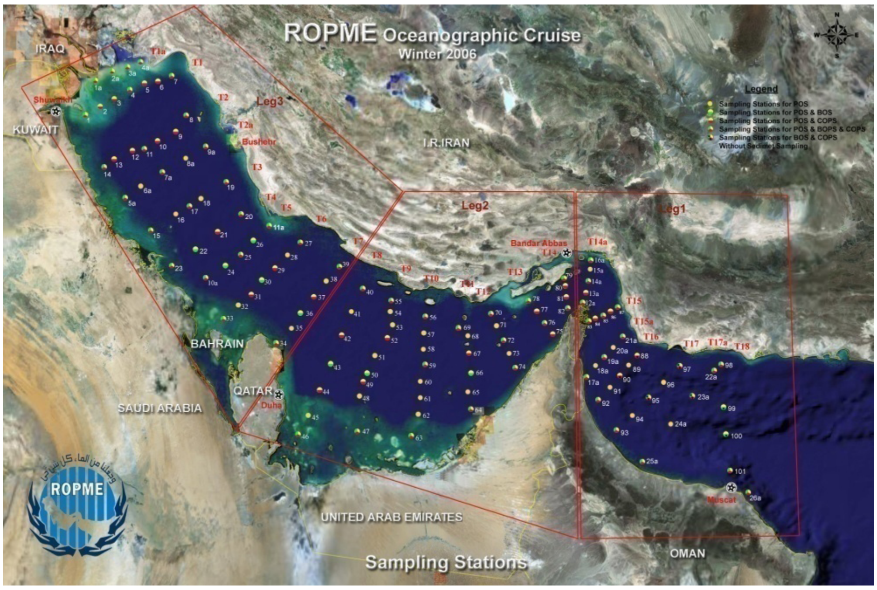
ROPME/GC-14/7
Dist.: RESTRICTED

Regional Organization for the Protection of the Marine Environment

ROPME Oceanographic Cruise - Winter 2006



Technical Report Series

Technical Report: No. 3

Nutrient Salts Distribution in ROPME Sea Area

2017

ROPME Oceanographic Cruise - Winter 2006

Technical Report Series:

1. Physical Oceanography
2. Contaminants in Marine Sediments
3. Nutrients
4. Chlorophyll-*a*
5. Phytoplankton
6. Zooplankton
7. Decapod Larvae
8. Ichthyoplankton
9. Tintinnids
10. Meiobenthos
11. Macrobenthos
12. Phytoplankton Cysts
13. Foraminifera

Disclaimer

This Report has been prepared by Marine Science Centre – University of Basrah, as the Principal Investigator on 'Nutrients' under a contract with ROPME. The Report is being separately subjected to peer review and linking with other relevant data and information, in order to develop an integrated understanding of the ROPME Sea Area. Meanwhile, in order to bestow the benefit of viewing the results in their preliminary form and promote a general level of understanding of the marine environment of the Region, notwithstanding the possible delay by peer review, this document is being brought out as part of a special Technical Report Series in the very form in which it was submitted by the Principal Investigator. Owing to this reason, ROPME shall not accept responsibility on the accuracy of data or interpretations contained in this Report. ROPME does not also subscribe to the inappropriate terms used to denote parts or full of the ROPME Sea Area inadvertently used by the Principal Investigator or provided in the published references and citations.

Copyright

Preface

In recognition of the importance of the Oceanographic Cruises in the ROPME Sea Area to understand the state of the marine environment, ROPME Council has assigned high priority to the scientific Cruises conducted in 2001 and 2006. In pursuance of the Council Decision CM12/7, ROPME had the responsibility to coordinate a comprehensive oceanographic Cruise in Winter 2006. The Cruise was planned in such a way that the results and reports of the studies can find their way into the synthesis of ROPME State of the Marine Environment Report, along with results of the oceanographic Cruise in Summer 2001.

As a result of sustained efforts, cooperation of Member States, guidance of the designated scientific committee for the Cruise, encouragements from the Executive Committee of ROPME and the generous provision made by the Council, the 2006 Winter Cruise was carried out successfully on board the research vessel M/V Ghods of I. R. Iran between February 1st and March 11th, 2006 (three legs). The Summer 2001 Cruise was conducted between August 6thand August 27th, 2001 (two legs) aboard the Al Quds research vessel.

In 2006, 115 stations covering the ROPME Sea Area were surveyed and 97 experts from ROPME Member States participated in the Cruise. The survey covered most of the main oceanographic disciplines. In 2001, 76 stations were surveyed with a comprehensive survey team covering several disciplines. The samples collected during the Cruises were distributed on a competitive basis to the competent laboratories in the Region and elsewhere for detailed analyses while sub-sample sets were kept in the ROPME Marine Sample Bank to enable repetitive analyses in future, when required.

To enhance the benefits of a better understanding of the ROPME Sea Area marine environment among the regional scientific community and to enable higher marine research, the ROPME Secretariat decided on the publication of the results in a series of Technical Reports as follows:

1. Physical Oceanography
2. Contaminants in Marine Sediments
3. Nutrients
4. Chlorophyll-*a*
5. Phytoplankton
6. Zooplankton
7. Decapod Larvae
8. Ichthyoplankton
9. Tintinnids
10. Meiobenthos
11. Macrobenthos
12. Phytoplankton Cysts
13. Foraminifera

The present Technical Report is devoted to the spatial distribution of nutrient salts in the ROPME Sea Area. The Report has been prepared by Dr. Ali Douabul and Dr.Sama Al Maarofi at the Marine Science Centre (MSC) - University of Basrah, under a contract with ROPME.

Table of contents

List of Tables

List of Figures

Figures from report text:

Figures from Appendix 4:

Executive Summary

The Regional Organization for the Protection of the Marine Environment (ROPME) plays a major role in the protection of the marine environment and prevention of its degradation, and provides technical co-ordination and assistance for its eight Member States (Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) in the implementation of the Kuwait Regional Convention and its Protocols. ROPME has been initiating and supporting a number of projects, covering environmental assessment and environmental management, as well as supporting public awareness and training programmes.

This report represents two of the projects supported by ROPME, namely, Oceanographic Cruises in 2001 and 2006 commissioned to enable an understanding of the state of the marine environment within the ROPME Sea Area. The Cruises were planned in such a way that the results and reports of the studies can find their way into the synthesis of subsequent ROPME State of the Marine Environment Reports. This report presents Technical Report No. 3 of the Technical Report Series.

The primary purpose of this report was to report nutrient salts distribution in the ROPME Sea Area from the 2001 and 2006 cruises. The results of the study identified spatial and temporal variation within the ROPME Sea Area with vertical distribution for some parameters. The study identified nutrient salt and related parameters that generally fall within expected ranges for the region. The nutrient salts and related parameters are subject to the effects of upwelling processes, inputs from inland freshwater sources (Shatt Al Arab and Mond Rivers) and impacts from monsoon activity within the Sea of Oman.

Continued research and monitoring is required to fully comprehend the processes related to ecological functioning in the ROPME Sea Area. Additional pressures related to coastal development and freshwater resources must be understood in order to fully protect the ROPME Sea Area. As a ROPME imperative, it has been identified that a set of reference criteria should be developed for use in the ROPME Sea Area.

Introduction

The Regional Organization for the Protection of the Marine Environment (ROPME) plays a major role in the protection of the marine environment and prevention of its degradation, and provides technical co-ordination and assistance for its eight Member States (Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) in the implementation of the Kuwait Action Plan (KAP), Kuwait Regional Convention and its Protocols. ROPME has been initiating and supporting a number of projects, covering environmental assessment and environmental management, as well as supporting public awareness and training programmes.

The term "ROPME Sea Area" was coined by Plenipotentiaries of the Member States to achieve unanimity in denoting the area covered by the Kuwait Regional Convention of 1978. According to Article II of the Kuwait Regional Convention, the ROPME Sea Area is defined as extending between the following geographic latitudes and longitudes, respectively: 16°39'N, 53°3'30"E; 16°00'N, 53°25'E; 17°00'N, 56°30'E; 20°30'N, 60°00'E; and 25°04'N, 61°25'E. ROPME Sea Area covers the Inner, Middle and Outer.

The region has seen rapid coastal development and urban change along with various regional wars, all of which combined to disturb the marine ecosystem. Anthropogenic pressures surpass the carrying capacity of the marine ecosystem as a result of high demands and consumption of energy, fresh water, and fisheries resources. An understanding of the physical - chemical and biological systems operating in the ROPME Sea Area is required, and the current studies provide insight into the ecosystem and anthropogenic balance. The nutrient salt (NS) elements and cycles of phosphorus, nitrogen and silicon have long been recognized as indices of potential fertility of seawater.

Figure 1: ROPME Sea Area. Source: U.S. Department of State Geographer

Aim

The aim of this study was to describe the spatial distribution of nutrients in the ROPME Sea Area during Winter 2006, with reference to the cruise conducted in Summer 2001. Our hypotheses include the following:

1. There is spatial distribution in the nutrient concentrations in the ROPME Sea Area.
2. The nutrient concentration results obtained from the analysis of the Summer 2001 and Winter 2006 samples are comparable.
3. There is a temporal difference between the nutrient concentrations in Summer 2001 and Winter 2006.

This report focuses on spatial distributional aspects related to the concentration of nutrients and related parameters in the inner RSA and Sea of Oman water column during Winter 2006. In addition to NS, related physical and chemical parameters such as salinity, dissolved oxygen (oxygen), electrical conductivity, temperature and water density were measured, along with biological parameters such as phytoplankton, zooplankton and chlorophyll-a (Chl-a). Parameters other than NS are discussed as they are relevant to the NS distribution.

Background

The inner RSA (refers to the waters west of the Strait of Hormuz), is a shallow semi-enclosed body of saline water located in a climatically arid region. It has an average depth of 35 m with a maximum depth of 107 m at the Strait of Hormuz. Seasonally, it is supplied with freshwater from Shatt Al-Arab and its associated river systems in the north as well as the Mond River along the coast of Iran. The Sea of Oman and the Arabian Sea are much deeper (over 2000 m) than the inner RSA. The inner RSA itself is separated from the Sea of Oman by the Strait of Hormuz which is 56 km wide.

Circulation

Circulation processes in the ROPME Sea Area are related to the `*Coreolis* Effect` and include currents, semi-diurnal tides and upwelling (Figure 2). Circulation in the inner RSA is salinity related and density driven, with a counter clock-wise pattern with a retention time of between 1 and 3 years. Thermal convection is also a driver in circulation. As there is no sill or saddle in bathymetry, there is circulation and free exchange of water between the inner RSA and Sea of Oman. Water of normal salinity entering the inner RSA from the Strait of Hormuz moves along the Iranian coast towards the northwest, and then south, following the coastline. Further movement is along the Saudi Arabia and UAE coasts, eventually exiting as (hyper saline) water through the Strait of Hormuz, at depth. Freshwater inflow occurs from rivers on the Iranian side (Mond River) and the Shatt Al Arab/Karun River complex in the northwest. A low energy area is located in the north central region, shown as ‘Stagnant Region” in Figure 2.

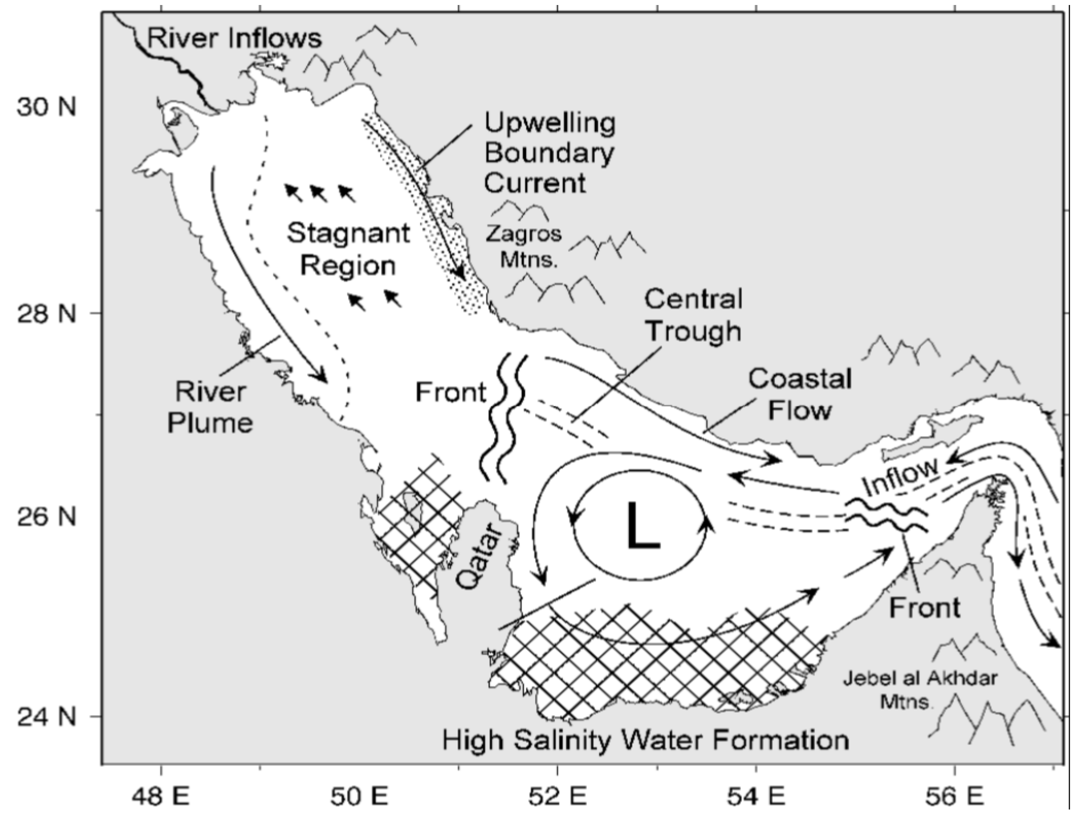


Figure 2: General winter circulation patterns (Reynolds, 1993)

Physico-chemical Characteristics

The inner RSA is a source region for one of the most saline water masses in the world ocean. The salinity of water in this region can exceed 50 ppm in some cases, as a result of an arid climate, high rate of evaporation, low fresh water input and restricted exchange with the open ocean.

Nutrient studies have been conducted by several investigators in the ROPME Sea Area. Though those studies were limited in space and time, they provide valuable background information on the relationship between NS and productivity and biodiversity of phytoplankton. Phytoplankton studies are important because they represent the first step of the food web in the marine ecosystem. Chl-a is an indicator of the quantity of plant growth in water and a proxy of the phytoplankton biomass. Information on chl-a provides insight into the dynamics of the ecosystem, on the food availability for upper trophic levels, and on the overall environmental quality and dynamics of the marine ecosystem.

Currently, a comprehensive set of background values for water quality in the ROPME Sea Area have not been developed. For reference purposes, typical concentrations of NS and other parameters discussed in this report are presented in Table 1. These values have been identified by the Abu Dhabi Environment Agency (EAD, 2007)) and represent water quality off the coast of Abu Dhabi. These values are presented solely for comparison purposes. The chl-a concentrations within the ROPME Sea Area have been well studied and the range of results is presented in Table 2.

Table 1: Background Water Quality in Abu Dhabi(EAD, 2007)

Parameter	Background
PO_4 (mg/L)	16 to 28
SiO_2 (µg/L)	60 to 120
NH_3 (mg/L)	33- 242
NO_2 (mg/L)	Up to 3
NO_3 (mg/L)	Up to 144
Chl-a (mg/m^3)	0.01 to 2
Salinity (psu)	45-50
Temperature (^oC)	18-36
DO (mg/L)	4-6

Table 2: Chl-a concentrations (mg/m^3) within the ROPME Sea Area (ROPME, 2012)

Region	Chl-a (mg/m^3)
Kuwait	0.12 to 23.7
Inner Area	0.4 to 2.8
Shatt Al Arab	0.3 to 3.3
NW Inner Area	0.7 to 9.1
SE Inner Area	1.11 to 1.23
Sea of Oman	0.43 to 0.67
Overall Range	0.12 to 23.7
Mean Range	0.51 to 6.8

Monitoring Survey

Material and Methods

ROPME's Winter cruise of 2006 on the research vessel Al Quds, covered the inner RSA and Sea of Oman. The cruise was divided into three legs and 23 transects (Figure 4); sampling was conducted at 113 locations (31 stations in Leg 1, 34 stations in Leg 2 and 48 stations in Leg 3) between February 3rd and March 9th, 2006. The dates and time of collection, depth of sampling and maximum depth for each station as well as coordinates of stations are included in Appendix 1.

The ROPME Summer cruise of 2001 on the research vessel T/V Ghods, was less extensive and only covered the inner RSA and Strait of Hormuz. The cruise was divided into two legs and 14 transects; sampling was conducted at a total of 76 locations (43 stations in Leg 1 and 33 stations in Leg 2) between August 6th and August 27th, 2001.

Sample Collection

Water quality monitoring was conducted at each station and water samples were collected at various depths. In-situ water quality measurements were recorded using a multi-parameter hand held submersible probe (Ocean Seven 316 manufactured by IDRONAUT, Italy) for general water quality parameters, as outlined below:

- Electrical conductivity;
- Temperature;
- Depth;
- Turbidity;
- pH;
- Dissolved oxygen; and
- Fluorescence.

Physical oceanography measurements were made using an IDRONAUT type of CTD (Conductivity, Temperature and Depth) meter with additional sensors for pH, Chl-a and turbidity. The CTD meter was attached to a Hydro Bios Rosette and Niskin water sampler with 12 bottles, each 2.5 L in volume. Deployment preparations included cocking of the Niskin bottles prior to casting (approximately 15 minutes).

The sampling apparatus was submersed at an approximate speed of 1 m/s. During the up-cast of the sampling apparatus, up to 12 samples were taken at regular depth intervals in each station. The ship's echo sounder enabled sample collection near the bottom without significant sediment disruption. The multi-valve system allowed closing the sampler bottles by computer command from the rosette operator at each selected depth to a maximum depth of 180 meters. A full outline of sampling details is provided in ROPME (2006).

Figure 3: Oceanographic Cruise 2001 tracks and sampling stations. Source: U.S. Department of State Geographer

Figure 4: Oceanographic Cruise 2006 tracks and sampling stations. Source: U.S. Department of State Geographer

Sample Analysis Procedure

Nutrient was analysed on-board using a Cecil 4003 spectrophotometer for the following parameters, as outlined in Appendix 2:

- Nitrite-N (NO_2);
- Nitrate-N (NO_3);
- Ammonia-N (NH_3);
- Dissolved oxygen (DO);
- Phosphate-P (PO_4); and
- Silicate-Si (SiO_2) concentrations.

Chl-a samples were distributed among specialized laboratories in the Region for analysis and procedures reported in ROPME (2012).

Statistical Analyses

Pearson Correlation was used to find the significant relation between nutrients variables and water quality parameters.

A Principal Component Analysis (PCA) of the relation between sampling transects and environmental variables were calculated with CANOCO for Windows 4.5 package. Average data of the sampling depth and one average data of each transect were used. Environmental data were standardized by basing the analysis on the correlation matrix.

Cluster analysis was performed to illustrate similarities between transects along the ROPME Sea Area. Average of each transect data on water column depth, water temperature, pH, dissolved oxygen, turbidity, salinity, ammonia, nitrate, nitrite, phosphate, silicate, and chl-a from Summer 2001 and Winter 2006, were standardized prior to the analyses (McGarial *et al.,* 2000). The cluster analysis was done by means of Ward's method, using squared Euclidean distances as a measure of similarity. Dendogram figures were developed using IBM SPSS Statistics programme version 21 for windows.

Graphical displays of the oceanographic view of the ROPME Sea Area were mapped using Ocean Data View (ODV) software programme version 4.6.3.1 for windows. Data was grouped by depth (surface, middle and bottom) to facilitate figure preparation. GPS coordination was transformed to UTM coordination.

