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Underwater Imaging and the effect of Inherent Optical Properties on image quality

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Marine Coastal Development
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Abstract

Underwater imaging has become a common tool for scientific research and is associated with a variety of platforms (ROV, AUV, Landers, Sledges, SCUBA). The image quality is highly degraded by the comprehensive light attenuation from inherent optical properties (IOP) in water and can be affected through different camera and light systems. In this study the effect of IOP on red, green and blue (RGB) colours and contrast were investigated in a controlled environment (aquarium). Three substances were used to simulate the IOP. Investigation of the isolated effect was conducted by the use of phytoplankton, coloured dissolved organic material (cDOM) and total suspended material (TSM), in four concentrations. The results show that RGB colours and contrast in images were highly dependent on the dominating substance in the water; Phytoplnakton produced a green hue, cDOM a yellow hue, and TSM a more dark blue hue. In addition to the controlled images in the aquarium, *in situ* images were taken by SCUBA divers and an ROV of benthic organisms. Identification success of benthic organisms was used to analyze image quality and resolution. The results shows that organisms smaller than 0.5 cm in length was not identifiable at an imaging distance on 0.3 m, when the focal length of the camera was 14 mm (wide angle). It was also evident that 13 out of 14 taxa were not possible to identify when the imaging distance increased from 0.3 m to 1.1 m due to lowered spatial resolution and attenuation from IOP. The results show also that colours in images are not only dependent on the IOP, but also the spectral resolution of the light source. The light sources; LED, Xenon, were investigated in terms of RGB colour output in the images. The results show the light sources affected the RGB colours due to its difference in colour temperatures and beam angle. From the light sources used, the Blitz gives the highest RGB colour intensities in the images and is probably the best choise for underwater imaging, when gathering images from SCUBA.

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1 Introduction

Conservation of marine benthic biodiversity has received global attention during the last few decades due to degradation and damage to the benthic ecosystems by both natural processes and human activity (Shortis 2009). Waste disposal, oil industry (Olsgard 1995), aquaculture (Lee & Jones 1990) and fisheries (Hobday et al. 2011) have been shown to have chemical and physical damaging effects on the marine environment, with emphasis on benthic organisms. In order to obtain a proper marine ecosystem management, information about different habitats and their species is required (Shumchenia and King 2010). To interpret long-term effects of human activity and to monitor natural fluctuations in an environment, time-series are needed to acquire trustworthy estimates of the expected changes in both disturbed and undisturbed environments (Green, 1984). Due to an improvement of imaging technology (Kocak et al. 2008), underwater imaging has become a common scientific tool for studies of the seafloor (Solan et al. 2003).The development of different instrument carrying platforms such as remotely operated vehicles (ROV, Fig. 1.1) (Ludvigsen et al. 2007; Sedlazeck et al. 2009; Karpov et al. 2012; Lindsay et al. 2012; Stierhoff et al. 2012), sledges (Shortis et al. 2008; Jones et al. 2009) and landers (Harvey and Watson 2007) allows seafloor data collection from larger areas and greater depths than earlier with the use of standard methods as trawl and grabs. However; there is still a need for optimization of image data collection and interpretation of these images, and there is a need for an evaluation on how these sampling methods compare to traditional methods used in benthic surveillance (e.g. sampling and photography by divers, grabs, sledges, dredges).

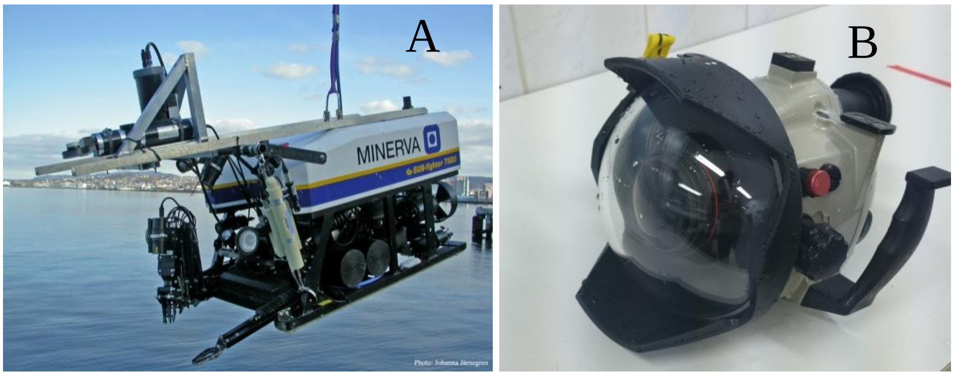

Figure 1.1: To show how far technology has reached: the remotely operated vehicle Minerva (NTNU) close before action time (A), and a hand held SCUBA operated underwater house (B).

Considerations for processing underwater images – Inherent optical properties (IOP) and its coefficients

When processing underwater images, the basic physics of light propagation in water has to be considered, as water is a much more complex environment than air. Due to absorption and scattering by the inherent optical properties (IOPs) of seawater and its constituents , light is exponentially attenuated with distance and is spectrally dependent (Jerlov 1951) (Fig. 1.2).

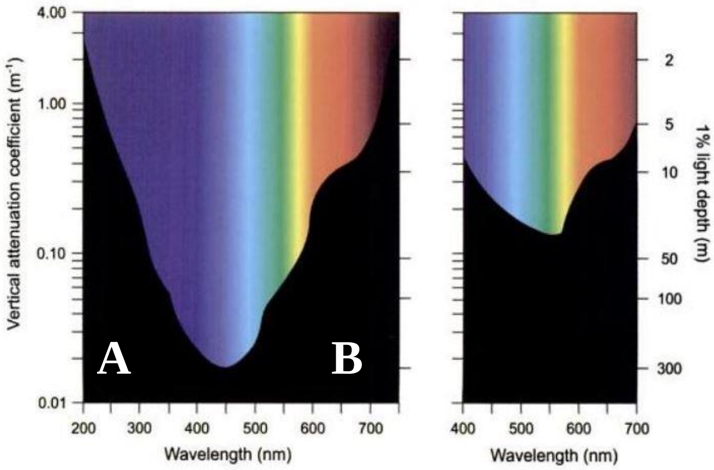

Figure 1.2: The 1 % the light penetration depth is indicated on a logarithmic scale to the right in both images (A and B) as a function of wavelength and depth in a clear oceanic (A) and a clear coastal (B), water type. The vertical attenuation coefficient is gathered from measurements mainly from the Sargasso Sea and the coastal water that comprises the Trondheimsfjord (Sakshaug et. al 2009).

The IOP in seawater is a function of absorption and scattering from the seawater itself, absortion and scattering by phytoplankton, absorption by coloured dissolved organic matter (cDOM) and finally, light scattering by total suspended matter (TSM) (Johnsen et al. 2011). The phytoplankton biomass is measured as chlorophyll *a* concentration [Chl *a*], and with [cDOM] and [TSM] the IOP´s affecting underwater images can be elucidated. Depending on the contribution of different IOP, different water types, generalized as blue clear oceanic waters and greenish coastal waters, can roughly be characterized as case I and case II waters, respectively (Morel & Prieur 1977, Fig. 1.3). As a result of the different composition of IOP, the attenuation lengths of visual light (400-700 nm) in Case I and Case II water differs (Fig.1.2).

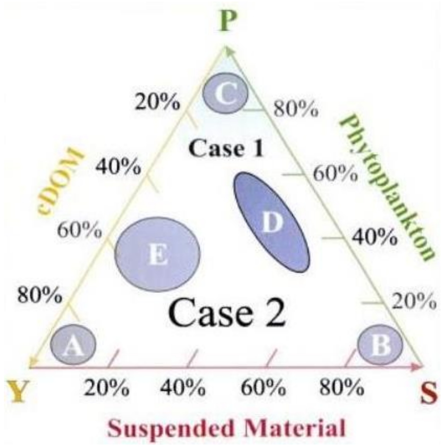

Figure 1.3: The relative amount of phytoplankton (termed P), cDOM (termed Y) and suspended material (termed S) characterizes the categorization of Case I and II waters. Each side of the figure shows the relative contribution from each substance. A-E indicates different subdivisions of the broad categorization of Case I and Case II; A – characteristic for coastal waters dominated by river-run off from areas rich in topsoil (terrestrial cDOM component), B – typical for the high arctic regions where river run off transports particles not dominated by topsoil, C and D – characteristic for open ocean water, high in phytoplankton and not substantially affected by river-run off from land, E – typically Norwegian and Siberian shallow productive areas influenced by both phytoplankton and cDOM. (Johnsen et al 2009).

For any object to be visible, it requires scattering of light back to the observer (eye or camera sensor). Due to the molecular scattering in water of the shorter wavelengths (blue) together with absorption of the longer wavelengths (green and red), the ocean in general reflects a blue colour (Raman, 1922). Attenuation in Case I waters is mainly comprised by the seawater itself and phytoplankton (termed P in Fig 1.3). As phytoplankton has shown to have a distinct absorption pattern with two peaks in the blue (440 nm) and the red (675 nm) wavebands due to mainly Chl *a* (Kishino et al. 1985; Kirk 1994) and the natural attenuation of red from the seawater itself, images taken in Case I waters is expected to have a blue to green hue. In Case II waters, the IOP composition is more diverged against cDOM and TSM contribution (Fig. 1.3). As cDOM absorbs mainly in the blue to green part of the spectrum (Bricaud et al. 1981) images taken in cDOM (termed Y in Fig 1.3) dominated waters will have a yellow hue. TSM (termed S in Fig 1.3) however, is an umbrella term for light scattering particles from various sources suspended in the seawater (Owen 1973; Kirk 1994). Scattering of light affects the sharpness and contrast in images through the blurred perception particles in front of the camera gives. Forward scattered light gives generally a blurred perception, where backscattered light affect mainly the contrast. Imagine taking images thorough a glass of milk; it appears white as milk molecules scatter the light back to the camera, without any substantial absorption, but is not possible to see through (as a total reflection of 400-700 nm gives a white colour, see review by Johnsen et al. 2009).

For any given wavelength, the IOP in water are specified in the terms of the absorption a(λ), and scattering coefficients b(λ), with units of 1/attenuation length (m^{-1}) which in turn gives the light beam attenuation coefficient c(λ) (Eq. 1.1 and 1.2).

$$c = a + b \qquad (1.1)$$

$$c\ total(\lambda) = c\ CDOM(\lambda) + c\ CHLa(\lambda) + c\ TSM(\lambda) + c\ water(\lambda) \qquad (1.2)$$

Absorption is linearly proportional with concentration (Beer 1852) and the amount of IOP will affect the attenuation length of light in water. As a result of different absorption spectrums, the reflection of colours will vary between different water types depending on amount of contribution from the different IOP. The concentration of IOP and the distance to the object of interest (OOI) is therefore an important factor when evaluating image quality (subjective measure of the perceived image degradation).

Technical constraints with underwater photography and illumination

In addition to light attenuation by IOP in seawater the technical constraints that follow the construction of a camera system and light source also affect the image quality, i.e; light and spectral sensitivity, size and type of imaging sensor, exposure control in the camera, focal length of the lens and the colour temperature and illumination area from the light source.

When analysing images with respect to identifying organisms, the type and size of the imaging sensor is important for the spatial, spectral and radiometric resolution in the image (Johnsen et al. 2013). The spatial resolution (often given in kilometres, meters or millimetres) is defined by how small an object can be and still be distinguishable per image pixel, which will be affected by numbers of pixels that cover the OOI. When the photographer increases the distance from the OOI, a larger area will be photographed, i.e. lower number of pixels per area captured in the image. The spatial resolution in an image taken by polar orbiting satellites for example has a spatial resolution ranging from 300-1200 m per image pixel (Johnsen et al.

2009), in contrast, an ROV flying 2 m over the seafloor can have a resolution down to 2-10 mm (Johnsen et al. 2013). When considering spatial resolution, an important aspect is the noise produced by the sensor itself (dark current) (Johnsen et al. 2013). Noise appears as a blurring of the image, highly affected by the dark current due to a consistent production of random inaccuracies when light is converted to an electric signal, easily seen when illumination is limited. Noise from the dark current is highly temperature sensitive, and is more or less always present in an image.

The radiometric resolution is defined by how many levels of light the sensor can capture (Mouroulis et al. 2012). This will be of great importance when the images are exposed to low light environments, which often is the case under water beneath the photic zone. The levels of light are directly linked to levels of colour that is produced in the camera, also abbreviated as dynamic range. In the same way as for human vision, where colours is a mixed signal from three receptors in the red, green and blue wavebands, colours in camera images is a product of pixel sensitivity of three RGB wavebands. However, the camera RGB-model is only an approximation as the human photoreceptors . A common dynamic range is cameras with 8 bits per pixel, which refers to 256 RGB intensities per RGB image pixel. The term *bits* refer to the amount of electric signal the pixels is able to convert to colour intensity.

Underwater imaging is rarely endorsed with enough solar radiation for sufficient lightning conditions. Artificial light sources are then the solution, but suffer from non-uniform illumination of OOI (Garcia et al. 2002), varying spectral composition, often indicated by different colour temperatures in Kelvin (Vasilescu et al. 2011). A camera balances all colours in the image from what it senses as the white colour based on a programmed colour temperature references (i.e. from artificial light sources as tungsten/halogen, fluorescent, and daylight), denoted as white balancing (WB) (ref webpage nr.1). In this way the camera can overcome, to some extent, the complication with different colour temperatures. However, it has been shown as to function poorly when it tries to do this automatically (AWB) (ref webpage nr.1). By putting the camera with AWB, this correction is often not good enough to provide true white balance and often comes out greenish, reddish or with a bluish hue. By applying manual white balance using a ”colour temperature” that adjust for a given light source used in an dark underwater environment, such as a tungsten/halogen lamp white balance – the user may have a better colour information control and can therefore relate changes in colours to the IOP in the water masses.

The most important property of the lens is the *focal length* (FL) which is the distance between the lens and imaging sensor, usually expressed in millimetres (mm) (ref webpage nr. 2). The focal length determines the field of view (FOV). Shorter FL has a larger angle of the FOV than the longer ones, e.g. FL on 14 mm has a diagonal angle of 114^o and FL on 24 mm has a diagonal angle of 84^o. When increasing the FL, and the view angle decreases, it results in projecting a narrower area onto the imaging sensor, giving the image a magnitude effect. A bird photographer will e.g. choose lenses with large FL to get closer to the birds. In digital photography, the reference format of the imaging sensor is 35 mm film format (24mm x 36 mm). Most camera produces sensors smaller than 24x35 mm (crop size of 1), which results in a more narrow FOV. It is commonly called that the image is subjected to a crop factor which is related to the ratio of the dimensions of the image sensor compared to the reference film format. The crop factor is also referred to as the focal length multiplier (FLM) as the smaller sensor narrows the FOV resulting in an image with the same measures as if a larger FL had been used.

When it comes to image quality, the amount of light reaching the sensor is crucial. The aperture of the lens, shutter speed and the light sensitivity, the latter is also often termed “gain” (abbreviates as ISO, International Standards Organization, note that also ASA and DIN are two other scales used for camera light sensitivity settings) are the settings that can adjust the exposure according to the level of light available. Imaging in low-light environments, the low amount of light available can be adjusted for, but comes with some trade off effects. The sensors sensitivity to light is abbreviated as ISO and is given in numbers from 100 up to several thousands. When increasing the light sensitivity (gain) of the sensor, which technically is a digital amplification of the signal, the noise is also amplified. When the ISO is tuned up the noise is larger, but image is brighter, i.e. a trade-off effect. If more light is needed to the camera sensor to obtain correct exposure, the shutter speed is usually between 1/30 - 1/500 of a second. At shutter speed lower than 1/30 of a second often results in a blurred image due to image movements. The aperture can also be adjusted and opened to pass more light to the sensor, but the trade-off is decrease of depth of field (DOF). Smaller sensor requires a narrowing of the light beam, which increased the DOF. Exploitation of this effect is often used in video cameras to get a high DOF in the video. The drawback is however a low spatial resolution due to the size of the sensor.

Organization of the thesis

Section [Material and methods] describes experimental setups as well as a description of image quality (colour and contrast) measurements in images and sensor measurements of irradiance and IOP concentrations. All findings are presented in the [Result] section along with general explanation of graphs and tables. [Discussion] explains trends and responses shown in result and provides suggestions to how the findings can be used in further work with image analysis and use of different platforms to enhance information obtained from images. [Conclusion] summarises the most important findings from the work done through this master thesis.

Scope of work

- Evaluate the effect of RGB colour and contrast alterations in underwater images as a function of varying concentrations from IOP, and as a function of distance (optical path length).
- Measure the absorption and scattering coefficients of discrete IOP components under controlled conditions (laboratory) and relate this information to elucidate underwater image contrast, sharpness and colour quality.
- Investigate the spatial resolution of *in situ* images of benthic organisms as a function of three distances.
- Evaluate the output from artificial light sources; one in air (LED lamp) and three in water (xenon, LED and flash)
- Evaluate the image quality between three cameras and relate this by using the instrument carrying platforms ROV and SCUBA divers.

2 Materials and Methods

The *in situ* underwater images were collected in Trondheimsfjorden 17th of December 2013, in the bay outside Trondheim biological station (TBS) (Fig 2.1). Characteristics for the Trondheimsfjord is the great supply of river water, carrying with it high amounts of organic and inorganic substances. The average annual river discharge is approximately 21.9 km^3. The seasurface is therefore dominated to some extent of brackish water. A substantial amount of CDOM is also carried from the Baltic sea with the north going coastal stream (Sakshaug 2000).

Figure 2.1: Map of the area where the *in situ* underwater images was taken. The coordinates (degrees minutes seconds) for the site was approximately: 63 26`30.04” (latitude) and 10 20`58.26” (longitude). The upper right image shows the depth curves in the water, and the red dot with the arrow indicates the site of investigation at approximately 8 m.

Collection of Underwater images

The object of interest (OOI) was a stone wall fouled with benthic organisms. The images were taken by Self Contained Underwater Breathing Apparaturs (SCUBA) divers and an ROV (Minerva, NTNU) in one operation, after sunset to avoid natural sunlight (Fig 2.2). The source of illumination was artificial light sources, and is listed in Table 2.x. Spcifications for camera systems is listed in Table 2.1. The distance from the OOI to the ROV was measured by a side scan sonar (SSS), and additionally calibrated post-dive with reference images in air (see section below).

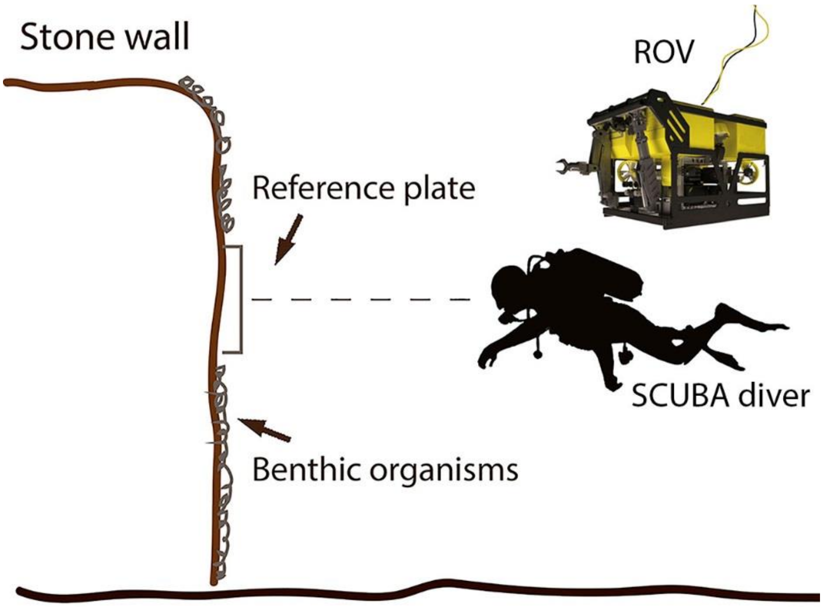

Figure 2.2 – Illustration of SCUBA divers and the ROV photographing a stone wall fouled with benthic organisms. A white reference plate with a reference colour palette was placed in the middle of the wall to appear in every image (Illustration by Ingrid Kjerstad).

Table 2.1 – Specifications of camera system and settings for photography/video taken by SCUBA and ROV.

