J. mar. biol. Ass. U.K. (1997), **77**, 891-898
Printed in Great Britain

RELATIVE IMPORTANCE OF CLEANING BEHAVIOUR IN *CENTROLABRUS EXOLETUS* AND OTHER WRASSE AT ARRÁBIDA, PORTUGAL

MIGUEL HENRIQUES* AND VITOR C. ALMADA†

*Parque Natural da Arrábida, Instituto da Conservação da Natureza, Praça da República, 2900 Setúbal, Portugal. †Unidade de Investigação em Eco-Etologia, Instituto Superior de Psicologia Aplicada, R. Jardim do Tabaco 44, 1100 Lisboa, Portugal

Underwater behavioural observations were conducted to evaluate the relative importance of cleaning behaviour in three species of common north-eastern Atlantic wrasse (Teleostei: Labridae). At the study site, the only cleaner was *Centrolabrus exoletus*. A total of 12 species was cleaned, with the wrasse, *Symphodus melops* and *Labrus bergylta* being the species most frequently cleaned. Neither *S. melops* nor *Ctenolabrus rupestris*, known to be cleaners in other sites or in captivity, could be observed cleaning other fishes. *Centrolabrus exoletus* was found to be a facultative cleaner fish with cleaning acts representing only 7% of the observed feeding acts. In focal observations of host fishes, the incidence of cleaning acts reached a level (11 h^{-1} per host) similar to that reported for tropical reef fishes and probably reflects the high numbers of cleaners available. Some factors that may affect the origin of the cleaning interactions are discussed.

INTRODUCTION

Cleaning behaviour has been most thoroughly investigated in tropical marine fishes after a number of pioneer studies (e.g. Limbaugh, 1961; Youngbluth, 1968; Losey, 1972; Potts, 1973a). A number of north-eastern Atlantic wrasse have also been implicated in cleaning interactions. Based on aquarium observations, Potts (1973b) showed that *Symphodus melops* (L.) and *Ctenolabrus rupestris* (L.) cleaned several fish species that shared the same tank. The same author reported cleaning behaviour of a *Centrolabrus exoletus* (L.) cleaning *Labrus bergylta* Ascanius in the wild. He also found parasitic larvae of a gnathiid isopod in stomachs of *S. melops* collected in the wild, but cautioned that these could have been taken from rock crevices while free living. Samuelsen (1981) observed *C. exoletus* cleaning *Lophius piscatorius* (L.) in captivity. Darkov & Mochek (1980) observed cleaning behaviour of *C. rupestris* in the Black Sea, while Hilldén (1983) reported a similar observation on the Swedish coast.

These findings stimulated great interest on the potential use of wrasse to control salmon ectoparasites in fish farms (for a review see Costello, 1991). Experimental work in fish cultures showed that *C. rupestris*, *C. exoletus*, *S. melops* and also females of *Labrus bimaculatus* L. can effectively pick ectoparasites, and skin material from salmon and that the first three species are effective in controlling lice infestations on the salmon cultures (Costello & Bjordal, 1990). However, studies on the gut contents of *S. melops* (Deady &

Fives, 1995) and *C. rupestris* (Sayer et al., 1995) in British waters failed to detect ectoparasites in the diet of these fishes in spite of the large numbers of fishes involved in both studies and their varied geographical origin. Thus more observations are needed to evaluate the relative importance of cleaning behaviour by these labrids in natural conditions.

In this paper we present the results of behavioural observations on *C. exoletus*, *C. rupestris* and *S. melops* at Arrábida (west coast of Portugal), aimed to assess the relative importance of cleaning behaviour among these wrasse and the contribution of cleaning to total feeding activities.

MATERIALS AND METHODS

The observations were made by Scuba diving at Arrábida coast (38°28′N 08°59′W) at depths ranging from 1 to 10 m, during the years 1994–1995. The study site is a sheltered rocky subtidal habitat with dense algal cover that in the summer is dominated by *Cystoseira* spp. and *Saccorhiza polyschides*. Observations were made at varying times of the day ranging from 1100 to 1700 hours and were evenly spread throughout all months except January. A total of 50 hours of observation were made.

A cleaning attempt was recorded when a potential cleaner approached another fish at very close proximity and visually inspected its body surface and/or when a potential host assumed a static posture upon the approach of another fish. If there was any indication that an interaction was of an agonistic nature it was discarded. In this study we did not try to assess the extent to which cleaning involved removal of ectoparasites, scales, mucous or any other cutaneous material.

Two sampling strategies were employed. During free observations all cleaning attempts that could be observed were recorded. The species of both participants was noted together with their estimated sizes, with the help of a ruler drawn on a plastic slate. For each cleaning attempt, the host was considered the initiator if it assumed a static posture prior to any movement of a cleaner specifically orientated to it. If a cleaner approached a potential host that did not solicit, the cleaner was considered to be the initiator. If upon a visual inspection the cleaner picked on the body surface of the host, the number and location of the picking acts were recorded. The fish that terminated the interaction was also noted. The host was considered to terminate the interaction if it moved away from the cleaner which in turn was considered the terminator if it moved away from a host that was still motionless.

The second strategy consisted of focal observations (Martin & Bateson, 1993) of randomly selected individuals of *Symphodus melops* (N=16, total time 130 min), *Centrolabrus exoletus* (N=17, total time 120 min), *C. rupestris* (N=16, total time 120 min) and *Labrus bergylta* (N=18, total time 139 min). Each fish was observed continuously for up to 10 min unless the observer lost sight of it or if it became impossible to identify among conspecifics. Since all the species studied are very abundant in the study site, the likelihood of observing the same fish more than once was very low, so the risk of pseudoreplication was probably minimal. During each focal observation, the number of cleaning interactions in which the fish was involved (as cleaner or host) was noted.

Since from free observations it became obvious that *C. exoletus* was the only cleaner in the study site, all the feeding bouts on the water column and the substratum were recorded to get a measure of the relative importance of the cleaning behaviour in the feeding activity of this species. In the case of *S. melops* and *C. rupestris*, the identity of any fish that approached the focal subject at a distance of <1 m was noted. For *L. bergylta* it was also possible to record the duration of the cleaning interactions in which each fish was engaged.

Statistical analysis was performed using STATISTICA version 4·5 (Statsoft Inc., 1993).

RESULTS

A total of 303 cleaning attempts were observed and in all of them *Centrolabrus exoletus* was the cleaner. A single observation involved an individual *C. rupestris* picking at the head tentacles of a *Parablennius gattorugine* (Brunnich) that rested motionless among the algae where this wrasse was foraging. It is doubtful if this event can be properly classified as cleaning.

A total of 12 species were cleaned (inspected and picked). Three others were only approached by *C. exoletus* but were not cleaned, either because the fish swam away (*Diplodus puntazzo* (Gmelin)) or attacked the cleaner (*Parablennius pilicornis* Cuvier and *Pollachius pollachius* (L.)). Cleaning behaviour occurred in all seasons with no apparent decline during the winter. The distribution of cleaning attempts according to host species is presented in Table 1.

Table 1. *Distribution of cleaning interactions by* Centrolabrus exoletus *according to host species.*

	Host species	Cleaning interactions	% of total interactions
Labridae	*Symphodus melops* (L.)	126	49
	Labrus bergylta Ascanius	82	32
	Coris julis (L.)	15	6
	Symphodus roissali (Risso)	10	4
	Symphodus rostratus (Bloch)	2	0·8
	Ctenolabrus rupestris (L.)	1	0·4
Sparidae	*Diplodus vulgaris* (Geoffr.)	9	3·5
	Sarpa salpa (L.)	3	1
	Diplodus sargus (L.)	2	0·8
	Spondyliosoma cantharus (L.)	1	0·4
Mugilidae	Mugilidae (unidentified)	2	0·8
Molidae	*Mola mola* (L.)	1	0·4
Total		**254**	–

Species approached but not cleaned

Sparidae	*Diplodus puntazzo* (Gmelin)
Blenniidae	*Parablennius pilicornis* Cuvier
Gadidae	*Pollachius pollachius* (L.)

In this table all the cleaning interactions involving more than one cleaner with the same host were counted only once and if the same cleaner and host were involved in more than one interaction, only the first occurrence was considered, leading to a total of 254 interactions. There is a wide variation in frequencies with the highest number of interactions directed to *Symphodus melops* and *Labrus bergylta*.

This variation could be a mere reflection of the relative abundances of the different host species. The focal observations of *C. exoletus* were centred on the feeding activities of the fish, thus not being appropriate to estimate the relative frequency with which members of different species met each other. *Symphodus melops* and *C. rupestris* share the same habitat with *C. exoletus* and show roughly similar patterns of movements, thus we used the focal observations of these two wrasse in which any fish that approached the focal fish was recorded, to provide a rough estimate of the relative frequencies with which these two species meet other fishes. Obviously this method does not provide any measure of the abundance of species in the study site. Instead, it estimates the relative frequencies of encounters between fishes of different species.

A highly significant positive correlation (Spearman rank correlation, r=0·88, N=9, P<0·002) was found between the relative frequencies with which different species were met by the two wrasse. In view of these results the frequencies of encounters obtained from the observations of *S. melops* and *C. rupestris* were averaged to compute expected frequencies for cleaning interactions with *C. exoletus*, assuming that they were randomly distributed in what concerns host species identity.

Species that were involved in <5% of the encounters were excluded, leaving six species for which expected frequencies were calculated (Table 2). A chi-squared goodness-of-fit test revealed a significant difference between the expected and observed frequencies (χ^2=159·113, df=5, P<0·001). Inspection of Table 2 revealed two distinct species groups: *S. melops* and *L. bergylta* (group 1) were much more frequently cleaned than expected while the reverse occurred with *Coris julis* (L.), *Ctenolabrus rupestris*, *Diplodus vulgaris* (Geoffr.) and *Symphodus roissali* (Risso) (group 2).

Table 2. *Observed and expected frequencies of cleaning interactions by* Centrolabrus exoletus *for the six species most frequently met by the cleaner. The expected frequencies were calculated assuming that they reflect the different abundance of the hosts. In the calculation of the expected frequencies, the cleaning interactions recorded during the focal observations of* Symphodus melops *and* Labrus bergylta *were excluded to ensure that the data for all the species are comparable.*

Host species	Relative abundance	Observed interactions	Expected interactions
Symphodus melops (L.)	0·26	105	52·78
Diplodus vulgaris (Geoffr.)	0·21	9	42·63
Coris julis (L.)	0·18	15	36·54
Labrus bergylta Ascanius	0·14	63	28·42
Ctenolabrus rupestris (L.)	0·12	1	24·36
Symphodus roissali (Risso)	0·09	10	18·27
Total	1	203	203

The two species groups also differed behaviourally. Group 1 actively solicited cleaning in 80% of the interactions (N=182), while group 2 initiated only 44% (N=34), (chi-squared test for independence, $\chi^2=19{\cdot}67$, df=1, $P<0{\cdot}001$). Moreover, group 1 rejected only 31% of the interactions initiated by *Centrolabrus exoletus* (N=36) while the rejection in group 2 reached 68% (N=19), (chi-squared test for independence, $\chi^2=8{\cdot}09$, df=1, $P<0{\cdot}01$). When the hosts solicited cleaning and *C. exoletus* did not respond, no significant differences were found among the two groups: 10% for group 1 (N=146) and 7% for group 2 (N=15) (chi-squared test of independence, $\chi^2=0{\cdot}14$, df=1, $P=0{\cdot}7108$).

These results suggest differences in the behaviour of the two groups of host fishes towards the cleaner, rather than different preferences of *C. exoletus*. This hypothesis is also supported by the more elaborate soliciting postures found in *S. melops* and *L. bergylta*.

All species exhibit a static posture with unpaired fins erected. However, *S. melops* commonly added a 'head-up' element (82%, N=112) and *L. bergylta* commonly displayed in 'head-up' (41%, N=58) or 'head-down' (10%, N=58). In group 2, the 'head-down' element was only sporadically observed and at a slight angle (<30° while in group 1 the angles often reached 90°).

Concerning the relative importance of the cleaning interactions in the feeding activity of *C. exoletus*, the focal observations showed that picking material from the body surface of other fish is not the dominant form of feeding behaviour in this species. Picking particles from the water column was observed at a rate of 1·06 acts per minute, which corresponds to 55% of the total number of feeding acts. Feeding on substrata occurred at a rate of 0·45 acts min^{-1} and comprised 23% of the total. Picking on other fishes occurred only at a rate of 0·14 acts min^{-1} comprising only 7% of the total. From a total of 17 fishes focally observed only ten engaged in cleaning attempts and six managed to pick on the host fishes. In addition small numbers of picking acts were observed on sand, stones, macroalgae and most interestingly on animals like sea urchins (with careful inspection and apparent removal of tube-feet) and sea cucumbers. Even a gorgonian was carefully inspected by a fish. Inspection and picking movements performed on the surface of other fishes did not differ from the movements employed while feeding on other substrata.

The rates of cleaning by *C. exoletus* during focal observations of *S. melops*, *L. bergylta* and *C. rupestris*, were 11 acts per hour (total cleaning interactions = 24, total observation time = 130 min), 10 acts h^{-1} (total cleaning interactions = 24, total observation time = 139 min) and none (total observation time = 120 min) respectively. When *S. melops* and *C. exoletus* came into a distance of less than a meter, this host solicited in 80% of the cases and was cleaned in 73% of the total. Equivalent values for encounters between *L. bergylta* and *C. exoletus* were 68% and 59% respectively. In 19 encounters between *C. rupestris* and *C. exoletus* no soliciting or cleaning were observed. In the case of *L. bergylta* the duration of inspections was measured. The inspections of fishes classified as larger than average were significantly longer than those of fishes classified as smaller than average (N=10, median = 7 s for larger fish and N=7, median = 5 s for smaller fish: Mann-Whitney *U*-test, Z=-2·07, $P<0{\cdot}05$).

Finally it is important to stress that in no case was any fish seen to solicit cleaning towards *C. rupestris*, *S. melops* or any other fish except *C. exoletus*.

DISCUSSION

The results presented in this paper fully confirm the pioneer observations of Potts (1973b) on the cleaning behaviour of *Centrolabrus exoletus* in nature. On the other hand neither *C. rupestris* nor *Symphodus melops* could be observed cleaning other fishes in our study site, although both species are quite common in the area. This findings contrast with previous studies both in captivity and nature by Potts (1973b); Costello & Bjordal (1990); Darkov & Mochek (1980) and Hilldén (1983).

In a discussion on the cleaning behaviour of some Californian fishes, Hobson (1971) noted that there was considerable variation between individuals of the wrasse *Oxijulis californica*, with some individuals specializing in different host species. The same author also noted that fishes that feed by picking small benthic organisms from the substratum and also take planktonic prey are in a sense preadapted to clean. The feeding behaviour of *C. exoletus* strongly supports this view. Picking from the body surface of other fishes is probably an extension of the behaviour used to pick from rocks, algae and echinoderms. It is not difficult to conceive that other labrid species, even if they do not clean in nature, may learn to take food from other fish heavily infested and densely aggregated, especially if the wrasse are hungry.

It is interesting to note that Deady et al. (1995) reported that wrasse are less effective when the nets in salmon cages are fouled and that it takes some time before some individuals of *S. melops* and *C. rupestris* begin to clean. These observations suggest that when the wrasse find sufficient food on the net, they are not likely to start cleaning and that cleaning behaviour is probably learned. *Centrolabrus exoletus*, the only cleaner in our site, is considered to be 'too effective' when feeding on salmon body surfaces, removing scales from the back of the salmon as well as parasites (Bjordal, 1988).

In the case of the cleaning association between *C. exoletus* and *S. melops* in our study area, there is another probable facilitating factor. We frequently observed a feeding association between these two species. When *S. melops* was feeding, large quantities of small particles were detached from the algal cover of the rocks and spread in the water column. The nearby *C. exoletus* often followed and approached the feeding *S. melops* and actively fed from this cloud of fragments. This feeding association increases the likelihood of the two species coming in close proximity and could facilitate the initiation of cleaning. During our observations, *C. exoletus* involved in feeding associations, frequently alternated between cleaning behaviour and particle intake.

These findings point to two main conclusions: (i) experience may play an important role in the ontogeny of cleaning behaviour, a point also extensively documented regarding the host fishes (e.g. Losey & Margules, 1974; Losey, 1979) and illustrated by the development of cleaning interactions in captivity between species of very different geographical origins (Wyman & Ward, 1972; French, 1980; Lemaire & Maigret, 1987; Darkov & Panyushkin, 1988). This role of experience in the development of the behaviour of host fishes could explain why, in our study area, they never solicited cleaning when they met *C. rupestris*, in spite of its black tail mark that is often considered a cleaner 'guildmark' (Potts, 1973b; Costello, 1993). (ii) The results obtained in fish farms and other captivity conditions may be poor predictors of the behaviour of the same wrasse in nature and vice versa. This would explain the absence of ectoparasites in the diet of *S. melops* (Deady & Fives, 1995) and *C. rupestris* (Sayer et al., 1995) despite their effectiveness as lice eaters in salmon farms. This could also explain the variability of cleaning behaviour in different natural habitats, a point previously made by Hobson (1971). More observations in natural conditions and detailed experiments on the ontogeny of cleaning behaviour are clearly needed.

Our results also showed that at our site, cleaning corresponds to a low proportion of the feeding acts, and that *C. exoletus* is clearly a facultative cleaner fish. However, the observed rates of cleaning on *S. melops* (11 acts h^{-1}) and *Labrus bergylta* (10 acts h^{-1}) are not very different from those reported for coral reef fish (e.g. 12 acts h^{-1} in interactions between the cleaner *Labroides dimidiatus* and the host *Siganus doliatus* around Lizard Island, Great Barrier Reef (Grutter, 1995)). The densities of specialized cleaners in coral reefs tend to be low, with the cleaners localized in 'cleaning stations', and each fish may clean at a very high rate. In our study area, each cleaner may be much less dependent on this form of feeding, but they are quite abundant and available almost everywhere in the habitat, leading to a similar overall impact of cleaning on the populations of host fishes.

The authors are grateful to Mr Jorge Martins for his help during dives and to Manuel E. dos Santos, Emanuel Gonçalves, Rui Rebelo and to anonymous referees for their useful suggestions and comments on the manuscript. This study was partially supported by Junta Nacional de Investigação Científica e Tecnológica through the project PBIC/1313/MAR/92.

REFERENCES

Bjordal, A., 1988. Cleaning symbiosis between wrasse (Labridae) and lice infested salmon (*Salmo salar*) in mariculture. *International Council for the Exploration of the Sea (CM Papers and Reports)*, CM1988/F:17, 1–8.

Costello, M.J., 1991. Review of the biology of wrasse (Labridae: Pisces) in Northern Europe. *Progress in Underwater Science*, **16**, 29–51.

Costello, M.J., 1993. Controlling sea-lice infestations on farmed salmon in Northern Europe: options and the use of cleaner fish. *World Aquaculture*, **24**, 49–55.

Costello, M.J. & Bjordal, A., 1990. How good is this natural control on sea-lice? *Fish Farmer*, **13**, 44–46.

Darkov, A.A. & Mochek, A.D., 1980. Cleaning symbiosis in Black Sea fishes. *Journal of Ichthyology*, **20**, 152–155.

Darkov, A.A. & Panyushkin, S.N., 1988. Cleaning symbiosis in six freshwater fish species. *Journal of Ichthyology*, **28**, 161–167.

Deady, S. & Fives, J.M., 1995. The diet of corkwing wrasse, *Crenilabrus melops*, in Galway Bay, Ireland, and in Dinard, France. *Journal of the Marine Biological Association of the United Kingdom*, **75**, 635–649.

Deady, S., Varian, S.J.A. & Fives, J.M., 1995. The use of cleaner-fish to control sea lice on two Irish salmon (*Salmo salar*) farms with particular reference to wrasse behaviour in salmon cages. *Aquaculture*, **131**, 73–90.

French, D.P., 1980. Cleaning behavior in sunfish hybrids under laboratory conditions. *Copeia*, **1980**, 869–870.

Grutter, A.S., 1995. Relationship between cleaning rates and ectoparasite loads in coral reef fishes. *Marine Ecology Progress Series*, **118**, 51–58.

Hilldén, N.-O., 1983. Cleaning behaviour of the goldsinny (Pisces, Labridae) in Swedish waters. *Behavioural Processes*, 8, 87–90.

Hobson, E.S., 1971. Cleaning symbiosis among California inshore fishes. *Fishery Bulletin. National Oceanic and Atmospheric Administration. Washington, DC*, **69**, 419–523.

Lemaire, P. & Maigret, J., 1987. Importance relative des différents stimuli dans le comportement de nettoyage de *Labroides dimidiatus* (Cuv. et Val., 1839). *Annales de l'Institut Océanographique*, **63**, 69–83.

Limbaugh, C., 1961. Cleaning symbiosis. *Scientific American*, **205**, 42–49.

Losey, G.S., 1972. The ecological importance of cleaning symbiosis. *Copeia*, **1972**, 820–833.

Losey, G.S., 1979. Fish cleaning symbiosis: proximate causes of host behaviour. *Animal Behaviour*, **27**, 669–685.

Losey, G.S. & Margules, L., 1974. Cleaning symbiosis provides a positive reinforcer for fish. *Science, New York*, **184**, 179–180.

Martin, P. & Bateson, P., 1993. *Measuring behaviour – an introductory guide*. Cambridge University Press.

Potts, G.W., 1973a. The ethology of *Labroides dimidiatus* (Cuv. & Val.) (Labridae, Pisces) on Aldraba. *Animal Behaviour*, **21**, 250–291.

Potts, G.W., 1973b. Cleaning symbiosis among British fish with special reference to *Crenilabrus melops* (Labridae). *Journal of the Marine Biological Association of the United Kingdom*, **53**, 1–10.

Samuelsen, T.J., 1981. Der Seeteufer (*Lophius piscatorius*, L.) in Gefangenschaft. *Zeitschrift des Kolner Zoo*, **24**, 17–19.

Sayer, M.D.J., Gibson, R.N. & Atkinson, R.J.A., 1995. Growth, diet and condition of goldsinny on the west coast of Scotland. *Journal of Fish Biology*, **46**, 317–340.

Wyman, R.L. & Ward, J.A., 1972. A cleaning symbiosis between the cichlid fishes *Etroplus maculatus* and *Etroplus suratensis*. I. Description and possible evolution. *Copeia*, **1972**, 834–837.

Youngbluth, M.J., 1968. Aspects of the ecology and ethology of the cleaning fish, *Labroides phthirophagus* Randall. *Zeitschrift fur Tierpsychologie, Berlin*, **25**, 915–932.

Submitted 11 January 1996. Accepted 17 July 1996.