Quality Assurance and Quality Control (QA/QC)

Typical QA/QC procedures were undertaken during the surveys and the methods were approved in advance during planning stages of the cruises. QA/QC procedures are outlined as follows:

- All monitoring equipment used was calibrated following manufacturer's instructions before use and after any change of battery;
- All water samples were collected (in duplicate) according to standard operating procedures and were chilled and delivered to the laboratory with laboratory supplied chain of custody documentation;
- Niskin bottles were cocked shortly before casting to avoid on-deck contamination;
- Niskin bottles were drained and lowered to depths with both caps open to ensure adequate flushing between samples;
- All sample containers were labeled with the sample location, time and date of sample collection and the sampler's initials;
- Field records were completed providing the following information:
    - Date and time;
    - Location using geographical positioning system (GPS) coordinates;
    - Weather;
    - and photographs;
- Industry standards for sample holding times prior to analyses were met for all sampling locations; and
- For QA purposes, the laboratories regularly used calibrated checks, surrogate matrix spikes, blanks, and laboratory duplicates during analyses. The results of these QA checks indicate that the appropriate guidelines were met.

Based on the review of QA/QC information, the overall data quality is considered acceptable to fulfill the stated objectives of the monitoring program.

Results

Data descriptive analysis of water quality parameters and nutrients for the 2001 and 2006 Cruises for each transect are listed in Appendix 3 and special distribution of the data graphically presented in Appendix 4.

Average concentrations of water quality parameters and nutrients of the ROPME Sea Area for the 2001 and 2006 Cruises are listed in Table 3 and Table 4, respectively. The results show that the concentrations of parameters varied spatially and temporally within the studied area. The recorded results for all parameters are within background ranges recorded for the ROPME Sea Area (Table 1).

The comparison of surface distributions of temperature, salinity, dissolved oxygen, phosphate, nitrate, nitrite, ammonia, turbidity, and silicates segregates the ROPME Sea Area zonally, namely: the Sea of Oman, the Strait of Hormuz, the south eastern and the north western inner RSA regions and relatively narrow central zone, where density fronts form and with year round upwelling occurs along the Iranian coast (ROPME, 2012).

Table 3: Average, minimum and maximum concentrations of Water Quality of 2001& 2006 Cruises. Data size is between two brackets; BDL = below detection limit (0.01 mg/m^3 for Chl-a)

	Depth (m)	**DO (sat%)**	**DO (ppm)**	**pH**	**Chl-a (mg/m^3)**	**Turb**	**Temp (°C)**	**Salinity (psu)**
Surface (2001)								
Average	2.9 (76)	90.6 (75)	5.2 (75)	8.1 (75)	0.4 (75)	2.2 (75)	33.5 (75)	39.3 (75)
±STD	0.5	6.4	0.4	0.1	0.3	1.5	0.9	0.9
Minimum	1.0	70.2	4.0	7.9	0.1	1.3	29.9	37.2
Maximum	4.0	112.2	6.4	8.2	1.5	9.8	35.5	41.1
Surface (2006)								
Average	3.0 (113)	100.9 (112)	7.1 (112)	8.2 (112)	1.2 (112)	2.9 (112)	21.5 (112)	38.8 (112)
±STD	0.5	9.7	0.8	0.2	1.3	1.4	1.9	2.3
Minimum	1.0	75.5	5.1	7.0	BDL	1.6	17.4	24.4
Maximum	4.0	142.0	9.8	8.5	6.9	14.4	25.1	41.4
Middle (2001)								
Average	21.1 (76)	82.2 (75)	4.9 (75)	8.0 (75)	1.1 (75)	2.3 (75)	30.7 (75)	39.7 (75)
±STD	10.3	11.6	0.6	0.1	0.9	1.8	3.4	0.9
Minimum	5.0	55.6	3.7	7.9	0.2	1.2	21.5	37.3
Maximum	41.0	101.0	5.9	8.2	6.0	12.3	34.6	41.2
Middle (2006)								
Average	25.5 (113)	94.3 (112)	6.6 (112)	8.2 (112)	1.0 (112)	2.9 (112)	21.1 (112)	39.1 (112)
±STD	13.5	12.1	1.0	0.2	1.0	1.6	1.9	1.8
Minimum	5.0	63.8	4.2	7.2	BDL	1.6	17.3	36.4
Maximum	50.0	119.5	8.9	8.5	5.5	17.1	23.8	41.6
Bottom (2001)								
Average	42.3 (76)	57.1 (75)	3.6 (75)	8.0 (75)	0.7 (75)	4.4 (75)	26.9 (75)	40.3 (75)
±STD	21.1	15.8	0.8	0.1	0.6	3.5	5.0	0.7
Minimum	10.0	26.7	1.8	7.8	0.1	1.3	20.5	37.4
Maximum	80.0	88.3	5.2	8.1	2.8	20.0	35.5	41.3
Bottom (2006)								
Average	51.1 (113)	87.1 (112)	6.9 (112)	8.1 (112)	0.8 (112)	3.6 (112)	20.8 (112)	39.5 (112)
±STD	27.3	17.2	8.1	0.2	1.1	2.0	1.9	1.8
Minimum	10.0	13.7	1.0	7.2	BDL	0.4	16.6	36.2
Maximum	100.0	119.9	90.9	8.5	8.4	18.3	23.4	44.0

Table 4: Average, minimum and maximum concentrations (µg/L) of 2001 & 2006 Cruises. Data size is between two brackets; BDL = below detection limit (0.05µg/L for nitrogen forms and phosphate, 0.1 µg/L for silicate)

	Nitrate-N	Nitrite-N	Ammonia-N	Phosphate-P	Silicate-Si
Surface (2001)					
Average	28.7 (76)	1.4 (76)	9.8 (76)	8.3 (75)	26.4 (76)
±STD	47.8	2.6	9.6	16.3	51.5
Minimum	BDL	BDL	BDL	BDL	BDL
Maximum	271	15.6	38.1	102	303.8
Surface (2006)					
Average	37.1 (113)	2.9 (113)	6.6 (113)	11.3 (113)	35.9 (113)
±STD	51.4	3.1	5.1	7.8	26.9
Minimum	0.9	BDL	0.7	1.1	3.5
Maximum	220.2	12.3	40.3	33.5	118.9
Middle (2001)					
Average	120.5 (76)	15.1 (76)	8.6 (76)	23.7 (76)	51.6 (76)
±STD	147.3	19.7	8	23.8	57.8
Minimum	BDL	BDL	BDL	BDL	BDL
Maximum	568.2	72.9	36.4	100.3	304.8
Middle (2006)					
Average	64.8 (113)	6.4 (113)	7.0 (113)	14.5 (113)	55.7 (113)
±STD	78.7	6.8	4.5	10.3	34.8
Minimum	BDL	BDL	BDL	BDL	BDL
Maximum	302.7	40.8	28.5	41	170.8
Bottom (2001)					
Average	340.8 (76)	18.9 (76)	8.1 (76)	63.1 (76)	136.7 (76)
±STD	233.9	29.6	6.7	43.7	86.6
Minimum	BDL	BDL	BDL	BDL	BDL
Maximum	804.1	171	25.4	247.3	324.4
Bottom (2006)					
Average	84.3 (113)	6.5 (113)	7.2 (113)	16.5 (113)	79.7 (113)
±STD	108.6	7.2	4.2	13.5	65.5
Minimum	BDL	BDL	0.6	0.4	4.4
Maximum	411.8	28.8	19.9	63.6	345.5

Temperature, Salinity and Turbidity

ROPME Sea Area is located in an arid zone where the air temperature ranges from cool in winter and warm in summer. The variation of water temperature during Summer 2001 and Winter 2006 cruises reflect the regional climate.

During the Winter 2006 cruise, the water column is thermally homogeneous with lower temperature than summer. During the Summer 2001 cruise, the influences of thermal stratification was pronounced with cooler temperatures measured at depth. Cooler waters and higher salinity during winter were observed entering the ROPME Sea Area from the Shatt Al Arab.

The salinity and density driven circulation patterns typical for the inner RSA are evident in the salinity results. The figures in Appendix 4 clearly show that the inflow of low-salinity surface water from the Sea of Oman penetrates the inner RSA and there is an outflow of saline bottom water through the Strait of Hormuz, consistent with previously reported circulation patterns. Areas of higher salinity were observed along the UAE coast and where cooler waters were observed, consistent with Figure 2.

Turbidity results (Appendix 4, Figure C) during both cruises were relatively low throughout the inner RSA and Sea of Oman. Slightly higher turbidity was observed in the vicinity of the Mond River (winter) and Shatt Al Arab (summer) and at depth. In 2001, the turbidity decreased from the northern inner RSA to the Sea of Oman.

Generally, Pearson Correlation result (Table 5 and Table 6) shows that salinity and temperature have an inverse relationship whereby salinity decreased and temperature increased in Winter from the northern part of the inner RSA towards the Sea of Oman, while such relationship was not significant in Summer. Salinity and temperature have an inverse relationship whereby salinity decreased and temperature increased in Winter from the northern part of the inner RSA towards the Sea of Oman, while such relationship was not significant in Summer. Pearson Correlation result also show that salinity reflects significant relationship with silicate during Summer 2001 cruise and pH during Winter 2006 cruise (Table 5 and Table 6).Water column depth was positively influencing the increase of nitrate, silicate, and phosphate both in Summer and Winter cruises. In winter temperature was positively influencing the increase of nitrate and phosphate.

Compared to typical background ranges (Table 1), temperatures recorded were well within that found in the ROPME Sea Area. In terms of salinity, the influences of freshwater inputs in some areas resulted in salinity levels slightly below salinity considered background for the overall ROPME Sea Area. Turbidity levels, with the exception of a single station (2001) were low.

Dissolved Oxygen

During the Winter 2006 cruise, the ROPME Sea Area was well oxygenated (> 5 ppm) and homogeneous throughout the water column with decreasing concentrations from the northwest inner RSA towards the Sea of Oman (Appendix 4, Figure I). Aerated water from Shatt Al Arab is apparent entering the inner RSA during the Winter cruise. During the Summer 2001 cruise, lower DO levels (< 5 ppm) were observed throughout the ROPME Sea Area with slightly lower concentrations at depth. DO is typically lower where high nutrients were recorded. The results indicate that oxygen is within the background ranges presented in Table 1.

Chlorophyll-a

The results of chl-a were consistent with expected background levels, and lower concentrations were observed with higher salinity and/or lower oxygen (Appendix 4, Figure J). During the Winter 2006 cruise, chl-a was generally <2mg/m^3 and slightly lower in Summer 2001, especially at the surface and open oligotrophic zones. During winter, saline water with elevated chl-a is observed entering from the Sea of Oman (Winter 2006) and the freshwater rivers (Summer 2001). Elevated turbidity was also observed with elevated chl-a at the Mond River discharge. Chl-a was in some cases, higher where some NS were present in lower concentrations. Chl-a concentrations obtained during the surveys were consistent with the background concentrations provided in Table 2.

Dependence between nutrient concentrations and chl-*a* distribution was not revealed by Pearson Correlation analysis (Table 5 and Table 6).

Nutrient Salts

NS concentrations varied temporally between Summer 2001 and Winter 2006 for all the measured nutrients and the vertical distribution of nutrients concentrations within the water column was not uniform (Appendix 4, Figure D through H).The spatial distribution of nitrates and phosphates within the studied area indicates decreasing trend of their concentrations from south to north in the inner RSA, while there was an increase in concentration towards the southern-eastern direction (to the Sea of Oman) during 2006.

The comparison of the three-dimensional maps in Appendix 4 shows that the most limiting nutrients for the sampled region were phosphate (Figure D) and nitrate (Figure E), with low surface values at all inner RSA locations during winter, except for the south eastern part of the Sea of Oman. Vertical distribution of phosphates demonstrates a pronounced increase in concentration from surface to bottom. A similar trend was found for nitrates and silicates in general. Phosphate upwelling evidenced by elevated surficial phosphate concentrations alongside lower temperature, originating from depth was observed during Summer 2001 off the coast of Bushehr, Iran.

Nitrite concentrations increased from the northern part of the inner RSA towards the Sea of Oman with higher concentrations at depth (Appendix 4, Figure F). Some elevated concentrations were observed at the location of the Mond River outflow. Higher concentrations were observed during Summer 2001.

During both cruises, homogeneity within the water column was observed for ammonia with elevated concentrations at depth in the Strait of Hormuz (Appendix 4, Figure G). Results during the Summer cruise showed decreasing concentrations of ammonia from the northern part of the inner RSA towards the Sea of Oman. The highest ammonia concentrations were recorded during Summer 2001, exceeding 22 µg/L.

Several areas in the ROPME Sea Area showed moderate silicates levels (Appendix 4, Figure H). Vertical distribution of silicates demonstrates a pronounced increase in concentration from surface to bottom during Winter. Silicate concentrations were elevated within the Sea of Oman for Winter 2006, reaching approximately 250 µg/L at depth. During winter, concentrations generally increased from the northern part of the inner RSA towards the Sea of Oman, however, the opposite was observed during Summer 2001. Of particular note are elevated concentrations of silicate at mid to lower depths at the Shatt Al Arab and Mond River outflows. In most cases, silicate showed an increase in concentration with decreasing values of salinity.

Pearson Correlation indicate a significant similarity ($r = 0.93$) between nitrate and phosphate spatial distributions. High negative correlations ($p < -0.5$) were observed also between nitrates and phosphates only and latitude, salinity, dissolved oxygen, pH and water density (all these parameters are indicators of water masses, which change mostly with latitude in the inner RSA). High significant interaction were lacking between nitrite, ammonia and silicate, as well as the other measured environmental factors. Pearson Correlation result (Table 5 and Table 6) shows that, in summer, silicate was positively correlated with salinity, while salinity was negatively influence the variation of nitrate and phosphate in winter.

Some of the results indicate that NS exceed background values presented in Table 1, in particular, areas of upwelling and water within the Sea of Oman. In particular, silicate levels in the vicinity of freshwater outflows and within the Sea of Oman, exceed the background levels identified in Table 1.

Table 5: Pearson Correlation for Summer 2001 cruise

	Depth	*O_2 - Sat%*	*O_2 – ppm*	*pH*	*Chl-a*	*Turbidity*	*Temp*	*Salinity*	*Nitrate-N*	*Nitrite-N*	*Silicate-Si*	*Phosphate-P*	*Ammonia-N*
Depth	1.00												
O2 - Sat%	**-0.82**	1.00											
O2 - ppm	**-0.74**	**0.98**	1.00										
pH	-0.34	**0.59**	**0.63**	1.00									
Chl-a	-0.08	0.08	0.11	-0.13	1.00								
Turbidity	0.05	-0.16	-0.19	-0.44	0.11	1.00							
Temp	**-0.91**	**0.79**	**0.67**	0.32	0.02	-0.04	1.00						
Salinity	0.35	-0.44	-0.45	**-0.65**	0.17	0.32	-0.38	1.00					
Nitrate-N	**0.84**	**-0.82**	**-0.76**	-0.39	-0.09	0.03	**-0.83**	0.31	1.00				
Nitrite-N	0.25	-0.32	-0.33	-0.22	0.18	0.04	-0.11	0.00	0.29	1.00			
Silicate-Si	**0.54**	**-0.62**	**-0.61**	**-0.66**	-0.03	0.48	**-0.54**	**0.52**	**0.59**	0.18	1.00		
Phosphate-P	**0.59**	**-0.59**	**-0.55**	-0.30	-0.12	0.11	**-0.61**	0.20	**0.66**	0.12	0.49	1.00	
Ammonia-N	-0.12	0.08	0.06	-0.32	0.07	0.22	0.07	0.23	-0.06	-0.12	0.14	0.12	1.00

Table 6: Pearson Correlation for Winter 2006 cruise

	Depth	*O_2 - Sat%*	*O_2 - ppm*	*pH*	*Chl-a*	*Turb*	*Temp*	*Salinity*	*Nitrate-N*	*Nitrite-N*	*Silicate-Si*	*Phosphate-P*	*Ammonia-N*
Depth	1.00												
O2 - Sat%	**-0.70**	1.00											
O2 - ppm	-0.14	0.03	1.00										
pH	-0.34	**0.54**	0.21	1.00									
Chl-a	-0.29	0.25	0.42	0.06	1.00								
Turbidity	0.01	0.04	-0.08	-0.06	0.10	1.00							
Temp	0.17	-0.39	-0.11	-0.48	0.10	-0.02	1.00						
Salinity	-0.15	0.39	0.17	**0.55**	-0.20	-0.13	**-0.71**	1.00					
Nitrate-N	**0.58**	**-0.80**	-0.22	-0.61	-0.12	0.02	**0.50**	**-0.71**	1.00				
Nitrite-N	0.35	-0.34	-0.06	-0.28	-0.06	-0.04	0.33	-0.31	0.35	1.00			
Silicate-Si	**0.67**	**-0.81**	-0.15	-0.41	-0.21	-0.06	0.32	-0.33	**0.76**	0.31	1.00		
Phosphate-P	**0.54**	**-0.78**	-0.19	**-0.63**	-0.05	0.02	**0.58**	**-0.76**	**0.94**	0.41	**0.76**	1.00	
Ammonia-N	0.01	-0.07	0.06	-0.14	0.09	0.04	0.24	-0.23	0.07	0.20	0.04	0.16	1.00

The PCA ordination of the ROPME Sea Area transect in Summer 2001 (Figure 5) shows the distribution of transects and the relationship of the original water quality and nutrients parameters to the new axes. Environmental variables with strong negative loadings on axis 1 included water column depth and nitrate. Chl-a, salinity and ammonia had strong positive loading on axis 1, where chlorophyll-a showed distinct differences between transect T5 and T3 and the rest of transects. Nitrite and pH had strong positive loadings on axis 2 and showed distinct differences between T12, T13, T14 and the rest of transects. Transects from T3 to T6 and T8 to T11 had highest phosphate concentrations. T1 is highly turbid and had the highest temperature among the rest of transects.

The PCA ordination of the ROPME Sea Area transect in Winter 2006 (Figure 6) shows the distribution of transects and the relationship of the original water quality and nutrients parameters to the new axes. Environmental variables with strong negative loadings on axis 1 included salinity and pH. Dissolved oxygen had strong positive loadings on axis 2. Water column depth, nitrate, and silicate had strong positive loadings on axis 1.Transects from T1 to T12 were high in salinity, pH and dissolved oxygen, where transects from T13, T14a, T15 and T16 where turbid and had high concentration of ammonia and chl-a. Transects T14, T15 to T18 were deep and had high concentration of phosphate, silicate and nitrate.