	Platform		
	SCUBA	**ROV**	**ROV**
Camera	Canon 5D EOS Mark II	Sony HD – video	Prosilica GE 4000C
Lens	Canon EF 14 mm f/2.8 II USM		Nikon 24mm f/2.8D AF Nikkor
- Focal length	14 mm	3mm – 9mm	24 mm
House	Subal underwater house 5D MII	Custom for Minerva	Custom for Minerva
Port	Dome (DP-230 + EXR40)	Flat	Flat
Settings:			
- Aperture	f/22	f/1.2-2.1	f/2.8
- White balance	Daylight	Auto	Auto
- Sensor type	CMOS	CMOS 5 V	CCD
- ISO	2000	Auto	Auto
- Sensor size	36 x 24 mm (full format)	5.37 x 4.04 mm (crop factor: 6.44)	36 x 24 mm (full format)
- Pixel resolution	21 mega pixels	1920 x 1080	10.1 mega pixels
- File size	33.9 MB	109 Kb	1.57 Mb

Calibration of distance

The distances from the OOI to the camera systems for the two platforms listed in table 2.1 was calibrated by images taken in air from 0.5, 1, 1.5, 2 and 2.5 m, using the same reference plate as used *in situ*. The pixels vertically covering the reference plate were counted in the images from known distances in air and compared to images of the reference plate from the stone wall. The distance was calculated from equation 2.3. However, as the reference plate in the underwater location did not appear exactly at the same angle as for the calibration situation, which was perpendicular to the camera photography axis, distances could only be estimated approximately.

$$\frac{d_{water}}{d_{air}} = 1{,}34^* \qquad (2.3)$$

d_{water} = distance in water

d_{air} = distance in air

* for the dome port this factor is equal to 1.

The refraction of light from air to water enlarges images with a factor of 1.34 (Herschel 1828), which was calibrated for when flat ports were used. For the images taken with a dome port camera, this refraction is more or less eliminated by the dome port construction and did not need additional calibration (Shortis 2009).

Aquarium experimental set up

To evaluate how Chl *a*, CDOM and TSM concentrations would change the optical properties of underwater images, a stereo camera (Canon 5D Mark II) took images through an aquarium filled with unfiltered seawater and the respective substances (Fig2.3). To obtain a concentration gradient from high -low for four concentrations, the start concentrations was diluted three times with unfiltered seawater taken from 100 m sea depth. Three image series were conducted of two reflectance reference plates (Spectralon, USA) (Fig 2.4):

1. White reflectance reference standard (reflecting 98% of the light in the range 400-700 nm)
2. Grey scaled reflectance standard (absorbing according to the grey scale level)

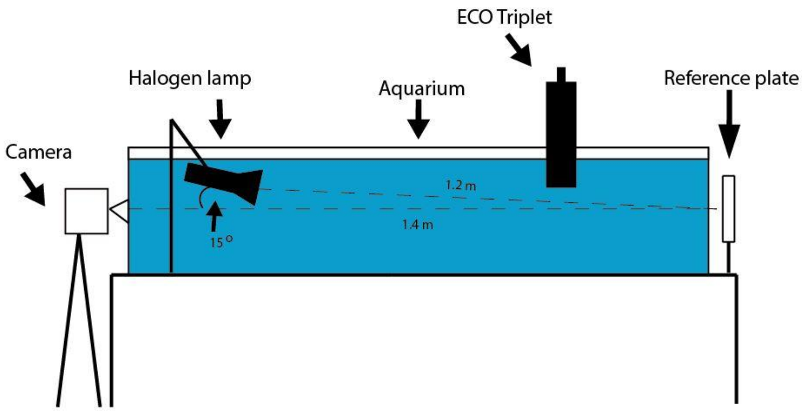

Figure 2.3 – Images as a function of inherent optical properties (IOP) in saltwater. Images were taken through the saltwater with different IOP properties, i.e. different concentrations of phytoplankton (Chl a), coloured dissolved organic matter (CDOM) and total suspended matter (TSM, marine clay. The light path from the lamp to the reference plate was 1.2 m and 1.4 m (total optical pathway of 2.6 m) to the camera. The ECO Triplet measured IOPs at different concentrations). The aquarium dimensions were; width: 0.15 m x: depth: 0.40m x length: 1.4 m (Illustration: Ingrid Kjerstad)

Table 2.2: Images series photographed through four concentrations of Chl a, CDOM, TSM towards reference plates (reflectance standards) 1 and 2.

Image series	Reference plate	Substance	Measured parameter	# Concentrations (measured with ECO Triplet)	# pictures taken
1	White and grey-scaled	Phytoplankton	Chl *a*	4	24
2	White and grey-scaled	Poly phenols	CDOM	4	24
3	White and grey-scaled	Marine clay	TSM	4	24

Figure 2.4 – White and greyscale spectral reference plate with colour palette above, picture taken in air from 1.4 m. White balance on camera set to Tungsten and lamp was Halogen (Green Force).

The camera and the reference plates were set up on each of the short sides of the aquarium (Fig. 2), together with an external light source (Green Force "Pro Head Solux Halogen Lighthead", Erembodegem – Belgium) mounted as shown in figure 2.3. The light-path from the lamp to the camera was 2.6 m and the lamp was tilted 15 degrees down from the horizontal plane.

The substances used were a culture of phytoplankton (*Phaeodactylum tricornutum),* poly phenols from decaying tissue of kelp (*Saccharina latissima, Fucus serratus* and *Laminaria digitata)* and marine clay to resemble respectively Chl *a,* CDOM and TSM. The poly phenols were filtered through a glass fiber filter (Whatman, type GF-F, pore size of 0.7µm). To avoid aggregates, the marine clay was filtered through a 1.5 mm mesh diameter sill. Concentrations were measured between each dilution by an optical three port sensor (Wetlabs, ECO Triplet, Philomath – USA, Table 2.3, Fig 2.3) and the irradiance detected at the camera lens was measured with the ECO PAR sensor. The concentration of Chl *a (*µg L^{-1}) and CDOM (ppb) were measured by means of fluorescence and TSM (m^{-1}), was measured as back scattered (bb) light at 700 nm. Normally the measurement of TSM gives an assessment on backscattered light from particles, but for simplicity, this is referred to as a measure of *concentrations* of TSM.

Table 2.3 – Optical specifications for the ECO Triplet fluorometric (Chl a and CDOM) and light scattering (TSM) measurements. Light emitting diode (LED) is the light source for the excitation. The data collection frequency for the ECO Triplet was 1 Hz, and an average from 30 samples from each port is used to present the concentrations. When the variation coefficient for the averages exceeded 10 %, this is noted. However, in general the concentrations are given as absolute values.

Parameter	Wavelength (Excitation/Emitting)	Range	Sensitivity
Chl *a*	470/695 nm	0–50 µg L^{-1}	0.025
CDOM	370/460 nm	0–375 ppb	0.184
TSM	700/700 nm	0–5 m^{-1}	0.03

Measurement of absorption and scattering coefficient for Chl *a*, CDOM and TSM

To find the absorption coefficients to Chl *a* and CDOM and the scattering coefficient TSM, the optical density (OD, dimensionless) from seven dilutions were measured by a spectrophotometer (UNICAM UV 500, Waltham, USA) through a five cm glass cuvette. The initial concentrations were diluted seven times with filtered seawater (Whatman, type GF-F glass microfiber, pore size 0.7µm), and three parallels were measured for each dilution. Optical density for all the spectra's was corrected for light scattering by subtracting the average OD measured between 750-800 nm. In the dilutions the concentration of Chl *a*, CDOM and TSM were measured by the ECO Triplet. OD (λ) is dependent on light absorption, hence the absorption and scattering coefficient, a(λ) and b(λ) (m^{-1}) were determined using the following equation (Kirk, 1994):

$$a(\lambda) = b(\lambda) = \frac{OD(\lambda) \times 2{,}3}{OPL} \qquad (2.1)$$

a(λ) and b(λ) = absorption and scattering coefficients in m^{-1}

OPL = optical path length of 0.05 m

OD (λ) = optical density

Image analysis

Images from the aquarium experiment and the *in situ* underwater images were analysed based on how the IOPs and distance changed the composition of RGB (red, green, blue) colours in the images of the white spectral plate, on the RGB output from organisms and how the contrasts were altered on the grey-scaled spectral plate. This was measured by the software Adobe Photoshop Creative Cloud (Adobe Systems, version 14.2.1, San Jose - USA) with the colour measurement tool from an average of 25 pixels (5x5). The dynamic range was set at 8 bits giving each pixel average a value between 0-255 for each colour (red, green or blue). The colour composition is calculated as per cent (%) of max intensity from each colour channel.

For the contrast measurements, the measurement tool was set to measure the grey-intensity in each pixel on a scale from 0 – 100 %, where 0 % is black and 100 % is white. The contrast was given by the fraction of the intensity between the light and the dark grey (see Fig 2.4). I.e. when grey intensity at the light grey was measured to 30 % grey-intensity and the dark grey was measured to 70 %, this resulted in a contrast of 57 %.

For colour, contrast and light intensities measurements, One Way analysis of variance (ANOVA) tests in the software SPSS Statistics (IBM, version 21.0, 2005, New York – USA) was used to compare differences in the average means. The data showed to not be normal distributed, most likely to a low number of measurements. The ANOVA test was still computed due to that non-normality is considered not to affect Type 1 error rate substantially. Whether the Levenes tests of homogeneity of variances were significant or not, a Welch-ANOVA or an ordinary ANOVA test was computed for the results of saturation of RGB colours from images in four concentrations of Chlorophyll *a*, CDOM or TSM.

Benthic species were identified and counted from the SCUBA *in situ* images, from three distances. Three areas in each image were selected as replicate measurements as there was only one image from each distance. The averages form each image were analysed with linear regression in IBM SPSS Statistics (version 21.0, 2005, New York - USA) to predict the number of Serpulidae as a function of distance.

Light sources for underwater photography

To show the distribution of light intensity from an artificial light source, the illumination evenness from two lamps consisting of four light emitting diodes (LED) each (Green Force, Erembodegem – Belgium) with and without diffusers, were measured with an irradiance (E) sensor (ECO Par, Wetlabs, Philomath, USA) (Table 2.4) in air. A white projector sheet (2 m x 2 m) was illuminated in steps of 1m distances from 1 to 4 m where the light source was perpendicular to the sheet. The light cone on the projector sheet was photographed with a stereo camera (Canon 5D Mark II), and the irradiance measured at 15 points (1.5 cm from the sheet with an angle of 45^o) evenly distributed. The light source bracket was assembled on a tripod together with the camera (Fig. 2.5 A-C).

Table 2.3 – Overview of light source specifications used when conducting the *in situ* underwater images.

Light source	Colour temperature	Beam	Power (Watt)	Dimensions (ø x L)	Platform
Green Force LED (Quadristar)	6300 K	40^o	13 W	44mm x 86mm	SCUBA
Green Force Halogen 24W (Pro Head Solux)	4.700 K	36^o	35 W	70mm x 95mm	SCUBA
Xenon	-	50^0	-	44mm x 86mm	SCUBA
Subtronic Flash	4300 -5200K	112^o	-	115mm x110 mm	SCUBA
Osram Metalhalide (HMI)	6,000 K	> 180^o	400 W	100 mm (diameter)	ROV

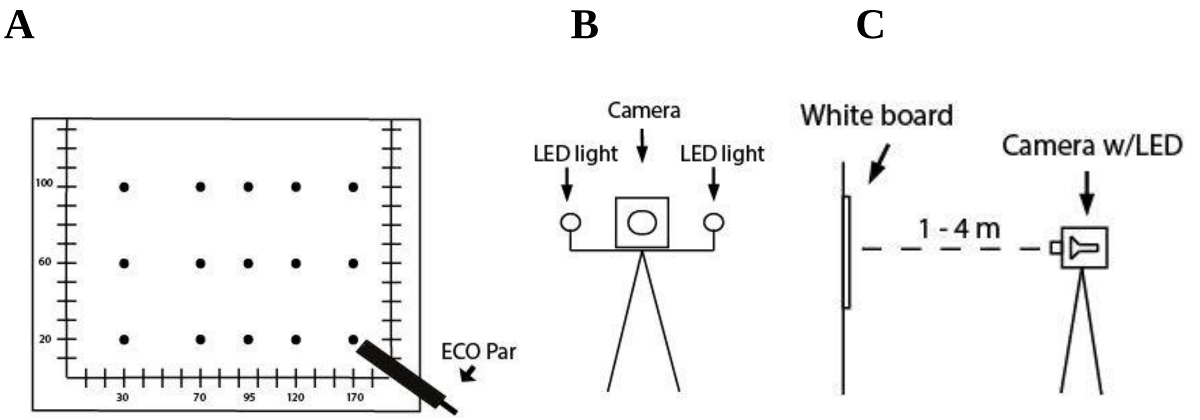

Figure 2.5(A-C) – Illustration of the white projector sheet showing the positioning of the ECO irradiance sensor (PAR, 400-700 nm) (A) and camera and LED configuration on the tripod (B). Measurements were made at 1-4 m (1 m increment) from the projector sheet. LED denotes LED lamp source (C) (Illustration: Ingrid Kjerstad).

Table 2.4 – Optical specifications for the “Eco Par” irradiance sensor. Sampling speed was 1Hz, and an average from 30 measurements was used to make an absolute value. The coefficient of variation for the average value did not exceed 10 % (±CV% of mean value).

Field of view	**Collector area**	**Detectors**	**Cosine response**	**Range**
Spectrally corrected cosine response	86 mm^2	Custom 17 mm^2 silicon photodiode	Within 3% at 0–60 °C	0–6500 µmol photons/m^2/s

3 Results

Inherent Optical properties (IOP) measured as spectral light absorption and scattering from phytoplankton (Phaeodactylum tricornutum), CDOM and TSM

Phaeodactylum tricornutum had two light absorption peaks in the blue and red spectra, respectively at 440-450 nm and 680-690 nm (Fig. 3.1). The absorption coefficient for *P. tricornutum* at 675 nm, were 4.6 m^{-1} (CV 8 %), where the concentration of Chl *a* was measured fluorometrically to 469 µg Chl *a* L^{-1} (CV 2.8 %). The poly phenols from kelp (CDOM) absorbed mostly in the entire blue spectra from 400-500 nm (Fig. 3.1), where the fluorometrically measured concentration of 25 ppb corresponded to an absorption coefficient on 16.8 m^{-1} at 400 nm. The TSM does not absorb light, so the spectra for TSM are forward scattered light. The values measured by the spectrophotometer corresponds to the concentration given as backscattered values measured by the ECO Triplet, where forward scattering at 400 nm measured to 32 m^{-1} corresponds to a backscattered value on 4.41 m^{-1}.

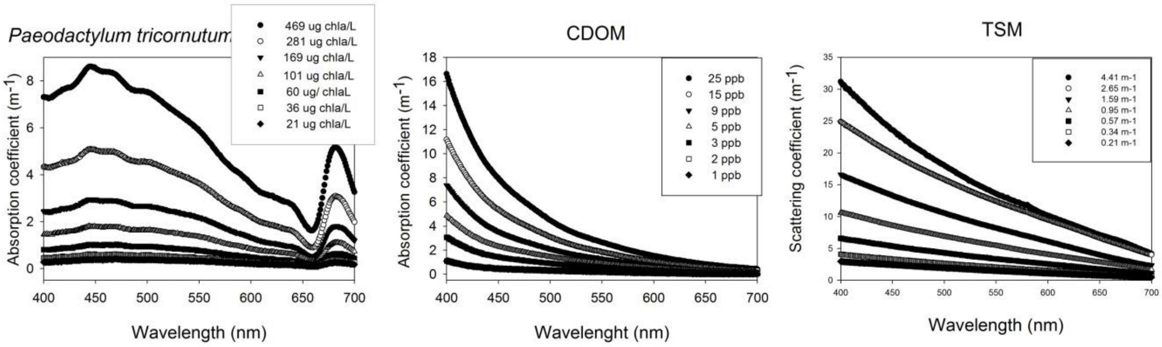

Figure 3.1: The absorption spectra for *P. tricornutum* and CDOM and the scattering spectra for TSM were measured at seven dilutions. The concentrations for the three substances is measured with the ECO Triplet sensor in a dilution and calculated to the concentration in the seven dilutions. The concentrations are presented in the upper right corner, and correspond respectively to the absorption/scattering spectra from high to low in the graph.

The effect of Inherent optical properties (IOP) on RGB colour and contrast in underwater images

The images taken of the two spectral reference standard plates (white and grey-scaled) in seawater dominated by either *P. tricornutum* (further referred to as Chl *a*), CDOM or TSM showed to be visually affected by the dominating substance (Fig. 3.2 and 3.3). This was also clear from the effect on RBG colour and contrast addressed in the two next sections.

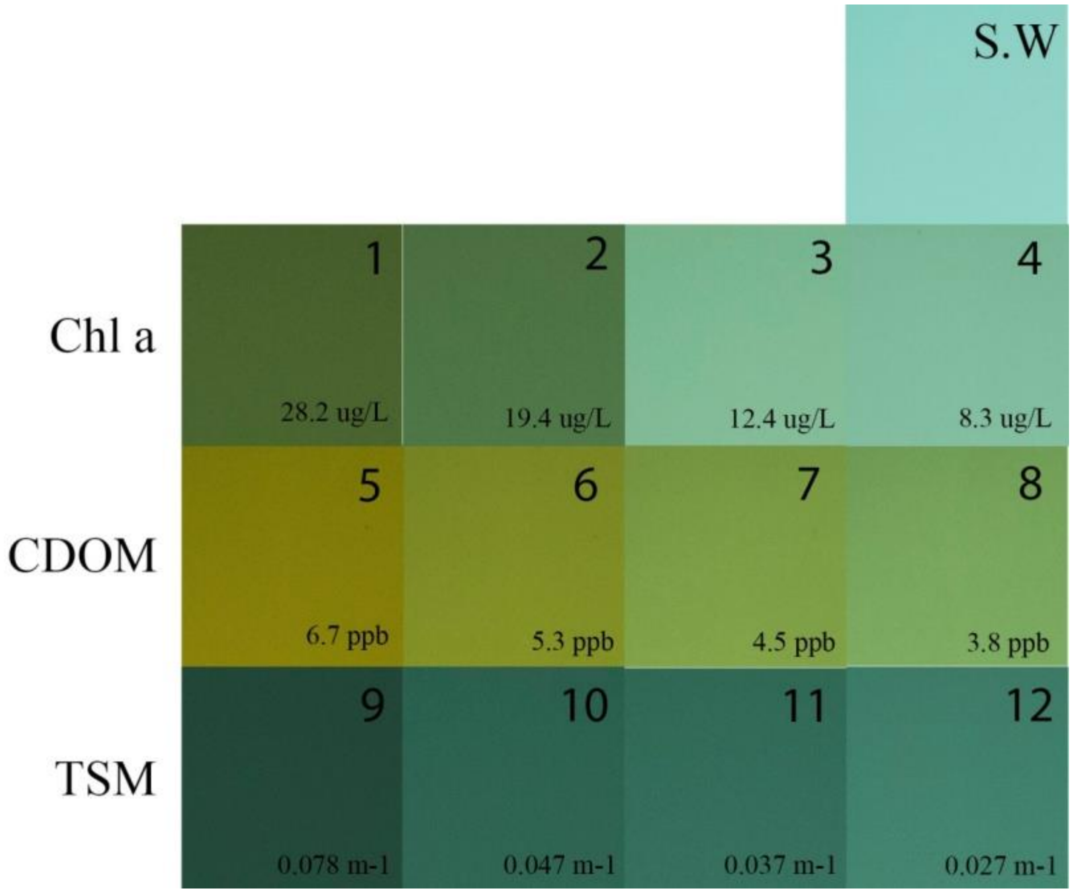

Figure 3.2: A Mosaic of the images of the white spectral reference standard. Box 1-12 shows how the image is being coloured by Chl *a*, CDOM and TSM as a function of decreasing concentration. The concentrations of each substance are marked in the lower right corner. The box marked with "S.W" represents the image taken in unfiltered seawater indicating "clear saltwater".

