CLEANING SYMBIOSIS AS AN ALTERNATIVE TO CHEMICAL CONTROL OF SEA LICE INFESTATION OF ATLANTIC SALMON

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ABSTRACT

Different wrasse species (Labridae) from Norwegian waters were identified as facultative cleaners of farmed Atlantic salmon (*Salmo salar*) infested with sea lice (*Lepeophtheirus salmonis*). In sea cage experiments, goldsinny (*Ctenolabrus rupestris*) and rock cook (*Centrolabrus exoletus*) were the most effective cleaners, while female cuckoo wrasse (*Labrus ossifagus*) showed a more moderate cleaning behavior. The corkwing wrasse (*Crenilabrus melops*) also performed cleaning, but this species had high mortality. Full scale trials in commercial salmon farming indicate that the utilization of cleaner-fish is a realistic alternative to chemical control of lice infestation in sea cage culture of Atlantic salmon.

INTRODUCTION

Mass infestation of ectoparasitic salmon lice (*Lepeophtheirus salmonis)* is a serious problem in intensive sea cage rearing of Atlantic salmon *(Salmo salar)*. The lice feed on the mucus, skin and blood of the host and if the parasites are not removed, they will 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, and thus creates additional skin damage.

The current treatment is de-lousing with the organophosphate pesticides Neguvon or Nuvan / Aquasafe, dichlorvos being the active agent (Brandal and Egidius 1979; Wootten et al. 1982; Pike 1989). This method has been proven effective for removal of adult lice. Younger (chalimus) stages that are embedded in the skin of salmon are, however, not removed and a second treatment after 3-4 weeks is therefore recommended (Brandal and Egidius 1979). Still, repeated treatments are often required, mainly during the summer and fall seasons.

Although adult lice are removed by the chemical treatment, this method has several negative effects. Bjordal et al. (1988) found that chemical delousing was a major stressor for farmed salmon, expressed by increased heart rate and cortisol levels. Dichlorvos may cause mortality in salmon (Salte et al. 1987), but has selective toxic effect on arthropods and can therefore be lethal to crustaceans in the vicinity of fish farms (Egidius and Møster 1987). If not properly used, the chemicals also represent a health risk to farm workers. The use of these chemicals is one of the most criticized aspects of salmon farming by environmental agencies, and proposals have been made to ban their use (Ross and Horsman 1988). 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 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 and 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.

BACKGROUND

In cleaning symbiosis, one species (the cleaner) has specialized in feeding on parasites from another species (the host or client). Most cases of cleaning symbiosis in fishes have been described from natural habitats in marine tropical waters. Several fish species have been identified as cleaners, particularly among the wrasses (Feder 1966). Records of cleaning behavior have been made in temperate waters, both in the wild and in aquaria. Among North Sea wrasses, Potts (1973) observed cleaning behavior 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)*, also from aquarium observations, while Hillden (1983) described cleaning in goldsinny from field observations on the Swedish west coast. According to Potts (pers. comm.) cleaning has also been observed in young individuals of ballan wrasse (*Labrus berggylta*) and cuckoo wrasse (*L. ossifagus*).

These findings on cleaning behavior in North Sea wrasses encouraged experiments to clarify if cleaning symbiosis could be established between Norwegian wrasses and farmed salmon, and if so, could this 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, behavioral observations of feeding in wrasse and effect of cleaning on salmon growth and mortality (Bjordal 1988, 1990; Bjordal and Kårdal

1989). Full scale trials have been conducted at several fish farms on the Norwegian West coast from 59 to 66° N (Bjordal and Kårdal 1989; Bjordal 1990, in press; Beltestad et al. 1990) and at one farm in Shetland (Smith in press).

Five wrasse species have been used: goldsinny, rock cook, cuckoo wrasse, corkwing wrasse and ballan wrasse, which in most cases were caught locally. However, due to scarcity of wrasse in Shetland and in northern Norway the trials in these areas were based on wrasse caught in Scotland and the Bergen area respectively and transported to the trial farms in oxygenated sea water.

The salmon used in the experimental work ranged from postsmolts (300 g, first year in sea) to adult fish (3.5 kgs) with lice infestation levels from 5 to 50 adult lice per fish, while the full scale trials were done mainly with postsmolts.

