UDC: 639.33:597.552.512(497.751)
Professional paper

ASSESSMENT OF FIN DAMAGE EXTENT IN AQUACULTURE TROUT IN THE LIKOVO REGION

Gazmend ISENI[1], Ajten RUSHITI-DAUTI[1], Besa ISENI[2]

[1] *Department of Biology, Faculty of Natural Sciences and Mathematics, University of Tetova, North Macedonia*
[2] *Elementary school „Kultura" village Matejce, Likovo, North Macedonia*
**Corresponding author e-mail: ajten.rushiti@unite.edu.mk*

Abstract

Fisheries and aquaculture have become vital contributors to human existence and progress. Over the last five decades, the supply of fish has outplaced the growth in the percentage of the world population, and today, fish meat stands as one of the most crucial sources of animal protein. Fin damage in aquaculture trout is a common occurrence in intensive trout production worldwide and in our country. The cultivators are aware of its presence, but they don't draw attention and regard it as a "cultivation phenomenon" that cannot be influenced. This research was conducted at the fish farm in the village Rezhanovtse (Likovo region). It analyzed the degree of fin damage in rainbow trout (*Oncorhynchus mykiss (Walbaum, 1792)*) in several months (February, April, June, and September 2023). The study included two groups of fish (<30 g and >100 g.) Among 430 individuals of fish included in the study, analysis revealed that all fins, totaling 2240 were damaged to different degrees, with a frequency of 100%. Superficial scarring was represented by 53%, breakage by 24%, burning by 9%, bleeding by 7%, and wound closure at 5%. Additionally, there were instances of fin folding and shedding of fin rays, each occurring at a rate of 1 %. In the group of fish weighing less than 30 g, the damage rates were as follows: 2.30 for the dorsal fin, 1.13 for the caudal fin, 1.29 for the subcaudal fin, 1.72 for the left pectoral fin, 1.71 for the right pectoral fin, 1.39 for the left ventral fin, and 1.42 for the right ventral fin. For fish weighing over 100 g, the damage rates were higher: 3.11 for the dorsal fin, 1.75 for the caudal fin, 1.90 for the subcaudal fin, 2.72 for the left pectoral fin, 2.70 for the right pectoral fin, 2.14 for the left ventral fin, and 2.17 for the right ventral fin. Additionally, in a small number of fish in the <30 g category, aside from fin damage, deformities (malformations) in their gill cover (operculum). The results of this study revealed that both categories of fish were affected with fin damage, and the dorsal, and pectoral fins were the most damaged fins. In addition to the visual observations of fins, also were analyzed (May and August 2023) the abiotic parameters of the water that supplies the farm's basins. The values measured in August were higher than those in May, and these changes can be taken as the cause of fin damage in the rainbow trout at this research farm.
We hope that this research will result in proposals for the modification of farming practices and the continuous improvement of the fin profile of cultivated rainbow trout.

Keywords: Rainbow trout, farming practices, fish welfare, fin profile.

1. Introduction

Aquaculture, as one of the fastest-growing sectors in animal production (average annual growth of 8.8%), contributes almost 50% to the consumption of fish in the world, and it is predicted that in the next decade, the total production of fish will exceed the production of beef, pork, or chicken [16].
In this regard, aquaculture plays an important role because it contributes to better food by improving the quality of fish meat as food for human consumption [17] [18].
Although there is a positive overview of the fish industry and its products among consumers [20], they warn of increased interest in the sustainability of fish production and the welfare of farmed fish [2].
There are a large number of fish welfare studies based on different measurement variables for assessment. Among them, feather damage is one of the frequently analyzed indicators due to its

https://doi.org/10.62792/ut.jnsm.v10.i19-20.p3093

obvious manifestation and potential modesty for determination [10], [11], [12], [19], [23], [25], [27], [28], [40], [41], [42], [45], [46], [48], [50].

In response to this phenomenon, the aquaculture industry took steps to ensure good fish welfare through the development and application of farming practices in which their welfare is also included.

An example of this is the Federation of European Aquaculture Producers, where "respect for the welfare aspects of farmed fish" is one of the guiding principles for aquaculture [15].

Fin damage is considered a very important indicator of fish welfare [42] and is a frequent and quite serious phenomenon that appears mainly in farmed fish [32], although it can also be found in the wild (natural) population of fish [29]. From the very fact that the occurrence of fin damage is greater in cultured fish than in natural ones, let us understand that the appearance of this phenomenon may be a consequence of the density of cultivation, the feeding regime, and environmental conditions [38].

Fin damage in rainbow trout cultivated in aquaculture is a common occurrence in our country as well.

Therefore, the main goal of this research is to gain a real insight into the condition of the fins, the factors that influence their damage, and the possibilities for reducing the frequency of their damage in rainbow trout cultivated in aquaculture in the Republic of North Macedonia.

2. Materials and methods

The research included 8 ponds of the trout farm in the village of Rezhanovtse, with a total annual production of 3000-5000 kg and a flow rate of the supply water from source 2, 64 m/s (Figure 1).

Figure 1. The fish farm in the village of Rezhanovtse, Likovo region, photographed by drone (top photo) and digital camera (bottom photo).

The fishpond research was carried out in two parts. In the first part, the owner or responsible technologist of the fish farm was surveyed, with which the main technological moments in production were included and data were provided on: the type of pool (circular or rectangular) and the surface, the material from which the pool was built and since it has been in operation, the purpose of cultivation and the annual production, the amount of water available, the temperature of the water and also the amount of oxygen dissolved in the water, the density of cultivation, the type of food, the frequency of daily feeding, the number of daily feeding and the method of their giving, selection and shooting, the presence of diseases and the frequency of mortality and the type of medication and the way of its application.

In the second part, the analysis of fin damage is included. Before starting the analysis of the fins, the fish were clinically observed to ascertain possible diseases.
The fins were analyzed in two categories of fish (with a body weight between 30g (min. 5g) and over 100g (max. 250g). From the breeding pools in which the mentioned categories were present, photos of the fins of 170 fish were analyzed according to categories (Figure 2).

Figure 2. Macroscopic damage of fins. A-Dorsal fin crack, B-Tail fin surface pitting, C-Tail fin crack, D-Dorsal fin injury (original photo).

The fish were caught in groups according to random selection using the existing pool equipment (net) (Figure 3).

Figure 3. Shooting fish with a net (original photo)

To include seasonal changes in cultivation, the research of all farms was carried out twice during a calendar year. The first research was carried out in late winter and early spring, and the second during the summer period (a total of 2240 fins of 430 fish were analyzed).
Fin damage analysis was done according to the valid macroscopic quantitative key [23] (fig. 4 and 5).

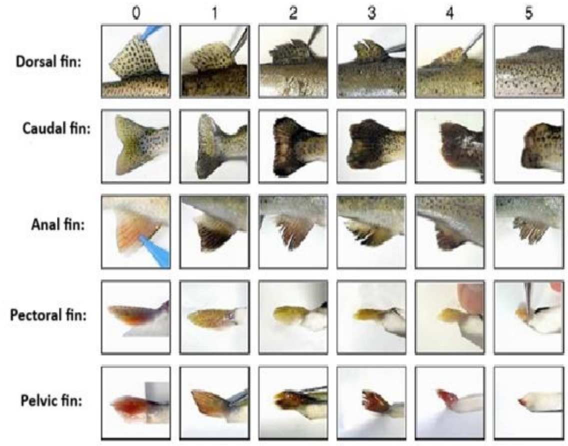

Figure 4. Photographic keys to fin damage in rainbow trout weighing > 50g (Hoyle et al. 2007)

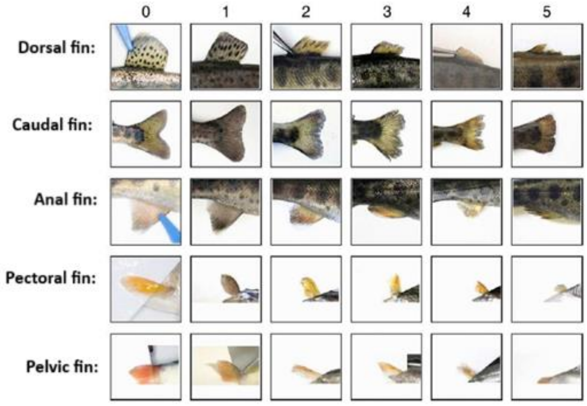

Figure 5. Photographic keys to fin damage in rainbow trout weighing < 50g (Hoyle et al. 2007)

The method is based on the fast macroscopic description of the damage of all fins (except the fat one) in field conditions and includes two parts. In the first part, based on the photographic key, the degree of lack of tissue in the fins was determined on a scale of 0-5 (0-no damage; 5-complete loss of fins), while in the second part, based on clinical descriptors the damages and lesions of the fins were qualitatively classified: damaged edges (surface gnawing), cracks (V-shaped cracks between the spicules); bat spicules (absence of soft tissue); bleeding (spots with clearly defined borders and dark red color); flashes (presence of unnatural redness); thickening (presence of adipose tissue with greater thickness compared to the normal fin) and folds (lateral, as a result of regrowth).

The time required for the analysis of the fins was 10-15 sec., [23] which is sufficient for damage analysis without negative impacts on fish welfare. After the analysis, the fish were returned to the pool.

Statistical analysis of the results was performed with the Statistica 8 software package, and the results were presented as percentages or as mean values.

One-way analysis of variance of multiple mean values (one-way ANOVA) was used to process the data for statistical differences between fish farms.

Student's t-test of two mean values was used to analyze statistical differences between two fish groups and seasonal variations. Results were considered statistically significant at the 0.001 significance level ($p<0.001$).

The analysis of the abiotic parameters of the spring water samples (water pH, conductivity, temperature, total hardness, carbonates, bicarbonates, calcium, magnesium, sodium, and potassium ions) from which the fish ponds were supplied was carried out in the analytical laboratory of the Center for Public Health in Kumanovo.

The pH of the water was determined according to the AOAC Official Method 973.41., which is based on the determination of the concentration of hydrogen ions and hydroxyl groups in water.

The reagents that were used for the determination of this parameter were buffer solutions with pH 4.0, pH 7.0, and pH 10.0. The Mettler Toledo digital pH meter and laboratory glasses were used as apparatus.

The water sample analyzed at room temperature was placed in a glass laboratory glass with a volume of 20 ml, in which the electrode of the pH meter was then immersed. After some time of its stay in the water, the device is keyed and the pH value is read, even at the moment when it has not changed. Before reading the pH value, the pH meter was initially calibrated with buffer solutions with pH values of 4.0, 7.0, and 10.0.

The reading of the pH value is made directly from the display of the device. The reporting of the results is done in numerical value with one decimal place.

The electrolytic conductivity was performed according to the AOAC Official Method 973.40. which is based on the determination of the electrolytic conductivity value. The reagents that were used for this purpose were solutions with electrolytic conductivity of 1413 µS/cm and 12.88 µS/cm, while the apparatus used was the Mettler Toledo digital conductometer and laboratory glasses.

The analyzed water sample of 20 ml at room temperature is placed in a laboratory glass in which the electrode of the conductivity meter is then immersed, and after a time of its stay, the device is keyed and the electrolytic conductivity value is read at the moment when it has not changed. Before reading the value, the device was initially calibrated with standard solutions with an electrolytic conductivity of 1413 µS/cm; 12.88 mS/cm. The reading of the conductivity value is taken from the display of the conductivity meter.

The determination of the water temperature was done with an Aswar TP-300 digital thermometer by immersing the electrode in the glass filled with 100 cm^3 of spring water and reading the temperature value from the thermometer screen.

The general hardness of the water is determined according to the AOAC Official Method 973.52, which is based on the determination of the hardness of the water thanks to the titration with Komplexon EDTA in the presence of ammonia buffer and Eriochrome black as an indicator. The reagents used to determine this parameter were Komplexon EDTA III, 0.05N, ammonia buffer, and black Eriochrome.

Using a beaker, 50 ml of spring water was placed in an Erlenmeyer flask (300-500 ml), then 5 ml of ammonia buffer and a spoonful of Eriochrome black were added with a pipette. The titration is done with Komplexon EDTA III 0.05 N until the color changes from purple to blue. The water hardness value is calculated using the formula:

$$^{0}D = V_t \text{ x } 0.05 \text{ x } 56 \text{ x } 1000/10 \text{ x } 50 = 5.6 \text{ x } V_t$$

The determination of carbonates was carried out according to the AOAC Method 920.194, which is based on the titration of the water sample with hydrochloric acid in the presence of the phenolphthalein indicator 0.05 N HCl and 1% phenolphthalein solutions were used as reagents. In the 250 cm^3 Erlenmeyer flask, add 100 cm^3 of the water sample and a few drops of phenolphthalein indicator. If a purple color appeared, then the sample was titrated with HCL 0.05 M until the color changed.

The amount of carbonates was calculated according to this formula:

$$CO^{3-}(mg/100ml) = V \times 3 \text{ (factor)}$$

Bicarbonates were determined according to the AOAC 920.194 method, which is based on the titration of the water sample with hydrochloric acid in the presence of the methyl orange indicator. The reagents used for the determination of this parameter were 0.1 N HCL solution, reagent 18, and Methyl-red.

In the Erlenmeyer flask of 250 cm^3, 100 cm^3 of the water sample and a few drops of the methyl red indicator were added with a graduated cylinder and titrated with the HCL solution 0.05 M until the color changes from yellow to orange.

The calculation of the amount of bicarbonates is made according to the formula:

$$HCO^{3-}(mg/100ml) = V \times 3.05 \text{ (factor)}$$

Where V-cm^3 represents the HCL solution (0.05 N).

The determination of macro-elements was carried out according to the EPA 200.7 method with the help of the MP-AES (Microwave Plasma Atomic Absorber) apparatus. The reagents that were used for the determination of macro-elements (Ca, Mg, Na, and K) were water distilled for holmium and HNO_3 in a ratio 1:1 with water.

20 ml of water sample was pipetted and placed in centrifuge tubes (50 ml) to which we added 0.4 ml of HNO_3 in a 1:1 ratio with distilled water. The lid was closed and the sample was mixed well, then the mixed sample was placed in the MP-AES atomic absorber, where the macro-element values were determined.

The results in ppm (mg/kg) were read directly into the computer after entering the data during the work procedure for the MP-AES method.

3. Results

The prevalence of fin damage was determined based on macroscopic, qualitative clinical descriptors of fin damage and the number of fish analyzed. In 430 fish, 2240 analyzed fins were damaged to different degrees, and the prevalence was 100% (Figure 6).

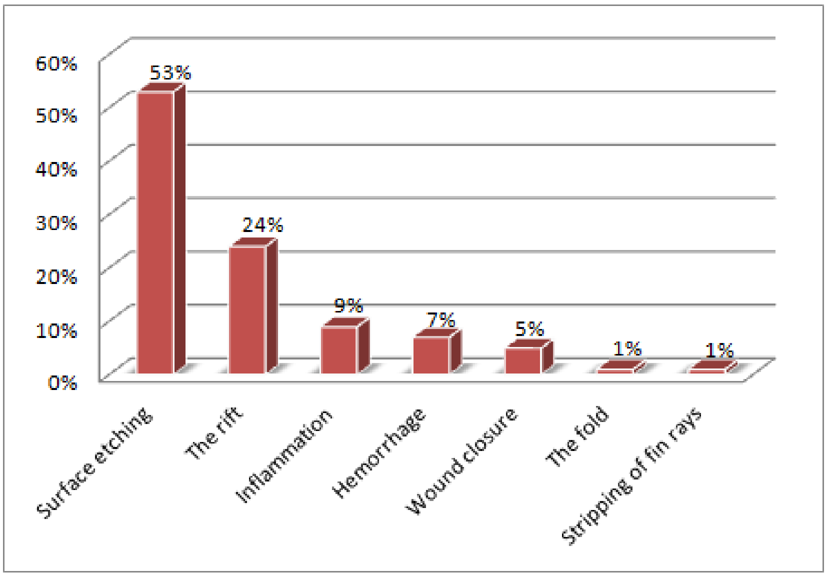

Figure 6. Prevalence and type of fin damage in rainbow trout cultured in fish ponds in the farm of village Rezhanovtse, Likovo region

From the graphic presentation, we can observe that surface crushing as a type of fin damage in the analyzed fish was represented by 53%, cracks by 24%, inflammation by 9%, hemorrhage by 7%, wound closure by 5%, while folding of the fins and stripping of spicules by 1%.
The macroscopic damages of fins in the analyzed fishes are presented in the following picture (Figure 7.).

Figure 7. A-crack of the dorsal fin, B-surface pitting of the caudal fin, C-injury of the dorsal fin, D-exfoliation of the fin rays of the dorsal fin, E-folding of the dorsal fin, F-injury of the pectoral fin, G -G-hemorrhage of the caudal fin, H-covering the wound of the dorsal fin (original photo from the field)

In a small number of fish of the <30g category (5 individuals), in addition to damage to the fins, malformations (deformities) of the branchial caps were also found (Figure 8).

Figure 8. Malformation (deformity) of the operculum in the trout of the water basins of the fish farm included in the study

The rate of damage to all fins from each category of fish and from each fish pool is shown in Table 1. An analysis of fin damage to confirm seasonal changes did not show statistical significance, data were processed for 30 individuals per category. The overall results of fin damage are presented in Tables 1 and 2.

Table 1. Fin damage rate in fish < 30 g in all water basins

No.	**Fin**	**Rating scale**
1	dorsal	2.30
2	caudal	1.13
3	Post caudal	1.29
4	left pectoral	1.72
5	right pectoral	1.71
6	left pelvic	1.39
7	right pelvic	1.42

Table 2. Fin damage rate in fish > 100 g in all water basins

No.	**Fin**	**Rating scale**
1	Dorsal	3.11
2	Caudal	1.75
3	Post caudal	1.90
4	left pectoral	2.72
5	right pectoral	2.70
6	left pelvic	2.14
7	right pelvic	2.17

From the tabular presentation of the degree of fin damage, it can be seen that in both categories of fish (<30 g and >100 g), the dorsal fins were the most damaged, while the pectoral and ventral fins were the most damaged.
The extent of damage and prevalence of all fins in both fish groups and across all farms are presented in Table 3.

Table 5. Degree of damage and prevalence of all fins in fish of both groups of all farms included in the study

Tip of fins **Size of fish**	**Farm 1**	**Farm 2**	**Farm 3**	**Farm 4,5**	**Farm 6**	**Farm 7**	**Farm 8**
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
Postcaudal (<30g)	1,73	1,67	1,52	1,47	1,10	1,73	1,33
Postcaudal (>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
Left pectoral (<30g)	2,10	2,02	1,78	1,82	2,10	2,03	1,73
Left pectoral (>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

Right pectoral. (<30g)	2,07	2,03	1,80	1,83	2,07	2,02	1,70
Right pectoral (>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
Left pelvic (<30g)	1,58	1,75	2,18	1,50	1,33	1,30	1,47
Left pelvic. (>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
Right pelvic (<30g)	1,57	1,77	2,20	1,53	1,43	1,33	1,43
Right pelvic (>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 average values obtained for the degree of damage to all fins in both groups of fish (< 30 g and > 100 g), it was found that except for farm 2 where for the ventral fins, the values obtained for the degree of damage to the fins were not statistically significant ($p<0.01$), and farm 7 where the values obtained for all fins also resulted in a statistically insignificant difference, in all other farms the results obtained for the degree of damage were statistically significant ($p<0.001$).
The results of the abiotic parameters of the analyzed water samples of the spring feeding the fish ponds for the spring and summer periods are shown in Tables 4 and 5.

Table 4. The results of the abiotic parameters of the analyzed water sample of the source supplying the fish farm in the village Rezhanovtse of the Likovo region in the spring period (May 13, 2023)

No.	**Analyzed abiotic parameters**	**Units of measurement**	**Results**	**Measurement limits**	**Methods/Apparatus**
1.	pH	pH units	6.32	≥ 6,5 and ≤ 9,5	AOAC official methods 973.41
2.	Electrolytic conductivity	μS cm^{-1} në 20°C	193.2	2500	AOAC official methods 973.40
3.	Temperature	˚C	19.5		Thermometer
4.	General hardness	d^0H	7.2	30	AOAC official methods 973.52
5.	Carbonates	mg/100 ml	<0.1		AOAC methods 920.194
6.	Bicarbonates	mg/100 ml	8.2		AOAC methods 920.194
4.	Ca^{++}	mg/l	40.6	150	EPA methods 200.7
5.	Mg^{++}	mg/l	3.51	100	EPA methods 200.7
6.	Na^{+}	mg/l	0.8	200	EPA methods 200.7
7.	K^{-}	mg/l	0.3	50	EPA methods 200.7
Regulation of limits: ISBN 978-92-4- 151376-0 (WHO)					

Table 5. The results of the analysis of abiotic parameters of the water sample of the source supplying the fish farm in the village.Rezhanovtse of the Likovo region in the summer period (05 August 2023)

No.	Analyzed abiotic parameters	Units of measurement	Results	Measurement limits	Methods/Apparatus
1.	pH	pH njësit	7.62	≥ 6,5 and ≤ 9,5	AOAC official Methods 973.41
2.	Electrolytic conductivity	μS cm^{-1} në 20°C	277.4	2500	AOAC official methods 973.40
3.	Temperature	˚C	22.2		Thermometer
4.	General hardness	d^0H	7.3	30	AOAC official methods 973.52
5.	Carbonates	mg/100 ml	<0.1		AOAC methods 920.194
6.	Bicarbonates	mg/100 ml	8.35		AOAC methods 920.194
4.	Ca^{++}	mg/l	43.9	150	EPA methods 200.7
5.	Mg^{++}	mg/l	4.47	100	EPA methods 200.7
6.	Na^{+}	mg/l	0.75	200	EPA methods 200.7
7.	K^{-}	mg/l	0.3	50	EPA methods 200.7
Regulation of limits: ISBN 978-92-4- 151376-0 (WHO)					

Based on the values obtained for the analyzed abiotic parameters of the spring water samples for both periods, we have managed to establish that, unlike the spring period, in the summer period, we had an increase in the values of almost all the analyzed parameters.
With the analysis of the state of fin damage in the fish farm pools in v. Rezhanovse, in the region of Likovo, the prevalence of 100% was confirmed, i.e., fin damage was found in the fish of all the pools analyzed. The main damages were characterized by "superficial bites" (damaged edges), while the finding of "baric fin rays" showed that there were no signs of active bacterial infection in the analyzed individuals. The finding of "damaged edges" shows that fin damage is present in trout production in our country. In all the fish analyzed, there were damaged fins to different degrees, which indicates the fact that all fins with fin rays are under the influence of damage [6], [25].

4. Discussion and conclusions

This research confirms the finding that fin damage is present in salmon culture production and is consistent with previous findings that fin damage is widespread in trout farms [13], in neighboring countries [25], and also in the Republic of North Macedonia [10].
The most damaged fins in both categories of fish analyzed were the dorsal and pectoral fins. The same dams were also damaged in the smallest individuals analyzed (5g), which indicates the fact that damages appear in the early productive stages at the breeding site [30], [54]. For this reason, research on the fin damage process in fish in the breeding grounds should be a priority for research in this field in the future.
The damage of other fins was much greater in the larger categories, which indicates that the conditions and technology of cultivation, to a considerable extent, influence the degree of damage.

Fin damage was to a lesser extent pronounced in the smaller categories analyzed. This finding is consistent with the findings of [4], [54], that fin damage at an early age continues throughout the cultivation process. The differences in fin damage between the two analyzed categories indicate that it is possible to improve the profile of fins in farmed trout, which would result in better welfare and better aesthetic qualities of commercial fish. In individuals of the largest categories, the degree of variation in fin damage between different pools on a farm was not very large. This suggests that injuries are certainly related to genetic factors that vary between farms and may affect all fish in a farming system.

The finding of severely damaged fins in some fish in a pool indicates that some factors probably influence the rate of fin damage more at the individual level than at the group level.

This finding, except the dorsal fin and ventral fin, is not consistent with other studies of fin damage in salmonid fish [1], [7], [44], [55]. Perhaps this finding is the result of the application of the other methodology for the assessment of damages, the effects of etiological and risk factors on the different fins due to their position in the body of the fish.

In this research, the difference in fin damage was proven depending on the cultivation season.

The same conclusion was reached by MacIntyre in his research on the influence of water quality on the well-being of rainbow trout in the United Kingdom [34]. This finding once again emphasizes the importance of farm practices for fin damage.

The perfect correlation between damage to pairs of fins indicates the fact that if a factor affects one pair of fins in a certain way, it will affect the other pair in the same way. St-Hilaire et al. reached the same conclusion [54].

The absence of fin damage in river trout and trout reared in isolation [30] indicates that farm conditions initiate fin damage. For this reason, fin damage is considered a breeding phenomenon. The differences in fin damage in the analyzed farms show that certain factors or groups of factors specific to each farm influence the degree of damage.

Several potential risk factors for fin damage were identified in this research. Concrete identification and association of risk factors and fin damage is experimentally dependent and requires a comparison between groups of affected and unaffected individuals. The greater the difference between the groups, the easier it is to identify the factors that influence the differences obtained. This research only hypothesizes possible cause-effect relationships. In this type of research, in the conditions of farm cultivation without manipulation of living conditions and cultivation practices, no real connection can be established with a certain factor due to the impossibility of excluding other risk factors. Thus, the proposed risk factors are related to fish welfare and are regularly present, regardless of whether their welfare is good or bad. For these reasons, this part is hypothesized for fish with the most damaged fins from the >100g category, separately for each factor, taking into account the multifactorial nature of fin damage.

Variations in the dynamics of water flow in the rectangular basins and the possible influence of other farming factors (water temperature, percentage of daily feeding, food retention, etc.) probably contributed to the high rate of fin damage on the researched farm. At the moment, there is no data in the literature about the different effects of circular and rectangular pools on fin damage.

Roque d'Orbcastel et al. [11] in their research on the growth and well-being of rainbow trout in recirculating and classic cultivation systems, found that fish in recirculating systems had greater damage to the dorsal and ventral fins. They concluded that changes in the hydrodynamics of recirculating systems are the cause of the greatest fin damage.

Water temperature certainly affected fin damage, with greater damage to dorsal and pectoral fins. According to our study, greater damage to the fins was found during the summer season, where, compared to the increase in temperature, changes were also observed in other abiotic parameters of the source water from which the pools of the cultivation farm were supplied (Table 5).

So, in all the fish, the damage to the dorsal fin and pectoral fin was probably caused as a result of the action of some other risk factors. In general, there is a confusing picture in the literature about the influence of temperature on fin damage.

According to Winfree et al. [61], fin damage was less during lower temperatures, while according to Schneider and Nicholson [52], damage was greater during higher temperatures. In the research of Wagner et al. [60], temperature did not affect fin damage, while Udomkusonsri, & Noga, [57] proposed that fin ulceration is directly related to water temperature.

Although there is evidence according to which fin damage is proportional to the high density of cultivation [7], [13], [43], [47], [58], [61], there are researches and papers reviewed according to who do not have such a relationship [13], [22], [33], [35], [50]. Ellis et al. [13], suggested that the effect of high stocking density on fin damage is mediated by water quality and behavioral interactions.

MacIntyre, [34], proved that water quality is not a mediator and supported the hypothesis that the effect of cropping density on fin damage is mediated by behavioral interactions. This research and the existing data from the literature show that the density of cultivation is a possible risk factor, but with smaller effects compared to other factors.

Fin damage was not affected by the percentage of daily feed, although damage to dorsal, pectoral, and ventral fins was greater in pool 1, where food was also given in a smaller percentage. In Basin 1, this risk factor is closely related to low water temperature and long periods of malnutrition during the year.

On the other hand, in pool 3, there was similar damage to dorsal and ventral fins to pool 1, the percentage of daily molting was more than twice as great, while the situation with pectoral fins was identical, but again, there was marked damage to the fins. Dorsal fins in pools 2 and 8 and pectoral fins in pools 6 and 8.

Data from the literature about the influence of the percentage of daily feeding on fin damage are contradictory. According to Jones et al. [28], Moutou et al. [39], and Winfree et al. [61], the smallest percentage of daily feed or food intake results in severe fin damage. On the other hand, Kindschi et al. [30] and Klontz et al. [31] prove that dorsal fin damage is not directly dependent on reduced daily intake or food intake.

About the daily average in the smallest categories in the breeding pools, there were only small variations. For these reasons, the number of daily meals as the only factor in this research cannot be hypothesized.

It is known that consumer fish farmers are often under pressure to produce as many kilograms as possible in the shortest possible time, and due to the needs of the market, they sometimes feed the fish with food or completely stop feeding for a certain period.

Perhaps these farming practices affect fin damage through increased aggression in fish or some other social interactions.

Although fish handling has been suggested as a cause of fin damage [24], in this study, the selection of fish did not affect the extent of fin damage.

In this study, the method of treatment (except selection) and transport of fish, quality of food, exposure to stressful agents, speed and currents of water, genetic differences of breeding varieties, and albinism were not included.

Perhaps the difference in fin damage in the analyzed pools is due to any of these factors or their combinations.

The process of fin damage is still unclear enough due to numerous studies that give conflicting results and probably do not reflect reality. The relevance of different etiological factors and risk factors remains to be determined due to the different significance in different conditions of production.

During the research period, there were no disturbances in the technological process, no signs of infectious, parasitic, or non-infectious diseases were detected, and there was no mortality in the fish of all the pools analyzed. This allows us to understand that fin damage by itself does not represent a serious threat to production parameters. This is to be expected, because fin damage as a cultivation phenomenon has been highly tolerated during the expansive development of salmon culture in the last four decades [12]. Thus, fin injuries are a legitimate part of fish welfare because they present injury to living tissue [13], which can induce pain [8], [53], allow entry of disease agents [14], [21], [36] and affect behavioral performance [1], [3], [5], [9], [24], [37], [49], [51], [56], [59].

Future research in this area should be focused on the impact of farming practices on individual fin damage, the impact of damaged fins on fish performance, and their behavioral needs. We think that in this way, useful information will be obtained which will be used to define the acceptable level and type of damage for each fin. Also, we consider that it would be necessary to have a standard method for fin damage analysis, which will enable comparison between researchers, especially when two or more rainbow trout farms are included in the study.

Based on this study, we can derive several conclusions, including:

1. The method applied for the analysis of fin damage will be shown to be efficient for the evaluation of their damage in pond-cultured trout.
2. Fin damage will be present and widespread in trout production in the Republic of North Macedonia.
3. All feather beam feathers will be exposed to damage.
4. Fin damage will be present in juvenile fish in breeding grounds and will continue to increase during the production process.
5. The most damaged fins in rainbow trout cultivated in ponds in our country will be the dorsal and pectoral fins.
6. A certain factor or set of specific factors for each bass can influence the degree of fin damage.
7. Factors with possible influence on fin damage in rainbow trout cultivated in North Macedonia may be temperature and other factors that we need to identify.
8. Damaged fins will not affect the productive performance of farmed trout.

From all these conclusions, the general conclusion emerges, according to which the high prevalence shows that fin damage is a significant indicator for the well-being of rainbow trout cultivated on farms in our country, but also more widely. Due to the diversity of injuries, it is understood that farm practices affect the feather profile. However, it should be noted that the analysis of risk factors only indicates the existence of statistical associations. For these reasons, experimental studies are needed to manipulate the proposed risk factors to validate statistical associations. This study would result in proposals for the modification of farm practices and the continuous improvement of the fin profile of farmed rainbow trout in the Republic of North Macedonia.

Therefore, based on the above-mentioned conclusions that emerged from this study, we can recommend the application of cultivation practices with which feather damage can be reduced:

- Throwing gravel at the bottom of the concrete pools to prevent rubbing of the fins, especially the pectoral, ventral, anal, and subcaudal fins.
- Covering the pools to form shadows, to prevent the negative action of the sun's rays (especially ultraviolet ones), during the warm summer months.
- Cultivation of fish in faster-flowing water. In this way, the fish will be in better physical condition, which also improves the condition of the fins.
- Increasing the number of water changes. This will reduce the accumulation of harmful nitrogenous products and the risk of low alkalinity.
- Cultivation of fish in the required technological limits of temperature, oxygen saturation, and light intensity.

- Shooting nets should be free of knots, and, as much as possible, the handling of fish should be reduced to avoid their injury.

- When hunting and transporting fish, it is preferable to use electric pumps with batteries instead of nets that would provide the necessary oxygen during transport to the destination.

- To use new food formulations that satisfy the nutritional needs and reduce the possibility of fin injury.

- The fish should be fed through feeders distributed evenly throughout the length of the pool. In this way, the fish themselves will dictate the size, frequency and time of the daily feeding.

- If the fish are fed by hand, then the food should be uniformly distributed throughout the length of the basin to avoid grouping of fish in the feeding area.

References

[1] Abbott, J. C., & Dill, L. M. (1985). Patterns of aggressive attack in juvenile steelhead trout (Salmo gairdneri). *Canadian journal of fisheries and aquatic sciences*, *42*(11), 1702-1706.

[2] Altintzoglou, T., Verbeke, W., Vanhonacker, F., & Luten, J. (2010). The image of fish from aquaculture among Europeans: impact of exposure to balanced information. *Journal of Aquatic Food Product Technology*, *19*(2), 103-119.

[3] Arnold, G. P., Webb, P. W., & Holford, B. H. (1991). The role of the pectoral fins in station-holding of Atlantic salmon parr (Salmo salar L.). *Journal of Experimental Biology*, *156*(1), 625-629.

[4] 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*(1-2), 167-175.

[5] Barthel, B. L., Cooke, S. J., Suski, C. D., & Philipp, D. P. (2003). Effects of landing net mesh type on injury and mortality in a freshwater recreational fishery. *Fisheries Research, 63*(2), 275-282.

[6] Bodammer, J. E. (2000). Some new observations on the cytopathology of fin erosion disease in winter flounder Pseudopleuronectes americanus. *Diseases of aquatic organisms, 40*(1), 51-65.

[7] Bosakowski, T., & Wagner, E. J. (1994). A survey of trout fin erosion, water quality, and rearing conditions at state fish hatcheries in Utah. *Journal of the World Aquaculture Society, 25*(2), 308-316.

[8] Chervova, L. S. (1997). Pain sensitivity and behavior of fishes. *Journal of Ichthyology, 37*(1), 98-102.

[9] Coble, D. W. (1971). Effects of fin clipping and other factors on survival and growth of smallmouth bass. *Transactions of the American Fisheries Society*, *100*(3), 460-473.

[10] Cvetkovikj, A., Radeski, M., Blazhekovikj-Dimovska, D., Kostov, V., & Stevanovski, V. (2013). Fin damage of farmed rainbow trout in the Republic of Macedonia. *Macedonian Veterinary Review, 36*(2), 73-83.

[11] d'Orbcastel, E. R., Person-Le Ruyet, J., Le Bayon, N., & Blancheton, J. P. (2009). Comparative growth and welfare in rainbow trout reared in recirculating and flow through rearing systems. *Aquacultural Engineering, 40*(2), 79-86.

[12] Ellis, T., Hoyle, I., Oidtmann, B., Turnbull, J. F., Jacklin, T. E., & Knowles, T. G. (2009). Further development of the "Fin Index" method for quantifying fin erosion in rainbow trout. *Aquaculture, 289*(3-4), 283-288.

[13] Ellis, T., Oidtmann, B., St-Hilaire, S., Turnbull, J. F., North, B. P., MacIntyre, C. M., ... & Knowles, T. G. (2008). Fin erosion in farmed fish. *Fish welfare*, 121-149.

[14] El–Matbouli, M., Hoffmann, R. W., & Mandok, C. (1995). Light and electron microscopic observations on the route of the triactinomyxon-sporoplasm of Myxobolus cerebralis from epidermis into rainbow trout cartilage. *Journal of Fish Biology, 46*(6), 919-935.

[15] Federation of European Aquaculture Producers *(FEAP),* 2011.

[16] Food and Agriculture Organization of the United Nations. (2012). *The state of world fisheries and aquaculture 2012*. Scribd. https://www.scribd.com/document/155490941/The-State-of-World-Fisheries-and-Aquaculture-2012

[17] Food and Agriculture Organization of the United Nations. (2014). The state of world fisheries and aquaculture 2014: Opportunities and challenges (223 pp.). *FAO.* http://www.fao.org/3/i3720e/i3720e.pdf.

[18] Food and Agriculture Organization of the United Nations. (2014b). *FAO yearbook: Fishery and aquaculture statistics*. Summary tables – World aquaculture production by species groups. FAO. http://www.fao.org/fishery/statistics/en.

[19] Good, C., Davidson, J., Welsh, C., Brazil, B., Snekvik, K., & Summerfelt, S. (2009). The impact of water exchange rate on the health and performance of rainbow trout Oncorhynchus mykiss in water recirculation aquaculture systems. *Aquaculture, 294*(1-2), 80-85.
[20] Hanson, G. D., Rauniyar, G. P., & Herrmann, R. O. (1994). Using consumer profiles to increase the US market for seafood: implications for aquaculture. *Aquaculture*, *127*(4), 303-316.
[21] Harmache, A., LeBerre, M., Droineau, S., Giovannini, M., & Brémont, M. (2006). Bioluminescence imaging of live infected salmonids reveals that the fin bases are the major portal of entry for Novirhabdovirus. *Journal of virology, 80*(7), 3655-3659.
[22] Hosfeld, C. D., Hammer, J., Handeland, S. O., Fivelstad, S., & Stefansson, S. O. (2009). Effects of fish density on growth and smoltification in intensive production of Atlantic salmon (Salmo salar L.). *Aquaculture*, *294*(3-4), 236-241.
[23] Hoyle, I., Oidtmann, B., Ellis, T., Turnbull, J., North, B., Nikolaidis, J., & Knowles, T. G. (2007). A validated macroscopic key to assess fin damage in farmed rainbow trout (Oncorhynchus mykiss). *Aquaculture, 270*(1-4), 142-148.
[24] Huntingford, F. (2008). Animal welfare in aquaculture. *In Aquaculture, Innovation and Social Transformation* (pp. 21-33). Dordrecht: Springer Netherlands.
[25] Iseni, G., Berisha, B., & Iseni, B. (2022). Analysis of Scale of Fin Damage (Erosion) in Farmed Rainbow Trout in the Republic of Kosova. *ANGLISTICUM. Journal of the Association-Institute for English Language and American Studies*, *11*(5), 34-45.
[26] Johnsen, B. O., & Ugedal, O. (1988). Effects of different kinds of fin-clipping on over-winter survival and growth of fingerling brown trout, Salmo trutta L., stocked in small streams in Norway. *Aquaculture Research*, *19*(3), 305-311.
[27] Jones, H. A. C., Hansen, L. A., Noble, C., Damsgård, 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 behaviour science, 127*(3-4), 139-151.
[28] Jones, H. A. C., Noble, C., Damsgård, B., & Pearce, G. P. (2012). Investigating the influence of predictable and unpredictable feed delivery schedules upon the behaviour and welfare of Atlantic salmon parr (Salmo salar) using social network analysis and fin damage. *Applied animal behaviour science*, *138*(1-2), 132-140.
[29] Khan, R. A., Campbell, J., & Lear, H. (1981). Mortality in captive Atlantic cod, Gadus morhua, associated with fin rot disease. *Journal of wildlife diseases*, *17*(4), 521-527.
[30] Kindschi, G. A., Shaw, H. T., & Bruhn, D. S. (1991). Effects of baffles and isolation on dorsal fin erosion in steelhead trout, Oncorhynchus mykiss (Walbaum). *Aquaculture Research, 22*(3), 343-350.
[31] Klontz, G. W., Maskill, M. G., & Kaiser, H. (1991). Effects of reduced continuous versus intermittent feeding of steelhead. *The Progressive Fish-Culturist, 53*(4), 229-235.
[32] Larmoyeux, J. D., & Piper, R. G. (1971). Reducing eroded fin condition in hatchery trout. *US Trout News*, *5*, 8-9.
[33] Latremouille, D. N. (2003). Fin erosion in aquaculture and natural environments. *Reviews in Fisheries Science*, *11*(4), 315-335.
[34] MacIntyre, C. M. (2008). Water quality and welfare assessment on United Kingdom trout farms.
[35] MacIntyre, C. M., Ellis, T., North, B. P., & Turnbull, J. F. (2008). The influences of water quality on the welfare of farmed rainbow trout: a review. *Fish welfare,* 150-184.
[36] Martínez, J. L., Casado, A., & Enríquez, R. (2004). Experimental infection of Flavobacterium psychrophilum in fins of Atlantic salmon Salmo salar revealed by scanning electron microscopy. *Diseases of aquatic organisms*, *59*(1), 79-84.
[37] McNeil, F. I., & Crossman, E. J. (1979). Fin clips in the evaluation of stocking programs for muskellunge, Esox masquinongy. *Transactions of the American Fisheries Society*, *108*(4), 335-343.
[38] Mork, J., Järvi, T., & Hansen, L. P. (1989). Lower prevalence of fin erosion in mature than in immature Atlantic salmon (Salmo salar) parr. *Aquaculture, 80*(3-4), 223-229.
[39] 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*(4), 756-770.
[40] 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 (Salmo salar L.) held in freshwater production cages. *Aquaculture research*, *38*(11), 1137-1143.
[41] Noble, C., Kadri, S., Mitchell, D. F., & Huntingford, F. A. (2008). Growth, production and fin damage in cage-held 0+ Atlantic salmon pre-smolts (Salmo salar L.) fed either a) on-demand, or b) to a fixed satiation–restriction regime: Data from a commercial farm. *Aquaculture*, *275*(1-4), 163-168.

[42] Noble, C., Mizusawa, K., Suzuki, K., & Tabata, M. (2007). The effect of differing self-feeding regimes on the growth, behaviour and fin damage of rainbow trout held in groups. *Aquaculture, 264*(1-4), 214-222.

[43] North, B. P., Turnbull, J. F., Ellis, T., Porter, M. J., Migaud, H., Bron, J., & Bromage, N. R. (2006). The impact of stocking density on the welfare of rainbow trout (Oncorhynchus mykiss). *Aquaculture, 255*(1-4), 466-479.

[44] Pelis, R. M., & McCormick, S. D. (2003). Fin development in stream-and hatchery-reared Atlantic salmon. *Aquaculture, 220*(1-4), 525-536.

[45] Person-Le Ruyet, J., Le Bayon, N., & Gros, S. (2007). How to assess fin damage in rainbow trout, Oncorhynchus mykiss?. *Aquatic Living Resources, 20*(2), 191-195.

[46] Person-Le Ruyet, J., Labbé, L., Le Bayon, N., Sévère, A., Le Roux, A., Le Delliou, H., & Quéméner, L. (2008). Combined effects of water quality and stocking density on welfare and growth of rainbow trout (Oncorhynchus mykiss). *Aquatic Living Resources, 21*(2), 185-195.

[47] Person-Le Ruyet, J., & Le Bayon, N. (2009). Effects of temperature, stocking density and farming conditions on fin damage in European sea bass (Dicentrarchuslabrax). *Aquatic Living Resources, 22*(3), 349-362.

[48] Peters, G. (1990). Problems concerning animal protection laws in connection with mass culture of fishes. *Deutsche Tieraerztliche Wochenschrift (Germany, FR), 97*(3).

[49] Pratt, T. C., & Fox, M. G. (2002). Effect of fin clipping on overwinter growth and survival of age-0 walleyes. *North American Journal of Fisheries Management, 22*(4), 1290-1294.

[50] Rasmussen, R. S., Larsen, F. H., & Jensen, S. (2007). Fin condition and growth among rainbow trout reared at different sizes, densities and feeding frequencies in high-temperature re-circulated water. *Aquaculture International, 15*, 97-107.

[51] Reimchen, T. E., & Temple, N. F. (2004). Hydrodynamic and phylogenetic aspects of the adipose fin in fishes. *Canadian Journal of Zoology, 82*(6), 910-916.

[52] Schneider, R., & Nicholson, B. L. (1980). Bacteria associated with fin rot disease in hatchery-reared Atlantic salmon (Salmo salar). *Canadian Journal of Fisheries and Aquatic Sciences, 37*(10), 1505-1513.

[53] Sneddon, L. U., Braithwaite, V. A., & Gentle, M. J. (2003). Do fishes have nociceptors? Evidence for the evolution of a vertebrate sensory system. *Proceedings of the Royal Society of London. Series B: Biological Sciences, 270*(1520), 1115-1121.

[54] St-Hilaire, S., Ellis, T., Cooke, A., North, B. P., Turnbull, J. F., Knowles, T., & Kestin, S. (2006). Fin erosion on commercial rainbow trout farms in the UK. *Vet Rec, 159*, 446-50.

[55] Turnbull, J. F., Adams, C. E., Richards, R. H., & Robertson, D. A. (1998). Attack site and resultant damage during aggressive encounters in Atlantic salmon (Salmo salar L.) parr. *Aquaculture, 159*(3-4), 345-353.

[56] Turnbull, J. F., Richards, R. H., & Robertson, D. A. (1996). Gross, histological and scanning electron microscopic appearance of dorsal fin rot in farmed Atlantic salmon, Salmo salar L., parr. *Journal of Fish Diseases, 19*(6), 415-427.

[57] Udomkusonsri, P., & Noga, E. J. (2005). The acute ulceration response (AUR): a potentially widespread and serious cause of skin infection in fish. *Aquaculture, 246*(1-4), 63-77.

[58] Wagner, E. J., Routledge, M. D., & Intelmann, S. S. (1996). Assessment of demand feeder spacing on hatchery performance, fin condition, and size variation of rainbow trout Oncorhynchus mykiss. *Journal of the World Aquaculture Society, 27*(1), 130-136.

[59] Wagner, E. J., Routledge, M. D., & Intelmann, S. S. (1996). Fin condition and health profiles of albino rainbow trout reared in concrete raceways with and without a cobble substrate. *The Progressive fish-culturist, 58*(1), 38-42.

[60] Wagner, E.J., Arndt, R., Routledge, M.D., Bradwisch, Q., 1988. Hatchery performance and fin erosion of Bonnevile cutthroat trout, Oncorhynchus clarki, at two temperatures. *J App Aquacult 3*: 1-12

[61] Winfree, R. A., Kindschi, G. A., & Shaw, H. T. (1998). Elevated water temperature, crowding, and food deprivation accelerate fin erosion in juvenile steelhead. *North American Journal of Aquaculture, 60*(3), 192-199.