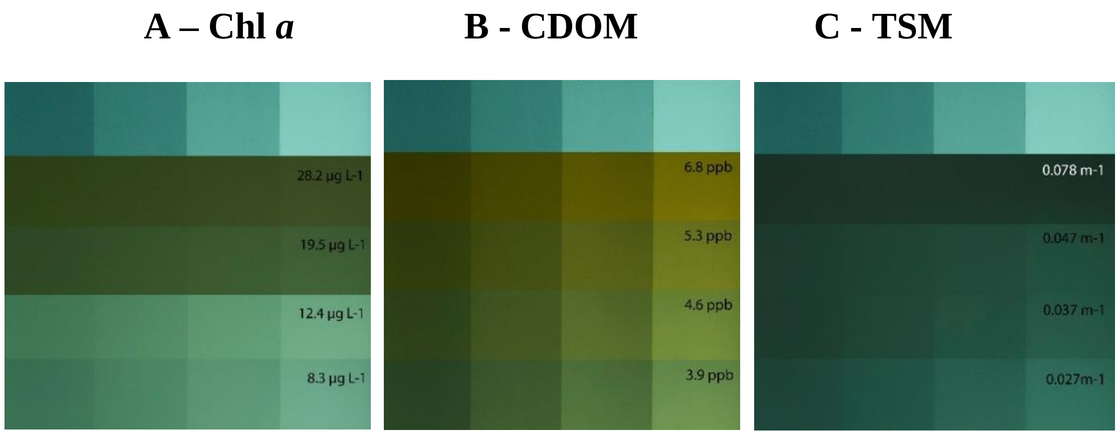

Figure 3.3: A mosaic of the images of the grey scaled reference standard (four shades of grey) from the image series dominated by different [Chl *a*] (A), [CDOM] (B) and [TSM] (C). The mosaic figure is build up from one vertical crop from each image of the reference plate, and is represented with the concentration marked to the right in each stripe. The top layer in A-C is from the reference plate in unfiltered saltwater indicating "clear seawater".

- RGB colour

The RGB colours in the images dominated by Chl *a*, CDOM and TSM showed to vary between the substance and between concentrations (Fig. 3.3). In the following sections, one-way ANOVA tests were computed to test when the mean intensity of the RGB colours was significantly different between concentrations in each image series.

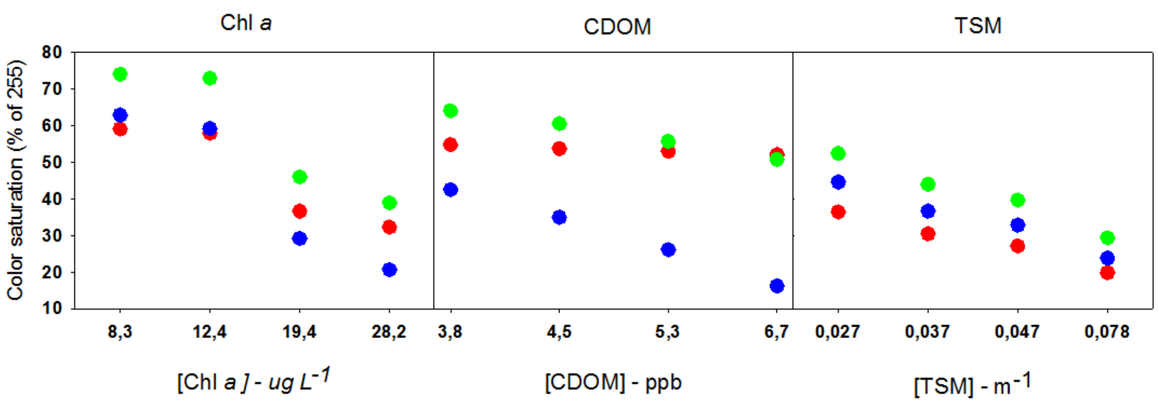

Figure 3.4: Scatter plot of colour intensity (%) of the red, green and blue colour channel in the image series of the white spectral reference standard dominated by Chl *a*, CDOM and TSM. Standard deviations from the results are not marked with error bars, as they were under 10 % for all measurements.

Chl *a*

The intensity of the red colour channel in images taken in decreasing [Chl *a*] increased significantly ($P < 0.0005$) as a result of decreasing concentration. This were also true for the green ($P < 0.0005$) and blue ($P < 0.0005$) colour channels. However, the post hoc test (Games-Howell) revealed that there were no significant difference, for all three colours (red: $p = 0.892$, green: $p = 0.895$, blue: $p = 0.156$), in the images between the next lowest (12.4 µg L^{-1}) and the lowest (8.3 µg L^{-1}) Chl *a* concentration.

CDOM

The intensity of the red colour channel showed no sig. difference between [CDOM] ($P = 0.334$). The intensity of the green and blue colour channel increased significantly ($P < 0.0005$, $P< 0.0005$) with increased [CDOM]. The post hoc test (Tukey HSD) revealed however that there was no sig. difference ($P = 0.194$) between green in the images taken in 4.5 and 3.8 ppb [CDOM].

TSM

For images taken in TSM dominated water, the intensity of RGB colours equally decreased significantly ($P< 0.0005$) for all three colours between all images. A Games-Howell test did not reveal any exceptions.

- **Contrast**

The contrast measure ments on the grey-scaled reference plate showed to decrease significantly between all images taken in dominating [Chl *a*], [CDOM] and [TSM] comprising an equal significance value (P<0.0005) (Fig. 3.4).

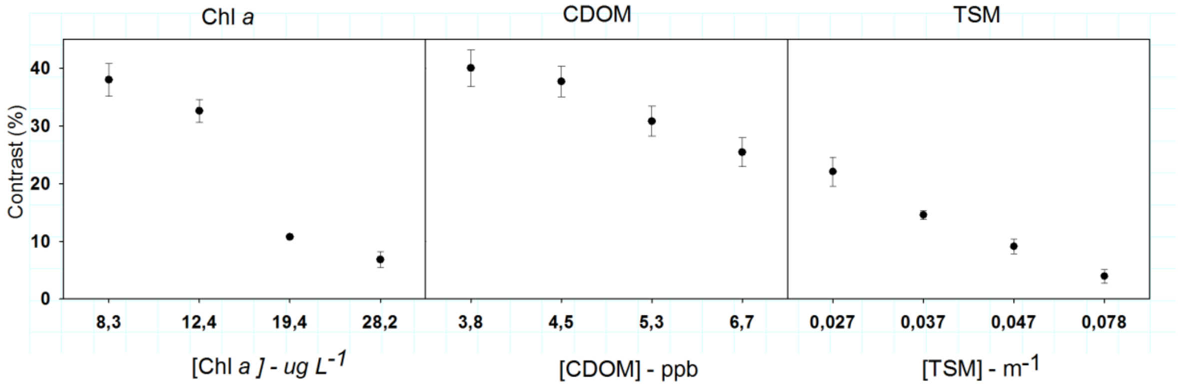

Figure 3.5: Scatter plot of the measured contrast (measured as difference in brightness) between the dark and the light grey scale in the grey-scaled reference plate for the images taken in dominating [Chl *a*], [CDOM] and [TSM].

Underwater images from SCUBA and ROV

From the in situ image taken with SCUBA and ROV, the results shows that taxa identification success was lowered with increased imaging distance. Image formation was different between camera systems. Different light sources affect the illumination area and RGB colours in underwater images.

- **Taxa identification from SCUBA images taken from three distances (0.3, 0.8 and 1.1 m)**

A total of 14 taxa (identified to family and species) were identified in the selected areas for comparisons in the image taken with the Canon camera by SCUBA from 0.3 m. Identification was based on shape, texture and colour. When the distance to the OOI increased to 0.8 m and 1.1 m, the identification decreased to respectively 2 and 1 taxa (Table 3.1). Due to this substantial decrease, a statistical test to prove whether the decrease were significant or not, was considered unnecessary. The images are resized for printing in Fig. 3.6 together with an enlarged crop form each image.

Table 3.1 – Identified benthic organisms at 0.3, 0.8 and 1.1 m photographed with Canon (5D Mark II, lens: 14 mm, light source: Subtronic flash). The benthic organisms are divided into benthic group, phylum, family/sub family and species. For evaluation of identification success in the images, number of taxa (family and species) was used for investigation.

Classification level	Distance from OOI to camera		
	0.3 m	0.8 m	1.1 m
Benthic Group			
Ascidians	x	-	-
Calcareous polychaetes	x	x	x
Calcareous red algae	x	x	-
Leafy red algae	x	-	-
Sea star	x	-	-
Soft coral	x	-	-
Phylum			
Annelida	x	x	x
Chordata	x	-	-
Cnidaria	x	-	-
Echinodermata	x	-	-
Rhodophyta	x	x	-
Family/sub family			
Serpulidae	x	x	x
Spirorbinae (sub)	x	-	-
Hildenbrandiaceae	x	x	-
Asteriidae	x	-	-
Palmariaceae	x	-	-
Alcyoniidae	x	-	-
Species (Author)			
Pomatoceros triqueter (Linnaeus, 1758)	x	-	-
Placostegus tridentatus (Fabricius, 1779)	x	-	-
Hydroides norvegicus (Gunnerus, 1768)	x	-	-
Alcyonium digitatum (Linnaeus, 1758)	x	-	-
Didemnum albidum (Verrill, 1871)	x	-	-
Asterias rubens (Linnaeus, 1758)	x	-	-
Marthasterias glacialis (Linnaeus, 1758)	x	-	-
Ciona intestinalis (Linnaeus, 1767)	x	-	-

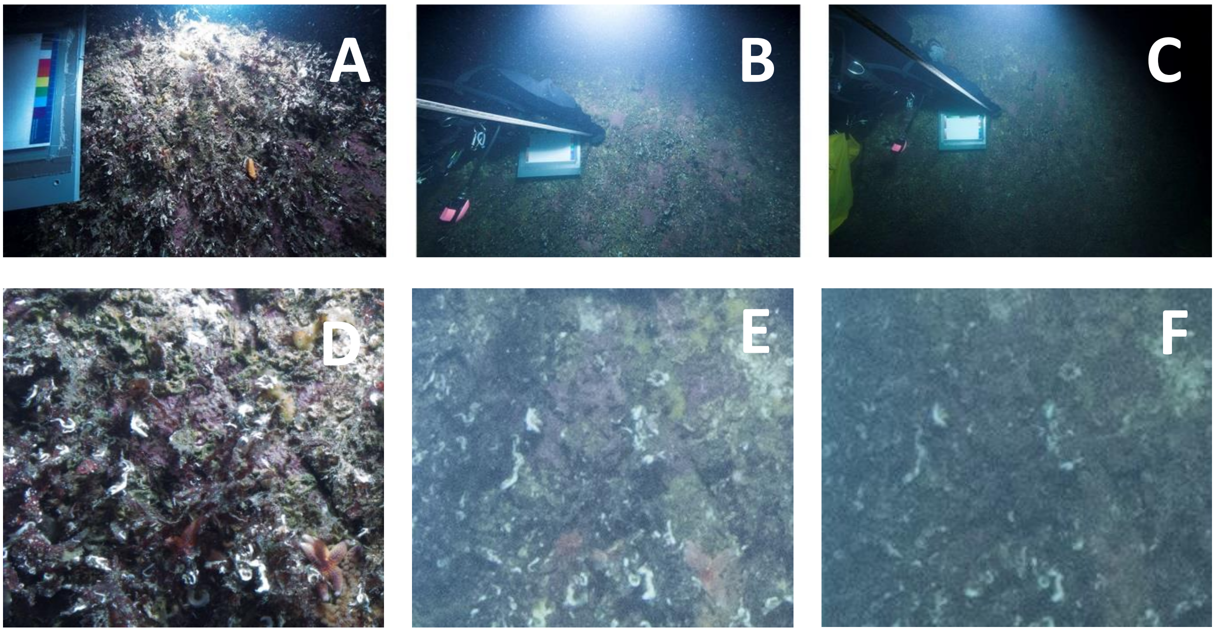

Figure 3.6: Images from SCUBA taken with the Canon camera (5D Mark II, l) (5D Mark II, lens: 14 mm, light source: Subtronic flash) from the distances; 0.3, 0.8 and 1.1 m, respectively marked with A-C. A resized crop from these images is marked respectively with D-F. The pixels size in the crops have been changed so that the area is presented in the same size.

- **Number of Serpulidae as a function of distance**

The only taxa that were detectable in all three distances were calcareous Serpulidae. As they occurred in various lengths from 0.5 – 2 cm, they were divided into two distributions based on length; small (length of 0.5 – 1 cm) and large (length of 1 – 2 cm). The organisms shorter than 0.5 cm were not counted, as the uncertainty of identification was considered too high. The diameter of the calcareous house differed also to some extent between individuals, but the length as a measure of size was considered sufficient.

It was detected in total 233 Serpulidae in the selected areas in the images taken from 0.3, 0.8 and 1.1 m (Fig. 3.7). Numbers of small Serpulidae in the image taken from 0.3 m had an average of 3.7 Serpulidae per 10 cm^2 (CV 24 %). For the images taken from 0.8 m and 1.1 m this average was respectively 0.89 (CV 58 %) and 0.68 (CV 51.96 %) per 10 cm^2. For the large Serpulidae a total of 69 organisms was identified with associated averages; image taken from 0.3 m: 0.81 per 10 cm^2 (CV 25 %), 0.8 m: 0.61 per 10 cm^2 (58.79 %) and 1.1 m: 0.13 per 10 cm^2 (CV 50 %). Linear regression established that distance could significantly predict number of Serpulidae, both small ($p = 0.001$) and large ($p = 0.016$) (Table 3.2). The goodness-of-fit (R^2) for the linear relationships was 0.791 and 0.587 for respectively small and large Serpulidae. This mean in turn that the distance accounted for respectively 79.1 % and 58.7 % of the variability in number of Serpulidae observed.

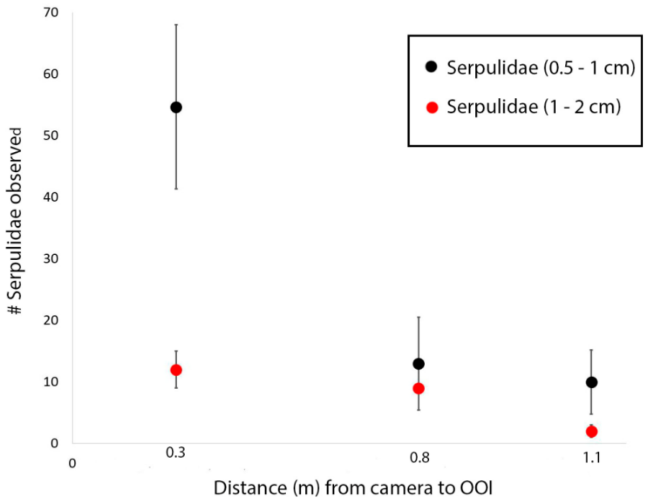

Figure 3.7: Numbers of identified Serpulidae as a function of the imaging distances; 0.3, 0.8 and 1.1m. The distance accounted for respectively 79.1% and 58.7 % of the variability of Serpulidae observed. Linear regression equations for the small and large size distributions is respectively; # Serpulidae = 68.891 – (58.639 x distance) and #Serpulidae = 16.347 – (11,837 x distance).

Image formation from Canon 5D Mark II, Prosilica GE-4000C, and Sony FCB-SE600 (HD-video)

The three images taken from approximately 1 m showed the effect of different focal lengths (FL) of the lenses associated with the SCUBA operated camera (Canon) and the on image formation. The image from the Canon camera was taken through a wide angle lens (FL - 14 mm, angle of view – 114^{o}), which captured a substantially larger area than the ROV cameras Prosilica (FL 24 mm, angle of view – 94.5^{o}) and Sony HD (22.4 mm, angle of view – 86^{o}) (Fig. 3.8). Notice the relative size of the reference plates and scale bars in the images in Figure 3.8. The illumination area between the images are also worth to notice, as the image from the SCUBA operated Canon camera (light source: Subtronic Flash) has very dark edges compared to the two images from the ROV cameras (light source: two HID lamps). The colours in the images seemed also to be different between the camera systems. The RGB colour output measured at a specimen of probably an *Alcyonium digitatum* (identified from an image taken from shorter distance) seems to have a higher red signal from the ROV-systems than the SCUBA image (Fig. 3.9, Table 3.3).

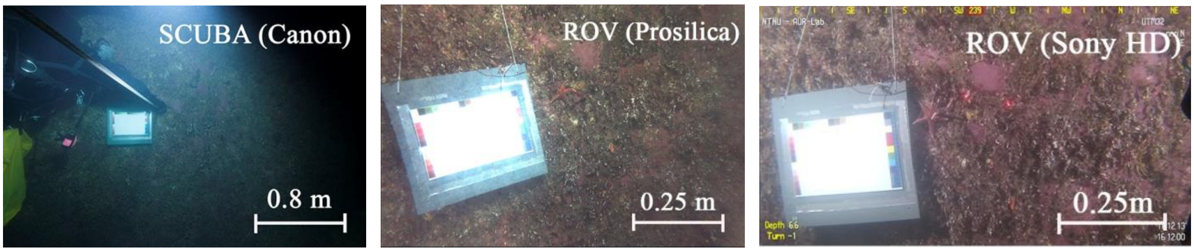

Figure 3.8: The relative field of view between the SCUBA operated Canon (FL 14 mm, angle of view - 114°) and the ROV operated Prosilica (FL 24 mm , angle of view - 94.5°) and Sony HD-Video (FL 22.4 mm, angle of view 86°). The image taken from the digital film produced by Sony HD-video has a slightly different construction (height x length) than Canon and Prosilica. Light source for SCUBA was Subtronic Flash, and two HID-lamps for ROV. The scale bars represent physical photographed area in metres. The images are resized for printing (i.e. the actual size of Sony HD-video image is approximately 10 times smaller than the Canon and Prosilica image).

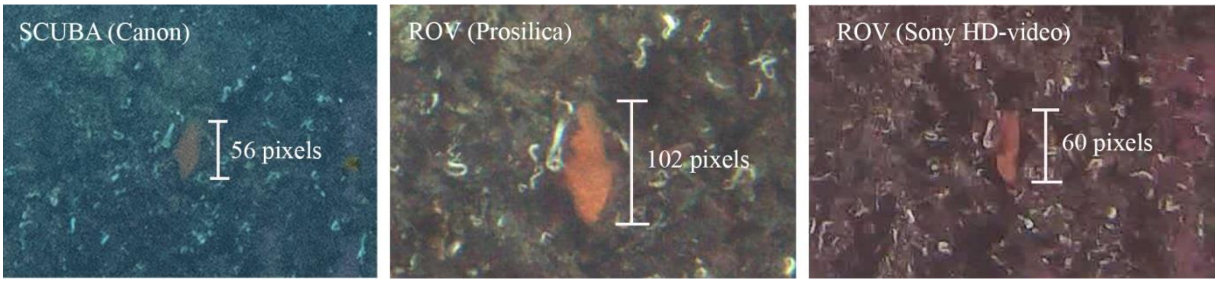

Figure 3.9: Crop of the images taken from approximately 1 m by the SCUBA operated Canon and ROV operated Prosilica and Sony HD-Video. Pixels vertically covering the *A. digitatum* (identified from a closer image) in images left to right were measured to: 56, 102 and 60 pixels. Light source, FL and angle of view are given in Fig. 3.8.

Table 3.3: RGB colour output measured at a specimen of *Alcynoim digitatum* in images taken with SCUBA operated Canon and ROV operated Prosilica and Sony HD – video. Coefficient of variation (CV) of colour measurements ranged from 1 – 6 % for all measurements, indicating a slightly uneven colour rendering from the texture as the measurement were taken at three different points on the specimen.

RGB colour	SCUBA (Canon)	ROV (Prosilica)	ROV (Sony HD-video)
Red	40 %	68 %	54 %
Green	40 %	46 %	37 %
Blue	40 %	36 %	35 %

Distance measurements with side scanning sonar

During the ROV survey the distance to the OOI was measured with a side scan sonar (SSS) mounted on the vehicle. To verify the SSS measurements post ROV survey, the images were calibrated from reference images in air from equation 2.3, and showed an overestimation in the range +/- 0.5 m.

Table 3.4: Distance from ROV to OOI measured by side scanning sonar compared to calibrated distance from reference images in air. Image 1-3 is taken by Prosilica GE-4000C.

Picture nr.	Distance measured by SSS	Calibrated distance
1	1 m	0.94 m
2	2 m	1.58 m
3	3 m	2.49 m

The effect of light source (LED, Xenon and Blitz) on illumination evenness and colour (SCUBA images)

- **Illumination area**

Different light sources affected the illumination area in the images taken by SCUBA (Canon) differently in terms of per cent illuminated area (Fig.3.10). The camera distance from the OOI was approximately the same, but the distance from the light source to the OOI differed, as visible in the images in Figure 3.10. This affected the illumination area where the LED source covered 17 % and the Xenon source covered 9 % of the image. The blitz covered a substantially larger area of 80 % of the image, as the Blitz was positioned together with the camera.