The experimental work was conducted in circular fiberglass tanks (1.5m diam. 1.5 m^3), in an aquarium (0.75 x 0.75 x 2m) or in small sea cages (4 x 4 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 6-10 m deep. The netting in the sea cages would normally have a mesh size of 12 x 12 mm square mesh.

CLEANING SYMBIOSIS BETWEEN WRASSE AND SALMON

Introductory trials were initiated on 11 June 1987 with 185 wrasse (90% rock cook, the rest goldsinny and cuckoo wrasse). These were split into two groups: 100 in an indoor tank and 85 in a small sea cage. The cage group was offered one lice-infested salmon the first day and another after five days, while the tank group was offered one lice-infested salmon (dead), dead and live lice after seven days. In both groups, no wrasse were seen to feed on lice and there was no reduction in lice infestation of the three salmon.

On 24 June 165 wrasse were pooled in the tank and fed once daily for 70 days, mainly on salmon feed randomly supplemented with live feed (amphipods and isopods collected in the littoral zone). Then on 2 Sept, two-lice infested salmon (one postsmolt and one adult) were offered to the wrasse. Now cleaning was observed after 10 minutes, and the next day (after 17 hours in the tank) both salmon were completely cleaned of adult lice. During the next 7 days this was repeated with 8 lice-infested salmon. The wrasse would start cleaning after a few minutes and the salmon was normally cleaned after 20-30 minutes in the tank. Goldsinny would start and do most of the cleaning, but rock cook were also observed to take lice. On 7 Sept., 24 rock cook, 2 goldsinny, 2 ballan and 1 cuckoo wrasse were transferred to the small sea cage and offered one lice-infested salmon. After five days wrasse were seen to swim alongside the salmon and nibble lice from the dorsal and posterior parts of the host. This was followed by cleaning experiments where different wrasse species in separate tanks were offered lice-infested salmon. Goldsinny, rock cook, and female cuckoo wrasse were identified as facultative cleaners, while cleaning behavior was not observed in ballan wrasse. Due to high mortality in holding tanks, no cleaning experiments were done with corkwing wrasse in tanks or aquaria. However, in later sea cage trials this species also showed good cleaning abilities. In these experiments the number of wrasse had by far exceeded the number of salmon, with wrasse to salmon ratios ranging from 5:1 to 165:1. To clarify if wrasse cleaning could be applied as a method for lice control, investigations on cleaning capacity were done.

One small experiment conducted in 1987 gave the first promising indications on wrasse cleaning capacity. On 26 Oct. 1987, the numbers of lice on 40 postsmolts (300 g) were recorded before the fish were released in 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. Figure 1 shows the lice distribution on the salmon before and after the stay in the wrasse cage. 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.

CLEANING UNDER NATURAL CONDITIONS IN SEA CAGES

A more extensive investigation was carried out in 1988 to study how different wrasse species could cope with lice infestation on salmon under natural conditions in sea cages. 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 on 17 Aug. 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 (Fig. 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). After the first heavy lice infestation, the cuckoo wrasse also were able to control lice infestation, although not as effectively as rock cook and goldsinny.

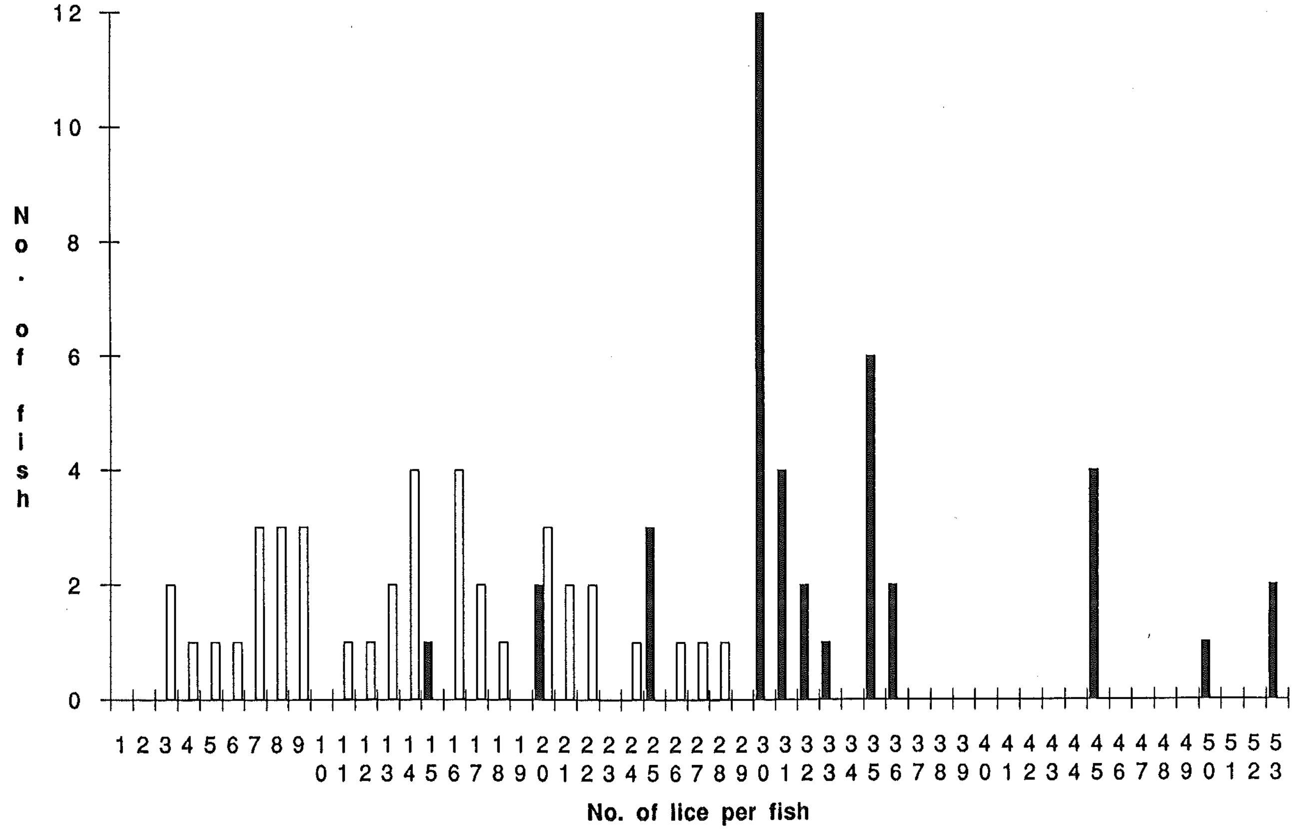

Figure 1. Lice infestation on 40 postsmolts before (black columns) and after (open columns) a 24-hour period in a sea cage with 29 wrasse.

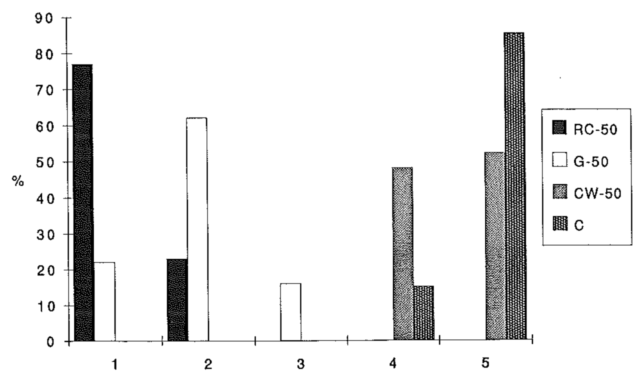

Figure 2. Small cage cleaning experiment 1988: lice infestation build-up in 4 postsmolt groups during a 2-week period. C-1: controls; 50CW: with 50 cuckoo wrasse; 50G: with 50 goldsinny; 50RC: with 50 rock cook (from Bjordal in press).

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 rock cook were left at the end of the experiment which means that on 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 Sept. 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), which gave a wrasse to salmon ratio of 1:43. Two adjacent cages with 20,000 and 30,000 post-smolts 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. The need for de-lousing was based on the farm manager's judgement.

