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An-Najah National University
Faculty Of Graduate Studies

Temporal Dynamics of phytoplankton in the Coral Reef and Open Water in Gulf of Aqaba Red Sea

BY

Abdul Karim . M . Farrah

Supervisors

Prof . Ziad Abdeen
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Submitted In Partial Fulfillment Of The Requirement For The Degree Of Master Of Environmental Science , Faculty Of Graduate Studies, At An-Najah National University At Nablus, Palestine.

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This Thesis was defended successfully on 13-1-2001 and approved by..

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4- Dr . Kamel Edwan .	

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DEDICATION

To My Mother , My Wife , My Kids , My Brothers

And Sisters

With My Love & Respect

A . Karim Farrah

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ACKNOWLEDGMENT

I would like to thank the Palestinian Consultancy Group(PCG) in Jerusalem for their financial support . And to my supervisors :

Prof . Z . Abdeen from Alquds University .
Prof . A . Z . Zohri from An-Najah University .
for their scientific support .

Also my deep thanks to Dr . A . Genin and his stuff from the Interuniversity Institute (I.U.I) for Marine Science in Eilat for their (scientific & practical) support and their kindly hospitality during my study.

Finally my special thanks to Alquds University presented in Faculty of Science and Life Science Department .

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ABSTRACT

The major objectives in this study were to quantify the short-term (minutes to weeks) variations of phytoplankton over the coral reef (Reef site) and at a near-by the open-water (Away site), and to evaluate the roles of currents, behavior and localized predation in the generation of the observed variations.

The study was carried out on 10th of October until 2nd of Dec 99 in the Gulf of Aqaba (Eilat) / Red Sea .

Phytoplankton are present throughout the lighted regions of all seas, including under ice in polar areas . Because the phytoplankton are the dominant plants in the ocean , their role in the marine food chain is very important.

One of the most ubiquitous characteristics of oceanic phytoplankton is its high level of temporal and spatial variations, termed "Patchiness" due to physical and biological parameters.

The low-frequency fluctuations (millennia, decadal, seasonal) are fairly well documented, but rapid changes, (The study) on the scale of minutes to hours, are poorly understood. Possible reasons for high-frequency fluctuations in plankton abundance include, physical advection, localized population growth, interactions with patchy food or predators, and behavior.

Water samples were obtained with two large submersible pumps, delivering the pumped water to shore via PVC pipes. Both pumps were deployed at 8 m depth: one at the reef site, 40 m off shore, attached to a tripod with the intake opening suspended 0.75 m above bottom, and the other at the open waters (away site), 163 m off shore, where the pump was attached to a mooring line with its intake positioned 34 m above bottom (42 m depth) .

The parameter used to quantified phytoplankton abundance was extracted *Chlorophyll a* this pigment is a good indicator for phytoplankton biomass .

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Over all the data sampling, the chlorophyll concentration (Away and Reef sites) varied from 135 to 509 ngr L^{-1}, with an average of 312 and CV of 18.1% (N=532).

Phaeopigments (Away and Reef sites) vary between 13 to 270 ngr L^{-1}, with an average of 81 and CV of 32.5% (N=529). . Shorter-term variations in the chlorophyll were much smaller for the hourly samples within single diel cycles, with average CV values 6.9 and 7.6%, for the Away and Reef sites, respectively.

Even smaller variations (CV=4.3 and 5.4%, respectively) were found in the series of 15 min sampling in the eight 4 hr long sessions.

Chlorophyll concentrations at day time in the (Away and Reef) were much higher than night time with an average of difference (Night minus day) .

Phaeopigment concentrations Away site at day time were more than Night time , but much less in the Reef site at day time with an average of different (Night minus Day) .

The phytoplankton community was dominated by *Synecochoccus*, which formed over 97% of the cells counted under the epi-fluorescent microscope.

The Coefficient of Variation (CV) was used throughout as our principal parameter of temporal variations in the plankton. Statistical analysis were made using Statistica for Windows (Version 99).

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CHAPTER ONE

1- INTRODUCTION

1-1 GENERAL BACKGROUND

The oceans occupy about 71% of the Earth's surface. The deepest parts of the sea floor are almost 11000 m, from the sea surface, and the average depth of the oceans is about 3800 m, the total volume of the marine environment (1370m x 10 ^{6} km³) provides approximately 300 times more space for life than that provided by land and fresh water combined . (**Biological Oceanography, 1993**).

The ocean is home to a tremendous variety of living organisms highly adapted to the special conditions of the sea. The general features of these organisms and the variety of marine life itself are products of the many properties of the ocean habitat. (**Sumich . J . L , 1996 . Marine Life**) .

The name " Earth " is synonym for dry land, but it is amisnomer in that it does not describe the dominant feature of the planet which is a vast expanse of blue water .

1-1-1 <u>Properties of seawater</u>

Seawater has accumulated during billions of years of eroding action of water on rocks and soil, the breakdown of organisms, and the condensation of rain from atmosphere.

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Many properties of seawater are crucial to the survival and well-being of the ocean's inhabitants. Water accounts for 80 to 90% of the volume of most marine organisms. It provides buoyancy and body support for swimming and floating organisms, thereby reducing the need for heavy skeletal structures. Water is also the medium for most chemical reactions needed to sustain life. The life processes of marine organisms in turn alter many fundamental physical and chemical properties of seawater, including its transparency and chemical makeup, making organisms an integral part of the total marine environment. Understanding the interactions between these organisms and their environment requires a brief study of some of the more important physical and chemical attributes of seawater.

About 3.5% of seawater is composed of dissolved compounds from these sources. The other 96.5% is pure water. Traces of all naturally occurring substances probably exist in the ocean and can be separated Into three general categories:

(1) Inorganic substances, usually referred to as salts, including nutrients necessary for plant growth .

(2) Dissolved gases .

(3) Organic compounds derived from living organisms.

Organic compounds dissolved in seawater include fats, oils, carbohydrates, vitamins, amino acids, proteins, and other substances. Scientists think that these compounds are an important source of nutrition for marine bacteria and several other types of organisms. Current research indicates that other organic compounds, especially synthetics such as DDT, PCBs, and other chlorinated hydrocarbons that accumulate in seawater, can have devastating effects on some forms of marine life.(**Sumich . J . L , 1996 . Marine Life**)

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1-2 CLASSIFICATION OF MARINE ENVIRONMENTS AND MARINE ORGANISMS.

The size and complexity of the marine environment make it a difficult system to classify conveniently. Many systems of classification have been proposed, each reflecting the interest and bias of the classifier. The system presented here is a slightly modified version of a widely accepted scheme proposed by Hedgpeth.

The terms used in **figure (1-2-1)** designate particular zones of the marine environment; these terms should not be confused with the names of groups of organisms that normally inhabit these zones. The boundaries of these zones are defined on the basis of physical characteristics such as water temperature, water depth, and available light.

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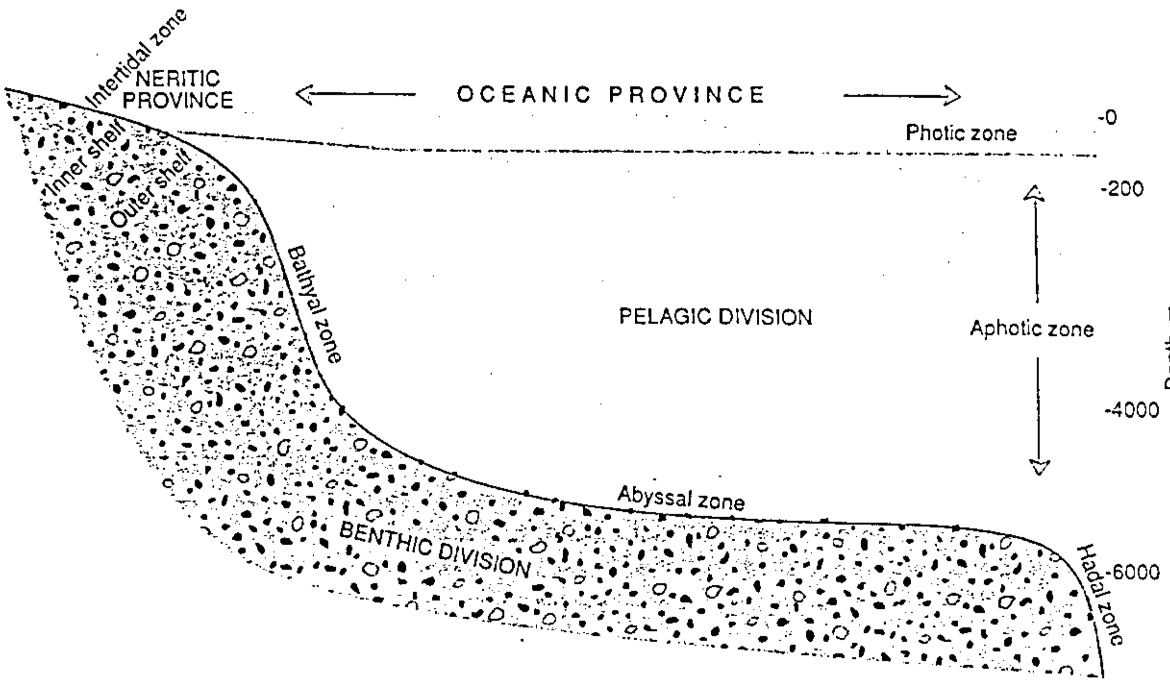

(FIG . 1-2-1)

A system for classifying the marine environment

(Sumich . J . L , 1996 . Marine Life)

The **pelagic** environment (open sea) is that of the water column , from the surface to the greatest depths . The **benthic** environment (bottom)encompasses the sea floor and includes such areas as shores , littoral orintertidal areas , coral reefs , and the deep seabed .The limits of the intertidal zones are defined by tidal fluctuations of sea level along the shoreline. The splash, Intertidal, and inner shelf zones occur in the photic (lighted) zone where the light intensity is great enough to accommodate photosynthesis.

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The depth of the photic zone depends on conditions that affect light penetration in water, extending much deeper in clear, tropical waters than in murky, coastal waters of temperate areas.

The average depth of the photic zone is 50-100 m. The remaining zones are located in the aphotic (unlighted) zone where the absence of sunlight prohibits photosynthesis.

The benthic division refers to the environment of the sea bottom. The inner shelf includes the seafloor from the low-tide line to the bottom of the photic zone. Beyond that, to the edge of the continental shelf, is the outer shelf. The bathyal zone is approximately equivalent to the continental slope areas. The abyssal zone refers to abyssal plains and other ocean bottom areas between 3,000 and 6,000 m in depth. The upper boundary of this zone is sometimes defined as the region where the water temperature never exceeds 4°C. The hadal zone is that part of the ocean bottom below 6,000 m, primarily the trench areas.

The pelagic division includes the entire water mass of the ocean., it will be sufficient to separate the pelagic region into two provinces: the neritic province, which includes the water over the continental shelves, and the oceanic province, Which includes the water that overlies the deep ocean basins. Each of these subdivisions of the ocean environment is inhabited by characteristic assemblages of marine organisms.(**Sumich . J . L , 1996 . Marine Life)** .

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The pelagic environment supports two basic types of marine organisms . One type comprises the plankton , or those organisms whose powers of locomotion are such that they are incapable of making their way against a current and thus are passively transported by currents in the sea .The word plankton comes from the Greek ***planktos*** , meaning that which is passively drifting or wandering . Depending upon whether a planktonic organism is a plant or animal , a distinction is made between ***phytoplankton*** and ***zooplankton*** .(**Sumich . J . L , 1996 . Marine Life)** .

1 – 3 PHYTOPLANKTON

Most of the plants in the marine environment are different types of planktonic ,unicellular algae ,collectively called phytoplankton . Although some phytoplankton are large enough to be collected by filtering or centrifuging sizable volumes of sea water .There are also macroscopic floating algae in some oceanic areas .
Phytoplankton are present throughout the lighted regions of all seas, including under ice in polar areas . Because the phytoplankton are the dominant plants in the ocean , their role in the marine food chain is of paramount importance .

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1-3-1 Classification of plankton

Plankton as general classified into many categories depending on many factors as it is shown as below : (Kimor . Lectures .1996)

By size (according to Dussart , 1965 , 1966)

- **Ultramicroplankton (picoplankton) < 2 µm .**
- ***Nanoplankton*** 2 – 20 µm .
- ***Microplankton*** 20 – 200 µm .
- ***Mesoplankton*** 200 –2000 µm .
- ***Macroplankton*** > 2000 µm..

By Nutritional Requirements .

- ***Phytoplankton*** : Chlorophyll – bearing plants capable of performing photosynthesis (producers , autotrophs) .
- ***Zooplankton*** : Animal feeding by ingesting food particles (consumers ,heterotrophs) .

By Distribution .

A - ***Horizontal***

- **Neritic** (closer to the shore).
- **Oceanic** (in the open sea) .

B - ***Vertical*** .

- ***Epipelagic*** (upper most layer of the ocean water column down to the depth of about 200m this is the euphotic zone) .
- ***Mesopelagic***- (200 – 500 / 1000 m , generally extending to the end of the continental slope) .
- ***Bathypelagic*** (from the edge of the continental slope and beyond) .
- ***Pleuston*** (animals living on the surface of the water , partly in the water and partly in the air and drifted by the wind such Velela & Physalia).
- ***Neuston*** (organisms that use the surface film of water for support) .

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By life History Criteria .

- ***Holoplankton*** (animals completing their life history without ever leaving planktonic life) .
- ***Meroplankton*** (temporary development stages that turn into adults that are **benthic** (fixed or bottom dwelling) or **nektonic** (swimming organisms) .

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1-3-2 PHOTOSYNTHESIS AND PRIMARY PRODUCTION

Phytoplankton are the dominant primary producers of the pelagic realm , converting inorganic materials (e.g . lipids , proteins) by the process of **photosynthesis** and thereby starting the marine food chain . The amount of plant tissue built up by photosynthesis over time is generally referred to as **primary production** ,so called because photosynthetic production is the basis of most of marine production .

There are other types of primary production that are carried out by bacteria capable of building organic materials through chemosynthetic mechanisms, but these are of minor importance in the oceans as whole .

(BIOLOGICAL OCEANOGRAPHY by CAROL & TIMOTHY . 1993)

Photosynthesis is a biochemical process that uses chlorophyll pigments to absorb some of the abundant energy of the sun's rays. In this process, ATP and other high-energy substances are made and then used to synthesize sugars, amino acids, and lipids from CO_2 and H_2O. For the present, photosynthesis can be summarized by the following general equation:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{12H_2O} \xrightarrow[\text{chlorophyl l}]{\text{sunlight}} \underset{\text{sugur}}{C_6H_{12}O_6} + \underset{\text{water}}{6H_2O} + \underset{\text{oxygen}}{6O_2}$$

Fossil evidence suggests that early procaryotes were the first to capitalize on photosynthesis as a solution to their energy needs. Fossil remains of cyanobacteria nearly 3 billion years old indicate that photosynthesis evolved an early stage at in the development of life on earth. **(Sumich . J . L , 1996 . Marine Life)** .

Most nonphotosynthetic organisms on earth rely directly or indirectly on the energy-rich organic substances produced by photosynthetic

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organisms. In environments with limited amounts of free O_2 (such as anoxic basins or deep ocean bottom muds) and abundant supplies of organic material, anaerobic respiration (respiration without O_2) provides a mechanism to obtain energy for use in cellular processes. Several variations of anaerobic respiration are exhibited by plants and animals, yet all release energy from organic substances without using O_2. In alcoholic fermentation, for example, sugar is degraded or broken down, to alcohol and CO_2. Energy is released in the form Of ATP:

$$\underset{\text{sugar}}{C_6H_{12}O_6} \xrightarrow[\text{enzymes}]{\text{respiratory}} \underset{\text{alcohol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2} + \underset{\text{(equicalen to 2ATP)}}{\text{ENERGY}}$$

In most eucaryotic organisms, respiratory processes more complex than that of anaerobic respiration completely oxidize high-energy compounds such as sugar to carbon dioxide and water and, in the process, release energy:

$$\underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{O_2} \xrightarrow[\text{enzymes}]{\text{respiratory}} \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \underset{\text{(equicalen to37ATP)}}{\text{ENERGY}}$$

This process utilizes oxygen and is called aerobic respiration. In aerobic respiration, each molecule of sugar yields 18 times as much energy as it would if used in anaerobic respiration. Organisms that metabolize food and oxygen in this manner secure a tremendous energetic advantage over their anaerobic competitors.

Autotrophs are self-nourishing organisms capable of absorbing solar energy and photosynthetically building high-energy organic substances such as carbohydrates. In the process, autotrophs use inorganic nutrients

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(primarily nitrate and phosphate), water, and dissolved gases. They are the primary **producers** of marine ecosystems and are placed in the first trophic level. Some bacterial autotrophs extract energy from inorganic compounds to build high-energy organic molecules. These autotrophs are **chemosynthetic**. The consumers and decomposers are unable to synthesize their own food from inorganic substances and must depend on autotrophs for nourishment. These are **heterotrophs**, each having some specialization in terms of nutrition.

Animals who feed on autotrophs are **herbivores** and occupy the second trophic level (**consumers**) , while those that prey on other animals are **carnivores** and
occupy the third and higher trophic levels.

The **decomposers**, primarily bacteria and fungi, exist on detritus, the excrement and other waste products of all types of organisms as well as the dead remains of the organisms themselves.
Whatever their specialized feeding role may be, all heterotrophs metabolize the organic compounds synthesized originally by primary producers to gain available energy.

Organic compounds produced by autotrophs become the vehicle for the transport of usable energy to the other inhabitants of the ecosystem. A distinction must be made between the flow of essential nutrients and the flow of energy in an ecosystem. The movement of nutrient compounds and dissolved gases is cyclic in nature, going from autotrophs to consumers to decomposing bacteria and fungi back to the autotrophs . Since there is limited input from outside ecosystems of most of these materials, the materials pass from one ecosystem component to another in cycles known as biogeochemical cycles.These cycles link living

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communities of organisms with nonliving reservoirs of important nutrients. **(Sumich . J . L , 1996 . Marine Life)**

1-3-3 SPECIAL ADAPTATIONS FOR PLANKTONIC EXISTENCE .

The evolutionary success of all phytoplankton hinges on their ability to obtain sufficient nutrients and light energy from the marine environment .Phytoplankton cells must be widely dispersed in their seawater medium to increase their utilization of dissolved nutrients , yet they must remain in the relatively restricted *photic zone* to absorb sufficient sunlight .

These opposing conditions for successful planktonic existence have established some fundamental characteristics to which all phytoplankton and indirectly , all other marine life have become adapted . **(Sumich . J . L , 1996 . Marine Life)**

Size

One of the most characteristic features of all phytoplankton is their size. Almost without exception, they are microscopic, which suggests that a strong selective advantage accompanies smallness in phytoplankton.
In contrast to land plants, phytoplankton are constantly bathed in a medium that not only provides nutrients and water but also carries away waste products. Exchange of these materials in a fluid medium is accomplished by diffusion in either direction across the cell membrane of the plant.

The quantity of materials required by the cell is dependent on a number

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of factors such as the rate of photosynthesis and growth. But if these and other variables are held constant, the basic material requirements of the cell are nearly proportional to the size or, more accurately, to the volume of the cell. However, the ability of the cell to satisfy its material requirements is not a function of the volume but of the extent of cell surface across which the materials can diffuse. Thus, the ratio of cell surface area to cell volume becomes quite important. Those cells with higher surface-area-to-volume ratios achieve an advantage in the competition to enhance diffusive exchange between their internal and external fluid environments.

Reduction of cell size is an effective and widespread means of achieving high surface-area-to-volume ratios, but there are other means. Many phytoplankton cells have evolved complex shapes that increase the surface area while adding little or nothing to the volume. Cell shapes resembling ribbons, leaves, or long bars and cells with bristles or spines are all common mechanisms to increase the amount of surface area relative to volume and thus increase frictional resistance to sinking. Cell vacuoles filled with seawater are common in diatoms. These cells are large, but the actual volume of protoplasm requiring sustenance is only a fraction of the total volume of the cell. **(Sumich . J . L , 1996 . Marine Life).**

Sinking

Phytoplankton, with their heavy cell walls, are generally a bit more dense than seawater and tend to sink away from surface waters and sunlight. The problem for phytoplankton is not to float, for that would create intolerable crowding at the sea surface. Instead, phytoplankton need to slow their sinking rates so that a small fraction of any reproducing cell line has a few members carried upward by turbulent

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mixing even as most continue their slow downward slide through the photic zone.

Phytoplankton exhibit many adaptations that slow the sinking rate and prolong their trip through the photic zone. One of the most effective adaptations is to increase the frictional resistance to their passage through water by increasing the surface-area-to-volume ratio. Reduced cell sizes accomplish this as do the production of horns, wings, or other cellular projections.

Other cells reduce their sinking rates with complex cell or chain shapes that trace zigzag or long spiral paths down through the water column, **(e. g *Asterionella* and *Rhizosolenia*).**

Adaptations for reducing the sinking rate are not limited to structural variations. Mechanisms that reduce the average cell density by "lightening the load" are also evident in some phytoplankton. Planktonic diatoms generally produce thinner and lighter frustules than do benthic diatoms. ***Ditylum***, for example, is capable of excluding higher density ions (calcium, magnesium, and sulphate) from its cell fluid and replacing them with less dense ions. In addition, the production and storage of low-density fats and oils also helps slow the rate of sinking.

Oscillatoria and some other planktonic ***cyanobacteria*** have evolved relatively sophisticated internal gas-filled vesicles to provide flotation. The walls of these vesicles are constructed of small protein units that can withstand outside water pressures experienced anywhere within the photic zone.

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1-3-4 Adjustments to Unfavorable Environmental Conditions

Plankton have little or no capability of large-scale horizontal propulsion and must depend on the ocean's surface currents for dispersal. All of the adaptive features discussed above that extend the residence time of plankton in the horizontally moving surface currents also serve to increase their geographical distribution.

For protection, long spines and horns render phytoplankton less desirable to herbivorous grazers. There is some evidence to suggest that copepods, for instance, prefer nonspiny diatoms to spiny ones. Slimy gelatinous masses that sometimes surround clumps or chains of diatom cells also discourage grazers. Spines, cell chaining, and cell elongation all may be economical methods of increasing apparent cell size to reduce mortality.

The optimum growth period for phytoplankton in nonupwelling temperate and polar seas is restricted by reduced sunlight in winter and limited nutrient supplies in summer. Faced with the prospect of weeks or months with reduced photosynthesis, phytoplankton in these regions have limited options. Some move, some switch to other energy sources, or some simply hang on until conditions improve. The first choice does not generally apply to diatoms, but motility, limited as it is, is extremely important to flagellated cells. A swim of merely one or two cell lengths is often sufficient to place the cell away from its extracted wastes and into an improved nutrient supply. Toxins of dinophytes also serve to discourage predation by herbivores and sometimes inadvertently improve their own nutrient supply by causing extensive fish kills and thus accelerating the renewal of critical nutrients.

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Strictly photosynthetic organisms must rely on stored lipids or carbohydrates for their short-term energy needs. When that source is depleted, some phytoplankton still have alternatives. Some species can improve their ability to harvest light by producing more chloroplasts that contain photosynthetic enzymes and pigments or by moving those chloroplasts closer to cell edges. Other species can absorb dilute but energy-rich dissolved organic material from surrounding seawater to tide them over. When these strategies have been exhausted, many diatoms produce dormant **cysts**, capsules which have reduced metabolic activity and increased resistance to environmental extremes .It is likely that many near-shore species of dinophytes also produce dormant stages during periods of unfavorable growth conditions. With the return of improved growing conditions, these dormant cells germinate and commence photosynthesis and growth. At this point, the growing phytoplankton populations come under the regulatory influence of complex physical and biological factors . **(Sumich . J . L , 1996 . Marine Life) .**

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1-3-5 Phytoplankton Distribution

It is generally accepted that many factors affected the distribution of a specific phytoplankton (presence or absence), (**Lindell and Post , 1995**)

- Temperature .
- Nutrients status .
- Water - column stability .
- Grazing .
- Competition .

Picophytoplankton depth distribution in stratified waters show a dominant presence of **Synechoccus** in the upper 50 meters , whereas **Prochlorococcus** occupies the lower half of the photic zone down to 120 ~ 130 meters depth . Both have typical densities of 20,000 – 200,000 cells per ml .

Eukaryotic cells densities are normally lower by an order of magnitude and they are spread rather evenly over all depths .

Prochlorophytes are not observed in mixing waters and during periods of mixing eukaryotic species may become the numerically dominant group .

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1-3-6 Ultraphytoplankton Importance

Due to the numerical dominance of ultraphytoplankton (phytoplankton < 8 µm) in oceanic waters , attention has focused on them over the past few years .

This size group is commonly reported to make up between 25 and 90% of the photosynthetic biomass in terms of chlorophyll **(Li et al ,1983 ; Gieskes and Kraay 1986)** and has been reported to carry out > 50 % of the primary production in the Indian, Pacific , and Atlantic Oceans (**Owent et al , 1993 ; Li et al ,1983)** .

Despite the importance of ultraphytoplankton in the oceans , few studies on their temporal dynamics have been carried out to date .

Ultraphytoplankton are often divided into three groups on the basis of their autofluorescence : **(Olsen et al , 1990 ;Veldhuis et al , 1993).**

1 - The diverse group of ***Eucaryotic algae*** .
2 - The cyanobacterium ***(Synechococcus)*** .
3 - The free –living unicellular prochlorophyte ***(Prochlorococus)*** .

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1-3-7 Phytoplankton Patchiness

One of the most ubiquitous characteristics of oceanic plankton is its high level of temporal and spatial variations, termed "Patchiness". Causes for zooplankton patchiness include physical and biological parameters. For example, large oceanic eddies near the Gulf Stream entrap zooplankton in highly defined patches which move across the ocean. Localized upwelling events may lead to the formation of phytoplankton patchiness which, under conditions of sufficient residence time, can leads to corresponding patchiness of zooplankton. Similarly, localized predation can generate patches "void" of prey. Ample evidence for such predation-related patchiness was recently documented above isolated underwater mountains in the Pacific Ocean. While low-frequency fluctuations (millennia, decadal, seasonal) are fairly well documented, rapid changes, on the scale of minutes to hours, are poorly understood. Possible reasons for high-frequency fluctuations in plankton abundance include, physical advection, localized population growth, interactions with patchy food or predators, and behavior.

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Coral reefs are sites of intense, localized predation on zooplankton and phytoplankton, generating sharp reef-ward gradients of declined plankton abundance. Zooplankton feeders at the reef include numerous species of fish and invertebrates (e.g., corals, anemones, echinoderms), while major phytoplanktivores include sponges, bivalves, polychaetes and ascidians. Some of these predators are active during the day (e.g., damsel fish), while other are nocturnal (e.g., corals). Some of the predators are highly aggregated (e.g., fish schools), while others are more homogeneously dispersed. The temporal and spatial dynamics of this predation and their effects on plankton patchiness are poorly understood. As food replenishment to those benthic, site-attached grazers and predators totally depends on currents, the short-term temporal and spatial patchiness of their planktonic prey is a complex outcome of physical advection, distribution of predators, and biological processes such as predation behavior and functional responses.

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1-3-8 Seasonal Cycle

In the Gulf of Aqaba (Red Sea) it was observed a yearly recurring succession among **picophytoplankton , (Anton Post Lectures , 1996) and (Lindell . D , & Post . A , 1995)** in which :

- **Eukaryotic algae are dominant during winter .**
- **Synechococus is dominant during the spring bloom and fall .**
- **Prochlorococcus is dominant during stable summer stratification .**

The seasons were defined according to the stability of the water column as mentioned in **(Lindell . D , & Post . A , 1995) study :**

- **Winter refers to (December - March) .**
- **Spring refers to (April and May) .**
- **Summer refers to (June - September) .**
- **Fall refers to (October and November) .**

Patchiness in plankton is a prominent feature of the marine environment at all scales where there are sufficient observations (Steel , 1978) . For the phytoplankton , there are often obvious correspondences with physical features of the environment , both **vertically** (thermoclines and upwelling) and **horizontally** (fronts and eddies) .
The causes of spatial variability in the herbivorous zooplankton are less clear , they are Capable of marked vertical movement and this combined with physical shears , can induce horizontal advection . **(Steel and Henderson , 1992)** .

