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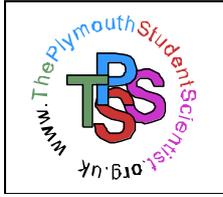
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# Influences on the cleaning activity and distribution of cleaner fish

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## Abstract

Cleaning interactions involve the removal of ectoparasites, mucus and dead tissue, by a cleaner from the skin of a cooperating fish – the client. These interactions generally benefit both the cleaner and the client, although this balance can shift if either party cheats, leading to antagonistic or exploitative behaviour. The activity of cleaner fish is affected by a variety of both physical and ecological factors. Ectoparasites make up a large portion of the diet of cleaner fish, thus ectoparasite availability is the major influence on cleaner activity, and so variations in ectoparasite densities tend to lead to variations in cleaner distribution. The ectoparasite load of a client is determined by client size, species, gregariousness and mobility. Habitat also influences the types of food available to cleaners, and thus determines their reliance on clients for food.

Keywords: cleaner fish; client; mutualism; ectoparasite; cleaning activity

## INTRODUCTION

Cleaning symbioses have been defined as “the removal by a cleaning organism of ectoparasites, diseased or injured tissue, or other particles from the external surfaces or even the buccal cavity of another cooperating organism” (Poulin & Grutter, 1996). Although these interactions occur throughout nature, this review focuses only on the cleaning symbioses of fish. 131 fish and crustacean species from 19 families have been identified as cleaners and these can be divided into two groups: facultative cleaners and obligate cleaners. Obligate cleaners acquire over 80% of their food through cleaning, whereas only a small portion of the diet of facultative cleaners comes from cleaning and they usually only clean opportunistically or as juveniles. The majority of cleaners are facultative (Côté, 2000).

Cleaning interactions are an example of mutualism as the client benefits from the removal of ectoparasites, while the cleaner gains food by consuming ectoparasites, mucus and dead tissue from the skin of the client (Poulin, 1993). Whilst the relationship is usually equally beneficial to both parties, both the cleaner and client are able to cheat. Cleaners can cheat by removing healthy tissue rather than parasites (Bshary & Grutter, 2002b), whereas clients are able to cheat by eating the cleaners, however this is only true for piscivorous clients. Therefore the interaction can range from being exploitative to mutualistic. This is often dependant on ectoparasite availability, although it has been shown that honesty is the most profitable strategy for both the cleaner and client (Bansemer *et al.*, 2002).

This paper will examine the major factors that influence both the cleaning activity and distribution of cleaner fish.

## FOOD CHOICE AND AVAILABILITY

Ectoparasites are an important factor influencing the behaviour of cleaner fish, with their abundance, species and size all playing a major role. The Hawaiian cleaner wrasse, *Labroides phthiophagus*, has demonstrated a preference for clients infected with crustacean and trematode ectoparasites over ectoparasite-free clients (Gorlick, 1984). The cleaner wrasse *Labroides dimidiatus* has been shown to feed selectively on gnathiid isopods (Grutter, 1997b), with a higher ratio of gnathiids to other crustaceans found in the diet of *L. dimidiatus* than on the host fish. A study by Grutter (1999) showed that 91% of the diet of *L. dimidiatus* in New Caledonia was parasitic gnathiid isopod larvae. As well as selective predation on gnathiids, cleaner fish have also been shown to demonstrate a preference for larger ectoparasites. In a study on the consumption of sea lice, *Lepeophtheirus salmonis*, on farmed Atlantic salmon, *Salmo salar*, by the goldsinny wrasse, *Ctenolabrus rupestris*, the wrasse preyed selectively on larger, mainly adult, lice (Treasurer, 1994). This size-selective predation, however, is dependent on ectoparasite availability. When comparing the feeding behaviour of *L. dimidiatus* at Lizard Island and Heron Island on the Great Barrier Reef, Grutter (1997a) found that at Heron Island, where there were fewer gnathiids, size-selective predation did not occur and more benthic copepods and mucus were eaten. This implies that cleaner fish feeding behaviour is flexible. Arnal *et al.* (2002) also suggested that cleaners may adapt their feeding behaviour according to environmental parameters and food availability.

