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Submerged camera for surveillance of fish stock and environmental conditions in cages, Grieg Cod Farming

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Preface

The company, Orbit AquaCam, has involved IRIS as R&D partner in order to assess the advantage of using a newly developed equipment for behavioural control of cod in deep cages. In addition to the ordinary camera function, the camera body is also equipped with sensors for monitoring of vital environmental parameters.

This report mainly describes the initial stage of camera use throughout the grow-out cycle of adult cod in cages at Grieg Cod Farming located in Erfjord, Suldal county, Rogaland.

Thanks to contributors.

The authors are grateful to the project involved staff at the farm in Erfjord, Charlie Erfjord and Per Inge Laugaland.

Thanks are due to Aanderaa Systems Ltd. contributing to the project by replacing the original DO sensor in the Aanderaa sampler by an optical Oxygen Optode on their own account.

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Stavanger, 24. January 2008

Asbjørn Bergheim, project leader

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Summary

Usage of submerged cameras in fish cages represents a real breakthrough for the operator in order to assess the fish behaviour throughout the production cycle. Observation of vital factors, such as fish distribution, appetite/feeding behaviour, signs of parasite attach or disease, fish escape, etc can be observed at close range. Combining movable cameras with sensors for monitoring of decisive environmental factors, especially temperature and dissolved oxygen, is almost a complete tool to better operate fish cages.

This report deals with use of a newly developed camera system connected to a sensor station in two deep cages stocked Atlantic cod during the first months after stocking of fry. The camera with the sensor station is controlled by a winch system for vertical motion in the cage. Most of the time, the camera with sensor station was vertically moved from the cage bottom to the surface twice a day, at the time of feeding in the morning and in the afternoon.

During the referred period, the average stocking density in the cages was below 5 kg/cu. m and thus the reduced oxygen concentration (DO) in the cages was moderate – around 10% in slack periods at feeding. The DO concentration range in the depth layer between 20 – 30 m was 65 – 80% of saturation most of the time at a temperature of 10 – 13 °C. The bulk of the fish stock dwelled in this layer close to the feeding point at 20 m depth. DO concentrations below 60 – 65% of saturation were rarely observed. A maximum of 30% of DO saturation difference was measured in the depth profile from surface (90% DO) to the cage bottom (60% of DO) at the same time.

On average, the current velocity was around 2 cm/s (0 – 10 cm/s) at 5 and 20 m depth outside the cages. The dominating current direction at 20 m depth, where the fish stock was concentrated, was from a western – south western direction. In general, the conditions seemed favourable for cod farming.

The fish stock was, as expected, crowded at the feeding point in the cages. This was clearly demonstrated in Cage 6 where the feeding outlet was moved from the surface to 20 m depth on 27 September. A smaller part of the stock seemed to be dwelling near the surface throughout the period independent of feeding.

This observations and sampling will continue until harvest of the cod stock in late 2008.

1 Introduction

Our knowledge of the variable physical environment in sea cages is limited (Johansson *et al.* 2006). There is an increasing focus on the environmental conditions and the welfare of the fish stock in cages. Especially, the oxygen level is a key factor that effects fish welfare and performance (e.g. Beveridge, 2004). Oxygen levels (DO) in sea cages are influenced by many other environmental factors, such as temperature, algal growth, light, tidal current and wind (Johansson et al. op. cit). Not least, the oxygen consumption of the fish stock itself may reduce the DO level by several mg/L within the cages (Bergheim *et al.* 2006). During periods of high temperature, i.e. in late summer and early autumn, the respiration of the fish stock is high, while the water's carrying capacity of DO is reduced. Monitoring at cage sites in fjords also demonstrate risky DO deficit incidents even during winter at low temperature. Thus, there is a certain risk of hypoxia, e.g. occurrence of reduced DO levels that limits the fish's appetite and growth.

Fish welfare in cages is a complex concept. Stocking density is one area often connected to welfare since farmed fish often are held at higher density than prevail in the wild. The term 'stocking density' is usually based on the average fish density of the cage assuming that the stock is equally distributed in the entire cage volume. In a study with increasing density of salmon in cages, Turnbull *et al.* (2005) concluded that "welfare can be maintained at high densities and conversely low densities are no guarantee of good welfare". So many different factors will vary from time to time and from site to site and influence on the fish throughout the production cycle that setting a threshold density is not an effective way to ensure the welfare.

Introduction of new advanced technology has made possible continuous surveillance of the conditions in fish cages. At The Norwegian Institute of Marine Research, an advanced tool to answer question about environmental and husbandry influences on fish welfare has been established. The 'Cage-environment laboratory' located in a fjord in Nord-Hordaland has a basic set-up of six 15 m deep cages where behavioural and environmental screening can be carried out with high resolution in time and space in all cages. This includes vertical profiles of oxygen-levels, temperature, salinity, light, pH, and turbidity controlled by programmable winches, as well as water current profilers. Swimming behaviour (speed, depth, fish density, group structure) and physiological parameters of both individuals and groups are monitored simultaneously by a range of different methods. Several reports/publications are presented from these studies, e.g. Johansson *et al.* (op.cit).

Centre for Aquaculture Competence AS (CAC) has established an advanced cage based research facility in site Langavik in Ryfylke (Tor André Giskegjerde, personnel communication, 2004). The environmental conditions are continuously recorded by sensors for temperature, salinity, light intensity, dissolved oxygen and current velocity. Besides, the climatic conditions are recorded in a local weather station. The site is further equipped with 30 cameras (both submerged and above the surface).

Commercial farming of Atlantic cod (*Gadus morhua* L.) is a rather new industry and thus some basic environment factors for successful farming of this species are included (Table 1). Cod is a typical cold water species with an optimum temperature range 2 – 3°C below the optimum for Atlantic salmon. The temperature should not exceed 17 – 18°C throughout the entire grow-out cycle and more than 14°C and below 6 - 7°C lasting for some days will reduce the growth rate and feed utilisation. Like other cold water species, cod is sensitive to DO deficit and concentrations below 80 % is considered sub-optimal reducing the performance. Table 1 also indicates optimal and critical ranges and limits for carbon dioxide gas, pH and total gas pressure.

Table 1. Optimum and sub-optimal water quality conditions for on-growing of Atlantic cod in aquaculture. - - : No data available

Parameter	**Optimum range**	**Sub-optimal**	**Critical**	**Reference**
Temperature, °C	10 - 13[1]	5 - 8 & 14 - 17	< 0 - 1 & > 24	Bye, 2006; Skretting (pers. comm.)
Salinity, ppt	10 - 34[2]	< 5 - 10 & > 35	< 2 & > 40	
Dissolved oxygen (DO), % of saturation	80 - 100 (> 6 mg/L)	60 - 80 & > 100 - 150[3] (?)	< 30 > ?	Chabot & Dutil, 1999 Foss *et al.* 2006; Remen, 2006; Plante *et al.* 1998
Carbon dioxide (CO_2), mg/L pH[4]	< 10 7.5 – 8.5	> 10 < 7 & > 9	- - - -	Foss *et al.* 2006
Total gas pressure, % of saturation[5]	100%	100 - 103%	> 105%	Otterlei *et al.* 1999

[1]: 1 - 2 °C higher for fry (< 5 g) compared to adults; [2]: approx. range, depends on acclimation; 3: hyperoxia assumed to reduce ammonia toxicity; [4]: pH level mainly a consequence of respiration and/or photosynthesis; [5]: depends on interacting effects of other parameters (e.g. hypoxia, hypercapnia)

Cod is a so-called *physoclist* species with a closed swim bladder and must rely on secretion and absorption of oxygen through their circulatory system (Kristiansen *et al.* 2006). In brief, cod needs time to absorb/secret gas at vertical migration. Consequently, there is a certain limit for fast vertical motion, e.g. from the dwelling depth to the feeding depth. In their tests, Kristiansen *et al.* (op. cit) found that the maximum tolerated pressure reduction for cod was about 50%, e.g. migration from 25 m depth up to ca. 10 m depth.

Usage of submerged cameras in fish cages have been occasionally reported over the last decade in order to study feeding behaviour in salmon cages (Ang & Petrell, 1997; Petrell & Ang; 2001), feeding habit and growth in open water cages (Michel *et al.* 2002) and to extract fish size directly underwater (Costa *et al.* 2006).

This report deals with use of submerged cameras permanently placed in deep cages in the initial stage of grow-out of Atlantic cod in a fjord in Northeast Ryfylke, Rogaland. The single camera per cage is equipped with sensors for frequent monitoring of temperature, DO and salinity. This unique technology makes possible continuous surveillance of the fish stock on indoor screens and gives momentary information of the fish behaviour at feeding, vertical distribution of the fish stock vs. environmental conditions, indications of irregular behaviour, such as disease, escape of fish, etc.

2 Equipment and sampling

2.1 Farm site and operation

The farm is situated in Erfjord in the NE part of the Boknafjord region (Fig. 1). Six squared cages of 15 x 15 m and 40 – 45 m depth are stocked with cod, while the remaining four cages in the western end of the farm will be stocked in spring 2008. In 2007, the cages were stocked with cod fry on 1 February.

Fish is fed commercial pelleted feed stored in onshore silos. The feed is brought through hoses by compressed air to the cages. During the first phase post stocking, feeding was performed at the surface but was later on moved to 20 m depth. There is one feeding point in each cage placed in the cage centre.

Dead fish are removed daily and recorded during summer and every second day from late autumn till spring (at temperature < 10 °C). The cage net is inspected by divers once a month and the health state of the fish is controlled bimonthly by veterinarian. In order to control the model based growth estimates, batches of approx. 100 individuals are weighed weekly – biweekly in each cage.

The operation and fish performance in the two cages involved in the present project, Cage 1 and 6, are briefly presented in Table 2. There was different number and individual size of fish stocked in the cages, but the density as kg/cu. m was about the same. The approximate growth rate and feed conversion rate (FRC, ca. 1.0) during the first 11 months were close to the model based figures and thus indicated favourable conditions for grow-out of cod.

Table 2. Operation of Cage 1 and 6, Grieg Cod Farming, Erfjord, February – December 2007.

Factor	**Cage 1**	**Cage 6**
FISH STOCK		
Stocking:		
Time	1 February	1 February
Number of fish	149,847	69,044
Individual mean size, g	90	125
Density, kg/m^3	0.6	0.4
31 December:		
Total mortality, %	3.42	5.88
Individual mean size, g	617.6	1051.6
Growth, SGR (%/day)	0.58	0.64
Density, kg/m^3	3.9	3.0
FEED		
Feed type	Skretting Cod Feed, Pellets, 3 – 9 mm	Skretting Cod Feed, Pellets, 3 – 9 mm
Feeding time	8 am – 4 pm	8 am – 4 pm
Feeding rate, %/day	0.58	0.64
Feeding depth	Surface till 21 June, then 20 m depth	Surface till 27 Sep, then 20 m depth
CAMERA W/ SENSORS:		
Start monitoring	21 September	21 September
Vertical depth motion	Twice a day (0 – 40 m)	Twice a day (0 – 40 m)
Parameters	Temp., DO, salinity*, depth	Temp., DO, depth
Logging frequency (intervals)	5 minutes	5 minutes

*: from 9 November

2.2 Set-up

All six fish cages were equipped with underwater cameras (Fig. 1). A sensor station including oxygen, temperature and depth sensors were attached to the cameras in Cage 1 and 6. These are the cages marked with yellow in the east (Cage 1) and west corner (Cage 6) of the farm. A salinity sensor was later added to the sensor station in Cage 1 in mid-November. These cameras are connected to a winch system that enables them to move from the bottom of the cage to the surface (0 – 40 m). The cameras can also be moved horizontally in the cages.

The sensor stations communicate with a data link placed at the surface of the fish cage via the camera cable. The data link at the surface of the fish cage inserts the measured variables in the picture as text overlay. Depth, temperature, oxygen concentration (DO) and salinity are shown on the video screen. In addition, the data link transfers the measured variables to the web server on request.

A data logger program is installed in the web server. With 20 seconds interval the data logger program asks the data link for the latest measured variables. These variables are shown in a graph on the desktop of the web server. Every 5 minutes the variables are stored in a database.

In Cage 1 and 6, the cameras are usually kept at a stable position in the cages at 20 – 30 m depth and daily moved vertically from bottom to surface in the morning at 9 – 10 am and in the afternoon at 2 – 3 pm. Thus, the fish distribution and environmental conditions in the water column were monitored twice a day.