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1-3-9 Phytoplankton Grazing .

The concept that phytoplankton is not a principal food source in coral reefs probably originated from an early comparison between zooplankton and phytoplankton removal rates in a Caribbian coral reef (**Glynn .1973**) which suggested that zooplankton are by far the most important source of heterotrophic carbon in this ecosystem . Racently , however (**Ayukai ,1995**) observed a substantial retention of picophtoplankton at the Great Barrier Reef in Australia , and (**Fabricius et al ,1995**) discovered phytoplankton feeding by some common soft – coral species that had previously been considered exclusive zooplanktivores .

Infact , strong phytoplankton grazing is to be expected at the reef , as numerous members of the coral reef community are known to feed on particles within the size range of phytoplankton . Such taxa include bivalves (**Klumpp et al . 1992 & Lesser et al . 1992**) , gastropode (**Lesser et al . 1992**) , sponges (**Ries wig . 1971 , 1974 ; Pile et al 1996 , 1997**) , ascidians (**Petersen & Riisgård , 1992**) and soft – coral (**Fabricius et al m1995**) .

The role of benthic grazing in the observed phytoplankton removal was obvious at the perforated reef . Because this reef was inhabited by

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massive colonies of soft - corals reported as plankton grazers (**Fabricius et al m1995) ,** high rates of phytoplankton removal were expected .

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1-3-10 CONTROL FACTOTORS OF THE DYNAMICS PHYTOPLANKTON DISTRIBUTION .

The dynamics of phytoplankton distribution in the euphotic zone is controlled by three factors : (**Astheimer ,And Haardt . 1984**)

1- Biological processes of growth depending on light nutrients

2- Hydrographical processes determining cell buoyancy , for Example . (light level , nutrient uptake) .

3 - Ecological processes within the food web such as zooplankton grazing .

And there are several processes affect the concentration of chlorophyll and pheopigment in the euphotic zone .

<u>These include</u> :

- **Cell sinking**
- **Cell senescence**
- **Photodegradation**
- **Fecal pellet sinking**
- **Physical mixing**
- **Advective transport**

The rates of these processes are of broad general interest and knowledge of them is fundamental to understand the causative factors underlying the dynamics of planktonic ecosystems (**Nicholas etal 1985)** .

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Some of these processes are amenable to experimental rate determination than others , for example a great deal of uncertainty exist for experimental measurements of phytoplankton growth and zooplankton grazing in the field **(Venrick etal 1977 , Heinbokel 1978 , Eppley 1980 , Landry and Hasset 1982)**.

The amplitude of the seasonal cycle in phytoplankton production and biomass is thought to be latitude –dependent with the smallest variations at low latitude (Heinrich ,1962) and (Sournia , 1969).Consequently , mid – low latitude oceanic regions require robust sampling schedules and precise analyses to discern seasonal fluctuation in phytoplankton biomass and production from variability produced by stochastic events **(Letelier et al , 1993)**.

The contribution of microphytoplankton (> 65 µm) of open water is less than 5% of total photosynthetic biomass at any location in the Red Sea at any time of the year .

Depletion of phytoplankton cells and pigments over coral reef was studied in the Gulf of Aqaba - Red Sea during (1994 – 1996) by **(Yahel et al , 1998)**

It showed that the phytoplankton abundance and chlorophyll a concentrations were 15 – 65 % lower near the reef than in the adjacent open water .The decrease in chlorophyll near the reef was typically associated with an increase in the concentration of its degradation products ,the pheopigments .

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1-4 FLUOROMETRY

Fluorometry , the measurement and use of fluorescence , is a technique of quantitative chemical analysis ideally suited to field use .This technique of optical measurement is inherently sensitive , offers specificity ,and is versatile , simple and relatively inexpensive . As a result , fluorometry has found a wide range of application in the study of natural waters including , phytoplankton and phaeopigment analysis , nephelometry , detection of fluororescence pollutants as well as a host of analyses which make use of fluorescent dyes as tracers .

1- 4 -1 Fluorescence as a measure of chlorophyll

Since the chlorophyll in phytoplankton is fluorescent , chlorophyll could be determined fluorometrically .

Subsequent development and standardization of techniques (Strickland and Parsons, 1968) have led to the widespread use of fluorometry techniques for chlorophyll and phaeopigments assy of natural waters **(Lorenzen ,1966)** , uses the term ***phaeopigments*** which encompasses phaeophobide and phaeophytin and possibly other products rather than the term phaeophytin .

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These techniques have replaced the traditional spectrophotometric methods in many labs and have made the analysis more practical for many reasons : **(Raymond etal ,1981)** :

- More sensitive .
- Faster and require smaller sample volumes
- Better adapted to routine field and lab use
- Not critically dependent on cuvette handing and matching .

There is a general procedure we followed to protect against pigment degradation :

- Extract sample is already buffered (sea water) .
- Extracts are kept in dark and cold (4 C°).
- Acetone was used (90%) .
- Work was carried out in darkness .

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1 - 5 Study Objectives

The major objectives in this study were to quantify the short-term (minutes to weeks) variations of phytoplankton over a coral reef (Reef site) and at a near-by open-water (Away site), and to evaluate the roles of currents, behavior and localized predation in the generation of the observed variations.

<u>Therefore our study objectives can be summarize as follow:</u>

1 - Determination the co variation of the Chlorophyll (Chl) and Phaeopigment concentrations between the two sites (Away & Reef).

2 - Determination the dominance taxa in the phytoplankton during the study period .

3 - Determination the correlation (R^2) of the Chlorophyll (Chl) concentrations between the two sites (Away & Reef) .

4 - Determination the short term scale variation (min , hrs , days) of the phytoplankton in the two sites (Away & Reef) .

5 - The covariation of Chlorophyll and Phaeopigment concentrations during day and night time (Diel Cycle) in both sites (Away & Reef)

6 - The main objective in this study was to understand the temporal & spatial dynamics of phytoplankton patchiness on scale of (minutes & hours) in the two sites (Away & Reef) .

7 - Determination the correlation between the Zoo (biomass & density) and Phytoplankton (Chlorophyll concentration).

8 - Determination the correlation between phytoplankton and the currents flow in the study area .

9 - The covariation of Chlorophyll and Phaeopigment concentrations during day and night time in the Reef site (Aloft & Bottom) .

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CHAPTER TWO

2- METHODOLOGY

2-1 Study site

This study was carried out in the Gulf of Aqaba (Red Sea) . The Gulf of Aqaba is a desert – enclosed , maximum deep 1820 meters basin, 180 km long and 6 – 25 km wide , (See Fig . 2-1).The climate in the region is hot and dry , the average daily temperature range from 34℃ in July – August to 16℃ in Jan - Feb . The average pricipitation is less than 30 mm / year and evaporation is approximately 1cm/day **(Morcos , 1970)**.

The waters of the Gulf Aqaba, (Red Sea) , undergo stronger seasonal fluctuation than do other subtropical seas . During summer , the water column is stratified and the surface layers are depleted of nutrients (Reis and Hottinger , 1984).However ,in winter the thermocline deteriorates and deep convective mixing persists for several months , often reaching 600 m or more (Wolf –Vecht etal , 1992).
During this period , the surface waters are enriched with nutrients brought up from the depths , seasonal succession among the microphytoplankton has been observed in the Gulf of Aqaba **(Kimor and Golandsky , 1977)**.

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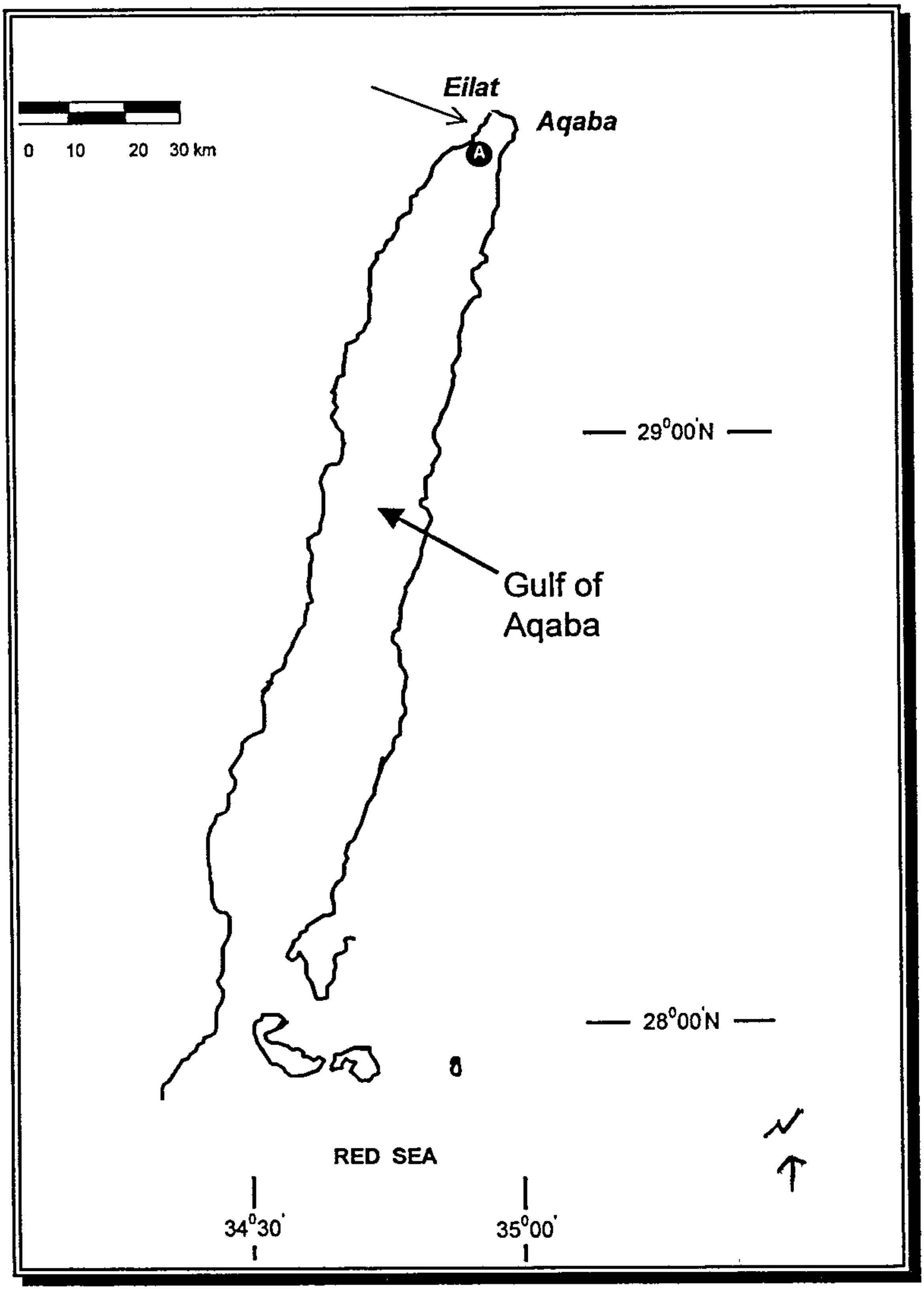

(FIG . 2-1)
Shows the study site (A)in Red Sea - Gulf of Aqaba .

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2-2 Frequency of Sampling :

The sampling plan consisted of four different interval-schedules, carried out during a 54 days period **(10 October - 2 December 1999; Fig. 2-2).** A "sample" in the following two sections indicates a pair of water samples, one from the reef and the other from the away site.

1- Once a day ,mid-day (around 10:00 am) throughout the period .
2- Twice a week a nocturnal sample (between 19:00 and 20:00 pm).
3- Once every two weeks (hourly sampling during twenty four hour) throughout the period .
4- Once every 15 minutes 8-hours long series (4 hours around mid-day & 4 hours around mid-night) during the 24 hours sampling .

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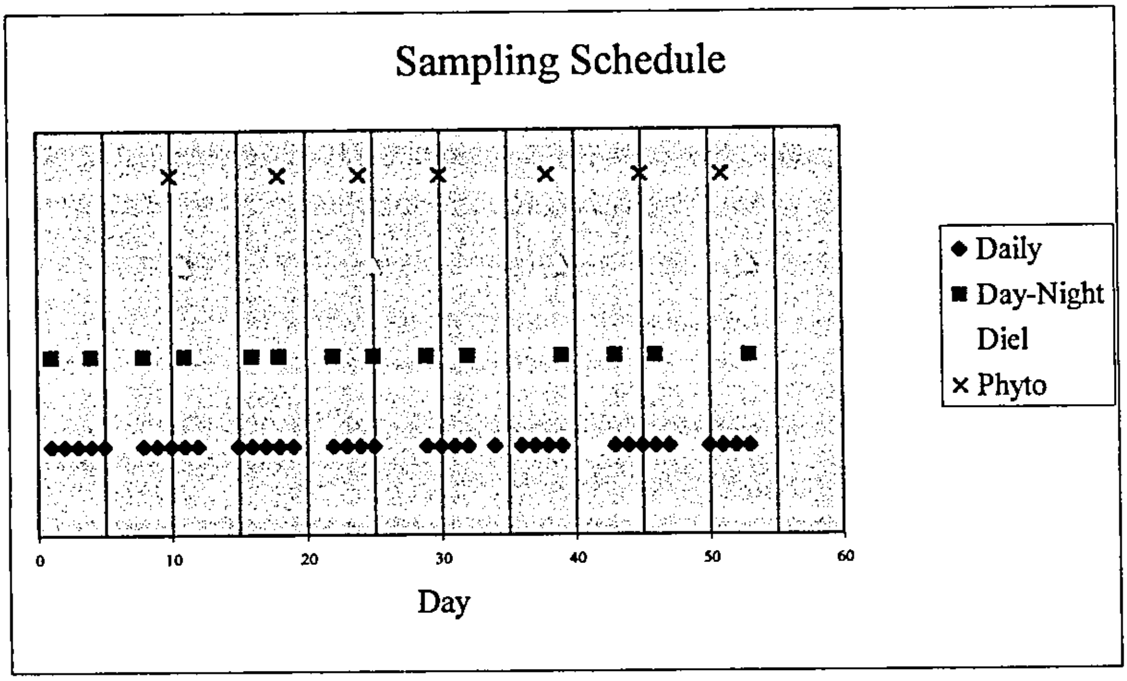

(Fig. 2-2)

Shows the time table schedule and the frequency of the sampling during (Oct 10th 1999 – Dec 2nd 1999).

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2-3 Samples collection

Water samples were obtained with two large submersible pumps, delivering the pumped water to shore via PVC pipes. Both pumps were deployed at 8 m depth: one at the reef, 40 m off shore, attached to a tripod with the intake opening suspended 0.75 m above bottom, and the other at the open waters, 163 m off shore, where the pump was attached to a mooring line with its intake positioned 34 m above bottom (42 m depth), **(hereafter "Reef" and "Away" sites, respectively).**

Two additional small pumps were deployed at the reef site: one 0.1 m above bottom and the other 5 m above (3 m below surface), delivering the pumped water to the shore via PVC pipes, (**hereafter additional Reef site, "Aloft" and "bottom "**).

2-3-1 Equipment set up

<u>Pumps</u>

As mentioned before four pumps were deployed in different sites (two large & two small). The two large pumps impellers design ensured an intact passage of plankton. Visual examination, using fluorescence dye, indicated that the pump created a minimal disturbance to the flow field around the pump, with no visible effect as far as 20 cm away from its intake.

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Nevertheless , to assure lateral suction at the intake depth and to avoid a re suspension of bottom particles by the reef pump , a 0.5 m 2 plastic sheet was attached to the tripod legs 20 cm below the pump .

Pumps type

- **Large pumps :**

Sub mersible sewage pumps
B . series .
Large pumps rates were 132 L/min .

- **Small pumps :**

Atman. AT- 2220
Q . MAX 1/ h = 2000
WATT = 38 - 40 H – M = 2
Small pumps rates were 16 L/ min .

Pipes .

It was used a PVC pipes , 45mm in diameter (for the large pumps), and 12 mm (for the small pumps) .

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Currentmeter .

Because currents can affect both the feeding rates of suspension – feeders **(Lenihan et al , 1996)** and the mixing of depleted and affluent layers and to measure corresponding changes of physical parameters .

Two electromagnetic **currentmeters** equipped with a temperature sensor. (Model S4, InterOcean, San Diego, USA) .
One **currentmeter** was deployed at the Away site, attached to a separate mooring line at 6.5 m depth, while the other **currentmeter** was deployed at 8 m depth at the reef site. Each current meter was positioned about 10 m away from the pump.

The current meters were set to record the average current speed and direction and the temperature of a 1 min interval every 10 minutes .
(Refer to the currentmeter Row Data appendix # 2-4-3-1)

2-4 Chlorophyll Sampling .

Water was collected in a known volume bottle .It was recommended to filter the water through a 100 μ net , so the zooplankton will not eat the phytoplankton in the bottle **(532 samples were processed for phytoplankton pigments) (refer to appendix # 2-4-1).**

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2-4-1 Filtering and Extraction.

The following method is used often as (**ARAR and COLLINS, 1992**).

1. Using tweezers put a GF/F filter **(0.2 μ)** in the filtering pipe.
2. Cover the filter with the funnel.
3. Pour the chlorophyll sample.
4. Turn the vacuum pump on **(pressure must not exceeding 200 mmHg).**
5. Open the valve of the filtering pipe.
6. Fill up a vial with 10 ml of acetone.
7. When the sample was all out of the funnel close the pipe valve and remove the funnel.
8. Using tweezers fold the filter on itself and place it in the vial with the acetone.
9. Put the vial in the dark at 4 ℃ in refrigerator for 24 hours.

2-4-2 Sample Processing.

The parameter used to quantified phytoplankton abundance was extracted (Chlorophyll α) this pigment is a good indicator for phytoplankton biomass at a single depth .

Chlorophyll concentrations and pheopigment were measured by using a pre – calibrated (Turner TD700 & TU10 Fluorometers).Phytoplankton abundance was estimated using measurements of Chlorophyll *a* and pheopigments, supplemented by occasional microscopic cell counts.

Water samples of nearly 300 ml were taken in glass bottles of pre-measured volumes (±1 ml). The collected water was pre-screened through a 100 μm mesh net to remove zooplankton from the sample.

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The sampled water was immediately filtered on a Whatman GF/F filter **(nominal pore size of 0.7 µm), followed by 24 h dark extraction at 4°C in 90% acetone solution .**

Chlorophyll *a* was measured using a Turner Designs **TD-700 Fluorometer,** as in (**Welschmeyer . 1994) .**

Phaeopigment concentrations were measured with a **Turner Designs AU-10** fluorometer, using the acidification method **(Parsons et al., 1985)**. Both fluorometers were calibrated prior to our study and routine calibration tests were made occasionally using Turner Design's solid standard.

2-4-2-1 TD700 Flourometer (For Chlorophyll)

Sample should be taken out from the fridge one hour at least before reading , shaked well and left in a dark box at the room temperature then

1- Pour the extract into a cuvette (not the filter) .
2- Clean the cuvette with a kimwipe .
3- Insert the cuvette into the sample adapter in the sample chamber and close the lid.
4- Press (*) .
5- Wait for the number to show on the screen .

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2-6 Reagent preparations.

Buffered Aqueous Acetone

1- Measure 100 ml saturated $MgCO_3$ solutions and add to the dispenser bottle.

2- Measure 900 ml acetone (Analytical grade) and add to the dispenser bottle .
3- Mix well and we mark the bottle with date ,acetone manufacturer , and buffering information.

HCL 10%

1- Pour 60 ml of DDW into a 100 ml graduated cylinder .
2- Measure 31.5 ml of concentrated HCL (32%) and add to the water .
3 - Make up to 100 ml with DDW .
4- Mark the bottle (HCL concentration , manufacturer , date)

2-7 Instrument setup

- Regularly the instrument is set and calibrated for operation with the Non – acidification filter kit where the excitation filter is of 436 nm and the emission filter is of 680 nm .(Filter cylinder in position A,Part #7000-962)

- Filter kit B is identical to the one install in the AU fluorometer where the excitation filter is of 340 – 500 nm and emission filter is > 665 nm .

  This setup is more suitable for chlorophyll invivo measurements .

  (Filter cylinder in position B . Part # 10 – 050 R & 10 – 051 R respectively) .

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2-8 Enumeration of ultraphytoplankton

100 ml of sea water (from 100 um mesh) were filtered at a vacuum of between 100 and 150 mm of Hg onto a 25 –mm , 0.22 - µm , Poretics polycarbonate membrane filter (upper filter).

A 0.45 - µm pore size, pure cellulose nitrate was placed underneath to facilitate smooth distribution of cells (base filter) . **(A very low fluorescence immersion oil was used) .**

2-8-1 Epi fluorescence microscopy (EFM)

Counts were carried out immediately on freshly prepared samples with a Nikon Labophot – 2 microscope equipped with episcopic –fluorescence attachments microscope and a super high –pressure mercury lamp (model HB 10101AF). A B –2A filter set with an excitation range of 450 –490 nm , adichroic mirror at 510 nm, and a barrier filter at 520 nm was used .

- Counting was carried out in the dark at a magnification 1250 ×.
- Twenty four fields chosen randomly representing all parts of the filter for each sample .
- The cells touching the out counting frame edges were counted
- The dividing cells were counted as two cells for all groups) .

(14 single samples were counted in the study under the epifluoresence microscope as mentioned before).

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2-8-2 Cells Count Catagories

Cells were placed in three different categories according to size and autofluorescence as described by : **(Li and Wood 1988).**

1- Faint red fluorescing cells which were < 1 µm in diameter and roundish ***(Prochlorococcus)***.
2- Yellow – orange fluorescing cells ~ 0.8 – 1.5 µm in diameter ***(Synechococcus)***
3- Strongly red fluorescing cells 1 - 8 µm in diameter of many shapes ***(Eucaryotes).***

2-9 Data Statistical Parameter

Statistical Package for Social Science (SPSS) Version - 9 were used in the data analysis processing .

Statistical analyses were made using Statistica for Windows (Version 99). Including (average , stander deviation , stander error , paired T – test , regression , and the coefficient of Variation (CV) was used throughout as our principal parameter of temporal variations in the plankton..

Temporal patchiness level was estimated using various indices of patchiness (e.g Lioyds Index).

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CHAPTER THREE

3 - RESULTS

3-1 The co variation of the Chlorophyll (Chl) and Phaeopigment concentrations between the two sites (Away & Reef) .

Over the entire data set, the chlorophyll concentration (Away and Reef sites) varied from 135 to 509 ngr L^{-1}, with an average of 312 and CV of 18.1% (N=532),with higher concentrations in the open water (Away site) than (Reef site) **(Refer to appendix # 3-1-1)**.

Phaeopigments (Away and Reef sites) vary between 13 to 270 ngr L^{-1}, with an average of 81 and CV of 32.5% (N=529), with lower concentrations in the open water (Away site) than the Reef site . **(Refer to the previous appendix # 3-1-1)**

3-2 The dominance taxa in the phytoplankton during the study period .

The phytoplankton community was dominated by ***Synecochoccus***, which formed over **97%** of the cells counted under the epi-fluorescent microscope. **(See Fig – 3- 2 - 1)** , As in the phytoplankton time series,

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an overall increase in the cell density , **chrlorophyll *a*** and **phaeopigments (Table 3-2-1) .**

(Refer to phyto counts Row Data appendix # 3-2-1) .

3-3 The relationship of the Chlorophyll (Chl) concentrations between the two sites (Away & Reef) .

Over the entire data set, the chlorophyll concentration (Away and Reef sites) varied from 135 to 509 ngr L^{-1}, with an average of 312 and CV of 18.1% (N=532),with very strong correlation between the two sites (Away & Reef) , **(R^2 = 0.83)** was relatively high , **(Fig . 3-3-1 –B)** .

3-4 The short term scale variation (min , hrs , days) of the phytoplankton in the two sites (Away & Reef) .

Shorter-term variations in the chlorophyll were much smaller for the hourly samples within single diel cycles, with average CV values 6.9 and 7.6%, for the Away and Reef sites, respectively.**(See table 3-4-1).** Even smaller variations (CV=4.3 and 5.4%, respectively) were found in the series of 15 min sampling in the eight 4 hr long sessions.

(See Table 3-4-2) and **(Table 3-4-3).**

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3-5 The covariation of Chlorophyll and Phaeopigment concentrations during day and night time (Diel Cycle) in both sites (Away & Reef) .

Chlorophyll concentrations at day time in the (Away and Reef) were much higher than night time with an average of difference (Night minus day) values **(- 1.8 and –5.3 ng / L)** Away and Reef respectively . Phaeopigment concentrations in the (Away site) at day time were more than Night time , but in the Reef site at day time the phaeopigment concentrations were much less than the night time with an average of different (Night minus Day) values **(-2.9 and 22.6 ng/L)** . Away and Reef respectively . **(See appendix 3-5-1).**

3-6 The temporal & spatial dynamics of phytoplankton patchiness on scale of (minutes & hours) in the two sites (Away & Reef)

The pigment concentrations co-varied at the Away and Reef sites, both on the scale of the entire series , **(See Fig . 3-3- 1-A)** , with strong correlation between Away and Reef sites **(Fig . 3-3-1-B)** as well as on the scale of diel and 15 min sampling. **(Fig . 3-6- 1 –A ,B ,C, D, E)** & **(Fig . 3-6-2-A,B).** For more details refer to **(Appendix # 3-6-1).**

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The concentration of chlorophyll was slightly 5.2% but very significantly P<0.0001 , Paired t-test) higher at the Away than the reef site (Fig . 3-6-1 -A) and (Fig . 3-6-2- A) .

No significant difference (P>0.14) was found for the phaeopigments. in the two sites (**Fig. 3-6-1 – D , E**).

A clear diel cycle was seen in the chlorophyll series at both sites, **(See Fig . 3-6-1 - A , B , C) .**

The chlorophyll concentrations increased in late afternoon early evening (14:00-17:00), starting to decline in early night (around 20:00 pm), reaching low values around midnight and remain low throughout the rest of the night and the morning.**(See Fig 3-6-1,A,B,C) .**

3-7 The relationship between the Zoo (biomass & density) and Phytoplankton (Chlorophyll concentration) .

Over the entire data set, the density of zooplankton and chlorophyll concentration was co – varied together although the correlation was relatively small R^2 - value of this regression (0.23), **Fig (3-7-1 – A).** But there was no correlation appear between Zoo- biomass and Chlorophyll concentration as shown in **Fig (3-7-1 – B) .**

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The apparent reason for the low R^2 value was the much higher variation of the zooplankton on the scale of days **(Fig. 3-7-2 -A, B)** and **(Fig . 3-7- 3 – A, B) .Refer to (Table 3-7-1)**

3-8 The relationship between phytoplankton and the currents flow in the study area .

Because currents can affect both the feeding rates of suspension – feeders **(Lenihan et al , 1996)** and the mixing of depleted layers and to measure corresponding changes of physical parameters ,two electromagnetic **current meters** equipped with a temperature sensor. (Model S4, InterOcean, San Diego , USA) .

The first **current meter** was deployed at the Away site, attached to a separate mooring line at 6.5 m depth, while the second **current meter** was deployed at 8 m depth at the reef site. Each current meter was positioned about 10 m away from the pump.

The current meters were set to record the average current speed and direction and the temperature of a 1 min interval every 10 minutes . **(Refer to the currentmeter Row Data appendix # 3-8-1) .**

According to **(Genin and Paldor , 1998)** four years study of current measurements near the northern end of the Gulf of Aqaba (Eilat –Red Sea) revealed consistent seasonal trends .

The net current along the coast was southward most of the year with a

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short period (November - January) of northward flow and an abrupt reversal in early February , this pattern did not correspond with changes in the wind , which was southward over 90% of the time .A semidiurnal peak dominated the current power spectrum during summer (May – October) , but was absent in (Feb – May) in spite of a year –round prevalence of a semidiurnal peak in the parotropic tide .

During winter ,when the water column was vertically mixed a clear onshore (westward) current was observed near the surface and a return (offshore) current over the bottom **(Genin and Paldor , 1998)** .

This cross-shore pattern was consistent with a wind-driven (Ekman circulation).The current reversal in Feb remains poorly understand while the disappearance of the semidiurnal periodicity in winter can be explained in terms of internal tides which disappear from the upper water column when it is vertically mixed .

The flow regime during our field study consisted of relatively medium-weak currents, with an average flow speed (scalar) of **9.7** and **5.3** cm/s at the Away and Reef sites, respectively.**(See table . 3-8- 1)**

Overall, the flow at the upper water column in the open-water area was a general northward flow with a weak **(0.8 cm/s)** component of on-shore flow **(Fig. 3-8-1-A)** and **(Fig 3-8-1 - B)** .

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At the reef, the flow was directed straight off shore, at a net advection speed of about 1.8 cm/s.

A clear correlation was found between the concentration of chlorophyll at the reef and the cross-shore component of the current : the stronger the on shore flow the higher was the chlorophyll concentration .
As shown in (**Fig . 3-8- 2**) .

3-9 The co variation of Chlorophyll and Phaeopigment concentrations during day and night time in the Reef site (Aloft & Bottom) .

In the entire data set, the chlorophyll concentration in the **Additional Reef site** , day time (**Aloft samples**) varied from **134.6 to 464.9 ngr** L^{-1}, and the (**Bottom samples**) varied from **160.2 to 509.0 ngr** L^{-1} , but in the (night) nocturnal time (**Aloft samples**) varied from **226.1 to 436.6 ng** $L^{-1}$and the (**Bottom samples**) varied from **184.3 to 320.6 ngr** L^{-1} with average of total different between the (**Aloft & Bottom**) samples of **42.3 ngr** L^{-1} and **standard deviation (SD) of 47 ngr** L^{-1} **See (Table 3-9-1) and (Fig 4-9-1)**

Phaeopigment concentrations in the Reef site , day time (Aloft samples) varied from **33 to 118 ngr** L^{-1}, and the (**Bottom samples**) varied from **27.9 to 270 ngr** L^{-1} , **but in the nocturnal time (Aloft samples) varied from 44.7 to 141.5 ngr** L^{-1} and the (**Bottom samples**

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) varied from **35 to 145.9 ngr L^{-1}** with average of total different between the **(Aloft & Bottom)** samples of **1.07 ngr L^{-1}** and **standard deviation (SD) of 35.5 (See Table 3-9-1) and (Fig 4-9-2) .**

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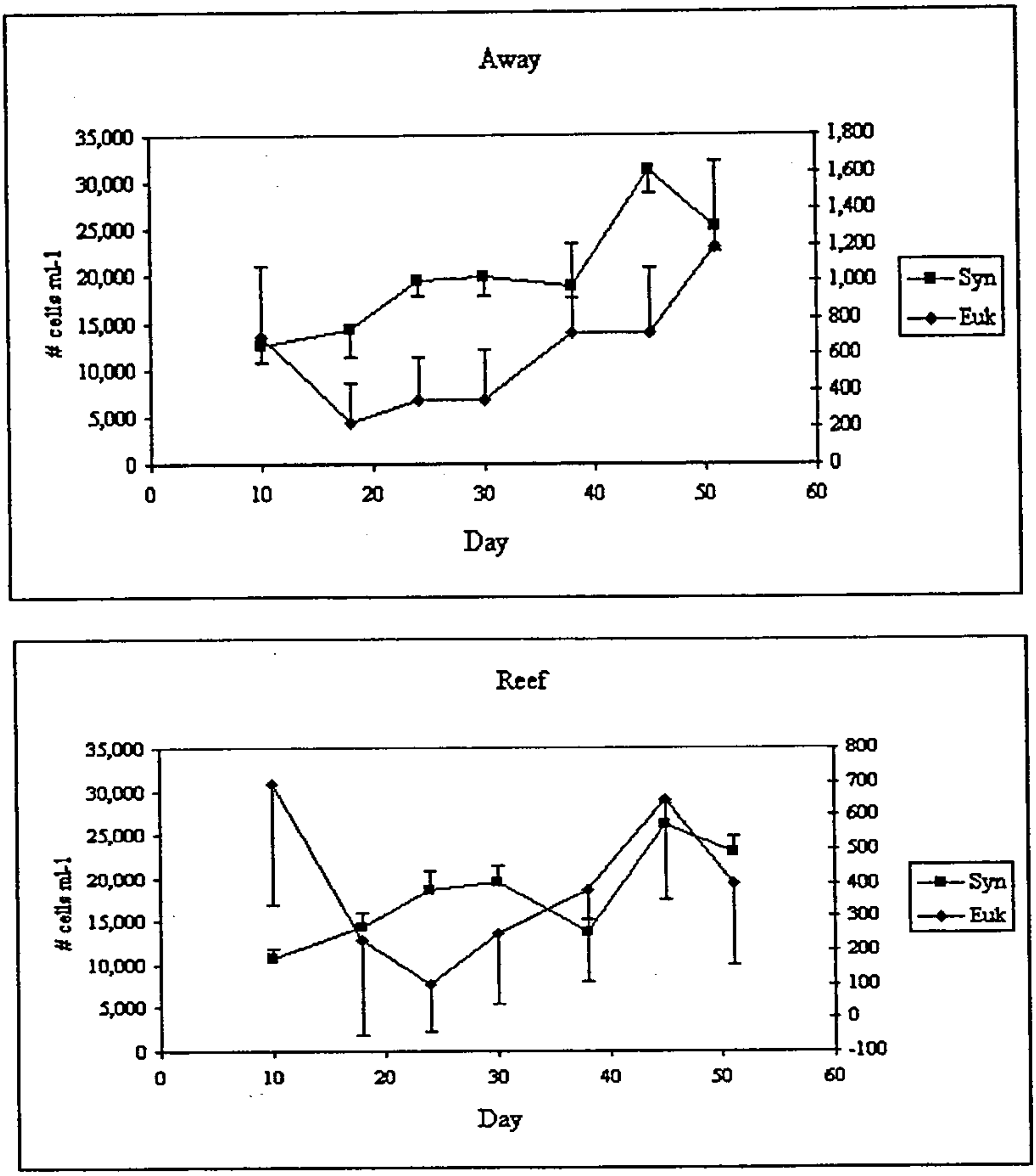
A

B



(FIG . 3-2-1)

(A & B)– Shows the cells counts for the entire period (Oct 10th 1999 – Dec 2nd 1999) in the two sites (Away & Reef)with the dominant Taxa Synechoccus by (cell/ml).

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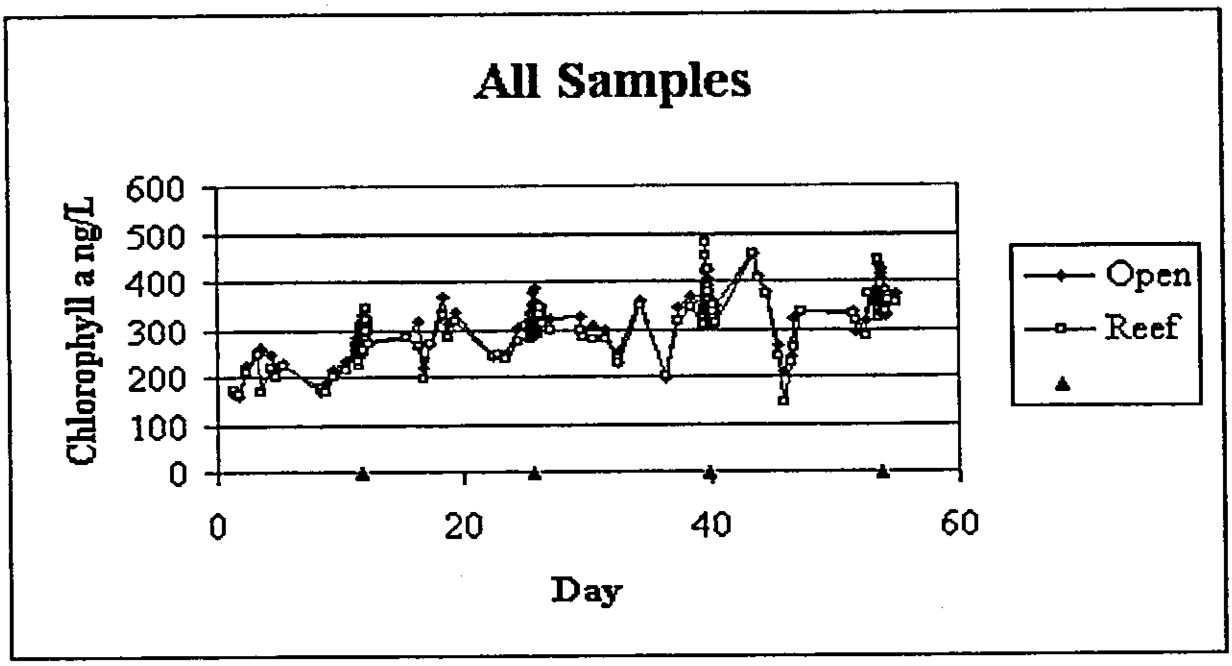
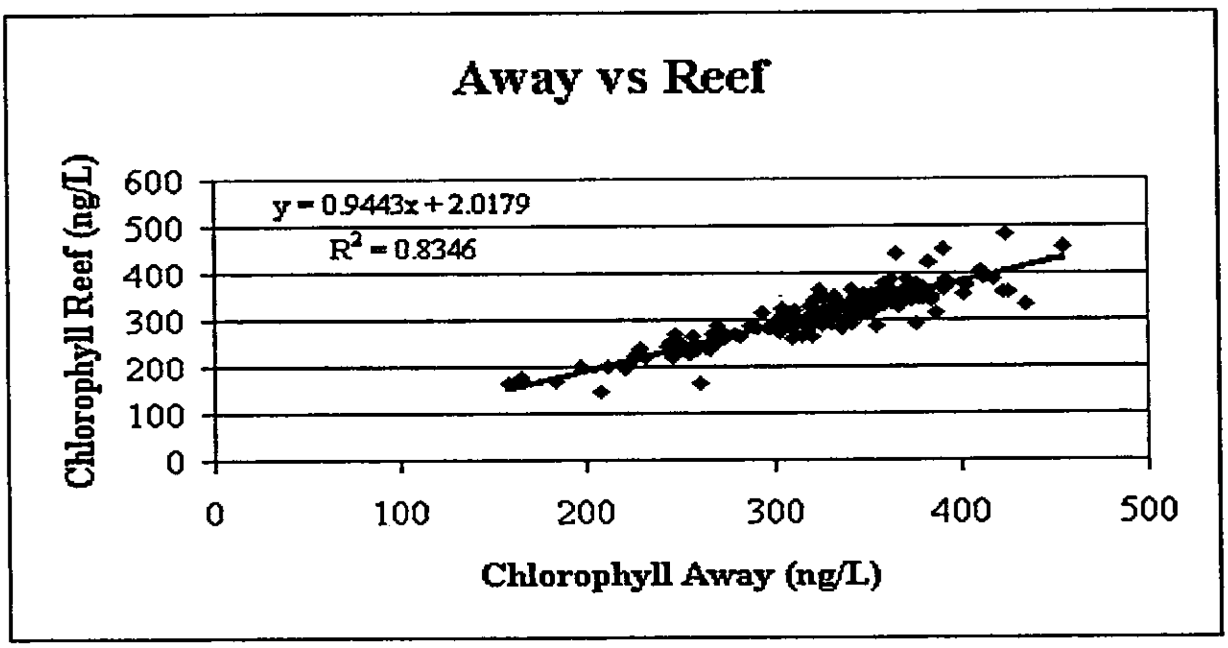


(A)



(B)

(FIG – 3-3-1)

A - Shows the co – variation of the pigments concentration between the (Away and Reef) sites in time series all samples .

B – Shows the Chlorophyll concentrations in all samples as Away versus the Reef and the the strong correlation between them (R 2) .

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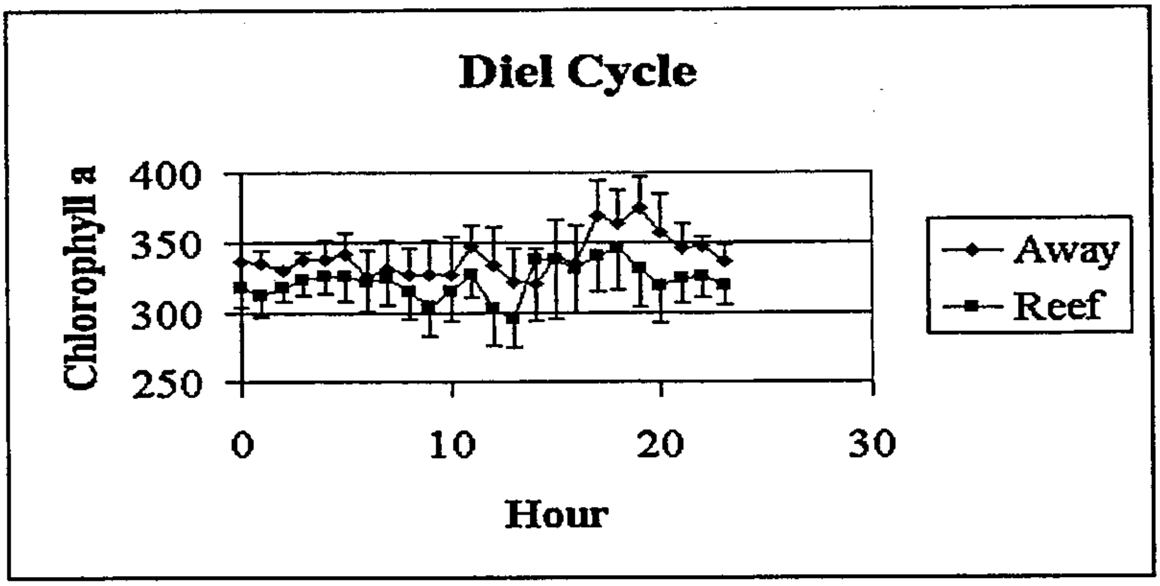
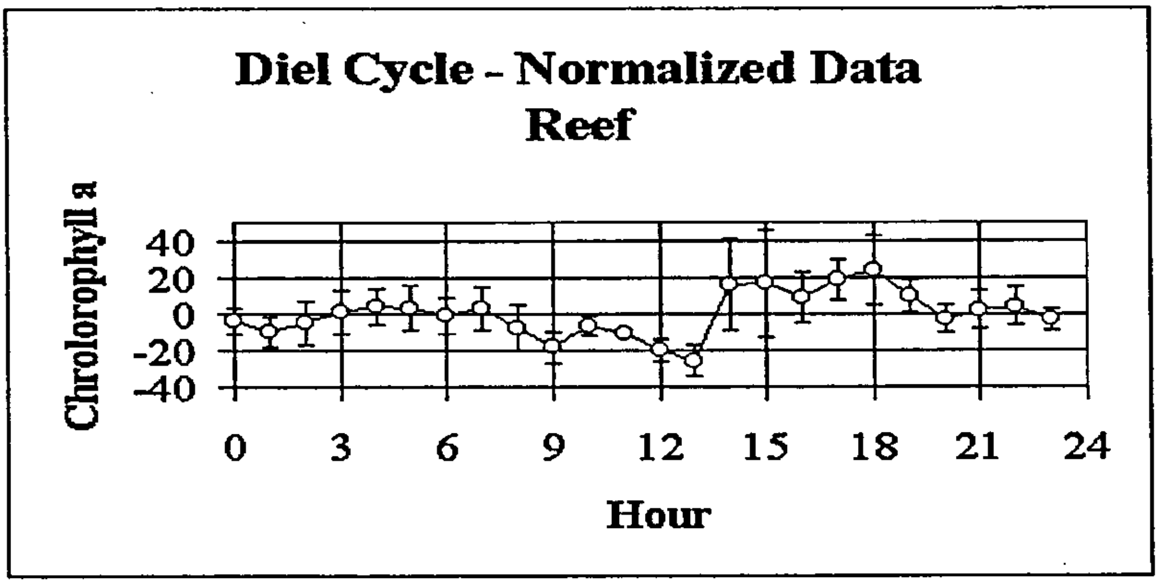
A

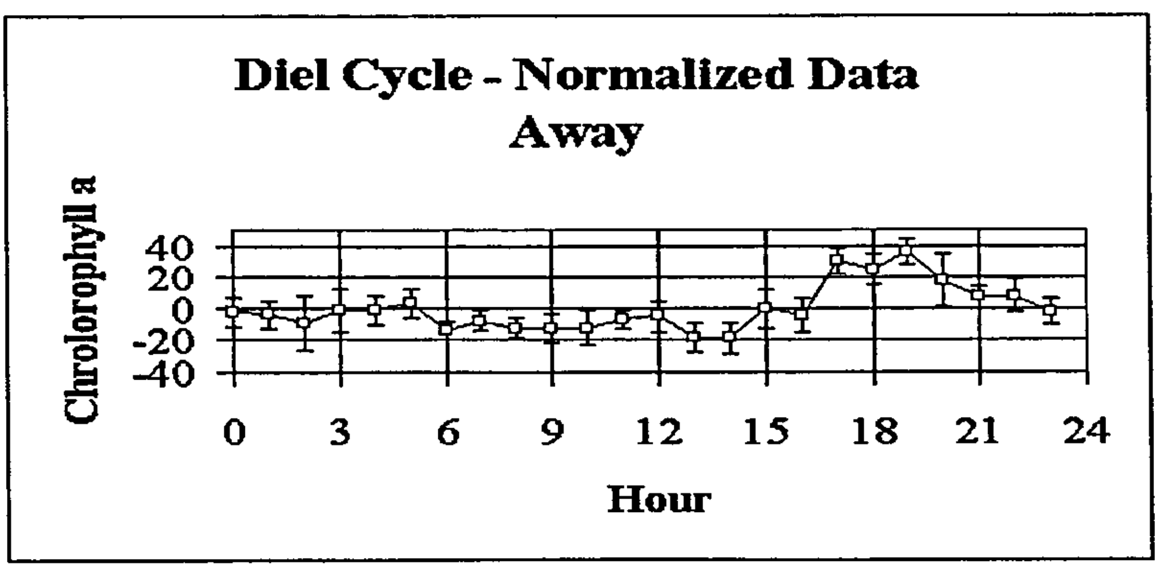


A

B



C



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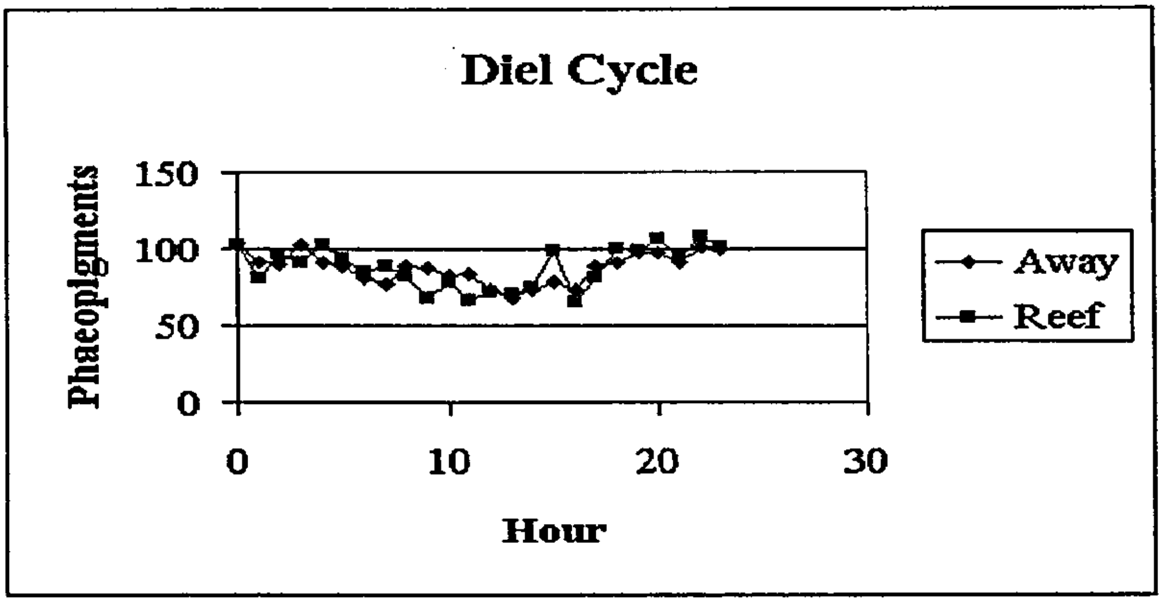
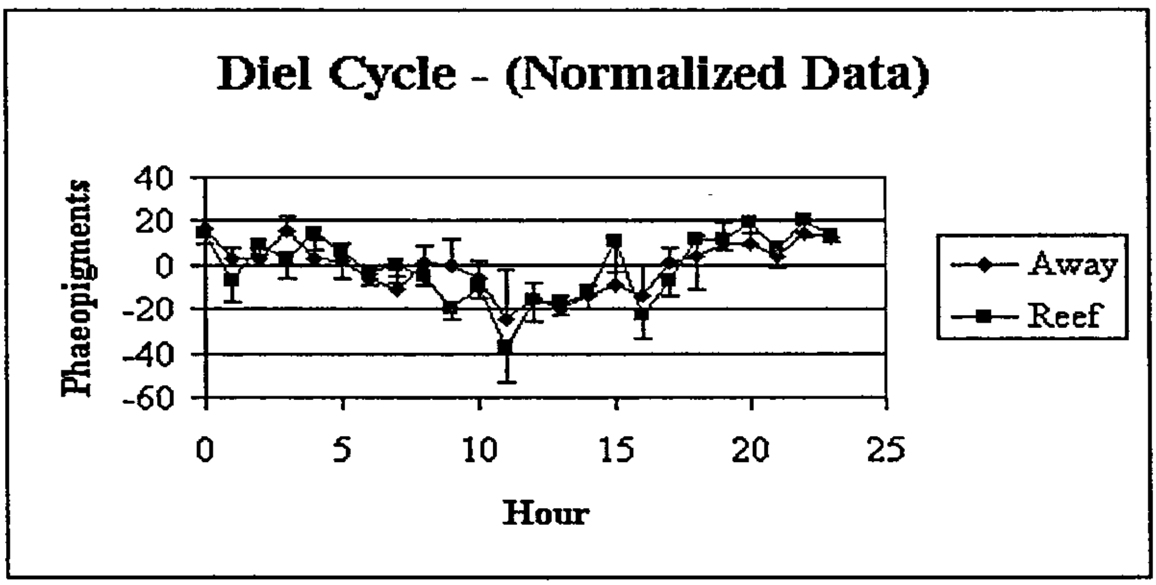


(D)



(E)

(Fig –3-6–1)

A – Shows the diel cycle during 24 h CHL sampljng
B – Shows the diel cycle during 24 h CHL Reef sampling Normalised data.
C – Shows the diel cycle during 24 h CHL Away sampling Normalised data.
D – Shows the diel cycle during 24 h PHAE sampljng .
E– Shows the diel cycle during 24 h PHAE Away and Reef sampling Normalised data. (Durjng the entire period Oct 10th until Dec2nd -1999)

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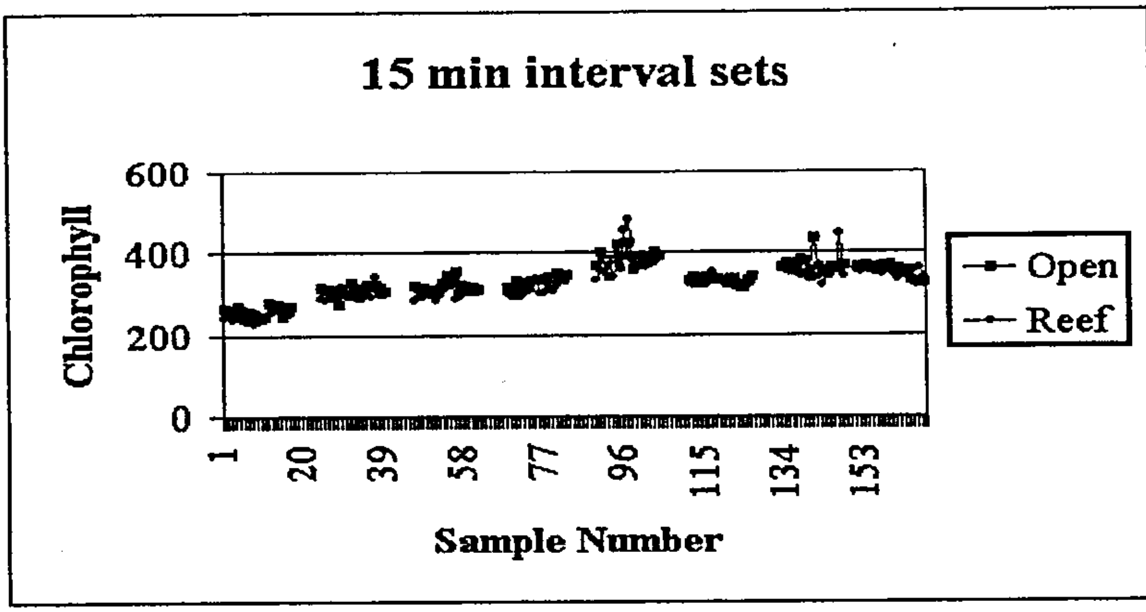
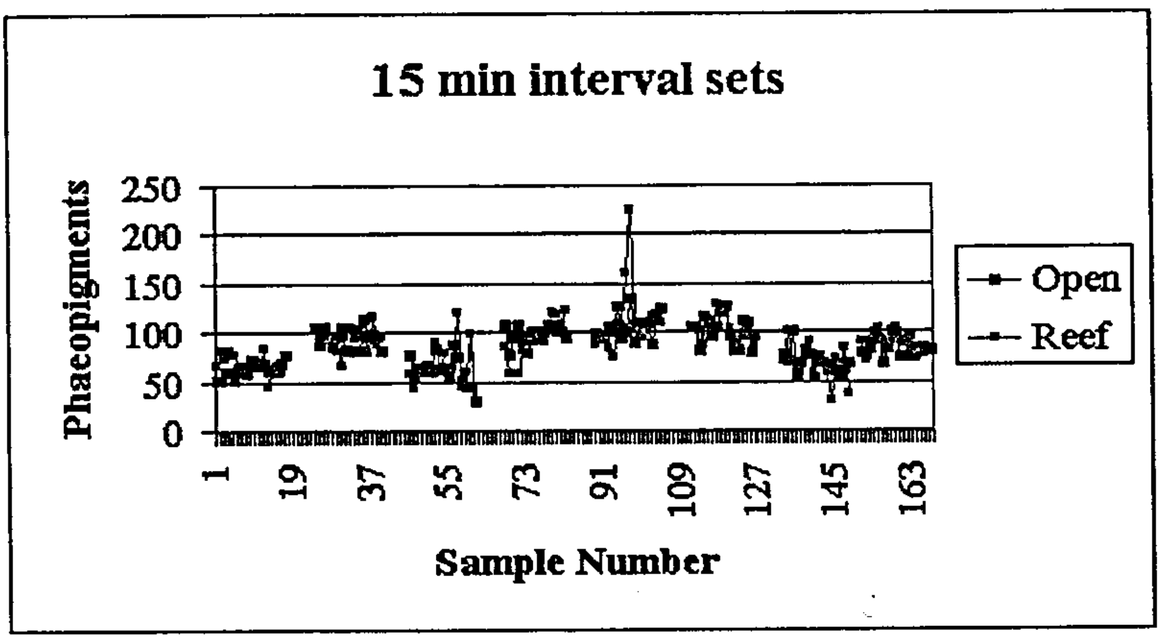


A



B

(FIG . 3-6-2)

A - Shows the 15 minutes inter val (during the 24 hours sampling) for the chlorophyll concentrations with clear co- variation in the two sites (Away more than Reef)

B – Shows the 15 minutes intervals (during the 24 hours sampling for the phaeopigments concentrations with no significant difference between the two sites (Away less than Reef)

(Durjng the entire period Oct 10th until Dec2nd –1999)

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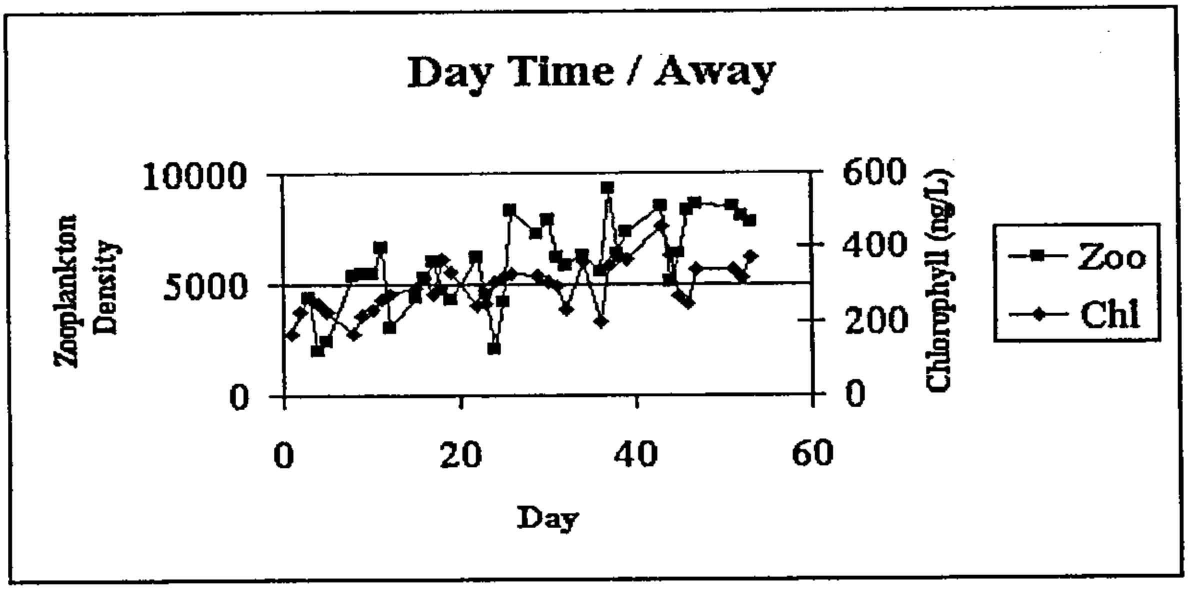
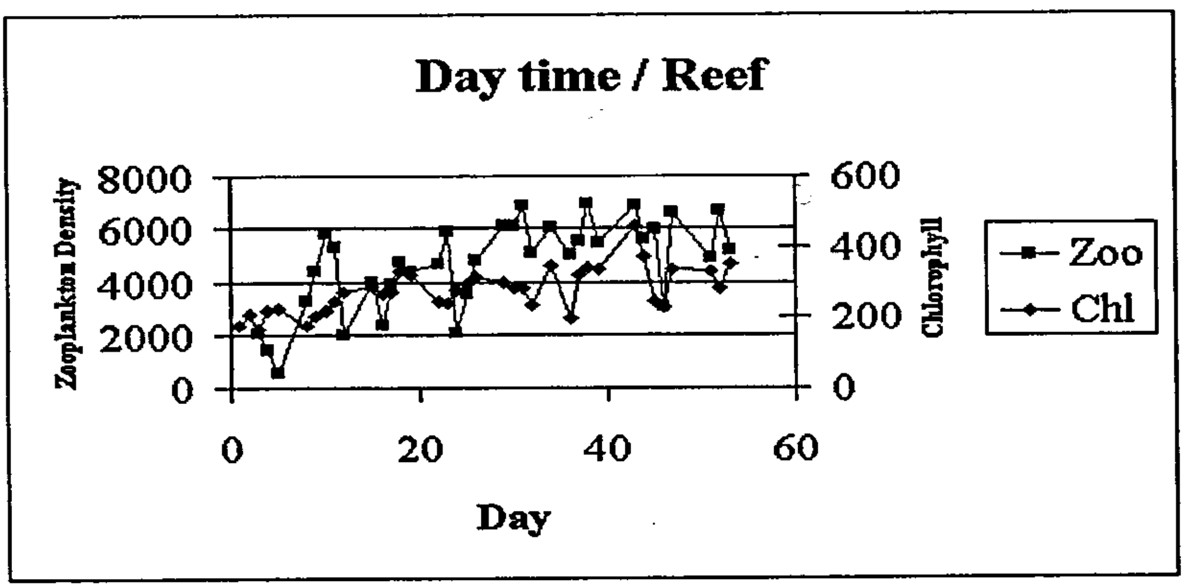


(A)



(B)

Fig . 3-7-2)
A – Shows the Chll concentration co- varied With Zoo density in Away site (day time)
B - Shows the Chll concentration co- varied With Zoo density in Reef site (day time)
(Oct 10th – Dec 2nd 1999)

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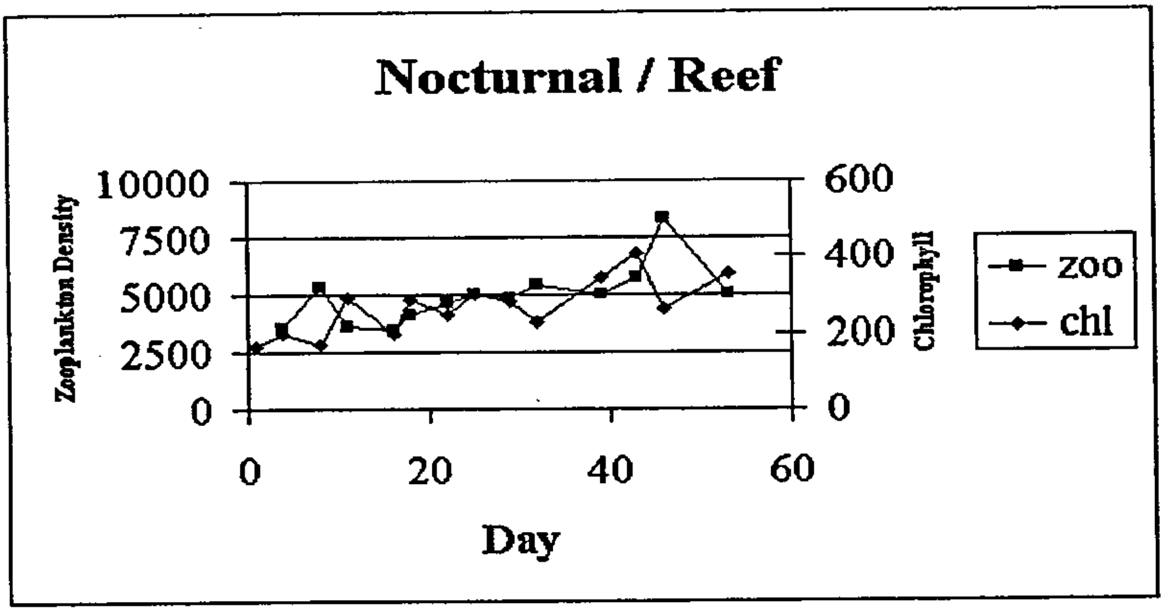
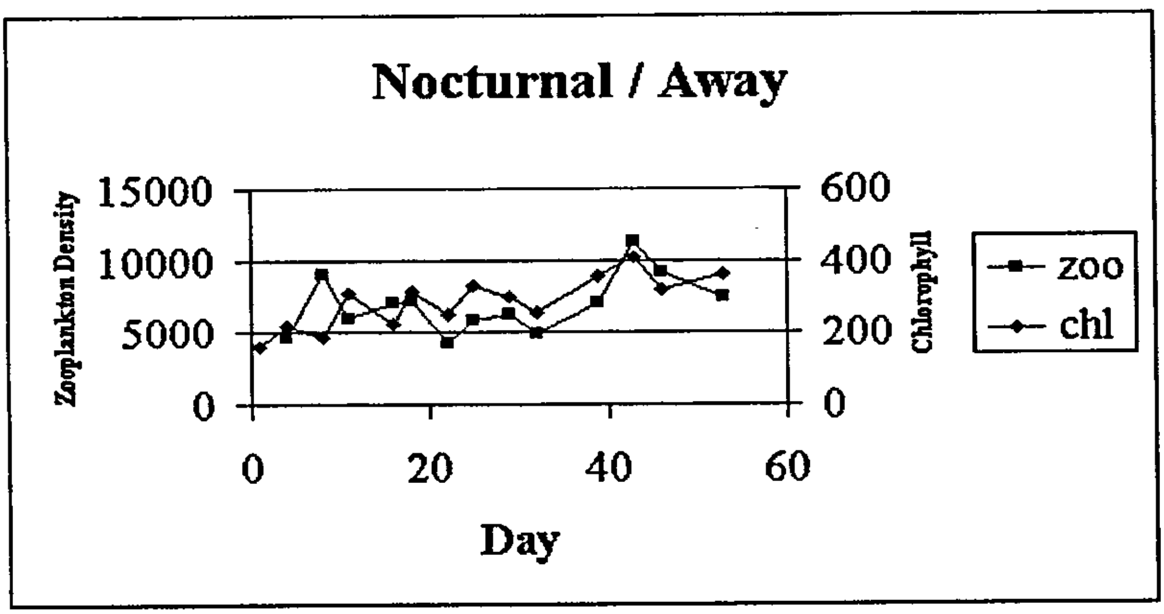


(A)



(B)

(Fig – 3-7-3)

A – Shows the Chll concentration co- varied With Zoo density in Reef site (Night time)
B - Shows the Chll concentration co- varied With Zoo density in Away site (Night time)

(During the sampling period Oct10th – Dec 2nd 1999)

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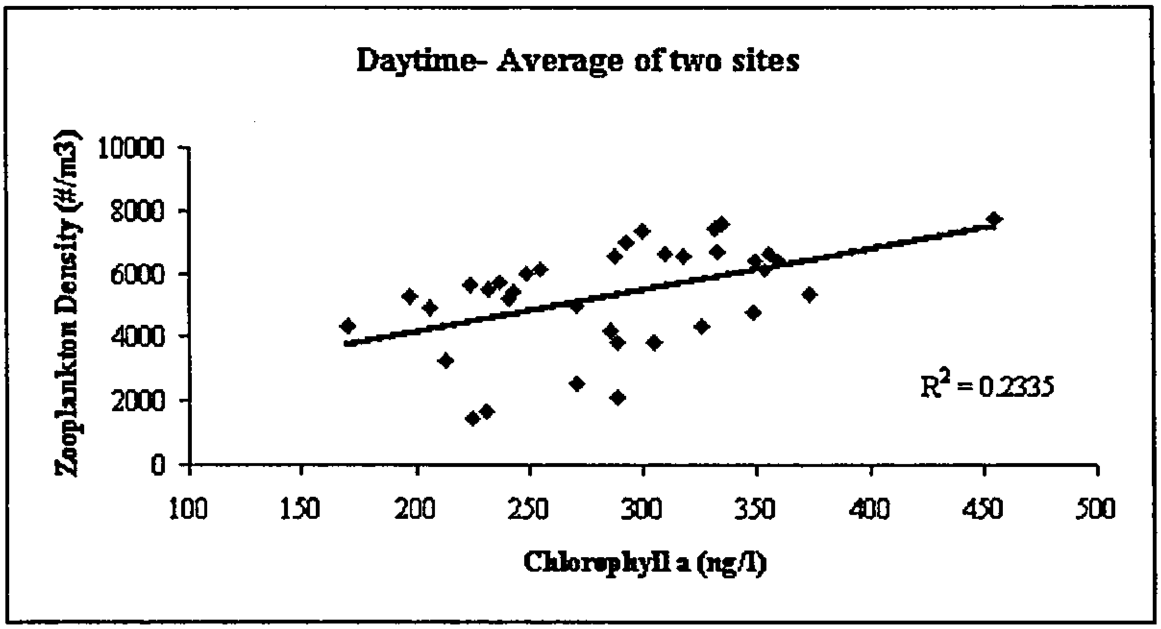
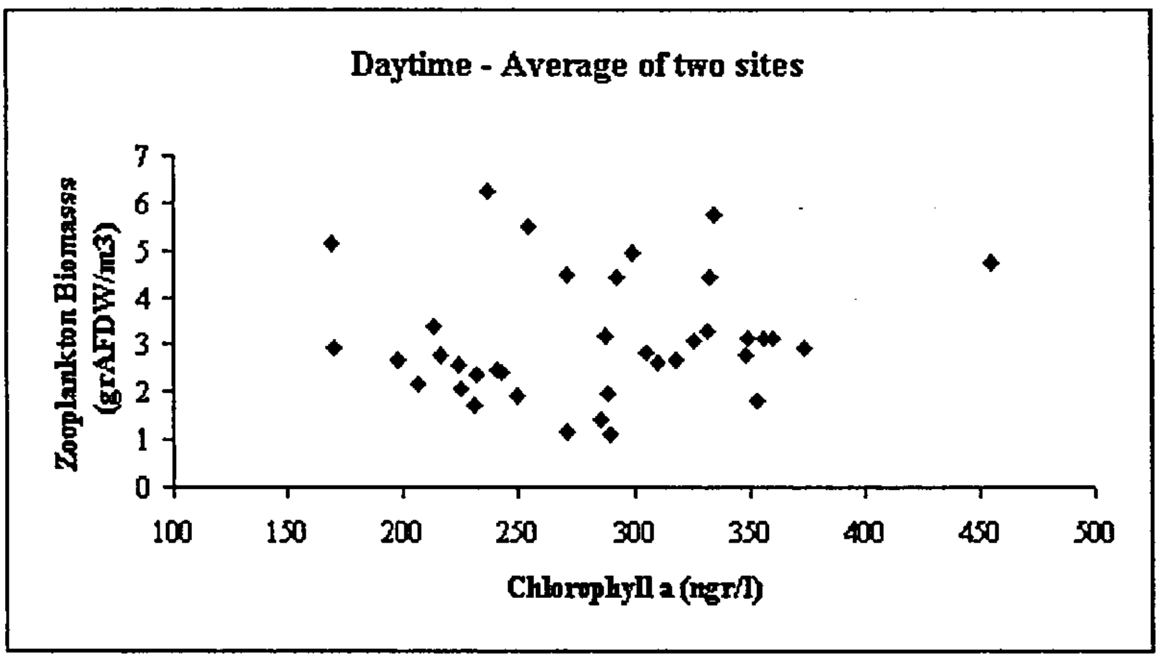


(A)



(B)

(Fig , 3-7-1)

Shows the variation of average two sites (Away and Reef) between Chlorophyll a concentration and Zoo density (A) and Chlorophyll a and Zoo Biomass (B) during Day time .

Durjng the entire period(Oct 10th until 2n Dec1999)

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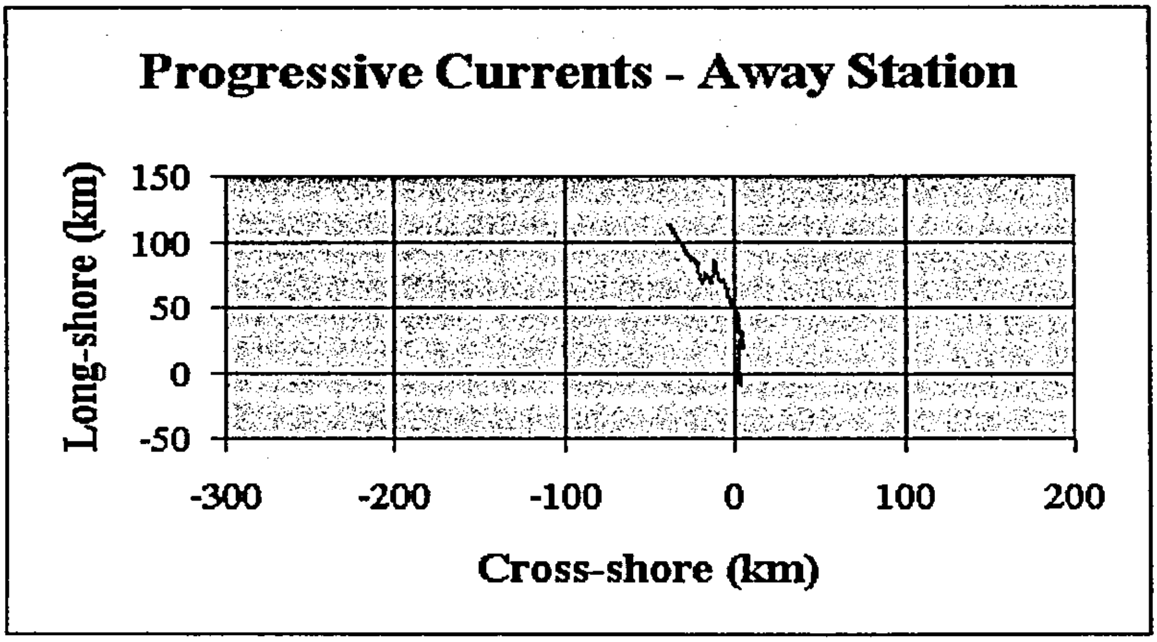
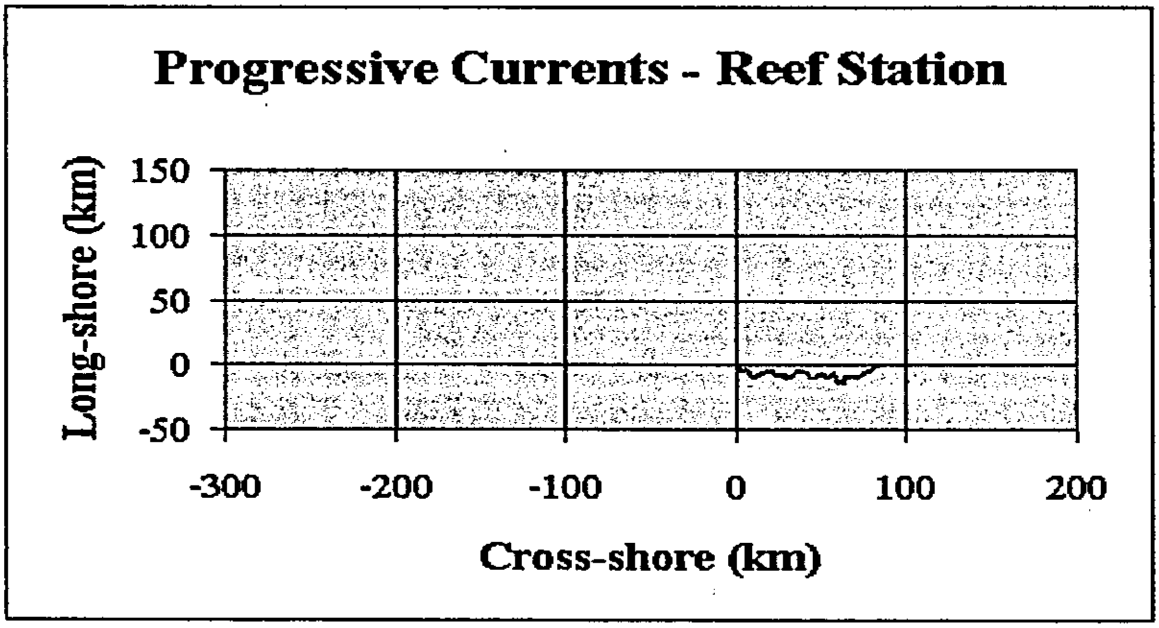


(A)



(B)

(FIG . 3-8-1)

A-The flow at the upper water column in the (Away Station) open-water area was a general northward flow with a weak (0.8 cm/s) component of on-shore flow .
B-At the reef (Reef Station) the flow was directed straight off shore, at a net advection speed of about 1.8 cm/s.
(During the period of 54 daysOct 10th until Dec 2nd 99) .

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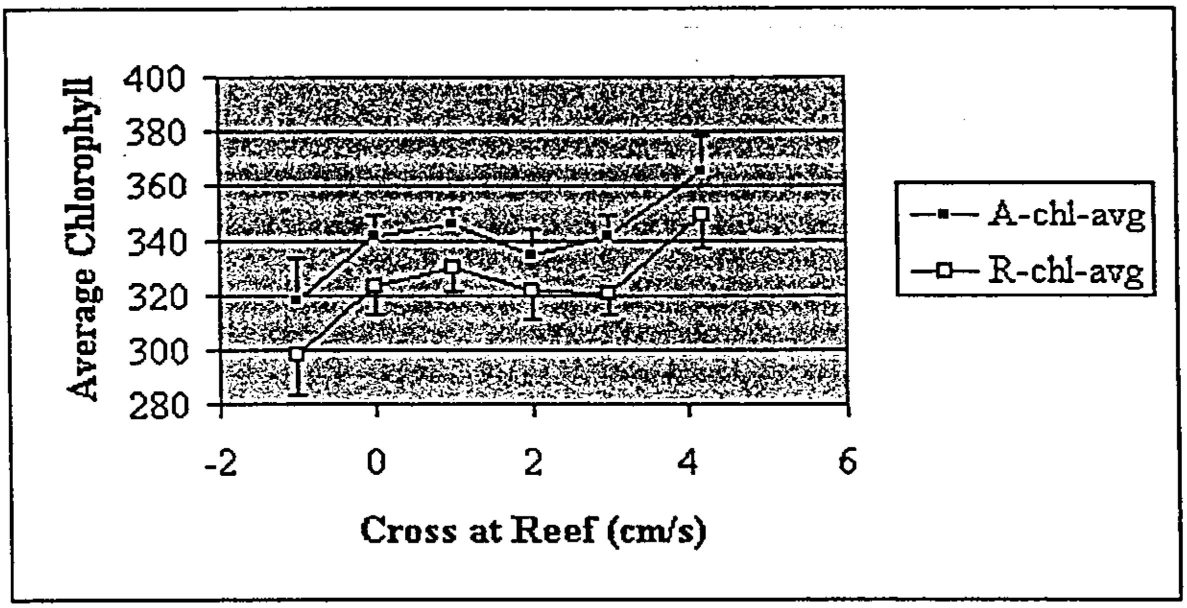
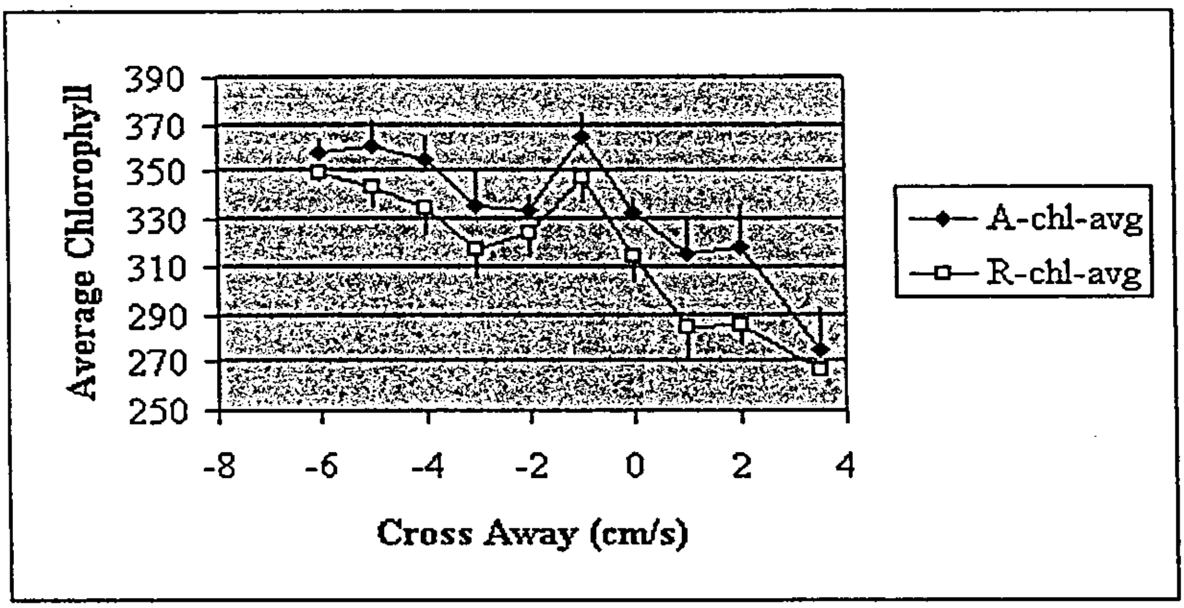


(A)



B B B B B B B B B

(B)

(FIG . 3-8-2)

The off-shoreward flow at the reef is relatively strong (right side in the Fig. A), the stronger this bottom off-shore flow (stronger on-shore flow aloft) the higher the concentrations of chlorophyll, and vice versa.

Reversed conditions are also indicated by a reversal of the typical on shore flow in the upper water column at the Away site (right side of the Fig. B).

(Oct 10th until Dec 2nd)1999

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CHAPTER FOUR

4 DISCUSSION

4-1 The co variation of the Chlorophyll (Chl) and Phaeopigment concentrations between the two sites (Away & Reef) .

Depletion of phytoplankton cells and pigments over coral reef was studied in the Gulf of Aqaba - Red Sea during by **(Yahel et al , 1998)** It showed that the phytoplankton abundance and chlorophyll a concentrations were 15 – 65 % lower near the reef than in the adjacent open water .

Infact , strong phytoplankton grazing is to be expected at the reef , as numerous members of the coral reef community are known to feed on particles within the size range of phytoplankton . Such taxa include bivalves **(Klumpp et al . 1992)** and **(Lesser et al . 1992)** , gastropode **(Lesser et al . 1992)** , sponges **(Ries wig . 1971 , 1974 ; Pile et al 1996 , 1997)** , ascidians **(Petersen & Riisgård , 1992)** and soft – coral **(Fabricius et al m1995)** .

The results clearly showed that phytoplankton were significantly less abundant at the Reef, compared with the Away site, located only 130 m

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seaward., this inter-site difference of planktonic abundance can be best interpreted in terms of intense phytoplankton grazing at the reef. See

(Fig.3-6-1-A) & (Fig.3-6-2-A)

The decrease in chlorophyll near the reef was typically associated with an increase in the concentration of its degradation products , the phaeopigments . **(Yahel et al , 1998)** .

Also the results clearly showed that phaeopigment were significantly less abundant at the open water (Away) , compared with the Reef site, this inter-site difference of phaeopigments abundance can be best interpreted in terms of intense phytoplankton grazing at the reef.

(Refer to appendix # 3-1-1) , (Fig.3-6-1-D,E) & (Fig.3-6-2-B).

4-2 The dominance taxa in the phytoplankton during the study period .

In the Gulf of Aqaba (Red Sea) it was observed a yearly recurring succession among **picophytoplankton** in which :

- **Eukaryotic algae** are dominant during winter .
- **Synechococus** is dominant during the spring bloom and fall .
- **Prochlorococcus** is dominant during stable summer stratification .

(Anton Post Lectures , 1996) and (Lindell . D , & Post . A , 1995)

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The results show that phytoplankton community was dominated by ***Synecochoccus***, during the study period (Oct 10th - Dec 2nd), which formed over **97%** of the cells counted under the epi-fluorescent microscope also the Eukaryotes were increasing by the time in both sites (Away & Reef) .

4-3 The relationship of the Chlorophyll (Chl) concentrations between the two sites (Away & Reef) .

There are several processes affect the concentration of chlorophyll and pheopigment in the euphotic zone Such as :

- **Cell sinking .**
- **Cell senescence .**
- **Photodegradation .**
- **Fecal pellet sinking .**
- **Physical mixing .**
- **Advective transport .**

The increase in chlorophyll was due to an increase of both the Synecochoccus and eukaryotic taxa ,as shown in **(Fig 3-2-1)** .

This strong correlation comes from the control factors of dynamic distributions such as (Biological & Ecological).

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4-4 The short term scale variation (min , hrs , days) of the phytoplankton in the two sites (Away & Reef)

The temporal variations of zooplankton at the coral reef and away from it were much higher than those of phytoplankton, on each temporal scale examined. The zooplankton's CV - values were twice as high as those of the phytoplankton for the entire 54 day long series , CV values of phytoplankton were 18.1% and nearly 3 times higher for the diel series CV values for phytoplankton were 6.9% and 7.6% for the Away and reef sites respectively . (**Refer to Table 3-4-1**).

Overall, the shorter-term variations (scale of a day or less) of phytoplankton were surprisingly low, indicating a highly predictable regime on this temporal scale.(**Refer to Table 3-4-2**)

Therefore , we can considered that the short-term variations **(scale of a day or hours**) of phytoplankton will be low, indicating a highly predictable regime on this temporal scale .

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4-5 The co-variation of Chlorophyll and Phaeopigment concentrations during day and night time (Diel Cycle) in both sites (Away & Reef) .

The depletion of the chlorophyll concentrations at night in the two sites (Away & Reef) were due to the nocturnal predators (e . g ., corals) , especially in the Reef site .

The role of benthic grazing in the observed phytoplankton removal was obvious at the perforated reef . Because this reef was inhabited by massive colonies of soft - corals reported as plankton grazers (**Fabricius et al 1995**) , high rates of phytoplankton removal were expected .

The increase of Phaeopigment concentrations in the (Away site) at day time were due to the active day time predators in the open water .

But in the Reef site at night time , Phaeopigment concentrations were much more than the day time due to nocturnal phytoplanktivores grazers in the coral reef community.(**Refer to Appendix 3-5-1**) .

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4-6 The Temporal & Spatial dynamics of Phytoplankton Patchiness on scale of minutes & hours in the two sites (Away & Reef) .

One of the most ubiquitous characteristics of oceanic phytoplankton is its high level of temporal and spatial variations, termed "Patchiness" due to Physical and biological parameters.

The low-frequency fluctuations of phytoplankton (millennia, decadal, seasonal) are fairly well documented, but rapid changes, (The study) on the scale of minutes to hours, are poorly understood. Possible reasons for high-frequency fluctuations in plankton abundance include, physical advection, localized population growth, interactions with patchy food or predators, and behavior.The concept that phytoplankton is not a principal food source in coral reefs probably originated from an early comparison between zooplankton and phytoplankton removal rates in a Caribbian coral reef which suggested that zooplankton are by far the most important source of heterotrophic carbon in this ecosystem (**Glynn .1973**) .

Racently , however (**Ayukai ,1995**) observed a substantial retention of picophtoplankton at the Great Barrier Reef in Australia , and discovered phytoplankton feeding by some common soft – coral species that had previously been considered exclusive zooplanktivores (**Fabricius et al ,1995**) .

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Strong **phytoplankton** grazing is to be expected at the reef , as numerous members of the coral reef community are known to feed on particles within the size range of phytoplankton . Such taxa include bivalves **(Klumpp et al . 1992)** and **(Lesser et al . 1992)** , gastropode **(Lesser et al . 1992)** , sponges **(Ries wig . 1971 , 1974 ; Pile et al 1996 , 1997)** , ascidians **(Petersen & Riisgård , 1992)** and soft – coral **(Fabricius et al ,1995)** .

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The temporal variations of zooplankton at the coral reef and away from it were much higher than those of phytoplankton, on each temporal scale examined. The zooplankton's **CV** values were twice as high as those of the phytoplankton for the entire 54 day long series , **(CV values of phytoplankton were 18.1%)** and nearly **3 times** higher for the diel series **(CV values for phytoplankton were 6.9% and 7.6% for the Away and reef sites respectively)** .

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The observed gradual increase in phytoplankton and zooplankton abundance coincided with the ensuing fall mixing and seasonal eutrophication in the northern Gulf of Aqaba **(Genin et al., 1995).**

Our results clearly showed that phytoplankton were significantly less abundant at the Reef, compared with the Away site, located only 130 m seaward. **(See Fig 3-6-1 & 3-6-2)** Together with the current-meter data, this inter-site difference of planktonic abundance can be best interpreted in terms of intense phytoplankton grazing and zooplankton predation at the reef. This scientific work supports earlier reports on the importance of plankton advection to the nutrition of coral reefs. Grazing at the reef, together with physical advection, seems to affect temporal variations of the plankton at our study sites, over comprising general seasonal trends.

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4-7 The Relationship Between the Zooplankton (biomass & density) and Phytoplankton (Chlorophyll concentration) .

Large amplitude variability in plankton at meso – scales (1-100 km) is frequently observed in the absence of marked physical patterns . in these cases , there are no simple relationships between the spatial distribution of temperature , chlorophyll , and Zooplankton biomass (**Mackas and Boyd , 1979 ; Steel and Henderson , 1979)** , **Fig . 3-7-1 – B** , there is no correlation between Chlorophyll a and Zoo biomass in the two sites (Away & Reef) , although a weak negative correlation are sometimes found between phytoplankton and zooplankton density , as it is clear in our results the weak correlation due to the short time scale in our two months sampling period as shown in **(Fig . 3-7-1 – A)** .

Under these conditions of relative physical uniformity , it is relevant to consider whether the patchiness is a consequence of ecological process rather than purely physical forcing **(Steel and Henderson , 1992)** .

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4-8 The Relationship Between Phytoplankton and the Currents flow in the study area .

As described by **Genin et al. (1998)**, the current measurements show the prevalence of a typical circulation for the west coast of the Gulf, where the surface water is moving with a shore-ward component generating down welling along the coast with a strong return, off-shoreward flow at the reef just above the bottom. Thus, open waters, rich with phytoplankton and zooplankton is advected onto the reef at the upper layers of the water column. This water replenishes food for the benthic grazers and predators at the reef, causing the return waters to be relatively depleted of plankton .

The above scenario can be best visualized when the strength of the cross-shore component at the two current-meter stations is compared with the concentration of chlorophyll at the two sites **(Fig. 3-8-2)**.
A situation where the off-shoreward flow at the reef is relatively strong **(right side in Fig. 3-8-2-A)**, indicates a situation where the reef is exposed to a relatively high rate of water replenishment from the open sea, that is a strong on-shore flow at the upper water column.
As seen in **(Fig . 3-8-2-A)** , the stronger this bottom off-shore flow (stronger on-shore flow aloft) the higher the concentrations of chlorophyll, and vice versa.

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Reversed conditions are also indicated by a reversal of the typical on shore flow in the upper water column at the Away site (right side of Fig. 3-8- 2-B). Such a-typical conditions indicate a situation where the source of water at the Reef station is from the deeper sections of the reef, via weak upwelling, and a general advection of water from the reef toward the open sea.

Under such conditions the chlorophyll concentrations are low at both stations (**Fig . 3-8-2 - B**) .

No similar trend was found for zooplankton, suggesting that animal behavior, primarily active swimming in the vertical, may over dominate passive advection. Phytoplankton seems to better follow the paths of water flow.

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4-9 The co variation of Chlorophyll and Phaeopigment concentrations during day and night time in the Reef site (Aloft & Bottom) .

The results of the chlorophyll and concentrations, of the Additional - **Reef sites** (Aloft & Bottom) , showed that no clear difference between the **(Aloft &Bottom)** samples during the day time as shown in **(Fig . 4-9-1-A)** , but a clear different in the nocturnal samples in the small scale of days (from day 22 to the day 54) , with average of total difference between the **(Aloft & Bottom)** samples of **42.3 ngr L^{-1}** and standard deviation **(SD) of 47 ngr L^{-1}** ' as shown in **(Fig . 4-9-1 -B)** .

Also the results of the phaeopigment concentrations, of the **(Additional Reef sites)(Aloft & Bottom)** showed that no clear difference between their samples during the day time as shown in **(Fig . 4-9-2 -A)** , but a clear difference in the nocturnal samples in the small scale of days **(from day 22 to the day 54)** , with average of total difference between the **(Aloft & Bottom)** samples of **1.07 ngr L^{-1}** and standard deviation **(SD) of 35.5** as shown in **(Fig . 4-9-2 -B)** , and **(Table 3-9-1)** .

Therefore , it can said that the average of the total difference between the **(Aloft & Bottom) , in** chlorophyll samples much higher than the total difference between the **(Aloft & Bottom)** , in phaeopigment samples at the night time but with no clear difference for (Chlorophyll & Phaeopigment) at the day time .

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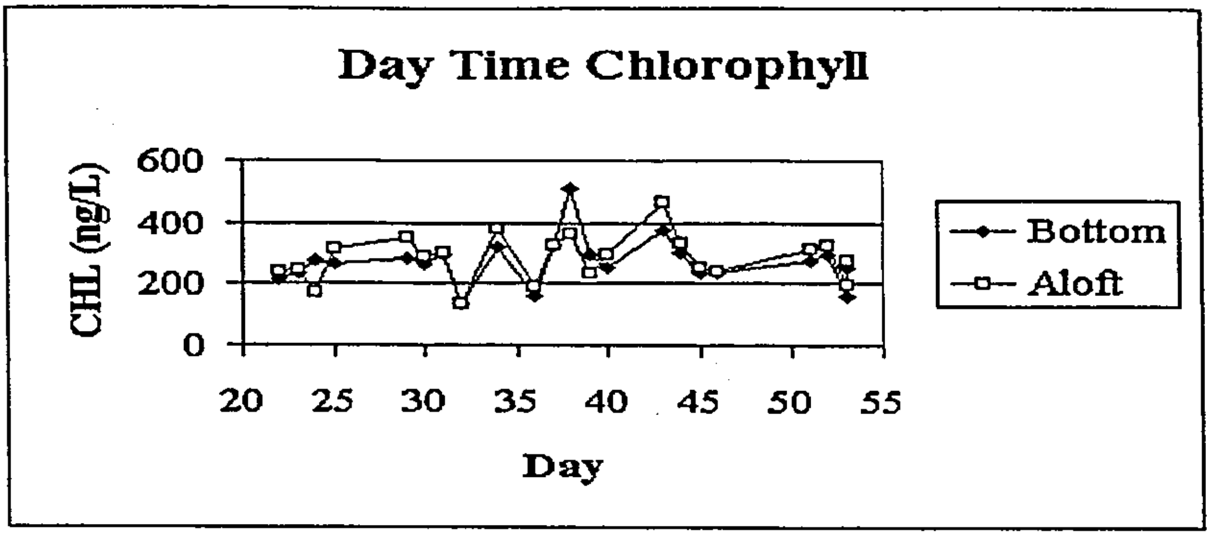
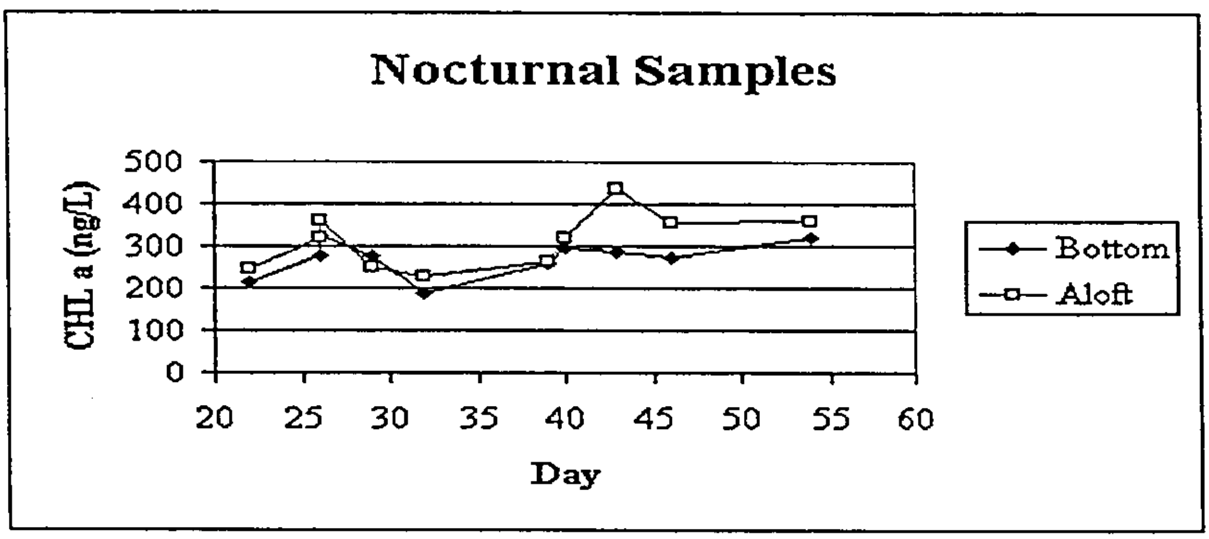


(A)



(B)

(FIG. 4-9-1)

A – Shows the Chlorophyll concentrations in the Additional Reef site (Aloft & Bottom) over the entire time series at the daytime .

B – Shows the Chlorophyll concentrations in the Additional Reef site (Aloft & Bottom) at night time (Oct 10th –Dec2n 1999)

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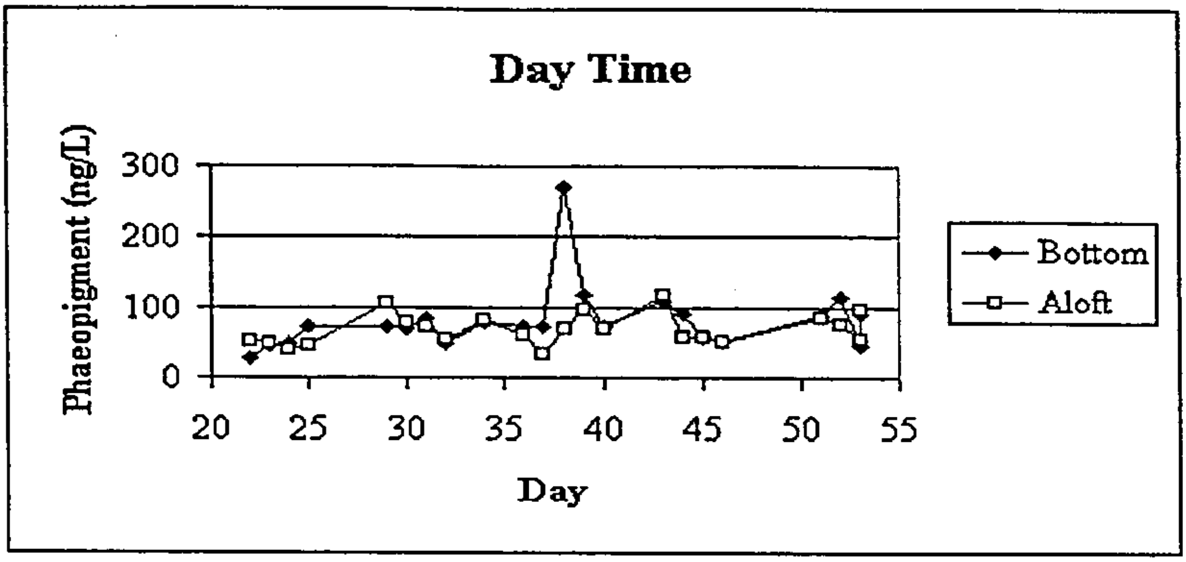
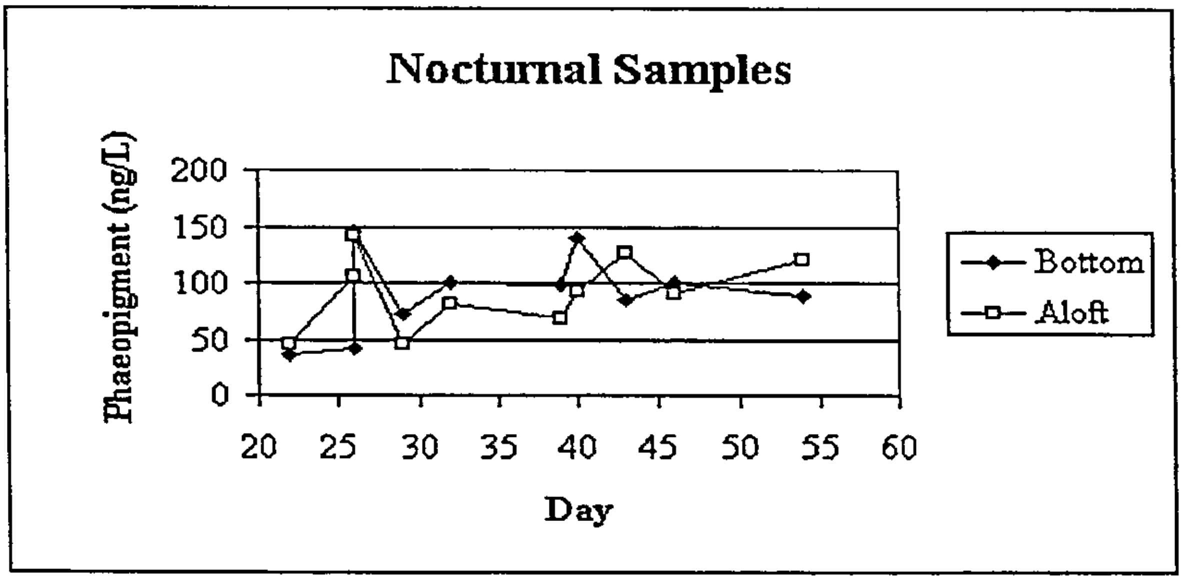


(A)



(B)

(Fig . 4-9-2)

A – Shows Phaeopigment concentrations in the Additional Reef site (Aloft & Bottom) over the entire time series at the daytime .

B - Shows the Phaeopigment concentrations in the Additional Reef site (Aloft & Bottom) over the entire time series at the Night time .

(During the period Oct 10th until Dec 2nd 99)

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TABLE (3-2-1)

DOMINANCE TAXA

site:		Away Avg Euk	Away Avg Syn	Away Avg ratio	Reef Avg Euk	Reef Avg Syn	Reef Avg ratio	Away Cl Euk	Away Cl Syn	Reef Cl Euk	Reef Cl Syn
date	day										
19/10/99	10	694	12,448	0.9472	694	10,662	0.9389	390	1,728	360	1,104
27/10/99	18	227	14,339	0.9844	227	14,339	0.9844	218	2,950	277	1,743
2/11/99	24	347	19,539	0.9825	99	18,647	0.9947	233	1,568	142	2,290
8/11/99	30	347	19,986	0.9829	248	19,589	0.9875	276	2,037	208	1,955
16/11/99	38	714	18,948	0.9637	381	13,807	0.9732	491	1,284	274	1,521
23/11/99	45	711	31,144	0.9777	645	26,135	0.9759	365	2,220	296	2,551
29/11/99	51	1,190	25,193	0.9549	397	22,961	0.9830	469	2,443	242	1,963
			avg:	0.97			0.977				
			std:	0.015			0.018				

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TABLE (3-4-1)

24 HOURS DATA SHEET

Hour	11 Chlorophyll Open	11 Chlorophyll Reef	25 Chlorophyll Open	25 Chlorophyll Reef	39 Chlorophyll Open	39 Chlorophyll Reef	53 Chlorophyll Open	53 Chlorophyll Reef	Raw Chl avg Away	Raw Chl avg Reef	Chl SdtErr Away	Chl SdtErr Reef
0	313.29825	287.7271	316.10061	301.7657	346.8517	326.8153	369.9671	355.3638	336.5544	317.918	13.48348	14.87093
1	311.35632	286.6543	330.73079	290.3035	344.8133	320.8994	353.848	348.3684	335.1871	311.5564	9.258589	14.47474
2	325.81292	288.5853	331.61747	321.8247	334.5577	322.7124	328.7574	335.3104	330.1864	317.1082	1.878075	9.993857
3	324.30253	303.6047	341.81427	315.6527	335.0135	320.2195	352.2066	353.032	338.3342	323.1272	5.862795	10.56625
4	302.40644	294.359	346.24765	327.3353	335.4693	328.8312	367.683	352.5656	337.9516	325.7728	13.60883	11.95993
5	304.02013	299.3134	350.45937	313.228	338.6599	313.8741	376.1247	375.1839	342.316	325.3998	14.97021	16.93112
6	267.04734	266.8365	334.49917	327.7762	340.939	321.8059	359.2413	367.2559	325.4317	320.9186	20.15465	20.65556
7	272.64672	265.5516	341.14926	342.9857	357.5757	334.2702	355.0205	355.8301	331.598	324.6594	19.97901	20.194
8	270.06239	263.8383	339.59757	329.5396	346.8644	311.1546	351.4805	352.0715	327.0012	314.151	19.13652	18.74192
9	256.92539	265.7657	336.05958	283.7977	339.8009	305.5554	373.9453	359.0524	326.6828	303.5428	24.76531	20.21209
10	247.66487	266.194	330.52864	303.1575	367.3216	325.4583	362.4789	365.3352	326.9985	315.0363	27.67534	20.74703
11			313.27213	291.0576	358.9062	337.2191	371.8392	353.0023	348.0058	327.093	15.38374	16.09494
12	263.38621	240.2814	318.36059	280.2777	373.69	343.0996	380.4975	343.9271	333.9836	301.8964	27.33772	25.37725
13	258.00219	235.3558	304.20139	296.3376	367.7765	332.6957	354.2886	319.9592	321.0672	296.0871	25.07832	21.59943
14	245.94199	231.7152	328.75874	312.3975	341.393	365.7165	365.755	441.66	320.4622	337.8723	25.99941	44.22056
15	271.56992	253.9872	312.16594	290.6176	390.2934	450.304	382.1356	359.0524	339.0412	338.4903	28.5169	43.16409
16	269.84703	249.9183	308.4049	312.8375	370.5058	388.5597	389.8578	372.5489	334.6539	330.9661	27.72149	31.54829
17	299.99754	297.0323	376.32478	292.1576	392.5678	384.4886	412.3226	390.0012	370.3032	340.9199	24.56368	26.78788
18	317.44176	300.0305	335.83834	300.2976	382.5603	423.1637	422.385	360.4486	364.5563	345.9851	23.65164	29.38949
19	309.68877	260.4119	386.72294	314.1574	402.1205	376.1203	403.4303	376.0393	375.4906	331.6822	22.2595	27.88201
20	310.11949	257.1996	313.93584	292.1576	425.5472	358.7053	380.4975	369.0584	357.525	319.2802	27.84189	26.80461
21	313.13454	304.5277	321.01544	286.2177	377.784	345.8136	375.8173	360.914	346.9378	324.3682	17.32086	17.42748
22	330.57876	308.1683	341.81175	293.0376	354.5847	349.6585	362.4789	354.1657	347.3635	326.2575	7.030704	15.15821
23	313.99599	289.5369	325.88266	299.1976	343.2126	337.8976	365.755	349.9772	337.2115	319.1523	11.24739	14.65386
CV	0.0946056	0.085932	0.0590311	0.0546	0.067302	0.103129	0.055577	0.061458	0.069129	0.07628		
	[illegible]	[illegible]	304.9215	361.2004	346.8766	371.5756	361.2551					

11 Phaeopigments Open	11 Phaeopigments Reef	25 Phaeopigments Open	25 Phaeopigments Reef	39 Phaeopigments Open	39 Phaeopigments Reef	53 Phaeopigments Open	53 Phaeopigments Reef	Raw Phaeo avg Away	Raw Phaeo avg Reef	Phaeo SdtErr Away	Phaeo SdtErr Reef
104.0538	101.7413	106.6628	86.46762	104.9235	118.6303	98.60563	101.627	103.56143	102.117	1.738684	6.569969
96.86625	94.59406	93.15749	57.99291	97.3011	87.44679	74.43399	81.59676	90.439707	80.4076	5.415629	7.930102
82.4912	101.7413	92.2878	99.78297	104.0538	102.6061	80.75182	81.16435	89.896151	96.3237	5.358873	5.087503
112.9807	95.45888	107.5325	106.0654	115.7047	87.44679	75.30368	74.8819	102.88041	90.9632	9.347893	6.57813
80.32321	95.14254	94.02718	122.0896	126.9209	118.1979	60.92863	75.31431	90.549975	102.686	13.89528	10.89048
88.80904	71.42262	94.02718	121.2248	80.75182	90.15561	92.2878	91.77089	88.96896	93.6435	2.946003	10.2882
75.59765	75.60663	85.10028	91.77089	95.99656	86.58197	68.11616	83.32639	81.202662	84.3215	6.032713	3.385536
68.41013	68.02696	62.66802	109.5247	104.9235	102.6061	71.70992	71.30827	76.927882	87.8665	9.516984	10.62276
83.65486	68.02696	103.9388	76.61154	104.0538	100.8765	60.92863	83.7588	88.144012	82.3185	10.26087	6.971917
113.2746	52.86761	85.10028	65.14018	74.43399	79.0023	77.91275	76.61154	87.680417	68.4054	8.815691	5.998053
81.04579	64.99509	92.2878	89.17643	76.17337	87.8792	77.04306	69.46427	81.637507	77.8787	3.705228	6.221192
		68.11616	50.84565	82.92605	81.16435	100.345	67.73463	83.79574	66.5815	8.066009	7.596103
52.2957	65.4325	76.17337	57.12809	84.23059	74.01708	77.91275	90.04125	72.653103	71.6547	7.003083	7.031975
52.2957	77.55998	59.18925	57.99291	99.04048	88.31161	60.05894	57.12809	67.646094	70.2481	10.60788	7.648956
65.80106	72.57977	61.79833	59.72255	104.0538	83.7588	60.92863	82.66527	73.145448	74.6816	10.35725	5.58514
61.15864	44.79191	75.30368	118.6303	101.2147	159.3268	77.04306	71.30827	78.680021	98.5143	8.311088	25.37893
76.40337	74.24579	29.56947	29.40385	106.6628	93.50053	81.50651	64.161	73.535551	65.3278	16.07844	13.43231
71.82492	79.43471	80.52182	57.99291	124.5167	108.2275	76.05837	77.47636	88.230442	80.7829	12.22502	10.34947
96.86625	80.29953	61.79833	58.85773	119.1835	184.3423	88.57904	75.74672	91.606781	99.8116	11.85274	28.55184
88.80904	91.9996	120.8079	90.90607	110.1416	130.1017	68.00116	83.7588	96.939924	99.1915	11.71725	10.46414
88.80904	83.98752	90.54842	126.6424	127.1257	136.3841	81.50651	80.18517	96.997424	106.8	10.23198	14.42711
96.86625	103.471	68.98585	88.31161	107.5325	90.04125	92.2878	95.34452	91.418109	94.2921	8.130804	3.405817
113.8504	103.471	101.2147	126.6424	112.9807	112.3479	79.33229	90.04125	101.84451	108.126	8.038199	7.688783
96.86625	94.59406	107.5325	97.18851	104.9235	111.483	91.41811	101.627	100.18509	101.223	3.700358	3.715415

104.7682 78.04168 80.33511

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TABLE (3-4-2)

CHLOROPHYLL & PHAEOPIGMENT CONC
15 Minutes Intervals

Day	Time	Chlorophyll		Phaeopigments		CV	CV
		Open	Reef	Open	Reef	Open	Reef
11	12:00	263.3862	240.2814	52.2957	65.4325	0.043277	0.04868
11	12:15	259.2944	243.7078	52.2957	81.45667		
11	12:30	258.6483	235.9983	59.4832	72.57977		
11	12:45	266.1859	238.5681	60.3529	80.59185		
11	13:00	258.0022	235.3558	52.2957	77.55998		
11	13:15	255.4179	228.5029	59.4832	64.56768		
11	13:30	254.7718	231.7152	59.4832	65.4325		
11	13:45	247.2342	224.0056	58.6135	64.56768		
11	14:00	245.942	231.7152	65.8011	72.57977		
11	14:15	242.9269	238.7823	65.8011	73.44458		
11	14:30	246.3727	234.4992	66.6707	65.4325		
11	14:45	279.1075	267.0507	69.2798	83.18631		
11	15:00	271.5699	253.9872	61.1586	44.79191		
11	15:15	273.2928	261.0543	61.1586	60.81608		
11	15:30	244.8652	247.7768	59.4193	67.09853		
11	15:45	268.9856	252.4882	69.2158	59.95126		
11	16:00	269.847	249.9183	76.4034	74.24579		
12	0:15	313.2982	287.7271	104.054	101.7413	0.04352	0.05274
12	0:30	290.8582	282.7922	87.0697	94.59406		
12	0:45	311.3563	287.298	104.054	94.59406		
12	1:00	311.3563	286.6543	96.8663	94.59406		
12	1:15	270.5758	287.9417	85.3303	94.59406		
12	1:30	311.7879	297.1678	96.8663	80.29953		
12	1:45	312.4352	292.4475	104.054	66.005		
12	2:00	325.8129	288.5853	82.4912	101.7413		
12	2:15	304.4517	322.9152	80.7518	105.2006		
12	2:30	304.8832	288.3708	80.7518	94.59406		
12	2:45	312.8667	285.796	81.6215	101.7413		
12	3:00	324.3025	303.6047	112.981	95.45888		
12	3:15	316.7506	290.9455	96.8663	79.43471		
12	3:30	322.1448	342.2257	97.7359	114.9423		
12	3:45	313.2982	294.5931	96.8663	87.44679		
12	4:00	302.4064	294.359	80.3232	95.14254		
25	12:15	318.3606	280.2777	76.1734	57.12809	0.047908	0.04636
25	12:30	315.7057	290.3976	52.8714	42.83356		
25	12:45	311.7235	289.5176	59.6241	65.14018		
25	13:00	304.2014	296.3376	59.1893	57.99291		
25	13:15	308.1837	293.2576	67.2465	57.99291		
25	13:30	310.396	283.3577	60.0589	65.14018		
25	13:45	313.7146	297.2176	82.926	89.17643		
25	14:00	328.7587	312.3975	61.7983	59.72255		
25	14:15	348.1022	314.1574	63.2336	78.45553		

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25	14:30	335.3959	318.1174	54.6108			
25	14:45	355.3072	285.1177	87.2745	65.14018		
25	15:00	312.1659	290.6176	75.3037	118.6303		
25	15:15	319.4668	325.3774	52.0017	45.42802		
25	15:30	306.8562	305.3575	43.9445	59.72255		
25	15:45	306.1925	312.1775	43.9445	98.05333		
25	16:00	308.4049	312.8375	29.5695	29.40385		
26	0:30	316.1006	301.7657	106.663	86.46762	0.035588	0.05382
26	0:45	314.5489	289.2013	76.1734	57.99291		
26	1:00	330.7308	290.3035	93.1575	57.99291		
26	1:15	315.2139	291.626	106.663	57.99291		
26	1:30	328.9574	300.884	92.2878	82.02916		
26	1:45	317.6523	303.0883	79.7671	97.18851		
26	2:00	331.6175	321.8247	92.2878	99.78297		
26	2:15	334.4992	337.2546	93.1575	93.50053		
26	2:30	330.2875	297.798	100.345	97.18851		
26	2:45	338.7109	300.2227	101.215	90.04125		
26	3:00	341.8143	315.6527	107.533	106.0654		
26	3:15	335.8292	306.6356	107.533	120.3599		
26	3:30	352.2327	319.3999	99.4753	116.672		
26	3:45	342.9226	341.2223	101.215	108.6599		
26	4:00	346.2477	327.3353	94.0272	122.0896		
39	13:15	367.7765	332.6957	99.0405	88.31161	0.055825	0.09835
39	13:30	400.9833	355.0866	94.0272	93.61488		
39	13:45	384.3799	350.337	93.1575	97.18851		
39	14:00	341.393	365.7165	104.054	83.7588		
39	14:15	383.925	343.5519	100.345	74.01708		
39	14:30	418.0415	385.6195	126.256	107.7951		
39	14:45	363.2276	384.4886	94.1422	107.7951		
39	15:00	390.2934	450.304	101.215	159.3268		
39	15:15	424.6374	481.0631	134.313	224.2883		
39	15:30	359.5885	378.6082	90.5484	107.7951		
39	15:45	390.9757	365.7165	108.402	98.91815		
39	16:00	370.5058	388.5597	106.663	93.50053		
39	16:15	390.5208	378.8344	108.402	100.6478		
39	16:30	392.5678	367.2997	86.8397	114.5099		
39	16:45	402.8028	372.954	117.329	114.0775		
39	17:00	392.5678	384.4886	124.517	108.2275		
40	2:15	334.5577	322.7124	104.054	102.6061	0.022483	0.02944
40	2:30	341.1669	320.6728	104.923	102.6061		
40	2:45	326.3533	318.6332	80.7518	79.43471		
40	3:00	335.0135	320.2195	115.705	87.44679		
40	3:15	339.7995	317.9533	104.054	99.03251		
40	3:30	330.2276	332.6839	95.9966	111.483		
40	3:45	332.9624	348.7742	104.054	128.372		
40	4:00	335.4693	328.8312	126.921	118.1979		
40	4:15	331.595	331.3241	126.486	118.6303		
40	4:30	333.6461	318.4066	95.9966	102.6061		
40	4:45	337.0646	316.3669	80.7518	86.58197		
40	5:00	338.6599	313.8741	80.7518	90.15561		
40	5:15	323.6185	307.9819	110.372	93.72924		

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40	5:30	311.5398	319.0864	108.197	109.7534		
40	5:45	332.2787	315.9137	79.8821	93.72924		
40	6:00	340.939	321.8059	95.9966	86.58197		
53	10:30	362.4789	365.3352	77.0431	69.46427	0.05376	0.07666
53	10:45	372.0732	354.1657	69.8555	99.78297		
53	11:00	371.8392	353.0023	100.345	67.73463		
53	11:15	363.6489	348.581	53.7411	60.15496		
53	11:30	353.3525	349.5118	68.1162	59.72255		
53	11:45	384.2416	341.1347	78.7824	82.02916		
53	12:00	380.4975	343.9271	77.9128	90.04125		
53	12:15	353.3525	333.4557	52.8714	57.99291		
53	12:30	434.5534	331.8268	74.204	66.005		
53	12:45	362.7129	335.5499	68.1162	66.005		
53	13:00	354.2886	319.9592	60.0589	57.12809		
53	13:15	351.7145	343.229	67.2465	29.40385		
53	13:30	365.521	340.4366	60.9286	73.58467		
53	13:45	359.9048	356.4927	52.8714	67.73463		
53	14:00	365.755	441.66	60.9286	82.66527		
53	14:15	367.627	339.2731	68.9858	36.55112		
53	22:00	362.4789	354.1657	79.3323	90.04125	0.045839	0.02369
53	22:15	365.989	352.7696	76.1734	71.30827		
53	22:30	368.3291	356.9581	84.2306	89.60884		
53	22:45	363.1809	353.7004	98.6056	98.05333		
53	23:00	365.755	349.9772	91.4181	101.627		
53	23:15	354.9906	348.8137	68.1162	89.60884		
53	23:30	366.691	347.6502	84.2306	85.6028		
53	23:45	367.861	359.2851	99.4753	90.04125		
54	0:00	369.9671	355.3638	98.6056	101.627		
54	0:15	359.9448	347.6689	75.3037	88.74402		
54	0:30	358.7723	330.4137	74.434	88.31161		
54	0:45	348.4547	353.032	96.8663	89.17643		
54	1:00	353.848	348.3684	74.434	81.59676		
54	1:15	330.8678	339.2745	84.3456	74.01708		
54	1:30	325.709	354.1979	79.8821	82.02916		
54	1:45	324.0676	361.8928	80.7518	82.89398		
54	2:00	328.7574	335.3104	80.7518	81.16435		
					Avg CV	**0.043525**	**0.05372**

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TABLE (3-4-3)

DAILY SERIES SAMPLING DATA

Day	Time	Day.time	Chlorophyll Open	Chlorophyll Reef	Phaeopigments Open	Phaeopigments Reef
1	10:08	1.42	164.2587	173.6541	56.47914	37.46806
1	20:11	1.84	157.9111	164.8087	39.47866	73.47961
2	10:55	2.45	223.9353	208.8287	53.87237	60.72244
3	10:10	3.42	251.6332	246.113	57.57484	74.10383
3	14:20	3.60	261.0637	165.1947	41.04584	23.82326
4	10:50	4.45	245.7344	217.0539	38.73275	
4	20:08	4.84	218.9502	199.0894	12.81747	34.18537
5	10:10	5.42	226.5647	224.4487	45.04421	43.92709
8	11:06	8.46	165.189	175.6775	36.34731	29.86127
8	20:19	8.85	183.8235	169.4141	30.73515	21.97588
9	9:37	9.40	211.7146	201.995	55.94049	47.61508
10	10:32	10.44	231.7193	216.1002	50.49235	26.17329
11	5:54	11.25	267.0473	266.8365	75.59765	75.60663
11	6:48	11.28	272.6467	265.5516	68.41013	68.02696
11	7:48	11.33	281.6919	264.2667	84.52456	83.18631
11	8:48	11.37	270.0624	263.8383	83.65486	68.02696
11	9:55	11.41	256.9254	265.7657	113.2746	52.86761
11	10:55	11.45	247.6649	266.194	81.04579	64.99509
11	12:00	11.50	263.3862	240.2814	52.2957	65.4325
11	12:15	11.51	259.2944	243.7078	52.2957	81.45667
11	12:30	11.52	258.6483	235.9983	59.48322	72.57977
11	12:45	11.53	266.1859	238.5681	60.35291	80.59185
11	13:00	11.54	258.0022	235.3558	52.2957	77.55998
11	13:15	11.55	255.4179	228.5029	59.48322	64.56768
11	13:30	11.56	254.7718	231.7152	59.48322	65.4325
11	13:45	11.57	247.2342	224.0056	58.61353	64.56768
11	14:00	11.58	245.942	231.7152	65.80106	72.57977
11	14:15	11.59	242.9269	238.7823	65.80106	73.44458
11	14:30	11.60	246.3727	234.4992	66.67075	65.4325
11	14:45	11.61	279.1075	267.0507	69.27982	83.18631
11	15:00	11.63	271.5699	253.9872	61.15864	44.79191
11	15:15	11.64	273.2928	261.0543	61.15864	60.81608
11	15:30	11.65	244.8652	247.7768	59.41926	67.09853
11	15:45	11.66	268.9856	252.4882	69.21585	59.95126
11	16:00	11.67	269.847	249.9183	76.40337	74.24579
11	17:00	11.71	299.9975	297.0323	71.82492	79.43471
11	18:00	11.75	317.4418	300.0305	96.86625	80.29953

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11	19:00	11.79	309.6888	260.4119	88.80904	91.9996
11	20:00	11.83	310.1195	257.1996	88.80904	83.98752
11	21:00	11.88	313.1345	304.5277	96.86625	103.471
11	22:00	11.92	330.5788	308.1683	113.8504	103.471
11	23:00	11.96	313.996	289.5369	96.86625	94.59406
12	0:15	12.01	313.2982	287.7271	104.0538	101.7413
12	0:30	12.02	290.8582	282.7922	87.06966	94.59406
12	0:45	12.03	311.3563	287.298	104.0538	94.59406
12	1:00	12.04	311.3563	286.6543	96.86625	94.59406
12	1:15	12.05	270.5758	287.9417	85.33028	94.59406
12	1:30	12.06	311.7879	297.1678	96.86625	80.29953
12	1:45	12.07	312.4352	292.4475	104.0538	66.005
12	2:00	12.08	325.8129	288.5853	82.4912	101.7413
12	2:15	12.09	304.4517	322.9152	80.75182	105.2006
12	2:30	12.10	304.8832	288.3708	80.75182	94.59406
12	2:45	12.11	312.8667	285.796	81.62151	101.7413
12	3:00	12.13	324.3025	303.6047	112.9807	95.45888
12	3:15	12.14	316.7506	290.9455	96.86625	79.43471
12	3:30	12.15	322.1448	342.2257	97.73594	114.9423
12	3:45	12.16	313.2982	294.5931	96.86625	87.44679
12	4:00	12.17	302.4064	294.359	80.32321	95.14254
12	5:00	12.21	304.0201	299.3134	88.80904	71.42262
12	10:00	12.42	273.5965	269.0602	80.93079	53.73243
15	10:00	15.42	287.3182	284.1983	70.14951	69.7566
16	10:01	16.42	315.2639	263.5546	89.7427	68.89178
16	20:20	16.85	220.3784	196.8006	51.08942	33.51375
17	10:50	17.45	271.4294	270.559	25.22102	33.09184
18	10:29	18.44	366.4577	330.1133	72.46461	76.61154
18	19:45	18.82	310.8016	285.6207	43.94452	72.28744
19	10:14	19.43	334.3617	318.1369	48.29297	61.45219
22	11:04	22.46	243.486	242.9971	45.04421	44.79191
22	20:00	22.83	248.5449	248.0277	37.85669	60.81608
23	10:32	23.44	244.8403	236.8946	31.10401	45.22432
24	10:32	24.44	303.8304	274.4628	25.10602	33.95666
25	9:05	25.38	336.0596	283.7977	85.10028	65.14018
25	10:05	25.42	330.5286	303.1575	92.2878	89.17643
25	11:05	25.46	313.2721	291.0576	68.11616	50.84565
25	12:15	25.51	318.3606	280.2777	76.17337	57.12809
25	12:30	25.52	315.7057	290.3976	52.87142	42.83356
25	12:45	25.53	311.7235	289.5176	59.6241	65.14018
25	13:00	25.54	304.2014	296.3376	59.18925	57.99291
25	13:15	25.55	308.1837	293.2576	67.24647	57.99291
25	13:30	25.56	310.396	283.3577	60.05894	65.14018
25	13:45	25.57	313.7146	297.2176	82.92605	89.17643

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25	14:00	25.58	328.7587	312.3975	61.79833	59.72255
25	14:15	25.59	348.1022	314.1574	63.23361	78.45553
25	14:30	25.60	335.3959	318.1174	54.6108	
25	14:45	25.61	355.3072	285.1177	87.2745	65.14018
25	15:00	25.63	312.1659	290.6176	75.30368	118.6303
25	15:15	25.64	319.4668	325.3774	52.00173	45.42802
25	15:30	25.65	306.8562	305.3575	43.94452	59.72255
25	15:45	25.66	306.1925	312.1775	43.94452	98.05333
25	16:00	25.67	308.4049	312.8375	29.56947	29.40385
25	17:00	25.71	376.3248	292.1576	80.52182	57.99291
25	18:00	25.75	335.8383	300.2976	61.79833	58.85773
25	19:00	25.79	386.7229	314.1574	120.8079	90.90607
25	20:00	25.83	313.9358	292.1576	90.54842	126.6424
25	21:00	25.88	321.0154	286.2177	68.98585	88.31161
25	22:00	25.92	341.8117	293.0376	101.2147	126.6424
25	23:00	25.96	325.8827	299.1976	107.5325	97.18851
26	0:30	26.02	316.1006	301.7657	106.6628	86.46762
26	0:45	26.03	314.5489	289.2013	76.17337	57.99291
26	1:00	26.04	330.7308	290.3035	93.15749	57.99291
26	1:15	26.05	315.2139	291.626	106.6628	57.99291
26	1:30	26.06	328.9574	300.884	92.2878	82.02916
26	1:45	26.07	317.6523	303.0883	79.76713	97.18851
26	2:00	26.08	331.6175	321.8247	92.2878	99.78297
26	2:15	26.09	334.4992	337.2546	93.15749	93.50053
26	2:30	26.10	330.2875	297.798	100.345	97.18851
26	2:45	26.11	338.7109	300.2227	101.2147	90.04125
26	3:00	26.13	341.8143	315.6527	107.5325	106.0654
26	3:15	26.14	335.8292	306.8356	107.5325	120.3599
26	3:30	26.15	352.2327	319.3999	99.47532	116.672
26	3:45	26.16	342.9226	341.2223	101.2147	108.6599
26	4:00	26.17	346.2477	327.3353	94.02718	122.0896
26	5:00	26.21	350.4594	313.228	94.02718	121.2248
26	6:00	26.25	334.4992	327.7762	85.10028	91.77089
26	7:00	26.29	341.1493	342.9857	62.66802	109.5247
26	8:00	26.33	339.5976	329.5396	103.9388	76.61154
26	9:40	26.40	325.1891	310.8033	68.551	90.04125
26	0:15	27.01	318.9823	299.5614	91.41811	104.3358
29	11:04	29.46	323.7608	297.114	43.94452	41.96874
29	19:03	29.79	297.6727	281.5931	42.20514	56.26327
30	10:15	30.43	305.4078	280.8144	69.10085	68.82817
31	10:20	31.43	296.6082	279.81	31.53885	
32	10:40	32.44	229.0079	235.7547	81.62151	104.3358
32	10:45	32.45	253.4563	225.7178	115.5897	89.17643
34	9:50	34.41	359.6727	347.0712	74.89171	66.38771

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36	10:11	36.42	197.1557	197.7761	77.28579	61.68898
37	10:26	37.43	345.6049	317.6556	50.85231	72.70659
38	10:15	38.43	369.0839	342.4134	76.17337	50.84565
39	8:22	39.35	339.5735	307.1386	81.62151	79.43471
39	9:20	39.39	339.8009	305.5554	74.43399	79.0023
39	10:20	39.43	367.3216	325.4583	76.17337	87.8792
39	11:20	39.47	358.9062	337.2191	82.92605	81.16435
39	12:20	39.51	373.69	343.0996	84.23059	74.01708
39	13:15	39.55	367.7765	332.6957	99.04048	88.31161
39	13:30	39.56	400.9833	355.0866	94.02718	93.61488
39	13:45	39.57	384.3799	350.337	93.15749	97.18851
39	14:00	39.58	341.393	365.7165	104.0538	83.7588
39	14:15	39.59	383.925	343.5519	100.345	74.01708
39	14:30	39.60	418.0415	385.6195	126.256	107.7951
39	14:45	39.61	363.2276	384.4886	94.14218	107.7951
39	15:00	39.63	390.2934	450.304	101.2147	159.3268
39	15:15	39.64	424.6374	481.0631	134.3132	224.2883
39	15:30	39.65	359.5885	378.6082	90.54842	107.7951
39	15:45	39.66	390.9757	365.7165	108.4022	98.91815
39	16:00	39.67	370.5058	388.5597	106.6628	93.50053
39	16:15	39.68	390.5208	378.8344	108.4022	100.6478
39	16:30	39.69	392.5678	367.2997	86.83966	114.5099
39	16:45	39.70	402.8028	372.954	117.3291	114.0775
39	17:00	39.71	392.5678	384.4886	124.5167	108.2275
39	18:00	39.75	382.5603	423.1637	119.1835	184.3423
39	19:00	39.79	402.1205	376.1203	110.1416	130.1017
39	20:00	39.83	425.5472	358.7053	127.1257	136.3841
39	21:00	39.88	377.784	345.8136	107.5325	90.04125
39	22:00	39.92	354.5847	349.6585	112.9807	112.3479
39	23:00	39.96	343.2126	337.8976	104.9235	111.483
39	0:00	40.00	346.8517	326.8153	104.9235	118.6303
40	1:00	40.04	344.8133	320.8994	97.3011	87.44679
40	2:15	40.09	334.5577	322.7124	104.0538	102.6061
40	2:30	40.10	341.1669	320.6728	104.9235	102.6061
40	2:45	40.11	326.3533	318.6332	80.75182	79.43471
40	3:00	40.13	335.0135	320.2195	115.7047	87.44679
40	3:15	40.14	339.7995	317.9533	104.0538	99.03251
40	3:30	40.15	330.2276	332.6839	95.99656	111.483
40	3:45	40.16	332.9624	348.7742	104.0538	128.372
40	4:00	40.17	335.4693	328.8312	126.9209	118.1979
40	4:15	40.18	331.595	331.3241	126.486	118.6303
40	4:30	40.19	333.6461	318.4066	95.99656	102.6061
40	4:45	40.20	337.0646	316.3669	80.75182	86.58197
40	5:00	40.21	338.6599	313.8741	80.75182	90.15561

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40	5:15	40.22	323.6185	307.9819	110.3716	93.72924
40	5:30	40.23	311.5398	319.0864	108.1974	109.7534
40	5:45	40.24	332.2787	315.9137	79.88213	93.72924
40	6:00	40.25	340.939	321.8059	95.99656	86.58197
40	7:00	40.29	357.5757	334.2702	104.9235	102.6061
40	8:00	40.33	346.8644	311.1546	104.0538	100.8765
43	10:22	43.43	454.8943	455.9886	93.91218	90.21738
43	19:55	43.83	411.1016	404.239	110.1416	169.7297
44	10:50	44.45	374.4852	372.3876	77.04306	79.86712
45	11:15	45.47	265.8942	243.573	78.6926	88.10791
45	18:22	45.77	207.2594	145.7547	55.94049	63.63925
46	10:52	46.45	243.828	229.846	36.1173	50.20954
46	18:25	46.77	320.6442	261.5015	65.50709	83.1227
47	8:53	47.37	334.9966	334.2966	85.62804	73.57642
51	10:19	51.43	336.4101	329.0418	82.92605	66.005
51	17:34	51.73	293.4067	315.6327	72.69461	82.89398
52	10:18	52.43	316.6624	283.307	57.88472	55.39845
52	17:17	52.72	372.4753	373.6401	73.4493	76.61154
53	8:30	53.35	351.4805	352.0715	60.92863	83.7588
53	9:30	53.40	373.9453	359.0524	77.91275	76.61154
53	10:30	53.44	362.4789	365.3352	77.04306	69.46427
53	10:45	53.45	372.0732	354.1657	69.85554	99.78297
53	11:00	53.46	371.8392	353.0023	100.345	67.73463
53	11:15	53.47	363.6489	348.581	53.74111	60.15496
53	11:30	53.48	353.3525	349.5118	68.11616	59.72255
53	11:45	53.49	384.2416	341.1347	78.78244	82.02916
53	12:00	53.50	380.4975	343.9271	77.91275	90.04125
53	12:15	53.51	353.3525	333.4557	52.87142	57.99291
53	12:30	53.52	434.5534	331.8268	74.20399	66.005
53	12:45	53.53	362.7129	335.5499	68.11616	66.005
53	13:00	53.54	354.2886	319.9592	60.05894	57.12809
53	13:15	53.55	351.7145	343.229	67.24647	29.40385
53	13:30	53.56	365.521	340.4366	60.92863	73.58467
53	13:45	53.57	359.9048	356.4927	52.87142	67.73463
53	14:00	53.58	365.755	441.66	60.92863	82.66527
53	14:15	53.59	367.627	339.2731	68.98585	36.55112
53	15:00	53.63	382.1356	359.0524	77.04306	71.30827
53	16:00	53.67	389.8578	372.5489	81.50651	64.161
53	17:00	53.71	412.3226	390.0012	76.05837	77.47636
53	18:00	53.75	422.385	360.4486	88.57904	75.74672
53	19:00	53.79	403.4303	376.0393	68.00116	83.7588
53	20:00	53.83	380.4975	369.0584	81.50651	80.18517
53	21:00	53.88	375.8173	360.914	92.2878	95.34452
53	22:00	53.92	362.4789	354.1657	79.33229	90.04125

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53	22:15	53.93	365.989	352.7696	76.17337	71.30827
53	22:30	53.94	368.3291	356.9581	84.23059	89.60884
53	22:45	53.95	363.1809	353.7004	98.60563	98.05333
53	23:00	53.96	365.755	349.9772	91.41811	101.627
53	23:15	53.97	354.9906	348.8137	68.11616	89.60884
53	23:30	53.98	366.691	347.6502	84.23059	85.6028
53	23:45	53.99	367.861	359.2851	99.47532	90.04125
54	0:00	55.00	369.9671	355.3638	98.60563	101.627
54	0:15	54.01	359.9448	347.6689	75.30368	88.74402
54	0:30	54.02	358.7723	330.4137	74.43399	88.31161
54	0:45	54.03	348.4547	353.032	96.86625	89.17643
54	1:00	54.04	353.848	348.3684	74.43399	81.59676
54	1:15	54.05	330.8678	339.2745	84.34559	74.01708
54	1:30	54.06	325.709	354.1979	79.88213	82.02916
54	1:45	54.07	324.0676	361.8928	80.75182	82.89398
54	2:00	54.08	328.7574	335.3104	80.75182	81.16435
54	3:00	54.13	352.2066	353.032	75.30368	74.8819
54	4:00	54.17	367.683	352.5656	60.92863	75.31431
54	5:00	54.21	376.1247	375.1839	92.2878	91.77089
54	6:00	54.25	359.2413	367.2559	68.11616	83.32639
54	7:00	54.29	355.0205	355.8301	71.70992	71.30827

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TABLE (3-7-1)

PHYTO/ZOO COMPINED DATA

Day	Day/Night	Chlorophyll		Zoo Biomass		Zoo counts	
		Away	Reef	Away	Reef	Away	Reef
1	D	164.258695	173.654073	6.33218107	3.990781893		
2	D	223.935286	208.828722	3.664979424	1.865987654		
3	D	261.063743	165.194696	4.016049383	2.699917695	4380	2079
4	D	245.734386	217.053928	2.001358025	1.407407407	1925	1446
5	D	226.564651	224.448667	2.249588477	1.89882716	2387	549
8	D	165.189039	175.677516	2.722912128	3.130329218	5343	3279
9	D	211.714615	201.994986	2.91473643	1.457748296	5425	4390
10	D	231.719252	216.100193	2.731760255	2.367582636	5452	5786
11	D	256.961278	242.13736	1.891072433	1.921037688	6648	5290
12	D	273.596543	269.060243	1.252757202	1.040658436	3064	2007
15	D	287.318185	284.198346	1.558148148	1.221761317	4349	3950
16	D	315.263885	263.554581	1.14462963	1.0818107	5227	2337
17	D	271.429439	270.559002	5.165740741	3.81335578	5988	3904
18	D	366.457732	330.11332	2.590804598	2.993533216	4732	4729
19	D	334.361735	318.136905	3.678506375	2.438470729	4289	4366
22	D	243.486045	242.997136	2.982777778	1.896215341	6172	4685
23	D	244.840293	236.894603	2.63537037	2.27961951	4555	5853
24	D	303.830438	274.462807	2.05563786	1.911353977	2089	2027
25	D	317.354962	292.797616	3.283592593	2.333528546	4167	3525
26	D	325.189058	310.803259	3.124074074	2.230864198	8327	4814
29	D	323.760835	297.114013	2.794814815	2.45041816	7238	6056
30	D	305.40784	280.814405	4.950123457	3.935802469	7813	6073
31	D	296.608231	279.810005	3.723132969	2.608297915	6154	6898
32	D	229.007869	235.754664	2.519547325	2.216288331	5810	5068
34	D	359.672747	347.071231	1.832510288	1.810411523	6275	6010
36	D	197.15567	197.776109	3.028662551	2.29808642	5514	5053
37	D	345.604874	317.655587	4.259958848	2.244814815	9254	5499
38	D	369.08391	342.413433	3.169444444	3.0609319	6336	6959
39	D	363.758305	335.811859	3.478123457	2.765234568	7327	5426
43	D	454.894337	455.988627	4.959259259	4.497354497	8484	6863
44	D	374.48516	372.387637	3.013004115	2.804398148	5085	5591
45	D	265.894233	243.573032	6.613333333	4.330393886	6351	5933
46	D	243.828031	229.846031	9.380082305	3.074074074	8313	3067
47	D	334.996592	334.296612	7.213535354	4.229547325	8602	6573
51	D	336.410138	329.041845	4.963292181	3.861258083	8455	4903
52	D	316.662421	283.307004	5.528757202	4.320234087	8075	6669
53	D	368.315298	351.140677	3.79654321	2.472191232	7731	5137
25	N	330.902365	302.04041	4.533474927	3.250977165	5832	5037
29	N	297.672668	281.593132	6.739444444	3.908641975	6176	4850
32	N	253	226	2.556296296	3.336049383	4971	5433
39	N	358.028085	341.481918	5.01558642	3.213487428	7096	4976
43	N	411.101586	404.239027	7.111111111	7.159082892	11287	5698
46	N	320.644241	261.501472	9.03	6.980452675	9127	8269
53	N	361.363678	353.106111	5.03539169	3.454168096	7492	5032

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'ABLE (3-8-1)

Dail;y averages of currents for entire 53 days

Day	Long away	Long reef	Cross away	Cross reef	Cross difference
1	-5.687875	-2.1656667	1.52191667	1.24929167	0.272625
2	-4.017	-2.1947083	0.70866667	1.57954167	-0.870875
3	0.88495833	-1.5336667	0.38379167	1.445	-1.0612083
4	7.26241667	0.84895833	-0.008875	1.49995833	-1.5088333
5	1.88983333	0.60608333	0.019375	0.93754167	-0.9181667
6	-5.8651667	-2.9631667	1.50041667	1.5035	-0.0030833
7	-3.321	-2.2760417	0.28108333	1.688125	-1.4070417
8	-1.854125	-1.81225	-0.4030417	1.81708333	-2.220125
9	7.06	1.69329167	-0.40425	1.51116667	-1.9154167
10	5.563875	0.97225	-0.3364167	1.56570833	-1.902125
11	6.249625	0.3445	-0.4038333	2.12679167	-2.530625
12	7.13516667	1.52291667	-0.2442083	1.76195833	-2.0061667
13	5.56945833	1.18354167	-0.0048333	1.604625	-1.6094583
14	2.99808333	0.006	-0.2815833	1.36516667	-1.64675
15	2.85704167	0.60804167	0.72075	1.29670833	-0.5759583
16	-0.7285	-0.4675833	0.66754167	0.954875	-0.2873333
17	-3.7953333	-2.4804167	1.48204167	1.56041667	-0.078375
18	0.980375	-1.3255	-0.0405417	1.61933333	-1.659875
19	3.89408333	0.33220833	0.26933333	1.36575	-1.0964167
20	2.86279167	-0.8618333	-0.6805833	1.25458333	-1.9351667
21	4.29758333	1.33508333	0.84804167	1.17308333	-0.3250417
22	0.315625	-0.8520417	-0.024125	1.28641667	-1.3105417
23	0.621125	-1.3961667	-1.327	2.20920833	-3.5362083
24	2.80008333	0.84641667	-0.8329167	1.56729167	-2.4002083
25	3.20491667	0.84595833	0.05	1.24204167	-1.1920417
26	6.6455	2.04283333	-1.218375	2.18016667	-3.3985417
27	3.76625	1.163625	-0.153125	0.986875	-1.14
28	3.193125	0.78229167	-0.63075	1.343125	-1.973875
29	2.48545833	-0.9970417	-1.7786667	2.06308333	-3.84175

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30	2.37775	-0.712	-1.5031667	1.73704167	-3.2402083
31	3.15145833	-0.2068333	-0.4494167	1.21975	-1.6691667
32	0.38016667	-1.4785417	0.27141667	1.08983333	-0.8184167
33	-1.6051667	-2.4715833	-0.1951667	2.08175	-2.2769167
34	4.00975	-0.6482917	-1.2219167	2.50516667	-3.7270833
35	5.68583333	1.257	-1.3325417	2.13108333	-3.463625
36	6.265125	1.24354167	-1.5104583	2.390625	-3.9010833
37	4.06891667	-0.03625	-2.0172083	2.71745833	-4.7346667
38	0.674625	-1.9692083	-1.5755417	2.46333333	-4.038875
39	6.84966667	1.48770833	-1.8730417	1.778625	-3.6516667
40	7.54541667	2.11983333	-1.2769583	1.18154167	-2.4585
41	2.51633333	0.15416667	-0.5995	1.12875	-1.72825
42	-14.321875	-5.3914583	-1.615625	1.87391667	-3.4895417
43	-3.5690417	-2.564625	-1.6222083	1.18695833	-2.8091667
44	8.40795833	1.768125	-3.9305417	2.08691667	-6.0174583
45	-8.3931667	-1.8432917	-1.7180417	2.185125	-3.9031667
46	12.9594583	5.09854167	-2.3005	1.06725	-3.36775
47	1.59083333	-0.64925	-0.7039167	1.25554167	-1.9594583
48	2.65708333	0.36579167	-1.698375	2.16854167	-3.8669167
49	1.52545833	-0.7879167	-1.9977083	2.88304167	-4.88075
50	6.815	2.308125	-3.9525	3.753	-7.7055
51	6.80216667	2.870375	-2.2960417	3.09854167	-5.3945833
52	4.883	0.74845833	-3.12325	3.05158333	-6.1748333
53	6.21633333	2.87079167	-3.241125	2.92133333	-6.1624583
54	6.84283333	2.28179167	-3.0917083	2.71725	-5.8089583

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TABLE (3-9-1)

BOTTOM & ALOFT SAMPLING
DAY TIME

Day	Time	period	Chlorophyll		Phaeopigments	
			Bottom	Aloft	Bottom	Aloft
22	11:01	D	214.4	240.8	27.91	52.17
23	10:34	D	235.6	242.6	45.66	49.45
24	10:37	D	273.3	169.9	49.49	38.74
25	10:09	D	260.3	310.9	72.61	44.57
29	11:09	D	282.9	346.4	71.74	106
30	10:24	D	261.5	289.1	69.14	79.45
31	10:24	D	291.6	297.9	85.23	72.41
32	10:44	D	135.2	134.7	49.27	54.77
34	10:00	D	316.5	379.2	79.46	81.18
36	10:12	D	160.3	192.1	73.4	61.16
37	10:27	D	323.4	323.6	72.61	33.97
38	10:13	D	509	364.1	270.1	67.74
39	12:24	D	294	230	118.3	95.7
40	6:01	D	252	295.1	73.28	68.84
43	10:41	D	375.6	464.9	107.4	118.3
44	10:56	D	298.6	330.2	89.69	57.14
45	11:19	D	234.8	248.4	57.18	58.23
46	11:00	D	235.3	238.8	51.3	51.08
51	10:22	D	275.4	312.6	86.1	84.75
52	10:22	D	296.2	321.7	114.7	74.03
53	8:33	D	160.2	194.5	44.35	54.77
53	16:03	D	250.8	277.4	90.68	95.59

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NOCTURNAL TIME

Day	Time	Diel	Chlorophyll Bottom	Chlorophyll Aloft	Phaeopigment Bottom	Phaeopigment Aloft	Chlorophy diff	Phaeo diff
22	19:46	N	212.4	246	35.05	45	33.23	9.939
26	2:06	N	279.4	319	42.16	106	40.01	63.92
26	18:04	N	320.6	358	145.9	142	37.4	-4.324
29	19:08	N	279.5	252	71.74	44.8	-27.39	-26.95
32	18:48	N	184.4	226	99.59	81.2	41.8	-18.42
39	18:22	N	259.2	265	97.86	67.1	5.657	-30.75
40	1:22	N	294.8	317	139.8	92.4	22.29	-47.39
43	20:01	N	285.6	437	85.23	126	151.1	41.2
46	18:31	N	274.7	354	100.9	91.4	78.87	-9.546
54	0:33	N	319.5	360	87.84	121	40.82	33.4
						avg:	42.38	1.108
						std:	47	35.51

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(2-4-1)

appendix

GLASS BOTTLES VOLUME

Residual water volume (water left after bottle drained) was measure for 5 bottles:

Bottle ID	Tara (g)	Wet Tara (g)	Residual weight(g)	Residual Volume (ml)
2	256.40	256.91	0.51	0.51
3	255.99	256.21	0.22	0.22
4	255.65	256.00	0.35	0.35
5	255.06	255.29	0.23	0.23
6	256.11	256.71	0.60	0.60
Average -	255.84		0.38	0.38
SD	0.51		0.17	0.17

Water temp	Water density (g/ml)
28.0	1.000

Glass bottles volume measurements

Brand new 250 ml brown borosilicate glass bottles with graduated glass stopper were marked with paint marker, weighted (Tara) rinsed once with DDW, filled with DDW (care was taken to assure no air bubbles will be left in the bottle) dried and weighted again (Gross) and the volume (V) of the bottle was determined as V = (net weight/water density) - Residual volume. Where net weight is: Gross-Tara, and Water density was taken from the Handbook of ****, page *** for the respective water temperature (28 centigrade)

Bottle ID	Tara (g)	Gross (g)	Net (g)	Volume (liter)
1	255.35	554.70	299.35	0.299
2	256.40	554.60	298.20	0.298
3	255.99	554.3	298.31	0.298
4	255.65	554.1	298.45	0.298
5	240.39	545.4	305.01	0.305
6	256.11	554.9	298.79	0.298
7	254.57	553.5	298.93	0.299
8	254.54	554.5	299.96	0.300
9	256.32	555.5	299.18	0.299
10	255.9	554.3	298.40	0.298
11	240.89	545.5	304.61	0.304
12	245.01	547.6	302.59	0.302
13	245.93	548.7	302.77	0.302
14	239.96	545.1	305.14	0.305
15	239.57	544.1	304.53	0.304
16	250.15	551.4	301.25	0.301
17	250.14	551.4	301.26	0.301
18	251.97	552.2	300.23	0.300
19	241.5	546.1	304.60	0.304

Bottle ID	Tara (g)	Gross (g)	Net (g)	Volume (liter)
51	255.23	554.9	299.67	0.299
52	255.39	553.9	298.51	0.298
53	255.36	555.2	299.84	0.299
54	255.28	555.1	299.82	0.299
55	255.24	555	299.76	0.299
56	255.83	554.4	298.57	0.298
57	255.55	555.4	299.85	0.299
58	255.11	554.9	299.79	0.299
59	255.76	555.4	299.64	0.299
60	255.82	554.3	298.48	0.298
61	256.01	554.5	298.49	0.298
62	255.45	554.4	298.95	0.299
63	254.69	553.8	299.11	0.299
64	255.2	553.9	298.70	0.298
65	255.6	554.2	298.60	0.298
66	255.17	554.9	299.73	0.299
67	255.15	554.8	299.65	0.299
68	255.09	554.7	299.61	0.299
69	256.03	554.5	298.47	0.298
70	255.43	555.3	299.87	0.299

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20	246.4	549.1	302.70	0.302
21	239.77	544.6	304.83	0.304
22	242.05	546.5	304.45	0.304
23	239.85	545	305.15	0.305
24	238.87	544.3	305.43	0.305
25	244.63	548.3	303.67	0.303
26	256.15	555.8	299.65	0.299
27	239.03	544.3	305.27	0.305
28	238.08	544.3	306.22	0.306
29	241.57	545.9	304.33	0.304
30	243.9	547.8	303.90	0.304
31	240.76	545.6	304.84	0.304
32	240.21	545	304.79	0.304
33	252.57	553.3	300.73	0.300
34	239.7	544.7	305.00	0.305
35	242.67	547.2	304.53	0.304
36	240.98	545.6	304.62	0.304
37	238.85	543.9	305.05	0.305
38	238.73	544.2	305.47	0.305
39	242.73	547.3	304.57	0.304
40	239.34	544.5	305.16	0.305
41	256.29	554.7	298.41	0.298
42	255.6	554.5	298.90	0.299
43	254.98	554.7	299.72	0.299
44	255.17	555.1	299.93	0.300
45	255.34	553.9	298.56	0.298
46	253.99	553.8	299.81	0.299
47	254.58	554.8	300.22	0.300
48	255.72	555.3	299.58	0.299
49	254.68	555.1	300.42	0.300
50	255.56	554.9	299.34	0.299

71	240.41	545.5	305.09	0.305
72	240.07	545	304.93	0.305
73	239.53	544.8	305.27	0.305
74	239.4	544.4	305.00	0.305
75	243.45	547.2	303.75	0.303
76	239.28	544.5	305.22	0.305
77	242.26	546.6	304.34	0.304
78	239.37	544.5	305.13	0.305
79	238.58	544	305.42	0.305
80	249.94	552.2	302.26	0.302
81	251.12	552.2	301.08	0.301
82	251.16	552.8	301.64	0.301
83	247.91	549.8	301.89	0.302
84	237.58	543.1	305.52	0.305
85	238.5	544	305.50	0.305
86	235.78	542.2	306.42	0.306
87	239.84	544.6	304.76	0.304
88	249.32	551	301.68	0.301
89	247.77	551	303.23	0.303
90	235.71	543.1	307.39	0.307
91	242.09	546.4	304.31	0.304
92	237.62	543.3	305.68	0.305
93	237.96	543.6	305.64	0.305
94	242.58	546.5	303.92	0.304
95	237.87	543.6	305.73	0.305
96	237.41	543	305.59	0.305
97	241.18	545.6	304.42	0.304
98	238.37	543.8	305.43	0.305
99	243.13	547.1	303.97	0.304
100	For regular pastic box			0.280
SD			2.720082	0.00272

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APPENDIX (3-1-1)

CHLOROPHYLL & PHAEOPIGMENT CONCENTRATIONS

ROW DATA

Date	Day	Time	Site	Bottle ID	TDBlank	FSU	SolidStd Readings	Solid Back Extrap.	AUblank	1/100	Range	Rb	Ra	TD700 Chl a (ng/liter)	Corrected TD700	AU Chl a (ng/liter)	AU Phae (ng/liter)
10/10/99	1	10:08	O	100		71.68		237.917	0.01	100	3.16	3.40	1.95	143	164	113	56
10/10/99	1	10:10	R	100		75.78		237.917	0.01	100	3.16	3.75	2.00	143	164	113	56
10/10/99	1	20:11	O	100		68.91		237.917	0.01	100	3.16	3.30	1.80	152	174	136	37
10/10/99	1	20:12	R	100		71.92		237.917	0.01	100	3.16	3.50	2.10	138	158	117	39
11/10/99	2	10:55	O	100		97.54		237.474	0.01	100	3.16	4.60	2.50	144	165	109	73
11/10/99	2	10:57	R	100		90.96		237.474	0.01	100	3.16	4.30	2.40	195	224	164	54
12/10/99	3	10:10	O	100		109.4		237.031	0.1	100	3.16	5.30	2.90	182	209	148	53
12/10/99	3	10:11	R	100		107		237.031	0.1	100	3.16	5.30	3.00	219	252	187	58
12/10/99	3	14:20	O	100		113.5		237.031	0.1	100	3.16	5.30	2.80	214	246	179	74
12/10/99	3	14:21	R	100		71.82		237.031	0.1	100	3.16	3.40	1.80	227	261	195	41
13/10/99	4	10:50	O	94	5.4	115.6		236.588	0.1	100	3.16	5.50	2.90	144	166	125	24
13/10/99	4	10:52	R	92	5.4	102.7		236.588	0.1	100	3.16	5.10	2.40	213	246	187	39
13/10/99	4	20:08	O	94	6.05	103		236.588	0.1	100	3.16	4.80	2.40	188	217	193	-9
13/10/99	4	20:10	R	92	6.05	94.2		236.588	0.1	100	3.16	4.50	2.40	190	219	173	13
14/10/99	5	10:10	O	99	6.05	106.4		236.145	0.1	100	3.16	5.20	2.80	173	199	150	34
14/10/99	5	10:12	R	92	6.05	106		236.145	0.1	100	3.16	5.00	2.70	196	227	173	45
17/10/99	8	11:06	O	99	6.7	77.14		234.816	0.1	100	3.16	3.20	1.80	194	226	164	44
17/10/99	8	11:11	R	92	6.7	82.5		234.816	0.1	100	3.16	3.50	1.90	142	165	101	36
17/10/99	8	20:19	O	96	6.7	86.3		234.816	0.1	100	3.16	3.70	2.00	151	176	114	30
17/10/99	8	20:20	R	94	6.7	79.1		234.816	0.1	100	3.16	3.40	1.80	158	184	122	31
18/10/99	9	9:37	O	99		98.68		234.373	0.1	100	3.16	4.20	2.40	146	170	115	22
18/10/99	9	9:39	R	92		94.68		234.373	0.1	100	3.16	4.10	2.30	182	212	129	56
19/10/99	10	10:32	O	99		107.8		233.93	0.1	100	3.16	4.70	2.60	174	202	129	48
19/10/99	10	10:34	R	92		101.1		233.93	0.1	100	3.16	4.40	2.30	199	232	151	50
20/10/99	11	5:54	O	99		124		233.487	0.01	100	3.16	5.30	3.00	185	217	150	33
20/10/99	11	5:55	R	92		124.6		233.487	0.01	100	3.16	5.40	3.05	229	267	165	76
20/10/99	11	6:48	O	99		126.6		233.487	0.01	100	3.16	5.40	3.00	229	267	168	76
20/10/99	11	6:50	R	92		124		233.487	0.01	100	3.16	5.40	3.00	234	273	173	68

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20/10/99	11	7:48	O	99		130.8		233.487	0.01	100	3.16	5.60	3.20	227	266	172	68
20/10/99	11	7:50	R	92		123.4		233.487	0.01	100	3.16	5.40	3.10	241	282	173	85
20/10/99	11	8:48	O	99		125.4		233.487	0.01	100	3.16	5.40	3.10	225	264	164	83
20/10/99	11	8:50	R	92		123.2		233.487	0.01	100	3.16	5.40	3.00	231	270	165	84
20/10/99	11	9:55	O	99		119.3		233.487	0.01	100	3.16	5.20	3.20	226	264	172	68
20/10/99	11	9:57	R	92		124.1		233.487	0.01	100	3.16	5.40	2.90	220	257	144	113
20/10/99	11	10:55	O	99		115		233.487	0.01	100	3.16	4.80	2.80	228	266	179	53
20/10/99	11	10:58	R	92		124.3		233.487	0.01	100	3.16	5.40	2.98	212	248	144	81
20/10/99	11	12:00	O	99		122.3		233.487	0.01	100	3.16	5.20	2.80	228	266	173	65
20/10/99	11	12:01	R	92		112.2		233.487	0.01	100	3.16	4.80	2.70	226	263	173	52
20/10/99	11	12:15	O	99		120.4		233.487	0.01	100	3.16	5.20	2.80	206	240	150	65
20/10/99	11	12:16	R	92		113.8		233.487	0.01	100	3.16	5.00	2.90	222	259	173	52
20/10/99	11	12:30	O	99		120.1		233.487	0.01	100	3.16	5.10	2.80	209	244	150	81
20/10/99	11	12:31	R	92		110.2		233.487	0.01	100	3.16	4.70	2.70	222	259	165	59
20/10/99	11	12:45	O	99		123.6		233.487	0.01	100	3.16	5.30	2.90	202	236	143	73
20/10/99	11	12:46	R	92		111.4		233.487	0.01	100	3.16	4.80	2.80	228	266	173	60
20/10/99	11	13:00	O	99		119.8		233.487	0.01	100	3.16	5.20	2.80	204	239	143	81
20/10/99	11	13:01	R	92		109.9		233.487	0.01	100	3.16	4.80	2.78	221	258	173	52
20/10/99	11	13:15	O	99		118.6		233.487	0.01	100	3.16	5.10	2.80	202	235	144	78
20/10/99	11	13:16	R	92		106.7		233.487	0.01	100	3.16	4.60	2.60	219	255	165	59
20/10/99	11	13:30	O	99		118.3		233.487	0.01	100	3.16	5.10	2.80	196	229	143	65
20/10/99	11	13:31	R	92		108.2		233.487	0.01	100	3.16	4.80	2.70	218	255	165	59
20/10/99	11	13:45	O	99		114.8		233.487	0.01	100	3.16	4.90	2.70	198	232	150	65
20/10/99	11	13:46	R	92		104.6		233.487	0.01	100	3.16	4.60	2.60	212	247	158	59
20/10/99	11	14:00	O	99		114.2		233.487	0.01	100	3.16	4.80	2.70	192	224	143	65
20/10/99	11	14:01	R	92		108.2		233.487	0.01	100	3.16	4.70	2.70	211	246	151	66
20/10/99	11	14:15	O	99		112.8		233.487	0.01	100	3.16	4.80	2.70	198	232	143	73
20/10/99	11	14:16	R	92		111.5		233.487	0.01	100	3.16	4.90	2.80	208	243	151	66
20/10/99	11	14:30	O	99		114.4		233.487	0.01	100	3.16	5.00	2.80	205	239	150	73
20/10/99	11	14:31	R	92		109.5		233.487	0.01	100	3.16	4.80	2.70	211	246	158	67
20/10/99	11	14:45	O	99		129.6		233.487	0.01	100	3.16	5.60	3.10	201	234	150	65
20/10/99	11	14:46	R	92		124.7		233.487	0.1	100	3.16	5.40	3.10	239	279	180	69
20/10/99	11	15:00	O	99		126.1		233.487	0.1	100	3.16	5.40	3.00	229	267	164	76
20/10/99	11	15:01	R	92		118.6		233.487	0.1	100	3.16	5.20	2.80	233	272	173	61
20/10/99	11	15:15	O	99		126.9		233.487	0.1	100	3.16	5.40	3.00	218	254	172	45
20/10/99	11	15:16	R	92		121.9		233.487	0.1	100	3.16	5.40	3.00	234	273	173	61
20/10/99	11	15:30	O	99		113.7		233.487	0.1	100	3.16	5.00	2.80	224	261	172	61
20/10/99	11	15:31	R	92		115.7		233.487	0.1	100	3.16	5.10	2.90	210	245	158	59
20/10/99	11	15:45	O	99		124.9		233.487	0.1	100	3.16	5.50	3.10	212	248	157	67
20/10/99	11	15:46	R	92		117.9		233.487	0.1	100	3.16	5.20	2.90	230	269	173	69
20/10/99	11	16:00	O	99		125.3		233.487	0.1	100	3.16	5.40	3.10	216	252	164	60

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2/12/99	54	2:00	O	99	217.5	140.2		214.438	0.1	100	3.16	6.40	3.60	285	362	222	83
2/12/99	54	2:01	R	92	217.5	143.8		214.438	0.1	100	3.16	6.60	3.70	259	329	201	81
2/12/99	54	3:00	O	99	217.5	150.2		214.438	0.1	100	3.16	6.90	3.80	264	335	207	81
2/12/99	54	3:01	R	92	217.5	151.4		214.438	0.1	100	3.16	6.90	3.80	277	352	223	75
2/12/99	54	4:00	O	99	217.5	156.8		214.438	0.1	100	3.16	7.10	3.80	278	353	222	75
2/12/99	54	4:01	R	92	217.5	151.2		214.438	0.1	100	3.16	7.00	3.85	289	368	237	61
2/12/99	54	5:00	O	99	217.5	160.4		214.438	0.1	100	3.16	7.30	4.10	277	353	225	75
2/12/99	54	5:01	R	92	217.5	160.9		214.438	0.1	100	3.16	7.30	4.10	296	376	230	92
2/12/99	54	6:00	O	99	217.5	153.2		214.438	0.1	100	3.16	7.00	3.80	295	375	229	92
2/12/99	54	6:01	R	92	217.5	157.5		214.438	0.1	100	3.16	7.10	3.95	283	359	230	68
2/12/99	54	7:00	O	99	217.5	151.4		214.438	0.1	100	3.16	6.95	3.80	289	367	225	83
2/12/99	54	7:01	R	92	217.5	152.6		214.438	0.1	100	3.16	6.95	3.80	279	355	226	72
														average:	312		81
														min	135		13
														max	509		270
														stdev	57.80881		26.88829
														cv	0.185541		0.331954
														N	532		530

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phyto_counts

APPENDIX (3-2-1)

Phytoplankton Counts

Date:	Time:	Open sea / Reef:	Analyzed by:	Taxa:	Optical filter kit:	Stain:
19/Oct/99	10:32	OW	Karim	Syn	Red	non
19/Oct/99	10:32	OW	Karim	Euk	Red	non
19/Oct/99	10:34	RW	Karim	Syn	Red	non
19/Oct/99	10:34	RW	Karim	Euk	Red	non
11/Oct/99	9:30	OW	Karim	Syn	Red	non
11/Oct/99	9:30	OW	Karim	Euk	Red	non
11/Oct/99	9:31	RW	Karim	Syn	Red	non
11/Oct/99	9:31	RW	Karim	Euk	Red	non
27/Oct/99	14:30	OW	Karim	Syn	Red	non
27/Oct/99	14:30	OW	Karim	Euk	Red	non
27/Oct/99	14:32	RW	Karim	Syn	Red	non
27/Oct/99	14:32	RW	Karim	Euk	Red	non
2/Nov/99	14:14	OW	Karim	Syn	Red	non
2/Nov/99	14:14	OW	Karim	Euk	Red	non
2/Nov/99	14:15	RW	Karim	Syn	Red	non
2/Nov/99	14:15	RW	Karim	Euk	Red	non
8/Nov/99	10:25	OW	Karim	Syn	Red	non
8/Nov/99	10:25	OW	Karim	Euk	Red	non
8/Nov/99	10:27	RW	Karim	Syn	Red	non
8/Nov/99	10:27	RW	Karim	Euk	Red	non
16/Nov/99	10:16	OW	Karim	Syn	Red	non
16/Nov/99	10:16	OW	Karim	Euk	Red	non
16/Nov/99	10:18	RW	Karim	Syn	Red	non
16/Nov/99	10:18	RW	Karim	Euk	Red	non
23/Nov/99	11:15	OW	Karim	Syn	Red	non
23/Nov/99	11:15	OW	Karim	Euk	Red	non
23/Nov/99	11:16	RW	Karim	Syn	Red	non
23/Nov/99	11:16	OW	Karim	Euk	Red	non
23/Nov/99	18:25	OW	Karim	Syn	Red	non
23/Nov/99	18:25	OW	Karim	Euk	Red	non
23/Nov/99	18:26	RW	Karim	Syn	Red	non
23/Nov/99	18:26	RW	Karim	Euk	Red	non
29/Nov/99	17:36	OW	Karim	Syn	Red	non
29/Nov/99	17:36	OW	Karim	Euk	Red	non
29/Nov/99	17:37	RW	Karim	Syn	Red	non
29/Nov/99	17:37	RW	Karim	Euk	Red	non

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Volume filtered (ml):	ation (12.5* objectiv e size):	Part of filed counted :	No of fields:	Avrege count:	SD of counts:	Average per field	Average Cell No. (#/ml)
100	1250	1	24	10.46	3.44	10.46	12,448
100	1250	1	24	0.58	0.78	0.58	694
100	1250	1	24	8.96	2.20	8.96	10,662
100	1250	1	24	0.58	0.72	0.58	694
50	1250	1	15	6.47	3.11	6.47	15,393
50	1250	1	15	2.33	1.63	2.33	5,554
50	1250	1	15	6.47	1.88	6.47	15,393
50	1250	1	15	1.20	0.94	1.20	2,857
100	1250	1	21	12.05	5.44	12.05	14,339
100	1250	1	21	0.19	0.40	0.19	227
100	1250	1	21	12.05	3.22	12.05	14,339
100	1250	1	21	0.19	0.51	0.19	227
100	1250	1	24	16.42	3.12	16.42	19,539
100	1250	1	24	0.29	0.46	0.29	347
100	1250	1	24	15.67	4.56	15.67	18,647
100	1250	1	24	0.08	0.28	0.08	99
100	1250	1	24	16.79	4.05	16.79	19,986
100	1250	1	24	0.29	0.55	0.29	347
100	1250	1	24	16.46	3.89	16.46	19,589
100	1250	1	24	0.21	0.41	0.21	248
100	1250	1	25	15.92	2.61	15.92	18,948
100	1250	1	25	0.60	1.00	0.60	714
100	1250	1	25	11.60	3.10	11.60	13,807
100	1250	1	25	0.32	0.56	0.32	381
100	1250	1	24	29.88	4.87	29.88	35,558
100	1250	1	24	0.67	0.76	0.67	793
100	1250	1	24	25.04	6.40	25.04	29,805
100	1250	1	24	0.46	0.66	0.46	546
100	1250	1	24	22.46	3.97	22.46	26,730
100	1250	1	24	0.67	0.76	0.67	793
100	1250	1	24	18.88	3.76	18.88	22,465
100	1250	1	24	0.54	0.59	0.54	645
100	1250	1	24	21.17	4.86	21.17	25,193
100	1250	1	24	1.00	0.93	1.00	1,190
100	1250	1	24	19.29	3.91	19.29	22,961
100	1250	1	24	0.33	0.48	0.33	397

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SD (#/ml)	CV (%)	95% Confidence interval	Current Precision (%)	Desired precision (%)	Fields remained to count	Number of fields per filter:
4,093	33%	1,728	14%	10%	22	119021.9
923	133%	390	56%	10%	732	119021.9
2,614	25%	1,104	10%	10%	2	119021.9
854	123%	360	52%	10%	623	119021.9
7,412	48%	4,105	27%	10%	92	119021.9
3,887	70%	2,153	39%	10%	210	119021.9
4,487	29%	2,485	16%	10%	24	119021.9
2,240	78%	1,241	43%	10%	268	119021.9
6,481	45%	2,950	21%	10%	68	119021.9
479	211%	218	96%	10%	1921	119021.9
3,829	27%	1,743	12%	10%	10	119021.9
609	269%	277	122%	10%	3120	119021.9
3,713	19%	1,568	8%	10%	-39	119021.9
553	159%	233	67%	10%	1060	119021.9
5,422	29%	2,290	12%	10%	12	119021.9
336	339%	142	143%	10%	4888	119021.9
4,825	24%	2,037	10%	10%	1	119021.9
655	189%	276	80%	10%	1498	119021.9
4,629	24%	1,955	10%	10%	-48	119021.9
494	199%	208	84%	10%	1673	119021.9
3,110	16%	1,284	7%	10%	-36	119021.9
1,190	167%	491	69%	10%	1158	119021.9
3,685	27%	1,521	11%	10%	5	119021.9
663	174%	274	72%	10%	1265	119021.9
5,792	16%	2,446	7%	10%	-35	119021.9
906	114%	383	48%	10%	534	119021.9
7,613	26%	3,215	11%	10%	4	119021.9
783	144%	331	61%	10%	858	119021.9
4,722	18%	1,994	7%	10%	-37	119021.9
906	114%	383	48%	10%	534	119021.9
4,472	20%	1,888	8%	10%	-41	119021.9
700	109%	296	46%	10%	481	119021.9
5,785	23%	2,443	10%	10%	-47	119021.9
1,110	93%	469	39%	10%	348	119021.9
4,649	20%	1,963	9%	10%	-42	119021.9
573	144%	242	61%	10%	869	119021.9

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APPENDIX (3-8-1)

CURRENT METERS ROW DATA

Date	GMT	Local sampling	Day	Away Speed	Away Long	Away Cross	Away Prog-L	Away Prog-C	Away Temp	Reef Speed	Reef Long	Reef Cross	Reef Prog-L	Reef Prog-C	Reef Temp
10/10/99	1	2	1	3.22	3.071	0.54	0.110556	0.01944	25.87	3.82	1.127	3.597	0.040572	0.129492	25.89
10/10/99	2	3	1	10.43	10.322	0.801	0.482148	0.048276	25.85	5.58	4.783	2.434	0.21276	0.217116	25.88
10/10/99	3	4	1	20.15	20.061	0.899	1.204344	0.08064	25.82	8	7.864	1.056	0.495864	0.255132	25.87
10/10/99	4	5	1	8.82	7.992	-0.388	1.492056	0.066672	25.78	5.23	-1.145	1.753	0.454644	0.31824	25.82
10/10/99	5	6	1	12.97	-12.894	0.664	1.027872	0.090576	25.76	10.62	-10.586	-0.166	0.073548	0.312264	25.84
10/10/99	6	7	1	30.42	-30.222	3.342	-0.06012	0.210888	25.8	18.63	-18.584	-0.349	-0.595476	0.2997	25.89
10/10/99	7	8	1	27.65	-27.57	1.91	-1.05264	0.279648	25.79	9.42	-5.598	4.169	-0.797004	0.449784	25.88
10/10/99	8	9	1	9.8	-9.71	1.026	-1.4022	0.316584	25.84	4.67	-1.549	3.169	-0.852768	0.563868	25.95
10/10/99	9	10	1	2.7	-2.17	0.869	-1.48032	0.347868	25.86	0.95	0.751	-0.538	-0.825732	0.5445	25.99
10/10/99	10	11	1	5.32	-5.222	0.467	-1.668312	0.36468	25.94	1.45	-0.915	0.577	-0.858672	0.565272	26.09
10/10/99	11	12	1	5.45	-4.937	1.596	-1.846044	0.422136	25.99	1.75	-1.378	-0.194	-0.90828	0.558288	26.17
10/10/99	12	13	1	10.42	-9.83	0.733	-2.199924	0.448524	26.07	5.53	-5.106	1.168	-1.092096	0.600336	26.23
10/10/99	13	14	1	10.48	-10.378	1.255	-2.573532	0.493704	26.16	3.4	-3.37	0.034	-1.213416	0.60156	26.31
10/10/99	14	15	1	8.8	-8.564	1.136	-2.881836	0.5346	26.14	2.17	-1.868	0.352	-1.280664	0.614232	26.24
10/10/99	15	16	1	2.98	-1.324	0.769	-2.9295	0.562284	26.12	2.42	2.078	0.369	-1.205856	0.627516	26.21
10/10/99	16	17	1	4.3	4.172	0.513	-2.779308	0.580752	26.09	2.4	1.631	0.078	-1.14714	0.630324	26.15
10/10/99	17	18	1	5.23	-4.975	-0.85	-2.958408	0.550152	26.05	4.18	-4.046	0.748	-1.292796	0.657252	26.11
10/10/99	18	19	1	19.38	-18.867	4.233	-3.63762	0.70254	26.02	9.02	-8.984	-0.295	-1.61622	0.646632	26.07
10/10/99	19	20	1	28.75	-28.287	5.085	-4.655952	0.8856	25.95	11.43	-11.41	-0.06	-2.02698	0.644472	26.04
10/10/99	20	21	1	19.33	-18.997	3.366	-5.339844	1.006776	25.9	8.48	-4.759	2.389	-2.198304	0.730476	25.96
10/10/99	21	22	1	6.02	-5.234	2.31	-5.528268	1.089936	25.82	2.6	2.321	0.457	-2.114748	0.746928	25.92
10/10/99	22	23	1	6.1	5.084	3.252	-5.345244	1.207008	25.81	5.13	3.422	3.792	-1.991556	0.88344	25.88

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10/10/99	23	0	1	7.62	7.192	2.474	-5.086332	1.296072	25.81	3.27	2.053	2.414	-1.917648	0.970344	25.87
10/10/99	24	1	1	4.85	4.778	0.524	-4.914324	1.314936	25.78	3.32	1.292	3.029	-1.871136	1.079388	25.81
10/11/99	1	2	2	5.57	5.523	-0.558	-4.715496	1.294848	25.79	3.35	1.679	2.875	-1.810692	1.182888	25.79
10/11/99	2	3	2	7.92	7.678	0.386	-4.439088	1.308744	25.78	4.22	2.427	3.297	-1.72332	1.30158	25.79
10/11/99	3	4	2	11.9	11.825	-1.193	-4.013388	1.265796	25.79	5.32	4.378	2.767	-1.565712	1.401192	25.79
10/11/99	4	5	2	20.93	20.915	0.417	-3.260448	1.280808	25.81	8.98	8.862	1.402	-1.24668	1.451664	25.84
10/11/99	5	6	2	17.83	17.802	-0.717	-2.619576	1.254996	25.79	5.32	1.907	3.146	-1.178028	1.56492	25.82
10/11/99	6	7	2	3.77	1.265	-2.712	-2.574036	1.157364	25.83	8.2	-7.451	1.831	-1.446264	1.630836	25.82
10/11/99	7	8	2	20	-19.84	0.321	-3.288276	1.16892	25.78	13.52	-13.474	0.636	-1.931328	1.653732	25.87
10/11/99	8	9	2	25.75	-25.675	1.59	-4.212576	1.22616	25.79	14.4	-14.337	0.93	-2.44746	1.687212	25.89
10/11/99	9	10	2	10.93	-10.796	0.523	-4.601232	1.244988	25.81	5	-2.911	2.905	-2.552256	1.791792	25.99
10/11/99	10	11	2	8.3	-8.152	-1.111	-4.894704	1.204992	25.85	0.92	-0.098	0.137	-2.555784	1.796724	26.07
10/11/99	11	12	2	8.18	-8.041	-1.243	-5.18418	1.160244	25.87	2.15	-2.044	-0.354	-2.629368	1.78398	26.1
10/11/99	12	13	2	9.3	-9.178	-0.84	-5.514588	1.130004	25.92	3.48	-3.398	-0.091	-2.751696	1.780704	26.15
10/11/99	13	14	2	15.27	-14.868	2.645	-6.049836	1.225224	25.98	4.07	-3.988	0.755	-2.895264	1.807884	26.13
10/11/99	14	15	2	13.28	-12.686	3.676	-6.506532	1.35756	25.99	2.78	-2.611	0.866	-2.98926	1.83906	26.13
10/11/99	15	16	2	5.88	-5.581	1.121	-6.707448	1.397916	25.96	0.43	-0.308	0.041	-3.000348	1.840536	26.09
10/11/99	16	17	2	2.42	-0.383	1.451	-6.721236	1.450152	25.94	0.75	0.62	0.337	-2.978028	1.852668	26
10/11/99	17	18	2	12.13	11.789	2.781	-6.296832	1.550268	25.94	5.18	4.943	1.404	-2.80008	1.903212	25.96
10/11/99	18	19	2	9.23	8.562	2.903	-5.9886	1.654776	25.93	4.85	0.034	3.226	-2.798856	2.019348	25.92
10/11/99	19	20	2	6.85	-6.068	0.92	-6.207048	1.687896	25.91	7.88	-7.337	1.157	-3.062988	2.061	25.94
10/11/99	20	21	2	24.85	-24.669	2.564	-7.095132	1.7802	25.86	13.62	-13.574	0.111	-3.551652	2.064996	25.93
10/11/99	21	22	2	28.32	-28.052	3.744	-8.105004	1.914984	25.84	12.28	-10.898	2.92	-3.94398	2.170116	25.87
10/11/99	22	23	2	9.48	-9.364	1.084	-8.442108	1.954008	25.84	5.6	3.576	2.643	-3.815244	2.265264	25.87
10/11/99	23	0	2	1.83	0.591	0.063	-8.420832	1.956276	25.82	1.83	0.321	1.678	-3.803688	2.325672	25.89
10/11/99	24	1	2	1.57	0.995	-0.807	-8.385012	1.927224	25.82	3.55	1.009	3.29	-3.767364	2.444112	25.81
10/12/99	1	2	3	2.28	-0.047	-0.712	-8.386704	1.901592	25.8	2.7	-0.996	2.301	-3.80322	2.526948	25.83
10/12/99	2	3	3	2.97	0.481	-1.435	-8.369388	1.849932	25.8	3.17	-0.35	2.707	-3.81582	2.6244	25.85
10/12/99	3	4	3	12.75	12.668	-0.201	-7.91334	1.842696	25.79	6.58	5.852	2.547	-3.605148	2.716092	25.81
10/12/99	4	5	3	24.98	24.925	0.686	-7.01604	1.867392	25.78	10.42	10.401	0.127	-3.230712	2.720664	25.82

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12/1/99	5	6	53	10.25	9.225	-4.398	102.7075	-33.71137	23.99	7.45	6.811	2.933	-4.666176	78.93274	24.01
12/1/99	6	7	53	9.45	8.272	-4.403	103.0053	-33.86988	24	5.83	4.914	2.817	-4.489272	79.03415	23.99
12/1/99	7	8	53	9.02	7.699	-4.618	103.2824	-34.03613	23.98	5.95	4.117	4.196	-4.34106	79.1852	23.97
12/1/99	8	9	53	9.2	7.885	-4.662	103.5663	-34.20396	23.98	6.48	5.272	3.655	-4.151268	79.31678	24.03
12/1/99	9	10	53	12.02	10.777	-5.239	103.9542	-34.39256	24	6.52	6.162	1.77	-3.929436	79.3805	24.1
12/1/99	10	11	53	16.35	15.662	-4.667	104.5181	-34.56058	24.02	8.13	8.053	0.971	-3.639528	79.41546	24.13
12/1/99	11	12	53	18.57	17.739	-5.474	105.1567	-34.75764	24.05	6.87	6.752	-0.104	-3.396456	79.41172	24.2
12/1/99	12	13	53	11.1	10.78	-2.563	105.5448	-34.84991	24.06	4.53	4.154	0.935	-3.246912	79.44538	24.26
12/1/99	13	14	53	2.82	2.043	-1.782	105.6183	-34.91406	24.11	3.23	0.038	2.348	-3.245544	79.5299	24.31
12/1/99	14	15	53	1.45	-0.855	-0.901	105.5875	-34.9465	24.06	5.07	-4.381	2.193	-3.40326	79.60885	24.17
12/1/99	15	16	53	2.2	-1.972	-0.468	105.5165	-34.96334	24.01	6.73	-5.969	2.781	-3.618144	79.70897	24.05
12/1/99	16	17	53	1.75	-0.739	-0.808	105.4899	-34.99243	23.96	6.38	-2.21	5.927	-3.697704	79.92234	23.85
12/1/99	17	18	53	5.08	4.305	-2.68	105.6449	-35.08891	23.96	4.93	2.779	3.969	-3.59766	80.06522	23.91
12/1/99	18	19	53	7.28	6.287	-3.508	105.8712	-35.2152	23.92	6.23	4.235	4.5	-3.4452	80.22722	23.91
12/1/99	19	20	53	6.33	4.903	-3.891	106.0478	-35.35528	23.9	5.28	3.478	3.949	-3.319992	80.36939	23.89
12/1/99	20	21	53	7.22	6.197	-3.607	106.2708	-35.48513	23.89	5.6	3.522	4.299	-3.1932	80.52415	23.89
12/1/99	21	22	53	8.43	7.453	-3.828	106.5392	-35.62294	23.89	6.08	4.722	3.701	-3.023208	80.65739	23.89
12/1/99	22	23	53	8.75	7.699	-4.107	106.8163	-35.77079	23.89	5.73	3.922	4.107	-2.882016	80.80524	23.87
12/1/99	23	0	53	12.12	11.321	-4.285	107.2239	-35.92505	23.88	7.58	6.556	3.579	-2.646	80.93408	23.86
12/1/99	24	1	53	16.75	15.834	-5.366	107.7939	-36.11822	23.88	9.75	9.687	0.994	-2.297268	80.96987	23.89
12/2/99	1	2	54	23.15	22.42	-5.665	108.601	-36.32216	23.89	12.35	12.125	2.305	-1.860768	81.05285	23.89
12/2/99	2	3	54	19.83	19.239	-4.686	109.2936	-36.49086	23.87	9.75	9.045	3.145	-1.535148	81.16607	23.87
12/2/99	3	4	54	12.05	10.804	-5.001	109.6826	-36.6709	23.87	7.25	5.743	2.803	-1.3284	81.26698	23.78
12/2/99	4	5	54	3.65	2.131	-2.62	109.7593	-36.76522	23.86	3.53	-0.581	2.334	-1.349316	81.351	23.87
12/2/99	5	6	54	1.77	-0.059	-1.179	109.7572	-36.80766	23.87	3.72	-3.202	1.266	-1.464588	81.39658	23.89
12/2/99	6	7	54	3.75	2.014	-2.988	109.8297	-36.91523	23.86	1.6	-0.251	0.588	-1.473624	81.41774	23.9
12/2/99	7	8	54	6.47	5.144	-3.865	110.0148	-37.05437	23.86	4.73	2.498	3.859	-1.383696	81.55667	23.89
12/2/99	8	9	54	8.23	6.511	-4.988	110.2492	-37.23394	23.88	4.37	2.686	3.425	-1.287	81.67997	23.91
12/2/99	9	10	54	7.52	6.506	-3.637	110.4835	-37.36487	23.89	4.63	2.957	3.561	-1.180548	81.80816	23.95
12/2/99	10	11	54	6.95	6.099	-3.256	110.703	-37.48208	23.89	2.77	1.791	2.1	-1.116072	81.88376	24.05

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12/2/99	11	12	54	7.9	7.148	-3.236	110.9604	-37.59858	23.92	4.6	3.875	2.1	-0.976572	81.95936	24.11
12/2/99	12	13	54	11.68	11.007	-3.869	111.3566	-37.73786	23.91	5.78	5.673	0.753	-0.772344	81.98647	24.13
12/2/99	13	14	54	16.62	15.973	-4.121	111.9316	-37.88622	23.9	7.22	7.084	1.081	-0.51732	82.02539	24.09
12/2/99	14	15	54	16.47	16.044	-3.44	112.5092	-38.01006	23.89	7.58	7.253	1.969	-0.256212	82.09627	23.99
12/2/99	15	16	54	12.58	11.689	-4.29	112.93	-38.1645	23.88	6.22	4.412	4.127	-0.09738	82.24484	23.86
12/2/99	16	17	54	6.48	5.329	-0.361	113.1219	-38.1775	23.86	2.48	0.614	1.984	-0.075276	82.31627	23.86
12/2/99	17	18	54	3.57	-0.284	-1.038	113.1116	-38.21486	23.81	8.22	-6.168	3.888	-0.297324	82.45624	23.82
12/2/99	18	19	54	4.53	-4.184	-1.122	112.961	-38.25526	23.81	5.83	-5.362	1.651	-0.490356	82.51567	23.87
12/2/99	19	20	54	6.27	-6.234	-0.409	112.7366	-38.26998	23.79	6.57	-5.975	2.237	-0.705456	82.5962	23.83
12/2/99	20	21	54	2.88	-1.496	0.072	112.6827	-38.26739	23.77	5.55	-2.068	4.753	-0.779904	82.76731	23.7
12/2/99	21	22	54	5.48	4.935	-1.975	112.8604	-38.33849	23.75	4.67	0.84	4.101	-0.749664	82.91495	23.73
12/2/99	22	23	54	10.32	9.031	-4.839	113.1855	-38.51269	23.78	5.75	4.076	4.028	-0.602928	83.05996	23.73
12/2/99	23	0	54	8.92	7.659	-4.429	113.4612	-38.67214	23.74	5.88	4.1	4.174	-0.455328	83.21022	23.74
12/2/99	24	1	54	7.63	6.802	-3.259	113.7061	-38.78946	23.74	4.93	3.598	2.982	-0.3258	83.31757	23.73

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APPENDIX (3-5-1)

CHLOROPHYLL COCENTRAYIONS
Day vs Night

DAYS	Open DayTime	Reef DayTime	Open DayTime	Reef DayTime	Open Nocturnal	Reef Nocturnal	Open Nocturnal	Reef Nocturnal	Difference: Night minus Day			
	Chlorophyll		Phaeopigments		Chlorophyll		Phaeopigments		Chlorophyll		Phaeopigments	
									Away	Reef	Away	Reef
1	164.2586953	173.6541	56.479139	37.4680647	157.9110866	164.80867	39.478664	73.479614	-6.34761	-8.8454	-17.0004749	36.01155
4	245.7343855	217.0539	38.732755	-8.698222	218.9501878	199.08939	12.817465	34.18537	-26.7842	-17.9645	-25.9152896	42.88359
8	165.1890388	175.6775	36.347305	29.8612747	183.8235189	169.41412	30.735154	21.975878	18.63448	-6.26339	-5.61215095	-7.8854
11	256.925385	265.7657	113.27465	52.8676072	310.1194924	257.19956	88.809038	83.987515	53.19411	-8.56618	-24.4656105	31.11991
16	315.2638853	263.5546	89.742697	68.8917761	220.3784344	196.80056	51.089419	33.513753	-94.8855	-66.754	-38.6532779	-35.378
18	366.4577317	330.1133	72.46461	76.6115375	310.8015544	285.62073	43.944517	72.287442	-55.6562	-44.4926	-28.5200924	-4.3241
22	243.4860452	242.9971	45.044208	44.791912	248.5449242	248.02768	37.856685	60.816081	5.058879	5.030544	-7.18752329	16.02417
25	330.5286426	303.1575	92.287799	89.17643	313.9358393	292.15762	90.548418	126.6424	-16.5928	-10.9999	-1.73938064	37.46597
29	323.7608349	297.114	43.944517	41.9687422	297.6726685	281.59313	42.205137	56.263273	-26.0882	-15.5209	-1.73938064	14.29453
39	367.3215895	325.4583	76.173372	87.8792013	425.5471789	358.70527	127.12572	136.38412	58.22559	33.24696	50.9523526	48.50492
43	454.8943367	455.9886	93.912179	90.2173798	411.1015856	404.23903	110.14161	169.72968	-43.7928	-51.7496	16.2294276	79.5123
46	243.8280311	229.846	36.117305	50.2095392	320.6442415	261.50147	65.507087	83.122696	76.81621	31.65544	29.3897827	32.91316
51	336.4101377	329.0418	82.92605	66.0049957	293.4066713	315.63271	72.694611	82.893984	-43.0035	-13.4091	-10.2314394	16.88899
52	316.6624211	283.307	57.884719	55.3984539	372.4753405	373.64014	73.449301	76.611537	55.81292	90.33313	15.5645817	21.21308
53	362.4788562	365.3352	77.043062	69.4642721	380.4974953	369.05839	81.506514	80.18517	18.01864	3.723162	4.46345197	10.7209
								avg:	-1.82599	-5.37176	-2.96433491	22.66437
								std:	48.89106	37.83689	23.7760553	26.99847

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REFERENCES

1- ARAR, J. E. AND COLLINS, C. B. 1992.
(EPA Methods 445.0- Invitro determination of chlorophyll a and Pheophytin a in marine and fresh water phytoplankton by fluorescence)

2- Astheimer, H., and Haardt, H. 1984 . (Small- scale patchiness of the chlorophyll fluorescence in the sea) ; aspects of instrumentation, data processing and inter precaution .
Mar . Ecol , Prog, Der . Vol. **15**: 233- 245 , 1984 .

3- AYUKAI , T . 1995 . (Retention of phytoplankton & planktonic micropes on coral reefs within the Great Barrier Reef, Australia .(Coral Reefs) **14** : 141- 147 .

4- AYUKAI , T . 1991 .(Standing stock of microzooplankton on coral reefs ; A preliminary study) . J . Plankton Res
13: 895 – 899 .

5- Dussart , 1965, 1966. In kimor . B. 1996. Lectures in Marine Plankton ,Red sea Programm, (R S P) . I.U.I, Eilat.

6- EPPLEY , R, W. 1980 .
(Estimating phytoplankton growth rates in the central oligotropicoceans) .
Book – haven Sump Boil . **31** : 231- 242, plenum .

7- FABRICIUS , K,E ,BENAYAHU ,AND A, GENIN . 1995
(Herbivory in asymbiotic soft corals) . Science **268** : 90-92

8- Genin, A. Paldor , N . 1998 . Changes in the circulation and current spectrum near the tip of the narrow seasonally mixed Gulf of Eilat Isr . J. Earth sci ; **47**: 87: 92

All Rights Reserved - Library of University of Jordan - Center of Thesis Deposit

9- Genin , A. et al. 1995 .
(Atmospheric cooling , unusual vertical minxing and coral mortality following the eruption of Mt . pinatubo .
Nature 377: 507- 510.

10- GLESKES , W. W. C., AND G. W. KRAAY 1986, (Floristic and physiological differences between shallow and the deep nanoplankton commurnity in the euphotic zone of the open tropical Atlantic revealed by HPLC analysis of pigments
Mar. Biol **91** : 567- 576.

11- GLYNN, P.W.1973 . Ecology of a Caribian Reef .The Porities Reef flat biotope II . Plankton community with evidence for depletion . MAR .BIO ,**22** : 1-21

12- Henrich , A. K. 1962.
(The life history of plankton) . J.Plankton Res. **41** : 711- 729

13- KESSER , M.P .S.E .SHUMWAY, T. CUCCI, AND J.SMITH,1992.
Impact of fouling organisms on mussel rope culture : Interspecific Competition for food among suspension-feeding invertebrates. MAR . BIO, Ecol. **165** : 91-102 .

14- Kimor, B. 1996 (Lectures in Marine Plankton) . Red Sea Program ,(RSP) , (I. U. I). Eilat

15- KIMOR, B., AND B, GoLANDSKY. 1977, (Micro plankton of the Gulf of Elat) . Mar. Biol **42** : 55- 67.

16- KLUMP, D. W. B. L ,AND A. J . S . HAWKING . 1992.
Nutrition of the giant clam . MAR . BIO. Ecol. **155**: 105-122

17- LALLI, C. M. And , Parsons, T. R. 1993 .
(Biological Oceanography An Introduction) .
Pergamon press ltd.

18- Letelier, R.M., etal ., 1993 .
(Tempaorat variability of phytoplankton community structure based on pigment analysis) . Limnol Oceanogr .
38(7) . 1993 . 1420 – 1437 .

All Rights Reserved - Library of University of Jordan - Center of Thesis Deposit

19- Lindell, D. Post, A.1995. (Ultraphytoplankton succession is triggered by deep winter mixing in Gulf of Aqaba)(Eilat), Red sea .
Limnol Oceanogr .40 (6). 1995 .1130 - 1141.

20- LENIHAN , H. S. et al , 1996 .
(Does flow speed also have a direct effect on growth of active suspension – feeders) : An experimental test on oysters. Limnol. Oceanogr . **41** : 1359- 1366.

21- L I , W. K. W. , AND OTHERS . 1983 .
(Autotrophic pico plankton in the tropical Ocean) .
Science **219** : 292- 295 .

22- LORENSEN , C. J., 1966 (A method for continuous measurement of in – vivo chlorophyll concentration).
Deep- Sea Res **13** : 223- 227.

23- MACKAS, D.L., and Boyd, C.M. 1979. (Spectral analysis of zooplankton spatial heterogereity) .
Scince . **204** : 62 - 64 .

24- Morcos , S. A. 1970 .
(Physical and Chemical oceanography of the Red sea .
Oceonogr. Mar. Bio . Annu. Rev. **8** : 73- 202.

25- Parsons, T.R. et al. 1985. (A manual of chmical and biological methods for sea water analysis) . Pergamon .

26- Post, A. 1996 . (Lectures in the Red sea picophy to plankton) (RSP) , (I.U.I). Eihat .

27- PETERSEN, J.K AND H.U RISGUARD.1992 .
Filteration capacity of the ascidian and its grazing impact in Shallow fjord . MAR .Ecol .Prog. Ser ,**88** : 9-17.

27- PILE , A.J . 1997 .Finding Reiswig missing carbon ; Quantification of sponges feeding using dual-beam flow cytometry . Prc. 8th .Int.Coral Reef Symp **2** : 1403 –1410 .

All Rights Reserved - Library of University of Jordan - Center of Thesis Deposit

28- Reiss, Z . Hottinger , L – (1984) .
(The Gulf of Agaba , ecological micro paleontology)
Spriger, Berlin 354pp .

29- REISWIG , H. M. 1974 . Water transport , respiration and energetics of three tropical marine sponges .
J . Exp .Mar . Bio . Ecol . **14** : 231- 249 .

30- Smith , R. C. et al , 1981.
(Fluorometric Techniques for the measurement of Oceanic chlorophyll in the support of remote sensing) – Visibility Laboratory . La Jolla, California 92093 SIO REF . 81- 17 .

31- STEELE, J. H. 1978 – (Some comments on plankton patches in Steele , J, H, (ed) . (spatial pattern in plankton community) plenum Press, New york, pp, 1 - 20 .

32- STEELE, J, H, and Hinderson , E.W. 1979, (Spatial patterns in North sea plankton) . Deep-sea Res., **26A** , 955 – 963.

33- Steel, J. H., and Henderson , E, W. 1992 . (A Simple model for plankton patchiness) . Journal of plankton Research . Vol . **14**, No. 10pp. 1397- 1403 , 1992.

34- Strickland , J. D. H., Parson , T. R. 1968, (A practical hand book of sea water analysis) . Fisheries Res. Ottawa , Canada .

35- SOURNIA, A . 1969 .
(Cycle annuel du phytoplancton . et delaproduction primaire dans les mers tropicales) . Mar. Bio **3** : 287- 303 .

36- Sumich , J.L., 1996 . An Introduction to the Biology of Marine life.(6th edition). U.S.A. Times Merror co .

37- TD- 700 Operation Manual , 03\ 08\ 95. Ver. 1.2 , Turner design part No ; 7000- 998.

38- VENRICK, E. L., et al. 1977.
(Possible consequences of containing microplankton for physiological rates measurements) . J. EXP. Mar, Biol. Ecol. **26** : 55-76.

All Rights Reserved - Library of University of Jordan - Center of Thesis Deposit

39- WELSCHMEYER, N. A., 1994.
(Fluorometric analysis of chlorophyll (a) in the presence of chlorophyll (b) and pheopigments . Limnol. Oceanger , 39 : 1985- 1992

40- WelshMeyer , N. A and Lorenzen , C, J. 1985 .
(Chlorophyll budgets : zoo plankton grazing and phytoplankton growth in a temperate fjord and the central pacific Gyres) . Limnology and Oceanography.
Vol 30 . Noil.

41- Wolf – Vecht, A, Paldor, N.,Brenner, S. 1992 .
(Hydrographic indication of a deviation convection in the Gulf of Eilat , Deep- Sea Res **39** : 1393- 1401.

42- Yahel , G. et al . 1998 (phyto plankton diztribution and grazing near coral reefs . Limnol Oceonogr .
43(4) . 1998. 551-563.

All Rights Reserved - Library of University of Jordan - Center of Thesis Deposit