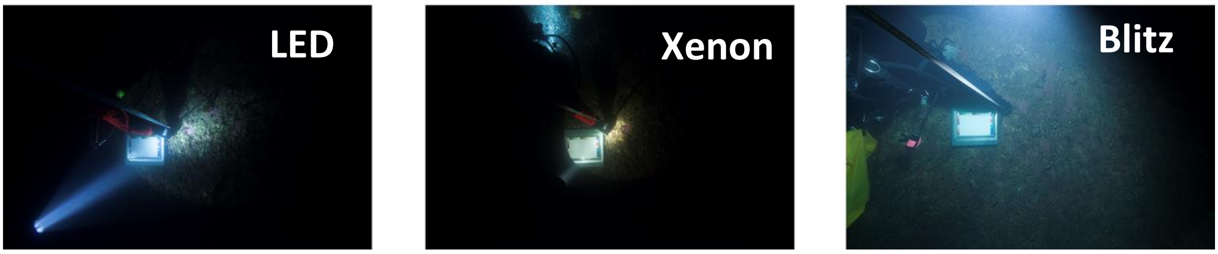

Figure 3.10 – Images taken by SCUBA (Canon) from approximately 1 m illuminated with LED, Xenon and blitz as marked in the upper right corner of each image. The illumination coverage between the three sources was 17 % (LED), 9 % (Xenon) and 80 % (Blitz).

- **RGB Colour**

The RGB colour intensities at the white reference plate in the SCUBA (Canon) images (imaging distance approximately 1 m) from the three light sources showed different trends according to the light source (Table 3.5). The intensity of all three RGB colours was highest when the blitz source was used. Between the Xenon and LED source the intensity of the red colour channel was highest (69 %) for the Xenon and lowest (45 %) for the LED, with the opposite trend for the blue colour channel (Table 3.5). Xenon showed higher (77 %) intensity of the green channel than the LED (61 %).

Table 3.5 – Effect of colour temperature from illumination source on underwater images taken by SCUBA operated camera (Canon 5D mark II). Intensity of red, blue and green in the reference colours red and blue from the reference colour palette. Max saturation of each colour is 255, and the saturations of red, blue and green are a fraction of this maximum.

Light source	Reference colour	Intensity of Red	Intensity of Green	Intensity of blue
LED	Red	45 %	61 %	78 %
Xenon	Red	69 %	77 %	70 %
Blitz	Red	79 %	91 %	96 %

The effect of distance and diffusors on illumination intensity from LED lamps

The illumination from two LED lamps showed to have an uneven distribution of irradiance (E), which is shown in Figure 3.11. However, the use of diffusers reduced this unevenness but reduced in general the E measured from the lamp.

The E measured in the centre of the light cone on the projector sheet from the LED lamps (L1 and L2) dropped with 82 and 88% as a function of distance in air (1-4 m) (Table 3.6). The illumination evenness, measured as E difference between centre- and surrounding points increased as a function of distance between light source and illuminated area (except for 1 m), when diffusers were used (Fig. 3.11).

Table 3.6: Irradiance (E, µmol photons $m^{-2}s^{-1}$) measured in the centre of the light cones from the two LEDs (L1 and L2) at 1-4 m distance. L1 and L2 are marked with "*w diff.*" when light diffusers were used.

Distance (m)	L1 (E)	L2 (E)	L1 w diff. (E)	L2 w diff. (E)	Relative diff. btw L1 and L1w diff.	Relative diff. btw L2 and L2w diff.
1 m	13.9	20.3	5.4	5.2	61,2 %	74,4 %
2 m	8.4	8.7	3.3	3.2	60,7 %	63,3 %
3 m	4.5	4.3	1.3	1.4	71,1 %	67,4 %
4 m	2.5	2.4	0.9	0.9	64 %	62,5 %
Attenuation between 1-4m	82 %	88,2 %	83,3 %	82,7 %	-	-

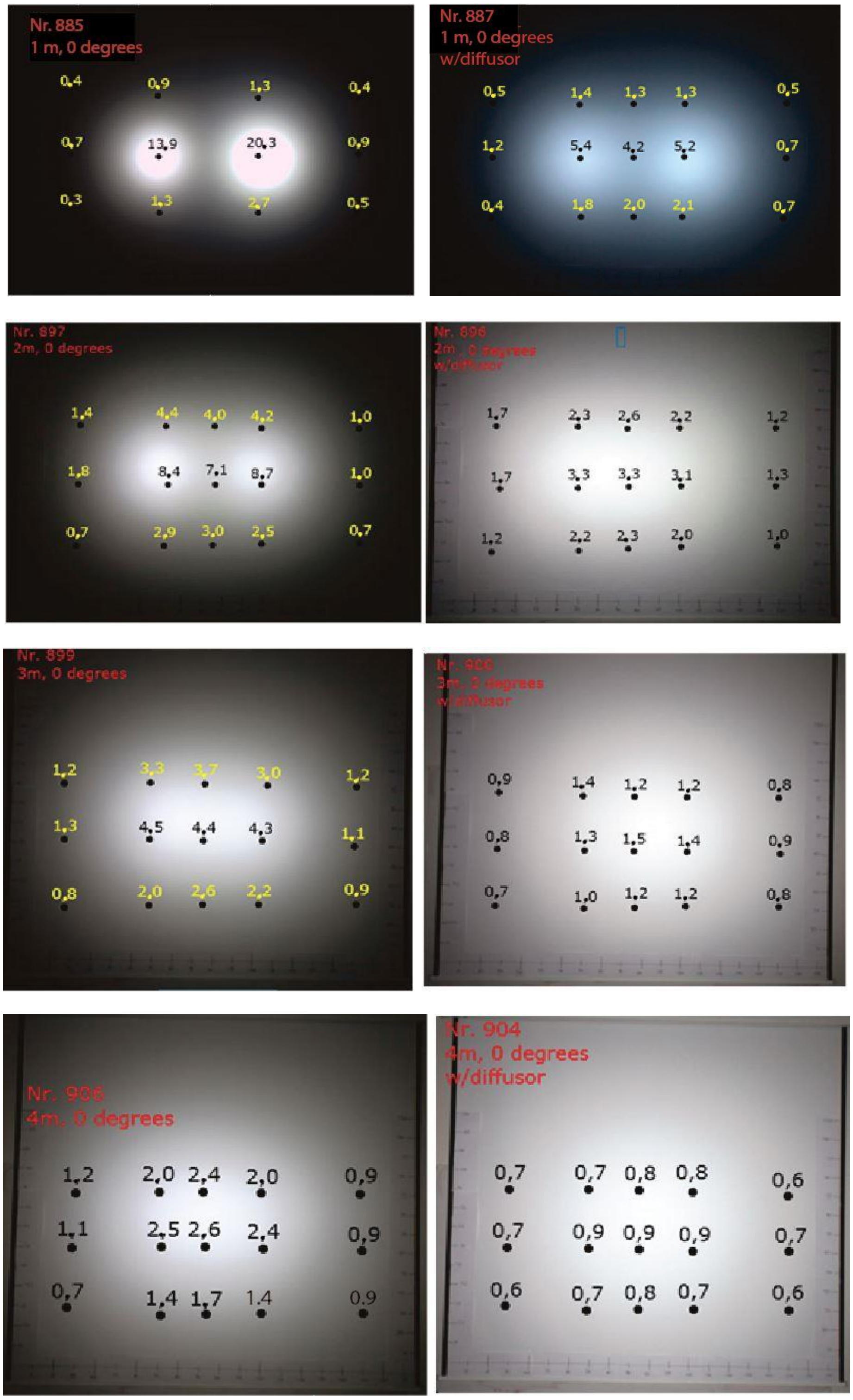

Figure 3.11: The illumination evenness, E (μ mol photons m^{-2} s^{-1}), measured at 1-4 m from the projector sheet to the camera/LED light source, without (left column of images) and with diffusers (right column). The black dots in each image represent where the ECO Par measurements took place across the projector sheet, with corresponding measured E above each point. Both LEDs were perpendicular to the sheet.

4 Discussion

The effect of inherent optical properties on underwater images with respect to RGB – colour and contrast

The results from this study showed that IOP significantly affected RGB colours (Fig. 3.2, Fig.3.4) and contrast in images (Fig 3.3, Fig. 3.4) relative to the absorption/scattering spectrums (Fig 3.1) for the three tested substances; phytoplankton (measured as Chl *a* concentration), poly phenols (measured as CDOM) and marine clay (measured as TSM). The increased absorption spectrums for [Chl *a*] and [CDOM] and scattering spectrum for [TSM] coincided with the decreased intensity of RGB colours and contrast as a function of concentration, and is visualized in Fig. For further reading of this thesis it is important to keep in mind that colours which are not absorbed or scattered is reflected to the observer.

Earlier absorption measurements of phytoplankton have in general showed two absorption peaks in the blue and the red waveband due to *in vivo* absorption mainly by the pigment Chl *a* (Itturiaga and Siegel 1989; Kirk 1994). As a result from this distinct absorption behaviour, the green waveband is left for reflection to the observer (in this case: camera). The reported absorption behaviour was consistent with the absorption measurement from the diatom *Phaeodactylum tricornutum* done in this study (Fig 3.1). The diatom absorbed highest in the blue and the red wavelength, which in turn gave the images dominated by *P. tricornutum*, a green colour hue (Fig 3.2). An increased concentration of the diatom (measured as Chl *a*) decreased also the intensity of RGB colours in the images, which illustrates that attenuation of light in water is dependent on the concentration of substances (IOP). The cell structure of phytoplankton is also a source for light scattering (Kirk 1994). As the contrast in images is dependent by the amount of backscattered light to the camera, this was consistent with the significant decreased contrast as [*P. tricornutum*] increased (i.e. higher number of light scattering cells) (Fig, 3.3, Fig 3.5).

CDOM is a variety of dissolved substances (e.g. poly phenols released by kelp) that arise from the degradation of organic material (Bricaud et al 1981, Kirk 1994), and is reported to absorb highest in the blue waveband with an exponential decrease towards the red waveband (Bricaud et al 1981; Hancke et al 2012). This leaves mainly a yellow to red colour for reflection. The reported absorption behaviour for CDOM was also seen in the absorption measurements from poly phenols released from degradation of kelp (*Saccharina latissima, Fucus serratus* and *Laminaria digitata*) used as source for CDOM in this study. In the images dominated by [CDOM], the RGB colours behaved according to this absorption behaviour with lowest intensity of the blue colour channel, leaving the images with a yellow hue. As CDOM is mainly an absorbing component (and not scattering) a significant decrease in contrast was not expected. However, as the contrast decreased significantly with increased [CDOM] it was apparent that the seawater used for dilution probably added extra scattering particles to the aquarium (unfiltered seawater).

The marine clay used as source for TSM, scatters light only (Kirk, 1994), and has earlier been reported to have a more or less flat scattering spectrum in the visible range (Kirk 1994). In the measurements of the scattering spectrum the high concentrations of TSM scattered the blue light much more extensively than in the red part of the visible spectrum (Fig 3.1), but the lower concentrations showed a more or less flat spectrum as earlier reported for TSM. As it was used relatively low concentrations of TSM in the aquarium experiment, all wavelengths in the visible range was scattered more or less in equal amount resulting in RGB colours with similar intensities. The red colour channel gave however the lowest intensity due to that seawater absorbs the red waveband extensively (Smith and Baker 1981). The contrast in the images showed as expected a significant decrease due to the highly scattering environment from TSM.

Evaluation of the ECO Triplet performance

The results from the evaluation between fluorometric Chl *a* concentration measured by the ECO Triplet and concentration derived from extracted Chl *a* absorption (spectrophotometer) returned values within the same range. The fluorometric determined [Chl *a*] resulted in a Chl *a* concentration of 469 µg L^{-1} and the concentration determined from absorption resulted in a concentration of 391 µg L^{-1}. As the fluorometric measurement with the ECO Triplet is a fast and easy measurement compared to absorption measurements in the lab, this deviation is considered acceptable as it allows direct *in situ* measurements. The advantage with the ECO Triplet is that can be deployed together with a camera (on various platforms) and give IOP concentration measures for further image analysis assessment.

In situ underwater imaging

Distance to object of interest (OOI) and identification success

Depending on the underwater imaging takes place in Case I or Case II waters (Fig 1.2) the attenuation length for the different colours vary due to composition of the IOP (Fig 1.2, Fig.1.3). The spatial resolution in images will also decrease as number of pixels decreases per area covered when the photographed area gets larger with increased imaging distance. This and implies that colour, details and shapes is affected by the IOP and imaging distance (i.e. spatial resolution), as observed in the images taken for this study. A good illustration on light attenuation as a function of distance is in Figure 4.1, where the camera is situated at different distances from the light source. This results in different attenuation lengths due to IOP, and clearly different colours in the image.

Figure 4.1: Two SCUBA divers holding different light sources (LED and Xenon) are situated in the front of the image. Further back in the image is the ROV with its light sources (both HMI) directed towards the camera. As a result of longer distance from the camera, the lights from the ROV is greener due to higher absorption by the Chl a and the seawater itself in the blue and the red waveband (Photo Geir Johnsen).

A significant decreased identification success for 13 out of 14 taxa was observed when the imaging distance increased form 0.3 – 1.1 m. The reduced spatial resolution was prominent in the shape and texture details and on *Asterias rubens*, *Marthasterias Glacialis* and *Alcyonium digitatum* when the imaging distance increased from 0.3 -1.1 m. This is clearly visualized in Fig. 4.2 and 4.3 which is original crops from the images. The specimens are much smaller in the image taken from 1.1 m, visualizing that number of pixels is lower per organism. As the red colours is most extensively attenuated by both Chl *a* and the seawater itself (Smith and Baker 1981), organisms that inhibit these colours will be the first to lose its colour characteristics and in turn be hard to distinguish in the images, which were the case for *A. rubens* and *A. digitatum (*as they inhibited red/orange colours) (Fig 4.2, 4.3). As especially the texture details for these two species was a feature for identification, the loss of detail due to lowered spatial resolution and increased attenuation from IOP is an explanation for the identification fail at longer imaging distances than 0.3 m. The sharpness and contrast in the images are also clearly reduced with increased imaging distance (Fig), as the image is perceived very blurry. This is due to backscattered light, which was discussed in the previous section.

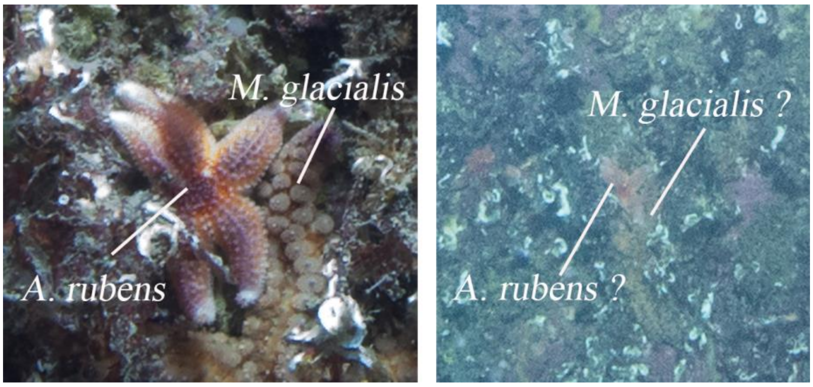

Figure 4.2: The identification of A. rubens and M. Glacialis was only possible in the closest taken image at 0.3 m (left image), when texture and shapes was visible. When the distance from the OOI to the camera increased (1.1 m), the organisms were more or less vanished from the image. The effect of backscattered light is also illustrated nicely in the rightmost image as the contrasts have clearly been lowered and the image appears blurry (Photo: Geir Johnsen)

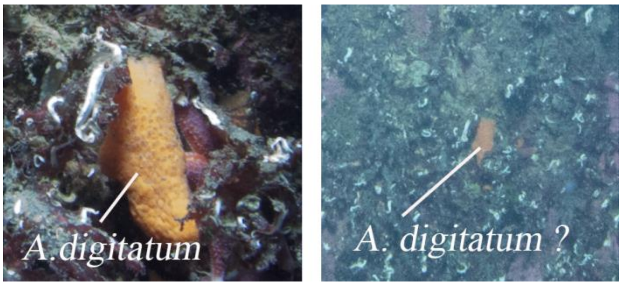

Figure 4.3: Identification of A. digitatum was only possible in the closest taken image at 0.3 m based on shape, colour and contrast characteristics. In the image from 1.1 m, the organisms appear much smaller due to the lowered spatial resolution, and the brightness of the colour is lower (Photo: Geir Johnsen)

A closer investigation was performed on the abundance of the polychaetes of the family Serpulidae, as they were the most numerous taxa in the three images. The number of both small and large specimens decreased as a function of distance and can be mostly be explained by the reduction of spatial resolution as previously discussed. This was especially evident in that the smaller Serpulidae had the highest reduction in number as spatial resolution affects naturally the smallest organisms first. However, some of the specimens were possible to distinguish in all three images. As the white (white is reflection of all wavelengths) surface of the housings reflected more or less all colours of visible light, the specimens identification success was not as extensively affected by the IOP as the *A. rubens* and *A. digitatum* were (they only reflected the red waveband). The goodness-of-fit (R^2) obtained by the linear regression was for small and large Serpulidae respectively 0.791 and 0.587, which in turn mean that the distance accounted for 79.1 % and 58.7 % of the variance. As some specimens were partly covered with micro algae this could have affected the identification success by making them look smaller from longer distances and not subjected to identification. It is important to point out that the level of knowledge by the observer is also a factor for identification success from images, and could be a factor for error.

The effect from LED and Xenon lamps and Subtronic Blitz on illumination area and evenness

The results from this study show that different light sources, image sensor size and focal length (FL) affect the images in terms of illuminated area and evenness, colour rendering, spatial resolution and area coverage.

In the *in situ* SCUBA images, the illumination areas between LED, Xenon and Subtronic Blitz was compared. The Blitz showed to illuminate a substantially larger area than the two lamps (LED and Xenon), but common for all images was that the middle of the image was brighter than the surroundings. The deficiency with artificial lightning is largely this centred intensity and uneven illumination also pointed out by Garcia et al 2012. From the in-air-measurements of the light cone from the LED lamp, it showed that the evenness could be smoothed with a diffuser. This comes however with some trade-off effects as the general light intensity was decreased. In addition as the light beam becomes more spread out by the diffuser it is reasonable to assume a higher effect from backscattered light and contrast decrease in the images. This decreased contrast effect was also observed from the Blitz which had a wider light beam than the LED and Xenon.

On the ROV, two HID lamps were used. As they have a large angle of illumination (over 180^{o}), this allows for more even illumination across a larger area (see Fig 4.4). The ROV compared to the SCUBA requires however external power supply from an umbilical cord.

Figure 4.4: LED, XENON (SCUBA), and Metal halide Lamps on ROV. The images are taken from the side of the light source and visualize the light beams (Photos: Geir Johnsen).

The spectral composition of the three light sources used by SCUBA also showed variable colour rendering in the images (Figure 3.10, Table 3.5). The LED lamp had a colour temperature on 6300 Kelvin, which returns colours highest in the blue part of the spectrum.

This was evident in the RGB colour measurements of the white reference plate where LED light gave the lowest intensity of the red colour channel (45 %) compared to Xenon and flash (respectively 69 and 79 % red intensity). The highest intensities of all RGB channels were however from the flash source, probably due to an overall higher light intensity. Common for all sources, as also reported by (Pettersen 2013), was that the artificial light sources inhibited in general poorer red colours than in green and blue (Table 3.5). The RGB output could also have been affected by the distance from the OOI to the light source which showed to vary between the three images (visual in Fig. 3.10).

Positioning of the light source is also an important aspect and is optimal with an off-set angle at 45^{o}. This provides shadow in the image and an idea of the 3D representation of objects in the image.