The broadstripe cleaning goby, *Elacatinus prochilos*, is just one example of a cleaner that varies its diet according to food availability. *E. prochilos* does not rely solely on client-gleaned items for food: coral polyps, along with sponge tissues and spicules make up a large part of its diet. *E. prochilos* eats more gnathiids in the morning than in the afternoon. This decrease in the consumption of gnathiids throughout the day coincides with a greater reliance on coral polyps from midday onwards, suggesting that *E. prochilos* cleans actively in the morning but switches to other forms of foraging in the afternoon (Arnal & Côté, 2000). This behaviour may be explained by the variation in ectoparasite availability throughout the day. Ectoparasite loads on host fish increase over night while cleaners are not active. This means their parasite loads are greatest in the morning. Therefore, there are more ectoparasites available as food for the cleaners in the morning, when they are most hungry, having not eaten all night. This is reflected by higher rates of cleaning and longer inspections in the morning than in the afternoon (Côté & Molloy, 2003). The higher parasite loads on host fish also mean that they visit the cleaning stations and pose for inspection more frequently in the morning.

Temporal variation in ectoparasite availability does not just occur diurnally, but also seasonally. Parasite abundance on *Signus doliatus* increased 7-fold between May 1992 and January 1993, mainly due to an increase in monogenean flatworms (Grutter, 1994). While the number and estimated biomass of gnathiids in the diet of *L. dimidiatus* on the Great Barrier Reef more than doubled in the same time period (Grutter, 1997b).

### CLIENT MORPHOLOGY

The client species plays a large role in the feeding behaviour of cleaner fish. Gorlick (1980) found that the chemical composition of the mucus on the surface of fish skin was species-specific and that the cleaner's preference for client species was correlated to mucus characteristics. Parasite abundances and assemblages are also species-specific to the host and even taxonomically related fish species have very different parasite communities (Grutter, 1994). This suggests that a variety of host characteristics determine parasite assemblages, such as host size, gregariousness and mobility. Because of this, areas with high fish species richness are likely to represent a greater choice of potential clients for cleaners, which may explain why *Labroides dimidiatus* density is positively correlated with fish species richness (Arnal *et al.*, 2002).

Several studies have found that fish size is positively correlated with ectoparasite load. For example, Bortone *et al.* (1978) found that fish with parasites were significantly longer than those without and that numbers of parasites increased with increasing host length. Grutter and Poulin (1998b) also found that mean gnathiid abundance per host species correlated with size and that within a species larger individuals had more gnathiids than the smaller fish. However, in a previous study, Grutter (1994) observed that the relationship between parasite load and host size varied among fish species and suggested that host size did not explain as much of the variation in parasite abundance as did host identity. The correlation between host size and parasite load would suggest that larger fish would be cleaned more frequently and have longer inspection times. When this was tested, it was found that larger fish with more parasites were inspected more often than smaller fish with fewer parasites (Grutter, 1995). Grutter and Poulin, (1998a) also found that client size did show a positive correlation with duration and frequency of inspection however, the relationship disappeared when the data was

corrected for phylogeny. This confirms Grutter's earlier suggestion that phylogeny has more effect than client size. Thus, the relationship between client size and cleaning rates is still unclear. However, because larger fish have greater loads of ectoparasites, cleaners would be able to use client size as an indicator of food availability, as the surface area of a fish can easily be estimated from a distance, whereas the cleaner cannot estimate parasite load until it has inspected the host (Grutter, 1995).

## CLIENT BEHAVIOUR

It is not just the morphology of the client that affects the cleaner's feeding, but also their behaviour. The client has a great influence on the nature of the cleaning interaction. In laboratory studies cleaners have been shown to prefer mucus and monogeneans over gnathiids, when offered plates containing each (Grutter & Bshary, 2003). This suggests that cleaners feed against their preference in natural conditions. Mucus is high in nitrogen and therefore, is expensive for the client to produce however, it would be a rich energy source for cleaners whereas gnathiids are only rich in protein (Gorlick, 1980). Thus, feeding on mucus would be more beneficial to the cleaner but very costly to the client. Consequently, the client must have developed a means to overcome this conflict of interests (Grutter & Bshary, 2003) as most cleaning interactions are mutualistic. There are two main methods that have been adopted by the clients to prevent cheating by cleaners. Clients with access to only one cleaning station, such as territorial fish, often chase the cleaner if they are cheated, making it less energetically beneficial to cheat. Clients with access to two or more cleaning stations will swim away and use a different station if cheated by the cleaner (Bshary & Grutter, 2002a). These punishments yield future benefits as cheating is less likely to occur again on a client that terminated the previous interaction. Clients are also more likely to return to the same station if the previous interaction ended without conflict, whereas they tend to change partners if they were cheated or ignored (Bshary & Schaffer, 2002). Only piscivorous fish are able to reciprocate by cheating, eating the cleaner, and this is very unlikely as cleaners are generally believed to benefit from protection from predation (Arnal et al., 2002).

