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Effect of water quality on rainbow trout performance

Water oxygen level in commercial trout farm

“Kala ja marjapojat”

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DESCRIPTION

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Abstract

Water quality is a combination of chemical, physical and biological parameters that affect the growth and prosperity of cultured fish. The success of a commercial aquaculture activity depends on the optimal environment conditions for accelerated growth at the lowest cost of resources. Water quality affects the general condition of the cultured body as it determines the conditions of health and growth of the cultured fish. The water quality is, therefore, an essential factor to consider when planning a high aquaculture production.

Although the environment of fish aquaculture is a complex system, consisting of some water quality variables, only few of them play a crucial role. Critical parameters are temperature, suspended solids and dissolved oxygen, nitrite, ammonia, alkalinity and carbon dioxide. However, the dissolved oxygen is the most important parameter, requiring continuous monitoring in aquaculture production systems, because fish aerobic metabolism requires dissolved oxygen. In this work the most significant changes in the quality of the water environment are described.

The range of environmental impact depends on the amount of wastes produced by the studied cages, and is evaluated by the stocking density, amount and type of feed, feed composition, size of granules and the physicochemical conditions where cages are located. The level of fish production that would be sustained in an area is variable depending on different impacts.

It was observed that the trout farm effluents had no significant impact on the water quality. There were no significant differences in most of water physicochemical factors between cages and the water nearby cages. The results suggest that oxygen saturation levels affect both feed conversion ratio and growth performance of the rainbow trout. The highest growth rate and lowest feed conversion ratio in cages can be found at higher oxygen saturation levels, between 80 - 100 %. However, more research is necessary in order to know at which saturation point the growth is maximized. The water temperature varied greatly. Also this factor influenced the fish growth extremely. The feeding tables presented incorrect coefficients for feeding the fish.

Subject headings, (keywords)

Aquaculture, water quality, dissolved oxygen, rainbow trout, growth performance.

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CONTENTS

1 INTRODUCTION

In the global fisheries aquaculture production over the past forty years has increased more than by 100 times, and in 2004 exceeded 50 million tons that means more than 55 per cent of a universal catch of fish and other hydrobionts. The Russian Federation has the reservoirs, which meet the requirements of cultivation of hydrobionts, ranking high place in the world. (Bogeruk 2005, 12-25.)

Today the aquaculture in Russia is the most developing branch of production of food. In the conditions of constant reduction of netting oceanic fish and other seafood when fish stocks of inland waters are in critical condition, the aquaculture is the only reliable source of increasing fish for food and is one of the guarantees of fish food safety in Russia.

The effectiveness of the fishery development of water resources of several reservoirs of the North-West Federal District of Russia, even under the conditions of a low biological productivity, can be considerably improved by using modern technology (Ryzhkov et al. 2007, 5).

On the inland waters of the Republic of Karelia, the trout-breeding is one of the priorities of fishery management. Now there is a steady development of commercial fish production, mainly due to the intensive cultivation of rainbow trout in cages. The total amount of trout production increased from 400 tons in 1993 to 6000 tons in 2005. Further development of the trout-breeding in Karelia is determined by “Concept for Fisheries of the Russian Federation up to 2020” (2010), and the “National Programme for Fisheries of the Republic of Karelia 2020” (2010), according to which the production of trout in Karelia in 2015, should be 10 thousand tons.

One type of fishery management in many regions of Russia, and in particular in the North-West Federal District, is the cage fish breeding, in Karelia, mainly - the production of commercial rainbow trout (Parasalmo mykiss Walbaum). This is due to favorable climatic conditions, abundance of natural water resources, good transport connection, energy and the availability of trained personnel. (Savosin 2010, 2-3.)

The aqueous medium inhabited by organisms is a part of the biosphere, which can vary significantly due to natural factors and human activities. The most influential scientific, social and economic problem in the modern society is the preservation and sustainable use of the environment. In addition to the traditional problems of biological study, there are some new reservoirs connected with providing the growing requirements for clean water and fish. In the Northern Europe there are freshwater ponds with different efficiency and abiotic conditions. Currently, due to the reduction of stocks and a sharp fall in fishing of valuable fish species, there is an intensification of work on the introduction of hydrobionts and the development of biotechnology cultivation of various organisms. (Savosin 2010, 34-38.)

The quality of feed is important for the health of fish in cages. Feed used in modern hatcheries must meet physiological requirements of trout, to be balanced in composition, and contain essential vitamins and minerals. Assimilation of feed granules should be high not only to ensure rapid growth of fish, but also to reduce the level of pollution. Inconsistency of feed for these requirements causes adverse interaction with the environment. The use of fish feed containing oxidized fats, and lacking or excess of vitamins also leads to various pathologies in fish. (Ryzhkov et al. 2007, 15-17.)

Along with the problem of food quality, reducing negative effects on the fish promotes observance of optimal modes of feeding. The basis for determining the favorable regime of feeding fish is the temperature conditions of the aquatic environment, as well as age and weight indicators of trout. Insufficient and especially excessive fish feeding impairs their physiological condition and may lead to disease and death.

Consequently, the success of the hatchery trout production depends on the following factors:

- The quality of the water environment;
- The availability of quality feed;
- Optimal feeding model;
- Effective use of biotechnology;
- The level of health protection for fish.

Water quality is a combination of chemical, physical and biological parameters that affect the growth and prosperity of cultured fish. The success of a commercial aquaculture activity depends on the optimal environment conditions for accelerated growth at the lowest cost of resources. Water quality affects the general condition of the cultured body as it determines the conditions of health and growth of the cultured fish. The water quality is, therefore, an essential factor to consider when planning a high aquaculture production. (Timmons et al. 2002, 27-30.)

Although the environment of fish aquaculture is a complex system, consisting of some water quality variables, only few of them play a crucial role. Critical parameters are temperature, suspended solids and dissolved oxygen, nitrite, ammonia, alkalinity and carbon dioxide. However, the dissolved oxygen is the most important parameter, requiring continuous monitoring in aquaculture production systems, because fish aerobic metabolism requires dissolved oxygen. (Timmons et al. 2002, 32-33.)

2 CHARACTERISTICS OF RAINBOW TROUT AND CONDITIONS OF CULTIVATION

Rainbow trout, as the object of growing is characterized by plasticity, rapid growth, and high feed conversion. Relatively short period of incubation of hard roe, and also possibility of spawning at any time of the year by creating optimal temperature for the producers have become rather profitable. These characteristics allow us to consider a rainbow trout as the main object of aquaculture in the countries of Europe. (Munro et al. 1987, 11.)

The trout is conventionally related to cold water production facilities, although the range of comfortable temperature for its growth is quite broad. Optimal temperatures for rainbow trout are in the range from 9 to 18 °C. Fish feed and growing at water temperatures of 4 to 20 °C is most optimal. At water temperatures below 4 °C and above 20 °C the intensity of its nutrition and growth is reduced. Temperature above 20 °C is not comfortable for trout, but the lethal temperature as a function of temperature acclimation is from 24.9 to 26.3 °C. (Matschak et al. 1998, 12-25.)

Rainbow trout is safe at diurnal temperature 5 °C and above, but prefers a particular temperature. Rainbow trout is extremely demanding on the level of dissolved oxygen in the water, the optimal concentration should not be less than 9 mg/l. Trout can tolerate water saturation with pure oxygen to 50 mg/l. Lethal concentration of oxygen in the water for trout is 2.5 mg/l. At high temperatures, the content of dissolved oxygen in water is not less than 9 mg/l. (Munro et al. 1987, 27-43.)

During the whole period of cultivation of a rainbow trout - especially during periods of intensive feeding, it is necessary to continuously monitor oxygen concentrations in cages because the concentration of oxygen limits the amount of fish breeding. The concentration of oxygen at the normal growth of fish and feed conversion ratio should be at the water temperature of 5 °C – not less than 5.0 mg/l, at 10 °C – not less than 6.0 mg/l, at 15 °C – not less than 7.0 mg/l and at 20 °C – not less than 8.0 mg/l. (Industry standard 1988, 13-19.)

Carbon dioxide content at trout farming in optimal conditions should not exceed 10 mg/l, although trout can survive in water with carbon dioxide concentration up to 50 mg/l with a significant slowdown of growth and increased feed conversion ratio (FCR). FCR is simply the amount of feed required to grow for one kilogram of fish. The maximum permissible value of carbon dioxide in water is 30 mg/l. (Industry standard 1988, 21-27.)

At cultivation of rainbow trout, it is more preferable to use water with pH values from 7 to 8. Water with pH within 6.5 – 8.5 is quite satisfactory for trout, but pH values lower 4.5 and higher than 9 are critical for trout. The toxic effect of pH is increased with different content of ions of calcium, sodium and chlorine in water. The presence of iron hydroxide in the water reduces the resistance of trout to low pH values. If the pH value is below 7, the iron concentration above 1.5 mg/l results in the death of trout. In general, the growth rate of a trout in acid waters is lower, than in alkaline, and at constant pH within its optimum values the growth rate is higher than at varying pH values. (Industry standard 1988, 27-31.)

Nutrients such as nitrogen and phosphorus have no toxic effect on trout at rather high concentrations, and the maximum allowable concentrations are not determined by the needs of trout, but by requirements for quality of the environment. The admissible concentration of phosphates in water is 0.3 mg/l, and that of nitrites is 0.1 mg/l. (Industry standard 1988, 31-35.)

The negative impact of ammonia on fish increases with increasing temperature and pH. By increasing pH of water from 7.0 to 7.3 and temperature by 10 °C, the toxicity of ammonia is doubled. Unionized ammonia (NH_3) is harmful to trout also at admissible concentration of 0.05 mg/l but preferably there is none at all. Admissible values of the concentration of ammonia in water at trout cultivation in various oxygen and temperatures is presented in Table 1.

Rather low concentrations of iron compounds are dangerous to trout in water, because iron hydroxide forms a brown cover on the gills, causing suffocation of fish. Especially dangerous for trout is ferrous iron. With a relatively high saturation of oxygen in water it oxidizes and precipitates in the gills. (Munro et al. 1987, 13-15.)

TABLE 1. Valid values of ammonia according to hydrochemical indexes (based on Medinor 1995, 24)

Indexes	**NH_3, g/m^3**	**O_2, g/m^3**	**Temperature, °C**	**Hardness, mmol/l**
Standard	0.01-0.07	8±2	18-22	$>1.5\times10^{-3}$
Allowed for 1-2 days	1.0-1.5	18±5	<20	$>1.0\times10^{-3}$
Allowed for 3-5 days	0.1-0.2	7±2	<20	$>1.0\times10^{-3}$

The hydrogen sulfide is also dangerous for the fish as sulfides, penetrating into the body and it reduces the ability of tissues to absorb oxygen. Lethal concentration of hydrogen sulfide for a trout is 0.86 mg/l. It should be noted that is required about 2.5 mg of O_2 for oxidation of 1mg of H_2S. Hydrogen sulfide can also bind iron hydroxide and can be utilized by sulfur bacteria. Optimal cultivation of trout requires the lack of hydrogen sulfide in water. (Industry standard 1988, 36-39.)

Chlorine in the form of hypochlorous acid and chloramines is toxic for trout, and its toxicity increases with decreasing concentration of dissolved oxygen in water. The maximum content of suspended matter in the water for cultivation of trout is not more than 10 mg/l. It is proved that the concentration up to 100 mg/l, without affecting mortality of rainbow trout, reduces the intensity of the feeding until the complete termination. (Matschak et al. 1998, 12-25.)

Phenols have harmful effects on trout, both because of the direct toxicity and rapid oxidizing, leading to a decrease in the concentration of dissolved oxygen in water. In addition, they give the sour taste for fish. The toxicity of phenols increases with decreasing concentration of dissolved oxygen, with decreasing temperature and increasing salinity of water. The maximum concentration of phenol at temperatures higher than 5°C is 0.5 mg/l, and at a temperature of 5 °C it is 0.25 mg/l. (Industry standard 1988, 40-49.)

The toxicity of zinc caused by zinc ion and it depends on the water composition. It decreases with increasing hardness, temperature, salinity, suspended solids, and increases with decreasing concentration of dissolved oxygen in water. The maximum concentration of dissolved zinc in water is 0.3 mg/l. (Medinor 1995, 33-38.)

Copper toxicity is associated with the divalent ion and increases with decreasing water hardness, temperature and dissolved oxygen and decreases in the presence of humic acids, amino acids and suspended solids. The maximum allowable concentration of copper is 1.0 mg/l. (Medinor 1995, 25-29.)

Cadmium is found in low concentrations in the sand and shale soils, from which cadmium is slowly leached into surface waters. The concentration of cadmium in uncontaminated fresh waters is typically 0.01 – 0.5 mg/l, and the maximum concentration that has no negative impact on the rainbow trout is in the range 0.5 – 2.0 mg/l. (Medinor 1995, 33.)

In general, requirements of rainbow trout for the chemical composition of the water environment are given in Table 2.

TABLE 2. The water quality requirements for cage rainbow trout farms (based on Industry standard 1988, 12-52)

Parameters	Standard value
Temperature, °C	<20
Transparency, m	1.5 – 1.8
pH	6.0 – 8.5
Suspended solids, mg/l	<10
Dissolved oxygen (DO), mg/l	≥9.0
Carbon dioxide (CO_2), mg/l	<10
Hydrogen sulfide (H_2S), mg/l	Absence
Ammonia (NH_3), mg/l	<0.07
Chemical oxygen demand (COD), mg/l	<15.0
Biochemical oxygen demand (BOD), mg/l	<30.0
Nitrites (NO_2^-), mg/l	<0.05
Nitrates (NO_3^-), mg/l	<1.0
Phosphates (PO_4^{3-}), mg/l	<0.3
Total iron, mg/l	<0.5

Among the above parameters in Table 2, the most unstable is dissolved oxygen in the water. When fouling or silty of cages the oxygen for a few hours may be reduced to a critical value (6 – 7 mg/l.) or even lethal concentration (2 – 3 mg/l). The lack of oxygen in the cages can be judged by the behavior of fish that float to the surface of the water. Eliminating such a situation can be achieved by aerators, which intensively pump air or oxygen through the water environment in the cages. (Mikheev 1982, 36-45.)

3 ADAPTIVE MECHANISMS IN FISH

Oxygen has a low solubility in water. In addition, the amount of oxygen in water varies depending on the salinity and temperature in a predictable manner. Less oxygen can be fixed in totally aerated warm salt water than fully aerated cold freshwater. While the oxygen concentration of water sets the absolute availability of oxygen in the water, it is the gradient of the partial pressure of oxygen, which determines how quickly oxygen can move from the water to the fish blood to maintain its metabolic rate. This is because the oxygen moves through the gills of trout.

The rate of diffusion of oxygen through the trout gills is identified by the gills area, the diffusion distance through the gill epithelium, the diffusion coefficient and the difference in partial pressure of oxygen over the gills, according to Fick's law of diffusion (Crampton et al. 2003, 12-20). Therefore, the partial pressure of oxygen is the most appropriate term to express the oxygen levels in the freshwater. However, the concentration of oxygen depends on temperature and salinity. Oxygen partial pressure and oxygen concentration in the water are linearly related. Other suitable method to indicate the oxygen levels in aquaculture is air saturation as percentage (often just % of saturation), which is also directly proportional to the partial pressure, and is reported in most of the oxygen studies that have create in dependence for salinity and temperature. (Bergheim et al. 2006, 41-46.)

3.1 The absorption of oxygen and carbon dioxide release from by the fish

During the respiration activity the trout take in oxygen and give out carbon dioxide, like other animals. The whole process is done by gills in almost all of fish, although some may also use the skin, and some trout have lungs as structures used in addition to the gills. When a fish breathes, a pressurized gulp of water flows from the mouth to the gill chamber on each side of the head. The gills are located in gill clefts within the gill chambers, composed of fleshy, skin like filaments transected extensions, and called lamellae. As water flows through the gills, the oxygen in the range is diffused in the blood circulating through the vessels in the filaments and lamellae. At the same time, the carbon dioxide in the blood of fish is diffused into the water and carried out of the body (see Figure 1).

Function of fish gills

For most species of fish, the gills are working in the directed flow of water through the gills epithelial surfaces, where the exchange of gases occurs. Cause of unidirectional flow of water is energetic nature of the system. The energy that is needed to move the water in the respiratory system and out of it will be much more than that used to move air as the water contains low levels of oxygen due of its low solubility. (Groot et al. 1995, 22-24.)

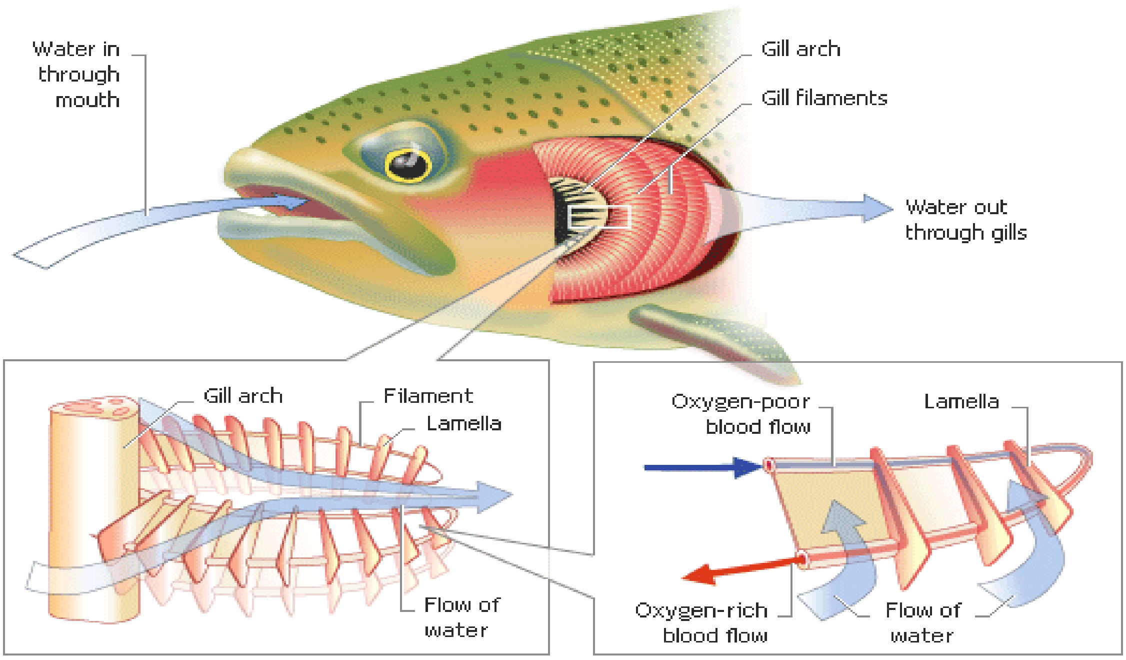


FIGURE 1. Structure of respiration in fish (based on Edmondson 2006)

The blood flowing just under the gill epithelial tissue usually moves in a counter current flow of the water moving over it. This covers most of O_2 to be taken with blood because the gradient diffusion kept up by the blood, raising the oxygen as it moves along, but always associated with water entry, which has a higher amount of O_2 (Groot et al. 1995, 30-35). The blood receiving the O_2 continues to pick up O_2 as it moves on because it is fresh water flooding the epithelial lining of gills. By doing so, this water is ventilated the gills of fish and also taking in oxygen and releases carbon dioxide. (Jobling 1995, 25-27.)

However, there are two ways in which the fish gills are aired: active ventilation and passive ventilation. In the active ventilation of fish, water is pulled through the mouth (buccal chamber) and pushed through the gills and out of the opercula chamber. At this time, the pressure in the buccal chamber is maintained higher than the pressure in the chamber opercula so as to allow fresh water to be continually flushed over the gills. In passive ventilation, a fish swims with its mouth open, allowing water to wash over the gills (Bailey et al. 1996, 13-18). This method of ventilation is regular for fast moving fish and this allows the trout to keep enough oxygen going to the gills surface, floating at a high speed. During this time, oxygen is absorbed into the blood while carbon dioxide diffuses from the blood to the water. (Boyd et al. 1998, 254-310.)

The pathway made by carbon dioxide explains that the CO_2 is transported in the blood in the form of bicarbonate. The bicarbonate moves from the blood passing through the erythrocyte, in which O_2 binds to hemoglobin at the respiratory surface, causing the hydrogen ions (H^+) to be released. The increase in H^+ ions combines with HCO_3^- to form CO_2 and OH^-. So more CO_2 is formed and can release the blood through the respiratory surface. Excess H^+ binds to OH^- forming water and allowing the pH to increase enough to sustain oxygen to hemoglobin. The O_2 released from hemoglobin in the tissues makes available to bind with H^+, promoting the conversion of CO_2 to HCO_3^-, which helps to pull CO_2 from the tissues. (Groot et al. 1995, 69-80.) Therefore, CO_2 which is transported in and out of red blood cells minimizes changes in pH in other parts of the body due to the releasing from hemoglobin and proton binding, as it is oxidized and deoxygenated respectively. However, carbon dioxide is rarely a problem when the concentration of dissolved oxygen is in saturation level. Because of these processes, the oxygen level must be maintained at or slightly higher during the entire culture period. (Bailey et al. 1996, 48-63.)

3.2 Effects of oxygen levels on oxygen uptake by rainbow trout

It is known that if there is not enough oxygen in the water, then the fish will be gasping at the surface, but this is the last means of breathing. The first sign of too little dissolved oxygen in the water is when fish are stop feeding and unusually passive. As oxygen level decreases generation, the fish do not have enough energy to swim and feeding uses more oxygen. Often the fish have trouble at this stage, and often some form of medication is added to water, which can cause the oxygen level to drop even lower, and leads to the deaths. This may lead to the erroneous conclusion that the fish suffer from some forms of the disease. (Yovita 2007, 14-30.) From the management's point of view of any aquatic system, it is always advisable to increase aeration when any trout start behaving abnormally before adding any form of medication in the water. Increased aeration will make the environment more comfortable for the fish, even if the level of dissolved oxygen has been satisfactory. Aeration improvement before adding medication will allow any level of oxygen depletion caused by chemical reaction with medication. (Svobodova et al. 1993, 13-28.)

Hypoxia in fish

The aquatic system lacking dissolved oxygen (0 % saturation) is called anaerobic. The system is anoxic with low concentration of dissolved oxygen (DO) in the range from 1 up to 30 %. DO satiation is called hypoxic. Most fish cannot live below 30 % saturation of DO. The "Suitable" aquatic environment should rarely experience dissolved oxygen of less than 80 %. In response to low concentrations of dissolved oxygen in the water the fish can react in two ways. The blood flow can be increased by opening up further secondary lamellae in order to increase the effective area of the respiratory tract (it can be difficult to increase significantly the flow of blood through the capillaries). The concentration of red blood cells can be increased to raise the oxygen capacity per unit volume. The last one can be achieved by reducing the amount of blood plasma (e.g. by increasing the flow of urine) in the short term and by releasing additional blood cells from the spleen in the long term. (Svobodova et al. 1993, 13-45.)

At the same time, the level of ventilation is increased to bring more water in contact with the gills at the unit of time. However, limits to the increased flow attainable. The space between the secondary lamellae is limited (in trout it is about 20 μm), and water is usually forced to pass tips of the primary lamellae when the respiratory water flow is high, thus, bypassing the respiratory surface (Boyd et al. 1998, 245-281). These reactions are quite enough to compensate for normal fluctuations in energy demand of trout and dissolved oxygen concentrations in the water. One of the consequences of increased ventilation rate is that there will be an increase in the amount of toxic substances in the water reaching the surface of the gill where they can be absorbed. (Svobodova et al. 1933, 13-45.)

3.3 Effects of oxygen level on growth of fish

The successful production of fish depends on good levels of oxygen in the water. Oxygen is required for respiration process in fish to maintain healthy fish and bacteria which decompose fish production waste and to meet the biological oxygen demand within culture system. Dissolved oxygen levels can affect respiration of fish, as well as ammonia and nitrite toxicity. When the oxygen level is near saturation or even near super saturation, it increases growth, reduces feed conversion ratio and increases in volumes of production of fish.

Oxygen plays a decisive role in breathing and metabolism of animals. In fish, the metabolic rate is heavily dependent on oxygen concentration in the environment. If the level of dissolved oxygen is reduced, breathing, and nutrition activities are also reduced. As a result, the growth rate is declining and the diseases increases. The fish are unable to digest the food where the oxygen level is low. (Wedemeyer 1996, 8-18.)

Several studies have examined the relationship between the saturation of oxygen and consumption of fish food. When oxygen levels fall below 60 % in the water, trout begins to lose appetite (Jobling 1995, 37-38).

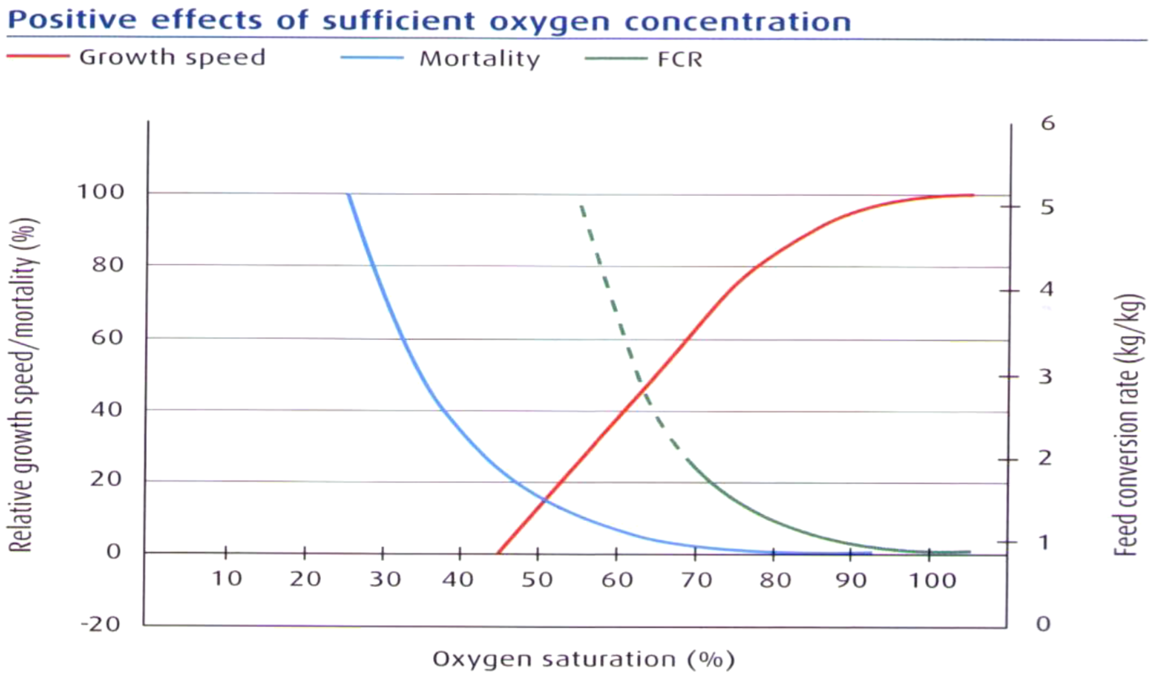


FIGURE 2. The effect of oxygen level on growth and food conversion ratios (based on Linde gas 2007)

Overall health and physiological conditions are better if dissolved oxygen is closer to saturation. When the level is lower, growth of fish can seriously suffer from increased stress. Tissue hypoxia declines in swimming activities and reduces resistance to disease. Therefore, it is necessary to maintain the dissolved oxygen at saturation level, which will not affect the physiological and metabolic activity to have a high performance in any culture. Moreover, it must be born in mind that the level of oxygen demand depends on the species, fish size and activity of the fish. (Wedemeyer 1996, 22-32.)

4 HARMFUL WATER QUALITY CHARACTERISTICS FOR RAINBOW TROUT

The following physical and chemical changes in the aquatic environment are the most frequently recorded as the underlying cause of harm to fish in trout farming. In this work the most significant changes in the quality of the water environment are described and the choice has been done based on the chemical analyses conducted in the company.

4.1 Temperature

Fish are poikilothermic animals that mean their body temperature is the same as the water in which they live or from 0.5 to 1 °C below or above the temperature of this water. Cold water fish, such as salmon and whitefish have a specific type of metabolism: their metabolic rate may continue at relatively low temperatures, otherwise at high temperatures, usually above 20 °C they consume less food and become less active. Water temperature also has a strong influence on the initiation and course of the fish diseases. The immune system of most fish species has optimal performance at a water temperature about 15 °C. (Schmidt-Nielsen 1991, 382-412.)

In fish natural habitats, the fish can easily bear seasonal temperature changes, for example, drop to 0 °C in winter and up to 20 – 30 °C (depending on species) in summer under central European conditions. However, these changes should not be sharp; thermal shock occurs when the fish are placed in a new environment where the temperature difference is 12 °C warmer or colder (8 °C in the case of trout), compared to original water temperature. In these circumstances fish may die with symptoms of paralysis of the respiration. With young fry problems can arise even when the temperature difference is only 1.5 – 3 °C. If the fish are fed, and then drastically transferred to the water cooler by 8 °C or more, fish digestive processes will slow down or stop. (Svobodova et al. 1993, 13-39.) The fed granules remain of undigested or half-digested in the gastrointestinal tract, and the formed gases can cause the fish to lose balance, bloat and eventually die. If the trout are given a high nitrogen feed (for example, high protein granules), a dramatic transfer to much colder water significantly increases levels of ammonia nitrogen in the blood serum, as the slowdown in the rate of metabolism reduces the diffusion of ammonia from the gills. This can lead to ammonia self-poisoning and death. (Finstad et al. 1988, 317-330.)

Significant progress has been made in recent years in warm water fishery. Methods for controlling water temperature will be maintained in optimal conditions, so that the fish can take full advantage of their growth potential to achieve maximum weight gain.

4.2 pH of water

The optimal pH range for fish is from 6.5 to 8.5. Alkalinity above pH 9.2 and acidity below pH 4.8 can damage and kill salmonids. So salmonids are more vulnerable to high pH and more resistant to low pH. Low pH water most often occurs in spring, especially when the acidified snow melts, and drainage of peat lands flow into water. Alkaline pH may occur in eutrophic waters, where green plants (green algae, blue-green algae) take significant quantities of CO_2 during the day for intense photosynthetic activity. (Bosawowsky et al. 1994, 300-318.)

This process influences the buffering capacity of water, and pH can rise to 9.0 – 10.0 or even higher, if bicarbonate is adsorbed from waters of medium alkalinity. The pH of the water can also be changed when the mineral acids and hydroxides, or other acidic or alkaline substances discharge or fall into the water. (Wagner et al. 1997, 979-990.)

As a protection against the effect of low or high pH water, fish can produce a high quantity of mucus on the skin and the inner side of the gill covers. Extremely high or low values of pH cause damage to the tissues of the fish, especially the gills and bleeding may occur in the gills and in the lower part of the body. Excess mucus, often with blood, can be seen in post mortem analysis on the skin and gills. (Bradley et al. 1985, 115-140.)

The pH of the water also has a significant influence on the toxic effect of a number of other substances (e.g. ammonia, cyanides, hydrogen sulfide and heavy metals) on fish.

4.3 Dissolved oxygen

Oxygen diffuses into the water from the air, particularly where surface is turbulent. The second source of dissolved oxygen is the photosynthesis of aquatic plants. Oxygen is removed with the help of aerobic decomposition of organic matter by bacteria and respiration of all organisms present in the water as previously mentioned. The concentration of dissolved oxygen in the water can be expressed in mg per liter, or as a percentage of the value of air saturation. Water temperature, air pressure and dissolved salts in the water must be taken into account when the mg per liter is converted to % of saturation or vice versa. (Davies et al. 1994, 1215-1354.)

Different species have different requirements for the concentration of dissolved oxygen in the water. Salmonids have higher requirements for oxygen in the water, and their optimal concentration is 8 - 10 mg\l. If the level drops below 3 mg per liter, the fish begin to show signs of choking (Svobodova et al. 1993, 120-125).

Oxygen requirements for fish also depend on many other factors, including temperature, pH and CO_2 from the water level and the metabolic rate of the fish. The main criteria of oxygen demand of fish include temperature and the average individual weight of fish and the total weight of fish per volume of water. Oxygen requirements increase at higher temperatures (e.g. increase in water temperature from 10 to 20 °C the need for oxygen at least doubles). A higher total weight of fish per volume of water can result in increased activity and, therefore, increases fish breathing as a result of the overflow. (Svobodova et al. 1993, 127-132.)

As noted earlier, the factor, most often causing a significant reduction in the concentration of oxygen in the water, is the contamination by biodegradable organic substances. These substances are decomposed by bacteria that use oxygen from the water for this process. A number of chemical substances can be oxidized in the absence of bacteria. The organic substances in water in terms of their capacity to consume oxygen out of the water can be measured by chemical oxygen demand (COD) and biochemical oxygen demand (BOD) within five days. For salmonids optimal levels are up to 10 mg O_2\l for COD and 5 mg O_2\l for BOD. (Svobodova et al. 1993, 145-168.)

The lack of oxygen causes choking and fish will die, depending on the oxygen consumption of species and a lesser extent on the rate of their adaptation. The main pathologico-anatomical changes include unusually pale skin color, the accumulation of blood in the gills, adherence of the gill lamellae, slight bleeding in the front part of the eye cavity and the skin of the gill covers. (Yovita 2007, 62-83.)

Corrective actions reduce access of degradable materials or the aeration of water. The latter is usually the best option. Aeration can be done by air or oxygen pumps, by spraying water into the air, like fountain system or by increasing the input of aerated water. It should be remembered that these corrective measures are most effective at night when the oxygen deficiency is the highest.

Damage caused to fish by too much dissolved oxygen in water is rare. However, this can happen, for example, when the fish is transported in plastic bags with oxygen filled air space. Critical oxygen level in water ranges from 250 to 300 per cent of the value of air saturation and the fish may suffer from higher values. When this fish is used for stocking they may suffer from secondary infections, fungi and some of them may die. The fish adapted to such a high level of oxygen should be gradually acclimated to normal concentrations. (Svobodova et al. 1993, 120-148.)

4.4 Ammonia

Ammonia contamination of water can be organic or inorganic origin. In water or biological fluids ammonia is present in the molecular form (NH_3) and the form of ammonia ion (NH_4^+). The relationship between these two forms depends on the pH and temperature of the water (see Table 3). The walls of the body's cells are relatively impermeable to the ammonia ion (NH_4^+) but molecular ammonia (NH_3) can easily diffuse through the tissue barriers where there is a concentration gradient. Therefore, ammonia is potentially toxic form for fish. (Thurston et al. 1981, 981-993.) In addition, under normal conditions there is the acid-base balance in the water-tissue interface. If this balance is changed, the side which the pH is lower will attract additional molecular ammonia. This justifies how molecular ammonia penetrates from water through the epithelium of gills in the blood and how it moves from the blood into the tissues. Ammonia has a harmful effect on the brain that is why nerve symptoms are pronounced in cases of ammonia toxicity to fish. (Svobodova et al. 1993, 152-167.)

TABLE 3. The total ammonia content as % in water in different temperature and pH values (based on Svobodova et al. 1993, 162)

pH	T, °C					
	0	5	10	15	20	25
7.0	0.082	0.12	0.175	0.26	0.37	0.55
7.2	0.13	0.19	0.28	0.41	0.59	0.86
7.4	0.21	0.30	0.44	0.64	0.94	1.36
7.6	0.33	0.48	0.69	1.01	1.47	2.14
7.8	0.52	0.75	1.09	1.60	2.32	3.35
8.0	0.82	1.19	1.73	2.51	3.62	5.21
8.2	1.29	1.87	2.71	3.91	5.62	8.01
8.4	2.02	2.93	4.23	6.06	8.63	12.13
8.6	3.17	4.57	6.54	9.28	13.02	17.95
8.8	4.93	7.05	9.98	13.95	19.17	25.75
9.0	7.60	10.73	14.95	20.45	27.32	35.46
9.2	11.53	16.00	21.79	28.95	37.33	46.55
9.4	17.12	23.19	30.36	39.23	48.56	57.99
9.6	24.66	32.37	41.17	50.58	59.94	68.63
9.8	34.16	43.14	52.59	61.86	70.34	77.62
10.0	45.12	54.59	63.74	71.99	78.98	84.60
10.2	56.58	65.58	73.59	80.29	85.63	89.70
10.4	67.38	75.12	81.54	86.59	90.42	93.24
11.0	89.16	92.32	94.62	96.26	97.41	98.21

Finally, table 3 shows that the concentration of ammonia is dependent on the acidity of the water and the temperature. Therefore, toxicity would be much more in warm alkaline waters than in the cold acid waters.

In addition to water temperature and pH, there are other factors that affect the toxicity of ammonia. Such factors include the dissolved oxygen concentration in water, the lower the concentration of oxygen in the water is, the greater the toxicity of ammonia will be.

To a small extent, the toxicity of ammonia is dependent on the number of free CO_2 in water. This is because diffusion of respiratory CO_2 lowers the pH of water on the surface of gill, thereby reducing the amount of abnormal ammonia inside. Reduction of pH depends on the quantity of CO_2 that is already presented in the water.

It should be noted that all of the standards of acceptable values apply to ammonia as a toxic substance. Other general standards for ammonia are used for control of eutrophication of water and prevent the excessive growth of algae and plants that can cause physical problems and influence the oxygen balance in the environment.

The first signs of ammonia toxicity display a slight anxiety, increased respiration. The fish are close to the surface of the water. In later stages, the fish gasp, anxiety grows with acceleration of movement and breathing becomes irregular followed by the stage of intense activity. Finally, the fish start rapidly responding to external stimuli, losing balance, jumping out of the water, their muscles are reduced in convulsions. Infected fish are lying on their sides, frantically and widely opening their mouths. Then a short recovery period begins and fish returns to regular swimming and seems a little calmer. This phase is replaced by another period of intense activity, in the end, the surface of the body becomes pale and the fish die. (Thurston et al. 1981, 744-812.)

Fish poisoned by ammonia have a light skin color and is covered with a thick layer of mucus. In some cases, there is small hemorrhage mostly based on the pectoral fins and in front of the ocular cavity. The gills are seriously overloaded and contain significant amounts of mucus. If fish are exposed to high concentrations of ammonia that cause severe bleeding from the gills. The sticky mucus can be seen on the inner side of the gill covers. (Thurston et al. 1981, 783-785.)

In recent years significant losses among cultivated trout were caused by toxic necrosis of the gills. Factors that affect the development of this disease include ammonia poisoning in which the amount of ammonia in the blood considerably increases. As has been noted earlier ammonia is the end product of nitrogen metabolism in fish and most of it goes through the gills in the water. If the rate of diffusion is reduced to one reason or another (oxygen deficiency, high pH water, damage to the gills, etc.), the level of ammonia in the blood will rise, leading to a condition known as self-poisoning which can lead to toxic necrosis of trout gills. (Solbe et al. 1989, 112-128.)

4.5 Nitrites and nitrates

Nitrites are usually together with nitrates and ammonia nitrogen found in the surface waters, but their concentrations are low due to their instability. They are easily oxidized to nitrates or reduced to ammonia chemically and biochemically using bacteria. Nitrates are the end product of aerobic decomposition of organic nitrogen compounds. In all surface waters nitrates are present in low concentrations. Practically nitrate is not present in the soil since it is easily washed away into reservoirs, ponds and lakes. The main source of nitrate contamination in the surface waters is the use of nitrogen fertilizers and manures on arable land and the dumping of sewage from the treatment plants. (Brune et al. 1991, 412-425.)

Nitrites can be associated with the concentration of ammonia in the water. Ammonia is oxidized to nitrite and nitrate by using two separate bacterium actions regularly in normal aerobic conditions. Nitrite concentration will increase if the second stage of oxidation is inhabited by bactericidal chemicals in the water (Russo et al. 1991, 45-59).

Toxic effect of nitrite on fish is not fully known. It depends on a number of internal and external factors (e.g. fish species and age, and the overall quality of the water). Value and role of these factors have been studied and analyzed for general comparison. Different authors often come to contradictory conclusions and usually do not provide a definite explanation or mechanisms of nitrite effected harmfully on fish or change the effects of various environmental factors. (Westin 1974, 79-85.)

It has long been known that the nitrite ions penetrate into fish through the chloride cells in gills. In the blood of fish nitrites are closely related to hemoglobin structure resulting in reduced transportation of the oxygen capacity of the blood. The increase in methaemoglobin can be seen as brown color of gills and blood. If its amount in the blood does not exceed 50 % of the total hemoglobin fish usually survive. If the fish have more methaemoglobin in the blood (70 – 80 %) they are torpid and with the further increase in the level of methaemoglobin they lose direction and may not respond to stimuli. (Svobodova et al. 1993, 135-138.) However, the fish may still be alive because the red blood cells in the blood contain an enzyme that can convert methaemoglobin into special cover. This process can return to a normal level of hemoglobin within 24 - 48 hours if the fish is placed in nitrite-free water (Westin 1974, 89).

It is known that chloride in gills of fish cannot distinguish form nitrite and both ions move across the gill epithelium. The level of nitrite uptake depends, therefore, on the nitrite-chloride ratio in the water.

Nitrite toxicity may also be influenced by bicarbonate, sodium, potassium, calcium and other ions but their impact is not as great as from the chloride. Among them, potassium is the most significant, whereas, sodium and calcium have a smaller effect. The monovalent ions are also involved in ion fluxes through the epithelium of gills and directly or indirectly affect the uptake of nitrites. The pH value is also considered being important for nitrite toxicity, pH and temperature affect the dissociation of HNO_2 into NO_2. The uptake of nitrites in blood plasma of fish depends on the diffusion of non-dissociated HNO_2 through the gill epithelium. However, experimental results later disproved this theory and found out that within the acidity-alkalinity range encountered in natural waters pH was of little significance in nitrite toxicity. (Solbe et al. 1989, 130-133.)

Another factor that affects the toxicity of nitrite is the concentration of dissolved oxygen and temperature. This is because the fish need water with high concentrations of oxygen when oxygen carrying capacity of blood decreases by the formation of methaemoglobin and oxygen demand of fish increases with increasing temperature. Prolonged exposure to sub lethal concentrations of nitrites do not do much damage to the fish. Concentrations 20 – 40 % of the minimum levels with lethal effect on fish can slightly depress growth but no serious damage was ever observed.

To evaluate the safe concentration of nitrite for different places, the ratio of chlorides to nitrite must be measured. These relationships should not be less than 17 for rainbow trout. Instead, nitrate toxicity for fish is exceedingly low, and mortality were only recorded where the concentration exceeded 1000 mg/l. 20 mg/l is considered the maximum allowable concentration of nitrates for rainbow trout. In fish farms where the water contains enough oxygen without risk of denitrification, the concentration of nitrates does not need to be monitored. However, like ammonia, water quality standards for nitrates should be installed to prevent eutrophication and excessive growth of plants and algae which can have a negative effect on the fish. (Solbe et al. 1989, 138-142.)

4.6 Hydrogen sulphide

Hydrogen sulphide (H_2S) in polluted waters is a result of the decomposition of proteins. It is also available in industrial effluents including those from chemical and metallurgical plants, and pulp mills. Hydrogen sulfide has from high to extremely high toxicity to fish. A dangerous concentration for salmonids is 0.4 mg/l. The toxicity of H_2S decreases with increasing of the pH of the water. The concentration of non-dissociated H_2S is transformed into less toxic HS ions. Hydrogen sulphide may form from organic rich muds and goes to the overlying waters together with other gases (such as carbon dioxide and methane) formed by the anaerobic decomposition. In aerobic waters H_2S quickly oxidized to sulfates. However, it is possible that fish can be exposed to hydrogen sulfide near the surface of such solutions. (Hellawell 1986, 488-495.)

4.7 Carbon dioxide

Carbon dioxide in water is dissolved in the gaseous state and only 10 % is in the form of carbonic acid (H_2CO_3). These two forms of carbon dioxide together constitute what is called free CO_2. Carbonate ions and bicarbonate ($CO_3^{2-}$and HCO^{3-}- respectively) are fixed carbon dioxide. Their presence is necessary for the buffering capacity of water. The quantity of CO_2 in the flowing surface water is usually in the order of a few mg/l, and rarely rises above 20 - 30 mg/l. (Svobodova et al. 1993, 215-220.) In the standing surface water CO_2 emission level is stratified because of photosynthetic assimilation of phytoplankton. Upper layers usually have less CO_2 than the lower layers. If all free CO_2 in the surface layers is used for photosynthesis the pH of the water can rise above 8.3 and originally moderate alkaline water rises up to pH 10.0. Ground water from limestone or chalk layers typically contains a few tens of milligrams per liter of free CO_2, and it may be relevant, where the water is used for fish farming. (Colt et al. 1991, 372-385.)

There are direct and indirect toxic effects of carbon dioxide. Indirect effect associated with CO_2 affects fish through its effect on the pH of the water, particularly as described earlier the values rise to toxic levels. In addition, changes in pH affects the toxicity of chemicals that exist in dissociated and non-dissociated forms of which only one is non-toxic, such as H_2S and ammonia. (Svobodova et al. 1993, 235-240.)

Direct negative impact occurs when there is an excess or deficiency of free CO_2. In water with low oxygen content, for example, in case of intensive biodegradation or wherever the fish is stored or transported in a high density or when farm use poorly aerated water free CO_2 could reach a dangerous level. In such cases the diffusion of CO_2 from the blood of fish into the respiratory water is reduced and then CO_2 in the blood rises and acidosis is developed. If the CO_2 concentration growth is relatively slow, fish can adapt to acidosis due to the increase of the bicarbonate concentration in the blood. Adapted fish can suffer from alkalinosis in case of return to the water with low content of CO_2. (Svobodova et al. 1993, 241-243.)

In the water with low oxygen and high CO_2 concentration where gaseous exchange in the respiratory surface is restricted, fish increase ventilation rate, the fish become restless, lose balance and can die. 20 mg/l of free CO_2 is considered to be the maximum allowable concentration for trout. Sensitivity of fish to the free carbon dioxide decreases with increasing acid capacity of water. (Svobodova et al. 1993, 255-258.)

However, more frequent is the lack of free carbon dioxide in the water. Carbon dioxide deficiency occurs when too much free CO_2 is used for photosynthetic activity of phytoplankton. Low carbon dioxide concentration below 1 mg/l affect the acid-base balance in the blood and tissues of fish and cause alkalosis. A low partial pressure of free CO_2 in the water leads to a high rate of diffusion of CO_2 from the body which leads to alkalosis and death. (Alabaster et al. 1980, 135-143.)

4.8 Iron

Iron is found in the surface waters in ferric state (Fe^{3+}, mostly insoluble compounds) or ferrous state (Fe^{2+}, soluble compounds). The ratio of these two forms of iron depends on the concentration of oxygen in the water and pH as well as other chemical properties of water. The fish may suffer from iron compounds in poorly oxygenated water with low pH where the iron is present mostly in the form of soluble compounds. Because the surface of the fish gills tends to be alkaline, soluble bivalent iron can be oxidized to insoluble ferric compounds which cover gills lamellar and respiration. (Svobodova et al. 1993, 155-178.) At a low temperature of the water and in the presence of iron, iron-depositing bacteria multiply rapidly at the gills and further oxidize iron compounds. Their filamentous colonies cover gills, which at first are colorless but eventually the residue of iron gives them brown color. The precipitated iron compounds and tufts of the iron bacteria reduce the space in the gills and damage the respiratory epithelium, thereby, suffocating fish. (Roch at al. 1984, 58-65.)

Lethal concentration of iron for fish is difficult to define because this value depends to a great extent on the physical and chemical properties of the water. The concentration of soluble forms of ionized iron should not exceed 0.1 mg/l for salmonids culture (Roch at al. 1984, 77-79).

Summary

The factors considered in this part of the work may occur in the natural environment and can be enhanced by human activities. The fish have a limited ability to adapt to the changes in these factors if they happen slowly enough but a rapid change can be harmful. If fish suffer to some extent from these changes, full recovery is possible by returning to normal place with better conditions. If irreparable damage has been inflicted on the tissues of fish, there are likely to be long-term implications for their health.

5 COMPANY PROFILE

The company “Kala ja marjapojat”, created in 1992, is engaged in cultivation, processing, distribution and sale of rainbow trout. Nowadays this is the biggest company in Russia in growing and processing of rainbow trout and the head office is located in the town of Kostomuksha, Karelia. Cultivation is carried out on five trout farms located on the clean lakes in Northern Karelia (Kuyto and Nyuk) in the near future the company has plans to create two more farms. At the moment overall output of the rainbow trout is 1200 tons per year. By 2015 it is planned to achieve the volume of 2000 tons per year. The cooperation takes place with Finnish companies as well as with Moscow region, St. Petersburg and other Russian regions.

The production cycle of “Kala ja marjapojat” is based on the traditions and practices of Finnish trout farmers. The primary attention is paid to correct feeding of trout, control of growth, timely sorting and changing cages.

The company always strives for environmental technologies and for improving its products through the introduction of new technologies. The boiler that works on fish oil is located on the main base of “Kala ja marjapojat”. It is important to admit that the boiler heats the whole base. This system is used for the purpose of environmentally friendly technologies.

The quality and relevance of products “Kala ja marjapojat” is caused by the following factors:

- Sustainable use of planting material from Finnish and domestic suppliers;
- Food for the fish is supplied by the leading Finnish manufacturer “Raisioagro”;
- Continuous monitoring of the environmental conditions and the state of the grown product;
- Constant veterinary supervision;
- Qualified personnel;
- Availability of advanced fleet, refrigerators and freezing chamber with capacity up to 1000 tons;
- All products are certified and delivered in high quality disposable packaging;
- Recycling in modern manufacturing plants with the equipment conforming European standards.

6 STUDY AREA

The deployment area of the studied cages is located at a distance of 50 – 55 km to the south-east of the town of Kostomuksha in the western part of the lake Nyuk, the distance of about 5 km south-east of the mouth of the river Aittayoki. The coordinates of module cages are 64025.9’N and 31021.7’E, 64025.8’N and 31021.8’E. It is possible to reach studied modules only by water. (The state committee for stand 1933.)

Lake Nyuk belongs to the basin of the river Chirko-Kem, which is the tributary of the river Kem. The area of the lake is 214 km^2, the maximum length is 39 km and the average width is 5.5 km and the widest part of the lake is 22.5 km. (The surface water resources in the USSR 1972, 115-116.)

The maximum depth of the lake is 40 m, the average 8.5 m, the volume of the water is 1.8 km^3, the height above the sea level is 134.5 m and the catchment area is 3090 km^2. On the lake there are 126 islands with a total area of 10.3 km^2. (The surface water resources in the USSR 1972, 120-122.)

The lake bottom is highly uneven and is replete with numerous depressions and elevations. Aquatic vegetation is unusually poor and occurs only in the shallow waters and the coastal zone. The lake belongs to the waters of the highest category as it is inhabited with animals with high sensitivity to oxygen content. In the past this area was used as permanent fishing in large volumes. Today the lake is used for recreational fishing and rainbow trout farming. Therefore, the settlements on the shores do not pour wastewater into the lake. (The surface water resources in the USSR 1972, 120-131.)

The cages for the analysis of data are located in the bay. The bay length is about 7 km and a maximum width is about 2 km (see Appendix 3). The greatest depths are in the southern part of the bay. This place has two modules with cages within the distance of 500 m from each other. The sensor for water quality control is on one of the modules (see Appendix 3).

6.1 Climate

The climate of Karelia is characterized by long winters and short cool summers, considerable cloudiness, high humidity and plenty of rainfalls and snowfalls throughout the year. These climatic features are caused by geographical location the proximity of the Baltic, the White and the Barents seas and the effect of the transfer of air masses from the Atlantic Ocean and the Arctic regions with the preponderance of cyclonic activity. Both winter and summer cyclones bring windy and overcast conditions (175 – 195 cloudy days per year). (Natural Resources and Ecology of Karelian Republic 2007, 48-50.)

Invasion of air masses from the Atlantic Ocean in winter follows by warm temperatures and sometimes by strong thaw with heavy snowfalls. Frequent invasion of arctic air at this time causes drastic frosts. Summer cyclones bring a decrease in temperature and rainfall. Mild weather is replaced with cold. (Climate handbook in the USSR 1968, 144-149.)

The territory with the cages is located in the severe climate, with late spring (the end of May – the beginning of June) and early autumn (the second half of August). (Natural Resources and Ecology of Karelian Republic 2007, 82) The period with a temperature above 10 °C is at least 75 – 85 days a year. On the territory the longest duration of daylight in summer is more than 20 hours in June and July. (Climate handbook in the USSR 1968, 183-185.)

6.2 Air temperature

The average annual temperature in the study area is 0.5 °C. The coldest months are January and February; their average monthly temperature is equal to -12 °C. Air temperature falling to -40 °C is observed once or twice in 10 years. The warmest month is July with an average temperature of 15 °C. The absolute maximum of air temperature is 31 - 32 °C. (Climate handbook in the USSR 1968, 177-180.)

TABLE 4. Average monthly, the absolute maximum and minimum air temperatures (based on Salo et al. 2012)

Description	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**Septem-**	**October**	**November**	**December**
The average monthly	-12	-12.1	-8.3	-1.3	5.3	11.6	15	12.8	7.4	1.2	-4.5	-9
Absolute minimum	-43	-50	-43	-34	-13	-5	0	-3	-9	-24	-38	-45
Absolute maximum	7	6	12	21	29	31	31	29	24	16	9	8

6.3 Rainfalls

The territory under the question belongs to the zone of excessive humidity. This explains the relatively low heat and well-developed cyclonic activity. Average annual precipitation is 586 mm. The annual distribution is given below. (Climate handbook in the USSR 1968, 195-213.)

TABLE 5. The annual distribution of rainfall in mm (based on Salo et al. 2012)

Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Sum of rainfalls	43	36	31	31	40	65	69	70	61	50	48	42

The average date of formation and destruction of the snow layer and a number of days per year with snow layer are shown in Table 6.

TABLE 6. Date of formation of the snow cover and the number of days per year with snow layer (based on Salo et al. 2012)

Number of days with snow layer	Date of occurrence of snow layer	Date of stable snow layer	Date of breakdown of the stable snow layer	Date of disappearance of snow layer
179	19 October	12 November	29 April	14 May

During the winter, the greatest snow depth is 57 cm with an absolute maximum of 94 cm and a minimum depth of 44 cm.

TABLE 7. Snow depth (based on Salo et al. 2012)

Month	November			December			January			February			March			April		
Part of the month	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Depth in cm	6	13	17	24	28	32	37	42	47	50	53	56	57	57	57	49	31	16

6.4 Wind

According to the wind rose of the study area, in this area there is no significant predominance of any wind direction. In the period between the beginning of May and the end of October the average monthly wind speed is 4 m/s and the average number of calm days is not more than 15 %.

7 PROCESS OF FISH GROWING AND FEEDING IN “KALA JA MARJAPOJAT”

Various designs of cages can be used at the trout cultivation farm. The company “Kala ja marjapojat” uses polygonal cages with depth of 7 m and the volume of 1450 m^3 for growing commodity trout. The most viable option of support structure can withstand the wind and wave loads. The integral framework is welded from polyethylene pipes with a diameter up to 500 mm.

Optimal place for cultivation of the fish in the cages in spring is the coastal area of lake Nyuk where the water is warmed faster than in the central part. The flowing areas of the lake, where the cages are located, improve oxygen conditions and reduce water pollution. However, the flow rate should not exceed the level of 1.5 the length of fish or 0.5 m/s. (Neville 1979, 84-87.)

When cultivating commodity fish in cages it is necessary to consider that the iridescent trout is physostomous fish. Therefore, it needs to rise to the surface to breathe in the air. In this case, the access of the fish to the air is constantly provided in the cages. In addition, to protect the trout from the birds that not only eat but also hurt and damage the fish, the nets are stretched over the cages.

The whole processes consist of the total care of cages, fish feeding, and monitoring oxygen regime and water temperature, controlling the growth of the fish, removing dead fish.

Trout feeding

When using dry granules for feeding the trout it is necessary to consider not only their quality but also the sizes of granules. Granule sizes should match the fish mass. Under or overestimation of the size of the granules will usually lead to the slowdown of the growth rate of the trout and the increase in metabolic cost, loss of food which eventually reduces the effect of the growing rate. (Kindschi et al. 1991, 197-200.)

One of the major operations for commercial fish farms is the frequency of feeding during the day. From the start of feeding it is necessary to set up a timetable and stick to it while feeding throughout the growth of the fish. Frequency of feeding of studied fish is twice a day from 10 to 12 am (60 % of daily volume) and 18 to 19 pm (40 % of daily volume).

In the company “Kala ja marjapojat” feeding is done by hand because the feed is distributed more evenly over the whole area of the cages. In this case, visual monitoring of fish behavior and their need for food is possible. Proper and careful hand-feeding reduces the degree of inequality in the distribution of the weight of fish in cages.

Another important parameter to be considered for trout feeding is the dissolved oxygen in the water often given as the saturation level in percent. The fish constantly needs oxygen for biotic processes. As a result of food consumption it is self-sufficient in nutrients and essential biotic energy which is released by the oxidation-reduction processes occurring in the body with the direct participation of oxygen. (Kindschi et al. 1991, 209-218.)

During the feeding process oxygen consumption increases dramatically due to the increased activity of the processes associated with digestion, absorption in the gut and activation of metabolism. The more nutrients absorbed by the body of fish the more oxygen is required for this. In the water the level of oxygen saturation changes depending on the temperature of the water (see Table 8). (Beveridge et al. 1996, 97-98.)

TABLE 8. Solubility of oxygen in water (mg/l) different temperatures at 100 % saturation (based on Beveridge et al. 1996, 105)

t, °C	**O_2**	**t, °C**	**O_2**
0	14.6	12	10.8
1	14.2	13	10.6
2	13.8	14	10.4
3	13.5	15	10.2
4	13.1	16	10.0
5	12.8	17	9.7
6	12.5	18	9.5
7	12.2	19	9.4
8	11.9	20	9.2
9	11.6	21	9.0
10	11.3	22	8.8
11	11.1	23	8.7

However, it should be noted that in freshwater absolute saturation of water practically almost never occurs. Commonly, for satisfaction of requirements of the trout a maximum level of water saturation is not required.

When using modern feed granules, potential risk is overeating by fish, leading to significant loss of feed, poor absorption and as a result reduces the rate of trout growth. Hungry trout eats more food than it needs for efficient growth which leads to overeating and reduces the appetite for the next day. Next day it becomes so hungry that again the risk of overeating rises. This situation can be repeated again and again. As a result, the body of fish is weakened so that it will not effectively absorb nutrients resulting in inefficient use of feed granules. The feeding process in “Kala ja marjapojat” is done with feeding tables from the company “Raisioagro” which provides dry food granules (see Appendix 2).

Energy value of food

Efficiency of fish growing is measured by feed conversion ratio. Feed conversion ratio (FCR) is calculated as the ratio of the mass of food consumed by increase of fish weight during this time:

$$FCR = \frac{Weight\ of\ food\ consumed, kg}{Biomass\ increase, kg}$$

To assess the development of fish in natural environment, the use of this indicator is suitable since the chemical composition of the food and the body of fish is similar. When feeding fish with pellets, the water concentration in the feed varies from 6 to 7. This means that the amount of feed conversion ratio is underestimated equally. Therefore, the feeding rate (FR) should be used in assessing the effectiveness of fish feeding. It shows the ratio of the weight of the fish feed to the general increase in biomass of fish in a given time:

$$FR = \frac{Weight\ of\ the\ feed, kg}{Biomass\ increase, kg}$$

Feeding rate should not be compared with the FCR as is sometimes done. FR indicator will always be lower than FCR since not all of given food is eaten by fish; some food is always lost. Index FR of 1.0 means that raising one kg of fish mass takes one kg of feed.

Common to both formulas is that the lower their value, the greater the effect of feeding is. This means that between the formulas and feed efficiency an inverse relationship is observed. From the economic point of view, using the FR indicator is more suitable. Usually when feeding fish with dry granules, FR value ranges from 0.9 to 1.4.

The fish was fed with commercial granule food and the chemical compositions of the food are shown in Table 9. The composition of the granules was the same throughout the experiment. The daily feeding of rainbow trout depends on the water temperature and the size of trout.

TABLE 9. Feeding granules composition

Parameter	**Compositions**
Digestible energy, MJ/kg	18
Total energy, MJ/kg	23
Protein, %	50
Fat, %	22
Water, %	9
Fibers, %	0.5
Ash, %	9
Carbohydrates, %	9.5

Specific growth rate

The fish were weighed every two weeks to get specific growth rate (SGR). Both the initial weight and final weight of the fish were used for the calculation of productivity growth in terms of SGR. The SGR of studied fish was calculated as:

$$\% SGR = [\ln w2 - \ln w1/t2 - t1] * 100$$

Where w_1 and w_2 are the initial and final weights of the fish at times t_1 and t_2 respectively.

8 CONTROL OF WATER QUALITY

In the process of cultivation of rainbow trout the organic compounds and nutrients, mainly phosphorus and nitrogen, are contaminating the environment. Sources of nutrient income are usually metabolism of organisms.

An intake of organic matter and nutrients into the aquatic environment depends on the content of these components in the feed used for growing trout. Therefore, properly digestible pellets with low phosphorus are used during the growing process. If necessary to minimize dust falling into the water from feed process screening before feeding is used. In addition, to reduce the loss of food in the process of feeding the following conditions are provided: adherence of feeding regarding the weight of the fish and the water temperature; the right choice of location of the cages; the use of modern feeding technology; proper storage of feed. Control over the quality of the aquatic environment in the area is carried out seasonally in cages and 500 meters away from cages and the samples are analyzed in a licensed laboratory.

On the trout farm the report with hydrochemical monitoring and temperature regimes are noted. Control of hydrochemical regime includes periodic determination of dissolved oxygen, temperature and pH. It is important to control them in spring when the reservoir with the melted water gets a large number of different substances. During the period of high water temperatures and strong fouling of cages or heavy water bloom, oxygen is monitored more carefully. Indicators of dissolved oxygen in the water and the pH and other hydrochemical indicators are recorded. If the oxygen concentration is reduced down to 4 - 5 mg/l, water should be aerated by mechanical pumps of air into the cages or with compressor. Such low levels were not observed during the studied period.

9 MATERIALS AND METHODS

The five cages with rainbow trout were selected to provide the study. Average weight of fish and the density of the studied fish in cages at the beginning of an experiment are presented in Table 10. The research lasted 7 months during the period of trout feeding.

TABLE 10. Size and density of the trout at the beginning of the experiment

Cage	**Initial number of fish**	**Average weight (g)**	**Biomass in cages (kg)**	**Density (kg/m^3)**
1	22626	0.165	3733.3	2.57
2	22296	0.165	3678.8	2.54
3	26985	0.168	4538.9	3.13
4	21917	0.169	3704	2.55
5	13934	0.169	2354.8	1.62

Sampling and water sample analysis

In this study water samples were collected from rainbow trout farm from May to November 2012. Water samples were kept in glass and plastic screw capped bottles. Glass bottles were used to determine dissolved oxygen (DO). The water samples in plastic bottles were used for determination of eight physicochemical parameters of water samples such as total suspended solids, BOD_5, total phosphate, ammonia, oil products, total iron, dissolved oxygen and pH which were determined by traditional and new methods. After sampling the labeled bottles were transferred to the laboratory within a few hours.

Physicochemical water quality parameters were measured in the site according to standard methods. All the methods and procedures were made in accordance with those recommended by APHA-standard method. (APHA 1991) ASTM – D5907 method was used to determine total suspended solid (TSS) in the water. The value of BOD_5 was calculated using the standard method described by Boyd (1979). Level of PO_4^{-3} was determined using the standard molybdenum blue method. Ammonia was determined using the standard method 4500-NH_3. The determination of dissolved oxygen was using the Winkler method according to Strickland and Parsons (1972). The pH of the samples was measured using a hand held Sigma Hanna Checker 1 pH meter.

The growth performance and body mass were measured every two weeks, while mortality, the temperature of water, the air temperature, pH, oxygen concentration in the water were recorded daily. Mortality was calculated at the end of the day in each studied cage. All other parameters were measured by the online monitoring station. The sensor worked online and collecting the data every hour. Excel 2010 was used for statistical analysis and drawing charts.

10 RESULTS AND DISCUSSION

The water quality forms one of the main factors governing the health of fish under culture environment. Hence, the management and monitoring of water quality are important in ensuring good fish health. The conservative nature of the marine environment, the large water volume and exchange, the water quality variables such as total alkalinity, total hardness, pH, nitrogen compounds and hydrogen sulphide were considered of little importance. (Hellawell 1986, 25-72.) However, there are variations during period of cultivation in pH, dissolved oxygen, ammonia, nitrites, nitrates, phosphorus and sulfates.

This information is relevant for the development of monitoring programs for freshwater aquaculture because it provides a basis for incorporating suitable management procedures. New technologies have lower environmental impact than traditional aquaculture methods and their implementation should be encouraged. For instance, quality feeds result in less release of wastes to the environment, as well as fast and effective fish growth. However, the magnitude of any effect depends mainly on the intensity of fish production, waste dispersion by currents and the environmental carrying capacity to assimilate any organic loading.

The range of environmental impact depends on the amount of wastes produced by the studied cages, and is evaluated by the stocking density, amount and type of feed, feed composition, size of granules and the physicochemical conditions where cages are located. The level of fish production that would be sustained in an area is variable depending on different impacts. Several studies have been carried out around the world about the relationship between the produced wastes by freshwater cages and their effect on the water quality and feeding procedure. (Hellawell 1986, 113-118.)

10.1 Physicochemical parameters of the water

Data of water quality parameters of studied cages of the rainbow trout and 500 m from the cages are given in Table 11. The results were taken from two points: top layer and bottom layer (see Appendix 1). The data were collected three times during the experiment in May, June and August. The trout farm has no significant impact on the environment and all the parameters are in standard limits. In both places the value of the water key parameters is kept close to the recommended values for salmonids aquaculture. (Industry standard 1988, 19-52.)

The pH value is not high enough to produce a toxic effect. Variability between the pH values was not high. The elevation of pH was not statistically significant. Even the pH near the cages of the trout farms was still within the acceptable limits of 6.5 – 8.5 proposed by different standards. (Boyd et al. 1998, 12-213.)

The average value of BOD_5 is also within limits range. This parameter is not toxic itself and may act as a surrogate for sediment quality since the settlement of particulates with a high BOD_5 leads to reduced interstitial dissolved oxygen. The change in the BOD_5 of the studied site due to output of organic matter by trout farming activities was found to be statistically significant. The rise in BOD_5 mean was found to be increased in summer months, most likely due to rising water temperatures and higher feeding rate applied by the farm. Higher feeding rates increase the output of organic matter from the farm either as uneaten feed and result in marked elevation in the BOD_5 of the receiving water. The measured value would be expected to decrease further downstream from the trout farm, since flowing water has the capacity of undergo self-purification which would result in lower BOD_5. (Miller et al. 2002, 35-114.)

TABLE 11. Water quality parameters of the studied cages and the point near the cages, the average data from three records

#	Parameters	Standard value	Cages top layer	Cages bottom layer	Point nearby cages top layer	Point nearby cages bottom layer
1	pH	6.0 – 8.5	5.9±0.2	6.25±0.2	5.86±0.2	5.84±0.2
2	Suspended solids, mg/l	<10	<3.0	<3.0	<3.0	<3.0
3	Biochemical oxygen demand (BOD_5), mg/l	<2.0	0.8±0.12	0.96±0.12	0.84±0.08	0.78±0.08
4	Phosphates (PO_4^{3-}), mg/l	<0.3	<0.05	<0.05	<0.05	<0.05
5	Ammonia ion (NH_4^+), mg/l	< 0.5	0.2±0.05	0.193±0.05	0.2±0.05	0.2±0.05
6	Oil products, mg/l	<0.05	<0.005	<0.005	<0.005	<0.005
7	Total iron, mg/l	<0.5	0.43±0.12	0.43±0.12	0.44±0.12	0.44±0.12
8	Dissolved oxygen (DO), mg/l	≥9.0	13.41±1.4	13.2±1.4	12.53±1.4	12.87±1.4

The average value of suspended solids was within the limit which explains a good fish appetite. Suspended solid can create the problem of slow growth rates caused by visibility during the feeding process and gills clogging.

Estimated mean load of phosphorus per ton of feed used and per ton of fish produced in the trout farm in studied cages does not exceed the values found in the literature. In this study, even in the cage with efficient feed management and the lowest FCR the estimated phosphorus load per ton of feed used (3.5 kg P) was less than loads reported by the other studies. The lower phosphorus loads on the trout farm investigated in this study seemed to be associated with the low phosphorus content of used feeds and sufficient feeding table. The phosphorus content of feed used at “Kala ja marjapojat” in 2009 was 1.5 %. Nowadays the phosphorus content in feed is less than 0.1 %.

The mean ammonia ion concentration in the trout farm in the both points same. The values were did not differ from each other significantly (see Appendix 1). The NH_4^+ concentration of the rainbow trout farm was not exceeding the recommended limit for salmonids farms (0.5 mg/l). The concentration is not sufficient to cause toxic effects on fish population, although the toxicity will vary not only with total ammonia concentration but also with the distribution between ionized and un-ionized forms. This distribution varies with pH, temperature and dissolved oxygen.

The value of oil products was measured in case that the farm used boats with engines running on gasoline. Values do not exceed permissible values and figures were low. From this data it can be concluded that the release of oil products is almost zero.

The value of total iron is selected as one of the important parameters due to the high iron concentration in lake Nyuk. Values of total iron approaching the highest allowed limit but did not exceed those limits. The total iron had no effect on other hydrochemical parameters and does not change the taste of the fish.

During the study a reduction in the dissolved oxygen concentration in the studied cages was found as a result of the trout farming activities. The dissolved oxygen concentration of the point nearby cages was lower than below the trout farm throughout the study. However, the pattern of reduction revealed a monthly variation. This variation was described in differences of the feeding levels during the studied period and the fish biomass. Higher fish biomass and intensive feeding increased the dissolved oxygen demand of the farm and resulted in higher dissolved oxygen intake from the feeding water. (Davies et al. 1994, 1312-1455.) All data were within the acceptable values and do not show the critical values. It can be concluded that the location of cages was well chosen.

10.2 Growth

The average body weight in grams of the experimental rainbow trout at the end of the study was on average 755.5 % higher than at the start of the experiment (see Figure 3). As shown in Figure 4, the total growth of fish was high at the end of the study and in the cage 5 the values were lower because the amount of the fish was lower. The total biomass of farmed fish of the study period increased on average by 694 %, compared to the amount at the beginning of the experiment.

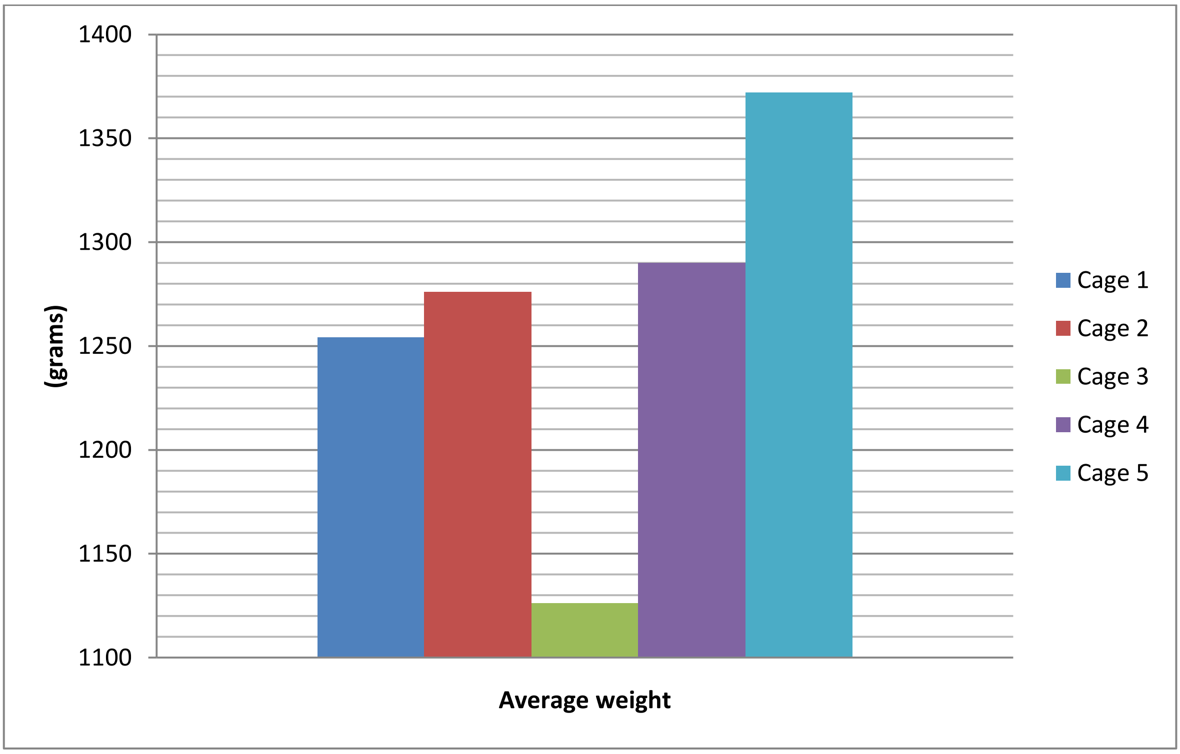


FIGURE 3. The average weight of cultivated rainbow trout

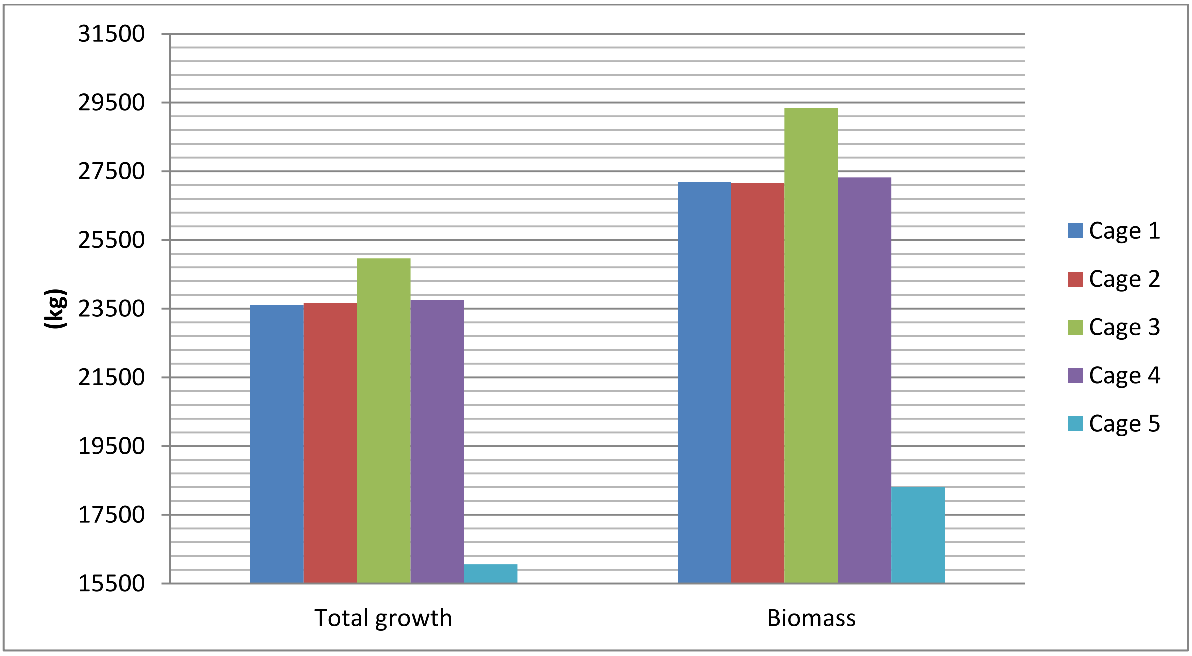


FIGURE 4. Total growth and biomass of cultivated fish

The initial average weight of the fish, average weight, average weight gain, final average weight, feeding rate and feeding factor are shown in Table 12.

TABLE 12. Feeding rate and growth rate of the studied fish

Cage	**Days of feeding**	**Initial average weight (g)**	**Final average weight (g)**	**Average weight during the experiment (g)**	**Average weight gain (g/day)**	**Feeding rate**	**Feeding factor**
1	144	165	1254	724	7.56	1.17	0.15
2	144	165	1276	735	7.71	1.16	0.15
3	144	168	1126	666	6.65	1.05	0.16
4	144	169	1290	745	7.78	1.04	0.13
5	144	169	1372	792	8.35	1.05	0.13

The initial average weight of the fish is calculated as the total weight divided by the number of the fish at the beginning of the experiment (see Appendix 5). The calculation of final average weight is done by the same way as initial average weight of the fish. The average weight during the experiment is the average value of the six weighing of the studied fish.

$$Average\ weight\ gain = \frac{Final\ average\ weigh}{Initial\ average\ weight\ of\ the\ fish}$$

$$Feeding\ rate = \frac{Weight\ of\ the\ feed, kg}{Biomass\ increase, kg}$$

$$Feeding\ factor = \frac{Feeding\ rate}{Average\ weight\ gain}$$

Average weight gain

The average weight gain is as low as about 6.65 g/day for cage number 3 and the biggest weight gain is 8.35 g/day for cage number 5. The growth rate of cage number 5 is very close to the higher level because the density of the fish is not so high. This means the conditions of this experiment were similar to optimal for fish farming and the fish in this group were adapted to the experimental environment faster than in the other cages. The main reason for the biggest difference of the growth rate of the fish is because the density in this cage was not very high.

Feeding rate and feeding factor

The scientific method by which feeding rate is calculated is based on the requirement for energy consumption by the fish. Most of methods commonly used have been based on the body length increase. For this experiment feeding amount was based on the amount of food which was consumed by the fish. An optimal feeding rate should make feeding factor equal to 0.30. That means all feed has been consumed by the fish. The feeding factor in the experiment was lower than the values provided by the most references. The reason is that feed amount was almost fully consumed by the studied fish.

Growth curve for each cage

The fish was weighed seven times during the experiment and the average weight of each group is presented in Table 13.

The growth rate of each cage in the first half of the experiment was higher than that of the second half. Many factors influence the growth of fish: size, diet, temperature and photoperiod. The most significant factor for the fast growth in the second studied period is the fact that the fish were adapted to the water conditions and food consumption was, therefore, much greater. It can be explained using a basic growth model calculated by fish intake of mass and output of mass at the end (Growth = In - Out).

TABLE 13. Average weight of fish

Day	**Cage (g)**				
	1	2	3	4	5
1st	165	165	168	169	169
34th	172	172	174	176	180
62th	383	386	367	394	422
90th	531	536	512	546	592
124th	862	877	789	887	944
153th	1145	1164	1027	1177	1244
183th	1254	1276	1126	1290	1372

Intake was greater than output in the second period so growth was fast. During the experiment the increase of weight was linear. The growth rate increased when the fish had adapted to the environment. Another reason of faster growth in the second period was because the temperature gradually decreased. The water temperature is a critical factor for determining how much food fish will eat (see Appendix 2). The average water temperature in the whole studied period is given in Figure 5. Water temperature fluctuated between 4.6 and 18.2 °C in the whole experiment but an overall decrease was seen in the period of time between July and October. It was seen that food consumed by the fish in the second period was much more than that of the first period and this means the food consumption of the fish became higher. The third reason is decreased oxygen saturation with time. This factor will be described in the next part.

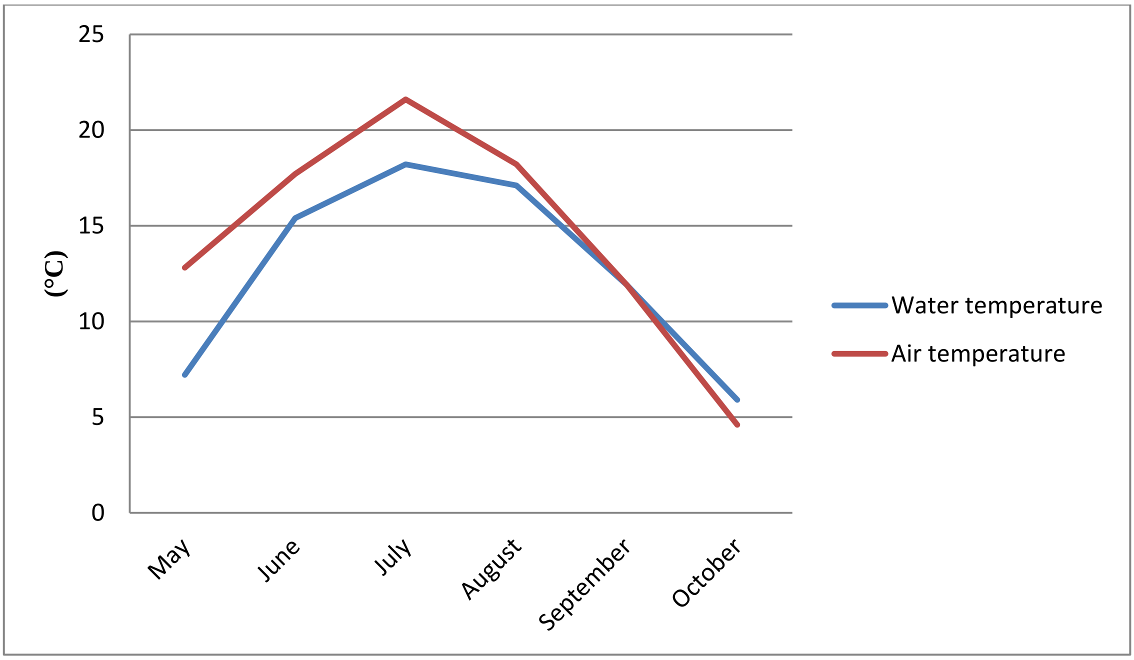


FIGURE 5. The average temperature of the water and air during the studied period

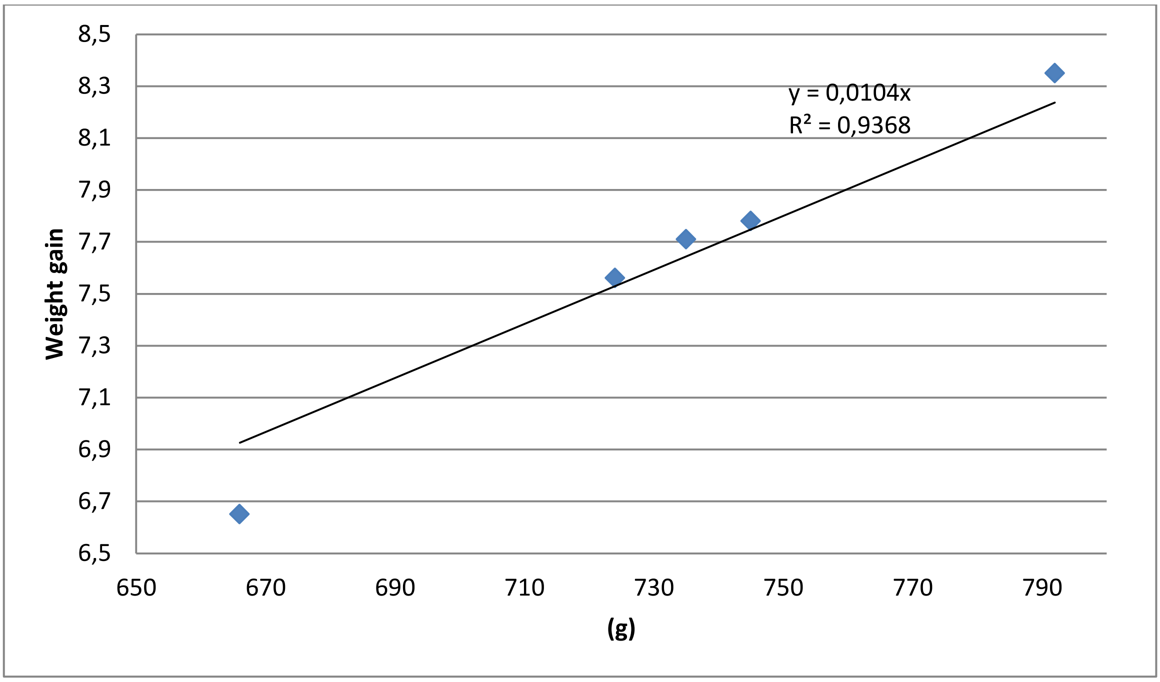


FIGURE 6. Correlation of the relationship between weight gain and average weight

The average weight in each cage during the experiment was calculated (see Table 13). The result of regression analysis for average weight and average weight gain is shown in Figure 6.

The average weight gain equation for all the groups is:

$$Average\ weight\ gain = 0.0104 * Average\ weight, R^2 \ = \ 0.9368$$

Since average weight gain is the weight gain of each fish during the experiment:

$$Average\ weight\ gain = \frac{d(Average\ weight)}{d\ (t)} = 0.0104 * Average\ weight$$

$$\frac{d(Average\ weight)}{Average\ weight} = 0.0104 * d(t)$$

The result of integration of this equation for weight 165 g at time 0 is as follows:

$$Average\ weight = 165e^{0.0104t}$$

The relationship between the weight gain and weight should be linear on a log-log scale. The reason for average weight gain to be linear with relation to weight in this experiment is probably long time duration of the experiment and almost similar length of the fish. Besides, the growth occurs under optimal conditions especially regarding oxygen saturation and density of the fish in cages.

According to this equation the growth developing for all the fish sizes is obtained (see Figure 7). It is known from the growth curve that it will take 144 days for the fish grow from 165 g to 1372 g. In this case the smallest average fish in this study and the largest average fish were used.

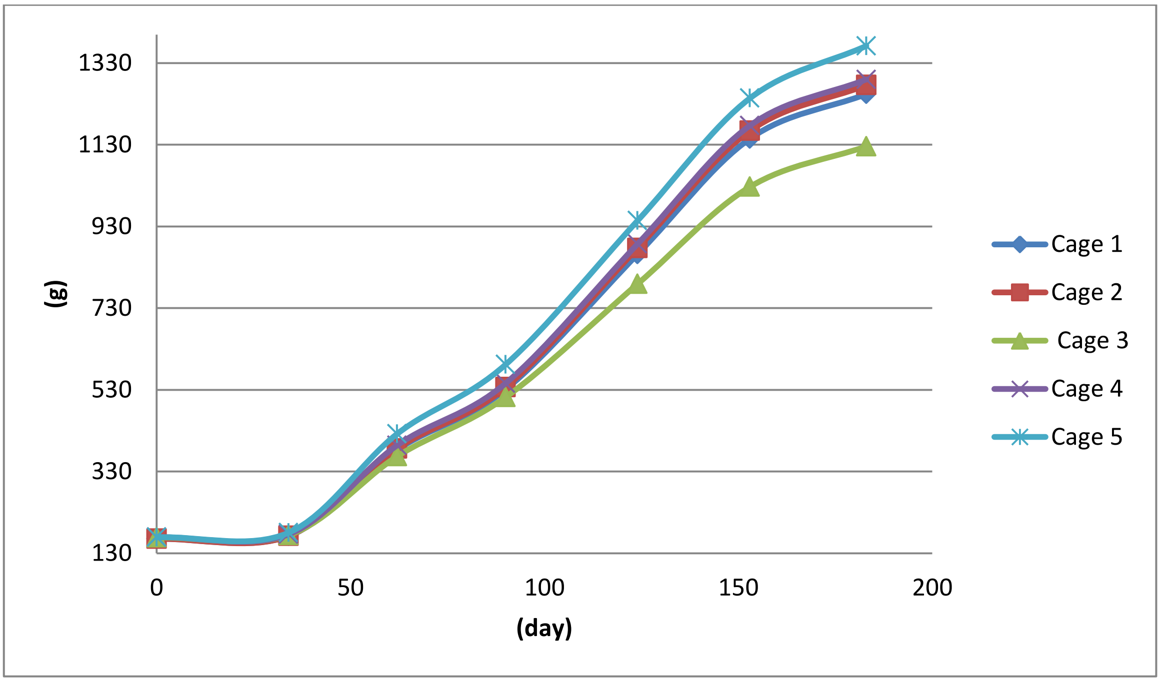


FIGURE 7. Growth curve of the fish during the experiment

The highest growth presented in cage number five is due to the fact that the feeding and growth of the fish proceed in optimal limits. Cages 1, 2, 4 are presented the growth rate at a high level but on the basis of the indicators of the fifth cage it can be concluded that the increase in the fish growth can be achieved more successfully. In case the fish cage number three shows the least growth of the fish, it is probably due to the fact that at the beginning of experiment the biomass in the cage was greater than in the other cages and the growth is slow down during the time.

Feeding rate equation

The regression result for average weight and feeding rate (see Table 12) is given in Figure 8.

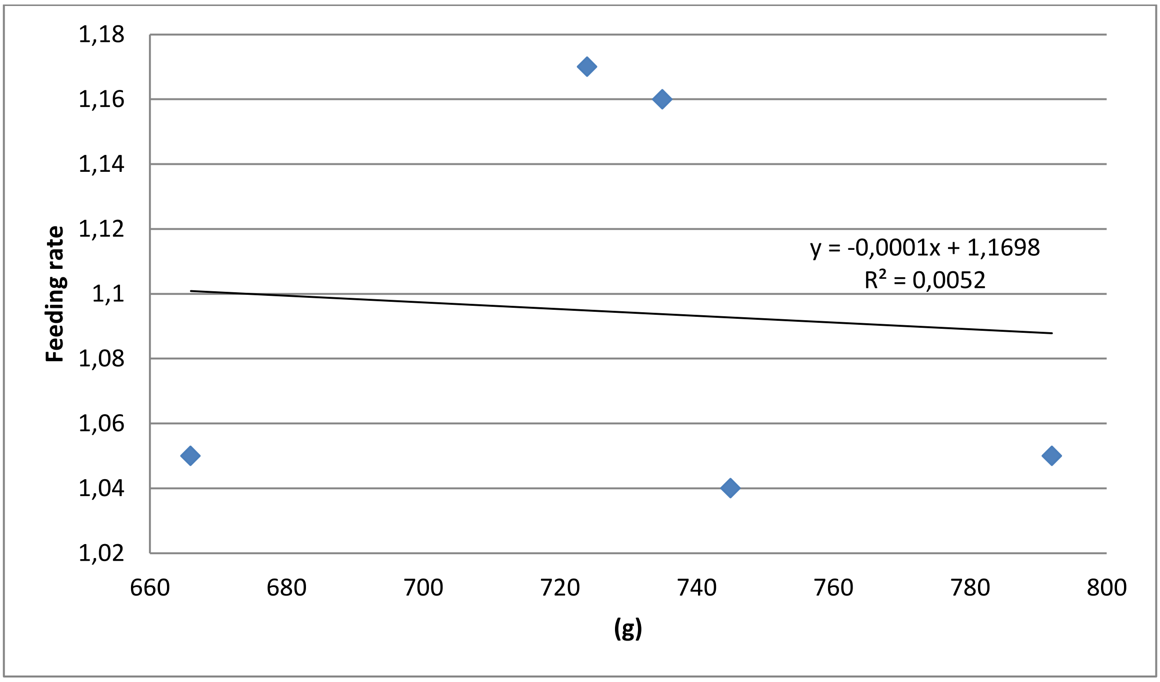


FIGURE 8. Correlation of the relationship between fish size and feeding rate

It is shown in figure 8 that the following equation fits the data:

$$\ln(Feeding\ rate) = -0.0001 * \ln(Average\ weight) + 1.1698$$

$$Feeding\ rate = e^{1.1698} * Average\ weight^{-0.0001}$$

$$Feeding\ rate = a * Average\ weight^{b}$$

There was no significant difference in feeding rate of fish reared at different oxygen saturation levels (Figure 9). However, the feeding rate was the lowest at 91.8 % and the highest at 95.5 % saturation.

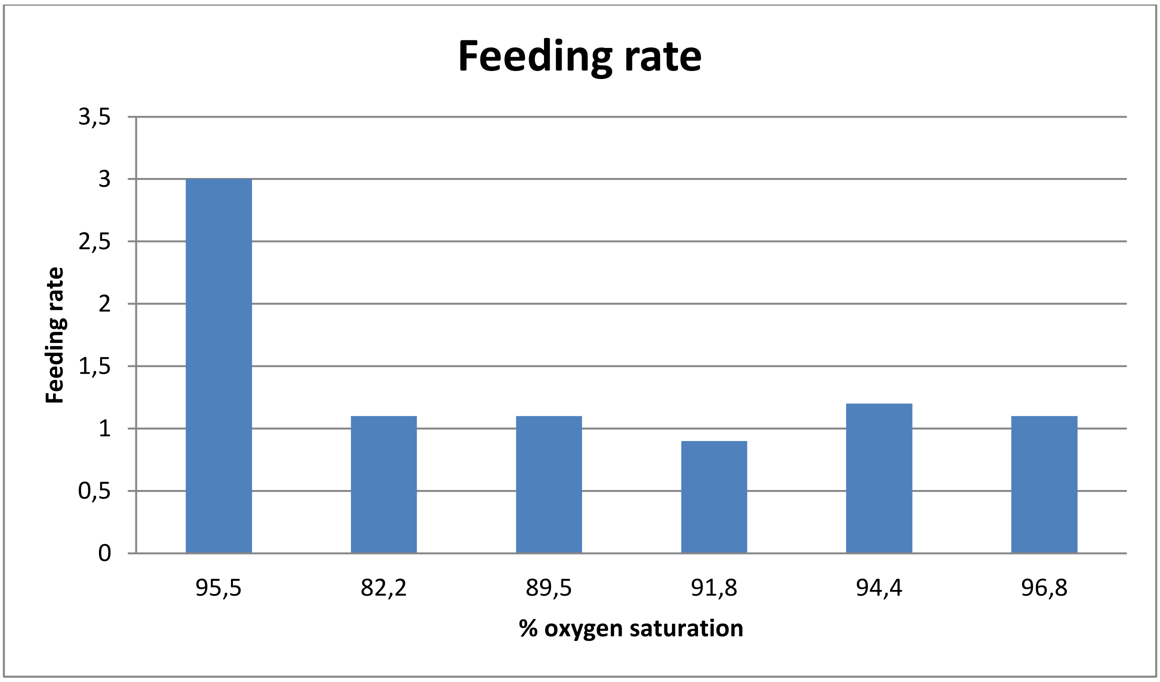
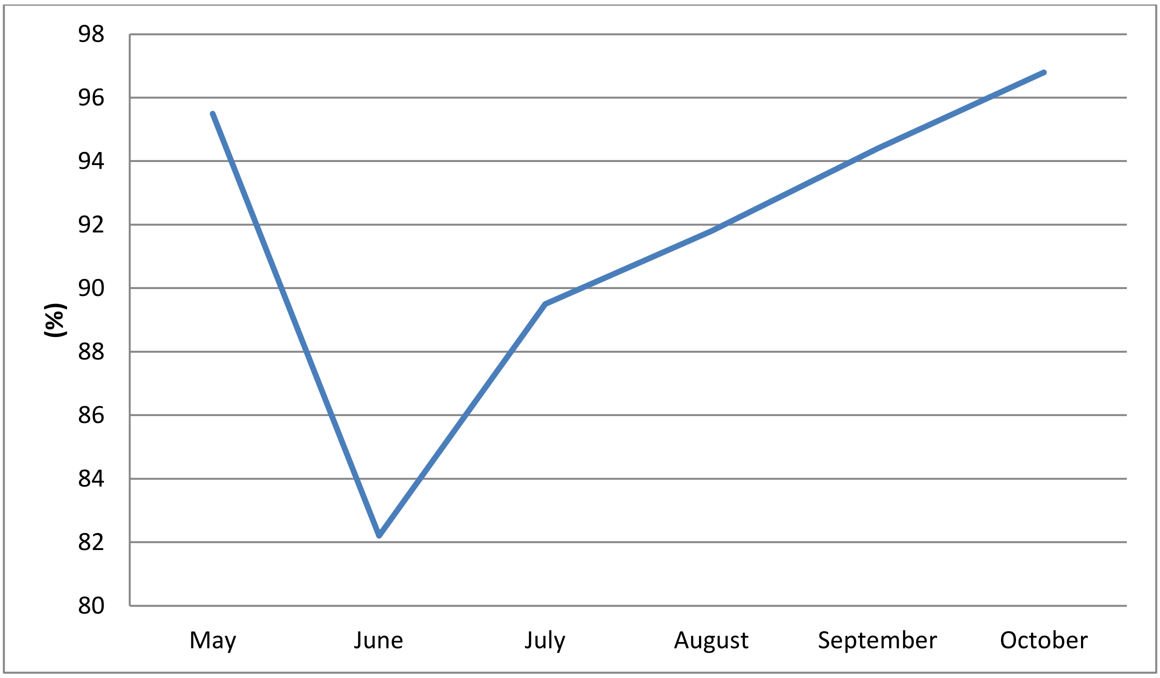


FIGURE 9. The feed conversion ratios of the rainbow trout reared at different oxygen saturation levels

10.3 Oxygen saturation

The oxygen saturation was lower in June and the value was 81.2 % (see Figure 10). The level of oxygen saturation was higher than the optimal value. The limiting dissolved oxygen levels for the rainbow trout is around 70% oxygen saturation. The reason for oxygen saturation decreasing was due to the rapid increase of the water temperature in the studied cages. Not keeping the same temperature during the experiment leads to the lower oxygen saturation resulted in a higher feeding factor. Therefore, the level of the feeding factor was not too high. The ideal value for feeding factor is minimal and this is always the aim in the aquaculture.



FUGURE 10. Average oxygen saturation during the experiment

There was no significant difference in growth rate of the rainbow trout reared at different oxygen saturation levels (see Figure 11) during the different periods of time. However, there was a significant difference in the growth rate of the fish during the summer period. Then the specific growth rate of fish reared at 82.2 % saturation was significantly higher than that of the fish reared at either 95.5 % or 96.8 % saturation. Also the specific growth rate at first value and the last one is not so high because the weight of the fish at the start of the experiment and at the end increased slowly.

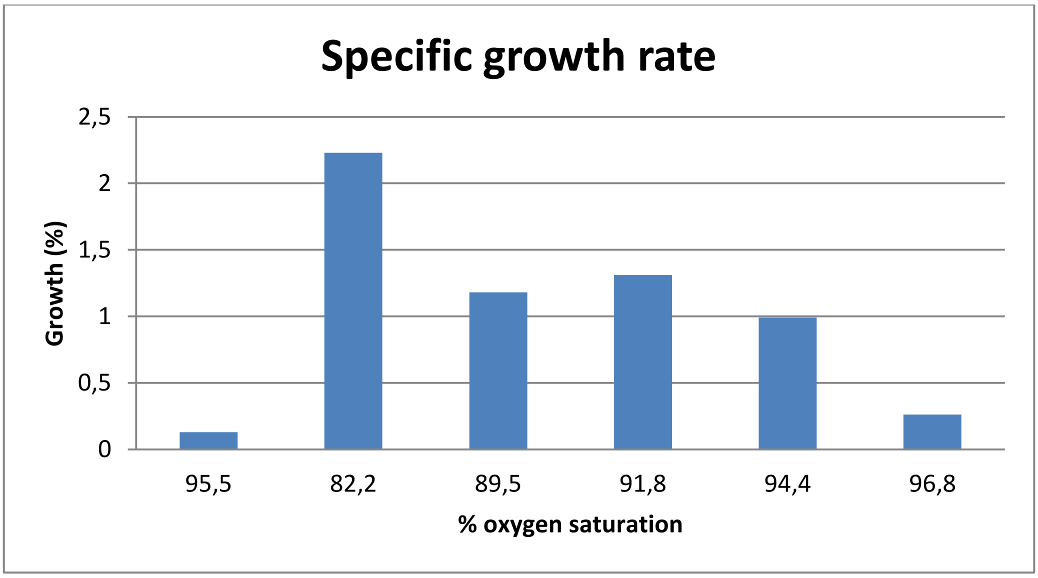


FIGURE 11. The average specific growth rate of the rainbow trout reared at different oxygen saturation levels

Under different oxygen levels, the results of the study clearly show that the growth is affected by the saturation level of oxygen. During the second part of the experiment the specific growth rate was highest at 82.2 % saturation. The temperature regime is also extremely important factor in this case. The best feeding rate was obtained in the cages with the highest growth rate although there was no significant difference in feeding rate of fish reared at different oxygen saturation levels. Only at the start of the studied period was the highest dependence on oxygen saturation in the water. The growth of rainbow trout increases with increasing saturation close to 100 % saturation. However, the salmonids appear to be more sensitive to oxygen saturation in the water. Of course other factors also affect the growth of the fish but they are not so critical.

10.4 Correlation of the mortality and other factors

Mortality of the fish is one of the most important parameters that affect the final study result. Since the mortality of the fish was counted every day it was possible to find the dependence on various factors (see Figure 12, 15, 16).

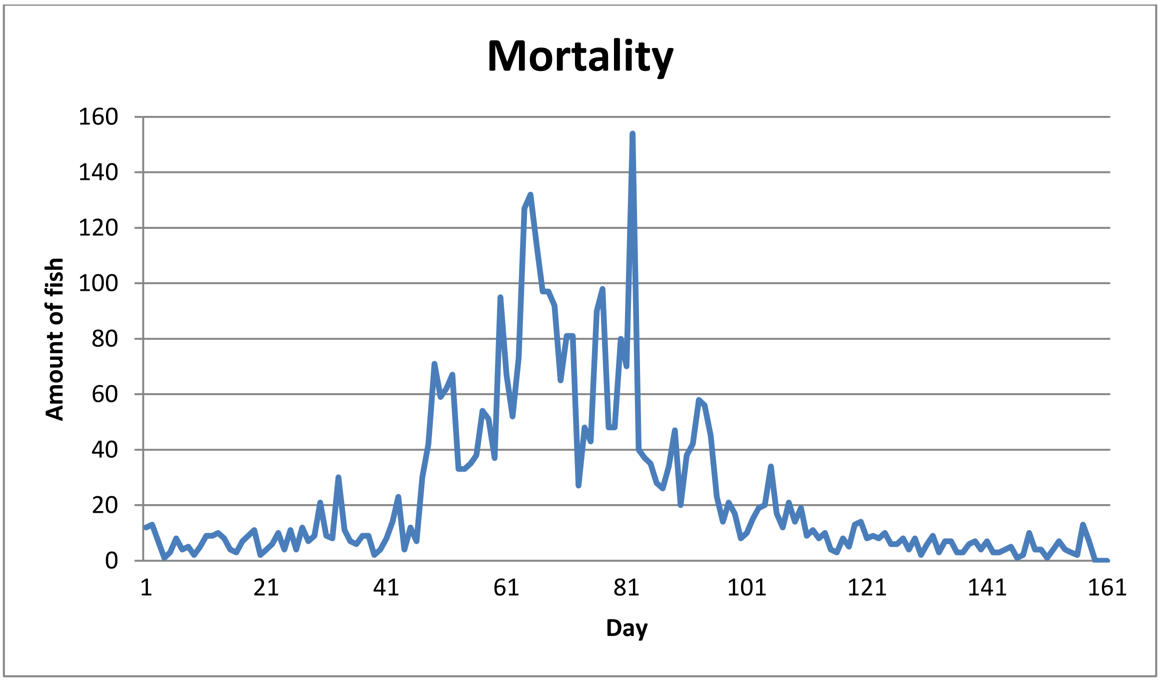


FIGURE 12. Mortality of the studied fish during the experiment

Mortality increases dramatically in the summer period when the water temperature begins to rise (see Figure 13) and the amount of feed increases (see Figure 14). Since feeding tables are provided by the producer company (see Appendix 2), it can be concluded that the coefficients presented in these tables are not suitable for the fish in the chosen area. Not only the water temperature but the oxygen concentration in the water should be considered before feeding process. Therefore, the feeding tables require improving.

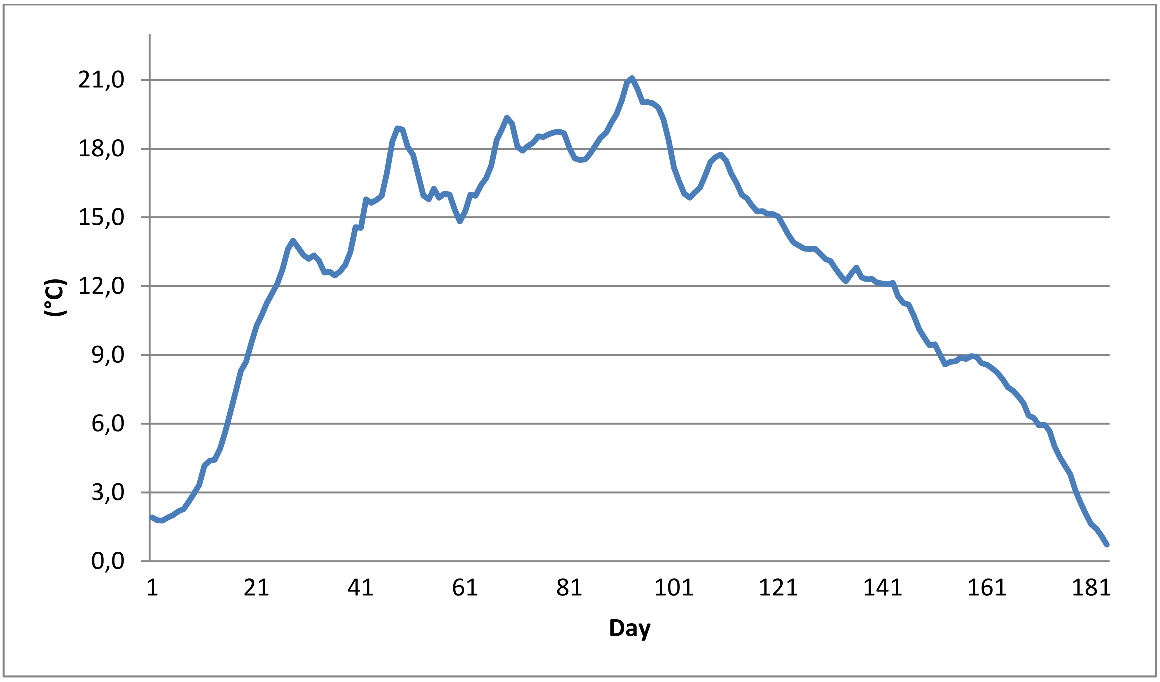


FIGURE 13. Temperature of the water during the study period

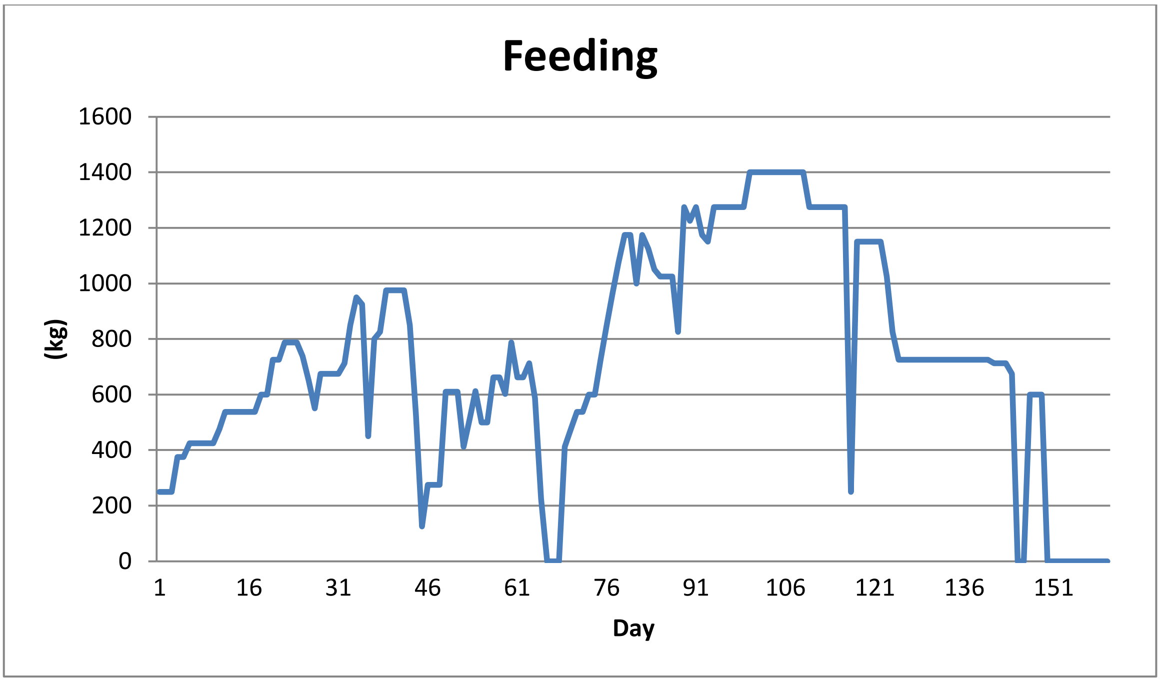


FIGURE 14. Weight of the feed during the experiment

There is a high mortality in the summer also connected with the fact that in the summer the feeding was stopped for a while (see Figure 15). This break in feeding is resulted in the failure of the digestion which leads to higher mortality rates. In the period of the high water temperature the volume of feed decreased but the fish continued dying. This can be explained that feeding of the fish should not have such large volumes of food and then the fish would take the optimal growth rate.

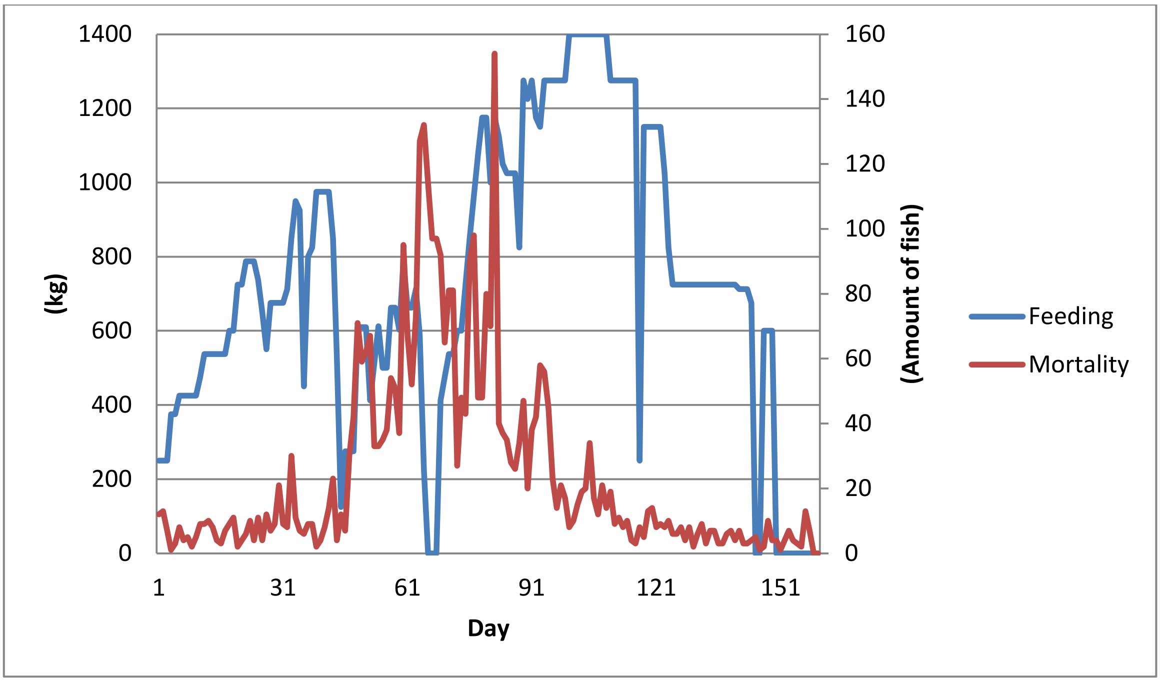


FIGURE 15. The relationship between mortality and feeding volume

In addition, based on information in the theoretical part of the thesis the oxygen content in the water can be considered the main aspect affecting the mortality of the fish in the cages. This parameter was measured every hour during the experiment and the values collected per day are presented in Appendix 4. For greater clarity this dependence in Figure 16 shows the dependence of mortality to the oxygen levels and the water temperature.

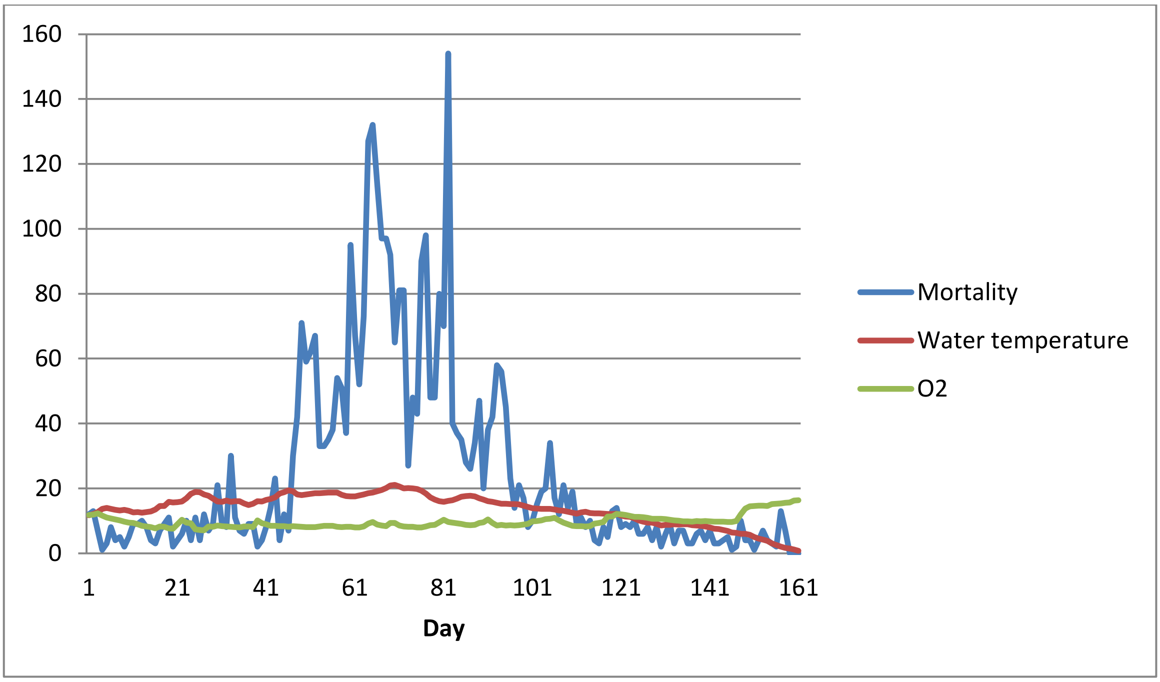


FIGURE 16. The relationship of the mortality, temperature of the water and oxygen concentration in the water

Fish mortality increases dramatically when the difference between temperature of water and oxygen curves is at largest value. To prevent such deaths the amount of feed could be reduced for further reducing the fish mortality.

11 CONCLUSION

The results of this study were obtained from the determination of eight water physicochemical factors of two sampling points: in the cages and the sampling point at 500 m away from the cages. It was observed that the trout farm effluents had no significant impact on the water quality. There were no significant differences in most of water physicochemical factors between cages and the water nearby cages. The flow and velocity rate of the lake caused reducing the level of some potentially harmful physicochemical water factors. Some of these factors have undesirable effects on the water environment of the lake, although they can be treated by self-purification potential of the lake regarding to the water discharge of the lake. It was found that the levels of all the studied physicochemical factors of the water were less than standard amounts for trout farming. It was concluded that there was a possibility to make other consecutive fish farm around 500 m or nearer along the lake, but further studies are necessary to consider other environmental aspects of the fish farm waste waters.

The results suggest that oxygen saturation levels affect both feed conversion ratio and growth performance of the rainbow trout. The highest growth rate and lowest feed conversion ratio in cages can be found at higher oxygen saturation levels, between 80 - 100 %, but the maximal value cannot be achieved in the natural environment. However, more study is necessary in order to know at which saturation point the growth is maximized. The actual oxygen saturation point at which rainbow trout has maximum growth should be identified. The water temperature varied greatly. Also this factor influenced the fish growth extremely. The feeding tables presented incorrect coefficients for feeding the fish (see Appendix 2).

From all figures it is possible to make the main conclusions:

- Growth rate is dependent on the fish size;
- Oxygen consumption increases with the weight of the trout;
- Mortality increases with the rise of the temperature;
- Mortality may be decreased if the feeding volume is changed slowly;
- Specific growth rate is dependent on the fish size.

Recommendations

To reduce fish mortality, the feeding tables provided by the manufacturer need modifications. Increasing and decreasing the amount of feed should be made gradually, without abrupt changes. In this case mortality of the fish will reduce by several times. Since the level of oxygen in the water is measured every hour the feeding tables may be changed according to the volumes of the oxygen concentration in the water. The oxygen saturation is the important factor that should be taken into consideration. If the water saturation and the water temperature are acceptable, the feeding volume may be increased but these changes should be done gradually. If all the recommendations are implemented, the profit of the company will be increased by several times.

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APPENDICES

Appendix 1 (1)

Record of the results of the chemical analysis of the water. Date: 12 May 2012

#	Parameters	Standard value	Cages top layer	Cages bottom layer	Point near-by cages top layer	Point near-by cages bottom layer
1	pH	6.0 – 8.5	6.21±0.20	6.20±0.20	6.22±0.20	6.22±0.20
2	Suspended solids, mg/l	Under 10	<3.0	<3.0	<3.0	<3.0
3	Biochemical oxygen demand (BOD_5), mg/l	Under 2.0	0.880±0.123	0.970±0.136	0.600±0.084	0.530±0.074
4	Phosphates (PO_4^{3-}), mg/l	Under 0.3	<0.05	<0.05	<0.05	<0.05
5	Ammonia ion (NH_4^+), mg/l	Under 0.5	0.14±0.05	0.11±0.04	<0.05	<0.05
6	Oil products, mg/l	Under 0.05	<0.005	<0.005	<0.005	<0.005
7	Total iron, mg/l	Under 0.5	0.525±0.120	0.525±0.120	0.526±0.121	0.526±0.121
8	Dissolved oxygen (DO), mg/l	Not less than 9.0	14.43±1.44	14.11±1.41	13.49±1.33	14.11±1.41

Record of the results of the chemical analysis of the water. Date: 13 June 2012

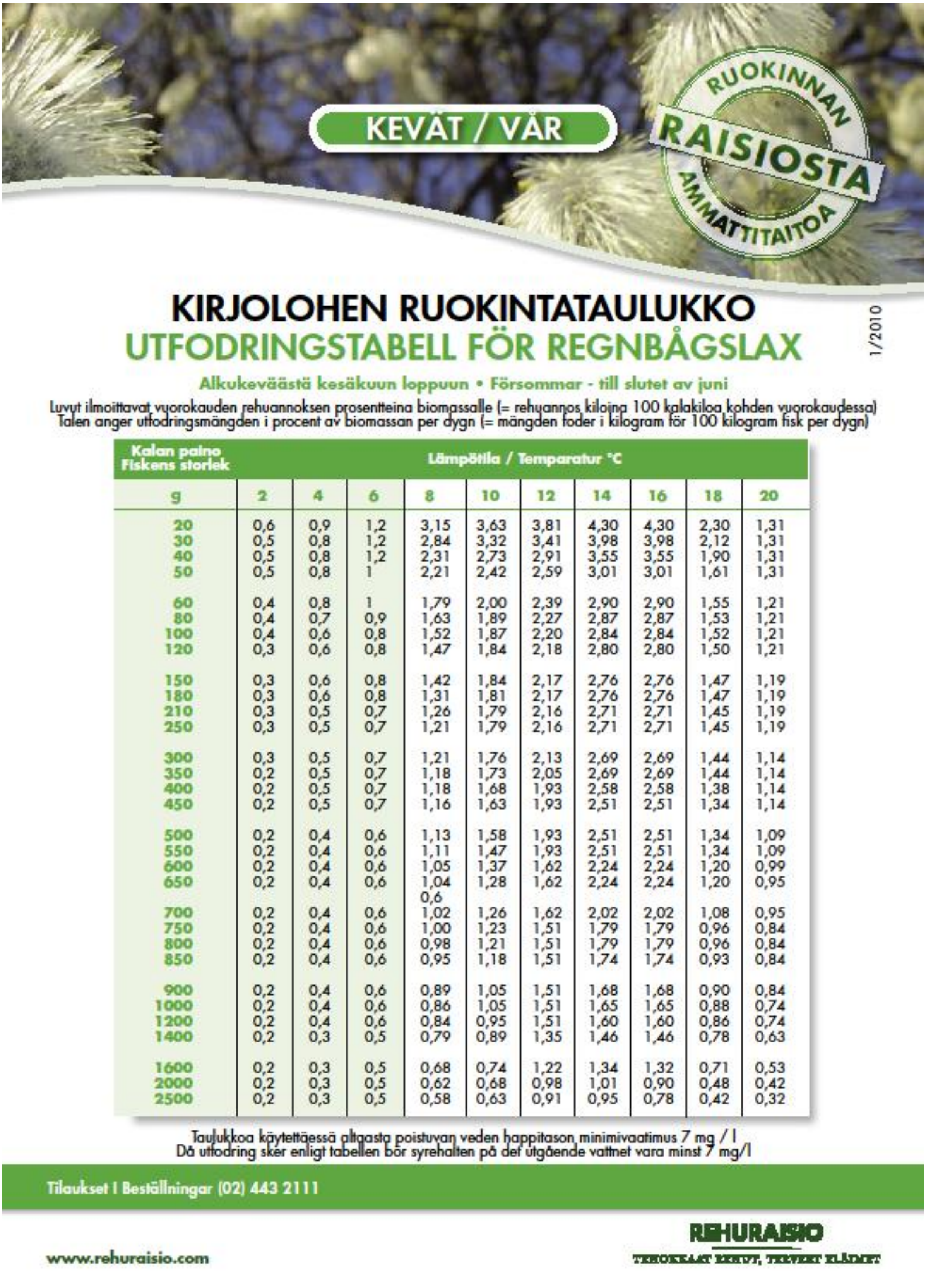
#	Parameters	Standard value	Cages top layer	Cages bottom layer	Point nearby cages top layer	Point nearby cages bottom layer
1	pH	6.0 – 8.5	5.21±0.20	6.31±0.20	5.31±0.20	5.05±0.20
2	Suspended solids, mg/l	Under 10	<3.0	<3.0	<3.0	<3.0
3	Biochemical oxygen demand (BOD_5), mg/l	Under 2.0	0.70±0.10	1.37±0.19	1.02±0.14	0.93±0.13
4	Phosphates (PO_4^{3-}), mg/l	Under 0.3	<0.05	<0.05	<0.05	<0.05
5	Ammonia ion (NH_4^+), mg/l	Under 0.5	0.192±0.067	0.189±0.066	0.228±0.080	0.223±0.078
6	Oil products, mg/l	Under 0.05	<0.005	<0.005	<0.005	<0.005
7	Total iron, mg/l	Under 0.5	0.347±0.080	0.347±0.080	0.367±0.084	0.367±0.084
8	Dissolved oxygen (DO), mg/l	Not less than 9.0	13.0±1.3	13.0±1.3	12.7±1.3	12.9±1.3

Record of the results of the chemical analysis of the water. Date: 15 August 2012

#	Parameters	Standard value	Cages top layer	Cages bottom layer	Point nearby cages top layer	Point nearby cages bottom layer
1	pH	6.0 – 8.5	6.30±0.20	6.24±0.20	6.06±0.20	6.24±0.20
2	Suspended solids, mg/l	Under 10	<3.0	<3.0	<3.0	<3.0
3	Biochemical oxygen demand (BOD_5), mg/l	Under 2.0	0.82±0.11	0.55±0.08	0.89±0.12	0.89±0.12
4	Phosphates (PO_4^{3-}), mg/l	Under 0.3	<0.05	<0.05	<0.05	<0.05
5	Ammonia ion (NH_4^+), mg/l	Under 0.5	0.282±0.099	0.280±0.098	0.180±0.063	0.179±0.063
6	Oil products, mg/l	Under 0.05	0.005±0.003	0.005±0.003	<0.005	<0.005
7	Total iron, mg/l	Under 0.5	0.42±0.10	0.42±0.10	0.43±0.10	0.43±0.10
8	Dissolved oxygen (DO), mg/l	Not less than 9.0	12.8±1.3	12.5±1.3	11.4±1.1	11.6±1.2

Appendix 2 (1)

Feeding table for rainbow trout early Spring – June



KIRJOLOHEN RUOKINTATAULUKKO
UTFODRINGSTABELL FÖR REGNBÅGSLAX

Alkukeväästä kesäkuun loppuun • Försommar - till slutet av juni

Luvut ilmoittavat vuorokauden rehuannoksen prosentteina biomassalle (= rehuannos kiloina 100 kalakiloa kohden vuorokaudessa)
Talen anger utfodringsmängden i procent av biomassan per dygn (= mängden foder i kilogram för 100 kilogram fisk per dygn)

Kalan paino Fiskens storlek	Lämpötila / Temparatur °C									
g	2	4	6	8	10	12	14	16	18	20
20	0,6	0,9	1,2	3,15	3,63	3,81	4,30	4,30	2,30	1,31
30	0,5	0,8	1,2	2,84	3,32	3,41	3,98	3,98	2,12	1,31
40	0,5	0,8	1,2	2,31	2,73	2,91	3,55	3,55	1,90	1,31
50	0,5	0,8	1	2,21	2,42	2,59	3,01	3,01	1,61	1,31
60	0,4	0,8	1	1,79	2,00	2,39	2,90	2,90	1,55	1,21
80	0,4	0,7	0,9	1,63	1,89	2,27	2,87	2,87	1,53	1,21
100	0,4	0,6	0,8	1,52	1,87	2,20	2,84	2,84	1,52	1,21
120	0,3	0,6	0,8	1,47	1,84	2,18	2,80	2,80	1,50	1,21
150	0,3	0,6	0,8	1,42	1,84	2,17	2,76	2,76	1,47	1,19
180	0,3	0,6	0,8	1,31	1,81	2,17	2,76	2,76	1,47	1,19
210	0,3	0,5	0,7	1,26	1,79	2,16	2,71	2,71	1,45	1,19
250	0,3	0,5	0,7	1,21	1,79	2,16	2,71	2,71	1,45	1,19
300	0,3	0,5	0,7	1,21	1,76	2,13	2,69	2,69	1,44	1,14
350	0,2	0,5	0,7	1,18	1,73	2,05	2,69	2,69	1,44	1,14
400	0,2	0,5	0,7	1,18	1,68	1,93	2,58	2,58	1,38	1,14
450	0,2	0,5	0,7	1,16	1,63	1,93	2,51	2,51	1,34	1,14
500	0,2	0,4	0,6	1,13	1,58	1,93	2,51	2,51	1,34	1,09
550	0,2	0,4	0,6	1,11	1,47	1,93	2,51	2,51	1,34	1,09
600	0,2	0,4	0,6	1,05	1,37	1,62	2,24	2,24	1,20	0,99
650	0,2	0,4	0,6	1,04 0,6	1,28	1,62	2,24	2,24	1,20	0,95
700	0,2	0,4	0,6	1,02	1,26	1,62	2,02	2,02	1,08	0,95
750	0,2	0,4	0,6	1,00	1,23	1,51	1,79	1,79	0,96	0,84
800	0,2	0,4	0,6	0,98	1,21	1,51	1,79	1,79	0,96	0,84
850	0,2	0,4	0,6	0,95	1,18	1,51	1,74	1,74	0,93	0,84
900	0,2	0,4	0,6	0,89	1,05	1,51	1,68	1,68	0,90	0,84
1000	0,2	0,4	0,6	0,86	1,05	1,51	1,65	1,65	0,88	0,74
1200	0,2	0,4	0,6	0,84	0,95	1,51	1,60	1,60	0,86	0,74
1400	0,2	0,3	0,5	0,79	0,89	1,35	1,46	1,46	0,78	0,63
1600	0,2	0,3	0,5	0,68	0,74	1,22	1,34	1,32	0,71	0,53
2000	0,2	0,3	0,5	0,62	0,68	0,98	1,01	0,90	0,48	0,42
2500	0,2	0,3	0,5	0,58	0,63	0,91	0,95	0,78	0,42	0,32

Taulukkoa käytettäessä altaasta poistuvan veden happitason minimivaatimus 7 mg / l
Då utfodring sker enligt tabellen bör syrehalten på det utgående vattnet vara minst 7 mg/l

Tilaukset I Beställningar (02) 443 2111

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TEHOKKAAT REHUT, TERVEET ELÄIMET

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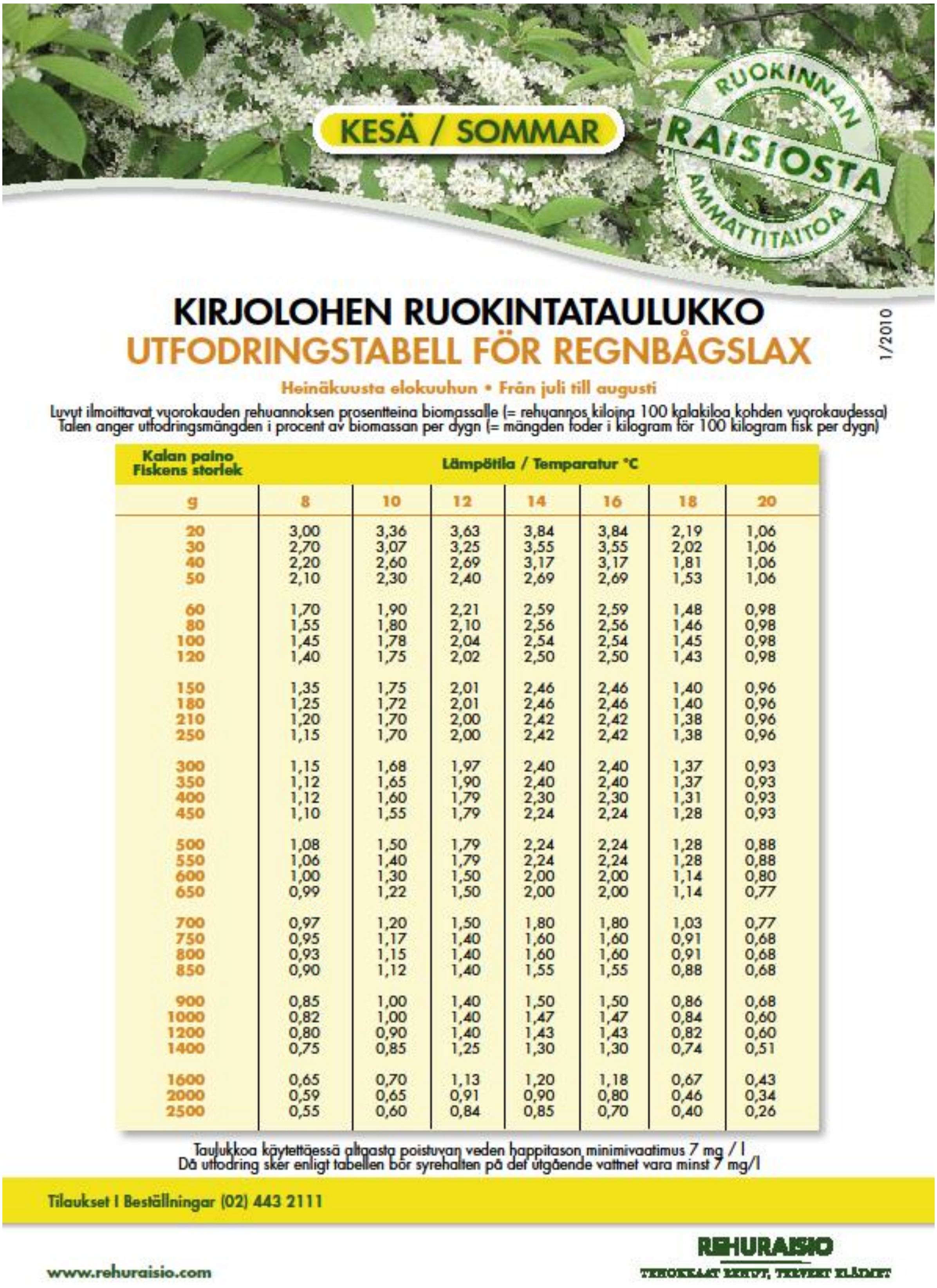
Appendix 2 (2).

Feeding table for rainbow trout July – August



KESÄ / SOMMAR

RUOKINNAN RAISIOSTA AMMATTITAITOA

KIRJOLOHEN RUOKINTATAULUKKO
UTFODRINGSTABELL FÖR REGNBÅGSLAX

1/2010

Heinäkuusta elokuuhun • Från juli till augusti

Luvut ilmoittavat vuorokauden rehuannoksen prosentteina biomassalle (= rehuannos kiloina 100 kalakiloa kohden vuorokaudessa)
Talen anger utfodringsmängden i procent av biomassan per dygn (= mängden foder i kilogram för 100 kilogram fisk per dygn)

Kalan paino Fiskens storlek	Lämpötila / Temparatur °C						
g	8	10	12	14	16	18	20
20	3,00	3,36	3,63	3,84	3,84	2,19	1,06
30	2,70	3,07	3,25	3,55	3,55	2,02	1,06
40	2,20	2,60	2,69	3,17	3,17	1,81	1,06
50	2,10	2,30	2,40	2,69	2,69	1,53	1,06
60	1,70	1,90	2,21	2,59	2,59	1,48	0,98
80	1,55	1,80	2,10	2,56	2,56	1,46	0,98
100	1,45	1,78	2,04	2,54	2,54	1,45	0,98
120	1,40	1,75	2,02	2,50	2,50	1,43	0,98
150	1,35	1,75	2,01	2,46	2,46	1,40	0,96
180	1,25	1,72	2,01	2,46	2,46	1,40	0,96
210	1,20	1,70	2,00	2,42	2,42	1,38	0,96
250	1,15	1,70	2,00	2,42	2,42	1,38	0,96
300	1,15	1,68	1,97	2,40	2,40	1,37	0,93
350	1,12	1,65	1,90	2,40	2,40	1,37	0,93
400	1,12	1,60	1,79	2,30	2,30	1,31	0,93
450	1,10	1,55	1,79	2,24	2,24	1,28	0,93
500	1,08	1,50	1,79	2,24	2,24	1,28	0,88
550	1,06	1,40	1,79	2,24	2,24	1,28	0,88
600	1,00	1,30	1,50	2,00	2,00	1,14	0,80
650	0,99	1,22	1,50	2,00	2,00	1,14	0,77
700	0,97	1,20	1,50	1,80	1,80	1,03	0,77
750	0,95	1,17	1,40	1,60	1,60	0,91	0,68
800	0,93	1,15	1,40	1,60	1,60	0,91	0,68
850	0,90	1,12	1,40	1,55	1,55	0,88	0,68
900	0,85	1,00	1,40	1,50	1,50	0,86	0,68
1000	0,82	1,00	1,40	1,47	1,47	0,84	0,60
1200	0,80	0,90	1,40	1,43	1,43	0,82	0,60
1400	0,75	0,85	1,25	1,30	1,30	0,74	0,51
1600	0,65	0,70	1,13	1,20	1,18	0,67	0,43
2000	0,59	0,65	0,91	0,90	0,80	0,46	0,34
2500	0,55	0,60	0,84	0,85	0,70	0,40	0,26

Taulukkoa käytettäessä altaasta poistuvan veden happitason minimivaatimus 7 mg / l
Då utfodring sker enligt tabellen bör syrehalten på det utgående vattnet vara minst 7 mg/l

Tilaukset I Beställningar (02) 443 2111

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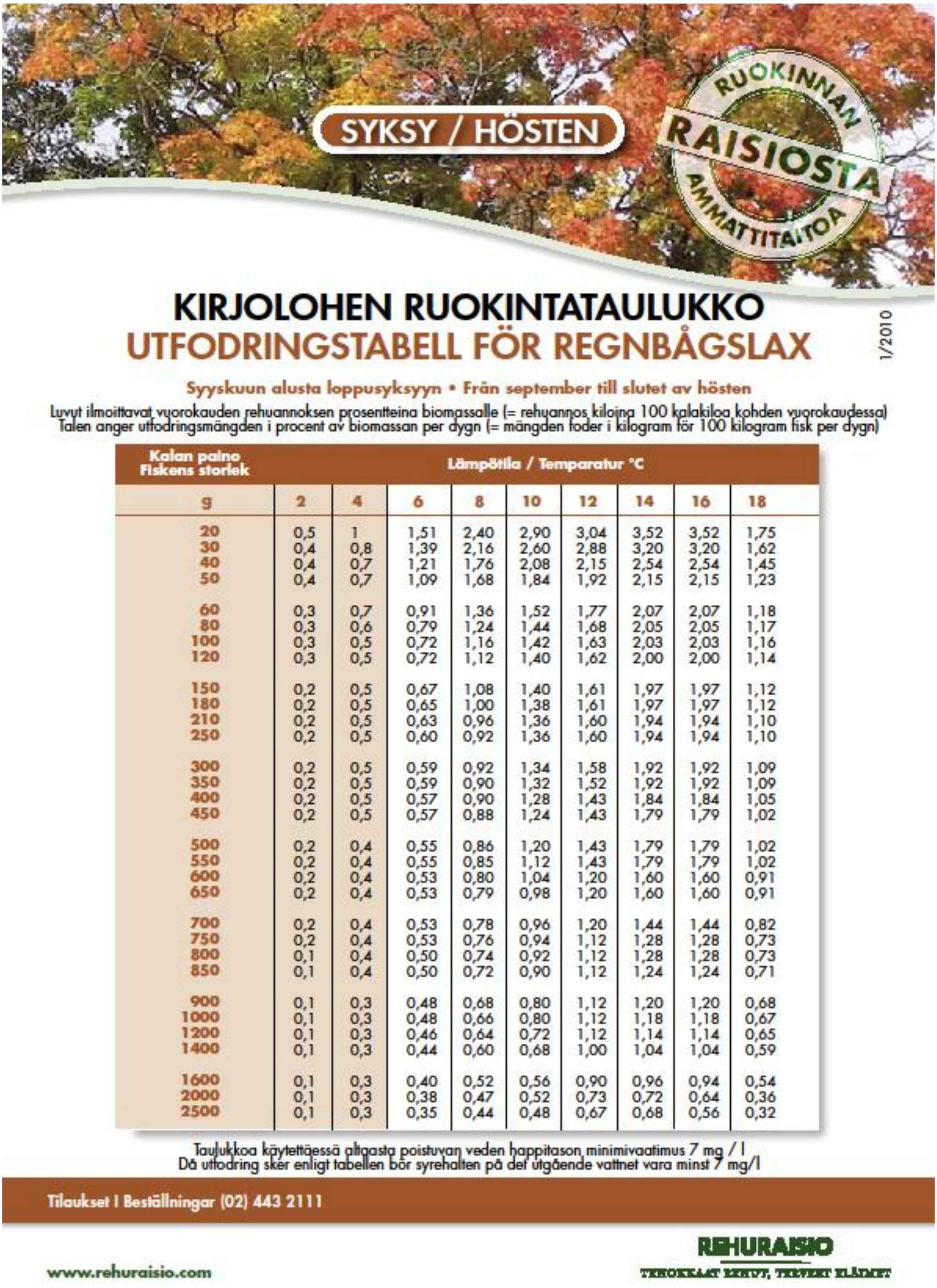
REHURAISIO
TEHOKKAAT REHUT, TERVEET ELÄIMET

Feeding table for rainbow trout September – end of feeding



KIRJOLOHEN RUOKINTATAULUKKO
UTFODRINGSTABELL FÖR REGNBÅGSLAX

1/2010

Syyskuun alusta loppusyksyyn • Från september till slutet av hösten

Luvut ilmoittavat vuorokauden rehuannoksen prosentteina biomassalle (= rehuannos kiloina 100 kalakiloa kohden vuorokaudessa)
Talen anger utfodringsmängden i procent av biomassan per dygn (= mängden foder i kilogram för 100 kilogram fisk per dygn)

Kalan paino Fiskens storlek	Lämpötila / Temparatur °C								
g	2	4	6	8	10	12	14	16	18
20	0,5	1	1,51	2,40	2,90	3,04	3,52	3,52	1,75
30	0,4	0,8	1,39	2,16	2,60	2,88	3,20	3,20	1,62
40	0,4	0,7	1,21	1,76	2,08	2,15	2,54	2,54	1,45
50	0,4	0,7	1,09	1,68	1,84	1,92	2,15	2,15	1,23
60	0,3	0,7	0,91	1,36	1,52	1,77	2,07	2,07	1,18
80	0,3	0,6	0,79	1,24	1,44	1,68	2,05	2,05	1,17
100	0,3	0,5	0,72	1,16	1,42	1,63	2,03	2,03	1,16
120	0,3	0,5	0,72	1,12	1,40	1,62	2,00	2,00	1,14
150	0,2	0,5	0,67	1,08	1,40	1,61	1,97	1,97	1,12
180	0,2	0,5	0,65	1,00	1,38	1,61	1,97	1,97	1,12
210	0,2	0,5	0,63	0,96	1,36	1,60	1,94	1,94	1,10
250	0,2	0,5	0,60	0,92	1,36	1,60	1,94	1,94	1,10
300	0,2	0,5	0,59	0,92	1,34	1,58	1,92	1,92	1,09
350	0,2	0,5	0,59	0,90	1,32	1,52	1,92	1,92	1,09
400	0,2	0,5	0,57	0,90	1,28	1,43	1,84	1,84	1,05
450	0,2	0,5	0,57	0,88	1,24	1,43	1,79	1,79	1,02
500	0,2	0,4	0,55	0,86	1,20	1,43	1,79	1,79	1,02
550	0,2	0,4	0,55	0,85	1,12	1,43	1,79	1,79	1,02
600	0,2	0,4	0,53	0,80	1,04	1,20	1,60	1,60	0,91
650	0,2	0,4	0,53	0,79	0,98	1,20	1,60	1,60	0,91
700	0,2	0,4	0,53	0,78	0,96	1,20	1,44	1,44	0,82
750	0,2	0,4	0,53	0,76	0,94	1,12	1,28	1,28	0,73
800	0,1	0,4	0,50	0,74	0,92	1,12	1,28	1,28	0,73
850	0,1	0,4	0,50	0,72	0,90	1,12	1,24	1,24	0,71
900	0,1	0,3	0,48	0,68	0,80	1,12	1,20	1,20	0,68
1000	0,1	0,3	0,48	0,66	0,80	1,12	1,18	1,18	0,67
1200	0,1	0,3	0,46	0,64	0,72	1,12	1,14	1,14	0,65
1400	0,1	0,3	0,44	0,60	0,68	1,00	1,04	1,04	0,59
1600	0,1	0,3	0,40	0,52	0,56	0,90	0,96	0,94	0,54
2000	0,1	0,3	0,38	0,47	0,52	0,73	0,72	0,64	0,36
2500	0,1	0,3	0,35	0,44	0,48	0,67	0,68	0,56	0,32

Taulukkoa käytettäessä altaasta poistuvan veden happitason minimivaatimus 7 mg / l
Då utfodring sker enligt tabellen bör syrehalten på det utgående vattnet vara minst 7 mg/l

Tilaukset I Beställningar (02) 443 2111

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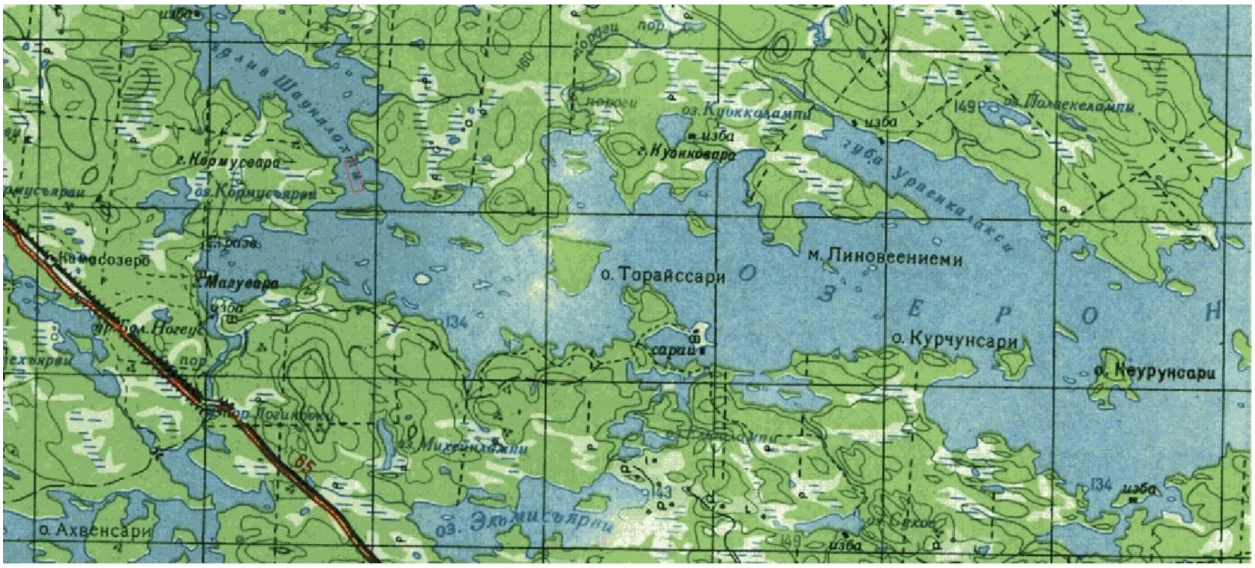
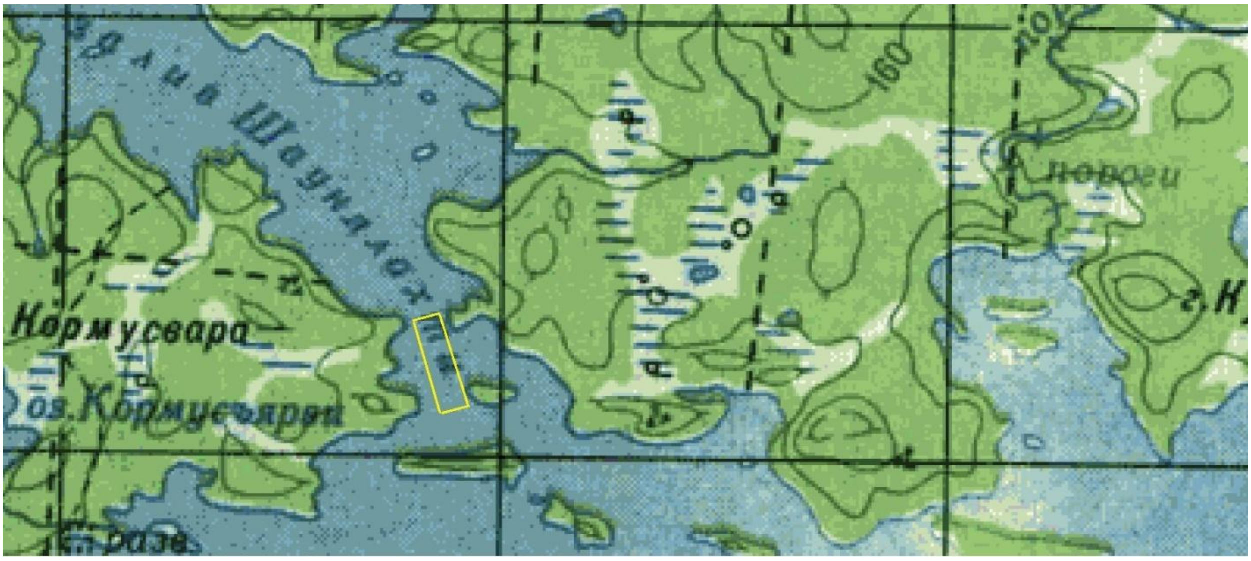
REHURAISIO
TEHOKKAAT REHUT, TERVEET ELÄIMET

Appendix 3

The bay location on the map



Location of the studied cages on the map



Appendix 4(1)

The collected data in May

May 2012	Nyuk										
	Tair	Twater	O2	Partial pressure	PH	Measurings	Mortality				
Day							Cage 1	Cage 2	Cage 3	Cage 4	Cage 5
1	7,0	1,9	9,5	144,2	6,0	8					
2	3,9	1,8	12,1	183,5	6,1	8					
3	5,2	1,8	14,0	212,2	6,1	8					
4	6,8	1,9	12,6	191,4	6,1	8					
5	3,8	2,0	12,0	183,0	6,1	8					
6	6,5	2,2	11,8	181,3	6,1	8					
7	6,0	2,3	11,7	179,9	6,1	8					
8	9,9	2,6	11,6	180,2	6,1	8					
9	12,5	2,9	11,6	181,8	6,1	8					
10	13,2	3,3	11,7	184,9	6,1	8					
11	11,8	4,2	11,6	177,3	6,1	8					
12	5,1	4,4	11,5	176,4	6,0	8					
13	9,1	4,4	11,2	171,3	6,1	8					
14	9,6	4,9	10,5	163,5	6,1	8					
15	14,9	5,6	10,0	167,5	6,1	8					
16	17,6	6,5	10,3	176,1	6,0	8					
17	16,3	7,4	10,2	177,6	6,0	8					
18	18,7	8,3	11,3	160,8	5,9	8					
19	15,5	8,7	11,4	157,8	5,9	8					
20	17,3	9,5	11,3	156,5	5,9	8					
21	17,6	10,3	11,6	157,9	5,9	8					
22	15,5	10,7	11,3	158,4	5,9	8					
23	15,4	11,3	11,7	163,4	5,9	92					
24	17,0	11,7	11,8	165,8	6,0	96	2	3	1	6	0
25	18,9	12,1	11,9	190,7	6,1	94	3	2	1	5	2
26	20,9	12,7	12,3	242,1	6,8	96	1	0	0	5	1
27	22,0	13,6	11,6	232,7	6,8	96	0	0	0	1	0
28	17,4	14,0	11,0	222,4	6,8	96	1	1	0	0	1
29	12,1	13,7	10,7	215,0	6,8	96	2	2	1	1	2
30	13,7	13,3	10,4	208,0	6,8	96	0	1	2	1	0
31	14,2	13,2	10,1	200,4	6,7	96	2	0	0	1	2
Avarage	**12,8**	**13,2**	**11,1**	**182,7**	**6,2**	**33**	**1**	**1**	**1**	**3**	**1**

The collected data in June

June 2012	Nyuk										
	Tair	Twater	O2	Partial pressure	PH	Measurings	Mortality				
Day							Cage 1	Cage 2	Cage 3	Cage 4	Cage 5
1	16,0	13,3	9,7	193,1	6,7	96	0	1	0	0	1
2	14,0	13,1	9,4	186,5	6,6	96	1	1	1	2	0
3	14,9	12,6	9,3	183,5	6,6	96	3	1	2	1	2
4	14,6	12,6	8,9	175,2	6,6	96	0	2	4	2	1
5	12,7	12,5	8,4	164,9	6,5	96	1	4	3	2	0
6	17,3	12,6	8,2	153,4	6,5	96	1	4	2	1	0
7	16,3	12,9	8,0	140,9	6,5	96	1	1	1	1	0
8	20,3	13,5	7,6	128,7	6,4	96	0	1	1	0	1
9	21,8	14,6	8,2	115,6	6,4	96	3	0	3	1	0
10	17,5	14,5	8,1	103,4	6,4	96	1	2	2	4	0
11	20,3	15,8	7,6	93,6	6,3	96	4	1	3	2	1
12	17,5	15,6	7,5	83,4	6,2	96	0	0	0	2	0
13	20,9	15,8	8,9	164,6	6,4	96	3	1	0	0	0
14	22,1	15,9	10,3	217,5	6,6	96	2	1	0	1	2
15	24,3	16,9	9,4	203,3	6,5	96	0	5	4	1	0
16	23,5	18,3	9,2	187,5	6,4	96	1	2	0	0	1
17	22,0	18,9	7,3	163,5	6,3	96	2	4	2	3	0
18	21,1	18,8	7,2	133,1	6,3	96	0	2	2	0	0
19	19,5	18,1	7,1	110,6	6,2	96	2	2	4	1	3
20	16,3	17,7	8,2	94,9	6,2	96	1	3	1	0	2
21	14,0	16,8	8,1	85,2	6,3	96	3	2	0	3	1
22	14,7	16,0	8,5	80,0	6,2	96	1	3	4	6	7
23	16,1	15,8	8,3	73,6	6,2	96	1	5	1	1	1
24	16,5	16,3	8,2	65,4	6,2	96	2	4	1	0	1
25	16,4	15,9	8,1	59,0	6,1	96	22	3	3	1	1
26	17,8	16,0	8,0	56,7	6,1	96	2	3	2	0	4
27	16,2	16,0	7,9	55,2	6,0	96	4	2	0	1	0
28	12,0	15,3	8,2	56,2	6,0	96	2	2	0	1	1
29	14,9	14,8	8,2	57,0	6,0	96	3	2	3	0	1
30	20,4	15,3	8,0	168,0	6,4	96	3	2	3	0	1
Avarage	**17,7**	**15,4**	**8,3**	**125,1**	**6,3**	**96**	**2,3**	**2,2**	**2**	**1,2**	**1,1**

The collected data in July

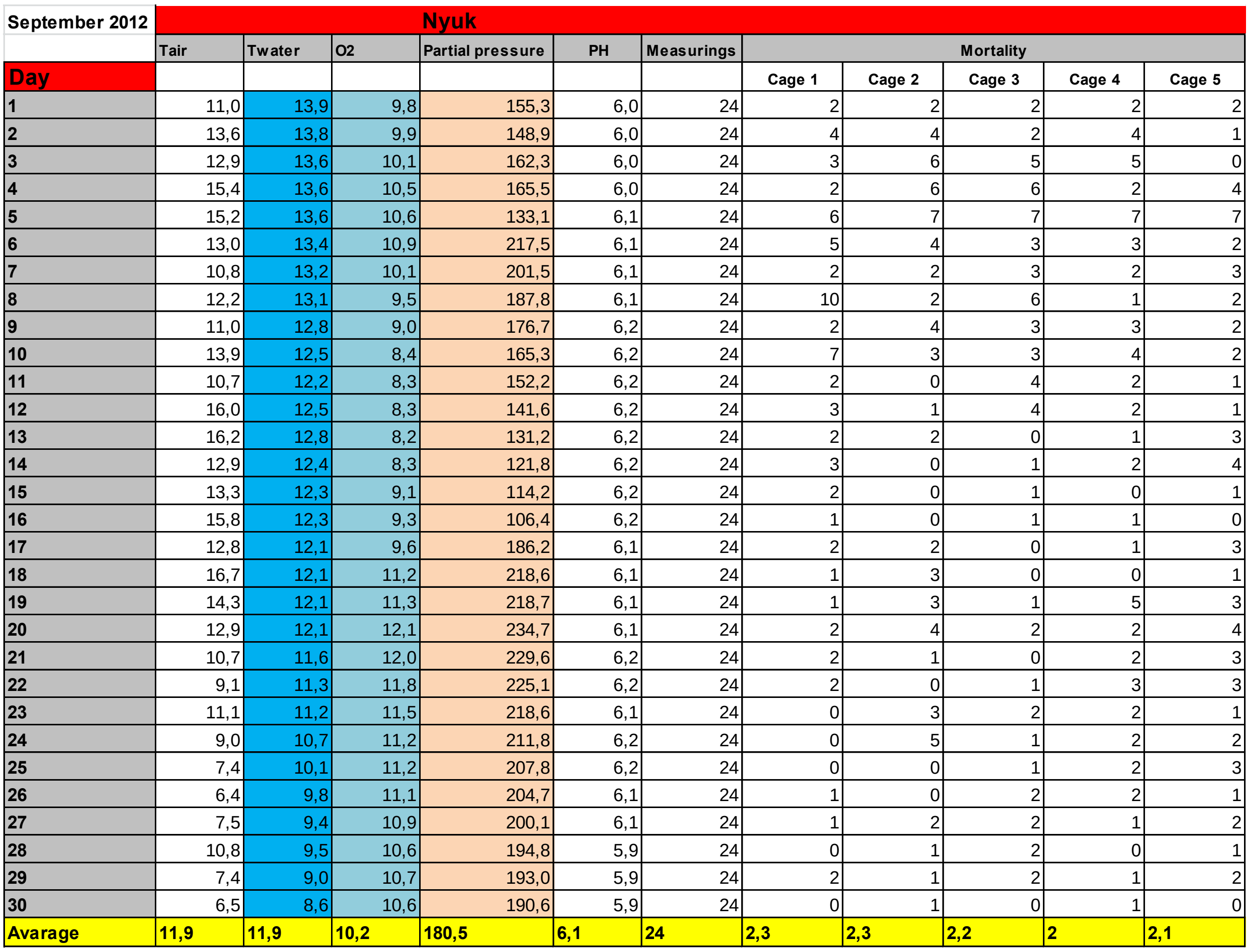
July 2012	Nyuk										
	Tair	Twater	O2	Partial pressure	PH	Measurings	Mortality				
Day							Cage 1	Cage 2	Cage 3	Cage 4	Cage 5
1	18,4	16,0	10,1	213,0	6,7	96	1	1	0	0	0
2	19,7	15,9	9,2	194,0	6,7	96	0	0	1	3	0
3	21,5	16,4	8,9	184,5	6,7	96	0	4	0	4	0
4	22,6	16,7	8,5	181,4	6,7	96	8	3	1	2	0
5	21,7	17,2	8,4	179,4	6,7	96	5	4	5	7	2
6	24,4	18,4	8,3	175,6	6,6	96	0	3	1	0	0
7	25,9	18,8	8,3	173,3	6,6	96	4	1	4	2	1
8	20,0	19,4	8,1	173,4	6,5	96	4	2	1	0	0
9	18,4	19,1	8,3	167,4	6,5	96	6	5	5	9	5
10	16,2	18,1	8,2	166,4	6,4	96	7	7	11	8	9
11	20,8	17,9	8,1	172,3	6,3	96	10	18	18	12	13
12	22,6	18,1	8,1	177,5	6,3	96	16	10	13	11	9
13	21,3	18,3	8,1	178,6	6,3	96	11	14	11	18	8
14	22,3	18,5	8,1	179,4	6,3	96	11	12	8	19	17
15	21,3	18,5	8,3	183,7	6,4	96	6	9	6	7	5
16	23,3	18,6	8,5	188,7	6,5	96	7	6	11	5	4
17	24,0	18,7	8,4	187,7	6,6	96	5	12	11	2	5
18	19,0	18,7	8,4	187,5	6,5	96	9	8	9	8	4
19	17,5	18,7	8,2	182,1	6,3	96	9	17	9	16	3
20	15,3	18,0	8,1	177,4	6,3	94	15	10	7	15	4
21	19,8	17,6	8,1	176,5	6,3	96	12	6	13	4	2
22	18,9	17,5	8,1	177,0	6,3	96	26	26	23	11	9
23	19,6	17,5	7,9	172,3	6,2	96	14	21	18	7	7
24	22,4	17,8	7,9	173,3	6,2	96	8	13	14	9	8
25	24,2	18,1	8,3	182,0	6,2	96	19	13	20	11	10
26	22,7	18,5	9,1	201,6	6,4	96	23	27	21	41	15
27	21,5	18,7	9,6	213,3	6,5	96	27	29	37	24	15
28	23,8	19,1	8,9	199,4	6,5	96	23	31	27	14	19
29	24,8	19,5	8,5	192,3	6,5	96	14	29	21	21	12
30	30,1	20,1	8,3	190,3	6,5	96	21	16	27	15	18
31	27,3	20,9	9,3	215,5	6,4	96	20	26	21	19	6
Avarage	21,6	18,2	8,5	184,4	6,4	96	11,0	12,4	12	10,5	6,8

The collected data in August

August 2012	Nyuk										
	Tair	Twater	O2	Partial pressure	PH	Measurings	Mortality				
Day							Cage 1	Cage 2	Cage 3	Cage 4	Cage 5
1	24,594	21,1	9,3	217,3	6,4	96	18	19	13	11	4
2	21,969	20,6	8,6	198,1	6,4	96	24	20	11	14	12
3	20,833	20,0	8,2	188,2	6,5	96	18	17	22	13	11
4	20,979	20,0	8,2	187,1	6,4	96	5	12	4	3	3
5	19,500	20,0	8,1	186,0	6,4	96	10	14	8	11	5
6	20,292	19,8	7,9	180,4	6,3	96	8	10	10	8	7
7	17,646	19,3	7,9	178,4	6,3	96	21	24	24	13	8
8	13,573	18,4	8,2	182,2	6,3	96	27	26	15	14	16
9	12,844	17,2	8,6	185,7	6,3	96	14	10	11	4	9
10	14,146	16,6	8,7	185,6	6,2	96	9	7	16	6	10
11	17,375	16,0	9,5	200,3	6,2	96	21	16	19	8	16
12	20,583	15,9	10,3	216,4	6,2	96	15	11	26	7	11
13	25,135	16,1	9,6	202,8	6,1	96	32	37	36	13	36
14	24,229	16,3	9,5	201,0	6,0	96	11	3	16	1	9
15	24,073	16,8	9,2	197,3	6,0	96	8	7	9	6	7
16	21,344	17,4	9,0	188,9	6,1	96	8	6	9	6	6
17	23,302	17,6	8,7	176,8	6,1	96	6	8	5	8	1
18	22,688	17,7	8,6	150,9	6,1	96	4	7	5	4	6
19	16,375	17,5	8,7	148,7	6,1	96	10	5	7	7	5
20	15,385	16,9	9,3	148,9	6,0	96	2	10	5	20	10
21	16,094	16,5	9,5	155,2	6,0	72	5	4	5	4	2
22	13,708	16,0	10,4	218,8	6,0	24	6	6	14	5	7
23	15,417	15,8	9,3	196,3	6,0	24	15	7	11	5	4
24	13,833	15,5	8,6	179,4	5,9	24	13	15	7	14	9
25	15,333	15,3	8,7	165,6	5,9	24	12	10	10	11	13
26	15,958	15,3	8,5	150,8	5,9	24	9	12	5	10	9
27	17,625	15,1	8,6	138,4	5,9	24	5	5	4	4	5
28	17,625	15,1	8,5	128,7	6,0	24	5	1	3	3	2
29	14,458	15,0	8,6	117,8	6,0	24	5	7	2	4	3
30	13,000	14,6	8,8	104,6	6,0	24	2	7	1	5	2
31	12,750	14,2	9,0	93,8	6,0	24	1	3	1	2	1
Avarage	**18,2**	**17,1**	**8,9**	**173,2**	**6,1**	**72**	**11,3**	**11,2**	**10,8**	**7,9**	**8**

Appendix 4(5)

The collected data in September

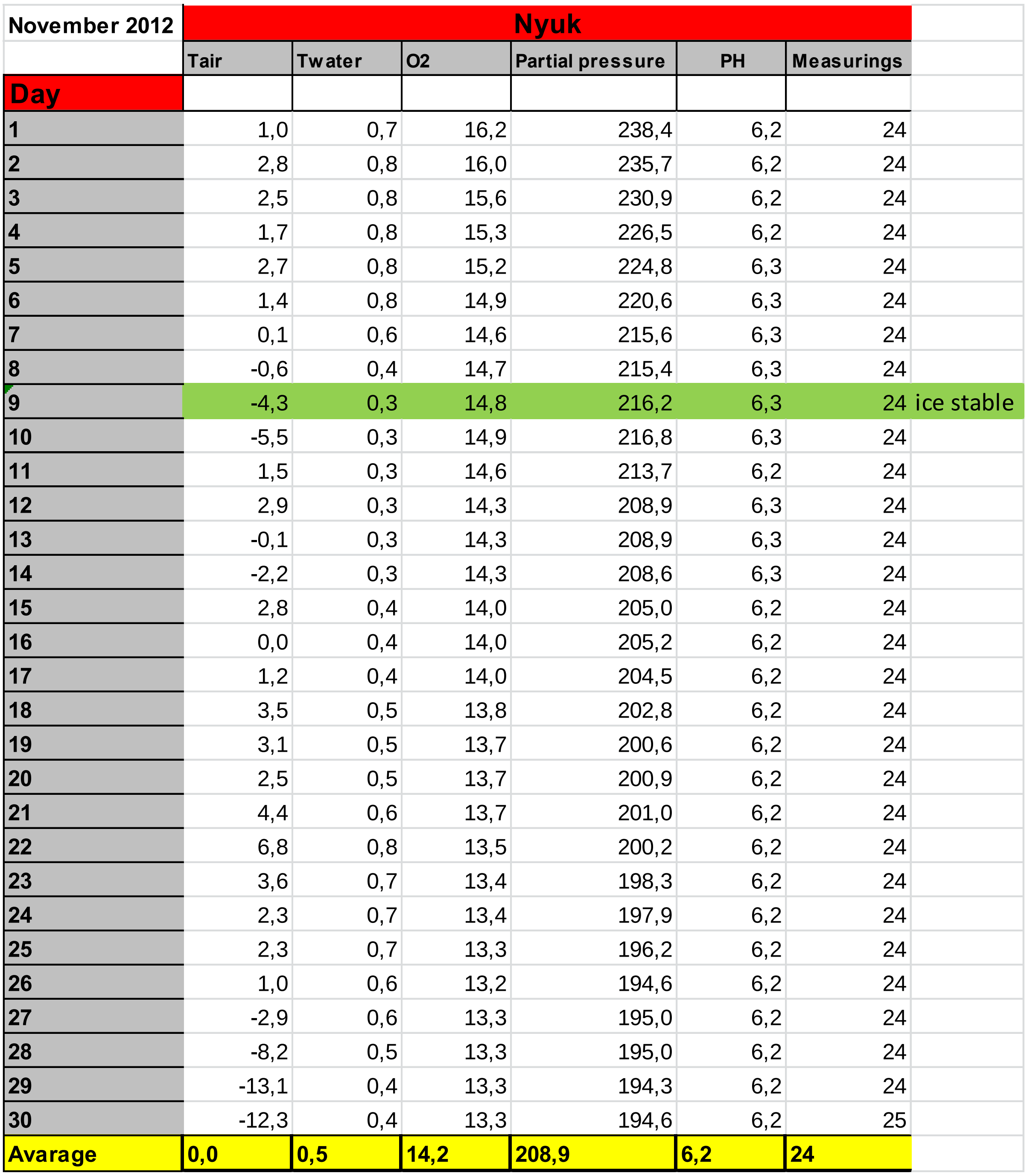


September 2012	Nyuk										
	Tair	Twater	O2	Partial pressure	PH	Measurings	Mortality				
Day							Cage 1	Cage 2	Cage 3	Cage 4	Cage 5
1	11,0	13,9	9,8	155,3	6,0	24	2	2	2	2	2
2	13,6	13,8	9,9	148,9	6,0	24	4	4	2	4	1
3	12,9	13,6	10,1	162,3	6,0	24	3	6	5	5	0
4	15,4	13,6	10,5	165,5	6,0	24	2	6	6	2	4
5	15,2	13,6	10,6	133,1	6,1	24	6	7	7	7	7
6	13,0	13,4	10,9	217,5	6,1	24	5	4	3	3	2
7	10,8	13,2	10,1	201,5	6,1	24	2	2	3	2	3
8	12,2	13,1	9,5	187,8	6,1	24	10	2	6	1	2
9	11,0	12,8	9,0	176,7	6,2	24	2	4	3	3	2
10	13,9	12,5	8,4	165,3	6,2	24	7	3	3	4	2
11	10,7	12,2	8,3	152,2	6,2	24	2	0	4	2	1
12	16,0	12,5	8,3	141,6	6,2	24	3	1	4	2	1
13	16,2	12,8	8,2	131,2	6,2	24	2	2	0	1	3
14	12,9	12,4	8,3	121,8	6,2	24	3	0	1	2	4
15	13,3	12,3	9,1	114,2	6,2	24	2	0	1	0	1
16	15,8	12,3	9,3	106,4	6,2	24	1	0	1	1	0
17	12,8	12,1	9,6	186,2	6,1	24	2	2	0	1	3
18	16,7	12,1	11,2	218,6	6,1	24	1	3	0	0	1
19	14,3	12,1	11,3	218,7	6,1	24	1	3	1	5	3
20	12,9	12,1	12,1	234,7	6,1	24	2	4	2	2	4
21	10,7	11,6	12,0	229,6	6,2	24	2	1	0	2	3
22	9,1	11,3	11,8	225,1	6,2	24	2	0	1	3	3
23	11,1	11,2	11,5	218,6	6,1	24	0	3	2	2	1
24	9,0	10,7	11,2	211,8	6,2	24	0	5	1	2	2
25	7,4	10,1	11,2	207,8	6,2	24	0	0	1	2	3
26	6,4	9,8	11,1	204,7	6,1	24	1	0	2	2	1
27	7,5	9,4	10,9	200,1	6,1	24	1	2	2	1	2
28	10,8	9,5	10,6	194,8	5,9	24	0	1	2	0	1
29	7,4	9,0	10,7	193,0	5,9	24	2	1	2	1	2
30	6,5	8,6	10,6	190,6	5,9	24	0	1	0	1	0
Avarage	**11,9**	**11,9**	**10,2**	**180,5**	**6,1**	**24**	**2,3**	**2,3**	**2,2**	**2**	**2,1**

The collected data in October

October 2012	Nyuk										
	Tair	Twater	O2	Partial pressure	PH	Measurings	Mortality				
Day							Cage 1	Cage 2	Cage 3	Cage 4	Cage 5
1	10,0	8,7	10,5	188,323	5,9	24	2	2	0	1	1
2	10,4	8,7	10,3	186,021	5,9	24	3	2	1	2	1
3	12,4	8,9	10,1	183,146	5,9	24	0	0	1	2	0
4	10,6	8,8	10,0	180,385	5,9	24	2	1	2	1	1
5	11,4	8,9	9,8	176,854	6,0	24	3	0	1	2	1
6	9,6	8,9	9,8	172,917	5,9	24	0	1	1	1	0
7	7,5	8,6	9,7	171,042	5,9	24	0	2	0	1	0
8	7,6	8,6	9,9	169,542	6,0	24	1	2	3	0	0
9	7,0	8,4	9,8	167,865	6,0	24	1	3	1	2	0
10	7,5	8,2	9,9	166,469	5,9	24	0	1	2	1	0
11	6,5	7,9	9,8	164,604	5,9	24	3	2	0	1	1
12	6,1	7,6	9,7	164,135	5,8	24	1	1	0	0	1
13	5,6	7,4	9,7	163,271	5,9	24	2	1	0	0	0
14	4,7	7,2	9,7	162,177	5,9	24	1	1	1	0	1
15	3,9	6,9	9,6	160,167	5,9	24	0	2	1	1	1
16	3,7	6,4	9,6	158,417	6,1	24	1	0	0	0	0
17	6,4	6,3	9,9	157,396	6,2	24	1	0	0	1	0
18	4,3	5,9	11,9	200,906	6,1	24	0	2	0	3	5
19	8,1	6,0	13,7	230,948	6,2	24	1	2	1	0	0
20	2,9	5,7	14,4	241,417	6,1	24	1	1	0	1	1
21	-0,1	5,0	14,6	239,833	6,1	24	0	1	0	0	0
22	-0,6	4,5	14,7	238,802	6,1	24	0	0	1	2	1
23	0,9	4,2	14,6	235,438	6,1	24	1	1	1	2	2
24	2,3	3,8	14,5	232,000	6,1	24	2	0	1	1	0
25	-0,5	3,1	15,2	237,688	6,1	24	2	0	0	1	0
26	-3,5	2,5	15,2	234,948	6,1	24	1	0	0	1	0
27	-1,8	2,1	15,4	234,490	6,1	24	3	0	0	6	4
28	-0,5	1,6	15,6	235,188	6,1	24	0	0	0	5	2
29	-0,1	1,4	15,6	234,531	6,2	24	0	0	0	0	0
30	0,0	1,1	16,2	241,479	6,2	24	0	0	0	0	0
31	-1,2	0,7	16,4	241,344	6,2	24	0	0	0	0	0
Avarage	**4,6**	**5,9**	**12,1**	**199,1**	**6,0**	**24**	**1,0**	**0,9**	**0,6**	**1**	**0,7**

The collected data in November



November 2012	Nyuk						
	Tair	Twater	O2	Partial pressure	PH	Measurings	
Day							
1	1,0	0,7	16,2	238,4	6,2	24	
2	2,8	0,8	16,0	235,7	6,2	24	
3	2,5	0,8	15,6	230,9	6,2	24	
4	1,7	0,8	15,3	226,5	6,2	24	
5	2,7	0,8	15,2	224,8	6,3	24	
6	1,4	0,8	14,9	220,6	6,3	24	
7	0,1	0,6	14,6	215,6	6,3	24	
8	-0,6	0,4	14,7	215,4	6,3	24	
9	-4,3	0,3	14,8	216,2	6,3	24	ice stable
10	-5,5	0,3	14,9	216,8	6,3	24	
11	1,5	0,3	14,6	213,7	6,2	24	
12	2,9	0,3	14,3	208,9	6,3	24	
13	-0,1	0,3	14,3	208,9	6,3	24	
14	-2,2	0,3	14,3	208,6	6,3	24	
15	2,8	0,4	14,0	205,0	6,2	24	
16	0,0	0,4	14,0	205,2	6,2	24	
17	1,2	0,4	14,0	204,5	6,2	24	
18	3,5	0,5	13,8	202,8	6,2	24	
19	3,1	0,5	13,7	200,6	6,2	24	
20	2,5	0,5	13,7	200,9	6,2	24	
21	4,4	0,6	13,7	201,0	6,2	24	
22	6,8	0,8	13,5	200,2	6,2	24	
23	3,6	0,7	13,4	198,3	6,2	24	
24	2,3	0,7	13,4	197,9	6,2	24	
25	2,3	0,7	13,3	196,2	6,2	24	
26	1,0	0,6	13,2	194,6	6,2	24	
27	-2,9	0,6	13,3	195,0	6,2	24	
28	-8,2	0,5	13,3	195,0	6,2	24	
29	-13,1	0,4	13,3	194,3	6,2	24	
30	-12,3	0,4	13,3	194,6	6,2	25	
Avarage	0,0	0,5	14,2	208,9	6,2	24	

Appendix 5 (1)

The hand noted data in May

May							
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
1M	30.04.2012 - 06.05.2012	22626	0,165	3733,3			0,0
	7.05.2012 - 13.05.2012	22626	0,165	3733,3			0,0
	14.05.2012 - 20.05.2012	22626	0,165	3733,3			0,0
	21.05.2012 - 27.05.2012	22626	0,165	3733,3	150,0	6	1,0
	28.05.2012 - 3.06.2012	22620	0,172	3890,2			0,0
	04.06.2012	**22620**	**0,172**	3890,2	**150,0**	**6**	**1,0**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
2M	30.04.2012 - 06.05.2012	22296	0,165	3678,8			0,0
	7.05.2012 - 13.05.2012	22296	0,165	3678,8			0,0
	14.05.2012 - 20.05.2012	22296	0,165	3678,8			0,0
	21.05.2012 - 27.05.2012	22296	0,165	3678,8	150,0	5	0,8
	28.05.2012 - 3.06.2012	22291	0,172	3835,9			0,0
	04.06.2012	**22291**	**0,172**	3835,9	**150,0**	**5**	**0,8**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
3M	30.04.2012 - 06.05.2012	26985	0,168	4538,9			0,0
	7.05.2012 - 13.05.2012	26985	0,168	4538,9			0,0
	14.05.2012 - 20.05.2012	26985	0,168	4538,9			0,0
	21.05.2012 - 27.05.2012	26985	0,168	4538,9	150,0	2	0,3
	28.05.2012 - 3.06.2012	26983	0,174	4696,5			0,0
	04.06.2012	**26983**	**0,174**	4696,5	**150,0**	**2**	**0,3**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
4M	30.04.2012 - 06.05.2012	21917	0,169	3704,0			0,0
	7.05.2012 - 13.05.2012	21917	0,169	3704,0			0,0
	14.05.2012 - 20.05.2012	21917	0,169	3704,0			0,0
	21.05.2012 - 27.05.2012	21917	0,169	3704,0	150,0	17	2,9
	28.05.2012 - 3.06.2012	21900	0,176	3859,0			0,0
	04.06.2012	**21900**	**0,176**	3859,0	**150,0**	**17**	**2,9**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
5M	30.04.2012 - 06.05.2012	13934	0,169	2354,8			0,0
	7.05.2012 - 13.05.2012	13934	0,169	2354,8			0,0
	14.05.2012 - 20.05.2012	13934	0,169	2354,8			0,0
	21.05.2012 - 27.05.2012	13934	0,169	2354,8	150,0	3	0,5
	28.05.2012 - 3.06.2012	13931	0,180	2512,2			0,0
	04.06.2012	**13931**	**0,180**	2512,2	**150,0**	**3**	**0,5**
Total:		**107725**	**0,174**	**18793,8**	**750,0**	**33**	**5,5**

The hand noted data in June

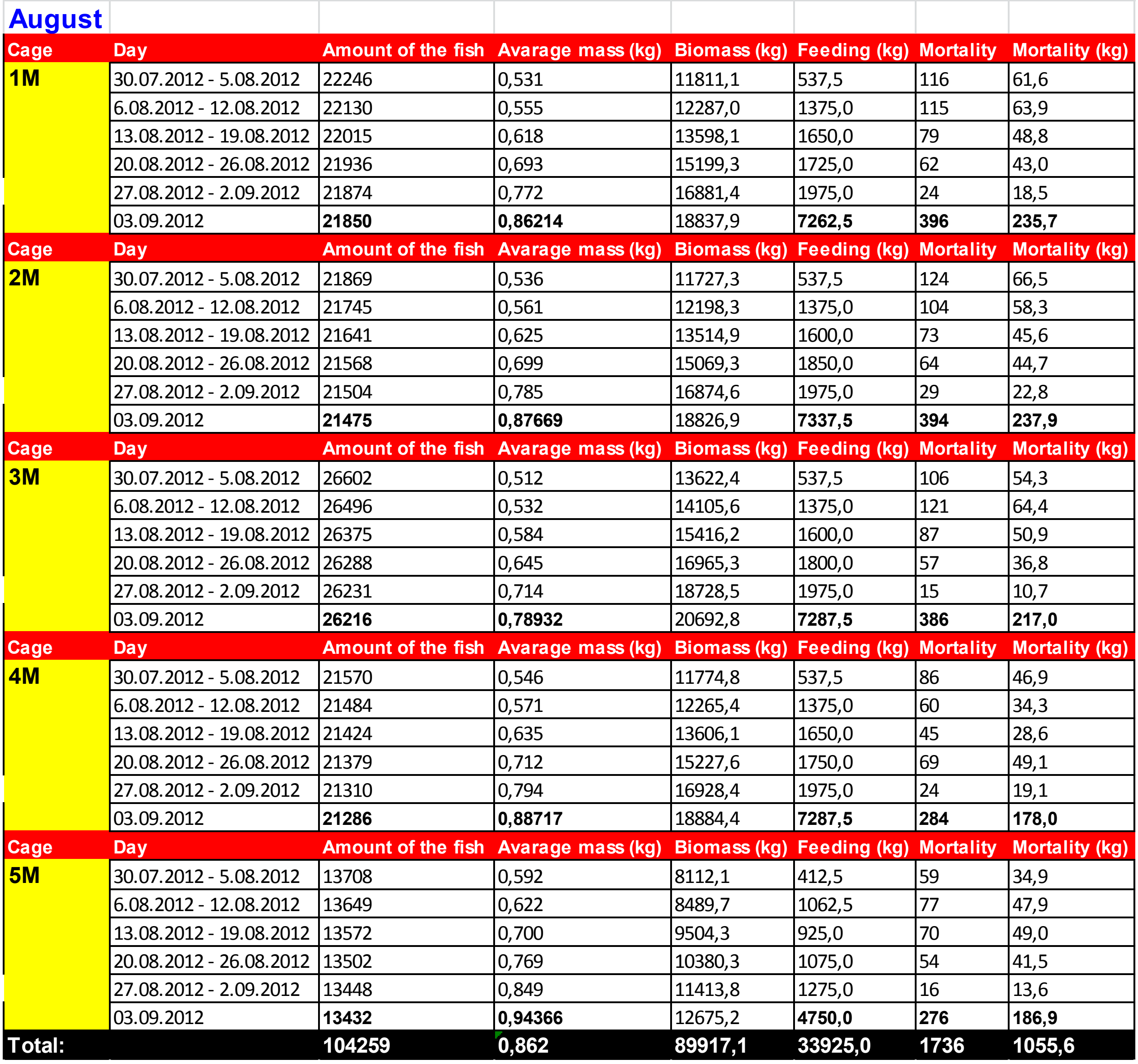
June							
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
1M	28.05.2012 - 03.06.2012	22620	0,172	3890,6	587,5	9	1,5
	4.06.2012 - 10.06.2012	22611	0,199	4507,5	775,0	7	1,4
	11.06.2012 - 17.06.2012	22604	0,235	5321,9	1037,5	12	2,8
	18.06.2012 - 24.06.2012	22592	0,284	6411,2	962,5	10	2,8
	25.06.2012 - 01.07.2012	22582	0,329	7421,5	1162,5	37	12,2
	02.07.2012	**22545**	**0,383**	8633,0	**4525,0**	**75**	**20,8**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
2M	28.05.2012 - 03.06.2012	22291	0,172	3834,1	587,5	7	1,2
	4.06.2012 - 10.06.2012	22284	0,200	4451,3	775,0	14	2,8
	11.06.2012 - 17.06.2012	22270	0,236	5264,3	1037,5	15	3,5
	18.06.2012 - 24.06.2012	22255	0,285	6352,8	950,0	31	8,8
	25.06.2012 - 01.07.2012	22224	0,330	7344,0	1162,5	15	5,0
	02.07.2012	**22209**	**0,386**	8562,7	**4512,5**	**82**	**21,4**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
3M	28.05.2012 - 03.06.2012	26983	0,174	4695,0	650,0	6	1,0
	4.06.2012 - 10.06.2012	26977	0,199	5378,2	850,0	16	3,2
	11.06.2012 - 17.06.2012	26961	0,233	6269,8	1187,5	9	2,1
	18.06.2012 - 24.06.2012	26952	0,279	7517,7	1050,0	13	3,6
	25.06.2012 - 01.07.2012	26939	0,320	8619,3	1200,0	11	3,5
	02.07.2012	**26928**	**0,367**	9878,9	**4937,5**	**55**	**13,5**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
4M	28.05.2012 - 03.06.2012	21900	0,176	3854,4	587,5	6	1,1
	4.06.2012 - 10.06.2012	21894	0,204	4471,8	775,0	11	2,2
	11.06.2012 - 17.06.2012	21883	0,242	5285,3	1037,5	9	2,2
	18.06.2012 - 24.06.2012	21874	0,291	6375,2	962,5	11	3,2
	25.06.2012 - 01.07.2012	21863	0,338	7385,2	1162,5	3	1,0
	02.07.2012	**21860**	**0,394**	8607,9	**4525,0**	**40**	**9,7**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
5M	28.05.2012 - 03.06.2012	13931	0,180	2507,6	462,5	8	1,4
	4.06.2012 - 10.06.2012	13923	0,215	2993,0	525,0	2	0,4
	11.06.2012 - 17.06.2012	13921	0,255	3545,2	712,5	4	1,0
	18.06.2012 - 24.06.2012	13917	0,309	4294,2	712,5	15	4,6
	25.06.2012 - 01.07.2012	13902	0,363	5039,5	787,5	8	2,9
	02.07.2012	**13894**	**0,422**	5865,6	**3200,0**	**37**	**10,4**
Total:		**107436**	**0,387**	**41548,1**	**21700,0**	**289**	**75,7**

The hand noted data in July

July							
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
1M	2.07.2012 - 8.07.2012	22545	0,383	8634,7	1115,0	21	8,0
	9.07.2012 - 15.07.2012	22524	0,433	9741,7	612,5	67	29,0
	16.07.2012 - 22.07.2012	22457	0,460	10325,2	825,0	83	38,2
	23.07.2012 - 29.07.2012	22374	0,497	11112,1	762,5	128	63,6
	30.07.2012	22246	0,531	11811,0			0,0
	30.07.2012	**22246**	**0,531**	11811,0	**3315,0**	**299**	**138,8**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
	2.07.2012 - 8.07.2012	22209	0,386	8572,7	1115,0	17	6,6
	9.07.2012 - 15.07.2012	22192	0,436	9681,1	612,5	75	32,7
	16.07.2012 - 22.07.2012	22117	0,464	10260,9	825,0	85	39,4
	23.07.2012 - 29.07.2012	22032	0,501	11046,5	762,5	163	81,7
	30.07.2012	21869	0,536	11727,2			0,0
	30.07.2012	**21869**	**0,536**	11727,2	**3315,0**	**340**	**160,4**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
3M	2.07.2012 - 8.07.2012	26928	0,367	9882,6	1312,5	13	4,8
	9.07.2012 - 15.07.2012	26915	0,416	11190,3	775,0	72	29,9
	16.07.2012 - 22.07.2012	26843	0,445	11935,4	975,0	83	36,9
	23.07.2012 - 29.07.2012	26760	0,481	12873,5	825,0	158	76,0
	30.07.2012	26602	0,512	13622,5			0,0
	30.07.2012	**26602**	**0,512**	13622,5	**3887,5**	**326**	**147,6**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
4M	2.07.2012 - 8.07.2012	21860	0,394	8612,8	1100,0	18	7,1
	9.07.2012 - 15.07.2012	21842	0,444	9705,7	612,5	84	37,3
	16.07.2012 - 22.07.2012	21758	0,473	10280,9	825,0	61	28,8
	23.07.2012 - 29.07.2012	21697	0,511	11077,1	762,5	127	64,8
	30.07.2012	21570	0,546	11774,8			0,0
	30.07.2012	**21570**	**0,546**	11774,8	**3300,0**	**290**	**138,1**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
5M	2.07.2012 - 8.07.2012	13894	0,422	5863,3	762,5	3	1,3
	9.07.2012 - 15.07.2012	13891	0,477	6624,5	455,0	66	31,5
	16.07.2012 - 22.07.2012	13825	0,510	7048,0	602,5	31	15,8
	23.07.2012 - 29.07.2012	13794	0,553	7634,7	525,0	86	47,6
	30.07.2012	13708	0,592	8112,1			0,0
	30.07.2012	**13708**	**0,592**	8112,1	**2345,0**	**186**	**96,1**
Total:		**105995**	**0,538**	**57047,6**	**16162,5**	**1441**	**681,0**

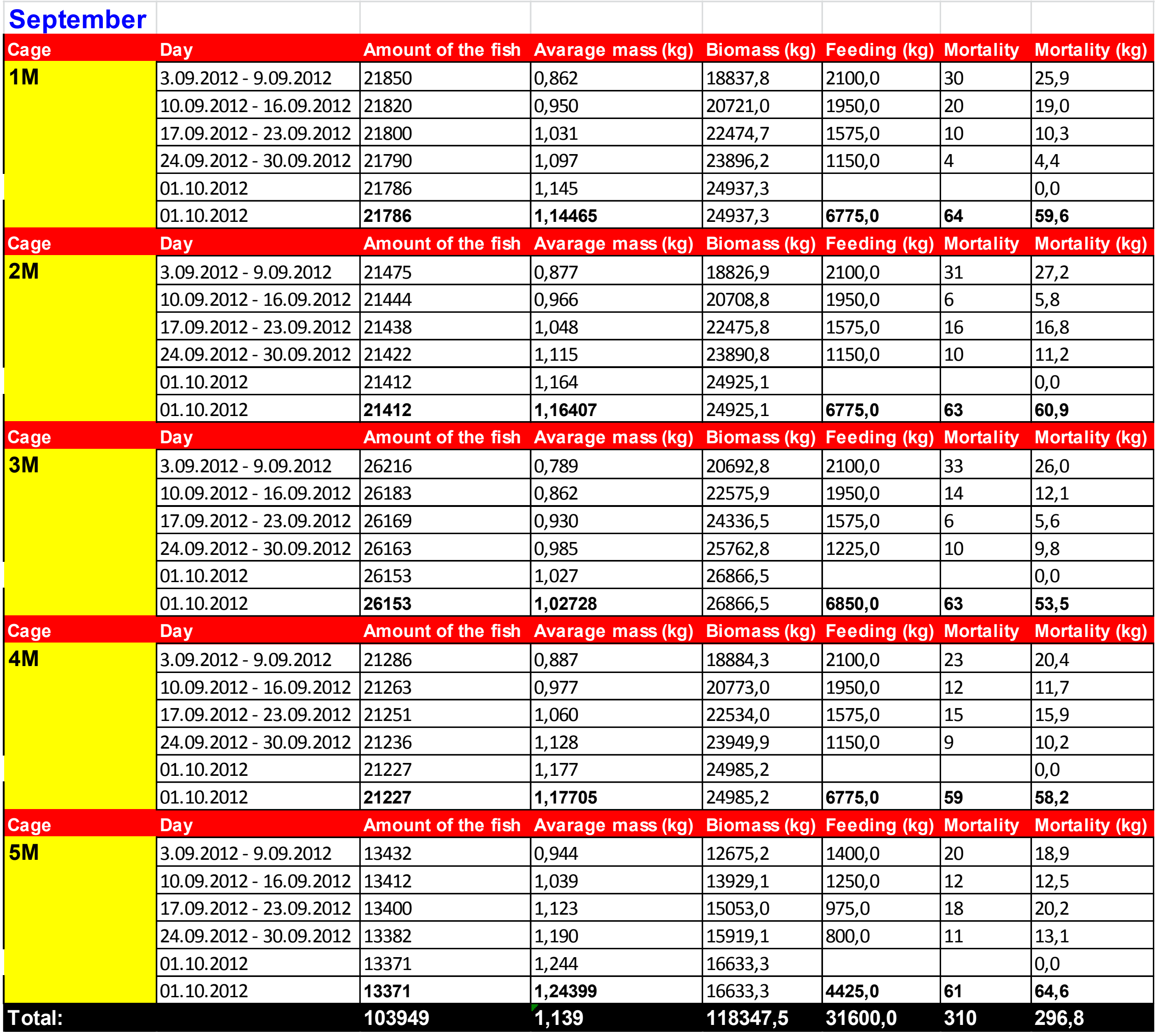
Appendix 5 (4)

The hand noted data in August



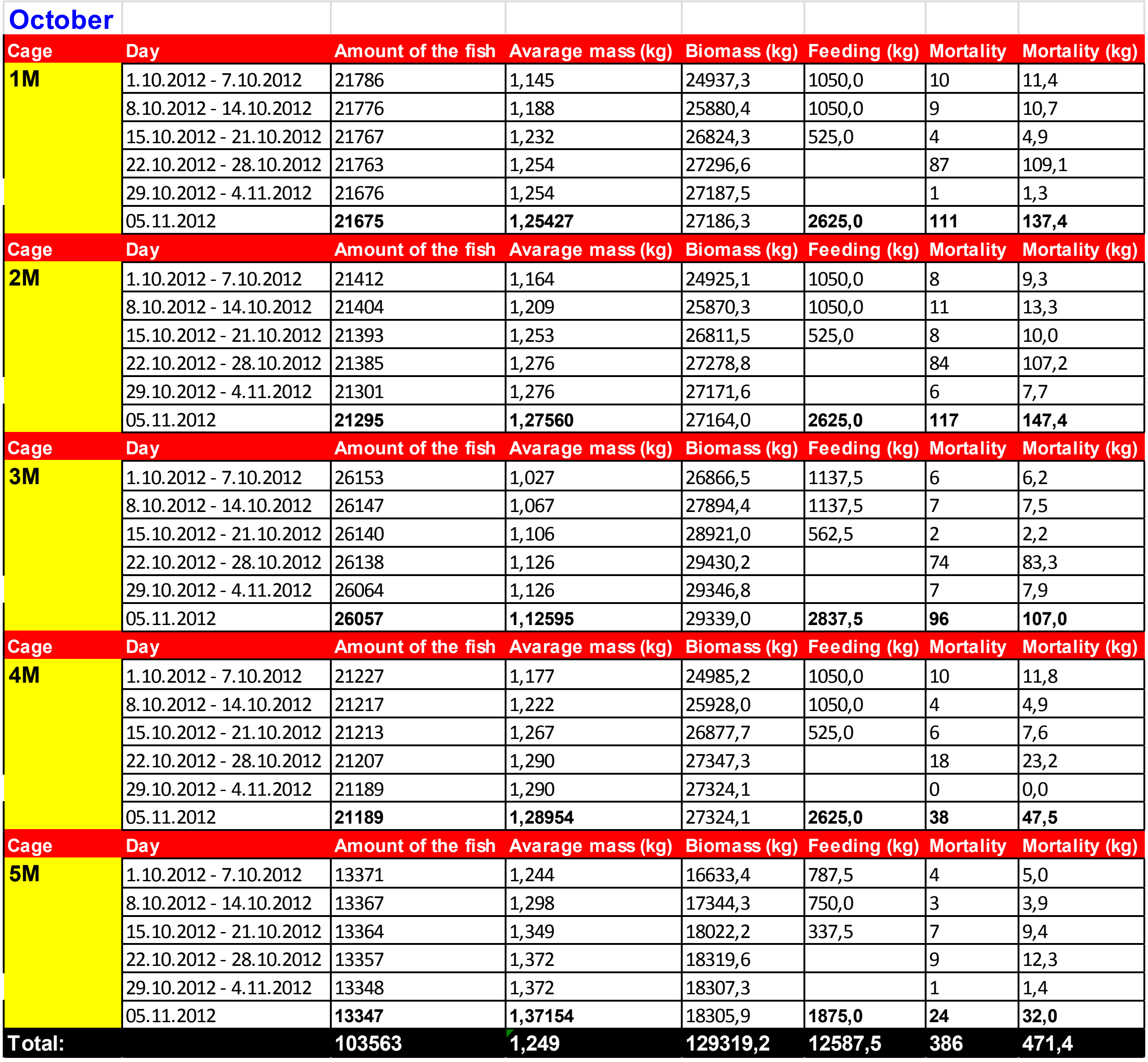
August							
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
1M	30.07.2012 - 5.08.2012	22246	0,531	11811,1	537,5	116	61,6
	6.08.2012 - 12.08.2012	22130	0,555	12287,0	1375,0	115	63,9
	13.08.2012 - 19.08.2012	22015	0,618	13598,1	1650,0	79	48,8
	20.08.2012 - 26.08.2012	21936	0,693	15199,3	1725,0	62	43,0
	27.08.2012 - 2.09.2012	21874	0,772	16881,4	1975,0	24	18,5
	03.09.2012	**21850**	**0,86214**	18837,9	**7262,5**	**396**	**235,7**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
2M	30.07.2012 - 5.08.2012	21869	0,536	11727,3	537,5	124	66,5
	6.08.2012 - 12.08.2012	21745	0,561	12198,3	1375,0	104	58,3
	13.08.2012 - 19.08.2012	21641	0,625	13514,9	1600,0	73	45,6
	20.08.2012 - 26.08.2012	21568	0,699	15069,3	1850,0	64	44,7
	27.08.2012 - 2.09.2012	21504	0,785	16874,6	1975,0	29	22,8
	03.09.2012	**21475**	**0,87669**	18826,9	**7337,5**	**394**	**237,9**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
3M	30.07.2012 - 5.08.2012	26602	0,512	13622,4	537,5	106	54,3
	6.08.2012 - 12.08.2012	26496	0,532	14105,6	1375,0	121	64,4
	13.08.2012 - 19.08.2012	26375	0,584	15416,2	1600,0	87	50,9
	20.08.2012 - 26.08.2012	26288	0,645	16965,3	1800,0	57	36,8
	27.08.2012 - 2.09.2012	26231	0,714	18728,5	1975,0	15	10,7
	03.09.2012	**26216**	**0,78932**	20692,8	**7287,5**	**386**	**217,0**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
4M	30.07.2012 - 5.08.2012	21570	0,546	11774,8	537,5	86	46,9
	6.08.2012 - 12.08.2012	21484	0,571	12265,4	1375,0	60	34,3
	13.08.2012 - 19.08.2012	21424	0,635	13606,1	1650,0	45	28,6
	20.08.2012 - 26.08.2012	21379	0,712	15227,6	1750,0	69	49,1
	27.08.2012 - 2.09.2012	21310	0,794	16928,4	1975,0	24	19,1
	03.09.2012	**21286**	**0,88717**	18884,4	**7287,5**	**284**	**178,0**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
5M	30.07.2012 - 5.08.2012	13708	0,592	8112,1	412,5	59	34,9
	6.08.2012 - 12.08.2012	13649	0,622	8489,7	1062,5	77	47,9
	13.08.2012 - 19.08.2012	13572	0,700	9504,3	925,0	70	49,0
	20.08.2012 - 26.08.2012	13502	0,769	10380,3	1075,0	54	41,5
	27.08.2012 - 2.09.2012	13448	0,849	11413,8	1275,0	16	13,6
	03.09.2012	**13432**	**0,94366**	12675,2	**4750,0**	**276**	**186,9**
Total:		**104259**	**0,862**	**89917,1**	**33925,0**	**1736**	**1055,6**

The hand noted data in September



September							
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
1M	3.09.2012 - 9.09.2012	21850	0,862	18837,8	2100,0	30	25,9
	10.09.2012 - 16.09.2012	21820	0,950	20721,0	1950,0	20	19,0
	17.09.2012 - 23.09.2012	21800	1,031	22474,7	1575,0	10	10,3
	24.09.2012 - 30.09.2012	21790	1,097	23896,2	1150,0	4	4,4
	01.10.2012	21786	1,145	24937,3			0,0
	01.10.2012	**21786**	**1,14465**	24937,3	**6775,0**	**64**	**59,6**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
2M	3.09.2012 - 9.09.2012	21475	0,877	18826,9	2100,0	31	27,2
	10.09.2012 - 16.09.2012	21444	0,966	20708,8	1950,0	6	5,8
	17.09.2012 - 23.09.2012	21438	1,048	22475,8	1575,0	16	16,8
	24.09.2012 - 30.09.2012	21422	1,115	23890,8	1150,0	10	11,2
	01.10.2012	21412	1,164	24925,1			0,0
	01.10.2012	**21412**	**1,16407**	24925,1	**6775,0**	**63**	**60,9**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
3M	3.09.2012 - 9.09.2012	26216	0,789	20692,8	2100,0	33	26,0
	10.09.2012 - 16.09.2012	26183	0,862	22575,9	1950,0	14	12,1
	17.09.2012 - 23.09.2012	26169	0,930	24336,5	1575,0	6	5,6
	24.09.2012 - 30.09.2012	26163	0,985	25762,8	1225,0	10	9,8
	01.10.2012	26153	1,027	26866,5			0,0
	01.10.2012	**26153**	**1,02728**	26866,5	**6850,0**	**63**	**53,5**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
4M	3.09.2012 - 9.09.2012	21286	0,887	18884,3	2100,0	23	20,4
	10.09.2012 - 16.09.2012	21263	0,977	20773,0	1950,0	12	11,7
	17.09.2012 - 23.09.2012	21251	1,060	22534,0	1575,0	15	15,9
	24.09.2012 - 30.09.2012	21236	1,128	23949,9	1150,0	9	10,2
	01.10.2012	21227	1,177	24985,2			0,0
	01.10.2012	**21227**	**1,17705**	24985,2	**6775,0**	**59**	**58,2**
Cage	Day	Amount of the fish	Avarage mass (kg)	Biomass (kg)	Feeding (kg)	Mortality	Mortality (kg)
5M	3.09.2012 - 9.09.2012	13432	0,944	12675,2	1400,0	20	18,9
	10.09.2012 - 16.09.2012	13412	1,039	13929,1	1250,0	12	12,5
	17.09.2012 - 23.09.2012	13400	1,123	15053,0	975,0	18	20,2
	24.09.2012 - 30.09.2012	13382	1,190	15919,1	800,0	11	13,1
	01.10.2012	13371	1,244	16633,3			0,0
	01.10.2012	**13371**	**1,24399**	16633,3	**4425,0**	**61**	**64,6**
Total:		103949	1,139	118347,5	31600,0	310	296,8

The hand noted data in October



October							
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
1M	1.10.2012 - 7.10.2012	21786	1,145	24937,3	1050,0	10	11,4
	8.10.2012 - 14.10.2012	21776	1,188	25880,4	1050,0	9	10,7
	15.10.2012 - 21.10.2012	21767	1,232	26824,3	525,0	4	4,9
	22.10.2012 - 28.10.2012	21763	1,254	27296,6		87	109,1
	29.10.2012 - 4.11.2012	21676	1,254	27187,5		1	1,3
	05.11.2012	**21675**	**1,25427**	27186,3	**2625,0**	**111**	**137,4**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
2M	1.10.2012 - 7.10.2012	21412	1,164	24925,1	1050,0	8	9,3
	8.10.2012 - 14.10.2012	21404	1,209	25870,3	1050,0	11	13,3
	15.10.2012 - 21.10.2012	21393	1,253	26811,5	525,0	8	10,0
	22.10.2012 - 28.10.2012	21385	1,276	27278,8		84	107,2
	29.10.2012 - 4.11.2012	21301	1,276	27171,6		6	7,7
	05.11.2012	**21295**	**1,27560**	27164,0	**2625,0**	**117**	**147,4**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
3M	1.10.2012 - 7.10.2012	26153	1,027	26866,5	1137,5	6	6,2
	8.10.2012 - 14.10.2012	26147	1,067	27894,4	1137,5	7	7,5
	15.10.2012 - 21.10.2012	26140	1,106	28921,0	562,5	2	2,2
	22.10.2012 - 28.10.2012	26138	1,126	29430,2		74	83,3
	29.10.2012 - 4.11.2012	26064	1,126	29346,8		7	7,9
	05.11.2012	**26057**	**1,12595**	29339,0	**2837,5**	**96**	**107,0**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
4M	1.10.2012 - 7.10.2012	21227	1,177	24985,2	1050,0	10	11,8
	8.10.2012 - 14.10.2012	21217	1,222	25928,0	1050,0	4	4,9
	15.10.2012 - 21.10.2012	21213	1,267	26877,7	525,0	6	7,6
	22.10.2012 - 28.10.2012	21207	1,290	27347,3		18	23,2
	29.10.2012 - 4.11.2012	21189	1,290	27324,1		0	0,0
	05.11.2012	**21189**	**1,28954**	27324,1	**2625,0**	**38**	**47,5**
Cage	**Day**	**Amount of the fish**	**Avarage mass (kg)**	**Biomass (kg)**	**Feeding (kg)**	**Mortality**	**Mortality (kg)**
5M	1.10.2012 - 7.10.2012	13371	1,244	16633,4	787,5	4	5,0
	8.10.2012 - 14.10.2012	13367	1,298	17344,3	750,0	3	3,9
	15.10.2012 - 21.10.2012	13364	1,349	18022,2	337,5	7	9,4
	22.10.2012 - 28.10.2012	13357	1,372	18319,6		9	12,3
	29.10.2012 - 4.11.2012	13348	1,372	18307,3		1	1,4
	05.11.2012	**13347**	**1,37154**	18305,9	**1875,0**	**24**	**32,0**
Total:		**103563**	**1,249**	**129319,2**	**12587,5**	**386**	**471,4**