Camera systems and carrier platforms (SCUBA and ROV)

The results show that the image quality between cameras was largely dependent on the focal length (FL) of the lens, size of the image sensor and white balance (WB) settings. The SCUBA operated camera (Canon) had the largest FL on 14 mm and due to its large angle of view (114^{o}) captured the largest area. This resulted in fewer pixels per organism compared to the larger focal lengths on the ROV operated Prosilica and Sony HD-video cameras (Fig 3.8 and 3.9). The results shows also the difference between the size of imaging sensors. As the Sony HD-video sensor was the smallest (subjected to a crop factor of 6.44), it produced a 6.44 times smaller image than the full-frame (24 x 35 mm) Canon and Prosilica sensors. The advantage with this small sensor is however that the light to the sensor is narrowed to hit the small sensor, and thus produces a high depth of field (DOF). For scientific use and detail investigation it will however require complementary high resolution still images from a camera as the Canon or the Prosilica.

In light of this, the choice of lens is an important feature depending on the required application. As a wide angle lens will cover more extensive areas at close range, longer focal lengths (zoom effect) can either allow longer imaging distance or a more close-up observation study. The use of larger focal lengths is also probably a better choice for surveys with ROVs as it can be more challenging for the pilot to operate it very close to the OOI (Ludvigsen et al. 2007). When using ROV for underwater photography, it is also important to have a sensor for OOI size reference using a laser ruler. When measuring distance with side scan sonar, the movement of the ROV can make the distance calculation difficult. As seen in the post calculation of the distance, the distance measured by the sonar, were over/underestimated with approximately 0.5 m.

The RGB output between the three images between SCUBA and ROV were also quite different, where the image from the SCUBA operated Canon is very dark compared to the two ROV images (Fig 3.8). This is reflected in the RGB intensities in the Canon image measured at the *Alcyonium digitatum* which indicates a grey colour (equal intensity of RGB gives a white-black colour) (Table 3.3). It is also apparent that the colour hue between the two ROV cameras is different; from a subjective observation and by looking at the histograms, where the Sony HD – video has a larger output of red colours than the Prosilica.

As the imaging distance was approximately the same in addition to the same light source, the colour change was subjected to the WB and colour sensitivity to the camera rather than the IOP as earlier discussed. To optimize the exposure of light to the image, the shutter speed, ISO and aperture can be adjusted, but balancing of these settings follows with some trade-off effects. A prolonged shutter speed allows light to enter the sensor for a longer time, but can cause disturbances if the camera is not hold very still. To obtain as fast shutter speed as possible, the light sensitivity to the senor can be adjusted, but this will return more noise to the image. The aperture can also be opened more, but will suffer from lower DOF.

As the radiometric resolution from the camera systems was only known for the Canon camera, a detailed discussion on the RGB output is limited, but it is worth to mention that high radiometric resolution is required when imaging in an environment that is subjected to either very light or very dark areas (Morouloulis 2012). The radiometric resolution is defined as the levels of light the pixels can capture and applies to detail rendering in very dark and very bright areas. This is often the case for underwater photography that can suffer from both overexposing from artificial light source and dark areas due to insufficient illumination and light attenuation from IOP. The RGB output is also dependent on the radiometric resolution as it also applies to the levels of colour the sensor can produce (e.g. 8 bit sensor produces 255 levels of light).

Summary and Conclusions

- IOP affects the image quality (sharpness, contrast and colour) in underwater images by decreasing the image RGB colour and contrast. This effect increases with IOP concentration.

- Increasing imaging distance to OOI decreases the spatial and colour resolution in underwater images to obtain positive taxa identification, and is an effect of distance to OOI and attenuation of light by IOP.
- Organisms smaller than 0.5 cm in length were not identifiable at a distance of 0.3 m when the focal length was 14 mm and flash light source was used.
- Spatial resolution is a result of sensor size, pixel density/quality in addition to focal length when images with different FL from the same distance are compared.
- Shutter speed, ISO (gain) and aperture can be adjusted for optimization of light environment, but comes with trade-off effects as lowered DOF and more movement disturbances of the image (blurred images)
- RGB colours and illumination area in images is dependent on spectral resolution to the light source and the distance from the OOI.

Future perspectives

When images are collected over a large area, the number of images can range from hundreds to thousands, which makes it extremely time consuming for manual analysis of each image. Automatic computer analysis of images is an increasing field of investigation, but requires pre-processing of the images before analysis. As it has been shown in this thesis, that especially IOP has an image degrading effect with respect to colour and contrast. As these degradations can affect the ability of the automatic computer analysis to function optimally, a correction of the IOP is necessary. By obtaining the absorption and scattering coefficients from the water the image is taken through, the attenuation and scattering of light is quantified and can be implemented in a pre-processing step to re-calculate the colours and contrast back to approximate original values as they should appear without the degradation. The absorption and scattering coefficients measured in this thesis have established a relationship with different concentrations of Chl *a*, CDOM and TSM and can be used in a pre-processing step.

All values are found in the appendix.

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Websites:

1. White balance: http://www.cambridgeincolour.com/tutorials/white-balance.htm
2. Focal length: http://www.cambridgeincolour.com/tutorials/camera-lenses.htm

Appendix

User guide for ECO Triplet use:

1. Connect the sensor to the computer with the USB-RS-232 cable (figure 1).

Figure 1 – overview of the sensor with all needed equipment.

2. Start the software Ecoview and press "select COM Port" (figure 2). The baud rate of 19200 is default. Check which COM port the sensor is connected to on your computer.

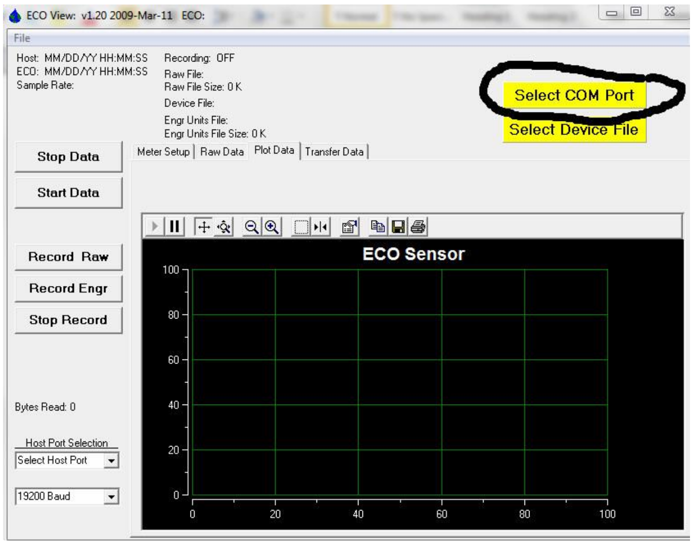


Figure 2 – screen shot of startup page for Ecoview.

3. Press “Select device file” (figure 2), and find the right file (figure 3), The file for the EcoTriplet is called BBFL2WB. The sensor is now ready to be programmed for either logging with the computer or in autonomous mode. For autonomous mode you need the blue start/Stop plug (figure 1, nr. 1)

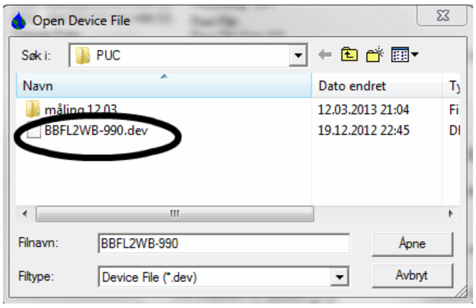


Figure 3 – BBFL2WB-990.dev is the correct device file.

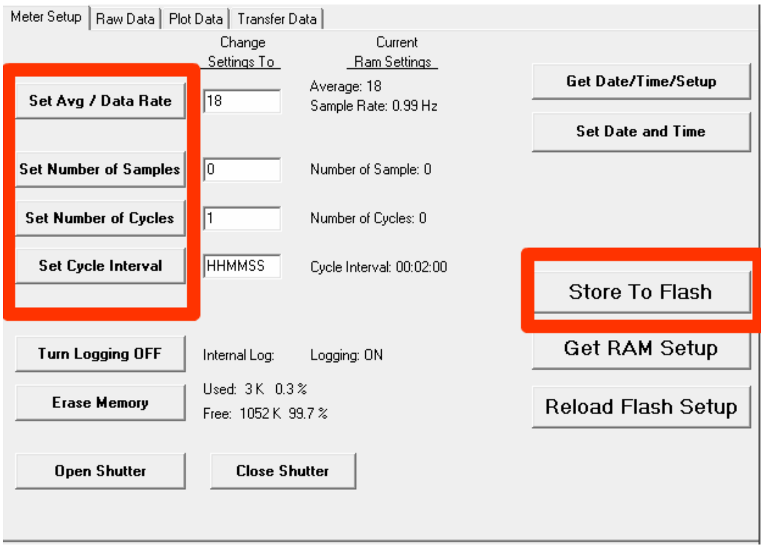
4. To select the sampling rate (and/or cycles if it is in autunomus mode) you must enter the “meter setup” tab in ecoview and type in your desired settings:

Example:

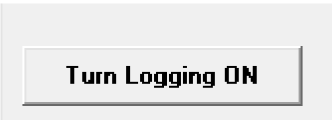
Avr/data Rate: 18 (=1 Hz)
Number of samples: 10
Number of cycles: 2
Cycle interval: 000200

These settings will give you an output of one sample per second for ten seconds. This cycle will start over after 2 min after the first sample were taken. Number of cycles is two, so in total you will get 20 samples after 2 min and ten seconds before the sensor will go in “sleeping mode”.

After changing a setting, ALWAYS press the button to the left for the column where you are typing in the values (look at red box in picture below) and then “store to flash” to store the values in the sensor.

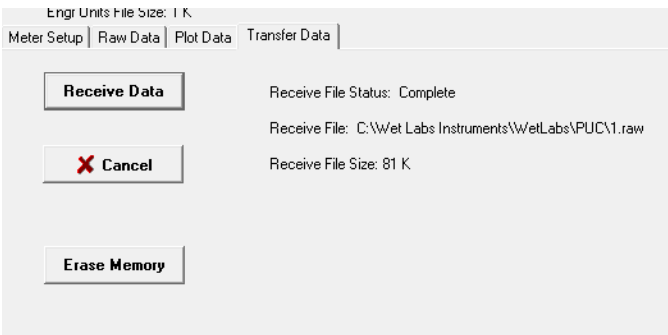


To turn on internally logging, press the “turn logging on” button (and then “store to flash”):



Now the sensor is ready for logging. It will immediately start to log when the blue start/stop plug is mounted on the sensor.

When the sensor is finished with the logging, press the “transfer data” tab and then the “Receive Data” button (look at picture below). You will now be asked to make a file to save your data in. Warning: now all data that is ever stored in the sensor will be transferred to the file you just made. It can therefore be wise to erase the internal memory in the sensor before starting to log autonomous (without cable).



When you received file status is complete, open your file in the program notepad and copy it over to excel or import it directly to excel.

5. When logging in autonomous mode all data is stored in a raw file. To get the absolute values the file has to be re-played in ecoview and stored in engineering output. Press “file” in upper left corner in ecoview, and press “replay raw file” which gives you the alternative to open a file to replay. Now, press the “Record Engr” and make a file were to store the absolute values. The last step will then be to press “start replay” to start the recording of engineering output in

the new file you just made. This process can take some time since the whole file has to be re-played.

WARNING: If you have trouble with programming the sensor, i.e. that Ecoview does not respond to your command, the sensor is probably in sleeping mode. If it is programmed to log in cycles, it will go in sleeping mode between the cycles. To wake it up, you have to do a trick: When you put on the battery on the logging cable, press the “STOP DATA” several times. This MUST be done at the same time to get contact.

CONCENTRATION AND ABSORPTION – ECO TRIPLET vs. SPECTROPHOTOMETER MEAUSREMENTS.

Relationship between ECO Triplet concentrations and absorption from Chl *a* and CDOM. Equations are established from a linear regression performed on the relationship between concentration and absorption coefficient (m-1) from Chl *a* at 675 nm and CDOM at 460 nm.

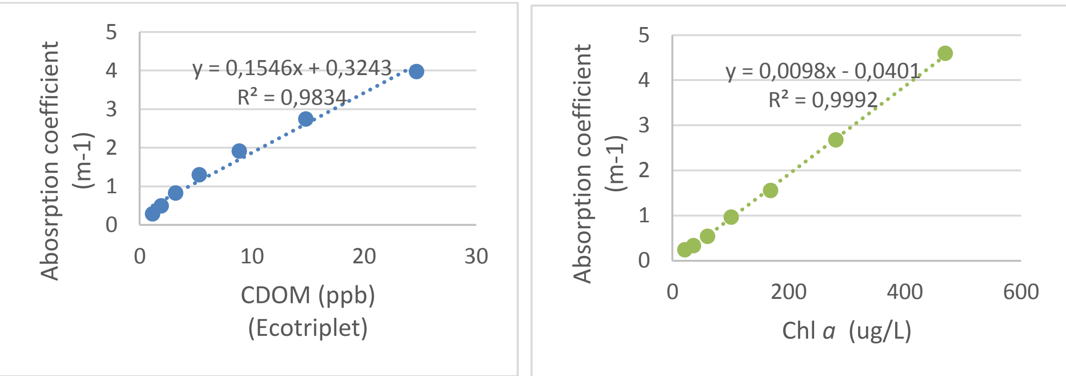


Figure: Linear relationship between concentration and absorption from Chl *a* (675 nm) and CDOM (460 nm).

For further use with these measurements I recomennd to use the absorption coefficients for wavelengths of interests to the end-user (colour correction algorithms). All the data can be found in this dokument for further use. The concentration measuremetns in the Chl *a* sensor was validated by test measuremetns form the Eco Triplet.

TABLE 1 – CDOM ABSORPTION COEFFICIENTS FROM SEVEN CONCENTRATIONS

Wavelength	Concentration 24,6 ppb a(m-1) coeff (3 paralells)	Concentration 14.8 ppb a(m-1) coeff (3 paralells)	Concentration 8,8 ppb a(m-1) coeff (3 paralells)	Concentration 5,3 ppb a(m-1) coeff (3 paralells)	Concentration 3,2 ppb a(m-1) coeff (3 paralells)	Concentration 1.2 ppb a(m-1) coeff (3 paralells)	Concentration 1,15 ppb a(m-1) coeff (3 paralells)
350	16,62	11,17	7,40	4,87	3,07	1,83	1,10
351	16,34	11,00	7,29	4,82	3,05	1,83	1,13
352	16,08	10,83	7,17	4,72	2,99	1,82	1,10

353	15,74	10,63	7,03	4,62	2,93	1,74	1,02
354	15,51	10,45	6,91	4,55	2,85	1,71	1,02
355	15,32	10,32	6,86	4,52	2,85	1,71	1,04
356	15,02	10,12	6,73	4,41	2,76	1,65	0,96
357	14,78	9,94	6,59	4,32	2,70	1,60	0,93
358	14,53	9,77	6,45	4,26	2,66	1,59	0,93
359	14,33	9,65	6,40	4,21	2,66	1,57	0,95
360	14,09	9,49	6,30	4,13	2,58	1,53	0,90
361	13,89	9,34	6,21	4,07	2,56	1,49	0,90
362	13,64	9,20	6,10	3,98	2,52	1,49	0,89
363	13,44	9,07	5,98	3,95	2,46	1,45	0,86
364	13,21	8,88	5,90	3,83	2,39	1,39	0,83
365	13,02	8,74	5,81	3,80	2,38	1,39	0,81
366	12,82	8,64	5,68	3,74	2,33	1,34	0,79
367	12,63	8,48	5,65	3,67	2,30	1,36	0,78
368	12,40	8,36	5,53	3,60	2,26	1,31	0,75
369	12,22	8,22	5,47	3,54	2,20	1,30	0,75
370	12,05	8,08	5,38	3,47	2,13	1,26	0,72
371	11,85	7,96	5,24	3,40	2,12	1,22	0,67
372	11,68	7,87	5,21	3,40	2,12	1,23	0,72
373	11,48	7,75	5,12	3,34	2,07	1,23	0,72
374	11,30	7,59	5,02	3,26	2,03	1,20	0,69
375	11,13	7,49	4,95	3,21	1,98	1,14	0,66
376	10,95	7,35	4,86	3,14	1,93	1,13	0,63
377	10,81	7,26	4,79	3,11	1,93	1,13	0,64
378	10,61	7,13	4,72	3,06	1,89	1,10	0,63
379	10,49	7,07	4,66	3,03	1,87	1,11	0,63
380	10,32	6,93	4,58	2,98	1,84	1,08	0,63
381	10,18	6,84	4,53	2,95	1,84	1,08	0,63
382	10,01	6,72	4,44	2,89	1,80	1,05	0,61
383	9,87	6,66	4,40	2,85	1,77	1,05	0,61
384	9,70	6,54	4,33	2,80	1,75	1,03	0,56
385	9,60	6,46	4,26	2,75	1,70	0,99	0,58
386	9,44	6,35	4,21	2,71	1,66	0,96	0,53
387	9,30	6,26	4,12	2,66	1,66	0,94	0,53
388	9,20	6,20	4,07	2,66	1,66	0,96	0,53
389	9,07	6,11	4,03	2,62	1,63	0,94	0,53
390	8,97	6,03	3,98	2,59	1,60	0,94	0,53
391	8,83	5,97	3,94	2,55	1,60	0,93	0,55
392	8,75	5,89	3,89	2,52	1,58	0,93	0,53
393	8,65	5,83	3,86	2,51	1,57	0,91	0,53
394	8,52	5,74	3,80	2,46	1,52	0,90	0,50
395	8,42	5,65	3,74	2,43	1,52	0,90	0,49
396	8,32	5,60	3,72	2,42	1,49	0,87	0,49
397	8,22	5,52	3,64	2,36	1,47	0,84	0,46
398	8,11	5,46	3,61	2,34	1,47	0,82	0,47

399	8,05	5,40	3,57	2,32	1,44	0,85	0,49
400	7,96	5,39	3,55	2,29	1,46	0,85	0,47
401	7,83	5,29	3,51	2,26	1,43	0,80	0,44
402	7,77	5,25	3,46	2,25	1,40	0,82	0,46
403	7,65	5,19	3,43	2,23	1,38	0,80	0,46
404	7,56	5,11	3,40	2,20	1,38	0,79	0,46
405	7,48	5,05	3,35	2,17	1,35	0,79	0,44
406	7,39	5,00	3,32	2,17	1,34	0,79	0,44
407	7,28	4,93	3,29	2,13	1,34	0,76	0,44
408	7,23	4,91	3,26	2,11	1,32	0,76	0,44
409	7,14	4,85	3,22	2,09	1,32	0,77	0,43
410	7,08	4,79	3,18	2,09	1,31	0,76	0,43
411	6,99	4,74	3,15	2,05	1,29	0,76	0,44
412	6,91	4,70	3,14	2,05	1,28	0,73	0,44
413	6,82	4,63	3,11	2,02	1,24	0,73	0,41
414	6,77	4,59	3,06	2,00	1,24	0,73	0,41
415	6,68	4,54	3,03	1,99	1,24	0,73	0,41
416	6,61	4,48	3,00	1,96	1,24	0,71	0,41
417	6,56	4,47	2,97	1,94	1,21	0,71	0,41
418	6,50	4,40	2,94	1,94	1,24	0,73	0,41
419	6,42	4,34	2,91	1,91	1,20	0,68	0,41
420	6,33	4,30	2,88	1,88	1,18	0,68	0,41
421	6,27	4,27	2,86	1,88	1,18	0,68	0,40
422	6,19	4,22	2,82	1,85	1,17	0,68	0,40
423	6,15	4,19	2,82	1,86	1,18	0,68	0,41
424	6,10	4,14	2,79	1,85	1,15	0,68	0,40
425	6,01	4,10	2,74	1,80	1,12	0,65	0,37
426	5,95	4,05	2,72	1,80	1,14	0,67	0,38
427	5,87	4,01	2,71	1,77	1,14	0,65	0,37
428	5,84	3,97	2,71	1,77	1,12	0,67	0,40
429	5,78	3,94	2,65	1,77	1,11	0,64	0,38
430	5,69	3,88	2,63	1,71	1,08	0,64	0,37
431	5,64	3,85	2,59	1,71	1,08	0,64	0,37
432	5,55	3,82	2,59	1,70	1,06	0,64	0,38
433	5,52	3,78	2,57	1,70	1,08	0,64	0,37
434	5,46	3,73	2,51	1,67	1,06	0,61	0,37
435	5,36	3,68	2,51	1,67	1,06	0,61	0,37
436	5,30	3,64	2,45	1,62	1,01	0,59	0,37
437	5,27	3,61	2,43	1,63	1,03	0,61	0,37
438	5,18	3,55	2,40	1,59	1,01	0,59	0,35
439	5,13	3,55	2,40	1,62	1,01	0,59	0,37
440	5,09	3,50	2,39	1,59	1,01	0,59	0,37
441	5,00	3,45	2,34	1,56	0,98	0,59	0,33
442	4,95	3,39	2,31	1,54	0,97	0,57	0,35
443	4,86	3,36	2,28	1,51	0,97	0,54	0,32
444	4,84	3,33	2,26	1,53	0,97	0,59	0,35

