NTNU – Trondheim
Norwegian University of
Science and Technology

Prevalence of fin erosion, shortened operculum and lesions in farmed Atlantic Salmon (Salmo salar)

Bruna Iannone Skipnes

Marine Coastal Development
Submission date: September 2014
Supervisor: Elin Kjørsvik, IBI

Norwegian University of Science and Technology
Department of Biology

NTNU – Trondheim
Norwegian University of
Science and Technology

“Prevalence of fin erosion, shortened operculum and lesions in farmed Atlantic Salmon (*Salmo salar*)”

(<u>Master thesis in Marine Coastal Development</u>)

Name of Msc. Student: BRUNA IANNONE SKIPNES
Supervisor: Professor Elin Kjørsvik
Department of Biology

Trondheim
September 2014

Acknowledgements

First I'd like to thank God, for keeping me focused and strong; even when times were though my faith kept me going.

My special family for their unconditional love and support and their belief in me.

A special thank you to Elin Kjørsvik, my supervisor, for her time, support and motivation through the course. Also Lisbeth Aune, head of the Biology department at NTNU, for her understanding, help and patience!

To all my friends and those who believed in me and cheered with me, and helped me somehow.

To Rolf Sivertsgård, from Salmar, and all his staff, for the opportunity to write my project with them.

At last but not least, a big thank you for all the staff at NTNU, for their comprehension, patience and help! And all my colleagues from the same course, wonderful people from all over the world, who marked my heart in a way I won't forget.

I'm very happy that I'm finally able to present my thesis. I'm very proud of myself for making it, throughout all adversities, and immensely thankful for all the angels that have crossed my path during this time.

THANK YOU!

Abstract

Welfare of farmed fish is an increase concern. In this study we focus on the 3 major disturbance factors for reared salmon: fin erosion, opercular deformities and body lesions.During 12 weeks, 8 groups of fish were formed according to their size, and once a week analyzed and recorded in a scale from 0-3 according to the severity of their disease. Larger fish had the more number of cases of fin erosion and the highest degree of severity, but little incidence and low severity of opercular deformities. Body lesions were highest in the smallest group.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

1.1 Atlantic salmon brief-overview

The culture of Atlantic salmon (*Salmo salar*) is a successful intensive aquaculture industry. Its great farming potential has to do with the fact that it is quite easy to handle , resistant to many adverse conditions (surviving well to farming conditions) and of course, has a very high market price and wide acceptation worldwide (Knapp, G. *et al*., 2007).

Its native habitat is the North Atlantic Ocean, present in North America in a range from Ungava Bay in Northern Quebec south to the Housatonic River in Connecticut. In Europe, the species' native range extends from the Pechora River in Siberia (Russia), west across Norway and down the coast to northern Portugal. Other European sights are the Baltic Sea, the British Isles and Iceland (MacCrimmon & Gots, 1979).

Norway has, since 1984, become the world's most important salmon producer (with 600,000 mt fish in 2004), with an annual average growth rate of 17 percent between 1984 and 2004 (FAO, 2006). This probably due to the geography of the country, surrounded by fjords and islands along the coast what offers excellent hydrographical conditions for the rearing of Atlantic salmon as well as the continuous investments from the government, by contributing to the development of infrastructure along the coast (Forster, 2002). In 2006, the value of the Norwegian aquaculture industry surpassed that of traditional fisheries, with a constant increase since the 1980s (Ministry of Fisheries and Coastal Affairs, 2010). In 2012, Norwegian salmon production was about 1 200,000 tons (Directorate of Fisheries, 2013). The total export of Norwegian salmon in 2013 was close to 40 billion Norwegian kroner.

Although salmon farming has proven to be successful, there are still many challenges that need to be evaluated, especially those concerning the welfare of the animals. The welfare of farmed fish as well as an increased concern about the impacts fish farming may have in the environment have been so much of an issue for recent fish costumers that a substantial 15% increase of market price would be rather desirable if followed by an increase of welfare rate of the animals and followed by less environmental damage (Altintzoglou et. al., 2010).

In this study, we focused on 3 major disturbance factors for reared salmon, since they are all quite common in salmon farms and at the same time they represent economic losses for the industry due to the increased mortality of the fish and a lower growth rate. Besides, sick or stressed fish have a low welfare rate, which has to be corrected. These conditions are: fin erosion, *operculum* deformities and body lesions.

1.2 The problem of fin erosion

Fin erosion or damage is considered to be one important measurement of welfare of the animals (Noble et. al., 2007) and is a common and serious situation that occurs mostly in intensively reared fish (Larmoyeux & Piper, 1971), although it can also be found in wild fish (Kahn et al., 1981).The fact that the occurrence of fin erosion is higher in farmed fish than in nature can probably be due to factors related to density, feeding regime and environmental conditions (Mork et al., 1989).

Fin erosion can mostly be seen in the fish dorsal fin, clinically described as a degraded, damaged fin, usually shortened in size, due to friction in the tank, pathogenic infection or aggressive attack (nipping) from other fish (Figure 1). When there is bacterial infection involved, the erosion can lead to necrosis of the fin and even worse, to fin rot (Bodammer, 2000). Fin rot disease may be characterized by grayish white spots on the fins, body and skin erosion and it is associated with high mortality of the infected animals (Rahman et al., 2010*). Khan et al. (1981)* associated the presence of fin rot with a high mortality rate of 52% of the sick animals, within an 8-year period. In the beginning, the symptoms were thin and discolored (whitish) fin extremities only; with the development of the disease petechiae (hemorrhage) was found in the fin and they later turned to ulcerative lesions.

Figure 1: *Salmo salar with fin erosion*.

Usually «mild» forms of damage (small area affected) may not be potentially harmful at first, but when fish are crowded or stressed, and if water quality deteriorates, the condition rapidly increases in severity and causes serious damage to the affected animals. Typically, seriously injured fish do not feed well and become weak and prone to secondary infections (such as furunculosis, caused by *Aeromonas salmonicida*) and attack from other fish, as described by Turnbull et. al. (1996). A change in the swimming pattern can also be noticed at this stage, which can reduce significantly their chances in the wild, making them susceptible to starvation, predator attacks and secondary infections (Barker, et. al., 1994).

Fin erosion has the following possible causes, appearing alone or in combination with one or more factors: 1. Behavioral; 2. Microbiological; 3. Environmental and 4. Nutrition-related causes (Latremouille, 2003).

The behavior of farmed salmon is one important key to understand and possibly reduce fin erosion incidence. High densities in cages/tanks tend to stress animals by elevating their plasma cortisol levels (Pickering & Pottinger, 1989), leading to aggression. Aggression is, in fact, quite common between Atlantic salmon parr both in the wild and especially in farmed conditions (Keenleyside & Yamamoto, 1962), being intensified by environmental disturbances such as lack of food, which leads to competition (Kadri et al., 1997). The dorsal fin seems to be the favorite spot in salmonids attacks (Abbott & Dill, 1985), being less frequent in dominant, sexually matured males, than in immature ones (Mork et al., 1989).

Better feeding systems, where the animals are fed to satiation by regulating the ideal feeding interval and proper meal size can reduce significantly competition (Noble et. al., 2007).

A slight change in the environmental condition the animals are reared and used to, such as a better water flow, that makes the animals swim harder than before, can be used as a way to reduce fin erosion by those aggressive encounters, simply because the animals now are forced to use their energy on something else (Christiansen & Jobling, 1989).

The tank surfaces too can have a negative effect on fin erosion. Abrasive surfaces like concrete can not only contribute to the appearance of fin erosion but of body lesions as well, the same applies to small pounds/tanks compared to bigger and wider ones (Larmoyeux & Piper, 1971).

Colder temperatures seem also to play a negative role in the severity and extension of fin erosion in salmonids (Schneider & Nicholson, 1980), in contrary to other species like the steelhead fish, which seemed to benefit from warmer temperatures (Winfree et al., 1998). The incidence of fin erosion in *Salmo salar* was (recorded to be) higher in the winter than in other seasons, according to Vehanen et. al., (1993). Low oxygen levels in the tanks have been associated with higher occurrence of fin erosion, compared to high oxygen levels (Larmoyeux & Piper, 1973).

Bacterial/ microbiological infection is related to a possible cause of fin erosion, being *Aeromonas salmonicida* and *Aeromonas liquefaciens* two of the most significant ones (Loganathan et al., 1989; Chowdhury, 1998), although those from *Pseudomonas* and *Vibrio* genera are also known agents of fin erosion and rot (Giles et al., 1978; Loganathan et al., 1989). The most susceptible group to bacterial infection seems to be salmon fingerlings and smolts who are over 2 years-old (Schneider & Nicholson, 1980). *Aeromonas salmonicida* was also the causer of haemorrhage on Atlantic salmon fry, particularly on fins and tail rot, but also visible on the opercula region and eyes (Godoy et al., 2010).

A balanced, well-formulated feed can avoid fin erosion or eventually stop its further development. A well-formulated feed in this case should contain required levels of vitamin C, since the vitamin is not only associated with lower fin erosion incidence but also helps promoting good growth rates and a stronger immune system (Mazik et al., 1987). Feed enriched with amino-acids such as lysine, arginine, histidine, isoleucine, threonine, valine and tryptophan showed good result in preventing and healing fin erosion in rainbow trout, also promoting good weight gain rates (Ketola, 1983).

Adding chitin to the diet of a group of steelhead trout (*Oncorhynchus mykiss)* lead to significantly less cases of fin erosion, supposedly because of its protective capacity against pathogenic microorganisms (Lelis & Barrows, 2000).

Water quality has a great influence of fin erosion also in the wild, with a higher prevalence in fish living in a degraded, modified habitat. By this we understand as an environment with wide temperature oscillation, unstable salinity, reduced dissolved oxygen levels and prone to mechanical injuries and bacterial/parasitic attacks (Barker et. al., 1994). The presence of oil (due to contamination/pollution) in the water can contribute to a disbalance in the normal exterior microflora, making the fish more prone to infection. *Vibrio* bacteria, for example, are resistant enough to survive in oil-filled waters (Giles et al., 1978).

Water with high concentrations of heavy metals such as zinc, lead and cadmium were associated with fin erosion in mullet (Bangaramma & Lakshmi, 1999).

The effects of pollution in a group of fishes in the wild showed not only a greater rate of fin erosion, when compared to those from an unpolluted environment, but with a higher severity of the disease (Reash & Berra, 1989).

1.3 Opercular deformities

In addition to fin erosion, problems related with the *operculum* (opercular membranes), such as its shortening and exposure of the gill tissue (Figure 2) are also a well-known phenomenon in hatchery reared fish. Opercular deformities are malformations that develop during the larval stage and affect fish growth rate and *opercula* morphology, with a significant economic loss as a consequence. (Galeotti et al., 2000).

Little has been known about its causes and consequences to the affected fish, although deformity mechanisms seem to be linked to the disruption of early development processes and they disturb the normal ion uptake balance in fresh water fish (McCormick, 1994) and its overall biological performance through diminished growth rates and survival (Andrades et. al., 1996).

Skeletal deformities in fish can usually have a genetic, infectious, environmental or nutritional cause, such as: lack of vitamin C and high levels of vitamin A, exposure to heavy metals, organophosphate and organochlorine chemicals, strong water current in very early developmental stages, inbreeding, traumatic injury and bacterial or viral infection (Yadegari et al., 2011).

Figure 2: *Fish with opercular deformity (shortening).*

1.4 Body lesions

Sores or physical injuries (lesions) can also be considered of great importance among farmed salmonids. Affected fish are associated with economic losses for the industry, since it loses much of its “quality”, by using extra energy to survive instead of growing. Besides, the visual aspect of a sick fish is also repulsive for the consumer. (Salte, R. *et. al.*, 1994).

Lesions seem to have both mechanical (excessive or wrong handling of the fish) and biological causes. Handling and grading impair the mucus and skin, if not done correctly and gently, making the skin prone to ulcers (Tørud & Håstein, 2008).

Infections with *Flavobacterium columnare* strains have been directly associated to body lesions and fin erosion in carps (*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and *Labeo calbasu* species), also leading to mortality of the enferm fish in 100% of the cases (Rahman et al., 2010). *Pseudomonas sp.* is also observed as a causing agent of petechial hemorrhages of the skin that can lead if untreated, to bigger lesions (Wiklund & Bylund, 1993). Winter ulcer disease is quite common in Atlantic salmon and it is caused by *Moritella viscosa*, during the winter months and has a mortality of up to 40% of the affected fish (Tørud & Håstein, 2008).

Sea lice (*Lepeophteirus salmonis, Caligus elongatus)* are also associated with body lesions in Atlantic salmon. Ectoparasites infestation irritates the skin, making it itchy, irritated and prone to ulcer formation (Roberts, 2001).

In all causes, lesions seem to usually start as small, round, epidermal lesions, with a red center surrounded by a white rim, that will most likely increase in size and depth and merge as the disease progresses (Figure 3). In septicemic disease caused by *Aeromonas salmonicida*, there is splenomegaly, ascites, and swelling of the kidneys. Histologically, there is necrosis of the affected tissue with abundant colonies of bacteria and few inflammatory cells due to the bacteria's leukocytolytic exotoxin (Noga, 2010).

Figure 3: *Fish with serious case of lesion.*

1.5 Possible causes and treatments for fin erosion, opercular deformities and body lesions

Many hypothesis have suggested that both fin erosion and body lesions can have a common cause: general water quality, superpopulation in the tanks, feed type and feeding regime, excessive exposure to sunlight, abrasive tanks surface, aggressive attacks between one another and handling (manipulating) techniques towards these animals (Pelis & McCormick, 2003). Bacterial and fungal infection can also be involved in those processes. As mentioned before, operculum deformities seem to have genetic causes in addition and is related mostly to problems occurred in early larval stages.

As for treatment, formalin (formaldehyde, CH2O) is usually the chosen medication for the cure of fin erosion and body sore conditions. Fish with opercular deformities have as well been treated with formalin, since they are prone to secondary bacterial and fungal infection. Formalin is an effective middle against pathogenic microorganisms and ectoparasites. It is proven to stop the progression of fin erosion, but with toxic effect to the treated fish (McVicar & White, 1982).

As disadvantages of its use, we can mention the high costs, toxicity (carcinogen effects) and the fact that relatively large volumes are needed to treat effectively even a small tank. Dosage for short-term baths consists on a concentration of 250mg/l, for a period of 30-60 minutes. For a prolonged (indefinite) bath a concentration of 15-25 mg/l is recommended (Francis-Floyd, 1996).

As for the toxic effects, besides a visible change in the swimming pattern (slower and uncoordinated movements) of the treated fish, due to the formalin ability to decrease dissolved oxygen (fish then hyperventilate), hyperplasia of secondary gill lamellae and fatty degeneration in the liver of some species have been observed (Chinabut *et. al.*, 1988).

Besides formalin baths, malachite green and nitrofurazone were found to be effective against fin erosion (Devesa et al., 1989). The use of malachite green has been prohibited in fish farming in the United States and the European Union (EU) due to its toxicological and potentially carcinogenic nature (Culp & Beland, 1996; Srivastava et al., 2004).

Antibiotics seem to have a positive effect against fin erosion as well as fin rot (when there is presence of pathogenic microorganisms in addition). The administration of oxytetracicline in combination to benzalkonium chloride was capable to eliminate fin rot in a variety of tropical fish (Conroy, 1963; McVicar et al., 1993), while low doses of chloramine-T seem to act as a good prophalytic method prior to fin erosion (Powell et. al., 1994).

1.6 Aim of the study

The aim of the present study is to study the occurrence of fin erosion, opercular deformities and body lesions in a smolt production cycle of Atlantic salmon (Salmo salar), in relation to environmental parameters and features.

2. MATERIAL AND METHODS

2.1 Sampling

The study was conducted at the "Salmar Settefiskanlegg" located in Kjørsvikbugen, Aure "kommune", Norway, during the period between June and October 2011.

All the fish used in the study come from "Aquagen" and were brought to Salmar as eggs and hatched between November 2010 and January 2011. By the beginning of the study, the minimum and maximum weight of the studied fish was 2g and 55 g, respectively.

Fish was placed in 8 different tanks with varying diameter (from 6 - 11 meters each and density of 120.000-200.000 fish each). Weight was the initial criteria used for separating the fish into the original tanks and they were selected into 4 different groups:

- "Mini" (average start weight of 18 g);
- "Small" (average weight of 21 g);
- "Medium" (average weight of 23 g) and
- "Large" (average weight of 25 g).

Each category had 2 tanks representing it (Figure 4).

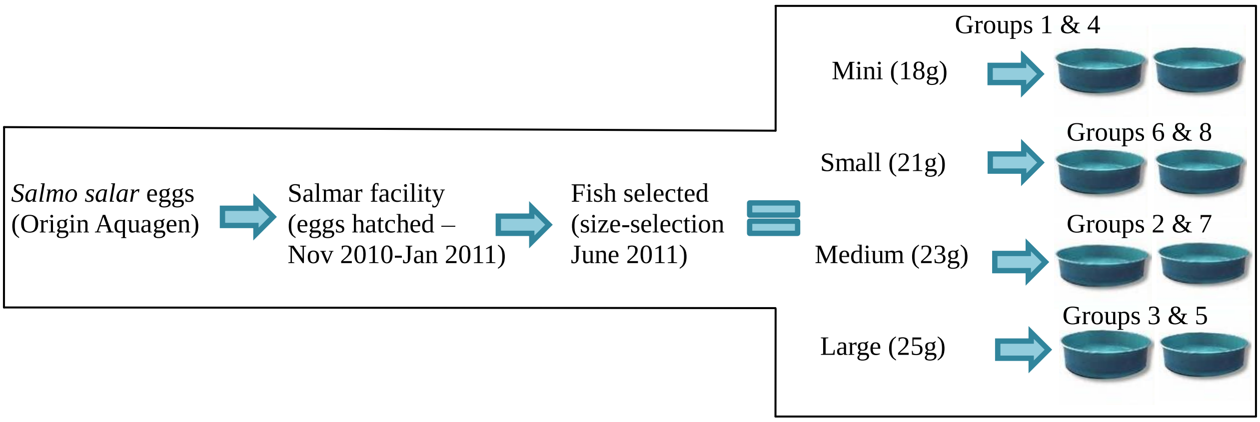

Figure 4. *Figure showing study start and separation criteria.*

Once a week and during 12 weeks, 60 fishes from each tank (480 fishes total per week) were randomly selected and examined according to their weight, length, possible presence of fin erosion, opercular deformities and body lesions. All information regarding the tanks was also recorded, such as: temperature, pH, O^2 levels, feeding regime (Figure 5).

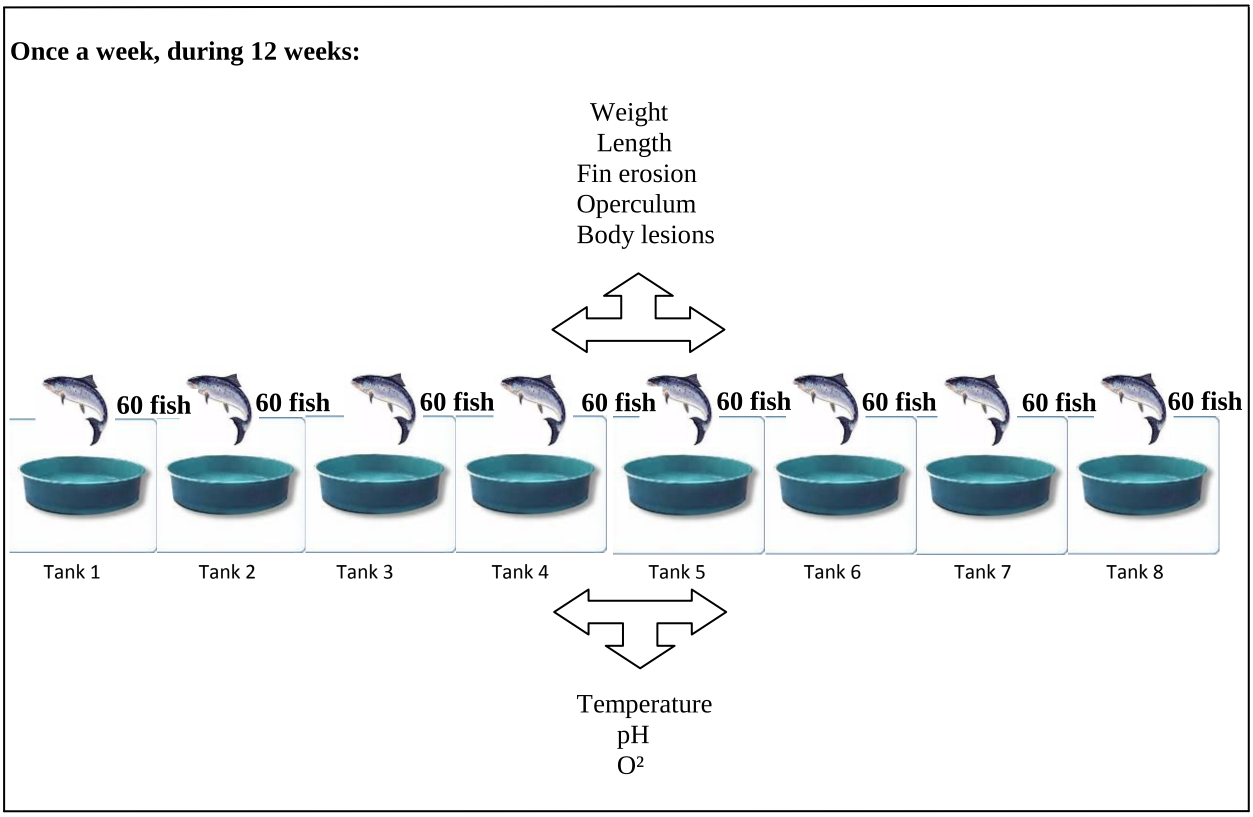

Figure 5. *Representation of parameters measured every week.*

The average temperature, pH and dissolved oxygen in the water of the tanks were measured every day before starting the data collection. Other factors as mortality, general water quality and feeding regime were also followed throughout the study.

The selected fish was subjected to a visual classification (following Salmar's own classification protocol), according to their fin, opercular membranes and body condition and were marked according to the severity of each injury (if present), using an ordinal scale of 0, 1, 2 or 3:

Type of injury			
Severity	**Fin erosion**	***Operculum***	**Body lesions**
0 (none)	No damage	No damage	No lesions
1 (mild)	Mild erosion (1-24% fin tissue damage) or previous damage that has healed over	One-side opercular deformity	Epithelial damage
2 (moderate)	Erosion with possible hemorrhaging (25-49% of fin tissue damaged)	Bilateral opercular deformity/damage	Open wound
3 (severe)	Fin erosion (>50% of tissue damage) with hemorrhaging and pathogenic infection	Severe *operculum* shortening	Spread, open wound

Figure 6: *Classification method for fin, operculum and body damages used at Salmar.*

The method for classification of injuries done according to the standard protocol at Salmar, and this is also similar: Goede & Barton, 1990; Canon Jones et. al., 2010.

Some challenges we experienced during the study was that, since it was a real-time functioning industry and the data collection happened in a busy period, fish from our study were sorted from time to time and put together in tanks according to their average length and weight. Fish considered having serious growth problem or who presented visible genetical problems were discarded along the day.

The study lasted 12 weeks. The first week of the experiment started in a period right after the first sorting/grouping of the fish. The goal was to follow the fish the next twelve weeks inside the establishment, before they were transported out and put in the sea.

2.2 Data collection

Each week, 60 fish were randomly collected with the aid of a fish net and placed in a container filled with an anesthetic benzocaine solution (Benzoak Vet, 200mg/ml – 20%, Europharma) of approximately 1ml/l for about 1 minute or until they were sedated enough to allow handling.

Fish size was then measured as fork length (measured from the tip of the snout to the fork of the tail, given in centimeters), total body weight and visually examined for the possible presence of any of the conditions described: fin erosion, operculum-related problems and sores/lesions (figure 7).

Figure 7: *Capture of fish followed by length and weight measure and visual inspection.*

The length and weight of each individual was taken and reported in centimeters and grams, respectively. Fin erosion, opercular deformities and body lesions were classified according to their severity in a scale from 0 to 3 (Figure 8).

Date	Fish nr.	Tank nr.	Length	Weight	Fin erosion	Operculum	Body lesions
04.07.11	1	1101	14,5	33	0	0	0
04.07.11	2	1101	15,5	41	0	2	0
04.07.11	3	1101	16	48	0	0	3
04.07.11	4	1101	16,5	44	1	0	0

Figure 8: *Example form used for recording information from the fish.*

In the end of the study, the Specific growth rate (SGR) and Condition factor (K) for each group was calculated, according to the following formulas:

SGR= ($\ln W_f$ - $\ln W_i$ x100) / t, where: $\ln W_f$ = the natural logarithm of the final weight, $\ln W_i$ = the natural logarithm of the initial weight and t = time (days) between $\ln W_f$ and $\ln W_i$);

Condition factor (K) =100*W/L³, where W = Weight of fish, L = Length of fish in cm).

2.3 Histopathology

Samples of both healthy fish and fish with fin erosion were taken from the various tanks each week to be used in histology. The fish were anesthetized first with the same anesthetic solution but kept there around 5 minutes or until complete death of the animal. Both the dorsal fin and the pectoral fins of the fish were removed (Figure 9) as well as a sample of the kidney (Figure 10). They were all fixed immediately in a 4 % phosphate buffered formalin solution (pH 7,0, Apotek 1) and stored in cool temperatures until further processing.

Figure 9: *Removal of pectoral fins.*

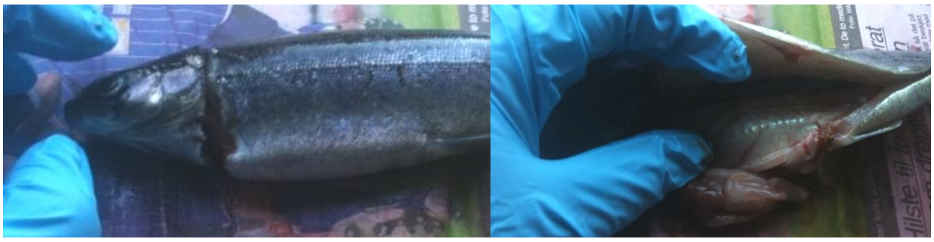

Figure 10: *Sectioning of the head and exposure of the kidney.*

Only samples from fish with fin erosion were considered for histopathology. The samples were collected between 23.08 – 13.09.11. They were sent to the “Veterinærinstituttet” in Trondheim, on 23.02.2012, to be analyzed for possible parasite, fungus or bacterial colonization.

The dorsal fins only were used for histology. A total of 14 samples, collected from all the eight tanks, were sent to the “National Veterinary Institute” (Veterinærinstituttet) in

Trondheim. They were then embedded in wax and sectioned (figure 11).

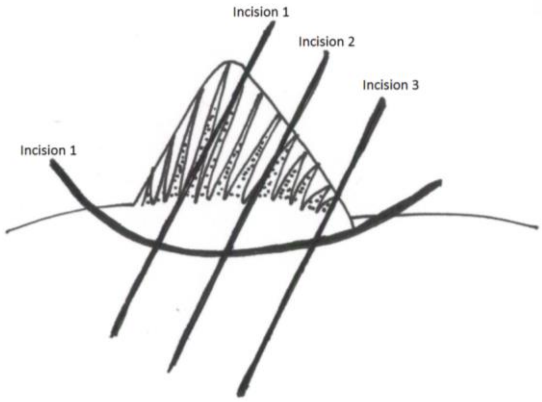

Figure 11: *Incisions' scheme on a dorsal fin ray used for histology.*

2.4 Statistical analysis

The study consisted of 8 groups of fish, with 60 individuals in each group per week, arranged in a randomized complete block design with 12 replications.

The data were analyzed to assess the homogeneity of variance (Bartllet) and normality (Lilliefors) tests for each variable. The response variables of characters 3, 4, 5, 6, 7 and 8 were transformed by $\sqrt{x+1,0}$ in order to meet the assumption of normality of distribution.

Later analysis of variance was performed using the model Yij = m + Gi + Bj + Eij, where m: is the overall average; Gi: corresponds to the effect of the treatment; Bj: corresponds to the block effect; Eij: corresponds to the effect error treatment / block. To understand the behavior of the response variables, we carried out the Tukey Comparison Test at 5% probability. We were then able to pair the groups according to their size and total number and severity of the different conditions. Also, the linear correlations between all variables were calculated by using the Pearson analysis, based on the significance of their coefficients. In the classification of intensity of correlation for $0.05 \leq p \geq 0.01$, this was considered very strong (r ± 0.91 to ± 1.00) , strong (r ± 0.71 to ± 0.90), mean (r ± 0.51 to ± 0.70) and weak (r ± 0.31 to ± 0.50) , according to Guerra & Livera (1999).

Using the period of the study (12 weeks) , and the total observations of injuries in this period , linear regression analyzes for each type of lesion were performed .

All statistical operations were performed using the Genes software (www.ufv.br/dbg/genes/Genes_EUA.htm).

3. RESULTS

3.1 Incidence of conditions according to external factors

Figure number 12 sums up the events, such as sorting, formalin treatment and vaccination that happened in each tank, during the study period.

After the first week, the incidence of fin erosion seems to increase in all groups. Around week 5 and 6 the values continue high for almost all groups when then, after week 9, there is a sudden decrease.

The incidence of shortened operculum has higher incidence in the mini and small groups, while it appears very low or doesn’t appear at all in the larger groups.

Body lesions follow the same pattern: present in the small groups and completely absent from the large group.

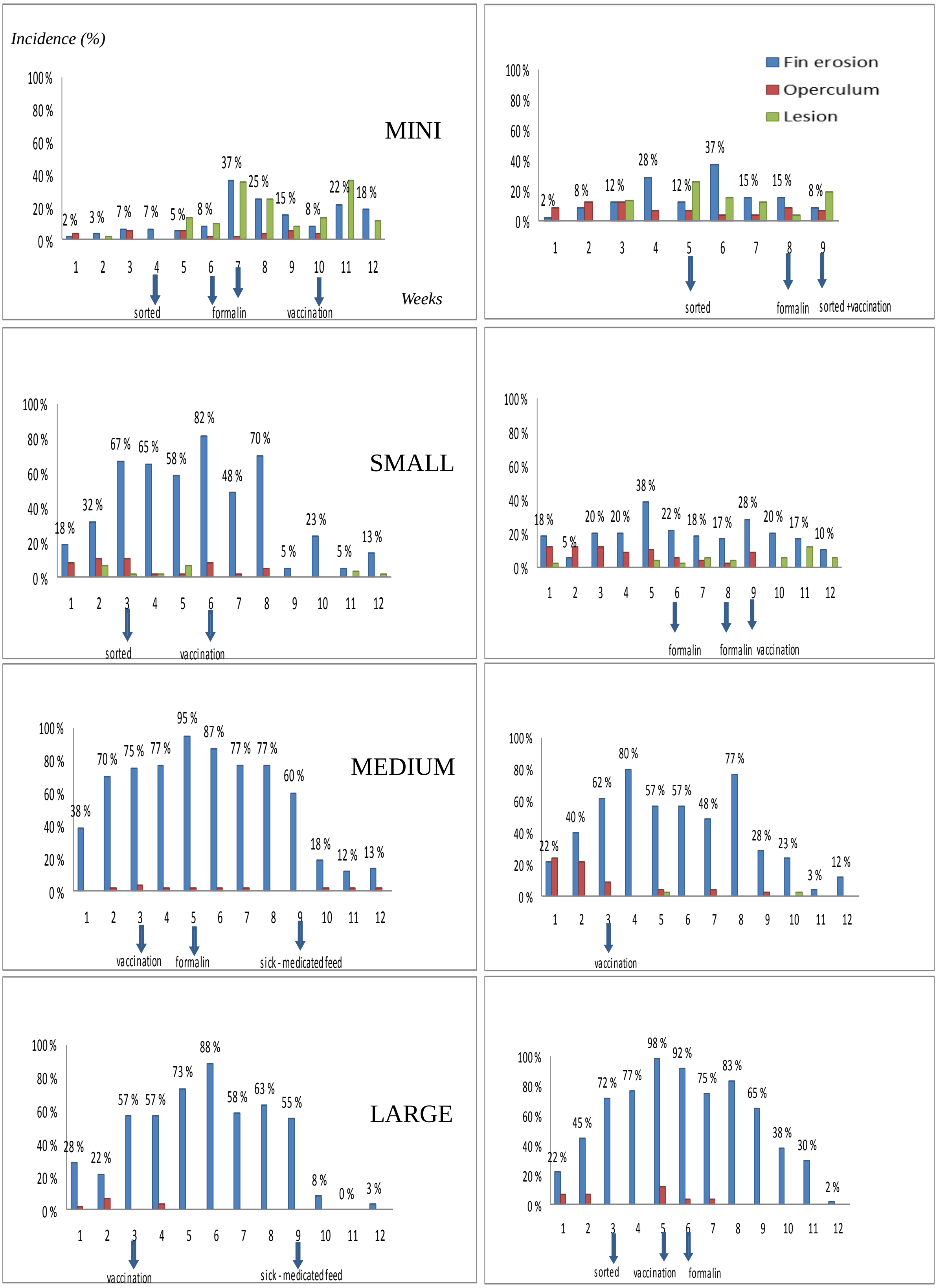

Figure 12: Incidence of the conditions in each group, every week, compared to external events.

3.2 General results

The average temperature for all the tanks in the beginning of the study was 13ºC and in the last week the average was 15ºC. The temperature maintained quite constant almost all the time with little variation.

The feeding regime was also similar for the entire study group. All tanks were fed with fish pellets “Ewos Micro 50”, by use following standard protocol for the farm, with the aid of feeding automats. The biomass in all 8 tanks varied from 1482-5902kg, at the start of the observation period, increasing to a maximum of 12.256kg at the end of the period. Water quality has been relatively good during the whole study period, with pH levels between 6-7 and dissolved oxygen levels around 70-100%.

3.3 Fish size

General

Fish who were in the “mini” and “small” groups (Groups 1,4, 6 & 8, respectively) had higher condition factor when compared to both heavier and longer ones, from groups “medium” and “large” , i.e. 2, 7, 5 & 3, respectively. (Figure 13).

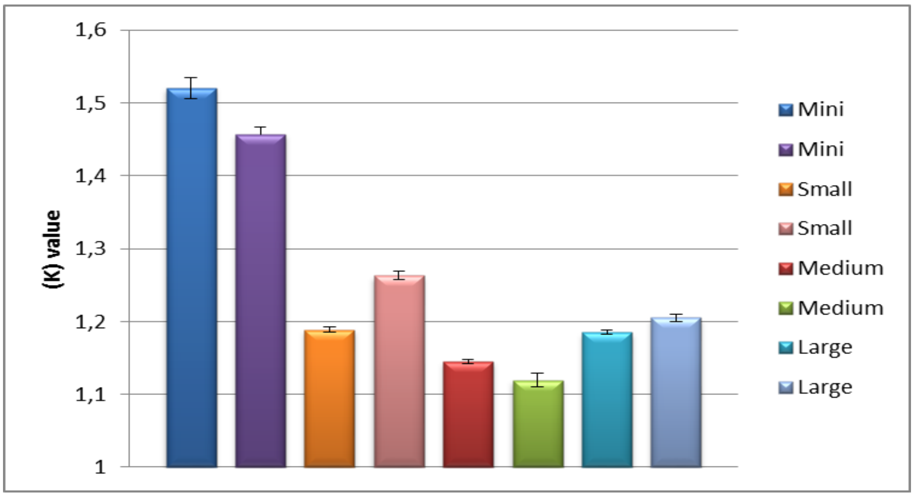

Figure 13: *Condition factor (K) of the fish from the eight groups, divided by weight (average of the groups per week, during 12 weeks).*

The length of the fish belonging to the same size category was very similar during the whole study, with a subtle growth after week 2, remaining almost constant all the period.

As for the weight, it seems to vary in all categories until week 6, when all groups then seem to have a significant weight gain until the end (Figure 14).

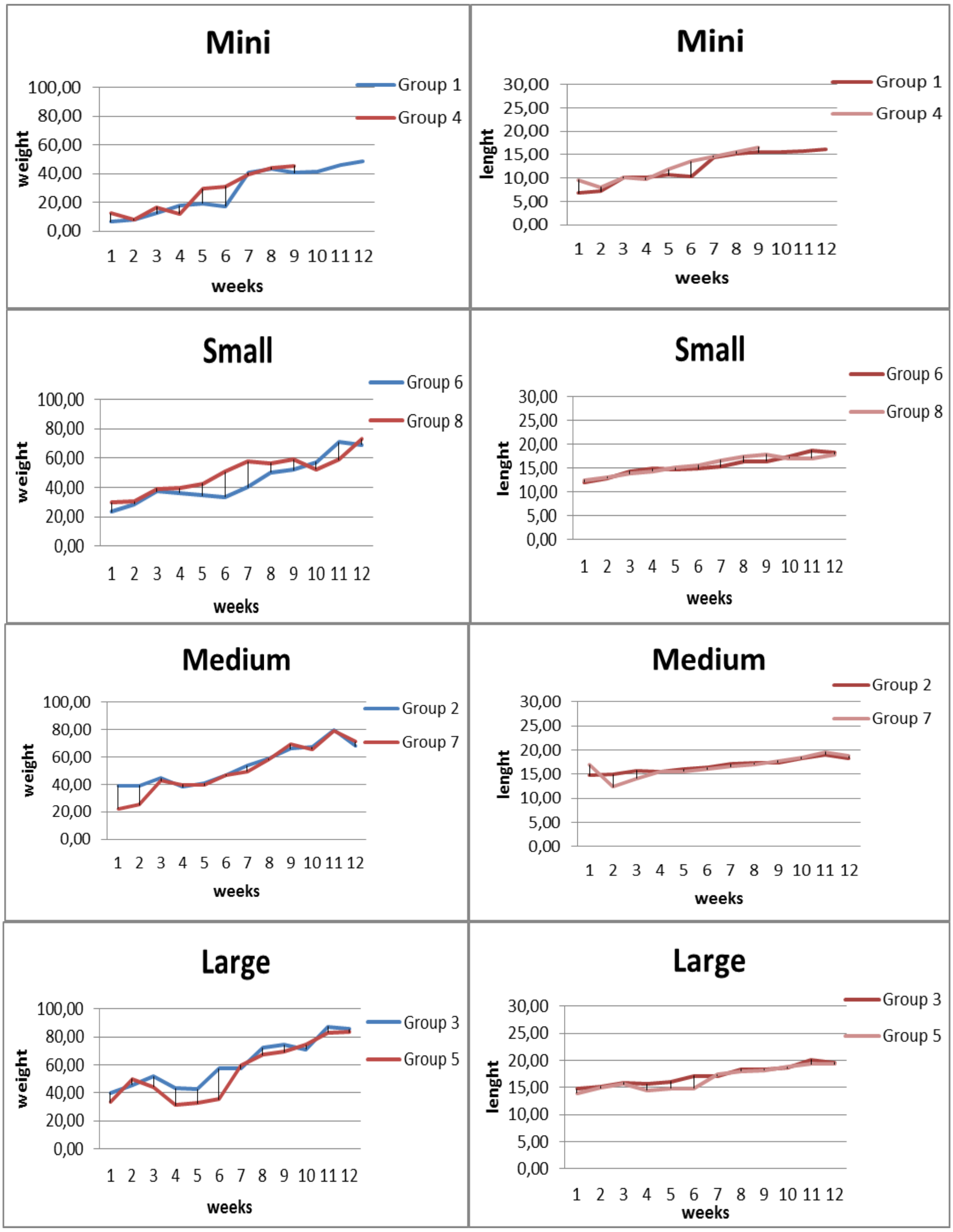

Figure 14: *Average weight and length of all the fish groups, divided by size, during the 12 weeks of study.*

Fish size and condition

Fish size seems also to be correlated with the happening of the three conditions. Table 1 divides the groups according to their size and total number and severity of the different conditions, during the whole 12 week-period. The letter “a” stands for the highest values in each category as “d” means the lowest values or the lower number of cases or severity.

Table 1*: Average Length, Weight, Severity of Fin Erosion, Operculum and Lesions and Total number of cases of Fin Erosion, Operculum and Lesions in 8 groups of fish, during 12 weeks.*

Group	Length (cm) ±1,25		Weight (g) ±46,92		Sev. Fin E.		Sev. Operc.		Sev. Lesions		Total Fin E.		Total Operc.		Total Lesions	
1	12,33	c	28,47	d	0,12	b	0,03	bc	0,16	a	6,88	c	1,25	bc	6,04	a
2	16,71	ab	53,48	ab	0,62	a	0,02	bc	0,00	c	32,15	a	0,78	c	0,00	b
3	17,23	a	60,64	a	0,43	a	0,01	c	0,00	c	21,67	ab	0,44	c	0,00	b
4	12,19	c	26,39	d	0,14	b	0,10	a	0,09	ab	8,44	c	4,34	a	4,83	a
5	16,62	ab	55,36	ab	0,59	a	0,03	bc	0,00	c	31,74	a	1,19	bc	0,00	b
6	15,52	b	44,45	c	0,40	a	0,04	abc	0,02	bc	21,27	ab	1,90	abc	0,88	b
7	16,55	ab	50,71	bc	0,39	a	0,07	abc	0,00	c	22,97	ab	2,04	abc	0,14	b
8	15,73	b	49,17	bc	0,44	a	0,07	ab	0,03	bc	11,20	bc	3,06	ab	1,54	b

* Means followed by the same letter in the column do not differ by Tukey test at 5% significance level.

Fin erosion: Smaller fish (“Mini” groups 1 & 4) had fewer and milder cases of fin erosion compared to the other groups.

Larger fish from groups “ Medium” and “Large” (groups 2 & 5) had the more number of cases of fin erosion and the highest degree of severity (Table 1 & Figure 15).

Opercular deformities: The highest incidence and severity of opercular deformities happened in fish from the “Mini” group 4.

Larger fish had little incidence of opercular deformities, with low severity (Table 1 & Figure 15).

Body lesions: The “Mini” groups (1& 4) had the highest total number and severity of body lesions. All the other groups had no lesions or very few cases with very low severity (Table 1 & Figure 15).

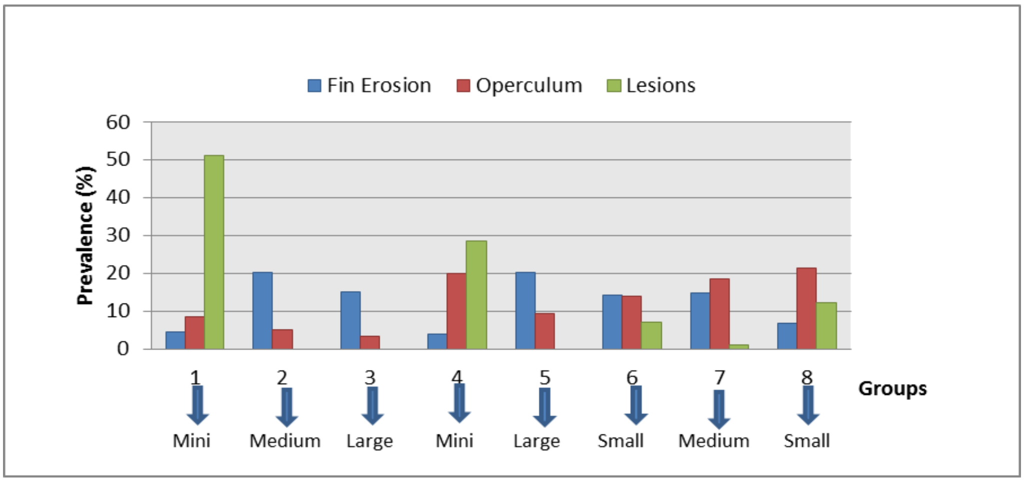

Figure 15*: Prevalence (percentage of fish affected) of the diverse conditions in each group.*

3.4 Correlation among the different variables

Table 2: *Pearson Linear correlation values for the response variables "Length", "Weight", "Fin Erosion", "Operculum" and "Lesions".*

	Length	Weight	Severity Fin Erosion	Severity Operculum	Severity Lesions	Total Fin Erosion	Total Operculum	Total Lesions
Length	1	0,9869**	0,8997**	-0,4553	-0,9313**	0,8469**	-0,5638	-0,9812**
Weight		1	0,8827**	-0,5085	-0,893**	0,8087*	-0,6089	-0,9521**
Severity Fin Erosion			1	-0,4333	-0,8768**	0,8917**	-0,4833	-0,9095**
Severity Operculum				1	0,2143	-0,5103	0,9778**	0,4085
Severity Lesions					1	-0,8616	0,3172	0,9691**
Total Fin Erosion						1	-0,5876	-0,9162**
Total Operculum							1	5184
Total Lesions								1

**** *: Significant at 1 and 5% probability levels by T test**

The positive and significant values in the table mean that there is strong and positive correlation between the two variables, meaning that when one changes the other changes as well. The most important positive and strong correlation we found is:

Total and severity of fin erosion x weight x length:

The prevalence of fin erosion had a strong positive correlation with both length and weight, which means that the larger the weight and the length of the fish, the higher the number and the severity of cases (Figure 16).

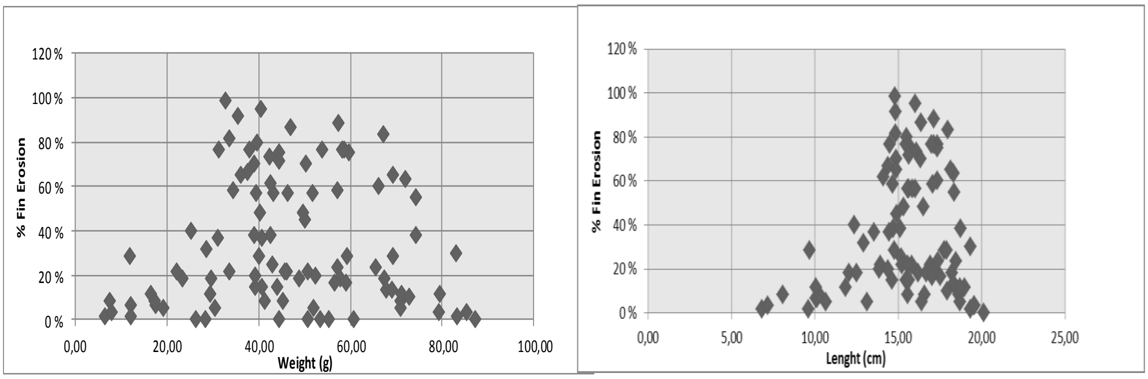

Figure 16 : *Prevalence of fin erosion in all fish groups, according to their weight and length.*

For the negative values, but that are still significant, we have an inverse dependent correlation, which means that the higher one variable value the lower the other one. The most relevant correlation was:

Total and severity of body lesions x weight x length x fin erosion

Body lesions had a negative correlation with weight, length and fin erosion, indicating that the lower the weight, the higher the severity and number of body lesions cases, and seem not be present in fish who had fin erosion, as well (Figure 17).

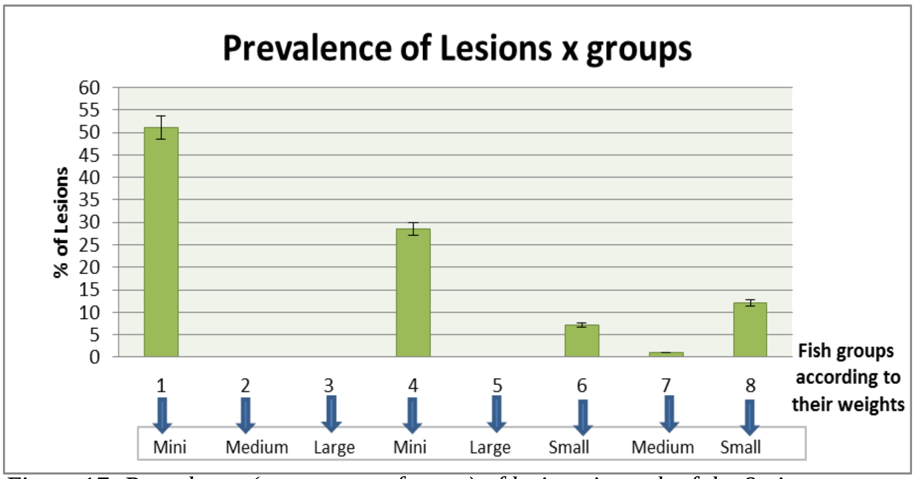

Figure 17: *Prevalence (percentage of cases) of lesions in each of the 8 given groups*

3.5 Histopathology

The tests received at 29.02.2012, from the dorsal fin samples with fin erosion, showed no sign of parasite or fungus infestation in any of the samples. In only one sample, though, was bacterial colonization found. That could be due to the presence of the bacteria in the fish itself or due to contamination during the collecting method. No bacteria type was described.

4. DISCUSSION

4.1 Fin erosion, dominance and fish size

Presence of fin erosion has been used to distinguish farmed salmon from wild salmon. Fin erosion seems to be a quite common trait in farmed salmon, while few fish in the wild present the same condition (Lund et. al, 1989). Fin erosion is involved in aggressive behavior due to food competition in the tanks. Competition for food can also be confirmed by the presence of vigorous and spontaneous swimming, including maneuvers with turning angles and acceleration rates (Krohn & Boisclair, 1994). On-demand feeding seems to reduce the frequency of aggression attacks, in comparison to a routine feeding regime (Almazan-Rueda et al., 2004), and aggression between fish is mostly observed during the feeding times (Ryer & Olla 1995). Fin erosion in fish seems to be a complex and seasonal happening, also related to fish size, rearing system and feeding regime, also happening when fish are overfed (Grant, 1997). That confirms the results that showed that fish who grew faster had higher incidence of fin erosion, probably due to stronger dominance.

Our results show that the larger and heavier the fish, the larger the number of cases as well as the severity of the fin erosion found. Similar studies showed an increased aggression and consequent fin erosion among larger individuals of studied salmonids, in the summer, more specifically in July, also month we started our sampling collection (MacLean et al., 2000). Most studies, though, found no correlation of fin erosion and fish size, although the smallest individuals from a group seem to be more prone to attacks from bigger fish (Abbott & Dill, 1989). Dominant individuals, which are fish who tend to gain more weight and achieved longer body lengths, exhibit less fin erosion than non-dominant fish. Removing of the dominant individuals from a tank is not the solution, though, since new dominant ones are formed, when density in the tank remains high (Canon Jones et al., 2011). In our study, fin erosion severity and occurrence had a decrease towards the end; it can be correlated with the fact that when the fish starts the smoltification process, it becomes less territorial and more likely to schooling, as a way to avoid predator attack in open waters (Steffansson *et*. al., 2008)

4.2 Fin erosion and development over time

Important data was found suggesting that handling of the fish, as in our case happened during size grading, vaccination and plain moving from one tank to another, for cleaning and convenience purposes, should have a strong affect in fin erosion and its severity (Landless, 1976). One of the reasons for this is the liberation of cortisol to the bloodstream when fish feels treated or stressed somehow and doses as low as 1 ng/ml seem to promote higher susceptibility to fin erosion formation (Pickering & Pottinger, 1989).

Formalin baths were used sporadically in the facility in order to treat fish with history of body lesions and fin erosion. In all groups, the number and severity of fin erosion seem to decrease towards the end of the study, independent if the groups has been treated or not with formalin. In this case, we can’t confirm the efficacy of those baths against lesions and fin erosion, since we also have the hypothesis that those lesions end up healing by itself after some time. Some periods with higher levels of incidence of fin erosion were found in some groups during vaccination period, what comproves that stress had a role in fin erosion.

4.3 Opercular deformities and body lesions

Episodes of operculum and body lesions were found mostly in smaller fish (Figure 19). Burnley et al. (2010) tested the occurrence of operculum and jaw deformities in Atlantic salmon and found out that fish with jaw and operculum deformities had significantly less weight gain over the production cycle, compared to normal fish, due to decreased energy intake or increased energy expenditure, respectively. Fish with operculum deformity are also more susceptible to diseases, such as bacterial kidney disease, and also show higher mortality rates, due to the greater exposure to environmental pathogens through increased area of gill tissue damage.

That could help explain our results that operculum deformities were found rather in fish with small weight. Either those fish ended up dying after a while due to secondary infections, very low body weight as well as bad general condition or they could have ended up being discarded after the tank change routine, done often, to discard those individuals with very low weight and therefore, low survival changes.

The same could happen for fish with body lesion. After following the fish during the study time, it was noticeable that after a couple days after the fish first started showing the first signs of epithelial damage (light discoloration), the progression of the disease happened very fast, with signs of visible open ulcers/sores, that in many cases made it incompatible with living conditions.

4.4 Future considerations

Minimizing aggression between fish and competition for food seem to be the best way to avoid fin erosion. The adoption of an on-demand feeding regime, specially adjusted to each tank, according to fish size, consumption and behavior can give good results.

It is important to pay attention to the handlings that happen on a daily basis in the industry, and to try to minimize the unnecessary stress that fish have to go through. A different sorting system, done less often and by milder ways, can be necessary.

Formalin baths should be reduced to a minimal use, due to its toxicity and questionable efficacy.

Heritability values show that it is possible to select the best individuals, free from fin erosion, opercular deformities and body lesions, and with good size, and try to do a genetic selection, so future generations have fewer or non-problems.

5. REFERENCES

Abbott, J.C. & Dill, L.M. 1985. Patterns of aggressive attack in juvenile steelhead trout (*Salmo gairdneri*). Can. J. Fish. Aquat. Sci. 42, 1702-1706.

Abbott, J.C. & Dill, L.M. 1989. The relative growth of dominant and subordinate juvenile steelhead trout (*Salmo gairdneri*) fed equal rations. Behaviour 108, 104-113.

Adams, C.E., Turnbull, J. F., Bell, A., Bron, J. E., Huntingford, F.A. 2007. Multiple determinants of welfare in farmed fish: stocking density, disturbance, and aggression in Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 64: 336-344.

Almazan-Rueda, P., Schrama, J.W. & Verreth, J.A.J. 2004. Behavioural responses under different feeding methods and light regimes of the African catfish (*Clarias gariepinus*) juveniles. Aquaculture 231, 347-359.

Altintzoglou, T., Einarsdottir, G., Valsdottir, T., Schelvis, R., Skåra, T., Luten, J. 2010. A voice-of-consumer approach in development of new sea food product concepts. Journal of Aquatic Food Product Technology, 19 2:130-145.

Andrades, J.A., Becerra, J. and Fernandez-Llebrez, P. 1996. Skeletal deformities in larval, juvenile and adult stages of cultured gilthead sea bream (*Sparus aurata* L.). *Aquaculture* 141, 1–11.

Bangaramma, L.M.R. & Lakshmi, B.B. 1999. Frequency of occurrence of external diseases in mullets from polluted waters of Visakhapatnam harbour. J. Environ. Biol., 20 (1) : 25-27.

Barahona-Fernandes, M.H. Body deformation in hatchery reared European sea bass *Dicentrarchus labrax* (L). Types, prevalence and effect on fish survival. J. Fish. Biol. 21, 239-249.

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. Can. J. Fish. Aquat. Sci., 51:2203-2209.

Becerra, J., Montes, G.S., Bexiga, S.R.R., Junqueira, L.C.U. 1983. Structure of the tail fin in teleosts. Cell and Tissue Research. 230:127-137.

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

Burnley, T.A., Stryhn, H., Burnely, H.J., Hammell, K.L. 2010. Randomized clinical field trial of a bacterial kidney disease vaccine in Atlantic salmon, *Salmo salar L*. Journal of Fish Diseases, 33: 545-557.

Canon Jones, H.A., Hansen, L.A., Noble, C., Damsgård, B., Broom, D.M., Pearce, G.P. 2010. Social network analysis of behavioral interactions influencing fin damage development in Atlantic salmon (*Salmo salar*) during feed-restriction. Applied Animal Behavior Science, 127:139-151.

Canon Jones, H.A., Noble, C., Damsgård, B., Pearce, G.P. 2011. Social network analysis of the behavioural interactions that influence the development of fin damage in Atlantic salmon parr (*Salmo salar*) held at different stocking densities. Applied Animal Behaviour Science, 133:117-126.

Carr, J.W. & Whoriskey, F.G. 2006. The escape of juvenile farmed Atlantic salmon from hatcheries into freshwater streams in New Brunswick, Canada. ICES Journal of Marine Science, 63:1263-1268.

Chinabut, S., Limsuwan, C., Tonguthai, K., Pungkachonboon, T. 1988. Toxic and sublethal effect of formalin on freshwater fishes. Food and Agriculture Organization of the United Nations (FAO) – December 1998.

Chowdhury, B.R. 1998. Involvement of aeromonads and pseudomonads in diseases of farmed fish in Bangladesh. Fish. Pathol., 33 (4): 247-254.

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. Can. J. Zool.,68:2185-2191.

Conroy, D.A. 1963. Otras observaciones sobre la putrefaccion de la aleta caudal en los peces. Microbiologia Espanola, 16:1-4.

Culp, S.J. & Beland, F.A., 1996. Malachite green: a toxicological review. J. Am. Coll. Toxicol.15, 219–238.

Cruz, C. D. 1997. Programa Genes: aplicativo computacional em genética e estatística. Viçosa: Editora UFV. 442 p.

Dawson, L.H.J. 1998. The physiological effects of salmon lice (*Lepeophtheirus salmonis*) infections on returning post-smolt sea trout (*Salmo trutta L*.) in western Ireland. ICES Journal of Marine Science, 55: 193-200.

Devesa, S., Barja, J.L. & Toranzo, A.E. 1989. Ulcerative skin and fin lesions in reared turbot, Scophthalmus maximus L. J. Fish. Dis., 12:323-333.

Directorate of Fisheries. 2013:Laks, regnbueørret og ørret – matfiskproduksjon. http://www.fiskeridir.no/statistikk/akvakultur/statistikk-for-akvakultur/laks-regnbueoerret-og-oerret. Fiskeridirektoratetatet.

Fjelldal, P.G., Hansen, T.J. & Berg, A.E. 2007. A radiological study on the development of vertebral deformities in cultures Atlantic salmon (*Salmo salar L.).* Aquaculture, 273:721-728.

Francis-Floyd, R. 1996. Use of formalin to control fish parasite. Institute of Food and Agricultural Sciences, University of Florida, publication VM77.

Fromser, M.R.; de Nys, R., 2005: The morphology and occurrence of jaw and operculum deformities in cultured barramundi (*Lates calcarifer*) larvae. Aquaculture 250 (1-2), 496-140.

Food and Agriculture Organization (FAO). 2006. FishStat Plus. Universal software for fishery statistical time series. Food and Agriculture Organization of the United Nations, Rome, Italy.

Forster, J. 2002. Farming salmon: an example of aquaculture for the mass market. Reviews in Fisheries Science 10:577-591.

Galeotti, M., Beraldo, P., de Dominis, S., Angelo, L., Ballestrazzi, R., Musetti, R., Pizzolito, S., Pinosa, M., 2000. A preliminary histological and ultrastructural study of opercular anomalies in gilthead sea bream larvae (*Sparus aurata*). Fish Physiol. Biochem.22: 151–157.

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

Gills, J.A., Rawlinson, K.A., Bell, J., Lyon, W.S., Baker, C.V.H. Shubin, N.H. 2011. Holocephalan embryos provide evidence for gill arch appendage reduction and opercular evolution in cartilaginous fishes. PNAS, v. 108, 4:1507-1512.

Godoy, M., Gherardelli, V., Heisinger, A., Fernandez, J., Olmos, P., Ovalle, l., Ilardi, P., Avendano-Herrera, R. 2010. First description of atypical furunculosis in freshwater farmed Atlantic salmon, *Salmo salar* L., in Chile. Journal of Fish Diseases, 33: 441-449.

Goede, R.W. & Barton, B.A. 1990. Organismic indices and an autopsy-based assessment as indicators of health and condition of fish. Am. Fish. Soc. Symposium, 8:93-108.

Grant, J.W.A 2007. Territoriality. In Behavioural Ecology of Teleost Fishes. Pp. 81-103. Oxford University Press. Oxford.

Guerra, N.B. & Livera, A.V.S. 1999. Correlação entre o perfil sensorial e determinações físicas e químicas do abacaxi cv. Pérola. Revista Brasileira de Fruticultura, Cruz das Almas, v. 21, n. 1, p.32-35.

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. J. Fish Biol., 50: 267–272

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.

Ketola, H.G. 1983. Requirementes for dietary lysine and arginine by fry of rainbow trout. J. Animal Sci, 56:101-107.

Knapp, G., Roheim, C.A.; Anderson, J.L. 2007. The great salmon run: competition between wild and farmed salmon: chap. 5 – The World salmon farming industry; 302 p. Traffic North America/WWF.

Korsøen, Ø.J., Dempster, T., Fjelldal, P.G., Oppedal, F., Kristiansen, T.S. 2009. Long-term culture of Atlantic salmon (*Salmo salar L.*) in submerged cages during winter affects behavior, growth and condition. Aquaculture, 296:373-381.

Krohn, M. & Boisclair, D. 1994. The use of stereo-video system to estimate the energy expenditure of free-swimming fish. Can. J. Fish. Aquat. Sci. 51, 1119–1127.

Laird, L.M. 1996. History and applications of salmonid culture. Pages 1-28 in W. Pennell and B.A. Barton, editors. Principles of Salmonid Culture. Elsevier, Amsterdam, The Netherlands.
Landless, P.J. 1976. Demand-feeding behaviour of rainbow trout. Aquaculture 7, 11-25.

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.

Larmoyeux, J.D. & Piper, J.D. 1973. Effects of water reuse on rainbow trout in hatcheries. Prog. Fish. Cult., 35:2-8.

Latremouille, D. N. 2003. Fin erosion in aquaculture and natural environments. Reviews in Fisheries Science, 11.4, 315-335.

Lellis, W.A. & Barrows, F.T. 2000. Effect of dietary ingredient substitution on dorsal fin erosion of steelhead. N. Am. J. Aquacult., 62:135-138.

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.

Lund, R.A., Hansen, L.P. & Jarvi, T. 1989. Identification of reared and wild salmon by external morphology, size of fins and scale characteristics. NINA Research Report 1.

McCormick, S. D. 1994. Opercular membranes and skin. Hochachka and Mommsen (eds.), Biochemistry and molecular biology of fishes, vol. 3, ch. 20.

Morton, A. & Volpe, J. 2002. A description of escaped farmed Atlantic salmon *Salmo salar* captures and their characteristics in one pacific salmon fishery area in British Columbia, Canada, in 2000. Alaska Fishery Research Bulletin, vol.9, no.2.

MacCrimmon, H.R. & Gots, B.L. 1979. World distribution of Atlantic salmon, *Salmo salar.* J. Fish. Res. Board Can. 36:422-457.

MacLean, A., Metcalfe, N.B., & Mitchell, D. 2000. Alternative competitive strategies in juvenile Atlantic salmon (*Salmo salar*): evidence from fin damage. Aquaculture 184, 291-302.

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. Prog. Fish. Cult., 49:13-16.

McVicar, A.H. & White, P.G. 1982. The prevention and cure of an infectious disease in cultivated juvenile Dover sole, *Solea solea L*. Aquacult., 26:213-222.

McVicar, A. H., Sharp, L. A., Walker, A. F., and Pike, A. W.1993. Diseases of wild sea trout in Scotland in relation to fish population decline. Fisheries Research, 17: 175-l 85.

Ministry of Fisheries and Coastal Affairs. 2010: Facts about Fisheries and Aquaculture 2010. Ministry of Fisheries and Coastal Affairs, Available at: http://www.fisheries.no/Key_statistics_fisheries_no/key_statistics_2008

Mork, J., Jarvi, T. & Hansen, L.P. 1989. Lower prevalence of fin erosion in mature than in immature Atlantic salmon (*Salmo salar*) parr. Aquaculture 80: 223-229.

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.

Noga, E.J. 2010. Fish disease: diagnosis and treatment. 2nd edition. Iowa State University Press.

Oppedal, F., Vågseth, T., Dempster, T. Juell, J.E. Johansson, D. 2011. Fluctuating sea-cage environments modify the effects of stocking densities on production and welfare parameters of Atlantic salmon (*Salmo salar L.*) Aquaculture, 315:361-368.

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

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.

Powell, M.D., Speare, D.J. & MacNair, N. 1994. Effects of intermittent Chloramine-T exposure on growth, serum biochemistry, and fin condition of juvenile rainbow trout (Oncorhynchus mykiss). Can. J. Fish. Aquat. Sci., 51:1728-1736.

Puebla, M., Gutierrez, F. & Alvarez-Guerra, S. 2000. Quality in the production processes in the aquaculture industry: Bases, procedures and economic implications. Workshop of the CIHEAM Networks on Technology of Aquaculture in the Mediterranean (TECAM) and Socio-Economic and Legal aspects of Aquaculture in the Mediterranean, Barcelona (Spain), 29 Nov - 1 Dec 1999.

Rafatnerzhad, S., Falahatkar, B.& Gilani, M.H.T. 2008. Effects of stocking density on haematological parameters, growth and fin erosion of great sturgeon (*Huso huso*) juveniles. Aquaculture research, 39:1506-1513.

Rahman, M.M., Ferdowsy, H., Kashem, M.A., Foysal, M.J. 2010. Tail and fin rot disease of Indian major carp and climbing perch in Bangladesh. Journal of Biological Sciences 10 (8): 800-804.

Reash, R.J. & Berra, T.M. 1989. Incidence of fin erosion and anomalous fishes in a polluted stream and a nearby clean stream. Water, Air ans Soil Pollution, 47: 47-63.

Roberts, R. J. 2001. Fish Pathology. Third edition. W.B. Saunders; 472.

Ryer, C.H. & Olla, B.L. 1995. The influence of food distribution upon the development of aggressive and competitive behaviour in juvenile chum salmon, *Oncorhynchus keta*. Journal of Fish Biology 46:264-272.

Salte, R., Rørvik, K.A., Reed, E., Norberg, K. 1994. Winter ulcers of the skin in Atlantic salmon, *Salmo salar*, L.: pathogenesis and possible aetiology. Journal of fish diseases, 1994, 661-665.

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

Steffansson, S.O., Bjørnsson, B.T, Ebbesson, L.O. McCormick, S. 2008. Smoltification. Fish Larval Physiology.CRC Press. 742 p.

Srivastava, S., Sinha, R. & Roy, D., 2004. Toxicological effects of malachite green. Aquat. Toxicol. 66, 319–329.

Turnbull, J. F., Bell, A., Adams, C., Bron, J., Huntingford, F. 2004. Stocking density and welfare of cage farmed Atlantic salmon: application of a multivariate analysis. Aquaculture 12: 626172.

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: 415-427.

Tørud, B. & Håstein, T. 2008. The role of the veterinarian in animal welfare. Animal welfare: too much or too little? *Acta Veterinaria Scandinavica,* **50**(Suppl 1):S7

Vehanen, T., Aspi, J. & Pasanen, P. 1993. The effect of size, fin erosion, body silvering and precocious maturation on recaptures in Carlin-tagged Baltic salmon (*Salmo salar L.*). Ann. Zool. Fennici 30: 277-285.

Verspoor, E., Olesen, I., Bentsen, H.B., Glover, K., McGinnity, P., Norris, A. 2007. Atlantic salmon – *Salmo salar*. Genimpact final scientific report: 23-31.

Wiklund, T. & Bylund, G. 1993. Skin ulcer disease of flounder *Platichithys flesus* in the northern Baltic sea. Dis Aquat Org 17:165-174.

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

Yadegari, M., Raissi, M. & Ansari, M.2011. A radiographical study on skeletal deformities in cultured rainbow trout (*Oncorhynchus mykiss*) in Iran. Global Veterinaria 7 (6): 601-604.

Ørnsrud, R., Gil, L. & Waagbø, R. 2004. Teratogenicity of elevated egg incubation temperature and egg vitamin A status in Atlantic salmon, *Salmo salar L*. J. Fish Dis. 27, 213-223.