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# Effects of oxygen deficit on post-smolt salmon. Trial II

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## Preface

The study at EWOS Innovation in Dirdal was conducted as collaboration between EWOS Innovation and Rogaland Research. Tests of the effects of dissolved oxygen (DO) deficit on salmon post-smolt are a vital part of the on-going R&D project involving EWOS Innovation – OxSeaVision (OSV) – RF. The reported study was carried out at high summer temperature (mainly ca. 15 °C) – unlike the formerly reported study conducted at 8 – 9 °C.

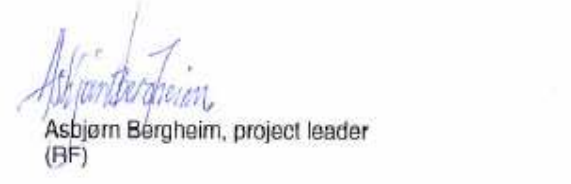
In the present project, Leif Pedersen, Marianne Gjesdal and Kristian Rage at Dirdal have played an important role in collecting data, inspecting measuring equipment, etc. throughout the sampling period. Per Arne Oftedal conducted the set-up of technical facilities prior to sampling. Besides, Dr. Viv Crampton, research manager at EWOS Innovation, is an important decision maker, especially in the planning process.

Generally, the authors have been involved in all project stages. Anne Brit Fjermedal, has been the local day-to-day head of the project.

The project was financially supported by EWOS and Nor. Res. Board (SkatteFUNN – based project). Per Hølland was project manager of the SkatteFUNN project (No. 24123).

Åge Molversmyr, senior research scientist at RF, has quality ensured the report.

Stavanger, 05 April 2005



Asbjørn Bergheim, project leader (RF)

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# 1 Summary

Performance of post-smolt Atlantic salmon was studied in tanks at four different levels of dissolved oxygen (DO) at 15 – 16 °C: 60 %, 75 %, 90 % and diurnally fluctuating between 60 and 90 % of saturation. Due to some technical problems, the fish stock in tanks representing the lowest DO group (pre-set: 60 %) experienced an overall average DO level of 66 - 67 % of saturation. After the 56-day test period, the fish was subject to a 2-month recovery phase without any oxygen deficit and lower temperature (10 - 12 °C). The trial was a follow-up of the DO deficit project performed at EWOS Innovation Dirdal in 2002 at lower temperature.

Salmon of 2.5 – 3 kg was stocked in 3 $m^3$ tanks in July 2004 at a density of 35 – 40 kg per $m^3$. Commercial extruded feed was fed to satiation and lost feed was collected in the individual tank.

A decreased growth rate and feed utilisation was observed with reduced DO level but the falling trend was not statistically proved. The obvious reason for the lacking significance was a highly varying performance among tanks within the different DO groups. This seemed to be partly due to varying sexual maturation, from 3 to 22 % in the individual tank, reducing the feed utilisation in several tanks irrespective of DO levels. In some tanks, there were also episodic problems to control the DO concentration. In the control group (90% of DO saturation) representing "optimum" rearing conditions, the fish performance was quite poorer than expected.

In the low DO group, the growth rate (SGR) was 40 – 50% lower and the feed conversion ration (FCR) ca. 30% higher compared with in the other groups. The feed quantity consumed in this group (low DO) was correspondingly reduced. During the succeeding recovery phase, the fish performance in the Low DO group was still poorer than at higher DO levels. The mortality rate was below 0.5% in all four groups.

Gill ventilation frequency, indicating respiratory stress, was found to increase significantly at low and fluctuating DO levels compared with at stable DO levels above 75% of saturation. A slight increase was also observed when reducing DO saturation from 90% to 75%, from ca. 60 to 65 – 70 opercular movements per minute (60% DO and fluctuating DO: 78 – 87 movements per min).

This trial will be repeated studying effects on younger post-smolt salmon (1 – 2 kg) of decreased DO concentrations in the range 95 to 65% of saturation at the same temperature level.

# 2 Introduction

Water temperature, dissolved oxygen concentration (DO) and photoperiod are potentially influencing on feed intake, metabolic rate and energy expenditure, and thus, on growth in fish (e.g. Brett, 1979). In salmonids, the link between DO and growth rate/feed consumption is well documented for juvenile rainbow trout (Pedersen, 1987) and young Pacific salmon (Brett and Blackburn, 1981), while there is limited available information of 'critical' DO levels for Atlantic salmon. Buentello *et al.* (2000) has estimated the optimal temperature – DO combinations for feed consumption, feed conversion efficiency and growth of channel catfish.

The basic connection between ambient DO and growth rate is described by Jobling (1993), Figure 1. When the level of DO is low, feed intake may be suppressed probably due to the fact that reduced oxygen availability would be unable to support the high energy demands of well-fed fish. At low DO, the reduced feed intake would obviously have consequences for growth. Therefore, it is highly important to determine the critical level of DO at which feed intake and growth become affected in farmed fish species.

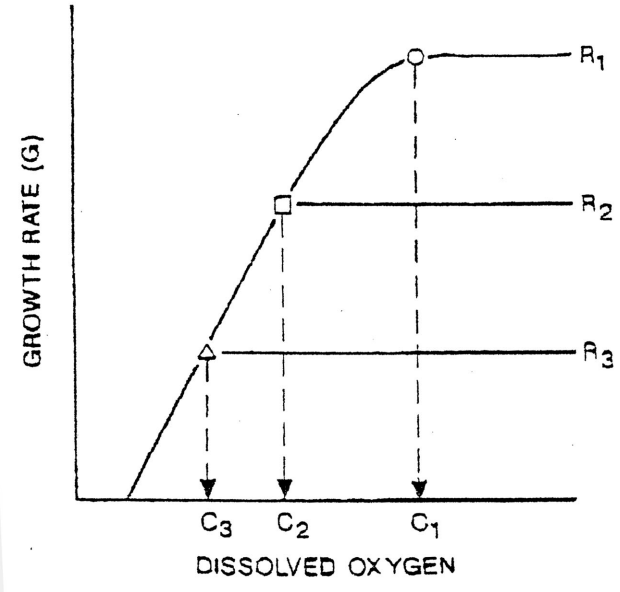


**Figure 1**. Influence of level of dissolved oxygen (DO) upon growth rate of fish fed three different feed levels ($R_1$: high, $R_2$: intermediate, $R_3$: low feeding rate), Jobling (1993). $C_1$, $C_2$, $C_3$: critical levels of DO required for the maintenance of maximum growth at high, intermediate and low feeding rates, respectively

In an elucidative experiment, metabolic rate, feed utilisation and growth rate in rainbow trout of 100 g were studied within the DO range 4 - 12 mg/L at 15 °C (Pedersen, 1985

& 1987, Figure 2). The critical level of DO for feed intake (appetite) was about 6 mg/L (ca. 60 % of saturation), while the critical level for growth rate and feed utilisation was about 7 mg/L (ca. 70 % of saturation) for fish fed maximum ration. Regarding assimilation of energy and excretion rate of ammonia ($NH_4$ + $NH_3$) no relation to DO was found.

At 50 % of DO saturation (5 mg/L), the growth rate (SGR) of rainbow trout is only half of the rate at DO above 70 % (7 mg/L), while the feed utilisation is 44 % lower (FCR: 1.56 and 1.08 kg/kg, respectively, Figure 2). In other words, this study indicates that DO in tanks stocked with rainbow trout should be kept above 70 – 80 % of saturation at optimal temperature in order to utilise the growth potential.

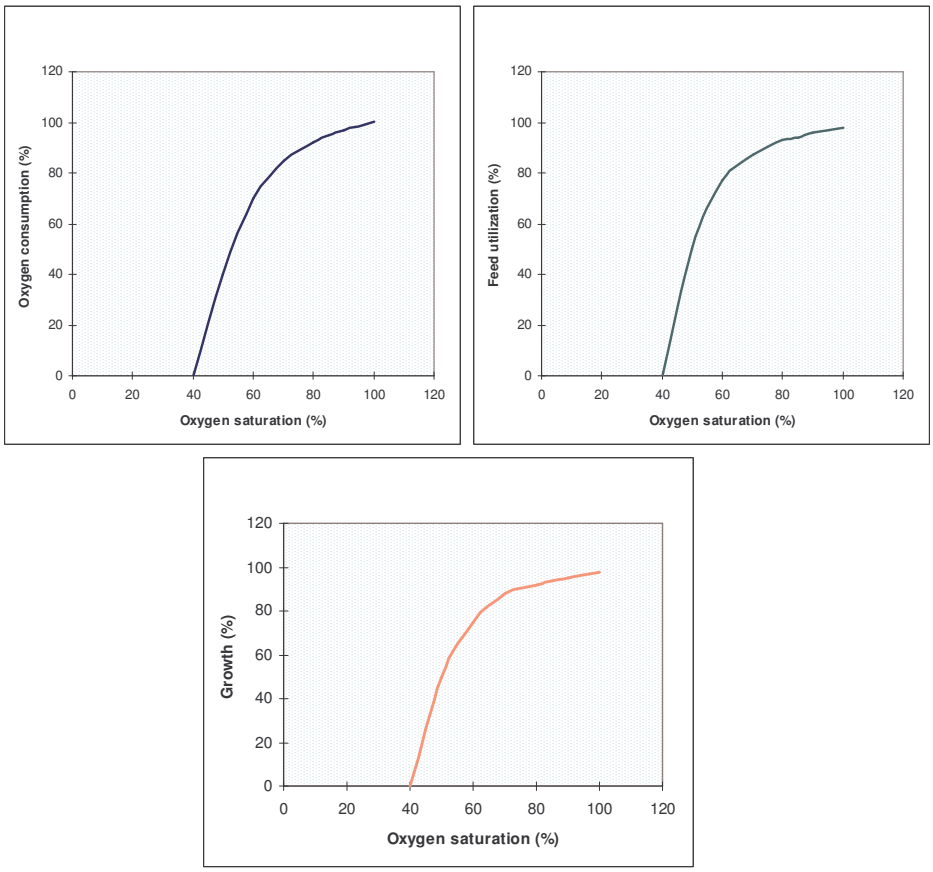


**Figure 2**. Oxygen consumption (a), feed utilisation (b) and growth rate (c) at maximum feed ration in rainbow trout (fish size: 100 g, temperature: 15 °C) in the following DO range: 4, 5, 6, 7, 8.5, 10 and 12 mg/L (40 – 120 % of saturation). Source: Pedersen (1985, 1987)

A few studies have been carried out to assess the effects of reduced DO on post-smolt Atlantic salmon. The lower limit for optimal growth of adult salmon in tanks has been reported to be 6 mg/L at temperature below 10 °C (Berg & Danielsberg (1993). Seymour *et al.* (1992) demonstrated 20 % reduced growth in tanks stocked with salmon (0.5 – 1.5 kg) when the frequency of low DO concentrations in the range 4 – 6 mg/L turned 10 % (8 – 10 °C, sampling time: 6 months).

Seland & Berg (1993) reported unaffected growth rate and feed conversion ratio (FCR) in salmon of 170 – 850 g exposed to short-term DO drops from 7 – 8 mg/L (ca. 75 % of saturation at 8 – 9 °C) down to 2 – 3 mg/L (< 25%). The DO drops were repeated 2 – 3 times during one week, each drop lasting for 6 – 8 hrs (< 5 mg/L for 3 – 6 hrs).

In another study, no negative effects were reported on growth, mortality, FCR or oxygen consumption in salmon at DO fluctuations of 4 – 13 mg/L during a 126 day period. Throughout the period, DO concentrations below 6 mg/L were rare (Forsberg & Bergheim, 1996).

The presented project is a follow-up of a trial studying the effects of reduced DO concentrations (50 – 100 % of saturation) on adult Atlantic salmon at relatively low temperature (8 – 9 °C), Bergheim et al. 2002. The first study (Trial I) clearly indicated reduced growth and feed utilisation even at moderate DO deficit (Figure 3).

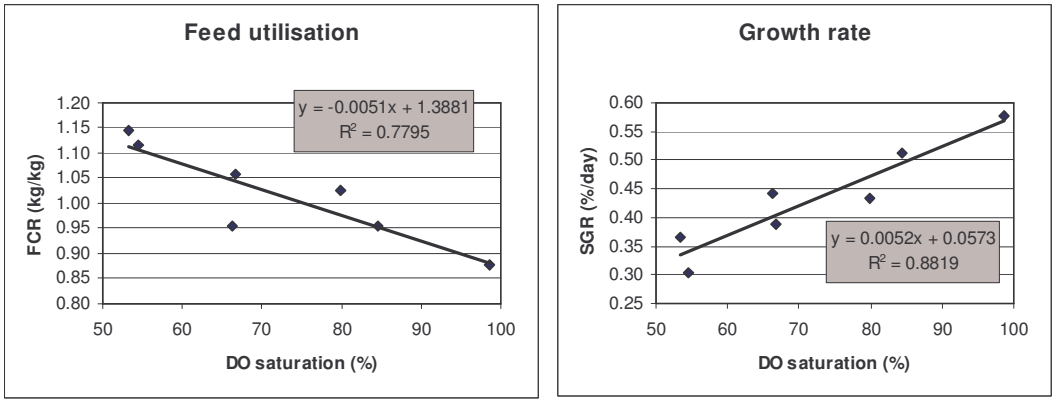


**Figure 3.** Feed utilisation (FCR) and growth (g) in post-smolt Atlantic salmon exposed to four levels of DO concentrations at low temperature (8 – 9 °C). Test period: 24 April – 17 June 2002. EWOS Innovation Dirdal

## Justification

The objectives of the described study were the following:

- To obtain basic knowledge of the relation between DO level and feed utilisation and growth in post-smolt Atlantic salmon at *summer temperature*

- To contribute to improved insight of stress reactions at decreased DO concentrations
- To estimate critical DO concentrations of salmon where oxygen addition is recommendable

# 3 Material and methods

## 3.1 Experimental set-up

The fish test was performed in the new Research Hall at EWOS Innovation in Dirdal during two phases:

Test phase: 24/25 August – 19/20 October 2004 (56 days), different DO levels (15-16 ºC)

Recovery phase: 19/20 October – 20/21 December 2004 (62 days), 90 – 100 % DO saturation, (10 – 12 ºC)

**Fish tanks**

The facilities of the new Research Hall are described by Hølland and Bergheim (2005). Introduction of the energy system allows a temperature range from 8 to 16 ºC in the tanks.

Eighteen circular tanks of 2.0 m diameter and 1.15 m water depth (water volume: 3,000 L) were used. The tanks were supplied seawater (27 – 30 ppt salinity, ca. 8.5 °C temperature) pumped from 90 m depth. A flow of 40 L/min per tank was kept throughout the period which corresponded to a specific flow above 0.3 L/kg · min. The DO level of inlet water to the tanks was ca. 100 % of saturation and oxygen was supplied by diffusors placed on the tank bottom (system: GasX II from OxSeaVision). Initially, the flow rate was adjusted to the DO consumption in the tanks based on a PLC control system. Four DO concentrations were kept: 66-67 %, 75 %, 90 % and diurnally fluctuating DO between 90 and 60 % of saturation. The tank arrangement was the following:

| | | |
|---|---|---|
| High DO group | (90 % of saturation): | Tank No. 1, 5, 11 (3 replicates) |
| Medium DO group | (75 % of saturation): | Tank No. 3, 10, 13, 17 (4 replicates) |
| Low DO group | (66 % of saturation): | Tank No. 6, 8, 16 (3 replicates) |
| Fluctuating DO group (8 replicates) | (90 – 60 % of saturation): | Tank No. 2, 4, 7, 9, 12, 14, 15, 18 |

From stocking in late July, temperature was gradually increased to 14 – 15 °C at the time of project start, kept around 16°C throughout the test phase and then reduced to 10 – 12 °C in the recovery phase.

The tanks are equipped with a system which separates lost feed and faeces, and collects the lost feed pellets (system: Hølland Teknologi).

**Fish stock**

About 700 adult salmon of the AquaGen strain were stocked in the tanks in July 2004 (Week 29). The eggs were delivered from Erfjord Stamfisk in January 2002 and became smolt in spring 2003. All fish were individually marked at time of stocking (pit tag). Until individual weighing and length measuring on 24 August, the temperature was gradually increased by about one degree per week and the DO concentration was kept stable at about 90% of saturation. The stocking density at start was 37 – 40 individuals with a mean weight of 2.5 – 2.8 kg (94 – 113 kg, i.e. 31 – 38 kg per $m^3$) and at the end of the trial in December: a mean weight of 3.0 – 3.8 kg, a biomass per tank of 115 – 149 kg corresponding to a density of 38 – 50 kg per $m^3$.

The feed applied was EWOS pyramid ytelse (37/40 prt/oil, GE 26.8 MJ/kg) and EWOS pyramid kvalitet (40/30 prt/oil, GE 24.4 MJ/kg). These are commercial products from EWOS Norway. EWOS pyramid kvalitet was fed to all tanks apart from four tanks at diurnally varying DO level.

Feed consumed per tank was calculated as follows:

Feed consumed (kg) = Supplied feed – Lost feed, where

supplied feed was calculated as feed quantity (kg) put in the automat less the residual feed after 14 days, while lost feed was the totally collected feed loss (kg) during 14 days (daily collected). In practice, the daily number of lost pellets is counted per tank and feed loss is then calculated based on the weight of 20 dry pellets.

## 3.2 Measuring program

The protocol is briefly described in Table 1.

**Oxygen, temperature and salinity**

DO and temperature in each tank were monitored continually (system: Visual Control Centre), readings were logged twice a minute (30 sec intervals). DO sensors (type: SensorX) were calibrated once a month (calibration in air). In the inlet water, salinity was measured daily (system: Aanderaa Instruments, Display Unit 3017/Sensor Unit 3210).

**Flow**

The flow rate of each tank was adjusted to 40 L/min twice (reading the flow meter), on 24-25 August and on 19-20 October. The rate was stable throughout the period (constant water pressure).

**Fish stock, feeding routine etc**

Individual fish weight (1 g) and length (fork length, 0.5 cm) was measured at start (24 Aug), at the end of the trial stage (19/20 Oct) and at the end of the recovery phase (20/21 Dec). Fish were anaesthetised using Aqui-S (clove oil) at start and in the intermediary sampling. At the final sampling, fish were killed and individual weight of bled fish was measured (UBW: body weight of bled, ungutted fish). Then, gonads were weighed (g) and sex determined.

**Table 1**. Sampling program of the oxygen deficit project (Part II) at EWOS Innovation Dirdal 24/25 August – 20/21 December 2004). Trial phase: 24/25 Aug – 19/20 Oct, Recovery phase: 19/20 Oct – 20/21 Dec.

| Parameter | Sampling point | Frequency |
|---|---|---|
| Water quality: | | |
| Temperature (°C) | Inlet water | Daily |
| DO (mg/L) | In each tank | Continuous |
| Salinity (ppt) | Inlet water | Daily |
| Water flow (L/min) | Inlet each tank | Adjusted 24-25 August & 19-20 October |
| Fish stock: | | |
| Individual size, weight (g) & length (cm) | Each tank | 24-25 August, 19-20 October & 20-21 December |
| Mortality | | Daily |
| Feed rate, g/day | Each tank | Fortnightly |
| Feed loss | Outlet each tank | Daily |

**Respiration frequency**

Respiration frequency of three individuals per tank was measured three times, on 10 September, 24 September and on 6 October. The readings were carried out through the inspection window based on a method described by Fivelstad *et al.* (2003): the time consumed of 25 respiratory cycles (mouth or operculum movements) measured by a stop watch. The results are expressed as respiratory cycles per minute.

**Sexual maturation**

The occurrence of sexually matured fish was examined at slaughtering on 20-21 December. In matured fish, the gonads were weighed (GW) and the gonadosomatic index (GSI) was calculated:

GSI = (GW/UBW)* 100, where UBW is body weight of bled, ungutted fish

**Statistical testing**

Student's t-Test (TTEST, Microsoft Excel) was applied for probability testing of differences between fish performance (SGR, FCR, maturation) and ventilation frequency of the four DO groups.

# 4 Results

## 4.1 Temperature and dissolved oxygen

Temperature turned 15 ºC on 4 September, gradually increased to 16 ºC towards the end of the month and then stayed stable (± 0.2 ºC) till 15 October (Figure 1).

Daily means and standard deviations of DO are presented for some tanks (Figure 2 – 5), while overall means, standard deviations and max – means are presented for all tanks in Table 2. The period with controlled DO levels was defined from 1 September till 15 October. Due to technical faults, such as power failure, temporary deviations were observed outside the acceptable range, i.e. in Tank 1 and 11. In most tanks, however, the pre-set DO level stayed relatively stable throughout the period. Due to technical problems, the mean DO concentrations in the Low DO tanks, pre-set 60 % of saturation, were 66 – 67 % of saturation. For the other DO groups, included the DO fluctuating group, the overall means did not deviate more than 2 % of saturation from pre-set level. Daily means and max – min are also presented in Appendix.

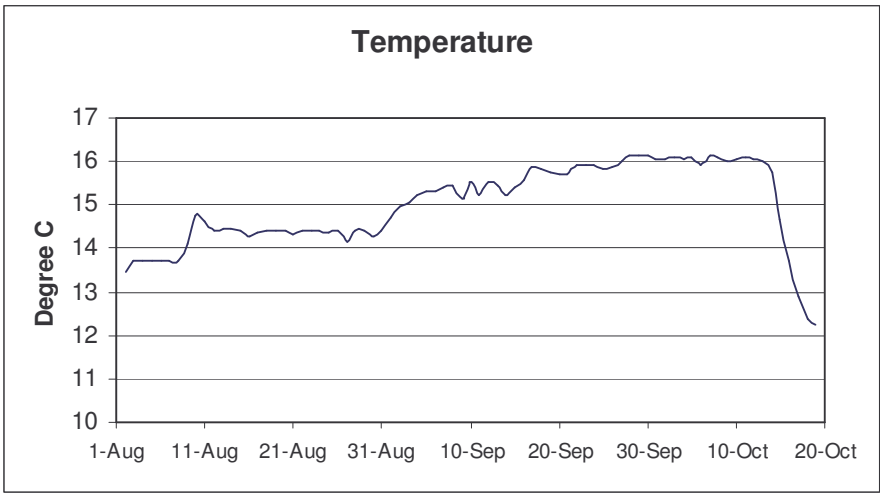


**Figure 1.** Daily average temperature (ºC), Research Hall, EWOS Innovation Dirdal, August – October 2004

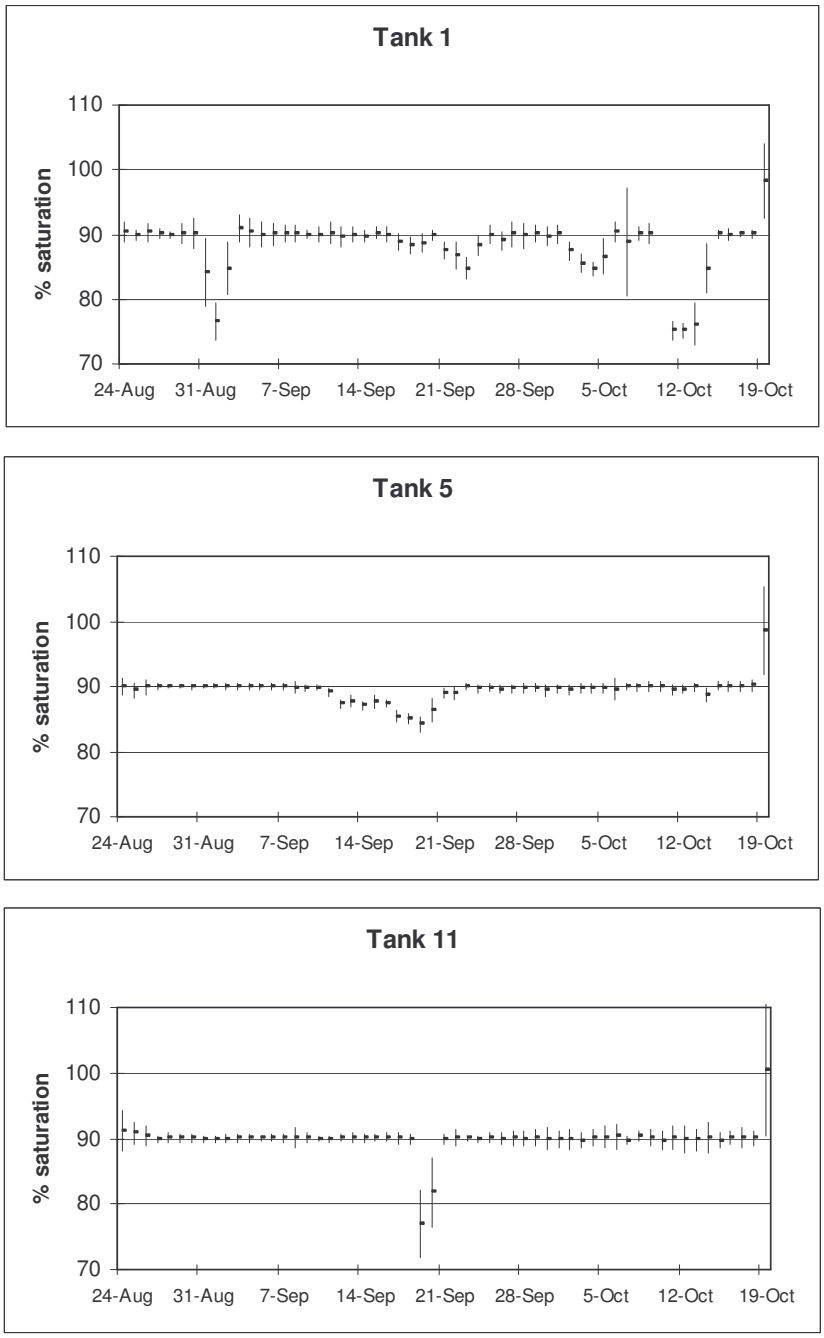


**Figure 2.** Daily DO means and standard deviations (S.D.) in tanks representing High DO level (90 % of saturation). EWOS Innovation Dirdal, 24 Aug. – 19 Oct. 2004 (DO was adjusted step-wise 24 – 31 Aug. and 15 – 17 Oct.)

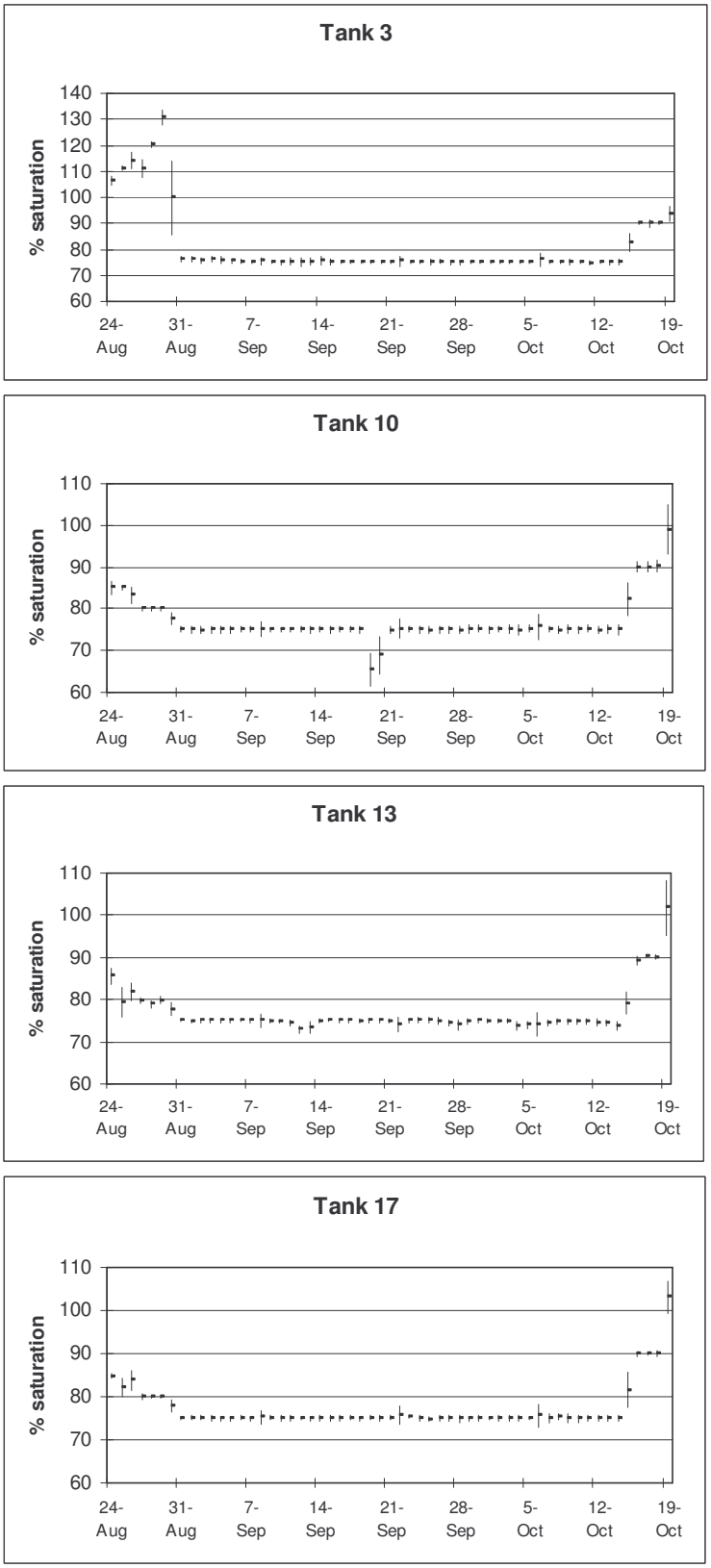


**Figure 3.** Daily DO means and standard deviations (SD) in tanks representing Medium DO level (75 % of saturation). EWOS Innovation Dirdal, 24 Aug. – 19 Oct. 2004

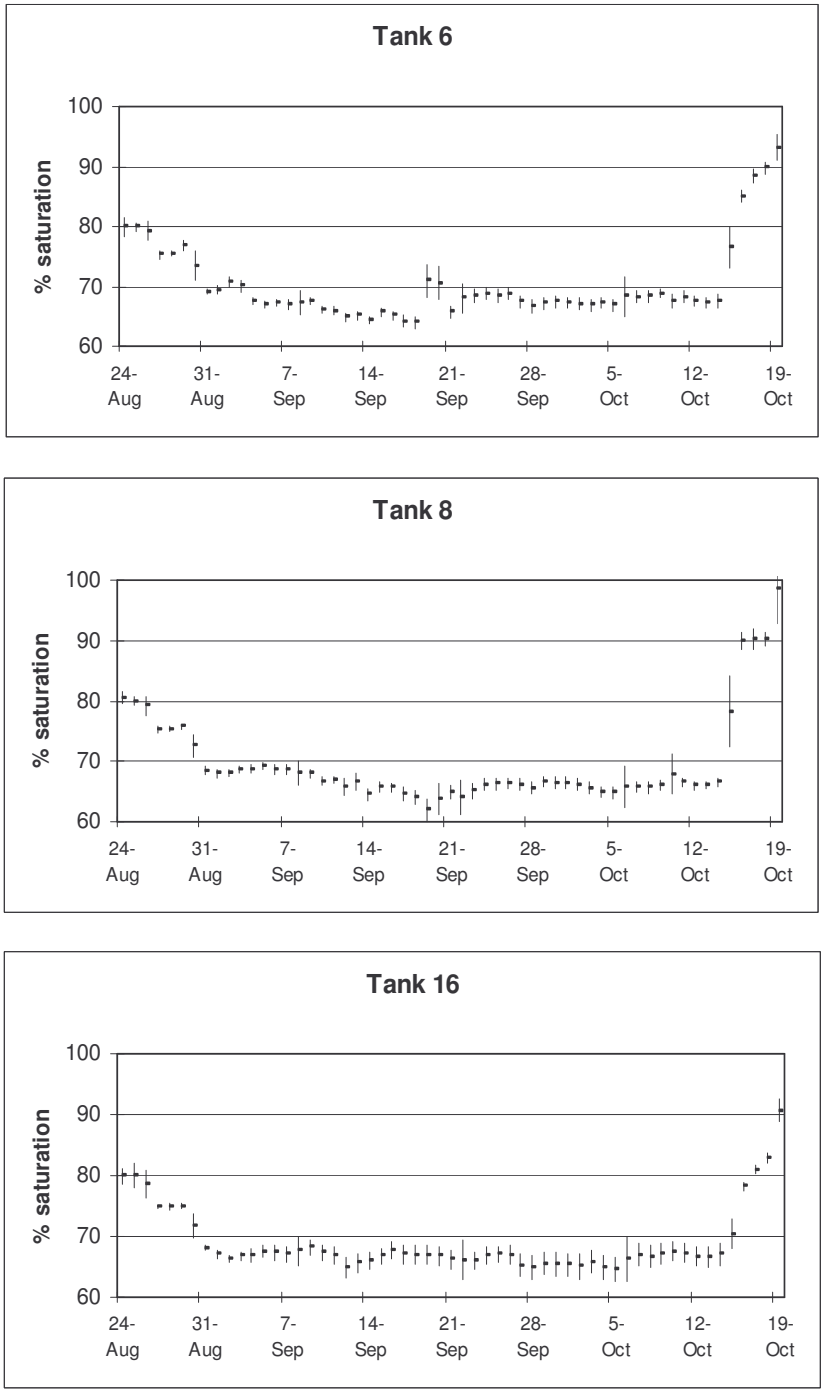


**Figure 4.** Daily DO means and standard deviations (S.D.) in tanks representing Low DO level (60 % of saturation). EWOS Innovation Dirdal, 24 Aug. – 19 Oct. 2004 (DO was adjusted step-wise 24 – 31 Aug. and 15 – 17 Oct.)

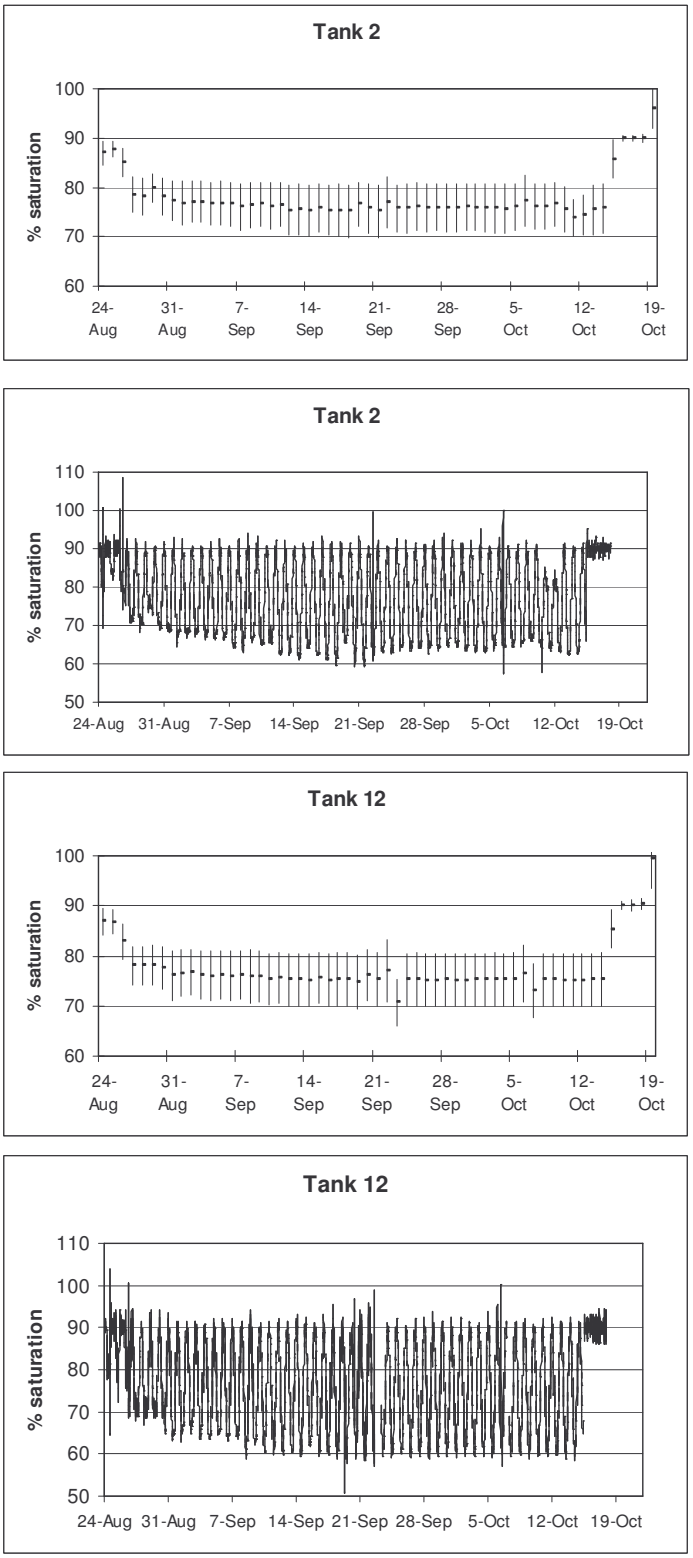


**Figure 5.** Daily DO means, S.D. and diurnal variations in two tanks with Fluctuating levels (90 - 60% of saturation). EWOS Innovation Dirdal, Aug – Oct. 2004 (DO was adjusted step-wise 24 – 31 Aug. and 15 – 17 Oct.)

**Table 2.** DO means, S.D. and max – min in 18 tanks with four pre-set DO levels, EWOS Innovation Dirdal, 1 September – 15 October 2004. Unit: % of DO saturation

| DO Group | Tank No. | Mean, % | S.D., % | Max – min, % |
|---|---|---|---|---|
| High | 1 | 87.9 | 5.3 | 112 - 60 |
| (pre-set: 90 %) | 5 | 89.0 | 2.1 | 100 - 77 |
| | 11 | 89.5 | 4.0 | 122 - 55 |
| Medium | 3 | 75.2 | 2.1 | 100 - 66 |
| (pre-set: 75 %) | 10 | 74.7 | 3.2 | 102 - 49 |
| | 13 | 74.7 | 1.8 | 101 - 67 |
| | 17 | 75.0 | 1.6 | 100 - 63 |
| Low | 6 | 67.3 | 2.9 | 102 - 58 |
| (pre-set: 60 %) | 8 | 66.2 | 3.0 | 118 - 49 |
| | 16 | 66.5 | 3.5 | 99 - 56 |
| Fluctuating | 2 | 75.9 | 9.5 | 100 - 58 |
| (pre-set: | 4 | 76.6 | 8.9 | 100 - 58 |
| 90 – 60 %) | 7 | 76.1 | 9.3 | 100 - 43 |
| | 9 | 75.3 | 10.3 | 103 - 42 |
| | 12 | 75.3 | 10.4 | 100 - 51 |
| | 14 | 76.2 | 9.6 | 100 - 58 |
| | 15 | 74.7 | 10.3 | 101 - 49 |
| | 18 | 75.0 | 11.0 | 110 - 51 |

## 4.2 Fish growth and feed utilisation

Within the different DO groups there were considerable fluctuations between tanks (Figure 6 - 9, Appendix).
The mean SGR and FCR were the following:

| Group | SGR, %/day | FCR, kg/kg |
|---|---|---|
| 90 % DO saturation | 0.27 (0.19) | 1.41 (1.50) |
| 75 % DO saturation: | 0.24 (0.20) | 1.39 (1.48) |
| 66 % DO saturation: | 0.13 (0.13) | 1.94 (1.80) |
| Fluctuating DO saturation: | 0.25 (0.21) | 1.29 (1.45) |

( ): 2nd period (October – December)

The Low DO group demonstrated a noticeably lower growth rate and feed utilisation compared to the three other groups. However, no significant differences were found ($p>0.05$) between any group during the two periods, August – October and October – December, due to the high variation between tanks within groups. This in-group variation is also demonstrated in Figure 9 (DO fluctuating group not included). The growth rate was similar in the High, Medium and Fluctuating DO groups (0.24 – 0.27, 0.19 – 0.21 %/day).

Only three individuals died throughout the test phase (one in Tank 4, 14 and 16), no mortality was observed in the recovery phase.

An overall high feed conversion ratio was calculated. In the High, Medium and Fluctuating DO groups, the FCR was 1.3 – 1.4 in the first period (Aug – Oct) which increased by 0.09 – 0.15 in the succeeding recovery phase. In the Low DO group, the FCR found was 40 – 50% higher compared with the other groups and remained 20 – 25 % higher during the recovery phase. The fluctuating FCR was in accordance with the feed quantity consumed (Figure 7 – 8). No significant differences were however observed ($p > 0.05$).

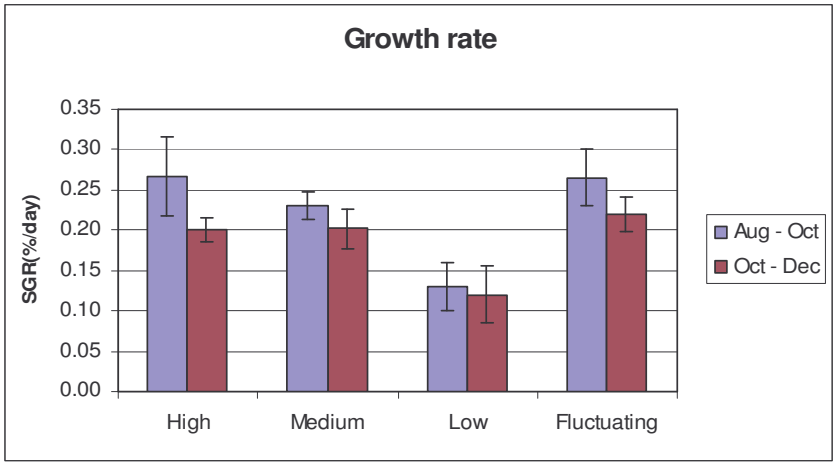


**Figure 6.** Growth rate (mean, S.D.) of adult Atlantic salmon at four different DO concentrations August – October (55 days) succeeded by a recovery phase October – December (61 days), EWOS Innovation Dirdal 2004

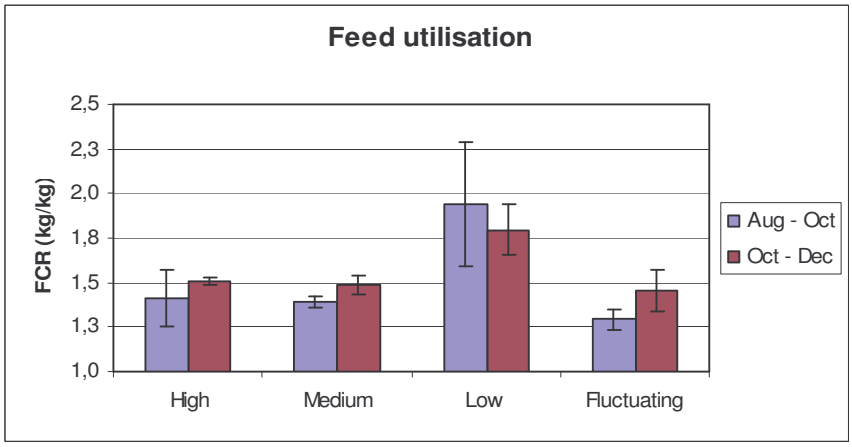


**Figure 7.** Feed conversion ratio (mean, S.D.) of adult Atlantic salmon at four different DO concentrations August – October (55 days) succeeded by a recovery phase October – December (61 days), EWOS Innovation Dirdal 2004

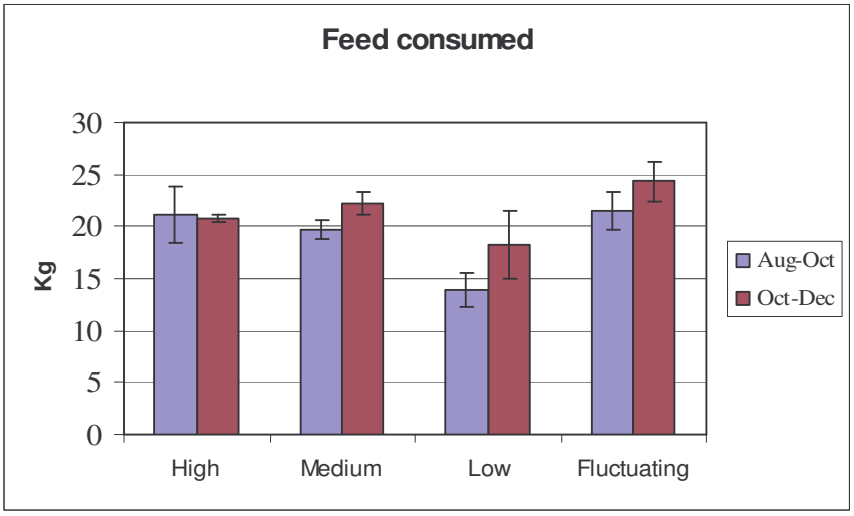


**Figure 8.** Feed consumed (mean, S.D.) by adult Atlantic salmon at four different DO concentrations August – October (55 days) succeeded by a recovery phase October – December (61 days), EWOS Innovation Dirdal 2004

## 4.3 Sexual maturation

The occurrence of sexually matured fish varied highly from one tank to another, e.g. 1 – 8 matured fish per tank within the Fluctuating DO group. 89% of all matured fish were males (GSI: 2.5 – 8.3), 11% were females (GSI: 11.0 – 21.2). 7.2 – 13.3% of the fish stock within the four DO groups was sexually matured (Figure 10) but no statistical differences were indicated ($p > 0.05$).

## 4.4 Ventilation frequency

The gill ventilation frequency indicated clear effects of reduced DO concentration (Figure 11):

High DO group: 59 – 62 movements/min

Medium DO group: 66 – 74 “

Low DO group: 81 – 87 “

Fluctuating DO group: 78 – 82 “

The fish stock of the High DO group had significantly lower $V_f$ compared to the three other groups (High vs. Medium: $p< 0.05$, High vs. Low/Fluctuating: $p< 0.01$). The $V_f$ of the Medium DO group was significantly lower compared to the Low/Fluctuating groups ($p< 0.01$).

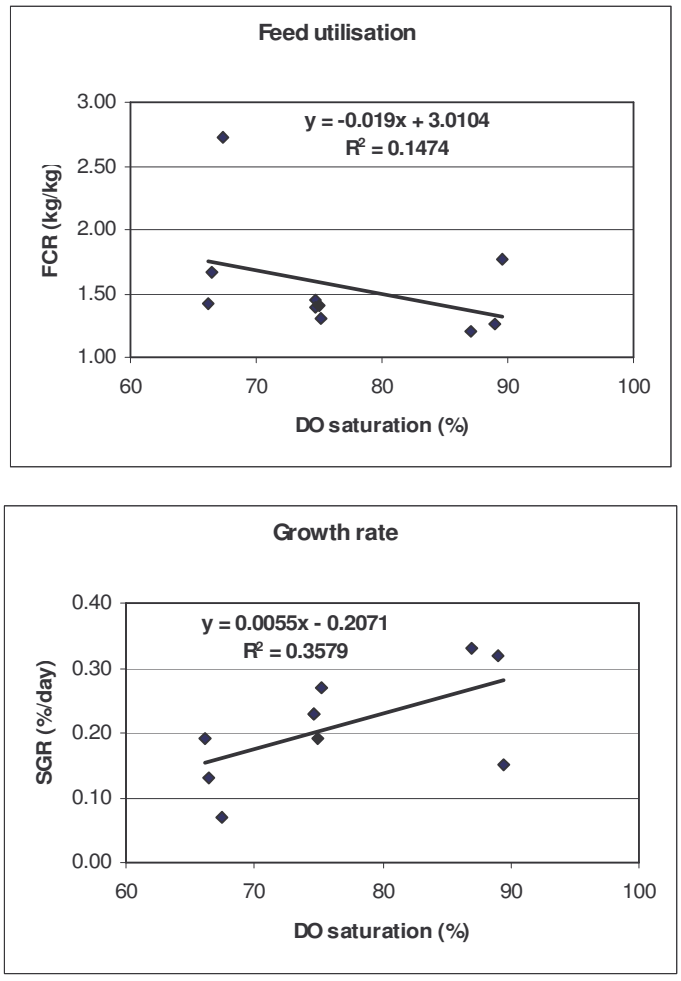


**Figure 9.** Feed utilisation and growth rate of adult Atlantic salmon of 2.5 – 3.5 kg exposed to three levels of DO concentrations at high temperature (14 – 16 ºC). Test period: FCR/SGR 24 Aug – 19/20 Oct ; DO conc. 1 Sep. – 15 Oct. EWOS Innovation Dirdal 2004

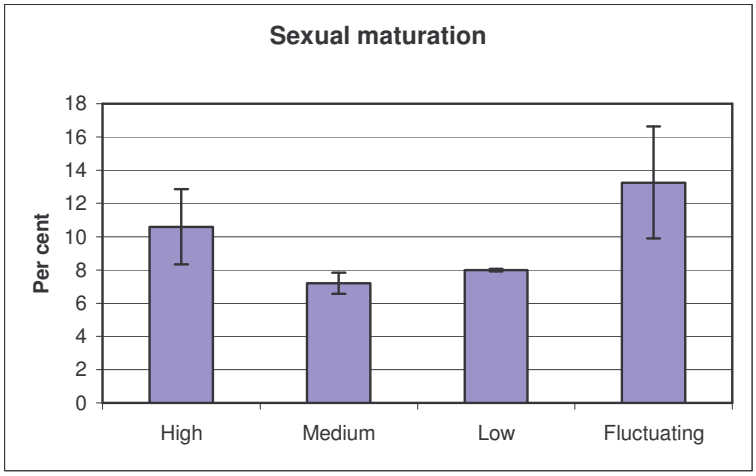


**Figure 10.** Frequency of sexual maturation (mean, S.D.) of adult Atlantic salmon of 2.5 – 3.5 kg exposed to four levels of DO concentrations at high temperature (14 – 16 ºC). EWOS Innovation Dirdal, 20-21 December 2004

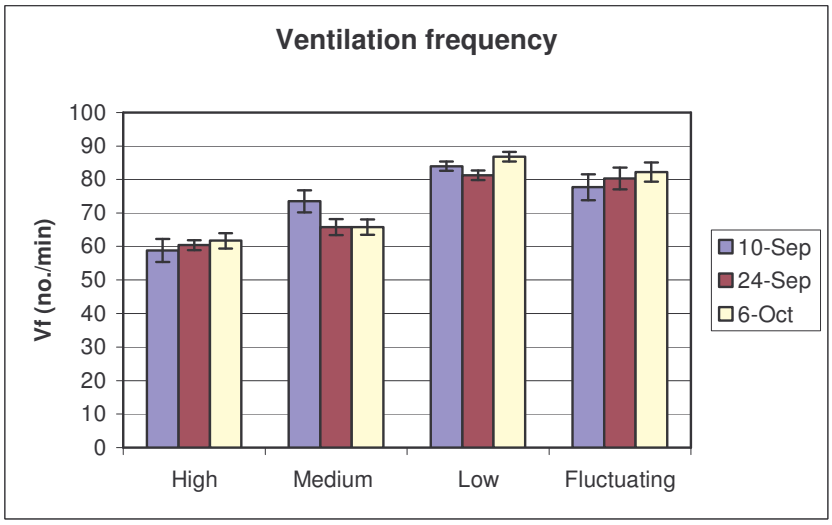


**Figure 11.** Gill ventilation frequency ($V_f$) of adult Atlantic salmon at four DO concentration levels, EWOS Innovation Dirdal, September – October 2004

# 5 Discussion

Fish performance in all DO groups was generally poor. At 14ºC, a mean daily growth rate of about 0.75 %/day is expected for adult salmon of 3 kg (Forsberg, 1996). However, a considerable seasonal variation is found in land-based farms: in autumn (August – October) the relative growth rate ("growth index") from several Norwegian farms was reported to be 70 – 100% of expected mean growth throughout the year (Forsberg, op. cit). Anyway, the growth rate in the present study was expected to be at least 0.5 %/day at "optimal" rearing conditions (SGR High DO group: 0.27 %/day). At moderate DO deficit (75% of saturation) and diurnally fluctuating DO (90 – 60% of saturation), the growth rate was at the same level (0.24 – 0.25%/day). One reason for the low growth rate is probably the high temperature (15 – 16 ºC), outside the valid temperature range of the growth model (4 - 14 ºC). According to this model, the observed growth in the recovery phase (SGR: 0.13 – 0.21%/day, 10 – 12 ºC) was still far below the expected growth rate for October – December.

There was no observed growth suppression in the Fluctuating DO group compared to the High DO group. Similar results are observed at low temperature (8±0.5 ºC, Forsberg and Bergheim, 1996) for adult salmon but are a somewhat surprising finding at this temperature level. The growth rate was almost reduced by 50% in the Low DO group compared to other groups and remained lower (ca. 35% less) during the recovery phase.

According to Jobling (1993), the reduced oxygen availability in the Low DO group (66 – 67% of saturation) was probably insufficient to support the high energy demand of well-fed fish and thus reduced the appetite. Levels of DO limiting feed intake in fish are usually between 50 and 70% of saturation, with values for salmonids being towards the top end of the range (Jobling, 1995). In this study, the "critical" DO limit allowing for maximum growth rate seems to be in the range 67 – 75% of saturation (5.5 – 6.3 mg/L). The "critical" DO limit in the former study (Bergheim *et al.* 2002) indicated a somewhat higher concentration even at lower temperature. This confusing result might partly be due to the large variation among tanks within the same DO group, especially in the High and Low DO groups (no significant differences indicated). Both physiological adaptation to low DO levels (Foss *et al.* 2002) and increased hypoxia tolerance in larger fish (Shepard, 1955) might be influencing factors.

Based on EWOS experience with this kind of test set-up at fully oxygen saturated water, salmon at this body weight should obtain lower FCR. According to an internal energy consumption model, the dietary energy level should allow for a FCR of 1.09 when fed EWOS pyramid kvalitet and 0.93 when fed EWOS pyramid ytelse, throughout the trial. Obviously, the fluctuating and partly high sexual maturation frequency (3 – 22 % in individual tanks) both increased the overall FCR and reduced the conformity vs. DO level. The strongly reduced feed intake in the Low DO group clearly indicated that the reduced oxygen availability suppressed the appetite of the fish (Jobling, 1993).

Generally, fish will try to compensate for limiting DO concentration by increasing the respiratory volume (gill ventilation frequency and opercular amplitude, e.g. Jones, 1964). "Moderate" short-term hypoxia conditions (ca. 41% DO saturation) provoked an increase in the ventilation frequency in rainbow trout followed by respiratory alkalosis

(Thomas and Hughes, 1982). In Atlantic salmon, ventilation frequency has been applied to study response of increased carbon dioxide (hypercapnia) and ammonia concentrations (Fivelstad *et al.* 2003, Knoph, 1996). In the present study, carbon dioxide and ammonia were not measured but based on calculations of expected excretion and tank flow the concentrations were below harmful levels.

The ventilation frequency ($V_f$) increased gradually from High DO to Medium and Low/Fluctuating DO levels. From an expected "normal" level of ca. 60 movements/min of adult salmon at high temperature (90 % DO saturation, i.e. normoxia/mild hypoxia), $V_f$ increased to 78 – 87 movements/min at more severe hypoxia (66 % DO saturation) and at diurnally fluctuating norm- and hypoxia (90 – 60 % DO saturation). The monitoring of $V_f$ took place before midday (9 – 11 am) when the DO concentration in the Fluctuating DO tanks was low, between 60 – 70 % of saturation. There were no signs of reduced $V_f$ in this group throughout the period indicating lack of physiological adaptation to the fluctuated diurnal DO concentrations. In this group, additional $V_f$ monitoring in the afternoon should have been carried out to clarify the diurnal $V_f$ range.

Despite little available literature, the obtained results generally match other findings describing growth of adult Atlantic salmon at different DO concentrations. Berg & Danielsberg (1990) reported a 30 % decrease in growth rate in Atlantic salmon of 1 – 2 kg at temperature above 10 - 12 °C when DO of the tank outlet water was permanently reduced from 8 – 9 mg/L (> 90 % of saturation) to 5 – 6 mg/L (50 – 60 % of saturation) over 6 months. In the first reported study, a correspondingly reduced SGR was found (from ca. 0.5 to 0.35 %/day) over the same DO range (Bergheim *et al*. 2002).

# 6 Conclusion

- At high summer temperature, reduced and diurnally fluctuating DO concentrations in the range 90 to 60% of saturation caused reduced growth and feed utilisation in adult Atlantic salmon
- The decreased fish performance was not significant due to high variation among replicate tanks, e.g. because of occurrence of sexual maturation
- Gill respiration frequency increased significantly with reduced DO concentration indicating stressing conditions at moderately hypoxia and high temperature
- Another high temperature – reduced DO concentration trial will be conducted with smaller post-smolt salmon

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# 8 Appendix

Daily DO concentrations in Tanks, EWOS Innovation Dirdal 2004.

Group: High DO Level (preset level: 90% of saturation 2 Sep – 14 Oct). Unit: % of saturation

| Date | Tank 1 | | | Tank 5 | | | Tank 11 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 24-Aug | 90 | 111 | 84 | 90 | 100 | 81 | 91 | 108 | 82 |
| 25-Aug | 90 | 93 | 87 | 89 | 95 | 80 | 91 | 103 | 83 |
| 26-Aug | 90 | 108 | 84 | 90 | 96 | 79 | 90 | 102 | 81 |
| 27-Aug | 90 | 94 | 87 | 90 | 93 | 87 | 90 | 92 | 88 |
| 28-Aug | 90 | 93 | 88 | 90 | 92 | 87 | 90 | 94 | 88 |
| 29-Aug | 90 | 99 | 83 | 90 | 92 | 87 | 90 | 94 | 87 |
| 30-Aug | 90 | 102 | 81 | 90 | 92 | 88 | 90 | 93 | 87 |
| 31-Aug | 84 | 106 | 69 | 90 | 91 | 88 | 90 | 93 | 88 |
| 1-Sep | 76 | 88 | 67 | 90 | 92 | 87 | 90 | 94 | 87 |
| 2-Sep | 85 | 110 | 74 | 90 | 92 | 87 | 90 | 93 | 86 |
| 3-Sep | 91 | 101 | 83 | 90 | 93 | 88 | 90 | 93 | 87 |
| 4-Sep | 90 | 100 | 80 | 90 | 92 | 88 | 90 | 94 | 86 |
| 5-Sep | 90 | 98 | 80 | 90 | 92 | 87 | 90 | 93 | 87 |
| 6-Sep | 90 | 97 | 80 | 90 | 93 | 87 | 90 | 93 | 89 |
| 7-Sep | 90 | 96 | 82 | 90 | 93 | 87 | 90 | 93 | 87 |
| 8-Sep | 90 | 100 | 81 | 90 | 94 | 85 | 90 | 97 | 82 |
| 9-Sep | 90 | 93 | 85 | 90 | 92 | 86 | 90 | 95 | 87 |
| 10-Sep | 90 | 94 | 82 | 90 | 91 | 88 | 90 | 92 | 89 |
| 11-Sep | 90 | 100 | 82 | 89 | 94 | 86 | 90 | 93 | 87 |
| 12-Sep | 90 | 96 | 83 | 87 | 90 | 85 | 90 | 93 | 88 |
| 13-Sep | 90 | 97 | 83 | 88 | 92 | 84 | 90 | 95 | 87 |
| 14-Sep | 90 | 94 | 83 | 87 | 90 | 85 | 90 | 94 | 87 |
| 15-Sep | 90 | 94 | 85 | 88 | 91 | 83 | 90 | 95 | 87 |
| 16-Sep | 90 | 96 | 83 | 87 | 90 | 85 | 90 | 94 | 87 |
| 17-Sep | 89 | 94 | 81 | 85 | 88 | 80 | 90 | 95 | 87 |
| 18-Sep | 88 | 95 | 83 | 85 | 88 | 83 | 90 | 93 | 87 |
| 19-Sep | 89 | 95 | 82 | 84 | 90 | 77 | 77 | 94 | 55 |
| 20-Sep | 90 | 94 | 86 | 86 | 92 | 80 | 82 | 114 | 67 |
| 21-Sep | 87 | 93 | 82 | 89 | 91 | 84 | 90 | 94 | 87 |
| 22-Sep | 87 | 100 | 77 | 89 | 99 | 84 | 90 | 98 | 84 |
| 23-Sep | 85 | 90 | 78 | 90 | 92 | 87 | 90 | 94 | 89 |
| 24-Sep | 88 | 100 | 83 | 90 | 92 | 87 | 90 | 92 | 88 |
| 25-Sep | 90 | 98 | 84 | 90 | 92 | 86 | 90 | 93 | 86 |
| 26-Sep | 89 | 97 | 82 | 90 | 93 | 86 | 90 | 94 | 85 |
| 27-Sep | 90 | 98 | 81 | 90 | 92 | 86 | 90 | 97 | 85 |
| 28-Sep | 90 | 105 | 80 | 90 | 93 | 86 | 90 | 97 | 86 |
| 29-Sep | 90 | 97 | 83 | 90 | 92 | 84 | 90 | 96 | 84 |
| 30-Sep | 90 | 97 | 84 | 89 | 94 | 86 | 90 | 102 | 84 |
| 1-Oct | 90 | 98 | 84 | 90 | 93 | 86 | 90 | 97 | 84 |
| 2-Oct | 87 | 96 | 82 | 89 | 93 | 84 | 90 | 98 | 82 |
| 3-Oct | 86 | 92 | 79 | 90 | 93 | 85 | 90 | 97 | 84 |
| 4-Oct | 85 | 90 | 81 | 90 | 93 | 86 | 90 | 96 | 82 |
| 5-Oct | 87 | 108 | 77 | 90 | 93 | 86 | 90 | 102 | 84 |
| 6-Oct | 90 | 100 | 76 | 90 | 100 | 77 | 90 | 101 | 75 |
| 7-Oct | 91 | 112 | 84 | 90 | 92 | 87 | 90 | 93 | 86 |
| 8-Oct | 90 | 96 | 85 | 90 | 92 | 87 | 90 | 95 | 86 |

Group: High DO Level *cont.*

| Date | Tank 1 | | | Tank 5 | | | Tank 11 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 9-Oct | 90 | 100 | 84 | 90 | 94 | 87 | 90 | 102 | 85 |
| 10-Oct | 86 | 101 | 68 | 90 | 94 | 86 | 90 | 98 | 84 |
| 11-Oct | 75 | 81 | 71 | 90 | 92 | 85 | 90 | 102 | 81 |
| 12-Oct | 75 | 82 | 71 | 90 | 92 | 85 | 90 | 102 | 82 |
| 13-Oct | 76 | 110 | 60 | 90 | 92 | 85 | 90 | 103 | 83 |
| 14-Oct | 85 | 97 | 72 | 89 | 93 | 84 | 90 | 122 | 81 |
| 15-Oct | 90 | 94 | 86 | 90 | 93 | 86 | 90 | 97 | 85 |
| 16-Oct | 90 | 95 | 83 | 90 | 93 | 86 | 90 | 95 | 86 |
| 17-Oct | 90 | 93 | 86 | 90 | 93 | 86 | 90 | 100 | 84 |
| 18-Oct | 90 | 94 | 86 | 90 | 96 | 83 | 90 | 97 | 85 |
| 19-Oct | 98 | 135 | 88 | 99 | 148 | 88 | 100 | 212 | 88 |

Daily DO concentrations in Tanks, EWOS Innovation Dirdal 2004.

Group: Medium DO Level (preset level: 75% of saturation 2 Sep – 14 Oct). Unit: % of saturation

| Date | Tank 3 | | | Tank 10 | | | Tank 13 | | | Tank 17 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 24-Aug | 106 | 117 | 97 | 85 | 93 | 65 | 86 | 93 | 77 | 85 | 88 | 81 |
| 25-Aug | 111 | 117 | 107 | 85 | 87 | 82 | 79 | 93 | 51 | 82 | 88 | 64 |
| 26-Aug | 114 | 135 | 98 | 83 | 98 | 76 | 82 | 100 | 72 | 84 | 107 | 77 |
| 27-Aug | 111 | 123 | 95 | 80 | 83 | 78 | 80 | 82 | 73 | 80 | 83 | 76 |
| 28-Aug | 121 | 126 | 117 | 80 | 83 | 78 | 79 | 84 | 74 | 80 | 82 | 77 |
| 29-Aug | 131 | 145 | 117 | 80 | 83 | 77 | 80 | 84 | 74 | 80 | 82 | 77 |
| 30-Aug | 99 | 148 | 72 | 78 | 82 | 73 | 78 | 84 | 72 | 78 | 82 | 73 |
| 31-Aug | 76 | 83 | 72 | 75 | 80 | 72 | 75 | 78 | 72 | 75 | 77 | 74 |
| 1-Sep | 76 | 83 | 70 | 75 | 79 | 71 | 75 | 78 | 73 | 75 | 78 | 72 |
| 2-Sep | 75 | 85 | 71 | 75 | 78 | 71 | 75 | 79 | 73 | 75 | 78 | 73 |
| 3-Sep | 76 | 85 | 72 | 75 | 79 | 71 | 75 | 80 | 73 | 75 | 78 | 73 |
| 4-Sep | 76 | 86 | 70 | 75 | 79 | 71 | 75 | 78 | 72 | 75 | 78 | 72 |
| 5-Sep | 76 | 81 | 72 | 75 | 81 | 71 | 75 | 77 | 72 | 75 | 77 | 73 |
| 6-Sep | 75 | 81 | 73 | 75 | 79 | 71 | 75 | 77 | 73 | 75 | 78 | 73 |
| 7-Sep | 75 | 80 | 71 | 75 | 79 | 72 | 75 | 77 | 72 | 75 | 78 | 73 |
| 8-Sep | 75 | 80 | 69 | 75 | 81 | 66 | 75 | 77 | 70 | 75 | 79 | 71 |
| 9-Sep | 75 | 80 | 71 | 75 | 77 | 73 | 75 | 76 | 72 | 75 | 78 | 73 |
| 10-Sep | 75 | 80 | 71 | 77 | 92 | 67 | 75 | 77 | 72 | 75 | 79 | 70 |
| 11-Sep | 75 | 85 | 69 | 77 | 91 | 67 | 74 | 78 | 72 | 75 | 80 | 71 |
| 12-Sep | 75 | 85 | 70 | 76 | 92 | 65 | 73 | 76 | 68 | 75 | 78 | 73 |
| 13-Sep | 75 | 84 | 69 | 76 | 92 | 65 | 73 | 81 | 68 | 75 | 78 | 72 |
| 14-Sep | 75 | 84 | 68 | 76 | 92 | 64 | 75 | 78 | 72 | 75 | 78 | 72 |
| 15-Sep | 75 | 81 | 70 | 77 | 92 | 66 | 75 | 77 | 72 | 75 | 78 | 72 |
| 16-Sep | 75 | 79 | 72 | 76 | 91 | 65 | 75 | 78 | 72 | 75 | 80 | 72 |
| 17-Sep | 75 | 77 | 72 | 76 | 93 | 62 | 75 | 77 | 72 | 75 | 78 | 72 |
| 18-Sep | 75 | 78 | 72 | 76 | 96 | 62 | 75 | 78 | 71 | 75 | 78 | 71 |
| 19-Sep | 75 | 77 | 72 | 69 | 97 | 43 | 75 | 77 | 73 | 75 | 78 | 73 |
| 20-Sep | 75 | 77 | 73 | 67 | 99 | 57 | 75 | 77 | 71 | 75 | 80 | 72 |
| 21-Sep | 75 | 79 | 72 | 76 | 91 | 62 | 75 | 77 | 71 | 75 | 79 | 72 |
| 22-Sep | 75 | 100 | 70 | 77 | 100 | 62 | 74 | 97 | 69 | 76 | 97 | 67 |
| 23-Sep | 75 | 78 | 71 | 72 | 89 | 64 | 75 | 77 | 72 | 75 | 76 | 74 |
| 24-Sep | 75 | 79 | 71 | 75 | 78 | 71 | 75 | 79 | 71 | 75 | 78 | 72 |
| 25-Sep | 75 | 83 | 71 | 75 | 80 | 70 | 75 | 79 | 70 | 75 | 77 | 72 |
| 26-Sep | 75 | 80 | 72 | 75 | 80 | 71 | 75 | 80 | 70 | 75 | 79 | 72 |
| 27-Sep | 75 | 80 | 71 | 75 | 80 | 69 | 74 | 78 | 70 | 75 | 81 | 72 |
| 28-Sep | 75 | 78 | 71 | 75 | 80 | 69 | 74 | 78 | 69 | 75 | 79 | 71 |
| 29-Sep | 75 | 78 | 71 | 75 | 81 | 69 | 75 | 79 | 71 | 75 | 79 | 72 |
| 30-Sep | 75 | 79 | 73 | 75 | 80 | 68 | 75 | 78 | 72 | 75 | 79 | 72 |
| 1-Oct | 75 | 78 | 72 | 75 | 80 | 71 | 75 | 77 | 71 | 75 | 77 | 72 |
| 2-Oct | 75 | 79 | 72 | 75 | 78 | 71 | 75 | 77 | 72 | 75 | 80 | 72 |
| 3-Oct | 75 | 78 | 72 | 75 | 80 | 69 | 75 | 77 | 72 | 75 | 79 | 71 |
| 4-Oct | 75 | 79 | 73 | 75 | 81 | 68 | 74 | 77 | 70 | 75 | 77 | 71 |
| 5-Oct | 75 | 79 | 71 | 75 | 80 | 70 | 74 | 77 | 70 | 75 | 77 | 71 |
| 6-Oct | 76 | 100 | 66 | 76 | 101 | 57 | 74 | 101 | 67 | 76 | 100 | 63 |
| 7-Oct | 75 | 78 | 71 | 75 | 79 | 71 | 74 | 77 | 71 | 75 | 81 | 68 |
| 8-Oct | 75 | 81 | 71 | 75 | 81 | 71 | 75 | 78 | 71 | 75 | 79 | 73 |

Group: Medium DO Level *cont.*

| Date | Tank 3 | | | Tank 10 | | | Tank 13 | | | Tank 17 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 9-Oct | 75 | 81 | 70 | 75 | 82 | 71 | 75 | 79 | 71 | 75 | 82 | 71 |
| 10-Oct | 75 | 82 | 72 | 75 | 81 | 70 | 75 | 78 | 71 | 75 | 79 | 71 |
| 11-Oct | 75 | 80 | 71 | 75 | 81 | 70 | 75 | 77 | 71 | 75 | 78 | 71 |
| 12-Oct | 75 | 79 | 71 | 75 | 79 | 68 | 75 | 78 | 70 | 75 | 79 | 71 |
| 13-Oct | 75 | 79 | 69 | 75 | 81 | 69 | 74 | 78 | 71 | 75 | 79 | 72 |
| 14-Oct | 75 | 80 | 69 | 75 | 81 | 70 | 74 | 79 | 70 | 75 | 79 | 71 |
| 15-Oct | 83 | 93 | 72 | 83 | 93 | 71 | 80 | 88 | 72 | 82 | 98 | 74 |
| 16-Oct | 90 | 94 | 85 | 90 | 96 | 84 | 89 | 94 | 83 | 90 | 92 | 87 |
| 17-Oct | 90 | 99 | 85 | 90 | 95 | 85 | 90 | 92 | 88 | 90 | 91 | 88 |
| 18-Oct | 90 | 95 | 86 | 90 | 100 | 81 | 90 | 94 | 88 | 90 | 93 | 87 |
| 19-Oct | 94 | 113 | 89 | 99 | 140 | 87 | 102 | 178 | 88 | 103 | 113 | 87 |

Daily DO concentrations in Tanks, EWOS Innovation Dirdal 2004.

Group: Low DO Level (preset level: 60% of saturation 2 Sep – 14 Oct). Unit: % of saturation

| Date | Tank 6 | | | Tank 8 | | | Tank 16 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 24-Aug | 80 | 99 | 67 | 80 | 92 | 75 | 80 | 89 | 75 |
| 25-Aug | 80 | 83 | 75 | 80 | 84 | 78 | 80 | 92 | 67 |
| 26-Aug | 79 | 94 | 66 | 79 | 93 | 74 | 79 | 100 | 71 |
| 27-Aug | 75 | 80 | 72 | 75 | 78 | 73 | 75 | 76 | 74 |
| 28-Aug | 75 | 78 | 74 | 75 | 77 | 73 | 75 | 80 | 72 |
| 29-Aug | 77 | 80 | 74 | 76 | 78 | 73 | 75 | 80 | 72 |
| 30-Aug | 73 | 80 | 67 | 72 | 81 | 67 | 72 | 82 | 66 |
| 31-Aug | 69 | 72 | 67 | 68 | 75 | 67 | 68 | 71 | 66 |
| 1-Sep | 69 | 71 | 65 | 68 | 73 | 64 | 67 | 71 | 63 |
| 2-Sep | 71 | 74 | 68 | 68 | 71 | 67 | 66 | 69 | 63 |
| 3-Sep | 70 | 74 | 66 | 69 | 71 | 66 | 67 | 70 | 63 |
| 4-Sep | 68 | 71 | 65 | 69 | 71 | 66 | 67 | 71 | 63 |
| 5-Sep | 67 | 69 | 64 | 69 | 72 | 67 | 68 | 71 | 64 |
| 6-Sep | 67 | 69 | 64 | 69 | 71 | 65 | 67 | 72 | 63 |
| 7-Sep | 67 | 70 | 63 | 69 | 72 | 66 | 67 | 72 | 63 |
| 8-Sep | 67 | 70 | 61 | 68 | 71 | 62 | 67 | 73 | 60 |
| 9-Sep | 68 | 69 | 64 | 68 | 70 | 64 | 68 | 73 | 63 |
| 10-Sep | 66 | 69 | 62 | 67 | 69 | 62 | 67 | 72 | 63 |
| 11-Sep | 66 | 68 | 61 | 67 | 69 | 63 | 67 | 73 | 62 |
| 12-Sep | 65 | 67 | 62 | 66 | 72 | 60 | 65 | 71 | 60 |
| 13-Sep | 65 | 68 | 61 | 67 | 71 | 63 | 66 | 72 | 60 |
| 14-Sep | 64 | 67 | 62 | 64 | 68 | 60 | 66 | 71 | 62 |
| 15-Sep | 66 | 69 | 62 | 66 | 69 | 61 | 67 | 71 | 62 |
| 16-Sep | 65 | 68 | 63 | 66 | 69 | 62 | 68 | 72 | 64 |
| 17-Sep | 64 | 67 | 60 | 65 | 68 | 59 | 67 | 72 | 63 |
| 18-Sep | 64 | 67 | 61 | 64 | 67 | 59 | 67 | 72 | 63 |
| 19-Sep | 71 | 80 | 61 | 62 | 76 | 49 | 67 | 72 | 63 |
| 20-Sep | 71 | 80 | 63 | 64 | 92 | 57 | 67 | 73 | 62 |
| 21-Sep | 66 | 70 | 62 | 65 | 69 | 61 | 66 | 73 | 62 |
| 22-Sep | 68 | 97 | 58 | 64 | 98 | 59 | 66 | 98 | 56 |
| 23-Sep | 68 | 73 | 64 | 65 | 69 | 59 | 66 | 71 | 62 |
| 24-Sep | 69 | 72 | 64 | 66 | 69 | 62 | 67 | 73 | 62 |
| 25-Sep | 68 | 72 | 64 | 66 | 70 | 62 | 67 | 73 | 62 |
| 26-Sep | 69 | 73 | 65 | 66 | 70 | 63 | 67 | 74 | 63 |
| 27-Sep | 67 | 72 | 64 | 66 | 69 | 61 | 65 | 73 | 60 |
| 28-Sep | 67 | 70 | 60 | 66 | 69 | 61 | 65 | 72 | 59 |
| 29-Sep | 67 | 70 | 64 | 67 | 70 | 62 | 66 | 73 | 60 |
| 30-Sep | 67 | 70 | 63 | 66 | 69 | 61 | 65 | 72 | 59 |
| 1-Oct | 67 | 70 | 64 | 66 | 70 | 62 | 65 | 72 | 59 |
| 2-Oct | 67 | 70 | 62 | 66 | 70 | 61 | 65 | 73 | 57 |
| 3-Oct | 67 | 70 | 63 | 66 | 69 | 61 | 66 | 73 | 61 |
| 4-Oct | 67 | 70 | 64 | 65 | 68 | 61 | 65 | 72 | 59 |
| 5-Oct | 67 | 70 | 62 | 65 | 67 | 59 | 65 | 72 | 58 |
| 6-Oct | 68 | 102 | 58 | 66 | 101 | 56 | 66 | 99 | 56 |
| 7-Oct | 68 | 73 | 63 | 66 | 70 | 60 | 67 | 73 | 60 |
| 8-Oct | 68 | 72 | 64 | 66 | 69 | 61 | 67 | 74 | 60 |

Group: Low DO Level *cont.*

| Date | Tank 6 | | | Tank 8 | | | Tank 16 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 9-Oct | 69 | 72 | 65 | 66 | 69 | 63 | 67 | 77 | 62 |
| 10-Oct | 68 | 72 | 62 | 68 | 118 | 60 | 68 | 74 | 63 |
| 11-Oct | 68 | 71 | 64 | 67 | 69 | 64 | 67 | 74 | 62 |
| 12-Oct | 68 | 71 | 63 | 66 | 68 | 63 | 67 | 74 | 62 |
| 13-Oct | 67 | 70 | 64 | 66 | 68 | 63 | 67 | 75 | 62 |
| 14-Oct | 68 | 71 | 62 | 67 | 70 | 63 | 67 | 74 | 61 |
| 15-Oct | 77 | 86 | 67 | 79 | 95 | 65 | 71 | 78 | 66 |
| 16-Oct | 85 | 88 | 82 | 90 | 97 | 84 | 78 | 80 | 75 |
| 17-Oct | 88 | 92 | 85 | 90 | 103 | 86 | 81 | 83 | 77 |
| 18-Oct | 90 | 94 | 83 | 90 | 96 | 87 | 83 | 86 | 79 |
| 19-Oct | 93 | 109 | 87 | 99 | 136 | 88 | 91 | 101 | 84 |

Daily DO concentrations in Tanks, EWOS Innovation Dirdal 2004.

Group: Fluctuating DO Level (preset level: 90 – 60 % of saturation 2 Sep – 14 Oct).
Unit: % of saturation

| Date | Tank 2 | | | Tank 4 | | | Tank 7 | | | Tank 9 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 24-Aug | 106 | 117 | 97 | 87 | 96 | 64 | 87 | 92 | 72 | 87 | 95 | 67 |
| 25-Aug | 111 | 117 | 107 | 87 | 93 | 77 | 87 | 92 | 77 | 87 | 92 | 77 |
| 26-Aug | 114 | 135 | 98 | 84 | 98 | 79 | 85 | 94 | 77 | 84 | 93 | 75 |
| 27-Aug | 111 | 123 | 95 | 80 | 92 | 74 | 81 | 92 | 74 | 78 | 90 | 71 |
| 28-Aug | 121 | 126 | 117 | 83 | 87 | 80 | 84 | 92 | 80 | 80 | 90 | 74 |
| 29-Aug | 131 | 145 | 117 | 85 | 87 | 80 | 85 | 92 | 80 | 81 | 92 | 74 |
| 30-Aug | 99 | 148 | 72 | 79 | 92 | 72 | 81 | 92 | 73 | 78 | 93 | 69 |
| 31-Aug | 76 | 83 | 72 | 76 | 88 | 70 | 78 | 93 | 70 | 77 | 91 | 67 |
| 1-Sep | 76 | 83 | 70 | 78 | 93 | 69 | 78 | 92 | 67 | 77 | 93 | 66 |
| 2-Sep | 75 | 85 | 71 | 78 | 92 | 69 | 78 | 94 | 67 | 77 | 95 | 67 |
| 3-Sep | 76 | 85 | 72 | 78 | 92 | 69 | 78 | 93 | 70 | 77 | 92 | 68 |
| 4-Sep | 76 | 86 | 70 | 78 | 93 | 69 | 78 | 94 | 69 | 77 | 91 | 68 |
| 5-Sep | 76 | 81 | 72 | 77 | 94 | 69 | 78 | 92 | 69 | 77 | 94 | 67 |
| 6-Sep | 75 | 81 | 73 | 77 | 92 | 69 | 77 | 91 | 68 | 77 | 93 | 66 |
| 7-Sep | 75 | 80 | 71 | 77 | 93 | 67 | 77 | 96 | 68 | 77 | 93 | 66 |
| 8-Sep | 75 | 80 | 69 | 77 | 91 | 65 | 77 | 91 | 66 | 76 | 94 | 63 |
| 9-Sep | 75 | 80 | 71 | 77 | 92 | 67 | 78 | 92 | 69 | 77 | 91 | 67 |
| 10-Sep | 75 | 80 | 71 | 76 | 91 | 67 | 77 | 92 | 67 | 76 | 90 | 64 |
| 11-Sep | 75 | 85 | 69 | 77 | 93 | 65 | 77 | 91 | 67 | 76 | 92 | 64 |
| 12-Sep | 75 | 85 | 70 | 76 | 92 | 64 | 76 | 92 | 65 | 75 | 94 | 62 |
| 13-Sep | 75 | 84 | 69 | 76 | 92 | 64 | 76 | 92 | 65 | 76 | 95 | 62 |
| 14-Sep | 75 | 84 | 68 | 76 | 95 | 64 | 76 | 92 | 64 | 75 | 94 | 61 |
| 15-Sep | 75 | 81 | 70 | 77 | 92 | 66 | 77 | 92 | 66 | 76 | 91 | 64 |
| 16-Sep | 75 | 79 | 72 | 76 | 92 | 64 | 76 | 91 | 65 | 75 | 91 | 62 |
| 17-Sep | 75 | 77 | 72 | 76 | 93 | 63 | 76 | 93 | 62 | 74 | 89 | 60 |
| 18-Sep | 75 | 78 | 72 | 75 | 93 | 63 | 76 | 96 | 62 | 74 | 88 | 60 |
| 19-Sep | 75 | 77 | 72 | 80 | 93 | 70 | 69 | 97 | 43 | 71 | 91 | 42 |
| 20-Sep | 75 | 77 | 73 | 76 | 91 | 62 | 67 | 99 | 57 | 75 | 95 | 59 |
| 21-Sep | 75 | 79 | 72 | 76 | 92 | 64 | 76 | 91 | 62 | 75 | 94 | 59 |
| 22-Sep | 75 | 100 | 70 | 77 | 98 | 62 | 77 | 100 | 62 | 76 | 97 | 59 |
| 23-Sep | 75 | 78 | 71 | 76 | 91 | 66 | 72 | 89 | 64 | 71 | 89 | 59 |
| 24-Sep | 75 | 79 | 71 | 76 | 91 | 66 | 76 | 93 | 64 | 75 | 93 | 59 |
| 25-Sep | 75 | 83 | 71 | 77 | 93 | 66 | 76 | 91 | 64 | 75 | 100 | 59 |
| 26-Sep | 75 | 80 | 72 | 77 | 99 | 65 | 76 | 93 | 64 | 75 | 103 | 59 |
| 27-Sep | 75 | 80 | 71 | 76 | 94 | 66 | 76 | 91 | 65 | 75 | 95 | 60 |
| 28-Sep | 75 | 78 | 71 | 76 | 99 | 65 | 76 | 92 | 64 | 75 | 98 | 60 |
| 29-Sep | 75 | 78 | 71 | 76 | 95 | 67 | 76 | 91 | 66 | 75 | 93 | 59 |
| 30-Sep | 75 | 79 | 73 | 78 | 95 | 68 | 76 | 92 | 65 | 75 | 93 | 60 |
| 1-Oct | 75 | 78 | 72 | 77 | 91 | 66 | 77 | 93 | 66 | 75 | 92 | 60 |
| 2-Oct | 75 | 79 | 72 | 76 | 92 | 65 | 76 | 94 | 65 | 75 | 93 | 59 |
| 3-Oct | 75 | 78 | 72 | 76 | 91 | 65 | 76 | 92 | 65 | 75 | 94 | 59 |
| 4-Oct | 75 | 79 | 73 | 76 | 93 | 65 | 76 | 93 | 65 | 75 | 92 | 59 |
| 5-Oct | 75 | 79 | 71 | 77 | 93 | 66 | 76 | 92 | 64 | 75 | 94 | 59 |
| 6-Oct | 76 | 100 | 66 | 78 | 100 | 60 | 77 | 100 | 58 | 76 | 101 | 55 |
| 7-Oct | 75 | 78 | 71 | 77 | 90 | 67 | 75 | 92 | 66 | 73 | 93 | 60 |
| 8-Oct | 75 | 81 | 71 | 77 | 91 | 66 | 77 | 91 | 65 | 75 | 94 | 59 |

Group: Fluctuating DO Level *cont.*

| Date | Tank 2 | | | Tank 4 | | | Tank 7 | | | Tank 9 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 9-Oct | 77 | 92 | 66 | 77 | 91 | 68 | 77 | 92 | 66 | 75 | 94 | 60 |
| 10-Oct | 76 | 91 | 58 | 76 | 94 | 58 | 76 | 92 | 59 | 75 | 96 | 60 |
| 11-Oct | 74 | 85 | 64 | 76 | 93 | 65 | 76 | 92 | 66 | 75 | 95 | 59 |
| 12-Oct | 74 | 90 | 63 | 76 | 96 | 66 | 76 | 94 | 64 | 75 | 97 | 59 |
| 13-Oct | 75 | 92 | 62 | 76 | 92 | 65 | 76 | 93 | 64 | 75 | 92 | 59 |
| 14-Oct | 76 | 91 | 63 | 76 | 92 | 64 | 76 | 93 | 62 | 75 | 96 | 59 |
| 15-Oct | 86 | 95 | 66 | 86 | 94 | 68 | 86 | 93 | 66 | 85 | 93 | 65 |
| 16-Oct | 90 | 94 | 87 | 90 | 95 | 86 | 90 | 94 | 87 | 90 | 95 | 86 |
| 17-Oct | 90 | 93 | 87 | 90 | 93 | 86 | 90 | 94 | 86 | 90 | 93 | 87 |
| 18-Oct | 90 | 95 | 86 | 90 | 96 | 84 | 90 | 96 | 85 | 90 | 93 | 87 |
| 19-Oct | 96 | 118 | 87 | 97 | 176 | 89 | 99 | 118 | 88 | 99 | 178 | 88 |

Daily DO concentrations in Tanks, EWOS Innovation Dirdal 2004.

Group: Fluctuating DO Level (preset level: 90 – 60 % of saturation 2 Sep – 14 Oct).
Unit: % of saturation

| Date | Tank 12 | | | Tank 14 | | | Tank 15 | | | Tank 18 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 24-Aug | 87 | 104 | 65 | 87 | 91 | 77 | 87 | 94 | 76 | 87 | 95 | 77 |
| 25-Aug | 87 | 94 | 72 | 87 | 97 | 65 | 86 | 95 | 69 | 87 | 99 | 64 |
| 26-Aug | 83 | 100 | 68 | 83 | 100 | 73 | 82 | 100 | 68 | 82 | 121 | 68 |
| 27-Aug | 78 | 95 | 68 | 78 | 92 | 70 | 78 | 91 | 68 | 72 | 95 | 62 |
| 28-Aug | 78 | 92 | 67 | 78 | 93 | 69 | 78 | 93 | 68 | 64 | 67 | 61 |
| 29-Aug | 78 | 94 | 67 | 79 | 93 | 69 | 78 | 93 | 68 | 64 | 67 | 61 |
| 30-Aug | 78 | 94 | 65 | 78 | 91 | 70 | 77 | 92 | 65 | 64 | 67 | 62 |
| 31-Aug | 76 | 94 | 63 | 78 | 92 | 70 | 75 | 91 | 64 | 66 | 73 | 62 |
| 1-Sep | 76 | 92 | 63 | 78 | 90 | 67 | 76 | 91 | 64 | 70 | 95 | 61 |
| 2-Sep | 77 | 92 | 65 | 78 | 91 | 70 | 76 | 93 | 64 | 75 | 92 | 60 |
| 3-Sep | 76 | 92 | 64 | 79 | 92 | 72 | 76 | 91 | 65 | 75 | 96 | 62 |
| 4-Sep | 76 | 92 | 64 | 78 | 91 | 70 | 76 | 93 | 64 | 75 | 94 | 61 |
| 5-Sep | 76 | 92 | 65 | 79 | 91 | 72 | 75 | 92 | 62 | 75 | 95 | 62 |
| 6-Sep | 76 | 91 | 63 | 78 | 93 | 70 | 75 | 92 | 60 | 76 | 99 | 62 |
| 7-Sep | 76 | 92 | 64 | 78 | 92 | 67 | 75 | 92 | 58 | 76 | 93 | 60 |
| 8-Sep | 76 | 92 | 59 | 77 | 93 | 65 | 75 | 93 | 56 | 75 | 99 | 57 |
| 9-Sep | 76 | 94 | 62 | 78 | 91 | 69 | 75 | 92 | 60 | 76 | 94 | 63 |
| 10-Sep | 75 | 91 | 60 | 77 | 91 | 68 | 75 | 92 | 59 | 75 | 93 | 60 |
| 11-Sep | 76 | 92 | 60 | 77 | 92 | 66 | 75 | 91 | 57 | 75 | 99 | 58 |
| 12-Sep | 75 | 92 | 60 | 76 | 93 | 63 | 75 | 89 | 59 | 75 | 100 | 59 |
| 13-Sep | 75 | 92 | 60 | 76 | 93 | 63 | 75 | 89 | 59 | 75 | 103 | 60 |
| 14-Sep | 75 | 93 | 59 | 76 | 91 | 63 | 75 | 91 | 58 | 75 | 96 | 59 |
| 15-Sep | 76 | 93 | 62 | 76 | 92 | 65 | 75 | 89 | 60 | 75 | 95 | 59 |
| 16-Sep | 75 | 91 | 59 | 76 | 91 | 63 | 75 | 92 | 59 | 75 | 96 | 59 |
| 17-Sep | 75 | 93 | 60 | 76 | 93 | 63 | 75 | 91 | 60 | 75 | 96 | 59 |
| 18-Sep | 75 | 95 | 59 | 76 | 92 | 63 | 75 | 89 | 60 | 75 | 95 | 59 |
| 19-Sep | 75 | 93 | 51 | 76 | 91 | 63 | 75 | 91 | 60 | 75 | 96 | 59 |
| 20-Sep | 76 | 96 | 59 | 75 | 91 | 59 | 74 | 89 | 58 | 75 | 95 | 57 |
| 21-Sep | 76 | 94 | 58 | 75 | 93 | 60 | 74 | 87 | 59 | 75 | 95 | 59 |
| 22-Sep | 76 | 99 | 57 | 76 | 97 | 59 | 74 | 98 | 55 | 76 | 97 | 55 |
| 23-Sep | 71 | 90 | 60 | 72 | 89 | 63 | 70 | 88 | 58 | 70 | 89 | 60 |
| 24-Sep | 75 | 91 | 59 | 76 | 92 | 62 | 74 | 90 | 59 | 75 | 99 | 60 |
| 25-Sep | 75 | 92 | 60 | 76 | 91 | 62 | 75 | 89 | 58 | 75 | 95 | 59 |
| 26-Sep | 75 | 91 | 59 | 76 | 91 | 63 | 74 | 89 | 59 | 74 | 105 | 58 |
| 27-Sep | 75 | 92 | 60 | 76 | 92 | 62 | 74 | 90 | 59 | 75 | 103 | 59 |
| 28-Sep | 75 | 93 | 59 | 75 | 94 | 59 | 74 | 91 | 57 | 75 | 99 | 57 |
| 29-Sep | 75 | 94 | 60 | 75 | 93 | 60 | 75 | 93 | 58 | 75 | 100 | 58 |
| 30-Sep | 75 | 92 | 60 | 75 | 92 | 59 | 75 | 95 | 57 | 74 | 97 | 58 |
| 1-Oct | 75 | 93 | 59 | 75 | 92 | 62 | 75 | 93 | 58 | 75 | 92 | 59 |
| 2-Oct | 75 | 93 | 60 | 75 | 95 | 60 | 75 | 96 | 59 | 75 | 96 | 59 |
| 3-Oct | 75 | 92 | 60 | 75 | 93 | 61 | 75 | 94 | 59 | 75 | 96 | 58 |
| 4-Oct | 75 | 91 | 60 | 75 | 92 | 59 | 75 | 91 | 57 | 75 | 95 | 60 |
| 5-Oct | 75 | 94 | 59 | 75 | 92 | 62 | 75 | 94 | 58 | 75 | 94 | 58 |
| 6-Oct | 76 | 100 | 57 | 77 | 100 | 58 | 76 | 101 | 49 | 76 | 100 | 51 |
| 7-Oct | 73 | 92 | 59 | 77 | 93 | 64 | 74 | 90 | 59 | 76 | 94 | 60 |
| 8-Oct | 75 | 92 | 60 | 75 | 93 | 62 | 74 | 89 | 58 | 75 | 104 | 58 |

Group: Fluctuating DO Level *cont.*

| Date | Tank 12 | | | Tank 14 | | | Tank 15 | | | Tank 18 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min |
| 9-Oct | 75 | 92 | 59 | 76 | 94 | 63 | 74 | 90 | 57 | 75 | 106 | 57 |
| 10-Oct | 75 | 91 | 59 | 76 | 93 | 61 | 74 | 91 | 59 | 75 | 97 | 59 |
| 11-Oct | 75 | 92 | 59 | 76 | 92 | 63 | 74 | 89 | 59 | 75 | 97 | 58 |
| 12-Oct | 75 | 93 | 60 | 76 | 92 | 62 | 74 | 87 | 58 | 75 | 110 | 59 |
| 13-Oct | 75 | 92 | 59 | 76 | 92 | 63 | 75 | 91 | 58 | 75 | 102 | 58 |
| 14-Oct | 75 | 93 | 58 | 76 | 91 | 63 | 75 | 92 | 57 | 75 | 93 | 57 |
| 15-Oct | 85 | 93 | 65 | 81 | 101 | 69 | 78 | 100 | 64 | 79 | 98 | 65 |
| 16-Oct | 90 | 93 | 86 | 90 | 93 | 88 | 90 | 97 | 87 | 90 | 100 | 82 |
| 17-Oct | 90 | 95 | 86 | 90 | 93 | 88 | 90 | 93 | 86 | 90 | 102 | 84 |
| 18-Oct | 90 | 98 | 85 | 90 | 92 | 88 | 90 | 92 | 88 | 90 | 97 | 88 |
| 19-Oct | 100 | 138 | 87 | 104 | 120 | 88 | 103 | 162 | 81 | 104 | 118 | 89 |

Growth, feed utilisation and mortality of adult Atlantic salmon at four levels of DO concentrations, EWOS Innovation Dirdal 25 August – 19/20 October 2004. *: dead fish not included

| **Fish group** | | **Start trial** | | | **End trial** | | | **Biomass increase, kg** | **Feed supplied, kg** | **SGR, %/day** | **FCR, kg/kg** | **Mortality, No.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DO level** | **Tank No.** | **Date** | **No. fish** | **Mean weight, g** | **Date** | **No. fish** | **Mean weight, g** | | | | | |
| 90% of | 1 | 25/08 | 37 | 2534 | 19/10 | 37 | 3099 | 20.919 | 25.181 | 0.37 | 1.20 | 0 |
| saturation | 5 | 25/08 | 38 | 2614 | 19/10 | 38 | 3099 | 18.454 | 23.190 | 0.31 | 1.26 | 0 |
| | 11 | 25/08 | 38 | 2587 | 19/10 | 38 | 2810 | 8.471 | 14.991 | 0.15 | 1.77 | 0 |
| 75% of | 3 | 25/08 | 38 | 2733 | 19/10 | 38 | 3184 | 17.134 | 22.268 | 0.28 | 1.30 | 0 |
| saturation | 10 | 25/08 | 40 | 2817 | 19/10 | 40 | 3192 | 14.980 | 21.780 | 0.23 | 1.45 | 0 |
| | 13 | 25/08 | 38 | 2687 | 19/10 | 38 | 3084 | 15.072 | 21.010 | 0.25 | 1.39 | 0 |
| | 17 | 25/08 | 38 | 2796 | 20/10 | 38 | 3136 | 12.927 | 18.185 | 0.21 | 1.41 | 0 |
| 60% of | 6 | 25/08 | 38 | 2776 | 19/10 | 38 | 2890 | 4.343 | 11.865 | 0.07 | 2.73 | 0 |
| saturation | 8 | 25/08 | 38 | 2815 | 19/10 | 38 | 3142 | 12.406 | 17.563 | 0.20 | 1.42 | 0 |
| | 16 | 25/08 | 38 | 2756 | 20/10 | 37 | 2955 | 4.605* | 12.398 | 0.12 | 1.66 | 1 |
| Fluctuating | 2 | 25/08 | 37 | 2833 | 19/10 | 37 | 3430 | 22.082 | 25.128 | 0.35 | 1.14 | ? |
| concentration | 4 | 25/08 | 38 | 2730 | 19/10 | 37 | 3211 | 15.060* | 22.458 | 0.29 | 1.21 | 1 |
| (diurnal: | 7 | 25/08 | 36 | 2686 | 19/10 | 36 | 3326 | 23.042 | 27.727 | 0.39 | 1.20 | 0 |
| 60-90%) | 9 | 25/08 | 38 | 2724 | 19/10 | 38 | 3130 | 15.404 | 20.449 | 0.25 | 1.33 | 0 |
| | 12 | 25/08 | 38 | 2778 | 19/10 | 38 | 3123 | 13.100 | 18.167 | 0.21 | 1.39 | 0 |
| | 14 | 25/08 | 38 | 2678 | 19/10 | 37 | 3005 | 9.424* | 17.165 | 0.21 | 1.42 | 1 |
| | 15 | 25/08 | 39 | 2735 | 19/10 | 39 | 3229 | 19.243 | 23.277 | 0.30 | 1.21 | 0 |
| | 18 | 25/08 | 38 | 2790 | 20/10 | 38 | 3113 | 12.260 | 17.479 | 0.20 | 1.43 | 0 |

Growth, feed utilisation and mortality of adult Atlantic salmon at four levels of DO concentrations, EWOS Innovation Dirdal 19/20 October – 20/21 December 2004. *: dead fish not included

| **Fish group** | | **Start trial** | | | **End trial** | | | **Biomass increase, kg** | **Feed supplied, kg** | **SGR, %/day** | **FCR, kg/kg** | **Mortality, No.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DO level** | **Tank No.** | **Date** | **No. fish** | **Mean weight, g** | **Date** | **No. fish** | **Mean weight, g** | | | | | |
| 90% of | 1 | 19/10 | 37 | 3099 | 20/12 | 37 | 3436 | 13.462 | 20.765 | 0.18 | 1.54 | 0 |
| saturation | 5 | 19/10 | 38 | 3099 | 20/12 | 38 | 3486 | 14.700 | 21.485 | 0.19 | 1.46 | 0 |
| | 11 | 19/10 | 38 | 2810 | 21/12 | 38 | 3161 | 13.346 | 20.216 | 0.19 | 1.51 | 0 |
| 75% of | 3 | 19/10 | 38 | 3184 | 20/12 | 38 | 3632 | 17.033 | 24.832 | 0.21 | 1.46 | 0 |
| saturation | 10 | 19/10 | 40 | 3192 | 21/12 | 40 | 3581 | 15.559 | 23.842 | 0.18 | 1.53 | 0 |
| | 13 | 19/10 | 38 | 3084 | 21/12 | 38 | 3590 | 19.262 | 25.923 | 0.24 | 1.35 | 0 |
| | 17 | 20/10 | 38 | 3136 | 21/12 | 38 | 3483 | 13.182 | 20.958 | 0.17 | 1.59 | 0 |
| 60% of | 6 | 19/10 | 38 | 2890 | 20/12 | 38 | 3037 | 5.556 | 11.095 | 0.08 | 2.00 | 0 |
| saturation | 8 | 19/10 | 38 | 3142 | 20/12 | 38 | - | - | - | - | - | 0 |
| | 16 | 20/10 | 37 | 2955 | 21/12 | 37 | 3302 | 12.833 | 20.356 | 0.18 | 1.59 | 0 |
| Fluctuating | 2 | 19/10 | 37 | 3430 | 20/12 | 37 | 3801 | 13.754 | 24.932 | 0.17 | 1.81 | 0 |
| concentration | 4 | 19/10 | 37 | 3211 | 20/12 | 37 | 3773 | 20.790 | 25.270 | 0.26 | 1.22 | 0 |
| (diurnal: | 7 | 19/10 | 36 | 3326 | 20/12 | 36 | - | - | - | - | - | 0 |
| 60-90%) | 9 | 19/10 | 38 | 3130 | 20/12 | 38 | 3607 | 18.133 | 26.518 | 0.23 | 1.46 | 0 |
| | 12 | 19/10 | 38 | 3123 | 21/12 | 38 | 3524 | 15.258 | 19.635 | 0.19 | 1.29 | 0 |
| | 14 | 19/10 | 37 | 3005 | 21/12 | 37 | 3326 | 11.876 | 20.502 | 0.16 | 1.73 | 0 |
| | 15 | 19/10 | 39 | 3229 | 21/12 | 39 | 3813 | 22.790 | 29.776 | 0.26 | 1.31 | 0 |
| | 18 | 20/10 | 38 | 3113 | 21/12 | 38 | 3508 | 14.993 | 19.897 | 0.19 | 1.33 | 0 |