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FACTORS AFFECTING FIN DAMAGE OF FARMED RAINBOW TROUT

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ABSTRACT

The aims of this study were to determine the influence of the factors affecting fin damage under different rainbow trout production systems and to compare the findings with the known experimental reports. The study was based on a questionnaire that included information about the main factors i.e. oxygen level in exit water, water temperature, stocking density, daily feed ration, number of meals and grading frequency on seven rainbow trout farms. Standard multiple regression analysis, based on a previously published fin damage dataset, was used to assess the relationship between the level of fin damage per fin and the factors. Daily feed ration received the strongest weight in the model for the caudal, anal and both pectoral fins, whereas number of meals received the strongest weight in the model for both pelvic fins. Grading frequency received the strongest weight only in the dorsal fin model. Lower levels of daily feed ration and number of meals combined with higher water temperature increased the level of fin damage, whereas stocking density had no effect. The results conform to the experimental research on fin damage in rainbow trout. The research model contributes to the overall assessment of fish welfare and the regression analysis used in this study could be used on rainbow trout farms to evaluate the effect of the main factors on the level of fin damage.

Key words: rainbow trout, factor, fin condition, fish welfare

INTRODUCTION

Fin damage is considered important for both economic and welfare reasons and continuous to be a significant problem in rainbow trout (*Oncorhynchus mykiss*) farms (1). The fin damage phenomenon has been studied for many decades, because fish with damaged fins are usually declared as less valuable by the consumers and the fishing public (2). Fin damage is considered as an operational welfare indicator that is increasingly gaining attention (3, 4) and represents one of the key welfare outcomes (5). The ubiquitous presence of fin damage results with a growing interest in understanding it's the etiology and the factors that increase or reduce fin damage in farmed rainbow trout (1).

There is a significant body of experimental research which identified that the main factors affecting fin damage are feeding practices, water quality, stocking density and routine handling, not excluding the bacterial infections (3, 6, 7, 8, 9). However, despite the experimental approach, there are few research reports that determine the important factors having effect on fin damage and fish welfare under different commercial production systems (5, 10). Nevertheless, there are also differences between species. For example, the most frequently damaged fin in Atlantic salmon (*Salmo salar*) and rainbow trout is the dorsal fin, whereas in brown trout (*Salmo trutta*) it is the caudal fin (10, 11).

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Table 1. Farming practices on the surveyed rainbow trout farms

Farm	Water temperature (°C)		Stocking density (kg/m^3)		Daily feed ration (% of body weight)		Number of meals per day		Grading on every X days
	Min.	**Max.**	**<30g**	**>100g**	**<30g**	**>100g**	**<30g**	**>100g**	
1	1	18	30	37	4	1.3	4	2	45
2	2	16	35	40	6	2	6	2	20
3	10	18	20	45	8	4	5	2	20
4	4	12	20	65	6	2	4	2	20
5	10	12	30	45	8	2	5	2	15
6	5	10	20	40	7	2	7	2	30
7	11	11	30	40	8	2	4	2	30

Farmed rainbow trout generally experience varying degrees of fin damage, and the farms in Republic of Macedonia are no exception. We have previously proposed that some factor or group of factors influence the degree of damage (10) and these factors should be identified in order to apply management practices that can minimize the level of fin damage.

The aims of this study were to determine the influence of the main factors on the level of fin damage in different commercial rainbow trout farms and to compare the (on farm) findings with the experimentally determined effects on the level of fin damage.

MATERIAL AND METHODS

We did a questionnaire survey with the farm owner or the responsible technologist on the seven rainbow trout farms described by Cvetkovikj et al. (10). The questionnaire was designed to include information about water quality [oxygen level in exit water (DO) and water temperature (WT)], stocking density (SD), feeding practices [daily feed ration (DF) and number of meals (NM)] and routine handling [grading frequency (GR)] per fish category (Table 1).

Table 2. Level of the fin damage and significance of the results between the different fish farms [adapted from Cvetkovikj et al. (10)]. Values represent mean ± SE

	Farm 1	**Farm 2**	**Farm 3**	**Farm 4**	**Farm 5**	**Farm 6**	**Farm 7**	**p**
Dorsal < 30g	3.63 ±0.06	2.53 ±0.13	3.02 ±0.15	2.30 ±0.11	1.50 ±0.09	2.35 ±0.12	2.13 ±0.15	p < .001
Dorsal > 100g	4.27 ±0.06	3.23 ±0.12	4.07 ±0.09	2.77 ±0.12	2.10 ±0.09	2.72 ±0.13	3.32 ±0.15	p < .001
Caudal < 30g	1.43 ±0.06	1.30 ±0.06	1.37 ±0.06	1.33 ±0.06	1.03 ±0.02	1.13 ±0.04	1.07 ±0.03	p < .001
Caudal > 100g	2.95 ±0.3	1.73 ±0.07	2.07 ±0.07	1.85 ±0.10	1.73 ±0.09	1.73 ±0.08	2.28 ±0.11	p < .001
Anal < 30g	1.73 ±0.07	1.67 ±0.09	1.52 ±0.09	1.47 ±0.06	1.10 ±0.04	1.73 ±0.08	1.33 ±0.06	p < .001
Anal > 100g	3.60 ±0.10	1.85 ±0.08	2.37 ±0.09	2.07 ±0.11	1.80 ±0.10	2.03 ±0.09	2.40 ±0.11	p< .001
Pectoral left < 30g	2.10 ±0.13	2.02 ±0.12	1.78 ±0.09	1.82 ±0.09	2.10 ±0.08	2.03 ±0.09	1.73 ±0.17	p > .05
Pectoral left > 100g	4.10 ±0.13	2.70 ±0.11	2.57 ±0.08	2.43 ±0.13	3.07 ±0.14	2.43 ±0.06	3.08 ±0.18	p < .001
Pectoral right < 30 g	2.07 ±0.14	2.03 ±0.12	1.80 ±0.10	1.83 ±0.10	2.07 ±0.07	2.02 ±0.09	1.70 ±0.12	p > .05
Pectoral right > 100 g	4.12 ±0.13	2.67 ±0.09	2.53 ±0.08	2.47 ±0.14	3.10 ±0.10	2.40 ±0.08	3.05 ±0.17	p < .001
Pelvic left < 30 g	1.58 ±0.11	1.75 ±0.09	2.18 ±0.14	1.50 ±0.09	1.33 ±0.06	1.30 ±0.06	1.47 ±0.09	p < .001
Pelvic left > 100 g	3.07 ±0.10	1.93 ±0.11	3.03 ±0.06	2.13 ±0.12	1.87 ±0.07	1.90 ±0.09	2.47 ±0.12	p < .001
Pelvic right < 30 g	1.57 ±0.10	1.77 ±0.11	2.20 ±0.14	1.53 ±0.09	1.43 ±0.08	1.33 ±0.07	1.43 ±0.09	p < .001
Pelvic right > 100 g	3.05 ±0.10	1.97 ±0.10	3.07 ±0.13	2.15 ±0.12	1.97 ±0.08	1.93 ±0.09	2.43 ±0.11	p < .001

Table 3. Pearson's correlations of the damaged fins and the predictors (n=840)

	WT	SD	DF	NM	GR
dorsal fin	.072	.147	-.348	-.302	.365
caudal fin	-.026*	.320	-.518	-.474	.254
anal fin	-.069	.258	-.472	-.373	.356
left pelvic fin	.110	.266	-.335	-.375	.118
right pelvic fin	.097	.259	-.320	-.359	.085
left pectoral fin	.072	.262	-.449	-.376	.192
right pectoral fin	.078	.273	-.463	-.385	.190

*Non-significant correlation

The DO did not significantly differ between the farms (all farms had DO between 6.5 and 6.7 mg/L) so we excluded it from further analysis. All farms used extruded fish feed and were manually feeding and grading the fish. This survey was conducted in parallel with the second scoring of the fins during the summer in 2012 (10).

To assess the relationship between the dependent variable (damaged dorsal, left and right pectoral, left and right pelvic, anal and caudal fin) and the predictor variables (WT, SD, DF, NM and GR), we performed standard multiple regression analysis [IBM SPSS Statistics 22 (©IBM, Armonk, NY, USA)] using the same fin damage dataset (Table 2) from our previous research (10).

As fin damage represents a continuous process (3, 12), we merged the fin damage data per fin from the two different categories (< 30g and > 100g) and performed the analysis separately for every fin. The results were considered statistically significant at p < .05

In addition, the results from Table 2 were used for a meta-analysis. First the mean and errors of means were used to calculate a t-value (the difference of the mean value from zero), the t-value was converted into r-values (13) and finally those r-values used for calculating effect sizes for each fin listed in Table 2. For that purpose we used the statistical package MetaWin (14).

RESULTS

The correlations of the predictor variables and the damaged fins are shown in Table 3. All correlations except between the caudal fin and WT were statistically significant. The regression coefficients of the predictors, together with their correlations with the damaged fins and their squared semi-partial correlations are shown in Tables 4, 5, 6, 7, 8, 9 and 10.

The prediction model for the dorsal fin was statistically significant, $F\,(5, 834) = 48.812$, p < .001, and accounted for approximately 22% of the variance of dorsal fin damage ($R^2 = .226$, Adjusted $R^2 = .222$). Dorsal fin damage was predicted by higher levels of GR (Beta = .315, p < .001) and WT (Beta = .114, p < .001) and lower levels of DF (Beta = -.178, p = .008) and NM (Beta = -.154, p = .010) (Table 4). Stocking density was not a significant predictor in this model (p = .469). Grading frequency received the strongest weight in the model. For every additional point on the GR measure, we would predict an increment of .039 points (3.90 %) on the dorsal fin damage measure (B = .039). On the other hand, for every additional point on the NM measure, we would predict a decrement of .108 points (10.80 %) on the dorsal fin damage measure (B = -.108) (Table 4).

Table 4. Standard regression of the dorsal fin and the predictors

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
	Model	B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	2.461	.358		6.873	.000			
	WT	.026	.007	.114	3.623	.000	.072	.124	.012
	SD	-.004	.005	-.037	-.724	.469	.147	-.025	.000
	DF	-.083	.031	-.178	-2.650	.008	-.348	-.091	.006
	NM	-.108	.042	-.154	-2.580	.010	-.302	-.089	.006
	GR	.039	.005	.315	8.672	.000	.365	.288	.069

Note: R^2=.226. Adjusted R2 = .222. Sr^2 is the squared semi-partial correlation

Table 5. Standard regression of the caudal fin and the predictors

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations		
		B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	2.234	.229		9.744	.000			
	WT	.002	.005	.012	.417	.677	-.026	.014	.000
	SD	-.003	.003	-.046	-.963	.336	.320	-.033	.000
	DF	-.103	.020	-.330	-5.165	.000	-.518	-.176	.022
	NM	-.104	.027	-.221	-3.883	.000	-.474	-.133	.012
	GR	.013	.003	.150	4.337	.000	.254	.149	.015

Note: R^2 = .299. Adjusted R^2 = .294. Sr^2 is the squared semi-partial correlation

The prediction model for the caudal fin was statistically significant, *F* (5, 834) = 71.023, p < .001, and accounted for approximately 30% of the variance of caudal fin damage (*R*^{2} = .299, Adjusted *R*^{2} = .294). Caudal fin damage was predicted by lower levels of DF (Beta = -.330, p < .001) and NM (Beta = -.221, p < .001) and higher levels of GR (Beta = .150, p < .001) (Table 5). Water temperature (p = .677) and SD (p = .336) were not significant predictors in this model. Daily feed ration received the strongest weight in the model. For every additional point on the DF measure, we would predict a decrement of .103 points (10.30 %) on the caudal fin damage measure (B = -.103). On the other hand, for every additional point on the GR measure, we would predict an increment of .013 points (1.30 %) on the caudal fin damage measure (B = .013) (Table 5).

The prediction model for the anal fin was statistically significant, *F* (5, 834) = 66.287, p < .001, and accounted for approximately 28% of the variance of anal fin damage (*R*^{2} = .284, Adjusted *R*^{2} = .280). Anal fin damage was predicted by lower levels of DF (Beta = -.351, p < .001) and higher levels of GR (Beta = .265, p < .001) (Table 6). Stocking density (p = .812), WT (p = .750) and NM (p = .336) were not significant predictors in this model. Daily feed ration received the strongest weight in the model. For every additional point on the DF measure, we would predict a decrement of .122 points (12.20 %) on the anal fin damage measure (B = -.122). On the other hand, for every additional point on the GR measure, we would predict an increment of .025 points (2.50 %) on the anal fin damage measure (B = .025) (Table 6).

The prediction model for the left pelvic fin was statistically significant, *F* (5, 834) = 32.254, p < .001, and accounted for approximately 16% of the variance of left pelvic fin damage (*R*^{2} = .162, Adjusted *R*^{2} = .157). Left pelvic fin damage was predicted by lower levels of NM (Beta = -.298, p < .001) and higher levels of WT (Beta = .114, p = .001) and GR (Beta = .106, p = .005) (Table 7). Daily feed ration (p = .583) and SD (p = .375) were not significant predictors in this model. Number of meals received the strongest weight in the model. For every additional point on the NM measure, we would predict a decrement of .164 points (16.40 %) on the left pelvic fin damage measure (B = -.164). On the other hand, for every additional point on the WT measure, we would predict an increment of .020 points (2.00 %) on the left pelvic fin damage measure (B = .020) (Table 7).

Table 6. Standard regression of the anal fin and the predictors

	Model	Unstandardized Coefficients		Standardized Coefficients			Correlations		
		B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	1.897	.259		7.321	.000			
	WT	-.002	.005	-.010	-.319	.750	-.069	-.011	.000
	SD	.001	.004	.012	.238	.812	.258	.008	.000
	DF	-.122	.023	-.351	-5.431	.000	-.472	-.185	.025
	NM	-.029	.030	-.055	-.963	.336	-.373	-.033	.000
	GR	.025	.003	.265	7.593	.000	.356	.254	.049

Note: R^2=.284. Adjusted R^2=.280. Sr^2 is the squared semi-partial correlation

Table 7. Standard regression of the left pelvic fin and the predictors

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
	Model	B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	2.003	.293		6.836	.000			
	WT	.020	.006	.114	3.482	.001	.110	.120	.012
	SD	.004	.004	.047	.887	.375	.266	.031	.000
	DF	-.014	.025	-.038	-.549	.583	-.335	-.019	.000
	NM	-.164	.034	-.298	-4.796	.000	-.375	-.164	.023
	GR	.010	.004	.106	2.806	.005	.118	.097	.007

Note: $R^2 = .162$. Adjusted $R^2 = .157$. Sr^2 is the squared semi-partial correlation

The prediction model for the right pelvic fin was statistically significant, *F* (5, 834) = 27.820, p < .001, and accounted for approximately 16% of the variance of right pelvic fin damage ($R^2 = .143$, Adjusted $R^2 = .138$). Right pelvic fin damage was predicted by lower levels of NM (Beta = -.281, p < .001) and higher levels of WT (Beta = .100, p = .003) (Table 8). Stocking density (p = .526), DF (p = .431) and GR (p = .081) were not significant predictors in this model. Number of meals received the strongest weight in the model. For every additional point on the NM measure, we would predict a decrement of .159 points (15.90 %) on the right pelvic fin damage measure (B = -.159). On the other hand, for every additional point on the WT measure, we would predict an increment of .018 points (1.80 %) on the right pelvic fin damage measure (B = .018) (Table 8).

Table 8. Standard regression of the right pelvic fin and the predictors

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
	Model	B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	2.186	.306		7.141	.000			
	WT	.018	.006	.100	3.019	.003	.097	.104	.009
	SD	.003	.004	.034	.635	.526	.259	.022	.000
	DF	-.021	.027	-.056	-.788	.431	-.320	-.027	.000
	NM	-.159	.036	-.281	-4.465	.000	-.359	-.153	.020
	GR	.007	.004	.067	1.749	.081	.085	.060	.003

Note: $R^2 = .143$. Adjusted $R^2 = .138$. Sr^2 is the squared semi-partial correlation

The prediction model for the left pectoral fin was statistically significant, *F* (5, 834) = 48.912, p < .001, and accounted for approximately 22% of the variance of left pectoral fin damage ($R^2 = .227$, Adjusted $R^2 = .222$). Left pectoral fin damage was predicted by lower levels of DF (Beta = -.489, p < .001) and higher levels of WT (Beta = .125, p < .001) (Table 9). Number of meals (p = .754), SD (p = .099) and GR (p = .066) were not significant predictors in this model. Daily feed

Table 9. Standard regression of the left pectoral fin and the predictors

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
	Model	B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	3.229	.337		9.586	.000			
	WT	.027	.007	.125	3.993	.000	.072	.137	.014
	SD	-.008	.005	-.083	-1.650	.099	.262	-.057	.002
	DF	-.213	.029	-.489	-7.282	.000	-.449	-.245	.049
	NM	-.012	.039	-.019	-.314	.754	-.376	-.011	.000
	GR	.008	.004	.067	1.843	.066	.192	.064	.003

Note: R^2=.227. Adjusted R^2=.222. Sr^2 is the squared semi-partial correlation ration received the strongest weight in the model. For every additional point on the DF measure, we would predict a decrement of .213 points (21.30 %) on the left pectoral fin damage measure (B = -.213). On the other hand, for every additional point on the WT measure, we would predict an increment of .027 points (2.70 %) on the left pectoral fin damage measure (B = .027) (Table 9).

The prediction model for the right pectoral fin was statistically significant, *F* (5, 834) = 52.680, p < .001, and accounted for approximately 24% of the variance of right pectoral fin damage (R^2 = .240, Adjusted R^2 = .235). Right pectoral fin damage was predicted by lower levels of DF (Beta = -.517, p < .001) and higher levels of WT (Beta = .134, p < .001) (Table 10). Number of meals (p = .961), SD (p = .101) and GR (p = .096) were not significant predictors in this model. Daily feed ration received the strongest weight in the model. For every additional point on the DF measure, we would predict a decrement of .221 points (22.10 %) on the right pectoral fin damage measure (B = -.221). On the other hand, for every additional point on the WT measure, we would predict an increment of .028 points (2.80 %) on the right pectoral fin damage measure (B = .028) (Table 10).

Table 10. Standard regression of the right pectoral fin and the predictors

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
	Model	B	Std. Error	Beta	t	Sig.	Pearson	Partial	Sr^2
1	(Constant)	3.220	.326		9.870	.000			
	WT	.028	.006	.134	4.304	.000	.078	.147	.016
	SD	-.008	.005	-.082	-1.641	.101	.273	-.057	.002
	DF	-.221	.028	-.517	-7.776	.000	-.463	-.260	.055
	NM	-.002	.038	-.003	-.049	.961	-.385	-.002	.000
	GR	.007	.004	.060	1.666	.096	.190	.058	.002

Note: R^2 = .240. Adjusted R^2 = .235. Sr^2 is the squared semi-partial correlation

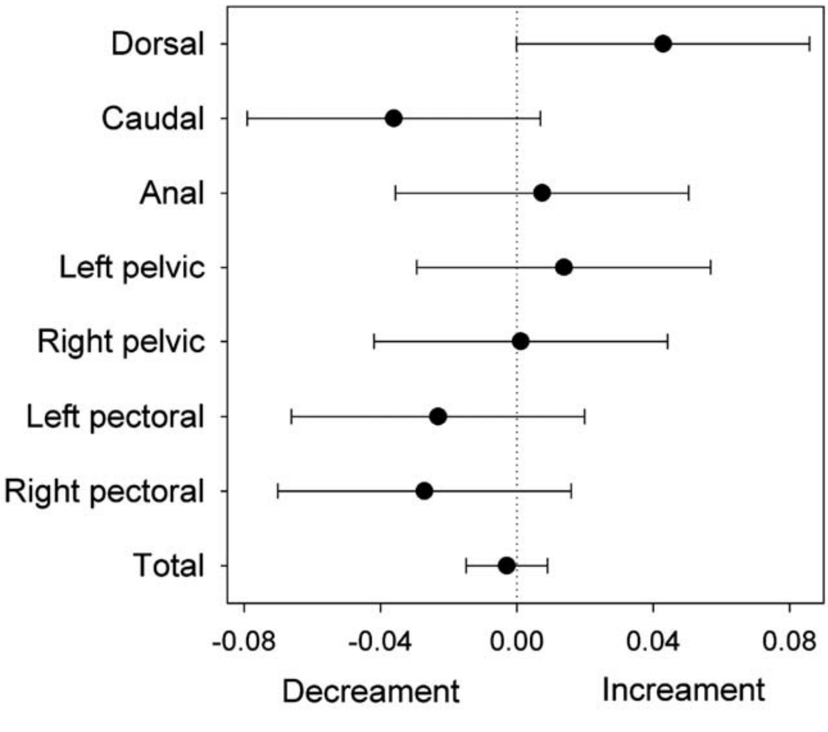

Figure 1a. Meta-analysis of the damaged fins. The dots in the figure show the mean effect sizes and the horizontal bars the range of 95% confidence interval. Thus, if the bar crosses the vertical dotted line (effect size=0) the mean is not significantly different from zero

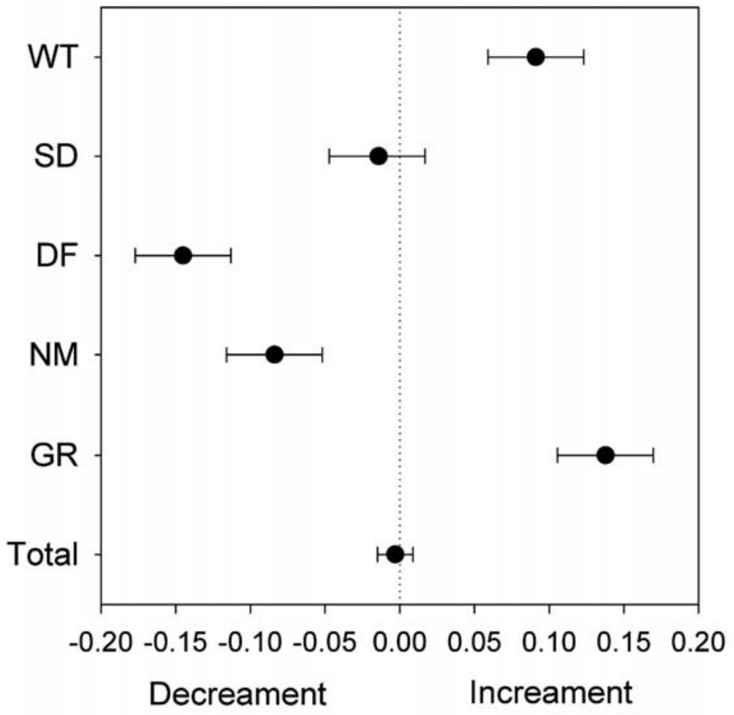

Figure 1b. Meta-analysis of the predictor variables. The dots in the figure show the mean effect sizes and the horizontal bars the range of 95% confidence interval. Thus, if the bar crosses the vertical dotted line (effect size=0) the mean is not significantly different from zero

The unique variance explained by each of the predictors indexed by the squared semi-partial correlations (Table 4 - Table 10) was low for every fin (GR accounts uniquely for about 7% of the variance of dorsal fin damage; DF accounts uniquely for about 2% of the variance of caudal fin damage; GR accounts uniquely for about 5% of the variance of anal fin damage; NM accounts uniquely for about 2% of the variance of the left and the right pelvic fin damage and DF accounts uniquely for about 5% of the variance of the left and the right pectoral fin damage, given the other variables in the model).

The meta-analysis based on the data in Table 2 revealed that there were no differences in fin damage among fins. Within the range of the variables studied, only the dorsal fin showed significant increment (Fig 1a). Increased DF and NM resulted in a decrement of fin damage. Decreased WT and fewer grading occasion also resulted in a decrement of fin damage (Fig 1b). Stocking density had no effect on the degree of fin damage.

DISCUSSION

This study shows that the feeding practices (DF and NM) have the most significant effect on the level of fin damage in different commercial rainbow trout farms. If the effects on all fins were combined, DF tended to be more important than NM (Fig. 1b), but the variables had different effects on different fins. Daily feed ration received the strongest weight in the model for the caudal, anal and both pectoral fins, whereas NM received the strongest weight in the model for both pelvic fins. Dorsal, caudal, anal, left pectoral and right pectoral fin damage were predicted by lower levels of DF. Lower levels of NM predicted the damage of the pelvic fins, and, the same as DF, predicted the damage of the dorsal and the caudal fin.

Fish aggregate in small area during feeding and this is the time when the incidence of fin damage is highest (3, 6, 15). Our findings agree with previous research that lower feed rations increase erosion of the dorsal and caudal fins of rainbow and brown trout (16, 17) and that feed restriction causes fin damage (erosion) in small steelhead trout and Atlantic salmon (15, 18). The lower feeding ration strengthens the social hierarchy among the fish and worsens the fin condition. When feeding rainbow trout to satiety from self-feeders, reducing the daily number of meals from 3 to 1 significantly reduces the recovery from historical dorsal fin erosion (19). However, when rainbow trout receive a fixed satiation ration, increasing the daily number of meals from 1 to 3 increases the damage of the left pectoral fin (7). Fish should have the opportunity to feed without undue competition (5) and the contemporary feeding strategies promote self-feeding or on-demand feeding regimes than fixed feeding regimes (19, 20, 21, 22, 23, 24). These regimes provide feed access during longer period of time and result with lower presence of damaged fins thus improving the welfare of the fish. In the feeding strategy design, it must be taken into account that the feeding regime affects the welfare of fish by increasing the risk of aggression that results with fin damage (25).

Although extensively referred to, it cannot be assumed that the level of fin damage is proportional to higher rearing densities (3). The regression analysis showed that SD was not a significant predictor in every examined fin model (Table 4 - Table 10). Fin damage is historically linked to SD (3) and the main approach was that higher densities will increase the level of fin damage (26-31). In our study, SD was the only factor that did not have an effect on the level of fin damage. This finding conforms to other research that there is no relationship between SD and the level of fin damage (3, 6, 7, 9, 32). The normal recommended SD for rainbow trout is 2 - 80 kg/m^3 (26). According to the welfare standards for farmed rainbow trout (5), the maximum SD for first feeding and on-growing tanks, raceways and ponds must not exceed 60 kg/m^3. Except Farm 4 (Table 1), all surveyed farms practiced lower SD that conforms to the welfare standards (5). Rasmussen et al. (7) found that in rainbow trout reared at high temperatures, the anal fin was in better condition at low densities, but the dorsal fin condition was better in high densities. They concluded that density had only a minor impact on fin condition, and suggest that young rainbow trout can be reared at relatively high densities (up to 120 kg/m^3) without significant impairment of their welfare. On the other hand, Bosakowski and Wagner (33) by using stepwise multiple linear regression suggested that fin erosion was correlated with higher fish densities. The differences between their and our findings may be a result of the different methodological approach and combination of farm variables. Macintyre (34) found that SD was associated with fin damage only on the rainbow trout farms that were breeding fish for restocking purposes, with an increase in SD associated with deteriorating fin condition. This finding did not exist for fish farmed for human consumption. His findings support the hypothesis that the SD effect on fin damage is mediated through behavioral interactions, so, before recommending the SD on a specific site, other factors must be considered, such as water quality and flow, feeding strategies, size of the fish and available space (5, 7).

Water temperature plays a role in the process of fin damage and affects the rate of healing and regeneration, but there is no common trend and the effects differ between species (32, 35). If the effect on all fins were combined, increased WT resulted in higher degrees of fin damage (Fig 1b), *nota bene*: within the temperature ranges included in this study. Higher levels of WT predicted the damage of the dorsal, pelvic and pectoral fins but WT was not a significant predictor in the models for the caudal and the anal fin. Higher WT promotes higher feeding activity and faster metabolism (15), therefore WT is in close relation to other factors such as DF and NM. The welfare standards for rainbow trout recommend WT between 1°C and 16°C, depending on the fish category (5). Except Farms 1 and 3, the other farms had WT in the recommended range. Our findings agree with the research of Winfree et al. (15) that juvenile rainbow trout reared at 10°C have less damaged fins than the same trout category reared at 15°C. In contrast, Atlantic salmon had increased fin erosion as WT decreased (36) and the level of fin damage in Bonneville cutthroat trout (*Oncorhynchus clarki*) was not clearly related to WT (37).

There is little information about the role of handling in fin damage (3). Routine handling affects the level of fin damage as fish come into physical contact with surfaces (nets, grading equipment, vaccination tables) and with other fish during crowding within the rearing units prior to vaccination, grading and processing (3, 30, 38). In our study, GR received the strongest weight in the model only for the dorsal fin, but higher levels of GR predicted the damage of the dorsal, caudal, anal and left pelvic fin. Contrary, GR was not significant predictor in the model for the right pelvic and both pectoral fins. If the effects on all fins were combined, increased GR values returned increased values for fin damage. Grading frequency was the most important variable, although not significantly different from WT (Fig. 1b). To our knowledge, there is no published data that specifically examines the influence of grading on the level of fin damage. According to the welfare standards for rainbow trout (5), grading must be performed when absolutely necessary and all equipment used during handling must be designed to avoid physical damage and stress to the fish. Grading can temporarily increase the aggressive behavior due to the disordered hierarchy (39, 40). However, it reduces the individual differences in the size of fish and positively affects welfare reducing the dominant hierarchical placement and the aggressive behavior (38).

CONCLUSION

In summary, our results support the experimental research on fin damage in rainbow trout and show that the feeding practices (lower levels of DF and NM) combined with the higher WT have the most dominant and proportional effect on the level of fin damage. The results also show that the standard multiple regression analysis predicts the level of fin damage inline as previously published experiments. This leads to the conclusion that the research model and the statistical analysis used in this study could be used on rainbow trout farms to evaluate the effect of the main factors on the level of fin damage, resulting with contribution to the assessment of fish welfare. Nevertheless, this study only explained less than 30% of the variance in fin damage, which suggests that further research has to statistically identify the effects of other factors (e.g. pH, alkalinity, ammonium concentration, water current, light regime, rearing unit surface, absence/presence of tank cover, etc.) on fin damage. This will lead to development of a management plan and modification of the husbandry practices that will result with low level of fin damage (according to the welfare standards for rainbow trout (5), the acceptable level is minimal damage i.e. score 1) and improved fish welfare.

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