliferum***