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Attack site and resultant damage during aggressive encounters in Atlantic salmon (*Salmo salar* L.) parr

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Abstract

Fin rot is a term used to describe a range of changes in fins, from splitting and erosion to nodular thickening. It is common among farmed Atlantic salmon (*Salmo salar*) parr and is of considerable economic and welfare importance. Fin rot is known to commence when fins become damaged, for example, following attacks by conspecifics; however, not all fins are equally affected, the dorsal fin being much more frequently damaged. This study examined the hypothesis that fin rot is more prevalent in the dorsal fin because it is more frequently attacked during aggressive encounters with conspecifics. Behavioural observations showed that the dorsal and caudal fin areas are much more frequently attacked than other areas of the body and significantly more attacks directed at the dorsal fin area resulted in physical contact than attacks directed at other parts of the body. Fin damage, scored as the total amount of fin splitting was highest in the dorsal and pectoral fins despite the pectoral fins being attacked less frequently than the dorsal or caudal fins. This suggests that pectoral fins may have sustained damage through contact with the tank as well as through attacks. We conclude that at least one reason for the observed prevalence of fin rot in the dorsal fin of Atlantic salmon in aquaculture systems is that it is a preferred site of attack by conspecifics and because attacks are more likely to end in physical contact than attacks on other areas of the body and, thus, they sustain more damage. © 1998 Elsevier Science B.V.

Keywords: Salmonids; Aggression; Fin rot

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1. Introduction

It is widely accepted that there is a strong relationship between the environment and disease, especially in farmed animals. Animals exposed to adverse environments or management practices may suffer either direct physical injury and/or increased susceptibility to opportunist pathogens (Wedemeyer, 1996). The effect of the social environment of farmed animals on health is less well understood. This is particularly true of farmed fish species (Pottinger and Pickering, 1992). It is possible, however, that social environment may have as significant an effect on the health of farmed animals as the physical one.

Aggression, as one form of social interaction, has the potential to cause both physical injury and increase susceptibility to infections through the effect of stress on the hosts defence mechanisms. Among the salmonid fishes, aggression has evolved as a behavioural strategy. It is used in the wild to obtain and defend territories, to gain preferential access to food and to maintain exclusive access to mates (Kalleberg, 1958).

In farmed salmonids held in tanks, aggression between individuals is common (Symons, 1968) and there are many examples of physical injury as a result of aggression including damage to eyes, opercula and fins (Turnbull, 1992).

Fin rot is a poorly defined and confusing term used to describe a variety of lesions including erosion, splitting of the fin rays, nodular thickening and extensive loss of tissue. In the Scottish Atlantic salmon (*Salmo salar*) farming industry, the term is usually used to describe pale nodular thickening with erosion of the distal fin. Fin rot is principally the result of physical damage and the affected animal's subsequent reaction. Such reaction is primarily epidermal hyperplasia with a fibrocellular reaction in the chronic phase. Bacteria are neither able to initiate nor maintain the lesions in the absence of physical damage (Turnbull, 1992), but affected fins become secondarily infected with a range of bacteria including pathogens such as *Aeromonas salmonicida*, the causative agent of furunculosis (Turnbull et al., 1996). Fin rot has such a high prevalence in farmed salmonids that its presence has been used to differentiate between fish from farmed and wild populations (Craik et al., 1987). Although it is difficult to determine the economic cost of the condition, its frequency has raised concern within the industry regarding the welfare of farmed fish.

Abbott and Dill (1985) found that considerable fin damage resulted from aggressive interaction in Rainbow trout (*Oncorhynchus mykiss*) held in tanks. In farmed Atlantic salmon parr, it is predominantly, but not exclusively, the dorsal fin that is affected by fin rot (Turnbull et al., 1996). In such fish, it has been demonstrated that dorsal fin rot starts with fin damage resulting from aggressive encounters with conspecifics whereas other fins may be damaged by contact with other objects in the environment (Turnbull, 1992). The reasons for the higher incidence of fin rot on the dorsal are unclear, but there are at least two possibilities: (1) either the dorsal fin responds to damage resulting from aggression in a different way from other fins, i.e., the dorsal fin develops more nodular thickening than other fins; and/or (2) the dorsal fin is subject to more damage than other fins, either because it is less robust or because it is subject to more damage from attacks.

In this study, we examined the second of these hypotheses by (a) examining the pattern of attacks directed at different parts of the body of salmon parr and (b) by quantifying the damage caused by aggression from conspecifics.

2. Materials and methods

2.1. Subjects

The Atlantic salmon parr used in these experiments were obtained from a commercial freshwater tank site in central Scotland and kept in a 1-m circular tank at the Institute of Aquaculture, University of Stirling, for at least 2 weeks before introduction to the experimental system. The fish were from a commercial strain of Norwegian origin.

Prior to being introduced to the observation tanks, each fish was examined and those with more than three splits on individual fins, or total splits exceeding 3 mm, were not used in the experiments.

2.2. Experimental system

A 100-l glass aquarium shielded from external light and visual interference was used for all the experimental observations. The tank was supplied with an internal water filter, aeration and artificial light producing 10.6 lx at the water's surface over an ambient daylength photoperiod (approximately 9 h of daylight). Temperature during the experimental period varied between 13 and 20°C.

2.3. Behavioural analysis

During each of the three trials, fish in the observation tank were videotaped for 9 h, the entire daylight period, on two occasions. The camera was situated in front of the aquarium with only the lens protruding through covers surrounding the tank. Time was recorded with the aid of a digital clock which was included in the field of view. Random numbers were used to select 50 random tape sequences during each 9-h observation period. The videotapes were analysed by examining and documenting the first aggressive interaction after each of the 50 random points within each observation period. For each aggressive encounter analysed, data were recorded on: (1) the position of both fish before the interaction; (2) the contact site on the body of the recipient of the attack, where actual contact was made and was ascribed to one of five areas on the victim's body (see Fig. 1 and the works of Abbott and Dill, 1985, for a more complete description). Pilot studies confirmed that these divisions were a practical method of categorising attacks; (3) the aim site on the victims' body, where no actual contact was made by the attacker with the victim's body. The site towards which attacks were aimed was determined by drawing a straight line through the attackers snout and tail, using a freeze frame function, and extrapolating this towards the victim. Interactions where this was not possible were not included further in analyses; (4) whether the attack was reciprocated; (5) a brief description of the sequence of events including recognisable behaviour patterns, e.g., frontal display, lateral display.

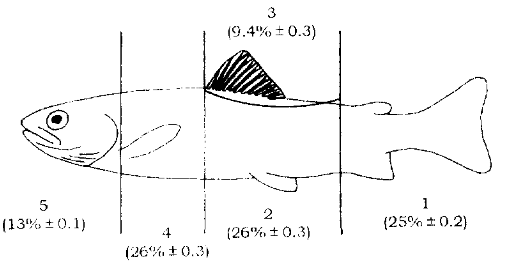

Fig. 1. Nominal target areas on the body of parr attacked by conspecifics during observation trials and their relative size (± S.E.).

2.4. Experimental protocol

Behavioural observations were made on three separate groups of parr. In the first trial, 11 fish were selected at random, placed into the main tank and allowed to settle for at least 2 days prior to filming. To examine the possibility that some physical damage may result from contact with the tank (rather than through social interaction) two control tanks, were set up by dividing a 30-l aquarium into to two equal portions. Into each, a single fish was introduced for the duration of each observation period. This smaller tank received the same conditions of filtration, aeration and photoperiod as the main observation tank.

In the first trial, it proved difficult to examine some of the interactions due to the density of the fish, therefore, for the first and second replicates, numbers were reduced to eight experimental plus two control fish.

The mean fork length of fish used in these experiments was 103 mm (± 0.134 S.E.). At the end of each observation period all the fish were individually inspected and the damage to the fins recorded. Since most of the damage consisted of splits, the number and size of the splits on each fin were recorded. To determine the relative size of each of the five potential target areas of the body, a sample of 17 fish used in these experiments were photographed in lateral view on a suitable scale. Using a digitising pad and irregular shape area measurement software, the area of each of the five potential target areas (Fig. 1) was measured.

3. Results

Only seven (3%) of the 235 agonistic incidents analysed were reciprocated, i.e., where there was immediate retaliation by the fish initially attacked. Only 17 (7.3%) of the agonistic events recorded were aggressive displays (comprising 6% frontal and 1.3% lateral displays). The vast majority of aggression recorded was overt, usually involving one brief charge often terminating in actual contact (51.1%). In 11.5% of occasions, especially when both fish were stationary, the approach was slower and resulted in a bite, often of a fin. Bites involving the actual grasping of a fin for a short period (up to a second) were observed in all three trials. In the 27 occasions when this was observed, the caudal fin was the target in 44%, the dorsal fin in 41% and a pectoral fin in 19% of occasions.

Repeated bouts of stereotypic escape swimming were observed in all the experiments. This behaviour which consisted of one or more of the fish swimming repeatedly up and down the side of the aquarium is common among many fish held in rectangular aquarium (Keenleyside, 1955; Fenderson and Carpenter, 1971).

The proportion of attacks directed to different target areas of the body (Fig. 1) differed significantly from that predicted using relative proportion of body target area alone. Fig. 2 shows the number of attacks directed at each target area that resulted in actual contact expressed as a proportion of that expected if attacks were randomly directed and predicted by area alone. Thus, the number of attacks that resulted in bites to the target area differs significantly from that expected by the relative size of the area ($\chi^2 = 45.2$; $N = 5$; $P < 0.001$). Both target area 3 and 5 received significantly more attacks resulting in contact than would be expected by relative size of these areas ($\chi^2 = 18.3$; $N = 5$; $P < 0.001$ and $\chi^2 = 10.6$; $N = 5$; $P < 0.01$ areas 3 and 5, respectively). Likewise, the number of attacks directed towards target areas which did not result in contact (Fig. 3) differed significantly from that expected by relative area ($\chi^2 = 38.3$; $N = 5$; $P < 0.001$). As with attacks resulting in contact, target areas 3 and 5 received more attacks than predicted by relative size alone but this was only significant for area 5 ($\chi^2 = 27.3$; $N = 5$; $P < 0.001$).

The proportion of attacks that resulted in eventual contact between the aggressor and its victim varied depending upon the target area to which attacks were directed (Fig. 4) (comparing the number of attacks that resulted in contact for each target area with the number predicted by the proportion of contact attacks overall [$\chi^2 = 21.9$; $N = 5$; $P < 0.001$]). Attacks to the areas 1 and 3 resulted in a higher proportion of attacks that

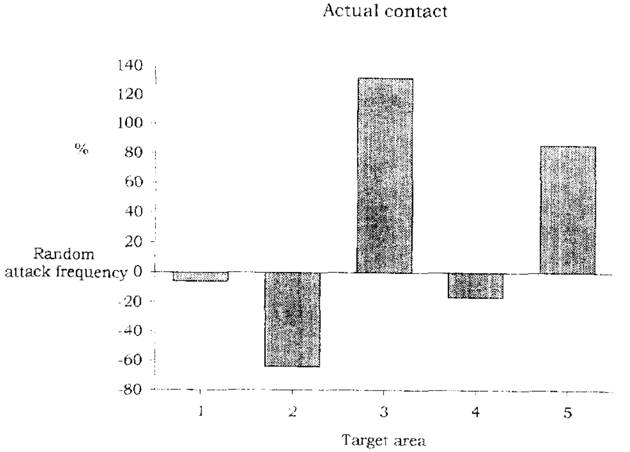

Fig. 2. The percentage of attacks where physical contact was made, expressed as a proportion of relative body area size.

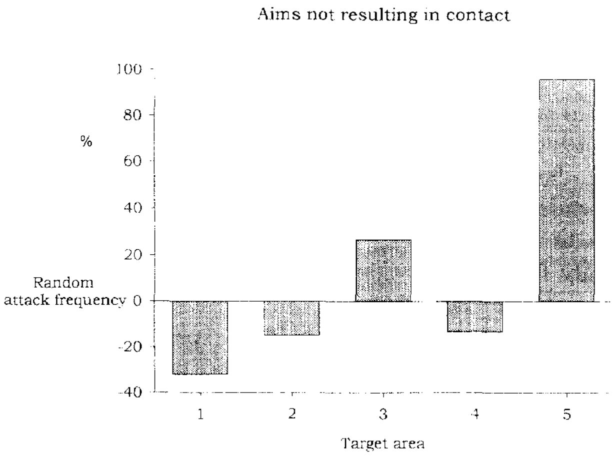

Fig. 3. The percentage of attacks where physical contact was not made, expressed as a proportion of relative body area size.

escalated to actual contact but this was only significantly different from expected for target area 3 ($\chi^2 = 8.8$; $N = 5$; $P < .001$).

Fins differed significantly in the amount of damage (mm of splitting) sustained (Fig. 5) (Kruskal Wallace $H = 64.9$ with 6 *df*, $P < 0.0001$). There was no significant difference between the damage suffered by the dorsal and the left pectoral fins (a posteriori Student–Newman–Keuls to identify significant differences). Neither was the damage suffered by the two pelvic fins significantly different ($q = 2.14$, $P > 0.05$). The dorsal fins and the left pectoral fins suffered significantly more damage than all the other fins ($q = 1.77$, $P > 0.05$). The right pectoral fins suffered the next most severe damage, followed by the caudals, the pelvic fins and finally the anal fins with the least damage ($P < 0.05$).

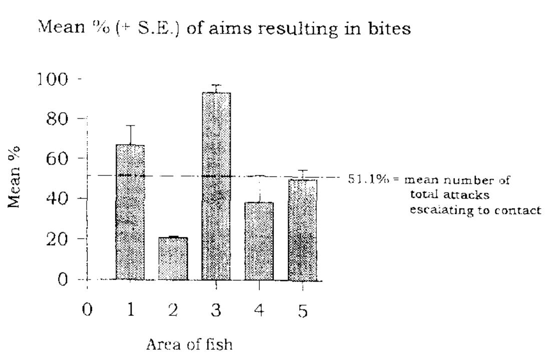

Fig. 4. The mean (± S.E.) number of attacks that resulted in actual contact between attacker and its victim, shown for each attack site. Overall mean number of contacts expressed as a proportion of aims is 51.1% (dotted line). The mean number of attacks suffered by each individual was 4.6.

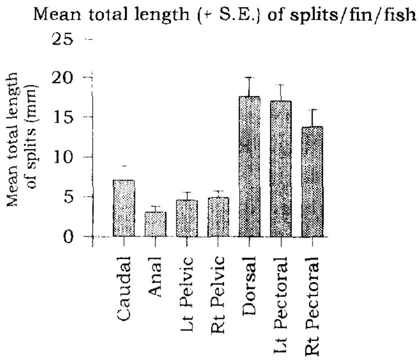

Fig. 5. The mean (±S.E.) total length of splits on each fin. The mean total length of splits sustained by each fish was 68.0 mm.

No significant damage was detected on the scales, eyes, opercula or any other superficial structures. Regression analyses showed no significant relationship between the length of the fish and fin damage.

4. Discussion

Damage to the fins observed in these experiments consisted of splits in the tissue, these were measured for each fin on each fish. The observed damage was identical to the mildest form of fin rot observed in farmed Atlantic salmon parr, i.e., peripheral erosion and ray splitting (Turnbull et al., 1996). It has been suggested that progression of such lesions to the typical pale nodular lesions is dependent on the frequency and severity of the damage combined with the temperature. At lower temperatures the hyperplastic response of salmonid epithelium to damage is more marked (Roberts and Bullock, 1976) and takes longer to resolve (Turnbull, 1992).

Attacks made by one Atlantic salmon parr were not directed randomly at the body of their victims. Significantly more attacks that ended in full bodily contact were directed at the dorsal and caudal fin areas of the victim than would be expected if attacks were random (Fig. 2). Of the attacks that were initiated, but which did not conclude in actual contact, a significantly higher than predicted number were directed at the caudal area, but not the dorsal fin area. Thus, more of the attacks directed towards the dorsal area escalated to actual contact, compared to attacks directed towards other areas (Fig. 4). Differences in the frequency of attacks directed at different body areas were not the result of differences between the size of the target areas since attack rate was corrected for target area. Rather non-random attack sites reflect genuine differences in the site toward which attackers directed their attacks. Abbott and Dill (1985), in a study of the frequency of attack sites in juvenile rainbow trout (*Onchorhyncus mykiss*), similarly found that attacks were more likely to be directed towards the caudal and dorsal fins. However, in their analyses there was no correction for the different sizes of the attack sites, therefore, it is unclear if differential attack rates in rainbow trout were the result of attack site preferences or differences between the sizes of the attack sites.

During these experiments, the fish held in groups sustained considerable damage to fins (Fig. 5). In 12% of aggressive encounters observed during these experiments, the aggressor was actually seen grasping the fin of its victim. Indicating that, at least on these occasions but probably on others, it was the fin that was attacked, rather than the adjacent area of the body. Damage to fins resulting from aggressive encounters is well documented in Atlantic salmon parr (Turnbull et al., 1996) as well as in rainbow (Abbott and Dill, 1985) and in Arctic charr (*Salvelinus alpinus*) (Christiansen et al., 1992). Not surprisingly, given that attacks resulting in physical contact were more frequently directed towards the dorsal area, the dorsal fins of fish sustained more damage during these experiments than did the caudal fin, which received the second highest frequency of attacks. The reason for the unexpectedly high level of damage to the pectoral fins (Fig. 5) is, however, unclear since two of the control fish sustained pectoral fin damage in the absence of any aggressive encounter. It is possible that pectoral fin damage can result from both aggression and some other source, perhaps, contact with the tank.

An explanation for the observed difference in the frequency of fin rot in the dorsal fin and other fins in farmed Atlantic salmon parr is provided by results presented here. Repeated physical damage leads to dorsal fin rot and it is clear that the dorsal fin suffers a higher frequency of attacks and resultant damage. It is considered that this is partly as a result of preferential targeting of this fin during aggressive encounters and partly because attacks directed at this fin are more likely to terminate in physical contact.

Fin rot in general, and especially dorsal fin rot results primarily from damage caused by conspecifics. Therefore, it is reasonable to assume that the social environment might be manipulated to reduce such damage. Although ongoing research continues to provide valuable data on the effect of the environment on aggression in salmonids (e.g., Adams et al., 1995; Mikheeve et al., 1996), there are still not any practical methods to eliminate damage from aggression in farmed salmonids.

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