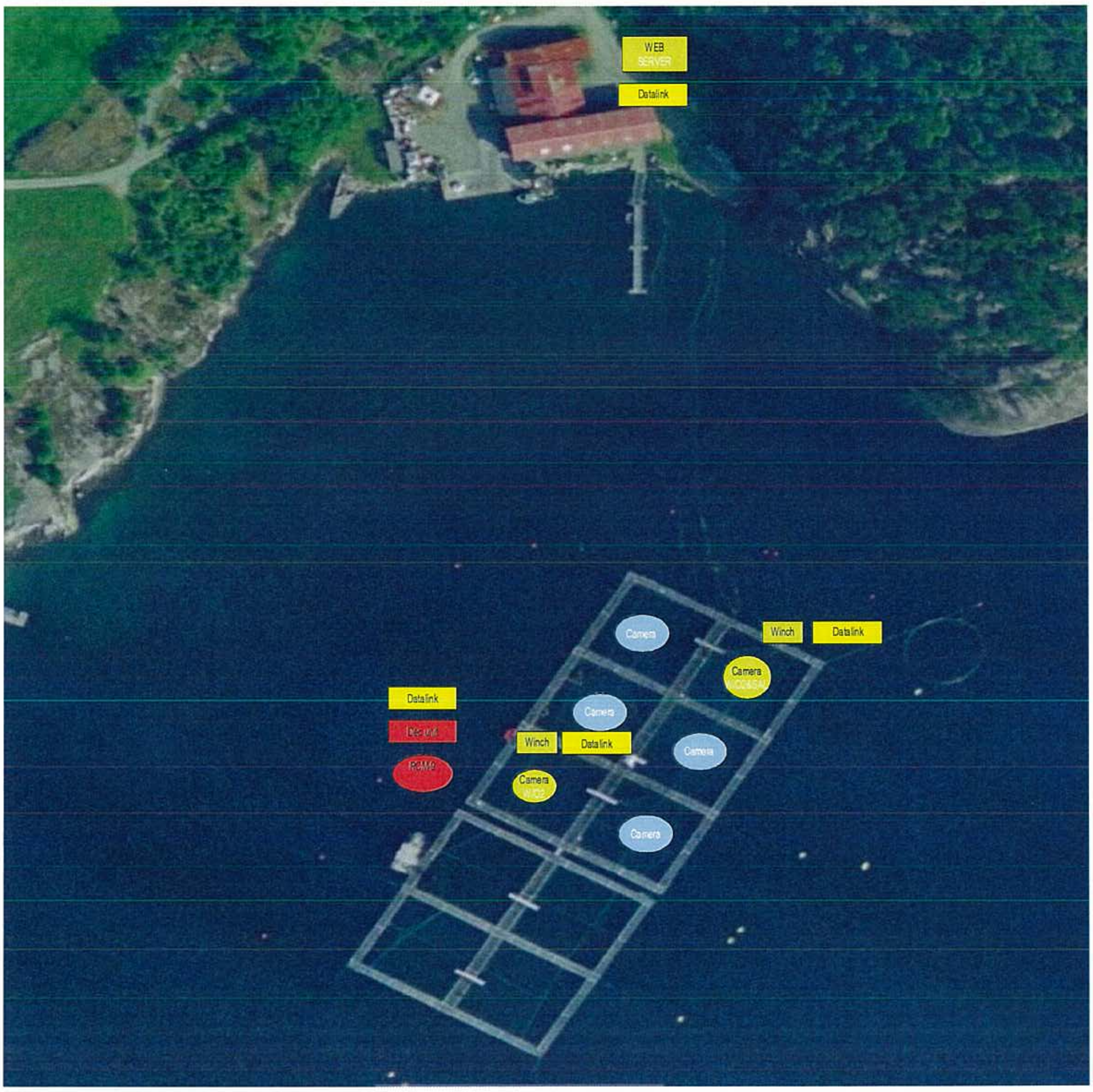
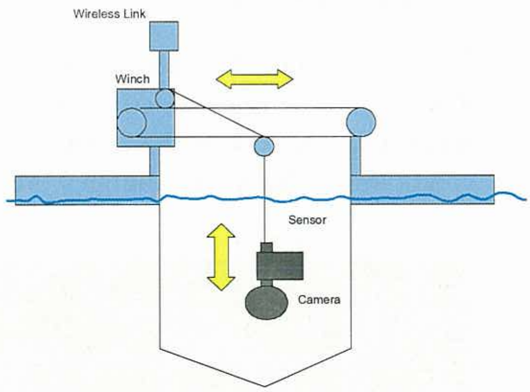


Figure 1. Placement of sensors on the farm site with onshore buildings and six cages with submerged cameras. Yellow marking: Cameras with winch system connected sensors (Ch. 2.1.1). Red marking: Aanderaa sampler (RCM) outside the cages. Grieg Cod Farming, Erfjord.

The Aanderaa sampler for monitoring of temperature, salinity, dissolved oxygen (DO) and current velocity and direction were placed ca. 10 m off the west corner of Cage 6. During the period 21 September – 14 November, the sampler was positioned at 5 m depth and then moved to 20 m depth. The sampling intervals were 10 minutes.

2.2.1 Orbit sensor system



The Orbit-800 Sensor Station is produced by Orbit AquaCam AS and can measure dissolved oxygen, temperature and depth. It is also possible to measure the salinity by adding a conductivity sensor. As shown in the sketch, the position of the camera and sensor station can be controlled by the winch system. This means that the operator can move the camera from the bottom of the fish cage to the surface. He can also move the camera and sensor station from side to side in the fish cage. The winch system is used to obtain vertical profiles of the water column.

The oxygen sensor used in the Orbit-800 Sensor Station is the Optode 3835 from Aanderaa Data Instruments AS. This sensor measures dissolved oxygen and temperature of the water. Salinity is measured by the Conductivity sensor 3919 from Aanderaa Data Instruments AS. The depth sensor is made by Orbit AquaCam AS and is based upon the PA-21G from Keller.

Oxygen Optode 3835

Oxygen:

Measuring range:	0 - 120%
Resolution:	0.4%
Accuracy:	< 5%
Settling time (63%) :	<10 s

Temperature:

Measuring Range:	-0°C - 36°C
Resolution:	0.01°C
Accuracy:	+/- 0.05°C
Settling time (63%):	<10 s

Conductivity Sensor 3919

Conductivity:

Measuring range:	0-7.5 S/m
Resolution:	0.0002 S/m
Accuracy:	0.005 S/m
Settling time (63%):	<3 s

Depth Sensor Orbit AquaCam

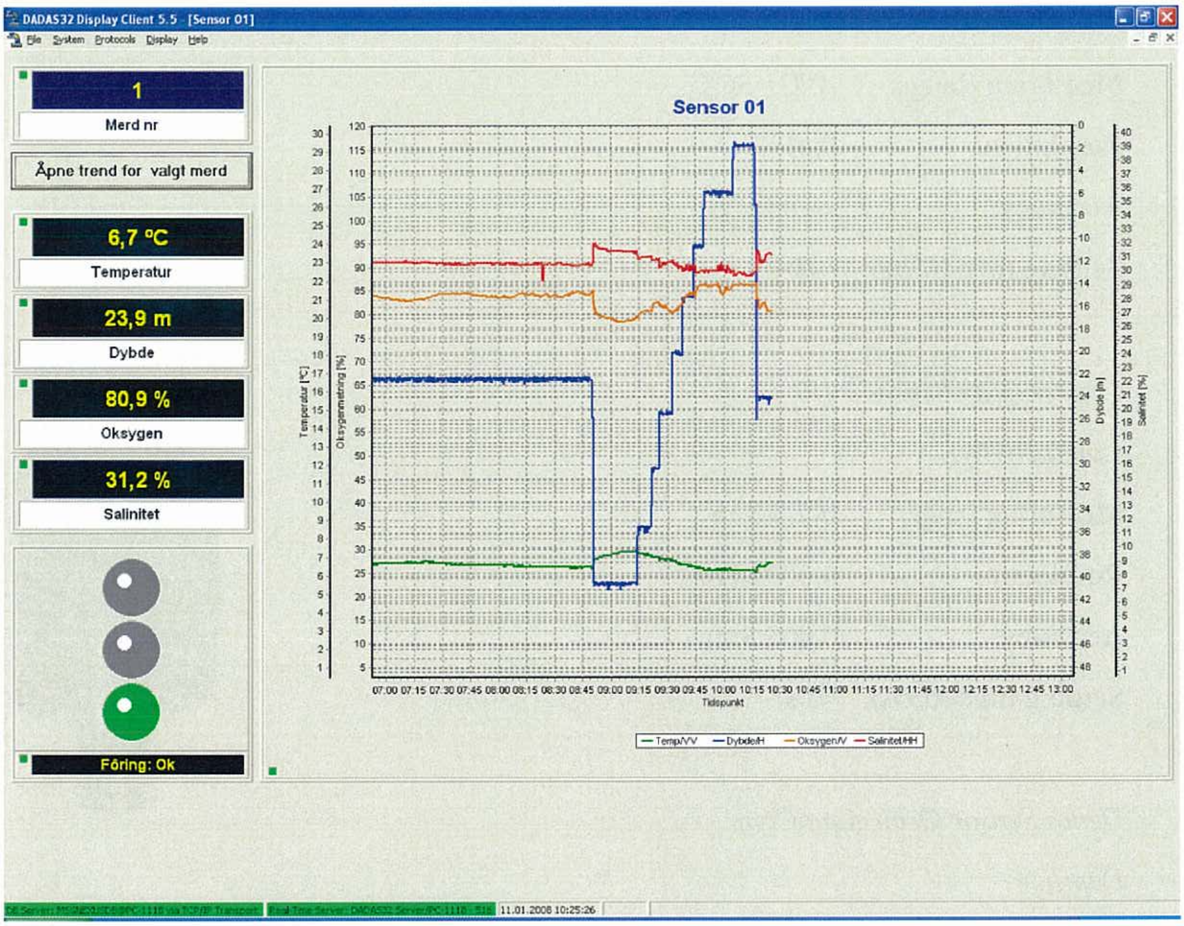
Depth:

Measuring range:	0 - 100 m
Resolution:	0.1 S/m (1m resolution shown on text overlay)
Accuracy:	0.5 m
Settling time (63%):	<5 s

Data logger program:

Data from the sensor station are received by a RF data link PCB placed inside the web server. The data logger program sends a telegram to the sensor stations with 20 seconds intervals where it requests for the last measured values. Then, the sensor stations reply to this telegram with the latest measured values. The values are then presented as a graph in the data logger program. On the left side of the screen, the latest measured values will be shown as figures. Every five minutes the measured values will be stored in a database.

An instantaneous screen view of a vertical camera movement is illustrated:



Aanderaa sampler:

Model RCM 9 Mk II. The instrument combines RCM Doppler Current Sensors and sensors for Temperature, Conductivity, Pressure and Oxygen measurements. The current is measured in the area from 0.4 to 2.2 m from the instrument which minimises the effect of marine fouling and local turbulence. This unit was used for continuous monitoring outside the cages.

The instrument sends the data to surface via a cable. A built-in quartz clock triggers the measuring cycle at regular, programmable intervals. On the topside of the fish cage, a Deck unit 3127 from Aanderaa converts the data from the instrument to a RS 232 stream. The RS 232 signal is connected to a comport on a wireless access point so that these data can be stored and used by the Aanderaa data logger program installed on the web server from Orbit AquaCam.

Ch. 1 Reference (a control and identification reading)

Ch. 2 Current speed (range: 0 - 300 cm/s, accuracy: 1 % of reading)

Ch. 3 Current direction (accuracy: ± 5 - 7.5°)

Ch. 4 Temperature (range: - 2.7 – 32.9 °C, accuracy: ± 0.05°)

Ch. 5 Conductivity (range: 0 –74 mS/cm, accuracy: 0.2 - 0.8 % of range)

Ch. 6 Pressure (range: 0 – 700 kPa, accuracy: ± 0.1 % of range)

Ch. 7 Turbidity (not connected at sampling)

Ch. 8 Oxygen (range: 0 - 20 mg/L, accuracy: ± 0.8 mg/L)

For further reading, see the Operating Manual from Aanderaa Instruments (www. aanderaa.com)

3 Results

3.1 Conditions outside cages

3.1.1 Current conditions

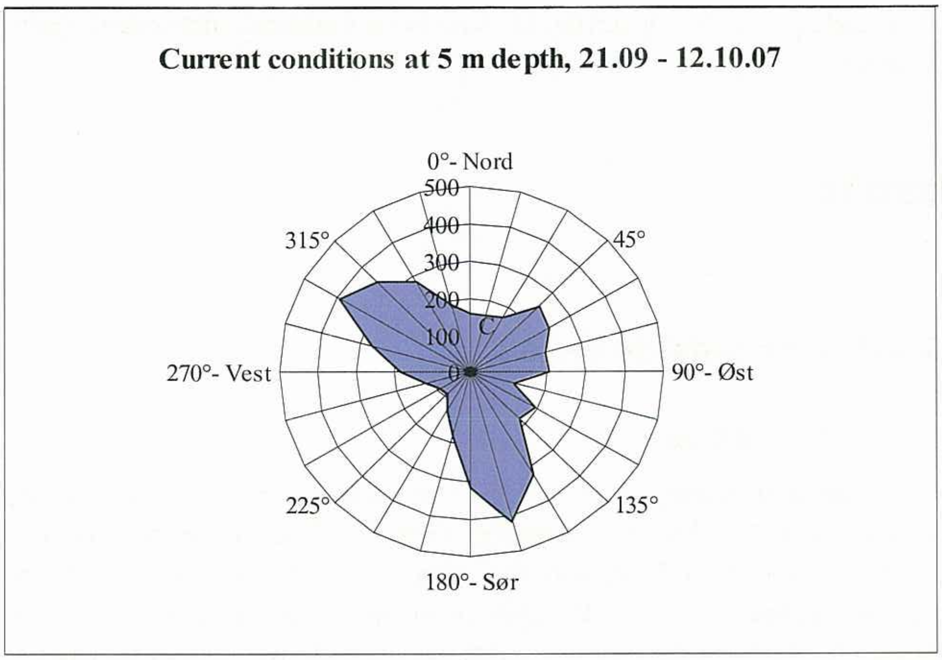
Based on monitoring during three weeks, the current conditions at 5 m depth seem irregular with steadily changing direction (Fig. 2). The dominating water transport directions found were from S-SE and NW directions and this irregular pattern indicates that different mechanisms affect the current in this layer, such as wind, stratification, tidal effects, etc. At 20 m depth, the conditions are more uniform dominated by a fairly stable current from SW. The average current velocity is around 2 cm/s in both depth layers and velocities of more than 5 - 7 cm/s are infrequent (Table 3, Figs 3 - 4). During the sampling periods, current velocities within the range 0.5 – 3 cm/s represented 70 and 79 % of total at 5 and 20 m depth, respectively.

3.1.2 Temperature, salinity and oxygen

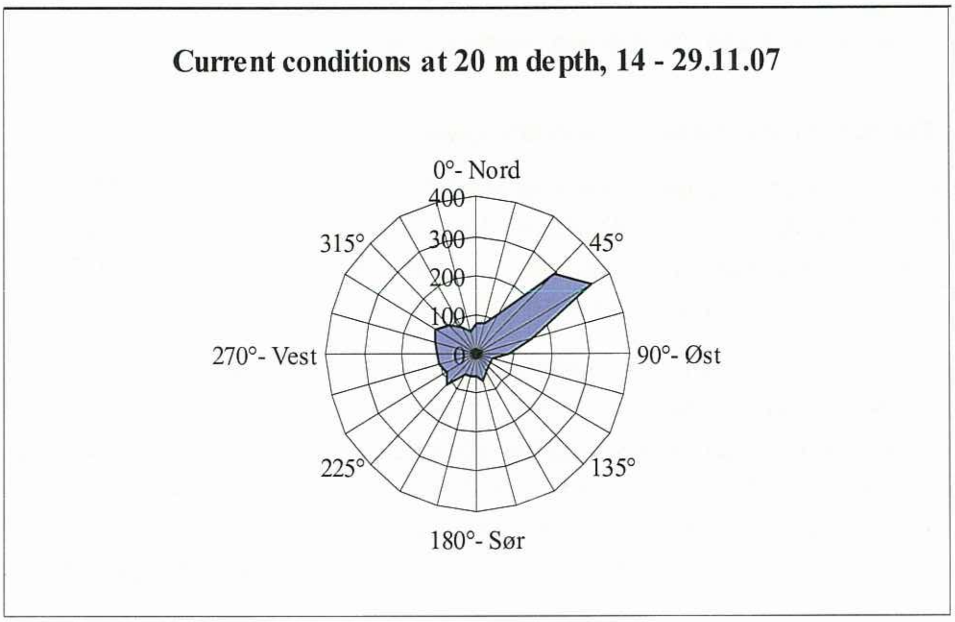
The overall temperature range measured at both depths in September – December was 8.0 – 13.1 °C (Table 3, Figs 3 - 4). Steep changes of 2 - 3 °C during a couple of days may occur at both depths during autumn. A clear temperature decrease at 20 m depth was observed from 20 November till 10 December.

Average salinity at this part of the year seems to be below 30 ppt down to 5 m depth. This strongly depends on the amount of rain and freshwater influx to the area. Most of the period was dominated by wet weather and occasionally heavy rainfalls. The apparently reduced salinity from 5 to 20 m depth, from 28 to 25 ppt, is obviously a measuring error due to a technical fault. According to the salinometer connected the camera in Cage 1, the average salinity at 20 – 25 m depth during this period was 31 – 32 ppt (see Table 4).

Dissolved oxygen (DO) fluctuated between 78 and 102 % of saturation at 5 m depth, averaging 92 – 95 %. In the following period, the average DO concentration at 20 m depth was 7 - 10 % lower. However, increasing DO concentrations were observed in the deeper part (Fig. 4) as the temperature and salinity decreased during November – December. Steeply reduced DO levels of 15 – 20 % of saturation may occur on rare occasions and seem to be connected to strong current velocity. The lowest DO levels measured at 20 m depth are mainly observed in episodes of current from an eastern direction, i.e. water more or less affected by the respiration of the cod stock in the cages. Due to technical faults, the readings occasionally got lost.



Mean: 2.33 cm/s Max: 9.4 cm/s Min: 0 cm/s



Mean: 1.87 cm/s Max: 10.0 cm/s Min: 0 cm/s

Figure 2. Current velocity and direction monitored outside the cod cages at 5 m and 20 m depth, Grieg Cod Farming, Erfjord. Sampling point: ca. 10 m off the NW corner. Summarised current velocity within 15° sectors.

Table 3. Hydrographical monitoring at 5 and 20 m depth outside cod cages, Grieg Cod Farming, Erfjord September - December 2007. Monitoring frequency: 10 mins.

a) 5 m depth

21 – 30 September

Criterion	**Temperature** °C	**Salinity** ppt	**Dissolved oxygen** % of saturation	**Current velocity** cm/s
Mean	11.9	28.8	92.8	2.59
Max	12.6	30.7	101	9.4
Min	11.3	25.0	79.1	0
SD	0.21	1.5	4.1	1.6

1 – 7 October

Criterion	**Temperature** °C	**Salinity** ppt	**Dissolved oxygen** % of saturation	**Current velocity** cm/s
Mean	12.4	29.9	92.4	2.11
Max	13.1	30.6	97.0	8.2
Min	12.0	29.0	77.9	0
SD	0.29	0.31	3.2	1.4

8 – 23 October

Criterion	**Temperature** °C	**Salinity** ppt	**Dissolved oxygen** % of saturation	**Current velocity** cm/s
Mean	12.4	29.1	94.9	2.06
Max	13.1	30.5	102	8.8
Min	11.5	26.7	85.7	0
SD	0.30	0.81	3.2	1.3

24 October – 6 November

Criterion	**Temperature** °C	**Salinity** ppt	**Dissolved oxygen** % of saturation	**Current velocity** cm/s
Mean	12.3	29.4	89.6	1.90
Max	12.8	30.7	97.4	7.0
Min	11.0	26.9	84.4	0
SD	0.48	0.82	3.1	1.2

b) 20 m depth

14 – 30 November

Criterion	**Temperature** °C	**Salinity** ppt	**Dissolved oxygen** % of saturation	**Current velocity** cm/s
Mean	11.0	28.2	83.0	1.86
Max	12.2	31.2	95.1	10.0
Min	8.9	26.0	69.0	0
SD	0.81	1.4	4.4	1.3

1 – 11 December

Criterion	**Temperature** °C	**Salinity** ppt	**Dissolved oxygen** % of saturation	**Current velocity** cm/s
Mean	9.7	25.7*	87.3	2.01
Max	10.7	28.5	93.8	9.1
Min	8.0	24.1	76.0	0
SD	0.58	0.58	3.3	1.4

‘: measuring error (technical fault)

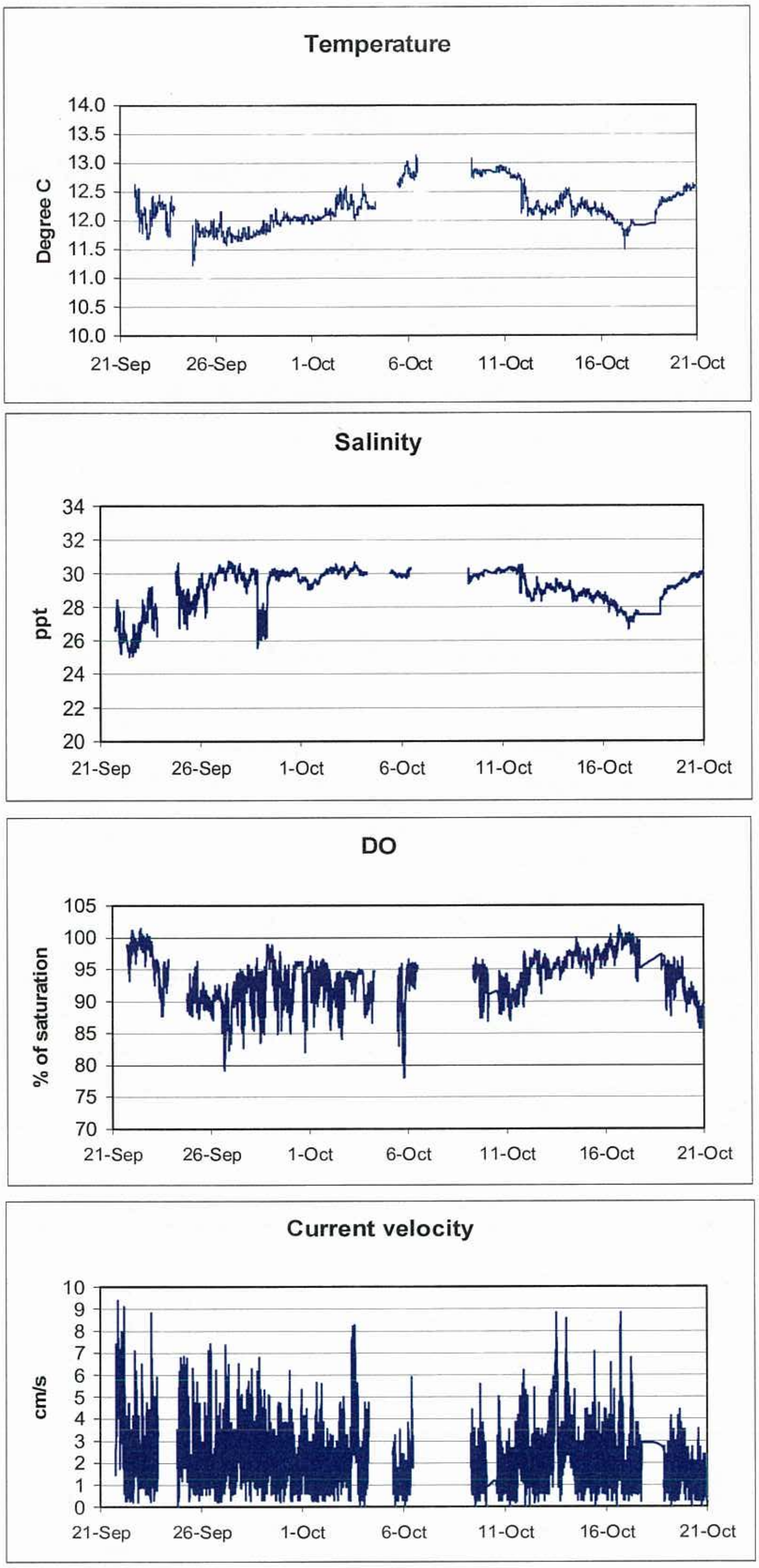


Figure 3. Hydrographical monitoring at 5 m depth outside cod cages, Grieg Cod Farming, Erfjord, 21 Sep – 21 Oct 2007. Monitoring frequency: 10 min. (lost data: 7 – 10 Oct, 17 – 18 Oct)

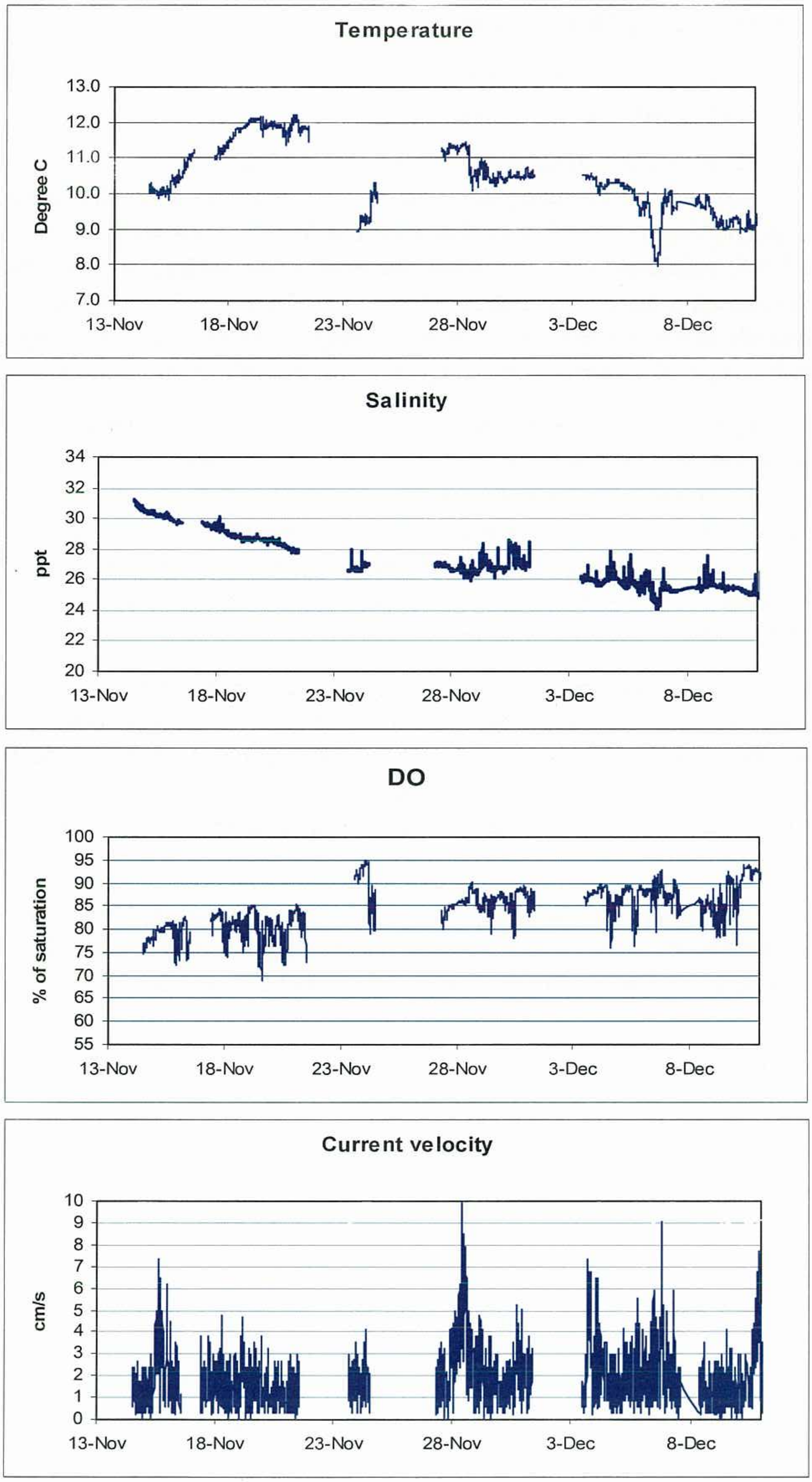


Figure 4. Hydrographical monitoring at 20 m depth outside cod cages, Grieg Cod Farming, Erfjord, 14 Nov. – 11 Dec. 2007. Monitoring frequency: 10 min. (lost data: 16 Nov, 21-23 Nov, 24-26 Nov, 2-3 Dec)

3.2 Conditions within cages

The running monitoring of temperature, oxygen and salinity in Cage 1 and 6 are presented in Table 4 and Figs. 5 – 6 and 8 – 9.

Temperature in the middle of the water column (20 – 25 m depth) was 12 - 13 °C during the first six weeks of the sampling, from end of September till early November. Then a gradual reduction to 10 – 11 °C was observed. The lowest levels were mainly measured at 40 m depth, maximum 4 – 5 °C below the level at the surface in November. In the end of November, a sharp temperature fall of 2 – 3 °C was measured during a couple of days. Throughout the whole period, the mean temperature was ca. 1.5 °C higher at 20-25 m depth compared to at the surface and at the bottom of the cage (Fig. 11).

Dissolved oxygen (DO) fluctuated between 56 and 102% of saturation throughout the sampling period. Within the same day, the DO saturation was 5 – 15% lower in the deeper part of the cages compared to at the surface. As much as 20 – 30% lower DO levels below 25 – 30 m was demonstrated a few times, e.g. in Cage 1 on 21 October(Fig. 7) and in Cage 6 on 20 October (Fig. 10). On average, the lowest DO levels occurred at 25 – 40 m depth, at or below the feeding outlet (Fig. 11), where frequent DO levels below 70% were demonstrated.

Without DO monitoring within the cages on one permanent spot, it is impossible to estimate the DO reduction caused by the respiration of the fish stock. During the period late November – early December, the average DO concentration outside the cages (Table 3) was ca. 85% while the concentration was ca. 75% within the nearest cage, Cage 6. Thus, some 10% DO reduction due to fish consumption might be suggested at that time.

Salinity monitoring was introduced in Cage 1 in mid-November (Table 4). At 20 – 25 m depth, salinity seems to be around 31 – 32 ppt. Maximum level at 40 m was 34.7 ppt and the lowest level measured towards the surface in late November was 21.3 ppt.

Table 4. Water column monitoring within cages at 0 – 40 m depth stocked with cod, Grieg Cod Farming, Erfjord September - December 2007. Monitoring frequency: 5 mins.

Cage 1

Period	Parameter	Mean	Max	Min
21 Sep - 10 Oct	Temperature (°C)	12.6	13.7	9.6
	DO (% of saturation)	83.9	102.4	62.1
	Salinity, ppt	-		
11 - 23 Oct	Temperature (°C)	12.7	13.3	10.2
	DO (% of saturation)	80.9	97.4	61.2
	Salinity, ppt	-		
24 Oct - 08 Nov	Temperature (°C)	12.7	13.4	7.9
	DO (% of saturation)	78.2	93.9	63.0
	Salinity, ppt	-		
09 Nov - 03 Dec	Temperature (°C)	10.8	14.5	7.3
	DO (% of saturation)	74.7	89.5	59.6
	Salinity, ppt	31.7	34.3	21.3

Cage 6

Period	Parameter	Mean	Max	Min
21 Sep - 10 Oct	Temperature (°C)	12.4	13.7	9.0
	DO (% of saturation)	81.7	95.2	68.6
	Salinity, ppt	-		
11 - 23 Oct	Temperature (°C)	12.9	13.4	11.7
	DO (% of saturation)	79.2	94.9	63.8
	Salinity, ppt	-		
24 Oct - 08 Nov	Temperature (°C)	12.8	13.4	9.7
	DO (% of saturation)	76.4	91.1	60.1
	Salinity, ppt	-		
09 Nov - 03 Dec	Temperature (°C)	10.9	12.8	7.1
	DO (% of saturation)	75.3	87.2	56.1
	Salinity, ppt	-		

- : not monitored

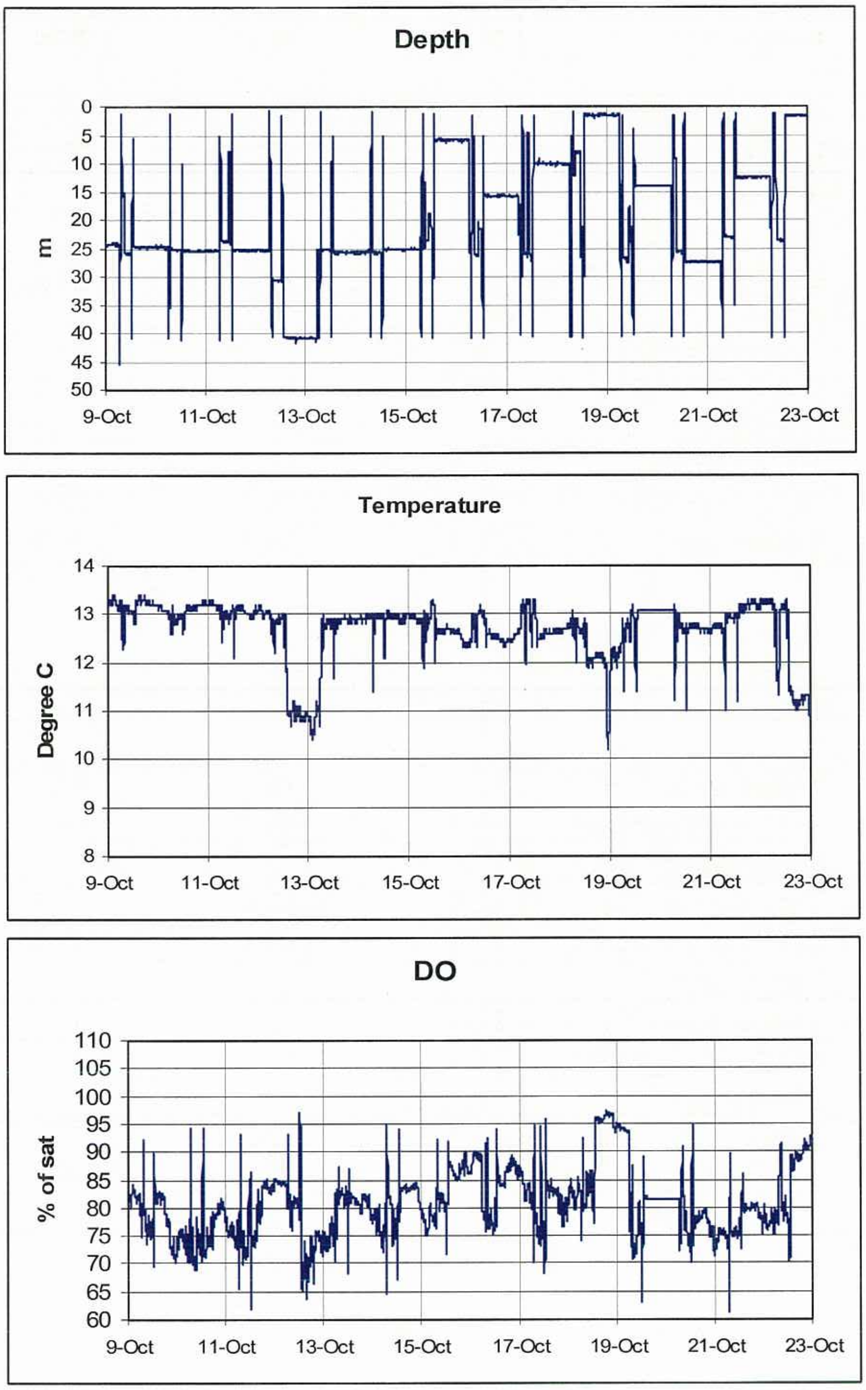


Figure 5. Temperature and dissolved oxygen conc. (DO) in Cage 1, 0 – 42 m depth, Grieg Cod Farming, Erfjord, 9 - 23 Oct. 2007

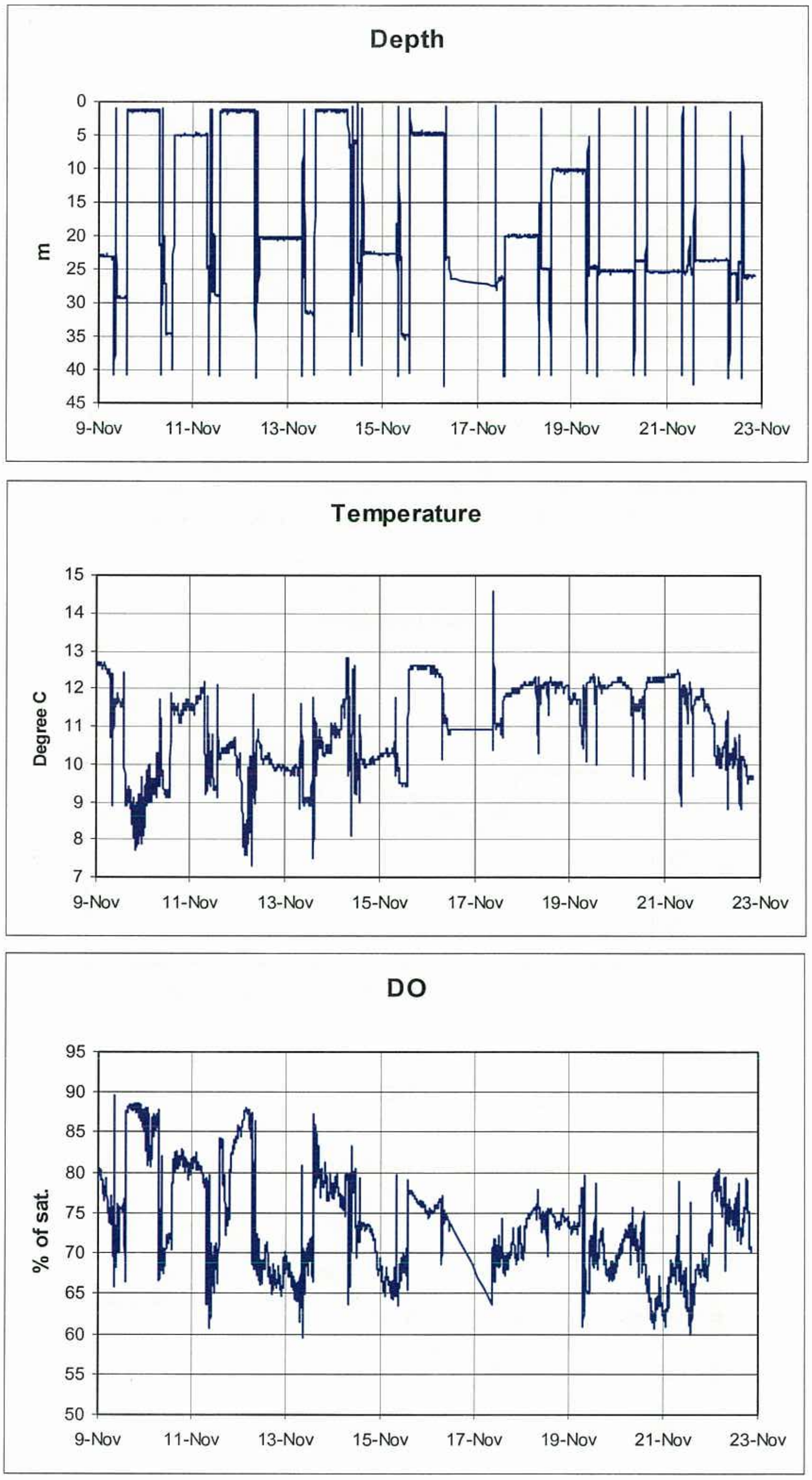


Figure 6. Temperature and dissolved oxygen conc. (DO) in Cage 1, 0 – 42 m depth, Grieg Cod Farming, Erfjord, 9 – 23 Nov. 2007

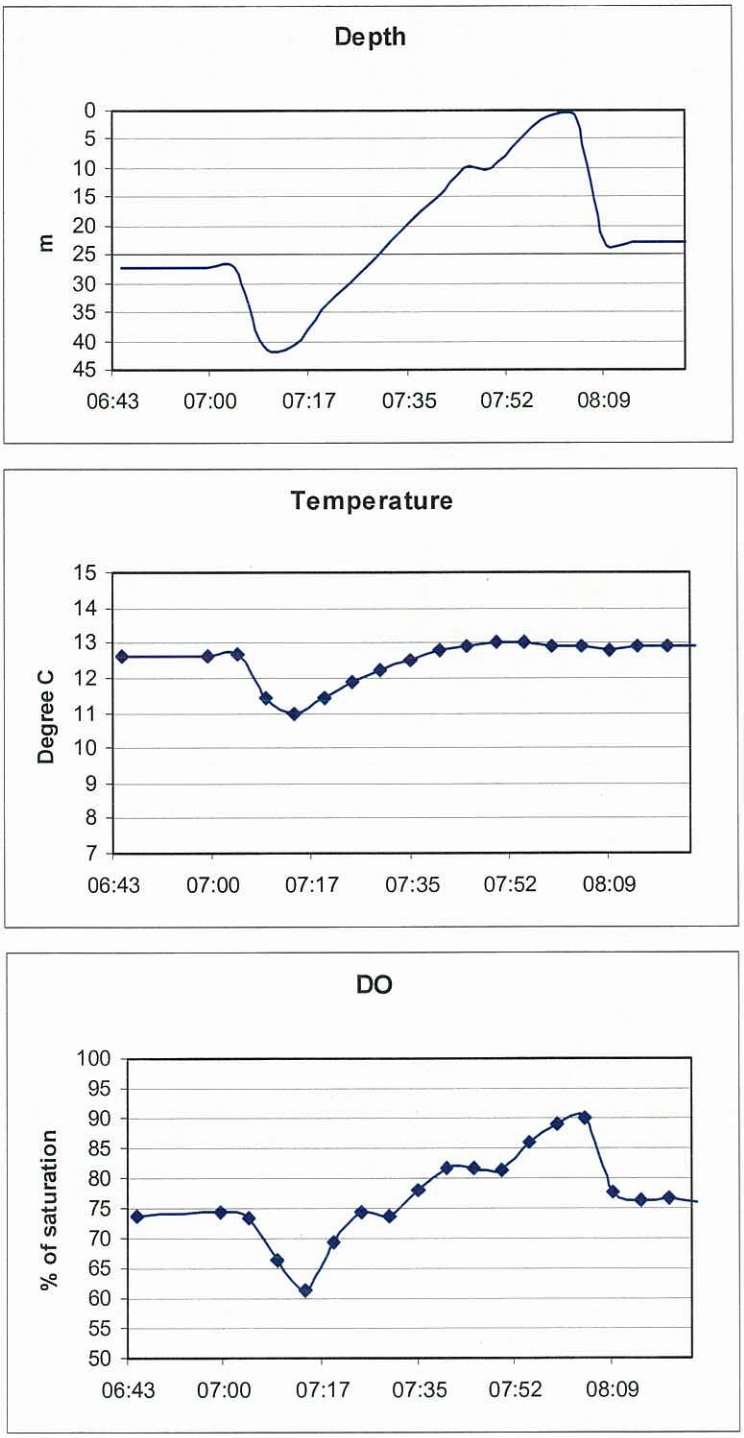


Figure 7. Vertical profile of Cage 1, Grieg Cod Farming, Erfjord, 06:45 – 08:25 am, 21 Oct. 2007

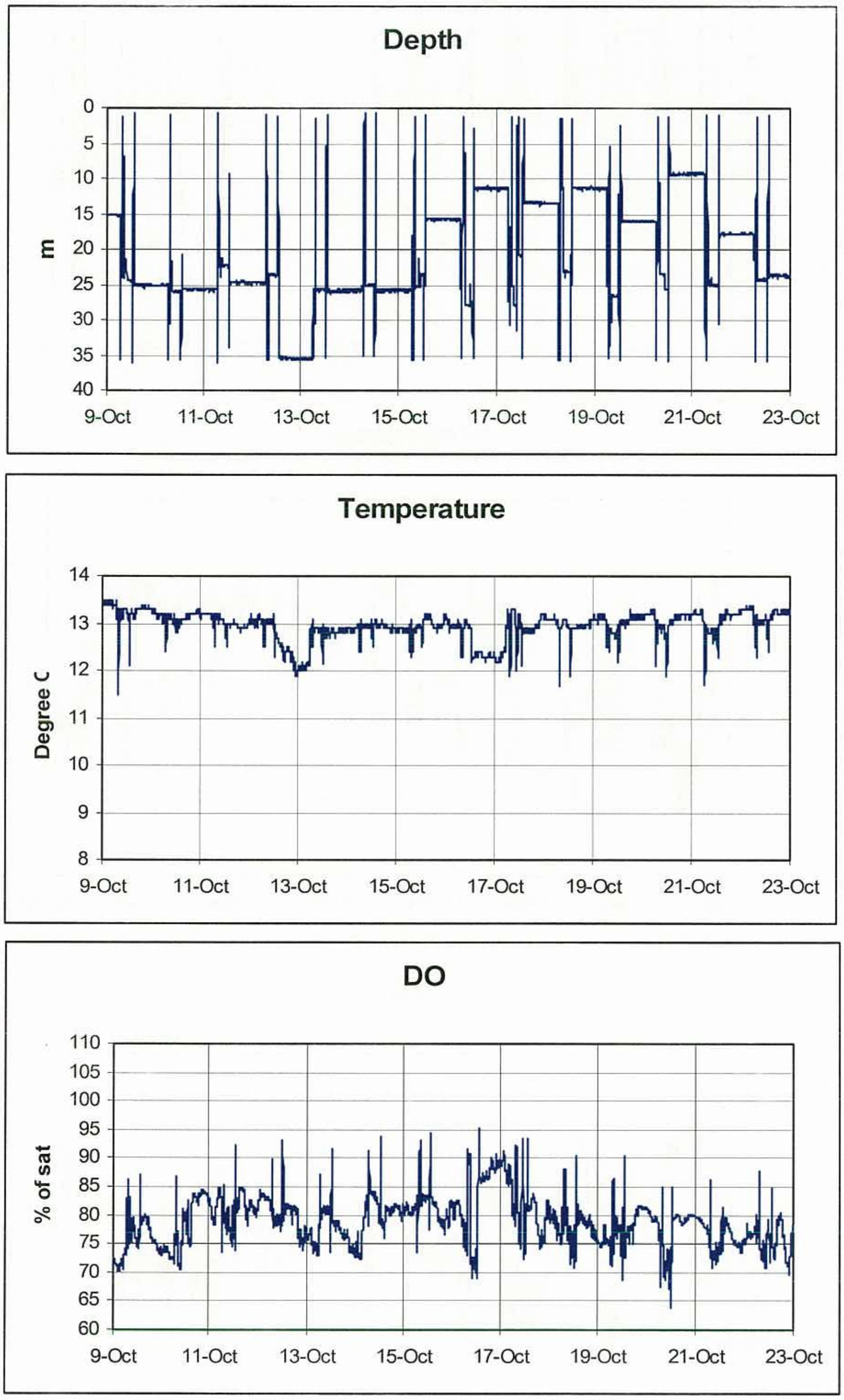


Figure 8. Temperature and dissolved oxygen conc. (DO) in Cage 6, 0 – 36 m depth, Grieg Cod Farming, Erfjord, 9 – 23 Oct. 2007

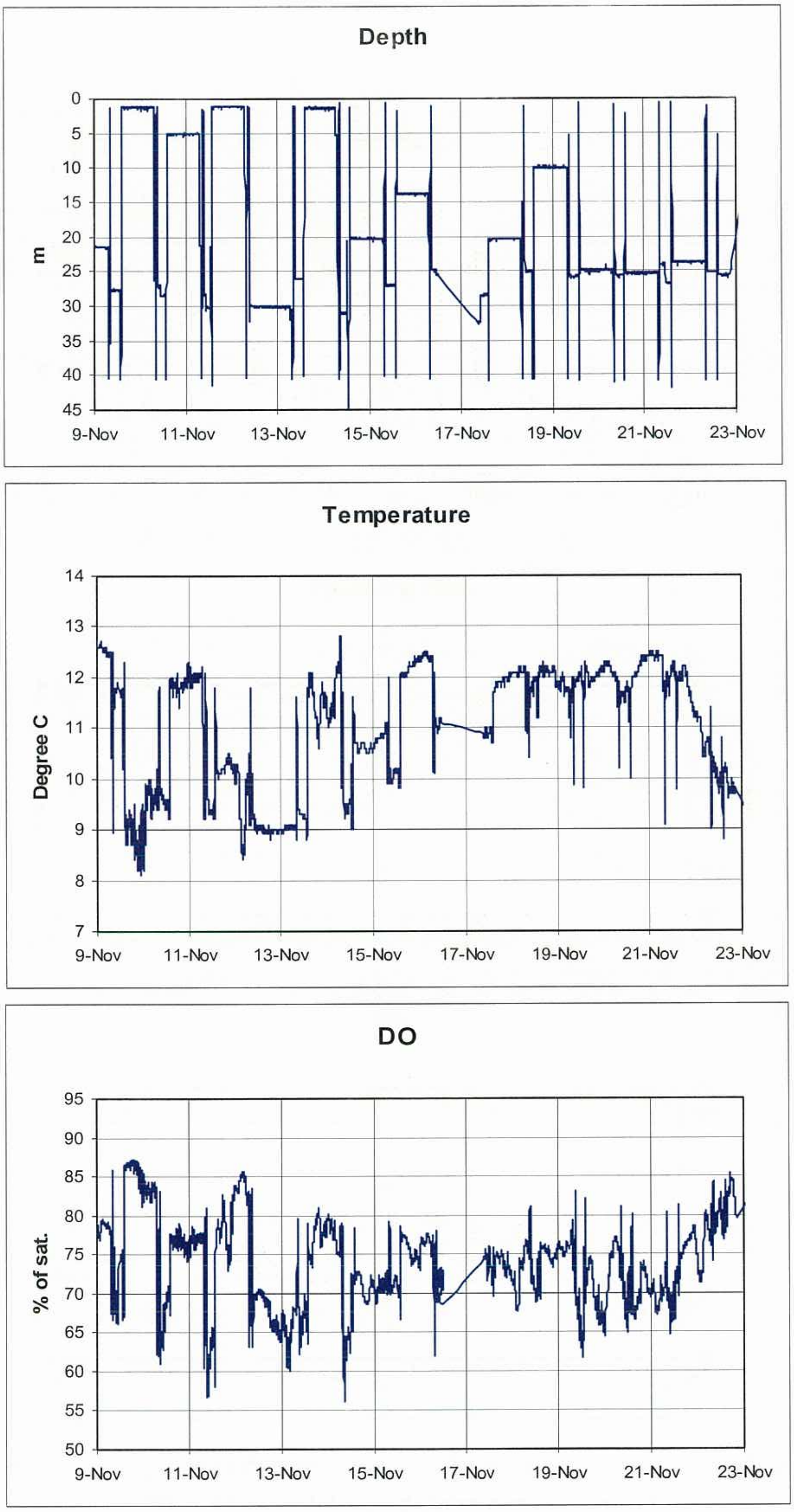


Figure 9. Temperature and dissolved oxygen conc. (DO) in Cage 6, 0 – 45 m depth, Grieg Cod Farming, Erfjord, 9 – 23 Nov. 2007

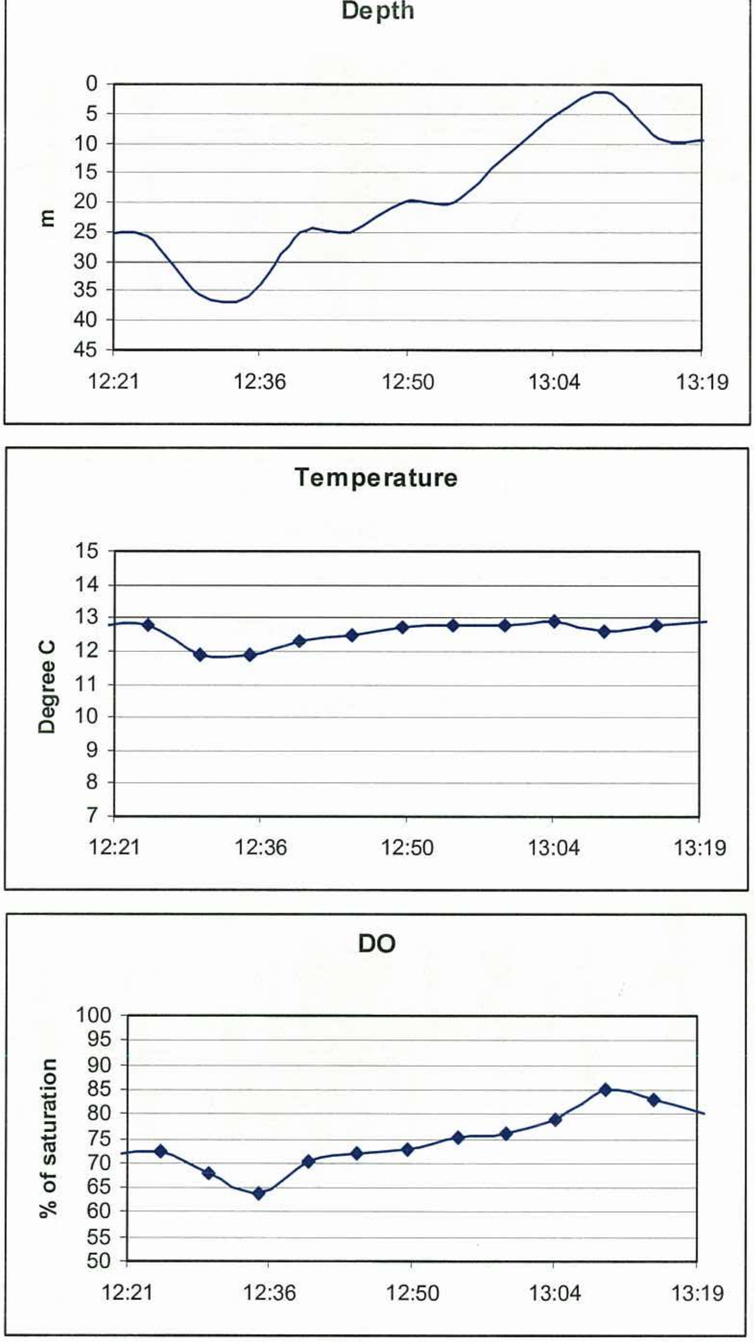
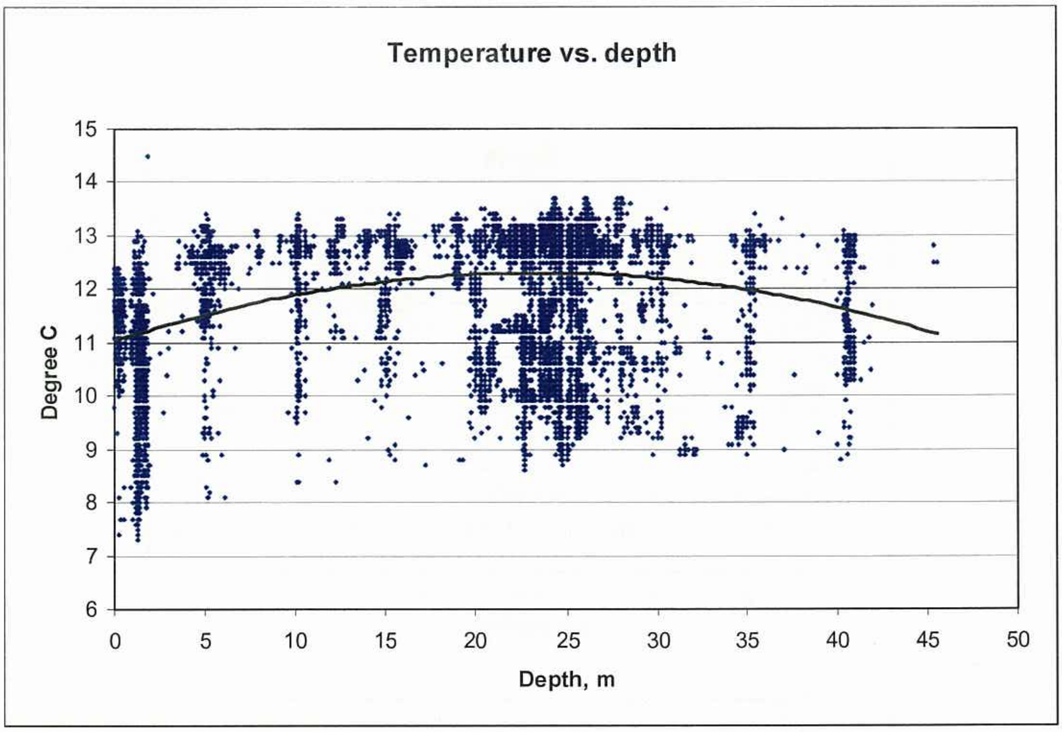
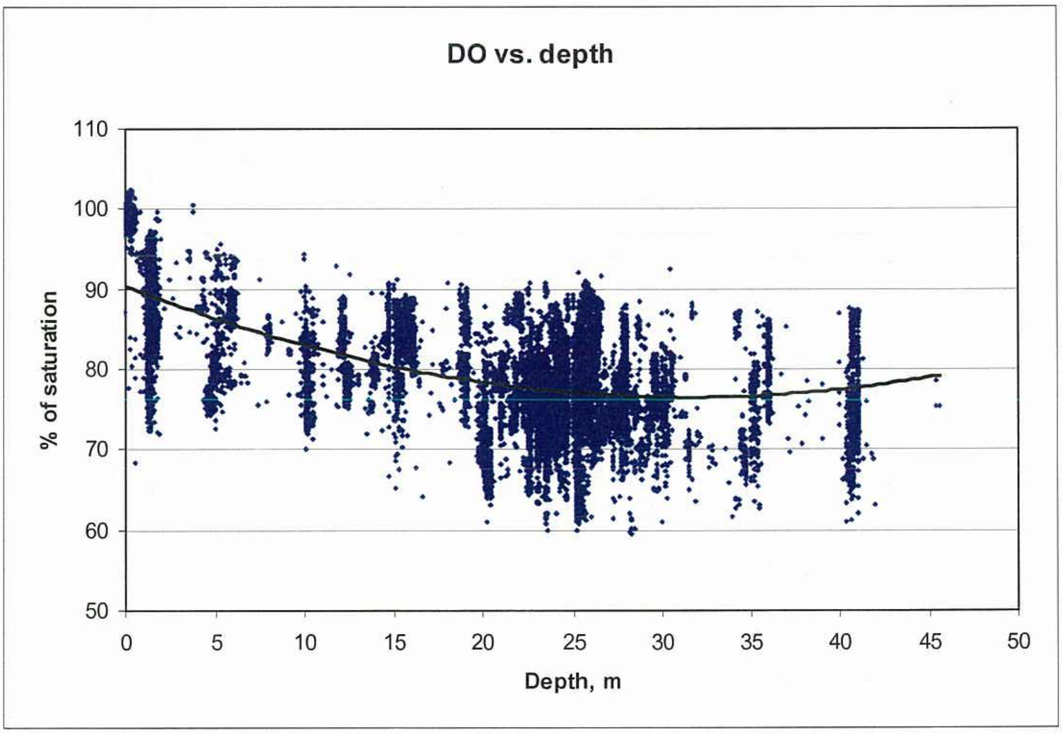


Figure 10. Vertical profile of Cage 6, Grieg Cod Farming, Erfjord, 12 am – 1:20 pm, 20 Oct. 2007



Trendline: $y = 0.002x^2 + 0.11x + 11.00$ $R^2 = 0.10$



Trendline: $y = 0.14x^2 - 0.88x + 90.4$ $R^2 = 0.34$

Figure 11. Temperature and dissolved oxygen conc. (DO) in the water column of Cage 1, Grieg Cod Farming, Erfjord, 21 September – 3 December 2007

3.3 Fish behaviour

On a daily basis, the relative density of the fish in the water column was observed when moving the camera vertically in the two cages (Table in Appendix). Figure 12 a, b demonstrates the distribution in Cage 1 in the morning (8 – 9 am) for the period 2 – 31 October. There was a considerable vertical motion from one day to another during some periods, but the fish stock seemed to be crowded at 20 – 30 m most of the time, e.g. at or beneath where the feeding took place. The occurrence of fish towards the surface, at 1 – 5 m depth, varied throughout the month. Most of the time a part of the stock was observed close to the bottom of the cage, at 40 m.

Figure 13 illustrates the average of all observations in the two cages during October and November. A conspicuous difference between the two cages was observed with regard to occurrence of fish towards the surface in October where the relative density was 2 – 3 times higher in Cage 6. However, this difference was almost evened out in November. In November, the vertical distribution was close to identical in both cages. The highest density was observed at 20 – 25 m in both cages throughout the period, except for a part of October where many individuals in Cage 1 stayed close to the bottom of the net.

In Cage 1, the fish stock was adapted to feeding at 20 m depth since early summer, June, while the stock in Cage 6 was surface fed till 27 September when the feeder outlet was moved to 20 m depth. This time lag explains the different fish behaviour in the two cages in October. The daily vertical camera movements, demonstrated normally 5 – 15% lower DO saturation in the deeper part of the cages compared to at the surface and occasionally as much as 25 – 30 % lower (e.g. 21 October in Cage 1, Fig. 7).

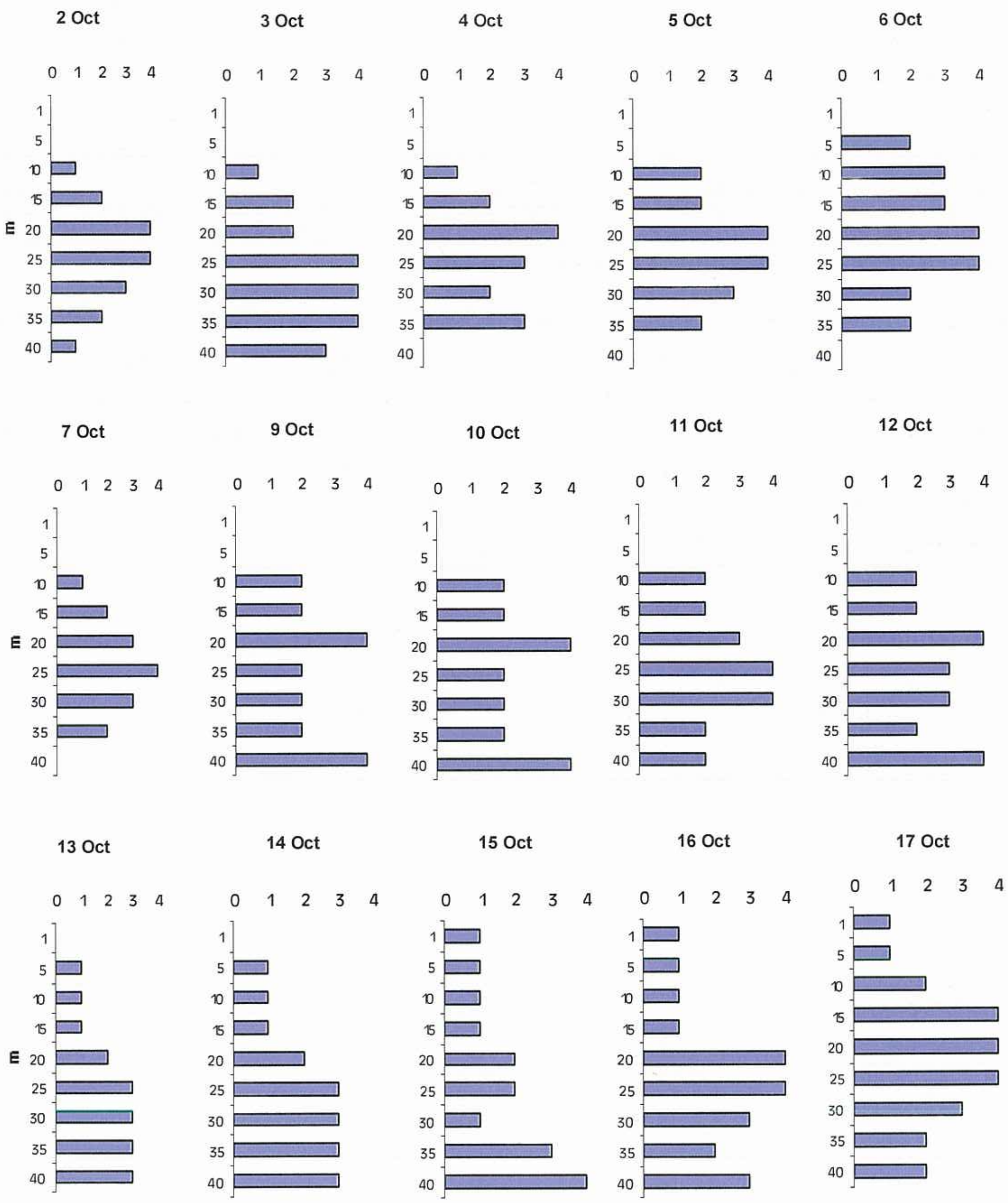


Figure 12 a. Relative vertical distribution of cod in Cage 1 at 8 – 9 am, Grieg Cod Farming, Erfjord, 2 – 17 October 2007 (no observation 8 October). Feeding at 20 m depth.

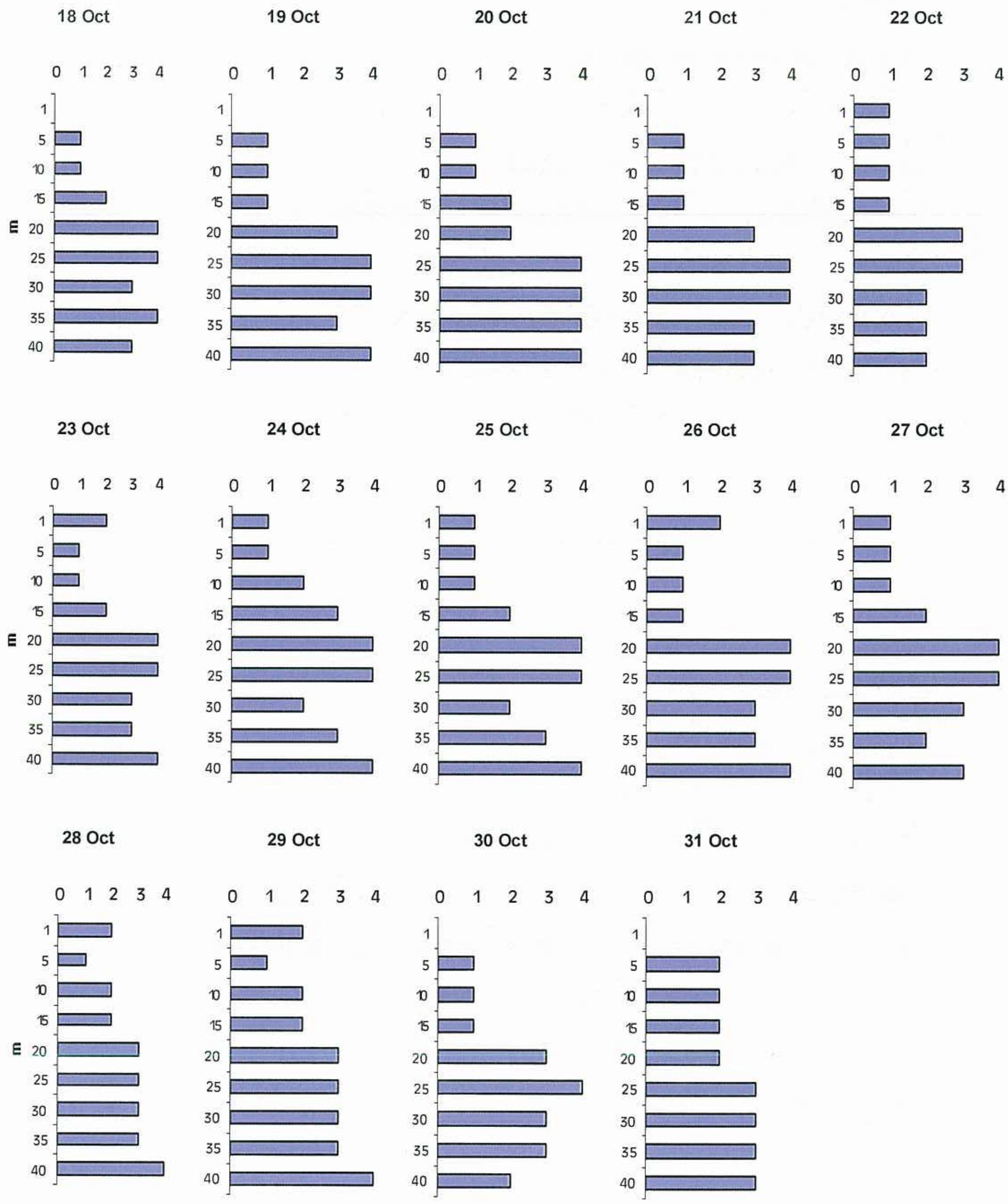
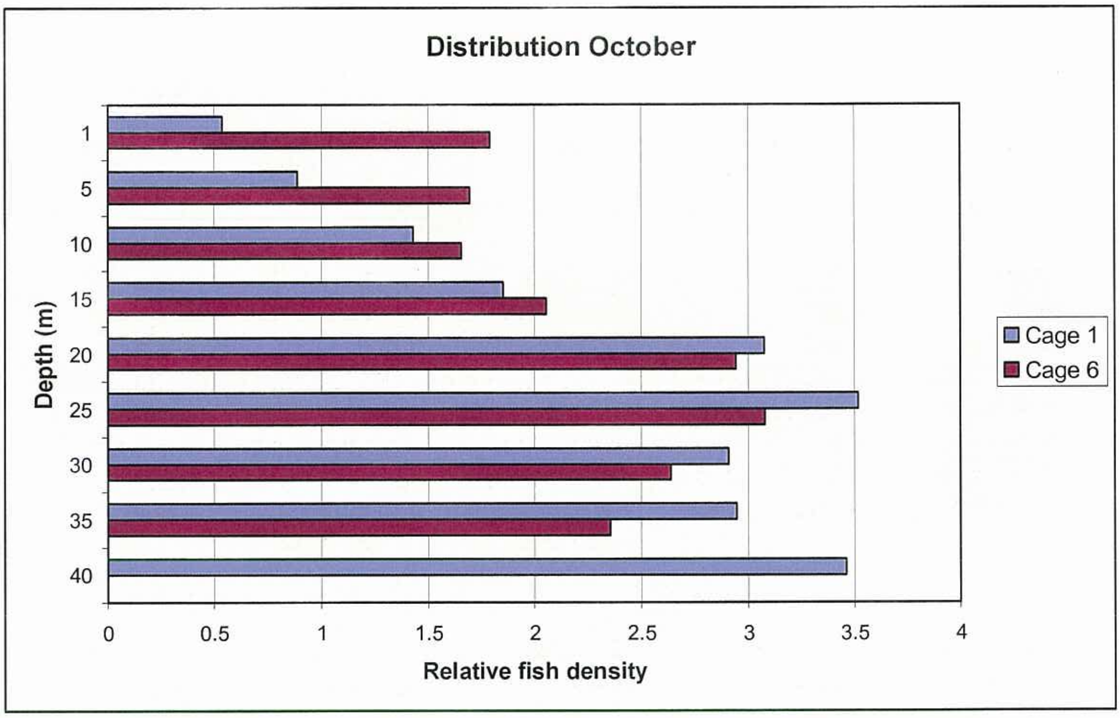


Figure 12 b. Relative vertical distribution of cod in Cage 1 at 8 – 9 am, Grieg Cod Farming, Erfjord, 18 - 31 October 2007. Feeding at 20 m depth.



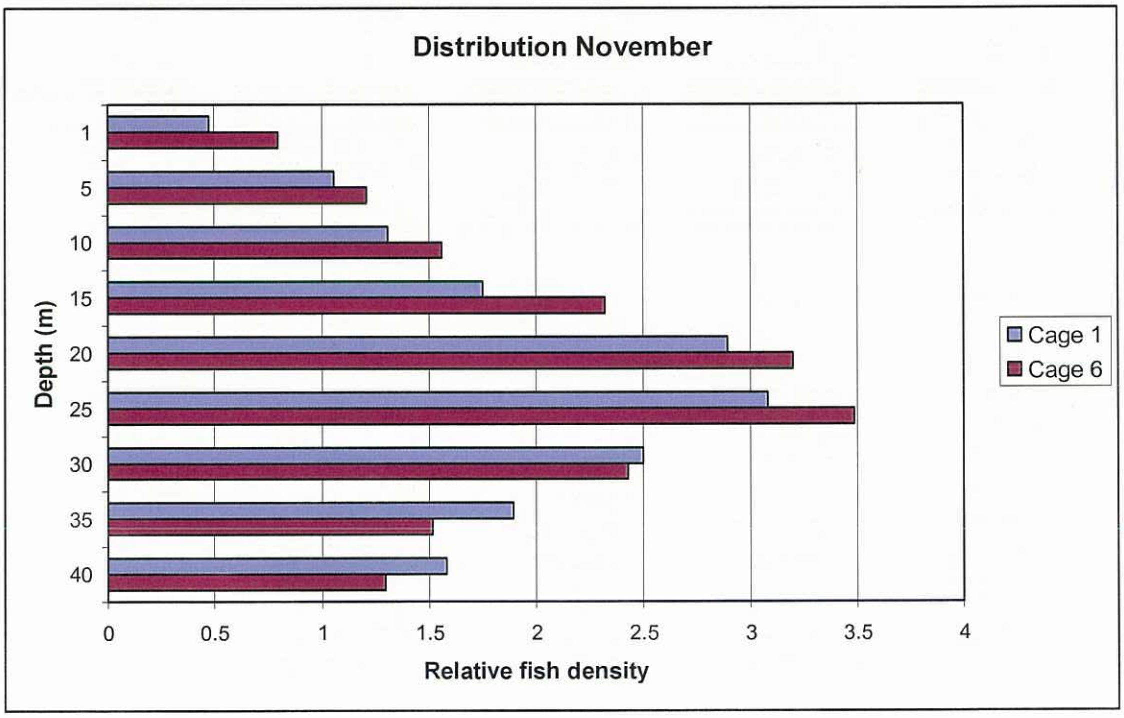


Figure 13. Overall vertical distribution of cod in two deep cages at feeding, Grieg Cod Farming, Erfjord, October and November 2007. Daily sampling at 8-9 am and 2-3 pm. Feeding point: 20 m depth.

4 Discussion

The initial results of the sampling mainly indicate favourable conditions for on-growing of cod. Both sampling of decisive environmental parameters, such as temperature, dissolved oxygen (DO) and water exchange rate, and cod performance in terms of growth rate, feed utilisation and mortality, demonstrate suitable conditions. The running surveillance of the fish stock on screen indicates the same.

During this initial stage with low fish density, the DO concentration in the cages was only moderately influenced by the consumption of the cod. However, the cod crowded together at and below the outlet of the feed supply at 20 m depth and considerable DO drops of more than 10% of saturation were observed in this layer. According to cited tests with cod performance under hypoxic conditions (e.g. Chabot & Dutil, 1999), the DO level at 20 – 30 m depth in the cages was in the sub-optimal range between 60 and 80% of saturation. The running appetite of the cod later on in the on-growing cycle at reduced DO concentration, especially at relatively high temperature in late summer/early autumn at peak fish density, is an obvious approach.

The measured temperature in the water column also indicated close to optimal conditions according to literature (Bye, 2006) with no readings of more than 14 °C. Summer 2007 was rather chilly without peak temperatures of up to 20 °C formerly monitored in the inner parts of the Ryfylke fjords in August – September. The optimal temperature for growth of cod declines with body weight (Björnsson *et al.* 2007) and was found to be 13.0 °C for 20-g and 9.2 °C for 2000-g cod, respectively. Thus, high summer – autumn temperature is a potential growth limiting factor for adult cod during the second year in sea in this region.

Under the existing conditions without evidential environmental constraints, cod seem to mainly dwell on the feeding point.

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Appendix

Vertical distribution of cod in Cage 1 and 6, 2 October – 26 November 2007, Grieg Cod Farming, Erfjord. Distribution at feeding in the morning, 8 – 9 am, and in the afternoon, 2 – 3 pm. Highest relative fish density: 4; lowest: 0. No reg. : no registration

Cage 1

2 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg
5	0	
10	1	
15	2	
20	4	
25	4	
30	3	
35	2	
40	1	

3 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg.
5	0	
10	1	
15	2	
20	2	
25	4	
30	4	
35	4	
40	3	

4 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg.
5	0	
10	1	
15	2	
20	4	
25	3	
30	2	
35	3	
40	0	

5 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg
5	0	
10	2	
15	2	
20	4	
25	4	
30	3	
35	2	
40	0	

6 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg.
5	2	
10	3	
15	3	
20	4	
25	4	
30	2	
35	2	
40	0	

7 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg.
5	0	
10	1	
15	2	
20	3	
25	4	
30	3	
35	2	
40	0	

8 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

9 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	0	0
10	2	2
15	2	2
20	3	4
25	4	2
30	2	2
35	3	2
40	4	4

10 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	0	0
10	2	1
15	2	1
20	2	2
25	4	2
30	4	2
35	4	2
40	4	4

11 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	0	0
10	2	1
15	2	1
20	3	2
25	4	4
30	4	4
35	2	4
40	2	4

12 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	0	0
10	2	2
15	2	2
20	4	2
25	3	3
30	3	2
35	2	3
40	4	4

13 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	1	1
10	1	1
15	1	3
20	2	3
25	3	3
30	3	3
35	3	3
40	3	3

14 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	1	0
10	1	2
15	1	2
20	2	3
25	3	3
30	3	3
35	3	3
40	3	3

15 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	1	0
5	1	1
10	1	1
15	1	2
20	2	2
25	2	3
30	1	3
35	3	3
40	4	4

16 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	1	0
5	1	1
10	1	1
15	1	1
20	4	1
25	4	2
30	3	3
35	2	3
40	3	4

17 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	1	1
5	1	1
10	2	1
15	4	2
20	4	3
25	4	4
30	3	3
35	2	3
40	2	4

18 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	1	0
10	1	2
15	2	1
20	4	4
25	4	4
30	3	3
35	4	2
40	3	4

19 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	1
5	1	1
10	1	1
15	1	1
20	3	1
25	4	4
30	4	3
35	3	4
40	4	4

20 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	1	1
10	1	1
15	2	2
20	2	3
25	4	4
30	4	4
35	4	4
40	4	4

21 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	1	1
10	1	1
15	1	1
20	3	1
25	4	4
30	4	4
35	3	4
40	3	4

22 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	1	2
5	1	1
10	1	1
15	1	1
20	3	3
25	3	3
30	2	2
35	2	3
40	2	4

23 Oct			24 Oct			25 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	2	1	1	1	1	1	1	1
5	1	1	5	1	2	5	1	2
10	1	1	10	2	1	10	1	3
15	2	4	15	3	1	15	2	3
20	4	4	20	4	4	20	4	4
25	4	4	25	4	4	25	4	4
30	3	3	30	2	3	30	2	3
35	3	2	35	3	4	35	3	3
40	4	4	40	4	4	40	4	4

26 Oct			27 Oct			28 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	2	2	1	1	No reg.	1	0	2
5	1	2	5	1		5	1	1
10	1	1	10	1		10	1	2
15	1	1	15	2		15	3	2
20	4	2	20	4		20	4	3
25	4	3	25	4		25	4	3
30	3	3	30	3		30	4	3
35	3	4	35	2		35	2	3
40	4	4	40	3		40	4	4

29 Oct			30 Oct			31 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	0	1	0	0	1	0	1
5	2	1	5	1	2	5	2	1
10	2	2	10	1	3	10	2	1
15	3	2	15	1	2	15	2	2
20	4	3	20	3	3	20	2	2
25	3	3	25	4	2	25	3	3
30	4	3	30	3	2	30	3	2
35	4	4	35	3	3	35	33	2
40	3	4	40	2	4	40	3	1

01 Nov			02 Nov			03 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	0	1	1	4	1	0	0
5	2	1	5	1	2	5	2	2
10	2	1	10	1	2	10	1	0
15	3	2	15	2	2	15	2	1
20	4	2	20	2	2	20	3	2
25	3	2	25	4	2	25	4	3
30	3	3	30	4	3	30	4	3
35	3	3	35	2	3	35	2	3
40	1	3	40	2	1	40	0	2

04 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	1	3
5	2	1
10	1	0
15	2	0
20	3	2
25	3	4
30	2	4
35	2	2
40	0	2

05 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	1	1
5	1	1
10	1	1
15	1	1
20	2	2
25	3	3
30	4	4
35	2	2
40	3	2

06 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	2	0
5	2	1
10	1	1
15	1	1
20	1	1
25	2	3
30	2	3
35	2	3
40	3	3

07 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

08 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	1	1
5	1	1
10	1	1
15	1	1
20	3	4
25	3	4
30	3	2
35	3	3
40	2	2

09 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	1	1
10	1	1
15	1	1
20	4	1
25	4	2
30	4	2
35	3	3
40	3	4

10 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

11 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

12 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

13 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

14 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	2	0
5	0	1
10	1	1
15	2	0
20	4	1
25	4	3
30	3	3
35	3	3
40	3	4

15 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg.
5	1	
10	1	
15	1	
20	4	
25	4	
30	4	
35	3	
40	3	

16 Nov / 17 Nov / 18 Nov

Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg.	1	0	0	1	0	No reg.
5	0		5	1	1	5	1	
10	1		10	1	1	10	1	
15	2		15	2	2	15	2	
20	3		20	3	4	20	4	
25	4		25	4	4	25	4	
30	2		30	2	3	30	4	
35	1		35	3	2	35	3	
40	0		40	4	3	40	3	

19 Nov / 20 Nov / 21 Nov

Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	0	1	0	0	1	0	0
5	2	1	5	1	2	5	1	1
10	2	1	10	2	2	10	2	2
15	2	1	15	2	2	15	2	3
20	4	3	20	4	3	20	3	4
25	4	3	25	4	3	25	3	4
30	3	3	30	2	2	30	2	3
35	2	2	35	1	2	35	1	2
40	2	2	40	1	2	40	0	1

22 Nov / 23 Nov / 24 Nov

Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	0	1	0	0	1	0	0
5	1	1	5	0	0	5	0	11
10	2	2	10	1	1	10	2	2
15	3	2	15	2	1	15	2	3
20	3	4	20	3	2	20	3	3
25	2	3	25	2	2	25	2	1
30	0	2	30	2	1	30	1	1
35	0	1	35	1	1	35	0	1
40	0	1	40	0	0	40	0	0

25 Nov / 26 Nov / 27 Nov

Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	0	1	0		1		
5	1	0	5	1		5		
10	3	1	10	1		10		
15	3	3	15	3		15		
20	3	3	20	3		20		
25	2	2	25	4		25		
30	1	1	30	2		30		
35	0	0	35	1		35		

Cage 6

2 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	No reg
5	0	
10	2	
15	1	
20	1	
25	2	
30	2	
35	1	
40		

3 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	3	No reg.
5	3	
10	2	
15	2	
20	1	
25	2	
30	3	
35	3	
40		

4 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	2	No reg.
5	3	
10	3	
15	2	
20	2	
25	1	
30	1	
35	1	
40		

5 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	4	No reg
5	4	
10	4	
15	4	
20	3	
25	2	
30	2	
35	2	
40		

6 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	4	No reg.
5	2	
10	4	
15	4	
20	3	
25	2	
30	2	
35	2	
40		

7 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	4	No reg.
5	4	
10	4	
15	2	
20	2	
25	1	
30	1	
35	2	
40		

8 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

9 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	4	0
5	3	2
10	2	2
15	2	2
20	2	4
25	2	4
30	2	2
35	2	2
40		

10 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	4	2
5	2	2
10	2	1
15	2	2
20	4	2
25	4	2
30	4	2
35	4	4
40		

11 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	0
5	2	2
10	2	1
15	2	2
20	3	2
25	3	3
30	2	2
35	2	4
40		

12 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	3	0
5	2	2
10	2	2
15	2	2
20	2	2
25	3	3
30	2	2
35	2	2
40		

13 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	2	0
5	2	1
10	2	1
15	2	2
20	2	2
25	3	2
30	3	3
35	3	3
40		

14 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	1	0
5	2	2
10	1	2
15	2	2
20	2	3
25	3	3
30	3	3
35	3	2
40		

15 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	3	0
5	1	1
10	1	1
15	1	2
20	3	4
25	2	2
30	1	3
35	1	2
40		

16 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	0	1
5	1	1
10	1	1
15	2	1
20	2	4
25	2	4
30	2	2
35	2	3
40		

17 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	2	1
5	2	1
10	1	2
15	3	2
20	3	4
25	2	4
30	4	2
35		2
40		

18 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	1	3
5	1	2
10	1	1
15	2	1
20	3	4
25	3	3
30	3	4
35	2	3
40		

19 Oct

Depth, m	8 – 9 am	2 – 3 pm
1	3	1
5	2	2
10	1	1
15	2	1
20	3	3
25	4	3
30	3	3
35	2	4
40		

20 Oct			21 Oct			22 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	2	3	1	2	3	1	2	2
5	1	2	5	2	3	5	1	1
10	3	1	10	2	2	10	1	1
15	1	2	15	1	1	15	3	1
20	3	3	20	2	4	20	3	4
25	2	4	25	4	4	25	3	4
30	3	4	30	4	4	30	3	3
35	4	3	35	3	3	35	2	3
40			40			40		

23 Oct			24 Oct			25 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	3	2	1	2	2	1	3	3
5	1	1	5	1	1	5	1	2
10	1	1	10	1	1	10	1	3
15	1	2	15	1	3	15	3	3
20	3	3	20	4	4	20	4	2
25	3	3	25	4	3	25	3	3
30	3	2	30	2	2	30	2	3
35	2	2	35	2	2	35	2	3
40			40			40		

26 Oct			27 Oct			28 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	2	2	1	2	No reg.	1	2	1
5	1	1	5	1		5	1	2
10	1	1	10	1		10	1	1
15	3	3	15	3		15	3	2
20	4	4	20	4		20	4	3
25	4	4	25	4		25	4	4
30	3	1	30	3		30	2	2
35	2	2	35	2		35	2	2
40			40			40		

29 Oct			30 Oct			31 Oct		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	1	0	1	1	2	1	1	1
5	2	2	5	1	3	5	1	1
10	3	2	10	1	2	10	3	1
15	3	2	15	1	2	15	3	2
20	4	4	20	2	2	20	4	4
25	3	4	25	4	4	25	4	4
30	4	4	30	3	3	30	4	3
35	2	2	35	1	3	35	3	1
40			40			40		

01 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	2	1
5	2	1
10	2	2
15	3	2
20	4	3
25	3	4
30	3	3
35	1	2
40		

02 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	1	1
5	1	1
10	2	2
15	2	2
20	3	2
25	4	3
30	2	3
35	2	1
40		

03 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	3	2
5	1	0
10	2	1
15	2	2
20	4	2
25	4	3
30	2	3
35	1	2
40		

04 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	3	1
5	1	1
10	1	1
15	3	1
20	2	2
25	4	4
30	4	3
35	0	2
40		

05 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	1	No reg.
5	1	
10	1	
15	1	
20	1	
25	4	
30	3	
35	2	
40		

06 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

07 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	
5		
10		
15		
20		
25		
30		
35		
40		

08 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	No reg.	1
5		1
10		1
15		2
20		3
25		2
30		2
35		2
40		

09 Nov

Depth, m	8 – 9 am	2 – 3 pm
1	1	0
5	1	1
10	1	1
15	2	1
20	3	2
25	2	2
30	2	2
35	2	3
40	2	2

10 Nov			11 Nov			12 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	No reg.		1	No reg.		1	No reg.	
5			5			5		
10			10			10		
15			15			15		
20			20			20		
25			25			25		
30			30			30		
35			35			35		
40			40			40		

13 Nov			14 Nov			15 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	No reg.		1	0	0	1	0	No reg.
5			5	0	1	5	1	
10			10	1	2	10	1	
15			15	2	2	15	2	
20			20	4	3	20	3	
25			25	4	4	25	4	
30			30	3	4	30	4	
35			35	3	2	35	3	
40			40	3	3	40	3	

16 Nov			17 Nov			18 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	2	No reg.	1	1	1	1	2	No reg.
5	1		5	1	1	5	1	
10	1		10	1	1	10	1	
15	2		15	2	2	15	2	
20	3		20	3	2	20	4	
25	4		25	4	4	25	4	
30	2		30	2	3	30	4	
35	1		35	3	2	35	3	
40	0		40	4	3	40	3	

19 Nov			20 Nov			21 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	1	0	1	1	0	1	0	0
5	3	1	5	1	3	5	3	1
10	2	1	10	2	2	10	2	2
15	3	2	15	3	2	15	3	3
20	4	3	20	4	4	20	4	4
25	4	4	25	4	3	25	4	4
30	3	3	30	2	3	30	2	2
35	2	2	35	1	2	35	1	0
40	2	2	40	1	1	40	0	0

22 Nov			23 Nov			24 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	1	0	1	0	0	1	0	0
5	1	1	5	1	1	5	1	1
10	3	2	10	2	1	10	2	2
15	3	3	15	3	2	15	3	3
20	4	4	20	4	2	20	4	4
25	2	4	25	3	3	25	3	3
30	0	2	30	2	2	30	1	2
35	0	1	35	2	1	35	0	1
40	0	1	40	0	0	40	0	1

25 Nov			26 Nov			27 Nov		
Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm	Depth, m	8 – 9 am	2 – 3 pm
1	0	0	1	0		1		
5	1	1	5	2		5		
10	2	1	10	2		10		
15	3	3	15	3		15		
20	4	4	20	4		20		
25	3	3	25	4		25		
30	1	1	30	3		30		
35	0	0	35	1		35		
40	0	0	40	0		40		