Clients are also able to facilitate cleaning interactions by posing. Posing is when the client adopts an immobile posture, often with a near vertical body orientation with the fins held erect, upon arrival at a cleaning station (Côté *et al.*, 1998). Côté *et al.* (1998) found that the probability of being cleaned was significantly higher if the client posed upon arrival at the cleaning station than if it did not. Bansemmer *et al.* (2002) also found that clients who posed were inspected for longer and received a better quality of cleaning.

## FISH COMMUNITY

In a study between the cleaning gobies *Elacatinus evelynae* and *E. prochilos* and the juvenile bluehead wrasse *Thalassoma bifasciatum*, it was discovered that the gobies have a very broad cleaning preference whereas the wrasse only cleans non-piscivores (Darcy *et al.*, 1974). This is mainly due to the fact that the gobies obtain protection from predation by exhibiting a cleaning behaviour that is easily recognized by piscivores. Whereas the juvenile wrasse have a less highly evolved specialisation as cleaners, so are less easily recognized as cleaners and thus, are readily preyed upon. This confirms that prominent cleaning behaviour does result

in protection from predation. Because of this, rates of predation on cleaners are extremely low. Although there have been a few recorded acts of predation on cleaners, these generally occur during non-cleaning interactions (Côté, 2000). Despite this, the presence of predators does seem to have an affect on the distribution of cleaners. Cleaners are significantly more abundant in areas with fewer predators, with the density of *Labroides dimidiatus* decreasing as predator numbers increase (Arnal *et al.*, 2002).

Territorial fish also have a negative affect on cleaner fish activity, when the cleaning station is within its territory (Arnal *et al.*, 1999). For example, damselfish show aggressive behaviour towards other fish intruding on their territory, so cleaning stations within a damselfish territory are visited by significantly fewer species and individuals than those outside damselfish territories. Also, at stations within damselfish territories the cleaners spent less time cleaning and they had a higher feeding rate than at stations outside damselfish territories (Arnal & Côté, 1998). Generally, at cleaning stations near territorial fish the main client is the territory holder itself.

There is conflicting evidence as to the effect of sedentary fish on cleaner fish. Arnal *et al.* (1999) found that cleaner wrasse occur in larger numbers on reefs where there are relatively few sedentary fish. This may be due to habitat competition, as both types of fish prefer sheltered habitats. Whereas in a second study Arnal *et al.* (2002) found that cleaner fish density is positively correlated with the occurrence of sedentary fish. There are several reasons why this might be so. One possible explanation is that parasite load is generally higher in sedentary than mobile fish however, cleaners may not use sedentary behaviour as an indicator of parasite load. Also, sedentary fish may represent a more faithful clientele than mobile fish, so would be more attractive to cleaners. More studies need to be done on this relationship to determine the effects of sedentary fish on cleaner activity and distribution.

The gregarious behaviour of fish also influences the density of cleaners, as the densities of cleaners are positively correlated with those of reef fish according to their size and gregariousness (Arnal *et al.*, 1999). This is due to the fact that fish gregarious behaviour is positively correlated with ectoparasite species richness, therefore solitary fish are less parasitized than those in groups and therefore, less attractive to cleaners. As well as group size influencing parasite diversity, abundance of parasites can influence host group size. Côté and Poulin (1995) found that increasing numbers of parasites lead to a larger host group size. They also found that there were positive correlations between host group sizes and the prevalence and intensity of contagious parasites, but negative correlations between host group size and mobile parasites. Thus, the modes of transmission adopted by the parasites can exert conflicting selection on host group size. There is however, still some debate as to the extent of this relationship, as it has been suggested that larger schools of fish would be less attractive to cleaners (Arnal *et al.*, 1999). Larger schools tend to stay much higher in the water column and are constantly moving, making it difficult for cleaners to access them. Also, fish in large schools are generally relatively short-lived, meaning that their densities fluctuate over time, making them a variable resource for the comparatively long-lived cleaner fish. Therefore, it would seem that moderate-sized groups of fish would make the best targets for cleaners.

## HABITAT

Habitat has a huge influence on the composition of fish communities, as well as the distribution and behaviour of cleaner fish. Reefs that are more structurally complex have an increased surface area, which provides a greater diversity of shelter and feeding sites (Bell & Galzin, 1984). This, in turn, leads to greater species richness, which is associated with higher densities of cleaner fish (Arnal *et al.*, 2002). Species richness and fish densities are also strongly correlated with live coral cover, as shown by Bell and Galzin (1984) who found significant differences in species composition with changing live coral cover on topographically similar reefs. Even small changes in the amount of live coral cover, lead to significant changes in species richness and abundance of reef fish. However, gaps between areas of live coral can lead to patchiness of reefs, which will help to separate competing fish and thus, lead to a greater abundance of cleaners (Arnal *et al.*, 1999).

The cleaner wrasse *Labroides dimidiatus* is ubiquitous across reefs, occurring on low densities in all habitat zones (Green, 1996). This is because labrids tend to have large home ranges, which may include a variety of a habitat types and substrates. Therefore, they are less likely to show strong association with particular habitat characteristics. *L. dimidiatus* also shows ontogenetic shifts in habitat use, with juveniles preferring to live in niches that are inaccessible to adults, such as in the holes underneath plate corals. These microhabitats are less abundant in areas used by adults (Green, 1996).

Differences in habitat can lead to both intra- and interspecific differences in the cleaning activity and the diet of cleaner fish. On Barbadian reefs broadstripe cleaning gobies, *Elacatinus prochilos*, offer one example of intraspecific variation generated by different habitat, where some individuals inhabit coral and others inhabit sponge. Coral-dwelling *E. prochilos* have a greater reliance on clients for food, as alternative food sources are very limited, whereas sponge-dwelling *E. prochilos* have a greater choice of foods, such as the sponges themselves and the parasitic polychaetes *Haplosyllis* spp. that live within sponges. This means that sponge-dwelling *E. prochilos* have less need to attract clients and tend to clean opportunistically (Whiteman & Côté, 2002). This also implies that the quality of cleaning received by the client will depend upon which station is visited.

Broadstripe cleaning gobies, *E. prochilos*, are much more strongly associated with the substrate they inhabit than are the cleaner wrasse, *L. dimidiatus*. This gives the gobies more opportunities to exploit non-cleaning food sources, while the wrasse rely heavily on client-gleaned food (Arnal & Côté, 2000). This interspecific variation in cleaning activity will also affect the quality of cleaning service provided.

## CONCLUSIONS

There are a great variety of factors that influence the distribution and cleaning activity of cleaner fish, the main factor being food availability. Despite the fact that mucus would be more energetically beneficial for cleaners, they feed on ectoparasites, mainly gnathiid isopods, to avoid conflict with the clients. Although, where there are few ectoparasites available honesty is less profitable, so the cleaners may be more inclined to cheat (Bansemer *et al.*, 2002). Thus, cleaners prefer clients that have higher ectoparasite loads, larger ectoparasites or more mucus, which tends to be species specific to the client. Fish size is generally correlated to ectoparasite load, so cleaners can use the surface area of a client as

an estimate of the number of ectoparasites and therefore they tend to clean larger fish, with more parasites, more frequently and for longer than smaller fish. It has been suggested that cleaner density is more influenced by the quality than by the number of potential clients (Arnal *et al.*, 1999), with factors such as client species, size, gregariousness and mobility all affecting the cleaner's feeding behaviour and distribution. These factors all have a direct affect on the ectoparasite load of the client, which in turn affects the cleaners. Therefore, ectoparasite density and diversity is the overriding factor influencing cleaner fish activity.

The fish community can have an affect on the distribution of cleaner fish. Territorial fish, such as damselfish, which are ubiquitous across coral reefs can generate significant variation in the levels of use of cleaning stations by chasing other clients away (Arnal & Côté, 1998). Also, while cleaners are generally considered protected from predation, abundance of predators has a negative impact on abundance of cleaners. Further work is needed to fully understand the effects of sedentary fish on cleaner activity.

Habitat influences both the distribution of cleaners and their reliance on clients for food. Cleaners inhabiting different substrates can have high variability in cleaning activity, both intra- and interspecifically, leading to differences in quality of service provided for the client. The research I will be conducting looks into the intraspecific differences in cleaning activity created by different quality of habitat. This will be done by looking at the activity of *Labroides dimidiatus* at three sites in the Wakatobi Park. The sites have differing amounts of live coral cover and one site is within a no-take zone, which is likely to create differences in the fish community. The results of this research should help us better understand the effects of habitat quality on the workload of cleaner fish.

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