445	4,80	3,32	2,25	1,51	0,97	0,57	0,33
446	4,72	3,27	2,25	1,50	0,97	0,57	0,35
447	4,66	3,22	2,20	1,48	0,94	0,54	0,33
448	4,58	3,18	2,16	1,45	0,94	0,54	0,32
449	4,52	3,13	2,14	1,44	0,92	0,54	0,32
450	4,47	3,10	2,13	1,44	0,91	0,54	0,32
451	4,43	3,07	2,13	1,42	0,92	0,54	0,33
452	4,37	3,02	2,08	1,40	0,91	0,54	0,32
453	4,32	3,01	2,07	1,40	0,89	0,53	0,32
454	4,28	2,96	2,03	1,37	0,88	0,51	0,30
455	4,21	2,92	2,02	1,36	0,88	0,51	0,30
456	4,17	2,87	2,00	1,34	0,88	0,51	0,30
457	4,11	2,87	1,97	1,34	0,86	0,51	0,30
458	4,06	2,84	1,96	1,33	0,85	0,50	0,30
459	4,01	2,79	1,94	1,31	0,85	0,50	0,30
460	3,97	2,75	1,91	1,30	0,83	0,50	0,29
461	3,92	2,73	1,91	1,28	0,83	0,50	0,30
462	3,89	2,70	1,88	1,27	0,83	0,48	0,30
463	3,85	2,69	1,87	1,27	0,83	0,50	0,30
464	3,78	2,66	1,84	1,25	0,80	0,47	0,30
465	3,75	2,61	1,82	1,24	0,80	0,45	0,27
466	3,71	2,58	1,80	1,22	0,80	0,47	0,29
467	3,66	2,56	1,77	1,21	0,78	0,45	0,29
468	3,62	2,53	1,77	1,21	0,78	0,45	0,27
469	3,59	2,50	1,74	1,17	0,78	0,45	0,26
470	3,54	2,47	1,73	1,17	0,78	0,45	0,27
471	3,52	2,46	1,73	1,17	0,75	0,45	0,27
472	3,48	2,43	1,70	1,16	0,77	0,45	0,27
473	3,43	2,41	1,68	1,16	0,74	0,45	0,27
474	3,40	2,36	1,65	1,14	0,75	0,45	0,26
475	3,39	2,36	1,65	1,13	0,74	0,44	0,27
476	3,32	2,30	1,64	1,11	0,74	0,42	0,26
477	3,29	2,30	1,64	1,11	0,72	0,42	0,26
478	3,26	2,27	1,61	1,11	0,71	0,41	0,26
479	3,25	2,26	1,59	1,08	0,71	0,42	0,26
480	3,20	2,26	1,59	1,08	0,71	0,41	0,26
481	3,17	2,21	1,56	1,08	0,69	0,41	0,24
482	3,16	2,18	1,54	1,07	0,69	0,41	0,23
483	3,11	2,17	1,54	1,07	0,69	0,41	0,26
484	3,09	2,17	1,51	1,05	0,69	0,41	0,24
485	3,06	2,12	1,50	1,04	0,66	0,41	0,23
486	3,02	2,12	1,47	1,02	0,65	0,39	0,23
487	3,02	2,12	1,50	1,02	0,68	0,41	0,26
488	2,97	2,07	1,45	1,02	0,66	0,41	0,23
489	2,94	2,07	1,45	0,99	0,65	0,39	0,23
490	2,93	2,03	1,45	0,99	0,65	0,39	0,23

491	2,88	2,03	1,41	0,99	0,65	0,39	0,23
492	2,83	1,98	1,41	0,96	0,63	0,36	0,23
493	2,83	1,98	1,39	0,96	0,63	0,38	0,23
494	2,82	1,98	1,41	0,98	0,65	0,39	0,23
495	2,79	1,95	1,38	0,98	0,63	0,36	0,23
496	2,76	1,94	1,36	0,94	0,63	0,38	0,23
497	2,73	1,90	1,36	0,93	0,62	0,36	0,23
498	2,71	1,90	1,36	0,93	0,62	0,38	0,23
499	2,67	1,87	1,31	0,91	0,60	0,36	0,21
500	2,63	1,83	1,30	0,90	0,57	0,34	0,20
501	2,62	1,83	1,28	0,88	0,59	0,34	0,23
502	2,60	1,81	1,28	0,88	0,59	0,34	0,21
503	2,57	1,80	1,27	0,90	0,57	0,36	0,23
504	2,56	1,78	1,27	0,88	0,57	0,34	0,23
505	2,51	1,75	1,24	0,87	0,57	0,31	0,18
506	2,48	1,74	1,24	0,84	0,57	0,33	0,20
507	2,47	1,72	1,22	0,85	0,55	0,31	0,18
508	2,44	1,72	1,22	0,84	0,54	0,31	0,18
509	2,42	1,69	1,19	0,82	0,55	0,31	0,20
510	2,39	1,67	1,19	0,82	0,54	0,31	0,18
511	2,36	1,66	1,18	0,82	0,55	0,31	0,20
512	2,34	1,63	1,15	0,79	0,52	0,31	0,18
513	2,30	1,60	1,15	0,78	0,52	0,28	0,18
514	2,30	1,61	1,15	0,79	0,52	0,31	0,18
515	2,25	1,58	1,13	0,78	0,52	0,31	0,18
516	2,25	1,57	1,11	0,78	0,49	0,30	0,18
517	2,21	1,54	1,10	0,75	0,48	0,27	0,18
518	2,17	1,52	1,07	0,73	0,48	0,27	0,18
519	2,16	1,51	1,07	0,75	0,48	0,28	0,18
520	2,14	1,51	1,05	0,73	0,48	0,27	0,18
521	2,11	1,48	1,05	0,73	0,48	0,27	0,17
522	2,07	1,43	1,02	0,71	0,46	0,27	0,18
523	2,07	1,43	1,02	0,70	0,46	0,27	0,14
524	2,04	1,43	1,01	0,70	0,46	0,27	0,18
525	2,02	1,41	1,01	0,70	0,45	0,27	0,18
526	2,01	1,38	0,99	0,68	0,45	0,27	0,17
527	1,98	1,38	0,98	0,68	0,45	0,27	0,18
528	1,96	1,37	0,96	0,67	0,43	0,27	0,14
529	1,93	1,35	0,98	0,67	0,43	0,27	0,15
530	1,91	1,34	0,95	0,64	0,43	0,25	0,14
531	1,88	1,31	0,93	0,64	0,43	0,24	0,14
532	1,88	1,29	0,93	0,65	0,43	0,25	0,14
533	1,84	1,29	0,92	0,64	0,43	0,24	0,14
534	1,84	1,29	0,90	0,64	0,42	0,22	0,14
535	1,81	1,26	0,90	0,62	0,42	0,22	0,14
536	1,79	1,26	0,90	0,61	0,42	0,24	0,17

537	1,76	1,21	0,88	0,59	0,39	0,22	0,14
538	1,75	1,21	0,85	0,59	0,39	0,22	0,14
539	1,75	1,21	0,87	0,59	0,39	0,22	0,14
540	1,71	1,21	0,85	0,59	0,39	0,22	0,14
541	1,70	1,17	0,82	0,56	0,37	0,22	0,14
542	1,67	1,17	0,84	0,58	0,39	0,22	0,14
543	1,65	1,14	0,82	0,55	0,36	0,22	0,14
544	1,64	1,15	0,81	0,56	0,37	0,22	0,14
545	1,62	1,14	0,81	0,55	0,37	0,21	0,14
546	1,61	1,11	0,79	0,55	0,34	0,21	0,14
547	1,58	1,11	0,79	0,53	0,34	0,19	0,14
548	1,56	1,08	0,78	0,53	0,34	0,19	0,12
549	1,55	1,08	0,76	0,52	0,34	0,19	0,10
550	1,53	1,06	0,76	0,50	0,34	0,18	0,12
551	1,50	1,03	0,73	0,50	0,32	0,18	0,10
552	1,50	1,05	0,73	0,50	0,34	0,18	0,10
553	1,48	1,03	0,72	0,50	0,34	0,18	0,10
554	1,45	1,02	0,72	0,50	0,32	0,18	0,12
555	1,45	1,02	0,72	0,50	0,32	0,18	0,10
556	1,42	1,00	0,72	0,48	0,31	0,18	0,10
557	1,42	1,00	0,72	0,48	0,32	0,18	0,12
558	1,39	0,97	0,69	0,45	0,31	0,18	0,10
559	1,38	0,97	0,69	0,45	0,31	0,18	0,12
560	1,36	0,95	0,67	0,45	0,31	0,18	0,10
561	1,35	0,94	0,65	0,45	0,29	0,18	0,10
562	1,35	0,92	0,65	0,45	0,31	0,18	0,10
563	1,30	0,91	0,64	0,44	0,29	0,18	0,07
564	1,30	0,91	0,62	0,44	0,29	0,16	0,10
565	1,27	0,89	0,62	0,41	0,28	0,15	0,07
566	1,27	0,89	0,62	0,41	0,29	0,16	0,10
567	1,25	0,89	0,62	0,41	0,29	0,16	0,10
568	1,24	0,86	0,61	0,41	0,26	0,13	0,10
569	1,22	0,85	0,59	0,41	0,28	0,15	0,09
570	1,21	0,85	0,58	0,41	0,26	0,15	0,10
571	1,19	0,85	0,59	0,41	0,28	0,15	0,09
572	1,18	0,82	0,58	0,39	0,26	0,13	0,09
573	1,16	0,80	0,58	0,38	0,26	0,15	0,09
574	1,16	0,80	0,58	0,39	0,26	0,16	0,09
575	1,16	0,80	0,58	0,36	0,26	0,13	0,09
576	1,12	0,80	0,53	0,36	0,25	0,13	0,07
577	1,12	0,80	0,53	0,36	0,25	0,13	0,09
578	1,10	0,77	0,53	0,36	0,25	0,15	0,07
579	1,10	0,79	0,53	0,36	0,25	0,15	0,09
580	1,09	0,75	0,53	0,36	0,25	0,13	0,09
581	1,06	0,75	0,52	0,35	0,23	0,13	0,06
582	1,04	0,75	0,50	0,36	0,25	0,13	0,09

583	1,02	0,72	0,49	0,33	0,23	0,13	0,07
584	1,02	0,72	0,49	0,35	0,22	0,13	0,07
585	1,01	0,71	0,49	0,32	0,22	0,11	0,06
586	1,01	0,71	0,49	0,35	0,22	0,13	0,09
587	0,98	0,68	0,47	0,32	0,22	0,13	0,04
588	0,96	0,66	0,44	0,32	0,22	0,11	0,04
589	0,96	0,66	0,46	0,32	0,20	0,10	0,06
590	0,93	0,66	0,44	0,30	0,20	0,10	0,06
591	0,93	0,66	0,44	0,30	0,19	0,10	0,04
592	0,92	0,65	0,44	0,32	0,20	0,10	0,04
593	0,92	0,65	0,42	0,29	0,19	0,08	0,06
594	0,89	0,63	0,42	0,27	0,19	0,08	0,04
595	0,89	0,63	0,41	0,27	0,19	0,10	0,04
596	0,87	0,62	0,42	0,27	0,19	0,11	0,04
597	0,87	0,62	0,41	0,27	0,17	0,08	0,04
598	0,84	0,59	0,39	0,27	0,17	0,08	0,04
599	0,83	0,59	0,38	0,25	0,16	0,08	0,04
600	0,83	0,59	0,39	0,27	0,20	0,08	0,04
601	0,83	0,59	0,39	0,25	0,16	0,08	0,04
602	0,81	0,56	0,38	0,24	0,16	0,08	0,04
603	0,81	0,59	0,38	0,25	0,19	0,08	0,04
604	0,78	0,56	0,38	0,24	0,16	0,08	0,04
605	0,78	0,54	0,38	0,25	0,16	0,08	0,04
606	0,78	0,54	0,35	0,24	0,16	0,08	0,04
607	0,78	0,54	0,38	0,24	0,16	0,08	0,04
608	0,75	0,54	0,35	0,22	0,16	0,08	0,04
609	0,73	0,51	0,33	0,22	0,16	0,07	0,04
610	0,73	0,52	0,35	0,24	0,16	0,08	0,04
611	0,73	0,51	0,33	0,22	0,16	0,08	0,04
612	0,70	0,49	0,33	0,22	0,16	0,07	0,04
613	0,72	0,49	0,33	0,22	0,16	0,08	0,04
614	0,69	0,49	0,33	0,22	0,16	0,08	0,04
615	0,69	0,49	0,33	0,22	0,14	0,08	0,04
616	0,69	0,48	0,32	0,22	0,16	0,07	0,04
617	0,67	0,48	0,32	0,21	0,16	0,05	0,04
618	0,64	0,45	0,29	0,19	0,11	0,05	0,01
619	0,64	0,48	0,29	0,22	0,14	0,07	0,04
620	0,64	0,46	0,30	0,19	0,14	0,08	0,04
621	0,64	0,45	0,29	0,19	0,13	0,07	0,04
622	0,61	0,45	0,27	0,18	0,11	0,05	0,03
623	0,61	0,43	0,27	0,19	0,11	0,05	0,03
624	0,60	0,43	0,29	0,19	0,11	0,07	0,04
625	0,61	0,43	0,29	0,18	0,11	0,05	0,04
626	0,60	0,42	0,27	0,18	0,11	0,05	0,04
627	0,60	0,43	0,29	0,19	0,13	0,07	0,04
628	0,60	0,42	0,27	0,18	0,14	0,07	0,03

629	0,60	0,40	0,27	0,18	0,11	0,05	0,04
630	0,58	0,40	0,26	0,18	0,11	0,07	0,04
631	0,56	0,40	0,27	0,18	0,13	0,07	0,04
632	0,55	0,39	0,24	0,18	0,11	0,05	0,04
633	0,55	0,37	0,24	0,16	0,11	0,07	0,04
634	0,55	0,37	0,24	0,16	0,11	0,04	0,04
635	0,52	0,37	0,24	0,18	0,09	0,05	0,04
636	0,55	0,37	0,24	0,18	0,11	0,05	0,03
637	0,53	0,37	0,24	0,18	0,11	0,07	0,04
638	0,52	0,34	0,24	0,16	0,09	0,04	0,04
639	0,50	0,34	0,24	0,13	0,11	0,05	0,04
640	0,52	0,36	0,24	0,15	0,11	0,05	0,04
641	0,50	0,34	0,23	0,15	0,11	0,05	0,04
642	0,47	0,34	0,21	0,13	0,09	0,05	0,03
643	0,47	0,34	0,21	0,13	0,09	0,04	0,03
644	0,47	0,34	0,21	0,15	0,09	0,05	0,04
645	0,46	0,33	0,21	0,15	0,09	0,04	0,03
646	0,46	0,29	0,19	0,13	0,09	0,04	0,03
647	0,46	0,33	0,21	0,15	0,09	0,05	0,04
648	0,46	0,31	0,19	0,13	0,06	0,04	0,04
649	0,46	0,29	0,19	0,13	0,09	0,05	0,04
650	0,43	0,29	0,21	0,13	0,08	0,04	0,03
651	0,43	0,29	0,19	0,13	0,09	0,04	0,03
652	0,43	0,29	0,19	0,13	0,06	0,04	0,04
653	0,41	0,29	0,19	0,13	0,06	0,04	0,03
654	0,41	0,28	0,18	0,13	0,06	0,04	0,01
655	0,40	0,26	0,16	0,12	0,06	0,04	0,03
656	0,38	0,26	0,18	0,10	0,06	0,02	0,01
657	0,38	0,26	0,16	0,10	0,06	0,02	0,01
658	0,38	0,26	0,15	0,10	0,06	0,02	0,01
659	0,38	0,28	0,16	0,12	0,08	0,04	0,04
660	0,38	0,26	0,16	0,13	0,06	0,04	0,03
661	0,37	0,26	0,15	0,10	0,06	0,04	0,01
662	0,38	0,25	0,16	0,10	0,08	0,04	0,03
663	0,37	0,25	0,15	0,10	0,06	0,02	0,03
664	0,38	0,26	0,18	0,12	0,08	0,04	0,04
665	0,35	0,25	0,15	0,10	0,06	0,04	0,03
666	0,33	0,23	0,15	0,09	0,05	0,02	0,01
667	0,33	0,25	0,15	0,10	0,06	0,04	0,03
668	0,33	0,23	0,15	0,09	0,06	0,04	0,03
669	0,33	0,23	0,15	0,10	0,06	0,04	0,03
670	0,32	0,22	0,15	0,09	0,06	0,02	0,03
671	0,32	0,22	0,15	0,09	0,06	0,04	0,03
672	0,29	0,20	0,15	0,09	0,06	0,04	0,01
673	0,30	0,20	0,12	0,09	0,05	0,02	0,03
674	0,29	0,20	0,13	0,07	0,05	0,02	0,01

675	0,29	0,20	0,15	0,09	0,06	0,04	0,01
676	0,29	0,20	0,12	0,07	0,06	0,04	0,01
677	0,29	0,20	0,12	0,09	0,06	0,04	0,03
678	0,29	0,20	0,13	0,10	0,06	0,04	0,03
679	0,29	0,20	0,12	0,09	0,06	0,02	0,03
680	0,29	0,20	0,12	0,09	0,06	0,04	0,03
681	0,27	0,20	0,12	0,09	0,06	0,04	0,03
682	0,27	0,19	0,12	0,07	0,05	0,04	0,01
683	0,26	0,17	0,10	0,07	0,06	0,02	0,03
684	0,24	0,16	0,10	0,06	0,03	0,02	0,01
685	0,26	0,16	0,10	0,09	0,06	0,02	0,01
686	0,24	0,17	0,10	0,06	0,03	0,01	0,00
687	0,24	0,19	0,12	0,07	0,06	0,04	0,03
688	0,24	0,16	0,10	0,07	0,03	0,02	0,01
689	0,24	0,17	0,10	0,06	0,03	0,01	0,01
690	0,23	0,16	0,10	0,06	0,03	0,01	0,01
691	0,20	0,16	0,10	0,07	0,05	0,02	0,01
692	0,24	0,16	0,10	0,09	0,05	0,04	0,01
693	0,20	0,16	0,07	0,04	0,03	0,02	0,00
694	0,20	0,16	0,09	0,06	0,03	0,02	0,03
695	0,20	0,14	0,09	0,06	0,02	0,02	0,00
696	0,20	0,14	0,09	0,06	0,02	0,02	0,00
697	0,18	0,11	0,07	0,06	0,02	-0,01	0,00
698	0,20	0,13	0,07	0,06	0,03	0,01	0,01
699	0,20	0,16	0,10	0,09	0,05	0,04	0,04
700	0,20	0,14	0,09	0,06	0,02	0,02	0,01
701	0,20	0,11	0,06	0,06	0,02	0,02	0,01
702	0,18	0,11	0,07	0,06	0,03	0,02	0,01
703	0,18	0,11	0,07	0,06	0,02	0,02	0,01
704	0,17	0,11	0,06	0,04	0,02	-0,01	0,00
705	0,15	0,11	0,07	0,04	0,02	0,01	0,01
706	0,15	0,11	0,06	0,04	0,02	0,01	0,01
707	0,15	0,11	0,07	0,04	0,02	0,02	0,01
708	0,15	0,11	0,07	0,04	0,02	0,02	0,01
709	0,15	0,11	0,07	0,04	0,02	0,01	0,01
710	0,17	0,11	0,06	0,04	0,02	0,02	0,03
711	0,15	0,11	0,06	0,04	0,02	0,02	0,01
712	0,14	0,11	0,03	0,04	0,02	-0,01	0,01
713	0,15	0,11	0,06	0,04	0,02	0,02	0,01
714	0,15	0,11	0,06	0,06	0,02	0,02	0,00
715	0,15	0,11	0,06	0,04	0,02	0,01	0,00
716	0,15	0,11	0,07	0,06	0,03	0,04	0,01
717	0,15	0,10	0,06	0,06	0,02	0,04	0,01
718	0,10	0,08	0,06	0,04	0,02	-0,01	0,01
719	0,14	0,10	0,06	0,04	0,02	0,01	0,01
720	0,12	0,08	0,06	0,04	0,02	0,02	0,01

721	0,10	0,06	0,03	0,04	0,00	0,01	0,01
722	0,14	0,08	0,06	0,04	0,02	0,02	0,01
723	0,10	0,06	0,03	0,02	0,00	0,01	0,01
724	0,10	0,06	0,03	0,02	0,00	-0,01	0,00
725	0,12	0,08	0,04	0,04	0,02	0,02	0,01
726	0,09	0,06	0,03	0,01	0,00	-0,01	0,00
727	0,10	0,06	0,04	0,02	0,02	0,01	0,01
728	0,10	0,08	0,04	0,04	0,03	0,04	0,01
729	0,10	0,06	0,03	0,02	0,00	-0,01	0,00
730	0,07	0,05	0,03	0,01	-0,01	-0,01	0,01
731	0,09	0,06	0,03	0,02	0,02	-0,01	0,01
732	0,10	0,06	0,04	0,04	0,02	0,02	0,01
733	0,09	0,06	0,03	0,02	0,02	0,02	0,01
734	0,07	0,05	0,03	0,01	0,02	-0,01	0,00
735	0,09	0,06	0,03	0,01	0,00	-0,01	0,01
736	0,07	0,03	0,03	0,02	-0,01	-0,01	0,01
737	0,07	0,06	0,03	0,01	0,00	0,01	0,00
738	0,06	0,02	0,01	-0,01	-0,01	-0,01	0,00
739	0,10	0,06	0,03	0,02	0,02	0,01	0,01
740	0,07	0,06	0,03	0,01	0,02	0,01	0,01
741	0,06	0,05	0,03	0,01	-0,01	0,01	0,00
742	0,06	0,05	0,03	0,01	0,00	-0,01	0,00
743	0,06	0,05	0,01	0,02	0,02	0,01	0,00
744	0,06	0,05	0,03	0,01	0,00	0,01	0,00
745	0,06	0,03	0,01	-0,01	0,00	0,01	0,00
746	0,03	0,05	0,03	0,01	-0,01	-0,01	0,00
747	0,06	0,03	0,03	0,01	0,02	-0,01	0,00
748	0,06	0,02	0,00	0,01	0,00	-0,02	0,00
749	0,06	0,05	0,03	0,02	0,03	0,04	0,04
750	0,03	0,02	-0,02	-0,02	-0,01	-0,01	0,00
751	0,01	0,03	0,01	-0,01	-0,01	-0,02	-0,02
752	0,03	0,03	0,01	0,01	0,00	-0,01	0,00
753	0,03	0,02	0,00	-0,01	0,00	-0,01	0,00
754	0,01	0,02	0,01	-0,01	-0,01	-0,01	0,00
755	0,01	0,02	0,01	0,01	-0,01	-0,01	0,00
756	0,03	0,02	0,00	-0,01	0,02	0,01	0,01
757	0,04	0,03	0,03	0,02	0,02	0,01	0,00
758	0,03	0,02	0,03	0,01	0,00	-0,01	0,00
759	0,03	0,02	0,01	0,01	-0,01	-0,01	0,00
760	0,03	0,03	0,03	0,02	0,00	0,01	0,00
761	0,01	0,02	0,03	0,01	0,02	0,01	0,00
762	0,03	0,02	0,03	0,01	-0,01	0,01	0,00
763	0,01	0,00	0,00	0,01	0,00	-0,01	-0,02
764	0,03	0,03	0,03	0,01	0,03	0,01	0,00
765	0,00	-0,01	0,00	-0,02	0,02	-0,01	-0,02
766	0,01	0,02	0,01	0,02	0,00	0,02	0,00

767	-0,02	-0,01	0,00	-0,01	-0,01	-0,02	-0,03
768	0,01	0,00	0,00	-0,01	-0,01	-0,01	0,00
769	0,00	0,03	0,01	0,02	0,02	-0,01	0,00
770	0,01	0,00	0,01	0,01	0,03	0,01	0,01
771	0,01	0,02	0,01	0,01	0,00	0,01	0,01
772	0,01	-0,01	0,00	-0,01	-0,01	-0,01	0,00
773	0,01	-0,01	0,01	0,01	0,02	0,01	0,03
774	0,01	-0,01	0,01	-0,02	0,00	0,01	0,00
775	0,01	0,00	0,01	0,01	0,02	0,01	0,01
776	0,00	0,02	0,00	0,01	0,00	0,02	0,01
777	0,00	0,00	0,03	0,01	0,00	0,01	0,00
778	0,01	0,00	0,01	0,01	0,00	0,02	0,01
779	0,01	0,00	0,03	0,01	0,02	0,02	0,01
780	0,01	0,02	0,01	-0,01	0,02	0,04	0,03
781	0,00	-0,01	0,03	-0,01	0,00	-0,01	0,01
782	-0,02	0,00	-0,02	-0,01	0,00	-0,01	0,00
783	-0,02	0,00	0,00	0,01	-0,01	-0,01	0,01
784	-0,03	-0,03	-0,02	-0,02	-0,01	-0,02	-0,02
785	-0,02	-0,01	-0,02	-0,01	-0,01	0,01	0,00
786	0,01	-0,01	0,00	0,01	0,03	0,01	0,01
787	0,01	-0,03	0,01	0,01	0,00	0,04	0,00
788	-0,05	-0,04	-0,05	-0,04	-0,04	-0,02	-0,03
789	-0,03	-0,01	-0,02	-0,02	-0,01	-0,01	0,00
790	-0,03	-0,01	-0,02	-0,01	-0,01	-0,01	0,00
791	-0,02	-0,01	-0,02	0,01	0,00	0,01	0,01
792	0,00	-0,01	0,01	0,01	0,02	0,01	0,01
793	-0,05	-0,03	-0,02	-0,01	-0,03	-0,01	0,00
794	0,00	-0,01	0,00	0,01	0,02	0,02	0,01
795	-0,02	-0,01	-0,02	-0,01	0,00	-0,01	0,00
796	-0,05	-0,06	-0,04	-0,04	-0,03	-0,02	0,00
797	-0,06	-0,03	-0,02	-0,04	-0,01	-0,01	-0,02
798	-0,03	-0,03	0,00	0,01	-0,01	0,01	0,00
799	-0,03	-0,06	-0,04	-0,01	-0,01	-0,02	-0,02
800	-0,03	-0,01	-0,02	-0,01	-0,01	-0,01	0,01

TABLE 2 – CHLA ABSORPTION COEFFICIENTS FROM SEVEN CONCENTRATIONS

	Concentration 469 ug/L a(m-1) coeff (3 paralells)	Concentration 281 ug/L a(m-1) coeff (3 paralells)	Concentration: 169 ug chla/L a(m-1) coeff (3 paralells)	Concentration 101 ug chla/L a(m-1) coeff (3 paralells)	Concentration 60 ug chla/L a(m-1) coeff (3 paralells)	Concentration 36 ug chla/L a(m-1) coeff (3 paralells)	Concentration 21 ug chla/L a(m-1) coeff (3 paralells)
350	8,64	5,17	2,94	1,77	1,01	0,51	0,26
351	8,59	5,12	2,93	1,74	1,01	0,51	0,26
352	8,50	5,09	2,87	1,72	0,96	0,51	0,26

353	8,47	5,08	2,88	1,75	0,99	0,54	0,30
354	8,36	5,02	2,85	1,69	0,95	0,50	0,26
355	8,33	4,97	2,81	1,66	0,92	0,47	0,26
356	8,28	4,97	2,81	1,68	0,95	0,50	0,26
357	8,19	4,91	2,76	1,62	0,89	0,44	0,23
358	8,18	4,91	2,76	1,66	0,93	0,47	0,26
359	8,16	4,89	2,79	1,66	0,93	0,48	0,26
360	8,09	4,88	2,76	1,65	0,92	0,48	0,26
361	8,02	4,80	2,74	1,60	0,90	0,47	0,25
362	7,99	4,77	2,70	1,60	0,89	0,47	0,25
363	7,92	4,72	2,68	1,59	0,90	0,44	0,23
364	7,87	4,71	2,65	1,59	0,86	0,44	0,23
365	7,87	4,69	2,65	1,56	0,87	0,47	0,25
366	7,82	4,69	2,65	1,57	0,87	0,47	0,25
367	7,79	4,68	2,65	1,57	0,89	0,48	0,26
368	7,73	4,62	2,62	1,54	0,87	0,45	0,23
369	7,72	4,63	2,61	1,56	0,89	0,45	0,25
370	7,67	4,59	2,61	1,51	0,86	0,45	0,23
371	7,66	4,59	2,58	1,52	0,86	0,45	0,25
372	7,64	4,59	2,59	1,54	0,86	0,50	0,28
373	7,59	4,56	2,58	1,54	0,84	0,48	0,26
374	7,61	4,59	2,59	1,54	0,87	0,48	0,28
375	7,59	4,56	2,58	1,54	0,86	0,47	0,28
376	7,58	4,56	2,56	1,54	0,87	0,48	0,28
377	7,56	4,54	2,56	1,51	0,82	0,50	0,28
378	7,55	4,52	2,54	1,52	0,86	0,48	0,28
379	7,56	4,56	2,56	1,51	0,86	0,48	0,30
380	7,56	4,54	2,58	1,52	0,87	0,50	0,30
381	7,55	4,51	2,54	1,51	0,84	0,47	0,30
382	7,56	4,52	2,56	1,51	0,87	0,48	0,28
383	7,53	4,51	2,54	1,51	0,84	0,48	0,28
384	7,53	4,51	2,54	1,52	0,86	0,48	0,30
385	7,53	4,51	2,54	1,51	0,84	0,48	0,28
386	7,52	4,49	2,54	1,51	0,84	0,47	0,28
387	7,47	4,49	2,53	1,49	0,84	0,48	0,28
388	7,49	4,48	2,53	1,51	0,84	0,48	0,28
389	7,50	4,48	2,54	1,51	0,86	0,50	0,30
390	7,46	4,46	2,51	1,49	0,84	0,48	0,30
391	7,44	4,43	2,50	1,49	0,82	0,45	0,28
392	7,41	4,42	2,50	1,49	0,84	0,45	0,26
393	7,44	4,46	2,50	1,49	0,82	0,48	0,30
394	7,41	4,43	2,50	1,49	0,84	0,48	0,30
395	7,38	4,42	2,50	1,49	0,82	0,47	0,28
396	7,36	4,40	2,48	1,48	0,82	0,47	0,28
397	7,36	4,39	2,47	1,48	0,82	0,48	0,28
398	7,32	4,39	2,47	1,45	0,82	0,47	0,28

399	7,32	4,34	2,45	1,45	0,81	0,45	0,28
400	7,30	4,33	2,44	1,45	0,81	0,45	0,28
401	7,30	4,34	2,45	1,46	0,81	0,47	0,26
402	7,29	4,31	2,42	1,43	0,81	0,45	0,26
403	7,29	4,31	2,45	1,48	0,81	0,47	0,28
404	7,27	4,31	2,42	1,43	0,81	0,44	0,28
405	7,24	4,29	2,42	1,46	0,79	0,45	0,26
406	7,27	4,29	2,42	1,43	0,81	0,45	0,28
407	7,29	4,33	2,44	1,46	0,81	0,47	0,28
408	7,29	4,31	2,42	1,43	0,81	0,44	0,28
409	7,35	4,36	2,45	1,48	0,82	0,47	0,30
410	7,35	4,36	2,47	1,48	0,81	0,45	0,28
411	7,41	4,37	2,50	1,51	0,84	0,50	0,33
412	7,43	4,39	2,47	1,48	0,82	0,47	0,30
413	7,47	4,40	2,51	1,51	0,86	0,48	0,30
414	7,49	4,42	2,50	1,52	0,84	0,48	0,28
415	7,53	4,43	2,51	1,52	0,86	0,50	0,31
416	7,53	4,45	2,51	1,51	0,84	0,48	0,31
417	7,58	4,46	2,54	1,52	0,86	0,50	0,28
418	7,63	4,52	2,59	1,56	0,89	0,53	0,33
419	7,63	4,49	2,56	1,52	0,87	0,50	0,33
420	7,64	4,49	2,56	1,52	0,86	0,48	0,33
421	7,67	4,52	2,59	1,57	0,89	0,50	0,33
422	7,67	4,52	2,56	1,56	0,87	0,51	0,31
423	7,70	4,51	2,59	1,56	0,87	0,50	0,31
424	7,72	4,56	2,61	1,57	0,89	0,50	0,33
425	7,70	4,57	2,59	1,57	0,87	0,51	0,33
426	7,72	4,56	2,59	1,57	0,87	0,50	0,33
427	7,75	4,57	2,62	1,57	0,89	0,50	0,33
428	7,76	4,59	2,64	1,57	0,87	0,53	0,34
429	7,81	4,62	2,64	1,60	0,92	0,54	0,36
430	7,84	4,62	2,65	1,60	0,92	0,54	0,34
431	7,90	4,65	2,68	1,62	0,92	0,53	0,36
432	7,93	4,68	2,68	1,62	0,92	0,53	0,34
433	7,99	4,71	2,73	1,65	0,93	0,53	0,36
434	8,05	4,74	2,73	1,65	0,95	0,54	0,34
435	8,12	4,75	2,73	1,66	0,93	0,54	0,34
436	8,19	4,85	2,79	1,69	0,96	0,56	0,37
437	8,24	4,86	2,81	1,71	0,96	0,56	0,37
438	8,30	4,89	2,82	1,71	0,95	0,56	0,37
439	8,36	4,94	2,85	1,72	0,98	0,57	0,37
440	8,44	4,98	2,88	1,74	0,99	0,59	0,37
441	8,48	5,00	2,90	1,75	0,98	0,59	0,37
442	8,53	5,03	2,91	1,75	0,99	0,57	0,37
443	8,58	5,08	2,94	1,80	1,02	0,62	0,39
444	8,61	5,08	2,96	1,80	1,02	0,60	0,37

445	8,61	5,09	2,96	1,79	1,02	0,59	0,39
446	8,61	5,08	2,94	1,77	1,01	0,59	0,37
447	8,59	5,08	2,96	1,79	1,01	0,59	0,37
448	8,56	5,08	2,94	1,77	0,99	0,59	0,37
449	8,58	5,08	2,96	1,80	1,02	0,62	0,40
450	8,53	5,05	2,94	1,77	1,02	0,59	0,39
451	8,50	5,03	2,94	1,77	1,02	0,59	0,39
452	8,47	5,02	2,93	1,77	1,01	0,59	0,39
453	8,45	5,02	2,93	1,77	0,99	0,59	0,39
454	8,42	4,98	2,90	1,75	0,99	0,59	0,39
455	8,41	5,00	2,91	1,77	1,01	0,59	0,39
456	8,41	4,98	2,93	1,75	1,01	0,59	0,39
457	8,38	4,97	2,88	1,74	0,98	0,57	0,36
458	8,39	5,00	2,91	1,75	1,02	0,59	0,40
459	8,39	4,98	2,91	1,75	1,01	0,59	0,39
460	8,38	4,97	2,93	1,77	1,02	0,59	0,39
461	8,38	5,00	2,91	1,75	1,01	0,60	0,39
462	8,38	4,97	2,91	1,75	1,01	0,59	0,39
463	8,38	5,00	2,91	1,75	1,02	0,60	0,42
464	8,36	5,00	2,93	1,77	1,02	0,60	0,40
465	8,35	4,97	2,91	1,75	0,99	0,59	0,39
466	8,35	4,98	2,91	1,75	0,99	0,59	0,39
467	8,32	5,00	2,91	1,75	1,01	0,59	0,39
468	8,30	4,95	2,91	1,75	1,01	0,60	0,42
469	8,28	4,95	2,91	1,75	1,01	0,62	0,42
470	8,25	4,94	2,90	1,75	1,04	0,60	0,42
471	8,21	4,91	2,88	1,75	1,01	0,60	0,40
472	8,16	4,91	2,88	1,75	0,99	0,59	0,40
473	8,12	4,86	2,87	1,74	1,02	0,60	0,40
474	8,07	4,86	2,87	1,75	0,99	0,60	0,40
475	8,02	4,82	2,82	1,71	0,99	0,59	0,39
476	7,98	4,80	2,82	1,71	0,99	0,59	0,39
477	7,93	4,77	2,82	1,71	0,99	0,59	0,39
478	7,89	4,72	2,79	1,69	0,99	0,59	0,39
479	7,84	4,72	2,77	1,66	0,96	0,59	0,37
480	7,79	4,68	2,77	1,66	0,95	0,59	0,39
481	7,75	4,65	2,76	1,66	0,96	0,59	0,39
482	7,70	4,63	2,73	1,66	0,96	0,59	0,37
483	7,69	4,63	2,73	1,66	0,95	0,59	0,39
484	7,66	4,60	2,70	1,63	0,95	0,57	0,37
485	7,61	4,59	2,68	1,62	0,93	0,56	0,37
486	7,61	4,59	2,68	1,63	0,95	0,57	0,39
487	7,61	4,59	2,68	1,65	0,95	0,57	0,39
488	7,56	4,56	2,68	1,63	0,95	0,56	0,37
489	7,56	4,56	2,68	1,63	0,95	0,56	0,39
490	7,56	4,56	2,68	1,62	0,95	0,56	0,37

491	7,56	4,54	2,68	1,62	0,93	0,56	0,37
492	7,56	4,54	2,68	1,62	0,93	0,56	0,37
493	7,56	4,54	2,68	1,63	0,93	0,56	0,37
494	7,55	4,57	2,68	1,63	0,93	0,54	0,37
495	7,56	4,54	2,68	1,63	0,95	0,57	0,37
496	7,56	4,56	2,68	1,65	0,95	0,59	0,37
497	7,55	4,57	2,68	1,63	0,95	0,59	0,37
498	7,53	4,54	2,68	1,62	0,93	0,56	0,37
499	7,53	4,54	2,68	1,63	0,93	0,57	0,37
500	7,53	4,54	2,68	1,63	0,95	0,56	0,39
501	7,49	4,52	2,67	1,62	0,93	0,56	0,37
502	7,49	4,54	2,68	1,65	0,95	0,59	0,39
503	7,47	4,54	2,65	1,63	0,95	0,56	0,37
504	7,44	4,49	2,65	1,62	0,93	0,56	0,37
505	7,43	4,49	2,65	1,62	0,93	0,56	0,39
506	7,36	4,45	2,64	1,62	0,93	0,54	0,37
507	7,35	4,45	2,64	1,62	0,93	0,54	0,37
508	7,30	4,45	2,64	1,60	0,93	0,54	0,37
509	7,29	4,42	2,61	1,60	0,92	0,54	0,37
510	7,26	4,40	2,61	1,60	0,92	0,54	0,37
511	7,21	4,37	2,59	1,57	0,90	0,54	0,36
512	7,18	4,37	2,59	1,59	0,92	0,56	0,37
513	7,15	4,34	2,58	1,57	0,90	0,54	0,36
514	7,12	4,33	2,56	1,57	0,90	0,54	0,37
515	7,07	4,31	2,54	1,56	0,89	0,54	0,37
516	7,03	4,28	2,54	1,56	0,89	0,54	0,36
517	7,00	4,28	2,53	1,54	0,89	0,54	0,36
518	6,97	4,23	2,50	1,54	0,89	0,53	0,34
519	6,94	4,23	2,50	1,52	0,89	0,54	0,36
520	6,89	4,19	2,48	1,51	0,86	0,51	0,34
521	6,87	4,19	2,47	1,51	0,87	0,53	0,34
522	6,81	4,14	2,47	1,51	0,86	0,51	0,34
523	6,80	4,14	2,47	1,51	0,89	0,53	0,34
524	6,77	4,14	2,47	1,51	0,87	0,51	0,36
525	6,74	4,10	2,45	1,51	0,86	0,53	0,34
526	6,71	4,10	2,45	1,51	0,84	0,53	0,36
527	6,67	4,08	2,42	1,49	0,86	0,50	0,34
528	6,63	4,05	2,42	1,46	0,84	0,50	0,34
529	6,61	4,05	2,42	1,51	0,86	0,51	0,36
530	6,58	4,00	2,41	1,46	0,84	0,50	0,34
531	6,54	4,00	2,38	1,46	0,84	0,50	0,34
532	6,51	4,00	2,38	1,46	0,84	0,50	0,34
533	6,49	3,96	2,38	1,46	0,84	0,50	0,34
534	6,44	3,94	2,36	1,45	0,82	0,50	0,34
535	6,41	3,93	2,35	1,43	0,84	0,50	0,34
536	6,38	3,91	2,33	1,42	0,81	0,50	0,34

