MASTER THESIS

AK306F MSc in Aquaculture

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Seasonal distribution of algal pigments in an enclosed harbour area in Saltenfjorden, Norway, viewing possible impacts from hydrographic changes

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Abstract

This work is meant to participate in building knowledge about different seasonal algal pigments in a semi enclosed bay area in a fjord, as well as underlining the different aspects to be considered in algal cultivation.

This study summarises different theories regarding the most important mechanisms, including biotic and abiotic factors reported to have an effect on algal growth and composition. The algal components play an important role as primary producers in the oceans and also in commercial industry. The main focus of this assignment are the microalgal community. Different methods for obtaining and processing seawater-samples for analyses are addressed.

The field sample analyses were performed in Mørkvedbukta, a bay-area in Saltenfjorden in Northern-Norway. It was performed probe measurements in the water column measuring water temperature, salinity, density, and fluorescence. The seawater samples was analysed using a HPLC-instrument with a special focus on specific algal pigments. Different datasets such as algal cell counting and meteorological measurements on cloud cover, air temperature and precipitation, was obtained from external sources.

During the experiment performed over a one-year period, there was found some possible correlations between the pigment concentration, the algal cell-count and fluorescent measurements regarding the spring point of the main blooming period. The top periods for the different periods was always correlating.

It is found that these studies might support previous examinations of phytoplankton communities, regarding the timing of the spring bloom.

It was found indications of specific pigments dominating different seasonal periods. There was found possible correlations between the pigment analyses, algal cell counts, and fluorescence held against the hydrographic- and meteorological measurements, which could indicate an influence on the pigment concentration, but tough in a larger seasonal scale.

Sammendrag

Dette arbeidet er ment å delta i å bygge kunnskap om ulike sesongmessige variasjoner i algepigmenter i et semi-lukket fjordområde, samt å understreke ulike aspekter som bør vurderes ved algedyrking.

Dette studiet oppsummerer ulike teorier om de viktigste mekanismene, herunder biotiske og abiotiske faktorer som er antatt å ha en effekt på algevekst og sammensetning. Betydningen av alge komponenter, både som en viktig primærprodusent i havet og til kommersielle formål. Hovedfokus for denne oppgaven er mikroalgesamfunnet. Ulike metoder for oppnåelse og bearbeiding av sjøvannsprøver for analyse er også adressert.

Feltarbeidet ble gjort i Mørkvedbukta, ei bukt i Saltenfjorden, Nord-Norge. Det ble utført målinger i vannsøylen med en sonde som målte vanntemperatur, saltholdighet, tetthet og fluorescens. Sjøvannsprøvene ble analysert i et HPLC-instrument, med spesielt fokus på bestemte algepigmenter. Ulike datasett fra algecelletelling, samt meteorologiske målinger av skydekke, lufttemperatur og nedbør ble innhentet fra eksterne kilder.

Ved dette eksperimentet, som ble utført over en ettårsperiode, ble det funnet enkelte mulige sammenhenger mellom pigmentkonsentrasjon, algecelletall og fluorescerende målinger, med tanke på selve vekstperioden. Maksimalmålingene for de ulike parameterne og for de ulike periodene var ikke alltid sammenfallende.

Det er dog funnet at disse studiene kan støtte tidligere undersøkelser av planteplankton samfunn angående tidspunktet for starten på våroppblomstringen.

Det ble funnet indikasjoner på at spesifikke pigmenter var dominerende i ulike perioder av sesongene. Det ble funnet mulige korrelasjoner mellom pigmentanalysene, algetellingene og fluorosens opp mot de de hydrografiske- og de meteorologiske målingene, noe som kan indikere en innflytelse på algeveksten, men da i en større sesongmessig målestokk.

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1. Introduction

1.1 General background

The sea holds tremendous amounts of life forms and many crucial and useful resources for the process industry, medicine technology, and specially food industry. Algae are regarded a very important part of this ecosystem, with a wide range of varying species. The ecosystems of sheltered areas, shows differences compared to more exposed areas. Divisions and species also vary by season and latitude.

It is useful to look at the benefits, as well the disadvantages that algae growth can provide. In aquaculture development today it is now an ongoing process of cultivating different microalgae cultures in containers, and macroalgae on sites in fjords. Different components in both the micro- and macroalgal cells, can be used for commercial purposes, hereunder in combination with the fish food industry, bio-fuel etc. Locally in Nordland, it is of interest to find out more about local wild grown algal species, to replace imported culture media. Particularly the sheltered areas, as the microalgal-aquaculture are produced in relative closed areas or in containers.

Facing global environmental challenges, the importance of phytoplankton primary production is essential, as to binding and transforming large amounts of carbon dioxide. A diversity of processes occurs in algal cells, aimed to adapt different environmental challenges.

Algal cell pigments are essential components in the photosynthetic process. They serve as light-harvesting pigments or as accessory pigments, enhancing light absorption at specific wavelengths. The accessory pigments might also reduce cell damage caused by intensive light, by exporting excess heat energy. These adjustment processes might take seconds or as the large acclimating adaptations might take several years.

Analysing pigment concentration of seawater samples might provide information about the algal components present in the water column. Pigments specific for certain algal groups, can be used indicators, and Chlorophyll *a* content might give an estimate on the total algal biomass. Based upon their compositional differences several methods are be used to classify or identify them, combining methods provides more certain data.

1.2 Aims

The purpose of this project was finding possible seasonal variations in the distribution of naturally occurring algal pigments in seawater collected in a shallow water column.

It was aimed to find possible correlations between detected pigments and fluorescence levels in present study held against relevant algal cell counting performed by others.

There were also examined if there could be found patterns of influences from hydrographic- and meteorological measurements, such as temperature, density, salinity and oxygen in the water column, and weather conditions such as temperature, cloud cover and precipitation.

Theory

1.3 Microalgae

Algae are a group of organisms that are rather difficult to place in the Kingdoms of Nature. Placed along with the Protista, might ignore their photosynthetic abilities. Their photosynthetic abilities might link them to land plants, and also the domain of bacteria even though Cyanobacteria, are no longer called algae (Larkum, 2003).

From many symbioses within heterotrophic hosts throughout time, the variety of different microalgal pigments evolved. Different algae with multiple abilities to make use of different lights withholding different wavelengths, being able to live within the different depths and adjustments in seasonal variations in light supply. These changes in adaptive composition might take seconds or days (Brunet et al., 2011).

When facing different radiances of light, the cells has the ability to do calibrated internal changes in processes such as photosynthesis, respiration, growth-rate and also divisions (Brunet et al., 2011, Egeland, 2016, Herzig and Dubinsky, 1993, Anning et al., 2000, Raven and Geider, 2003).

The marine phytoplankton makes out at least one fourth of the total vegetation on the planet. They make up the baseline of primary production in the world`s oceans, and so affects all the levels of life up the levels of the aquatic food pyramid (Aiken et al., 2009).

The plankton production gives ocean zoo-species different colours important for camouflage and curtsies etc. The levels of oxygen in the water column, is also an important factor in

sustaining life in the water column. The prime producer helps oxygenating the water masses, as well as playing an important role as a food source (Aiken et al., 2009).

The spring bloom usually takes place in April-May in higher latitudes, often dominated by diatoms, and smaller amounts dinoflagellates (Carstensen et al., 2015, Huseby, 2002, Degerlund and Eilertsen, 2010). Bloom-periods that are dominated by chlorophytes and cyanobacteria are more common in areas of low salinity and higher temperatures (Carstensen et al., 2015).

Degerlund and Eilertsen (2010), summarises the quantitatively most abundant species from the spring bloom of the north Norwegian coast, and the Barents Sea along the northern to be the prymnesiophyte, *Phaeocystis pouchetii* and the cold water to temperate diatoms *Chaetoceros socialis, Skeletonema costatum* sensu lato*, Fragilariopsis oceanica, Thalassiosira* spp*., Chaetoceros furcellatus, Chaetoceros compressus, Chaetoceros debilis* and *Bacterosira bathyomphala.* Diatoms and *Phaeocystis a*bundance varies highly.

P. pouchetii are found during all stages of the spring bloom and are sometimes completely dominating (Degerlund and Eilertsen, 2010). Figure 1 gives an illustration of varieties in shapes of diatoms.

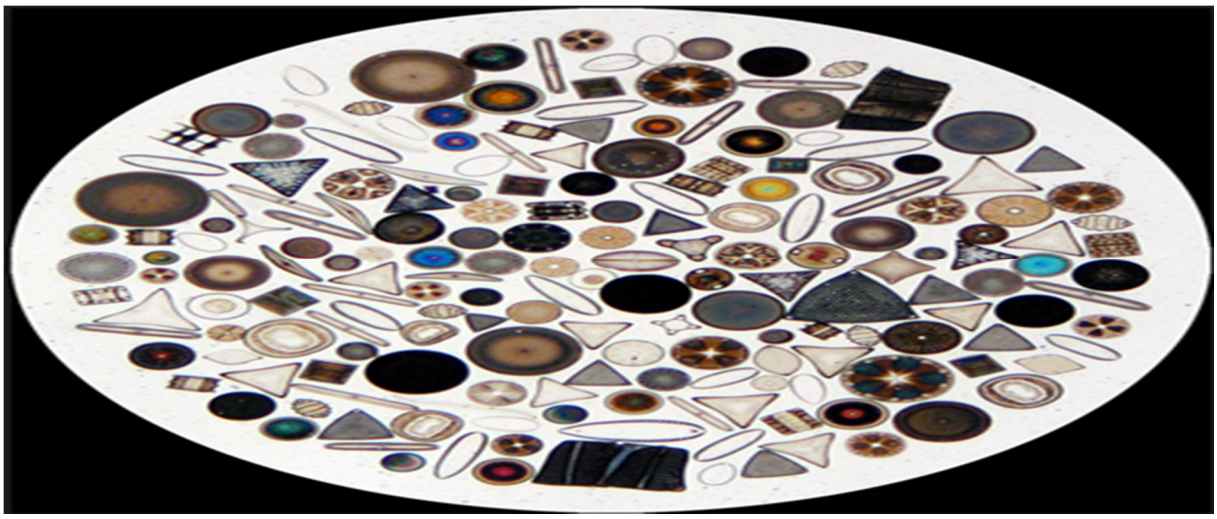

Figure 1. Sketch illustration of diatoms.
A Sketch illustration of diatoms many different shapes(from WmC via Gemini.no (Ekra, 2011))

1.3.1 Algae aquaculture

Commercially growth of algal cultures are still increasing in popularity because of the micro algal many functional abilities and high valued contents, (Brunet et al., 2011)such as carotenoids and fatty acids. This includes human food, animal feed products, wastewater treatments (Oswald, 1988a, Chen et al., 2016) and agriculture soil conditioners (Metting, 1988, Tseng, 2003). The algal species *Skeletonema* spp. , *Tetraselmis suecica* and *Thalassiosira pseudonana* are frequently grown as aquaculture feed (Tseng, 2003), others for instance *Dunaliella* spp. (β, β-carotene) and *Haematococcus pluvialis* (astaxanthin), are grown as for their ability to synthesize carotenoids (Dufossè, 2009).

Many algal pigment, and other components might also be used in cosmetics (Wang et al., 2015), pharmaceutical industry, disease preventers, and dietary supplements (Pangestuti and Kim, 2011). As for commercial production especially pigments such as, β, β-Carotene, canthaxanthin, astaxanthin, lutein, lycopene and zeaxanthin can be mentioned (Mortensen, 2009). For instance has zeaxanthin been found to play an important role in preventing age-related macular degeneration (AMD) (Sajilata et al., 2008).

In large scale production it is a requirement that the systems are shallow to assure sufficient light exposure, usually performed in large ponds (Oswald, 1988b), in tanks or microalgae plant facilities (Nurra et al., 2014), that allows temperature and light regulations.

With the view on future aspects regarding climate change, and limitations in existing resources, there are also focus upon finding new sustainable, non-fossil sources of energy (Fedoroff et al., 2010). In this matter of concern, extremophilic microalgae for use in biotechnology have also been examined (Varshney et al., 2015, Stetter, 1999).

1.3.2 Morphological features of microalgae

The size and composition of microalgae varies highly, but there are some basic features that can be mentioned are thin rigid cellulosic cell wall, eukaryotic nucleus with pores, chromatin, nucleolus, karyolymph and lamellar, discoid or tubular cristae shaped mitochondria, and chloroplasts having an enclosed thylakoid as a place of photosynthesis. In addition to this some have flagella and proteinaceous (pyrenoid) for starch synthesis and storage (Singh et al., 2014). Figure 2, gives the composition of the *Chlamydomonas reinhardtii* cell, presented by Singh et al. (2014).

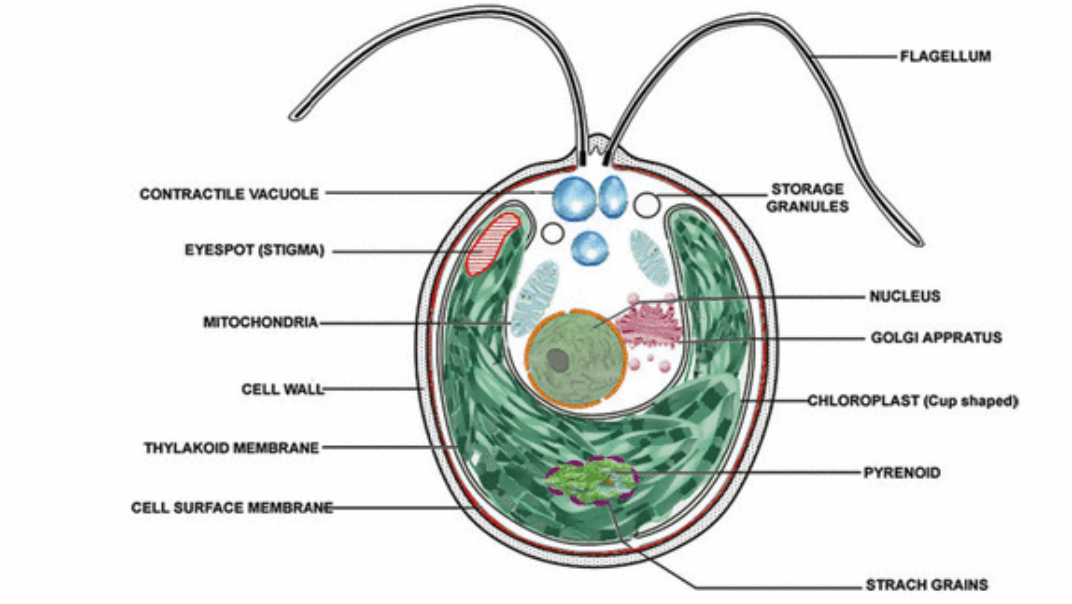

Figure 2. Algal example structure.

A sketch illustration of the algae Chlamydomonas reinhardtii cell (Singh et al., 2014).

1.3.3 Algae pigments

Pigments in algae include chlorophylls, carotenoids and phycobilins. They reflect at certain wavelengths of light and radiance different colours.

Pigments are considered important because if their function in the bio-system, but they can also benefit as natural food ingredients and others purposes, as mentioned in sub-chapter 1.3.1.

Pigments in phytoplankton are, according to Johnsen et al. (2011), usually revived as reaction centre pigments of photosystems I (PSI) and II (PSII), in the process of harvesting light as phytoplankton light-harvesting pigments (LHP) or photo-protective carotenoids (PPC).

Absorbing different colours of the light-spectra, LHP uses inductive resonance transferring light energy to the photosystems that induce electron flow, allowing the production of reducing power (NADPH) and chemical energy (ATP) in the cell (Johnsen et al., 2011). The energy transfer are found very efficient (Johnsen et al., 2011, Govindje, 1995, Green et al., 2003, Larkum, 2003). Photo-protective carotenoids (PPC) also have light-harvesting functions, but the efficiency of these carotenoids are lower (Johnsen et al., 2011).

In the peripheral LHC of PSII, the bound carotenoids are heterogeneous depending on their classes (Takaichi, 2011).

Many species of phytoplankton has the ability to adjust carotenoids in their cells to make photosynthesis more efficient when exposed to certain light regimes, and they also creates photo-protective pigments aimed to minimalize cellular damage by excess radiation (Higgins et al., 2011, Falkowski, 2007).

Some pigments are considered division or class specific signal pigments, others more widespread among the divisions or classes. Table 1 gives a brief overview of the most common carotenoids distribution in algae. More detailed information and specifications regarding the abundance among the species are complex. Many pigments occur as trace elements in some algae, and they might be more dominating in others, or crossing divisions, some classes also has groups or species with varying pigment compositions. For a more thorough overview and worksheets, see for instance Egeland (2016), Wright (2005), Liaaen-Jensen and Egeland (1999) or Jeffrey et al. (2011).

Table 1. Division and class distribution of some common algal pigments.

Brief overview of some common algal pigments and a rough survey of their abundance among different algal divisions or classes (Takaichi, 2011).

Division	Carotene		Xanthophyll											Chlorophyll		
Class	β	α	Ze	Vi	Ne	Da	Dd	Fx	Va	Lu	Lo	Sx	Other xanthophyll(s)	*a*	*b*	*c*
Cyanophyta	H	L	H										No, L; Ec, H; My, H	H	L	
Glaucophyta	H		H											H		
Rhodophyta																
Unicellular type	H		H											H		
Macrophytic type	L	L	H	L				L		H				H		
Cryptophyta		H	L										Al, L; Cr, L; Mo, L	H		H
Heterokontophyta																
Chrysophyceae	H		L			L	L	H	L					H		H
Raphidophyceae	H		H	L		L	L	L						H		H
Bacillariophyceae	H		L			L	L	H						H		H
Phaeophyceae	H		H	H		L	L	H						H		H
Xanthophyceae	H		L			H	H						Va-FA, L	H		H
Eustigmatophyceae	H			H					L					H		
Haptophyta	H		L			L	H	H					Fx-FA, L	H		H
Dinophyta	L		L			L	H	L					Pe, H	H		H
Euglenophyta	H		L		L	L	H				L	L		H	H	
Chlorarachniophyta	H		L	L	L					L	L		Lo-FA, L	H	H	
Chlorophyta																
Prasinophyceae	H	L	L	H	H					L	L	H	Pr, L; Lo-FA, L; Sx-FA, H	H	H	
Chlorophyceae	H	H	L	H	H					H	L	L	Sx-FA, L	H	H	
Ulvophyceae	H	L	L	H	H					L	L	L	Sx-FA, H	H	H	
Trebouxiophyceae	H		L	H	H					H				H	H	
Charophyceae	H		L	H	H					H				H	H	
Land Plants	H	L	L	H	H					H				H	H	

H, Major carotenoid in most species of the class; L, Low content in most species or major carotenoid in some species. α, α-carotene; β, β-carotene; Al, alloxanthin; Cr, crocoxanthin; Da, diatoxanthin; Dd, diadinoxanthin; Ec, echinenone; -FA, fatty acid ester; Fx, fucoxanthin; Lo, loroxanthin; Lu, lutein; Mo, monadoxanthin; My, myxol glycosides and oscillol glycosides; Ne, neoxanthin; No, nostoxanthin; Pe, peridinin; Pr, prasinoxanthin; Sx, siphonaxanthin; Va, vaucheriaxanthin; Vi, violaxanthin; Ze, zeaxanthin. Red, α-carotene and its derivatives.

1.3.3.1 Chlorophylls, carotenoids and phycobilins

Chlorophylls

The green reflecting chlorophyll pigments are the most abundant photosynthetic pigments in nature. Their molecular structure contains cyclic tetrapyrroles and they generally contain a central magnesium ion. As chlorophylls often generate toxic reactive oxygen species, because of their ability to maintain long-lived excited states, which can cause cellular damage, they often generate radicals during bright light conditions. Chlorophyll molecules, that are bound to proteins, serve as light receivers, and photo enzymes makes up the reaction centre (Green et al., 2003). Chlorophylls have the ability to function within the reaction centre performing a charged separation across the cell membrane.

Chlorophyll *a* makes photosynthesis possible, as by passing its energized electrons on to molecules participating in creating sugars. The pigment exists in all algae cells and cyanobacteria with the ability to photosynthesize. DV-Chl *a* concentration might, for instance give a rough index for total prochlorophyte biomass in the ocean water (Wright et al., 1996, Higgins et al., 2011).

Chlorophyll *b* are present in green algae, some of the prochlorophytes (Egeland et al., 2011) and frequently found in prasinophytes (Barlow et al., 2016).

Chlorophyll c_x exists in different forms with polar or non-polar structures. Some structures of non-polar chlorophyll *c* pigments are found in dinoflagellates (Barlow et al.) and haptophytes, though the structure of chl c_x differs among to species or class. (Higgins et al., 2011).

According to Higgins et al. (2011), polar chlorophyll c_x pigments such as MgDVP, occur as trace pigments in just about all taxa, but are considered a useful marker to detect prasinophytes type 3. Others such as polar c1,c2 and c3 are more generally found among the chromophytes, such as diatoms, haptophytes and chrysophytes (Higgins et al., 2011).

One structural difference to mentioned are between Chl *a* and *b,* are the connected aldehyde group (-CHO) positioned at the third carbon where Chl *a* has the connected methyl group (-CH_3).

Carotenoids

Carotenoids might be considered accessory pigments to chlorophyll in the light-harvesting antenna within algal cells. The colour of carotenoids usually varies from red, orange and yellow (Liaaen-Jensen and Egeland, 1999). Along with phycobilins carotenoids help absorb energy in the "green gap" near 500 nm.

Carotenoids are isoprenoid compounds with different structures that gives potential to gain or lose electrons easily, enabling absorption of photons and transferring excitation energy (Britton, 1995).

Among carotenoids are for instance carotenes (β,β-carotene, β,ε-carotene), simple carotenols (zeaxanthin, lutein),epoxides (violaxanthin, diadinoxanthin), acetylenic (diatoxanthin, alloxanthin, heteroxanthin),C_{37}- skeletal (pyrrhoxanthin, peridinin), allenic (neoxanthin, vaucheriaxanthin, fucoxanthin), ketones (echinenone, canthaxanthin, astaxanthin, siphonaxanthin, prasinoxanthin) and glycosidic (myxoxanthophyll) carotenoids (Liaaen-Jensen and Egeland, 1999).

Some are more or less connected to specific algal divisions or classes such as; alloxanthin (Cryptophyta); fucoxanthin (Chrysophyceae, Raphidophyceae, Bacillariophyceae, Phaeophyceae and Haptophyta); diadinoxanthin and vaucheriaxanthin (Xanthophyceae); violaxanthin and vaucheriaxanthin (Eustigmatophyceae); peridinin (Dinophyta); diadinoxanthin (Euglenophyta); siphonaxanthin (Chlorophyceae and Ulvophyceae); lutein (chlorophytes, chlorarachniophytes, prasinophytes, mesostigmatophytes); violaxanthin (chrysophytes, eustigmatophytes, synurophyses, mesostigmatophytes, chlorophytes prasinophytes, among others) and neoxanthin (chlorophytes, prasinophytes, among others (Takaichi, 2011, Jeffrey et al., 2011, Egeland et al., 2011).

It is important to keep in mind that many carotenoids are not micro algal specific and might be naturally occurring in for instance macroalgae just as well as in terrestrial land plants and other phototrophs. As carotenoids are pigments synthesized by photosynthetic organisms, and also a number of non-photosynthetic fungi and bacteria (Britton, 1995, Sajilata et al., 2008).

Among the microalgal community alone, there are more than one hundred known carotenoids (Liaaen-Jensen and Egeland, 1999), involving many different structures.

Figure 3 gives examples of common carotenes that are common in algal cells.

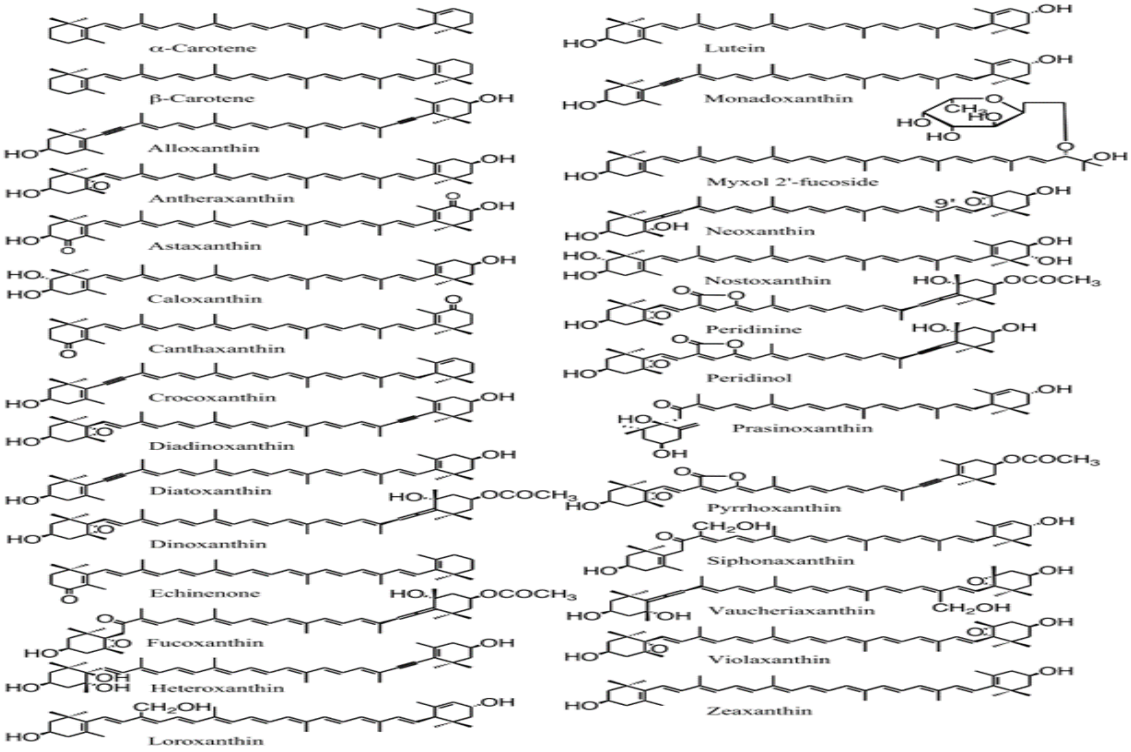

Figure 3. Structures of common algal carotenoids.
Among many different structures in algal carotenoids, some of the most common carotenoids as presented by Takaichi (2011).

Different groups in the structures of carotenoids and chlorophylls, provides different abilities. For instance the keto groups at C-8 of fucoxanthin, siphonaxanthin and prasinoxanthin for example, which are found exclusively in algae, are reported to might having light-harvesting functions (Takaichi, 2011).

Another example are the water-soluble peripheral LHC of peridinin-chlorophyll-protein (PCP) isolated from *Amphidinium carterae* (Dinophyta) has a trimeric structure, and the monomer contains eight peridinin and two chlorophyll a molecules (Takaichi, 2011).

Carotenoids are, in most divisions, found in the reaction-centre complexes (RC) and the light-harvesting complexes (LHC) of photosystem I (PSI) as well as the RC and the core LHC of photosystem II (PSII), with the exception of zeaxanthin that is presented in some red algae of the LHC of PSI (Takaichi 2011). The cytochrome b6f complexes of the green alga *Chlamydomonas reinhardtii* (Figure 2.) contain two β,β-carotene and two chlorophyll *a* molecules carotenoids that might have protective functions. As found β,β-carotene in both RC

might have protective functions, and carotenoids in the peripheral LHC of PSII mainly might have light-harvesting functions.

Epoxidation, de-epoxidation and the xanthophyll cycles

Important cell mechanisms for quick response to different light intensities are the processes of the xanthophyll cycles. Lohr (2011) refers to three major xanthophyll cycles; the violaxanthin/antheraxanthin/zeaxanthin cycle (epoxidizing by zeaxanthin epoxidase (ZEP), during high light conditions, and reverted by violaxanthin de-epoxidase (VDE), the diadinoxanthin/diatoxanthin and the lutein-epoxide/lutein cycle (Lohr, 2011, La Rocca et al.), whereas the last one only has been reported to exist in land plants. (Lohr, 2011, García-Plazaola et al., 2007) According to García-Plazola et al. (2007), at least six xanthophyll cycles has been proposed to exist, where of four in algae.

The diadinoxanthin cycle occurs in Heterokontophyta, Haptophyta and Dinophyta, which contain diadinoxanthin and diatoxanthin.

Phycobiliproteins

Phycobiliproteins are light-harvesting pigments found in cyanobacteria, red algae, glaucocystophytes and cryptophytes (Zhao et al., 2011), where they help to optimise the photosynthetic processes in phytoplankton (Sobiechowska-Sasim et al., 2014).

Often consisting of a linear tetrapyrrolic chromophores, bilins, bound covalently to cysteins of apoproteins. They harvest light more efficient in the 'green gap', at wavelengths where chlorophyll do not absorb light (Zhao et al., 2011, Sidler, 1994), they also have the ability to regulate their harvesting abilities, for instance light acclimations by reigning intensity and light-quality and (Zhao et al., 2011, Grossmann et al., 1993) supplies of nutrients, specially carbon, nitrogen and sulphur (Tandeau de Marsac and Houmard, 1993).

Phycobiliproteins are located in Photosystem II, and includes former names such as allophycocyanins (blue-green), phycobilliproteins (blue) and phycoerythrins (red) (Sidler, 1994). Now it is common to use prefixes such as C-,(cyanobacterial pigments), M-(biliproteins from marine cyanobacteria), R-(red-algal biliproteins) B- /b (red algae *Bangiales*), or they might also be characterized according to their light absorption maximum (Zhao et al., 2011, Glazer and Wedemayer, 1995). As the light produced by their fluorescence is distinctive and these can be used as bio-markers, especially detecting cyanobacteria (Sobiechowska-Sasim et al., 2014).

1.4 Interactions and different effects on phytoplankton growth and distribution

There are multiple factors triggering the growth and decline of primary production. Some of the most important factors that influencing phytoplankton blooms are pulsed inputs of nutrients from river inflow, costal upwelling, atmospheric deposition, wind-induced entrainment of bottom water and neap-spring variability of tidal mixing and stratification (Carstensen et al., 2015). Wind enhancing water retention, heatwaves, stratification, increased retention time in flushed systems, benthic grazing pressure and changes in temperature and solar radiation are also important factors (Carstensen et al., 2015).

Shoreline coastal locations tend to show different seasonally qualitative and quantitative differences in algal communities (Metaxatos and Ignatiades, 2002).

The dynamics of stratified and partly mixed estuaries show recognizable patterns, on the other hand dynamics in shallow estuaries seem to be more variable and difficult to comprehend (Mann, 2006).

Temperature

Temperature effects might influence the timing of annual spring blooms in temperate waters. In rate of growth, physiological processes, internal chemical compositions and also the entire composition of species in the pelagic phytoplankton communities (Lassen et al., 2010).

Lassen et al. (2010) found that a water temperature shift of only 3°C had an effect on the composition of the phytoplankton community. Although there has been many experiments conducted on temperature effect on phytoplankton communities, most have been carried out on lab monocultures (Lassen et al., 2010).

Irradiance

Changes in cloud cover other aerosols can cause big changes in total influx of UV-radiation. Clouds attenuate UV, but even light broken cloud cover leads to an increased insolation (Diaz et al., 2000, Estupiñán et al., 1996).

The cycles if photosynthetic algae growth, is dependent on varying day length in accordance to the site latitude (Diaz et al., 2000, Johnsen and Sakshaug, 200). The point where the photosynthesis equals, called the compensation irradiance (Ec), are usually estimated by calculating the time course of decreasing amounts of fluorescence-derived chlorophyll *a* at specific depths during spring blooms (Diaz et al., 2000). Ec seems to be difficult to measure (Marra, 2004).

As phototrophic algae are depended on the radiance of light entering the water column, the thickness of the ozone layer, especially controlling UVB spectra and cloud cover (Diaz et al., 2000, Huseby, 2002)

Freshwater inflow - salinity

In areas with periods of high freshwater run off, fresh water might flush away salt and the marine phytoplankton (Mann, 2006). Especially in estuaries, periods of high freshwater might away most of the phytoplankton, and in other periods, areas can turn into a salt-wedge estuary with high primary production (Rendell et al., 1997).

Both primary production and the secondary production can be affected by high freshwater inputs. The planktonic community might be affected, both in abundance and in composition, also by hydrodynamic conditions caused by freshwater inflow (Viličić et al., 2008, de Madariaga et al., 1992).

Thompson et al. (2008) found that in bay-areas, phytoplankton bloom first appeared in the shallow water and later in the deeper regions. This was consistent with low benthic grazing rates, relatively bright light conditions and high nutrient levels (Thompson et al., 2008).

Carstensen et al. (2015) did a research program on phytoplankton blooms in estuarine and coastal waters covering 86 costal sites in North America and Europe. This study included phytoplankton species counts, measurements of salinity, temperature, Secchi depth, nutrients and chlorophyll a concentrations. In this large study there was found similarities in the timing of the spring blooms, but otherwise there was not found any notable combined patterns regarding the frequencies of blooming-periods, that could consistently related to latitude, tides, temperature, salinity, depth of the water column, stratifications or nutrients (Carstensen et al., 2015).

There has been found possible correlations between grainsize of sediments and distribution of different algae (Lucas and Holligan, 1999).

The timing and success of phytoplankton blooms has been shown to have a major impact on the survival of zooplankton, and further affect recruitment of fish larvae for such as for the Atlantic cod (*Gadhus morhua*) and haddock (*Melanogrammus aeglefinus*) (Buckley and Durbin, 2006, Campana et al., 1989).

1.5 A view on climatic changes

The global air temperature has increased dramatically in later years. Changes and abnormalities, over millennia and decades are shown in figure 4. The data are estimated by using latest analyses, named HadCRUT4.4 (Morice et al., 2012, Jones, 2016).

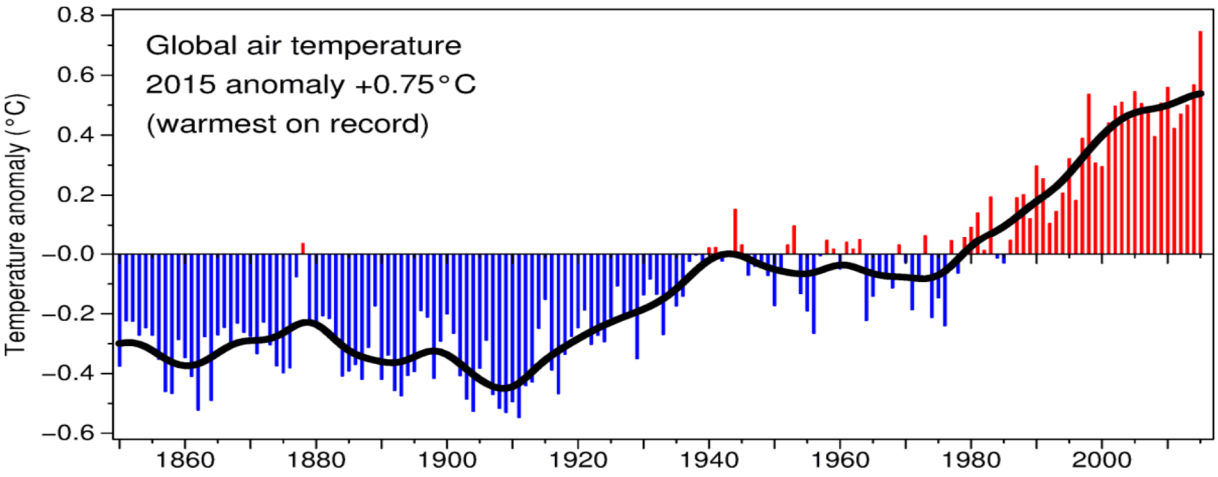

Figure 4. Global average air temperature abnormalities.
Data presented by Climatic Research Unit ©, University of East Anglia (Jones, 2016).

In Northern Norway similar trends are found, as can be seen in figure 5, presenting temperature deviations from 1900-2015. The data from Northern Norway shows a strong rise in average temperatures, especially from the late 80`s.

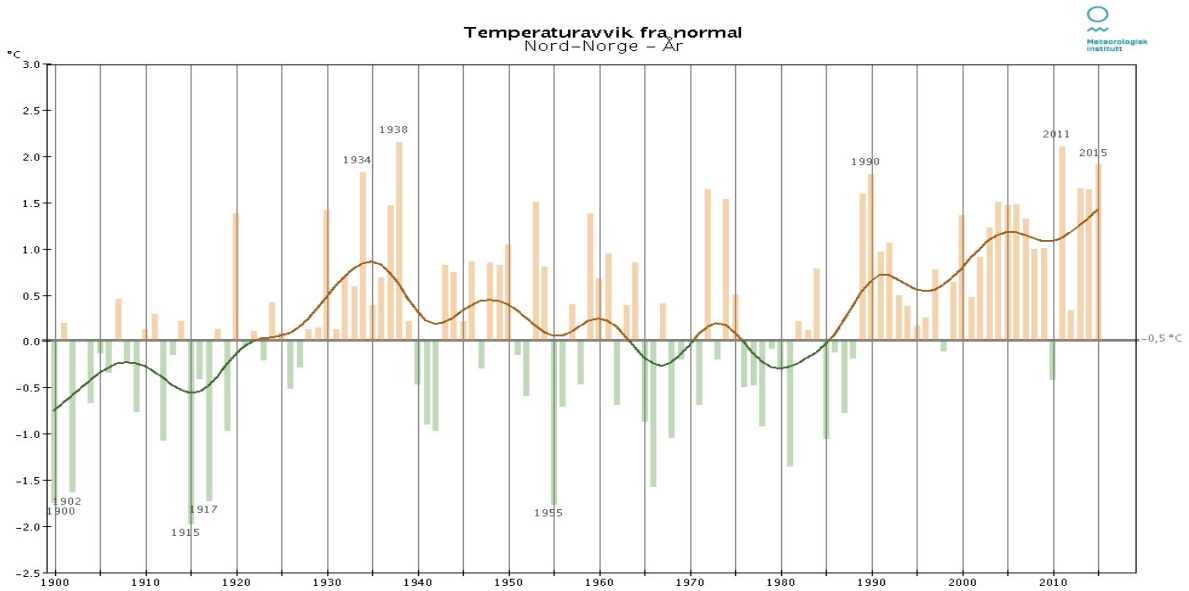

Figure 5. Temperature deviations in Northern Norway.
Temperature values are given as deviations of trend normal for the region Northern Norway (MET, 2015f).

In the winter-period the temperatures has increased in the last decades, as can be seen in figure 6. According to this data the winter-temperatures has increased later years, but 2010, was cooler than normal.

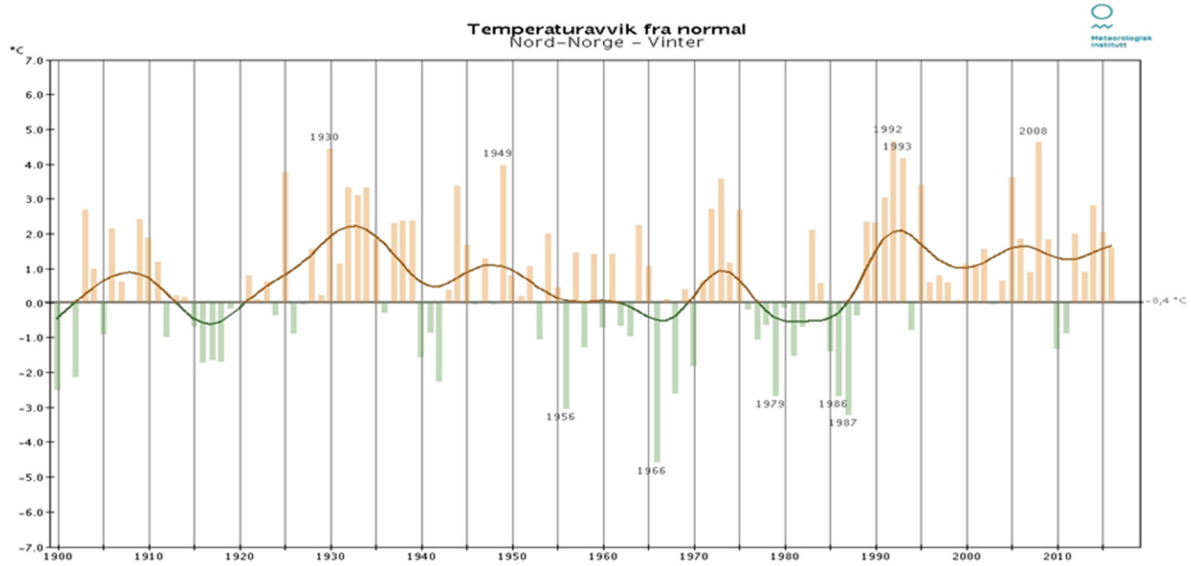

Figure 6. Temperature winter-trend Northern Norway.
Temperatures are given as deviations of trend normal for the Northern-Norway in the winter-season from 1900-2016 (MET, 2015d).

The trend seem show increased spring-temperatures, especially from the early 2000 and onwards (Figure 7). In 2010 the spring-temperatures was 0.5°C higher than trend normal in this region.

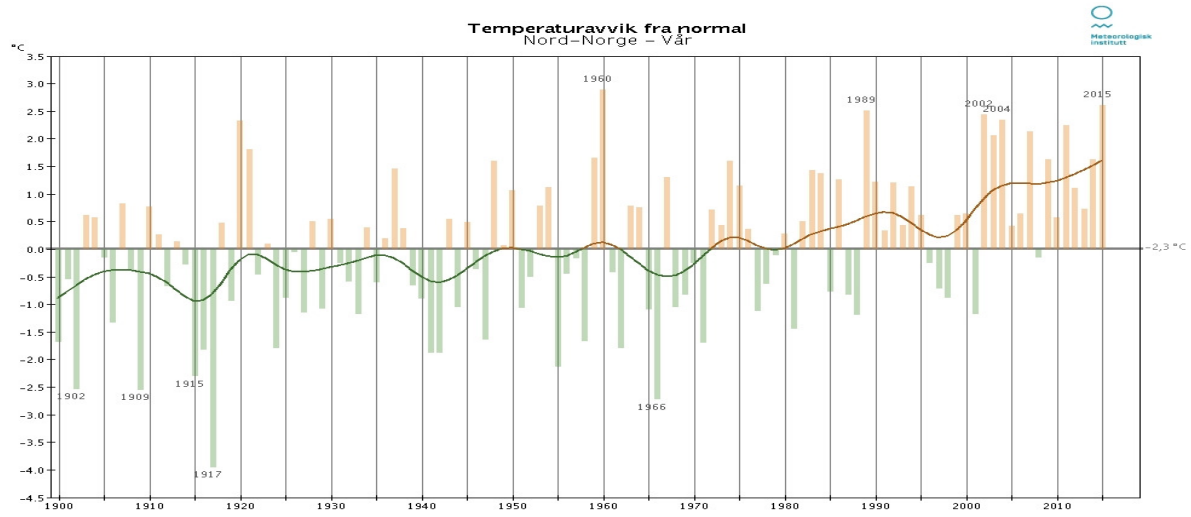

Figure 7. Spring-temperature deviations in Northern Norway.
Temperatures are given as deviations of trend normal for the Northern-Norway in the winter-season from 1900-2016 (MET, 2015e).

The temperature deviations in summer temperatures from 1900-2016 in Northern Norway, are given in Figure 8. This data show tendencies of increase, especially from the early 2000 and onwards. In 2010 the summer temperatures was approximately 0.5ºC lower than trend normal for this region, on the contrary national measurements was 0.4ºC higher than trend normal (MET, 2011).

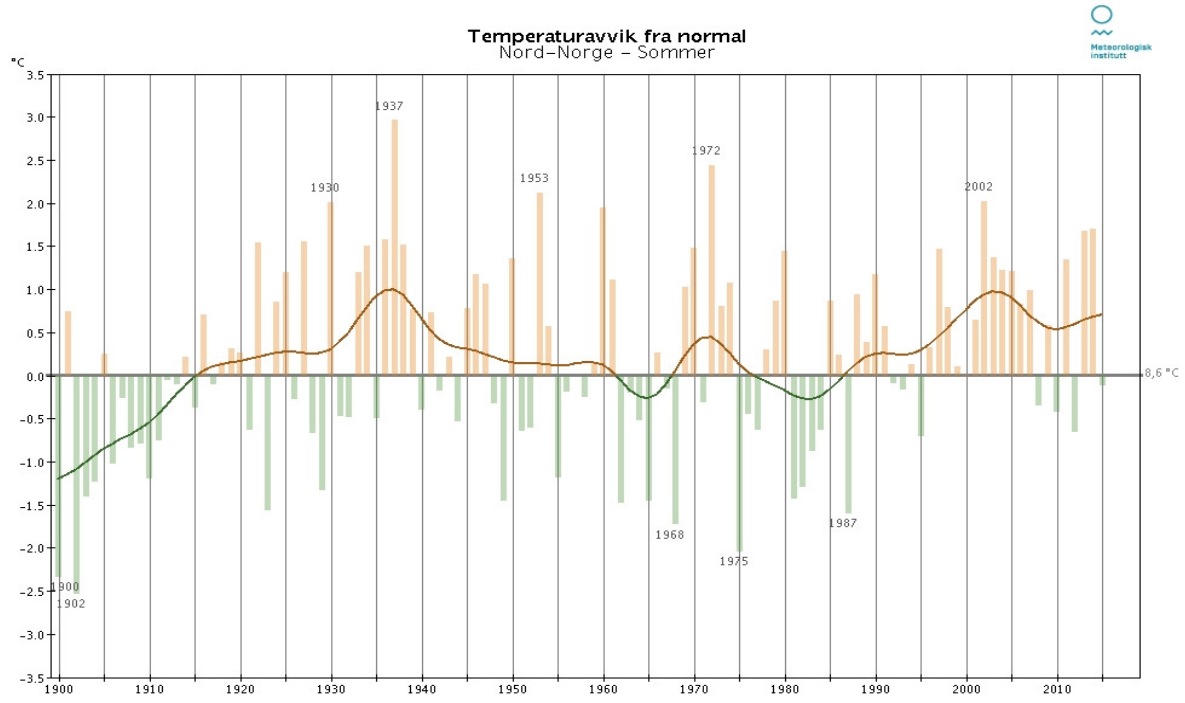

Figure 8. Temperature summer-trend Northern Norway.
Temperatures are given as deviations of trend normal for the Northern-Norway in the summer-season from 1900-2016 (MET, 2015c).

Autumn temperature-deviations in Northern Norway from 1900-2016, are given in Figure 9. As the figure show, also the autumn periods in this region has become warmer in the last decades. In 2010 the temperatures was approximately a quarter of a degree lower than trend normal for this season (MET, 2011), but still quite colder than the pervious and following years.

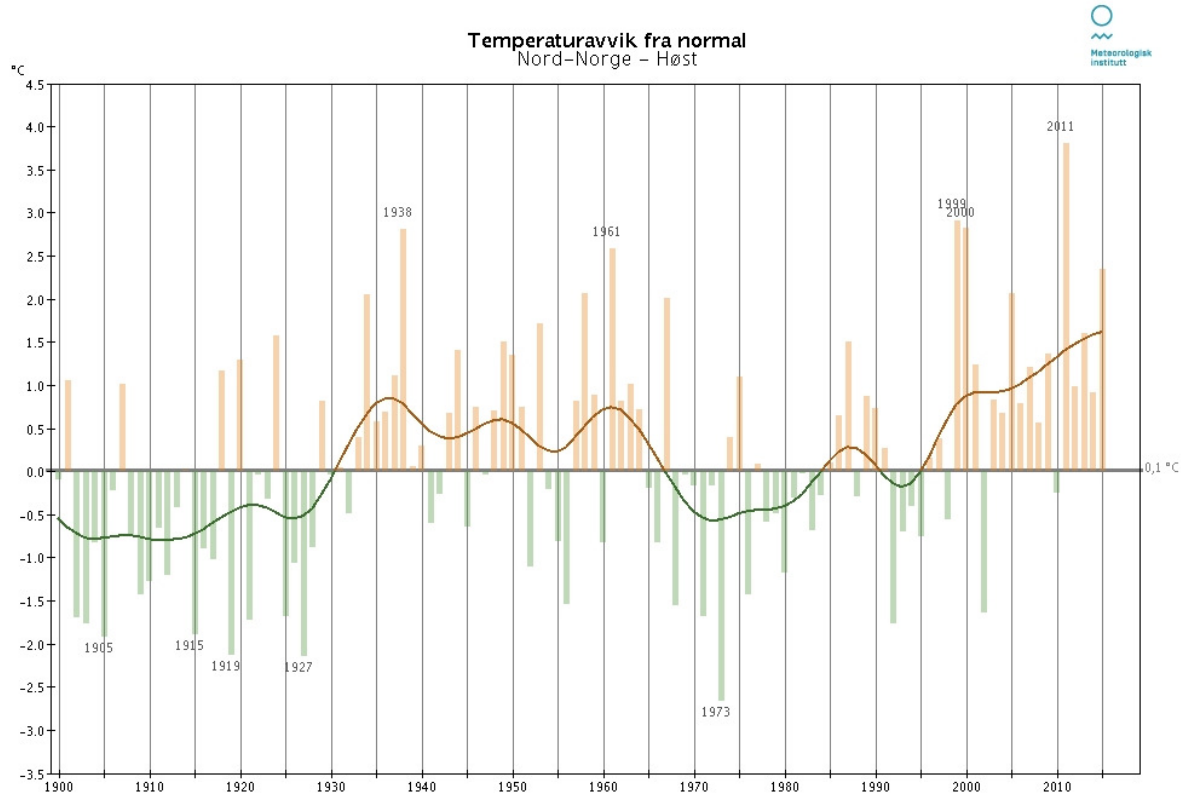

Figure 9. Temperature autumn-trends in Northern Norway.
Observed measurements are given as ºC deviations of trend normal for the region Northern Norway Average in the autumn-season from 1900-2016 (MET, 2015b).

In a national scale, the summer of 2010 was considered a wet year, so as ranked as number four on a scale going back to the year 1900 (MET, 2011). Figure 10 gives the precipitation for Northern Norway, showing that in this region, the precipitation for 2010 was below the estimated trend-normal. The tendency also for this region over the last decades shows tendencies of increased amounts of precipitation. There are naturally large local variations in Northern Norway. As parts of Nordland also was above trend normal precipitation in 2010 (MET, 2011). Local measurements for regarding present study are given in Appendix C and in processed figures in section 3. Results.

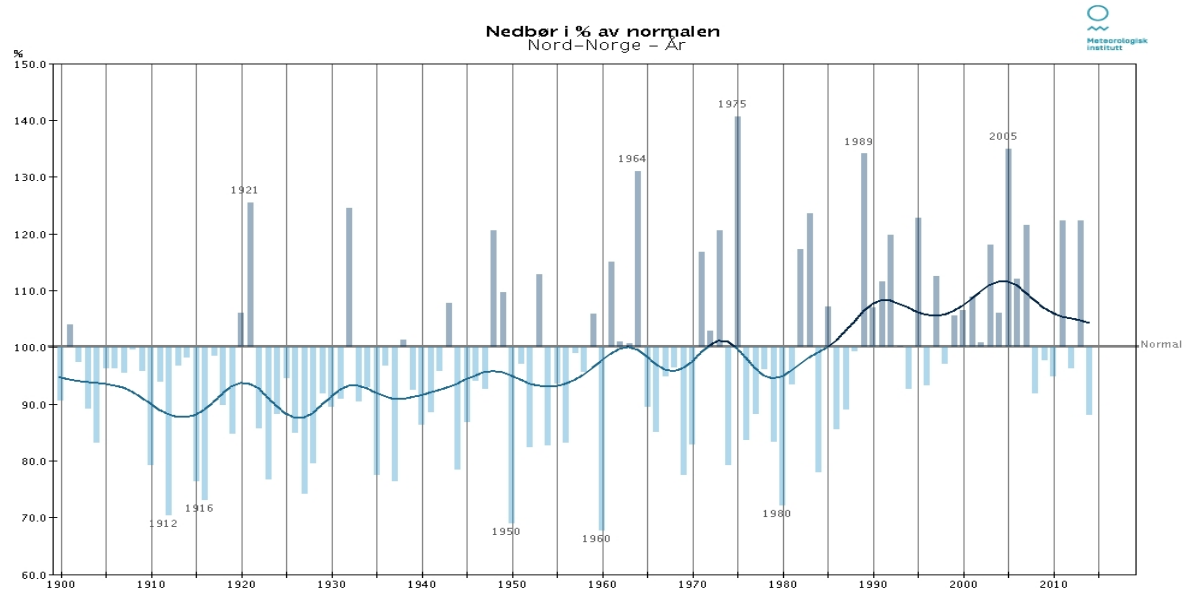

Figure 10. Precipitation trends in Norway.
Calculated measurements are given as percent (%) of trend normal for the region Northern Norway (MET, 2015a).

1.6 Field and lab analyses algae – different methods

Information on the abundance and species composition can be enumerated by using different methods. One of these methods is based on light microscopy. According to Mackey et al. (1996), this method requires using extensive time on sample preparation and counting to find valid counts. This is especially difficult for identifications of less abundant species, since many of these lack external morphological feature that are taxonomically useful (Mackey et al., 1996, Li et al., 1983, Platt et al., 1983). Many species are also very fragile and might be damaged during sample fixation (Li et al., 1983).

Another method in algae class determination from unknown multi cultures, is examining amounts of reserve polymer synthesized from photosynthetic processes. During this process algae can produce different reserve substances (Madigan and Martinko, 2006). According to Madigan et al. (2006), the group Dinoflagellate produce starch (α-1,4-glucan) and Chlorophyta (Green algae) the same in addition to sucrose. Euglenophyta produce paramylon (β-1,2-glucan), Chrystophyta (Golden brown algae and diatoms) produce lipids. The brown algae (Phaeophyta) produce laminarin (β-1,3,-glucan and mannitol), while as red algae (Rhodophyta) produce floridian starch (α-1,4- and α-1,6-glucan) (Madigan and Martinko, 2006).

It is common to use spectrophotometric and spectrofluorometric methods identifying pigments (Neveux et al., 2011). DNA-analyses can also be used to determine the algal cell conditions in a known culture media (Leu and Hsu, 2005), as to find limits of exposition tolerances and cell damage. It is also possible to study the photosynthetic membrane using force microscopy (AFM), (Liu and Scheuring, 2013) and x-Ray analyses of membrane protein structure (Feld and Frank, 2014). (Volent et al., 2011)

As for monitoring phytoplankton in fjords, satellite data and Ferry boxes might be useful in combination to algal cell counts and HPLC-pigment analyses (Volent et al., 2011).

A useful method for finding correlations between algal classes, based on specific signal pigments are the CHEMTAX-method (Mackey et al., 1996, Higgins et al., 2011). This method is aimed to estimate the contributions of different phytoplankton classes up against the pigment concentrations in water samples (Mackey et al., 1996).

Chromatography, especially HPLC-analyses are further addressed under sub-section 1.6.1.

1.6.1 Chromatography

Chromatography analysis are different techniques for separating components based on the distribution of the components between a moving liquid or gaseous phase and a solid stationary phase, that usually consists of a large surface area (Sharp, 2003).

HPLC is analyses are a preferred method when analysing pigments in cells, especially if the aim is to find amount contents in samples (Egeland, 2016, Garrido et al., 2011).

In the column that makes up the primary part of a HPLC system, where pigments are separated for identification. Different pigments passes through a column at different retention times (t_R) in accordance to their polarity and the polarity of the mobile phases. In the array the pigments are detected and presented in different peaks as a function of time (Bidigare et al., 2005). There are many different HPLC-systems available, and the choice of specifications and accessory equipment, must be done in accordance to the purpose and needs (Neeley et al., 2011).

For seawater for algae culture analyses in mesotrophic waters, it is recommended to filtrate from 1 to 2 litres of seawater per sample. Pre filtrating the cultures for removal of zooplankton will also could exclude the chain forming phytoplankton, and is therefore not a recommended procedure for this purpose (Bidigare et al., 2005).

It is recommended to use positive pressure filtrating system so that larger amounts can be filtrated. It can be used different filters, but preferably Whatman GF/F glass fibre filters, with minimum 0.7 µm pore size are recommended to filtrate natural seawater (Bidigare et al., 2005). Oher studies has been performed using different pore sizes, and it was then found important to use filters to be able to trap particles that are at least 0.2 µm or smaller, or the results might give to low values (Li et al., 1983).

To minimalize the risk of degeneration of the pigment samples must never be exposed to bright light, high temperature, uncleaned environments, this to avoid changes in the pigment concentrations. The samples exposition to room temperature must be kept as short as possible, the samples are preferably kept in a deep freezer, and during the analysing process the sampling bottles must be stores at 4°C in a vial compartment (Bidigare et al., 2005, Egeland, 2012).

2 Materials and methods

2.1 Study site

The study was performed at the research station Mørkvedbukta, run by Nord University in Bodø, Northern-Norway. The fieldwork were performed from January-December 2010 from a small floating dock located inside a semi enclosed loch (67´16,655´´N 14´ 33,390´E) (Figure 11).

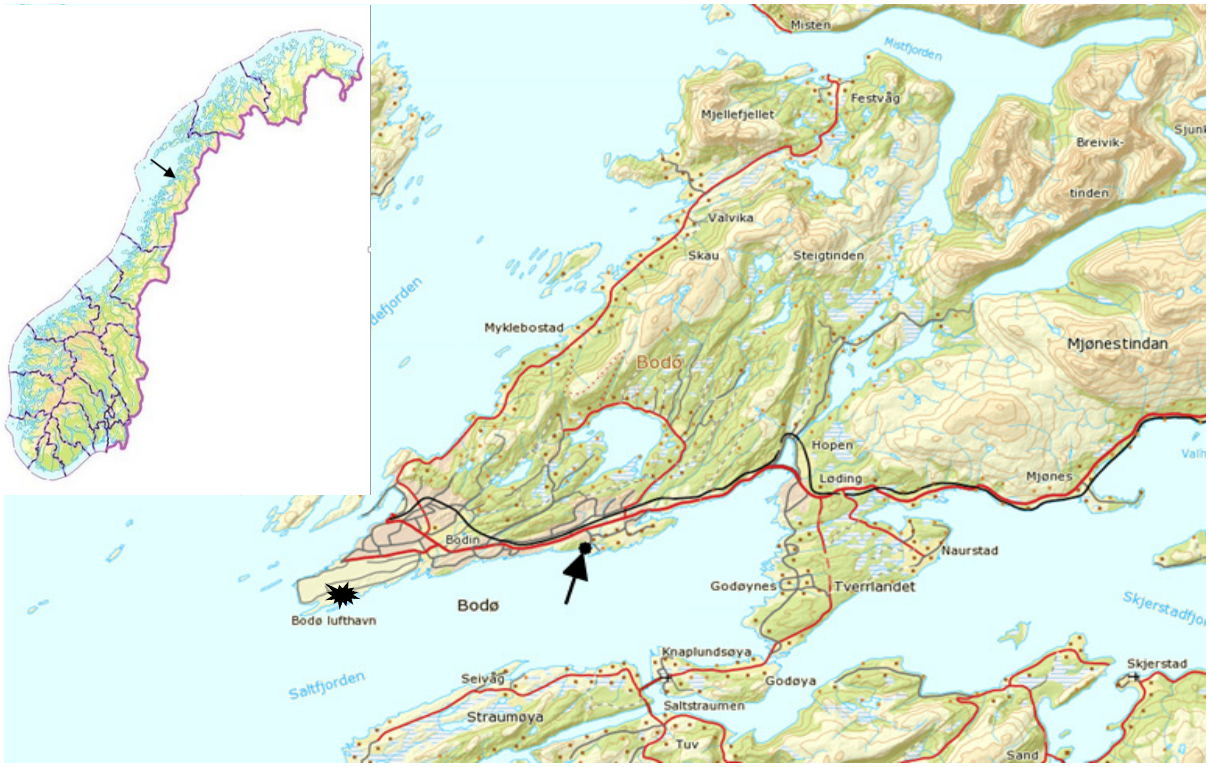

Figure 11. Destination map.
The symbol (→●) marks the sampling site for seawater-material, SD-probe measurements, and algal cell counts.
The symbol (*) marks the meteorological station located near Bodø airport (Processed from ArcMap).

Close access to the research station enabled regular sampling regime. A molo-construction provides protection from the open fjord system of Saltenfjorden, as shown in figure 12.

Figure 12. Sampling destination site picture.
The arrow (→) marks the sampling site (Processed from ArcMap via OrthoPhoto).

2.2 Field sampling and hydrographic measurements

Samples of seawater were collected two or three times a week from December 2009 to December 2010. The samples were taken either in the morning or in the afternoon. The column was uneven and it was experienced depths between 8 and 9 m, due to different tides.

2.2.1 Hydrographic field measurements

Measurements of seawater conditions was performed using an CTD/STD Sound Vel. probe SD-204 equipment, frequently used and approved for scientific and commercial purposes. The instrument measured salinity, oxygen, fluorescence, water temperature, depth, density and pressure. The instrument was set to register and save the results each minute.

Connected to a rope, the activated probe was slowly lowered towards the bottom, pulled back up, and immediately deactivated. The instrument was thoroughly cleaned using sterilized freshwater after each measurement. Measurements data then were transferred to the corresponding computer program (section 2.6).

2.2.2 Ocean water sampling

A flexible tube with a sized diameter of 10 cm, with a connecting rope and a stone, was used to collect ocean water. The tube was lowered into the water column, then by rising the lower end pulling the rope, to get an estimate of the water column from top to bottom.
Approximately 8 – 10 litres of seawater were collected in a bucket each time.

2.3 Sample preparations

Immediately after, the seawater was transported to the Wet-lab at the research station, for a vacuum filtration process. The filter samples were afterwards transported to the lab facilities at the university for further lab-processes.

2.3.1 Filtration and freezing

Seawater were filtrated through Whatman® glass GF/F 42.5 mm (47 mm from October samplings and onward) filters provided by Sigma-Aldrich (Sigma-Aldrich, 2009) in a water-driven vacuum filter array. An amount of 2 L seawater was carefully vacuumed through each filter, making sure that the filters did not dry completely. The filers were then folded, put into separate aluminium foil wrappings, and enclosed in zipper-bags. Four replicate filter samples were produced each day.

The samples were sealed in an expanded polystyrene-box placed in a deep freezer holding approximately minus 20ºC, in a deep-freezer, at the wet-lab and at the University. All the equipment was thoroughly cleaned using sterilized water to avoid contaminations/inferences from unsterilized tap water.

2.4 Extraction

For the extraction process, the frozen filters were cut into squares of approximately 1 mm size and put into separate reagents tubes. Using ice-cold pre-mixture of 30 % methanol in propanone, 5 mL were added to each tube, then top coated with nitrogen gas and a sealed with a tight lid. The tubes were kept in upright position at about minus 20ºC in a deep freezer overnight, or for around 24 hours.

2 ml of each sample was pipetted into amber 2 ml HPLC-sampling vials, top flushed with nitrogen gas, capped and placed in a HPLC trey-compartment holding 4ºC.

This procedure was performed on three filters of each selected day. As long time storage, and the fact that the set HPLC-program uses two hours per vial/sample, could degenerate the samples, different batches was processed throughout the year. Consecutively the data sets were evaluated, based upon quality or interest, and if needed, extra filter samples from parallel replicates and days in between were analysed. To examine if prolonged storage, or other factors, might have had an influence on the result, the parallel samples run at different analyses was compared.

2.5 HPLC analysis

The HPLC analyses was performed by using a Hewlett Packard Agilent 1100 HPLC instrument, equipped with a quaternary pump system, vacuum degasser, thermostatted auto sampler with enlarged injection loop, thermostatted column compartment and a diode array detector (Egeland, 2012). Specifications and instructions for use was found in; Agilent 1100 Series HPLC Value system User´s Guide (Agilent-Technologies, 1999).

The procedure was performed in accordance to the UN method, for analysing oceanographic field samples. The method is based on using two C_{18} columns and a lower solvent flow. (Egeland, 2012).

Two identic C_{18} columns were used after each other (ACE 5 C_{18} part no. ACE-121-2546, 4.6x250 each, 5.0 µm pack) with a separate guard column (ACE), at a column temperature held at 25° C.

The auto sampler drew 50 µL from each sample extract. The injection flow was 0.5 mL/m and air temperature at 4°C in the vial tray compartment.

1 M ammonium acetate (AmAC), methanol (MeOH), acetone and hexane were used as eluants, specifications for gradients are given in table 2.

Table 2 HPLC solvents gradients.

Time given in minutes and solvents in percentage (%) of total amounts.

Time	**1 M AmAc (%)**	**MeOH (%)**	**Acetone (%)**	**Hexane (%)**
≤0	20	80	0	0
60	0	70	30	0
100	0	30	50	20
110	0	0	40	60
120	0	100	0	0
130	20	80	0	0

Detection wavelengths for the chromatograms were 390 nm (Signal 1), 420 nm (Signal 2), 450 nm (Signal 3) and 480 nm (Signal 4).

The instrument had been pre-calibrated in accordance to method. Each analyse consisted of twelve vial samples, in addition to one control blank/non-sample vial.

It was briefly examined if prolonged storage might have had an influence on the results. This was performed by comparing data from the extra samples from the same batch, analysed at different days. Result sheets obtained was further processed and calculated into excel tables and figures (see section 2.6).

2.6 Obtaining and processing external meteorological- and algal rapports

The weather rapports used in this experiment were downloaded from the Meteorological Institute (MET), a national database. Data are distributed from their website, given credit, if used for scientific purpose. Specific information about daily measurements from 2010 was provided on request. The collected information also included the meteorological climate trends over millennia and decades, based on average normal weather conditions (section 1.8). The institute has many different measuring stations. The station for was at Bodø airport observation station (82290) located about 11 metre above sea level, approximately 10 kilometres in westerly direction of the sampling site, was considered the most representative shoreline station (see figure 11 in section 2.1).

The processed datasets obtained from Meteorologist institute, such as precipitation, air temperature and estimated cloud cover was set in tables and processed. The data from 2010 were compared to the measured SD and HPLC-results.

Data obtained regarding climatic conditions of normal averages the past 100 years, and conditions from 2010 to 2014 is presented in section, 1.5.

Data from algal cell counting performed in the bay in 2010, was obtained from SINTEF. Additional information and permission to use the data was also given from Norwegian Food Safety Authority, responsible for the connecting project. Data are published with permission. The obtained raw data was processed and compared to the data from the presented study. The this sampling was, performed as described in Norwegian Standard (NS 9429:2007) according to one of the participants (Forbord, 2016).

The data from the cell counting was reported to be from collecting samples at approximately the same spot, from the floating dock (Larsen, 2016) as illustrated in figure 11 and 12.

2.7 Data reporting and statistical analyses

Results from probe measurements in the water column was uploaded, using software; Mini Soft SD 200 W for STD/CTD Sound Vel. Probe SD204, version 3.7.2.109, from SAIV AS Bergen, Norway (SAIV-A/S, 2009).

The results from the HPLC-analyses was obtained using the connecting computer program Value Solution Chem Station software, for 1100 series HPLC modules from Agilent Technologies (Agilent-Technologies, 1999). The HPLC automatically calculated the amounts of pigments for the injected samples. The concentration in µg/L s.w. (as presented raw-data in tables) and mg/L s.w. (as presented in figures) of each pigment per litre seawater was calculated. Calculating on the injected sample volume (50 µl), against the total volume of the sample, and the volume of seawater filtrated per sample (2 L).

Excel-work sheets were used for calculations, tables and graphic figures. Microsoft Office Excel 2010 for Windows was used to prepare all tables and graphs presented as results in this report. All result graphs presented are based on produced tables.

Full list of results from SD-probe measurements and HPLC-results are given in Appendixes A and B. The processed reports from meteorological reports and algal cell counts are presented in Appendix C and D respectively. Please note that not all measurements are given in accordance to The international System of units (SI).

3 Results

The results are presented in different terms. Section 3.1, gives schematic dispositions of the pigment analyses, summarising the data presented in Appendix B. The hydrographic measurements and obtained meteorological data sets are given in section 3.2 and 3.3, based on data presented in Appendixes A and C. Section 3.4 gives figures processed from obtained algal count raw-data given in Appendix D, before the summarising disposition of selected combined results. Note the different scales and calculated translations.

3.1 Pigment analyses

The results presented in this section are based on HPLC- analyses of seawater samples from data given in Appendix B.

3.1.1 Estimated total seasonal pigment distribution

The concentration of monthly average pigment-concentration over the year-period is summarised in figure 13. The highest monthly average was in May with an estimated concentration of 2.5 mg total detected pigments per litre of seawater. The average monthly pigment distribution rises from April on to May, with a slow decline through the months onto October.

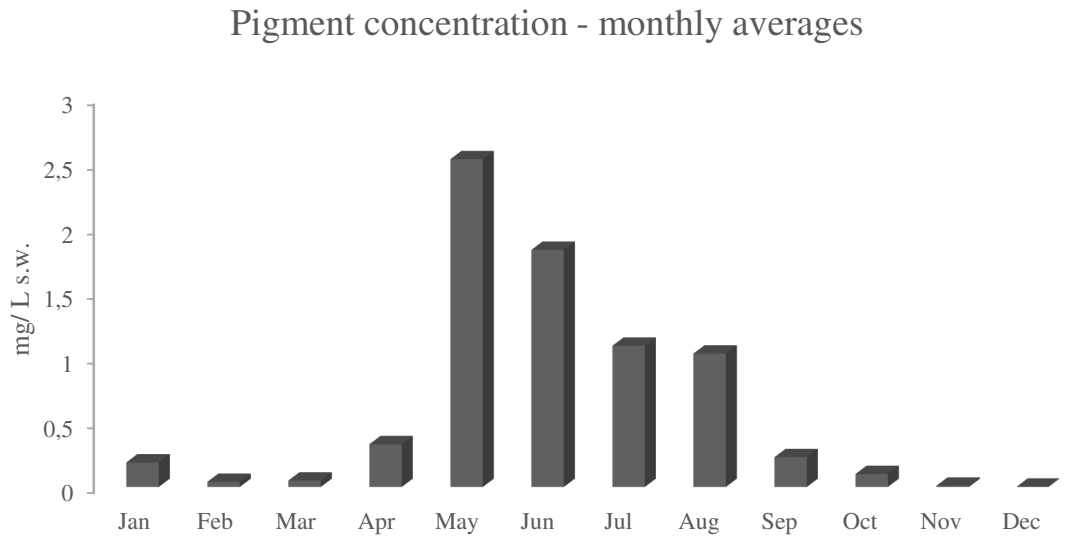

Figure 13. Seasonal distribution of total pigments- monthly averages
Calculated concentration per litre of seawater, based on average monthly values (Appendix B).

The distribution of total pigment distribution, given as based on average from each sampling day show a more fluctuating concentration pattern (Figure 14).

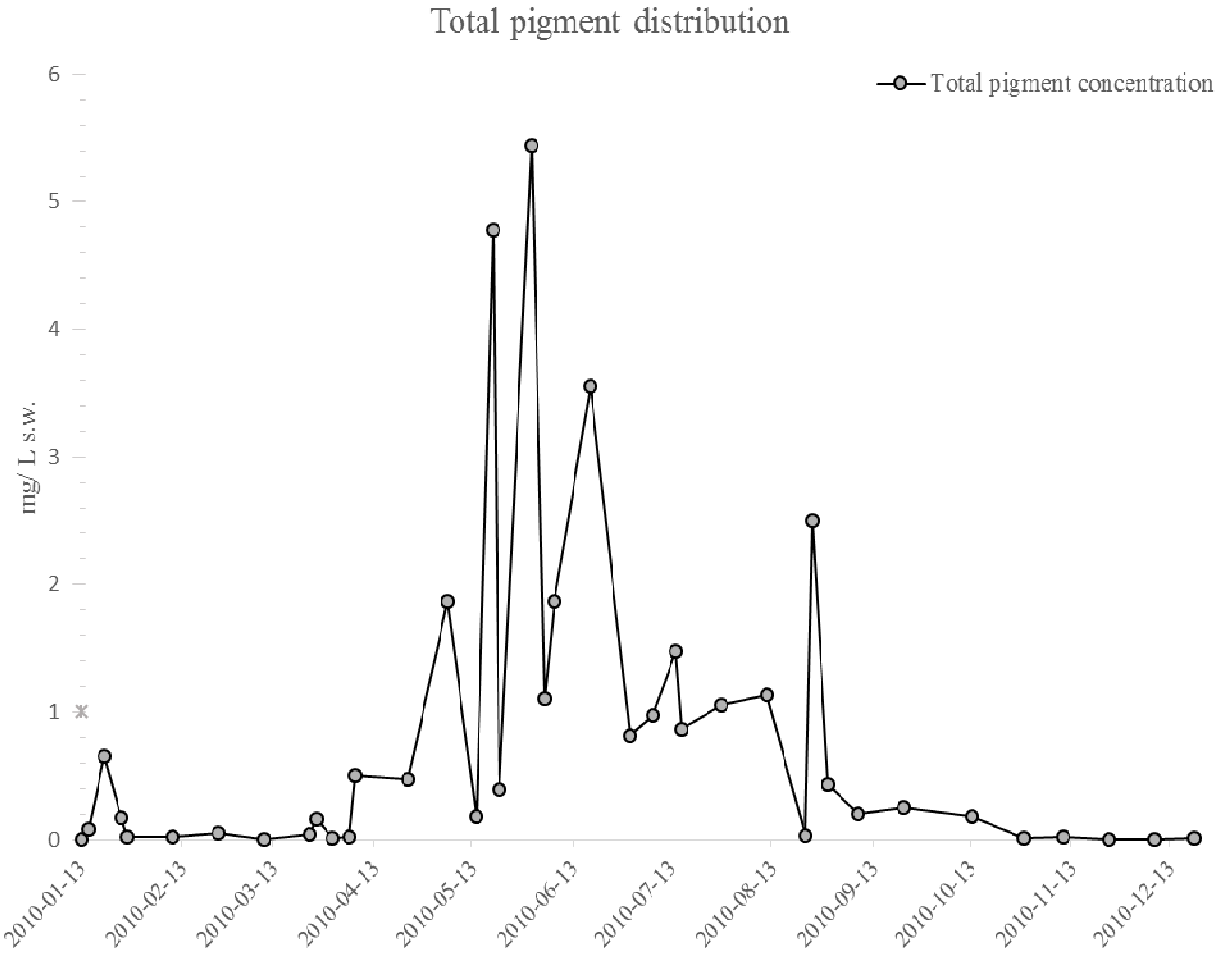

Figure 14. Total pigment concentration based on daily averages.
Pigment concentration based on average daily samples.

3.1.2 Seasonal distribution of pigments

Estimated concentrations of the most abundant pigments in 2010 are presented given concentrations are milligrams per litre seawater. Numbers calculated from tables in appendix B, gives the monthly average. Note the different scales in the schemes.

3.1.2.1 Chlorophyll a

Concentration of chlorophyll *a* shows a rising peak from April, on to a steeper curve rising in May (Figure 15). The concentration drops drastically onto July and declining towards September. Highest monthly average concentrations of Chlorophyll *a* was in May, measuring 1.9 mg/L s.w. In February and October, the concentration dropped more than by the half from its previous month, from 0.1 mg/L in January to 0.03 mg/L in February, and from 0.1 mg/L in September, to measuring 0.04 mg/L in October.

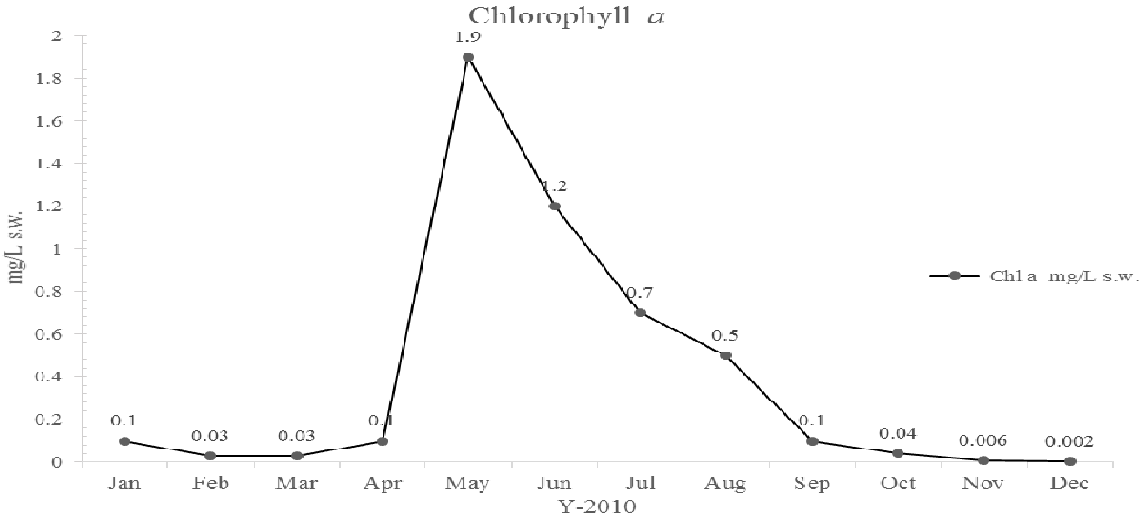

Figure 15. Chlorophyll a.
Average concentration of chlorophyll a during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.2 Chlorophyll b

Two distinct peaks of chlorophyll *b* can be observed, a small peak in May and a larger top in August, with a distinct drop in pigment concentration in June-July (Figure 17). From January to April the measurements varied from zero to 0.004 mg/L s.w., rising to a small top at 0.086 mg/L s.w. in May. Afterwards there was a decline in June at 0.026 mg/L and July at 0.033 mg/L. In August the concentration of Chlorophyll *b* was at 0.15 mg/L s.w., before a downfall in September measurements at 0.022 mg/L. In October 0.007 mg/L, going on zero values for November and December.

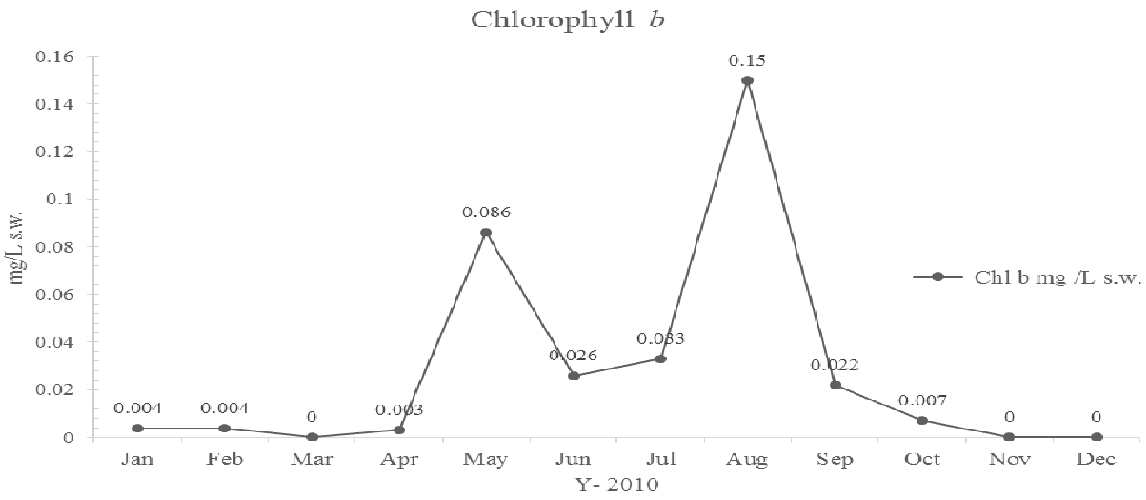

Figure 16. Chlorophyll b.
Average concentration of chlorophyll b during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.3 Fucoxanthin

Fucoxanthin concentration maximum was in June this year, and was found in all months except December (Figure 17). January had a monthly average of 0.0019 mg/L seawater, with declining values in February and March at respectively 0.003 mg/L seawater and 0.006 mg/L s.w. In April at 0.08 mg/L and May 0.017 mg/L seawater. Top average concentration values was in June at 0.32 mg/L seawater, before declining to 0.2 in July and 0.075 mg/L seawater. in August. From September- December, the concentration was at 0.047; 0.012; 0.001; 0 mg/L seawater respectively.

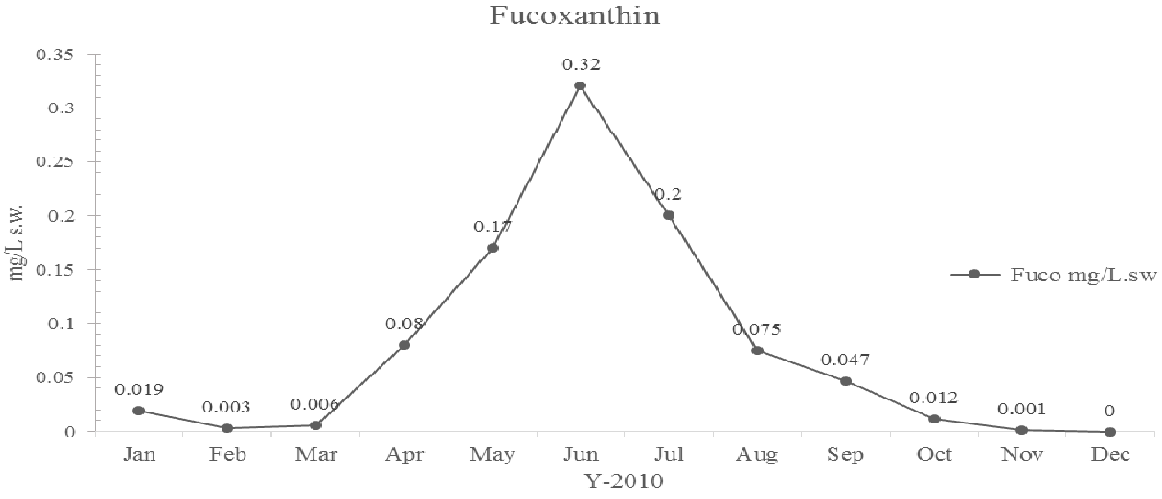

Figure 17. Fucoxanthin.
Average concentration of fucoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.4 Cryptoxanthin

A small amount of cryptoxanthin was found from January to April, increasing to top-average concentrations in May (Figure 18). There were a steep decline downwards from May onto June, and then a slack curve further. The calculated average monthly concentration gives 0.17 mg/L s.w.in May. The slope curve towards September slack curve forms after a peak in May.

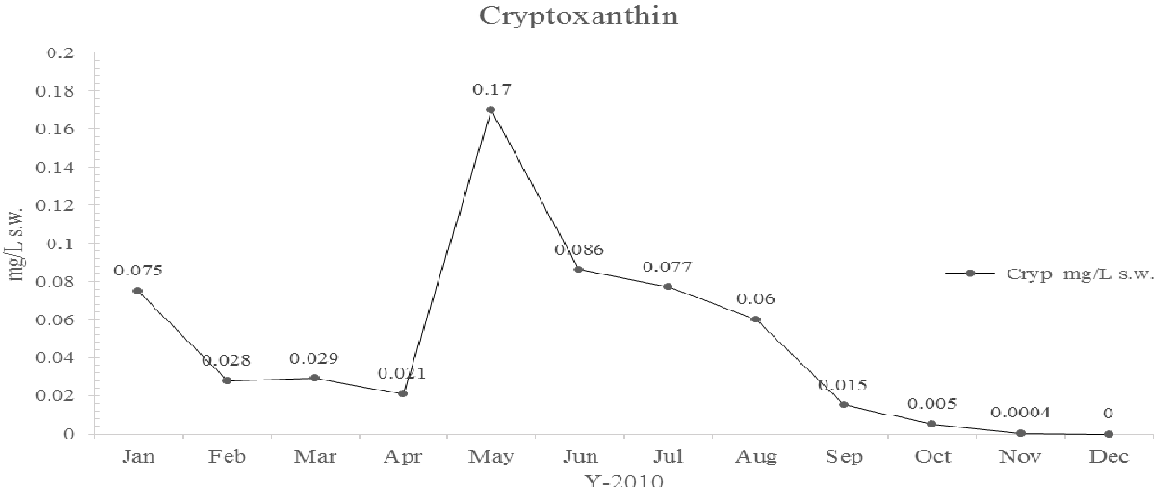

Figure 18.Cryptoxanthin.
Average concentration of cryptoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.5 Diadinoxanthin and diatoxanthin

The concentration of diadinoxanthin and diatoxanthin shows a distinct curve in June, steeply rising and declining (Figure 19). Diatoxanthin was only found in samples from June. The top in June at maximal average of 0.028 mg/L.

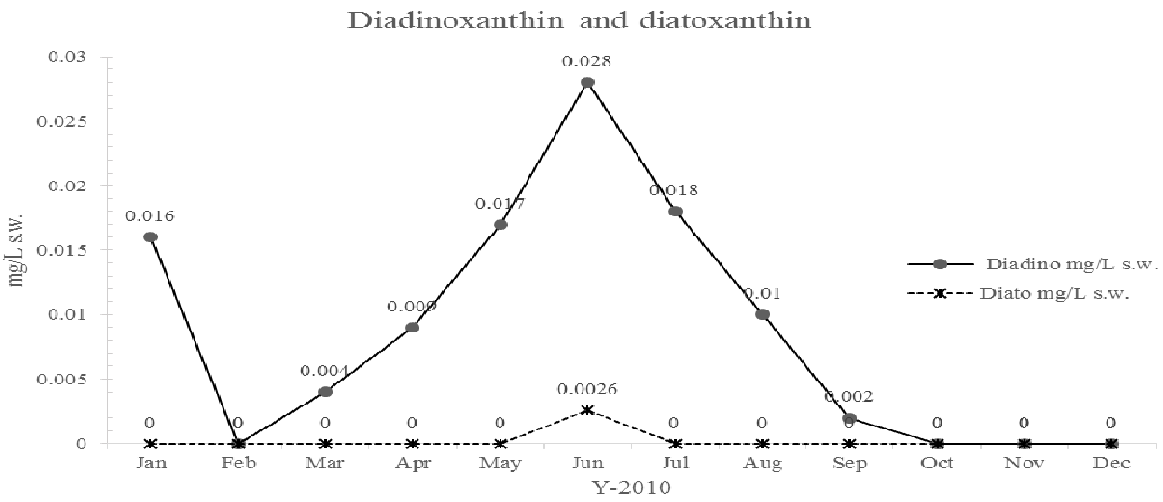

Figure 19. Diadinoxanthin and diatoxanthin.
Average concentration of diadinoxanthin and diatoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.6 Crocoxanthin

Maximum concentration of crocoxanthin was found in May this year, with a successive decline on to end of August (Figure 20). The pigment was present in January samples, and from March to August.

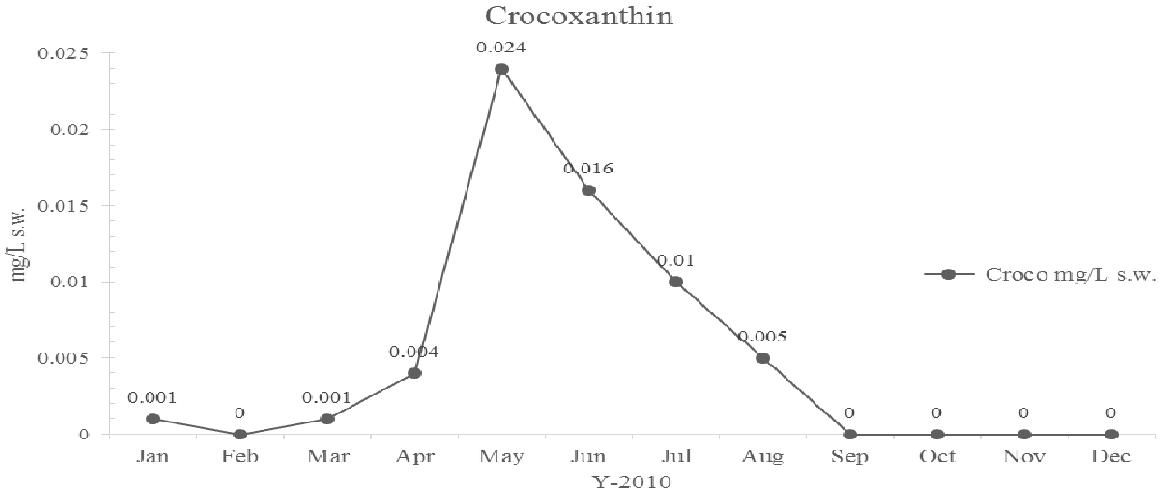

Figure 20. Crocoxanthin.
Average concentration of cryptoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.7 Zeaxanthin

Zeaxanthin was only found in samples from January to October (Figure 21). Maximal amounts were in August, with maximal daily average of 0.103 mg/L seawater on August 11 (Appendix B).

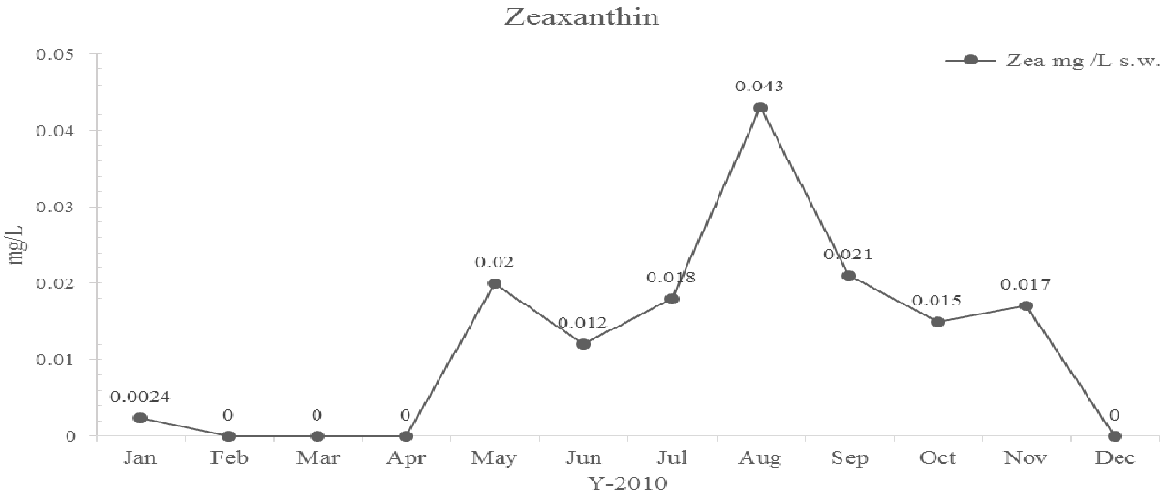

Figure 21. Zeaxanthin.
Average concentration of zeaxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.8 Neoxanthin

Maximal amounts of neoxanthin were found in January and May, with average monthly concentrations with respectively of 0.034 mg/L and 0.028 mg/L seawater (Figure 23).

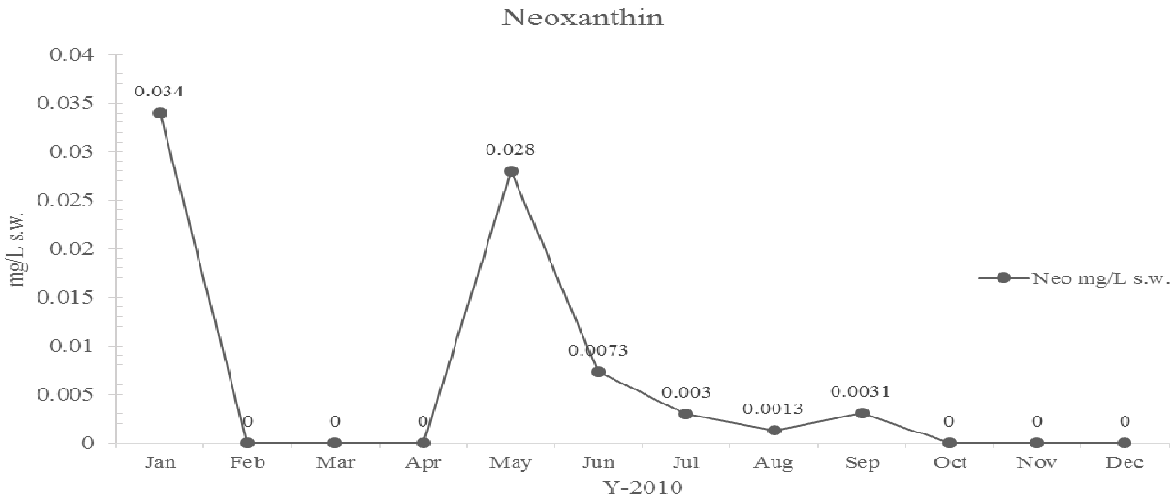

Figure 22. Neoxanthin.
Average concentration of neoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.9 β,β-carotene

Highest concentration of β,β-carotene was in July with an average concentration of 0.033 mg/L seawater (Figure 23). The concentration levels started rising from April and onward.

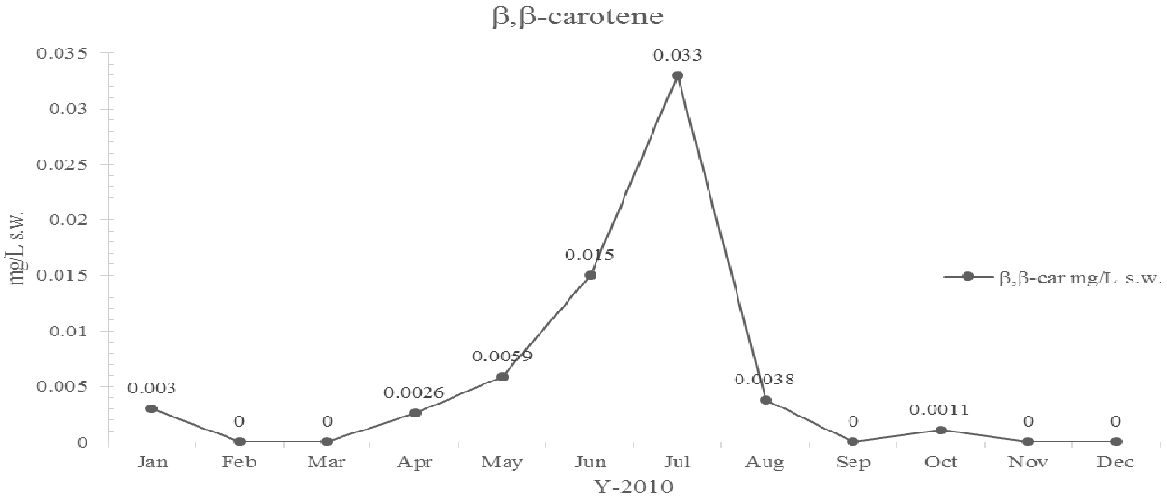

Figure 23. β,β-carotene.
Average concentration of neoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.10 Prasinoxanthin

The maximum levels of prasinoxanthin concentration were in June and August (Figure 24).

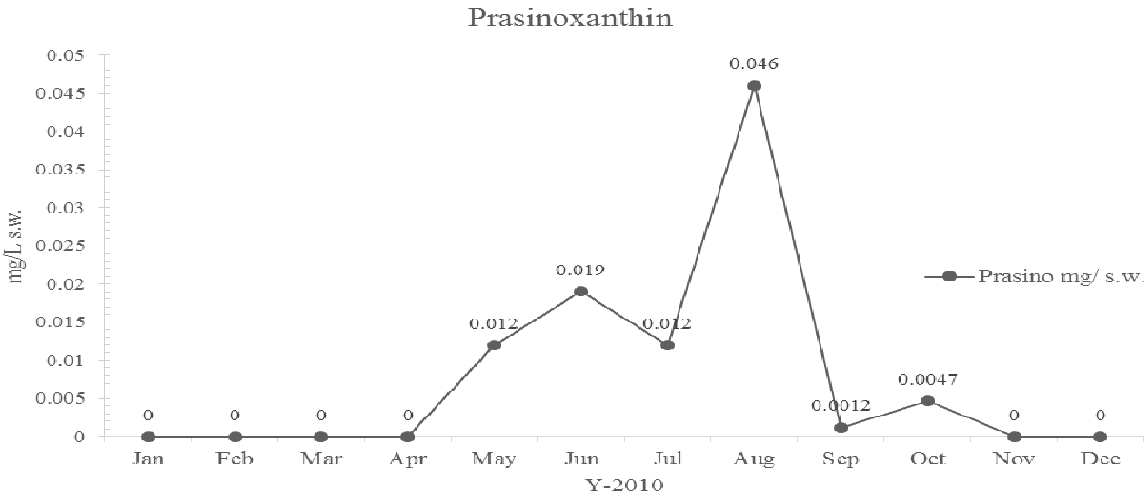

Figure 24. Prasinoxanthin.
Average concentration of prasinoxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.11 Lutein

A maximum concentration level of lutein was in August, but smaller peak-levels are also measured in January-February and in June (Figure 25).

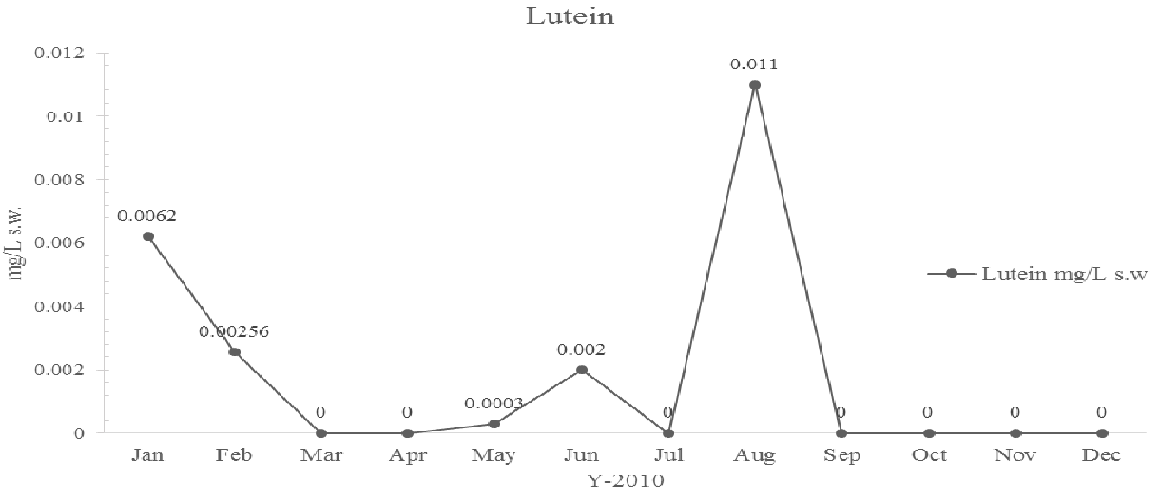

Figure 25. Lutein.
Average concentration of lutein during each month of 2010, given as mg/L seawater (Appendix B).

3.1.2.12 Violaxanthin and antheraxanthin

The pigments violaxanthin and antheraxanthin only present in the seawater samples from May to August (Figure 26).

The concentration curve of violaxanthin divides in two dominant peaks, one in May-June, and one in August (Figure 26; left scheme). Top single day result was on May 19 measuring ~0.106 mg/L seawater (Appendix B).

Antheraxanthin concentration was measured at monthly concentrations between 0.034 and 0.035 mg/L seawater. The period of highest concentration levels was in August (Figure 26; right). Summarized the major peaks was in May going on a larger combined peak in August.

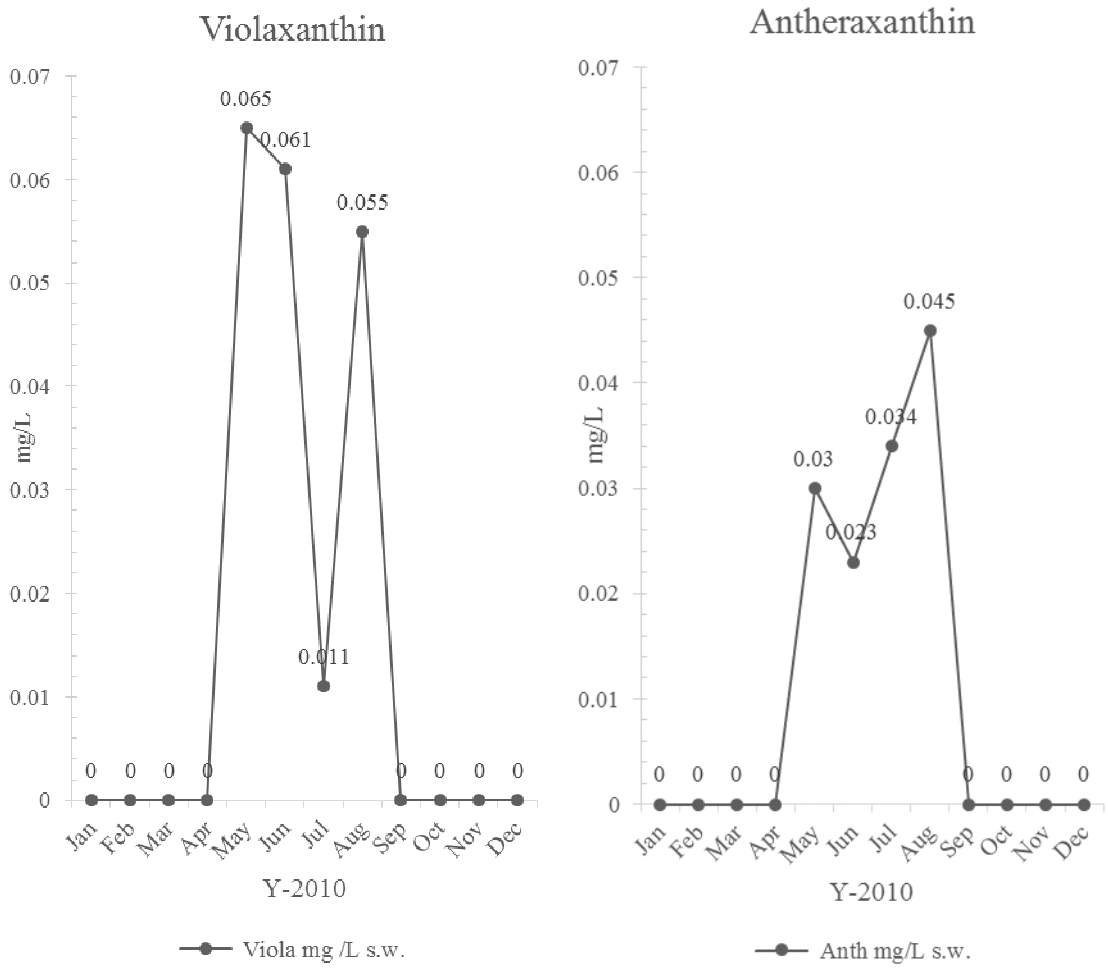

Figure 26. Violaxanthin and antheraxanthin.
Average concentration of violaxanthin and antheraxanthin during each month of 2010, given as mg/L seawater (Appendix B).

3.2 Hydrographic SD-measurements

In order to study possible influences between the parameters on the amount of pigments in the water samples, the different parameters measured and presented are salinity, water temperature, amount of oxygen and fluorescence in the water column.

3.2.1 Fluorescence

Estimated concentration fluorescence in the water column, shows distinct top measurements in June, with a steep increase from April-May (Figure 26). The curve then shows a gradually decrease onwards the rest of the summer and onto autumn.

A steep increase in measured values at June 4 measuring 10~ µg/L, with another distinct high July 19 measuring ~4 µg /L s.w. (Appendix A). Highest concentration of fluorescence was from May onto beginning of October. Lowest estimated amounts in January to the beginning of March varying from 0.2 to 0.4 µ/L, and further on a slow decrease from October towards the late autumn.

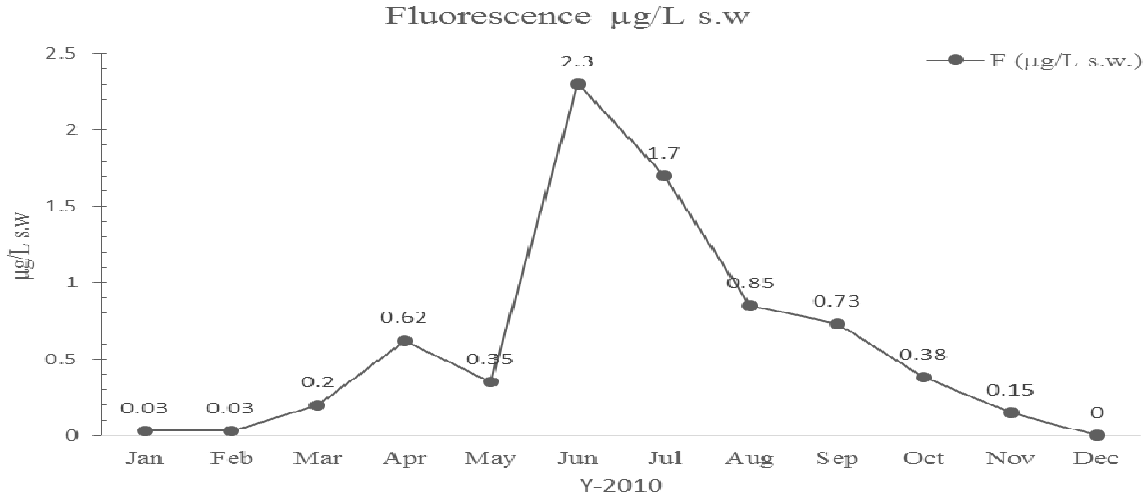

Figure 27. Fluorescence.
Estimated concentration of fluorescence in micrograms per litre of seawater (µg /L s.w.) (Appendix A).

3.2.2 Seawater temperature

The seawater temperature varied in an uneven curve, declining in mid-winter and rising as the illumination caused by increased length of diurnal daylight, combined with increased earth-crust heat radiation (Figure 28).

Seawater temperature varied through the period from 3.1°C in February 19 up to a maximum at 10.4°C on August 6. The average temperature in the water column started rising above 5°C in the beginning of May onto a downfall below 5°C in November. Maximal seawater temperature was in July-August. In the beginning of May, the temperature exceeded 5°C

(Figure 28; appendix A). Note that the measurements from February 17 at 9.6ºC, have been removed from the scheme.

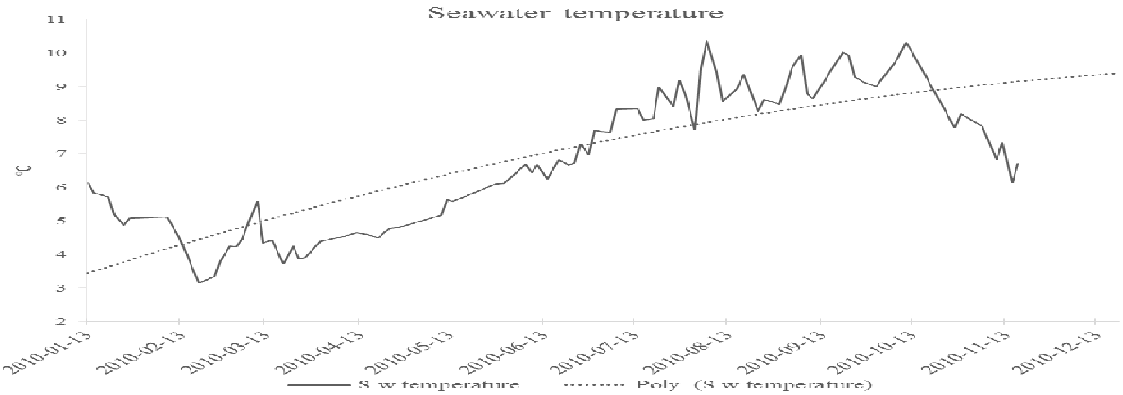

Figure 28. Seawater temperature.
Seawater temperature in the water column based on probe measurements, given in degrees Celsius (ºC) (Appendix A).

3.2.3 Oxygen

Measurements of oxygen indicates variations from 8 mg/l or 80 % and upwards. There are two main periods with noticeable variations (Figure 29). The oxygen levels dropped remarkably in the period from April 16 to April 19.This occurs after a period of rising values on April 12. After the oxygen dropped, on April 23 and 26 (Appendix A).

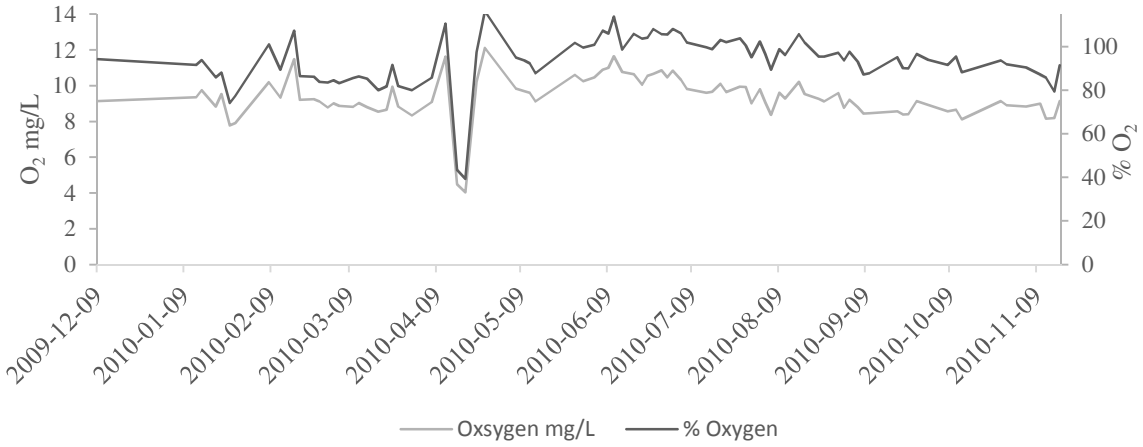

Figure 29. Oxygen levels.
Average levels of oxygen in the water column over the year 2010. The measurements are given as milligrams per litre seawater (mg/L s.w.) and percent (%) saturation, calculated from values in the entire water column (Appendix A).

3.2.4 Salinity and density

The schemes in figure 30 and 31, show probe measurements for density and salinity vary through the year. Calculations of standard derivation estimates that average levels of salinity vary from S ≈ 30 to S ≈ 33. It was found low levels of salinity, in various degrees, and in varying in amplitudes, the fluctuations in May-September and in November (figure 30, left). Most of the values from the density measurements are in the area between approximately 26.5 and 23.5 g/ml.

Figure 30. Salinity and density.
Seasonal average measurements, including calculated standard derivations, of Salinity (S ≈), (left) and water column density (Dn ~ g/ml) (right) (from SD-Probe measurements).

Salinity and density levels seem to have relatively correlating values, through the year. One specific difference was in the beginning of March, with a sudden increased density, but no effect on the salinity was found. This occurred on March 5 (Figure 31 and Appendix A).

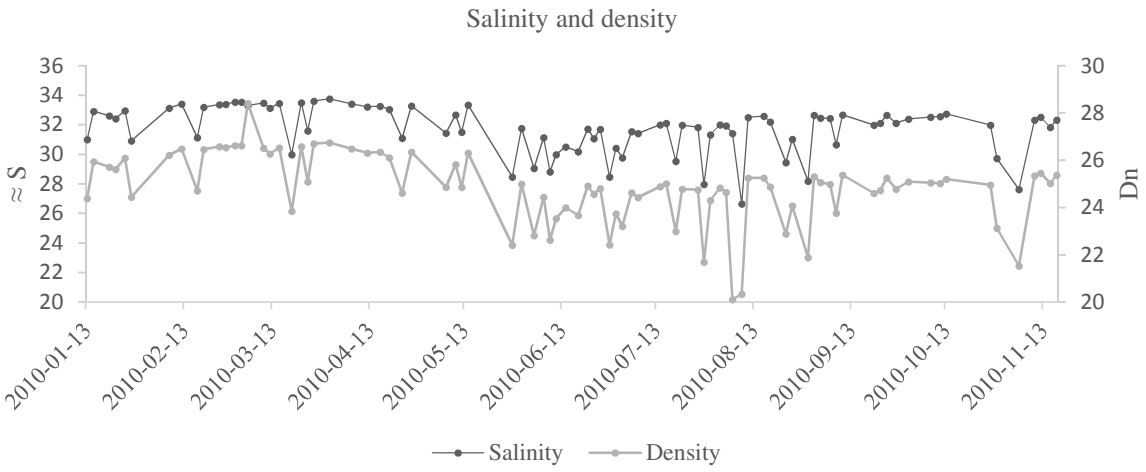

Figure 31. Salinity and density.
Seasonal average measurements of Salinity (S ≈) and density (Dn g/ml), combined values through the year 2010 (Appendix A).

3.3 Meteorology - Weather reports

3.3.1 Cloud cover

The recorded and processed data from the estimated cloud cover (c.c), are given as estimated parts of 0 and 1/8, where 8 is total cloud cover, and 0 is no clouds in the sky are given in figure 31. Results observed mid-day over the year 2010. Through the year, there were periods with continuous cloud coverage, and few non-cloudy days.

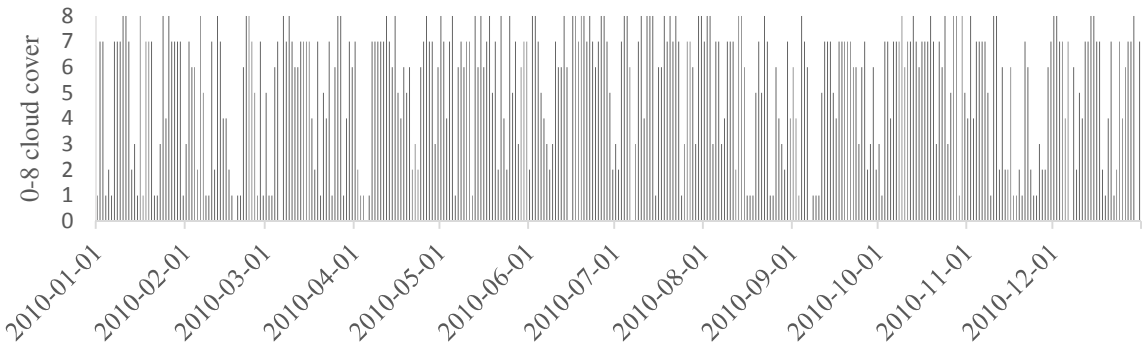

Figure 32. Cloud cover.
The observed cloud covers each day are given as estimated parts of eight, where zero is cloudless and eight is total cloud cover (Appendix C).

3.3.2 Precipitation

The precipitation over the year 2010 varies in periods through the year with dry periods followed by wet periods. Figure 30, gives the average precipitation each day given in millimetre. From January through July, measurements show shorter period intervals. From mid-July through September might be considered a drier period, going on October-November with a distinct wet-period.

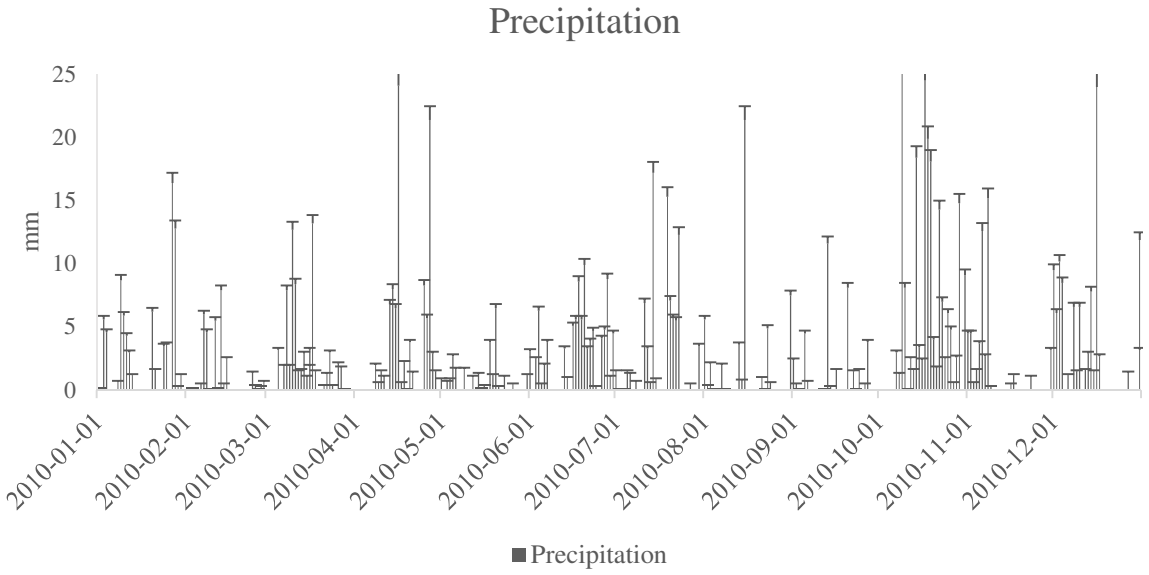

Figure 33. Precipitation.
The estimated precipitation reported each day are given as millimetre per day (Appendix C).

3.3.3 Air temperature

Average daily air temperature varies through the year in a slow peaked curve, changing throughout the different seasons, as can be seen in figure 31. This year of the present study, the temperatures starts rising from end of April, and the beginning of May. As figure 31 shows, the maximum temperature was measured 21.3 ^{o}C. The air temperature starts declining in the end of October going on November. The lowest air temperature was measured in the beginning of March at minus 15 ^{o}C. The daily mean temperatures were shifting rapidly. A few persistent temperature periods occurred in March, May and in the mid-summer period.

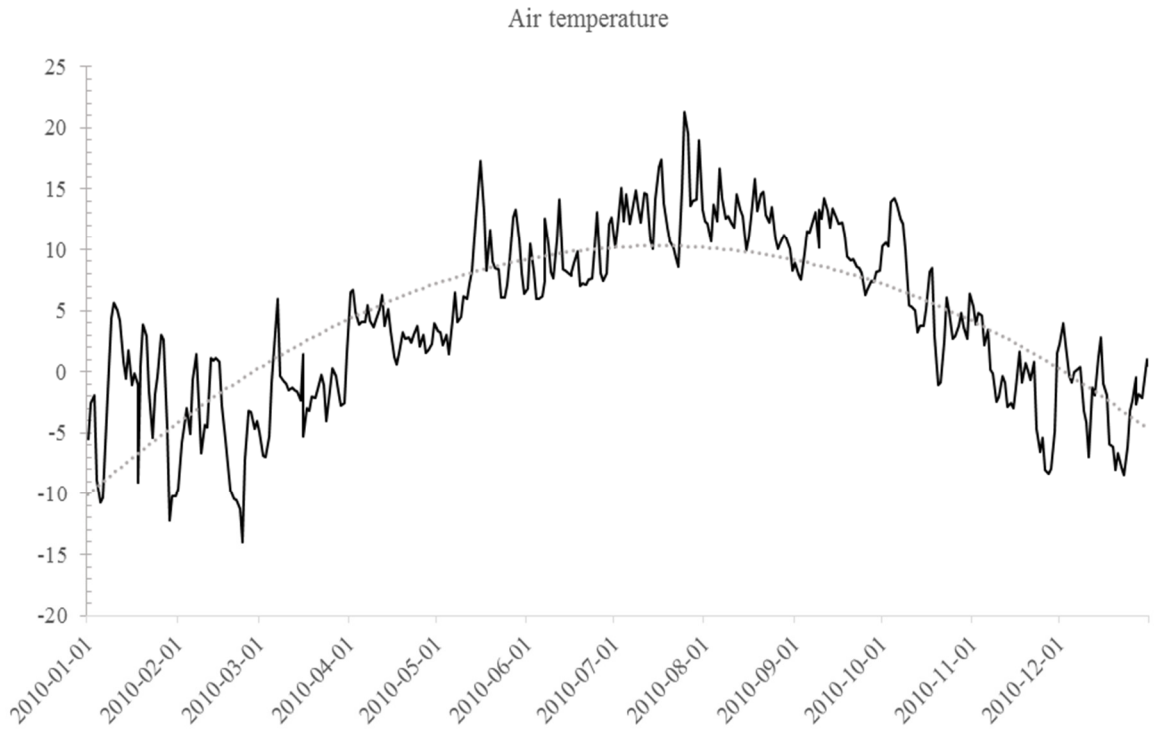

Figure 34. Air temperature.
Seasonal changes air temperatures based on median temperatures. Graph produced from data obtained datasets.

3.4 Processed algal reports

Processed algae reports are presented in figure 32 as total cell per litre of water in the samples from Mørkvedbukta. Data labels give measurements of total cell count, given as cells/100000. The measurements of the algal cell counting, shows that different diatoms was most dominant. A maximum algae cell was found on July 20, with total amounts of 4.2 million cells per litre seawater. Diatoms present in only sparse amounts, but shown in countable numbers from the beginning of July. The most dominant diatoms through the year were found to be *Skeletonema* sp. and *Chaetoceros sp.* (see. table results given in Appendix D).

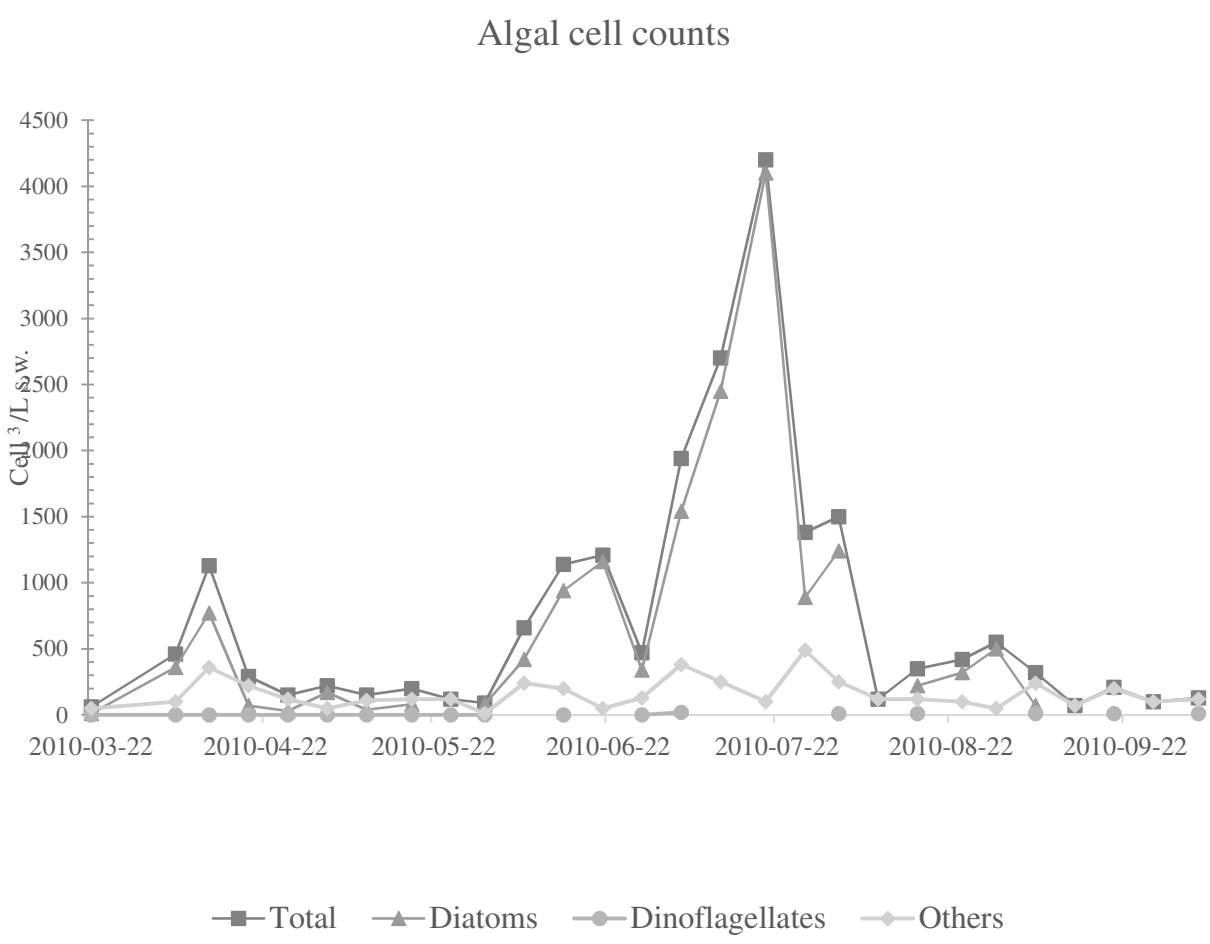

Figure 35. Algal cell counts.
Detected cells per litre of seawater, processed based on weekly observations by SINTEF (Appendix D).

3.5 Combined results

In this section, combined datasets from different parameters compared in this study are presented in figures. Note that some comparisons are done based on monthly averages, while some are based on weekly measurements.

3.5.1 Biomarkers - combined results

The measurements of the biomarkers indicating presence of algae or algal components in the water column are presented in a combined sheet in figure 36. Note the different scales in the figure. The overall results show an increase in amounts of nearly all parameters from April and onward.

Levels of florescence concentration, shows a slightly different path, with a steeper rising curve from May with maximum levels in June.

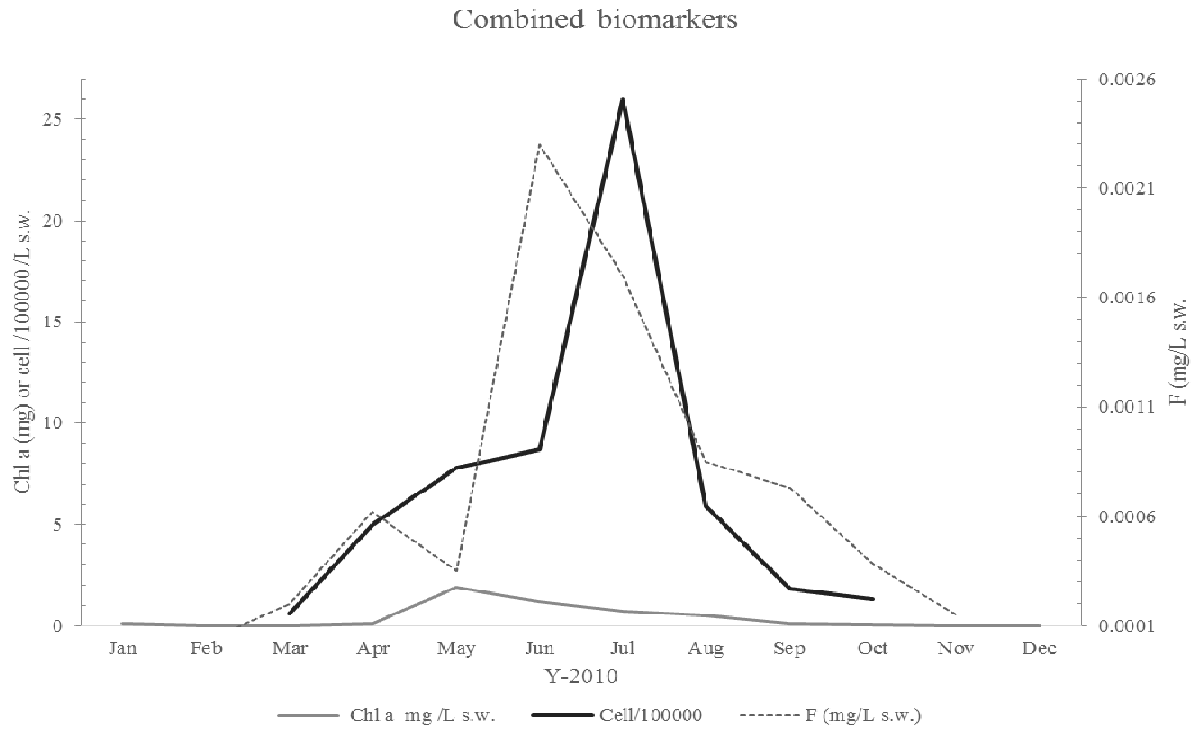

Figure 36. Combined biomarkers.
Comparing results from HPLC-pigment analyses on monthly average chlorophyll a concentrations given as mg/L s.w., results from fluorescence calculated average from SD-measurements (given as µg/L s.w.) and result from obtained raw-data from algal cell counts, given in cells/100000 per litre seawater (Appendixes A-B and D).

Combined results from seasonal distribution of pigments are shown in figure 37. Note the different scales. The average concentrations measured for total Chlorophyll *a* and fucoxanthin are highest in June. The scheme shows that different pigments are more dominant than others during different periods over the year.

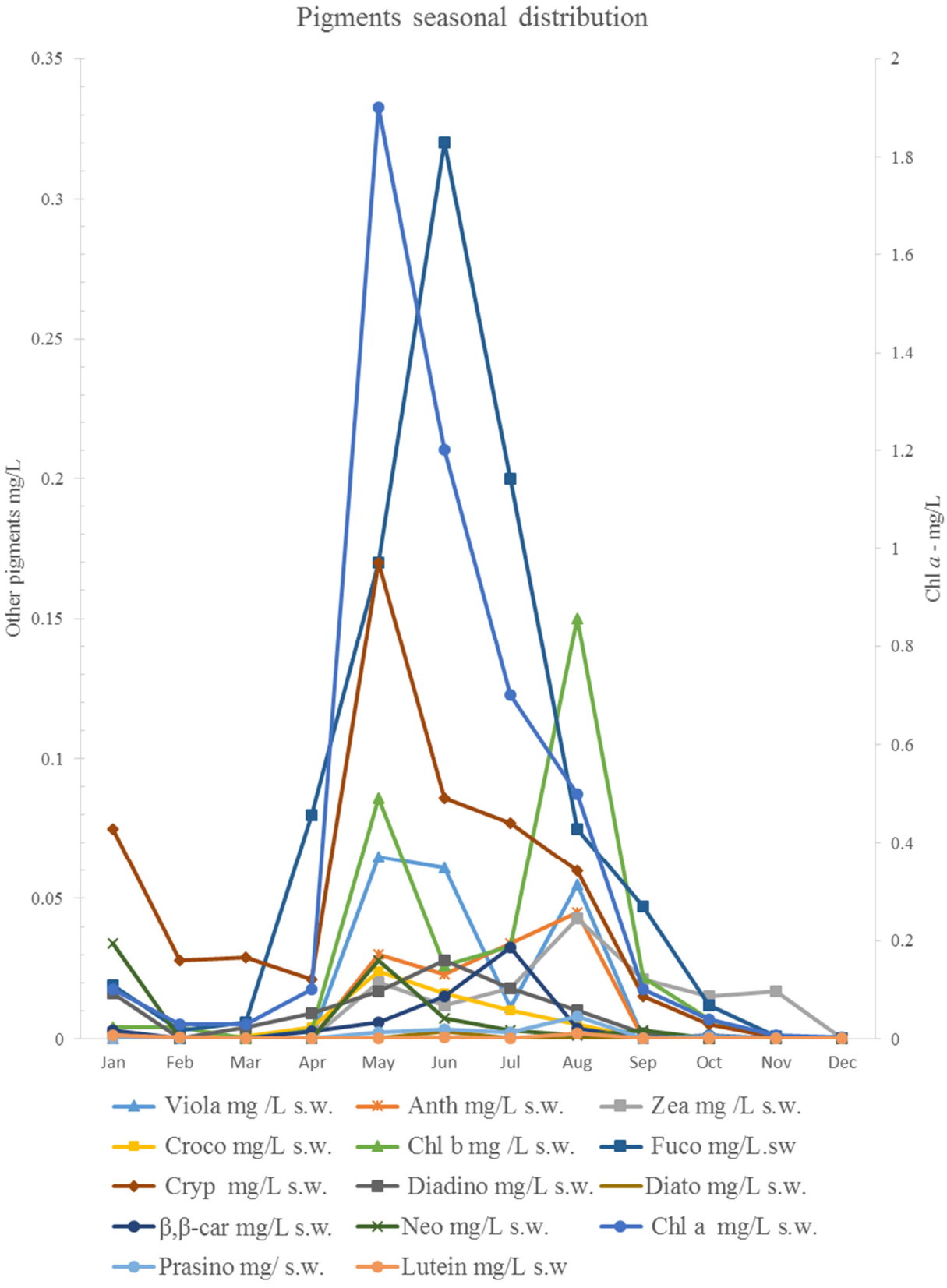

Figure 37. Distribution of dominant pigments.
Measurements given as monthly average pigment concentration based on calculations from HPLC-analyses (Appendix B).

Weekly comparisons – blooming period

The concentration of measured chlorophyll *a* compared to the number of cells are compared in the weeks when the cell counts and the analyses were done the same week (Figure 38). The measurements does not correlate as highest concentrations of chl *a*, was measured between week 22 and 26, whilst the maximum algal counts was found between week 23 and 30.

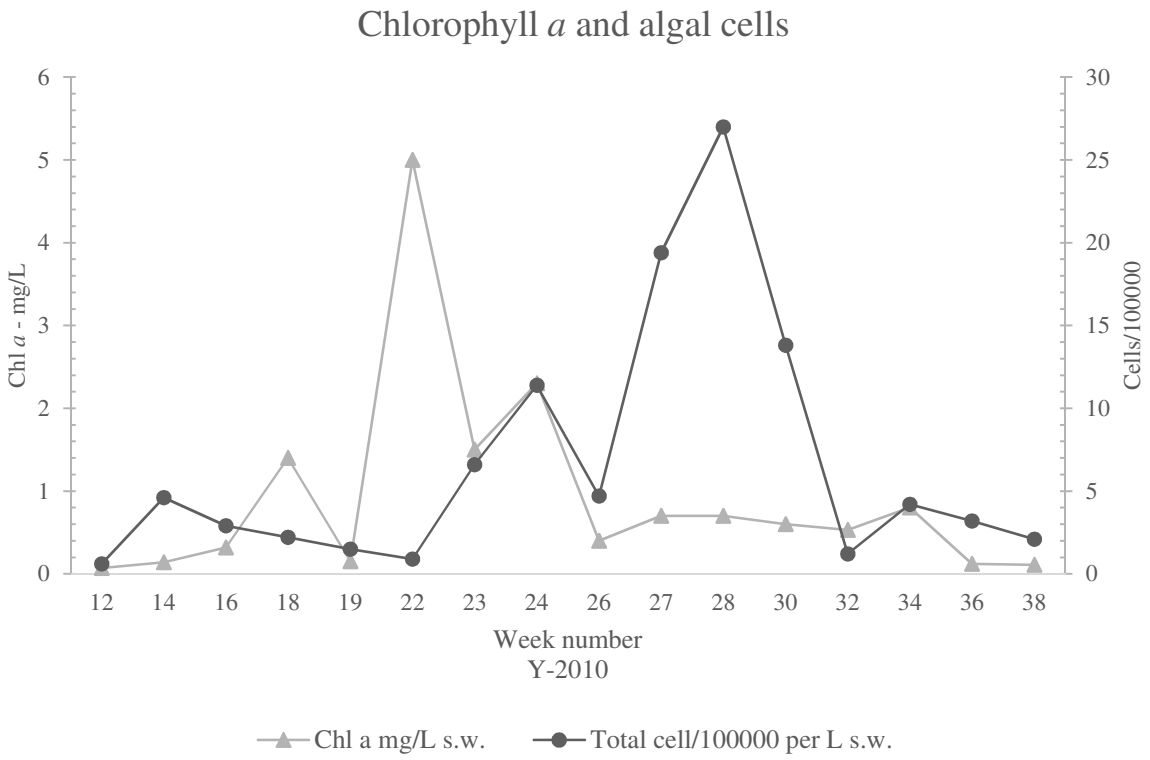

Figure 38. Chlorophyll a and algal cell-counts.
Combined results from concentration of chlorophyll a (left grade-line) and algal cell counts (right grade-line).

Pigments involved in the xanthophyll cycle (Violaxanthin, antheraxanthin and zeaxanthin) are given in figure 39. The tree pigments all seems to have an increased abundance from May and onwards. Joined peaks in May going on a small decline in June, then a rise in concentration for all three pigments in August. Violaxanthin and Zeaxanthin were only present in May-August, whilst Zeaxanthin was found present also in January and from May going on November.

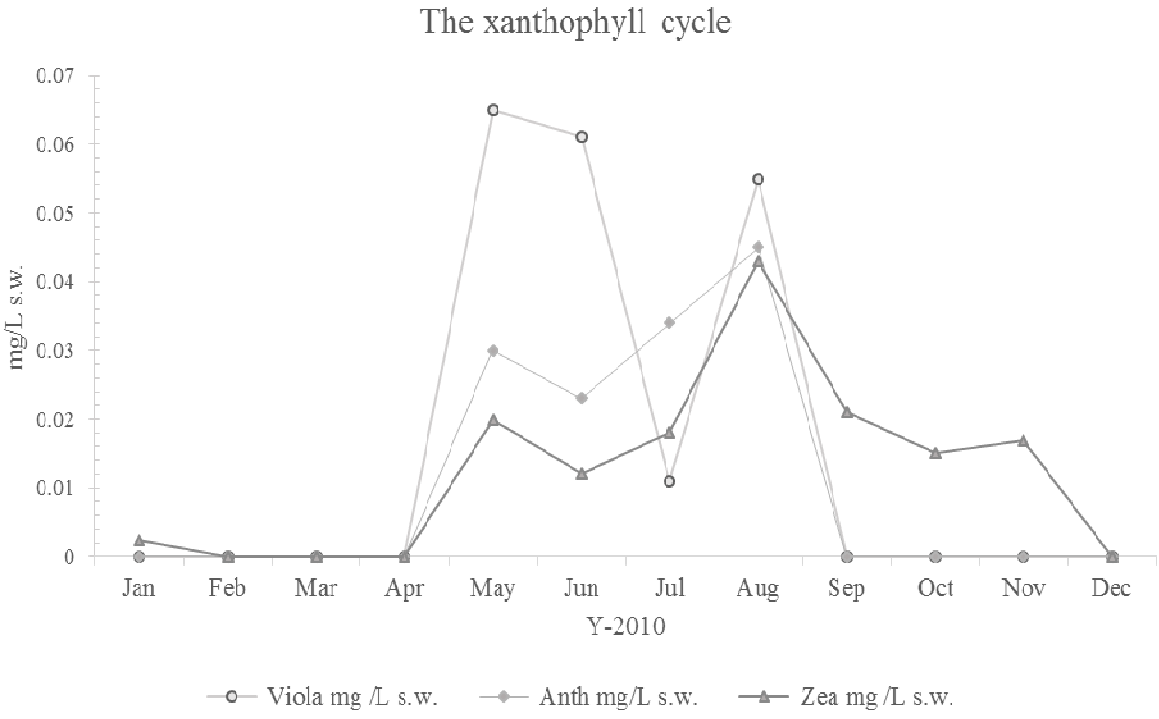

Figure 39. Seasonal distribution of pigments involved in the Xanthophyll cycle.
Seasonal distribution of pigments involved in the Xanthophyll cycle, Viola-cycle (Viola, Anth and Zea), presented as average per month.

3.5.2 Hydrographic conditions and biomarkers - combined results

The hydrographic conditions and biomarkers, such as temperature, Oxygen, Salinity, fluorescence, algal cell counts and chlorophyll *a*, are presented in figure 40. The weeks where chlorophyll a marks are missing, there were not run pigment analyses. The combined figure focuses on comparing different parameters from the weeks where algal cell counting had been performed. The numbers of algal cells increase drastically between week 23 and 31. The pigment maximum concentrations were in week 22, and had fluctuating values, through the period. Fluorescence levels were at a maximal level in week 29, the same as for the algal cells.

Oxygen had a drop in week 16, the same week levels of fluorescence and algal cell numbers dropped. In week 32, there was a rise in seawater temperature and a drop in density, number of algal cells and fluorescence.

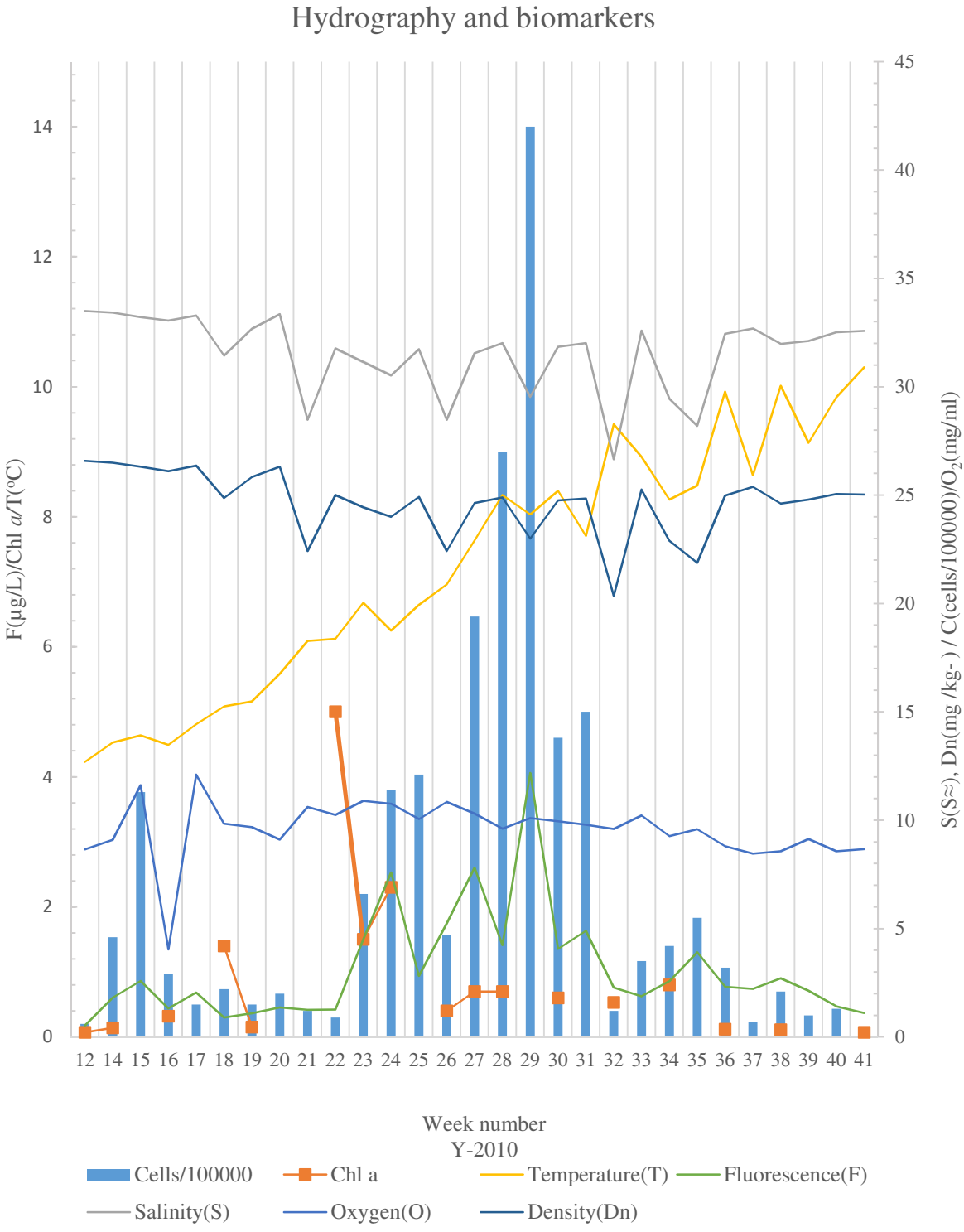

Figure 40. Hydrography and biomarkers.
Combined results from measuring algal cells, chlorophyll a, temperature C°, fluorescence, salinity oxygen and density.

3.5.3 Meteorological conditions and biomarkers - combined results

The meteorological conditions and biomarkers, such as air temperature, cloud cover, precipitation, fluorescence, algal cell counts and total pigment concentration, are presented in figure 41. The weeks where chlorophyll *a* columns are missing, there were not run pigment analyses. The combined figure focuses on comparing different parameters from the weeks where algal cell counting had been performed.

In week 15-18 there was observed a drop in air temperature, number of algal cells and low levels of precipitations.

From week 27, there is a rise in air temperature and the numbers of algal cells. In week 37 to 40, the temperature and number of algal cells dropped, levels of precipitation and less cloud cover. In the weeks 33-35 there was increased numbers of algal cells, less cloudy, and small amounts of precipitations.

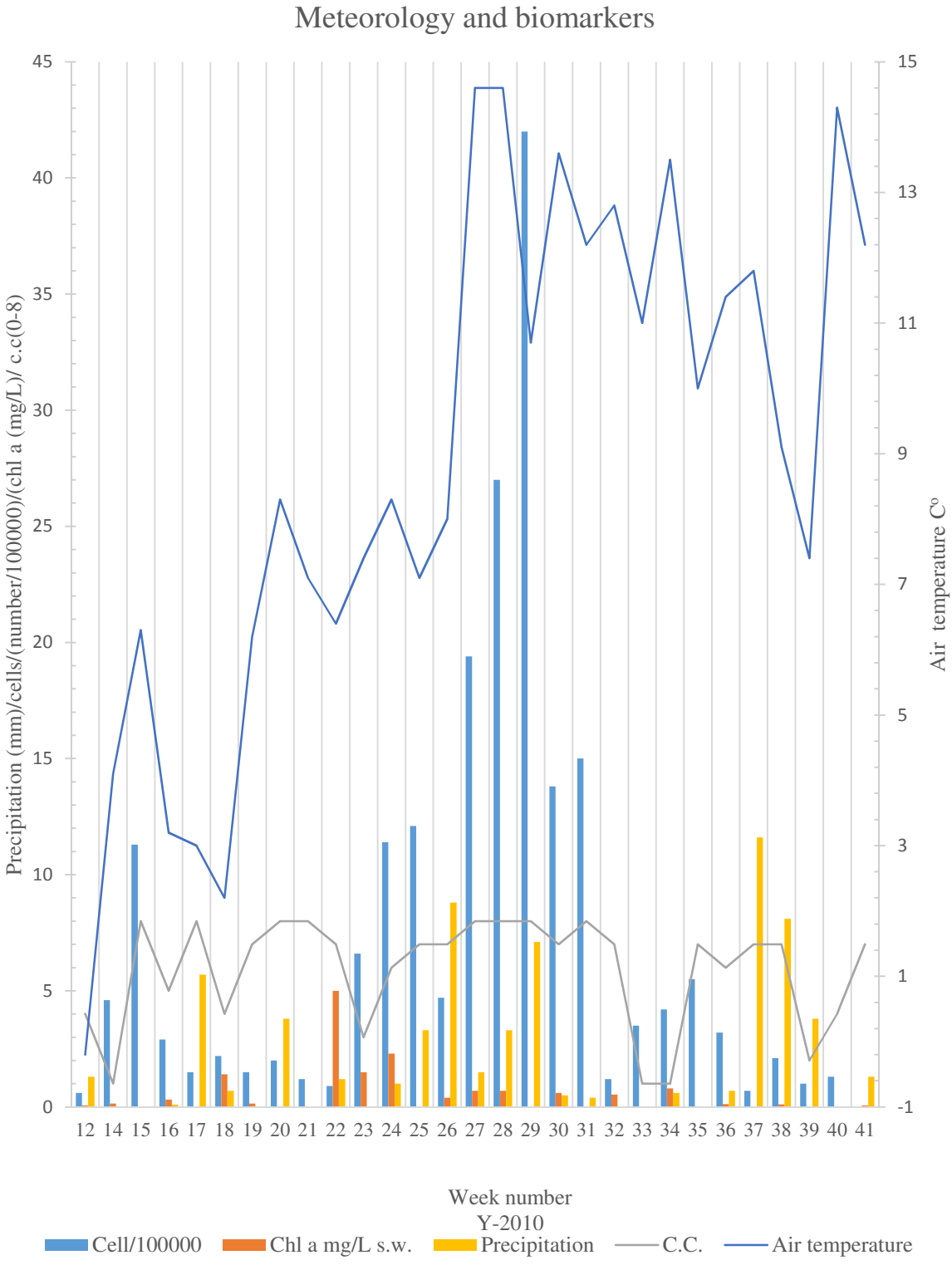

Figure 41. Meteorology and biomarkers.
Comparing weekly meteorological conditions and biomarkers; precipitation (mm), algal cells (number/100000), chlorophyll a (mg/L s.w.) and air temperature (C°).

4 Discussion

In summary, the results from the study suggest that there might be different correlations between the different compared parameters.

Before discussing these findings, some technical and statistic considerations will be addressed.

4.1 Technical and statistical considerations

In this study different equipment apparatus was used and raw-data from other sources where used. This including other general considerations will be discussed in this section.

An important issues as to the given concentrations in this study, is the uncertainty of the method. In this meaning that all given concentrations must be considered guiding, meant for indication of the presence and estimated values only.

It was observed a slight displacement in the retention time during the HPLC-processes. It was observed that t_R seemed to be slightly delayed from the first sample vial, and respectively going on to the next. According to Wright (2005), diurnal shifts, or slight changes in retention time might be caused by unstable temperatures in the injected solvent that the thermostatted column does not adequately compensate for (Wright, 2005, Wright and Jeffrey, 2006). However, no such problems are reported regarding the HPLC-apparatus used in present study.

The CHEMTAX- method (see section 1.6) could not be used, as this program was not available at the university.

As chlorophylls are considered unstable compounds, it is common to find degeneration products during HPLC- analyses.

It was observed that chlorophyll c, did not separate well, but detections in the nearby area.

It is important as to keep in mind when comparing the results from pigment analyses, cell counting and hydrographic measurements, are the ultraplanktonic and microplanctonic community. According to Fogg (1991), there has been found drastically differences size, morphology, physiology and ecological strategies between phototrophs in an equilibrium ultraplanktonic system compared to a non-equilibrium microplanktonic society. Seen in comparison to many studies performed of microplankton, one might be careful to assume a pattern that combines with the entire phytoplankton community (Fogg, 1991).

Reports based on examinations of signature pigments in relations to hydrographic conditions in the sea suggests that as different phytoplankton taxa usually adapts to specific conditions in the water column this might not always be the case in small scales as nutrition can play an important role (Bustillos-Guzmàn et al., 1995). In this present study, there was not performed measurement of nutrients in the water column, so this effect parameter could have had an effect on algal growth, and so on influenced on the result of the measured pigment concentration. If there had been performed a combined algal cell counting using the same sampling batches, that might have given more comparable results.

It must be taken under consideration that pronounced temperature drops/rises might be related to possible equipment errors, or process failures.

4.2 Comparing different algal biomarkers

This section will address possible correlations in the parameters examined by using HPLC-separation analyses, the fluorescence measurements in the water column and the obtained raw-data from algal cell counts. Note a special focus on the period of reported blooms.

4.2.1 Pigment analyses, fluorescence and cell counts

The overall comparing of the measured concentration of chl *a*, fluorescence and the obtained cell counts show that singled large high peaks was observed. However, the timing of the peaks was slightly different. The maximum levels for fluorescence in June, chl *a*, was top in May, whilst the maximum cell counts was observed in July. When taking a closer look into the weekly data sets, this presents a different view. More nuanced pattern might be observed regarding amount fluctuations. For instance, more correlating levels between algal cells and the measurements of fluorescence are observed.

Algal seasonal blooms, in spring and summer are generally more overlapping in higher latitudes of Northern-Norway compared to the southern areas of the Norwegian coast (see section 1.3) (Mohus and Angell, 2007). The finding in present study might support this, as there was found a high rising pigment concentration with a top in May and a slight decline the rest of the summer. The measurements for Chl *a* shows about the same with a large peak in May and a smaller peak formation in August. On the other hand, the HPLC-analyses of Chl *b*, and the pigments involved in the xanthophyll cycle (violaxanthin, antheraxanthin and zeaxanthin) had a distinct increase in August.

In a project on toxic algae program, as referred to by Mohus and Angel (2007), it was stated that different algal groups varies through the seasons. Further they summarises that diatoms seems to be most dominant in the spring and summertime, declining in the autumn. Dinoflagellates on the other hand more present in the high summer and autumn period (Mohus and Angell, 2007, Huseby, 2002). This was also the case regarding the findings in the algal counting from 2010 performed by SINTEF (Forbord, 2016).

In a study performed by Olsen (2002) based on the lipid content *Calanus finmarchicus* (Gunerus) in Saltfjorden, the results could indicate that the diet was mainly based on diatoms in the spring period.

In other samplings from Saltenfjorden performed on April 23 and 24 in 2013, the diatoms was dominating diatoms and flagellates, and scares amounts of dinoflagellates (Busch et al., 2014). In the cell-counts from April 26 in 2010, there was found small amounts of diatoms and larger amounts of other algae, but no dinoflagellates (Forbord, 2016) (Appendix D). It is though difficult to compare different years as in some years might be quite distinct in bloom patterns compared to others (Mohus and Angell, 2007).

Interesting though, was the results from the combined pigments in the xanthophyll cycle. The pigment zeaxanthin was found in samples from January and October-November, where not antheraxanthin nor violaxanthin was present. This as during the xanthophyll cycle low light intensities might convert zeaxanthin to violaxanthin via the intermediate state antheraxanthin (La Rocca et al.).

It is found that in June and onwards that the separation shows more amount in signal (chlorophyll *c*) retention time similar to the retention time of Chl *c*. This can correlate with the findings on diatoms, that was based on lipid compositions (Olsen, 2002).Though this bares along high levels of insecurity, as based on Chl c_1, c_2 and c_3 are common components in chromophyte algae, such as diatoms, haptophytes and chrysophytes (Higgins et al., 2011) (Wright and Jeffrey, 2006).

The Pigment analyses showed that the chlorophyll c pigment MgDVP was found in August 25, (Table 21) this might indicate presence of prasinophytes type 3, tough this bares uncertainty because of the pigment is also present as trace elements in others (Higgins et al., 2011).

4.3 Hydrographic measurements compared to algal biomarkers

Based upon different studies there has been found that changing hydrographic conditions of the water column might have an effect on algal growth and distribution. The parameters examined in this study will be addressed further in this section.

4.3.1 Salinity, density and freshwater run-off

The salinity levels from std. estimations trough out the year, the mean levels varied between S ≈ 30 and S ≈ 33. Periods of even lower salinity, could indicate that the harbour area, in periods are highly influenced by freshwater runoffs. Anyway, the influx of water from the fjord seems to compensate. As the lowest drop point August 9 at S ≈ 26.7 (Appendix A), still not classify the area as brackish, compared to levels of Standard Mean Ocean water (SMOW) at about S ≈ 35 (35‰), and around S ≈ 25 (25‰) and downwards are regarded brackish water (Wright and Colling, 1995). The salinity levels in present study was found to be slightly lower than other results from the main areas of Saltenfjorden, with variations in salinity between 32 and 35 PSU (Busch et al., 2014).

The bay area is assumed to have periods of stratification with relatively limited mixing of the water column because of the inclosing. The amount of freshwater in the bay area will also wary through the seasons as the water in the connected small rivers differs in water levels. It must tough anyway be considered the possibility of brackish or freshwater algae species disturbances.

In present experiment, there was found increasing pigment concentration in May which correlates to earlier examinations of phytoplankton stating that spring bloom usually takes place in late May to early June, as the snow and ice melting leads to a pronounced freshwater supply from the rivers (Wassmann et al., 1996).

Further, the measurements of Salinity and density corresponded mostly, with exception of March 3. As this occurs, this seems to correspond to increased levels of fluorescence (Appendix A).

4.3.2 Seawater temperature

The temperature in the water changed naturally in a linear curve through the year. The change in seawater temperature varied from about 3.0ºC, in the winter period and up to approximately 10ºC in the summer period. However, this is based on the days recorded, and variations in between measurements must be considered. Similar patterns was found in a

project performed in 1997-98, where the water temperature varied between 5°C up to 11°C, and the temperature rise began from April/May (Olsen, 2002). Similarities can also be found in comparing lowest seawater temperatures found between February and April. There might be a correlation between the temperature of the water column and the time of blooming, as the water temperature seems to be rising in May.

4.4 Meteorological measurements compared to algal biomarkers

Based on previous studies there is a perception that different meteorological factors can have an influencing effect on algal growth and distribution. The parameters from obtained weather reports and algal biomarkers will be discussed in this section.

4.4.1 Irradiation influences, cloud cover, air temperature and biomarkers

Earlier finding conclude that the correlation of incident light, seems to be the primary trigger of the spring bloom in Northern Norway (Lutter et al., 1989, Huseby, 2002). Lutter et al. (1989) found that spring bloom started to increase in the middle of March with a peak in late April in Balsfjord (~70°N). Even though this location is further north, and irradiation might be slightly different, the results from pigment analyses in present study, including the obtained results from cell counts, showed similarities.

In comparison to data from other years, notice that the average air temperatures in Northern Norway this year was about to 0.5°C lower than trend normal (see figure 5).

4.5 Possible multiple combined effects

In week 15 onto 16 there was observed a sudden temperature drop, which correlated to decreased levels of algal cells and the cloud cover decreased. In the next week (17) there were cloudburst and high levels of precipitations, though this did not seem to have an effect on the cell-counting numbers, but lowered the temperature even more.

In week 26, there were high levels of precipitation, and low temperatures. Followed by a drier week (27), where the number of algal cells increased drastically and so did the temperatures and chlorophyll *a* and the total pigment concentration.

It was observed that in the months of October and November, there were periods with lots of precipitation, and in accordance to this corresponding to lower levels of salinity.

The results from the pigment concentration in January showed surprisingly high levels, compared to December and February. There has tough been some researchers that based on satellite recordings, has challenged the known theory of Sverdrup from 1953, and suggested

that bloom initiations starts in the winter-periods when mixed layer depths are at maximum, so small blooms might occur in the winter-period (Behrenfeld, 2010).

4.6 Future considerations

Based on the results from this study, other methods that could be considered are the conjuncture of the measurements. Enhancing the validity of comparing the most relevant parameters in such analyses, the timing of the measurements might be reconsidered. Instead of year round sampling, the focus might be more concentrated on increased frequencies in the period of the blooms. Though on the other hand as there has been found, some interesting rise in the measured concentrations of pigments, that otherwise not would have been found.

For future considerations, it might be recommended to compare algal counts of the same sampling batch. Though performing valid microscopic identification of algal structural components, it is highly recommended using microscopic equipment that can detect also the minor algal species.

5. Conclusions

There were found possible seasonal variations in the distribution of naturally occurring algal pigments in the collected seawater samples in the shallow water column. It was observed that different pigments were found more or less dominant during different seasons.

The results from this study show that the concentration of pigments and fluorescence are found to correspond roughly to the timing of phytoplankton springtime bloom, reported by others during different projects and samplings in Northern Norway (Huseby, 2002, Eilertsen and Degerlund, 2010, Lutter et al., 1989, Olsen, 2002). There was also found similarities to other reporting from Northern Norway, as to have one rather continuous bloom period, instead of two distinct spring and autumn blooms.

There were found fluctuating, larger and smaller bloom-periods within the main period. Comparing might briefly be held against the levels of analysed pigments and results of the most common microalgae based on algal cell counting the same year. The data therefore suggest that experiments based solely on HPLC, can give an indicator on the algal community compositions through the year.

There were found possible combined effects from the hydrographic measurements, the meteorological weather patterns, and the biological measurements. Periods of interest are

pointed out, but as influences from combined effects are complex, it is found difficult to conclude upon each element.

Considering the significant role of the complexity in chemical- and physical conditions, it is therefore important to consider the fact that climate changes might have an effect on the conditions of the seawater and its organisms.

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APPENDIX A SD-Measurements

Table 3. Table SD-results January-March 2010.

Daily mean values of conditions in the water column; Salinity (S ≈), Temperature (T °C) Oxygen (percentage (%) O_2 and O_2 mg/L), Fluorescence (F µg/L) and Density (D ~kg m-3). Table values from January-March 2010 (SD-Probe).

Date	Time	S	T	O_2	O_2	F	D
2010-01-13	09:24	31.00	6.14	91.73	9.35	0.03	24.39
2010-01-15	09:33	32.92	5.83	93.81	9.74	0.03	25.95
2010-01-20	09:22	32.61	5.71	85.90	8.84	0.03	25.71
2010-01-22	09:28	32.41	5.17	88.12	9.54	0.03	25.62
2010-01-25	09:45	32.97	4.85	74.18	7.78	0.02	26.10
2010-01-27	09:55	30.92	5.07	77.46	7.91	0.04	24.45
2010-02-08	09:31	33.12	5.11	101.01	10.19	0.03	26.21
2010-02-12	09:47	33.42	4.54	89.52	9.34	0.02	26.49
2010-02-17	09:00	31.13	9.65	107.40	11.49	0.03	24.72
2010-02-19	08:00	33.21	3.14	86.53	9.21	0.03	26.46
2010-02-24	10:12	33.38	3.34	86.25	9.24	0.04	26.58
2010-02-26	10:08	33.39	3.81	83.88	9.12	0.04	26.54
2010-03-01	09:12	33.54	4.23	83.54	8.78	0.04	26.62
2010-03-03	09:00	33.55	4.22	84.58	9.02	0.014	26.62
2010-03-05	09:00	33.31	4.46	83.24	8.86	0.018	28.41
2010-03-10	09:51	33.48	5.59	85.60	8.81	0.011	26.51
2010-03-12	10:25	33.12	4.34	86.43	9.04	0.08	26.28
2010-03-15	09:42	33.46	4.42	85.41	8.80	0.13	26.53
2010-03-19	09:42	30.00	3.71	80.00	8.55	0.11	23.85
2010-03-22	10:33	33.49	4.23	81.76	8.65	0.18	26.58
2010-03-24	09:38	31.59	3.87	91.73	9.95	0.17	25.10
2010-03-26	08:54	33.60	3.89	81.95	8.83	0.62	26.70
2010-03-31	09:02	33.75	4.39	79.99	8.33	0.47	26.75

Table 4. SD-results April-June 2010.

Daily mean values of conditions in the water column; Salinity (S ≈), Temperature (T °C) Oxygen (percentage (%) O_2 and O_2 mg/L), Fluorescence (F µg/L) and Density (D ~kg m-3). Table values from April-June 2010 (SD-Probe).

Date	Time	S	T	O_2	O_2	F	D
2010-04-07	12:21	33.42	4.53	85.82	9.09	0.61	26.49
2010-04-12	09:42	33.21	4.64	110.57	11.62	0.86	26.32
2010-04-16	10:02	33.26	4.60	43.38	4.48	0.74	26.36
2010-04-19	10:00	33.05	4.49	39.38	4.04	0.44	26.11
2010-04-23	10:04	31.09	4.78	97.53	10.23	0.38	24.62
2010-04-26	09:54	33.29	4.81	116.31	12.11	0.68	26.36
2010-05-07	10:17	31.44	5.08	95.10	9.84	0.30	24.87
2010-05-10	10:11	32.67	5.16	93.67	9.69	0.36	25.83
2010-05-12	13:22	31.51	5.62	92.42	9.61	0.13	24.86
2010-05-14	09:34	33.35	5.59	87.83	9.11	0.45	26.32
2010-05-28	10:27	28.48	6.09	101.82	10.61	0.42	22.42
2010-05-31	10:36	31.77	6.12	99.65	10.25	0.42	25.00
2010-06-04	09:59	29.05	6.43	100.96	10.47	10.20	22.83
2010-06-07	09:39	31.14	6.68	107.46	10.89	1.50	24.44
2010-06-09	09:44	28.82	6.43	106.05	11.00	1.47	22.64
2010-06-11	09:56	30.00	6.67	113.85	11.65	2.24	23.54
2010-06-14	09:14	30.52	6.25	98.71	10.76	2.53	24.00
2010-06-18	16:14	30.19	6.81	105.95	10.65	1.15	23.67
2010-06-21	16:24	31.73	6.65	103.77	10.04	0.94	24.91
2010-06-23	17:21	31.08	6.72	104.16	10.56	1.17	24.57
2010-06-25	16:19	31.71	7.28	108.19	10.66	2.12	24.81
2010-06-28	16:13	28.48	6.96	105.84	10.85	1.75	22.42
2010-06-30	16:37	30.42	7.69	105.62	10.46	0.68	23.74

Table 5. SD-results July-August 2010.

Daily mean values of conditions in the water column; Salinity (S ≈), Temperature (T °C) Oxygen (percentage (%) O_2 and O_2 mg/L), Fluorescence (F µg/L) and Density (D ~kg m-3). Table values from July-August 2010 (SD-Probe).

Date	Time	S	T	O_2	O_2	F	D
2010-07-02	15:55	29.77	7.66	108.19	10.83	0.88	23.22
2010-07-05	15:48	31.55	7.64	106.04	10.31	2.60	24.64
2010-07-07	16:16	31.42	8.32	102.04	9.83	1.09	24.43
2010-07-14	16:02	32.01	8.34	99.73	9.61	1.41	24.89
2010-07-16	16:05	32.11	8.01	98.95	9.65	1.43	25.02
2010-07-19	16:09	29.53	8.04	103.12	10.10	4.06	22.99
2010-07-21	17:18	31.99	8.98	102.09	9.65	2.60	24.78
2010-07-26	17:37	31.84	8.40	103.91	9.95	1.35	24.75
2010-07-28	16:18	27.97	9.17	100.66	9.93	0.69	21.70
2010-07-30	15:57	31.34	8.73	95.19	9.01	0.95	24.31
2010-08-02	16:20	32.02	7.71	102.37	9.79	1.63	24.84
2010-08-04	16:28	31.94	9.54	96.65	9.06	0.53	24.65
2010-08-06	15:46	31.43	10.36	89.53	8.36	1.04	20.11
2010-08-09	16:29	26.65	9.42	98.82	9.60	0.76	20.35
2010-08-11	16:09	32.51	8.55	96.24	9.29	0.33	25.25
2010-08-16	16:42	32.58	8.92	105.80	10.22	0.62	25.25
2010-08-18	16:05	32.19	9.37	101.95	9.54	0.52	24.88
2010-08-23	17:08	29.44	8.26	95.43	9.26	0.86	22.89
2010-08-25	16:57	31.02	8.60	95.55	9.12	0.87	24.08
2010-08-30	16:58	28.19	8.48	97.22	9.58	1.30	21.88

Table 6. SD-results September-November 2010.

Daily mean values of conditions in the water column; Salinity (S ≈), Temperature (T °C) Oxygen (percentage (%) O_2 and O_2 mg/L), Fluorescence (F µg/L) and Density (D ~kg m-3). Table values from September-November 2010 (SD-Probe).

Date	Time	S	T	O_2	O_2	F	D
2010-09-01	10:11	32.66	8.96	93.72	8.76	0.92	25.31
2010-09-03	09:32	32.47	9.53	97.69	9.22	1.33	25.07
2010-09-06	16:54	32.44	9.93	93.11	8.80	0.77	24.98
2010-09-08	16:20	30.65	8.78	87.30	8.44	0.26	23.77
2010-09-10	10:19	32.69	8.64	87.82	8.46	0.74	25.38
2010-09-20	16:42	31.97	10.01	95.19	8.57	0.90	24.61
2010-09-22	10:02	32.12	9.94	90.23	8.38	0.58	24.73
2010-09-24	11:04	32.66	9.28	90.09	8.40	0.40	25.26
2010-09-27	16:15	32.11	9.14	96.60	9.13	0.71	24.79
2010-10-01	10:16	32.39	8.99	94.10	8.93	0.58	25.09
2010-10-08	10:41	32.52	9.84	91.67	8.57	0.47	25.06
2010-10-11	16:17	32.58	10.30	95.56	8.66	0.37	25.03
2010-10-13	12:07	32.75	10.03	88.35	8.11	0.39	25.21
2010-10-27	16:20	31.99	7.77	93.70	9.14	0.26	24.96
2010-10-29	15:42	29.74	8.19	91.95	8.91	0.20	23.13
2010-11-05	18:50	27.64	7.81	90.44	8.83	0.19	21.54
2010-11-10	12:08	32.32	6.82	87.26	8.99	0.15	25.35
2010-11-12	15:09	32.53	7.32	85.77	8.16	0.14	25.47
2010-11-15	16:51	31.84	6.13	79.41	8.18	0.13	25.03
2010-11-17	11:12	32.33	6.70	91.55	9.14	0.13	25.38

APPENDIX B; HPLC

Tables of HPLC-separation. Daily average amounts of substances are given as substance µg/L seawater. Tables include linear retention time (t_R) in minutes, divided in signal wavelength (λ) (see method chapter).

Table 7. HPLC - Result-sheets January 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Carotenoid	**t_R**	**2010-01-13**	**2010-01-15**	**2010-01-20**	**2010-01-25**	**2010-01-27**
				µg/L s.w.		
Sig. 1						
	37.228		12.2			
	45.870			183.04		
Pheide *a*	54.139 -95.922			36.08	25.8	
	61.827			33.72		
	61.922				13.16	
	62.870			198.8		
	62.899					3.92
	62.911				76.2	
	63.625			38.72		
	63.668				12.8	
	64.412			30.16		
Phe *a*	96.402 -96.945			22.28		
Sig. 2						
	57.820			22.72		
Chl *a*`````	82.200 -82.663			15.04		
Chl *a*``	84.672 -85.271			42.32		
Chl *a*```	85.932 -86.702	3.48		43.08		22.64
Chl *a*`	87.687 -88.171			143.64	53.68	

Table 8. HPLC- Result-sheets January 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Carotenoid	t_R	2010-01-13	2010-01-15	2010-01-20	2010-01-25	2010-01-27
				µg/L s.w.		
Chl *a*	89.141 - 90.333		48.44	50.8		
Sig. 3						
Fuco	52.238 - 53.124		13.612	49.28	29.4	
c-Neo	56.429 - 56.845			158.52	13.52	
Diadino	60.346 - 61.782			8.08		
Allo	63.568 - 64.810				4.96	
Zea	66.750 - 67.450		11.88			
Lut	67.556 - 67.644			18.32	12.76	
	71.039			5.8		
	74.716			10.8		
Chl *b*	81.667 - 82.596			17.72		
Croco	84.565 - 85.559			5.6		
α-Cryp	86.406 - 86.800			6.76		
Cryp	87.448 - 88.390		7.2	23.28	6.84	
β,β-Car	101.20 - 101.52			6.44	8.6	
	56.704					6.48
	56.715		14.04			
Sig. 4						
	56.790				19.48	
Myxo	63.569 - 64.807				15.92	

Table 9. HPLC - Result-sheets February-March 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Carotenoid	**t_R**	**2010-02-10**	**2010-02-24**	**2010-03-10**	**2010-03-24**	**2010-03-26**	**2010-03-31**
					µg/L s.w.		
Sig. 1							
	53.696					22.4	
	53.776					4.16	
	53.797					5.6	
	61.559						7.08
	61.577					13.8	
	61.591					9.6	
	61.592						8.04
	61.710					18.4	
	62.894	5.88					
Sig. 2							
Chlide *a*	38.687 - 38.917					17.88	
	49.629					6.04	
Mutato	60.349 - 60.838					15.2	
	62.567					6.68	
Chl *a*````	83.700 - 83.915					11.6	
Chl *a*`````	82.200 - 84.663					29.52	
DVCl *a*	87.400 - 87.537					54.44	
Chl *a*`	87.687 - 88.171	16.8	28.88		20.52		
DVCl *a*`	88.507 - 89.125		4.6			2.16	
Sig. 3							
	37.684					12.4	
	37.704					6.2	
	37.717					7.88	
	43.738					48.8	
	43.741					23	
	43.767						6.48
	43.805					30.84	
Fuco	52.238 - 53.124	1.88	3.76		17.2		6
Diadino	60.346 - 61.782					16.2	
Lut	67.556 - 67.644	2	3.12				
Chl *b*	81.667 - 82.596		7.24				
Croco	84.565 - 85.559					3.88	
Cryp	87.448 - 88.39	1.68	3.84		2.8	8.64	
Sig. 4							
	76.756					8.08	

Table 10. HPLC - Result-sheets April 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Carotenoid	t_R	2010-04-05	2010-04-07	2010-04-23
			µg/L s.w.	
Sig. 1				
	43.801	18.4		
	53.724			5.72
	53.759	12.72		
	53.764	19.6		
	53.776	17.12		
Pheide *a*	54.139 - 54.922		29.28	6.36
	61.550	14.52		
	61.504			9.32
	61.522	26		
	61.533	10.28		
	62.097		13.88	
	62.104		19.64	
	62.106			5.32
	62.113			17.44
Phe *a*	96.402 - 96.945			5.56
Sig. 2				
	43.733			14.92
	49.836		7.84	
Mutato	60.349 - 60.838	8.36	9.76	11.32
	62.122			5
Chl *a*````	83.700 - 83.915			6.32
Chl *a*`````	82.200 - 84.663		9.2	17.84
Chl *a*``	84.672 - 85.271		55.72	22.68
Chl *a*```	85.932 - 86.702			17.32
DVCl *a*	87.400 - 87.537			82.4
Chl *a*`	87.687 - 88.171		174.92	152.12
DVCl *a*`	88.507 - 89.125			
Chl *a*	89.141 - 90.333			10.64
	100.90			3.28

Table 11. HPLC - Result-sheets April 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Carotenoid	t_R	2010-04-05	2010-04-07	2010-04-23
			µg/L s.w.	
Sig. 3				
	37.839		12.92	
	43.683			9.92
	43.764	21.76		
	43.771	24.31		
	43.846	27.4		
	44.268		41.4	
	44.296		14.24	
	44.303		12.68	
	44.316			
Fuco	52.238 - 53.124		174.76	62.72
Hex-kfuco	54.471 - 55.255			7
Diadino	60.346 - 61.782	8.4	10.52	11.72
Chl *b*`	81.150 - 81.674			5.8
Chl *b*	81.667 - 82.596			3.08
Croco	84.565 - 85.559		8.72	4.2
Cryp	87.448 - 88.390		26.96	35.6
β,ε-Car	100.70 - 100.964			1.4
β,β-Car	101.198 -101.516		1.84	4.32
Sig. 4				
	44.301		11	
Myxo	63.569 - 64.807			3.8

Table 12. HPLC - Result-sheets May 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-05-05**	**2010-05-14**	**2010-05-19**	**2010-05-21**	**2010-05-31**
				µg/L s.w.		
Sig. 1						
	53.761	11.04				
	53.771					10.84
	53.774					11.96
	53.837			9.48		
Pheide *a*	54.139 - 54.922	22.32		37.56		
	59.617					
	60.078			10.24		
	60.165			5.84		
	60.475					12.68
	61.050			7.08		
	61.056			15.6		
	61.106			5.12		
	61.549	29.72				
	61.617		6.68			
	61.629		4.24			
	62.074	3.64				
	62.076	23.8				
	62.132					
	62.387					16.36
	62.409					10.16
	62.876			4.08		
	63.739			30.48		
	77.414					22.8
	79.928					8.64
	79.949			2.48		
	80.250			6		
	81.487	6.64				
	89.688			22		
	91.173			3.8		
	91.218			6.32		
	92.094			13.64		
	92.180			8.24		
	92.219			5.76		
	92.236	3.92				
	92.286					4

Table 13. HPLC - Result-sheets May 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-05-05**	**2010-05-14**	**2010-05-19**	**2010-05-21**	**2010-05-31**
				µg/L s.w.		
Sig. 1						
	93.603			6		
	93.620	4.04				3.32
	93.631					14.32
	93.815			10.88		
	93.853			27.28		
	94.293			4.76		
	94.305	2.04				
	94.325					4.28
	94.537			5.28		
	94.576			10.56		
	94.578	1.92				
	94.597					
	94.813			6.44		
	94.852			12.8		
Phe *a*	96.402 - 96.945	170.64		1910.52	72.96	379.24
	97.281					
	97.287					11.44
	97.289			14.24		
	97.303	12.84				
	97.313					39.12
	97.326					5.8
	97.335				5.04	
	97.589			2.04		
	97.621			36.68		
	97.625	5.84				
	97.633	1.08				
	97.634			69.76		
	100.97	5.08				
Sig. 2						
	37.738	26.36				
Chlide *a*	38.687 - 38.917			20.64		69.44
	49.535					19.92
	49.545					28.8
	49.714			22.68		
	49.805			5.52		

Table 14. HPLC - Result-sheets May 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-05-05**	**2010-05-14**	**2010-05-19**	**2010-05-21**	**2010-05-31**
				µg/L s.w.		
Sig. 2						
	49.843			6.08		
	55.117			5.72		
	55.576			12.4		
	57.704					22.96
	58.984					7.72
	59.680					16.08
	59.695			7.72		
	59.703					7.52
	60.044			25.76		
	60.047			13.8		
Mutato	60.349 - 60.838	23.24	2.24	45.8	3.6	32.64
	61.609					16.52
	61.621			44.96		
	61.623					29.2
	61.643					17.52
	62.047			65.52		
	62.086			37.8		
	62.428			21.6		
	62.851			29.32		
	64.813					12.2
	65.106			16.4		
	74.393					8.6
	74.412					4.88
	74.423			3.4		
	79.008	9				
	79.057			6.84		
	79.262			5.32		
	81.545			8		
Chl *a*````	83.700 - 83.915	29.4	3.76	19.72	9.32	83.64
Chl *a*`````	82.200 - 84.663	130.56		133.68	18.4	55.56
Chl *a*``	84.672 - 85.271	101.44	23	134.72	6.28	270.04
Chl *a*```	85.932 - 86.702	28.64		39.28		37.24
DVCl *a*	87.400 - 87.537	303.2	119.16	262.56	158.36	3193.76
Chl *a*`	87.687 - 88.171	523.56		899.96		

Table 15. HPLC - Result-sheets May 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-05-05	2010-05-14	2010-05-19	2010-05-21	2010-05-31
				µg/L s.w.		
Sig. 2						
DVCl *a*`	88.507 - 89.125	11.44		29.48	8.4	167.92
Chl *a*	89.141 - 90.333	28.28		17.68		6
	90.502			4.28		
	90.760	4.94				
	92.136			10.76		
	92.971			8.64		
	93.012			14.2		
	93.839					9.16
Sig. 3						
	37.529					24.64
	37.665	16.04				
	37.729			17.12		
	37.796			25.48		
	39.808					23.92
	43.548					79.2
	43.595					400
	43.684	46.8				
	43.769			117.32		
	43.788					
	43.813		7.24			
	44.208			37.84		
	44.211	26.08				
	44.214	20.16				
	44.221			113.96		
	44.264			80.64		
	44.294	25.2				
But-fuco	50.729 - 51.003					2.28
Hex-kfuco	51.619 - 52.210					0
	52.331					
Fuco	52.238 - 53.124	219.8		604.48		
	53.362			1.84		
	54.528			1.32		
Hex-kfuco	54.471 - 55.255			14.44		9.04
Hex-fuco	55.470 - 55.78			3.48	4.36	5.64
c-Neo	56.429 - 56.845	2.68			3.28	132.8

Table 16. HPLC - Result-sheets May 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-05-05	2010-05-14	2010-05-19	2010-05-21	2010-05-31
				µg/L s.w.		
Sig. 3						
Pras	56.858 - 57.291	9.52		49.16		
	60.244			3.2		
Diadino	60.346 - 61.782	20.16	5.64	35.8	3.92	19
Anth	62.166 - 62.831	3.16		25.82		35.84
	63.682			3		
	63.986			2.96		
	63.996			1.68		
Allo	63.568 - 64.810	4.28		6.52		23.4
	64.824					3.64
	64.841			1.8		
Uri	65.146 - 65.900			9.2		3.36
Zea	66.750 - 67.450	11.64		16.4	33.48	37.52
Lut	67.556 - 67.644	1.56				
Chl *b*`````	77.063 - 77.800			8.96		12.48
	78.678					7.92
Chl *b*````	78.665 - 79.441			19.44		27.164
Chl *b*```	79.952 - 80.241	3.4		4.48		10.64
Chl *b*`	81.150 - 81.674	18.24	8.24	33.84	24.96	191.2
Chl *b*	81.667 - 82.596	18.48		20.04	5.52	23.44
Chl *b*`	83.100 - 83.995			0.33		
Croco	84.565 - 85.559	31.6		35.88	1.36	52.04
Cryp	87.448 - 88.39	127.56	18.48	177.84	23.88	487.48
	88.530			1.44		
	93.853					2.08
	93.867					3.16
β,ε-Car	100.70 - 100.96	4.68				26.92
β,β-Car	101.20 - 101.52	11.48		10.52		7.44
Signal 4						
	43.737			35.2		
Aphanizophyll	55.900 - 55.989				3.32	
	57.244	31.12				
	62.503			5.36		
	62.936			3.8		
Myxo	63.569 - 64.807	1.2		2.68		19.56
	69.345			1.56		
Lyco (Ly)	96.460 - 96.805	7.08		41.76	3.64	15.76

Table 17. HPLC - Result-sheets June 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-06-04**	**2010-06-07**	**2010-06-18**	**2010-06-30**
			µg/L s.w.		
Sig. 1					
	44.269				20.4
	44.283				22.36
	53.417			4.8	
	53.781		4.52		
	53.789		7.44		
	53.797		6.04		
Pheide *a*	54.139 - 54.922	21.16		62.88	41.76
	57.297			45	
	59.706		5.2		
	60.146			6.28	
	60.151			13.36	
	60.158	6.88			
	60.213			9.8	
	61.093			8.48	
	61.109	9.6			
	61.118			16.68	
	61.170			11	
	61.269	12.32			
	62.105	28.64			
	62.121	11.64			
	62.123			66.4	
	62.141				24
	62.150				11.64
	62.861			9.96	
	62.900			11.4	
	62.934			8.2	
	79.958		3.4		
	81.742			11.8	
	91.273			4.12	
	92.204		6.04		
	92.310			7.96	
	93.789	4.32			
	93.857			11.8	
	94.554			6	
	94.830			4.6	

Table 18. HPLC - Result-sheets June 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-06-04**	**2010-06-07**	**2010-06-18**	**2010-06-30**
			µg/L s.w.		
Sig. 1					
Phe *a*	96.402 - 96.945	190.76	190.68	601.24	36.8
	97.286		10.8		
	97.318		2.04		
	97.580	8.6			
	97.581			45.92	
	97.591			3.72	2.04
	97.604	7.44			
Sig. 2					
	43.733	34.68			
	49.804			19.16	
	49.820	7.48			
	49.838				19.32
	49.873				21.04
	49.883				19.68
	49.895			7.88	
	49.932			11.24	
	53.437			9.24	
	55.669			14.56	
	57.745		22.24		
	58.271	29.76			
	58.303	15.12			
	60.128			17.92	
Mutato	60.349 - 60.838	22.08	49.4	55.88	18.92
	61.638		10.48		
	61.653		24.56		
	61.661		10.76		
	62.088			50.52	
	62.157			68.08	
	62.393		22.88		
	62.398		23.6		
	62.411		10.68		
	62.891	9.68			
	65.159	6.84			
	74.392		3.84		
	79.049		8.28		

Table 19. HPLC - Result-sheets June 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-06-04	2010-06-07	2010-06-18	2010-06-30
			µg/L s.w.		
Sig. 2					
	79.335			7.4	
Chl *a*````	83.700 - 83.915	4.72	49.72		
Chl *a*`````	82.200 - 84.663	26.84		58.84	5.08
Chl *a*``	84.672 - 85.271	45.08	124.8	187.84	32.48
Chl *a*```	85.932 - 86.702	5.2	23.96	22.36	
DVCl *a*	87.400 - 87.537	100.4	1010.2		
Chl *a*`	87.687 - 88.171	301.8		1314.56	319.4
DVCl *a*`	88.507 - 89.125	3.04	40.52	7.4	
Chl *a*	89.141 - 90.333	8.52		30.84	
	93.046			6.84	
	93.609		7.76		
	94.287		5.16		
Sig. 3					
	37.897				
	43.502		74.24		
	43.549		42.92		
	43.604		57.2		
	43.702	20.36			
	44.038				28.44
	44.177			65.68	
	44.203			102.16	
	44.216			121.04	
	44.236				26.44
	44.263	54.96			
	44.304				27.28
	44.313	13.6			
Fuco	52.238 - 53.124	209.52		824.32	232.88
	53.480			4	
Prepras	55.984 - 56.290		22.28		
c-Neo	56.429 - 56.845	1.8	27.56		
Pras	56.858 - 57.291	7.2		59.64	9.28
Viola	57.337 - 58.184	5.44		35.04	
	60.246			24.92	
Diadino	60.346 - 61.782	16.52	35.6	41.68	20.04
Anth	62.166 - 62.831		19.76	16.84	

Table 20. HPLC - Result-sheets June 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-06-04	2010-06-07	2010-06-18	2010-06-30
			µg/L s.w.		
Sig. 3					
	63.672		4.56		
Allo	63.568 - 64.810	12.64	5.6	7.36	4.24
	65.149			1.88	
Diatoxanthin	65.181 - 65.216			10.4	
Uri	65.146 - 65.900	2.36	8.44	11.16	10.44
Zea	66.750 - 67.450	4.64	16.48	16.16	11.28
Lut	67.556 - 67.644			5.68	
Chl *b*```	79.952 - 80.241			3.04	
Chl *b*`	81.150 - 81.674	3.88	41.2		
Chl *b*	81.667 - 82.596	11.84		36.64	7.24
Croco	84.565 - 85.559	9.16	22.12	29.68	3.81
Cryp	87.448 - 88.390	61.04	154.28	80.84	47.92
	93.842		2.2		
β,ε-Car	100.700 - 100.960	1.52	11.88		
β,β-Car	101.198 - 101.520	4.68	2.64	14.56	4.48
β,ε-Car	101.880			1.64	
Sig. 4					
	44.181			4.08	
	53.390			3	
Aphanizophyll	55.900 - 55.989		1.52		
	57.237			17.4	
Asta	61.625 - 62.502		0	0	
Myxo	63.569 - 64.807	15.76	6.28		
Lyco	96.4600 - 96.805	9.16	6.2	14.68	

Table 21. HPLC - Result-sheets July 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-07-07**	**2010-07-14**	**2010-07-16**	**2010-07-28**
			µg/L s.w.		
Sig. 1					
	53.734			23.4	
	53.746			28.28	
	53.771	34.8			
	53.801	39.28			
	53.818		10.68		
	53.836	46.72			
	54.155		11.36		
Pheide *a*	54.139 - 54.922		21.28		71.2
	54.229				4.96
	59.724	38.24			
	59.730	4.44			
	59.761	3.96			
	60.135				5.6
	60.486	3.36			
	60.743	9.32			
	61.064				4.56
	61.070				9.72
	61.600			17.72	
	61.607			20.8	
	61.644			13.36	
	61.673		5.16		
	62.071				41.48
	62.078				4.4
	62.085		24.64		
	62.136		8.64		
	62.188				33.2
	62.840				48.16
	62.846				10.48
Phe *a*	96.402 - 96.945	43.8	11.72	14.48	7.8
	97.330	5.08			
Sig. 2					
Chlide *a*	38.687 - 38.917	38.04	13.36		
	44.291		27.92		

Table 22. HPLC - Result-sheets July 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-07-07	2010-07-14	2010-07-16	2010-07-28
			µg/L s.w.		
Sig. 2					
	49.503			21.32	
	49.504			10.92	
	49.520	28.88			
	49.568	20.44			
	49.584			9.84	
	49.607	26.76			
	49.748				9.16
	49.752				15.56
	49.760				16.08
	49.762		27.2		
	49.838		5.6		
	53.047	8.16			
	53.066	7			
	53.333				5.8
	56.796			5.72	
	56.831	11.8			
	56.880	11.84			
	57.180				5.52
	57.200				5.92
Mutato	60.349 - 60.838	39.64	20.24	23.96	20.72
	62.344			10.6	
	62.379			8.68	
	62.393			11.44	
	62.406	20.04			
	62.412	25.2			
	62.428	15.36			
	62.887				26.12
	79.534		7.28		
Chl *a*````	83.700 - 83.915	24.36	8.04	30.96	
Chl *a*`````	82.200 - 84.663	40.76	33.04	91.88	21.16
Chl *a*``	84.672 - 85.271	30.88	39.96		38.04
Chl *a*```	85.932 - 86.702	13.68		11.36	
DVCl *a*	87.400 - 87.537	476.64	96.8	528	
Chl *a*`	87.687 - 88.171	11.4	474.32		447.04
DVCl *a*`	88.507 - 89.125	18.96		15.68	

Table 23. HPLC - Result-sheets July 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-07-07	2010-07-14	2010-07-16	2010-07-28
			µg/L s.w.		
Sig. 2					
Chl *a*	89.141 - 90.333		10		
	100.980	13.16			
	101.008	4.88			
	101.326				6.28
	101.333		12.2		
	101.337				9.4
Sig. 3					
	43.512	50.76			
	43.525	53.76			
	43.601			32.64	
	43.623		14.36		
	43.625	55.72			
	43.669			43.64	
	43.748			30.52	
	44.155				59.08
	44.185		118.28		
	44.205				26.84
	44.261		17.4		
	44.286		6.56		
Fuco	52.238 - 53.124	4.76	489.6		272.48
	53.362				4.2
	53.368		2.16		
Hex-kfuco	54.471 - 55.255		14.64		
Prepras	55.984 - 56.290		11.08		
c-Neo	56.429 - 56.845	5.6	1.72	4.52	
Pras	56.858 - 57.291	14.84	15.72	2.76	13.52
Viola	57.337 - 58.184	7			
Diadino	60.346 - 61.782	12.96	20.28	22.48	18.32
Anth	62.166 - 62.831	18.48	6.12	3.28	5.08
Allo	63.568 - 64.810	11.36	2.24		3.52
	65.131		1.84		
Uri	65.146 - 65.9	6.92	1.96	2.72	10.56
Zea	66.750 - 67.45	14.32	28.16	13.2	17.52
Chl *b*`````	77.063 -77.8	6			
	78.609	3.96			

Table 24. HPLC - Result-sheets July 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-07-07	2010-07-14	2010-07-16	2010-07-28
			µg/L s.w.		
Sig. 3					
Chl *b*````	78.665 - 79.441	3.24			
Chl *b*`	81.150 - 81.674	32.36	28.88	7.8	21.6
Chl *b*	81.667 - 82.596		31.12		
Croco	84.565 - 85.559	10.92	9.16	14.64	6.24
Cryp	87.448 - 88.390	72.16	87.68	80.16	67.84
β,ε-Car	100.700 - 100.960	6.2	1.08	5.64	
β,β-Car	101.198 - 101.520	2.44	5.24		5.44
Sig. 4					
	43.475	19.96			
	43.490	20.6			
	43.578	19.32			
Aphanizophyll	55.900 - 55.989		1.52		
	56.875	14.44			
Asta	61.625 - 62.502	0	0		
Myxo	63.569 - 64.807	3.88			0.84

Table 25. HPLC - Result-sheets August 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-08-11**	**2010-08-23**	**2010-08-25**	**2010-08-30**
			µg/L s.w.		
Sig. 1					
	44.188			17.6	
	53.118		11.16		
	53.752			24.36	
	53.754				22.04
	53.756				24.6
	53.766				46.48
	53.769		9.2		
	53.818		12.4		
	54.099			104	
Pheide *a*	54.139 - 54.922	30.36		54	
	59.690			10.64	
	59.712				4.36
	59.714				4.11
	60.023			9.2	
	60.048	1.96			
	60.135			54.68	
	60.976			27.2	
	60.986			255.88	
	60.988	11.23			
	60.994			7.64	
	60.990	8.24			
	61.627				25.81
	61.631		10.8		
	61.632				47.84
	61.653		20.52		
	61.656		16.28		
	61.965			41.36	
	62.011	43.36			
	62.048	13.2			
	62.717			19.68	
	62.778	4.92			
	62.783	3.8			
	69.292			9.4	

Table 26. HPLC - Result-sheets August 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-08-11	2010-08-23	2010-08-25	2010-08-30
			µg/L s.w.		
Sig. 1					
	94.448			3.48	
Phe *a*	96.402 - 96.945	22.12		134.28	5.68
	97.850			11.6	
	97.512	2.48			
	100.966				4.51
	100.976			24.64	
Sig. 2					
Chlide *a*	38.687 - 38.917			66.8	
	40.019			22	
	49.702			10.6	
	49.741			58.76	
	52.904			29.8	
	55.531			27.96	
	56.848			20.12	
	56.873				13.36
	57.157			4.36	
	58.515			26.56	
	60.385			21.16	
Mutato	60.349 - 60.838	6.72	8.48	42.92	18.32
	62.347				19.72
	62.358				24.72
	62.364			65.88	
	62.381				44.96
	62.399		10.24		
	62.748			28.88	
	62.750			192.96	
	62.786			5.44	
	63.566			4.44	
	64.960			7.48	
	71.025			4.24	
	74.35			12.72	
Chl *a*````	83.700 - 83.915			12.28	10.88
Chl *a*`````	82.200 - 84.663	12.28		36.16	0.597
Chl *a*``	84.672 - 85.271	25.32		80.64	
Chl *a*```	85.932 - 86.702	6.08		9.48	

Table 27. HPLC - Result-sheets August 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-08-11	2010-08-23	2010-08-25	2010-08-30
			µg/L s.w.		
Sig. 2					
DVCl *a*	87.400 - 87.537	71.24		916.52	5.243
Chl *a*`	87.687 - 88.171	358.2		3.64	
DVCl *a*`	88.507 - 89.125			17.76	0.152
	92.878			5.8	
	93.733			4.84	
	100.949				10
	101.245	9.08			
	101.251			22.36	
	101.252			7.32	
	101.253			4.88	
	101.256	13.6			
Sig. 3					
	37.784			13.8	
	43.559			33.4	
	43.588				33.4
	43.651				17.28
	43.751		11.8		
	43.758		7.24		
	43.880		9.84		
	44.052	10.64			
	44.092	15.8			
	44.157			24.16	
	44.159			232.56	
	44.223			8.32	
Magnesium 2,4-divinylpheoporpyrin	45.400 - 45.836			12.72	
	47.979			6.92	
	48.860			2.24	
But-fuco	50.729 - 51.003			22.88	
	52.331			492.4	

Table 28. HPLC - Result-sheets August 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-08-11	2010-08-23	2010-08-25	2010-08-30
		µg/L s.w.			
Sig. 3					
Fuco	52.238 - 53.124	82.92	2.24	63.68	11.12
	53.267			3.84	
	53.315	3			
	53.317			31.16	
	54.528			3.32	
Hex-kfuco	54.471 - 55.255	11.8		96.44	
Hex-fuco	55.470 - 55.780			8.96	
Prepras	55.984 - 56.290	33.36		34.44	
c-Neo	56.429 - 56.845			5.28	
Pras	56.858 - 57.291	18.4	2.92	152.84	9.64
Viola	57.337 - 58.184			27.36	
	58.52			2.56	
	59.219			3.44	
	59.983			13.2	
	60.347			7.52	
	60.36				3.48
	60.646			24.16	
Diadino	60.346 - 61.782	6.24	6.12	21.36	7.64
Anth	62.166 - 62.831	4.8		27.84	13.52
	62.404			24.28	
	63.577			12	
	63.601			12.04	
Allo	63.568 - 64.810	8.52	2.56	26.48	12.08
	64.996			5.84	
Uri	65.146 - 65.900	7.08		12.32	
Zea	66.750 - 67.450	103.28	8.4	33.52	28.44
Lut	67.556 - 67.644			44.44	
Siph	71.950 - 71.967			9.96	
	73.747			3.16	
	74.146	3.96			
	74.193			3.52	
	75.166	4.28			
	75.174			5.52	

Table 29. HPLC - Result-sheets August 2010 cont.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-08-11**	**2010-08-23**	**2010-08-25**	**2010-08-30**
			µg/L s.w.		
Sig. 3					
	76.979			4.52	
Chl *b*`````	77.063 - 77.800	15.32		30.28	
Chl *b*````	78.665 -79.441	3.48		8.4	
	78.726			3.96	
Chl *b*```	79.952 - 80.241	3.8		4.72	
Chl *b*``	80.600	3.96			
Chl *b*`	81.150 - 81.674	226.64		262.64	0.962
Croco	84.565 - 85.559	1.84		16.24	0.090
Cryp	87.448 - 88.390	65.24		144.16	0.793
	97.114			1.8	
β,ε-Car	100.700 - 100.960			2.2	
β,β-Car	101.198 - 101.520	7.68		7.6	
Sig. 4					
	43.885			99.8	
	45.175			7	
Peri	46.000			12.76	
	51.588			11.28	
Aphanizophyll	55.900 - 55.989	4.28		11.64	
	56.894				2.88
	58.108			6.88	
	59.811			14.12	
	60.349				3.68
	63.551			17.08	
Myxo	63.569 - 64.807	2.72		19.36	0.046
	69.239			3.04	
Lyco	96.460 - 96.805			4.48	

Table 30. HPLC - Result-sheets September-October 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	t_R	2010-09-08	2010-09-22	2010-10-13	2010-10-29
			µg/L s.w.		
Sig. 1					
Pheide *a*	54.139 - 54.922	25.24		15.2	
	62.030	12.88			
	62.052	10.24			
	62.054		7.28		
	62.056		8.68		
	62.059			13.52	
	62.060			10.68	
	62.061			21.2	
Sig. 2					
Mutato	60.349 - 60.838		1.2		
Chl *a*``	84.672 - 85.271		4.6		
DVCl *a*	87.400 - 87.537	60.56	100.28	33.16	13.68
Chl *a*`	87.687 - 88.171	30.56		24.28	
	101.252	3.04			
Sig. 3					
Fuco	52.238 - 53.124	35.4	32.48	23.96	
	53.368	1.44			
	53.421			2.44	
Hex-kfuco	54.471 - 55.255		19.6		
Prepras	55.984 - 56.290			12.68	
c-Neo	56.429 - 56.845		6.2		
Pras	56.858 - 57.291		2.48	9.32	
Diadino	60.346 - 61.782		3.8		
Allo	63.568 - 64.810	3.6	5.44	5.92	
Zea	66.750 - 67.450	20.16	21.92	29.28	
Chl *b*`	81.150 - 81.674	15.88	27.6	14.56	
Cryp	87.448 - 88.390	13.76	15.8	8.76	1.12
β,β-Car	101.198 - 101.520			2.24	
Sig. 4					
Aphanizophyll	55.900 - 55.989		4.4	1.56	
Myxo	63.569 - 64.807	0.6	3	2.32	

Table 31. HPLC - Result-sheets November-December 2010.

Daily average concentration in µg/L s.w. Giving actual retention time observed (t_R). Retention intervals given for each pigment gives the range of amplitudes in all samplings combined.

Pigment	**t_R**	**2010-11-10**	**2010-11-24**	**2010-12-08**	**2010-12-20**
			µg/L s.w.		
Sig. 1					
	62.161	3.48			
	62.163	6.84			
Sig. 2					
Chl *a*`	87.687 - 88.171	12.8			6.48
Sig. 3					
Fuco	52.238 - 53.124	2.8			
Zea	66.750 - 67.450	3.44			
Cryp	87.448 - 88.390	0.84			

APPENDIX C Meteorological reports

Tables presenting meteorological reports on cloud cover, precipitation and air temperature.

Table 32. Cloud cover, precipitation and air temperature from January-May.

Daily measurements Daily measurements of precipitation, cloud cover and air temperature (MET, 2011).

	C.c	Pr	A.t		C.c	Pr	A.t		C.c	Pr	A.t		C.c	Pr	A.t
2010-01-01	1	0	-5.5	**2010-02-03**	6	0.2	-4.4	**2010-03-07**	8	1.9	5.9	**2010-04-09**	7	0.6	3.6
2010-01-02	7	0.2	-2.6	**2010-02-04**	6		-3	**2010-03-08**	7	7.9	-0.3	**2010-04-10**	7	1.5	4.3
2010-01-03	7	5.6	-1.9	**2010-02-05**	2		-5.1	**2010-03-09**	8	1.9	-0.8	**2010-04-11**	7	1.1	5.1
2010-01-04	1	4.6	-8.9	**2010-02-06**	8	0.5	-0.7	**2010-03-10**	7	12.7	-1	**2010-04-12**	8		6.3
2010-01-05	2		-10.7	**2010-02-07**	5	6	1.4	**2010-03-11**	6	8.4	-1.5	**2010-04-13**	7	6.8	3.7
2010-01-06	1	0	-10.3	**2010-02-08**	1	4.6	-2.4	**2010-03-12**	6	1.5	-1.3	**2010-04-14**	6	8	5.1
2010-01-07	7		-6	**2010-02-09**	1	0.1	-6.6	**2010-03-13**	7	1.6	-1.5	**2010-04-15**	8	6.5	3.3
2010-01-08	7	0.7	0.3	**2010-02-10**	7	0	-4.3	**2010-03-14**	7	2.9	-1.6	**2010-04-16**	5	24.1	1.2
2010-01-09	7	8.7	4.4	**2010-02-11**	2	5.5	-4.5	**2010-03-15**	7	1.1	-2.3	**2010-04-17**	4	0.6	0.6
2010-01-10	8	5.9	5.6	**2010-02-12**	8	0.2	1.1	**2010-03-16**	5	1.9	-5.3	**2010-04-18**	6	2.2	1.5
2010-01-11	8	4.3	5	**2010-02-13**	7	7.9	0.9	**2010-03-17**	4	13.2	-3	**2010-04-19**	5	0.1	3.2
2010-01-12	7	3	4.2	**2010-02-14**	4	0.5	1.1	**2010-03-18**	2	1.5	-3.2	**2010-04-20**	6	3.8	2.7
2010-01-13	2	1.2	0.8	**2010-02-15**	4	2.5	0.8	**2010-03-19**	7		-2	**2010-04-21**	2	1.4	2.8
2010-01-14	3		-0.6	**2010-02-16**	2	0	-2.8	**2010-03-20**	1	0	-2.1	**2010-04-22**	3		2.4
2010-01-15	1		1.8	**2010-02-17**	1		-5.6	**2010-03-21**	5	0.4	-1.4	**2010-04-23**	2		3
2010-01-16	8		-1.1	**2010-02-18**	6		-9.1	**2010-03-22**	4	1.3	-0.2	**2010-04-24**	6	0	3.7
2010-01-17	1		-0.1	**2010-02-19**	1	0	-9.7	**2010-03-23**	7	3	-1.1	**2010-04-25**	7	8.3	2.1
2010-01-18	7		-1.1	**2010-02-20**	1		-10.4	**2010-03-24**	1	0.4	-4	**2010-04-26**	8	5.7	3
2010-01-19	7	0	0.5	**2010-02-21**	6		-10.5	**2010-03-25**	6		-1.5	**2010-04-27**	7	21.4	1.5
2010-01-20	7	6.2	3.9	**2010-02-22**	8		-11.3	**2010-03-26**	8	2.1	0.3	**2010-04-28**	7	2.9	1.8
2010-01-21	1	1.6	2.9	**2010-02-23**	8	0	-14	**2010-03-27**	8	1.8	-0.4	**2010-04-29**	3	1.5	2.3
2010-01-22	1		-1.6	**2010-02-24**	7	1.4	-7.2	**2010-03-28**	1	0.1	-1.6	**2010-04-30**	6		4
2010-01-23	3		-5.4	**2010-02-25**	5	0.4	-3.2	**2010-03-29**	4		-2.8	**2010-05-01**	8	0.9	3.3
2010-01-24	8	3.5	-1.8	**2010-02-26**	1	0.1	-3.3	**2010-03-30**	7		-2.6	**2010-05-02**	7	0	3.2
2010-01-25	4	3.6	-0.4	**2010-02-27**	7	0.3	-4.7	**2010-03-31**	6		1.5	**2010-05-03**	4	0.7	2.2
2010-01-26	8	0	3	**2010-02-28**	1	0.7	-4	**2010-04-01**	7		6.5	**2010-05-04**	7	0.9	3
2010-01-27	7	16.4	2.6	**2010-03-01**	5		-5	**2010-04-02**	2		6.7	**2010-05-05**	8	2.7	1.4
2010-01-28	7	12.8	-4.6	**2010-03-02**	1		-6.9	**2010-04-03**	1	0	4.9	**2010-05-06**	1	1.7	4.3
2010-01-29	7	0.3	-12.2	**2010-03-02**	1		-6.9	**2010-04-04**	1	0	3.9	**2010-05-07**	6		6.5
2010-01-30	7	1.2	-10.2	**2010-03-03**	1		-7	**2010-04-05**	0		4.1	**2010-05-08**	7	0	4.1
2010-01-31	1		-10.2	**2010-03-04**	6		-5.3	**2010-04-06**	1		4.1	**2010-05-09**	6	1.7	4.5
2010-02-01	3		-9.6	**2010-03-05**	7	3.2	-0.9	**2010-04-07**	7		5.4	**2010-05-10**	7		6.2
2010-02-02	7		-5.8	**2010-03-06**	7	3.2	1.4	**2010-04-08**	7	2	4.2	**2010-05-11**	7		6

Table 33. Cloud cover, precipitation and air temperature from May-September.

Daily measurements of precipitation, cloud cover and air temperature (MET, 2011).

	C.c	Pr	A.t		C.c	Pr	A.t		C.c	Pr	A.t		C.c	Pr	A.t
2010-05-12	1	1.1	7.2	**2010-06-14**	6	1	8.3	**2010-07-17**	6	0	17.4	**2010-08-19**	5		13.2
2010-05-13	8		8.3	**2010-06-16**	7	0	7.8	**2010-07-18**	8	0	13.8	**2010-08-20**	7		14.6
2010-05-14	6	1.3	12.4	**2010-06-16**	8	5.1	8.2	**2010-07-19**	7	15.3	11.8	**2010-08-21**	5	1	14.8
2010-05-15	8	0.2	14.8	**2010-06-17**	8	5.6	8.9	**2010-07-20**	8	7.1	10.7	**2010-08-22**	8	0.1	12.9
2010-05-16	6	0.4	17.3	**2010-06-18**	7	8.6	9.8	**2010-07-21**	7	5.7	10.2	**2010-08-23**	7	4.9	12.3
2010-05-17	7	0	13.1	**2010-06-19**	8	5.6	7	**2010-07-22**	8	5.5	9.3	**2010-08-24**	1	0.6	13.5
2010-05-18	8	3.8	8.3	**2010-06-20**	8	9.9	7.2	**2010-07-23**	7	12.3	8.6	**2010-08-25**	1		10.9
2010-05-19	5	1.2	11.6	**2010-06-21**	7	3.3	7.1	**2010-07-24**	1	0	15	**2010-08-26**	6		10
2010-05-20	7	6.5	9	**2010-06-22**	8	3.9	7.5	**2010-07-25**	3		21.3	**2010-08-27**	4		10.6
2010-05-21	2	0.3	8.5	**2010-06-23**	7	4.7	7.6	**2010-07-26**	7		19.5	**2010-08-28**	3		11.2
2010-05-22	8		8.4	**2010-06-24**	6	0.3	10.1	**2010-07-27**	7	0.5	13.6	**2010-08-29**	2		10.9
2010-05-23	4	1.1	6.1	**2010-06-25**	7	0	13.1	**2010-07-28**	6	0	14	**2010-08-30**	7		10
2010-05-24	2	0	6.1	**2010-06-26**	8	4.1	8.1	**2010-07-29**	3		14.1	**2010-08-31**	4	7.5	8.3
2010-05-25	8	0	7.1	**2010-06-27**	8	4.8	7.4	**2010-07-30**	8	3.5	19	**2010-09-01**	6	2.4	8.9
2010-05-26	5	0.5	9.1	**2010-06-28**	7	8.8	8	**2010-07-31**	8	0	13.3	**2010-09-02**	4	0.5	7.9
2010-05-27	7		12.7	**2010-06-29**	5	1.1	12.1	**2010-08-01**	7	5.6	12.4	**2010-09-03**	1	0.1	7.5
2010-05-28	3		13.3	**2010-06-30**	2	4.5	12.7	**2010-08-02**	8	0.4	12.2	**2010-09-04**	8	0	9.7
2010-05-29	6		10.8	**2010-07-01**	3	1.5	10.2	**2010-08-03**	8	2.1	10.7	**2010-09-05**	7	4.5	11.5
2010-05-30	7	0	8.1	**2010-07-02**	2	0.1	11.9	**2010-08-04**	3	0.1	13.7	**2010-09-06**	6	0.7	11.4
2010-05-31	7	1.2	6.4	**2010-07-03**	7	0	15.1	**2010-08-05**	7		12.4	**2010-09-09**	1		10.2
2010-06-01	2	3.1	6.8	**2010-07-04**	8	0.1	12.4	**2010-08-06**	7		16.7	**2010-09-08**	1		13.1
2010-06-02	8		10.5	**2010-07-05**	8	1.5	14.6	**2010-08-07**	3	2	14.3	**2010-09-09**	1		13.3
2010-06-03	8	2.5	8.2	**2010-07-06**	6	1.3	12.1	**2010-08-08**	4	0.1	12.6	**2010-09-10**	1		12.6
2010-06-04	7	6.3	5.9	**2010-06-07**	2	3.8	12.6	**2010-08-09**	7		12.8	**2010-09-11**	5		14.3
2010-06-05	5	0.5	5.9	**2010-07-08**	3	0.7	14.9	**2010-08-10**	7		12.2	**2010-09-12**	7	0.1	13.2
2010-06-06	4	2	6.2	**2010-07-09**	7	0	13.4	**2010-08-11**	7	0	11.8	**2010-09-13**	7	11.6	11.8
2010-06-07	3	0	7.4	**2010-07-10**	8	0	12.3	**2010-08-12**	2		14.6	**2010-09-14**	7	0.3	13.4
2010-06-08	2		10.4	**2010-07-11**	4	6.9	14.7	**2010-08-13**	8	3.6	13.3	**2010-09-15**	5	0	12.7
2010-06-09	3		8.2	**2010-07-12**	8	3.3	14.6	**2010-08-14**	8	0.8	12.8	**2010-09-16**	4	1.6	12.1
2010-06-10	7	0	7.6	**2010-07-13**	8	0.6	10.8	**2010-08-15**	6	21.4	9.9	**2010-09-17**	7		12.3
2010-06-11	6		10.8	**2010-07-14**	8	17.2	10	**2010-08-16**	1	0	11	**2010-09-18**	7		11.2
2010-06-12	6		14.1	**2010-07-15**	1	0.9	14.1	**2010-08-17**	1		12.8	**2010-09-19**	7		9.4
2010-06-13	8	3.3	8.4	**2010-07-16**	6	0	16.8	**2010-08-18**	1		15.8	**2010-09-20**	7	8.1	9.1

Table 34. Cloud cover, precipitation and air temperature from September-December.

Daily measurements of precipitation, cloud cover and air temperature (MET, 2011).

	C.c	Pr	A.t		C.c	Pr	A.t		C.c	Pr	A.t		C.c	Pr	A.t
2010-09-21	7	0	9.2	**2010-10-17**	7	24.5	8.2	**2010-11-12**	2		-0.9	**2010-12-08**	6	6.6	0.4
2010-09-22	6	1.5	8.6	**2010-10-18**	7	19.9	8.5	**2010-11-13**	6		-2.9	**2010-12-09**	2	1.5	-3.2
2010-09-23	6	0.1	8.5	**2010-10-19**	8	18.1	2.9	**2010-11-14**	2	0	-2.6	**2010-12-10**	5	6.6	-4.1
2010-09-24	3	1.6	8.1	**2010-10-20**	7	4	-1.1	**2010-11-15**	2		-3	**2010-12-11**	4		-7
2010-09-25	6		6.3	**2010-10-21**	3	1.8	-0.9	**2010-11-16**	6	0.5	-1.3	**2010-12-12**	7	1.6	-1.3
2010-09-26	7	0.5	6.8	**2010-10-22**	7	14.3	2.5	**2010-11-17**	1	1.2	1.6	**2010-12-13**	7	2.9	-1.9
2010-09-27	2	3.8	7.4	**2010-10-23**	6	7	6.1	**2010-11-18**	1		-0.9	**2010-12-14**	8	7.8	1.2
2010-09-28	3		7.3	**2010-10-24**	8	2.5	4.9	**2010-11-19**	2		0.7	**2010-12-15**	8	1.5	2.8
2010-09-29	6		8.2	**2010-10-25**	3	6.1	2.7	**2010-11-20**	1		0.1	**2010-12-16**	7	24	-1
2010-09-30	2		8.3	**2010-10-26**	5	4.8	2.9	**2010-11-21**	7		-0.7	**2010-12-17**	7	2.7	-1.9
2010-10-01	3		10.3	**2010-10-27**	8	0.6	3.7	**2010-11-22**	6	0	0.8	**2010-12-18**	2		-5.9
2010-10-02	1		10.6	**2010-10-28**	8	2.6	4.8	**2010-11-23**	2	1.1	-4.7	**2010-12-19**	1		-6.1
2010-10-03	7		10.3	**2010-10-29**	1	14.8	3.6	**2010-11-24**	1		-6.5	**2010-12-20**	4		-8
2010-10-04	7		13.9	**2010-10-30**	8		2.7	**2010-11-25**	1		-5.4	**2010-12-21**	7		-6.7
2010-10-05	4	0	14.3	**2010-10-31**	5	9.1	6.4	**2010-11-26**	3		-8	**2010-12-22**	1		-7.8
2010-10-06	7		13.7	**2010-11-01**	4	4.5	5.3	**2010-11-27**	2		-8.3	**2010-12-23**	2		-8.4
2010-10-07	7	3	12.6	**2010-11-02**	8	4.5	3.9	**2010-11-28**	2		-7.9	**2010-12-24**	7		-6.1
2010-10-08	7	1.3	12.2	**2010-11-03**	4	0.6	4.8	**2010-11-29**	6		-4.9	**2010-12-25**	4	0	-3.2
2010-10-09	8	25.3	9.9	**2010-11-04**	7	1.6	4.6	**2010-11-30**	7	3.2	1.5	**2010-12-26**	6		-2.3
2010-10-10	6	8.1	5.4	**2010-11-05**	7	3.7	2.2	**2010-12-01**	8	9.5	2.3	**2010-12-27**	3		-2.7
2010-10-11	7	0.1	5.3	**2010-11-06**	7	12.6	3.4	**2010-12-02**	8	6.1	4	**2010-12-28**	7		-1.8
2010-10-12	7	2.5	5	**2010-11-07**	7	2.7	0.2	**2010-12-03**	7	10.2	2.2	**2010-12-29**	8		-2.1
2010-10-13	8	1.6	3.2	**2010-11-08**	5	15.2	-0.1	**2010-12-04**	7	8.5	-0.3	**2010-12-31**	7	3.2	1
2010-10-14	7	18.4	3.7	**2010-11-09**	1	0.3	-2.5	**2010-12-05**	4	0	-0.9	**2010-12-31**	6	11.9	0.5
2010-10-15	6	3.4	3.7	**2010-11-10**	8		-2	**2010-12-06**	7	1.2	0				
2010-10-16	7	2.4	5.1	**2010-11-11**	8	0	-0.3	**2010-12-27**	7	1.4	-0.5				

APPENDIX D Algal cell counts

Processed table from algal cell count raw-data (Mattilsynet, 2013, SINTEF, 2010)

Table 35. Algal cell counts given in number of cells.

Processed table giving algal cell counts.

Sample date	Total cell/L s.w.	Diatoms	Dinoflagellates	Others	Comments	Dominant
2010-03-22	60 000	10 000	0	50000		
2010-04-06	460000	360000	0	100000		
2010-04-12	1130000	770000	0	360000	Moderate	Diatoms
2010-04-19	290000	70000	0	220000	Weak growth	Diatoms
2010-04-26	150000	30000	0	120000	Few	
2010-05-03	220000	170000	0	50000	Few	
2010-05-10	150000	40000	0	110000		
2010-05-18	200000	80000	0	120000	Few/moderate	Diatoms
2010-05-25	120000		0	120000	Few	Mixed
2010-05-31	90000	80000	0	10000	Low total	
2010-06-07	660000	420000		240000		Skeletonema domin
2010-06-14	1140000	940000	0	200000	Bloom	Diatoms
2010-06-21	1210000	1160000		50000	Bloom	Diatoms
2010-07-05	1940000	1540000	20000	380000	Bloom	Diatoms, Skeletonema domin.
2010-06-28	470000	340000	0	130000		Mixed, moderate diatoms
2010-07-12	2700000	2450000		250000	Moderate	Diatoms, Skeletonema domin.
2010-07-20	4200000	4100000		100000	Bloom	Diatoms, skeletonema num. 2900000
2010-07-27	1380000	890000		490000	Moderate	Diatoms skeletonema og chaetoceros
2010-08-02	1500000	1240000	10000	250000	Oppblomstring av kiselalger, skeletonema (1100000)	
2010-08-09	120000			120000	Few	
2010-08-16	350000	220000	10000	120000	Moderate	skeletonema dom.
2010-08-24	420000	320000		100000	Weak	Diatoms
2010-08-30	550000	500000		50000	Moderate	Diatoms, chaetoceros sp.(30000
2010-09-06	320000	70000	10000	240000	Moderate	Diatoms
2010-09-13	70000			70000	Few	Weak bloom, large dinoflagellates (dinophysis norvegica)
2010-09-20	210000		10000	200000	Few	Mixed
2010-09-27	100000			100000	Few	
2010-10-05	130000		10000	120000	Few	

APPENDIX E Pigment abbreviations

Table 36. Recommended abbreviations.

Recommended abbreviations (Egeland et al., 2011)

Pigment	Recommended abbreviations
Antheraxanthin	Anth (An)
Alloxanthin	Allo (Al)
Aphanizophyll	Aphanizophyll
Astaxanthin	Asta (As)
β,β-Carotene and β,ε-Carotene	β,β-Car (β,β) and β,ε-Car (β,ε)
19`- Butanoyloxyfucoxanthin	But-fuco (BF)
Canthaxanthin	Cantha (Ct)
Chlorophyll *a* (allomer `)	Chl *a* (C*a*) (Chl *a*(C*a*al)`)
Chlorophyllide *a*	Chlide *a* (Cd*a*)
Chlorophyll b	Chl *b* (C*b*)
Crocoxanthin	Croco (Co)
Cryptoxanthin	Cryp (Cy)
Deepoxyuriolid (Uriolide)	Uri (U)
Divinyl chlorophyll *a*	DVCl *a* (Dc*a*)
Diadinoxanthin	Diadino (Dd)
Dinoxanthin	Dino (Dn)
Fucoxanthin	Fuco (F)
19`-Hexanoyloxyfucoxanthin	Hex-fuco (HF)
19`-Hexanoyloxy-4- ketofucoxanthin	Hex-kfuco (HKf)
Lutein	Lut (L)
Magnesium 2,4-divinylpheoporpyrin	`Mgdvp`
Mutatoxanthin	Mutato (Mu)
Myxol quinovoside	Myxo(My)
9`-cis- Neoxanthin	c-Neo (cN)
Peridinin	Peri (P)
Pheophorbide *a* and Pheophythin *a*	Pheide *a* (Pd*a*) and Phe *a* (Ph*a*)
Prasinoxanthin	Pras (Pr)
φ,φ- Carotene (Lycopene)	Lyco (Ly)
Siphonaxanthin	Siph (S)
Violaxanthin	Viola (V)
Zeaxanthin	Zea (Z)