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

In 1989 wrasse cleaning was applied 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 wrasse used were goldsinny (65%), rock cook (15%), corkwing wrasse (5%) and cuckoo wrasse (5%). Nineteen of these farms reported positive results from wrasse cleaning, at ratios up to 100 smolts per wrasse. Table 2 gives data from the farm that used wrasse cleaning most extensively in 1989. Wrasse (90% goldsinny and 10% rock cook) were fished locally and 17

Table 1. Small cage experiment 1988. Lice infestation levels (according to category values given in the text, n=50) and de-lousings with Nuvan (from Bjordal in press).

Date	C-1	C-11*	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 + 15C. DL:de-lousing.

*due to high mortality caused by severe lice infestation, the C-11 control group was taken out on 30 August. A new group of 200 postsmolts was stocked in the cage on 5 October.

smolt-cages (15 x 15 x 10 m, with 33,000 to 60,000 smolts in each) were stocked successively 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.

Full scale trials with wrasse cleaning were also carried out at a fish farm in Shetland, from the end of September 1989 (Smith in press). In cages with 5,000 postsmolts (400 g), sea lice infestation was successfully controlled with goldsinny at ratios from 50 to 150 salmon per wrasse, while control groups suffered repeated lice infestation.

EFFECT OF CLEANING ON GROWTH AND MORTALITY OF SALMON

Growth and mortality data from the 1988 small cage experiment are given in Table 3. The results clearly indicate that lice control by cleaning might reduce mortality and increase growth of salmon. Although other factors, such as unequal densities of smolts due to different mortalities, might have affected growth rates, it is reasonable to believe that repeated lice attacks and chemical treatments would have retarded growth as compared with that of salmon that had a continuously low lice infestation.

BEHAVIOR OF WRASSE AND SALMON

Behavior 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 it would maintain 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 behavior was not significantly affected by the presence of wrasse.

Aggressive behavior 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.

Table 2. Dates of chemical lice treatments (Nuvan) of postsmolt groups at the MOWI (Haveroy) fish farm 1989. C: control cages; W: wrasse cages. * indicates cages not yet stocked with wrasse (from Beltestad et al. 1990).

Cage No.	June	July	Aug	Sep	Oct	Nov
02C	-	-	21	-	27	-
08W	-	-	-	-	-	-
09W	-	-	-	-	-	-
10W	-	-	-	-	-	-
13W	-	-	-	-	-	-
19C	08	-	21	29	-	-
21W	-	-	-	-	-	-
22W	-	-	-	-	-	-
23W	-	06*	-	-	-	-
26C	-	06	-	11	20	-
28W	-	06*	-	-	-	-
29W	-	06*	-	-	-	-
30W	-	-	-	-	-	-
31W	-	-	-	-	-	-
32W	-	07	-	-	-	-
33W	-	07*	-	-	-	-
34C	-	07	-	12	-	-
35W	-	07*	-	-	-	-
36W	-	07*	-	-	-	-
37W	-	07*	-	-	-	-
38C	-	07	-	13	20	-
39C	-	06	-	13	20	-
40W	-	06*	-	-	-	-

Table 3. Percentage mean weight increment (%G) and percentage mortality (%M) of postsmolts in the small cage experiment between 17 August and 1 November 1988 (Abbreviatons as in Table 1) (After Bjordal 1990).

	C-1	25CW	50CW	25G	50G	50RC	15/15
G%	162	200	201	229	245	248	254
M%	66	70	52	16	6	0	1

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. With resting salmon, wrasse could also stay still for longer periods inspecting a small part of the salmon body (Fig. 3).

There was a marked difference in cleaning behavior 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 behavior 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 behavior 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 behavior of corkwing wrasse, mainly because it adapted poorly to and had high mortality in the tank situation. Cleaning behavior in cages was observed mainly with goldsinny. The wrasse normally stayed along the side walls or

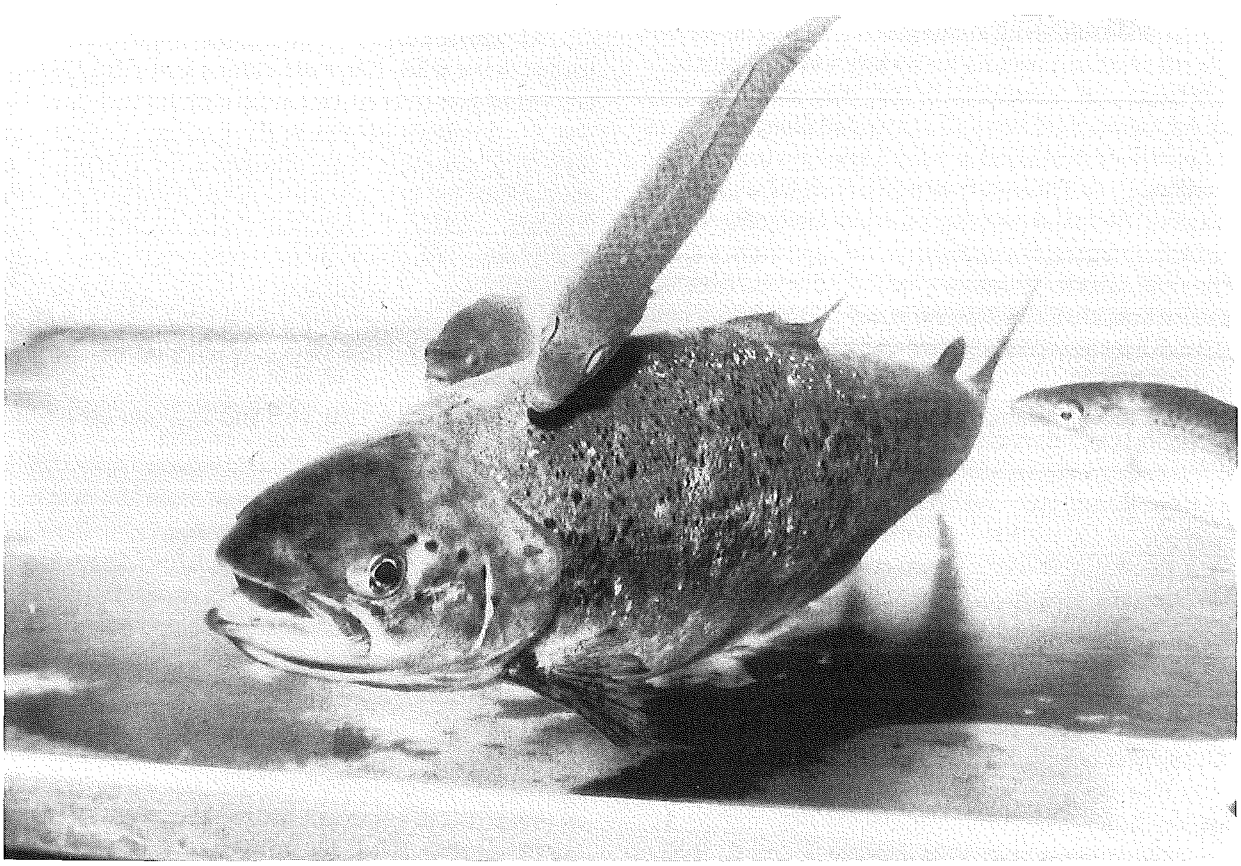

Figure 3. Goldsinny inspecting salmon during cleaning experiments in aquarium (Photo: J.E.Fosseidengen).

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 as it would actively inspect it and nibble several lice before returning to the cage wall.

Interspecific aggressiveness 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 behavior were observed in cuckoo wrasse, rock cook and goldsinny, but 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 behavior were also expressed through chasing, fighting (mouth against mouth) and change from normal color pattern to distinct vertical bar coloration. Chasing and territorial behavior were also observed in sea cages, the latter mainly related to the underwater camera, which a goldsinny would occupy quickly as a habitat and defend it 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 contents from wrasse in sea cages 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, also. A cleaning study in 1989 included two adjacent sea cages (12 x 12 x 6 m), one with 3,500 smolts the other with 3,500 smolts and 500 goldsinny. On March 5, the net bags of both cages were replaced due to heavy fouling. In the upper 2 meters of the net panel there was no difference in fouling (mainly algal growth). However, from 2-6 m depth the control cage was fouled with tunicates (100-500 m^{-2}, increasing with depth), while the wrasse cage had no tunicate growth. During 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. Up to 15 goldsinny could be seen feeding on one fish.

CAPTURE AND HOLDING OF WRASSE IN CAPTIVITY

All wrasse utilized for de-lousing of salmon have so far been caught in the wild. The main fishing gears that have been used are: baited pots (creels), baited dip nets and fyke nets. Goldsinny was the dominant species in the catches. It is unclear if this reflects a relatively high abundance of goldsinny or higher catchability for this species with the applied fishing methods. Also beach seining has been successful, mainly for rock cook that tend to swim pelagically in small shoals and are not easily caught in baited gears. Catchability of wrasse seems to be strongly related to temperature, with a main fishing season for wrasse in Norwegian waters from June to November.

Table 4. Retention of goldsinny and cuckoo wrasse with netting of different mesh sizes: 12.0, 16.5 and 22.4 mm bar (square mesh). (Ret.: retention; Esc.: escapement; Fish total length in mm).

Mesh size	12.0 mm		16.5mm		22.4 mm	
	Esc.	Ret.	Esc.	Ret.	Esc.	Ret.
Goldsinny						
n	5	45	38	13	44	5
Length: mean	85	111	101	125	124	145
min.	80	90	80	110	100	123
max.	90	145	120	143	144	157
Cuckoo Wrasse						
n	0	14	3	19	8	5
Length: mean	-	152	129	176	168	209
min.	-	122	128	128	140	190
max.	-	190	130	220	185	225

After capture, the wrasse are normally stored in small holding pens of knotless small meshed netting between each transportation to the fish farm. Some sea-weed is often added to the cages, as experience has shown that this will reduce wrasse mortality, presumably because it provides shelter from bird predators, and microhabitats that might reduce aggression.

Wrasse have so far been applied mainly in smolt cages (normally 12 x 12 mm mesh size), because larger meshed netting increases the risk of wrasse escapement or entanglement. Length data of wrasses escaping from or remaining inside mini cages of different mesh sizes during a four day tank experiment are given in Table 4.

To improve the living conditions for wrasse in sea cages, trials were made with an artificial habitat constructed from stacks of 10 oyster rearing trays with entrances. This unit was suspended in the sea cage and after some days it could be observed that wrasse frequently entered and left this type of habitat.

In the introductory trials (1987), mortalities were high for ballan wrasse, corkwing wrasse and to a lesser degree for rock cook. This was probably caused by too high stocking densities particularly in the tank experiments. The experience from later trials in sea cages indicates that the survival of wrasse in captivity is fairly good, given that they are not injured or heavily stressed during capture and transport.

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 sea lice invasion. A relatively low number of wrasse may thus be able to control moderate lice infestations, but not heavy lice attacks. One likely strategy will therefore be to stock salmon cages with sufficient wrasse to control medium lice infestations. During severe lice invasions one solution is to add more wrasse, as tried with good results at one Norwegian fish farm where the wrasse number was increased to one per 20 salmon until the lice were depleted. As wrasse are shown to be opportunistic feeders in sea cages, deprivation of alternative food sources is likely to increase the overall cleaning efficiency. During heavy lice attacks care should therefore be taken to restrict salmon feeding, exchange fouled net pens and regularly remove dead fish from the cage. The fact that wrasse do occupy artificial habitats (like stacks of oyster baskets) also suggests easy recapture and transfer of wrasse to cages with high lice infestation. Wrasse are capable of cleaning larger salmon as shown in tank experiments and by observation in sea cages. However, little is known of the efficiency of wrasse cleaning with larger salmon in full scale trials. The mesh-size retention experiments clearly indicate that a large proportion of goldsinny will escape through the meshes larger than 12 mm (smolt net). Application of wrasse cleaning in larger salmon seems therefore to imply use of small meshed netting in the cages.

An adequate supply of wrasse is the major uncertainty with respect to wrasse cleaning as an extensively used method for delousing. Little knowledge exists on the size and reproduction potential of wrasse stocks and on the possibilities of breeding wrasse (Costello and Bjordal 1990). Besides further investigations on optimizing husbandry and application of wrasse in sea lice control, future research should therefore be focussed on stock assessment, capture technology and breeding of wrasse.

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