537	6,35	3,88	2,33	1,42	0,81	0,50	0,33
538	6,31	3,87	2,33	1,42	0,81	0,48	0,34
539	6,31	3,88	2,33	1,42	0,82	0,50	0,34
540	6,26	3,83	2,33	1,42	0,81	0,50	0,34
541	6,21	3,82	2,28	1,40	0,81	0,47	0,31
542	6,18	3,79	2,28	1,39	0,79	0,48	0,33
543	6,15	3,77	2,28	1,39	0,79	0,48	0,33
544	6,12	3,76	2,27	1,39	0,81	0,50	0,33
545	6,06	3,73	2,24	1,37	0,79	0,47	0,31
546	6,05	3,71	2,24	1,37	0,79	0,47	0,33
547	6,00	3,70	2,22	1,37	0,79	0,45	0,33
548	5,95	3,67	2,21	1,36	0,76	0,45	0,31
549	5,94	3,65	2,19	1,36	0,78	0,45	0,33
550	5,86	3,62	2,19	1,36	0,76	0,45	0,33
551	5,83	3,60	2,18	1,34	0,76	0,45	0,33
552	5,79	3,57	2,15	1,33	0,75	0,45	0,31
553	5,74	3,53	2,15	1,31	0,75	0,45	0,33
554	5,69	3,53	2,15	1,31	0,76	0,45	0,33
555	5,63	3,48	2,12	1,31	0,75	0,45	0,31
556	5,60	3,44	2,10	1,29	0,73	0,45	0,31
557	5,52	3,44	2,07	1,28	0,73	0,45	0,30
558	5,48	3,39	2,05	1,26	0,72	0,45	0,30
559	5,42	3,34	2,02	1,26	0,72	0,45	0,30
560	5,37	3,34	2,02	1,26	0,70	0,42	0,30
561	5,33	3,30	1,99	1,22	0,70	0,44	0,30
562	5,28	3,25	1,98	1,22	0,70	0,41	0,31
563	5,20	3,25	1,96	1,22	0,70	0,44	0,30
564	5,14	3,21	1,95	1,20	0,69	0,41	0,31
565	5,10	3,16	1,92	1,19	0,70	0,41	0,30
566	5,03	3,11	1,90	1,16	0,66	0,41	0,28
567	4,97	3,10	1,89	1,17	0,67	0,41	0,28
568	4,91	3,05	1,85	1,13	0,66	0,39	0,28
569	4,87	3,01	1,84	1,13	0,66	0,41	0,28
570	4,83	3,01	1,82	1,13	0,67	0,41	0,28
571	4,77	2,98	1,81	1,13	0,64	0,39	0,28
572	4,70	2,93	1,78	1,10	0,63	0,41	0,28
573	4,65	2,88	1,76	1,08	0,63	0,37	0,26
574	4,60	2,87	1,75	1,06	0,63	0,36	0,25
575	4,56	2,82	1,72	1,06	0,61	0,37	0,26
576	4,51	2,81	1,72	1,03	0,61	0,36	0,26
577	4,48	2,78	1,70	1,03	0,61	0,36	0,26
578	4,45	2,73	1,67	1,03	0,58	0,36	0,26
579	4,39	2,73	1,66	1,02	0,59	0,36	0,25
580	4,34	2,68	1,62	1,02	0,58	0,36	0,25
581	4,30	2,65	1,62	0,99	0,58	0,36	0,26
582	4,27	2,64	1,61	0,99	0,58	0,36	0,25

583	4,22	2,61	1,58	0,97	0,58	0,37	0,26
584	4,21	2,61	1,58	0,97	0,58	0,34	0,25
585	4,16	2,56	1,53	0,97	0,55	0,33	0,22
586	4,16	2,55	1,53	0,96	0,58	0,36	0,25
587	4,11	2,55	1,53	0,96	0,55	0,34	0,23
588	4,08	2,52	1,53	0,96	0,55	0,34	0,23
589	4,05	2,50	1,50	0,94	0,53	0,33	0,23
590	4,02	2,49	1,49	0,93	0,53	0,34	0,23
591	3,98	2,45	1,49	0,93	0,53	0,33	0,23
592	3,93	2,42	1,47	0,91	0,53	0,33	0,23
593	3,90	2,39	1,44	0,90	0,53	0,33	0,23
594	3,84	2,36	1,44	0,88	0,53	0,31	0,22
595	3,82	2,35	1,41	0,88	0,50	0,31	0,22
596	3,79	2,32	1,41	0,88	0,52	0,31	0,22
597	3,75	2,30	1,39	0,88	0,52	0,33	0,23
598	3,68	2,26	1,35	0,83	0,49	0,30	0,20
599	3,65	2,24	1,35	0,85	0,49	0,30	0,22
600	3,61	2,21	1,32	0,83	0,49	0,28	0,20
601	3,56	2,18	1,32	0,83	0,49	0,28	0,22
602	3,50	2,13	1,30	0,80	0,47	0,28	0,20
603	3,47	2,12	1,27	0,80	0,46	0,28	0,19
604	3,42	2,10	1,27	0,80	0,47	0,30	0,22
605	3,38	2,07	1,24	0,79	0,44	0,28	0,20
606	3,35	2,04	1,23	0,79	0,46	0,28	0,19
607	3,33	2,03	1,23	0,76	0,44	0,28	0,19
608	3,29	2,01	1,21	0,76	0,44	0,28	0,19
609	3,24	1,98	1,18	0,74	0,43	0,24	0,19
610	3,24	1,98	1,18	0,76	0,44	0,28	0,19
611	3,21	1,96	1,18	0,74	0,43	0,25	0,19
612	3,19	1,93	1,15	0,73	0,43	0,25	0,19
613	3,19	1,93	1,15	0,74	0,43	0,25	0,19
614	3,16	1,92	1,13	0,74	0,44	0,25	0,20
615	3,15	1,90	1,13	0,71	0,41	0,24	0,19
616	3,15	1,90	1,13	0,71	0,41	0,27	0,19
617	3,12	1,89	1,12	0,71	0,40	0,24	0,19
618	3,10	1,86	1,10	0,70	0,40	0,24	0,17
619	3,10	1,86	1,10	0,71	0,41	0,24	0,19
620	3,10	1,86	1,10	0,71	0,43	0,27	0,19
621	3,10	1,84	1,10	0,71	0,40	0,24	0,19
622	3,06	1,84	1,10	0,71	0,40	0,24	0,17
623	3,01	1,81	1,07	0,68	0,38	0,24	0,16
624	3,01	1,80	1,07	0,68	0,38	0,24	0,19
625	3,01	1,80	1,07	0,70	0,38	0,24	0,17
626	2,96	1,78	1,06	0,67	0,38	0,24	0,17
627	2,96	1,76	1,04	0,67	0,38	0,24	0,17
628	2,92	1,75	1,04	0,67	0,38	0,24	0,16

629	2,92	1,75	1,03	0,67	0,38	0,24	0,17
630	2,87	1,70	1,01	0,65	0,36	0,24	0,17
631	2,89	1,70	1,01	0,67	0,38	0,24	0,17
632	2,84	1,69	1,00	0,64	0,36	0,24	0,17
633	2,84	1,67	0,98	0,64	0,36	0,24	0,17
634	2,83	1,67	0,98	0,64	0,35	0,24	0,17
635	2,83	1,66	0,98	0,64	0,36	0,24	0,17
636	2,81	1,66	0,98	0,62	0,36	0,24	0,16
637	2,78	1,64	0,98	0,62	0,36	0,24	0,17
638	2,75	1,64	0,98	0,62	0,35	0,22	0,17
639	2,73	1,61	0,95	0,62	0,33	0,21	0,16
640	2,70	1,60	0,93	0,60	0,33	0,24	0,17
641	2,67	1,57	0,93	0,59	0,33	0,19	0,14
642	2,60	1,53	0,90	0,59	0,33	0,19	0,14
643	2,55	1,50	0,89	0,57	0,30	0,19	0,13
644	2,49	1,47	0,89	0,57	0,33	0,21	0,14
645	2,43	1,43	0,84	0,57	0,30	0,19	0,16
646	2,35	1,38	0,83	0,53	0,29	0,19	0,14
647	2,26	1,32	0,80	0,51	0,29	0,18	0,13
648	2,20	1,29	0,75	0,51	0,29	0,19	0,14
649	2,12	1,24	0,75	0,50	0,29	0,19	0,14
650	2,03	1,18	0,70	0,47	0,24	0,14	0,13
651	1,98	1,15	0,67	0,45	0,24	0,14	0,13
652	1,89	1,09	0,63	0,44	0,24	0,16	0,13
653	1,81	1,04	0,61	0,41	0,24	0,14	0,11
654	1,78	1,01	0,58	0,41	0,21	0,14	0,10
655	1,74	0,97	0,57	0,37	0,21	0,14	0,10
656	1,66	0,94	0,55	0,36	0,20	0,13	0,10
657	1,65	0,92	0,54	0,36	0,20	0,14	0,10
658	1,61	0,91	0,52	0,36	0,20	0,13	0,10
659	1,61	0,91	0,52	0,36	0,20	0,13	0,10
660	1,63	0,89	0,51	0,36	0,20	0,10	0,10
661	1,68	0,92	0,52	0,36	0,20	0,11	0,10
662	1,74	0,94	0,55	0,36	0,18	0,10	0,10
663	1,83	1,01	0,57	0,39	0,21	0,13	0,10
664	1,94	1,06	0,60	0,41	0,21	0,13	0,10
665	2,09	1,15	0,64	0,42	0,23	0,14	0,10
666	2,29	1,29	0,74	0,47	0,26	0,16	0,13
667	2,50	1,40	0,80	0,51	0,27	0,18	0,14
668	2,73	1,53	0,87	0,56	0,30	0,19	0,14
669	3,01	1,72	0,98	0,62	0,35	0,22	0,17
670	3,29	1,86	1,06	0,67	0,35	0,21	0,16
671	3,56	2,06	1,18	0,73	0,40	0,24	0,19
672	3,87	2,21	1,29	0,79	0,44	0,27	0,19
673	4,14	2,39	1,39	0,87	0,49	0,28	0,19
674	4,37	2,53	1,46	0,91	0,49	0,30	0,20

675	4,59	2,67	1,55	0,96	0,53	0,33	0,23
676	4,76	2,81	1,62	0,99	0,56	0,34	0,23
677	4,91	2,90	1,69	1,02	0,58	0,34	0,25
678	5,02	2,96	1,72	1,05	0,59	0,36	0,23
679	5,10	3,01	1,76	1,08	0,61	0,37	0,25
680	5,14	3,05	1,79	1,08	0,63	0,37	0,25
681	5,19	3,08	1,81	1,11	0,63	0,39	0,28
682	5,17	3,10	1,81	1,11	0,64	0,37	0,26
683	5,14	3,05	1,82	1,11	0,64	0,37	0,25
684	5,13	3,05	1,79	1,11	0,64	0,39	0,26
685	5,06	3,04	1,78	1,10	0,63	0,37	0,25
686	5,00	3,01	1,78	1,08	0,63	0,37	0,25
687	4,93	2,96	1,76	1,10	0,64	0,39	0,26
688	4,83	2,91	1,73	1,06	0,61	0,37	0,23
689	4,74	2,87	1,70	1,05	0,61	0,36	0,23
690	4,64	2,79	1,67	1,03	0,59	0,37	0,23
691	4,50	2,73	1,62	1,02	0,59	0,36	0,23
692	4,36	2,64	1,58	0,96	0,55	0,33	0,23
693	4,21	2,55	1,52	0,93	0,53	0,33	0,20
694	4,08	2,47	1,49	0,93	0,55	0,34	0,23
695	3,93	2,36	1,43	0,87	0,50	0,31	0,22
696	3,78	2,30	1,38	0,87	0,50	0,30	0,19
697	3,64	2,22	1,33	0,82	0,50	0,30	0,19
698	3,50	2,13	1,29	0,80	0,46	0,28	0,19
699	3,36	2,06	1,24	0,77	0,44	0,28	0,19
700	3,26	1,98	1,20	0,73	0,43	0,27	0,17
701	3,13	1,92	1,15	0,73	0,41	0,25	0,19
702	3,04	1,84	1,10	0,70	0,41	0,25	0,17
703	2,95	1,80	1,09	0,68	0,38	0,25	0,17
704	2,86	1,75	1,06	0,65	0,36	0,24	0,14
705	2,76	1,67	1,01	0,62	0,36	0,21	0,14
706	2,69	1,63	0,97	0,62	0,36	0,22	0,14
707	2,63	1,58	0,97	0,60	0,33	0,22	0,14
708	2,55	1,55	0,92	0,59	0,35	0,22	0,14
709	2,49	1,49	0,90	0,57	0,32	0,19	0,14
710	2,40	1,46	0,87	0,56	0,32	0,21	0,14
711	2,35	1,41	0,86	0,56	0,32	0,21	0,14
712	2,27	1,37	0,83	0,53	0,30	0,19	0,11
713	2,21	1,32	0,81	0,50	0,30	0,18	0,13
714	2,14	1,29	0,78	0,50	0,27	0,19	0,14
715	2,07	1,26	0,74	0,50	0,27	0,18	0,10
716	2,06	1,23	0,74	0,48	0,27	0,19	0,14
717	2,00	1,18	0,72	0,47	0,27	0,16	0,13
718	1,92	1,15	0,69	0,44	0,23	0,16	0,10
719	1,88	1,14	0,67	0,44	0,24	0,16	0,11
720	1,83	1,09	0,64	0,42	0,23	0,16	0,10

721	1,77	1,06	0,64	0,41	0,23	0,16	0,10
722	1,74	1,04	0,61	0,39	0,23	0,14	0,10
723	1,69	1,00	0,60	0,39	0,23	0,16	0,10
724	1,65	0,97	0,57	0,36	0,21	0,14	0,10
725	1,58	0,95	0,58	0,36	0,23	0,14	0,10
726	1,55	0,91	0,54	0,34	0,20	0,13	0,10
727	1,51	0,91	0,54	0,34	0,20	0,14	0,10
728	1,46	0,86	0,54	0,34	0,18	0,13	0,10
729	1,42	0,86	0,49	0,33	0,18	0,11	0,07
730	1,37	0,80	0,47	0,28	0,17	0,11	0,05
731	1,35	0,80	0,47	0,30	0,18	0,11	0,05
732	1,29	0,77	0,44	0,30	0,15	0,11	0,05
733	1,26	0,74	0,44	0,28	0,15	0,11	0,05
734	1,20	0,72	0,41	0,27	0,15	0,10	0,05
735	1,19	0,71	0,40	0,27	0,17	0,10	0,05
736	1,14	0,69	0,40	0,25	0,13	0,11	0,05
737	1,11	0,65	0,40	0,25	0,13	0,10	0,05
738	1,09	0,65	0,37	0,25	0,13	0,08	0,05
739	1,05	0,61	0,35	0,22	0,13	0,07	0,05
740	1,03	0,60	0,35	0,25	0,13	0,08	0,05
741	0,99	0,58	0,35	0,22	0,12	0,07	0,05
742	0,92	0,54	0,29	0,21	0,12	0,07	0,03
743	0,91	0,54	0,31	0,19	0,09	0,07	0,02
744	0,88	0,52	0,31	0,21	0,12	0,07	0,05
745	0,85	0,49	0,29	0,18	0,09	0,07	0,03
746	0,80	0,48	0,28	0,18	0,10	0,07	0,03
747	0,82	0,48	0,26	0,19	0,10	0,08	0,05
748	0,76	0,45	0,24	0,18	0,09	0,07	0,00
749	0,73	0,45	0,26	0,16	0,10	0,07	0,05
750	0,68	0,40	0,21	0,13	0,06	0,04	0,00
751	0,65	0,38	0,23	0,13	0,09	0,04	0,03
752	0,63	0,38	0,21	0,14	0,07	0,05	0,05
753	0,62	0,38	0,21	0,11	0,07	0,07	0,03
754	0,56	0,34	0,18	0,13	0,06	0,04	0,00
755	0,53	0,32	0,20	0,11	0,09	0,04	0,00
756	0,50	0,31	0,17	0,08	0,06	0,02	0,00
757	0,50	0,31	0,17	0,10	0,07	0,05	0,02
758	0,45	0,28	0,14	0,08	0,04	0,02	0,00
759	0,42	0,26	0,17	0,08	0,07	0,05	0,02
760	0,36	0,22	0,12	0,07	0,03	0,02	-0,01
761	0,34	0,22	0,11	0,08	0,04	0,02	0,02
762	0,30	0,19	0,11	0,05	0,03	0,01	0,00
763	0,28	0,19	0,11	0,07	0,03	0,02	0,00
764	0,25	0,15	0,08	0,07	0,04	0,02	0,00
765	0,25	0,14	0,09	0,04	0,04	0,02	0,00
766	0,20	0,14	0,11	0,07	0,03	0,02	0,02

767	0,17	0,11	0,06	0,04	0,00	-0,01	0,00
768	0,14	0,12	0,08	0,05	0,03	0,04	0,03
769	0,14	0,09	0,06	0,04	0,03	0,01	0,00
770	0,10	0,06	0,03	0,02	0,01	0,01	0,00
771	0,08	0,03	0,03	0,01	0,00	0,01	0,00
772	0,07	0,06	0,03	0,04	0,03	0,02	0,02
773	0,04	0,03	0,01	0,02	0,01	0,01	0,00
774	0,00	0,02	0,01	0,02	0,00	-0,01	0,00
775	-0,01	0,00	-0,02	-0,01	0,00	-0,01	0,00
776	-0,03	-0,03	0,01	0,01	0,00	0,01	0,00
777	-0,06	-0,03	-0,02	-0,01	0,00	-0,01	0,00
778	-0,09	-0,06	-0,03	-0,04	-0,02	-0,01	0,00
779	-0,12	-0,08	-0,06	-0,01	-0,02	0,01	0,00
780	-0,15	-0,09	-0,08	-0,04	-0,05	-0,04	-0,04
781	-0,18	-0,12	-0,08	-0,04	-0,02	-0,02	-0,03
782	-0,19	-0,12	-0,06	-0,05	-0,03	-0,01	-0,01
783	-0,21	-0,12	-0,06	-0,04	0,00	0,01	0,00
784	-0,24	-0,15	-0,09	-0,05	-0,03	-0,04	0,00
785	-0,29	-0,20	-0,12	-0,09	-0,05	-0,02	-0,04
786	-0,30	-0,17	-0,11	-0,07	-0,03	-0,04	-0,01
787	-0,33	-0,20	-0,11	-0,09	-0,05	-0,04	-0,01
788	-0,33	-0,23	-0,12	-0,09	-0,05	-0,04	-0,01
789	-0,35	-0,20	-0,12	-0,09	-0,03	-0,01	-0,01
790	-0,38	-0,26	-0,14	-0,09	-0,05	-0,04	-0,04
791	-0,38	-0,23	-0,14	-0,09	-0,03	-0,02	-0,01
792	-0,42	-0,27	-0,14	-0,10	-0,03	-0,04	-0,01
793	-0,46	-0,29	-0,15	-0,09	-0,05	-0,04	-0,03
794	-0,49	-0,32	-0,18	-0,13	-0,08	-0,04	-0,04
795	-0,52	-0,34	-0,18	-0,12	-0,08	-0,04	-0,06
796	-0,52	-0,31	-0,18	-0,09	-0,05	-0,04	0,00
797	-0,52	-0,32	-0,18	-0,10	-0,06	-0,04	0,00
798	-0,53	-0,32	-0,18	-0,12	-0,06	-0,02	0,00
799	-0,58	-0,35	-0,18	-0,12	-0,05	-0,04	0,00
800	-0,58	-0,34	-0,18	-0,09	-0,05	0,01	0,00

Statistics: