Demonstration of Environmental Effects of Marine Fish-farms: Quantification of Nutrient-and Particle-outputs as a Potential Food-resource in Integrated Seaweed-and Mussel-farming

Thesis · January 2006

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STUDIENGANG DIPLOM - MARINE UMWELTWISSENSCHAFTEN

Diplomarbeit

TITEL:

Demonstration of environmental effects of marine fish-farms: Quantification of nutrient- and particle-outputs as a potential food-resource in integrated seaweed- and mussel-farming

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Oldenburg, 30.01.2006

Preface

This study was performed at SINTEF, Norway. The project was a challenge, both, personal and regarding matters of work. Boats sunk and were stolen, storms made it impossible to work and health problems did their additional fair - but whatever happened, there was always people caring and helping, more than I could ever have expected. I want to thank all of them, tusen tusen takk!

First off I want to thank my examining supervisors Prof. Dr. Meinhard Simon and Dr. Gerd-Peter Zauke. My additional supervisor in Trondheim was Dr. Kjell Inge Reitan - thank you so much for making this whole work possible and for all your support. I want to thank Aleksander Handå for always being there for me in every situation. I hope, I did not steal too much of your time and nerves. Thomas Mcclimans helped me with any problem regarding the current data and teached me some english. I am very thankful for that. I want to thank Prof. Dr. Yngvar Olsen and Prof. Dr. Helge Reinertsen for the possibility to use the laboratories at Brattøra and at Trondheim Biological Station. I want to thank Kjersti Andresen and Svenn Ove Linde for their help in the laboratory and with technical equipment. I want to thank Anders Storler for lending out the current profiler and for giving some lectures on how to use it. Whatever was missing or did not work, Bjørn Hosen and the crew at the fish farm always found a way to make things work. I do not know, where I could start to thank for, for trusting me enough to just let me go with the boats, for teaching, how actually to use a boat, for accepting extra work, by trying to fit my plans or for all the other small and big things. Thank you so, so much. I really enjoyed working with you! I want to thank Astrid Harendza for all the help. I know, it was not always easy to deal with me. Thank you so much. I want to thank Tim Dempster for good talks, not only about work, and especially for caring.

I also want to thank Eirin Helland for reading through my english in the middle of the night, but also for coffee-distraction. I want to thank Tine for being so patient with me. Finally, I want to thank my parents, Udo and Hildegard Gansel, and my aunt, Erika Bruns, for all their support.

Abstract

Distributions of dissolved nutrients and particulate matter downstream from a marine fish farm at the Norwegian coast were examined. The samples were taken on transects from 25 m to 215 m distance to a specific fish cage. The samplings were carried out repeatedly while there was fish in that cage and once, after the fish were taken out. The outflow from a fish cage was estimated and a time series of current velocities was recorded downstream from a fish farm. The concentrations of nitrate, nitrite and phosphate were at very low levels and did not reveal any dependence on the distance to the fish cages. An influence of the fish farm on nutrient levels was only visible in the ammonia concentrations, which ranged around 15 μg NH_4-N $\cdot$ l^{-1} on average and showed heavy fluctuations along the transects. Seaweed profits from higher ammonia concentrations in general, but enhanced growth in the study area would be limited by phosphate. On average, the concentrations of total particulate matter and particulate organic matter were at low levels, but showed an increase from 20.04.2005 to 02.06.2005 and a decrease after the fish were taken out of the net cage. This may have reasons other than the clearance of the fish cage, as an effect of the discharge from the cage on the concentrations of particulate matter within more than 50-60 m distance is highly unlikely. The fraction of organic matter was on high levels around 80% throughout the whole period of the study and did not show any dependence on the distance to the fish farm. Structures were found in the wake of a fish farm, that indicate the existence of eddies or swirls in the flow. It is very likely, that a vortex street develops downstream of a net cage, which would be associated with a recirculation area close to the cage. Such a wake characteristic might suppress the horizontal spreading of particles leaving the cage. A net outflow out of a fish cage was found from 3-23 m depth, which indicates the existence of some internal force. This might well be generated by fish swimming in circles. Fish behaviour, therefore, might play a role in the spreading of particles, as already small changes in the strength of the outflow might change the characteristics of the wake flow.

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1 Introduction

1.1 *Overview*

The world aquaculture production has rapidly increased within the last decades (FAO, 2004). According to Tacon and Forster (2001) a further increase of 50 million Mt by 2050 will be necessary to meet the future demands for food fish. As most of the worlds fishing areas have reached their maximal potential for capture fisheries production (Troell *et al.*, 2003) and as the availability of freshwater is decreasing, most of this growth will take place in seawater aquaculture (Neori *et al.*, 2004). A growth of that magnitude constitutes a huge challenge and there is a whole range of potential problems, that need to be addressed. Marine aquaculture is not a closed system, but interacts with the benthic and pelagic ecosystem (Olsen *et al.*, 2005). It releases a large amount of waste (Islam, 2005) and thus a further intensification of aquaculture might have a large impact on coastal zones. Besides causing environmental concerns, higher aquacultural production leads to an increased demand for fish meal and oil. This demand can not be met by capture fisheries, as a big fraction of feed grade fish stocks already are overexploited or depleted (FAO, 2004) and therefore supplies of fish oil is expected to become limiting within the next years (Bell and Sargent, 2003). A sustainable aquaculture thus is important for economic feasibility as well as for protection of the environment (Olsen *et al.*, 2005). In southern Asia, there is a long tradition in maintaining species of different trophic levels together (FAO, 2001). This type of aquaculture generally promises among other things a more efficient use of feed, lower overall costs of maintenance, infrastructure and logistics, while leading to lower impact on the environment at the same time. The development of integrated multi-trophic aquaculture (IMT-aquaculture) is challenging in several ways. Scientific knowledge is crucial for designing a farm that supports beneficial interactions of the cultivated species, but the ideal solution must be economically feasible, practicable by engineering means and should meet public acceptance. Western countries generally have little experience wit IMT-aquaculture. The general idea is to combine feeding aquaculture with extractive aquaculture.

1.2 *Aims of this study*

This study examines biological and environmental effects of a sea cage fish farm at the Norwegian coast and tries to assess the potential for an integrated aquaculture system with salmon, mussel and/or seaweed. Determination of ammonia, nitrate, nitrite and phosphate concentrations in dependence of distance to a marine fish farm is used to assess the potential for integrated seaweed farming. An evaluation of the distribution of particulate matter and its organic contents is used together with the distribution of particle densities to assess the potential for integrated mussel farming. Chlorophyll a distributions and phytoplankton densities are used to estimate the possibility of concurrence between seaweed and phytoplankton and the use of possibly enhanced growth of microalgae close to the fish farm. All parameters are combined to assess the environmental effect of the fish farm in the near surrounding. Current measurements are used to characterize the turbulence and the formation of structures in the wake of a fish cage as well as to estimate the divergence from fish cages.

1.3 *Nutrient discharge from fish farms*

The major bulk of effluents from fish farms are attributed to feed waste (Islam, 2005). The main part of loss in particulate form consists of feed particles and faeces. The amount of waste feed depends on a number of factors, such as stocking density, feeding regime and feeding rate (Islam, 2005), but generally there is a good agreement between the amount of feed consumed by fish and the amount of faecal matter, that is produced. About 26% of the eaten feed is excreted as faeces (Islam, 2005). The excess feed ranges around 1-5% for dry diets, 5-10% for moist diets and 10-30% for wet diets in pond cultures (Warrer-Hansen, 1982a, b) and it is assumed, that cage culture results in even higher losses (Beveridge, 1996). The concentrations of particulate matter usually are higher in the near surrounding of fish farms, but levels exceeding the ambient concentrations significantly are raraly found in greater distances than 50-60 m around fish cages (Brown *et al.*, 1987; Gowen and Bradbury, 1987; Findlay *et al.*, 1995; Cheshuk *et al.*, 2003).

Aquaculture is characterized by a huge loss of nitrogen compounds and phosphorus. The amounts range around 75% (salmon) and 77-94% (shrimps) of the input as feed (Troell *et al.*, 2003). The major part of nitrogen is discharged in dissolved form (Troell *et al.*, 2003; Kelly *et al.*, 2005; Islam, 2005; Davis *et al.*, 2005) and about 68-86% of the consumed nitrogen is discharged as ammonia and urea (Islam, 2005), whereby urea accounts up to 10% (Fivelstad *et al.*, 1990). While the major part of nitrogen originating from fish farms is readily available for algal growth (Enell, 1987), a large fraction of phosphate from aquaculture accumulates in the sediment (Holby and Hall, 1991; Phillips *et al.*, 1985). Anyway, highly increased phytoplankton biomass can not be expected in the near surrounding of well flushed marine fish farms, as algal growth normally occurs on time scales of days (Kelly *et al.*, 2005) and short residual time for water at coastal farming areas will lead to a transport of algae, that benefit from fish farm discharges (Cheshuk et al, 2003).

This nutrient discharge from aquaculture sites may result in negative environmental effects, such as eutriphication, oxygen depletion, biodiversity modifications and pollution (Phillips *et al.*, 1985; Gowen and Bradbury, 1987; Braaten *et al.*, 1988; Rönneberg *et al.*, 1992; Beveridge *et al.*, 1994; Richardson and Jørgensen, 1996; Bonsdorff *et al.*, 1997; Mattila and Räisänen, 1998; Pitta *et al.*, 1999; Hänninen*et al.*, 2000; Naylor *et al.*, 2000). The local impact depends on a wide range of factors, such as local and regional hydrodynamic condition, the physical, chemical and biological characteristics of the ecosystem and amount and character of additional waste input (Troell *et al.*, 2003). Whatsoever, the primary response to eutriphication will be an increase in biomass and chlorophyll *a* concentration and a rise in primary production (Islam, 2005).

1.4 *Integrated aquaculture with seaweed and mussel*

Mussels can control the quantity and quality of their diet, whereby the size of filtered particles is a substantial criteria for retention or rejection as pseudofaeces (Gosling, 2003). Most mussels retain particles with sizes 3-4μm with an efficiency of 100% (Shumway *et al.*, 1985), by many species are able to retain particles in a wide range above 4 μm (Riisgard, 1988). Blue mussel (*Mytilus edulis*) shows high retention efficiencies for particles of 3-5 μm, but also retains particles, that are bigger than 6 μm. Whatsoever, the retention of particles is limited, when the seston concentration rises above the pseudofaeces treshold, which generally ranges around 1-6 mg $\cdot$ l^{-1}

(Bayne and Newell, 1983). Faeces and excess feed particles initially are too big to be filtered, but if these particles are broken down to smaller sizes, filter feeders like mussels might be suitable for absorbing these wastes (Wallace, 1980; Jones and Iwama, 1990; Stirling and Odumus, 1995). Some studies have shown a better growth for mussels adjacent to fish cages (Wallace, 1980; Jones and Iwana, 1990, Lefebvre *et al.*, 2000). Not every aquaculture site might be suitable and it might be necessary to place mussels very close to fish cages, to achieve enhanced growth due to particle discharge from the fish farm (Stirling and Okumus, 1995; Cheshuk, 2003).

Traditional integrated aquaculture has a long tradition especially in China, Japan and South Korea, where an otpimal integration of seaweed was reached through trial and error (Neori *et al.*, 2004). Unfortunately, the results were seldom published. In westren countries, seaweed has received little attention for use in integrated cultures (Asare, 1980; Edwards, 1998), but recent studies have shown a potential for use of seaweed in integrated mariculture (Troell *et al.*, 1997; Ahn *et al.*, 1998; Chopin and Bastarache, 2002, Kelly *et al.*, 2005). A number of basic criteria have been identified, that must be met by seaweed to allow an inclusion in integrated applications. The algae must show a high growth rate and tissue nitrogen concentration, they must be easy to cultivate and it must be possible to controll the life cycle. They must show a good resistance to epiphytes and disease causing organisms, their ecophysiological characteristics must match the environment and they should be local species (Neori *et al.*, 2004). Additionally, the intended application will influence the choice of seaweed. A high uptake rate requires high areal loads of nutrients. It will result in high areal yield and high protein content, but the reduction efficiency will be low (Troell *et al.*, 2003). In contrary, a high reduction efficiency is combined to low uptake rates, low areal yield and low protein content, but leads to a high average reduction of the nutrient concentration. It is crucial to know about the requirements and performance of potential species for use in integrated aquaculture, but to date, very few seaweed have been thoroughly investigated regarding that use. Kelp and red algae have been found to efficiently take up dissolved inorganic nitrogen from fish farm effluents (Subander *et al.*, 1993; , Buschmann *et al.*, 1996; Ahn et al,. 1998). The red algae *Gracilaria* showed improved agar yield and gel strength, when cultivated in salmon culture effluents (Martinez and Buschmann, 1996). *Gracilaria* *chilensis* has the ability to rapidly assimilate and store nitrogen for later growth (Bird *et al.*, 1982; McLachlan and Bird, 1986), which will result in a better use of nutrient pulses. An increase of ammonia concentration through discharge from fish cages, even when the concentrations of nitrate, nitrite and phosphate are at ambient level, can enhance seaweed growth (Kelly *et al.*, 2005). An increased growth under such conditions has been found to a distance of about 200 m from fish cages for *Laminaria saccharina* and *Palmaria palmata* (Kelly *et al.*, 2005). Anyway, the distance to fish cages, in which enhanced seaweed growth takes place will differ with the environmental conditions and generally, integrated seaweed culture only functions well close to fish cages (Neori *et al.*, 2004).

1.5 *Flow around bluff bodies*

Dissolved substances as well as suspended material ultimately are spread by currents. This may be a trivial fact, but it is the key to understanding the distribution of nutrients discharged from fish farms. Unfortunately, there is no literature available concerning current characteristics around or in the wake of net cages. Whatsoever, fish cages might be considered porous cylinders by approximation. A lot of work was done on two-dimensional as well as on three-dimensional bluff body wakes, but most of it was performed on solid obstacles (Williamson, 1996). The characteristics of the wake behind bluff bodies mainly depends on the Reynolds number, which in turn is dependent on current velocity, characteristic length and kinematic viscosity. In general, bluff bodies evoke vortex streets over a wide range of Reynolds numbers, whereby there always exists a mean recirculating region. At high enough Reynolds numbers, the boundary layer on the surface of the obstacle becomes turbulent itself, but Roshko (1961) showed that there is strong evidence of periodic vortex shedding even for this post critical regime (Williamson, 1996). The use of porous materials can induce a significant change in flow patterns and might suppress the Karman vortex in a wake region (Kakimoto *et al.*, 2005). This effect on the flow patterns increases with increase of permeability of the porous material and with increase of the Reynolds number. Fransson *et al.* (2004) showed, that a continuous suction applied to a porous cylinder results in rearward motion of the separation point and causes a narrower wake, whereas the application of continuous blowing had the opposite effect. It will be the task of future research to find out, if these findings, at least to some degree, are transferable on the flow around fish cages

2 Materials and methods

2.1 *The study sides*

The main part of this study was carried out from April to July 2005 at a commercial Atlantic salmon fish farm (SalMar Farming A/S) located on the Norwegian shore at about N63° 59.530; E09° 55.620 (Fig. 1). This farm, named *Jektholmen*, consisted of four net cages, each with a diameter of 30 m and a depth of 23 m, which were arranged in a row aligned in the NNE-SSW direction (Fig. 42). The cages labelled *10*, *11* and *13* in Fig. 42 contained fish, that were fed for 2.5 hours with feed blowers every day, while cage *12* was empty during the whole sample period. The total biomass increased from about 860 t in mid April to approximately 1180 t in the end of June, when fish from cage *10* were slaughtered. The daily feed ratio varied from 0.27% to 0.75% of the biomass, depending on the appetite of the fish.

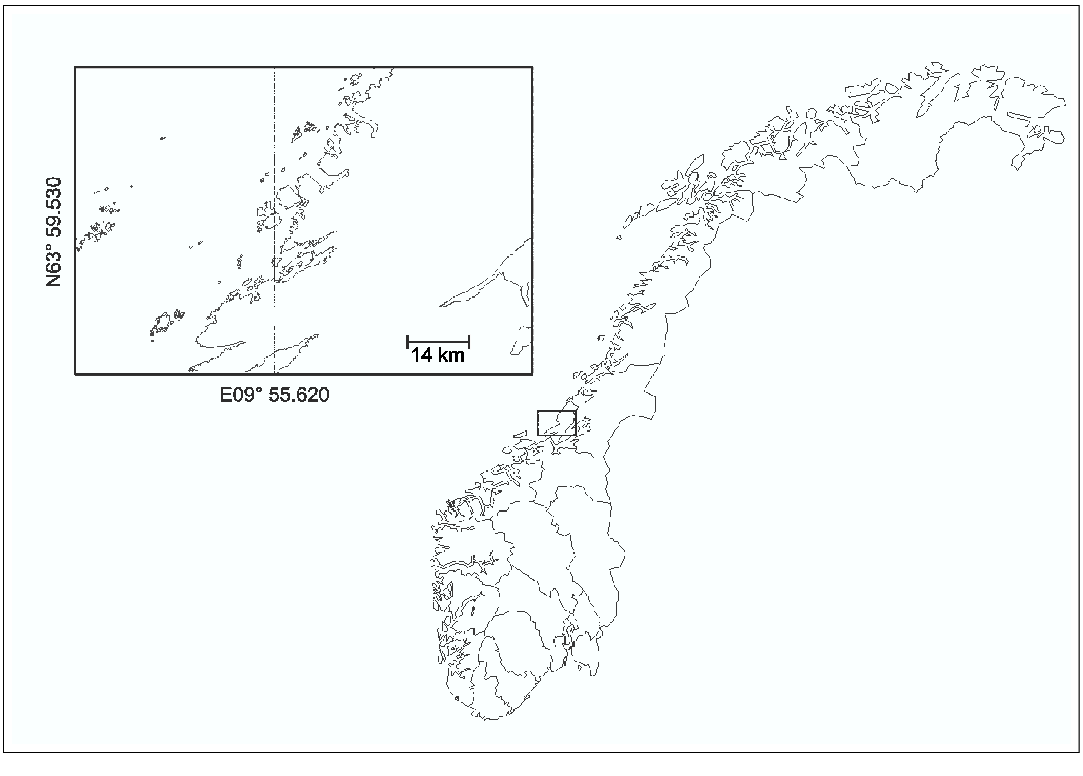


Fig. 1: *The Atlantic salmon fish farm Jektholmen islocated at the Norwegian coast. Jektholmen is situated at N63° 59.530; E09° 55.620 and is sheltered by a bigger island just north of the farm. Another Atlantic salmon fish farm, Gjaesingen, is located about 14 km NNE of Jektholmen and is much more exposed to the coastal current.*

As can be seen from Fig. 42, the topography at the site, located on the flank of Linesøya close to a slope, is complex. Directly under the cages the depth varies between 30 and 50 m. The shoulder extends north and southwestwards, while the depth rapidly increases to 130 m south and eastwards. To the northwest and west of the farm there are several small islands embedded in a shallow area of one to 5 m depth. The bottom under the cages consists mainly of stones, gravel and sand (Havbrukstjenesten AS, 2002), towards the shallow area in the north-west of the farm it becomes sandy.

The currents are greatly influenced by the tides and show a large variability in speed and direction. The main current direction is towards SSW, but directions ranging from E to WSW can as well occur as northward going currents.

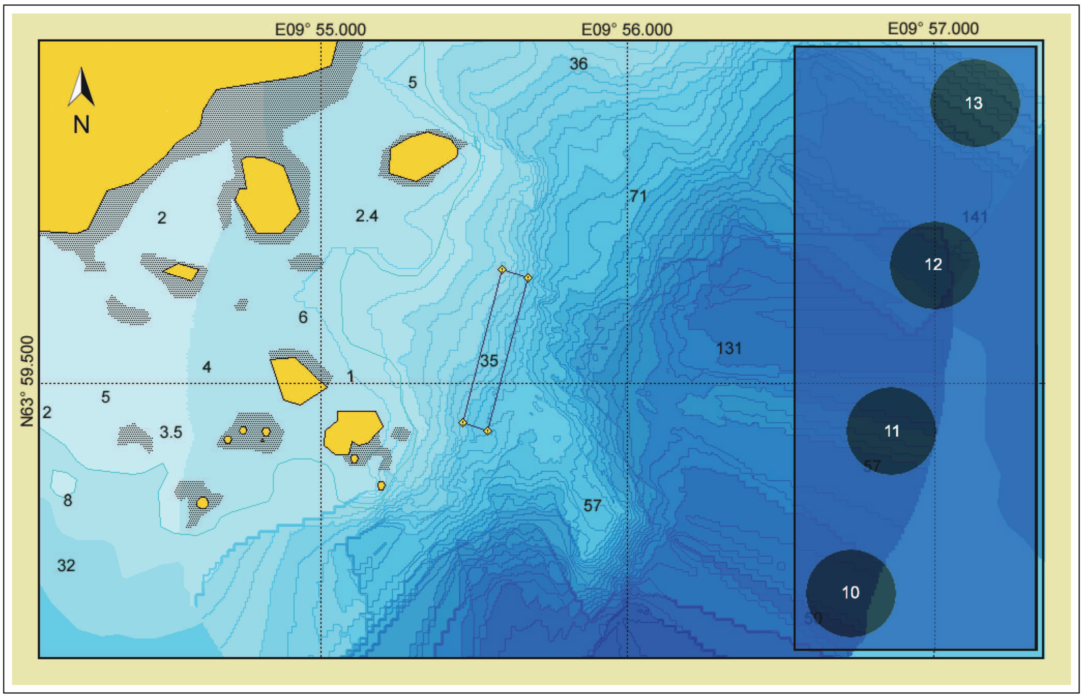


Fig. 2: *The Jektholmen fish farm is located at about N63° 59.530; E09° 55.620 on the flank of the Island Linesøya. The farm consists of four net cages in one row, aligned in the NNE-SSW direction.*

In October 2005 additional current measurements were carried out at a second Atlantic salmon fish farm (SalMar) approximately 14 km north of *Jektholmen*, located at about N64° 07.060; E° 09 58.800. This farm, *Gjaesingen*, contained a double-row of net cages of 40 m diameter each, aligned in the WNW-ESE-direction (Fig. 3). The nearest landmass is the island Gjaesingen about 300 m to the southwest, but within the first 300 m around the cages, the water depth does not fall below 30 m. By and large, the *Gjaesingen* fish farm is less sheltered by shallow areas and islands than *Jektholmen* fish farm. The measurements were carried out at the fish farm Gjaesingen, because the fish cages were removed from the farm *Jektholmen* before the current measurements could be conducted.

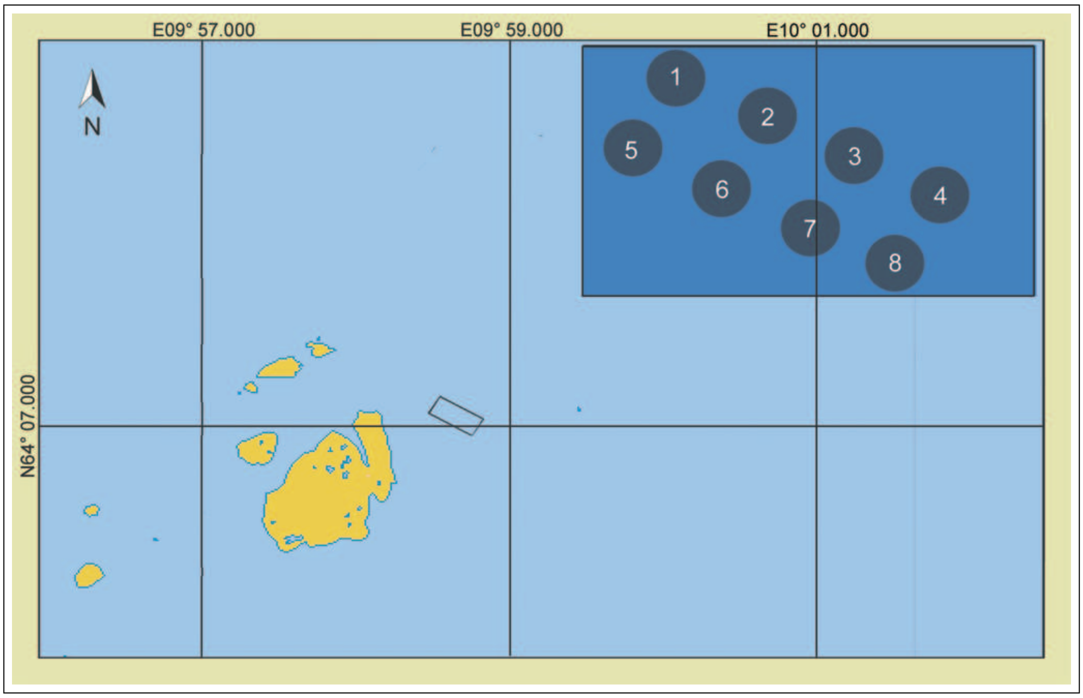


Fig. 3: *The Gjaesingen fish farm is located at about N64° 07.060; E° 09 58.800, approximately 300 m northeast of the island Gjaesingen. The farm consists of eight net cages arranged in a double-row, aligned in the WNW-ESE direction.*

2.2 *Experimental design and sampling procedures*

During the study, water samples were taken at *Jektholmen* for the determination of particle numbers and sizes as well as for the analysis of marine macronutrients, thereby focusing on possibly limiting elements in marine environments. The samplings were carried out during feedings and were timed so feedings occurred within a time-frame of two to six hours after high tide. This was chosen on the basis of earlier current meter data to secure a SW current. The study was split up into two sampling cycles, *A* and *B*. Cycle *A* contained samplings for total and organic particulate matter, phytoplankton, chlorophyll *a* and nutrients, namely ammonia, nitrate/nitrite and phosphate (Fig. 4). Cycle *B* focused on particle-sampling only and contained water samples for particle countings as well as samples for analysis of total and organic particulate matter (Fig. 5). All samples were taken using either a self closing 5 l sampler or a 2,5 l Ruttner-sampler. CTD measurements were carried out on three days throughout the main sampling period, current measurements were taken coarsely during every sampling event. Additional direct current measurements, providing much finer temporal and spatial resolution, were taken in the very near field around a net cage, as well as in the wake of net cages at the end of the study. All dates for the measurements and samplings are found in Table 1. The Fish in *cage 10* (Fig. 42) was slaughtered in late June, so the last two samplings serve as "relative reference" for the previous samplings.

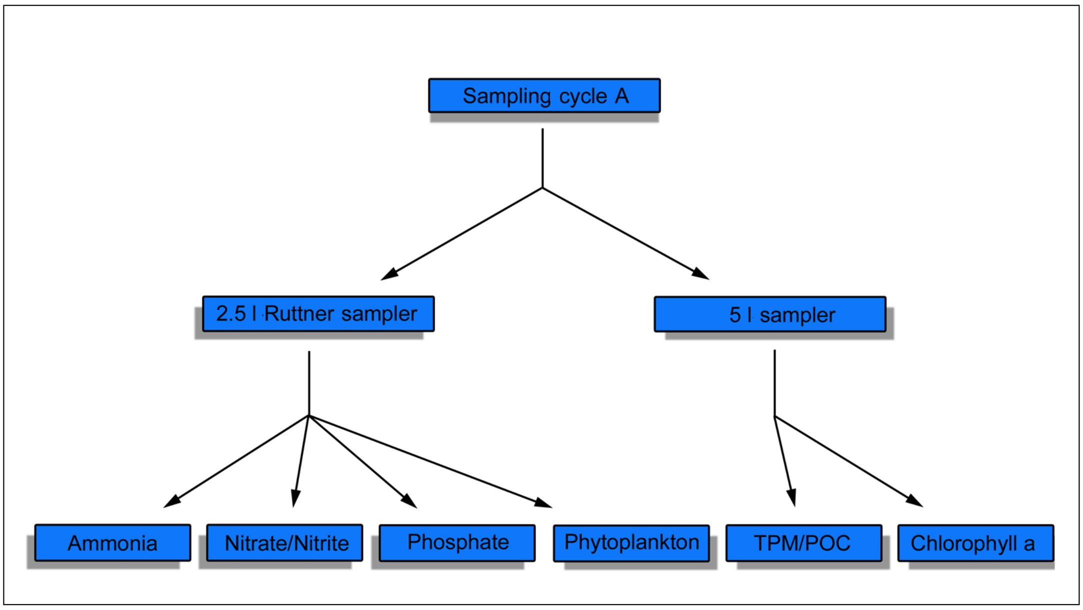


Fig. 4: *Scheme of sampling cycle A*

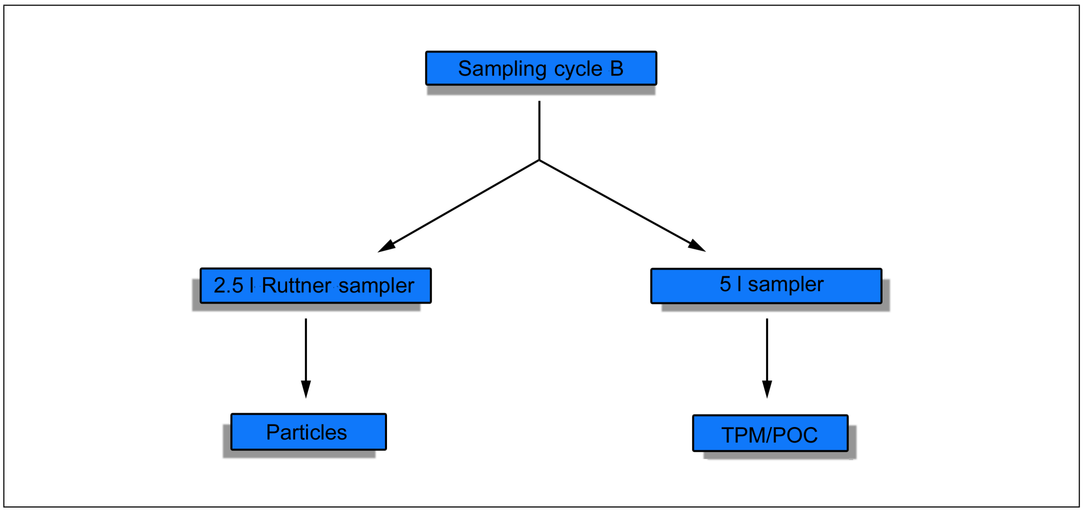


Fig. 5: *Scheme of sampling cycle B*

The sampling cycles *A* and *B* were both conducted at one fixed position about 200 m north of *cage 13* and on direction-variable transects. The distances in relation to *cage 10*, where samplings were carried out, were fixed within one cycle, while the direction always was adjusted so it matched the average current direction. Samples were collected on 5 different days for each of the cycles. For *in situ* evaluation of the average current direction, two drifters were set out about 30 m downstream from *cage 10* at least 15 minutes before the first sampling, one having its sail adjusted to 5 m depth, the other to 15 m depth. The angle between the position, in which the drifters were set out and their current position was estimated and translated to the middle of *cage 10* before every sampling event. Using this technique, the sampling transects always followed the current with only a minor spatial offset. As this offset might have an effect on the measurements, cycle *A* was taken in four different positions near the drifters for comparison.

On the transects one full cycle *A* - except samplings for chlorophyll *a* and phytoplankton - was conducted at 25 m, 65 m, 115 m, 165 m and 215 m distance to the middle of *cage 10* in 5 m and 15 m depth for each position. Chlorophyll a and phytoplankton samples were taken in 25 m and 215 m distance from *cage 10* (Table 2). For cycle B the distances on the transects were fixed at 25 m, 35 m, 45 m, 55 m, 65 m, 85 m, 115 m, 165 m and 215 m for the samplings (Table 2). At every position one full cycle was completed at 5 different depths, namely 1 m, 5 m, 10 m, 15 m and 20 m. The water samples for analysis of the nutrients, phytoplankton and particle-countings were transferred from a 2.5 l Ruttner-sampler into 250 ml HDPE-bottles and - for the Phytoplankton-samples - in 150 ml brown glass-bottles respectively. The bottles for the nutrient samples were filled up completely, whereby special attention was paied to avoiding any bubbles during the transfer. The Phytoplankton samples and the samples for particle countings were preserved with 0,3 ml of Lugol‘s solution per 100 ml sample volume, as described in the UNESCO Phytoplankton manual (1978). The water for the analysis of total particulate matter, particulate organic matter and chlorophyll a was taken with a 5 l -sampler and stored in 10 l PE-cans until filtration through Whatman GF/F filters (diameter: 47 mm) within eight hours after sampling. The samples were kept cold at all times, the chlorophyll a-samples additionally were kept dark until filtration. All samples, except the phytoplankton samples, which were kept cold and dark, were frozen within four hours after sampling or filtration.

Table 1: *Overview over all samplings at the Jektholmen fish farm. Cycle A and Cycle B mark the dates, on which sampling cycles A or B were conducted on a transect while there were fish in cage 10, Reference A and Reference B stand for the same transects after the fish were taken out of cage 10. Drifter denotes a day in which samplings were taken near the drifters. CTD and current measurements mark the days on which CTD and direct current measurements were carried out.*

	Cycle *A*	Cycle *B*	Reference A	Reference B	Drifter	CTD measurement	Current measurement
20.04.2005		X					
21.04.2005	X					X	
19.05.2005	X						
20.05.2005		X					
30.05.2005					X		
31.05.2005		X					
01.06.2005	X						
02.06.2005		X					
03.06.2005	X						
16.06.2005						X	X
30.06.2005			X			X	
01.07.2005				X			
12.10.2005							X

Table 2: *Overview over the depths and distances in the sampling cycles A and B.*

					Cycle *A*					
Sampling distance [m]	25	65	115	165	215					
Sampling depth [m]	5	15								
					Cycle *B*					
Sampling distance [m]	15	25	35	45	55	65	85	115	165	215
Sampling depth [m]	1	5	15	20	25					

2.3 *Analytical methods*

2.3.1 *Ammonia*

The frozen ammonia samples were allowed to warm up to room temperature before the analysis was conducted following the procedure described in Norsk Standard (NS 4746, 1975). All preservatives, namely natriumcarbonate, salycilic acid and chloroform, were omitted, because all chemicals were used within six hours after fabrication. The samples were allowed six hours reaction-time before measuring the absorbance in a 5 ml cuvette at 630 nm, using a Shimandzu UV-150-02. The calculations for the ammonia concentrations are described in 2.6. A description of the chain of analysis is found in the appendix.

2.3.2 *Nitrate and Nitrite*

Nitrate is reduced to nitrite during the analysis, thus the observed values represent the sum of nitrate and nitrite in the samples (NS 4745). It is therefore necessary to perform a separate measurement for nitrite in order to recalculate nitrate concentrations. The corresponding nitrate and nitrite measurements were always done using water from the same sample bottle. Both, the analysis of nitrate and nitrite were carried out according to Norsk Standard (NS 4745, 1991). Prior to the analysis, the samples were filtered through Whatman GF/F filters after they had warmed up to room temperatur. The reductor column was about one centimeter wide instead of having a diameter of 3-5 mm, as suggested by Grasshoff *et al.* (1999). No pump was used to press the sample through the column. An efficiency test was performed, showing an efficiency of $> 90\%$, thus the reductor was working within an acceptable range (Grasshoff *et al.*, 1999). The absorbance was measured at 545 nm in a Shimadzu UV 1200, using 50 mm cuvettes for all samples and standards with concentration below 30 $\mu\text{mol} \cdot \text{l}^{-1}$ and 10 mm cuvettes for the standards exceeding a concentration of 30 $\mu\text{mol} \cdot \text{l}^{-1}$. The concentrations were calculated as described in 2.6. A description of the chain of analysis is found in the appendix.

2.3.3 *Phosphate*

Total phosphate and dissolved inorganic phosphate were analysed after Grasshoff *et al.* (1999). All samples were allowed to warm up to room temperature before analysis. Total and dissolved inorganic phosphate were always analysed from one sample bottle. Prior to the analysis of dissolved inorganic phosphate, the sample was filtered through Whatman GF/F filters. The absorbance was measured at 880 nm in a Shimadzu UV-150-02. The phosphate concentrations were calculated according to 2.6.

2.3.4 *Total particulate matter and particulate organic matter*

All filters (Whatman GF/F, 47 mm) were pre-ashed at 450°C prior to sampling. The filters were dried at 60°C for at least 12 hours and subsequently weighed twice, using a Mettler Toledo UMX2. The dried filters were ashed for two hours at 450°C and weighed in duplicate again. The amounts of total particulate matter and organic particulate matter were obtained from the same filter and were calculated as described in 2.6.

2.3.5 *Particles*

The Lugol-preserved water samples were defrosted and screened through a sift with a 200 μm mesh size. The particles in the filtered sample were classified into 1013 classes from 0-120 μm and the number of particles in each class was counted, using a Schärfe System CASY 1 cell counter and analyzer system, model TTC with a 150 μm capillary. The number of size classes was reduced to 24, whereby the classes had a size range of 2 μm up to 20 μm, a size range of 5 μm from 20 μm to 60 μm and a size range of ten μm for particles bigger than 60 μm.

Linear regressions were performed on the numbers of particles at one sampling location against the distance of the locations. This was done for each sampling day. The numbers of particles per location represent the particle density as an average of all six sampling depths.

2.4 *Phytoplankton*

The preserved phytoplankton samples were transferred to sedimentation chambers of 10-50 ml volume and were allowed to settle for about 24 hours. Plankton cells were counted according to Utermöhl (1958), using a Leica DM IRB inversed microscope. For the determination of cells, Drebes (1974) and Tomas (1997) were used.

2.5 *Chlorophyll a*

Chlorophyll a was analyzed according to Strickland and Parsons (1972), after the samples were allowed to defrost and warm up to room temperature. The absorbances were measured in a Shimadzu UV 1200 at the wavelenghts of 750 nm, 665 nm, 645 nm, 630 nm. The concentrations were calculated following Strickland and Parsons (1972). The calculations are given in 2.6.

2.6 *Current measurements*

The average current direction and speed were recalculated from the drifter movements as described in 2.6 on every sampling event. Additional current measurements were carried out at 8 locations around *cage 10* and in one location north-west of the fish farm at *Jektholmen* and in a position 225 m north-northeast of the *Gjaesingen* Farm (Fig. 3) using an Aquadopp *profiler*. The measurements at *Jektholmen* included ten layers of two m depth each and ranged from three to 23 m water depth, thereby integrating the current speed and direction over 170 seconds for each measurement. Two measurements were taken for every location. The measurements were conducted between 11:20 UTC + 1:00 and 13:15 UTC + 1:00, High tide occurred at 7:00 UTC + 1:00. Based on these measurements, the divergence out of *cage 10* was calculated for each layer as described in 2.6.

At *Gjaesingen*, current measurements were conducted as a continuous time series from 9:22 UTC + 1:00 until 12:43 UTC + 1:00, High tide appeared at 7:30 UTC + 1:00. The averaging interval was set to 80 seconds. The temporal information within these data can be converted into spatial information with the help of *Taylor's* *hypothesis* (Stull, 1988), which suggests that for special cases turbulence can be thought of as frozen in the flow. The central hypothesis is that turbulent structures do not change within the time they need to pass the current meter. By combining the information within every single measurement with the average current speed and direction, it is especially possible to estimate the size and, if applicable, the frequency of structures passing the sensor. More detailed information on *Taylor's hypothesis* and corresponding calculations can be found in 2.6. Furthermore for every measurement the current speed in the average current direction was calculated, so it was possible to test for the distribution of the deviations of velocities (see 2.6). The distribution gives information about the characteristics of the turbulence.

2.7 *CTD measurements*

CTD measurements were carried out on three different days spread over the whole sampling period (Table 1) using a CTD probe (SAIV). On 21.04.2005 measurements were taken at two different locations: directly at and approximately 100 m downstream from *cage 10*. On 16.06.2005 and on 30.06.2005 one measurement was made at *cage 10*.

2.8 *Methods of calculations*

2.8.1 *Nutrients*

All nutrients were analysed using spectrophotometry. This technique does not allow a direct measurement of the concentrations within the samples. Instead, the samples need to be compared with standards containing known concentration of the nutrients (Grasshoff *et al.* , 1999). The absorbance and the concentration are linearly related to each other, thus a linear regression can be performed on results of measurements of artificial samples with known concentrations. The solution expresses the association in a formula of the form:

$$C = F \cdot A + B. \tag{1}$$

with:

C	concentration
F	slope of the calibration curve,
A	extinction of the sample,
B	offset from origin (A_{reag} + A_{cell} + $A_{nutrient}$).

The offset results from absorption of chemicals used during the analysis (A_{reag}), small optical differences between the sample and the cuvettes (A_{cell}) and traces of nutrients in the water used to prepare standards for the calibration ($A_{nutrient}$). The latter is not a property of the samples. A correction of the offset therefore only needs to be performed for A_{reag} and A_{cell}. The sum of A_{reag} and A_{cell} is determined by measuring pure water against a sample volume of pure water treated the same way as the samples during analysis. The difference in the absorbances is the blank absorbance (A_{blank}) and needs to be substracted from the sample absorbance before calculating the concentration. The formula for the calculation of the nutrient concentration in the samples is gained by applying the corrections to formula (1):

$$C = F \cdot (A - A_{blank}) \tag{2}$$

In this study, formula (2) was used for the calculation of the concentrations of ammonia, nitrate, nitrite and phosphate. The concentrations of ammonia-N, nitrate-N, nitrite-N and phosphate-P were then calculated by multiplication of the nutrient concentrations with the element/nutrient ratio in weight as shown in Table 3.

Table 3: *Element/nutrient ratios for ammonia, nitrate, nitrite and phosphate.*

N/ammonia [g/mol]	N/nitrate [g/mol]	N/nitrite [g/mol]	P/phosphate [g/mol]
14/18	14/62	14/46	31/95

The total of dissolved inorganic nitrogen is considered to be the sum of ammonia-N, nitrate-N and nitrite-N, so the concentrations of the nitrogen load contained in those were summed up to obtain the concentrations of dissolved inorganic nitrogen.

The N/P ratio, that is referred to in the results, was calculated as the ratio of dissolved inorganic nitrogen and the dissolved inorganic phosphate-P.

2.8.2 *Chlorophyll a*

The calculation of chlorophyll *a* concentrations was performed after Strickland and Parsons (1972, S.194):

$$C = \frac{26.7 \cdot ([Ao_{665} - Ao_{750}] - [Aa_{665} - Aa_{750}]) \cdot v}{V \cdot l} \tag{3}$$

with:

Ao_{665}	extinction at 665nm before acidification,
Ao_{750}	extinction at 750nm before acidification,
Aa_{665}	extinction at 665nm after acidification,
Aa_{750}	extinction at 750nm after acidification,
v	volume of acetone used for extraction [ml],
V	volume of water filtered [l],
l	path length of the cuvette.

