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Research Article

Animal Biology

ANALYSIS OF SCALE OF FIN DAMAGE (EROSION) IN FARMED RAINBOW TROUT IN THE REPUBLIC OF KOSOVA

Keywords: Rainbow trout, fish farms, fins, erosion.

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Abstract

This study has utilized a non-invasive, rapid, and reliable method of assessing the scale of fin damage in rainbow trout from aquacultures in eight locations throughout the Republic of Kosova. The method is based on a visual assessment of the fin in profile and the loss of surface area of all fins on a scale from 0-5, compared to a healthy fin. The scale of fin damage was analyzed in two groups of fish, those weighing less than 30 grams and those weighing over 100 grams. The study demonstrated that the average indicator of fin damage was higher in larger fish than in smaller fish. Fin damage also depended on the season. Thus, greater fin damage was observed during the summer, compared to the winter and spring months, when the scale of damage was less severe. Moreover, the shape of the pond also impacted fin damage. Thus, the scale of fin damage was greater in circular-shaped ponds compared to rectangular-shaped ponds. The dorsal and pectoral fins were both exposed to damage. The average value of fin damage on the dorsal fin was 3.11, on the left pectoral fin 2.72, whereas on the right pectoral fin 2.70. The reasons behind the fin damage could be related to metabolic adaptations or adaptations to rearing conditions, which should be further looked into in the future in hopes of improving fin condition.

Introduction

The world is continuously developing; new technologies are being created, whereas industrial processes are becoming increasingly efficient. In the food industry, new ingredients are produced, and new methods are being developed each day, which correspond to the ever-growing needs of the world's population.

The fishing sector is no exception to this development, even though it is limited by the availability of the natural resources of freshwater and seawater. In this respect, aquaculture plays a critical role as it provides higher quality food by improving the quality of the fish reared for human consumption. (FAO 2014a; 2014b).

Fin damage or erosion is considered a fairly important indicator of fish welfare (Noble *et al*., 2007) and it is a common and rather serious occurrence found primarily in farmed fish (Larmoyeux & Piper, 1971) even though it can also be found among wild fish populations (Kahn *et al*., 1981).

Since the degree of fin erosion is greater in farm-reared fish than in wild fish, it could be that this occurrence may result from stocking density, feeding method and environmental conitions (Mork *et al*., 1989). Higher stocking density in ponds causes stress by increasing plasma cortisol levels and heightening aggression (Pickering & Pottinger, 1989).

Aggressive behavior in trout is fairly common in natural as well as farm conditions (Keenleyside & Yamamoto, 1962) and is intensified by environmental disturbances such as insufficient feeding, which leads to competition (Kadri *et al*., 1997). Dorsal fins are the preferred target of attack for trout (Abbott & Dill, 1985), which are more common for sexually mature males than younger fish (Mork *et al*., 1989).

Improved feeding methods used to typically feed fish at regular intervals as well as daily feed rations could significantly lower competition and minimize the rate of fin damage (Noble *et al*., 2007).

A slight change in the environmental conditions to which fish have adapted, such as improved water circulation, which makes swimming more difficult than in lower circulation, can reduce fin erosion by avoiding aggressive encouters between individuals, given that the fish are forced to expend their energy swimming (Christiansen & Jobling, 1989). The surface of pond walls may have an adverse effect on fin erosion. An abrasive surface, such as concrete, may contribute not only to fin erosion, but also to lesions on the body, and this is true of smaller as well as larger ponds (Larmoyeux & Piper, 1971).

Low water temperature plays a negative role in the spread of fin erosion in trout (Schneider & Nicholson, 1980). Low oxygen levels in ponds can also have an adverse effect on fin erosion (Larmoyeux & Piper, 1973). Bacterial/microbiological infection can also lead to fin erosion and rot (Giles *et al*., 1978; Loganathan *et al*., 1989).

A balanced and nutritious diet can help avert fin erosion or prevent it altogether. In these cases, fish feed should contain sufficient amounts of vitamin C, since this particular vitamin, in addition to minimizing the prevalence of this phenomenon, also strengthens their immune system (Mazik *et al*., 1987).

A diet rich in amino acids such as lysine, arginine, histidine, isoleucine, threonine, valine and tryptophan has also shown good results in preventing fin erosion in trout as well as in increasing body weight (Ketola, 1983). Water quality plays an important role in fin erosion of wild fish populations living in degraded habitats. This implies that in habitats with high temperature variations, unstable salinity and reduced levels of dissolved oxygen; fish are more prone to mechanical injuries and bacterial/parasitical infections (Barker *et al.,* 1994).

Fin damage in rainbow trout reared in aquacultures is a common occurance in intensive trout production throughout the world, including in the Republic of Kosova.

There is currently no data on the presence and prevalence of fin damange in farm-raised rainbow trout in the Republic of Kosova.

Thus, the main objective of this study is to provide a clear understanding of fin condition, the causes that lead to fin damage and the possibilities of minimizing the scale of damage in farm-reared rainbow trout in the Republic of Kosova.

Research Methodology

Rainbow trout farms in eight cities throught the Republic of Kosova were selected for this study (Fig. 1).

Figure 1. Locations of rainbow trout farms in the Republic of Kosova included in this study. 1-rainbow trout farm in Istog, 2-rainbow trout farm in Peja, 3-rainbow trout farm in Gjakova, 4-rainbow trout farm in Prizren, 5-rainbow trout farm in Kaçanik, 6-rainbow trout farm in Ferizaj, 7-rainbow trout farm in Gjilan, 8-rainbow trout farm in Podujeva.

The analysis of fin damage was carried out during the months of December, May and July 2020.

Fins were analyzed in two categories of fish (weight under 30g (min. 5g) and over 100g (max. 250g). Photographs of the fins of 50 fish from both categories were analyzed in the aquacultures where these groups were present (Figure 2).

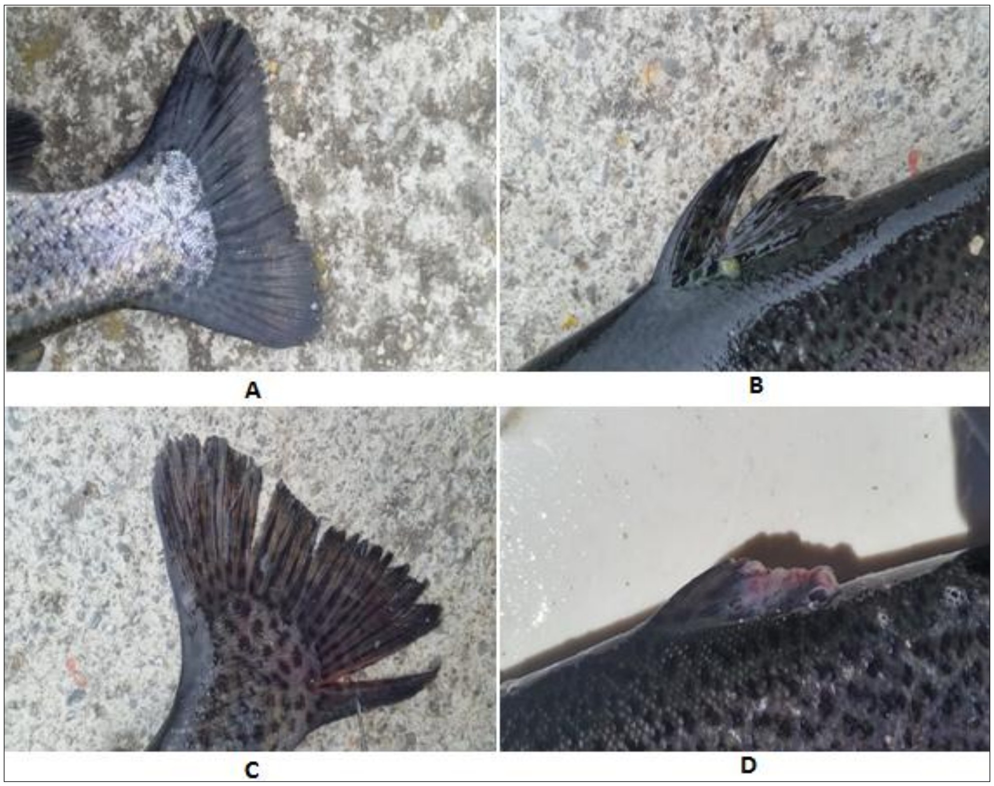

Figure 2. Macroscopic fin damage. A – Surface erosion on caudal fin, B – split on dorsal fin, C – inflammation on caudal fin, D – injury on dorsal fin (Original photography from the field).

The fish were netted randomly using the farms equipment (fishing net). The study was carried out biannually in all of the selected farms in order to include seasonal variations of fish.

The first study was carried out during the late winter and early spring, whereas the second was carried out during the summer (in total 5580 fins from 840 fish were analyzed).

The validated quantitative macroscopic key was used to analyze the degree of fin damage (Hoyle *et al*. 2007) (Figure 3).

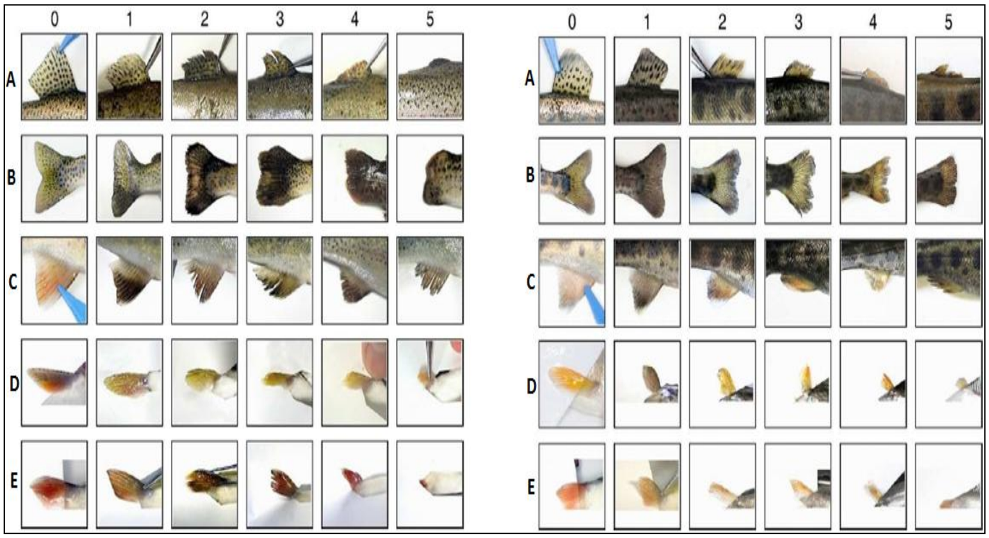

Figure 3. Photographic key to fin damage in rainbow trout weighing > 50 g (right) and < 50 g (left) (Hoyle *et al*. 2007). A-dorsal fin, B-caudal fin, C-anal fin, D-pectoral fin, E-pelvic fin.

The study was based on rapid macroscopic description of damage in all fins (expect adipose fin) in field conditions and included two parts. In the first part, based on the photographic key, the lack of fin tissue was quantified on a scale of 0-5 (0 – no damage; 5 near complete loss of fin). In the second part, based on the qualitative clinical descriptors, the injuries and lesions of the fins were classified as [damaged edges (surface abrasions), splits (V-shaped tears between the rays); exposed rays (lack of soft tissue); hemorrhages (dark red spots with clearly defined margins); inflammation (presence of unnatural redness); thickening (presence of white tissue with greater thickness compared to a normal fin) and side folding (as a consequence of re-growth)]. The time needed for the analysis was 10-15 seconds (Hoyle *et al*. 2007), which was sufficient for analysis of the damage without adversely effecting the welfare of the fish. After the analysis, the fish were returned to their pond.

Statistical analyses of the results were performed using the Statistica 8 software package, whereas the results were expressed in percentages or as mean values. To determine whether there are statistical differences among the fish farms, the one-way analysis of variance of mean values were used (one-way ANOVA).

To analyze the statistical differences between the two categories of fish and the seasonal variations, the Student’s test for the comparison of two means was applied. The results were considered statistically different at 0,001 significance level ($p<0,001$).

Results and Discussion

The prevalence (%) of fin damage was determined on the basis of macroscopic observation. All the fins analyzed (n=2540) were damaged in various degrees in all the fish analyzed (n=420), and prevalence reached 100% (Figure 4).

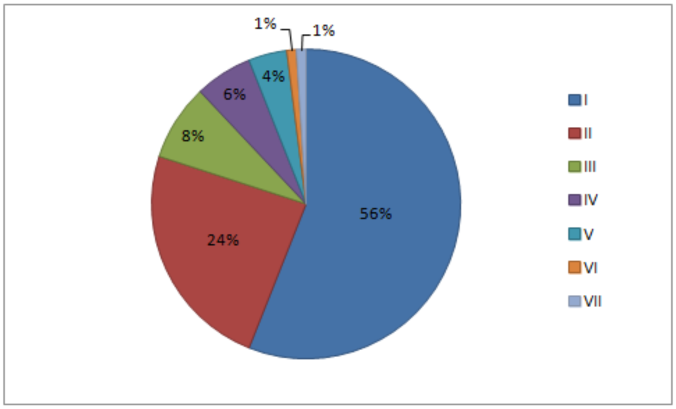

Figure 4. Prevalence and type of fin damage in farm-raised rainbow trout in eight locations throughout the Republic of Kosova. I – surface abrasions, II – splits, III – inflammation, IV – hemorrhages, V – healing of wounds, VI – folding, VII – exposed rays.

The graph clearly shows that surface abrasions comprised 56% of fin damage in the selected fish, splits 24%, inflammation 8%, hemorrhages 6%, healing 4%, whereas folding and exposed rays 1% each.

The results of fin damage in the selected fish are presented in figure 5.

Figure 5. Fin damage in tested fish. A-surface biting of caudal fin, B-split of dorsal fin, C-inflammation of caudal fin, D-hemorrhage of pectoral fin, E-healing of dorsal fin, F-exposed rays of dorsal fin (original photographs from the field).

Since the analysis of fin damage for seasonal variations showed no significant differences, the data was processed on 40 individual fish per category. The overall results of the fin damage are presented in Table 1.

Table 1. Level of fin damage of two fish categories (< 30 g and > 100 g) in all farms.

No.	Fin	Level of damage in fish < 30 g	Level of damage in fish > 100 g
1.	Dorsal	2.30	3.11
2.	Cuadal	1.13	1.75
3.	Anal	1.29	1.90
4.	Pectoral left	1.72	2.72
5.	Pectoral right	1.71	2.70
6.	Pelvic left	1.39	2.14
7.	Pelvic right	1.42	2.17

Based on the values obtained of the level of fin damage in both categories of fish, it was determined that fin damage was greater for dorsal and pectoral fins in larger fish (>100g). The level of damage and prevalence of all fins in both fish categories and all farms are presented in Table 2.

Table 2. Damage level and prevalence of all fins in both fish categories in all farms included in the study.

Fin type	**Farm 1**	**Farm 2**	**Farm 3**	**Farms 4,5**	**Farm 6**	**Farm 7**	**Farm 8**
Fish size							
Dorsal (<30g)	3,63	2,53	3,02	2,30	1,50	2,35	2,13
Dorsal (>100g)	4,27	3,23	4,07	2,77	2,10	2,72	3,32
prevalence	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,01**	**p<0,001**
Caudal (<30g)	1,43	1,30	1,37	1,33	1,03	1,13	1,07
Caudal (>100g)	2,95	1,73	2,07	1,85	1,73	1,73	2,28
prevalence	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**
Anal (<30g)	1,73	1,67	1,52	1,47	1,10	1,73	1,33
Anal (>100g)	3,60	1,85	2,37	2,07	1,80	2,03	2,40
prevalence	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,01**	**p<0,001**
Pectoral L. (<30g)	2,10	2,02	1,78	1,82	2,10	2,03	1,73
Pectoral L. (>100g)	4,10	2,70	2,57	2,43	3,07	2,43	3,08
prevalence	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**
Pectoral R. (<30g)	2,07	2,03	1,80	1,83	2,07	2,02	1,70
Pectoral R. (>100g)	4,12	2,67	2,53	2,47	3,10	2,40	3,05
prevalence	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,01**	**p<0,001**
Pelvic L. (<30g)	1,58	1,75	2,18	1,50	1,33	1,30	1,47
Pelvic L. (>100g)	3,07	1,93	3,03	2,13	1,87	1,90	2,47
prevalence	**p<0,001**	**p<0,01**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,01**	**p<0,001**
Pelvic R. (<30g)	1,57	1,77	2,20	1,53	1,43	1,33	1,43
Pelvic R. (>100g)	3,05	1,97	3,07	2,15	1,97	1,93	2,43
prevalence	**p<0,001**	**p<0,01**	**p<0,001**	**p<0,001**	**p<0,001**	**p<0,01**	**p<0,001**

From the mean level of damage on all fins for both categories of fish (<30g and > 100g), it was determined that, except for Farm 2, where the values of damage of pelvic fins were of no significant statistical difference (p<0,01), and Farm 7, where the values obtained for all fins also resulted in non-significant statistical differences, in all other farms the results of fin damage level were of significant statistical difference (p<0,001).

The analysis of fin damage in farms in the Republic of Kosova demonstrated 100% prevalence, i.e. fin damage occurred in all fish throughout the selected farms (Figure 4). Damages were primarily characterized by "surface biting" (damaged edges), whereas for the positive finding of “exposed caudal rays” there were indications of active bacterial infections in the selected individuals. Recording of “damaged edges” indicates that fin damage is present in the harvesting of salmonids in the Republic of Kosova. Fin damage occurred in a range of levels in all the tested fish, which is an indication that all rayed fins are susceptible to damage (Bodammer, J.E., 2000). This is the first study in the Republic of Kosova that confirms the suggestions that fin damage is widespread in salmonoid harvesting and is consistent with previous research that fin damage occurs in rainbow trout farms worldwide (Ellis *et al*., 2008), including neighboring countries, such as in the Republic of North Macedonia (Cvetkovikj *et al*., 2013).

Although the fish were randomly selected, we consider them to be specimens' representative of the harvesting systems and habitats for the production of this type of fish in this area. Due to a lack of earlier research, we were unable to determine whether fin damage in salmonoid harvesting in the Republic of Kosova increased or decreased by 2020. As a result, the data obtained on the level of fin damage can serve as a basis for future research. The most damaged fins in both fish categories were the dorsal and pectoral fins. The same fins were damaged even in the smallest fish tested (5g), which indicates that the damage occurred in the early stages of production in the hatchery (Kindschi *et al*., 1991b; St-Hilaire *et al*., 2006).

For this reason, research on the process of fin damage in hatcheries should be a priority for future research in this field of study. Other fins had higher levels of damage in the larger fish category, which implies that the conditions and ongrowing technology significantly affect the level of damage. Fin damage was present to a lesser degree in the small fish category (Table 1). This finding is consistent with the findings of Barrows & Lellis 1999 and St-Hilaire *et al*., 2006, that fin damage in the early stages continues throughout the entire farming process.

Severe fin damage in some fish in a particular farm indicates that some factors may affect the level of fin damage, more so on the individual than the group level.

The greatest level of dorsal and pectoral fin damage, as compared to pelvic, anal and caudal fins, was the same for both fish categories tested in all farms, although there were differences at a farm level. This pattern, with the exception of dorsal and pectoral fins, is not consistent with other research on fin damage in salmonoid fish (Abbott and Dill., 1985; Bosakowski and Wagner., 1994b; Pelis and McCormik., 2003; St-Hilaire *et al*., 2006; Turnbull *et al*., 1998). This finding may be due to the different methodology used for fin damage assessment, the influence of etiological factors and the risk to different fins due to their position on the body.

This study confirmed that there are seasonal differences in the level of fin damage in hatcheries, thus there was a greater level of fin damage in the summer than in the winter and spring.

MacIntyre (2008) arrived at the same conclusion in his study on the effect of water quality on the welfare of rainbow trout in the United Kingdom. This finding further emphasizes the importance of farm practices in fin damage.

The perfect correlation between fin pair damage indicates that if one factor affects one fin pair, it will similarly affect the other fin pair. This is consistent with the findings of St-Hilaire *et al*., (2006).

The lack of fin damage of river trout and trout reared in isolation (Kindschi *et al*., 1991b), indicates that farm conditions initiate the fin damage. Therefore, fin damage is considered as a phenomenon occurring in farmed trout. The differences in fin damage in the selected farms indicate that some factor or group of factors specific to each farm influence the extent of the damage.

Changes in water current in habitats and the possible influence of other factors in farming (water temperature, feed ration, feed distribution etc.) may certainly have contributed to the greater level of fin damage in Farm 1.

The other farms had rectangular ponds, but different fin damage, most certainly as a result of the influence of other risk factors. At this time, there is a lack of data on the different influences of circular and rectangular ponds on fin damage.

Fin damage was not influenced by daily feed ration, even though dorsal, pectoral and pelvic fin damages were greater in Farm 1, where feed ration was lower. In Farm 1, this risk factor is closely linked to low water temperature and long periods of feed-restrictions throughout the year. On the other hand, in Farm 3 there were similar dorsal and pectoral fin damages as in Farm 1, the daily feed ration was twice as large, whereas the condition of the pectoral fins was similar, although there was still significant damage on dorsal fins in Farms 2 and 8 and in pectoral fins in Farms 6 and 8. The existing data in relation to the influence of daily feed ration on fin damage is contradictory. According to Canon Jones (2010), Moutou *et al*., (1998) and Winfree *et al*., (1998), small daily rations or feed distribution results in greater fin damage. On the other hand, Kindschi (1988) and Klontz *et al*., (1991) confirm that dorsal fin damage is not directly linked to reduced daily feed ration or feed distribution.

In relation to daily feed ration, there was less variation in smaller fish categories. As a result, the daily feed rations cannot be hypothesized as the singular factor in this study.

It is well known that hatcheries producing fish for consumption are often under pressure to produce as much as possible in as little time, whereas due to market demand fish are either given feed or left completely unfed for certain periods of time. These practices may influence fin damage by increasing aggression in fish or through some other social interactions.

Although bad management of fish is suggested as a cause of fin damage (Farm Animal Welfare Council, 1996), fish selection for this study did not influence the level of fin damage.

Differences in fin damage between the two tested categories indicate that it may be possible to improve the fin profile on farmed rainbow trout, which would result in increased welfare and aesthetic quality of commercial fish.

In larger individuals, the level of fin damage variation was higher between different farms than between different ponds in a single farm. This implies that fin damage is certainly linked to causes, which vary between farms and could affect all fish in a single hatchery. The process of fin damage has not been sufficiently explained due to the existence of numerous studies that deliver conflicting results and may not reflect reality. The relevance of different etiological and other risk factors is yet to be determined due to the varying significance in the different production conditions.

Future studies in this field should focus on the influence of farm practices on damage in each fin, the influence of fin damage on fish performance and their behavioral needs. Thus, necessary data would be obtained on each fin. Moreover, it would be beneficial to have another standard method for studying fin damage, which would also enable a comparison between different studies.

Conclusion

1. The method used for fin damage analysis proved effective for assessing damages in the field.
2. Fin damage was present and widespread in trout farming in the Republic of Kosova.
3. All rayed fins were exposed to damage.
4. Fin damage is present in younger fish in hatcheries and continues throughout the rearing process.
5. Dorsal and pectoral fins were the worst affected fins in pond-reared rainbow trout in the Republic of Kosova.
6. A single factor or a group of factors specific for each farm influenced the level of fin damage.
7. Possible factors influencing fin damage in farm-reared rainbow trout in the Republic of Kosova include temperature and other factors that are yet to be identified.
8. Fin damage does not affect performance of farmed trout.

From all these deductions comes the principal conclusion, namely that the high prevalence implies that fin damage is a significant indicator of the welfare of farm-reared rainbow trout in the Republic of Kosova. Given the range of damages, it is evident that farm practices affect fin profile. However, an analysis of the risk factors shows only statistical association. Thus, experimental studies are necessary in which the proposed risk factors would be manipulated in order to confirm the statistical association. These studies would result in proposals for modifying farm practices and continually improve fin profile of farm-reared rainbow trout in the Republic of Kosova.

References

Abbott, J.C. & Dill, L.M. 1985. Patterns of aggressive attack in juvenile steelhead trout (*Salmo gairdneri*). Canadian Journal Fisheries and Aquatic Sciences 42, 1702-1706.

Bodammer, J. 2000. Some new observations on the cytopathology on fin erosion disease in winter flounder *Pseudopleuronectes americanus*. Disease Aquatic Organism 40:51-65.

Barrows, F.T., Lellis, W.A., 1999. The effect of dietary protein and lipid source on dorsal fin erosion in rainbow trout, *Oncorhynchus mykiss*. Aquaculture 180, 167-75.

Bosakowski, T., Wagner, E.J., 1994b. Assessment of fin erosion by comparison of relative fin length in hatchery and wild trout in Utah. Canadian Journal Fisheries and Aquat Science 51, 636-41.

Barker, D.E, Khan, R.A. & Hooper, R. 1994. Biondicators of stress in winter flounder, *Pleuronectes americanus*, captures adjacent to a pulp and paper mill in St. George’s Bay, Newfoundland. Canadian Journal Fisheries and Aquatic Science 51:2203-2209.

Cvetkovikj, A., Radeski, M., Blazhekovikj, D, Kostov, V., Stefanovski V., 2013. Fin damge of farmed rainbow trout in the Republic of Macedonia. Macedonian Veterinary Reviev 2013; 36 (2): 73-83.

Canon Jones, H.A., Hansen, L.A., Noble, C., Damsgard, B., Broom, D.M., Pearce, G.P., 2010. Social network analysis of behavioural interactions influencing fin damage development in Atlantic salmon (*Salmo salar*) during feed-restriction. Applied Animal Behavior Science 127, 139-51.

Christiansen, J.S. & Jobling,M. 1989. The behavior and the relationship between food intake and growth of juvenile Arctic charr, *Salvelinus alpines L*., subjected to sustained exercise. Canadian Journal of Zoology 68:2185-2191.

Ellis, T., Oidtman, B., St-Hilaire, S., Turnbull, J., North, B., Maclntyre, C., Nikolaidis, J., Hoyle, I., Kestin, S., Knowles, T., 2008. Fin erosion in farmed fish, In: Branson, E. (Ed.), Fish Welfare, Blackwell, Oxford, pp. 121-149.

FAO, 2014a. The State of World Fisheries and Aquaculture 2014. Rome. 223 pp.

FAO, 2014b. FAO Yearbook - Fishery and Aquaculture Statistics. Summary tables - World aquaculture production by species groups.

Farm Animal Welfare Council, 1996. Report on the welfare of farmed fish. *FAWC*, Surbiton, Surrey.

Giles, R.C., Brown, L.R. & Minchew, D.C. 1978. Bacteriological aspects of fin erosion in mullet exposed to crude oil. Journal of Fish Biology 13: 113-117.

Larmoyeux, J.D. & Piper, J.D. 1971. Reducing eroded fin condition in hatchery trout: feeding to satiation may eliminate or reduce so-called eroded fins commom in raceway-reared trout. American Fishes and U.S. Trout News, September-October, 8-9.

Loganathan, B.A., Ramesh, A. & Venugopalan, V.K. 1989. Pathogenic bacteria associated with *Lates calcarifer* and *Ambassis commersoni*. J. Appl. Microbiol. And Biotech, 5:463-474

Hyole, I, Oidtmann, B., Ellis, T., Turnbull, J., North, B., Nikolaidis, J., Knowles, T.G., 2007. A validatet macroscopic key to assess fin damage in farmed rainbow trout (*Oncorhynchus mykiss*). Aquaculture 270, 142-8.

Kahn, R.A., Campbell, J. & Lear, H. 1981. Mortality in captive atlantic cod, *Gadus morhua*, associated with fin rot disease. Journal of Wildlife Diseases vol. 17:4.

Keenleyside, M.H.A., Yamamoto, F.T., 1962. Territorial behaviour of juvenile Atlantic salmon (*Salmo salar L.*). Behaviour19:139-169.

Kadri, S., Metcalfe, N.B., Huntingford,F.A., Thorpe, J.E. 1997. Daily feeding rhythms in Atlantic salmon: I. Feeding and aggression in parr under ambient environmental conditions. Journal of Fish Biology 50: 267–272

Kindschi, G.A., Shaw, H.T., Bruhn, D.S., 1991b. Effects of baffles and isolation on dorsal fin erosion in steelhead trout, Oncorhynchus mykiss (Walbaum). Aquacult Fish Manage 22, 343-50.

Kindschi, G.A., 1988. Effect of intermittent feeding on growth of rainbow trout, *Salmo gairdneri* Richardson. Aquaculture Fish Managery 19, 213-5.

Klontz, G.W., Maskill, M.G., Kaiser, H., 1991. Effects of reduced continous versus intermittent feeding of steelhead. Progres Fish Culture 53, 229-35.

Macinture, C., 2008. Water quality and welfare assessment on United Kingdom trout farms. PhD thesis. Institute of Aquaculture, University of Stirling.

Moutou, K.A., McCarthy, I.D., Houlihan, D.F., 1998. The effect of ration level and social rank on the development of fin damage in juvenile rainbow trout. Journal of Fish Biology 52, 756-70.

Mazik, P.M, Brandt, T.M. & Tomasso, J.R. 1987. Effects of dietary vitamin C on growth, caudal fin development, and tolerance of aquaculture-related stressors in channel catfish. Progresiv Fish Culturist 49:13-16.

Noble, C., Kadri, S., Mitchell, D.F., Huntingford, F.A. 2007. Influence of feeding regime on intraspecific competition, fin damage and growth in 1+ Atlantic salmon parr (*Salmon salar L*.) held in freshwater production cages. Aquaculture research, 38:1137-1143.

Pickering, A.D. & Pottinger, T.G. 1989. Stress responses and disease resistance in salmonid fish: effects of chronic elevation of plasma cortisol. Fish Physiology and Biochemistry, 7:253-258.

Pelis, R.M. & McCormick, S.D. 2003. Fin development in stream-and hatchery-reared Atlantic salmon. Aquaculture 220: 525-536.

St-Hilaire S., Ellis, T., Cooke, A., North, B.P., Turnbull, J.F., Knowies, T., Kestin, S., 2006. Fin erosion on commercial rainbow trout farms in the UK. Vet Rec 159, 446-50.

Schneider, R. & Nicholson, B. L. 1980. Bacteria associated with fin rot disease in hatcheryreared Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 37: 1505-1513.

Turunbull, J., Adams, C., Richards, R., Robertson, D., 1998. Attack site and resultant damage during aggressive encounters in Atlantic salmon (*Salmo salar* L.) parr. Aqauculture 159, 345-53.

Winfree, R.A., Kindschi, G.A. & Shaw, H.T. 1998. Elevated water temperature, crowding, and food deprivation accelerate fin erosion in juvenile steelhead. Progress in Fish Culture 60:192-199.