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WRASSE AS CLEANER-FISH FOR FARMED SALMON

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ABSTRACT

In aquarium and sea cage experiments four wrasse species from Norwegian waters were identified as facultative cleaners, with lice infested salmon (*Salmo salar*) as the host: goldsinny (*Ctenolabrus rupestris*), rock cook (*Centrolabrus exoletus*), female cuckoo wrasse (*Labrus ossifagus*) and corkwing wrasse (*Crenilabrus melops*).

In this assumingly artificial cleaning symbiosis the wrasses played the active role while the salmon showed little response, neither aggressiveness nor invitation to cleaning.

Experiments in sea cages have shown that wrasse might be utilized to control sea lice infestation on salmon postsmolts, as an alternative to treatment with chemicals.

INTRODUCTION

The salmon louse (*Lepeophtheirus salmonis* Krøyer) is an ectoparasitic copepod, parasitizing salmonids (*Salmo sp.*, *Onchorhynchus sp.*) of the Northern hemisphere (Kabata, 1979). Although severe damage and mortality caused by salmon lice in wild salmon have been reported (White, 1940), this seems to be exceptional. In sea cage rearing of Atlantic salmon (*Salmo salar*), however, repeated lice infestations are a major problem. The lice feed on the mucus, skin and blood of the host and, if the parasites are not removed, they cause open wounds, exposing the fish to osmotic stress and secondary infections (Pike, 1989). Furevik *et al.* (1988) found that 6-7% of leaping salmon hit the net wall and indicated that leaping frequency increases with lice infestation, which may cause additional skin damage. The current treatment is delousing with the organophosphate pesticides Neguvon® or Nuvan®/Aquasafe, (Brandal & Egidius, 1979; Wootten *et al.*, 1982; Pike, 1989).

Although adult lice are effectively removed by the chemical treatment, this method has several negative effects. The method is expensive and laborious, it is shown to be a major cause of stress to the salmon (Bjordal *et al.*, 1988), it might cause salmon mortality (Salte *et al.*, 1987), it represents a health risk to farm workers (Ross & Horsman, 1988) and might be lethal to marine organisms in the vicinity of the fish farm (Egidius & Møster, 1987). Particularly from the possible negative environmental impacts, proposals have been made to ban the use of Neguvon®/ Nuvan® in the salmon farming industry. There is therefore an urgent need for alternative, less harmful solutions to the problem and different approaches have been made. Capturing lice in light traps or repelling lice by sound or electrical stimuli have been tried, without promising results. Huse *et al.* (1990) found that the shading of sea cages gave slightly reduced lice infestation and promising results were obtained in introductory trials with pyrethrum (an organic insecticide) mixed in an oil layer on the water surface (Jakobsen & Holm, 1990). However, utilization of cleaner-fish is at present the most developed alternative method for lice control and this paper will focus on different aspects of wrasse cleaning in salmon farming.

In cleaning symbiosis, one species (the cleaner) feeds on parasites from another species (the host), (see Feder, 1966; Losey, 1987). Most cases of cleaning symbiosis in fishes have been described from natural habitats in marine tropical waters. Records of cleaning behaviour have also been made in temperate waters, both in the wild and in aquaria. Among northern European wrasses, Potts (1973) observed cleaning behaviour in corkwing wrasse (*Crenilabrus melops*), goldsinny (*Ctenolabrus rupestris*) and rock-cook (*Centrolabrus exoletus*) in aquaria. Samuelsen (1981) reported cleaning symbiosis between rock cook and angler fish (*Lophius piscatorius*) in aquaria, while Hillden (1983) described cleaning in goldsinny from field observations on the Swedish west coast. Cleaning has also been observed in juvenile ballan wrasse (*Labrus berggylta*) and cuckoo wrasse (*Labrus ossifagus*), (G.W. Potts, pers. comm.). These findings encouraged experiments to clarify whether cleaning symbiosis could be established between Norwegian wrasses and farmed salmon and, if so, whether this could be applied in full-scale fish farming as a method to control lice infestation.

This paper gives a review of different experiments on the utilization of wrasse as cleaner-fish for salmon from 1987 to 1989. The experimental work was conducted at the Austevoll Marine Aquaculture Station (near Bergen, Norway), including cleaning experiments in tanks and sea cages, behaviour observations, feeding in wrasse and the effect of cleaning on salmon growth and mortality (Bjordal, 1988, 1990; Bjordal & Kårdal, 1989). Full scale trials have been conducted at several fish farms on the Norwegian West coast from 59 to 66 degrees north (Bjordal & Kårdal, 1989; Bjordal, 1990; Beltestad *et al.*, 1990).

Five wrasse species have been used: goldsinny, rock cook, cuckoo wrasse, corkwing wrasse and ballan wrasse, which in most cases were caught locally with baited pots, baited dip nets, fyke nets or beach seine-nets. The salmon used ranged from postsmolts (first year in sea) to adult fish (up to 3 kgs) with lice infestation levels from 5 to 50 adult lice per fish.

Cleaning experiments were conducted in circular fiberglass tanks (1.5 m diam., 1.5 m^3), in an aquarium (0.75 x 0.75 x 2.00 m) or in small sea cages (5 x 5 x 4 m), while full scale trials were done in smolt cages, most of which were 12 x 12 m to 15 x 15 m by 6-10m deep. The netting in the sea cages would normally have a mesh size of 12 x 12 mm square mesh.

CLEANERS AND CLEANING CAPACITY

Introductory experiments (1987) in tanks and aquaria revealed that goldsinny, rock cook and female cuckoo wrasse were facultative cleaners for lice infested salmon (Fig. 1), while cleaning was not observed by ballan and male cuckoo wrasse, (Bjordal, 1988). In a later sea cage experiment, corkwing wrasse were also found to clean salmon.

Figure 1. Goldsinny cleaning salmon in aquarium. (Photo: J.E. Fosseidengen).

One experiment conducted in 1987 gave the first promising indications of wrasse cleaning capacity in sea cages. On 26 October 1987, the number of adult lice on 40 postsmolts (300 g) were recorded before the fish were released into a small sea cage with 24 rock cook, 2 goldsinny, 2 ballan and 1 cuckoo wrasse. After 24 hours the smolts were taken out and the number of adult lice recorded. The total number of lice was reduced by 57%, from 1329 to 565 lice. Assuming that the ballan wrasse did not perform cleaning, this experiment suggested that the average cleaning capacity was 28.3 lice per wrasse per day.

In aquarium experiments individual goldsinny were observed to clean 45 lice in 1.5 hours, and up to 20 lice have been found in the stomach of goldsinny that had been cleaning salmon in a sea cage.

CLEANING EFFICIENCY IN SEA CAGES

A more extensive investigation was carried out in 1988 to study how different wrasse species could cope with lice infestations on salmon in sea cages (see Bjordal, 1990). Eight small sea cages (5 x 5 x 4 m) with 10 x 10 mm square mesh netting were each stocked with 220 salmon (postsmolts, mean weight: 84 g), which had no visible lice infestation at the start of the experiment (August 17 1988). The salmon in two of the cages were used as control groups, while the remaining six cages were stocked with different species and numbers of wrasse: 25- and 50 cuckoo wrasse, 25- and 50 goldsinny, 50 rock cook and a mixed group of 15 goldsinny and 15 rock cook. The average total body length of cuckoo wrasse was 19.2 cm, goldsinny 14.3 cm and rock cook 13.1 cm. Dead wrasse were replaced, except for rock cook as there was no surplus available of this species.

After a few days, lice were observed on the salmon and after 13 days the control and cuckoo wrasse groups were so heavily infested that chemical de-lousing (Nuvan®) was needed. Samples were taken from all groups and lice infestation and growth data were recorded. Lice infestation was categorized in five levels (number of adult lice in parenthesis): 1 (0), 2 (1-5), 3 (6-10), 4 (11-20) and 5 (>20).

There was a marked difference in lice infestation: the control and cuckoo wrasse groups were heavily infested, while the other wrasse groups only had slight to moderate lice infestation as illustrated by the example in Figure 2. Until December two additional Nuvan®-treatments were needed in the control groups, while lice infestation in the wrasse groups was insignificant to moderate (Table 1). Cuckoo wrasse were able to control subsequent lice infestations, although not as effectively as rock cook and goldsinny.

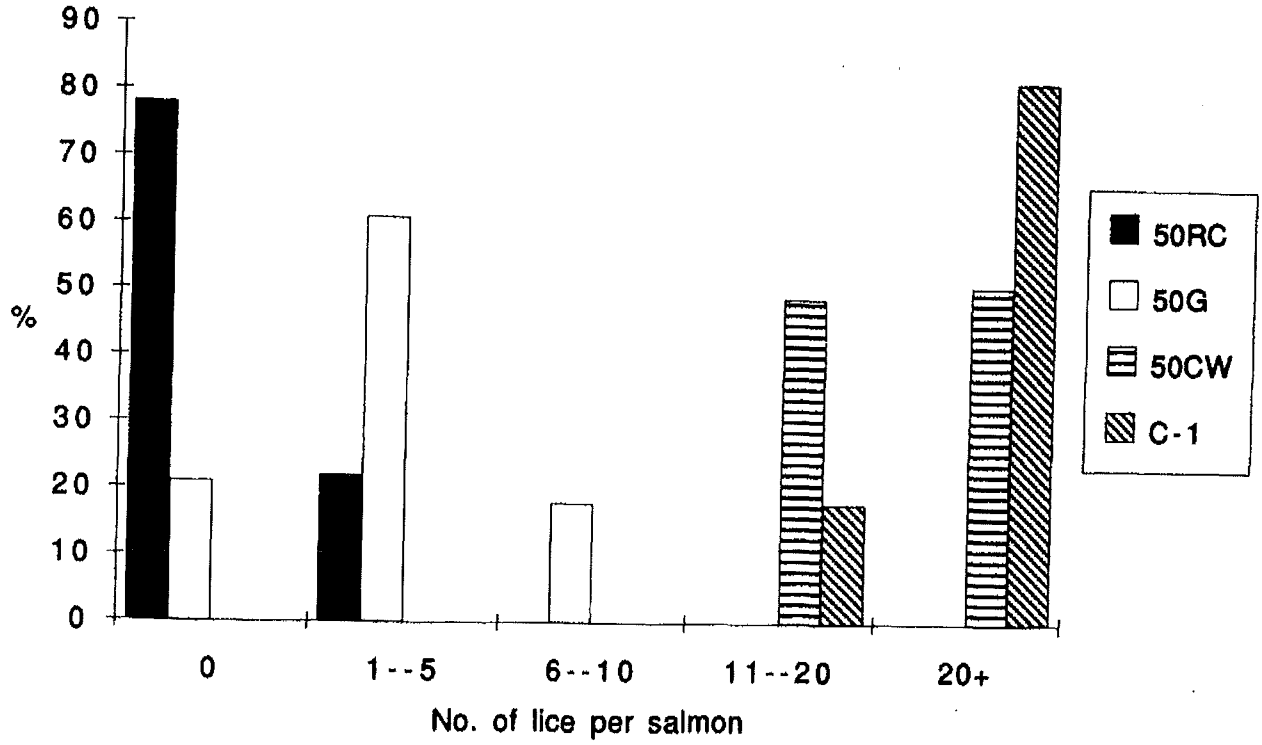

Figure 2. Small cage cleaning experiment, 1988. Lice infestation build up in 4 postmolt groups during a 2 week period, given as percentage of salmon in different infestation categories. C-1 = control group, 50CW = with 50 cuckoo wrasse, 50G = with 50 goldsinny and 50RC = with 50 rock cook.

TABLE 1. Small cage experiment, 1988. Mean lice infestation levels (according to category values given in text, n=50) and de-lousings (DL) with Nuvan® (from Bjordal, 1990).

Date	C-1	C-2*	25CW	50CW	25G	50G	50RC	15/15
August 17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
August 30	4.80	5.00	4.70	4.50	2.30	1.90	1.20	1.20
August 31	DL	*	-	-	-	-	-	-
September 1	-	*	DL	DL	-	-	-	-
September 29	3.66	*	2.26	1.94	1.22	1.06	1.02	1.04
October 5	DL	1.00	-	-	-	-	-	-
November 1	3.52	3.28	1.68	1.28	1.36	1.30	1.06	1.02
November 4	DL	DL	-	-	-	-	-	-

C = control, CW = cuckoo wrasse, G = goldsinny, RC = rock cook, 15/15 = 15G + 15 RC.
* Due to high mortality caused by severe lice infestation, the C-2 control group was taken out of the experiment on 30 August. A new group of 200 postsmolts was stocked in the cage on 5 October.

In this experiment lice control was obtained at ratios of 4.4 and 8.8 salmon per wrasse. However, due to heavy mortality and no replacement in the 50 rock cook group, only 10 wrasse remained at the end of the experiment. This indicated that (at average) one rock cook could clean 22 salmon.

FULL SCALE TRIALS

The first full scale trial was done at a fish farm at the island of Sotra (west of Bergen). On 12 September 1988, 500 goldsinny and 100 rock cook were stocked in a sea cage with 26,000 salmon (postsmolts, 400 g, in sea water since 8 June 1988), which gave a wrasse to salmon ratio of 1:43. Two adjacent cages with 20,000 and 30,000 salmon, respectively, were used as control groups. The cages were 12 x 12 x 6 m. All the smolt groups had been de-loused with Nuvan® one week earlier.

During the 7 weeks trial period salmon with lice were rarely observed in the wrasse cage, while the control group with 20,000 salmon needed 3 Nuvan®-treatments (September 19, October 10 and November 14) and the other control group was treated once (November 14). A clear difference was also noticed in skin pigmentation, as the salmon in the control groups generally had distinct grey spots on the dorsal side caused by lice while the salmon in the wrasse cage had a uniformly dark appearance when inspected from above.

In 1989 wrasse were used for lice control in smolt cages at a number of fish farms in Norway and one in Shetland. Data collected from 20 Norwegian farms revealed that a total of 50,000 wrasse were stocked with 2.3 million postsmolts in 115 cages. The wrasses used were goldsinny (65%), rock cook (15%), corkwing wrasse (15%) and cuckoo wrasse (5%). The farms reported positive results from wrasse cleaning, at ratios up to 100 salmon per wrasse. Table 2 gives data from the Norwegian farm that used wrasse cleaning most extensively in 1989. Wrasse (90% goldsinny and 10% rock cook) were fished locally and 17 smolt-cages (15 x 15 x 10 m, with 33.000 to 60.000 smolts in each) were successively stocked with wrasse from June to September, with ratios ranging from 21 to 83 salmon per wrasse. No chemical lice treatment was needed, except in the control groups. However, during a heavy lice attack in October-November the infestation on smolts in the wrasse cages also rose to critical levels, but stabilized and decreased so that Nuvan® treatment was avoided (see Beltestad *et al.*, 1990).

TABLE 2. Dates of chemical lice treatments (Nuvan®) of postsmolt groups at the MOWI (Haverøy) fish farm, 1989. C = control cages, W = wrasse cages, C/W = cages stocked with wrasse 1-2 weeks after the chemical treatment in July (from Beltestad *et al.*, 1990).

CAGE NO.	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
02 C	-	-	21	-	27	-
19 C	08	-	21	29	-	-
26 C	-	06	-	11	20	-
34 C	-	07	-	12	-	-
38 C	-	07	-	13	20	-
39 C	-	06	-	13	20	-
23 CW	-	06	-	-	-	-
28 CW	-	06	-	-	-	-
29 CW	-	06	-	-	-	-
32 CW	-	07	-	-	-	-
33 CW	-	07	-	-	-	-
35 CW	-	07	-	-	-	-
36 CW	-	07	-	-	-	-
37 CW	-	07	-	-	-	-
40 CW	-	06	-	-	-	-
08 W	-	-	-	-	-	-
09 W	-	-	-	-	-	-
10 W	-	-	-	-	-	-
13 W	-	-	-	-	-	-
21 W	-	-	-	-	-	-
22 W	-	-	-	-	-	-
30 W	-	-	-	-	-	-
31 W	-	-	-	-	-	-

EFFECT OF CLEANING ON SALMON GROWTH AND MORTALITY

Growth and morality data from the 1988 small cage experiment are given in Table 3. The results strongly suggest that lice control by cleaning may reduce mortality and increase growth of salmon, although other factors such as unequal densities of smolt due to different mortalities might have affected growth rates (see Bjordal, 1990).

TABLE 3. Growth and mortality of postsmolt control group and groups with wrasse cleaning, given as mean weight (g) and number of dead salmon at the end of the experiment, on 1 November 1988, (from original 220 postsmolts of 84g mean weight, August 17 1988). Explanation of abbreviations is given in Table 1. (adapted from Bjordal 1990).

	C-1	25CW	50CW	25G	50G	50RC	15/15
Growth	220	252	253	276	290	292	297
Mortality	145	153	115	36	14	0	3

INTER AND INTRASPECIFIC BEHAVIOUR

Behaviour of salmon and wrasse was observed in tanks, aquaria and sea cages (either by direct observations at the cage side or by underwater television). When put in tanks or aquaria the salmon would normally swim around vigorously during the first 3-5 minutes and then come to rest on the bottom, a position maintained for several hours, only interrupted by a few short periods of swimming. In sea cages the salmon would normally swim in a ring-formed school, and their behaviour was not significantly affected by the presence of wrasse. Aggressive behaviour of salmon towards wrasse was not observed. On the other hand, salmon did not solicit cleaning by performing typical inviting postures as described for many host species in cleaning symbiosis (Losey, 1979, 1987).

In general salmon did not cause fright reactions in wrasse. When a salmon was introduced to an aquarium or tank with wrasse, the wrasse would keep a distance until the salmon came to a resting position. Then after 5-15 minutes, one or a few wrasse would approach the salmon and start to inspect and clean it. Wrasse that were inexperienced with salmon would normally start cleaning at the tail region, then the central parts of the fish and eventually clean lice from the head. A wrasse would normally swim slowly alongside a salmon, inspecting it before nibbling one or several lice. There was a marked difference in cleaning behaviour between cuckoo wrasse, goldsinny and rock cook. Cuckoo wrasse may be described as a slow cleaner. When a salmon was introduced for the first time it could take several hours before the cuckoo wrasse started cleaning. In a mixed group of wrasse, goldsinny would normally be the first to start cleaning and even when offered a lice infested salmon for the first time, the goldsinny could start cleaning as soon as 5 minutes after the salmon had come to a resting position. Rock cook also started cleaning after a relatively short time, and from aquarium observations it was characterized as the most aggressive cleaner of the three species. When a salmon was cleaned, the rock cook would continue to perform cleaning behaviour, often resulting in severe scale loss and wounds on the dorsal side of the salmon. This problem was, however, not observed in later sea cage experiments.

In sea cages the specific difference in cleaning behaviour seemed to be correlated to cleaning effectiveness, which was highest for goldsinny and rock cook and more moderate for cuckoo wrasse. No good observations were made on cleaning behaviour of corkwing wrasse, mainly because it adapted poorly to, and had high mortality in the tank situation. Cleaning behaviour in cages was observed mainly with goldsinny. The wrasse normally stayed along the side walls or deeper than the salmon. As salmon were cruising slowly in the central part of the cage, goldsinny would typically enter the salmon school, swim alongside a salmon for a half to one round, inspect it and nibble several lice before returning to the cage wall.

Interspecific aggression was observed in aquarium studies, as rock cook frequently would attack the black spot on the caudal peduncle of goldsinny resulting in open wounds. This phenomenon was, however, not observed when goldsinny and rock cook were kept in larger holding facilities like the small sea cages. Intraspecific aggression and territorial behaviour were observed in both cuckoo wrasse, rock cook and goldsinny, but was most closely studied in the latter species. When lice infested salmon were introduced to an aquarium with six goldsinny, all cleaning was done by one dominant individual and when this fish was removed, another took its position. Aggressiveness and territorial behaviour were also expressed through chasing, biting, mouth-fighting and change from normal colour pattern to a mottled coloration of distinct vertical bars. Chasing and territorial behaviour were also observed in sea cages, the latter mainly related to the underwater camera, which a goldsinny would occupy as a habitat and defend against intruders.

WRASSE FEEDING

When adapted to captivity, the wrasse would feed on various food items. In tanks and aquaria the wrasse were fed regularly with fish feed (dry or moist pellets), but they showed higher preference for natural food items (lice, crushed blue mussels, or intertidal amphipods and isopods). After a few days in a tank, the wrasse (particularly goldsinny) would take food from the hand. Besides feeding on lice, wrasse in sea cages were observed to feed on planktonic organisms, epifauna on the cage walls, salmon feed and on dead salmon. Stomach contents of wrasse from sea cages included lice, crustaceans, polychaetes, mussels and tunicates. Stomach content analysis also revealed great variation both with respect to overall feeding (empty/full stomachs) and food types, e.g. in one sample, lice were only found in 12 of 65 stomachs examined (goldsinny and rock cook). Up to 20 lice have been found in the stomach of a wrasse (goldsinny) from sea cages, while in an aquarium experiment a dominant goldsinny was observed to clean 45 lice off two salmon during 1.5 hours.

The effect of wrasse foraging on fouling organisms may be significant. A cleaning study in 1989 included two adjacent sea cages (12 x 12 x 6 m), one with 3500 postsmolts the other with 3500 postsmolts and 500 goldsinny. On March 5 the net bags of both cages were replaced due to heavy fouling. In the upper 2 metres of the net panel there was no difference in fouling (mainly algal growth). However, from 2-6m depth the control cage was fouled with tunicates (100-500/m^2, increasing with depth), while the wrasse cage had no tunicate growth.

During the feeding of salmon, wrasse did take salmon feed, but they would stay deeper in the cage and feed on pellets that were not taken by the salmon. Wrasse did also feed on dead salmon at the cage bottom, and up to 50 goldsinny could be seen feeding on one fish.

DISCUSSION

Four wrasse species have been identified as facultative cleaners for farmed salmon parasitized by sea lice, and full scale trials have proven that cleaner-fish can be used to control sea lice infestation in commercial salmon farming at ratios up to 150 salmon per wrasse (postsmolts and goldsinny). However, the number of wrasse needed to clean a salmon population may vary according to the intensity of the sea lice invasion.

Behaviour observations and stomach analysis showed that cleaning is not performed by all wrasse, which indicates that a certain proportion of the wrasse population will function as cleaners, while the rest will feed on other food items. It is, however, unclear if this foraging pattern is likely to change with changes in the relative availability of food (e.g. lice versus fouling organisms) or if cleaning is only performed by certain individuals.

The small cage experiment indicated improved growth and survival of salmon that were cleaned by wrasse. Although this has not been verified in full scale trials, there is reason to believe that repeated lice attacks and chemical treatments will impair salmon growth and immunity compared to a situation with continuously low lice infestation.

Supply of wrasse is the major uncertainty with respect to wrasse cleaning as extensively used method for de-lousing. Little knowledge exists on the size and reproduction potential of wrasse stocks and on the possibilities of breeding wrasse (Costello & Bjordal, 1990). However, if wrasse can be supplied in adequate quantities, this form of biological delousing represents a clearly beneficial alternative to chemical treatment. The successful application of wrasse cleaning in salmon farming also suggests utilization of cleaning symbiosis for parasite control in different fields of aquaculture.

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