2.8.3 *Total particulate matter and particulate organic matter*

The amounts of total particulate matter and particulate organic matter were calculated from the same filter using the following formulas:

$$TPM = \frac{F_{dried} - F_{blank}}{V} \tag{4}$$

with:

TPM	total particulate matter [mg/l],

F_{dried}	weight of the filter after drying at 60°C [mg],
F_{blank}	weight of the preashed filter before filtration [mg],
V	volume of water filtered [l].

$$POM = TPM - \frac{F_{ashed} - F_{blank}}{V} \tag{5}$$

with:

POM	particulate organic matter [mg/l],
TPM	total particulate matter [mg/l],
F_{ashed}	weight of ashed filter after filtration and drying [mg],
F_{blank}	weight of the preashed filter before filtration [mg],
V	volume of water filtered.

2.8.4 *Currents*

2.8.4.1 *Drifter* In this study, drifters of the Chalmers type were used in each field experiment. The average angle, in which a drifter moved from its start-location to its end-location, was calculated using the GPS-software *MapSource*. The angle is given in degrees, whereby 0° points directly north and 90° is east.

The average speed of the drifters was calculated from distance and time:

$$v = \frac{l}{t} \tag{6}$$

with:

v	average speed [cm/s],
l	distance covered [cm],
t	time from start to stop [sec].

2.8.4.2 *Divergence* Divergence means discharge from a specific volume (Sverdrup et al, 1942). The discharge has positive values for matter leaving the volume and negative for matter entering the volume. For water in a volume without sources, the discharge is zero.Thus a horizontal outflow must be compensated by a vertical inflow to the volume.

In case of a fish cage, the amount of water entering or leaving the cage can not be measured directly. However, it is possible to measure the velocity and direction of currents at different locations around the cage. The measurements described above give only the horizontal velocity field. It is then possible to calculate the horizontal divergence from these measurements and the diameter of the fish cage. As the measured directions will not point directly into or out of the fish cage, it is necessary to calculate the components of the currents, that point directly into the center of the cage or in exactly the opposite direction. The horizontal direction of a current is broken down into a component pointing eastwards and one component pointing northwards. The value of each of these components marks the associated speed. Stating that all measurements are taken on a circle around the middle of a fish cage, the horizontal velocity directly out of the cage can be calculated by:

$$\vec{v_h} = \vec{v_1} \cdot sin\alpha + \vec{v_2} \cdot cos\alpha \tag{7}$$

with:

$\vec{v_h}$	horizontal velocity directly out of the cage in one location [cm $\cdot$ s^{-1}],
$\vec{v_1}$	velocity in eastward direction [cm $\cdot$ s^{-1}],
$\vec{v_1}$	velocity in northward direction [cm $\cdot$ s^{-1}],
α	angle [°] (0°: north, 90°: east).

This formula gives the velocity for water leaving the fish cage (or entering the fish cage) at one position and at one depth on the cage wall. The outflow for one depth layer is then calculated by summing up all locations around the fish cage and multiplying by the unit side area. Thus, the outflow for each layer j is:

$$V_j = [\sum_{i=1}^{8} \vec{v_h}_{i,j}] \cdot \frac{1}{8} \cdot \pi \cdot D \cdot H_j \tag{8}$$

with:

$\vec{v_h}_{i,j}$ horizontal velocity directly out of the fish cage in the i-th position of the j-th layer [cm $\cdot$ s^{-1}]

D diameter of the fish cage,

H_j height of layer.

The average horizontal velocity and the divergence was calculated from eight locations around *cage 10* at *Jektholmen* for ten depth-layers, thereby averaging over two m vertically in each layer and enveloping the water from three to 23 m depth.

2.8.4.3 *Volume flow* The total horizontal volume flow out of an imaginary cylinder can be calculated from current measurements at different locations, of which all have to lie uniformly around the circle. The components of the currents that point directly into the center of the cage or in the opposite direction are calculated for the depths of interest, as described in Formula (7). As a next step the arithmetic mean of these components is calculated, which gives the average outflow velocity at every single measurement location on the circle at one depth, as described in Formula (8). As the volume flow needs to be calculated from three dimensions, an integration of the velocity contribution over the whole circle and over the total depth is necessary and gives the following formula:

$$V_H = \sum_{i=1}^{10} v_{aj} \cdot \pi \cdot D \cdot H_j \qquad (9)$$

where v_{aj} is the average horizontal velocity directed out of the circle through the wall of layer j [$\mathrm{cm} \cdot \mathrm{s}^{-1}$] and $H_j = 2$ m are the layer thicknesses.

2.8.4.4 *Turbulence and patterns* Water-movement in the sea never can be considered to be laminar, because the flow gets disturbed by obstacles, shear-layers, waves, currents and many more processes. Therefore one has to regard the movement of water masses to be turbulent, which does not mean, there will not exist coherent patterns. Only, how can one recognize and determine a pattern without covering a wide area with simultaneous measurements? *Taylor's hypothesis* offers a possible solution. Basically, *Taylor's hypothesis* suggests, that for cases where the standard deviation in speed is small compared to the mean speed (Willis and Deardorff, 1976), a turbulent pattern can be thought of as "frozen" on small time scales (Stull, 1988). That means it is possible to reconstruct the size and other qualities of a pattern from a time series of measurements at one single location. Imagine an eddy passing by a current meter. One quality of the eddy is rotation, so if the measurement intervals are short enough to give a good resolution, the current meter will record turning current directions. It is then possible to calculate the size of the eddy by combining the time period it took the eddy to pass the current meter with the mean horizontal current:

$$l = M \cdot \xi \qquad (10)$$

with:

l	length of the eddy,
M	mean horizontal current,
ξ	time period it took the eddy to pass.

A time series of current measurements can not only be used to determine patterns like eddies, but can also be used to take a closer look at the characteristics of turbulence within the measurements. Most velocity time series reveal rapid fluctuations in velocity. These fluctuations will not be totally random, but appear around local means (Stull, 1988). So one could imagine a mean current on which rapid fluctuations are superimposed. The first step towards characterisation of turbulence is to separate the rapid fluctuations from the mean. This can be done by *Reynolds Decomposition*: The velocity is averaged over time and the difference to the mean velocity is calculated for every single measurement. The velocity can then be expressed by:

$$U = \bar{U} + u' \tag{11}$$

with:

U	velocity,
$\bar{U}$	mean velocity,
u’	superimposed microscale turbulence.

The superimposed microscale turbulence (or deviations from the mean) can be tested on their distribution for further characterisation of the turbulence.

In this study *Taylor’s hypothesis* was used to determine eddies downstream from fish cages. Furthermore, *Reynolds Decomposition* was used to split up the speed data. The deviations from the mean speed were tested on normal-distribution using the non-parametric *Lillifor’s test.* The data furthermore were fitted with a normal-distribution.

3 Results

3.1 *Nutrients*

3.1.1 *Ammonia*

The ammonia concentrations showed a large variability within single transects as well as between sampling-days at both, 5 and 15 m depth (Figs. 6 and 7). There was at least one very distinct peak in each of the transects until 03.06.2005. The lowest concentrations were found to be lower than the detection limit, the highest concentrations ranged around 35 μg NH_3/NH_4-N $\cdot$ l^{-1} in 5 m depth and up to 50 μg NH_3/NH_4-N $\cdot$ l^{-1} in 15 m depth. The average transect in 5 m depth showed concentrations around 15 μg NH_3/NH_4-N $\cdot$ l^{-1}, thereby reaching a maximum of about 21 μg NH_3/NH_4-N $\cdot$ l^{-1} 65 m downstream from *cage 10* and a minimum of nine μg NH_3/NH_4-N $\cdot$ l^{-1} about 165 m downstream from *cage 10.* The average transect at 15 m depth revealed a steady ammonia concentration of about 16 - 17 μg NH_3/NH_4-N $\cdot$ l^{-1} up to 115 m downstream. The concentration then fell to a minimum of eight μg NH_3/NH_4-N $\cdot$ l^{-1} at 165 m distance to *cage 10* and afterwards increased to about 13 μg NH_3/NH_4-N $\cdot$ l^{-1} at 215 m distance. at both depths the average transect showed lower concentrations upstream of the fish farm than within the first 115 m downstream from *cage 10.* There was no clear small scale correlation between ammonia-concentration and distance to the fish farm, but generally the concentrations decreased with increasing distance downstream.

A comparison between the concentrations upstream of the fish farm and the concentrations 25 m downstream from *cage 10* did not show similar results for all samplings. In fact the number of samplings showing higher values upstream of the fish farm exactly equaled the number of samplings showing the opposite behavior. This relationship was opposite at the two depths on all sampling days.

The distribution of ammonia concentrations along the transect was not always similar at both depths, but it did almost match on 30.05.2005, the day on which the samples were taken directly beneath the drifters. At both depths there was a pronounced peak at about 125 m (5 m depth) and about 150 m (15 m depth) downstream from *cage 10.* The ammonia concentrations further downstream stayed elevated in relation to the concentration less than 75 m downstream from *cage 10.*

After the fish were taken out of *cage 10*, the ammonia concentrations were much lower than the average concentrations, reaching only about one tenth of the values of the averages at both depths.

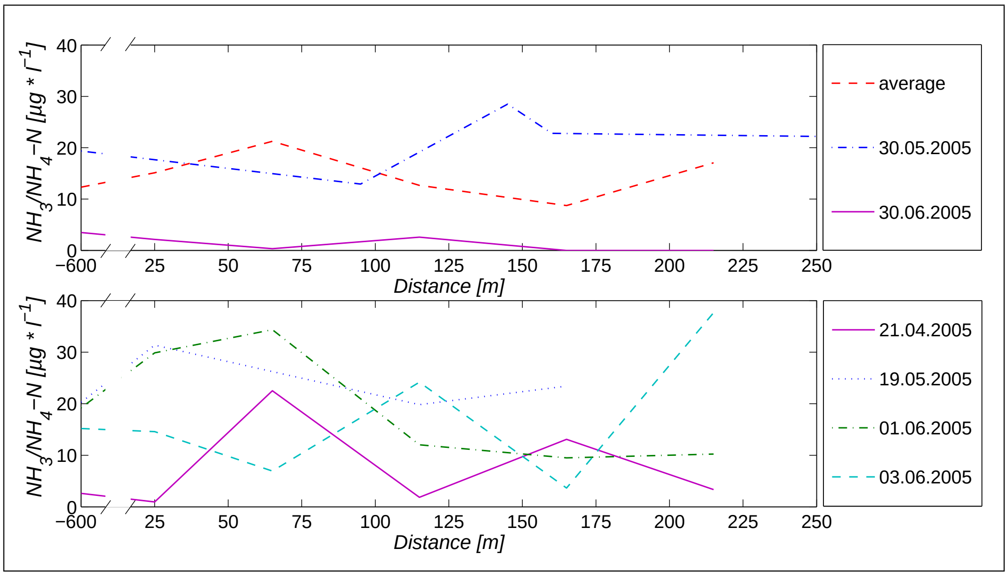


Fig. 6: *Spatial distribution of ammonia concentrations at 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

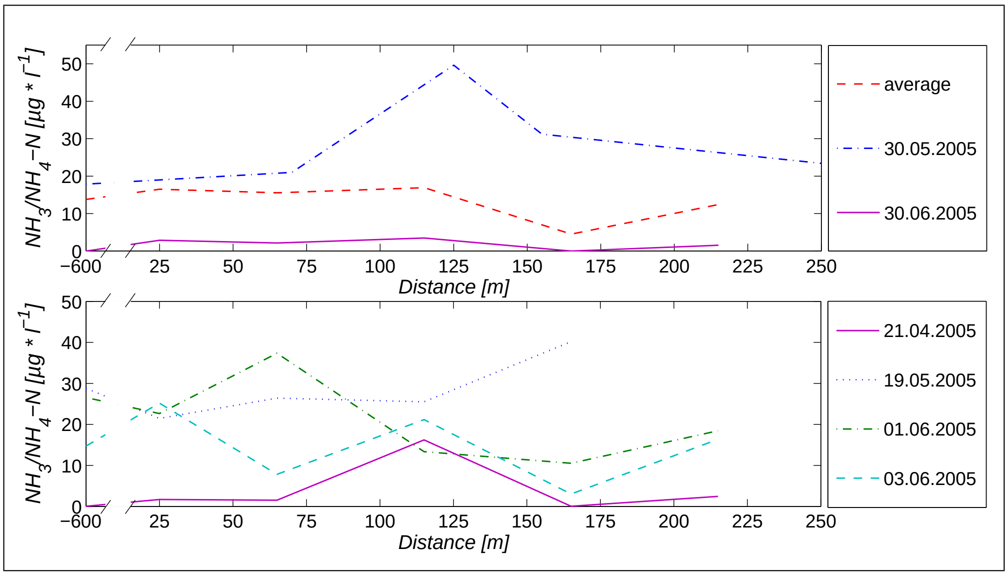


Fig. 7: *Spatial distribution of ammonia concentrations at 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.1.2 *Nitrate*

The nitrate-concentrations displayed a large variability within single transects and even more between sampling days, whereby the differences between days were bigger at 5 m, than at 15 m depth (Figs. 8 and 9). The lowest nitrate concentrations were lower than the detection limit, the highest reached over four μg NO_3-N $\cdot$ l^{-1}. There was no straight evolution of nitrate concentration with time, but concentrations on 21.04.2005 were much higher than on the other days throughout the whole transect.

On average there was no significant increase or decrease in nitrate concentration with distance from *cage 10*, the concentrations ranged between one and two μg NO_3-N $\cdot$ l^{-1} at both depths and throughout the whole transect.

For half of the samplings the nitrate concentration upstream of the fish farm was higher than the concentration 25 m downstream from *cage 10*, for the other half of the samplings this relation was opposite.

At 5 m depth the sampling on 30.05.2005 revealed a distribution of nitrate concentration along the transect quite similar to the average distribution, but on 30.05.2005 the concentrations were lower and the decrease of nitrate with increasing distance past the fish farm happened faster. The distributions of nitrate downstream from *cage 10* on 30.05.2005 and the average distribution match almost perfectly up to a distance of about 150 m.

The sampling after the fish were taken out of *cage 10* revealed nitrate-concentrations of around 0.05 μg NO_3-N $\cdot$ l^{-1} (5 m depth) and about 0.3 μg NO_3-N $\cdot$ l^{-1} (15 m depth) respectively. at both depths the nitrate concentration upstream of the fish farm exceeded the concentrations on the whole transect downstream from *cage 10*. At 5 m depth, one prior sampling showed lower nitrate concentrations in distances over approximately 100 m distance downstream from *cage 10*, while at 15 m depth even on two prior samplings the nitrate concentrations were lower than on 30.06.2005 over wide sections of the transect.

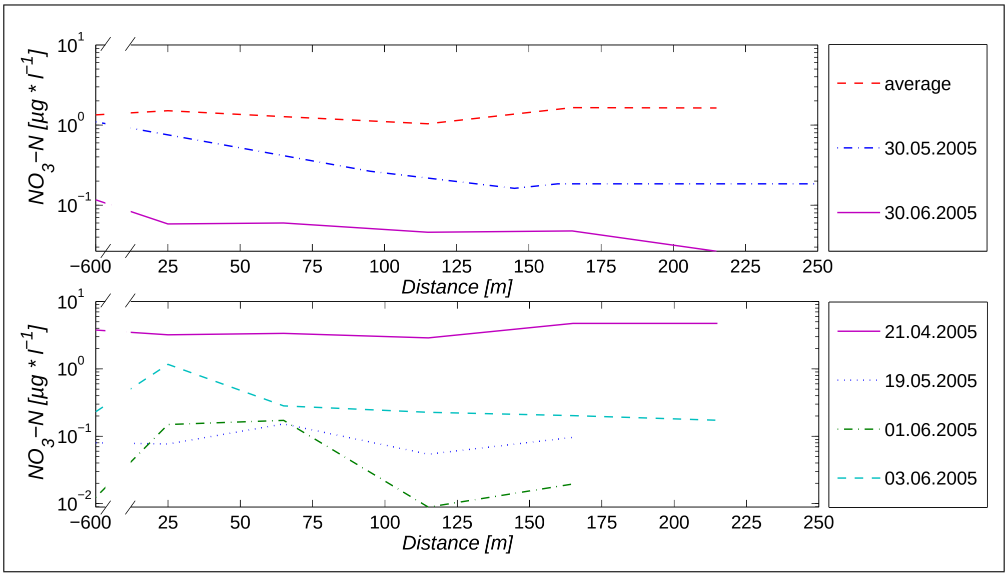


Fig. 8: *Spatial distribution of nitrate concentrations at 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

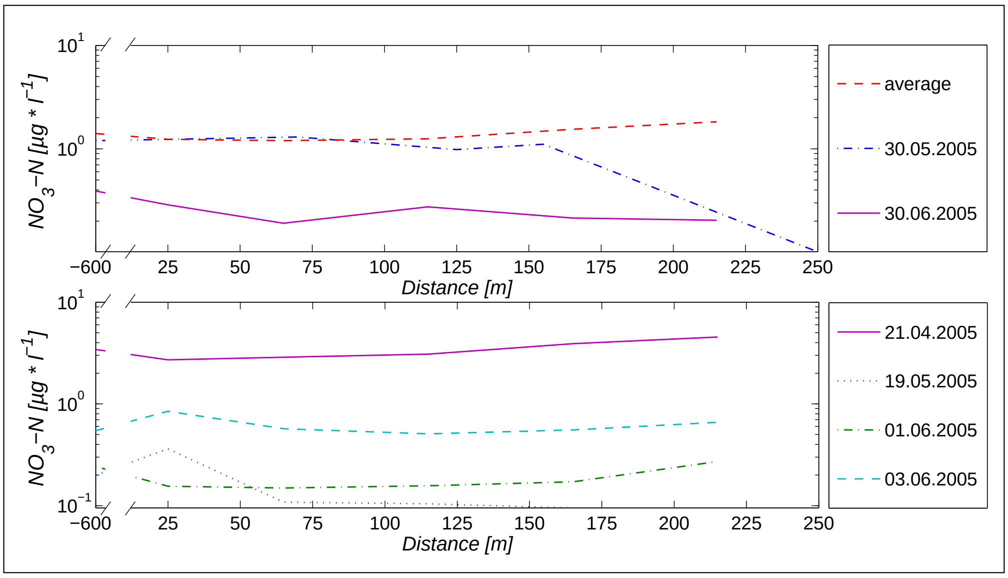


Fig. 9: *Spatial distribution of nitrate concentrations at 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.1.3 *Nitrite*

The distribution of nitrite concentrations along the transects showed less variability than the distribution of nitrate concentrations. All values lay within a relatively small range of concentrations from the lower limits of detection to slightly above 0.3 μg NO_2-N $\cdot$ l^{-1} (Figs. 10 and 11). Only the samplings on 21.04.2005 revealed nitrite concentrations, that were elevated in relation to the other sampling days. On that day the nitrite concentrations were up to three times higher than the average at 5 m depth, while an elevation of concentrations in relation to the other sampling days was clearly visible in 15 m depth and greater distances than 100 m downstream from *cage 10.* On average the nitrite concentrations ranged around 0.1 μg NO_2-N $\cdot$ l^{-1} (5 m depth) and 0.12 μg NO_2-N $\cdot$ l^{-1} (15 m depth) respectively. The nitrite concentrations were at the same level upstream and downstream from the fish farm at 5 m depth, while they were much elevated upstream of the fish farm at 15 m depth. The relation between nitrite concentrations upstream of the fish farm and 25 m downstream from *cage 10* was different on different sampling days.

The samplings on 30.05.2005 revealed a slow decrease of nitrite with increasing distance downstream from *cage 10.* On 30.06.2005 the nitrite concentration appeared to range around half of the average concentrations throughout the whole transect and did not show any increase or decrease.

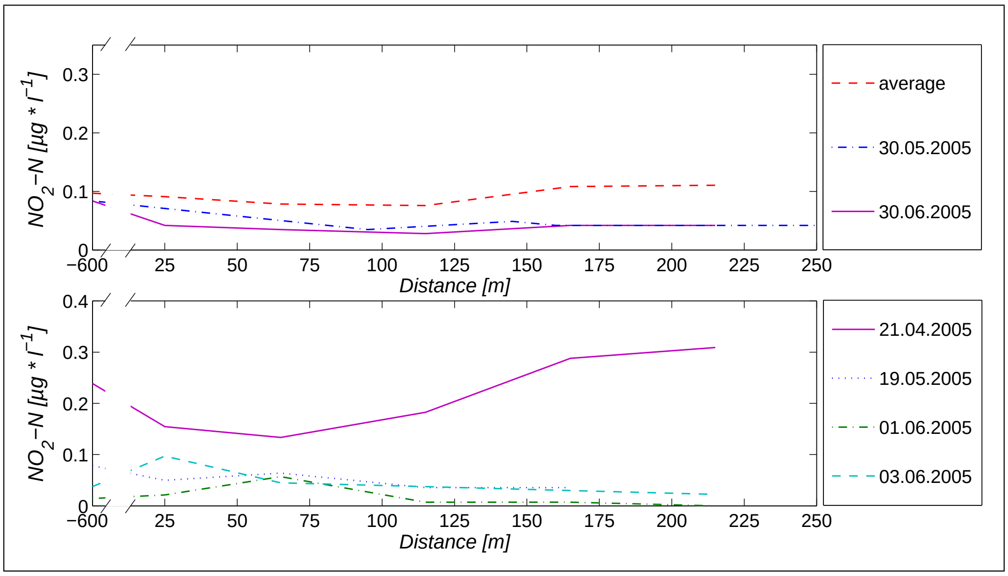


Fig. 10: *Spatial distribution of nitrite concentrations at 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

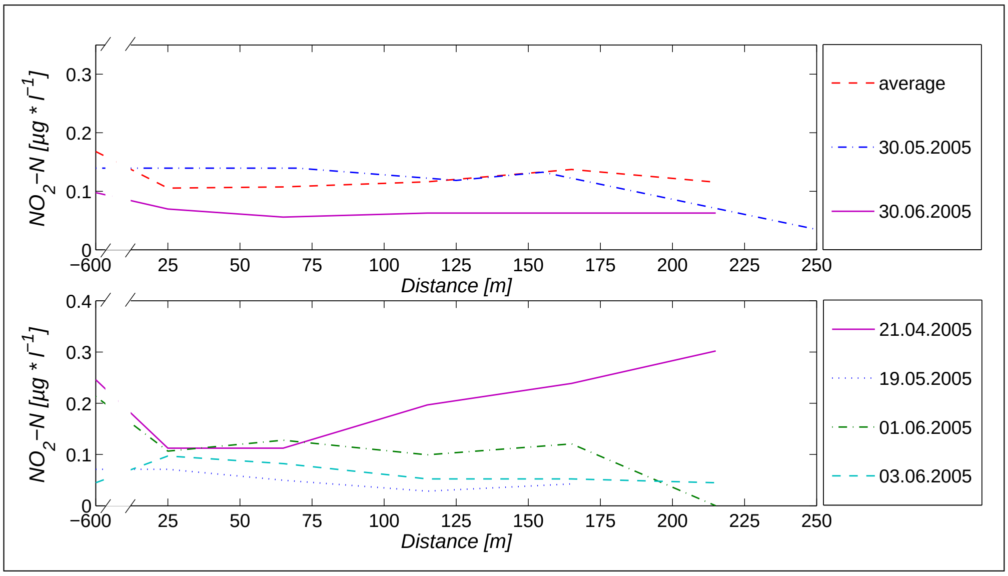


Fig. 11: *Spatial distribution of nitrite concentrations at 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.1.4 *Dissolved inorganic nitrogen*

The distribution of dissolved inorganic nitrogen (DIN) mirrored the distribution of ammonia throughout the transects at both sampling depths, thereby always showing slightly elevated values. Thus the lowest values did not lie under the detection limits, but around 0.3 μg DIN $\cdot$ l^{-1} (Figs. 12 and 13). The highest values occurred at over 50 μg DIN $\cdot$ l^{-1}. As for ammonia, very distinct peaks occurred within every transect. The average transect at 5 m depth showed concentrations ranging around 17 to 18 μg DIN $\cdot$ l^{-1}, thereby reaching a maximum of 22 μg DIN $\cdot$ l^{-1} about 65 m downstream from *cage 10* and a minimum just over ten μg DIN $\cdot$ l^{-1} 165 m downstream from *cage 10.* At 15 m depth the concentrations of dissolved inorganic nitrogen on average ranged around 17 to 18 μg DIN $\cdot$ l^{-1} up to 115 m downstream from *cage 10.* The minimum concentration of about 6 μg DIN $\cdot$ l^{-1} was reached in 165 m distance. Further downstream the concentration increased to about 15 μg DIN $\cdot$ l^{-1}. At both depths the concentrations of dissolved inorganic nitrogen within the first 115 m downstream from *cage 10* were elevated in comparison to concentrations upstream of the fish farm. On average, the concentration of dissolved inorganic nitrogen decreased with increasing distance downstream from the fish farm.

A comparison of concentrations upstream of the fish farm and 25 m downstream from *cage 10* did not show consistent results for all days an depths. As for the ammonia-concentrations, the number of cases, in which the concentration upstream was less than the concentration downstream, matched the number of cases with inverse results.

On 30.06.2005 the concentrations of dissolved inorganic nitrogen were much lower than the average concentrations throughout the whole transect.

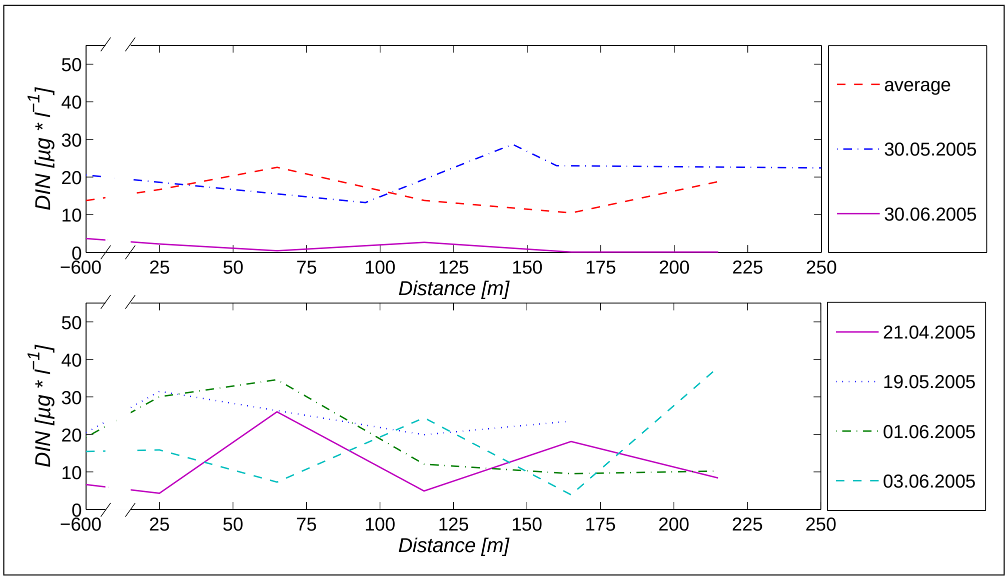


Fig. 12: *Spatial distribution of concentrations of dissolved inorganic nitrogen at 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

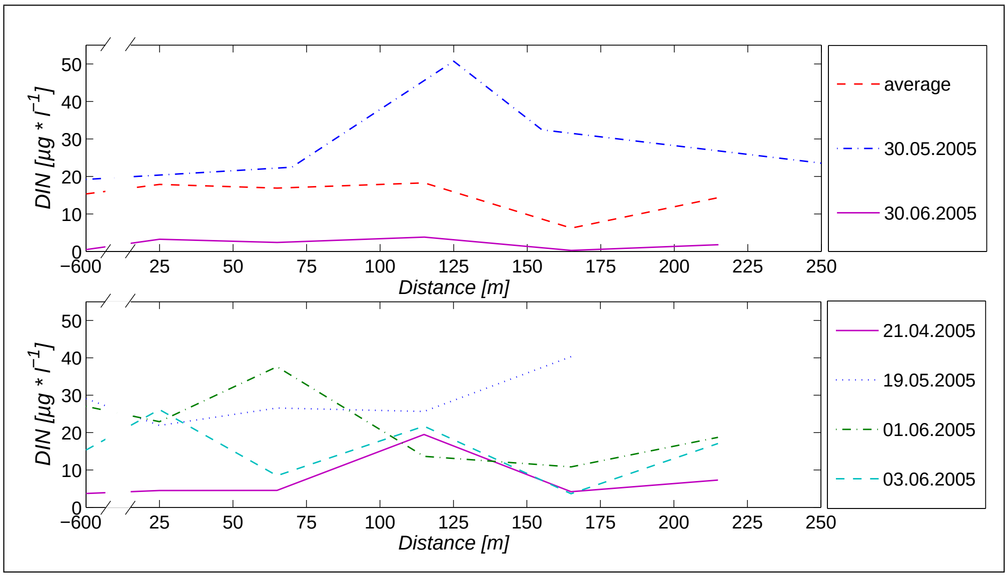


Fig. 13: *Spatial distribution of concentrations of dissolved inorganic nitrogen at 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.1.5 *Phosphate*

3.1.5.1 *dissolved inorganic phosphate* The analysis of dissolved inorganic phosphate gave quite similar results for the distribution along the transects on the different sampling days. The concentrations of dissolved inorganic phosphate did not vary a lot throughout the transects or between different days. The only exception was on 21.04.2005, when concentrations were much higher than on the other sampling days (Figs. 14 and 15). At 5 m depth the concentrations ranged around 0.175 μg $PO_{4dissolved}$-P $\cdot$ l^{-1} on 21.04.2005 and between 0.025 and 0.11 μg $PO_{4dissolved}$-P $\cdot$ l^{-1} on the other sampling days. The concentrations were higher in 15 m depth, ranging from about 0.5 μg $PO_{4dissolved}$-P $\cdot$ l^{-1} to approximately 0.14 μg $PO_{4dissolved}$-P $\cdot$ l^{-1}, on 21.04.2005 the range of concentrations was 0.15 - 0.23 μg $PO_{4dissolved}$-P $\cdot$ l^{-1}.

The average concentrations did not show any differences in distributions between the depths of 5 and 15 m. At both depths the concentrations were almost constant at a level of 0.1 μg $PO_{4dissolved}$-P $\cdot$ l^{-1} throughout the whole transect. On average the concentrations upstream of the fish farm matched the concentrations downstream from *cage 10*, but on single days the concentration upstream was lower or higher than the concentration 25 m downstream from *cage 10*.

On 30.05.2005 the concentrations of dissolved inorganic phosphate did not change throughout the transect and ranged around 0.75 μg $PO_{4dissolved}$-P $\cdot$ l^{-1} at 5 m depth. At 15 m depth, there was a decrease of dissolved inorganic phosphate from about 0.16 μg $PO_{4dissolved}$-P $\cdot$ l^{-1} 25 m downstream from *cage 10* to 0.05μg $PO_{4dissolved}$-P $\cdot$ l^{-1} around 250 m downstream from *cage 10* occurred.

The distribution of dissolved inorganic phosphate on 30.06.2005 matched the average distribution perfectly to 165 m downstream from *cage 10*, but then showed a decrease of dissolved inorganic phosphate within the next 50 m.

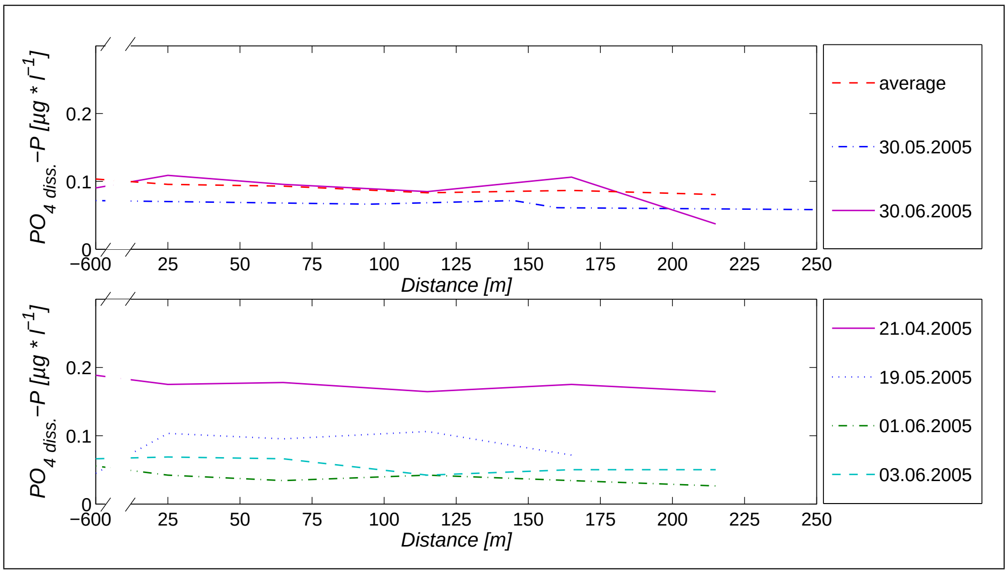


Fig. 14: *Spatial distribution of dissolved inorganic phosphate concentrations in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

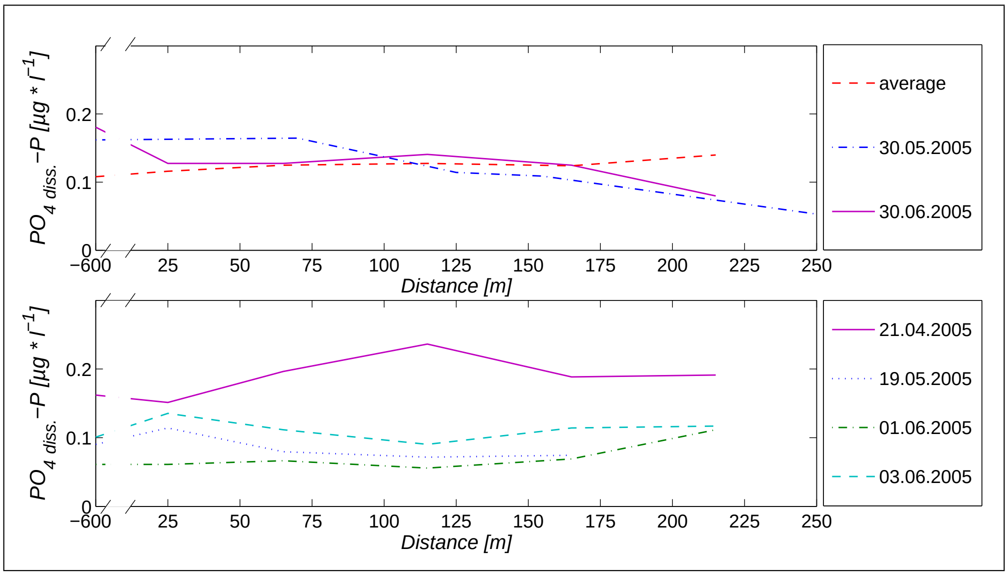


Fig. 15: *Spatial distribution of dissolved inorganic phosphate concentrations in 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.1.5.2 *Total phosphate* There was nearly no variability in concentrations of total phosphate downstream from the fish farm before *cage 10* was emptied. The concentrations at both depths ranged in between 0.18 and 0.4 μg PO_{4total}-P $\cdot$ l^{-1} downstream from *cage 10*with an exception at 15 meter depth on 21.04.2005, where the highest value of about 0.5 μg PO_{4total}-P $\cdot$ l^{-1} was reached at 225 m downstream from *cage 10* (Figs. 16 and 17). The concentrations upstream of the fish farm were mostly lower than 25 m downstream from *cage 10* and revealed a higher variability than the concentrations downstream, showing concentrations between 0.05 and 0.37 μg PO_{4total}-P $\cdot$ l^{-1}.

In 5 m depth the average concentration lay just under 0.3 μg PO_{4total}-P $\cdot$ l^{-1} and did not fluctuate at all throughout the transect, while there was little fluctuation in the average concentrations at 15 m depth. Here, the concentration upstream, with a value of 0.2 μg PO_{4total}-P $\cdot$ l^{-1}, was about two third of the average concentration downstream.

The distribution on 30.05.2005 showed a decrease of total phosphate with increasing distance downstream from *cage 10*, which was more distinct at 15 m depth.

The concentrations of total phosphate were highly elevated on 30.06.2005, revealing concentrations just above 0.4 μg PO_{4total}-P $\cdot$ l^{-1} upstream of the fish farm at both depths. At 5 m depth an increase from 0.47 μg PO_{4total}-P $\cdot$ l^{-1} 25 m downstream from *cage 10* to about 0.75 μg PO_{4total}-P $\cdot$ l^{-1} 115 m downstream from *cage 10* occurred. Further downstream, the concentrations stayed at the same level, ranging around 0.75 μg PO_{4total}-P $\cdot$ l^{-1}. At 15 m depth the concentrations fluctuated around 0.6 μg PO_{4total}-P $\cdot$ l^{-1} throughout the whole downstream transect.

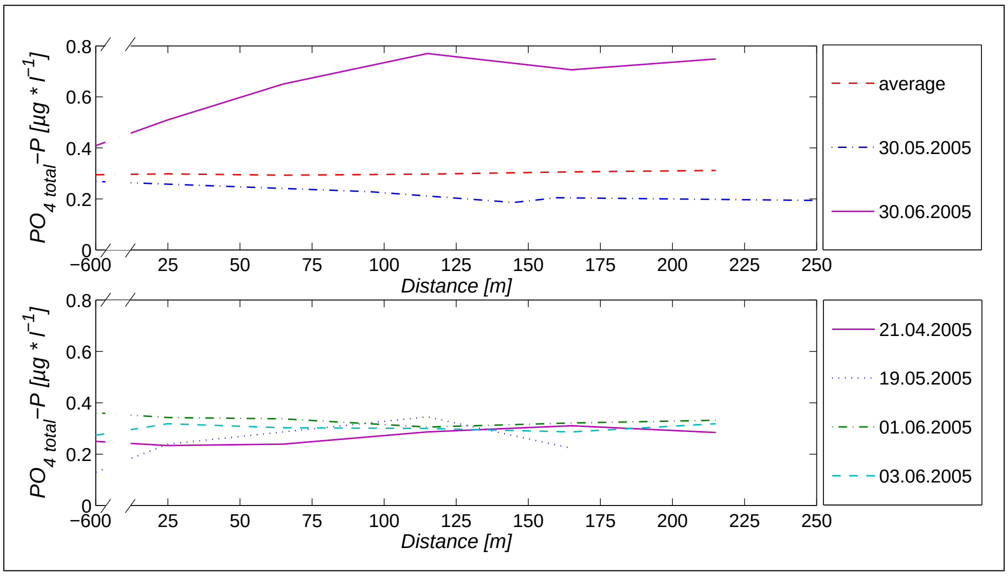


Fig. 16: *Spatial distribution of total phosphate concentrations in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

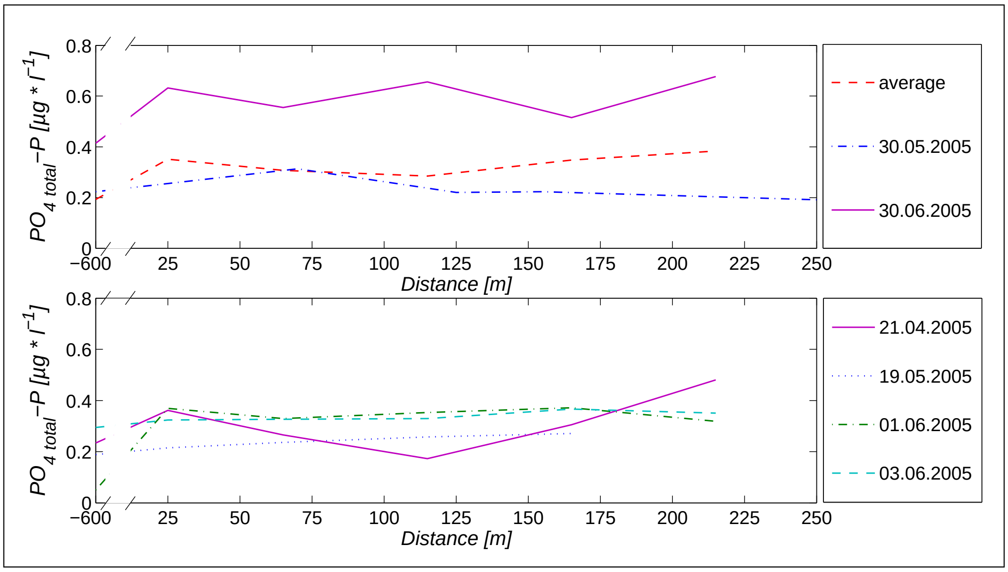


Fig. 17: *Spatial distribution of total phosphate concentrations in 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.1.6 *N/P ratio*

The N/P weight ratio displayed an extreme variability within transects as well as between sampling days at both, 5 and 15 m depth. Before *cage 10* was emptied, ratios from <25 to >1000 (5 m depth) and <23 to >560 (15 m depth) were found

(Figs. 18 and 19). On some of the sampling days, very distinct peaks were visible, increasing N/P ratios with increasing distance downstream from *cage 10* occurred as well as decreasing ratios. At 5 m depth the ratio on average showed a little increase from 25 to 65 m downstream from *cage 10* from about 330 to 430, followed by a decline to well under 200 at 165 m distance from *cage 10* and an increase to about 400 within the last 50 m of the transect. At 15 m depth the N/P ratio stayed at about 200 at 25 m and 65 m downstream from *cage 10*, but showed a decline to well under 100 within the next 100 m. 215 m downstream from *cage 10* the ratio increased to about 125.

The N/P ratio was generally lower upstream of the fish farm than 25 m downstream from *cage 10* at 5 m depth, but did not show any difference at these two sampling locations at 15 m depth. On the other days the ratio was not consistently higher or lower 600 m upstream or close to *cage 10*. On 30.05.2005 the N/P ratio fluctuated within a range between 200 and 400, whereby it was higher in distances greater than about 150 m than it was closer than about 100 m downstream from *cage 10*. At 15 m depth the ratio was about 125 upstream as well as 25 m and 70 m downstream from *cage 10*, from where it increased with increasing distance to the fish farm, showing a distinct peak at about 125 m distance. The ratio was approximately 450 at that location as well as 250 m downstream from *cage 10*.

The N/P ratio was extremely reduced after the fish were taken out of *cage 10*. It remained well under 50 throughout the whole transect in both depths.

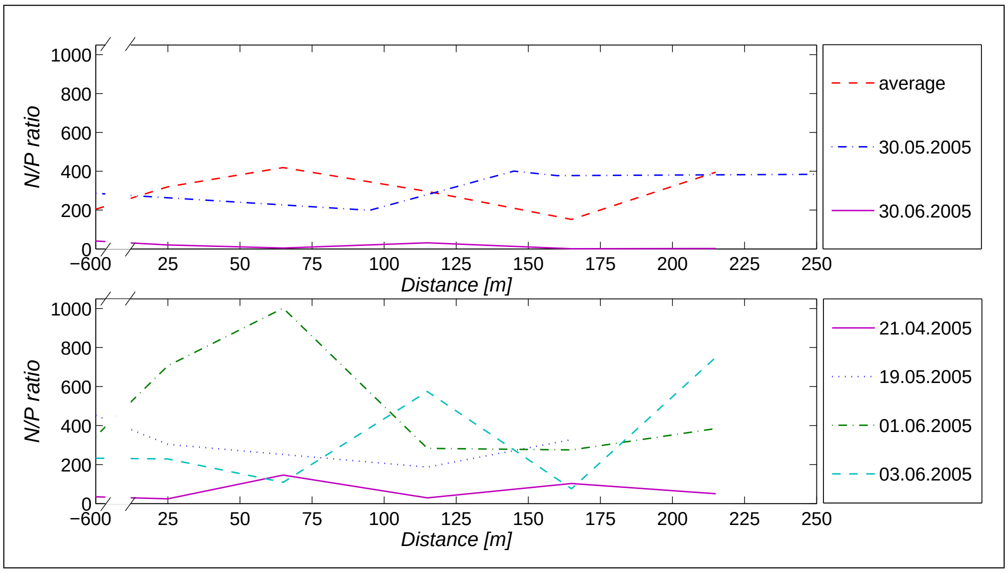


Fig. 18: *Spatial distribution of N/P ratios in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

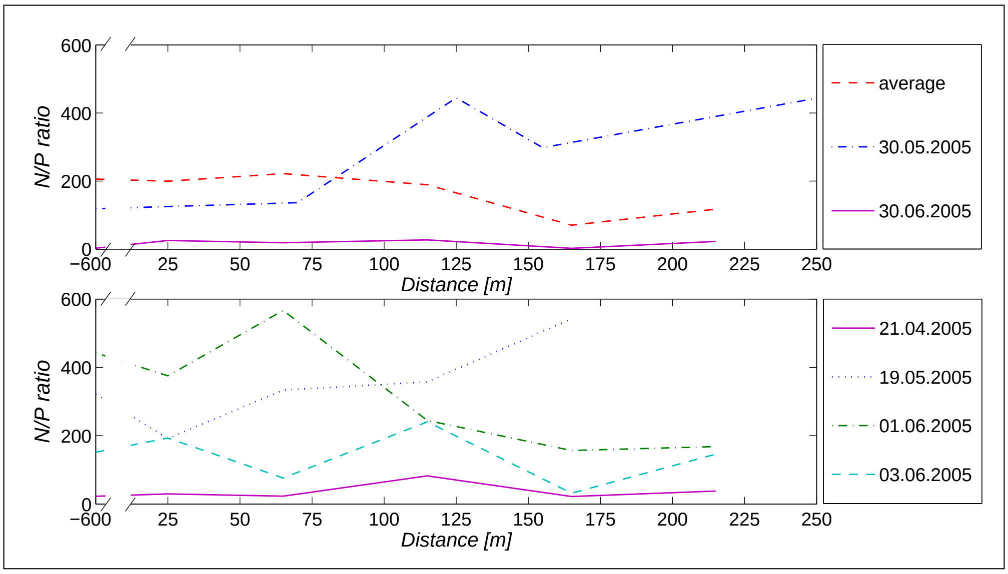


Fig. 19: *Spatial distribution of N/P ratios in 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.2 *Total particulate matter*

The distribution of total particulate matter (TPM) showed only moderate variability within and between transects at both, 5 and 15 m depth. Although there were some peaks occurring on several transects, the concentrations of total particulate matter ranged between 0.45 and 1.0 mg $\cdot$ l^{-1} on 21.04.2005, 01.06.2005 and 03.06.2005 (Figs. 20 and 21). On 19.05.2005 concentrations exceeding 1.5 mg $\cdot$ l^{-1} at 5 m depth were found. Before *cage 10* was emptied, the lowest concentrations ranged just under 0.5 mg $\cdot$ l^{-1}, the highest were found to be about 1.8 mg $\cdot$ l^{-1}. On average, concentrations at 5 meter depth ranged around 0.65 mg $\cdot$ l^{-1}, showing a slight overall decrease of total particulate matter with increasing distance downstream from *cage 10.* The average concentrations at 15 m depth ranged around the same concentration as at 5 m depth, but there is no clear decrease in the concentration with increasing distance downstream from the fish farm. The concentration of total particulate matter consistently was higher 25 m downstream from *cage 10* than upstream of the fish farm, with two exceptions at 15 m depth (21.04.2005 and 30.05.2005).

On 30.05.2005 the concentrations of total particulate matter did not show any increase or decrease with increasing distance to the fish farm and ranged in between 0.6 and 0.65 mg $\cdot$ l^{-1} throughout the whole transect except for one measurement about 165 m downstream from *cage 10*, which revealed a concentration of about 1.8 mg $\cdot$ l^{-1}. This peak was not visible at 15 m depth, but in the deeper layer there was an overall decrease in total particulate matter with increasing distance downstream from *cage 10.*

The concentrations of total particulate matter did not decrease after the fish was taken out of *cage 10* at 5 m depth and at least not significantly at 15 m depth. While the distribution of total particulate matter indicated a decrease with increasing distance downstream from the fish farm at 15 m depth, it did not show any increase or decrease in dependence of distance to *cage 10.*

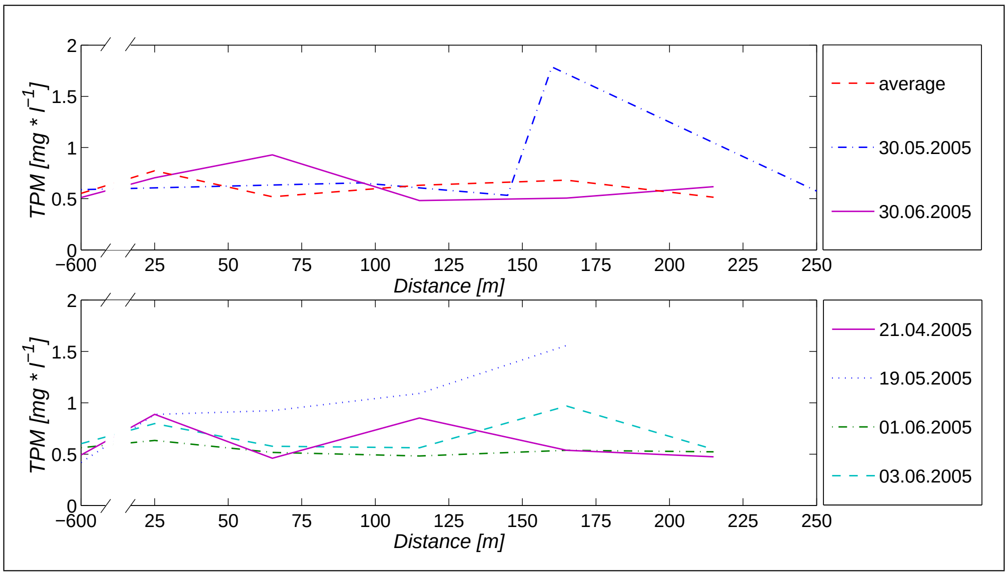


Fig. 20: *Spatial distribution of concentrations of total particulate matter in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

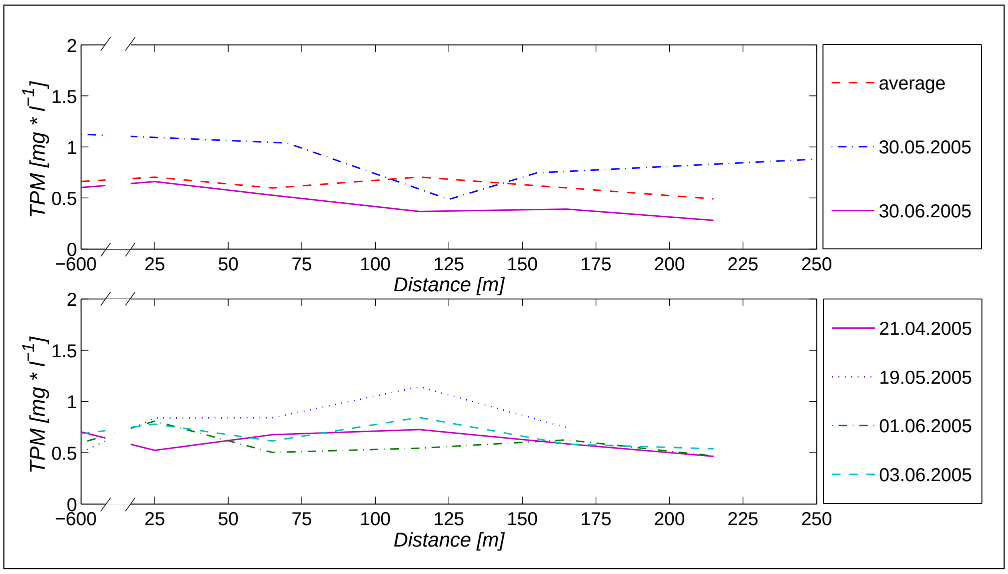


Fig. 21: *Spatial distribution of total particulate matter in 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

Fig. 22 shows the distributions of total particulate matter for the samplings in sampling cycle *B*. These results approved most of the insights based on the results from cycle *A*, shown in Figs. 20 and 21, but, in contrast to those, revealed a slight increase in total particulate matter in time. Most measurements revealed concentrations under 1.0 mg $\cdot$ l^{-1}, but but peaks showed values up to about 1.8 mg $\cdot$ l^{-1}. Those peaks seemed to occur randomly distributed over the depths and over the transects. There also was a tendency for more total particulate matter to occur within the first ten meters in depth than in the following fifteen meters, whereby the lowest values within one single depth at one sampling-location did not characteristicly appear in the lowest layer. In general there was no recognizable increase or decrease of total particulate matter with increasing distance from *cage 10*. But the concentrations were relatively high in 25 and 35 m distance downstream from *cage 10*. On 01.07.2005, after *cage 10* was emptied, the concentrations of total particulate matter were reduced in comparison to the concentrations in May and June and matched approximately the values that were found in April. The sampling on 01.07.2005 also was the only one that did not show any peaks exceeding 1.0 mg $\cdot$ l^{-1}.

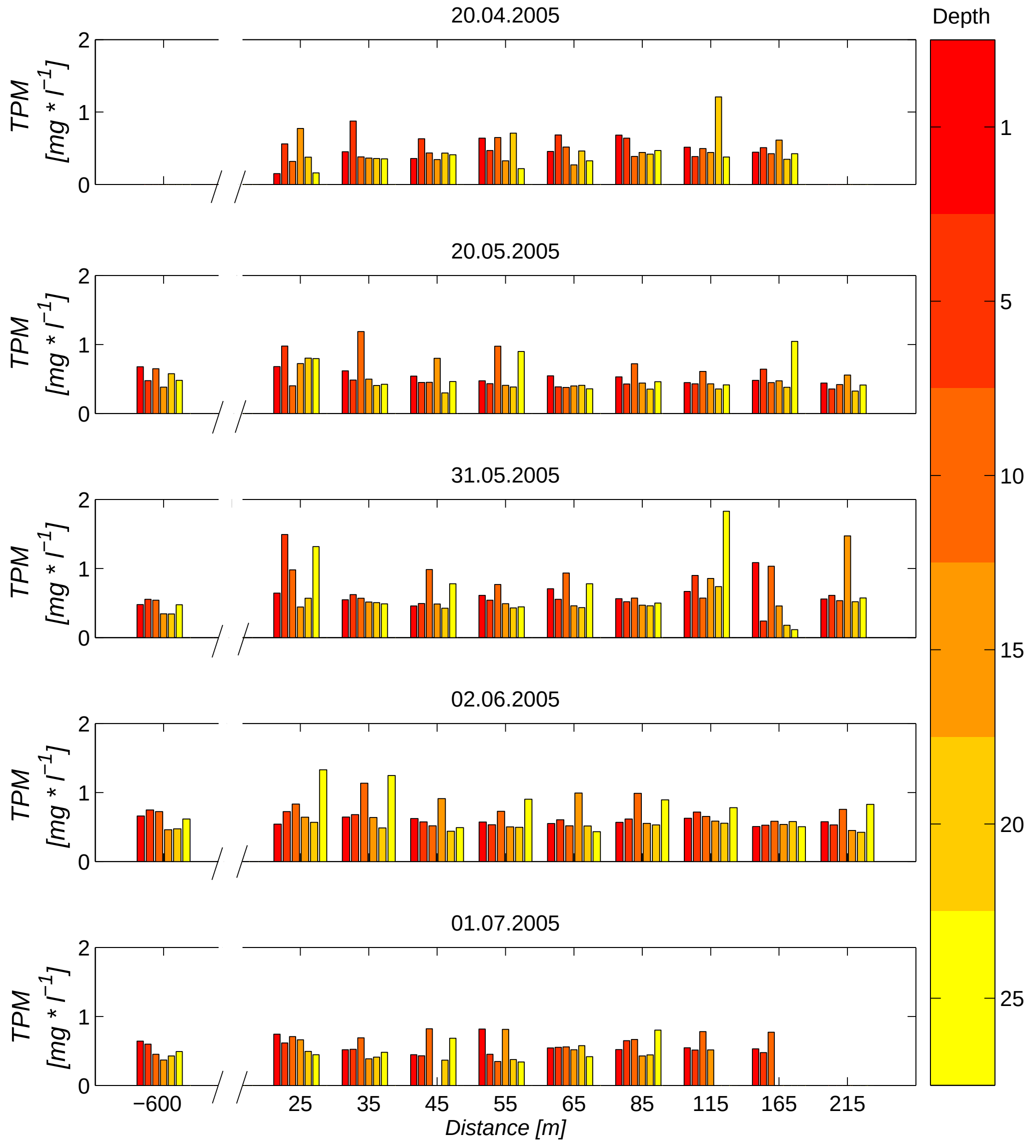


Fig. 22: *Spatial distributions of total particulate matter in six depth layers. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. Each depth is marked by one specific color - the colorbar defines the depths in meter.*

3.3 *Particulate organic matter*

The concentrations of particulate organic matter (POM) ranged from 0.3 to 0.7 mg $\cdot$ l^{-1} at 5 and at 15 m depth in all transects before *cage 10* was emptied (Figs. 23 and 24). There was a moderate variability between transects as well as some fluctuations along the transects, but distinct peaks occurred only 25 m downstream from *cage 10* - once at 5 m depth (21.04.2005) and twice at 15 m depth (19.05.2005 and 01.06.2005).

On average, the concentrations of particulate organic matter ranged around 0.45 to 0.5 mg $\cdot$ l^{-1} throughout the whole transect at both depths, thereby showing a very slight decrease with increasing distance downstream from *cage 10*, which however can not be considered significant at either depth. Furthermore there was no significant difference between the concentrations upstream and 25 m downstream from *cage 10* within the average distributions. On some single transects, however, there were distinct differences in the concentrations between these two sampling locations.The distribution of particulate organic matter did not reveal a steady increase or decrease with distance from the fish farm at either depth. The concentrations ranged between 0.5 and 0.55 mg $\cdot$ l^{-1}, which was nearly within the same range than the average concentrations.

At 5 meter depth the distribution of concentrations of particulate organic matter ranged just under 0.5 mg $\cdot$ l^{-1}, lying in the same range than the average concentration. At 15 m depth, the concentrations clearly decreased from 0.5 mg $\cdot$ l^{-1} 25 m downstream from *cage 10* to about 0.05 mg $\cdot$ l^{-1} 140 m further downstream. There was an increase of about 0.2 mg $\cdot$ l^{-1} within the last 50 m of the transect at both depths.

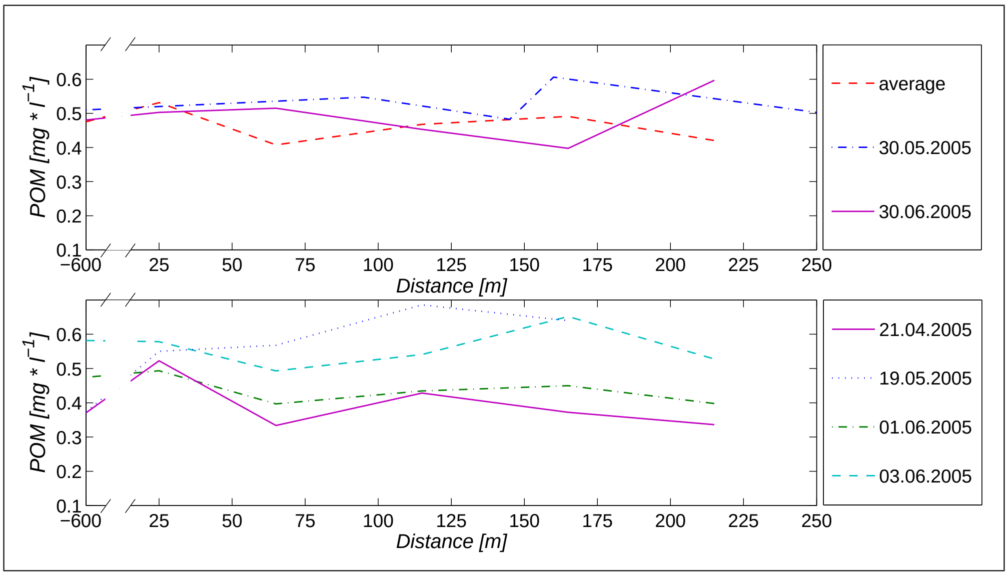


Fig. 23: *Spatial distribution of concentrations of particulate organic matter in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

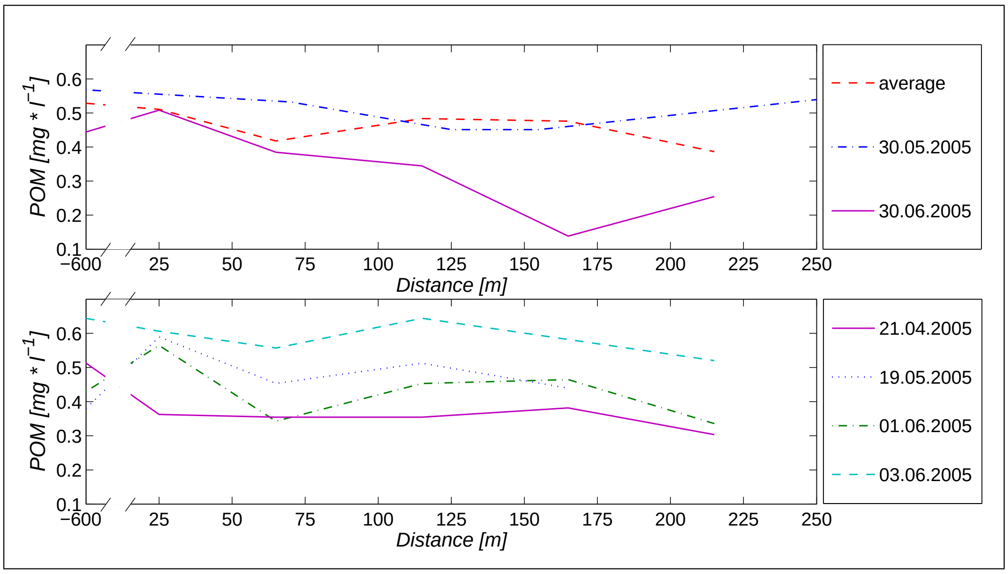


Fig. 24: *Spatial distribution of concentrations of particulate organic matter in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

The results from sampling cycle B displayed in Fig. 25 clearly show an evolution of particulate organic matter from 20.04.2005 to 02.06.2005. While concentrations were under 0.5 mg $\cdot$ l^{-1} at all depths throughout the whole transect in April, this concentration was exceeded at some depths upstream and up to 45 m downstream from *cage 10* on 20.05.2005. On 31.05.2005 as well as on 02.06.2005 the concentrations exceeded 0.5 mg $\cdot$ l^{-1} at all depths and throughout the whole transect downstream from the fish farm. The highest concentration ranged around 0.8 mg $\cdot$ l^{-1} before the fish were taken out of *cage 10*. On 01.07.2005 a concentration close to 0.9 mg $\cdot$ l^{-1} was found, but except for this there were no distinct peaks. There was no general or depth-selective decrease of particulate organic matter along the transects. In contrast a consistent vertical distribution was found - there was a tendency for a slight decline in concentration with increasing depth, whereby the highest concentrations often were not found at one meter depth, but some meters deeper.

On 01.07.2005, after the fish were taken out of *cage 10*, the concentrations of particulate organic matter along the transect exceeded the concentrations in April, but ranged well under the concentrations found on 31.05.2005 and 02.06.2005.

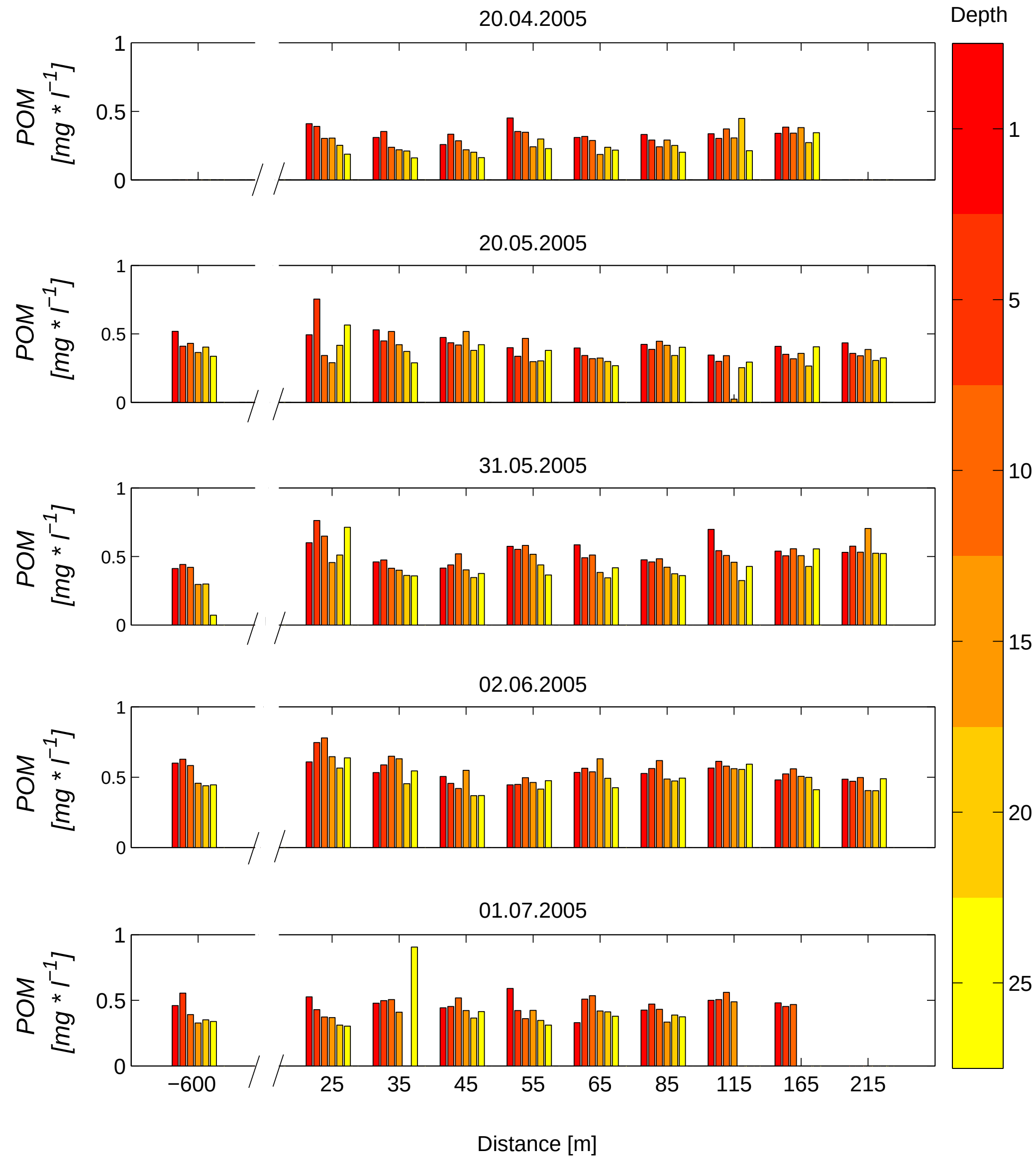


Fig. 25: *Spatial distributions of total particulate matter in six depth-layers. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. Each depth is marked by one specific color - the colorbar defines the depths in meter.*

3.4 *Fraction of organic matter*

The distribution of organic matter as percentage of the total particulate matter was characterized by a high variability within and between transects (Figs. 26 and 27). Before the fish were taken out of *cage 10*, the lowest values were as low as 45%, the highest almost reached 100%. At 5 m depth the average percentages ranged around 75% within a range of 70% to 82% downstream from *cage 10.* The sampling location upstream of the fish farm showed a slightly higher percentage of 85 % on average. At 15 m depth the average percentages ranged between 70% and 80% throughout the whole transect, thereby showing the highest value upstream of the fish farm and at the distances 165 m and 215 m downstream from *cage 10.* There was no clear correlation between organic matter in percent of total particulate matter and distance to *cage 10* at either depth.

Organic matter as a percentage of the total particulate matter was higher upstream of the fish farm than 25 m downstream from *cage 10* on all transects and both depths. There was no steady evolution in percentages visible in time, but while the percentages of organic matter fluctuated within the same range in April and May, the samplings on 01.06.2005 and 03.06.2005 revealed clearly elevated percentages of organic matter in relation to the earlier samplings.

At 5 m depth the samplings on 30.05.2005 showed an even distribution with very high values over 85% throughout nearly the whole transect with one exeption about 160 m downstream from *cage 10*, where the lowest percentage of organic matter of about 35% was found. On that day the values were much lower at 15 m depth, showing percentages of 50% to about 62% along the transect also with one exeption - a high value of over 90% was found 125 m downstream from *cage 10.*

The distribution of the percentage of organic matter along the transect on 30.06.2005 was characterized by extreme fluctuations at both depths. At 5 m depth the percentages of organic matter ranged around high levels of at least 78%, except 25 and 65 m downstream from *cage 10*, where lower percentages of about 70% and 55% were found. The percentages of organic matter at 15 m depth showed fluctuations from under 40% to over 90%.

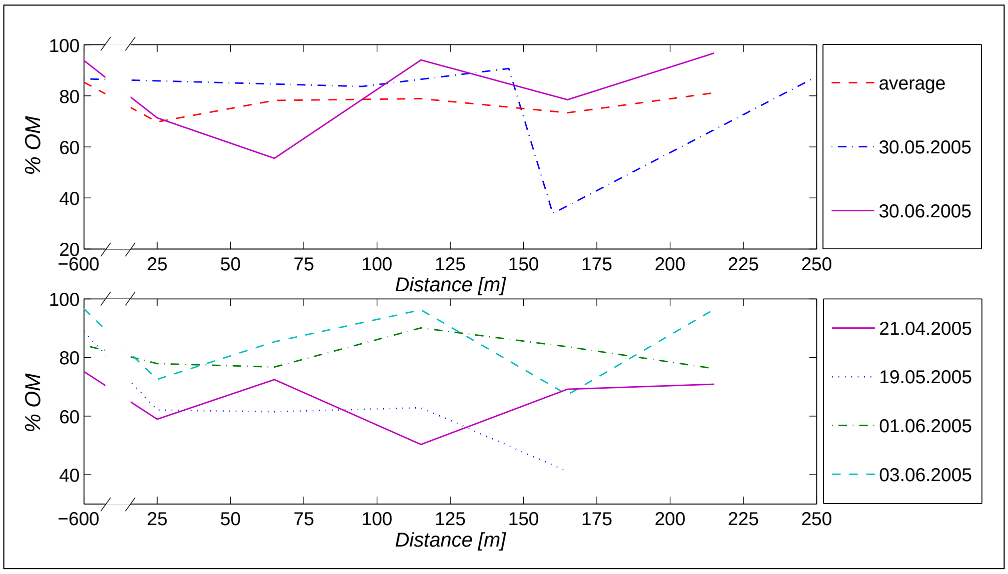


Fig. 26: *Spatial distribution of the percentage of organic matter within the total particulate matter in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

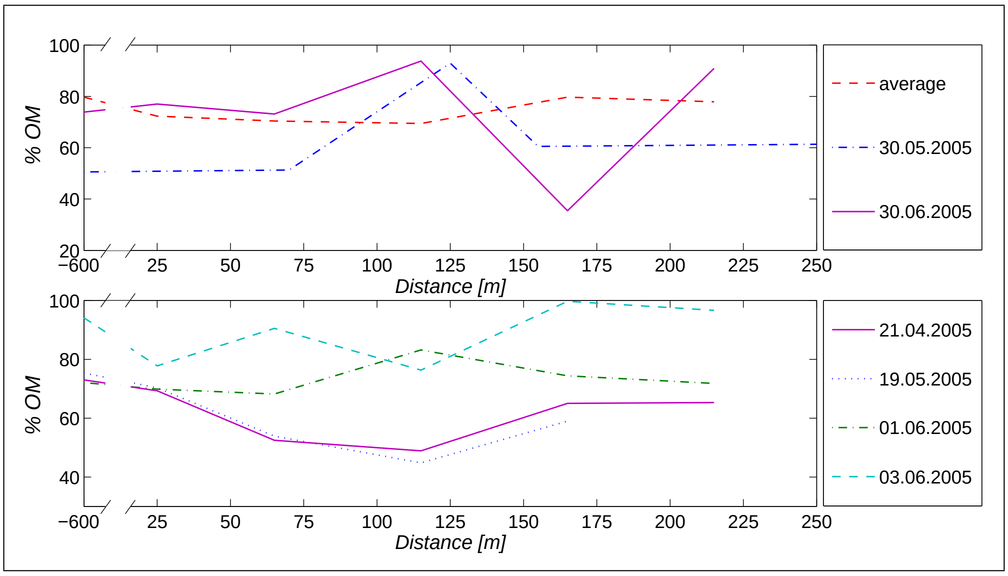


Fig. 27: *Spatial distribution of the percentage of organic matter within the total particulate matter in 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.5 *Particles*

The number of particles between 0 and 120 μm per liter, averaged over the six sampling depths and averaged over the sampling stations, downstream from *cage 10* at *Jektholmen* steadily increased about 400% from 20.04.2005 to the 02.06.2005, as shown in Fig. 28 and Table 4. In total numbers, that means an increase from $0.35 \cdot 10^6$ particles $\cdot\, l^{-1}$ to $1.4 \cdot 14^6$ particles $\cdot\, l^{-1}$ within about six weeks. After the fish in *cage 10* were slaughtered in mid of June, the number of particles decreased to less than 60% of the numbers at the beginning of June.

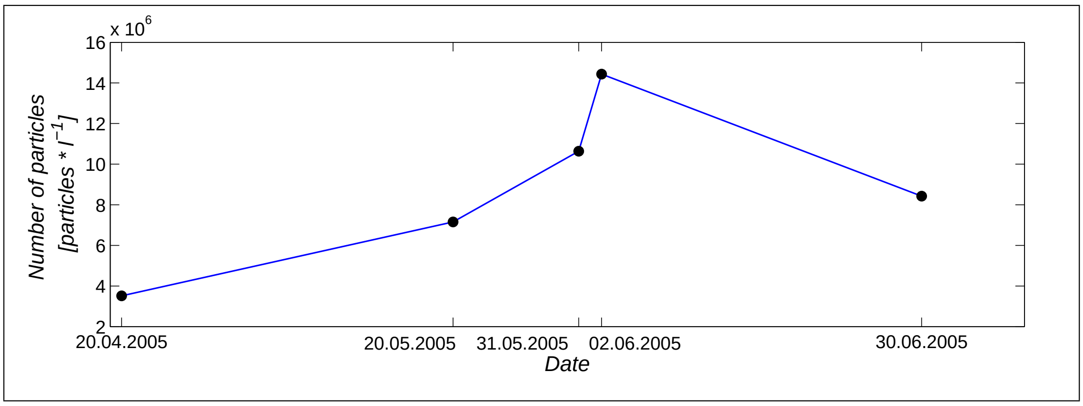


Fig. 28: *Temporal distribution of average particle numbers between 25 m and 215 m downstream from cage 10 at the Jektholmen farm from 20.04.2005 to 30.06.2005. The numbers represent averages over six depths from 1 m to 25 m.*

Table 4: *Overview over decreases/increases of particle densities with distance to cage 10 at the Jektholmen farm and average particle densities.*

	Slope of Regression line	Average number of particles per station [particles $\cdot\, l^{-1}$]
20.04.2005	$1e + 005 \cdot x$	$3.5e + 007$
20.05.2005	$-4.9e + 003 \cdot x$	$7.1e + 007$
31.05.2005	$-1.2e + 004 \cdot x$	$10.6e + 007$
02.06.2005	$1.8e + 004 \cdot x$	$14.4e + 007$
30.06.2005	$3.9e + 004 \cdot x$	$8.4e + 007$
Average	$2.5e + 002 \cdot x$	$10.7e + 007$

As Fig 29 shows, the lowest particle densities at one sampling location was found on 21.04.2005 with about $0.3 \cdot 10^7$ particles $\cdot\, l^{-1}$ and the highest number was found on 02.06.2005 with about $1.85 \cdot 10^7$ particles $\cdot\, l^{-1}$. There was some variability visible within the transects, which was most distinct on 31.05.2005. A linear regression revealed no consistent behaviour regarding an increase or decrease of particle numbers with distance downstream from the fish farm. In fact, both of these developments were registered twice before 30.06.2005. The average distribution showed a very slight increase of particles with distance downstream (Table 4), but it also showed higher particle densities from 25 m to 65 m, than between 85 m and 165 m downstream. The distribution of particle densities on 30.06.2005 revealed an increase with increasing distance downstream from the fish farm.

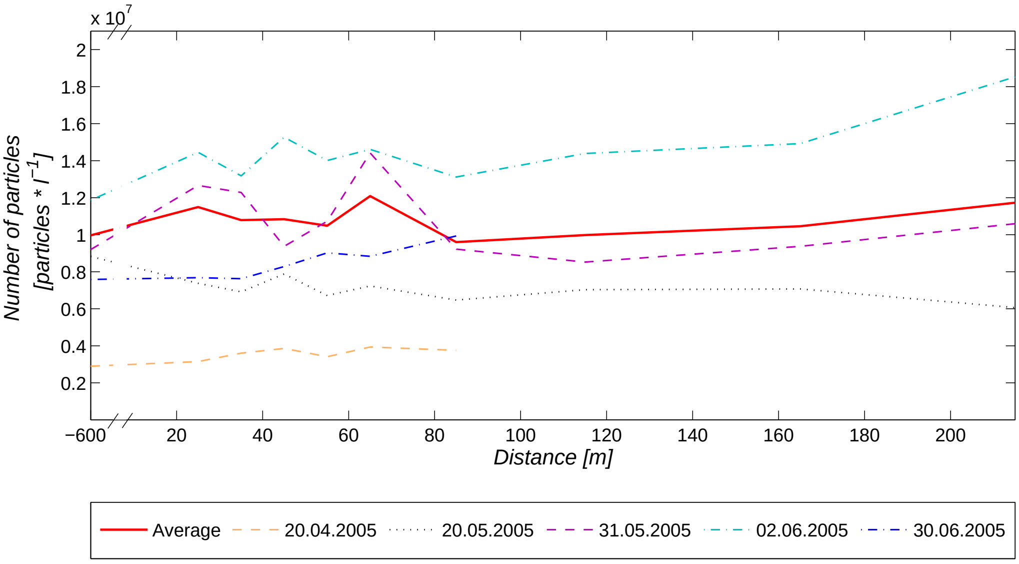


Fig. 29: *Spatial distribution of the number of particles, averaged over six layers from one meter to 25 m depth. Distance marks the distance downstream from the middle of cage 10 at the Atlantic salmon fish farm Jektholmen. The data set labelled average is calculated from the results from 20.05.2005, 31.05.2005 and 02.06.2005.*

Fig. 30 shows the particles densities split up into discrete size-classes with an amplitude of 2 μm each at six different depths per sampling station. The highest numbers of particles were found within the first ten meters depth at almost every station. There was only one common pattern visible. An overall decrease of particle densities with increasing depth at every station except two (02.06.2005: 215 m distance, 30.06.2005: 85 m distance). Apart from the upper water layers containing more particles, than the deeper layers, the particle distribution within the first 25 m depth was highly variable. Still, one given pattern did not undergo extreme changes from one sampling station to the next within one transect, so neighbouring sampling stations could be considered to have a similar distribution of particle numbers over the first 25 m depth. This observation was not only true for the total numbers, but also for the numbers within the different size classes of particles. There was no obvious shift in the size composition with distance from *cage 10*. In fact, the distribution of size classes in one depth nearly stayed the same throughout the whole transect on all sampling days, meaning there was no evidence that e.g. bigger particles can be found in smaller numbers at the upper and in higher numbers at the deeper water layers within the first 200 m distance from the farm. More than that, the highest number of particles within one size class always was found for the class from 4-6 μm, followed by the classes from 2-4 μm and from 6-8 μm.

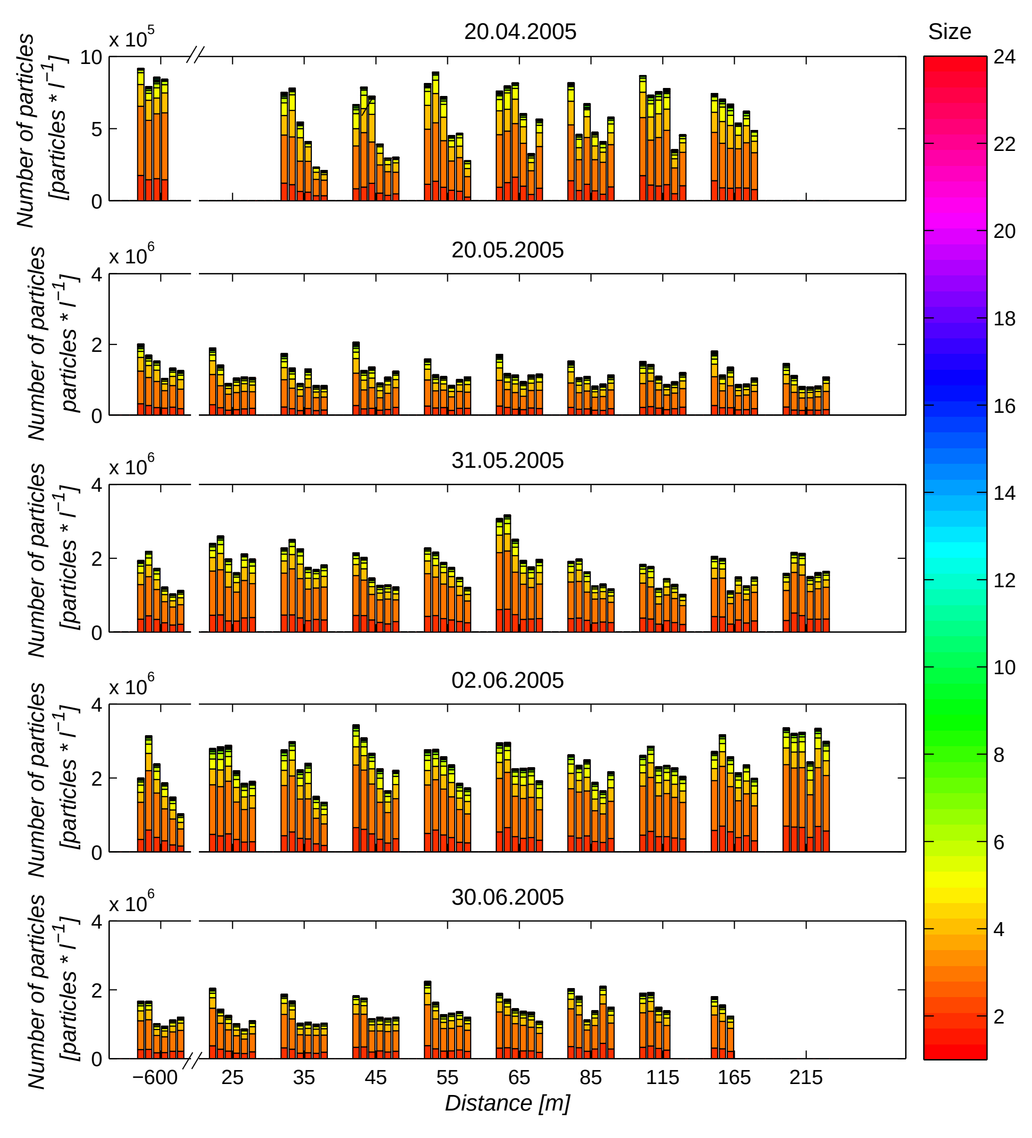


Fig. 30: *Spacial distribution of particle densities along transects on 5 different days. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. Each group shows particle densities in up to six different depths - 1 meter, 5 m, 10 m, 15 m, 20 m and 25 m (from left to right). The particle numbers are grouped in size classes, that are defined by the colorbar.*

3.6 *Phytoplankton*

On 20.05.2005 a higher concentration of phytoplankton cells was found at 5 m and 15 m depth upstream of the Atlantic salmon fish farm *Jektholmen* in relation to concentrations found on 30.05.2005 (Table 5). The difference was only marginal at 5 m depth, but the total number of phytoplankton cells per liter in the deeper layer was elevated by a factor of 1.5 on 20.05.2005. The concentration 80 m downstream from *cage 10* on 30.05.2005 almost matched the mean of the concentrations 25 m and 215 m downstream on 20.05.2005 at 15 m depth, but was about 5 times higher than at 25 m distance to *cage 10* and about three times higher than the average of the concentrations at 25 m and 215 m distance from *cage 10* on 20.05.2005 at 5 m depth. The concentrations of phytoplankton found 250 m downstream from *cage 10* on 30.05.2005 exceeded the concentrations 215 m downstream on 20.05.2005 by 50% (5 m depth) and 200% (15 m depth) respectively. The main part of phytoplankton consisted of diatoms on 20.05.2005, while on 30.05.2005 flagellates contributed the main part.

Almost no phytoplankton cells were found on 30.05.2005 25 m downstream from *cage 10* at 15 m depth, while its concentration increased about 50% in relation to the concentration on 20.05.2005 in the same depth. 215 m downstream from *cage 10* the concentrations at both depths were slightly lower on 30.06.2005 than on 20.05.2005. Overall, there was no clear decrease of phytoplankton after the fish were taken out of *cage 10*. The main part of phytoplankton consisted of diatoms at 5 m depth, while both, diatoms and flagellates contributed about half of the total numbers of phytoplankton per liter each on 30.06.2005.

Table 5: *Overview over the phytoplankton abundances on three different days at the fish farm Jektholmen. Samplings were conducted in two depths. Upstream marks samplings upstream of the fish farm, 25 m marks samplings in 25 m distance to cage 10 and 215 m marks samplings in 215 m distance to cage 10 downstream from the farm.*

20.05.2005 5m				
		upstream	25 m	215 m
Diatoms [cells $\cdot$ l^{-1}]		248583	62145	176625
Dinoflagellates [cells $\cdot$ l^{-1}]		6542	3271	5888
Other flagellates [cells $\cdot$ l^{-1}]		98125	13083	17663
20.05.2005 15m				
		upstream	25 m	215 m
Diatoms [cells $\cdot$ l^{-1}]		94854	42520	56912
Dinoflagellates [cells $\cdot$ l^{-1}]		22896	0	0
Other flagellates [cells $\cdot$ l^{-1}]		0	6542	25513
30.05.2005 5m				
		upstream	25 m	215 m
Diatoms [cells $\cdot$ l^{-1}]		25513	17663	35325
Dinoflagellates [cells $\cdot$ l^{-1}]		9813	5888	7850
Other flagellates [cells $\cdot$ l^{-1}]		290450	394463	227650
30.05.2005 15m				
		upstream	25 m	215 m
Diatoms [cells $\cdot$ l^{-1}]		32708	13738	9813
Dinoflagellates [cells $\cdot$ l^{-1}]		0	3925	11775
Other flagellates [cells $\cdot$ l^{-1}]		45792	43175	239425
30.06.2005 5m				
		upstream	25 m	215 m
Diatoms [cells $\cdot$ l^{-1}]			104667	109900
Dinoflagellates [cells $\cdot$ l^{-1}]			6542	3925
Other flagellates [cells $\cdot$ l^{-1}]			32708	47100
30.06.2005 15m				
		upstream	25 m	215 m
Diatoms [cells $\cdot$ l^{-1}]			1833	19625
Dinoflagellates [cells $\cdot$ l^{-1}]			167	0
Other flagellates [cells $\cdot$ l^{-1}]			2000	21588

3.7 *Chlorophyll a*

The concentrations of chlorophyll *a* ranged from 0.1 to 0.7 $\mu g \cdot l^{-1}$ at 5 m depth and from 0 to 0.8 $\mu g \cdot l^{-1}$ at 15 m depth on the sampling days between 21.04.2005 and 30.06.2005. In the upper layer there was a clear tendency for lower chlorophyll *a* concentrations 25 m downstream from *cage 10* than in greater distance, except for one day (19.05.2005). At 15 m depth exceptions from this tendency were found on two days (21.04.2005 and 19.05.2005), but still, the distribution of the average concentrations showed a clear increase of chlorophyll *a* from 25 m to 215 m downstream. The increase of chlorophyll *a* on the transects was more distinct in 5 m depth, but the average concentration of chlorophyll *a* was nearly 0.1 $\mu g \cdot l^{-1}$ lower than the concentration in 15 m depth. Higher values of chlorophyll *a* upstream of the fish farm than 25 m downstream from *cage 10* occurred as well as lower values on different days. On 30.05.2005 at both depths the concentrations of chlorophyll *a* 250 m downstream from *cage 10* were higher than those 25 m downstream. The difference in the concentrations was bigger at 5 meter depth.

After the fish were taken out of *cage 10*, the concentrations of chlorophyll *a* were clearly reduced in relation to the average concentration. At both depths the concentrations on 30.06.2005 were higher 215 m downstream from *cage 10*, than at 25 m downstream, as with the average concentrations, but were about 0.1 $\mu g \cdot l^{-1}$ lower than the average concentrations.

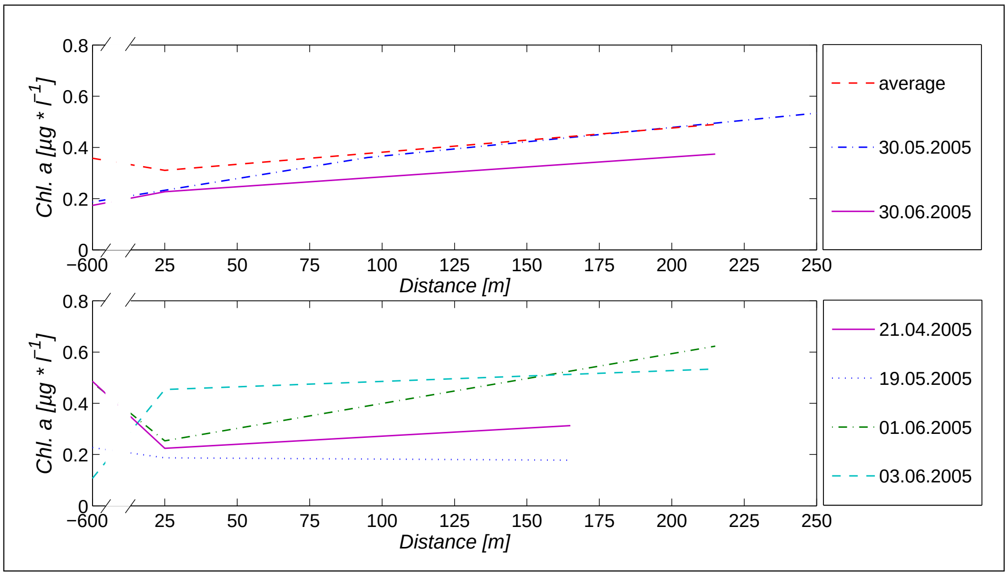


Fig. 31: *Spatial distribution of chlorophyll a concentrations in 5 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

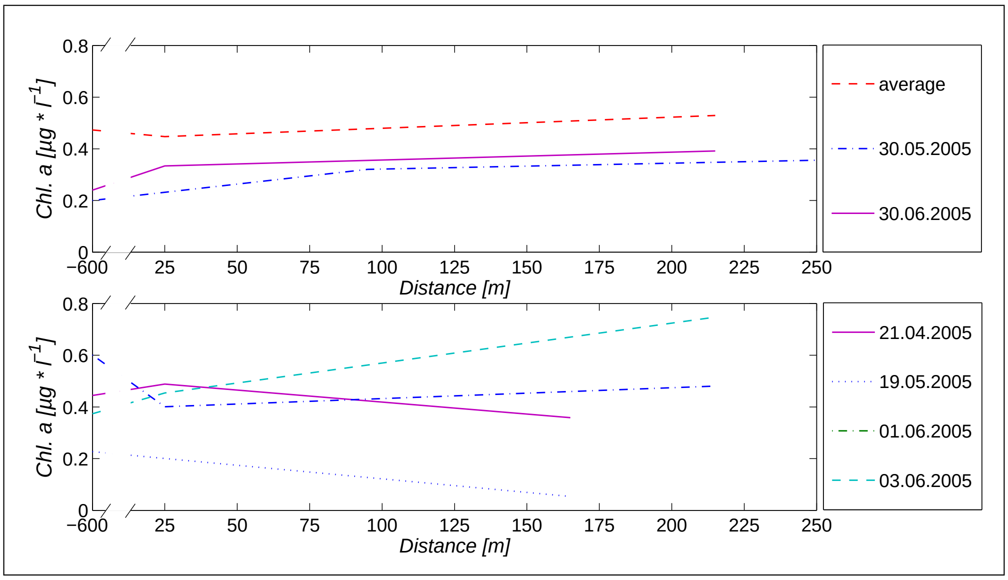


Fig. 32: *Spatial distribution of chlorophyll a concentrations in 15 m depth. Distance marks the distance downstream from the middle of cage 10 at the Jektholmen farm. The data set labelled average is calculated from the results displayed in the lower panel.*

3.8 *Current-measurements*

3.8.1 *Drifters*

The calculations from the drifter movements revealed a high variability of current velocities and directions at both 5 and 15 m depth (Figs. 33 and 34). At 5 m depth velocities from at least 1.2-8.5 cm $\cdot$ s^{-1} occurred, which is similar the results of measurements carried out by Havbrukstjenesten A/S from 25.09.2002 to 25.10.2002. The average velocity was found to be about 4.1 cm $\cdot$ s^{-1}, a value approximately 50% higher than from 25.09.2002 to 25.10.2002 (Havbrukstjenesten A/S). The velocities at 15 m depth, ranging from 1.4-8.5 cm $\cdot$ s^{-1} with an average of 4.8 cm $\cdot$ s^{-1}, showed similar results. The currents, on average, pointed mostly to the south, preferably to SSW at 15 m depth and towards south or ESE at 5 m depth. The variability in directions was much higher in the upper layer, while the current directions at 15 m depth lay within a sector of just over 90°, nine of ten observations at 5 m depth spanned over almost 140° and even a northward flowing current was found once.

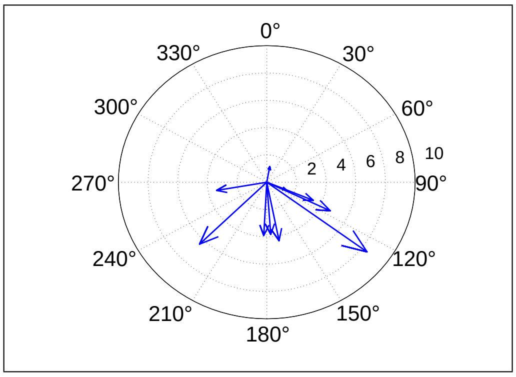


Fig. 33: *Average current velocities at 5 m depth on nine different days. The speed scale is in cm $\cdot$ s^{-1}. The data were acquired from drifter movements. 0° marks north, 90° points east.*

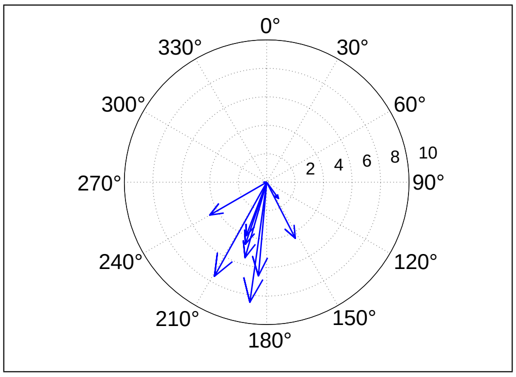


Fig. 34: *Average current-directions at 15 m depth on nine different days. The speed scale is in cm $\cdot$ s^{-1}. The data were acquired from drifter movements. 0° marks north, 90° points east.*

3.8.2 *Direct current measurements*

3.8.2.1 *Stationary measurements* The continuous measurements at one location at *Gjaesingen* revealed an extreme variability of current directions and speeds across different depths and, in deeper layers, even within one layer (Fig. 35). While the main flow pointed north or northwest within the upper two layers (3-7 m), the main direction pointed nearly westwards at depths from 7 m to 15 m. In the deeper water layers, the currents showed extreme changes in time and, especially in the deepest layer below 20 m depth, did not follow one main direction.

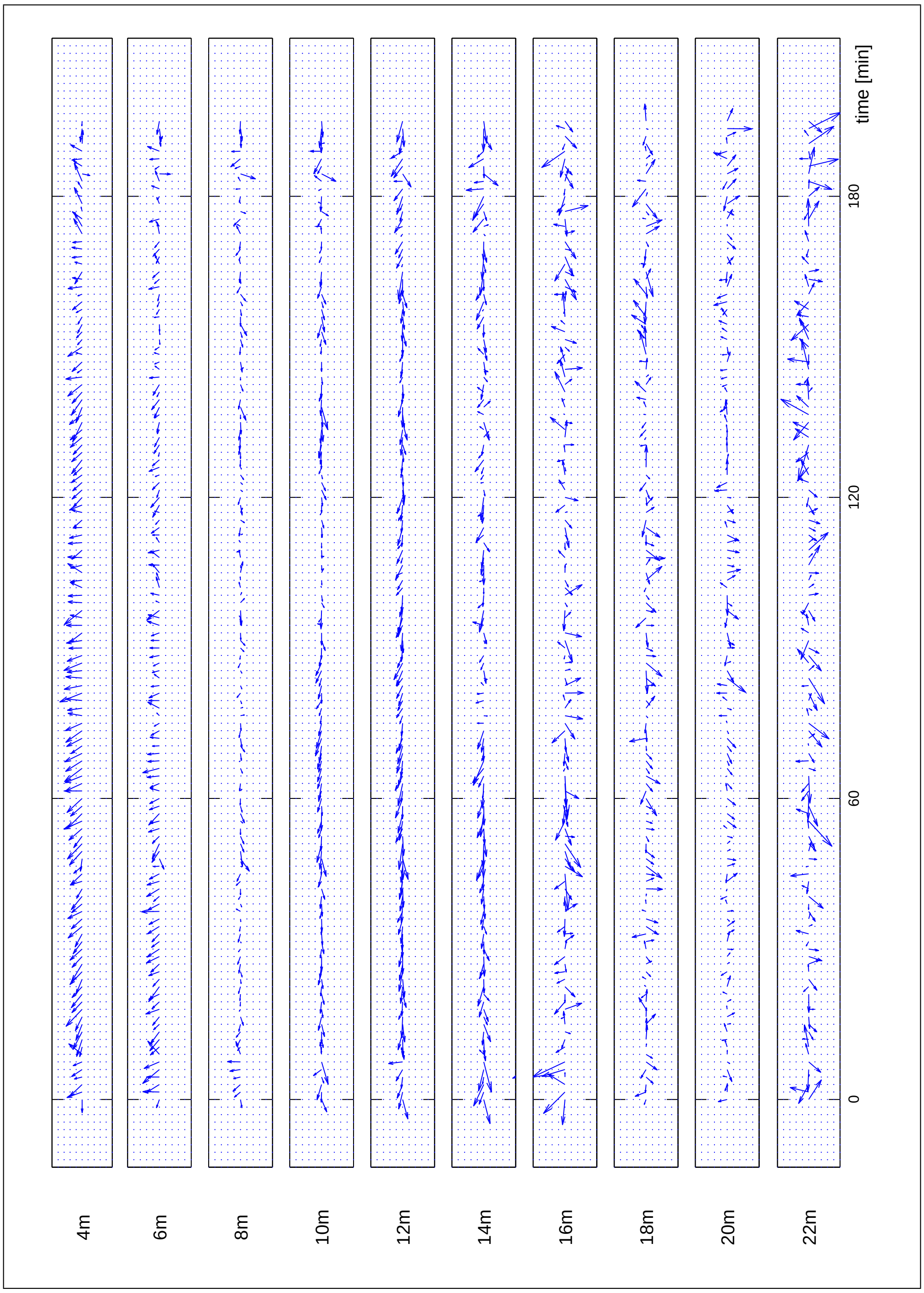


Fig. 35: *Time series of current measurements in ten depth layers at the Gjaesingen farm. The directions of the arrows indicate the direction of the currents, whereby up marks north and right marks east. The distance between two dots in the vertical and horizontal equals a velocity of 0.023* $m \cdot s^{-1}$ *(4-16 m depth), 0.046* $m \cdot s^{-1}$ *(18 m depth) and 0.092* $m \cdot s^{-1}$ *(20-22 m depth).*

While the current direction within the upper two layers was nearly stable over time, the total velocity fluctuated constantly. Figs. 36 and 37 show the total velocities in 4 m and 6 m depth. At both depths, fluctuations occurred within about the same range, 0.014-0.11 $m \cdot s^{-1}$ at 4 m depth and 0.003-0.1 $m \cdot s^{-1}$ at 6 m depth. The mean velocitiy throughout the time series was about 0.064 $m \cdot s^{-1}$ in 4 m depth, but variations on time scales of about 20 minutes were clearly visible. At 6 m depth, the mean velocity throughout the whole time-seris was 0.042 $m \cdot s^{-1}$. On average there was a decline in velocity from about 0.06 $m \cdot s^{-1}$ to approximately 0.03 $m \cdot s^{-1}$ within the first 150 minutes of the time-series, which was followed by a slight increase to about 0.04 $m \cdot s^{-1}$ during the next 45 minutes.

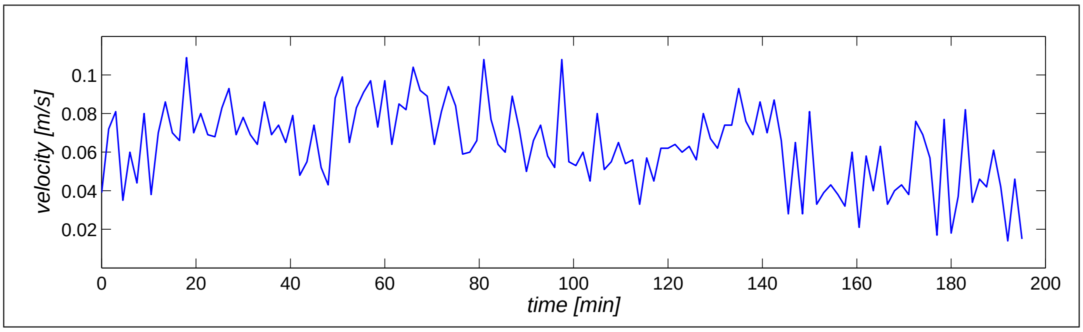


Fig. 36: *Time series of current speed at 4 m depth at the Gjaesingen fish farm.*

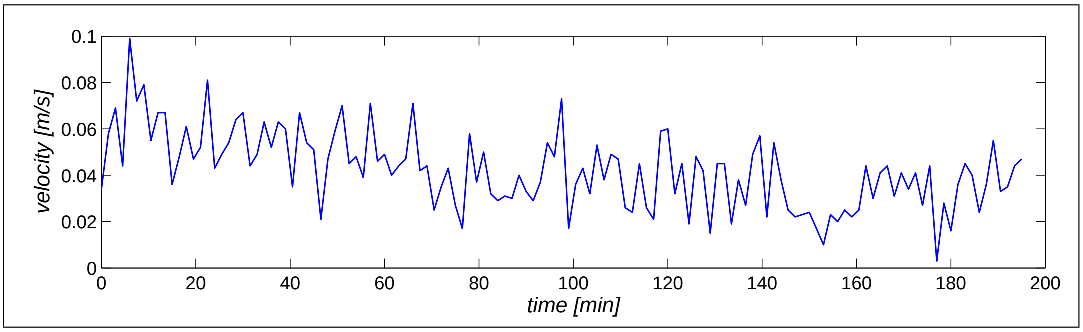


Fig. 37: *Time series of current speed at 6 m depth at the Gjaesingen fish farm.*

Figs. 38 and 39 show the current speeds and the average velocities in the main current direction of the 4 meter and the 6 m layer respectively. The small scale fluctuations were about as strong as within the time series of current speed, the standard deviations of the time series showed a difference of only 0.002 at 4 m depth and no difference at all at 6 m depth (Table 6). In any event, the mean of the time series of velocities in the main current direction was 2/3 of the mean current speed. In addition, there appeared to be a smoothening of the development of average velocities on time scales of a few tens of minutes within the time series of velocities in the main current direction. Small fluctuations around 0.05 m $\cdot$ s^{-1} and a distinct decrease nearly to a stop within the last 40 minutes were visible in 4 m depth, but they were clearly not as strong as the fluctuations of the average of the total speed on the same time scales. At 6 m depth, a constant decrease in average velocity occurred from approximately 0.045 m $\cdot$ s^{-1} to about 0.005 m $\cdot$ s^{-1}.

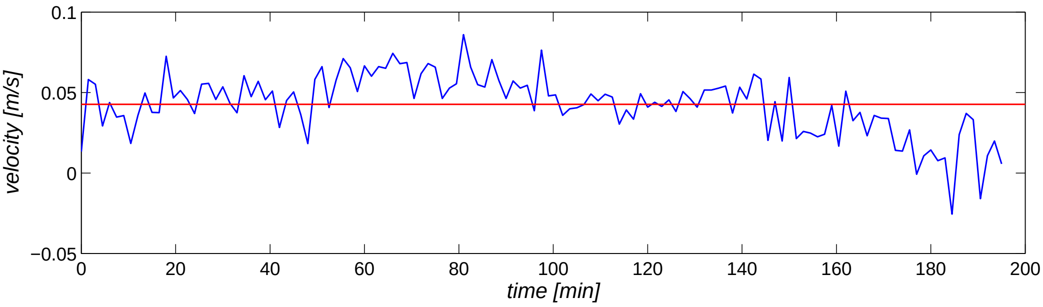


Fig. 38: *Time series of velocities in the main current direction at 4 m depth at the Gjaesingen farm.*

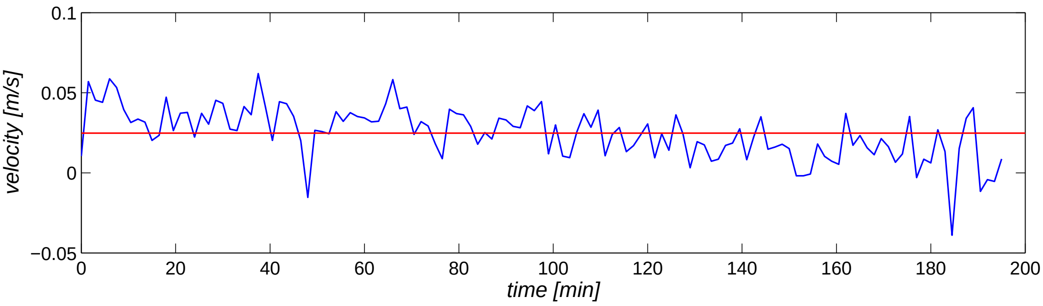


Fig. 39: *Time series of velocities in the main current direction at 6 m depth at the Gjaesingen farm.*

Lillifor's Test on the deviations of the velocities from the average velocity was not significant at 5% level for either, the 4 m and the 6 m layers (Table 6). Thus the deviations can be claimed to be normally distributed.

Table 6: *Overview over mean speeds, deviations from mean velocities and the h-value from the Lilliefor's test, performed on the deviations from the mean velocities. h = 0 means the hypothesis of a normal distribution can not be rejected.*

	mean $[\mathrm{m} \cdot \mathrm{s}^{-1}]$	σ	h
timeseries: velocity (4m)	0.064	0.021	
timeseries: velocity (6m)	0.042	0.016	
timeseries: velocity* (4m)	0.043	0.019	
timeseries: velocity* (6m)	0.025	0.016	
deviations from mean of velocity* (4m)			0
deviations from mean of velocity* (6m)			0

Within the measurements taken at *Gjaesingen*, three consistent patterns occurred at both, 4 m and 6 m depths. Additionally, one other phenomenon appeared two times within three hours at 6 m depth. All of these structures are shown magnified from the time series in Figs. 40 and 41. While the current direction was pointing north-north west almost throughout the whole time series in 4 m as well as in 6 m depth, a triplet of measurements occurred simultaneously at both depths twice, containing the direction sequence NW - NNW - NE (event 1). These sequences were found between six and nine minutes and between 142.5 and 145.5 minutes (Figs. 40 and 41). Almost in the middle between these sequences, another event was found (event 2). This event also was a triplet of measurements and showed the following sequence: NE - N - NW. This sequence, as the first one, was found both at 4m and 6 m depth and occurred simultaneously from 78 minutes to 81 minutes.

Furthermore an extreme deflection from the average current direction was noticed 40.5 minutes after the appearance of event 1 (Fig. 41). This phenomenon was more distinct at 6 m depth after the first appearance of event 1 (48 minutes), but it was clearly visible at both depths at 184.5 minutes, 40.5 minutes after the second appearance of event 1.

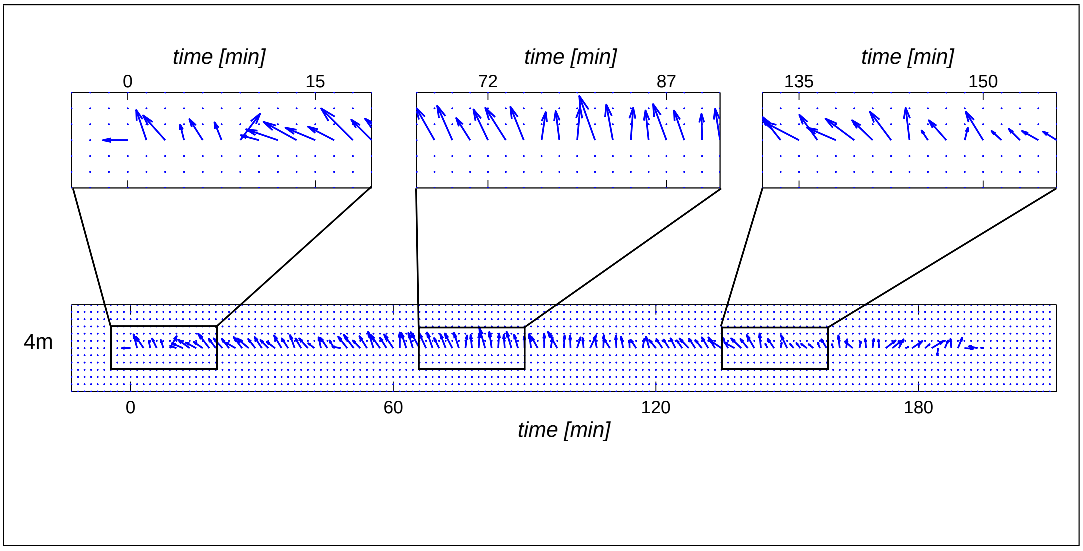


Fig. 40: *Zoom on three events within the current-measurements at the Gjaesingen farm at 4 m depth.*

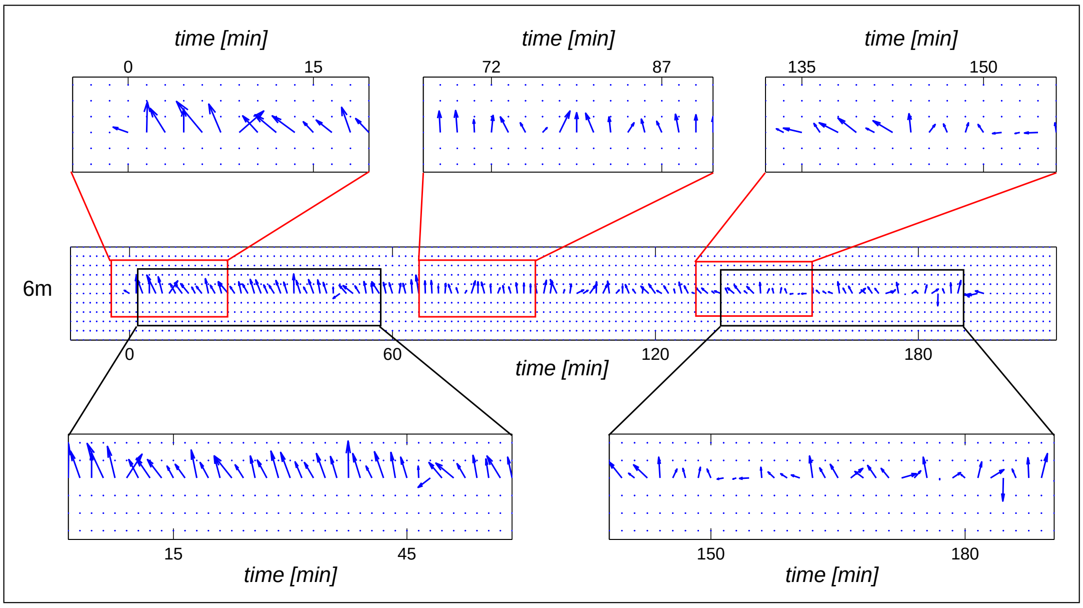


Fig. 41: *Zoom on three events (upper panel) and two extreme deflections from the average direction 40.5 minutes after two of the events (lower panel) within the current measurements at 6 m depth at the Gjaesingen farm.*

3.8.2.2 *Measurements around a net cage* Fig. 42 displays the current directions and speeds around *cage 10* at eight locations around the cage in ten different depth layers. It shows very clearly, that there was a high degree of variability in current direction and speed between different depths and locations. The measurements in the 4 m layer revealed no consistent main current direction, while one distinct main direction is visible within most of the deeper layers. This main direction preferably pointed northwards above 15 m depth and westwards in the deeper layers, whereby there was some westward pointing movement in the 6 m and t10 m layer. The velocities were clearly higher to the west of *cage 10* from 6 m depth downwards with an exception in about 14 m depth, where the velocities were found to be lowest to the east and south of the cage. Furthermore currents pointing clearly into the fish cage were very rare throughout the whole water column down to 23 m depth.

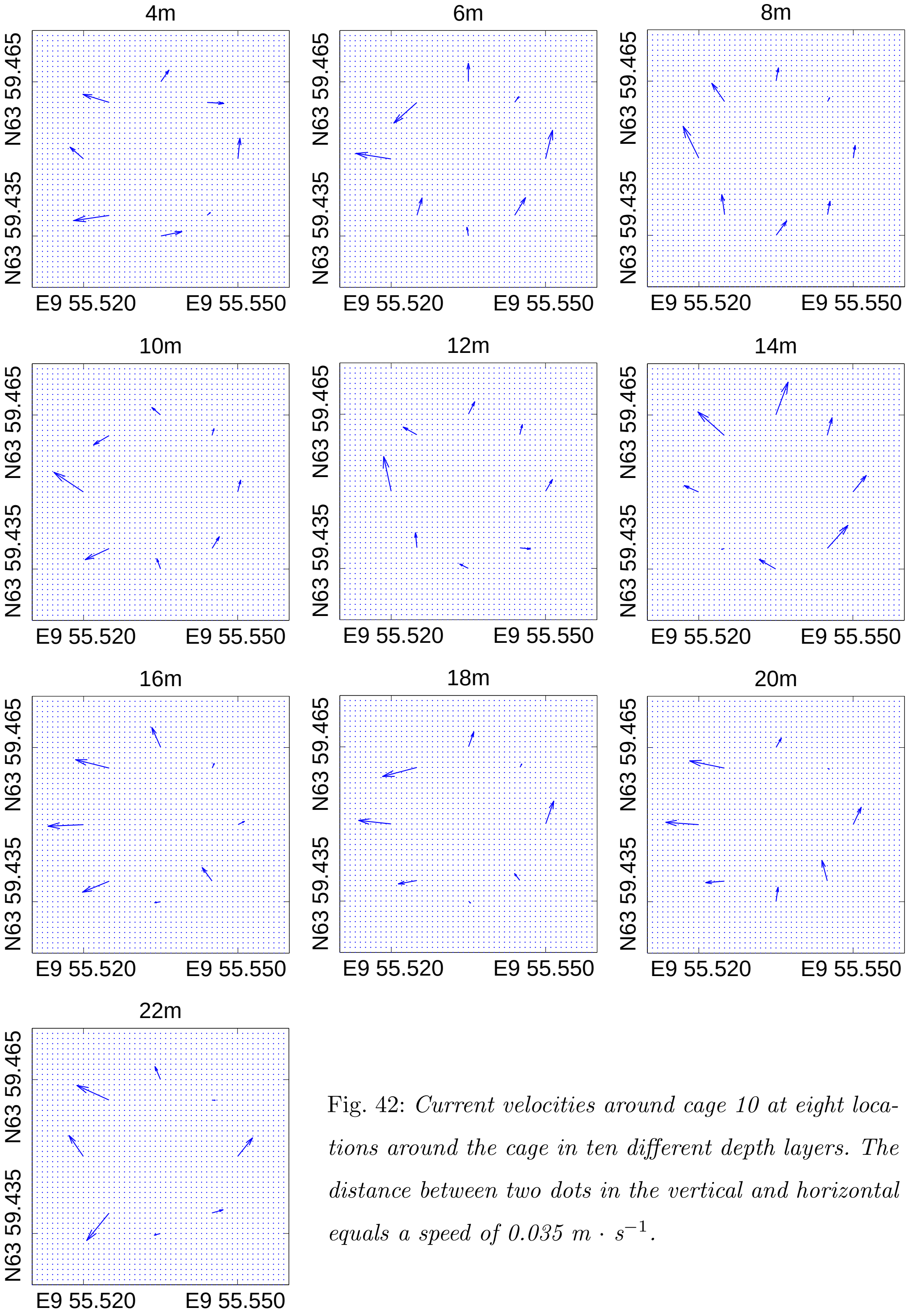


Fig. 42: *Current velocities around cage 10 at eight locations around the cage in ten different depth layers. The distance between two dots in the vertical and horizontal equals a speed of 0.035* $m \cdot s^{-1}$.

The measurements around the fish cage were used to calculate the average horizontal velocity pointing directly into the center of the cage or out of the cage. The connection between depth and the horizontal outflow from the cage is displayed in Fig. 43, which also shows the dimensions of *cage 10* in scale with the velocity plot for reference.

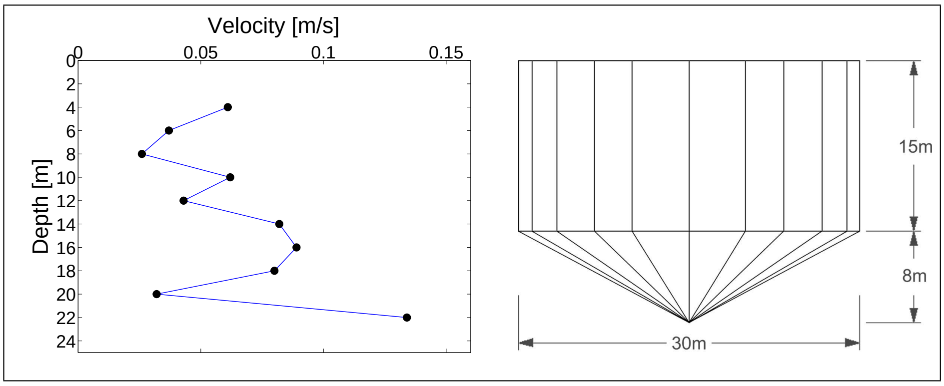


Fig. 43: *Depth dependence of the average velocity out of cage 10 at Jektholmen farm. The scheme in the right panel shows the dimensions of cage 10 in scale with the plot in the left panel.*

The information about the average horizontal velocities also is shown in Table 7, which in addition contains information about the corresponding divergences and the volume outflows over time in the different depth layers. There was a large variability between the layers, but on average there was an outflow of water in all depths. The velocities ranged from a minimum of 0.026 $\mathrm{m \cdot s^{-1}}$ in the 8 m layer to a maximum of 0.134 $\mathrm{m \cdot s^{-1}}$ in the 22 m layer. The divergence and volume flows ranged from 0.007-0.036 $\mathrm{s^{-1}}$ to 290-1510 $\mathrm{m^3 \cdot min^{-1}}$ respectively. Apart from the maximum in the deepest layer, there was a section from 14 m to 18 m depth, which clearly showed elevated values in relation to the other depths. This section also marks the transition of the form of the fish cage from cylindrical to conical.

Table 7: *Overview over the average velocity out of cage 10, the divergence and the corresponding outflow in ten depth layers around cage 10 at the Jektholmen fish farm. The volume flux is the total outflow through a cylinder with a diameter of 30 m and a hight of two meters.*

	average velocity $[\mathrm{m} \cdot \mathrm{s}^{-1}]$	divergence $[\mathrm{s}^{-1}]$	volume $[\mathrm{m}^3 \cdot \mathrm{min}^{-1}]$
4m	0.061	0.016	680
6m	0.037	0.01	420
8m	0.026	0.007	290
10m	0.062	0.017	700
12m	0.043	0.011	480
14m	0.082	0.022	920
16m	0.089	0.023	990
18m	0.08	0.021	900
20m	0.032	0.008	360
22m	0.134	0.036	1510

The measurements about 300 m north-west of the fish farm revealed a current in direction south-east.

3.9 *CTD-measurements*

Salinity and temperature showed exactly the same depth profile on 16.06.2005 and 30.06.2005 (Figs. 45 and 46). The temperature steadily decreased from nearly 12 °C at the surface to under nine °C in approximately 34 m depth. The salinity in contrast steadily increased from about 31.5 ‰to circa 33.5 ‰from the surface to about 34 m depth. On both days the change in salinity and temperature was fasted between 5 and 10 m depth. At the very surface the temperature was elevated by about one °C in comparison to the value in on meter depth, while the salinity was reduced by about 0.5 ‰.

On 21.04.2005 in contrast, on the surface the temperature and salinity on the surface were about 0.3 °C lower and approximately 0.3 ‰higher, respectively, than in about one meter depth (Fig. 44). There was a slight increase of salinity from about 34.25 ‰in circa one meter depth to approximately 34.65 ‰in over 40 m depth.

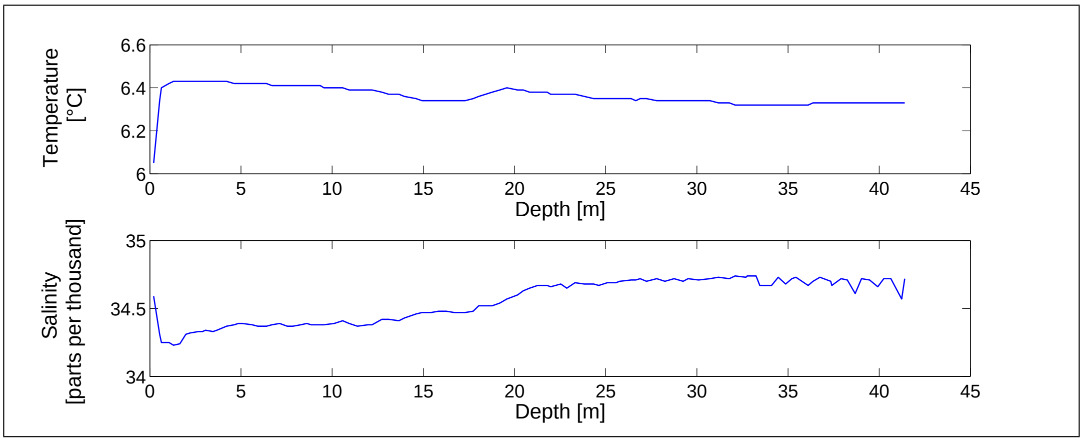


Fig. 44: *Dependence of salinity and temperature on depth at the Atlantic salmon fish farm Jektholmen on 21.04.2005.*

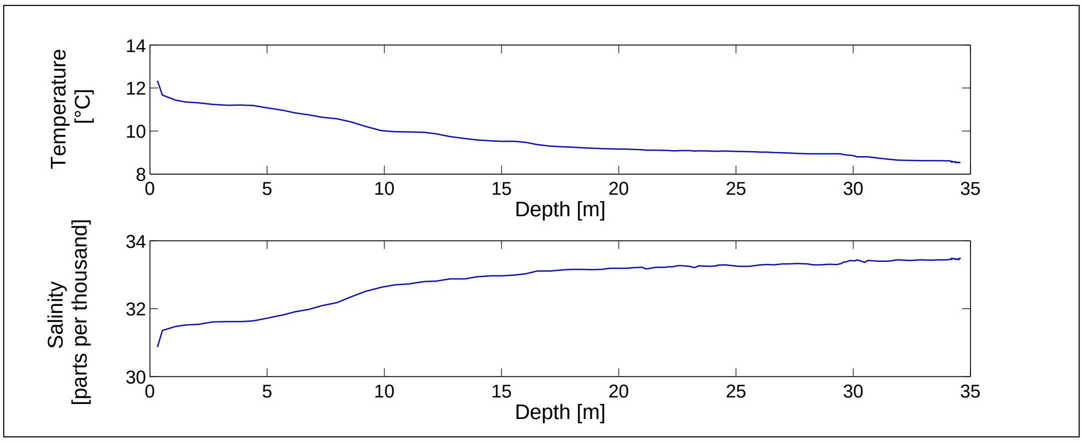


Fig. 45: *Dependence of salinity and temperature on depth at the Atlantic salmon fish farm Jektholmen on 16.06.2005.*

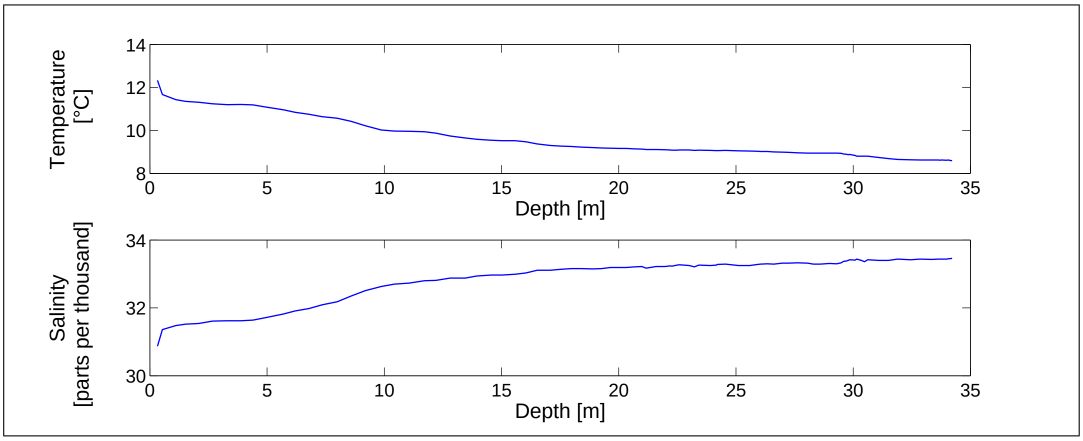


Fig. 46: *Dependence of salinity and temperature on depth at the Atlantic salmon fish farm Jektholmen on 30.06.2005.*

4 Discussion

4.1 *Nutrients*

The ammonia-N concentrations at the fish farm *Jektholmen* ranged around 15 μg $\cdot$ l^{-1}, which is conform to slightly under 1 μM. In a similar study, Kelly *et al.* (2005) found higher levels of up to 3.5 μM ammonia, which conforms to about 2.7 μM ammonia-N extending more than 50 m from a fish farm group. The findings of the present study showed ammonia-N to account for about 95% of the dissolved inorganic nitrogen. The amount of nitrogen loss to the environment in open water aquaculture and particularly in salmon farming was suggested to be about 70-80% of the nitrogen supplied with the feed (Troell et *al.*, 2003; Kelly et *al.*, 2005). About 75-80% of the nitrate loss is in dissolved form (Islam, 2005; Davis et *al.*; 2005). Fivelstad et *al.* (1990) found ammonia to account for 61-67% and urea for up to 10% of the total nitrogen excreted by salmonids. Taking these findings into account, ammonia is expected contribute well over 90% to the dissolved inorganic nitrate, which aligns with the findings of this study. Bergheim et *al.* (1991) did study the diurnal ammonia excretion rhythm of salmonids. He found an excretion peak several hours after the feeding had ceased and relatively low excretion rates between the early morning hours and noon. This means, the ammonia concentrations found in the present study represent the lower limit of diurnal variations. According to Bergheim *et al.* (1991), the release of ammonia from the fish cages can be expected to be about 1.5 times the concentrations found in this study.

The nitrate-N discharge from the *Jektholmen* farm is supposed to be about 5% of dissolved inorganic nitrogen. Assuming the background concentration to match the concentrations found by Jacobsen et *al.* (1995) at the Norwegian coast, the nitrate-N concentrations downstream of the farm should range around 1.5-1.75 μg $\cdot$ l^{-1}. On average, the nitrate-N concentrations found during this study ranged slightly over 1.0 μg $\cdot$ l^{-1} in 5 and 15 m depth and thus can be considered very low. Furthermore it needs to be taken into account, that the sampling on 20.04.2005 revealed much higher concentrations of up to 4 μg $\cdot$ l^{-1} and thus the nitrate-N concentrations mostly were by far lower than 1.0 μg $\cdot$ l^{-1}. The nitrate concentrations on 30.06.2005, after *cage 10* was emptied, were under the average concentrations, but were not the lowest concentrations found during this study. Distinct fluctuations along the transects were found, which would not be expected for high background concentrations and a small additional input. Thus, at least one major source of nitrate is suggested. The fact that the nitrate concentrations did not decrease significantly after all fish was taken out of *cage 10* might point to a very small dilution of water leaving the remaining two fish cages within the first 250 m or to the existence of a second source of nitrate.

The average concentrations of dissolved inorganic phosphate in 5 m depth found during this study (about 0.1 $\mu g \cdot l^{-1}$) match well with the results from Jacobsen *et al.* (1995), before and after the fish was taken out of *cage 10.* The concentrations of dissolved inorganic phosphate were slightly higher in 15 m depth, than in 5 m depth, but, in contrast to the ammonia-, nitrate- and nitrite-distributions, did not vary much along the transects and upstream of the fish farm at both, 5 and 15 m depth. Taking these findings into account, it can be suggested that the *Jektholmen* farm did not have a strong effect on the concentration of dissolved inorganic phosphate in the near surrounding. It is not clear, whether the difference in concentrations between the two depths is due to a small non-uniform discharge of dissolved inorganic phosphate from the fish farm - possibly because the density of fish there might usually be higher than in 5 m depth - or if it is caused by consumption within the first few m from the surface.

Total phosphate was evenly distributed throughout the transects on most sampling days, showing no extreme variations between samplings. The sampling on 30.06.2005, after *cage 10* was emptied, revealed elevated concentrations of total phosphate - about 200% in relation to all prior samplings (Figs. 16 and 17). This gives rise to the assumption that there might be a source of phosphate other than the fish farm. Conceivably, currents under certain conditions might push through the islands west of *Jektholmen*, thereby taking up sediment and organic material and carry that load in direction of the fish farm and its surrounding. This scenario is supported by the fact, that the area west of the fish farm is overgrown by seaweed, which will results in a sediment rich of organic components and would also explain the nitrate concentrations on 30.06.2005 not to be significantly lower than on the prior sampling days. Furthermore a current-measurement about 300 m north-west of the fish farm on 16.06.2005 showing a current pointing south-east. There is even more indication for some source of material and especially organic matter influencing the composition of the water south of the fish farm *Jektholmen* - neither did the total particulate matter categorical decrease with distance downstream from the fish farm as supposed, when the only source is a fish farm (Brown et *al.*, 1987; Cheshuk et *al.*, 2003), nor did the percentage of organic matter within the total particulate matter.

The concentrations of total phosphate-P ranged around 0.3 $\mu g \cdot l^{-1}$. Olsen et *al.* (2005) stated the nutrient emmission from a typical Norwegian salmon fish farm to be 119 kg inorganic N and 19 kg inorganic P. This gives a weight ratio of about 6.2/1 (N/P), which conforms to an atomic ratio of 13.7/1. This is close to the N/P ratio of the Redfield ratio. The N/P ratio found in this study was found to be much higher and therefore indicate phosphate to be the limiting factor for algal growth. With average dissolved inorganic nitrogen concentrations found to range around 15-20 $\mu g \cdot l^{-1}$, the total phosphate concentrations were expected to range around at least 1-1.4 $\mu g \cdot l^{-1}$. In fact the concentrations should be even higher, because in this study only dissolved nitrogen was measured and the concentrations of total phosphate also include organic phosphate.

The samplings on 20.04.2005 did reveal a series of irregularities, namely significantly elevated concentrations of nitrate, nitrite and dissolved phosphate in relation to the other samplings, while no significant difference occurred in the ammonia concentrations. The average current direction calculated from drifter movements did differ significantly from the findings on the other sampling days in 5 m, but not in 15 m depth. As the irregularities did occur at both depths, it is not clear what might have caused the increased concentrations.

4.2 *Particles, phytoplankton and chlorophyll a*

The average number of particles per sampling location and depth was found to increase about 400% from 20.04.2005 to 02.06.2005, while the total particulate matter did not show any increase over time. This means, that the weight per particle decreased with time. Thus, there was a change in particle composition, that also was visible in an increase of the fraction of organic matter of the total particulate matter from 20.04.2005 to 02.06.2005. These observations are consistent, as organic material generally is lighter than inorganic matter.

The increase in average particle numbers is in line with the phytoplankton concentrations being higher on 30.05.2005, than on 20.05.2005. The increase of the fraction of organic matter is consistent with the deferral of the composition of phytoplankton in favor of small flagellates. In fact, the change of the fraction of organic matter might have caused the shift in the phytoplankton composition. This finding again explains, why the chlorophyll *a* concentration did not increase together with the total phytoplankton density, as different phytoplankton species have different average chlorophyll *a* contents.

Lower concentrations of particle numbers, total and organic particulate matter were found throughout the whole transect on 30.06.2005 in relation to the prior samplings. This clearly indicates the influence of the fish farm on these measures. It is consensus, that particulate waste emerging from fish farms rarely increases the ambient concentrations of particulate matter significantly in distances greater than 50-60 m to fish cages (Cheshuk *et al.*, 2003; Brown *et al.*, 1987; Gowen and Bradbury, 1987; Findlay *et al.*,1995). *Cage 12* was about 80 m upstream of the first sampling position on the transect, which means, that the sampling in 25 m distance to *cage 10* on 30.06.2005 should have shown about the same results as the samplings in 80 m distance on the previous sampling. This was not the case, which gives rise to the question, whether the discharge the fish farm did lead to an elevation of particle densities throughout the whole transect. This question can not be answered with the available information, but an influence to over 200 m distance still seems unlikely. There was a strong increase in particle numbers between the sampling days until 02.06.2005 and it might have been followed by a decrease in June, even without a clearance of *cage 10*.

There seems to be an influence of the fish farm on the phytoplankton density, as fewer phytoplankton were found after the fish were taken out of *cage 10*. The chlorophyll *a* concentration was higher at 215 m, than at 25 m downstream from the fish farm, but it is not clear how that can be explained. This might be connected to the nutrient discharge from the fish farm, to zooplankton dynamics and a higher grazing rate close to *cage 10*, or to other influences at greater distances from the *Jektholmen* fish farm. The particle density, total particulate matter, particulate organic matter, the fraction of organic matter and phytoplankton densities did not show a consistent distribution along the transects, but the highest concentrations of total particulate matter and particulate organic matter were found at the sampling location closest to *cage 10*, which might indicate that some heavy particles, rich in organic matter, might have fallen to depths under 25 m within the first 35 m distance to the fish cage.

The highest densities of particles, as well as the highest concentrations of total particulate matter and particulate organic matter per sampling depth were found mostly within the upper 10 m. This might be connected to the observation of rapid temperature and salinity changes between 5 and ten m depth, but as there was no distinct discontinuity layer visible, there may well be another explanation.

The concentrations of particulate organic matter found in the present study are about 5 times lower than the concentrations found by Cheshuk et *al.* (2003) in a similar study. The concentrations of total particulate matter were even 10 times lower. These findings are consistent, since the fraction of organic matter found by Cheshuk et *al.* (2003) was about 2 times lower than the fraction of organic matter found in this study. The concentrations of chlorophyll *a* found by Cheshuk et *al.* (2003) exceeded the concentrations found in this study by factors of 2-5.

4.3 *Currents*

The small scale turbulence within the time series of current measurements at the Gjaesingen fish farm was found have a normal distribution. The small scale velocity fluctuations can therefore be considered random and explain the patchiness in diluted substances and suspended material found in this study to some degree. It seems, however, highly unlikely that turbulent fluctuations on small scales cause as distinct peak values as those found in this study (Figs. 6, 7, 20, 26 and 27). The strong fluctuations can rather be explained by the existence of larger structures with longer periods. Those could be swirls or eddies, which are known to occur behind obstacles under certain circumstances (Williamson, 1996). The events 1 and 2 (Figs. 40 and 41) suggest structures moving with the average flow, but for a further evaluation, the temporal information needs to be translated into spacial information. This can be done using *Taylor's hypothesis*, which basically suggests that for cases, where the standard deviation in speed is small compared to the mean speed (Willis and Deardorff, 1976), a turbulent pattern can be thought of as "frozen" on small timescales (Stull, 1988). That means it is possible to reconstruct the size and other qualities of a pattern from a time series of measurements at one single location. . Events 1 and 2 found in the time series of current measurements at the fish farm Gjaesingen (Figs. 40 and 41) show a series of measures with directions shifting clockwise or anticlockwise respectively. This could be caused by eddies passing the current meter with a lateral offset. The ambient current direction was to northwest, therefore event 1 might represent an eddy passing the sensor with an offset to the northwest and event 2 an eddy passing the current meter with an offset to the northeast. The average current speed and the size of the fish cages at the Gjaesingen farm result in a very large Reynolds number (approximately $1.4 \cdot 10^6$), which causes a high degree of turbulence, but Roshko (1961) showed that there is strong evidence for periodic vortex shedding, the so-called Karman vortex street, even in post critical regimes, in which the boundary layer on the surface of a bluff body becomes turbulent. Net cages, howoever, must be treated as porous, allowing throughflow and divergence. The measurements at the *Jektholmen* farm revealed flow divergence from 3m to 23m, which makes a big difference for the characteristics of the wake flow. Kakimoto et *al.* (2005) found that the Karman vortex disappears with increase of permeability of an obstacle and with increase of the Reynolds number of the flow, while Fransson et *al.* (2004) found that continuous blowing through the sides of a porous cylinder at Reynolds number of the order of 10^4 results in a widening of the wake and a rearward moving of the separation point.

In a steady state, which is assumed for an empty fish cage, the amount of water flowing into a cage due to a constant flow is expected to equal the water that is forced out of the cage, thus divergence in a fish cage must result from internal forces. It was observed that the fish at the *Jektholmen* farm swam in circles. This circular motion requires a centripetal force (Tippler, 1998). The counterforce (the fish propulsion) is applied to the water and results in water being pressed out through the sides of the cage, thus creating horizontal divergence. It is therefore possible, that fish in net cages create divergence. Kakimoto *et al.* (2005) found, that an increase of permeability of a porous obstacle can lead to suppression of Karman vortex streets in the wake flow. Fransson *et al.* found a widening of the wake and an increased vortex formation length, when blowing is applied to a porous cylinder. This leads to the assumption, that fish creates secondary circulation, could change the wake characteristics.

The measurements around *cage 10* at the *Jektholmen* fish farm showed the average current direction in one layer to point north above and west below 15m depth. Above this transition depth the fish cage is cylindrical, while it is conical below. The drifter movements showed the ambient current mostly to point south, thus the current might have been blocked by the cages north of *cage 10*, while an area of reversed flow (Williamson, 1996) suppressed a water flow directed southwards. Below 15 m depth the blockage by the cone-shaped part of the fish cages might have been less efficient.

4.4 *Application for integrated aquaculture*

4.4.1 *Integrated mussel farming*

The results from this study showed that the influence of particulate waste discharged from *cage 10* was most likely not visible at greater distances than 25 m from the cage. The Chlorophyll a concentrations and the phytoplankton densities were higher in distances about 215 m from the fish farm, then close to *cage 10*. This aligns with the findings by Cheshuk *et al.* (2003), who suggest, that it is highly unlikely that phytoplankton production that is stimulated by nutrients evolving from a fish farm would remain in the immediate surrounding of the farm. Anyway, algal growth normally is on time scales in the order of days (Gowen *et al.*, 1988), thus an increase of phytoplankton in the direct surrounding of a fish farm would presume a residence time of days, which will not be the case for well flushed fish farms. Therefore nutrient discharge from fish cages will most likely not lead to higher phytoplankton biomasses within or in the near surrounding of fish farms. Thus, an enhanced growth of mussel in integrated mussel farming relies on the discharge of particulate matter from the fish cages. The concentrations of total particulate matter found in this study ranged under the pseudofaeces threshold of mussel, which generally is about 1-6 $\mathrm{mg} \cdot \mathrm{l}^{-1}$ (Bayne and Newell, 1983). Thus any additional particulate waste will be ingested by mussel. The highest numbers of particles in this study were found within the range from 2-8 μm, which is within the size range in which the best retention efficiency for a wide range of mussel species was found (Shumway *et al.*, 1985; Riisgard, 1988).

The results found in this study do not promise an enhanced growth of mussel downstream from the *Jektholmen* fish farm from April to June due to particulate waste,. That is because the particles discharged from the fish farm neither seem to have increased the ambient particle density nor do they seem to have altered the ambient particle composition in distances greater than a few m from the fish cages within the time period of this study. Anyway, there might be potential for enhanced growth of mussel close to the fish farm in the winter, as Wallace (1980) found continuous growth for mussels attached to floats supporting fish cages, while other mussels from the same area, that were not in the vicinity of any fish farm, showed growth stoppage rings.

4.4.2 *Integrated seaweed farming*

The results of this study show that the influence of the fish farm on nutrient concentrations was more distinct for ammonia, than for nitrate and nitrite. There was nearly no increase of phosphate concentrations visible due to discharge from the fish cages. Kelly *et al.* (2005) found similar results at salmon fish cages in Scotland, but did still find enhanced growth of *Laminaria saccharina* and *Palmaria palmata* up to 200m distance to the fish cages. This leads to the assumption, that enhanced seaweed growth due to nitrogen discharge from fish cages can occur, although the growth is phosphate limited (Figs. 18 and 19). Several studies identified a range of factors, which determine the selection of species that are best suitable for integrated aquaculture in general as well as for particular fish farms (Neori *et al.*, 2004; Troell *et al.*, 2003), aspired compromise of nutrient uptake rate and reduction efficiency, growth rate and nitrogen content in tissue of algae, the ease of cultivation and resistence to epiphytes. Further information about diurnal and annual cycles of nutrient discharge from the *Jektholmen* farm will be needed to decide, which algal species are suitable best for integrated culture at *Jektholmen.* Additionally, it would be crucial to further investigate the characteristics of the currents in the wake behind fish cages. Nevertheless, the information gained in this study leads to some suggestions regarding the demands on seaweed, that would be suitable for integrated culture at the *Jektholmen* farm. The conditions found call for species preferring ammonia-N over nitrate-N and showing high nitrogen uptakes rates at ammonia concentrations of about 15-25 μg ammonia-N $\cdot$ l^{-1}. The ammonia concentrations were found to be highly variable along transects in the present study, which leads to the assumption that a seaweed area located downstream from the fish farm would encounter nutrient pulses. For an efficient use of these pulses, the chosen algae species should have the ability to rapidly assimilate nitrogen and use it for later growth like shown for *Gracilaria chilensis* (Bird *et al.*, 1982; McLachlan and Bird, 1986). Furthermore, the seaweed should have the ability to take up phosphate at very low concentrations and have a high tissue N/P ratio, so more biomass could be gained at low phosphate concentrations. Additionally, all seaweed used in integrated the seaweed should be a local species, it should be easy to cultivate and show a high resistance to epiphytes (Neori *et al.*, 2004). It is not clear, whether there is local species, which meet the ecophysiological requirements and also promises economic feasibility.

4.5 *Methods and experimental design*

All analytical methods used in this study are standard methods and were sufficiently evaluated, as were the modes of sample storage. All analyzed parameters are consistent with other parameter, which they do not depend on. Thus, it can be claimed, that the analytical results mirror the actual contents in the samples. The current measurements were done by simply holding the sensor, mounted on a long stick, into the water. This might be a source of errors, but the instrument did internally integrate the currents over a period of time of 170 and 80 seconds respectively, at least two measurements were taken at the *Jektholmen* farm and the time series of currents at the Gjaesingen farm did show consistent results. Therefore the current data can be suggested to be afflicted with only minor errors, which would not lead to different results.

In retrospective, the sampling design resulted in some uncertainties in the assessment of the nutrient and particle results. Only one sampling occurred in each sampling location per sampling day. As the results from the current measurements indicate the existence of swirls or eddies and a high degree of turbulence, it is hard to assess peak values on the transects. It is not clear, if such peaks represent a concentration, that is stable over time in that location, if it results from high or low nutrient or particle concentrations trapped in some rotating structure or if it results from an entrainment of water from the sides. A repetition of samplings on the transects would smooth out irregular peaks, but in this study only four repetitions were conducted, which would not be sufficient to smooth very distinct irregular peaks. It is suggested, that in further studies either more repetitions are be carried out, or that two samplings at intervals of at least 15 minutes are conducted in one position.

The sampling station upstream of the fish farm was chosen for reference, but the results from the samplings at that station clearly did not mirror the ambient conditions. It is possible, that effluents from the fish farm were carried northwards with the tidal flow, which - at times - resulted in elevated concentrations.

4.6 *Conclusions*

The nutrient discharge from the fish farm *Jektholmen* seems to be very low, which may be connected to a very good feed conversion ratio. The concentrations of nitrate, nitrite and dissolved phosphate most likely were approximately at ambient levels. The ammonia concentrations were low, but clearly originated from the fish farm. Ammonia concentrations might have been up to 1.5 times higher in the afternoon (Bergheim *et al.*, 1991). The density of particles increased from 20.04. until 02.06.2005 and showed lower levels, after the fish were taken out of *cage 10*. The total particulate matter did not show any evolution in time. The concentrations of total particulate matter and particulate organic matter were low. The effect of the fish cage on those measure only was visible at the sampling location closest to *cage 10*. This could indicate, that there is a discharge of particles from the fish cages, but that most of those particles fall to depth below 25 m within the first 35 m distance to the fish cage. A shift in the phytoplankton composition occurred between the 20.05.2005 and the 30.05.2005 and again between 30.05.2005 and 30.06.2005. The first shift fell together with an increase in the fraction of organic matter within the total particulate matter and the second with the clearance of *cage 10*.

A certain patchiness in the distributions of all measures can be explained by small scale turbulence. The results from studies on bluff body wakes could explain structures, that were found trough current measurements downstream from net cages containing fish. Current measurements around *cage 10* revealed a net water outflow from the fish cage, which might be linked to fish movement. If that is the case, the fish itself has some influence on the flow around the cage. If the effect of fish swimming in circles is of that magnitude, the fish would actively contribute to a higher water exchange, as the water pushed out of the cage is replaced from the surface or the bottom.

An enhanced mussel growth due to fish farm waste relies on the direct discharge, which is feed waste and faeces. The farm *Jektholmen* showed low particle numbers and low total particulate matter, which ranged under the general pseudofaeces threshold and the fraction of organic matter was very high. Although this might indicate good conditions for mussel growth, an integrated mussel farming might not lead to enhanced mussel growth at the farm *Jektholmen*, as the concentrations of particulate material seemed to range at ambient levels in distances greater then 25 m from the fish cages.

Seaweed might benefit from the nutrient release from the fish farm *Jektholmen*, but it is unclear, whether there is local species, that meet the ecophysiological requirements and promise economic feasibility. The seaweed would need to have the ability to take up phosphate at very low concentrations, it would need to be able to rapidly assimilate nutrients for later growth, it would need to have a high tissue N/P ratio, it would need to be easy to cultivate, it should be easy to controll its life cycle, it would need to be resistant to epiphytes, it should be fast growing and highly valuable.

Integrated multi-trophic aquaculture has been subject to intensive research for only a short time. Clearly there still is a lot to learn about biological and biochemical processes, temporal variabilities, factors affecting growth, uptake rates and uptake capacities of seaweed, design of farms to meet the requirements for integrated aquaculture and economic feasibility, the environmental effects of integrated aquaculture on large scale. There is much more, that needs to be investigated. This study gives one major conclusion for further research - it will be necessary to investigate the current characteristics around fish farms. It might not be always, that there is a net water outflow from fish cages and the divergence might vary temporal and spacial (in depth). Considering the results from Fransson *et al.* (2004), the amount of divergence might strongly affect the flow characteristics in the wake and thus the distribution of nutrients and particles. Furthermore, the recirculation zone behind fish cages should be examined. That could especially be important in respect to integrated mussel farming, as particles might be trapped in that zone. The flow characteristics in greater distance to the farm should be examined to find out, if fish cages (always) evoke structures, that occur periodically. It needs to be investigated, which factors influence divergence, recirculation zone and periodically occurring structures to understand their relevance for the design of integrated aquaculture farms.

References

Ahn, O., Petrell, R.J., Harrison, P.J., 1998. Ammonium and nitrate uptake by *Laminaria saccharina* and *Nereocystis luetkeana* originating from a salmon sea cage farm. Journal of Applied Phycology 10, 333-340.

Asare, S.O., 1980. Animal waste as a nitrogen source for *Garcilaria tikvahiae* and *Neoagardhiella baileyi* in culture. Aquaculture 21, 87-91.

Bayne, B.L., Newell, R.C., 1983. Physiological energetics of marine molluscs. In: Saleuddin, A.S.M., and Wilbur, K.M. (Eds.), The mollusca. Vol. 4. Physiology, Part 1. Academic Press, New York.

Bell, J.G., Sargent, J.R., 2003. Arachidonic acid in fish feeds: Current status and future opportunities. Aquaculture 218, 491-499.

Bergheim, A., Seymour, E.A., Sanni, S., Tyvold, T., 1991. Measurements of Oxygen Consumption and Ammonia Excretion of Atlantic Salmon (*Salmo salar* L.) in Commercial-Scale, Single-Pass Freshwater and Seawater Landbased Culture Systems. Aquacultural Engineering 10, 251-267.

Beveridge, M.C.M., Ross, L.G., Kelly, L.A., 1994. Aquaculture and biodiversity. Ambio, 23, 497-502.

Bird, K.T., Habig, C., DeBusk, T, 1982. Nitrogen allocation and storage pattern in *Gracilaria tikvahiae*. J. Phyc. 18, 344-348.

Bonsdorff, E., Blomqvist, E.M., Mattila, J., Norkko, A., 1997. Coastal eutriphication: causes, consequences and perspectives in the archipelago ares of the northern Baltic Sea. Estuar. Coast. Shelf sci. 44, 63-72.

Braaten, B., Poppe, T., Jacobsen, B., Maroni, K., 1988. Risks of self pollution in aquaculture: evaluation and consequences. In: Grimaldi, E, Rosenthal, H. (Eds.), Efficiency in aquaculture production. Disease control. Edizioni del Sole 24 Ore Milano, pp. 139-166.

Brown, J.R., Growen, R.J., McLusky, D.S., 1987. The effect of salmon farming on the benthos of a scottish sea loch. Journal of Experimental Marine Biology and Ecology 109, 39-51.

Buschmann, A.H., Troell, M., Kautsky, N., Kautsky, L., 1996. Integrated tank cultivation of salmonids and *Gracilaria chilensis* (Gracilariales, Rhodophyta). Hydrobiologia 326/327, 75-82.

Cheshuk, B.W., Purser, G.J., Quintana, R., 2003. Integrated open-water mussel (*Mytilus planulatus*) and Atlantic salmon (*Salmo salar*) culture in Tasmania, Australia. Aquaculture 218, 357-378.

Chopin, T., Bastarache, S., 2002. Finfish, shellfish and seaweed mariculture in Canada. Bull. Aquac. Assoc. Can. 102, 119-124.

Davis, I.M, Gubbins, M.J., Greathead, C., 2005. Comparison of nitrogen discharge rates from cultivated marine finfish species. In: Lessons from the Past to Optimise the Future, European Aquaculture Society, Special Publication No. 35.

Drebes, G., 1974. Marines Phytoplankton. Georg Thieme Verlag, Stuttgart, 185 pp.

Edwards, P., 1998. A system approach for the promotion of integrated aquaculture. Aquac. Econ. Mang. 2, 1-12.

Enell, M., 1987.Environmental impact of cage fish farming with special reference to phosphorus and nitrogen loadings. Commom meeting of the international council for Exploration of sea, CM-ICES/F, 44.

FAO 2001. Integrated agriculture-aquaculture. Rome (www.FAO.org).

FAO 2004. The State of World Fisheries and Aquaculture 2004. Sofia (www.FAO.org).

Findlay, R.H., Watling, L., Mayer, L.M., 1995. Environmental impact of salmon net-pen culture on marine benthic communities in Maine: A case study. Estuaries 18, 146-179.

Fivelstad, S., Thomassen, J.M., Smith, M.J., Kjartansson, H., Sandø, A-B., 1990. Metabolite Production Rates from Atlantic Salmon (*Salmo salar* L.) and Arctic Char (*Salvelinus alpinus* L.) Reared in Single Pass Land-Based Brackish Water and Sea-Water Systems. Aquacultural Engineering 9, 1-21.

Fransson, J.H.M., Konieczny, P., Alfredsson, P.H., 2004. Flow around a porous cylinder subject to continuous suction or blowing. Journal of Fluids and Structures 19, 1031-1048.

Gosling, E., 2003. Bivalve molluscs: biology, ecology and culture. Blackwell Publishing. 454 pp.

Gowen, R.J., Bradbury, N.B., 1987. The ecological impact of salmon farming in coastal waters: a review. Oceanogr. Mar. Biol. Annu. Rev. 25, 173-182.

Gowen, R.J., Brown, J., Bradbury, N.B., McLusky, D.S., 1988. Investigations into benthic enrichment, hypernutrification and eutrophication associated with mariculture in Scottish coastal waters (1984-1988). Report to Highlands and Islands Development Board, Crown Estates Commissioners, Nature Conservancy Council, Countryside Commission for Scottland, and the Scottish Salmon Growers Association, 289 pp.

Grasshoff, K., Kremling, K, Ehrhardt, M. (Eds.), 1999. Methods of Seawater Analysis. Wiley-VCH, 600 pp.

Havbrukstjenesten AS, 2002. Evaluation of the area Jektholmen on basis of current data and sediment samples. Commercial study for Salmar Farming A/S.

Holby, O., Hall, P.O.J., 1991. Chemical fluxes and mass balances in a marine cage farm. II. Phosphorus. Marine ecology progress series 70, 263-272.

Hänninen, J., Vuorinen, I., Helminen, H., Kirkkala, T., Lehtilä, K., 2000. Trends and gradients in nutrient concentrations and loadings in the Archipelago Sea, Northern Baltic, in 1970-1997. Estuar. Coast. Shelf sci. 50, 153-171.

Islam, Md. S., 2005. Nitrogen and phosphorus budget in coastal and marine cage aquaculture and impacts of effluent loading on ecosystem: review and analysis towards model development. Marine Pollution Bulletin 50, 48-61.

Jacobsen, A., Egge, J.K., Heimdal, B.R., 1995. Effects of increased concentration of nitrate and phosphate during a springbloom experiment in mesocosm. Journal of Experimental Marine Biology and Ecology 187, 239-251.

Jones, T.O., Iwama, G.K., 1991. Polyculture of the Pacific oyster, *Crassostrea gigas*, with chinook salmon, *Oncorhynchus tsawytscha*. Aquaculture 92, 313-322.

Kakimoto, Y., Masuoka, T., Nomura, A., Ooba, M., 2005. Fluid flow through a permeable porous obstacle. Transactions of the Japan Society of Mechanical Engineers, Part B, 71 (702), pp. 590-595.

Kelly, M.S., Black, K.D., Sanderson, J.C., Cook, E.J., 2005. Can we integrate to accumulate? Utilising "waste" in open water systems. In: Lessons from the Past to Optimise the Future, European Aquaculture Society, Special Publication No. 35.

Lefebvre, S., Barille, L., Clerc, M., 2000. Pacific oyster (*Crassostrea gigas*) feeding responses to a fish-farm effluent. Aquaculture 187, 185-198.

Martinez, A., Buschmann, A.H., 1996. Agar yield and quality of *Gracilaria chilensis* (Gigartinales, Rhodophyta) in tank culture using fish effluents. Hydrobiologia 326/327, 341-345.

Mattila, J., Räisänen, R., 1998. Periphyton growth as an indicator of eutrophication: an experimental approach. Hydrobiologia 377, 15-23.

McLachlan, J, Bird, C.J., 1986. *Gracilaria* (Gigartinales, Rhodophyta) and productivity. Aquat. Bot. 26, 27-49.

Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenko, J., Mooney, H., Troell, M., 2000. Effect of aquaculture on world fish supplies. Nature 405, 1017-1024.

Neori, A., Chopin, T., Troell, M., Buschmann, A.H., Kraemer, G.P., Halling, C., Sphigel, M., Yarish, C., 2004. Integrated aquaculture: rationale, evolution and state of the art emphazising seaweed biofiltration in modern mariculture. Aquaculture 231, 361-391.

Norsk Standard 4745, 1991. Bestemmelse av summen av nitritt- og nitrat-nitrogen. Norges Standardiseringsforbund, 2. utg. aug. 1991.

Norsk Standard 4746, 1975. Bestemmelse av ammonium-nitrogen. Norges Standardiseringsforbund, 1. utg. aug. 1975.

Olsen, Y., Slagstad, D., Vadstein, O., 2005. Assimilative carrying capacity: contribution and impact on the pelagic system. In: Lessons from the Past to Optimise the Future, European Aquaculture Society, Special Publication No. 35.

Phillips, M.J., Beveridge, M.C.M., Ross, L.G., 1985. The environmental impact of salmon cage culture on inland fisheries: present status and future trends. Journal of fish biology 27, 123-127.

Pitta, p., Karakassis, I., Tsapakis, M., Zivanovic, S., 1999. Natural vs. mariculture induced variability in nutrients and plankton in the eastern Mediterranean. Hydrobiologia 391, 181-194.

Richardson, K., Jørgensen, B.B., 1996. Eutriphication: definition, history and effects. In: Richardson, K., Jørgensen, B.B. (Eds.), Eutriphication in Coastal Marine Ecosystems. Coastal and estuarine studies, vol. 52. American Geophysical Union, pp. 1-20.

Riisgård, H.U., 1988. Efficiency of particle retentionand filtration rate in 6 species of Northeast American bivalves. Marine ecology progress series 45, 217-223.

Roshko, A., 1961. Transition in incompressible near-wakes. Phys. Fluids Suppl., p. 181.

Rönneberg, O., Ådjers, K., Roukolahti, C., Bondestam, M., 1992. Effects of fish farming on growth epiphytes and nutrient content of *Fucus vesiculosus* L. in the Åland archipelago, northern Baltic Sea. Aquat. Bot. 42, 109-120.

Shumway, S.E., Cucci, T.L., Newell, R.C., Yentch, C.M., 1985. Particle selection, ingestion, and absorption in filter-feeding bivalves. J. Exp. Mar. Biol. Ecol. 91, 77-92.

Stirling, H.P., Okumus, I., 1995. Growth and production of mussel (*Mytilus edulis* L.) suspended at salmon cages and shellfish farms at two Scottish sea lochs. Aquaculture 134, 193-210.

Strickland, J.D.H., Parsons, T.R., 1972. A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada. (2nd Edition).

Stull, R.B., 1988. An Introduction to Boundary Layer Meteorology. Kluwer Academic, 666pp.

Subander, A., Petrell, R.J., Harrison, P.J., 1993. *Laminaria* culture for reduction of dissolved inorganic nitrogen in salmon farm effluent. J. Appl. Phyc. 5, 455-463.

Sverdrup, H.U., Johnson, M.W., Flemming, R.H., 1942. The Oceans. Prentice Hall, 1087 pp.

Tacon, A.G.J., Forster, I.P., 2001. Global trends and challenges to aquaculture and aquafeed development in the new millenium. International Aqua Feed - Directory and Buyer's Guide. Turret RAI PLC, Uxbridge, pp.4-24.

Tippler, P. A., 1998. Physik. Spektrum Akademischer Verlag, 1522 pp.

Tomas, C. R. (Ed.), 1997. Identifying Marine Phytoplankton. Academic Press.

Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky, N., Yarish, C., 2003. Integrated mariculture: asking the right questions. Aquaculture 226, 69-90.

Troell, M., Halling, C., Nilsson, A., Buschmann, A.H., Kautsky, N., Kautsky, L., 1997. Integrated marine cultivation of *Gracilaria chilensis* (Gracilariales, Rhodophyta) and salmon cages for reduced environmental impact and increased economic output. Aquaculture 156, 45-61.

UNESCO, 1978. Phytoplankton manual. United Nations Educational, Paris, 337 pp.

Utermöhl, H., 1958. Zur Vervollkommnung der quantitativen Phytoplamktonmethodik. Mitteilungen der Internationalen Vereinigung für Theoretische und angewandte Limnologie 9, 1-38.

Wallace, J.F., 1980. Growth rates of different populations of the edible mussel *Mytilus edulis* in north Norway. Aquaculture 19, 303-311.

Warrer-Hansen, I., 1982. Methods of treatment of wastewater from trout farming. FIFAC Technical Paper 41, 113-121.

Williamson, C.H.K., 1996. Vortex dynamics in the cylinder wake. Annu. Rev. Fluid. Mech. 28, 477-539.

Willis, G.E., Deardorff, J.W., 1976. On the use of Taylor's translation hypothesis for diffusion in the mixed layer, Quart. J. Roy. Meteor. Soc. 102, 817-822

Yokoyama, H., 2003. Environmental quality criteria for fish farms in Japan. Aquaculture 226, 45-56.

5 *Appendix*

5.1 *Analytical methods*

5.1.1 *Ammonia*

The samples were analyzed according to Norsk Standard (NS 4746, 1975). 25 ml of the sample were transfered into a reaction flask. 1ml sodiumcitrate solution, 1 ml reagent A and 1 ml reagent B were added in this order. The addition of a chemicals alsways was followed by mixing the sample. The reaction flasks were closed and allowed 6 hours reaction time, before the absorption was measured at 630 nm.

Natriumcitrate solution:

175 mg trisodium-dihydrate are dissolved in 600 ml distilled water. 15 ml of 0.01 M sodiumhydroxide solution are added and the solution is boiled until the volume is less than 500 ml. the solution is cooled to room temperature and dilute to a volume of 500 ml with distilled water.

Reagent A:

13.5 g phenole and 0.15 g disodiumpentacyanonitrosylferrate-dihydrate are dissolved in 500 ml distilled water.

Reagent B:

$106/y$ ml sodiumhypochlorid solution are dissolved in 100 ml 0.34 M sodiumhydroxide solution. y is the concentration of active chloride in $\mathrm{mg} \cdot \mathrm{l}^{-1}$.

5.1.2 *Nitrate and nitrite*

The samples were analysed according to Norsk Standard (NS 4745, 1991). The samples were filtered through Whatman GF/F filters prior to analysis. 2 ml buffer were added to 80 ml sample and 25 ml of this was transfered into a graduated flask. 5 ml of the remaining 57 ml were given into a reduction column filled with cadmium as reductor. Another 5 ml from this bottle were given into the column. Finally, the remaining 47 ml of that flask were allowed to run through the reduction column. The reductor now was flushed with sample and the 25 ml were transfered from the graduated flask into the reduction column. These 25 ml were collected in a glass flask, after passing through the reductor. Reagent I was added. One minute later reagent II was added. the absorption was measured at 545 nm earliest 20 minutes and latest 2 hours after reagent II was added.

Nitrite was analyzed the same way, but the sample is not passed through the reduction column.

Buffer:

270 g ammoniumchloride are dissolved in 700 ml distilled water. Ammonia is added to a pH of 8.5. The solution is filled up to a volume of 1000 ml with distilled water.

Reagent I:

210 ml concentrated hydrochloric acid are diluted to about 400 ml. 5 g sulfanylamide are dissolved in the acid. The solution is diluted to a volume of 500 ml with distilled water.

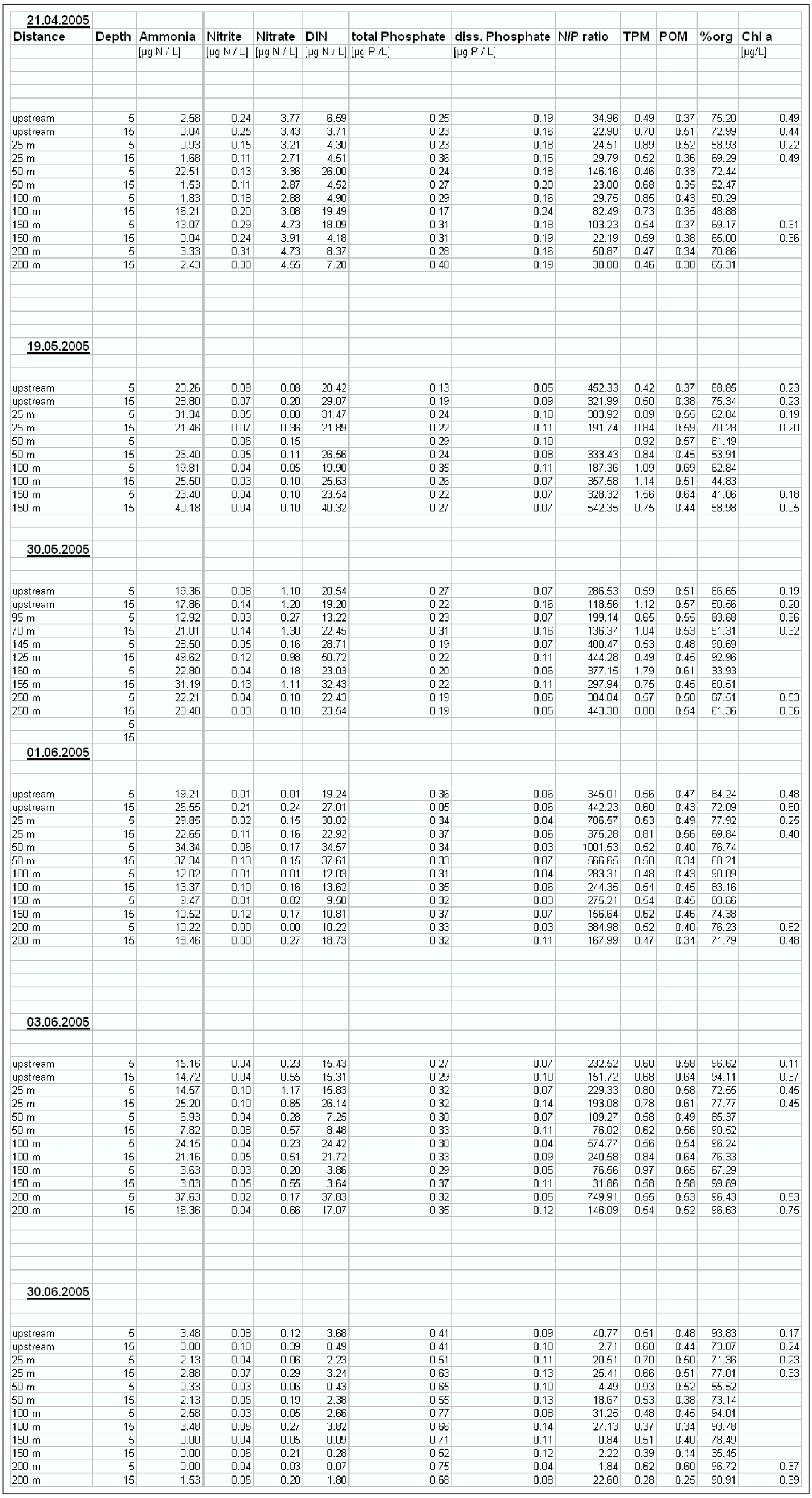
Reagent II:

0.2 g N-(1-naphtyle)-ethylenediaminedihydrochloride are dissolved in 500 ml distilled water.

5.2 *Results*

5.2.1 *Sampling cycle A*

The following table presents from sampling cycle *A* on six sampling days. Upstream marks the samplings upstream of the fish farm *Jektholmen*. Distance marks the distance to the middle of *cage 10* in downstream direction and depth stands for the sampling depth.

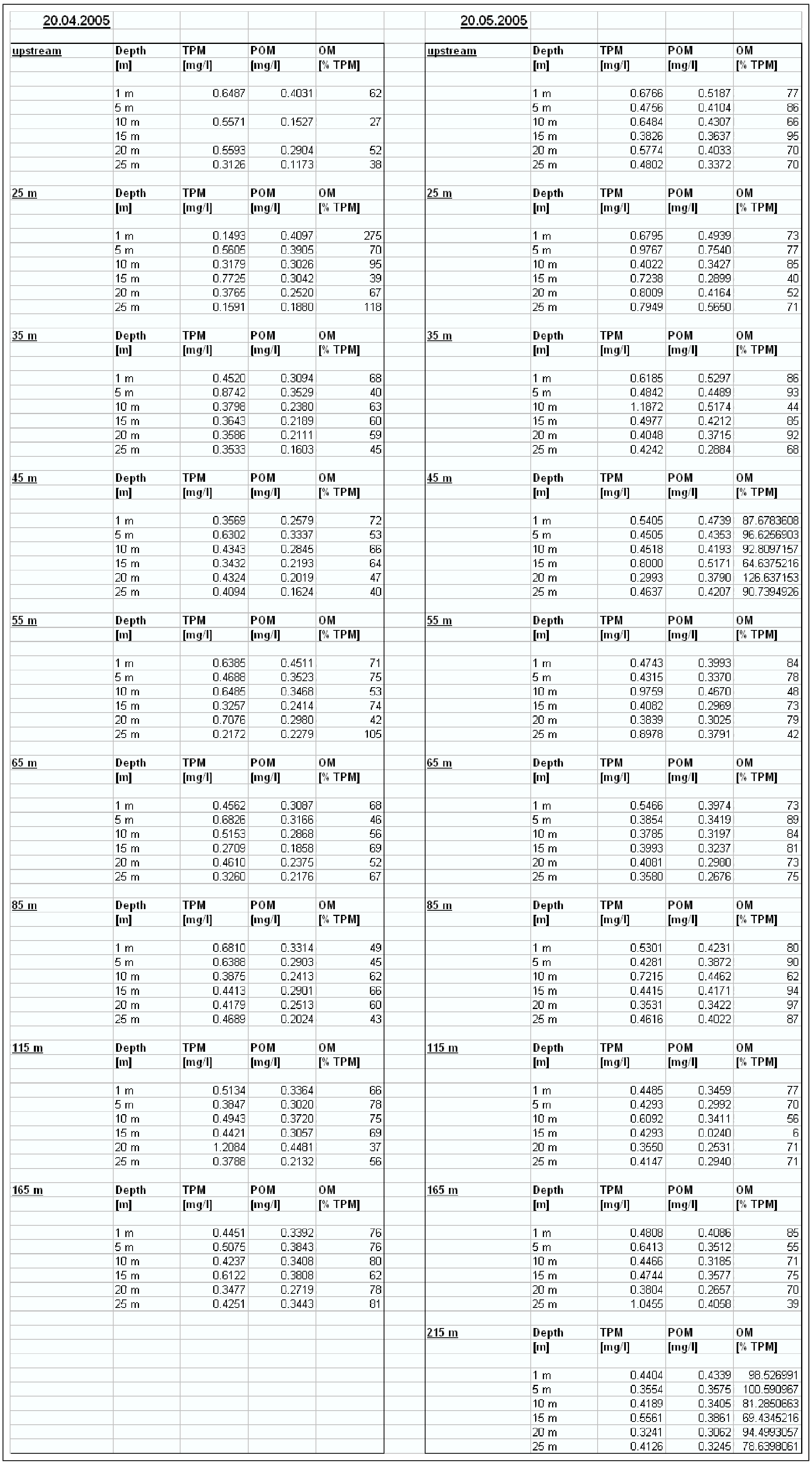


21.04.2005												
Distance	**Depth**	**Ammonia**	**Nitrite**	**Nitrate**	**DIN**	**total Phosphate**	**diss. Phosphate**	**N/P ratio**	**TPM**	**POM**	**%org**	**Chl a**
		[µg N / L]	[µg N / L]	[µg N / L]	[µg N / L]	[µg P /L]	[µg P / L]					[µg/L]
upstream	5	2.58	0.24	3.77	6.59	0.25	0.19	34.96	0.49	0.37	75.20	0.49
upstream	15	0.04	0.25	3.43	3.71	0.23	0.16	22.90	0.70	0.51	72.99	0.44
25 m	5	0.93	0.15	3.21	4.30	0.23	0.18	24.51	0.89	0.52	58.93	0.22
25 m	15	1.68	0.11	2.71	4.51	0.36	0.15	29.79	0.52	0.36	69.29	0.49
50 m	5	22.51	0.13	3.36	26.00	0.24	0.18	146.16	0.46	0.33	72.44	
50 m	15	1.53	0.11	2.87	4.52	0.27	0.20	23.00	0.68	0.35	52.47	
100 m	5	1.83	0.18	2.88	4.90	0.29	0.16	29.75	0.85	0.43	50.29	
100 m	15	16.21	0.20	3.08	19.49	0.17	0.24	82.49	0.73	0.35	48.88	
150 m	5	13.07	0.29	4.73	18.09	0.31	0.18	103.23	0.54	0.37	69.17	0.31
150 m	15	0.04	0.24	3.91	4.18	0.31	0.19	22.19	0.59	0.38	65.00	0.36
200 m	5	3.33	0.31	4.73	8.37	0.28	0.16	50.87	0.47	0.34	70.86	
200 m	15	2.43	0.30	4.55	7.28	0.48	0.19	38.08	0.46	0.30	65.31	
19.05.2005												
upstream	5	20.26	0.08	0.08	20.42	0.13	0.05	452.33	0.42	0.37	88.85	0.23
upstream	15	28.80	0.07	0.20	29.07	0.19	0.09	321.99	0.50	0.38	75.34	0.23
25 m	5	31.34	0.05	0.08	31.47	0.24	0.10	303.92	0.89	0.55	62.04	0.19
25 m	15	21.46	0.07	0.36	21.89	0.22	0.11	191.74	0.84	0.59	70.28	0.20
50 m	5		0.06	0.15		0.29	0.10		0.92	0.57	61.49	
50 m	15	26.40	0.05	0.11	26.56	0.24	0.08	333.43	0.84	0.45	53.91	
100 m	5	19.81	0.04	0.05	19.90	0.35	0.11	187.36	1.09	0.69	62.84	
100 m	15	25.50	0.03	0.10	25.63	0.26	0.07	357.58	1.14	0.51	44.83	
150 m	5	23.40	0.04	0.10	23.54	0.22	0.07	328.32	1.56	0.64	41.06	0.18
150 m	15	40.18	0.04	0.10	40.32	0.27	0.07	542.35	0.75	0.44	58.98	0.05
30.05.2005												
upstream	5	19.36	0.08	1.10	20.54	0.27	0.07	286.53	0.59	0.51	86.65	0.19
upstream	15	17.86	0.14	1.20	19.20	0.22	0.16	118.56	1.12	0.57	50.56	0.20
95 m	5	12.92	0.03	0.27	13.22	0.23	0.07	199.14	0.65	0.55	83.68	0.36
70 m	15	21.01	0.14	1.30	22.45	0.31	0.16	136.37	1.04	0.53	51.31	0.32
145 m	5	28.50	0.05	0.16	28.71	0.19	0.07	400.47	0.53	0.48	90.69	
125 m	15	49.62	0.12	0.98	50.72	0.22	0.11	444.28	0.49	0.45	92.96	
160 m	5	22.80	0.04	0.18	23.03	0.20	0.06	377.15	1.79	0.61	33.93	
155 m	15	31.19	0.13	1.11	32.43	0.22	0.11	297.94	0.75	0.45	60.51	
250 m	5	22.21	0.04	0.18	22.43	0.19	0.06	384.04	0.57	0.50	87.51	0.53
250 m	15	23.40	0.03	0.10	23.54	0.19	0.05	443.30	0.88	0.54	61.36	0.36
	5											
	15											
01.06.2005												
upstream	5	19.21	0.01	0.01	19.24	0.36	0.06	345.01	0.56	0.47	84.24	0.48
upstream	15	26.55	0.21	0.24	27.01	0.05	0.06	442.23	0.60	0.43	72.09	0.60
25 m	5	29.85	0.02	0.15	30.02	0.34	0.04	706.57	0.63	0.49	77.92	0.25
25 m	15	22.65	0.11	0.16	22.92	0.37	0.06	375.28	0.81	0.56	69.84	0.40
50 m	5	34.34	0.06	0.17	34.57	0.34	0.03	1001.53	0.52	0.40	76.74	
50 m	15	37.34	0.13	0.15	37.61	0.33	0.07	566.65	0.50	0.34	68.21	
100 m	5	12.02	0.01	0.01	12.03	0.31	0.04	283.31	0.48	0.43	90.09	
100 m	15	13.37	0.10	0.16	13.62	0.35	0.06	244.35	0.54	0.45	83.16	
150 m	5	9.47	0.01	0.02	9.50	0.32	0.03	275.21	0.54	0.45	83.66	
150 m	15	10.52	0.12	0.17	10.81	0.37	0.07	156.64	0.62	0.46	74.38	
200 m	5	10.22	0.00	0.00	10.22	0.33	0.03	384.98	0.52	0.40	76.23	0.62
200 m	15	18.46	0.00	0.27	18.73	0.32	0.11	167.99	0.47	0.34	71.79	0.48
03.06.2005												
upstream	5	15.16	0.04	0.23	15.43	0.27	0.07	232.52	0.60	0.58	96.62	0.11
upstream	15	14.72	0.04	0.55	15.31	0.29	0.10	151.72	0.68	0.64	94.11	0.37
25 m	5	14.57	0.10	1.17	15.83	0.32	0.07	229.33	0.80	0.58	72.55	0.45
25 m	15	25.20	0.10	0.85	26.14	0.32	0.14	193.08	0.78	0.61	77.77	0.45
50 m	5	6.93	0.04	0.28	7.25	0.30	0.07	109.27	0.58	0.49	85.37	
50 m	15	7.82	0.08	0.57	8.48	0.33	0.11	76.02	0.62	0.56	90.52	
100 m	5	24.15	0.04	0.23	24.42	0.30	0.04	574.77	0.56	0.54	96.24	
100 m	15	21.16	0.05	0.51	21.72	0.33	0.09	240.58	0.84	0.64	76.33	
150 m	5	3.63	0.03	0.20	3.86	0.29	0.05	76.56	0.97	0.65	67.29	
150 m	15	3.03	0.05	0.55	3.64	0.37	0.11	31.86	0.58	0.58	99.69	
200 m	5	37.63	0.02	0.17	37.83	0.32	0.05	749.91	0.55	0.53	96.43	0.53
200 m	15	16.36	0.04	0.66	17.07	0.35	0.12	146.09	0.54	0.52	96.63	0.75
30.06.2005												
upstream	5	3.48	0.08	0.12	3.68	0.41	0.09	40.77	0.51	0.48	93.83	0.17
upstream	15	0.00	0.10	0.39	0.49	0.41	0.18	2.71	0.60	0.44	73.87	0.24
25 m	5	2.13	0.04	0.06	2.23	0.51	0.11	20.51	0.70	0.50	71.36	0.23
25 m	15	2.88	0.07	0.29	3.24	0.63	0.13	25.41	0.66	0.51	77.01	0.33
50 m	5	0.33	0.03	0.06	0.43	0.65	0.10	4.49	0.93	0.52	55.52	
50 m	15	2.13	0.06	0.19	2.38	0.55	0.13	18.67	0.53	0.38	73.14	
100 m	5	2.58	0.03	0.05	2.66	0.77	0.08	31.25	0.48	0.45	94.01	
100 m	15	3.48	0.06	0.27	3.82	0.66	0.14	27.13	0.37	0.34	93.78	
150 m	5	0.00	0.04	0.05	0.09	0.71	0.11	0.84	0.51	0.40	78.49	
150 m	15	0.00	0.06	0.21	0.28	0.52	0.12	2.22	0.39	0.14	35.45	
200 m	5	0.00	0.04	0.03	0.07	0.75	0.04	1.84	0.62	0.60	96.72	0.37
200 m	15	1.53	0.06	0.20	1.80	0.68	0.08	22.60	0.28	0.25	90.91	0.39

5.2.2 *Sampling cycle B*

The following tables present the results from sampling cycle *B* on six sampling days.

5.2.2.1 *Total particulate matter, particulate organic matter and fraction of organic matter* The following tables present the results for total particulate matter, particulate organic matter and the fraction of organic matter.



20.04.2005

	Depth	TPM	POM	OM
upstream	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6487	0.4031	62
	5 m			
	10 m	0.5571	0.1527	27
	15 m			
	20 m	0.5593	0.2904	52
	25 m	0.3126	0.1173	38
25 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.1493	0.4097	275
	5 m	0.5605	0.3905	70
	10 m	0.3179	0.3026	95
	15 m	0.7725	0.3042	39
	20 m	0.3765	0.2520	67
	25 m	0.1591	0.1880	118
35 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4520	0.3094	68
	5 m	0.8742	0.3529	40
	10 m	0.3798	0.2380	63
	15 m	0.3643	0.2189	60
	20 m	0.3586	0.2111	59
	25 m	0.3533	0.1603	45
45 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.3569	0.2579	72
	5 m	0.6302	0.3337	53
	10 m	0.4343	0.2845	66
	15 m	0.3432	0.2193	64
	20 m	0.4324	0.2019	47
	25 m	0.4094	0.1624	40
55 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6385	0.4511	71
	5 m	0.4688	0.3523	75
	10 m	0.6485	0.3468	53
	15 m	0.3257	0.2414	74
	20 m	0.7076	0.2980	42
	25 m	0.2172	0.2279	105
65 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4562	0.3087	68
	5 m	0.6826	0.3166	46
	10 m	0.5153	0.2868	56
	15 m	0.2709	0.1858	69
	20 m	0.4610	0.2375	52
	25 m	0.3260	0.2176	67
85 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6810	0.3314	49
	5 m	0.6388	0.2903	45
	10 m	0.3875	0.2413	62
	15 m	0.4413	0.2901	66
	20 m	0.4179	0.2513	60
	25 m	0.4689	0.2024	43
115 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5134	0.3364	66
	5 m	0.3847	0.3020	78
	10 m	0.4943	0.3720	75
	15 m	0.4421	0.3057	69
	20 m	1.2084	0.4481	37
	25 m	0.3788	0.2132	56
165 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4451	0.3392	76
	5 m	0.5075	0.3843	76
	10 m	0.4237	0.3408	80
	15 m	0.6122	0.3808	62
	20 m	0.3477	0.2719	78
	25 m	0.4251	0.3443	81

20.05.2005

	Depth	TPM	POM	OM
upstream	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6766	0.5187	77
	5 m	0.4756	0.4104	86
	10 m	0.6484	0.4307	66
	15 m	0.3826	0.3637	95
	20 m	0.5774	0.4033	70
	25 m	0.4802	0.3372	70
25 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6795	0.4939	73
	5 m	0.9767	0.7540	77
	10 m	0.4022	0.3427	85
	15 m	0.7238	0.2899	40
	20 m	0.8009	0.4164	52
	25 m	0.7949	0.5650	71
35 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6185	0.5297	86
	5 m	0.4842	0.4489	93
	10 m	1.1872	0.5174	44
	15 m	0.4977	0.4212	85
	20 m	0.4048	0.3715	92
	25 m	0.4242	0.2884	68
45 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5405	0.4739	87.6783608
	5 m	0.4505	0.4353	96.6256903
	10 m	0.4518	0.4193	92.8097157
	15 m	0.8000	0.5171	64.6375216
	20 m	0.2993	0.3790	126.637153
	25 m	0.4637	0.4207	90.7394926
55 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4743	0.3993	84
	5 m	0.4315	0.3370	78
	10 m	0.9759	0.4670	48
	15 m	0.4082	0.2969	73
	20 m	0.3839	0.3025	79
	25 m	0.8978	0.3791	42
65 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5466	0.3974	73
	5 m	0.3854	0.3419	89
	10 m	0.3785	0.3197	84
	15 m	0.3993	0.3237	81
	20 m	0.4081	0.2980	73
	25 m	0.3580	0.2676	75
85 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5301	0.4231	80
	5 m	0.4281	0.3872	90
	10 m	0.7215	0.4462	62
	15 m	0.4415	0.4171	94
	20 m	0.3531	0.3422	97
	25 m	0.4616	0.4022	87
115 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4485	0.3459	77
	5 m	0.4293	0.2992	70
	10 m	0.6092	0.3411	56
	15 m	0.4293	0.0240	6
	20 m	0.3550	0.2531	71
	25 m	0.4147	0.2940	71
165 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4808	0.4086	85
	5 m	0.6413	0.3512	55
	10 m	0.4466	0.3185	71
	15 m	0.4744	0.3577	75
	20 m	0.3804	0.2657	70
	25 m	1.0455	0.4058	39
215 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4404	0.4339	98.526991
	5 m	0.3554	0.3575	100.590967
	10 m	0.4189	0.3405	81.2850663
	15 m	0.5561	0.3861	69.4345216
	20 m	0.3241	0.3062	94.4993057
	25 m	0.4126	0.3245	78.6398061

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upstream	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.4783	0.4118	86
	5 m	0.5533	0.4413	80
	10 m	0.5400	0.4207	78
	15 m	0.3436	0.2962	86
	20 m	0.3429	0.2989	87
	25 m	0.4763	0.0722	15

25 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6439	0.6004	93
	5 m	1.4921	0.7615	51
	10 m	0.9804	0.6479	66
	15 m	0.4427	0.4560	103
	20 m	0.5703	0.5103	89
	25 m	1.3173	0.7131	54

35 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5481	0.4601	84
	5 m	0.6216	0.4744	76
	10 m	0.5690	0.4146	73
	15 m	0.5149	0.4004	78
	20 m	0.5064	0.3619	71
	25 m	0.4882	0.3588	73

45 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.4575	0.4148	91
	5 m	0.4933	0.4378	89
	10 m	0.9841	0.5187	53
	15 m	0.4868	0.4023	83
	20 m	0.4253	0.3458	81
	25 m	0.7788	0.3757	48

55 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6107	0.5737	94
	5 m	0.5405	0.5521	102
	10 m	0.7692	0.5802	75
	15 m	0.4908	0.5162	105
	20 m	0.4299	0.4378	102
	25 m	0.4449	0.3650	82

65 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.7068	0.5845	83
	5 m	0.5534	0.4904	89
	10 m	0.9338	0.5106	55
	15 m	0.4596	0.3832	83
	20 m	0.4339	0.3436	79
	25 m	0.7797	0.4169	53

85 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5629	0.4756	84
	5 m	0.5191	0.4596	89
	10 m	0.5720	0.4835	85
	15 m	0.4684	0.4222	90
	20 m	0.4595	0.3740	81
	25 m	0.4985	0.3608	72

115 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6678	0.6970	104
	5 m	0.8989	0.5426	60
	10 m	0.5716	0.5070	89
	15 m	0.8549	0.4579	54
	20 m	0.7380	0.3247	44
	25 m	1.8276	0.4269	23

165 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	1.0842	0.5385	50
	5 m	0.2392	0.5052	211
	10 m	1.0329	0.5562	54
	15 m	0.4588	0.5065	110
	20 m	0.1777	0.4274	240
	25 m	0.1146	0.5553	484

215 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5575	0.5300	95
	5 m	0.6113	0.5752	94
	10 m	0.5347	0.5314	99
	15 m	1.4725	0.7037	48
	20 m	0.5200	0.5239	101
	25 m	0.5748	0.5210	91

02.06.2005

upstream	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6600	0.5998	91
	5 m	0.7468	0.6279	84
	10 m	0.7235	0.5823	80
	15 m	0.4610	0.4564	99
	20 m	0.4741	0.4384	92
	25 m	0.6166	0.4449	72

25 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5415	0.6081	112
	5 m	0.7230	0.7462	103
	10 m	0.8332	0.7785	93
	15 m	0.6422	0.6453	100
	20 m	0.5671	0.5647	100
	25 m	1.3288	0.6373	48

35 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6450	0.5321	82
	5 m	0.6784	0.5873	87
	10 m	1.1348	0.6482	57
	15 m	0.6374	0.6304	99
	20 m	0.4862	0.4531	93
	25 m	1.2458	0.5445	44

45 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6227	0.5043	80.9885048
	5 m	0.5740	0.4555	79.360655
	10 m	0.5179	0.4194	80.9795071
	15 m	0.9117	0.5486	60.1716526
	20 m	0.4390	0.3685	83.9198269
	25 m	0.4902	0.3699	75.4571188

55 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5715	0.4452	78
	5 m	0.5325	0.4487	84
	10 m	0.7281	0.4966	68
	15 m	0.5013	0.4620	92
	20 m	0.4952	0.4150	84
	25 m	0.9027	0.4748	53

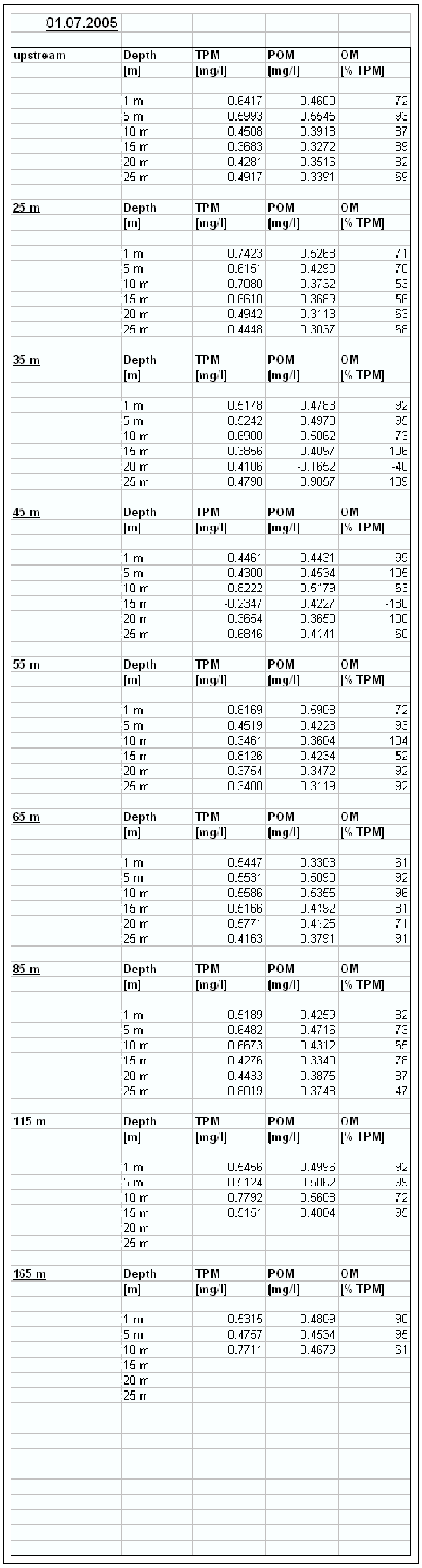
65 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5500	0.5335	97
	5 m	0.6043	0.5635	93
	10 m	0.5174	0.5383	104
	15 m	0.9930	0.6307	64
	20 m	0.5155	0.4922	95
	25 m	0.4318	0.4246	98

85 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5674	0.5259	93
	5 m	0.6170	0.5611	91
	10 m	0.9873	0.6181	63
	15 m	0.5525	0.4862	88
	20 m	0.5298	0.4724	89
	25 m	0.8930	0.4933	55

115 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.6272	0.5643	90
	5 m	0.7164	0.6121	85
	10 m	0.6541	0.5779	88
	15 m	0.5849	0.5605	96
	20 m	0.5539	0.5553	100
	25 m	0.7804	0.5919	76

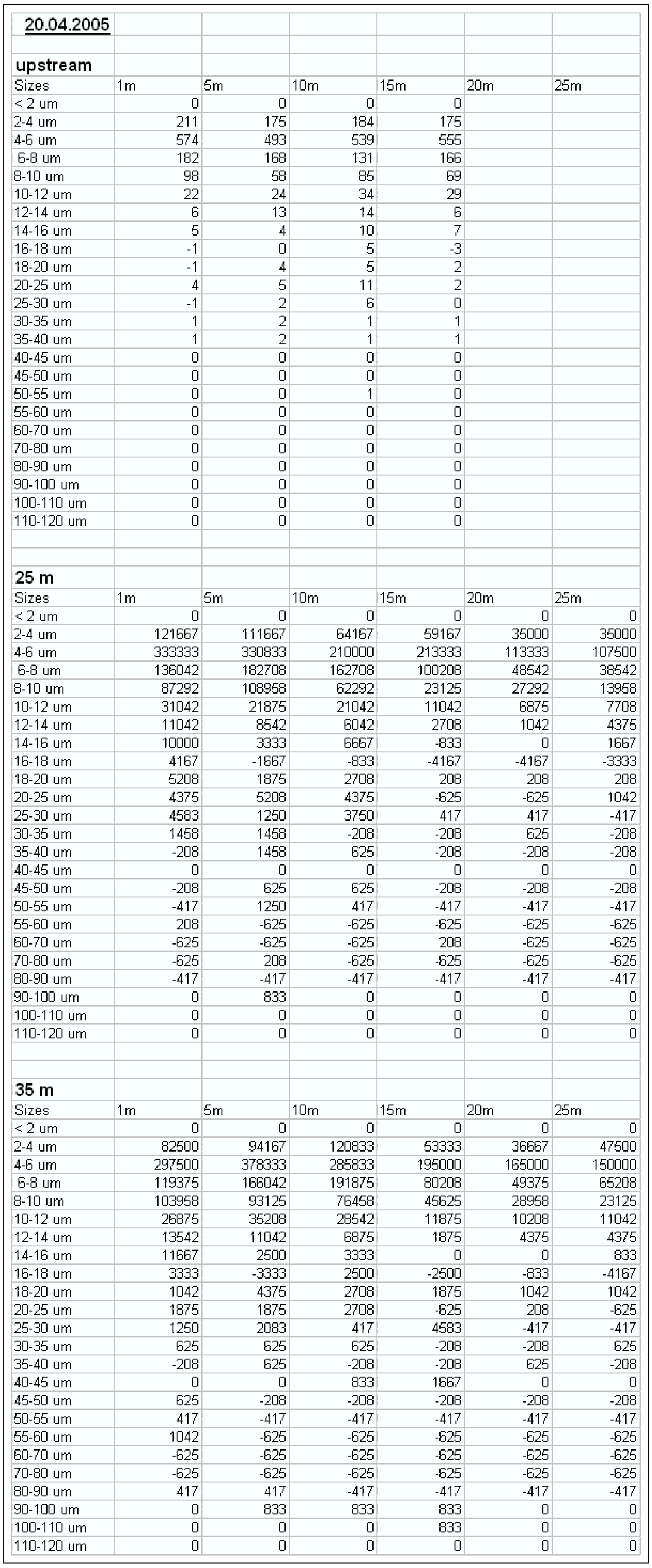
165 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5070	0.4800	95
	5 m	0.5272	0.5227	99
	10 m	0.5833	0.5594	96
	15 m	0.5377	0.5056	94
	20 m	0.5793	0.4983	86
	25 m	0.5044	0.4105	81

215 m	Depth [m]	TPM [mg/l]	POM [mg/l]	OM [% TPM]
	1 m	0.5771	0.4851	84
	5 m	0.5301	0.4702	89
	10 m	0.7549	0.4977	66
	15 m	0.4487	0.4050	90
	20 m	0.4241	0.4038	95
	25 m	0.8288	0.4891	59



01.07.2005				
upstream	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.6417	0.4600	72
	5 m	0.5993	0.5545	93
	10 m	0.4508	0.3918	87
	15 m	0.3683	0.3272	89
	20 m	0.4281	0.3516	82
	25 m	0.4917	0.3391	69
25 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.7423	0.5268	71
	5 m	0.6151	0.4290	70
	10 m	0.7080	0.3732	53
	15 m	0.6610	0.3689	56
	20 m	0.4942	0.3113	63
	25 m	0.4448	0.3037	68
35 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5178	0.4783	92
	5 m	0.5242	0.4973	95
	10 m	0.6900	0.5062	73
	15 m	0.3856	0.4097	106
	20 m	0.4106	-0.1652	-40
	25 m	0.4798	0.9057	189
45 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.4461	0.4431	99
	5 m	0.4300	0.4534	105
	10 m	0.8222	0.5179	63
	15 m	-0.2347	0.4227	-180
	20 m	0.3654	0.3650	100
	25 m	0.6846	0.4141	60
55 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.8169	0.5908	72
	5 m	0.4519	0.4223	93
	10 m	0.3461	0.3604	104
	15 m	0.8126	0.4234	52
	20 m	0.3754	0.3472	92
	25 m	0.3400	0.3119	92
65 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5447	0.3303	61
	5 m	0.5531	0.5090	92
	10 m	0.5586	0.5355	96
	15 m	0.5166	0.4192	81
	20 m	0.5771	0.4125	71
	25 m	0.4163	0.3791	91
85 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5189	0.4259	82
	5 m	0.6482	0.4716	73
	10 m	0.6673	0.4312	65
	15 m	0.4276	0.3340	78
	20 m	0.4433	0.3875	87
	25 m	0.8019	0.3748	47
115 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5456	0.4996	92
	5 m	0.5124	0.5062	99
	10 m	0.7792	0.5608	72
	15 m	0.5151	0.4884	95
	20 m			
	25 m			
165 m	**Depth**	**TPM**	**POM**	**OM**
	[m]	**[mg/l]**	**[mg/l]**	**[% TPM]**
	1 m	0.5315	0.4809	90
	5 m	0.4757	0.4534	95
	10 m	0.7711	0.4679	61
	15 m			
	20 m			
	25 m			

5.2.2.2 *Particle numbers* The following tables show the results from particles countings on 5 different days. Each stack represents the countings in one distance to *cage 10* and in up to 6 different depths. Upstream marks the samplings upstream of the fish farm *Jektholmen.* The bold distances (25 m, 35 m, 45 m, 55 m, 65 m, 85 m, 115 m, 165 m and 215 m) mark the distance to *cage 10* in downstream direction. The distances 1 m, 5 m, 10 m, 15 m, 20 m, and 25 m indicate the depth of the sampling and the sizes stand for the sum of particles counted in the corresponding size class.



20.04.2005

upstream

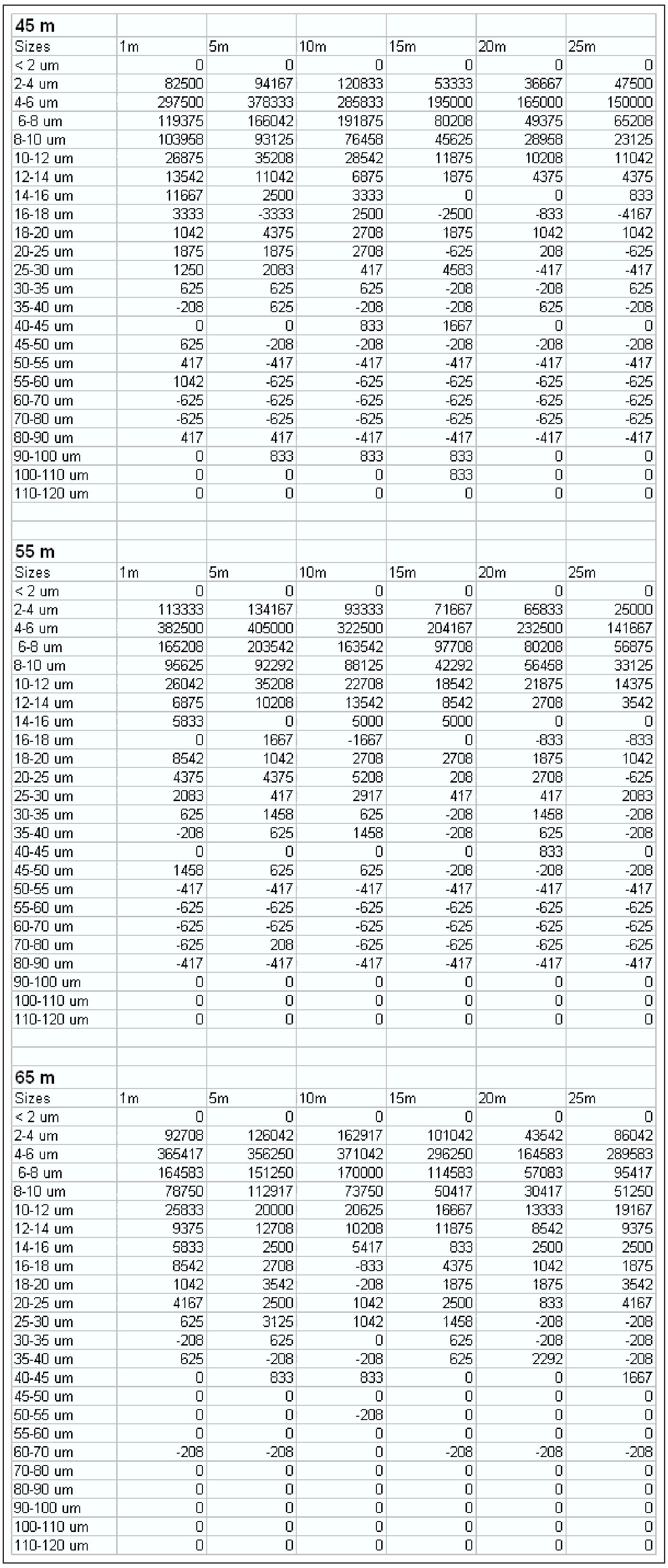
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0		
2-4 um	211	175	184	175		
4-6 um	574	493	539	555		
6-8 um	182	168	131	166		
8-10 um	98	58	85	69		
10-12 um	22	24	34	29		
12-14 um	6	13	14	6		
14-16 um	5	4	10	7		
16-18 um	-1	0	5	-3		
18-20 um	-1	4	5	2		
20-25 um	4	5	11	2		
25-30 um	-1	2	6	0		
30-35 um	1	2	1	1		
35-40 um	1	2	1	1		
40-45 um	0	0	0	0		
45-50 um	0	0	0	0		
50-55 um	0	0	1	0		
55-60 um	0	0	0	0		
60-70 um	0	0	0	0		
70-80 um	0	0	0	0		
80-90 um	0	0	0	0		
90-100 um	0	0	0	0		
100-110 um	0	0	0	0		
110-120 um	0	0	0	0		

25 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	121667	111667	64167	59167	35000	35000
4-6 um	333333	330833	210000	213333	113333	107500
6-8 um	136042	182708	162708	100208	48542	38542
8-10 um	87292	108958	62292	23125	27292	13958
10-12 um	31042	21875	21042	11042	6875	7708
12-14 um	11042	8542	6042	2708	1042	4375
14-16 um	10000	3333	6667	-833	0	1667
16-18 um	4167	-1667	-833	-4167	-4167	-3333
18-20 um	5208	1875	2708	208	208	208
20-25 um	4375	5208	4375	-625	-625	1042
25-30 um	4583	1250	3750	417	417	-417
30-35 um	1458	1458	-208	-208	625	-208
35-40 um	-208	1458	625	-208	-208	-208
40-45 um	0	0	0	0	0	0
45-50 um	-208	625	625	-208	-208	-208
50-55 um	-417	1250	417	-417	-417	-417
55-60 um	208	-625	-625	-625	-625	-625
60-70 um	-625	-625	-625	208	-625	-625
70-80 um	-625	208	-625	-625	-625	-625
80-90 um	-417	-417	-417	-417	-417	-417
90-100 um	0	833	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

35 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	82500	94167	120833	53333	36667	47500
4-6 um	297500	378333	285833	195000	165000	150000
6-8 um	119375	166042	191875	80208	49375	65208
8-10 um	103958	93125	76458	45625	28958	23125
10-12 um	26875	35208	28542	11875	10208	11042
12-14 um	13542	11042	6875	1875	4375	4375
14-16 um	11667	2500	3333	0	0	833
16-18 um	3333	-3333	2500	-2500	-833	-4167
18-20 um	1042	4375	2708	1875	1042	1042
20-25 um	1875	1875	2708	-625	208	-625
25-30 um	1250	2083	417	4583	-417	-417
30-35 um	625	625	625	-208	-208	625
35-40 um	-208	625	-208	-208	625	-208
40-45 um	0	0	833	1667	0	0
45-50 um	625	-208	-208	-208	-208	-208
50-55 um	417	-417	-417	-417	-417	-417
55-60 um	1042	-625	-625	-625	-625	-625
60-70 um	-625	-625	-625	-625	-625	-625
70-80 um	-625	-625	-625	-625	-625	-625
80-90 um	417	417	-417	-417	-417	-417
90-100 um	0	833	833	833	0	0
100-110 um	0	0	0	833	0	0
110-120 um	0	0	0	0	0	0



45 m

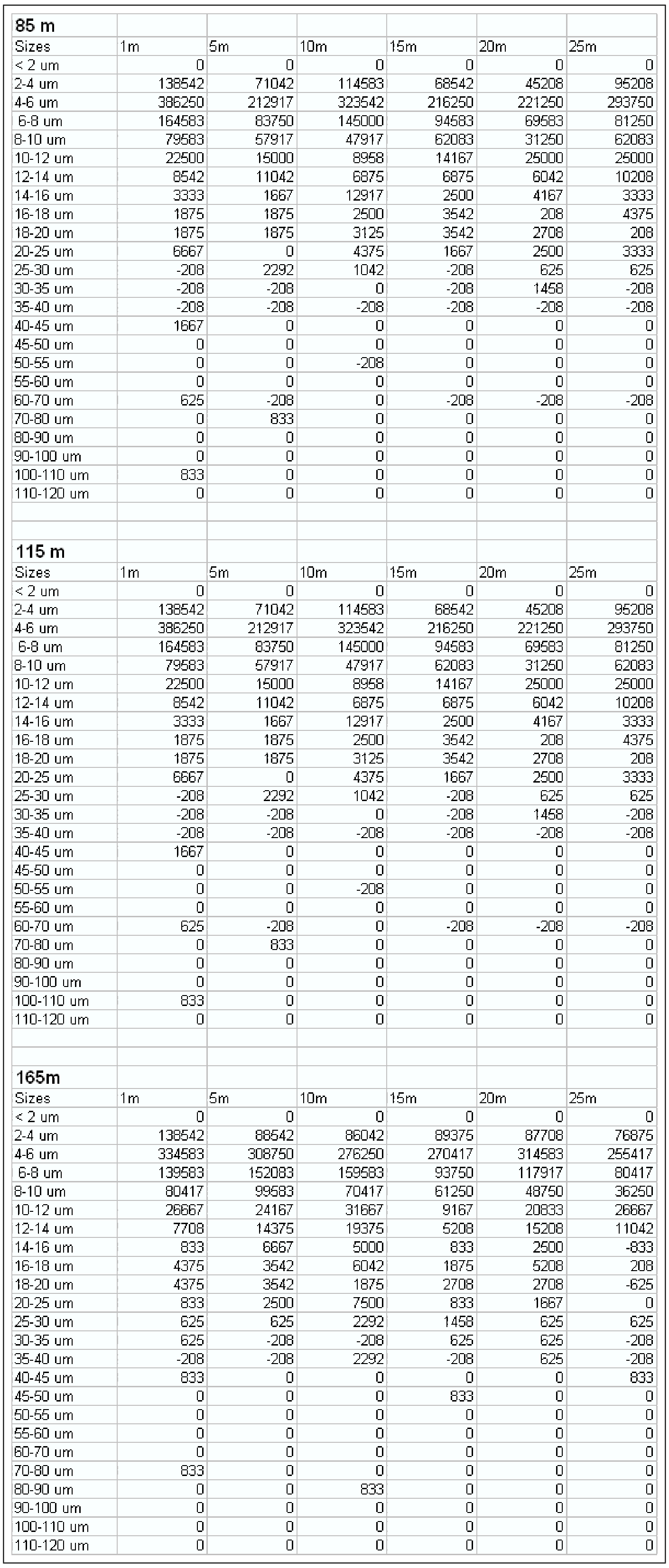
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	82500	94167	120833	53333	36667	47500
4-6 um	297500	378333	285833	195000	165000	150000
6-8 um	119375	166042	191875	80208	49375	65208
8-10 um	103958	93125	76458	45625	28958	23125
10-12 um	26875	35208	28542	11875	10208	11042
12-14 um	13542	11042	6875	1875	4375	4375
14-16 um	11667	2500	3333	0	0	833
16-18 um	3333	-3333	2500	-2500	-833	-4167
18-20 um	1042	4375	2708	1875	1042	1042
20-25 um	1875	1875	2708	-625	208	-625
25-30 um	1250	2083	417	4583	-417	-417
30-35 um	625	625	625	-208	-208	625
35-40 um	-208	625	-208	-208	625	-208
40-45 um	0	0	833	1667	0	0
45-50 um	625	-208	-208	-208	-208	-208
50-55 um	417	-417	-417	-417	-417	-417
55-60 um	1042	-625	-625	-625	-625	-625
60-70 um	-625	-625	-625	-625	-625	-625
70-80 um	-625	-625	-625	-625	-625	-625
80-90 um	417	417	-417	-417	-417	-417
90-100 um	0	833	833	833	0	0
100-110 um	0	0	0	833	0	0
110-120 um	0	0	0	0	0	0

55 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	113333	134167	93333	71667	65833	25000
4-6 um	382500	405000	322500	204167	232500	141667
6-8 um	165208	203542	163542	97708	80208	56875
8-10 um	95625	92292	88125	42292	56458	33125
10-12 um	26042	35208	22708	18542	21875	14375
12-14 um	6875	10208	13542	8542	2708	3542
14-16 um	5833	0	5000	5000	0	0
16-18 um	0	1667	-1667	0	-833	-833
18-20 um	8542	1042	2708	2708	1875	1042
20-25 um	4375	4375	5208	208	2708	-625
25-30 um	2083	417	2917	417	417	2083
30-35 um	625	1458	625	-208	1458	-208
35-40 um	-208	625	1458	-208	625	-208
40-45 um	0	0	0	0	833	0
45-50 um	1458	625	625	-208	-208	-208
50-55 um	-417	-417	-417	-417	-417	-417
55-60 um	-625	-625	-625	-625	-625	-625
60-70 um	-625	-625	-625	-625	-625	-625
70-80 um	-625	208	-625	-625	-625	-625
80-90 um	-417	-417	-417	-417	-417	-417
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

65 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	92708	126042	162917	101042	43542	86042
4-6 um	365417	356250	371042	296250	164583	289583
6-8 um	164583	151250	170000	114583	57083	95417
8-10 um	78750	112917	73750	50417	30417	51250
10-12 um	25833	20000	20625	16667	13333	19167
12-14 um	9375	12708	10208	11875	8542	9375
14-16 um	5833	2500	5417	833	2500	2500
16-18 um	8542	2708	-833	4375	1042	1875
18-20 um	1042	3542	-208	1875	1875	3542
20-25 um	4167	2500	1042	2500	833	4167
25-30 um	625	3125	1042	1458	-208	-208
30-35 um	-208	625	0	625	-208	-208
35-40 um	625	-208	-208	625	2292	-208
40-45 um	0	833	833	0	0	1667
45-50 um	0	0	0	0	0	0
50-55 um	0	0	-208	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-208	-208	0	-208	-208	-208
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



85 m

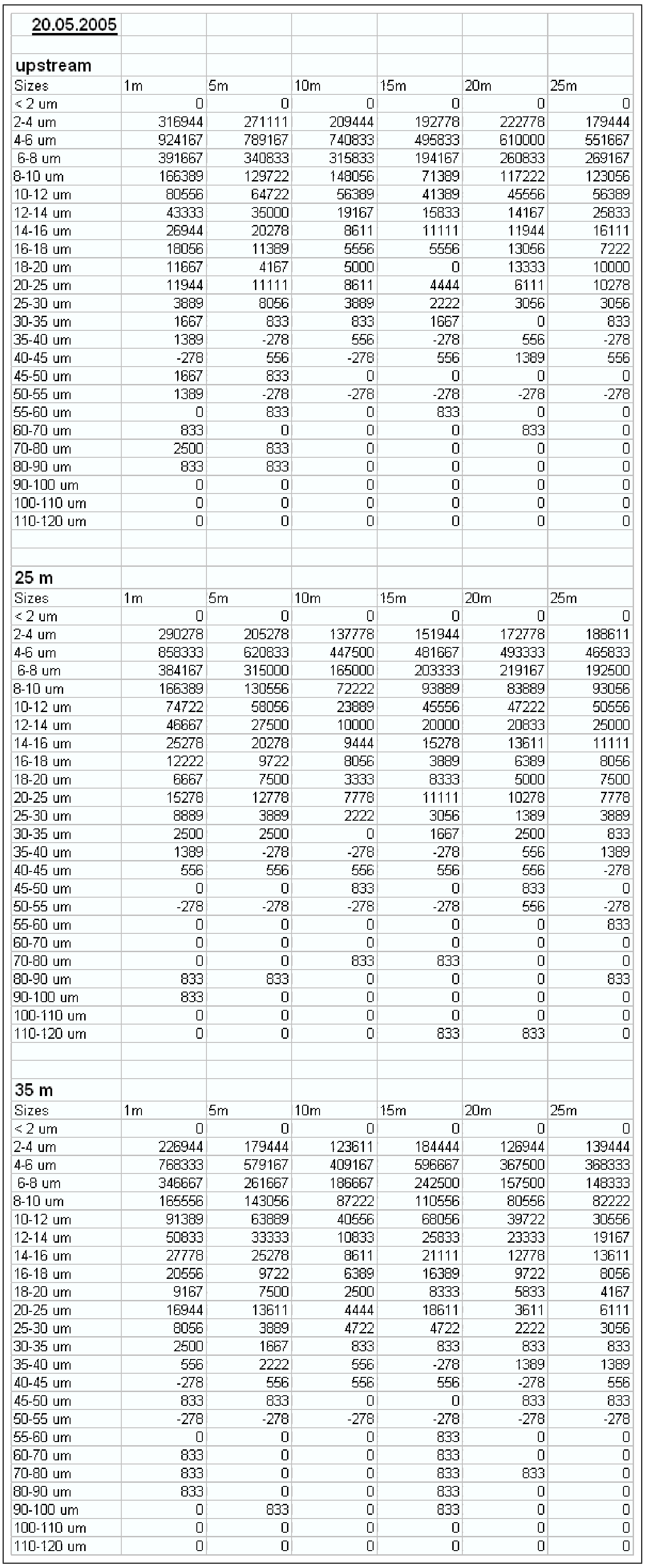
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	138542	71042	114583	68542	45208	95208
4-6 um	386250	212917	323542	216250	221250	293750
6-8 um	164583	83750	145000	94583	69583	81250
8-10 um	79583	57917	47917	62083	31250	62083
10-12 um	22500	15000	8958	14167	25000	25000
12-14 um	8542	11042	6875	6875	6042	10208
14-16 um	3333	1667	12917	2500	4167	3333
16-18 um	1875	1875	2500	3542	208	4375
18-20 um	1875	1875	3125	3542	2708	208
20-25 um	6667	0	4375	1667	2500	3333
25-30 um	-208	2292	1042	-208	625	625
30-35 um	-208	-208	0	-208	1458	-208
35-40 um	-208	-208	-208	-208	-208	-208
40-45 um	1667	0	0	0	0	0
45-50 um	0	0	0	0	0	0
50-55 um	0	0	-208	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	625	-208	0	-208	-208	-208
70-80 um	0	833	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	0	0	0	0	0	0
100-110 um	833	0	0	0	0	0
110-120 um	0	0	0	0	0	0

115 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	138542	71042	114583	68542	45208	95208
4-6 um	386250	212917	323542	216250	221250	293750
6-8 um	164583	83750	145000	94583	69583	81250
8-10 um	79583	57917	47917	62083	31250	62083
10-12 um	22500	15000	8958	14167	25000	25000
12-14 um	8542	11042	6875	6875	6042	10208
14-16 um	3333	1667	12917	2500	4167	3333
16-18 um	1875	1875	2500	3542	208	4375
18-20 um	1875	1875	3125	3542	2708	208
20-25 um	6667	0	4375	1667	2500	3333
25-30 um	-208	2292	1042	-208	625	625
30-35 um	-208	-208	0	-208	1458	-208
35-40 um	-208	-208	-208	-208	-208	-208
40-45 um	1667	0	0	0	0	0
45-50 um	0	0	0	0	0	0
50-55 um	0	0	-208	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	625	-208	0	-208	-208	-208
70-80 um	0	833	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	0	0	0	0	0	0
100-110 um	833	0	0	0	0	0
110-120 um	0	0	0	0	0	0

165m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	138542	88542	86042	89375	87708	76875
4-6 um	334583	308750	276250	270417	314583	255417
6-8 um	139583	152083	159583	93750	117917	80417
8-10 um	80417	99583	70417	61250	48750	36250
10-12 um	26667	24167	31667	9167	20833	26667
12-14 um	7708	14375	19375	5208	15208	11042
14-16 um	833	6667	5000	833	2500	-833
16-18 um	4375	3542	6042	1875	5208	208
18-20 um	4375	3542	1875	2708	2708	-625
20-25 um	833	2500	7500	833	1667	0
25-30 um	625	625	2292	1458	625	625
30-35 um	625	-208	-208	625	625	-208
35-40 um	-208	-208	2292	-208	625	-208
40-45 um	833	0	0	0	0	833
45-50 um	0	0	0	833	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	0	0	0	0	0	0
70-80 um	833	0	0	0	0	0
80-90 um	0	0	833	0	0	0
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



20.05.2005

upstream

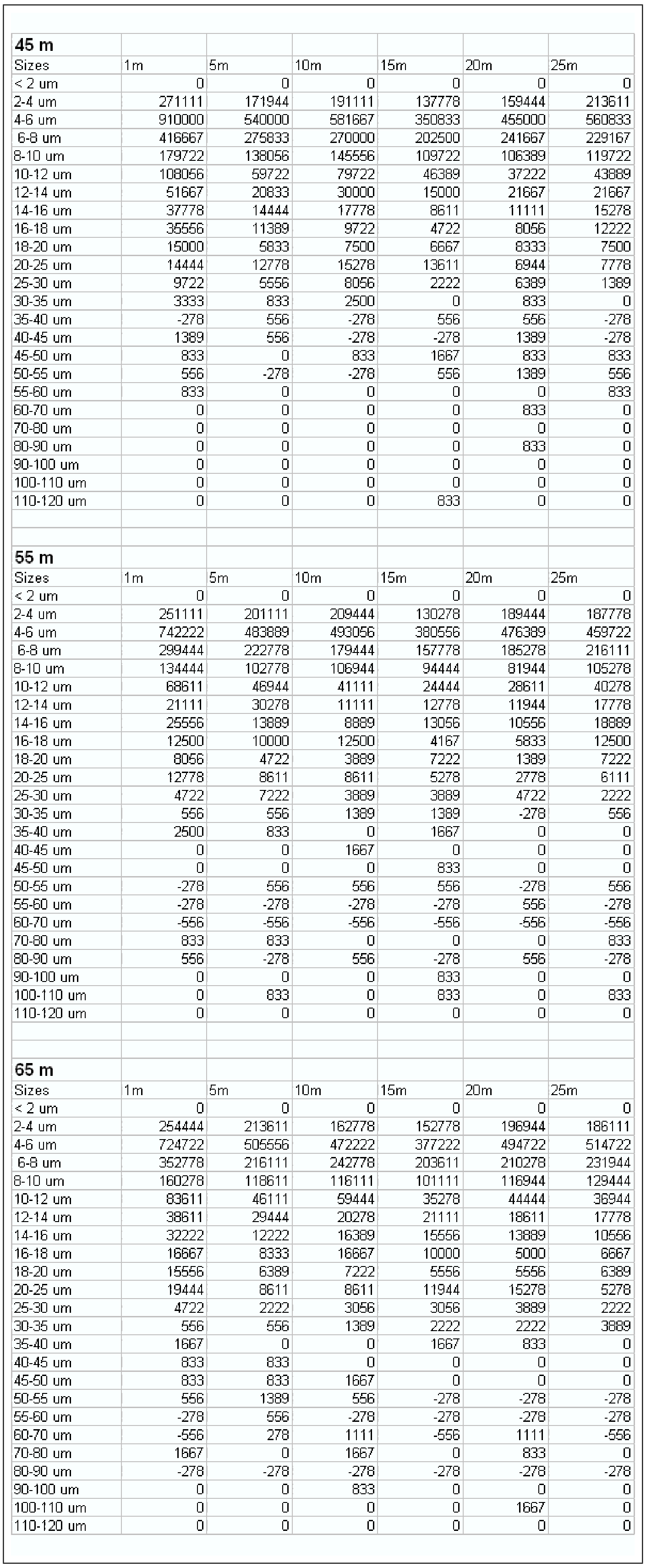
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	316944	271111	209444	192778	222778	179444
4-6 um	924167	789167	740833	495833	610000	551667
6-8 um	391667	340833	315833	194167	260833	269167
8-10 um	166389	129722	148056	71389	117222	123056
10-12 um	80556	64722	56389	41389	45556	56389
12-14 um	43333	35000	19167	15833	14167	25833
14-16 um	26944	20278	8611	11111	11944	16111
16-18 um	18056	11389	5556	5556	13056	7222
18-20 um	11667	4167	5000	0	13333	10000
20-25 um	11944	11111	8611	4444	6111	10278
25-30 um	3889	8056	3889	2222	3056	3056
30-35 um	1667	833	833	1667	0	833
35-40 um	1389	-278	556	-278	556	-278
40-45 um	-278	556	-278	556	1389	556
45-50 um	1667	833	0	0	0	0
50-55 um	1389	-278	-278	-278	-278	-278
55-60 um	0	833	0	833	0	0
60-70 um	833	0	0	0	833	0
70-80 um	2500	833	0	0	0	0
80-90 um	833	833	0	0	0	0
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

25 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	290278	205278	137778	151944	172778	188611
4-6 um	858333	620833	447500	481667	493333	465833
6-8 um	384167	315000	165000	203333	219167	192500
8-10 um	166389	130556	72222	93889	83889	93056
10-12 um	74722	58056	23889	45556	47222	50556
12-14 um	46667	27500	10000	20000	20833	25000
14-16 um	25278	20278	9444	15278	13611	11111
16-18 um	12222	9722	8056	3889	6389	8056
18-20 um	6667	7500	3333	8333	5000	7500
20-25 um	15278	12778	7778	11111	10278	7778
25-30 um	8889	3889	2222	3056	1389	3889
30-35 um	2500	2500	0	1667	2500	833
35-40 um	1389	-278	-278	-278	556	1389
40-45 um	556	556	556	556	556	-278
45-50 um	0	0	833	0	833	0
50-55 um	-278	-278	-278	-278	556	-278
55-60 um	0	0	0	0	0	833
60-70 um	0	0	0	0	0	0
70-80 um	0	0	833	833	0	0
80-90 um	833	833	0	0	0	833
90-100 um	833	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	833	833	0

35 m

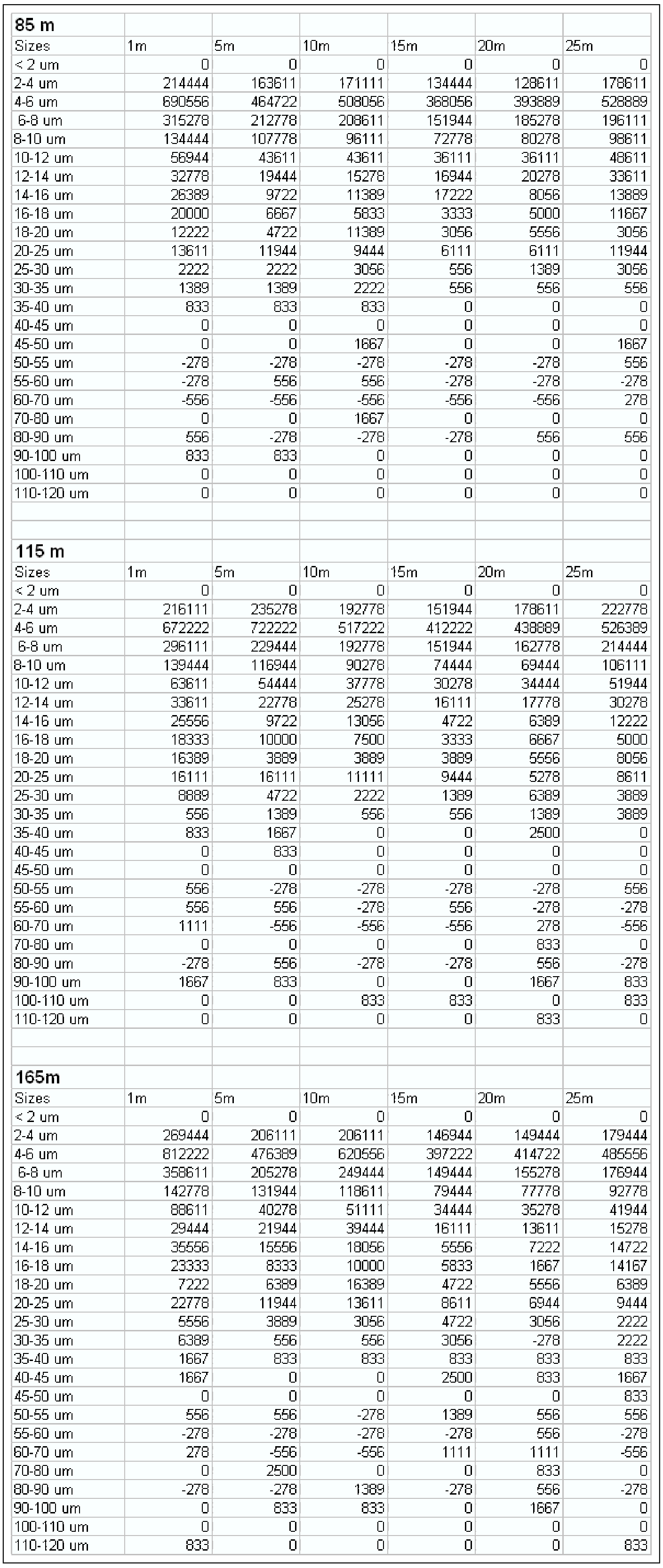
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	226944	179444	123611	184444	126944	139444
4-6 um	768333	579167	409167	596667	367500	368333
6-8 um	346667	261667	186667	242500	157500	148333
8-10 um	165556	143056	87222	110556	80556	82222
10-12 um	91389	63889	40556	68056	39722	30556
12-14 um	50833	33333	10833	25833	23333	19167
14-16 um	27778	25278	8611	21111	12778	13611
16-18 um	20556	9722	6389	16389	9722	8056
18-20 um	9167	7500	2500	8333	5833	4167
20-25 um	16944	13611	4444	18611	3611	6111
25-30 um	8056	3889	4722	4722	2222	3056
30-35 um	2500	1667	833	833	833	833
35-40 um	556	2222	556	-278	1389	1389
40-45 um	-278	556	556	556	-278	556
45-50 um	833	833	0	0	833	833
50-55 um	-278	-278	-278	-278	-278	-278
55-60 um	0	0	0	833	0	0
60-70 um	833	0	0	833	0	0
70-80 um	833	0	0	833	833	0
80-90 um	833	0	0	833	0	0
90-100 um	0	833	0	833	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



45 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	271111	171944	191111	137778	159444	213611
4-6 um	910000	540000	581667	350833	455000	560833
6-8 um	416667	275833	270000	202500	241667	229167
8-10 um	179722	138056	145556	109722	106389	119722
10-12 um	108056	59722	79722	46389	37222	43889
12-14 um	51667	20833	30000	15000	21667	21667
14-16 um	37778	14444	17778	8611	11111	15278
16-18 um	35556	11389	9722	4722	8056	12222
18-20 um	15000	5833	7500	6667	8333	7500
20-25 um	14444	12778	15278	13611	6944	7778
25-30 um	9722	5556	8056	2222	6389	1389
30-35 um	3333	833	2500	0	833	0
35-40 um	-278	556	-278	556	556	-278
40-45 um	1389	556	-278	-278	1389	-278
45-50 um	833	0	833	1667	833	833
50-55 um	556	-278	-278	556	1389	556
55-60 um	833	0	0	0	0	833
60-70 um	0	0	0	0	833	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	833	0
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	833	0	0

55 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	251111	201111	209444	130278	189444	187778
4-6 um	742222	483889	493056	380556	476389	459722
6-8 um	299444	222778	179444	157778	185278	216111
8-10 um	134444	102778	106944	94444	81944	105278
10-12 um	68611	46944	41111	24444	28611	40278
12-14 um	21111	30278	11111	12778	11944	17778
14-16 um	25556	13889	8889	13056	10556	18889
16-18 um	12500	10000	12500	4167	5833	12500
18-20 um	8056	4722	3889	7222	1389	7222
20-25 um	12778	8611	8611	5278	2778	6111
25-30 um	4722	7222	3889	3889	4722	2222
30-35 um	556	556	1389	1389	-278	556
35-40 um	2500	833	0	1667	0	0
40-45 um	0	0	1667	0	0	0
45-50 um	0	0	0	833	0	0
50-55 um	-278	556	556	556	-278	556
55-60 um	-278	-278	-278	-278	556	-278
60-70 um	-556	-556	-556	-556	-556	-556
70-80 um	833	833	0	0	0	833
80-90 um	556	-278	556	-278	556	-278
90-100 um	0	0	0	833	0	0
100-110 um	0	833	0	833	0	833
110-120 um	0	0	0	0	0	0

65 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	254444	213611	162778	152778	196944	186111
4-6 um	724722	505556	472222	377222	494722	514722
6-8 um	352778	216111	242778	203611	210278	231944
8-10 um	160278	118611	116111	101111	116944	129444
10-12 um	83611	46111	59444	35278	44444	36944
12-14 um	38611	29444	20278	21111	18611	17778
14-16 um	32222	12222	16389	15556	13889	10556
16-18 um	16667	8333	16667	10000	5000	6667
18-20 um	15556	6389	7222	5556	5556	6389
20-25 um	19444	8611	8611	11944	15278	5278
25-30 um	4722	2222	3056	3056	3889	2222
30-35 um	556	556	1389	2222	2222	3889
35-40 um	1667	0	0	1667	833	0
40-45 um	833	833	0	0	0	0
45-50 um	833	833	1667	0	0	0
50-55 um	556	1389	556	-278	-278	-278
55-60 um	-278	556	-278	-278	-278	-278
60-70 um	-556	278	1111	-556	1111	-556
70-80 um	1667	0	1667	0	833	0
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	833	0	0	0
100-110 um	0	0	0	0	1667	0
110-120 um	0	0	0	0	0	0



85 m

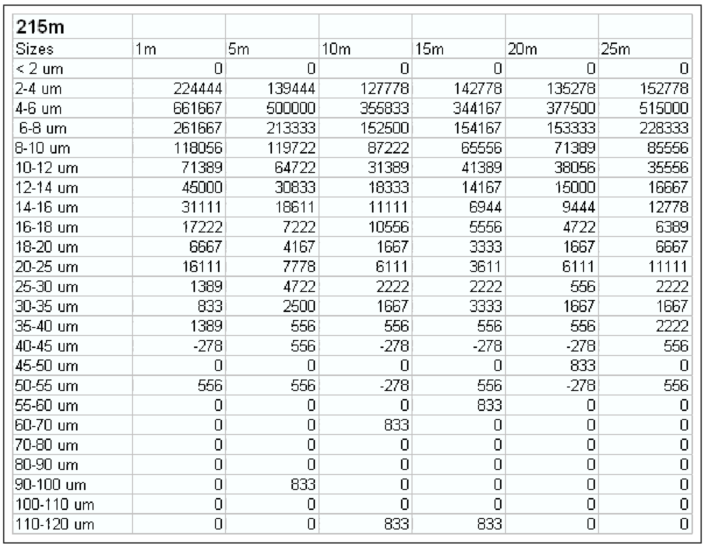
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	214444	163611	171111	134444	128611	178611
4-6 um	690556	464722	508056	368056	393889	528889
6-8 um	315278	212778	208611	151944	185278	196111
8-10 um	134444	107778	96111	72778	80278	98611
10-12 um	56944	43611	43611	36111	36111	48611
12-14 um	32778	19444	15278	16944	20278	33611
14-16 um	26389	9722	11389	17222	8056	13889
16-18 um	20000	6667	5833	3333	5000	11667
18-20 um	12222	4722	11389	3056	5556	3056
20-25 um	13611	11944	9444	6111	6111	11944
25-30 um	2222	2222	3056	556	1389	3056
30-35 um	1389	1389	2222	556	556	556
35-40 um	833	833	833	0	0	0
40-45 um	0	0	0	0	0	0
45-50 um	0	0	1667	0	0	1667
50-55 um	-278	-278	-278	-278	-278	556
55-60 um	-278	556	556	-278	-278	-278
60-70 um	-556	-556	-556	-556	-556	278
70-80 um	0	0	1667	0	0	0
80-90 um	556	-278	-278	-278	556	556
90-100 um	833	833	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

115 m

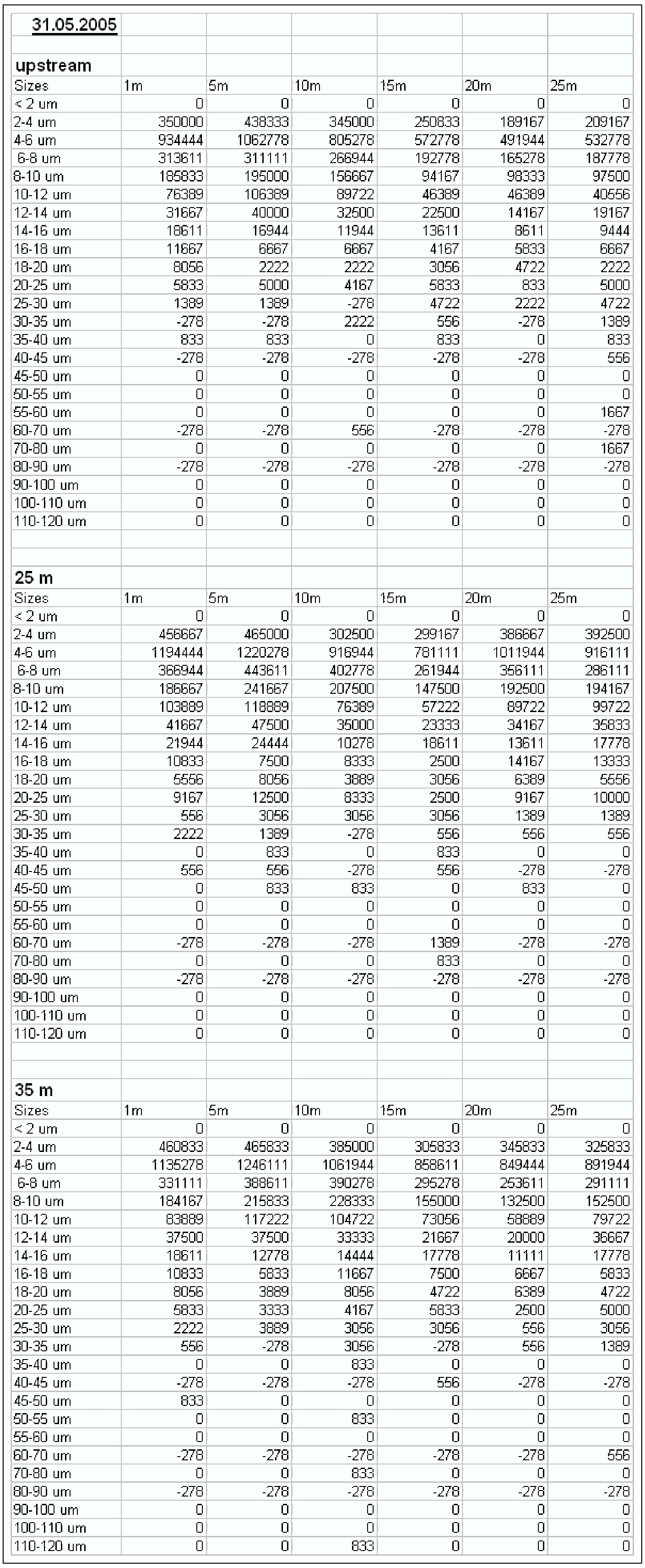
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	216111	235278	192778	151944	178611	222778
4-6 um	672222	722222	517222	412222	438889	526389
6-8 um	296111	229444	192778	151944	162778	214444
8-10 um	139444	116944	90278	74444	69444	106111
10-12 um	63611	54444	37778	30278	34444	51944
12-14 um	33611	22778	25278	16111	17778	30278
14-16 um	25556	9722	13056	4722	6389	12222
16-18 um	18333	10000	7500	3333	6667	5000
18-20 um	16389	3889	3889	3889	5556	8056
20-25 um	16111	16111	11111	9444	5278	8611
25-30 um	8889	4722	2222	1389	6389	3889
30-35 um	556	1389	556	556	1389	3889
35-40 um	833	1667	0	0	2500	0
40-45 um	0	833	0	0	0	0
45-50 um	0	0	0	0	0	0
50-55 um	556	-278	-278	-278	-278	556
55-60 um	556	556	-278	556	-278	-278
60-70 um	1111	-556	-556	-556	278	-556
70-80 um	0	0	0	0	833	0
80-90 um	-278	556	-278	-278	556	-278
90-100 um	1667	833	0	0	1667	833
100-110 um	0	0	833	833	0	833
110-120 um	0	0	0	0	833	0

165m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	269444	206111	206111	146944	149444	179444
4-6 um	812222	476389	620556	397222	414722	485556
6-8 um	358611	205278	249444	149444	155278	176944
8-10 um	142778	131944	118611	79444	77778	92778
10-12 um	88611	40278	51111	34444	35278	41944
12-14 um	29444	21944	39444	16111	13611	15278
14-16 um	35556	15556	18056	5556	7222	14722
16-18 um	23333	8333	10000	5833	1667	14167
18-20 um	7222	6389	16389	4722	5556	6389
20-25 um	22778	11944	13611	8611	6944	9444
25-30 um	5556	3889	3056	4722	3056	2222
30-35 um	6389	556	556	3056	-278	2222
35-40 um	1667	833	833	833	833	833
40-45 um	1667	0	0	2500	833	1667
45-50 um	0	0	0	0	0	833
50-55 um	556	556	-278	1389	556	556
55-60 um	-278	-278	-278	-278	556	-278
60-70 um	278	-556	-556	1111	1111	-556
70-80 um	0	2500	0	0	833	0
80-90 um	-278	-278	1389	-278	556	-278
90-100 um	0	833	833	0	1667	0
100-110 um	0	0	0	0	0	0
110-120 um	833	0	0	0	0	833



215m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	224444	139444	127778	142778	135278	152778
4-6 um	661667	500000	355833	344167	377500	515000
6-8 um	261667	213333	152500	154167	153333	228333
8-10 um	118056	119722	87222	65556	71389	85556
10-12 um	71389	64722	31389	41389	38056	35556
12-14 um	45000	30833	18333	14167	15000	16667
14-16 um	31111	18611	11111	6944	9444	12778
16-18 um	17222	7222	10556	5556	4722	6389
18-20 um	6667	4167	1667	3333	1667	6667
20-25 um	16111	7778	6111	3611	6111	11111
25-30 um	1389	4722	2222	2222	556	2222
30-35 um	833	2500	1667	3333	1667	1667
35-40 um	1389	556	556	556	556	2222
40-45 um	-278	556	-278	-278	-278	556
45-50 um	0	0	0	0	833	0
50-55 um	556	556	-278	556	-278	556
55-60 um	0	0	0	833	0	0
60-70 um	0	0	833	0	0	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	0	833	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	833	833	0	0



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upstream

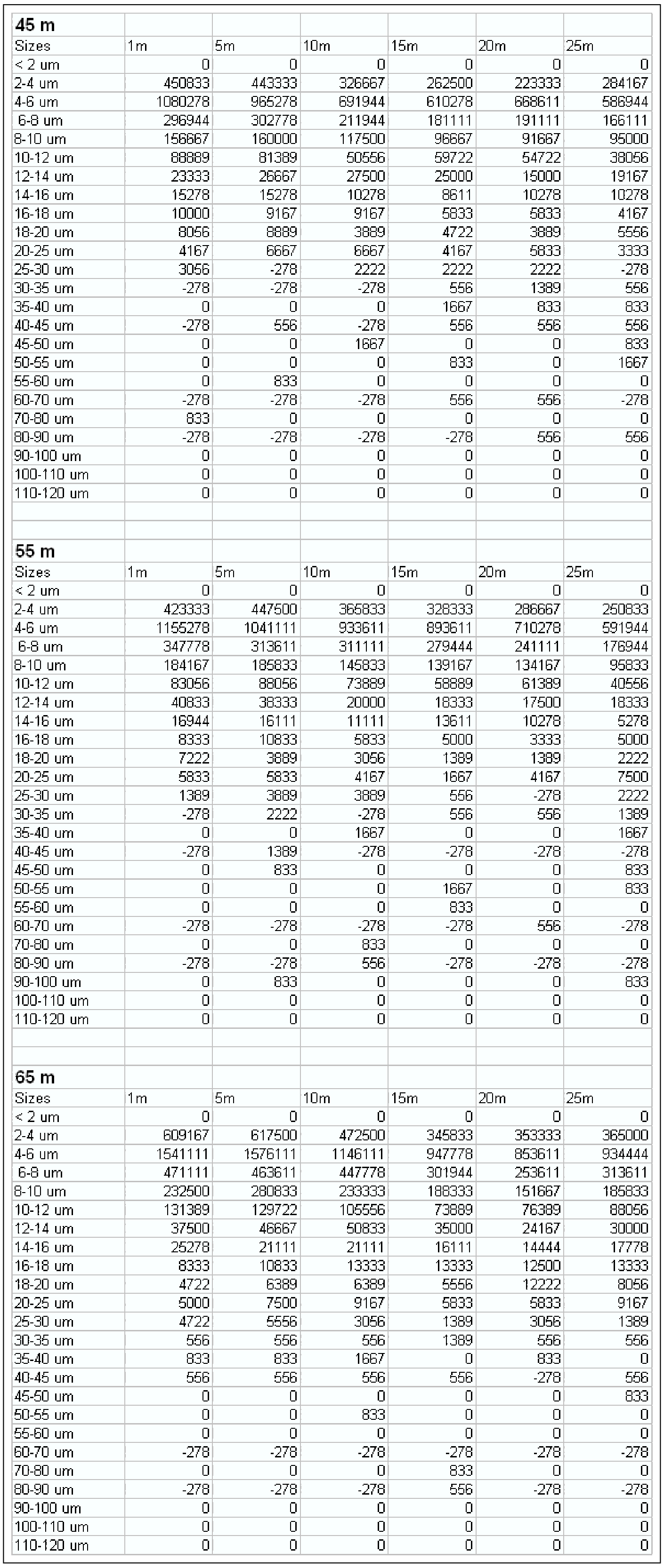
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	350000	438333	345000	250833	189167	209167
4-6 um	934444	1062778	805278	572778	491944	532778
6-8 um	313611	311111	266944	192778	165278	187778
8-10 um	185833	195000	156667	94167	98333	97500
10-12 um	76389	106389	89722	46389	46389	40556
12-14 um	31667	40000	32500	22500	14167	19167
14-16 um	18611	16944	11944	13611	8611	9444
16-18 um	11667	6667	6667	4167	5833	6667
18-20 um	8056	2222	2222	3056	4722	2222
20-25 um	5833	5000	4167	5833	833	5000
25-30 um	1389	1389	-278	4722	2222	4722
30-35 um	-278	-278	2222	556	-278	1389
35-40 um	833	833	0	833	0	833
40-45 um	-278	-278	-278	-278	-278	556
45-50 um	0	0	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	1667
60-70 um	-278	-278	556	-278	-278	-278
70-80 um	0	0	0	0	0	1667
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

25 m

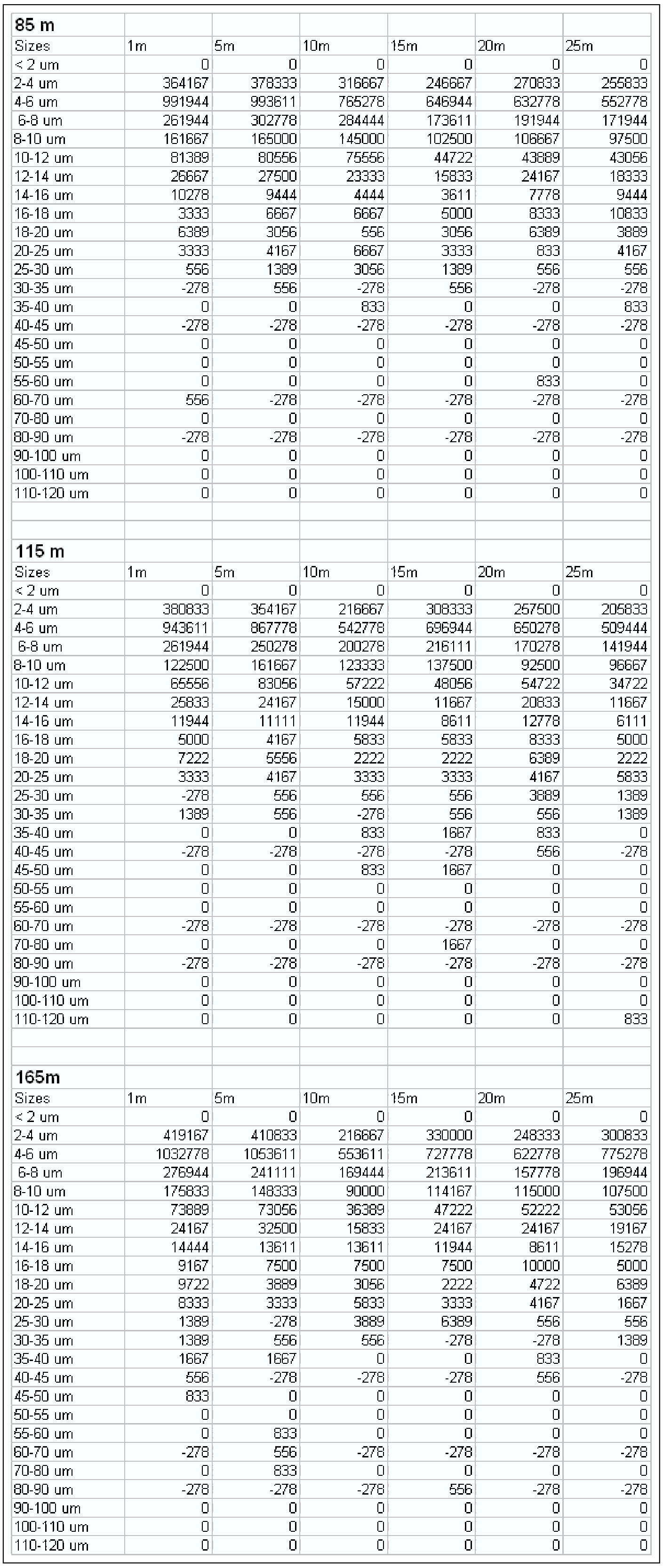
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	456667	465000	302500	299167	386667	392500
4-6 um	1194444	1220278	916944	781111	1011944	916111
6-8 um	366944	443611	402778	261944	356111	286111
8-10 um	186667	241667	207500	147500	192500	194167
10-12 um	103889	118889	76389	57222	89722	99722
12-14 um	41667	47500	35000	23333	34167	35833
14-16 um	21944	24444	10278	18611	13611	17778
16-18 um	10833	7500	8333	2500	14167	13333
18-20 um	5556	8056	3889	3056	6389	5556
20-25 um	9167	12500	8333	2500	9167	10000
25-30 um	556	3056	3056	3056	1389	1389
30-35 um	2222	1389	-278	556	556	556
35-40 um	0	833	0	833	0	0
40-45 um	556	556	-278	556	-278	-278
45-50 um	0	833	833	0	833	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-278	-278	-278	1389	-278	-278
70-80 um	0	0	0	833	0	0
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

35 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	460833	465833	385000	305833	345833	325833
4-6 um	1135278	1246111	1061944	858611	849444	891944
6-8 um	331111	388611	390278	295278	253611	291111
8-10 um	184167	215833	228333	155000	132500	152500
10-12 um	83889	117222	104722	73056	58889	79722
12-14 um	37500	37500	33333	21667	20000	36667
14-16 um	18611	12778	14444	17778	11111	17778
16-18 um	10833	5833	11667	7500	6667	5833
18-20 um	8056	3889	8056	4722	6389	4722
20-25 um	5833	3333	4167	5833	2500	5000
25-30 um	2222	3889	3056	3056	556	3056
30-35 um	556	-278	3056	-278	556	1389
35-40 um	0	0	833	0	0	0
40-45 um	-278	-278	-278	556	-278	-278
45-50 um	833	0	0	0	0	0
50-55 um	0	0	833	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-278	-278	-278	-278	-278	556
70-80 um	0	0	833	0	0	0
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	833	0	0	0



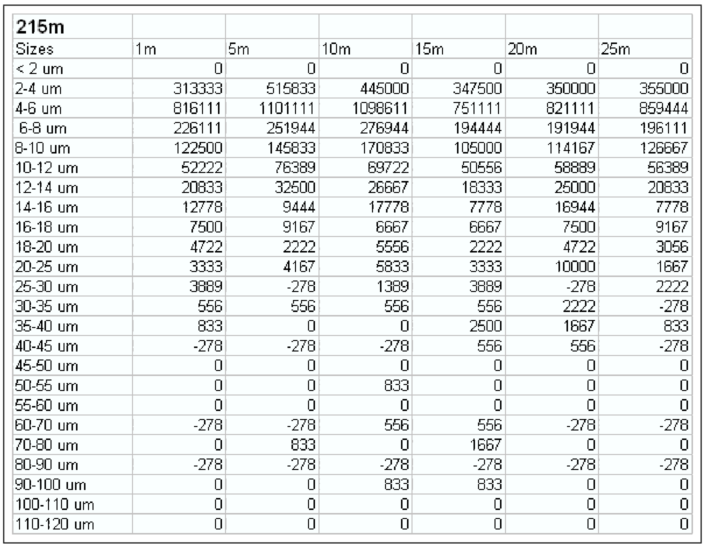
45 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	450833	443333	326667	262500	223333	284167
4-6 um	1080278	965278	691944	610278	668611	586944
6-8 um	296944	302778	211944	181111	191111	166111
8-10 um	156667	160000	117500	96667	91667	95000
10-12 um	88889	81389	50556	59722	54722	38056
12-14 um	23333	26667	27500	25000	15000	19167
14-16 um	15278	15278	10278	8611	10278	10278
16-18 um	10000	9167	9167	5833	5833	4167
18-20 um	8056	8889	3889	4722	3889	5556
20-25 um	4167	6667	6667	4167	5833	3333
25-30 um	3056	-278	2222	2222	2222	-278
30-35 um	-278	-278	-278	556	1389	556
35-40 um	0	0	0	1667	833	833
40-45 um	-278	556	-278	556	556	556
45-50 um	0	0	1667	0	0	833
50-55 um	0	0	0	833	0	1667
55-60 um	0	833	0	0	0	0
60-70 um	-278	-278	-278	556	556	-278
70-80 um	833	0	0	0	0	0
80-90 um	-278	-278	-278	-278	556	556
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0
55 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	423333	447500	365833	328333	286667	250833
4-6 um	1155278	1041111	933611	893611	710278	591944
6-8 um	347778	313611	311111	279444	241111	176944
8-10 um	184167	185833	145833	139167	134167	95833
10-12 um	83056	88056	73889	58889	61389	40556
12-14 um	40833	38333	20000	18333	17500	18333
14-16 um	16944	16111	11111	13611	10278	5278
16-18 um	8333	10833	5833	5000	3333	5000
18-20 um	7222	3889	3056	1389	1389	2222
20-25 um	5833	5833	4167	1667	4167	7500
25-30 um	1389	3889	3889	556	-278	2222
30-35 um	-278	2222	-278	556	556	1389
35-40 um	0	0	1667	0	0	1667
40-45 um	-278	1389	-278	-278	-278	-278
45-50 um	0	833	0	0	0	833
50-55 um	0	0	0	1667	0	833
55-60 um	0	0	0	833	0	0
60-70 um	-278	-278	-278	-278	556	-278
70-80 um	0	0	833	0	0	0
80-90 um	-278	-278	556	-278	-278	-278
90-100 um	0	833	0	0	0	833
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0
65 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	609167	617500	472500	345833	353333	365000
4-6 um	1541111	1576111	1146111	947778	853611	934444
6-8 um	471111	463611	447778	301944	253611	313611
8-10 um	232500	280833	233333	188333	151667	185833
10-12 um	131389	129722	105556	73889	76389	88056
12-14 um	37500	46667	50833	35000	24167	30000
14-16 um	25278	21111	21111	16111	14444	17778
16-18 um	8333	10833	13333	13333	12500	13333
18-20 um	4722	6389	6389	5556	12222	8056
20-25 um	5000	7500	9167	5833	5833	9167
25-30 um	4722	5556	3056	1389	3056	1389
30-35 um	556	556	556	1389	556	556
35-40 um	833	833	1667	0	833	0
40-45 um	556	556	556	556	-278	556
45-50 um	0	0	0	0	0	833
50-55 um	0	0	833	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-278	-278	-278	-278	-278	-278
70-80 um	0	0	0	833	0	0
80-90 um	-278	-278	-278	556	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



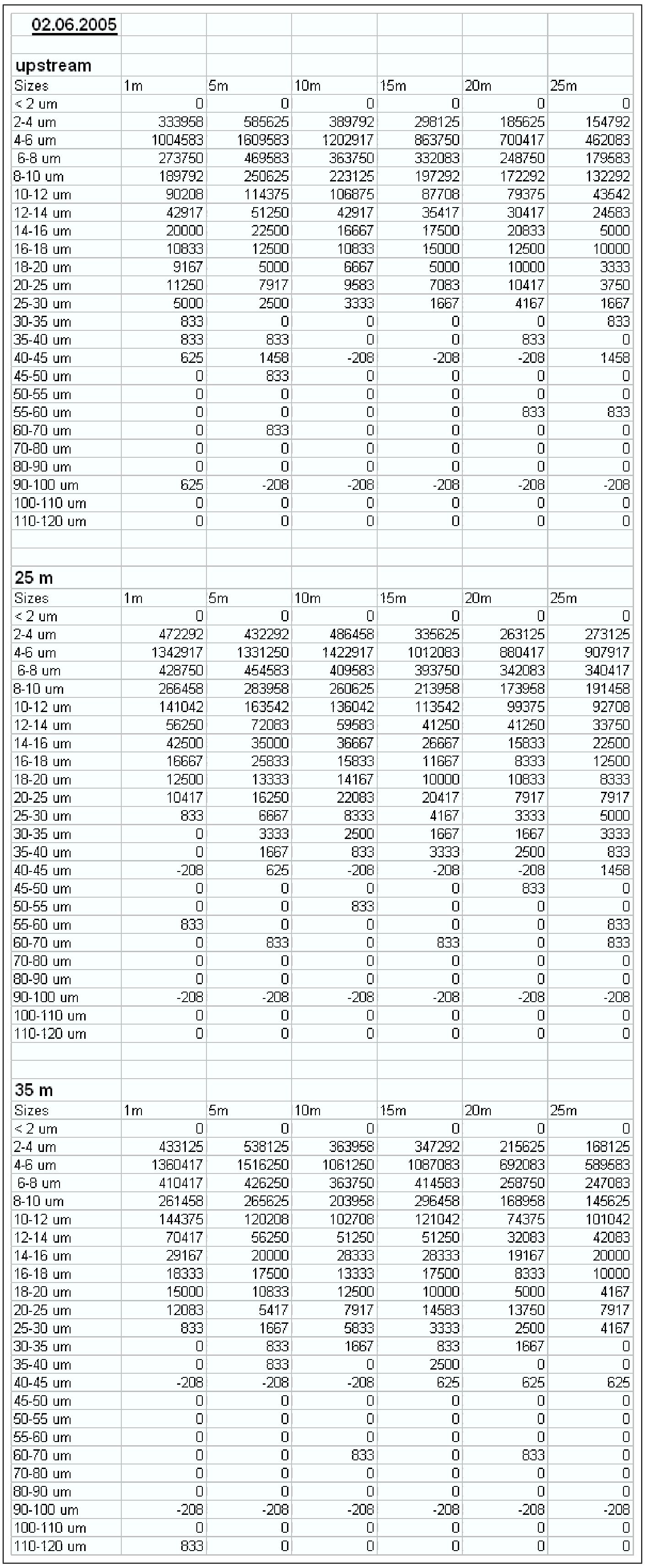
85 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	364167	378333	316667	246667	270833	255833
4-6 um	991944	993611	765278	646944	632778	552778
6-8 um	261944	302778	284444	173611	191944	171944
8-10 um	161667	165000	145000	102500	106667	97500
10-12 um	81389	80556	75556	44722	43889	43056
12-14 um	26667	27500	23333	15833	24167	18333
14-16 um	10278	9444	4444	3611	7778	9444
16-18 um	3333	6667	6667	5000	8333	10833
18-20 um	6389	3056	556	3056	6389	3889
20-25 um	3333	4167	6667	3333	833	4167
25-30 um	556	1389	3056	1389	556	556
30-35 um	-278	556	-278	556	-278	-278
35-40 um	0	0	833	0	0	833
40-45 um	-278	-278	-278	-278	-278	-278
45-50 um	0	0	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	833	0
60-70 um	556	-278	-278	-278	-278	-278
70-80 um	0	0	0	0	0	0
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

115 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	380833	354167	216667	308333	257500	205833
4-6 um	943611	867778	542778	696944	650278	509444
6-8 um	261944	250278	200278	216111	170278	141944
8-10 um	122500	161667	123333	137500	92500	96667
10-12 um	65556	83056	57222	48056	54722	34722
12-14 um	25833	24167	15000	11667	20833	11667
14-16 um	11944	11111	11944	8611	12778	6111
16-18 um	5000	4167	5833	5833	8333	5000
18-20 um	7222	5556	2222	2222	6389	2222
20-25 um	3333	4167	3333	3333	4167	5833
25-30 um	-278	556	556	556	3889	1389
30-35 um	1389	556	-278	556	556	1389
35-40 um	0	0	833	1667	833	0
40-45 um	-278	-278	-278	-278	556	-278
45-50 um	0	0	833	1667	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-278	-278	-278	-278	-278	-278
70-80 um	0	0	0	1667	0	0
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	833

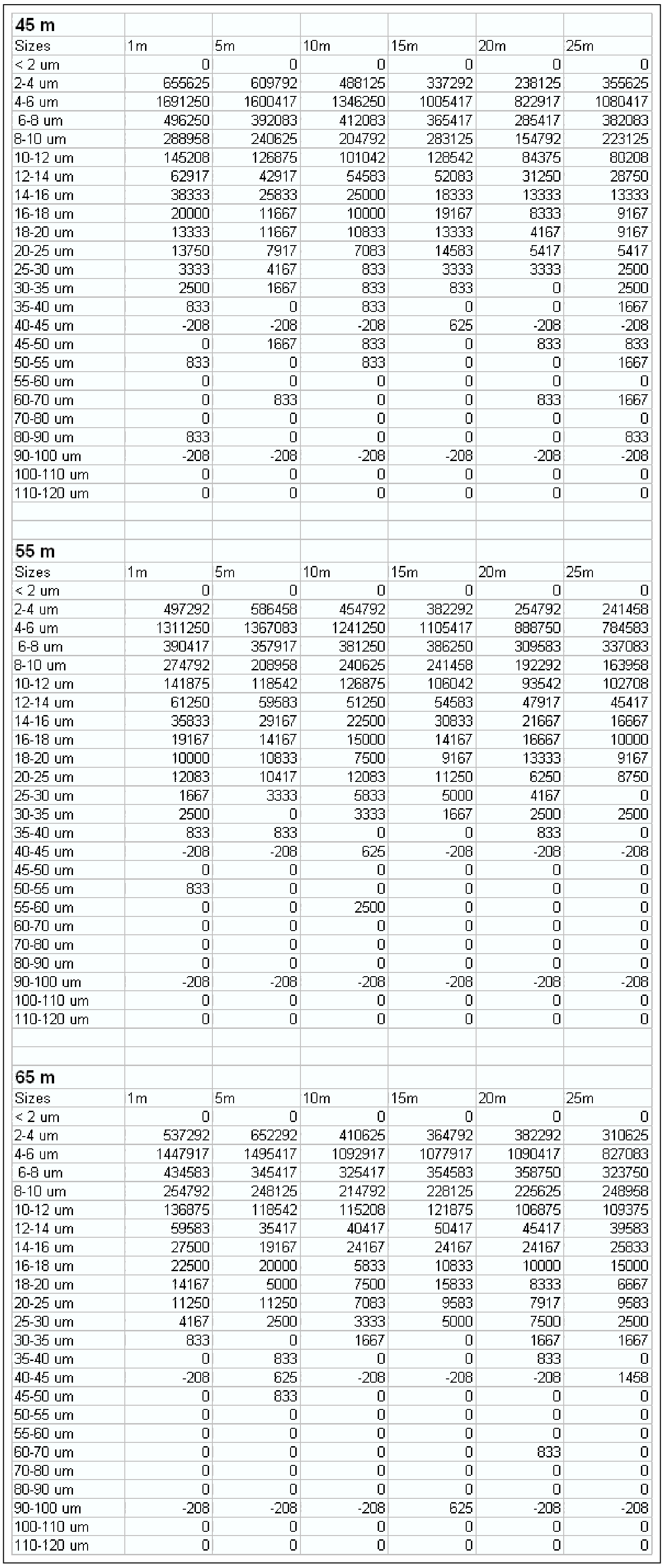
165m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	419167	410833	216667	330000	248333	300833
4-6 um	1032778	1053611	553611	727778	622778	775278
6-8 um	276944	241111	169444	213611	157778	196944
8-10 um	175833	148333	90000	114167	115000	107500
10-12 um	73889	73056	36389	47222	52222	53056
12-14 um	24167	32500	15833	24167	24167	19167
14-16 um	14444	13611	13611	11944	8611	15278
16-18 um	9167	7500	7500	7500	10000	5000
18-20 um	9722	3889	3056	2222	4722	6389
20-25 um	8333	3333	5833	3333	4167	1667
25-30 um	1389	-278	3889	6389	556	556
30-35 um	1389	556	556	-278	-278	1389
35-40 um	1667	1667	0	0	833	0
40-45 um	556	-278	-278	-278	556	-278
45-50 um	833	0	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	833	0	0	0	0
60-70 um	-278	556	-278	-278	-278	-278
70-80 um	0	833	0	0	0	0
80-90 um	-278	-278	-278	556	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



215m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	313333	515833	445000	347500	350000	355000
4-6 um	816111	1101111	1098611	751111	821111	859444
6-8 um	226111	251944	276944	194444	191944	196111
8-10 um	122500	145833	170833	105000	114167	126667
10-12 um	52222	76389	69722	50556	58889	56389
12-14 um	20833	32500	26667	18333	25000	20833
14-16 um	12778	9444	17778	7778	16944	7778
16-18 um	7500	9167	6667	6667	7500	9167
18-20 um	4722	2222	5556	2222	4722	3056
20-25 um	3333	4167	5833	3333	10000	1667
25-30 um	3889	-278	1389	3889	-278	2222
30-35 um	556	556	556	556	2222	-278
35-40 um	833	0	0	2500	1667	833
40-45 um	-278	-278	-278	556	556	-278
45-50 um	0	0	0	0	0	0
50-55 um	0	0	833	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-278	-278	556	556	-278	-278
70-80 um	0	833	0	1667	0	0
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	833	833	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



02.06.2005						
upstream						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	333958	585625	389792	298125	185625	154792
4-6 um	1004583	1609583	1202917	863750	700417	462083
6-8 um	273750	469583	363750	332083	248750	179583
8-10 um	189792	250625	223125	197292	172292	132292
10-12 um	90208	114375	106875	87708	79375	43542
12-14 um	42917	51250	42917	35417	30417	24583
14-16 um	20000	22500	16667	17500	20833	5000
16-18 um	10833	12500	10833	15000	12500	10000
18-20 um	9167	5000	6667	5000	10000	3333
20-25 um	11250	7917	9583	7083	10417	3750
25-30 um	5000	2500	3333	1667	4167	1667
30-35 um	833	0	0	0	0	833
35-40 um	833	833	0	0	833	0
40-45 um	625	1458	-208	-208	-208	1458
45-50 um	0	833	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	833	833
60-70 um	0	833	0	0	0	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	625	-208	-208	-208	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0
25 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	472292	432292	486458	335625	263125	273125
4-6 um	1342917	1331250	1422917	1012083	880417	907917
6-8 um	428750	454583	409583	393750	342083	340417
8-10 um	266458	283958	260625	213958	173958	191458
10-12 um	141042	163542	136042	113542	99375	92708
12-14 um	56250	72083	59583	41250	41250	33750
14-16 um	42500	35000	36667	26667	15833	22500
16-18 um	16667	25833	15833	11667	8333	12500
18-20 um	12500	13333	14167	10000	10833	8333
20-25 um	10417	16250	22083	20417	7917	7917
25-30 um	833	6667	8333	4167	3333	5000
30-35 um	0	3333	2500	1667	1667	3333
35-40 um	0	1667	833	3333	2500	833
40-45 um	-208	625	-208	-208	-208	1458
45-50 um	0	0	0	0	833	0
50-55 um	0	0	833	0	0	0
55-60 um	833	0	0	0	0	833
60-70 um	0	833	0	833	0	833
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	-208	-208	-208	-208	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0
35 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	433125	538125	363958	347292	215625	168125
4-6 um	1360417	1516250	1061250	1087083	692083	589583
6-8 um	410417	426250	363750	414583	258750	247083
8-10 um	261458	265625	203958	296458	168958	145625
10-12 um	144375	120208	102708	121042	74375	101042
12-14 um	70417	56250	51250	51250	32083	42083
14-16 um	29167	20000	28333	28333	19167	20000
16-18 um	18333	17500	13333	17500	8333	10000
18-20 um	15000	10833	12500	10000	5000	4167
20-25 um	12083	5417	7917	14583	13750	7917
25-30 um	833	1667	5833	3333	2500	4167
30-35 um	0	833	1667	833	1667	0
35-40 um	0	833	0	2500	0	0
40-45 um	-208	-208	-208	625	625	625
45-50 um	0	0	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	0	0	833	0	833	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	-208	-208	-208	-208	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	833	0	0	0	0	0



45 m

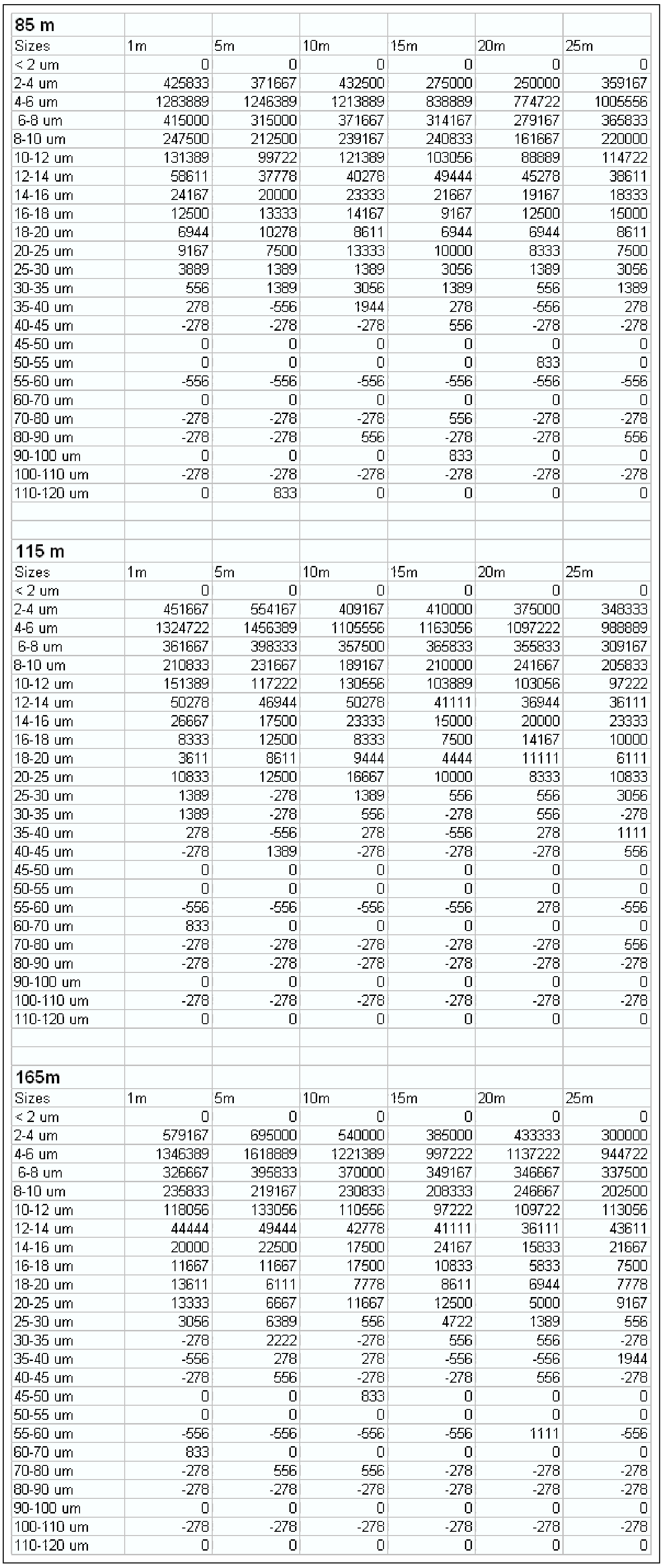
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	655625	609792	488125	337292	238125	355625
4-6 um	1691250	1600417	1346250	1005417	822917	1080417
6-8 um	496250	392083	412083	365417	285417	382083
8-10 um	288958	240625	204792	283125	154792	223125
10-12 um	145208	126875	101042	128542	84375	80208
12-14 um	62917	42917	54583	52083	31250	28750
14-16 um	38333	25833	25000	18333	13333	13333
16-18 um	20000	11667	10000	19167	8333	9167
18-20 um	13333	11667	10833	13333	4167	9167
20-25 um	13750	7917	7083	14583	5417	5417
25-30 um	3333	4167	833	3333	3333	2500
30-35 um	2500	1667	833	833	0	2500
35-40 um	833	0	833	0	0	1667
40-45 um	-208	-208	-208	625	-208	-208
45-50 um	0	1667	833	0	833	833
50-55 um	833	0	833	0	0	1667
55-60 um	0	0	0	0	0	0
60-70 um	0	833	0	0	833	1667
70-80 um	0	0	0	0	0	0
80-90 um	833	0	0	0	0	833
90-100 um	-208	-208	-208	-208	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

55 m

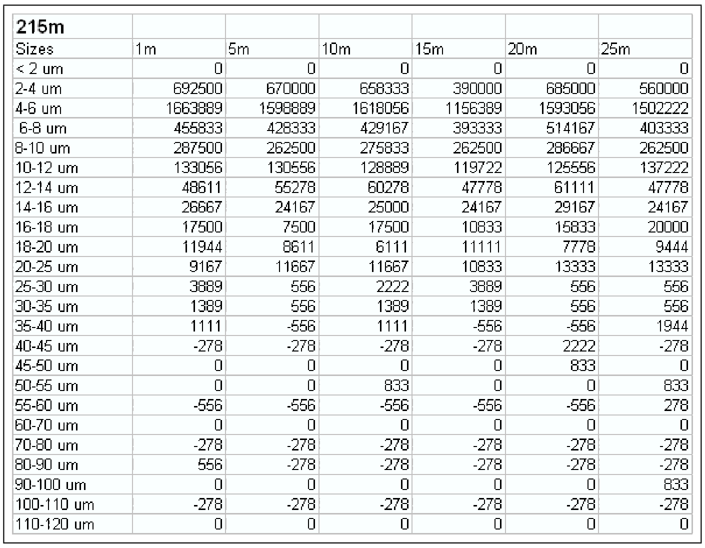
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	497292	586458	454792	382292	254792	241458
4-6 um	1311250	1367083	1241250	1105417	888750	784583
6-8 um	390417	357917	381250	386250	309583	337083
8-10 um	274792	208958	240625	241458	192292	163958
10-12 um	141875	118542	126875	106042	93542	102708
12-14 um	61250	59583	51250	54583	47917	45417
14-16 um	35833	29167	22500	30833	21667	16667
16-18 um	19167	14167	15000	14167	16667	10000
18-20 um	10000	10833	7500	9167	13333	9167
20-25 um	12083	10417	12083	11250	6250	8750
25-30 um	1667	3333	5833	5000	4167	0
30-35 um	2500	0	3333	1667	2500	2500
35-40 um	833	833	0	0	833	0
40-45 um	-208	-208	625	-208	-208	-208
45-50 um	0	0	0	0	0	0
50-55 um	833	0	0	0	0	0
55-60 um	0	0	2500	0	0	0
60-70 um	0	0	0	0	0	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	-208	-208	-208	-208	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

65 m

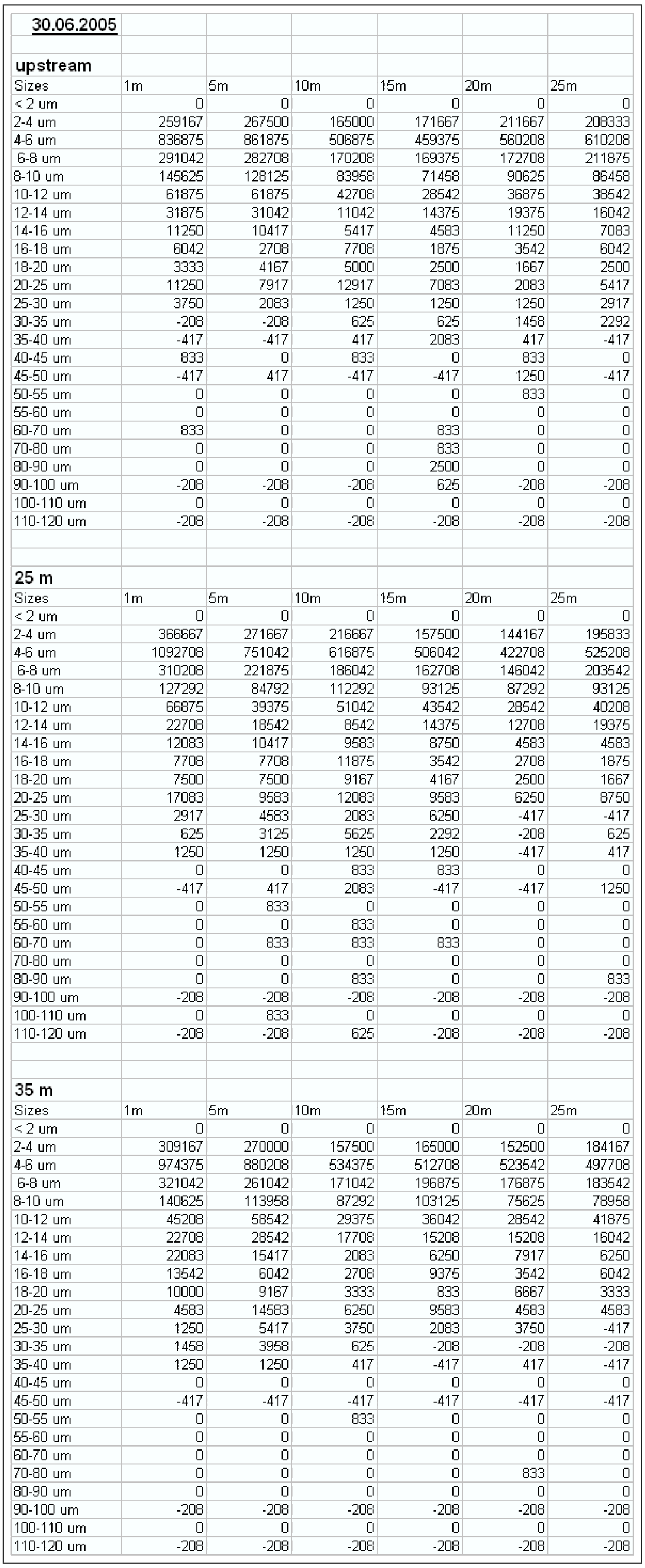
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	537292	652292	410625	364792	382292	310625
4-6 um	1447917	1495417	1092917	1077917	1090417	827083
6-8 um	434583	345417	325417	354583	358750	323750
8-10 um	254792	248125	214792	228125	225625	248958
10-12 um	136875	118542	115208	121875	106875	109375
12-14 um	59583	35417	40417	50417	45417	39583
14-16 um	27500	19167	24167	24167	24167	25833
16-18 um	22500	20000	5833	10833	10000	15000
18-20 um	14167	5000	7500	15833	8333	6667
20-25 um	11250	11250	7083	9583	7917	9583
25-30 um	4167	2500	3333	5000	7500	2500
30-35 um	833	0	1667	0	1667	1667
35-40 um	0	833	0	0	833	0
40-45 um	-208	625	-208	-208	-208	1458
45-50 um	0	833	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	0	0	0	0	833	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	0
90-100 um	-208	-208	-208	625	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



85 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	425833	371667	432500	275000	250000	359167
4-6 um	1283889	1246389	1213889	838889	774722	1005556
6-8 um	415000	315000	371667	314167	279167	365833
8-10 um	247500	212500	239167	240833	161667	220000
10-12 um	131389	99722	121389	103056	88889	114722
12-14 um	58611	37778	40278	49444	45278	38611
14-16 um	24167	20000	23333	21667	19167	18333
16-18 um	12500	13333	14167	9167	12500	15000
18-20 um	6944	10278	8611	6944	6944	8611
20-25 um	9167	7500	13333	10000	8333	7500
25-30 um	3889	1389	1389	3056	1389	3056
30-35 um	556	1389	3056	1389	556	1389
35-40 um	278	-556	1944	278	-556	278
40-45 um	-278	-278	-278	556	-278	-278
45-50 um	0	0	0	0	0	0
50-55 um	0	0	0	0	833	0
55-60 um	-556	-556	-556	-556	-556	-556
60-70 um	0	0	0	0	0	0
70-80 um	-278	-278	-278	556	-278	-278
80-90 um	-278	-278	556	-278	-278	556
90-100 um	0	0	0	833	0	0
100-110 um	-278	-278	-278	-278	-278	-278
110-120 um	0	833	0	0	0	0
115 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	451667	554167	409167	410000	375000	348333
4-6 um	1324722	1456389	1105556	1163056	1097222	988889
6-8 um	361667	398333	357500	365833	355833	309167
8-10 um	210833	231667	189167	210000	241667	205833
10-12 um	151389	117222	130556	103889	103056	97222
12-14 um	50278	46944	50278	41111	36944	36111
14-16 um	26667	17500	23333	15000	20000	23333
16-18 um	8333	12500	8333	7500	14167	10000
18-20 um	3611	8611	9444	4444	11111	6111
20-25 um	10833	12500	16667	10000	8333	10833
25-30 um	1389	-278	1389	556	556	3056
30-35 um	1389	-278	556	-278	556	-278
35-40 um	278	-556	278	-556	278	1111
40-45 um	-278	1389	-278	-278	-278	556
45-50 um	0	0	0	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	-556	-556	-556	-556	278	-556
60-70 um	833	0	0	0	0	0
70-80 um	-278	-278	-278	-278	-278	556
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	-278	-278	-278	-278	-278	-278
110-120 um	0	0	0	0	0	0
165m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	579167	695000	540000	385000	433333	300000
4-6 um	1346389	1618889	1221389	997222	1137222	944722
6-8 um	326667	395833	370000	349167	346667	337500
8-10 um	235833	219167	230833	208333	246667	202500
10-12 um	118056	133056	110556	97222	109722	113056
12-14 um	44444	49444	42778	41111	36111	43611
14-16 um	20000	22500	17500	24167	15833	21667
16-18 um	11667	11667	17500	10833	5833	7500
18-20 um	13611	6111	7778	8611	6944	7778
20-25 um	13333	6667	11667	12500	5000	9167
25-30 um	3056	6389	556	4722	1389	556
30-35 um	-278	2222	-278	556	556	-278
35-40 um	-556	278	278	-556	-556	1944
40-45 um	-278	556	-278	-278	556	-278
45-50 um	0	0	833	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	-556	-556	-556	-556	1111	-556
60-70 um	833	0	0	0	0	0
70-80 um	-278	556	556	-278	-278	-278
80-90 um	-278	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	0
100-110 um	-278	-278	-278	-278	-278	-278
110-120 um	0	0	0	0	0	0



215m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	692500	670000	658333	390000	685000	560000
4-6 um	1663889	1598889	1618056	1156389	1593056	1502222
6-8 um	455833	428333	429167	393333	514167	403333
8-10 um	287500	262500	275833	262500	286667	262500
10-12 um	133056	130556	128889	119722	125556	137222
12-14 um	48611	55278	60278	47778	61111	47778
14-16 um	26667	24167	25000	24167	29167	24167
16-18 um	17500	7500	17500	10833	15833	20000
18-20 um	11944	8611	6111	11111	7778	9444
20-25 um	9167	11667	11667	10833	13333	13333
25-30 um	3889	556	2222	3889	556	556
30-35 um	1389	556	1389	1389	556	556
35-40 um	1111	-556	1111	-556	-556	1944
40-45 um	-278	-278	-278	-278	2222	-278
45-50 um	0	0	0	0	833	0
50-55 um	0	0	833	0	0	833
55-60 um	-556	-556	-556	-556	-556	278
60-70 um	0	0	0	0	0	0
70-80 um	-278	-278	-278	-278	-278	-278
80-90 um	556	-278	-278	-278	-278	-278
90-100 um	0	0	0	0	0	833
100-110 um	-278	-278	-278	-278	-278	-278
110-120 um	0	0	0	0	0	0



30.06.2005

upstream

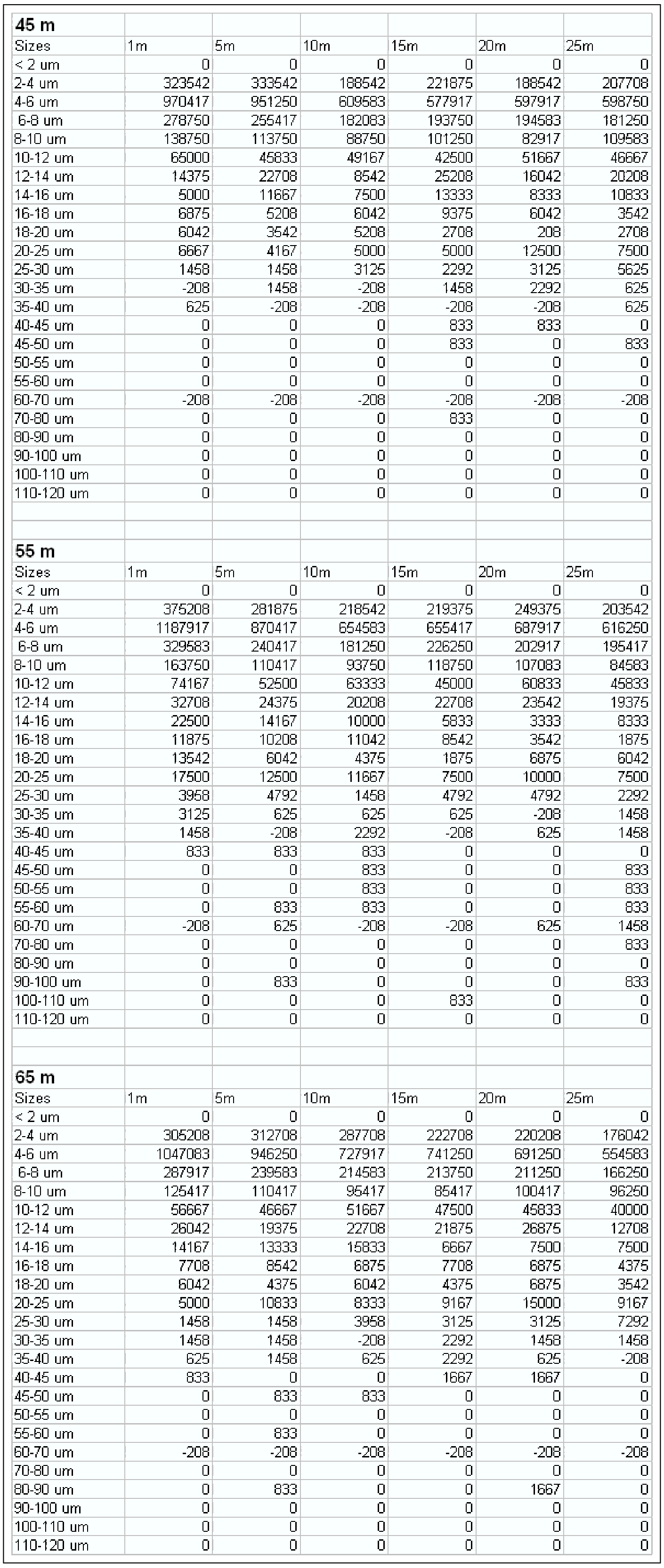
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	259167	267500	165000	171667	211667	208333
4-6 um	836875	861875	506875	459375	560208	610208
6-8 um	291042	282708	170208	169375	172708	211875
8-10 um	145625	128125	83958	71458	90625	86458
10-12 um	61875	61875	42708	28542	36875	38542
12-14 um	31875	31042	11042	14375	19375	16042
14-16 um	11250	10417	5417	4583	11250	7083
16-18 um	6042	2708	7708	1875	3542	6042
18-20 um	3333	4167	5000	2500	1667	2500
20-25 um	11250	7917	12917	7083	2083	5417
25-30 um	3750	2083	1250	1250	1250	2917
30-35 um	-208	-208	625	625	1458	2292
35-40 um	-417	-417	417	2083	417	-417
40-45 um	833	0	833	0	833	0
45-50 um	-417	417	-417	-417	1250	-417
50-55 um	0	0	0	0	833	0
55-60 um	0	0	0	0	0	0
60-70 um	833	0	0	833	0	0
70-80 um	0	0	0	833	0	0
80-90 um	0	0	0	2500	0	0
90-100 um	-208	-208	-208	625	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	-208	-208	-208	-208	-208	-208

25 m

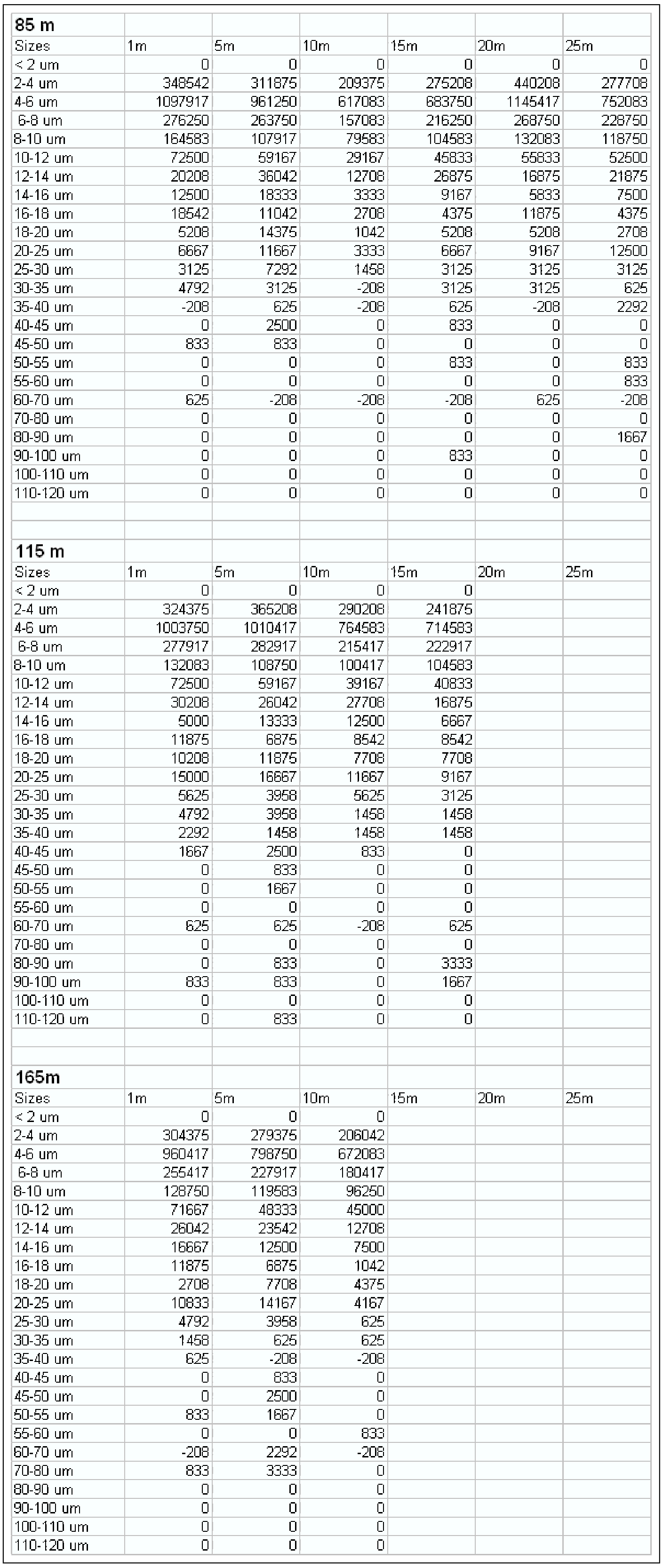
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	366667	271667	216667	157500	144167	195833
4-6 um	1092708	751042	616875	506042	422708	525208
6-8 um	310208	221875	186042	162708	146042	203542
8-10 um	127292	84792	112292	93125	87292	93125
10-12 um	66875	39375	51042	43542	28542	40208
12-14 um	22708	18542	8542	14375	12708	19375
14-16 um	12083	10417	9583	8750	4583	4583
16-18 um	7708	7708	11875	3542	2708	1875
18-20 um	7500	7500	9167	4167	2500	1667
20-25 um	17083	9583	12083	9583	6250	8750
25-30 um	2917	4583	2083	6250	-417	-417
30-35 um	625	3125	5625	2292	-208	625
35-40 um	1250	1250	1250	1250	-417	417
40-45 um	0	0	833	833	0	0
45-50 um	-417	417	2083	-417	-417	1250
50-55 um	0	833	0	0	0	0
55-60 um	0	0	833	0	0	0
60-70 um	0	833	833	833	0	0
70-80 um	0	0	0	0	0	0
80-90 um	0	0	833	0	0	833
90-100 um	-208	-208	-208	-208	-208	-208
100-110 um	0	833	0	0	0	0
110-120 um	-208	-208	625	-208	-208	-208

35 m

Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	309167	270000	157500	165000	152500	184167
4-6 um	974375	880208	534375	512708	523542	497708
6-8 um	321042	261042	171042	196875	176875	183542
8-10 um	140625	113958	87292	103125	75625	78958
10-12 um	45208	58542	29375	36042	28542	41875
12-14 um	22708	28542	17708	15208	15208	16042
14-16 um	22083	15417	2083	6250	7917	6250
16-18 um	13542	6042	2708	9375	3542	6042
18-20 um	10000	9167	3333	833	6667	3333
20-25 um	4583	14583	6250	9583	4583	4583
25-30 um	1250	5417	3750	2083	3750	-417
30-35 um	1458	3958	625	-208	-208	-208
35-40 um	1250	1250	417	-417	417	-417
40-45 um	0	0	0	0	0	0
45-50 um	-417	-417	-417	-417	-417	-417
50-55 um	0	0	833	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	0	0	0	0	0	0
70-80 um	0	0	0	0	833	0
80-90 um	0	0	0	0	0	0
90-100 um	-208	-208	-208	-208	-208	-208
100-110 um	0	0	0	0	0	0
110-120 um	-208	-208	-208	-208	-208	-208



45 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	323542	333542	188542	221875	188542	207708
4-6 um	970417	951250	609583	577917	597917	598750
6-8 um	278750	255417	182083	193750	194583	181250
8-10 um	138750	113750	88750	101250	82917	109583
10-12 um	65000	45833	49167	42500	51667	46667
12-14 um	14375	22708	8542	25208	16042	20208
14-16 um	5000	11667	7500	13333	8333	10833
16-18 um	6875	5208	6042	9375	6042	3542
18-20 um	6042	3542	5208	2708	208	2708
20-25 um	6667	4167	5000	5000	12500	7500
25-30 um	1458	1458	3125	2292	3125	5625
30-35 um	-208	1458	-208	1458	2292	625
35-40 um	625	-208	-208	-208	-208	625
40-45 um	0	0	0	833	833	0
45-50 um	0	0	0	833	0	833
50-55 um	0	0	0	0	0	0
55-60 um	0	0	0	0	0	0
60-70 um	-208	-208	-208	-208	-208	-208
70-80 um	0	0	0	833	0	0
80-90 um	0	0	0	0	0	0
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0
55 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	375208	281875	218542	219375	249375	203542
4-6 um	1187917	870417	654583	655417	687917	616250
6-8 um	329583	240417	181250	226250	202917	195417
8-10 um	163750	110417	93750	118750	107083	84583
10-12 um	74167	52500	63333	45000	60833	45833
12-14 um	32708	24375	20208	22708	23542	19375
14-16 um	22500	14167	10000	5833	3333	8333
16-18 um	11875	10208	11042	8542	3542	1875
18-20 um	13542	6042	4375	1875	6875	6042
20-25 um	17500	12500	11667	7500	10000	7500
25-30 um	3958	4792	1458	4792	4792	2292
30-35 um	3125	625	625	625	-208	1458
35-40 um	1458	-208	2292	-208	625	1458
40-45 um	833	833	833	0	0	0
45-50 um	0	0	833	0	0	833
50-55 um	0	0	833	0	0	833
55-60 um	0	833	833	0	0	833
60-70 um	-208	625	-208	-208	625	1458
70-80 um	0	0	0	0	0	833
80-90 um	0	0	0	0	0	0
90-100 um	0	833	0	0	0	833
100-110 um	0	0	0	833	0	0
110-120 um	0	0	0	0	0	0
65 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	305208	312708	287708	222708	220208	176042
4-6 um	1047083	946250	727917	741250	691250	554583
6-8 um	287917	239583	214583	213750	211250	166250
8-10 um	125417	110417	95417	85417	100417	96250
10-12 um	56667	46667	51667	47500	45833	40000
12-14 um	26042	19375	22708	21875	26875	12708
14-16 um	14167	13333	15833	6667	7500	7500
16-18 um	7708	8542	6875	7708	6875	4375
18-20 um	6042	4375	6042	4375	6875	3542
20-25 um	5000	10833	8333	9167	15000	9167
25-30 um	1458	1458	3958	3125	3125	7292
30-35 um	1458	1458	-208	2292	1458	1458
35-40 um	625	1458	625	2292	625	-208
40-45 um	833	0	0	1667	1667	0
45-50 um	0	833	833	0	0	0
50-55 um	0	0	0	0	0	0
55-60 um	0	833	0	0	0	0
60-70 um	-208	-208	-208	-208	-208	-208
70-80 um	0	0	0	0	0	0
80-90 um	0	833	0	0	1667	0
90-100 um	0	0	0	0	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0



85 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0	0	0
2-4 um	348542	311875	209375	275208	440208	277708
4-6 um	1097917	961250	617083	683750	1145417	752083
6-8 um	276250	263750	157083	216250	268750	228750
8-10 um	164583	107917	79583	104583	132083	118750
10-12 um	72500	59167	29167	45833	55833	52500
12-14 um	20208	36042	12708	26875	16875	21875
14-16 um	12500	18333	3333	9167	5833	7500
16-18 um	18542	11042	2708	4375	11875	4375
18-20 um	5208	14375	1042	5208	5208	2708
20-25 um	6667	11667	3333	6667	9167	12500
25-30 um	3125	7292	1458	3125	3125	3125
30-35 um	4792	3125	-208	3125	3125	625
35-40 um	-208	625	-208	625	-208	2292
40-45 um	0	2500	0	833	0	0
45-50 um	833	833	0	0	0	0
50-55 um	0	0	0	833	0	833
55-60 um	0	0	0	0	0	833
60-70 um	625	-208	-208	-208	625	-208
70-80 um	0	0	0	0	0	0
80-90 um	0	0	0	0	0	1667
90-100 um	0	0	0	833	0	0
100-110 um	0	0	0	0	0	0
110-120 um	0	0	0	0	0	0

115 m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0	0		
2-4 um	324375	365208	290208	241875		
4-6 um	1003750	1010417	764583	714583		
6-8 um	277917	282917	215417	222917		
8-10 um	132083	108750	100417	104583		
10-12 um	72500	59167	39167	40833		
12-14 um	30208	26042	27708	16875		
14-16 um	5000	13333	12500	6667		
16-18 um	11875	6875	8542	8542		
18-20 um	10208	11875	7708	7708		
20-25 um	15000	16667	11667	9167		
25-30 um	5625	3958	5625	3125		
30-35 um	4792	3958	1458	1458		
35-40 um	2292	1458	1458	1458		
40-45 um	1667	2500	833	0		
45-50 um	0	833	0	0		
50-55 um	0	1667	0	0		
55-60 um	0	0	0	0		
60-70 um	625	625	-208	625		
70-80 um	0	0	0	0		
80-90 um	0	833	0	3333		
90-100 um	833	833	0	1667		
100-110 um	0	0	0	0		
110-120 um	0	833	0	0		

165m						
Sizes	1m	5m	10m	15m	20m	25m
< 2 um	0	0	0			
2-4 um	304375	279375	206042			
4-6 um	960417	798750	672083			
6-8 um	255417	227917	180417			
8-10 um	128750	119583	96250			
10-12 um	71667	48333	45000			
12-14 um	26042	23542	12708			
14-16 um	16667	12500	7500			
16-18 um	11875	6875	1042			
18-20 um	2708	7708	4375			
20-25 um	10833	14167	4167			
25-30 um	4792	3958	625			
30-35 um	1458	625	625			
35-40 um	625	-208	-208			
40-45 um	0	833	0			
45-50 um	0	2500	0			
50-55 um	833	1667	0			
55-60 um	0	0	833			
60-70 um	-208	2292	-208			
70-80 um	833	3333	0			
80-90 um	0	0	0			
90-100 um	0	0	0			
100-110 um	0	0	0			
110-120 um	0	0	0			

Hiermit versichere ich, dass ich diese Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

Lars Gansel