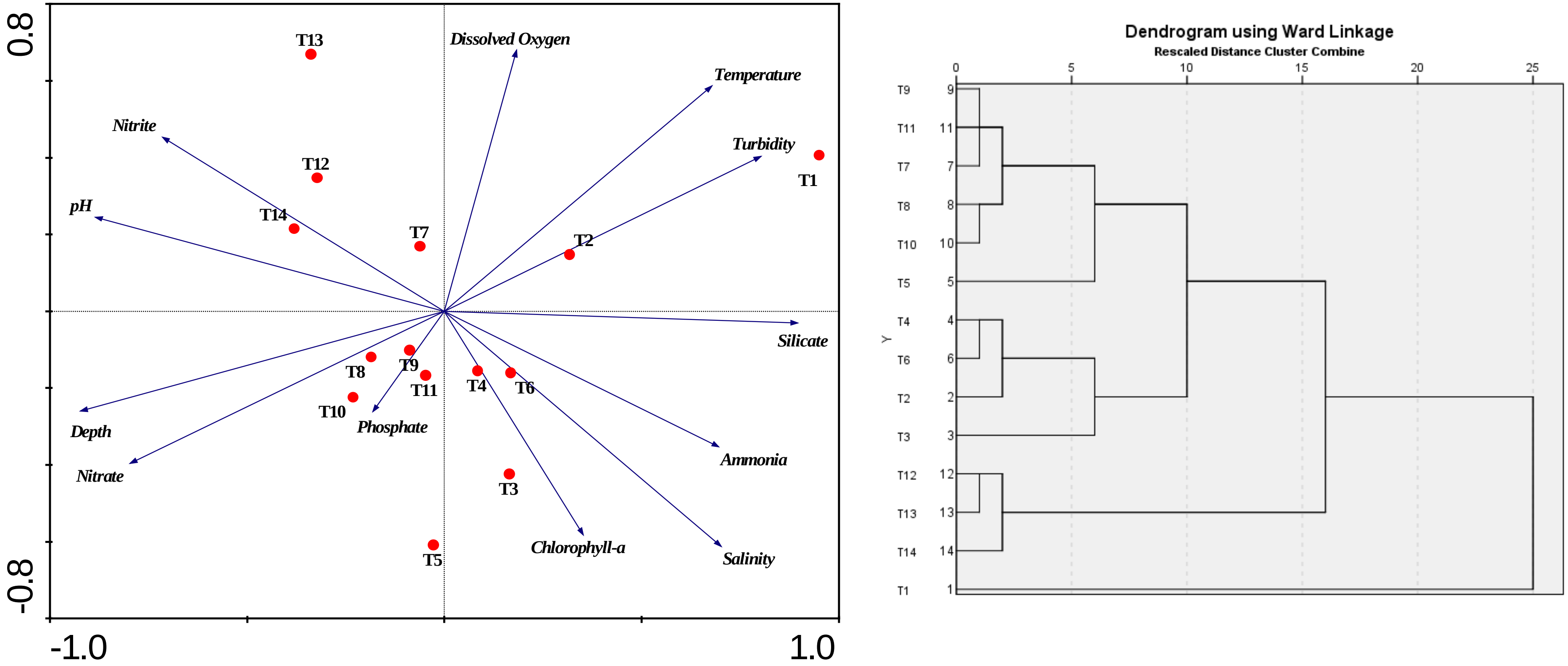
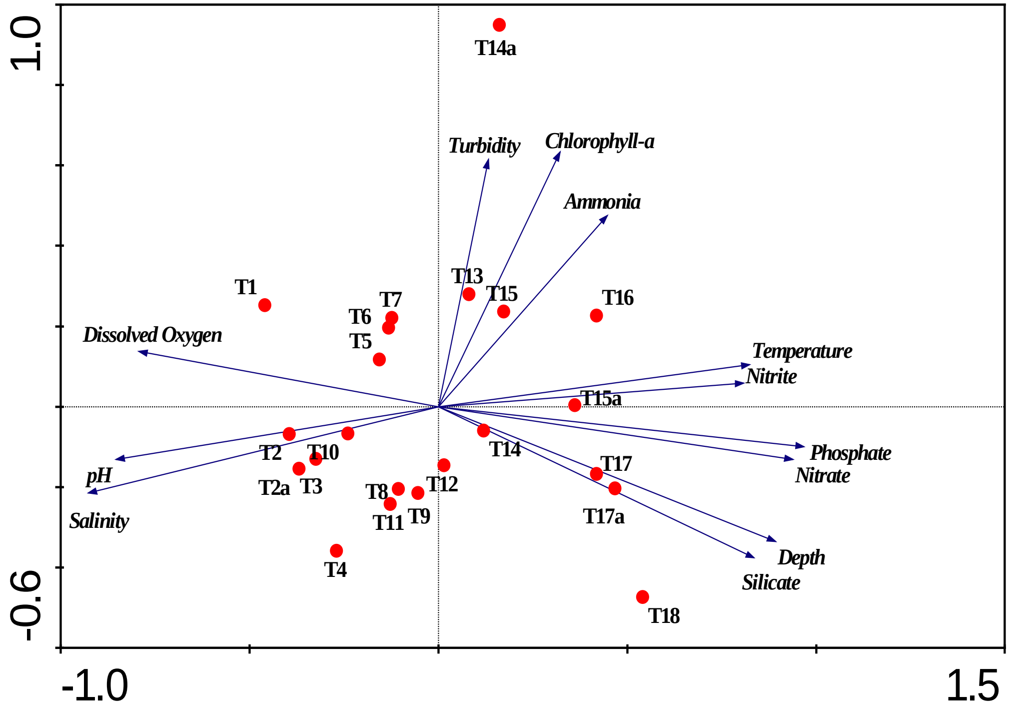


Figure 5: Principal components ordination of the ROPME Sea Area during Summer Cruise 2001(left) and the relationship of the original variables to the first two principal components. Eigen values: 0.49 for Axis 1, 0.20 for axis 2, 0.11 for axis 3. Dendrogram illustrating the similarities among transects based on Ward's linkage method (right)



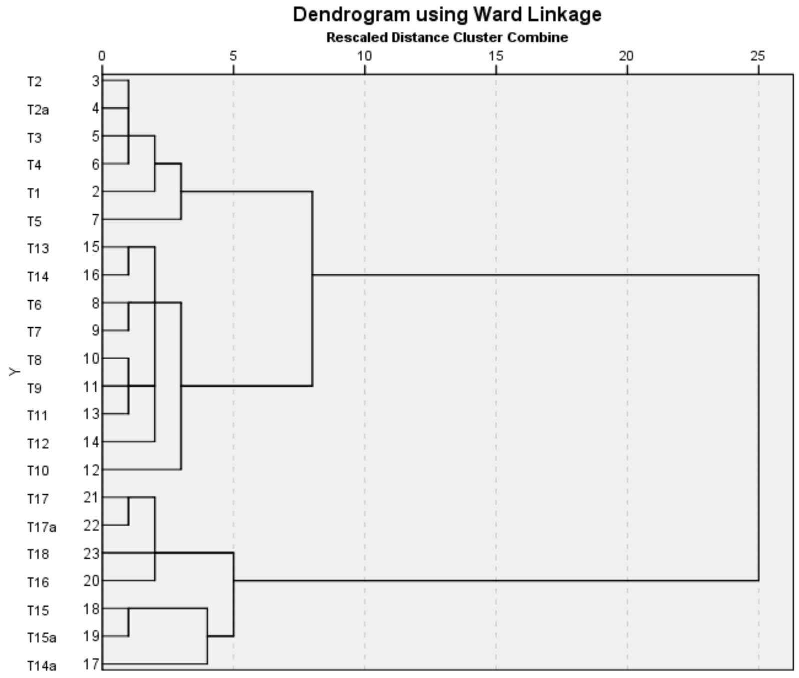


Figure 6: Principal components ordination of the ROPME Sea Area during Winter cruise 2006 (left) and the relationship of the original variables to the first two principal components. Eigen values: 0.60 for Axis 1, 0.12 for axis 2, 0.10 for axis 3. Dendrogram illustrating the similarities among transects based on Ward's linkage method (right)

Discussion

The major micronutrient elements, phosphorus, nitrogen and silicon have long been recognized as an index of potential fertility of seawater (Ibrahim, 2010). Furthermore, these NS encourage seaweed growth and support blooms of phytoplankton which form the ultimate energy base for large animal populations higher in the food chain, including fish, marine mammals and seabirds. Because of the potential importance of these NS as limiting factors affecting the growth of phytoplankton, the levels of nitrate, nitrite, ammonium, phosphate and silicate are integral to our understanding. The interactions of NS with other factors such as temperature and salinity as well as oxygen and turbidity, represent ecological cycles with quantifiable characteristics.

Influxes of nutrient rich river water from Iran and Iraq and seasonal monsoon conditions impacting the Sea of Oman are partially responsible for the injection of turbid, nutrient rich, saline and oxygenated water entering the Arabian Sea. In winter, these waters bring cooler temperatures however, in summer, warmer water is released.

The results demonstrate clearly the oceanographic phenomenon of upwelling along the Iranian coast. Driven by wind and the Coriolis effect, dense, cooler, and nutrient-rich water moves along the ocean surface, replacing the warmer, usually nutrient-depleted surface water. The nutrient-rich upwelled water stimulates the growth and reproduction of primary producers such as phytoplankton. Upwelling zones can be identified by cool sea surface temperatures and high concentrations of Chl-a, representing the biomass of phytoplankton. Within the ROPME Sea Area, upwelling has been identified by Reynolds (1993) and UNEP (1999) where Coriolis effects, monsoons and winds contribute to upwelling of elevated nutrients, particularly NO_3 and PO_4. These regions of upwelling typically represent good fishing grounds are important economically within the region.

During the last decades, rapid development in the industrial (e.g. oil and gas), recreation, transportation, residential and tourism sectors have occurred in the coastal and marine environment of the ROPME Sea Area. Consequently, most of this development is concentrated in the vicinity of urban centres along ROPME Sea Area coastlines and these developments are likely a significant contributor to degrading water quality. Additionally, contributions from inland water sources such as the Shatt Al Arab and Iranian rivers, as a result of agricultural run-off and uncontrolled effluent and waste discharges present water quality issues.

Within the ROPME Sea Area, oil and gas industries are the main source of solid and liquid industrial waste releasing common contaminants (hydrocarbons, metals, salts, sulphides). Spent catalysts that originate in ammonia and urea production are the main sources of hazardous wastes from nitrogenous fertilizer plants. Other sources of liquid waste are dairy industry, poultry farms, and slaughter houses. Run-off from agricultural land and direct discharge to the ROPME Sea Area contributes to elevated nutrient concentrations.

The assimilative capacities of the ROPME Sea Area for effluent discharges are predominantly determined by the rates at which effluents are dispersed and flushed from the coastal region into the ROPME Sea Area (Alosairi, *et al.,* 2011). The 'assimilative capacity' is defined as that loading, which properly dispersed throughout the receiving domain, can be rendered harmless without jeopardizing the health of the ecosystem (Alosairi, *et al.,* 2011). The results of the current assessment assist in the understanding of the assimilative capacity of the ROPME Sea Area.

Temperature, Salinity and Turbidity

The results of temperature and salinity are consistent with other studies in the region. Clearly, water temperatures are lower in winter as a result of higher wind speeds and lower humidity in the ROPME Sea Area, contributing to higher evaporation rates than in summer. Although the coast is open and circulation is largely unrestricted, evaporation rates are high enough to increase salinity in some areas. During winter, the cold wind blows over the ROPME Sea Area and surface waters cool compared to water at depth. As a result of thermal convection, the water column is thermally homogeneous.

The results of turbidity clearly show the impact of water from rivers entering the inner RSA where more turbid water enters from the Iraq in the northwest during summer and from the Mond River in the winter. These water sources bring in nutrient rich water which, while contributing to elevated turbidity, stimulates the primary producers and present elevated Chl-a concentrations. There were some observations of elevated turbidity at depth, however, in some cases sampling equipment may have disturbed sediments (e.g. 12.5 NTU in 2001 bottom sample). Overall the inner RSA exhibits clear water with extensive photic zones allowing photosynthetic activity.

The results support the findings by Ibrahim (2010) showing that NS concentrations are often higher in the Sea of Oman than in the inner RSA potentially related to monsoon activity and the suspension of nutrients from wind action.

Nutrients

The occurrence of a thermocline and high primary production in the euphotic zone can deplete nutrients above the thermocline, thus the assessment of nutrients is important to identify the ecological health of the ROPME Sea Area.

As indicated, low energy regions exist in the inner RSA, as shown in Figure 2. In most cases, with respect to NS, inland freshwater influxes which are greatest in winter and have lower NS concentrations, are somewhat ‘trapped’ by the low energy region and are only slightly propagated into the ROPME Sea Area, probably by winter north westerly *shamal* winds rather than currents and tides.

Phosphate

Phosphate is an important and often limiting NS in ecosystems. It is released by processes such as weathering and is an essential nutrient for marine flora and fauna. During the period of active growth of phytoplankton, the concentration of phosphate is readily reduced in the aquatic environment, and is restricted to the euphotic zone. Due to metabolic activity of plants, animals and bacteria, phosphate is regenerated into the water column from the organic phase. Part of the regeneration occurs at the surface layers but there is a continuous transport of these elements away from the surface layers. Physical processes like vertical diffusion, convection and upwelling replenish the surface layers with these elements from the subsurface layers.

Dramatic results were seen in this study with respect to phosphate: clear patterns of upwelling (elevated surficial phosphate with cooler temperatures) were observed along the Iranian border, consistent with trends observed by Reynolds (1993). Typically, phosphate is subject to an annual cycle with maximum concentrations observed in summer. It is clear that the upwelling forces override the seasonal aspect typical for phosphate.

Nitrogen Cycles

The presence and relationship between nitrate, nitrite and ammonia are essential for ecosystem function. Nitrate is an essential nutrient for the growth of many photosynthetic autotrophs and has been identified as a growth-limiting nutrient in many ecosystems. Other important forms of nitrogen for biogeochemical process are nitrite, ammonia and dissolved and particulate organic nitrogen compounds. Nitrite is present generally in low concentrations, as an intermediate product of microbial reduction of nitrate or oxidation of ammonia and as an excretory product of plankton. In marine environments, inorganic nitrogen compounds exist in their oxidizing or reducing forms. These NS exist under the following equation:

$$NO_3 \leftrightarrow NO_2 \leftrightarrow NH_4$$

Nitrite is an intermediate between ammonia and nitrate, occurring in natural processes. The relationship of these NS is important in considering the results of this study as nitrogen is known as limiting nutrient in some marine systems. Generally, low ammonia occurs with low nitrite concentrations and ammonia is preferred by phytoplankton for assimilation.

Various other processes contribute to the concentrations of nitrate and related compounds in the ROPME Sea Area. The discharge of effluents, including sewage, from coastal areas increases the concentration of nitrate and other NS, particularly in near shore areas. In some cases where these nitrogen compounds are completely removed from the surface waters this results in 'limiting' the further growth of primary producers. Below the euphotic layer, the decomposition of sinking dead cells and faecal pellets of living organisms start, thereby liberating nitrogen compounds first as ammonia, which is oxidized to nitrate via nitrite as intermediate product. The decomposition of organic matter is accompanied by the utilization of dissolved oxygen present in water.

Elevated nitrate can also result from the decomposition of organic matter or a decrease in uptake by living organisms. In natural processes, nitrite is oxidized to nitrate. Lower concentrations of nitrite were generally observed in areas with high oxygen, such as where fresh, cooler water enters the inner RSA or where there is less effluent. Where lower nitrite is observed, reduction to nitrate may be the process responsible, as well as the reduction to ammonia or uptake of nitrite by organisms. Chemically, temperature affects not only the rate of reaction but also the extent to which the reactions take place.

Silicate

Important for skeletal growth and development for organisms such as diatoms, the uptake of silicon during phytoplankton growth and development results in the depletion of silicon in the seawater. However, when these organisms die and disintegrate, silicon is rapidly liberated into the marine environment. Silicate is also liberated into seawater as a result of weathering and can be brought into the system through river discharge, as was observed in the current results.

Diatoms are particularly characteristic of upwelling areas, where they produce intense blooms and provide the primary production base for short and tropically efficient food chains which are responsible for the most productive fisheries of the world's oceans (Ryther, 1969).

Several areas in the ROPME Sea Area showed moderate silicates levels, which are in contrast with what was reported by Brewer and Dryssen (1985), that the silicates are very low in the inner RSA during winter.

Chlorophyll-a

The concentrations of NS in the ROPME Sea Area play an important role in photosynthetic rates of phytoplankton. Based on chl-a measurements, phytoplankton can be estimated, however, substantial variability is common as the processes are a complex interaction between ecological factors and rates of nutrient regeneration. As such, in areas of elevated NS, elevated chl-a concentrations were often also observed. High positive and statistically significant correlations were also detected between total phytoplankton abundance and chl-a concentrations (ROPME, 2010b).

The enhanced plankton biomass and the elevated production in coastal waters reflect the combined effects of geophysical, chemical, metrological and biological processes. For the primary producers of the ROPME Sea Area, factors such as the availability of nutrients, along with sufficient light, dissolved oxygen, and a suitable ambient temperature for metabolic activity are critical parameters for some areas in this region (Al-Yamani, *et al.*, 2006). Summer Chl-a concentrations may be somewhat regulated by available nutrients. Chl-a distribution appears to be related to the freshwater outflows and monsoon induced inflow from the Sea of Oman. Moreover, water temperature and salinity do not appear to be limiting factors for phytoplankton development during this study.

The production of oxygen during photosynthesis is related to these Chl-a-plankton biomass quantities. In general, the water throughout the inner RSA is well oxygenated. Typical water quality criteria require at least 4 ppm to meet objectives and this was met at most locations, with the exception of Summer 2001 at depth. It is expected that oxygen would be depleted at depth where photosynthetic activities are limited. Aeration of freshwater sources in the northwest contribute to oxygen levels in the inner RSA during winter, however, during summer, the oxygen can be diminished once NS concentrations become limited following rapid primary production growth and during periods of lower flow volumes from freshwater sources. Additionally, below the photosynthetic zone, in situ processes such as the oxidation of organic matter, can contribute to the reduction of oxygen at depth.

In cases where chl-a and thereby phytoplankton abundance are high and concentrations of nutrients are low can be attributed to the active consumption of nutrients by the microalgae during their growth and bloom conditions leading toward water column depletion.

Land-based Activities

The contribution of land based sources of NS, salinity and others cannot be overlooked and has been studied extensively by ROPME and others (UNEP, 1999). Some areas of elevated parameters in this study can be resultant from desalinization plants, or other industrial effluents, such as elevated salinity at depth in the vicinity of Bahrain (2006) and Kuwait (2001) or elevated ammonia offshore from Kuwait (2001) and Iran (2006). Elevated salinity, oxygen, some NS and chl-a offshore from Abu Dhabi (2001) could be the result of effluent releases that are manifested in elevated primary productivity.

The demand for certain nutrients, especially phosphorus and nitrogen, is usually much greater than their supply in different aquatic systems. However, human activities have profoundly change nitrogen and phosphorus dynamics by increasing their availability in aquatic systems, resulting in eutrophication of lakes, rivers, and coastal environments worldwide (Carpenter, *et al.,* 1998). From water quality point of view, the concern about eutrophication is usually due to cultural eutrophication. Increased input of nutrients could be due to leaching from fertilizers used in agriculture, storm runoff from urbanized land, industrial waste, watershed disturbance, and direct discharge of treated and untreated sewage into aquatic ecosystems (Wetzel, 2001). Eutrophication of coastal areas is considered a globally challenge, though water of these environments is impacted by transport of large quantities of nutrients by river waters which results in degradation of water quality of coastal environments (Rabalias, *et al.,* 1996).

Shatt Al-Arab River is the main water resource to the inner RSA which is formed by the joining of Tigris and Euphrates Rivers. These two rivers and with the associated marshes represents the nutrients organic materials more over pollutants resources (Hydrocarbon, pesticides, and trace elements; Abaychi, *et al.,* 1988). So many hydrological and environmental changes come about in the last few years which could results in alteration in water characteristics of the Rivers and NW inner RSA, among which are nutrients (Hameed, 1977; Al-Asadi, 1983; Al-Shawi, *et al.,* 2005).Many ecological studies have studied the physical, chemical, and biological aspects of Shatt Al-Arab and NW inner RSA (Table 7).

Table 7: Comparison of nutrient salts concentrations (μg/L) with previous studies

Area	Country	NO_2-N	NO_3-N	PO_4-P	SiO_2-Si	Reference
Kuwait Coast	Kuwait	-	10.6-10	0.4-0.1	-	Al-Yamani *et al*(1997)
Kuwait Bay	Kuwait	-	May-70	-2Apr	24.1-12.1	Glibert*et al*(2002)
Al-Khiran Area	Kuwait	6.1-0.1>	0.6-0.3	0.6-0.24	-	El-Sammak*et al*(2004)
Kuwait Coast	Kuwait	4.8-0.1>	27.1-0.1>	5.7-0.1>	-	Al-Yamani *et al*(2004)
Kuwait Bay	Kuwait	0.5-0.1>	14.1-0.1>	5.2-0.1>	52.5-2.0	Al-Yamani *et al*(2006)
Kuwait Bay	Kuwait	3.0-0.1>	5.7-0.1>	3.0-0.1>	32.3-0.1>	Ismail *et al*(2007)
North Kuwait	Kuwait	5.3-0.1>	111.3-0.1>	9.1-0.1>	-	Al-Yamani *et al*(2007)
Khor Al-Zubair	Iraq	1.9-0.1>	0.13.1>	0.7-0.1>	80-4.1	Al-Handal& Al-Rikabi(1994)
Iraqi Costal	Iraq	0.7-0.5	38.7-2.1	1.7-0.6	75-31	Al-Handal(2009)
Khor Al-Zubair	Iraq	5.3-0.1>	89.9-3.8	11.6-0.4	217.6-10.9	Al-Shawi (2010)
Shatt Al Arab & North west inner RSA	Iraq	0.23-1.57	3.3-26.7	0.4-7.5	61.1-72.2	SOMER (2012)

A further study, Al-Yamani et al. (2006) shows the impact of the incoming water discharge from south west of Iraq including the land wash for the southern marshes of Iraq and their general effects on the marine coast of Kuwait. Low salinity and high concentration of nutrients and chlorophyll-*a* were recorded; they conclude that Shatt Al-Arab River has noticeable effect on the north part of Kuwait marine coast. The results also show the positive role of Shatt Al-Arab River to improve the productivity of the coastal zone.

Eutrophication measurements on the north coastal area of Kuwait were estimated by further studies. Ismail et al. (2007) recorded red tide phenomena that is mainly caused by eutrophication. They also record 21 undesirable and toxic algal species that may affect marine fishes. The impact of the algal bloom of the inner RSA was studied by Thangaraja *et al.* (2007), which found most of the algal bloom belongs to the Dinoflagellates that affect the marine fishes. Monthly variation of phytoplankton in NW of inner RSA (marine coast of Kuwait) was measured by (Polikarpov et al. (2009). They show the positive role of Shatt Al-Arab to increase the nutrients content in the north coastal zone of Kuwait and lead to a high biodiversity.

Future Investigations

Limitations are inevitable in any short-term investigation and a full understanding of some of the more complex issues would require a more detailed study extending over more than two seasons. Clearly the results presented herein identify areas of data gaps and alternative theoretical rationales for various stages of NS and phytoplankton (measured by chl-a) cycling. The investigations, although intensive, represent only two seasons and were conducted years apart. The ephemeral nature of nutrient cycling and the impacts on primary productivity require more extensive research.

Furthermore, the industrial and other development within the ROPME Sea Area since 2006 is substantial and an understanding of the impacts of these developments is integral to our understanding of the ROPME Sea Area ecosystem. Continued research and support by the ROPME Member States will strengthen our understanding and provide insight to the spatial and temporal distribution of the parameters and the overall role played by each one individually. The State of the Marine Environment Reports commissioned by ROPME should assimilate the information and continue to identify areas where additional data and research is required, particularly with respect to industrial and other coastal developments throughout the region.

The results of the 2001 and 2006 cruises clearly identify the integral role of freshwater inputs to the ROPME Sea Area. In light of continuing pressures on the freshwater resources of the region, future attention and resources should be devoted to the protection and conservation of water entering the ROPME Sea Area from Iraq and Iran, including the inland dynamics and influences on these freshwater sources.

In an attempt to unify research conducted throughout the region, an effort should be made to consolidate background data and to identify a set of comparative criteria for various parameters. Currently, various jurisdictions have reference or comparative criteria to assess the health and state of degradation of the ecosystem. As a ROPME imperative, a clear legislative framework should be made in this regard.

Conclusion

The primary purpose of this report was to report nutrient salts distribution in the ROPME Sea Area from the 2001 and 2006 cruises. The postulated hypotheses for this study were:

- There is spatial distribution in the nutrient salts concentrations in the ROPME Sea Area.
- There is temporal distribution in the nutrient salts concentrations in the ROPME Sea Area.
- The NS concentration results are comparable to previous published results.

This study confirmed the above hypothesis, and the following main points summarize the key findings of this study:

- The study results indicate that the ROPME Sea Area has heterogeneity horizontal and vertical distribution for its physic-chemical as well as its biological (chl-a) properties.
- There is variability in the spatial distribution of seawater temperature, salinity, turbidity, oxygen, chl-a and NS concentrations as well as other parameters discussed in this report and other ROPME reports.
- Difference in vertical distribution is evident for temperature, turbidity, nutrients and chl-a.
- The study was able to demonstrate significant differences in the chemical and biological characteristics of the ROPME Sea Area waters between Summer 2001 and Winter 2006

Continued research and monitoring is required to fully comprehend the processes related to ecological functioning in the ROPME Sea Area. Additional pressures related to coastal development and freshwater resources must be understood in order to fully protect the ROPME Sea Area. As a ROPME imperative, a set of reference criteria should be developed for use in the ROPME Sea Area.

References

Abaychi J K, Darmoian S A and Douabul A A The Shatt Al-Arab River: A nutrient salts and organic matter source to the Arabian Gulf [Journal] // Hydrobiologia. - [s.l.] : Hydrobiologia, 1988. - Vol. 166. - pp. 217-224.

Al-Asadi M K The regime of some nutrients in Shatt Al-Arab River and number of its branches at the city of Basra [Report]. - Basra, Iraq : University of Basra, 1983.

Alosairi Yousef, Imberger Jorg and Falconer Roger Mixing and Flushing in the Arabian Gulf [Journal] // J. Geophys. Res. 116. - 2011. - p. 31.

Al-Shawi I M, Al-Rubaie A A and Resan A K Levels of nutrients in water and total organic carbon pollutionof Shatt Al-Arab river [Journal]. - [s.l.] : Basra Journal of Agriculture Science, 2005. - Vol. 18. - pp. 97-108.

Al-Yamani F. [et al.] Primary production off Kuwait, an arid zone environment, Arabian Gulf [Journal] // International Journal of Oceans and Oceanography. - 2006. - pp. 67-85.

APHA Standard Methods for examiniation of Water and Waste Water [Journal] // American Public Health Association. - 2005.

Brewer P. G and Dryssen D Chemical Oceanography of the Persian Gulf [Journal] // Prog. Oceanog. - 1985. - Vol. 14. - pp. 41-55.

Carpenter S R [et al.] Nonpoint pollution of surface waters with phosphorus and nitrogen [Journal] // Ecological Applications. - 1998. - Vol. 8. - pp. 559-568.

EAD Marine and Environmental Resources of Abu Dhabi [Report]. - [s.l.] : Environment Agency Abu Dhabi (EAD), 2007.

Hameed H A Studies on the ecology of phytoplankton of Shatt Al-Arab river at Basrah (Iraq). [Report]. - Basra, Iraq : University of Basra, 1977.

Ibrahim Emara Hosny Nutrient Salts, Inorganic and Organic Carbon Contents in the Waters of the Persian Gulf and the Gulf of Oman [Journal] // Journal of the Persian Gulf. - 2010. - pp. Vol. 1, No. 2.

Ismail W A, Al-Yamani F Y and Al-Rifaei K S Field survey and perturbation experiment in testing the role of eutrophication in initiating red tide in Kuwait bay [Journal] // International Journal of Ocean nad Oceanography. - [s.l.] : International Journal of Ocean nad Oceanography, 2007. - 1 : Vol. 2. - pp. 187-211.

NOAA National Ocean Service [Online] // National Oceanic and Atmospheric Administration Service. - 2013. - 10 October 2014. - http://oceanservice.noaa.gov/facts/upwelling.html.

Polikarpov I, Al-Yamani F and Saburova M Space-time variability of phytoplankton structure and diversity in the north-western part of the Arabian Gulf (Kuwait Water's) [Journal] // BioRisk . - [s.l.] : BioRisk, 2009. - Vol. 3. - pp. 83-96 .

Rabalias N N [et al.] Nutrient changes in the Mississippi River and system responses on the adjacent continental shelf [Journal]. - [s.l.] : Estuaries, 1996. - Vol. 19. - pp. 386-407.

Reynolds R. Michael Physical Oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman-Results from the Mt Mitchell Expedition [Journal] // Marine Pollution Bulletin, Volume 27. - 1993. - pp. 35-59.

ROPME Cruise Plan for the Oceanographic Cruise in the ROPME Sea Area - Winter 2006 [Report]. - Kuwait : ROPME, 2006.

ROPME Establishment of ROPME [Online] // www.ropme.org. - 2013. - 23 September 2014. - http://ropme.org/home.clx.

ROPME Physical Oceanography Technical Report 1 [Report]. - 2010a.

ROPME Phytoplankton in the ROPME Sea Area Technical Report 5 [Report]. - 2010b.

ROPME Spatial Distribution of Chlorophyll-a Technical Report 4 [Report]. - 2012.

Thangaraja M, Al-Aisry A and Al-Kharusi L Harmful algal blooms and their impact in the middle and outer ROPME Sea area [Journal] // International Journal of Oceans and Oceanography. - [s.l.] : International Journal of Oceans and Oceanography, 2007. - 1 : Vol. 2. - pp. 85-98.

UNEP Overview on Landbased Sources and Activities Affecting the Marine Environment in the ROPME Sea Area [Report]. - 1999.

Wetzel R G Limnology: Lake and River Ecosystems [Book]. - California : Academic Press, 2001. - 3rd : Vol. 3.

Appendix 1: Sampling Stations

	Summer 2001 Cruise			Winter 2006 Cruise		
Transect	**Station**	**Latitude**	**Longitude**	**Station**	**Latitude**	**Longitude**
T1	1	29.34183333	48.55225	1	29.35	48.48333333
	2	29.37051667	48.70556667	2	29.1789	48.64238333
	3	29.54506667	48.84393333	3	29.19968333	49.0546
	4	29.65068333	49.18631667	4	29.22075	49.44145
	5	29.75588333	49.42915	5	29.75428333	49.42166667
	6	29.78275	49.63493333	6	29.79436667	49.6268
	7	29.84825	49.87241667	7	29.86843333	49.86748333
T2	8	29.2813	50.0918	8	29.293	50.0915
	9	29.05091667	49.51648333	9	29.06	49.92646667
	10	28.93288333	49.63525	10	28.93706667	49.62733333
	11	28.81528333	49.41531667	11	28.81866667	49.41866667
	12	28.79283333	49.2267	12	28.80535	49.22213333
	13	28.67823333	48.92538333	13	28.673	48.92063333
	14	28.57516667	48.76218333	14	28.56475	48.53141667
T2a				5a	28.14168333	49.0918
				6a	28.29366667	49.36168333
				7a	28.51908333	49.82201667
				8a	28.69083333	50.08868333
				9a	28.85333333	50.40333333
T3	15	27.64935	49.51633333	15	27.66403333	49.51546667
	16	27.88238333	49.91771667	16	27.89498333	49.91866667
	17	28.00926667	50.14173333	17	28.01858333	50.1316
	18	28.11761667	50.33243333	18	28.11721667	50.33256667
	19	28.3491	50.7432	19	28.35055	50.73853333
T4	20	27.89278333	50.98998333	20	27.90683333	50.99196667
	21	27.64095	50.60916667	21	27.65695	50.6049
	22	27.38503333	50.22928333	22	27.39811667	50.23253333
	23	27.15633333	49.89031667	23	27.15935	49.87271667
T5	24	27.15633333	50.71471667	24	27.16833333	50.725
	25	27.30586667	50.9851	25	27.30483333	50.97333333
	26	27.5053	51.18418333	26	27.50828333	51.18433333

	Summer 2001 Cruise			Winter 2006 Cruise		
Transect	**Station**	**Latitude**	**Longitude**	**Station**	**Latitude**	**Longitude**
				10a	26.99666667	50.395
				11a	27.71965	51.45146667
T6	27	27.47553333	51.95011667	27	27.48666667	51.95
	28	27.29131667	51.73503333	28	27.30666667	51.725
	29	27.1284	51.52586667	29	27.11866667	51.52333333
	30	26.92956667	51.3116	30	26.95166667	51.30833333
	31	26.74783333	51.14363333	31	26.75	51.14333333
	32	26.59183333	50.92561667	32	26.58666667	50.91166667
	33	26.36381667	50.75761667	33	26.36333333	50.75833333
T7	34	26.02868333	51.52031667	34	26.04166667	51.52
	35	26.24778333	51.76821667	35	26.25	51.76666667
	36	26.4638	51.92386667	36	26.46983333	51.915
	37	26.67938333	52.15173333	37	26.70166667	52.14833333
	38	26.89656667	52.36126667	38	26.91	52.35333333
	39	27.11251667	52.57148333	39	27.11666667	52.56833333
T8	40	26.78153333	52.9385	40	26.78333333	52.95666667
	41	26.45633333	52.74078333	41	26.455	52.73833333
	42	26.10946667	52.5837	42	26.12741667	52.57491667
	43	25.70838333	52.38846667	43	25.72521667	52.38616667
	44	25.33826667	52.19676667	44	25.36833333	52.195
T9	47	24.74736667	53.769			
	48	25.25006667	52.8145			
	49	25.4291	52.90275	49	25.43483333	52.9
	50	25.564	52.96988333	50	25.58486667	52.97041667
	51	25.79666667	53.103	51	25.81041667	53.09416667
	52	26.06306667	53.303	52	26.06988333	53.30098333
				53	26.24386667	53.39218333
				54	26.44588333	53.37105
				55	26.60083333	53.40095
T10	53	26.24891667	53.38536667	56	26.34841667	53.93106667
	54	26.4305	53.36696667	57	26.07818333	53.89866667
	55	26.59865	53.40153333	58	25.88815	53.87641667
	56	26.32988333	53.93338333	59	25.66475	53.89906667
	57	26.10248333	53.90643333	60	25.421	53.81023333
	58	25.87051667	53.87946667	61	25.20578333	53.79181667
	59	25.64648333	53.84608333	62	25.20578333	53.79181667
	60	25.42361667	53.81205			
T11	61	25.18766667	53.78731667			
	62	24.98031667	53.75115			
	63	24.65585	54.61611667			
	65	25.22746667	54.56146667	65	25.2489	54.55783333
	66	25.51351667	54.6199	66	25.51816667	54.61926667
				67	25.78545	54.56198333
				68	26.04526667	54.59591667

	Summer 2001 Cruise			Winter 2006 Cruise		
Transect	**Station**	**Latitude**	**Longitude**	**Station**	**Latitude**	**Longitude**
				69	26.1397	54.45843333
T12	67	25.77905	54.6028	70	26.53506667	54.96595
	68	26.03168333	54.60283333	71	26.2	55.05
	69	26.13968333	54.42026667	72	25.95423333	55.168
	70	26.35133333	54.9817	73	25.74831667	55.2787
T13	71	26.1762	55.067	76	26.17	55.84183333
	72	25.95178333	55.15178333	77	26.34451667	55.72601667
	73	25.7575	55.24235	78	26.47948333	55.6079
T14	76	26.16401667	55.84335	79	26.85076667	56.17296667
	77	26.33448333	55.72283333	81	26.57555	56.20401667
	78	26.49855	55.61078333	82	26.39618333	56.22638333
	79	26.84881667	56.1732			
	80	26.69218333	56.18961667			
	81	26.5414	56.20681667			
T14a				14a	26.72	52.55333333
				15a	26.89333333	56.61666667
				16a	27.02333333	56.655
T15				83	26.14605	56.52945
				84	26.175	56.65833333
				85	26.21666667	56.76666667
				86	26.25	56.9
				87	26.315	57.03
T15a				18a	25.51088333	56.60373333
				19a	25.6231	56.76311667
				20a	25.74261667	56.91201667
				21a	25.89	57.18833333
T16				88	25.66738333	57.4008
				89	25.47595	57.14166667
				90	25.3385	56.9755
				91	25.18626667	56.80826667
				92	25.02233333	56.63
T17				93	24.55245	56.84565
				94	24.75	57.12
				95	24.99325	57.41263333
				96	25.19443333	57.6828
				97	25.63666667	57.9
T17a				98	25.44668333	58.61523333
				22a	25.30116667	58.48181667
				23a	24.97016667	58.105
				24a	24.60433333	57.72375
				25a	24.09175	57.23021667
T18				99	24.76893333	58.585
				100	24.39006667	58.59033333
				101	23.87366667	58.61318333
				26a	23.51666667	58.76833333

Appendix 2: Cruise Plan (ROPME 2006) including analytical methods

Cruise Plan

Oceanographic Cruise in the ROPME Sea Area
Winter 2006

Regional Organization for the Protection of the Marine Environment
State of Kuwait

CHEMICAL OCEANOGRAPHY STUDIES (COPS)

Equipment Onboard

- Rosette-Niskin assembly (12 bottles - 2.5 lit)
- Van Veen sediment grab (bite area 0.1 m2)
- Filtration system for 47 mm diameter filter
- Spectrophotometer
- Freezer (-20°C)
- Weighing balance (0.01 accuracy, 800 gm capacity)

Rosette Sampling

Water sampling with multi-bottle Rosette (Niskin) arrays, Model:

MWS 12, Hydro Bios, was done simultaneously with casting of the CTD for sampling from three different layers of Bottom, Middle and Surface of water column at all stations for determination of nutrients content of seawater.

The Rosette system had 12 bottles with 2.5 lit capacity, which every 4 of them were programmed to close 3 sets of depths, surface, middle and bottom.

After checking the water depth at the station by the vessel depth gauge, closing depth of each bottle (starting from the maximum depth for the bottle no.1 to the depth of 1m (from the sea surface) for bottle no.12 was input to the Rosette data acquisition PC and internal memory, and then the data cable was disconnected. The following routines for preparation of the Rosette deployment and retrieval were done at each station:

- The Niskin bottles were cocked prior to casting (about 15 min) to avoid on-deck contamination.

- Niskin bottles were drained by pulling the bottom cap straight down after ensuring that all sampling from the previous cast for the other studies has been fully accomplished. Bottle samplers were lowered to depths with both caps open which allowed adequate flushing during lowering.

- The top caps of all Niskin bottles were lifted up and connected loops were attached to the top of the Bottles.

Niskin Bottle Sampling

Niskin bottles were used whenever the Rosette assembly was not working due to water shallowness. They are designed to collect subsurface water samples; they are non-metallic, free-flushing sample bottles that can be lowered as a series along a wire line to the desired sampling depths. Their self-closing mechanism is activated by a messenger to close both ends thus collecting a water sample from the desired depth. The top and bottom caps are held open by a clamp against the tension of a rubber connecting them through the bottle. These bottle samplers are lowered to depths with both caps open which allows adequate flushing during lowering.

Niskin bottles alone were used to collect water samples from different depths at the same time. The bottles were attached to the wire in a series, at intervals according to the desired depths. Each bottle in a series, except the lowest (first bottle fastened to the wire), was rigged with a messenger to activate closure of the one below it. The action of a messenger released the clamp that holds the bottle open, thus closing it. The closure also released a messenger which slided down the wire to trip the next bottle and so on until the lowest bottle was closed. Prior to retrieval, the bottles were kept suspended for about 1 minute for the wire line to be stabilized at the desired depth. The samplers were then hauled in on deck and the water samples were obtained by opening the stopcock.

Nutrient Analysis On-Board

Spectrophotometer

On board chemical analysis of water samples for nutrient measurement was carried out, using 1 unit of Cecil 4003 spectrophotometer.

A spectrophotometer is a photometer (a device for measuring light intensity) that can measure intensity as a function of the color, or more specifically, the wavelength of light. It is in fact a detector instrument that measures the amount of monchromatic light passing through a solution by means of an adjustable monochromator such as a prism or diffraction grating.

For calibration curve, in the case of any nutrient a blank and at least four calibration standards in graduated amounts in the appropriate range was prepared. To be able to avoid the complexity of the sample matrix, the best way is to use the method of standard addition. This technique relies on the addition of small, known amounts of the given nutrient to portions of the sample and the absorbance difference between those and the original sample (blank) giving the slope of the calibration curve. Generally, in the method of standard addition, equal volumes of sample are added to a deionized distilled water blank and at least to three standards containing different known amounts of determinant. The volume of the blank and the standards must be the same. The absorbance of each solution is determined and then plotted on the vertical axis of a graph, with the concentrations of the known standards plotted on the horizontal axis. When the resulting line is extrapolated back to zero absorbance, the point of interception of the abscissa is the concentration of the unknown. The abscissa on the left of the ordinate is stalled the same as on the right side, but in the opposite direction from the ordinate. The slope of the plot can be considered as the slope of the calibration curve.

<u>Phosphate - P04</u>

The phosphate ions in the sample react in acidic solution with ammonium molybdate to yield a phosphomolybdate complex. This heteropoly acid is reduced by ascorbic acid with trivalent antimony ions as catalyst to a blue-colored complex, the absorbance of which is then measured in a spectrophotometer at 882 nm. In order to obtain a rapid color development and to depress the interference to silicate, it is important that the final reaction pH is less than 1, and that the ratio between sulphuric acid (in mol/1) and molybdate is kept between 2 and 3 percent.

- **Reagents:**

1. Mixed reagent (Sulphuric acid 9N, Ammonium heptamolybdate solution, Potassium antimonyltrutrate solution)
2. Ascorbic acid

- **Analysis of samples:**

1. 50 ml of the filtered sample transferred reaction flask by means of the graduated cylinder.
2. 1.5 ml of the mixed reagent was added and mixed well.
3. 1.5 ml of ascorbic acid solution was added to the sample and mixed well.
4. After l 0-15 minutes the absorbance of the sample was measured at 882 nm.

<u>Ammoniacal-N</u>

In moderately alkaline solution ammonia reacts with hypochlorite to form monochloramine which, in the presence of phenol, catalytic amounts of nitroprusside ions and excess hypochlorite, gives indophenol blue. The reaction is quantitative in the pH range between 10.8 and 11.4. The precipitation of magnesium and calcium hydroxides in the sample solution (occurring at a pH higher than 9.6) is avoided by the addition of a complexing reagent (citrate) which keeps the Mg and Ca ions in solution.

- **Reagents:**

1. Phenol reagent
2. Buffer solution
3. Hypochlorite reagent

- **Analysis of samples:**

1. 50 ml of the sample was measured with a graduated cylinder and transferred into reaction flasks.
2. 2 ml phenol reagent was added and mixed well.
3. 1 ml buffer solution was added and mixed well.
4. 2 ml hypochlorite reagent was added and mixed well.
5. The reaction bottles was closed properly and kept in a dark place for at least 6 hours.
6. The absorbance of the sample was measured at 630 nm.

<u>Nitrite-N</u>

The determination of nitrite is based on the reaction of nitrite with an aromatic amine (sulphanilamide) which leads (at pH 1.5 - 2.0) to the fonnation of a diazonium compound. This diazo compound then couples with a second aromatic amine N-(1-naphthyl)-ethylenediamine to form the highly colored azo dye.

- Reagents:

1. Sulphanilamide
2. N-(1-naphthyl)-ethylenediamine

- Analysis of samples:

1. 50 ml of the sample was transferred into the reaction bottle.
2. 1 ml of the sulphanilamide reagent was added and mixed well.
3. After reaction time of 1 minute, 1 ml of the diamine solution was added and mixed well to allow the azo dye to develop.
4. After 20-30 minutes the absorbance of the sample was measured at 540 nm.

<u>Nitrate- NO3</u>

Nitrate is reduced to nitrite in a reduction column filled with copper-coated cadmium granules. The yield of the reduction depends of the pH of the solution and on the activity of the metal surface. The conditions of the reduction described in the method are adjusted to a pH of about 8.5, so that nitrate is converted to nitrite almost quantitatively (90-95%) and not reduced further. Ammonium chloride buffer is used to control the pH and to complex the liberated cadmium ions.

- **Reagents:**

1. Ammonium chloride buffer
2. Sulphanilamide
3. N-(1-naphthyl)-ethylenediamine

- **Preparation of the reduction column:**

Commercially available granulated cadmium was sieved and the fraction between 40 and 60 mesh was retained and used. The sieved cadmium granules were freed from oxides by washing them in 2 mol/1 hydrochloric acid. Then the granules shook in a 200 ml beaker vigorously for about 3 min with I 00 ml of the copper sulphate solution. Afterwards the copperized cadmium granules were rinsed under gentle shaking, the washing continued until the water was free from finely dispersed copper.

Then the copperized granules were poured into the reduction column with the aid of distilled water and a funnel.

The metal activated by passing through about 250 ml buffer solution (ammonium chloride) containing about l00µmol/1 nitrate. Then the column rinsed thoroughly with buffer solution. The reduction efficiency of the reduction
column was checked by analyzing a nitrate standard solution of suitable concentration.

- **Analysis of samples:**

1. 25 ml of the sample was transferred into the reaction flask.
2. 25 ml of the ammonium chloride buffer was added and mixed well.

3. About 20 ml of the mixture was passed through the reduction column in order to rinse the system. This fraction was discarded.
4. Another fraction was passed through the column until the level in the Erlenmeyer flask had reached the 25 ml mark.
5. 0.5 ml of the sulphanilamide reagent was added and mixed well.
6. 0.5 ml of N- (1-naphthyl I)-ethylenediamine was added and mixed well.
7. After 1 hour the absorbance of the sample was measured at 540 nm.

Silicate-Si

Reactive silicate in acid solution, forms a heteropoly acid when treated with molybdate ions. This silicomolybdic complex exists in two isomeric forms depending on the pH at formation. The isomers have different stabilities, are both yellow colored, showing however, only low molar absorptivities in the range of about 1200 and 3300 absorbance units/mole. Therefore the heteropoly acids are reduced to intensely blue-colored complexes by addition of oxalic acid (to avoid the reduction of any excess molybdate reagent and to eliminate the influence of any phosphate present) and the use of ascorbic acid as the reductant.

- **Reagents:**

1. Mixed reagent (Sulphoric acid 7.2N and Ammonium heptamolybdate solution)
2. Oxalic acid
3. Ascorbic Acid

- **Analysis of samples:**

1. 50 ml of the sample was transferred into a plastic reaction bottle.
2. 1.5 ml of the mixed reagent was added and mixed well.
3. After 10-20 minutes, 1 ml of oxalic acid was added and mixed well.
4. I ml of ascorbic acid was added immediately and mixed well.
5. The absorbance of the sample was measured after 30-40 minutes at 810 nm.

The number of samples collected during the cruise is summarized in table 4.

Appendix 3: Descriptive Analysis

Descriptive analysis (Summer Cruise 2001)

		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
Temperature (°C)															
Surface	**Avg.**	33.04	33.49	33.99	34.30	34.54	34.27	34.55	33.81	33.87	33.34	33.48	32.87	32.22	31.98
	Min	32.44	32.86	32.96	33.45	34.36	33.76	33.55	33.29	33.65	32.99	33.32	32.64	32.13	29.91
	Max	33.80	34.01	35.47	34.95	34.72	34.62	35.01	34.18	34.05	33.56	33.62	33.09	32.33	32.70
	SD	0.43	0.45	0.86	0.56	0.15	0.33	0.53	0.38	0.13	0.17	0.12	0.16	0.08	1.05
Middle	**Avg.**	32.91	32.69	30.08	30.82	25.80	30.80	32.23	30.62	30.21	26.63	33.25	29.25	30.92	31.26
	Min	32.28	30.47	24.00	28.18	23.93	22.75	31.19	26.17	23.11	21.48	32.95	25.50	29.71	28.68
	Max	33.80	33.64	33.37	33.03	28.86	34.60	33.10	33.43	34.07	32.80	33.57	32.50	32.09	32.62
	SD	0.50	0.95	3.20	1.92	2.18	4.46	0.69	3.19	3.62	4.17	0.25	2.52	0.97	1.40
Bottom	**Avg.**	32.89	29.88	25.77	24.57	21.97	28.17	24.98	25.56	27.83	22.56	32.22	23.44	24.52	26.84
	Min	32.10	25.20	22.29	21.30	21.40	21.71	21.14	20.91	20.70	20.53	29.11	21.41	21.19	22.43
	Max	34.05	32.80	33.48	32.46	23.07	35.46	31.55	33.13	34.21	29.66	33.64	28.25	30.03	31.43
	SD	0.61	2.84	4.31	4.58	0.78	5.73	4.13	4.95	4.37	3.11	1.69	2.82	3.92	3.66
Depth (m)															
Surface	**Avg.**	2.00	3.00	3.00	3.40	3.00	2.71	2.83	3.00	3.00	3.00	3.00	3.25	3.67	3.67
	Min	1.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00
	Max	3.00	3.00	7.00	3.00	3.00	3.00	3.00	3.00	4.00	3.00	3.00	4.00	4.00	4.00
	SD	0.53	0.00	0.00	0.00	0.00	0.45	0.37	0.00	0.58	0.00	0.00	0.43	0.47	0.47
Middle	**Avg.**	6.14	17.14	20.20	19.60	29.33	19.71	22.67	23.60	17.67	30.88	11.80	29.00	27.00	26.67
	Min	5.00	9.00	9.00	17.00	29.00	7.00	7.00	8.00	7.00	13.00	9.00	18.00	15.00	16.00
	Max	9.00	22.00	24.00	26.00	30.00	35.00	32.00	36.00	32.00	41.00	16.00	39.00	36.00	35.00
	SD	1.25	3.91	5.81	3.63	0.47	10.32	9.41	11.88	8.38	9.18	2.48	7.45	8.83	7.52
Bottom	**Avg.**	12.57	32.43	40.40	38.40	58.33	38.29	45.00	47.60	34.67	63.88	24.80	59.75	53.33	53.33
	Min	10.00	18.00	16.00	34.00	58.00	11.00	11.00	14.00	16.00	27.00	16.00	38.00	29.00	30.00
	Max	16.00	40.00	49.00	53.00	59.00	68.00	66.00	74.00	65.00	80.00	34.00	78.00	71.00	73.00
	SD	1.99	6.43	12.66	7.46	0.47	21.12	20.32	24.31	17.36	17.26	8.06	14.46	17.78	17.22
Dissolved Oxygen (mg/L)															
Surface	**Avg.**	4.95	5.12	5.11	5.06	5.17	4.96	5.59	5.01	5.11	5.47	5.18	5.40	5.34	5.41
	Min	4.72	5.00	4.97	4.90	5.07	4.00	4.57	4.68	4.66	5.13	4.63	5.30	5.27	4.87

		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
	Max	5.16	5.27	5.21	5.28	5.28	6.04	6.35	5.36	5.56	5.70	5.62	5.52	5.41	5.69
	SD	0.17	0.09	0.09	0.14	0.09	0.60	0.57	0.27	0.31	0.21	0.35	0.08	0.06	0.27
Middle	**Avg.**	4.97	5.36	4.98	5.41	5.20	4.64	4.39	4.66	5.39	4.45	5.09	4.83	4.70	4.94
	Min	4.74	5.06	4.59	4.72	4.41	3.82	3.68	3.90	4.68	3.87	4.64	3.94	3.70	3.99
	Max	5.21	5.88	5.62	5.94	5.69	5.39	5.73	5.48	5.82	5.59	5.55	5.42	5.54	5.70
	SD	0.17	0.30	0.35	0.44	0.57	0.57	0.66	0.51	0.42	0.56	0.34	0.58	0.76	0.59
Bottom	**Avg.**	4.71	3.09	2.92	3.28	3.52	3.92	3.60	3.45	3.31	3.29	3.77	3.47	3.82	3.88
	Min	4.35	2.41	1.80	2.62	3.28	3.07	2.68	2.59	2.84	3.07	2.61	2.95	3.32	2.97
	Max	5.07	5.05	4.77	4.28	3.80	4.77	4.20	4.23	4.54	3.63	4.62	4.23	4.58	5.20
	SD	0.24	0.88	1.01	0.62	0.21	0.55	0.57	0.53	0.56	0.17	0.94	0.47	0.55	0.75
pH															
Surface	**Avg.**	7.95	8.03	8.06	8.06	8.09	8.02	8.13	8.13	8.13	8.11	8.08	8.13	8.15	8.15
	Min	7.92	7.98	7.96	7.98	8.07	7.96	8.01	8.08	8.07	8.09	8.05	8.10	8.12	8.09
	Max	8.00	8.07	8.10	8.11	8.10	8.15	8.20	8.16	8.16	8.13	8.11	8.14	8.16	8.18
	SD	0.03	0.03	0.05	0.05	0.01	0.07	0.06	0.03	0.03	0.01	0.03	0.02	0.02	0.03
Middle	**Avg.**	7.95	8.01	7.99	8.00	8.02	7.98	8.01	8.08	8.11	8.02	8.08	8.06	8.08	8.12
	Min	7.92	7.96	7.95	7.93	8.01	7.92	7.95	8.03	8.07	7.97	8.05	8.01	8.00	8.05
	Max	8.00	8.06	8.03	8.04	8.03	8.07	8.09	8.14	8.15	8.12	8.11	8.13	8.15	8.17
	SD	0.03	0.03	0.03	0.04	0.01	0.05	0.04	0.05	0.03	0.05	0.02	0.05	0.06	0.05
Bottom	**Avg.**	7.94	7.84	7.92	7.94	8.01	7.95	7.98	8.05	8.03	7.99	7.99	7.99	8.01	8.05
	Min	7.90	7.77	7.88	7.90	8.00	7.93	7.91	8.02	8.01	7.98	7.87	7.95	7.99	7.99
	Max	7.99	7.94	7.94	7.96	8.01	8.00	8.03	8.06	8.05	8.00	8.06	8.01	8.03	8.12
	SD	0.03	0.06	0.02	0.03	0.01	0.02	0.04	0.02	0.02	0.01	0.07	0.02	0.02	0.05
Chlorophyll-a (mg/m^3)															
Surface	**Avg.**	0.65	0.20	0.22	0.17	0.12	0.37	0.38	0.52	0.39	0.30	0.56	0.25	0.40	0.54
	Min	0.29	0.06	0.16	0.13	0.11	0.15	0.18	0.17	0.14	0.18	0.21	0.13	0.13	0.25
	Max	1.53	0.31	0.35	0.23	0.13	0.76	1.00	1.20	0.61	0.49	1.15	0.36	0.66	1.04
	SD	0.40	0.08	0.07	0.04	0.01	0.22	0.29	0.36	0.16	0.08	0.33	0.11	0.22	0.26
Middle	**Avg.**	0.90	0.52	1.75	1.18	2.91	1.01	0.93	1.40	1.78	1.01	0.92	1.73	0.89	0.69
	Min	0.36	0.35	0.20	0.78	1.23	0.39	0.22	0.40	0.49	0.33	0.49	0.42	0.80	0.26
	Max	1.50	0.98	7.00	1.88	6.03	2.22	1.73	2.39	3.63	3.06	1.20	3.30	1.05	1.14
	SD	0.42	0.20	0.58	0.42	2.21	0.64	0.54	0.65	1.00	0.87	0.25	1.26	0.11	0.30

		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
Bottom	**Avg.**	1.19	1.17	1.66	0.39	0.35	0.50	0.66	0.72	0.84	0.43	1.20	0.19	0.51	0.17
	Min	0.57	0.47	0.30	0.21	0.30	0.19	0.10	0.07	0.25	0.09	1.05	0.16	0.10	0.08
	Max	1.78	2.79	7.00	0.65	0.39	0.79	1.87	2.04	2.25	1.79	1.29	0.21	1.31	0.36
	SD	0.41	0.72	0.26	0.16	0.04	0.25	0.64	0.72	0.66	0.54	0.11	0.02	0.57	0.11
Turbidity															
Surface	**Avg.**	6.06	1.78	1.79	1.68	1.88	1.97	1.95	1.79	1.70	1.54	1.65	1.44	2.06	2.05
	Min	3.21	1.60	1.62	1.55	1.66	1.72	1.76	1.49	1.54	1.37	1.30	1.26	1.77	1.84
	Max	9.82	1.97	2.19	1.75	2.22	2.22	2.29	2.23	2.00	1.76	2.24	1.54	2.47	2.35
	SD	2.63	0.10	0.22	0.08	0.24	0.16	0.19	0.24	0.17	0.12	0.35	0.11	0.30	0.18
Middle	**Avg.**	6.87	1.81	1.93	1.93	2.02	1.97	1.88	1.76	1.88	1.65	1.67	1.43	1.79	2.13
	Min	2.75	1.66	1.66	1.81	2.02	1.74	1.49	1.44	1.58	1.25	1.40	1.23	1.69	1.79
	Max	12.27	2.01	2.64	2.20	2.03	2.23	2.71	2.22	2.15	2.24	2.06	1.71	1.97	2.37
	SD	3.30	0.12	0.36	0.16	0.00	0.19	0.39	0.28	0.18	0.31	0.24	0.17	0.13	0.22
Bottom	**Avg.**	12.94	5.58	5.17	3.80	3.52	3.37	2.99	2.64	2.90	2.12	2.61	3.64	2.30	4.64
	Min	6.58	3.94	2.85	2.71	2.74	2.18	1.88	1.83	2.13	1.74	1.32	2.37	2.05	3.10
	Max	19.99	6.53	8.43	5.81	3.94	6.15	5.63	3.49	5.32	2.71	4.11	7.26	2.55	7.42
	SD	4.76	0.83	2.29	1.21	0.55	1.42	1.24	0.65	1.11	0.34	1.13	2.09	0.20	1.60
Salinity (psu)															
Surface	**Avg.**	40.30	39.82	39.51	39.45	39.40	39.41	38.83	39.14	39.81	39.06	39.95	39.15	37.72	37.52
	Min	39.48	39.23	38.85	39.10	39.25	38.28	38.28	38.11	39.33	38.01	39.40	37.90	37.55	37.20
	Max	41.07	40.31	40.34	40.06	39.53	40.00	40.16	40.10	40.84	39.62	40.16	39.69	38.03	37.80
	SD	0.53	0.35	0.57	0.36	0.11	0.56	0.67	0.80	0.49	0.63	0.29	0.73	0.22	0.18
Middle	**Avg.**	40.53	40.05	39.90	39.98	40.55	40.20	38.99	39.81	39.85	39.91	40.00	39.50	38.45	37.86
	Min	39.48	39.21	39.33	39.32	40.48	39.34	38.28	39.13	39.11	38.70	39.40	38.00	37.59	37.30
	Max	41.20	40.76	40.60	40.58	40.62	40.93	40.01	40.07	40.82	40.51	40.30	40.40	39.68	39.00
	SD	0.58	0.52	0.49	0.48	0.06	0.62	0.55	0.34	0.55	0.56	0.32	0.90	0.89	0.60
Bottom	**Avg.**	40.67	40.52	40.44	40.76	40.80	40.19	40.33	40.41	40.26	40.37	40.17	40.19	39.90	39.04
	Min	39.79	39.66	40.19	40.65	40.79	38.70	39.72	40.07	39.78	39.94	39.87	39.70	38.99	37.44
	Max	41.35	41.10	40.80	40.96	40.82	40.92	40.83	40.80	40.71	40.51	40.40	40.43	40.45	40.32
	SD	0.50	0.57	0.23	0.12	0.01	0.75	0.37	0.30	0.33	0.18	0.18	0.29	0.65	1.11
Nitrate (µg/L)															
Surface	**Avg.**	14.94	8.99	30.08	24.73	11.74	91.76	1.82	4.47	18.76	24.56	67.10	14.33	26.19	45.90

		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
	Min	5.87	0.67	9.33	15.93	4.67	3.73	0.00	0.00	0.00	11.93	6.30	0.00	15.57	0.00
	Max	30.53	18.70	47.27	35.00	15.47	141.73	4.47	14.00	42.43	38.40	270.97	28.60	43.73	258.27
	SD	8.82	6.80	15.14	6.80	5.00	39.42	1.75	5.27	13.94	10.33	102.25	12.49	12.49	95.03
Middle	**Avg.**	25.61	10.86	53.36	29.67	158.20	159.15	83.30	174.66	74.15	343.05	18.08	354.29	301.11	130.79
	Min	7.93	0.00	18.67	21.13	36.33	21.50	1.57	7.27	7.63	31.93	7.07	97.47	3.61	0.00
	Max	71.47	19.87	107.00	39.67	381.33	475.67	225.60	414.00	334.33	568.17	42.23	521.67	586.40	351.27
	SD	19.40	7.30	29.14	6.81	158.00	147.14	75.83	134.04	117.24	158.46	13.25	157.70	238.08	123.37
Bottom	**Avg.**	32.83	294.54	376.06	524.79	492.44	331.33	278.04	331.95	208.60	540.60	253.23	319.61	365.75	409.09
	Min	14.13	14.80	35.60	373.50	472.33	65.53	0.00	12.93	7.83	338.50	5.30	36.33	221.93	155.87
	Max	69.73	633.33	712.00	649.83	509.33	571.83	525.67	655.17	616.17	651.00	804.13	531.27	547.00	580.80
	SD	16.72	199.91	293.88	99.02	15.28	202.05	201.96	222.04	228.04	88.61	315.76	178.62	135.32	160.11
Nitrite (µg/L)															
Surface	**Avg.**	0.79	0.09	0.82	0.15	0.28	3.53	0.67	0.68	1.71	0.72	2.25	0.90	1.64	4.13
	Min	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	3.17	0.57	2.00	0.53	0.50	12.40	2.40	3.40	5.87	2.77	7.37	3.60	3.80	15.63
	SD	1.12	0.20	0.76	0.22	0.21	3.68	0.83	1.36	2.11	0.89	2.72	1.56	1.59	5.35
Middle	**Avg.**	1.62	0.15	13.45	2.37	14.92	8.61	33.46	38.52	8.47	24.47	1.45	24.43	28.80	20.77
	Min	0.00	0.00	0.00	0.13	8.53	0.00	0.43	0.10	0.00	4.00	0.00	0.20	2.50	0.00
	Max	4.17	0.63	48.13	5.47	19.67	30.93	72.93	70.00	35.00	63.33	2.77	49.40	42.17	60.05
	SD	1.47	0.25	17.78	2.10	4.69	9.66	25.93	28.26	12.11	17.32	1.11	17.85	18.60	18.80
Bottom	**Avg.**	2.92	42.76	9.29	26.12	8.79	7.69	13.01	13.05	14.68	14.30	37.25	23.62	29.13	28.44
	Min	0.30	0.00	1.40	3.50	5.23	1.77	0.00	0.03	0.00	2.97	0.00	6.63	0.53	1.83
	Max	6.83	108.07	22.33	83.60	11.30	12.93	43.37	51.57	42.90	57.27	170.97	71.27	76.77	95.90
	SD	2.17	35.74	7.02	33.27	2.59	3.38	14.13	19.55	15.11	17.58	67.01	27.52	33.91	31.43
Silicate (µg/L)															
Surface	**Avg.**	139.83	18.48	36.39	22.58	7.62	18.96	5.43	6.37	2.97	18.16	24.27	6.25	18.30	7.08
	Min	0.00	0.00	14.83	8.87	5.33	3.00	0.00	0.00	0.00	5.67	2.30	0.00	8.60	0.17
	Max	303.77	68.63	92.53	52.47	9.87	47.47	20.37	15.20	10.87	55.30	74.53	11.03	32.10	15.00
	SD	106.21	23.54	28.82	17.46	1.85	14.30	7.11	6.58	4.35	16.01	25.95	4.55	10.02	6.08
Middle	**Avg.**	142.71	29.63	68.12	33.91	66.47	45.59	38.92	41.24	14.95	79.66	11.75	47.81	49.98	25.59
	Min	0.00	0.00	0.63	1.30	24.17	5.43	10.73	7.57	0.00	16.50	3.03	8.93	10.30	8.30
	Max	304.83	70.00	133.70	91.00	148.53	142.07	112.00	125.07	52.97	151.93	27.20	82.47	74.33	55.07

		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
	SD	104.36	23.66	53.04	34.93	58.04	41.48	33.99	43.41	20.87	40.89	8.27	26.99	28.30	17.31
Bottom	**Avg.**	144.13	225.34	169.38	230.54	171.73	109.17	128.62	109.79	75.80	152.43	65.82	142.75	105.82	89.87
	Min	0.00	85.30	2.87	191.13	157.53	27.77	0.00	22.70	0.00	65.47	10.80	108.53	43.40	21.03
	Max	324.43	299.83	296.17	304.50	184.87	176.27	227.13	177.53	232.70	242.53	214.73	196.53	154.00	186.83
	SD	108.24	68.75	99.03	43.81	11.19	60.31	86.62	59.17	81.22	67.55	76.79	33.15	46.26	56.65
Phosphate (μg/L)															
Surface	**Avg.**	22.59	0.14	100.37	29.04	0.17	1.43	2.86	5.90	3.64	6.02	8.80	4.83	5.51	14.51
	Min	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.33	0.00	0.00	1.67	1.83	5.00	2.57
	Max	77.50	0.67	448.00	102.00	0.33	3.83	6.33	13.00	8.50	20.33	33.33	6.33	5.87	43.33
	SD	25.16	0.24	174.36	42.23	0.13	1.31	2.88	3.78	3.54	6.75	12.29	1.78	0.37	14.07
Middle	**Avg.**	26.38	2.52	18.37	14.09	32.28	19.69	14.95	25.10	13.39	53.65	15.87	38.09	31.17	30.25
	Min	0.00	0.00	0.00	1.50	14.33	0.17	4.83	6.00	0.00	5.67	3.50	10.17	10.50	9.83
	Max	100.33	9.00	64.33	21.17	59.33	68.67	30.50	64.50	50.33	78.17	78.17	67.67	41.50	60.67
	SD	32.45	2.93	22.48	7.81	19.47	22.09	10.06	20.36	17.33	22.62	2.09	23.25	14.61	17.48
Bottom	**Avg.**	32.24	45.62	89.61	73.13	69.45	52.50	55.92	55.30	42.61	85.42	38.26	88.38	72.00	88.39
	Min	0.00	0.00	0.00	33.00	66.17	2.67	0.00	7.83	3.50	36.67	3.50	67.83	36.67	46.17
	Max	120.67	102.50	247.33	91.00	72.50	94.50	97.00	98.33	99.83	121.67	121.67	99.17	91.33	127.67
	SD	39.43	32.86	82.35	23.36	2.59	38.76	36.18	33.42	35.82	23.03	34.54	12.70	25.02	25.90
Ammonia (μg/L)															
Surface	**Avg.**	18.05	14.46	19.86	13.92	17.37	20.86	4.72	2.40	2.97	5.80	5.12	2.12	3.72	2.69
	Min	8.72	4.90	8.90	3.38	5.68	10.88	0.00	0.00	0.00	0.45	1.33	1.07	2.77	1.15
	Max	30.20	24.15	31.47	25.03	38.07	34.93	7.78	9.43	10.00	10.97	11.97	4.02	4.38	3.72
	SD	7.21	6.31	9.72	8.94	14.68	10.09	2.91	3.57	3.38	3.55	3.73	1.14	0.69	0.93
Middle	**Avg.**	14.59	11.82	17.04	11.54	14.97	18.73	4.46	2.29	2.57	6.02	3.52	1.78	3.26	5.08
	Min	7.87	5.15	10.70	3.68	3.58	10.15	0.00	0.00	0.00	0.82	1.38	1.10	1.73	2.52
	Max	25.43	18.40	26.53	19.67	35.40	36.40	8.03	5.35	7.80	9.58	5.73	2.93	5.12	12.27
	SD	5.38	4.44	7.07	6.31	14.48	9.38	2.82	2.30	2.62	2.97	1.60	0.69	1.40	3.33
Bottom	**Avg.**	14.19	9.94	15.21	11.38	11.47	15.01	4.68	1.87	2.62	5.53	6.37	2.50	5.34	5.79
	Min	4.80	6.62	6.25	1.68	4.68	5.10	0.00	0.00	0.00	0.57	1.02	1.02	4.47	2.53
	Max	22.38	12.82	25.37	16.77	24.07	21.67	7.27	5.82	8.37	9.20	19.03	6.53	6.53	13.58
	SD	5.52	1.94	7.90	5.75	8.92	5.94	2.75	2.13	2.89	2.95	6.58	2.33	0.87	3.61

Descriptive analysis (Winter Cruise 2006)

		T1	T2	T2a	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T14a	T15	T15a	T16	T17	T17a	T18
Temperature (°C)																							
Surface	**Avg**	18.62	18.65	19.00	19.62	19.87	21.33	20.55	20.90	21.00	21.74	22.21	23.47	23.39	23.46	23.31	23.08	23.43	23.25	23.22	23.08	23.03	21.10
	Min	17.90	17.38	17.92	19.50	19.34	19.73	19.59	19.63	20.13	20.96	21.89	23.04	23.18	23.07	23.09	22.88	23.19	22.99	22.58	22.85	22.52	17.92
	Max	19.37	19.48	19.47	19.78	20.20	25.14	21.53	21.57	21.52	22.26	22.43	23.77	23.59	23.77	23.43	23.24	23.69	23.51	23.61	23.23	23.38	23.38
	SD	0.53	0.74	0.57	0.10	0.36	1.95	0.61	0.72	0.53	0.47	0.18	0.24	0.15	0.29	0.16	0.15	0.22	0.19	0.34	0.13	0.29	2.56
Middle	**Avg**	17.96	18.05	18.23	19.32	19.55	20.01	20.27	20.92	20.93	21.64	22.08	22.53	22.76	22.73	22.75	22.83	23.11	22.87	22.78	22.88	22.74	20.83
	Min	17.50	17.26	17.45	19.10	19.08	19.44	19.12	19.63	20.14	20.96	21.57	22.04	22.45	22.61	22.62	22.77	22.81	22.78	22.21	22.51	22.33	17.63
	Max	18.78	18.73	18.98	19.50	19.87	20.97	21.42	22.06	21.35	22.24	22.58	22.73	23.12	22.90	22.86	22.91	23.75	22.96	22.93	23.01	23.02	23.08
	SD	0.42	0.47	0.63	0.16	0.29	0.53	0.67	0.82	0.46	0.41	0.36	0.25	0.28	0.12	0.10	0.06	0.36	0.06	0.28	0.19	0.25	2.58
Bottom	**Avg**	17.56	17.85	18.08	19.08	19.15	19.54	20.19	20.43	20.75	21.42	21.64	21.85	22.48	22.61	22.52	22.64	22.97	22.94	22.22	22.78	22.19	20.19
	Min	17.27	16.59	17.33	18.89	18.77	18.33	18.92	19.63	20.14	20.89	21.35	20.96	22.34	22.57	22.42	22.54	22.69	22.33	21.31	22.53	21.02	17.51
	Max	17.97	18.44	18.92	19.47	19.59	20.97	21.47	21.70	21.03	21.89	21.87	22.46	22.78	22.65	22.62	22.78	23.14	23.35	22.71	23.02	22.78	23.04
	SD	0.25	0.64	0.59	0.20	0.35	0.85	0.70	0.77	0.32	0.32	0.15	0.49	0.18	0.03	0.08	0.10	0.18	0.38	0.49	0.16	0.66	2.26
Depth (m)																							
Surface	**Avg**	2.14	3.00	3.00	3.00	3.00	2.80	2.71	2.83	3.00	3.29	3.00	3.00	3.75	4.00	3.67	3.00	22.80	3.00	3.00	3.00	3.00	2.80
	Min	1.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00
	Max	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	4.00	3.00	3.00	4.00	4.00	4.00	3.00	70.00	3.00	3.00	3.00	3.00	3.00
	SD	0.64	0.00	0.00	0.00	0.00	0.40	0.45	0.37	0.00	0.45	0.00	0.00	0.43	0.00	0.47	0.00	26.66	0.00	0.00	0.00	0.00	0.40
Middle	**Avg**	8.71	17.00	17.80	19.60	23.25	21.00	20.00	22.67	23.40	27.57	20.86	20.60	24.75	26.67	18.33	15.67	34.40	41.25	44.00	40.00	41.67	28.40
	Min	5.00	8.00	8.00	6.00	17.00	7.00	7.00	7.00	7.00	15.00	3.00	3.00	15.00	19.00	4.00	11.00	11.00	24.00	25.00	25.00	25.00	6.00
	Max	18.00	22.00	24.00	24.00	26.00	29.00	35.00	32.00	36.00	35.00	41.00	39.00	36.00	35.00	35.00	24.00	70.00	48.00	50.00	50.00	50.00	50.00
	SD	4.74	4.21	5.71	6.97	3.63	9.88	10.24	9.41	12.14	8.31	14.79	14.83	8.26	6.55	12.76	5.91	19.64	10.03	9.70	12.25	11.79	18.70
Bottom	**Avg**	17.43	33.71	35.40	39.60	47.25	41.40	38.71	45.00	47.40	56.14	42.14	41.60	50.00	54.67	35.33	31.33	47.80	82.25	88.00	78.00	81.67	55.20
	Min	10.00	16.00	16.00	11.00	35.00	11.00	11.00	11.00	12.00	30.00	3.00	3.00	29.00	40.00	4.00	22.00	22.00	47.00	50.00	45.00	45.00	11.00
	Max	35.00	43.00	48.00	49.00	53.00	58.00	68.00	66.00	74.00	73.00	82.00	80.00	72.00	72.00	70.00	47.00	70.00	96.00	100.00	100.00	100.00	100.00
	SD	8.96	7.99	11.31	14.72	7.15	20.63	20.86	20.32	24.69	17.50	31.02	32.33	16.63	13.20	27.05	11.15	17.99	20.50	19.39	26.94	25.93	38.24
Dissolved Oxygen (mg/L)																							
Surface	**Avg**	7.96	7.50	7.48	7.31	7.32	7.35	7.34	7.44	6.64	6.69	6.78	7.29	7.78	8.12	7.12	7.33	7.04	6.21	6.94	5.97	5.49	6.72
	Min	7.32	7.21	7.42	7.09	7.26	6.91	7.02	7.01	6.54	6.48	6.48	7.01	7.03	7.00	6.68	6.93	6.51	6.00	6.76	5.54	5.08	5.79
	Max	8.86	8.30	7.63	7.44	7.41	7.81	7.69	8.20	6.75	6.83	6.94	7.76	9.75	9.00	7.71	7.54	8.25	6.45	7.21	6.62	6.57	7.66

		T1	T2	T2a	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T14a	T15	T15a	T16	T17	T17a	T18
	SD	0.59	0.34	0.08	0.12	0.06	0.30	0.21	0.45	0.08	0.13	0.14	0.26	1.14	0.83	0.43	0.29	0.65	0.16	0.17	0.37	0.50	0.74
Middle	**Avg**	8.16	7.66	7.76	7.39	7.43	7.27	7.24	7.17	6.48	6.24	6.37	6.60	6.68	6.40	6.02	6.99	5.66	5.19	5.40	5.12	5.30	6.71
	Min	7.61	7.43	7.53	7.13	7.37	6.94	7.05	5.67	5.79	5.40	5.47	5.79	6.36	5.79	5.47	6.20	4.23	4.73	5.13	5.02	4.69	5.82
	Max	8.87	8.32	8.24	7.57	7.47	7.44	7.47	8.04	6.75	6.76	7.08	7.39	7.00	7.51	6.98	7.43	6.64	5.54	6.00	5.19	6.74	7.83
	SD	0.51	0.28	0.25	0.14	0.04	0.18	0.17	0.73	0.35	0.52	0.52	0.58	0.25	0.79	0.68	0.56	0.79	0.29	0.32	0.07	0.68	0.87
Bottom	**Avg**	8.15	7.47	7.60	7.15	7.06	6.98	7.00	6.70	6.24	6.01	18.34	5.92	5.94	5.42	5.69	6.19	5.38	5.03	4.18	5.07	3.92	5.44
	Min	7.41	7.23	7.26	7.05	6.71	6.64	6.51	5.85	5.81	5.44	5.59	5.62	5.30	4.97	5.19	5.74	4.75	4.80	2.03	4.77	0.96	2.91
	Max	9.05	7.95	8.26	7.26	7.27	7.40	7.36	7.17	6.73	6.68	90.90	6.66	6.52	6.21	6.61	6.55	6.36	5.39	5.62	5.46	5.19	7.86
	SD	0.62	0.24	0.35	0.07	0.23	0.24	0.28	0.44	0.40	0.45	29.63	0.39	0.47	0.56	0.65	0.34	0.56	0.22	1.22	0.23	1.54	2.11
pH																							
Surface	**Avg**	8.46	8.29	8.25	8.25	8.23	8.22	8.18	8.18	8.20	8.20	8.38	8.44	7.99	8.25	8.23	8.00	8.07	7.98	8.05	7.95	7.94	8.26
	Min	8.40	8.25	8.24	8.23	8.22	8.19	8.15	8.14	8.18	8.19	8.18	8.43	6.97	8.19	8.20	7.97	7.95	7.97	8.00	7.87	7.92	7.99
	Max	8.54	8.41	8.26	8.27	8.24	8.24	8.20	8.21	8.22	8.22	8.47	8.46	8.55	8.28	8.28	8.03	8.39	8.00	8.23	7.99	8.00	8.41
	SD	0.06	0.06	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.12	0.01	0.60	0.04	0.03	0.03	0.16	0.01	0.09	0.04	0.03	0.16
Middle	**Avg**	8.45	8.29	8.25	8.25	8.23	8.20	8.17	8.15	8.18	8.17	8.35	8.38	7.98	8.14	8.17	7.96	7.99	7.92	7.96	7.91	7.92	8.24
	Min	8.41	8.25	8.24	8.23	8.22	8.19	8.14	8.07	8.13	8.12	8.18	8.35	7.17	8.09	8.14	7.93	7.88	7.90	7.91	7.89	7.86	7.96
	Max	8.54	8.41	8.26	8.26	8.23	8.21	8.20	8.18	8.20	8.22	8.46	8.42	8.34	8.20	8.21	8.00	8.24	7.93	8.11	7.91	7.99	8.42
	SD	0.05	0.06	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.04	0.11	0.02	0.47	0.04	0.03	0.03	0.13	0.01	0.08	0.01	0.04	0.17
Bottom	**Avg**	8.45	8.28	8.25	8.24	8.21	8.20	8.16	8.14	8.17	8.17	8.34	8.37	7.97	8.13	8.17	7.95	7.99	7.94	7.87	7.90	7.82	8.16
	Min	8.42	8.24	8.24	8.22	8.20	8.19	8.14	8.10	8.12	8.13	8.16	8.36	7.17	8.09	8.14	7.92	7.92	7.93	7.67	7.88	7.65	7.95
	Max	8.52	8.41	8.25	8.25	8.22	8.21	8.20	8.18	8.20	8.21	8.44	8.38	8.36	8.15	8.21	7.96	8.23	7.95	8.14	7.94	7.94	8.41
	SD	0.04	0.06	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.11	0.01	0.47	0.03	0.03	0.02	0.12	0.01	0.15	0.02	0.11	0.21
Chlorophyll-a (mg/m^3)																							
Surface	**Avg**	0.74	0.30	0.30	0.38	0.48	0.58	1.07	1.98	1.16	0.92	0.37	0.46	0.80	3.46	1.96	2.83	1.22	1.10	3.56	2.62	1.57	1.54
	Min	0.15	0.13	0.12	0.14	0.12	0.44	0.13	0.18	0.84	0.35	0.00	0.00	0.05	1.27	1.55	2.20	0.60	0.70	1.40	1.20	1.00	0.21
	Max	2.06	0.59	0.55	0.67	1.08	0.69	1.91	4.90	1.77	2.02	1.68	0.65	1.90	5.71	2.52	3.60	1.50	1.50	6.92	5.20	3.60	3.64
	SD	0.65	0.18	0.15	0.23	0.37	0.09	0.66	1.58	0.33	0.51	0.57	0.24	0.70	1.81	0.41	0.58	0.34	0.32	1.83	1.50	0.91	1.34
Middle	**Avg**	1.02	0.75	0.79	1.01	0.83	0.81	1.54	2.25	0.81	0.78	0.51	1.58	0.55	1.35	1.01	2.40	0.53	0.23	0.67	0.42	0.93	0.91
	Min	0.30	0.47	0.55	0.48	0.38	0.60	0.27	0.32	0.42	0.18	0.00	0.29	0.39	0.31	0.31	0.80	0.10	0.10	0.20	0.20	0.30	0.46
	Max	2.31	1.42	0.99	1.75	1.55	1.15	3.58	5.54	1.26	1.35	1.09	3.16	0.85	2.77	1.78	3.80	1.40	0.30	1.20	0.70	3.10	2.60
	SD	0.64	0.29	0.15	0.47	0.48	0.19	1.20	2.16	0.28	0.44	0.34	1.26	0.18	1.04	0.60	1.23	0.45	0.08	0.40	0.23	0.98	0.85
Bottom	**Avg**	2.02	1.13	1.07	0.62	0.76	0.59	1.18	0.44	0.64	0.47	1.65	0.39	0.23	0.30	0.33	0.63	0.25	0.35	0.59	1.14	0.33	0.72

		T1	T2	T2a	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T14a	T15	T15a	T16	T17	T17a	T18
	Min	1.03	1.02	0.90	0.47	0.59	0.23	0.21	0.13	0.17	0.11	0.08	0.12	0.13	0.12	0.14	0.20	0.10	0.10	0.10	0.10	0.00	0.06
	Max	4.66	1.24	1.32	0.94	1.17	1.03	3.07	0.97	1.18	1.16	8.41	0.85	0.40	0.54	0.69	1.20	0.60	1.10	2.47	4.50	0.80	1.30
	SD	1.25	0.08	0.16	0.17	0.24	0.33	1.10	0.26	0.39	0.38	2.80	0.29	0.11	0.18	0.25	0.42	0.19	0.43	0.94	1.69	0.31	0.55
Turbidity																							
Surface	**Avg**	2.87	2.56	2.54	2.57	2.50	4.92	2.74	2.62	2.67	2.64	1.96	1.77	2.02	2.25	2.90	4.40	4.51	4.60	4.93	2.30	2.22	3.42
	Min	1.89	2.37	2.34	2.35	2.35	2.39	2.31	2.39	2.39	2.36	1.66	1.66	1.61	1.93	2.83	4.20	3.26	4.10	4.03	2.10	2.10	2.10
	Max	4.29	2.76	2.82	3.10	2.78	14.42	3.74	2.80	3.17	3.05	2.47	2.06	2.37	2.72	3.02	4.80	5.20	4.80	5.30	2.50	2.50	4.39
	SD	0.81	0.13	0.19	0.27	0.17	4.75	0.45	0.14	0.28	0.21	0.33	0.15	0.32	0.34	0.09	0.28	0.69	0.29	0.46	0.14	0.13	0.85
Middle	**Avg**	3.08	2.86	2.73	2.67	2.48	5.43	2.87	2.57	2.60	2.57	1.89	1.85	1.71	3.15	2.84	4.30	4.20	4.13	4.24	2.02	2.12	3.22
	Min	2.32	2.49	2.57	2.45	2.33	2.37	2.42	2.39	2.32	2.37	1.60	1.59	1.62	1.98	2.75	4.10	3.10	4.00	4.01	1.90	1.90	2.00
	Max	4.61	3.42	2.88	3.13	2.81	17.12	3.64	2.86	3.18	2.82	2.44	2.40	1.78	5.09	2.95	4.60	5.50	4.20	4.60	2.20	2.60	4.00
	SD	0.73	0.31	0.12	0.26	0.19	5.84	0.46	0.17	0.32	0.16	0.35	0.30	0.06	1.38	0.08	0.22	0.77	0.08	0.20	0.12	0.28	0.74
Bottom	**Avg**	5.27	3.56	3.49	3.46	3.25	6.08	3.68	3.14	3.21	3.26	2.32	2.07	2.65	4.88	3.49	5.03	4.88	4.63	4.31	2.60	2.06	3.52
	Min	2.94	3.09	2.88	2.72	2.60	2.65	2.42	2.56	2.58	2.66	0.37	1.62	1.70	2.96	3.16	4.00	3.31	4.50	4.10	1.90	1.80	2.00
	Max	11.11	4.77	4.34	5.49	4.44	18.28	5.46	4.32	4.08	4.33	3.00	2.46	4.58	6.45	3.92	6.60	8.90	4.80	5.13	5.10	2.97	5.06
	SD	2.83	0.51	0.53	1.03	0.75	6.11	1.10	0.62	0.52	0.52	0.86	0.32	1.14	1.45	0.32	1.13	2.04	0.13	0.41	1.25	0.41	1.00
Salinity (psu)																							
Surface	**Avg**	39.94	40.80	40.88	40.70	40.55	37.12	40.42	40.06	40.28	39.72	39.82	38.63	37.64	37.09	37.15	36.68	36.66	36.51	36.54	36.48	36.54	38.24
	Min	37.76	39.95	40.62	40.54	40.35	24.38	39.81	39.11	39.98	38.60	38.84	37.91	36.89	37.04	36.67	36.58	36.56	36.51	36.47	36.45	36.39	36.56
	Max	41.05	41.07	41.03	40.78	40.70	40.83	41.43	41.04	40.84	40.61	41.12	40.04	38.18	37.17	37.75	36.76	36.83	36.52	36.62	36.52	36.65	40.70
	SD	1.20	0.36	0.16	0.09	0.13	6.38	0.51	0.60	0.32	0.76	0.76	0.75	0.49	0.06	0.45	0.08	0.12	0.01	0.06	0.02	0.08	1.98
Middle	**Avg**	39.96	40.82	40.93	40.72	40.56	40.38	40.51	40.27	40.41	40.32	40.32	39.83	38.56	37.51	36.92	36.74	37.16	36.50	36.52	36.48	36.51	38.29
	Min	37.75	40.15	40.63	40.55	40.34	39.94	39.91	39.80	40.23	40.06	39.78	39.24	37.87	37.22	36.67	36.73	36.55	36.47	36.50	36.43	36.44	36.55
	Max	41.08	41.10	41.14	40.78	40.69	40.89	41.61	41.06	40.88	40.79	41.16	40.82	39.11	37.76	37.06	36.76	38.24	36.54	36.56	36.52	36.54	40.72
	SD	1.22	0.29	0.19	0.09	0.14	0.31	0.53	0.42	0.24	0.24	0.42	0.57	0.46	0.22	0.18	0.01	0.72	0.03	0.02	0.03	0.04	1.97
Bottom	**Avg**	39.99	40.86	40.93	40.74	40.62	40.49	40.90	40.60	40.51	40.53	40.92	40.90	39.50	39.17	39.01	36.80	38.10	38.11	36.43	36.50	36.41	38.18
	Min	37.75	40.41	40.62	40.53	40.36	39.95	39.98	40.16	40.30	40.23	40.30	39.76	38.25	37.31	37.07	36.69	36.54	36.47	36.21	36.44	36.24	36.40
	Max	41.13	41.10	41.15	40.80	40.81	40.88	43.97	41.15	40.88	40.70	41.71	42.65	40.32	40.29	40.59	36.89	39.84	38.95	36.61	36.53	36.51	40.73
	SD	1.25	0.22	0.20	0.10	0.17	0.33	1.28	0.40	0.19	0.18	0.47	0.96	0.80	1.32	1.46	0.08	1.43	0.96	0.13	0.03	0.10	2.07
Nitrate (µg/L)																							
Surface	**Avg**	6.06	5.70	4.20	4.31	6.00	13.77	19.02	13.61	18.07	12.67	12.68	6.56	10.54	29.00	51.12	32.13	28.75	116.44	67.00	143.88	157.21	95.02
	Min	3.59	3.07	1.83	0.85	1.02	1.44	3.67	6.70	10.07	8.85	1.50	1.33	2.30	17.29	24.17	16.07	11.90	99.77	50.50	94.25	84.04	5.41

		T1	T2	T2a	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T14a	T15	T15a	T16	T17	T17a	T18
	Max	7.39	11.49	9.18	7.57	8.68	23.62	52.50	19.23	36.91	21.15	53.76	13.55	24.28	35.51	70.77	61.09	61.09	126.42	93.06	190.46	220.22	157.27
	SD	1.26	2.53	2.78	2.26	2.94	7.97	15.71	4.10	9.83	3.93	17.12	4.63	8.24	8.30	19.71	20.52	17.10	10.09	14.05	33.55	41.25	72.67
Middle	**Avg**	4.36	4.15	4.36	3.29	5.54	16.24	14.32	15.33	33.45	40.30	35.08	29.83	41.81	64.42	71.22	84.51	135.64	237.23	173.33	217.85	181.40	116.18
	Min	0.00	0.90	1.75	1.05	1.39	1.50	3.70	3.05	7.31	6.79	1.04	5.97	13.01	42.66	28.45	53.22	70.96	178.59	154.56	188.01	95.81	2.26
	Max	6.57	9.85	7.51	6.50	7.82	36.30	40.37	49.11	70.53	95.00	88.04	62.26	100.25	91.37	97.13	111.88	166.52	302.70	230.43	242.80	250.33	195.20
	SD	2.12	2.85	1.84	1.96	2.46	12.17	11.85	15.72	22.03	34.57	33.17	21.66	34.34	20.22	30.47	24.11	33.64	51.60	29.06	17.55	50.63	90.52
Bottom	**Avg**	4.43	4.02	5.66	4.47	16.19	19.21	24.71	41.86	42.63	42.90	36.99	41.21	64.03	94.48	70.97	83.70	127.88	146.80	340.98	235.25	181.40	221.07
	Min	1.03	1.74	3.83	0.03	12.81	3.13	2.27	4.55	6.92	7.19	3.82	11.97	42.19	47.88	8.83	67.14	105.66	134.71	225.88	216.89	95.81	2.65
	Max	6.65	5.58	10.89	9.36	25.10	42.23	55.62	86.75	93.49	102.21	91.05	66.51	79.92	150.57	119.15	113.37	142.35	155.84	397.34	246.51	250.33	377.94
	SD	2.05	1.28	2.66	3.31	5.15	15.75	18.19	31.76	31.10	37.80	31.13	20.32	15.02	42.46	46.11	21.03	12.79	8.50	71.46	12.72	50.63	177.36
Nitrite (µg/L)																							
Surface	**Avg**	0.62	0.48	0.50	0.71	0.94	3.04	3.99	1.28	3.64	2.11	0.99	1.56	1.27	4.75	6.51	3.10	2.18	7.14	4.00	6.95	8.86	2.68
	Min	0.13	0.11	0.22	0.31	0.02	0.33	0.92	0.83	1.55	0.72	0.31	0.63	0.17	0.94	3.23	2.36	0.03	6.19	2.98	5.22	6.15	0.76
	Max	1.01	1.05	0.94	1.81	2.52	11.75	11.50	2.16	8.49	7.25	1.57	3.23	4.32	7.49	11.58	4.04	3.96	8.50	5.45	9.20	12.27	9.90
	SD	0.28	0.29	0.25	0.56	0.96	4.39	3.65	0.46	2.55	2.14	0.45	0.88	1.76	2.78	3.63	0.70	1.46	0.99	0.85	1.33	2.01	3.61
Middle	**Avg**	0.38	0.59	0.71	1.50	1.57	10.61	5.88	2.31	6.33	6.64	7.64	6.21	6.38	7.54	8.69	11.10	5.28	13.57	12.61	12.16	11.34	10.02
	Min	0.00	0.01	0.32	0.80	0.31	0.09	0.46	0.96	1.45	1.37	0.59	3.23	3.75	5.36	3.57	5.27	0.73	5.85	12.13	7.21	6.73	0.77
	Max	0.74	1.09	0.99	2.33	4.81	25.53	24.00	6.39	11.40	13.36	40.80	16.43	9.36	11.34	15.91	18.88	10.87	17.75	13.87	17.57	13.95	18.54
	SD	0.30	0.41	0.22	0.59	1.88	9.42	7.73	1.90	3.60	4.62	13.62	5.12	2.23	2.69	5.25	5.72	3.27	4.57	0.68	4.17	2.58	7.87
Bottom	**Avg**	0.37	1.13	1.00	3.50	8.59	12.01	9.81	6.02	9.84	8.69	5.13	11.83	6.41	6.15	4.61	15.61	4.54	3.07	3.74	11.62	6.95	8.20
	Min	0.02	0.00	0.81	0.99	2.14	0.07	0.45	0.95	1.48	1.66	1.49	1.80	2.53	0.73	1.17	6.62	0.22	0.16	1.03	7.05	0.66	0.66
	Max	0.75	2.04	1.21	4.63	15.60	28.83	25.80	16.95	24.20	23.78	14.25	26.00	9.47	13.09	9.45	23.47	9.71	10.44	10.46	17.74	14.28	13.45
	SD	0.26	0.68	0.14	1.29	5.19	12.46	10.54	5.42	8.83	9.30	4.59	8.54	2.52	5.16	3.52	6.93	3.34	4.27	3.59	4.31	5.03	6.12
Silicate (µg/L)																							
Surface	**Avg**	14.60	12.27	28.22	20.89	27.89	38.15	55.91	36.01	53.58	48.36	37.51	9.48	17.83	27.71	53.58	15.40	28.86	33.57	16.28	58.31	75.47	66.18
	Min	6.23	5.60	11.47	9.47	19.20	16.53	6.67	6.37	28.90	14.93	19.67	4.00	6.53	15.67	41.70	3.50	12.23	4.43	7.03	28.67	25.30	33.43
	Max	23.70	27.57	63.40	29.33	36.97	91.03	105.30	63.70	74.03	74.93	59.57	13.93	34.80	37.57	65.47	25.47	75.03	43.73	39.15	84.67	118.93	105.33
	SD	5.83	7.43	19.10	7.34	7.96	27.88	33.30	18.28	17.34	22.48	13.69	3.51	10.45	9.07	9.70	9.06	23.85	16.82	11.77	22.32	29.74	32.17
Middle	**Avg**	15.67	13.17	37.94	20.10	29.23	45.70	45.21	57.74	64.41	78.34	60.49	43.84	46.36	56.94	89.48	31.32	79.96	112.24	74.05	91.56	85.24	73.93
	Min	0.00	3.23	8.33	9.33	15.50	17.70	12.20	9.63	29.83	62.40	20.90	16.27	31.37	46.43	85.43	17.80	26.57	83.53	48.80	84.10	41.07	34.53
	Max	38.87	26.63	59.73	29.67	38.30	79.13	66.67	120.50	88.87	112.80	101.90	74.13	77.27	76.87	97.00	43.00	126.60	170.83	115.97	98.75	122.60	120.93
	SD	10.78	7.05	17.97	7.79	8.53	24.15	19.28	33.46	20.16	18.44	33.42	20.83	18.21	14.10	5.32	10.37	33.29	35.50	29.34	6.04	27.87	38.69

		T1	T2	T2a	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T14a	T15	T15a	T16	T17	T17a	T18
Bottom	**Avg**	20.70	18.27	43.08	30.21	66.97	50.22	60.37	69.25	74.51	84.61	76.36	71.51	94.96	96.88	117.88	41.70	73.11	86.44	173.92	95.31	184.31	168.84
	Min	9.00	4.40	11.23	15.37	33.13	24.00	17.53	5.30	32.23	59.57	25.60	45.43	61.33	49.40	107.00	29.50	32.80	70.20	78.53	74.20	76.40	43.37
	Max	41.13	35.37	60.63	43.80	116.50	101.90	126.70	117.60	107.70	118.10	126.67	111.10	129.27	154.27	138.80	66.00	94.43	111.50	218.30	108.67	345.50	343.25
	SD	10.49	9.87	18.84	9.84	33.18	27.71	32.10	40.85	27.25	18.09	34.86	25.12	24.09	43.38	14.80	17.18	22.50	15.41	57.04	12.87	103.83	142.72
Phosphate (µg/L)																							
Surface	**Avg**	3.06	5.94	4.07	5.58	7.36	6.61	8.52	7.22	8.19	8.33	7.95	8.35	10.29	13.02	14.95	12.95	14.98	22.97	16.09	25.29	27.79	19.61
	Min	1.33	4.20	1.07	4.83	5.47	4.00	4.03	5.47	3.53	6.40	5.70	2.33	8.93	9.57	11.80	10.80	11.70	22.07	14.80	20.93	21.93	1.60
	Max	5.77	7.13	6.80	6.17	10.27	9.80	13.27	8.67	11.23	10.63	10.63	13.03	13.87	15.83	17.73	15.93	19.20	24.07	18.90	28.43	33.53	32.50
	SD	1.53	0.84	1.85	0.46	1.77	2.17	3.20	1.25	2.60	1.49	1.91	3.50	2.07	2.60	2.44	2.17	3.07	0.71	1.44	2.74	4.12	12.97
Middle	**Avg**	3.37	6.06	4.63	5.77	7.74	7.67	9.23	10.05	9.58	10.33	10.66	10.76	15.33	19.59	20.09	19.78	22.19	33.72	29.75	31.59	30.34	21.24
	Min	0.00	5.23	1.47	2.87	5.77	4.13	3.43	5.30	6.47	1.03	6.27	6.40	11.37	17.17	16.33	15.17	19.37	29.77	28.13	29.87	24.43	0.66
	Max	7.43	7.27	7.37	8.17	11.87	13.00	14.37	19.00	12.90	18.57	15.77	16.87	22.13	24.16	25.53	23.30	28.90	40.97	31.73	34.53	35.20	35.50
	SD	2.60	0.72	2.07	1.70	2.45	3.06	4.07	4.31	4.15	5.61	3.58	3.82	4.10	3.24	3.94	3.41	3.45	4.37	1.55	1.70	3.44	14.56
Bottom	**Avg**	4.35	7.06	5.01	6.55	11.78	8.89	9.73	12.95	10.79	12.27	12.43	9.89	15.57	18.47	16.96	22.32	18.83	23.57	41.05	32.18	44.06	32.55
	Min	1.93	5.23	1.67	2.97	8.53	4.77	2.27	6.13	8.13	8.00	8.70	3.20	11.90	15.73	14.87	19.23	12.87	19.57	26.37	26.83	29.70	0.37
	Max	6.80	8.83	6.87	8.43	16.27	13.30	16.00	19.40	14.13	19.77	15.07	15.50	18.77	22.40	20.33	25.13	24.70	27.37	47.60	34.67	60.83	63.57
	SD	1.78	1.23	1.90	1.88	2.93	3.25	5.16	4.92	4.68	4.04	2.49	5.20	2.49	2.85	2.41	2.42	4.52	2.77	8.54	2.81	12.86	26.95
Ammonia (µg/L)																							
Surface	**Avg**	5.44	5.07	4.83	3.63	2.07	2.57	8.63	8.02	5.33	5.96	8.49	5.25	13.10	4.37	5.51	6.53	12.18	9.59	8.55	5.00	9.30	5.14
	Min	3.10	2.05	3.35	2.90	1.05	0.73	1.80	1.68	2.13	3.82	5.67	2.90	2.30	2.62	5.33	4.02	6.47	6.28	2.22	3.35	3.00	4.64
	Max	8.41	6.97	5.78	4.38	3.10	5.27	18.59	15.67	8.63	9.13	13.70	8.30	40.33	7.78	5.78	8.35	18.48	16.47	12.12	6.27	20.59	5.85
	SD	1.71	1.59	0.85	0.61	0.81	1.60	5.43	5.20	2.07	1.87	3.22	1.94	15.79	2.41	0.19	1.84	4.78	4.04	3.89	1.01	6.90	0.42
Middle	**Avg**	4.78	7.02	5.34	5.24	0.95	2.52	8.62	8.74	5.23	7.21	7.85	7.38	7.62	8.51	6.12	8.84	9.62	10.92	9.52	5.41	9.92	5.21
	Min	0.00	2.73	4.40	3.05	0.29	1.72	1.65	2.87	2.57	3.78	6.03	3.34	2.60	2.95	4.70	6.37	6.28	3.42	5.18	2.45	5.35	4.02
	Max	8.17	18.14	7.18	18.14	1.75	4.47	17.62	15.43	9.10	14.33	10.33	14.57	18.50	13.43	8.63	11.03	17.27	28.53	13.12	9.37	17.87	6.80
	SD	2.41	4.76	1.01	1.23	0.55	1.00	5.34	4.64	2.18	3.14	1.60	3.89	6.42	4.30	1.78	1.91	4.06	10.25	3.14	2.28	4.91	1.08
Bottom	**Avg**	5.22	5.18	5.49	7.72	4.08	3.80	8.81	9.18	4.96	7.72	9.60	6.94	4.75	7.23	9.16	16.07	9.76	8.13	5.62	7.57	8.40	5.44
	Min	3.72	2.45	0.57	3.30	1.02	1.17	2.35	4.67	2.57	3.83	5.40	5.28	3.38	2.43	6.09	11.25	6.10	4.07	1.63	3.10	4.77	3.32
	Max	7.27	8.12	9.67	11.70	8.63	7.40	18.05	17.75	9.50	11.67	15.43	9.88	7.50	12.80	13.83	19.28	19.92	18.83	10.37	13.82	15.08	7.07
	SD	1.06	1.74	2.97	2.71	2.82	2.21	5.56	5.10	2.39	2.73	3.87	1.60	1.62	4.27	3.35	3.47	5.16	6.19	2.78	3.57	3.53	1.46

Appendix 4: Parameter Distribution Figures (2001 and 2006)

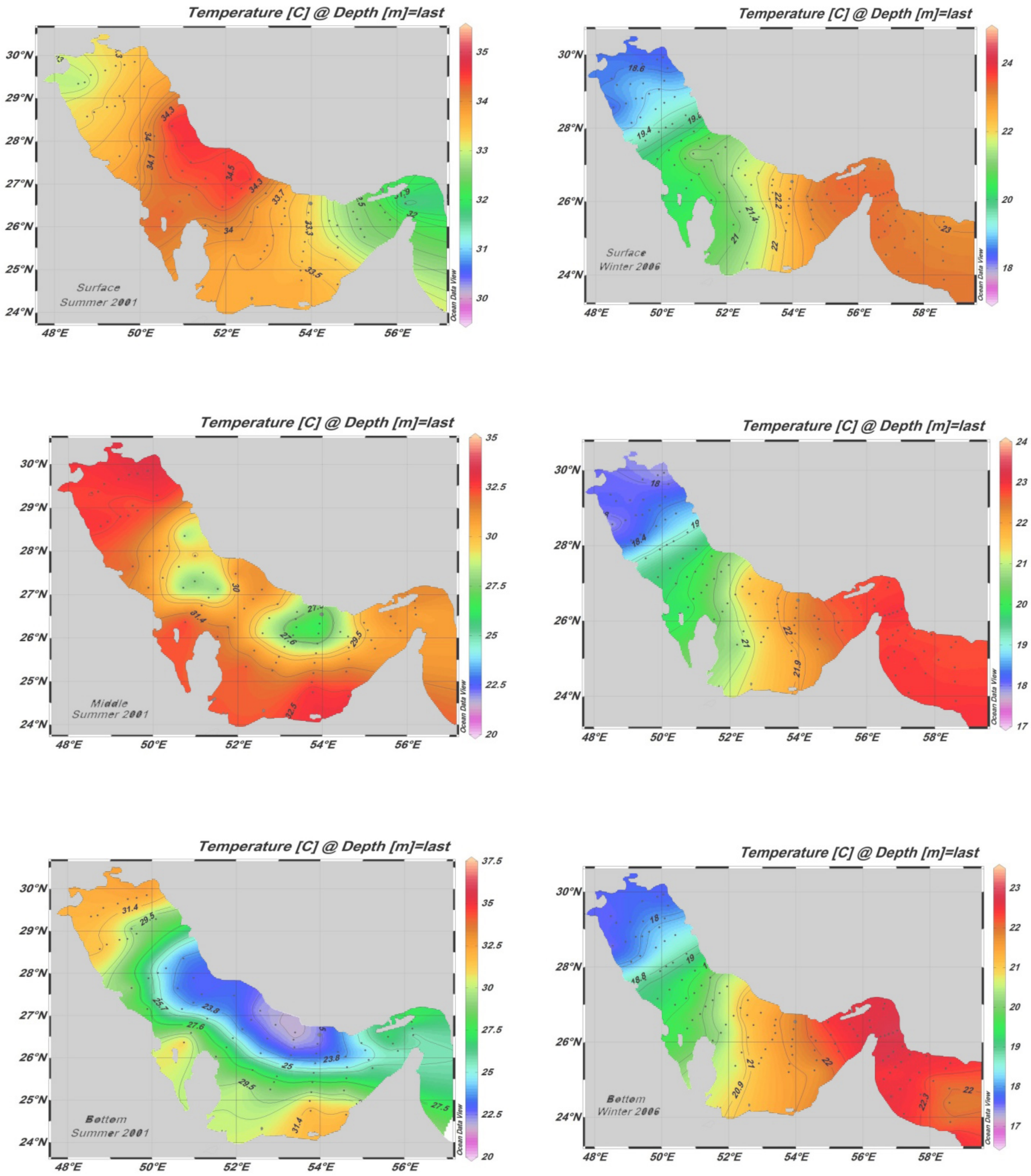


Figure A: Distribution of Temperature (2001 and 2006)

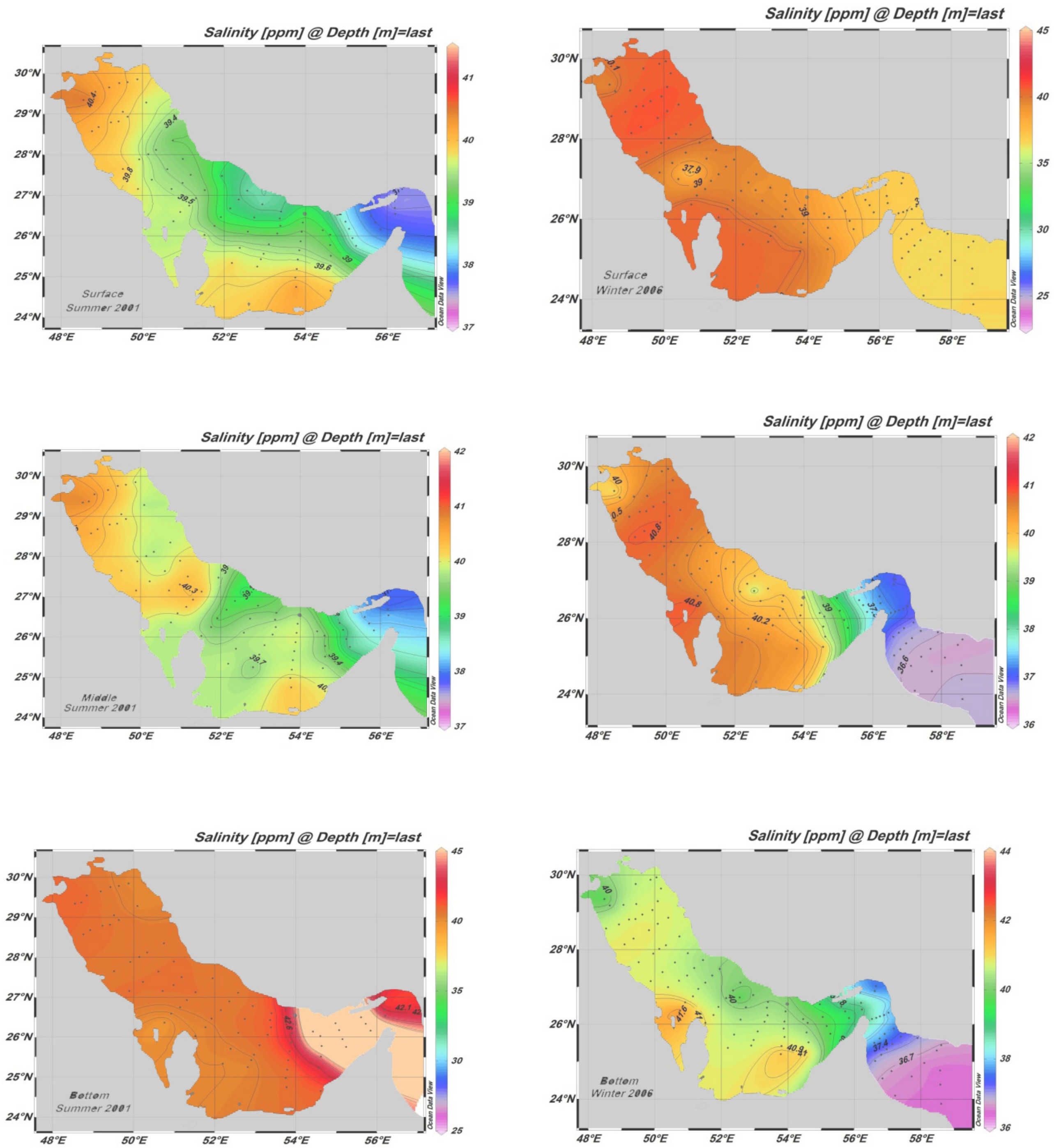


Figure B: Distribution of Salinity concentrations (2001 and 2006)

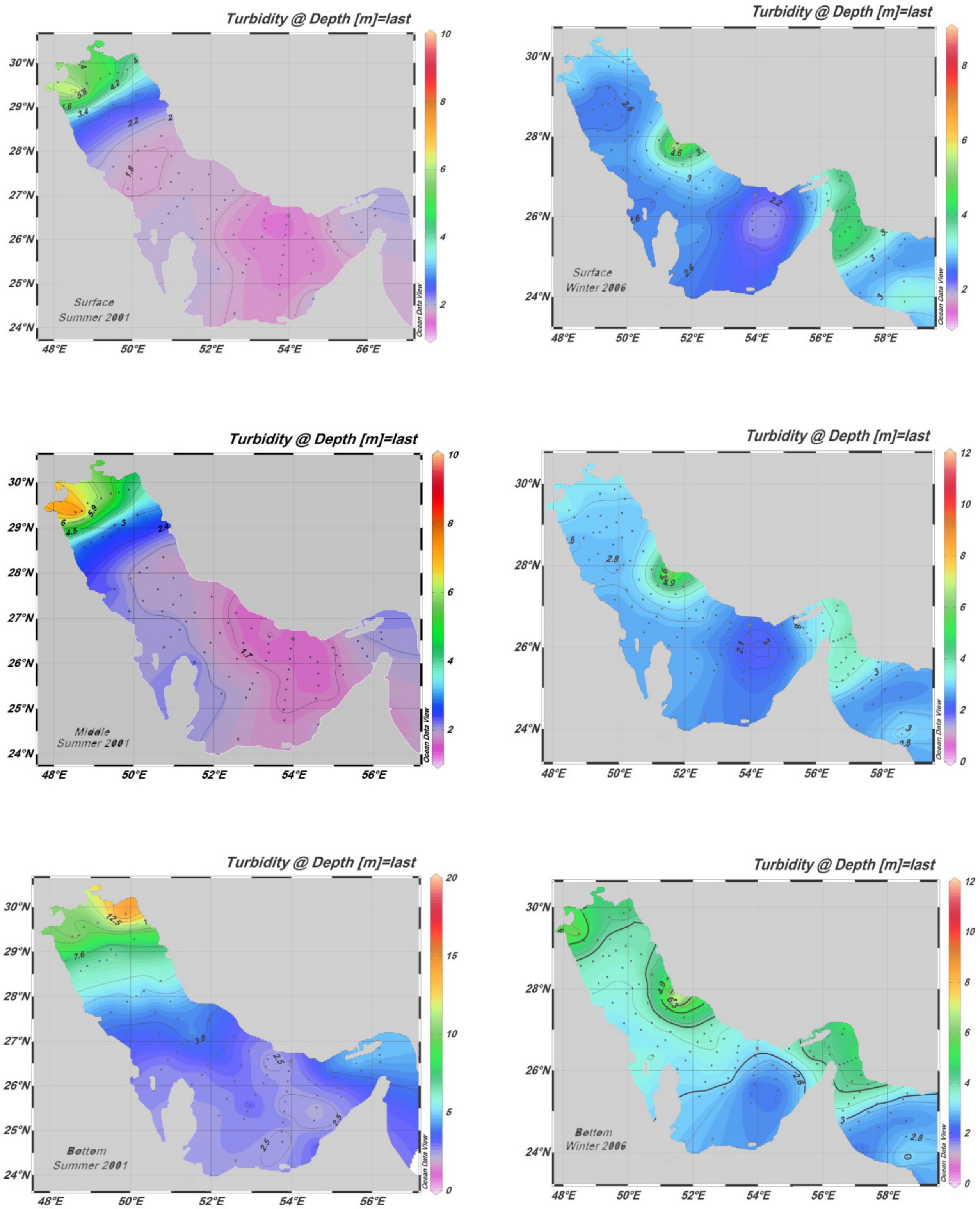


Figure C: Distribution of Turbidity (2001 and 2006)

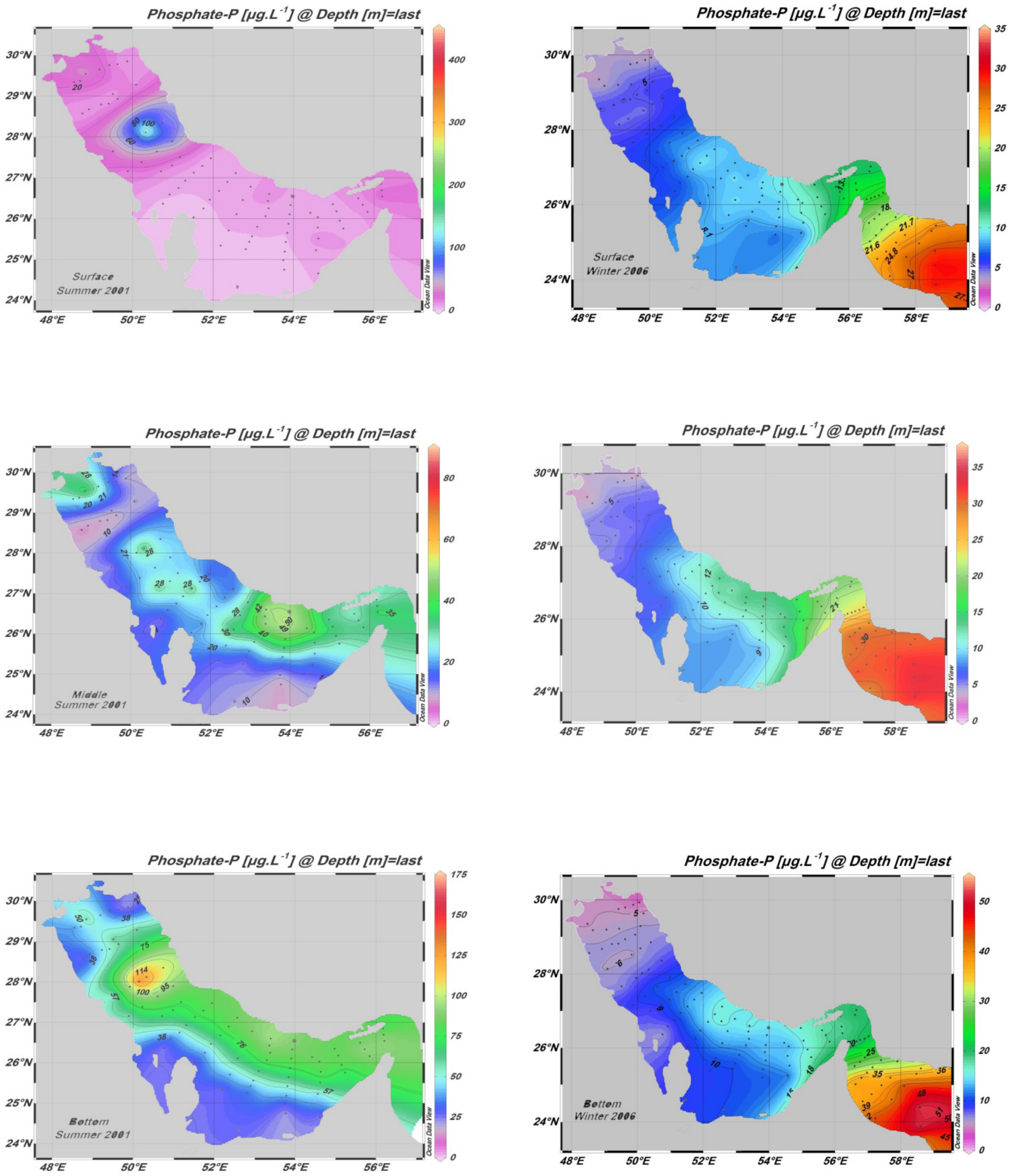


Figure D: Distribution of PO4 concentrations, µg/L (2001 and 2006)

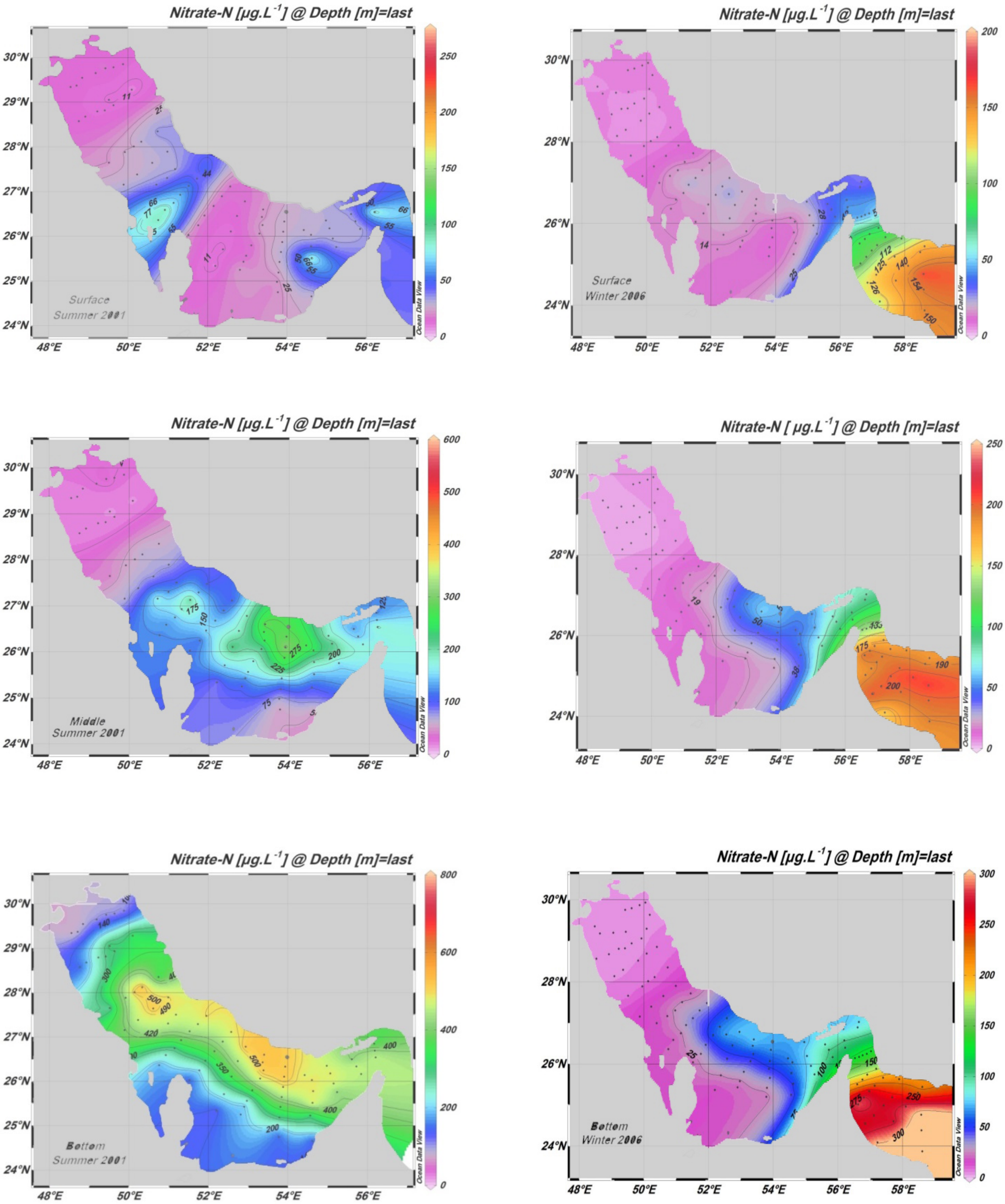


Figure E: Distribution of NO_3 concentrations, µg/L (2001 and 2006)

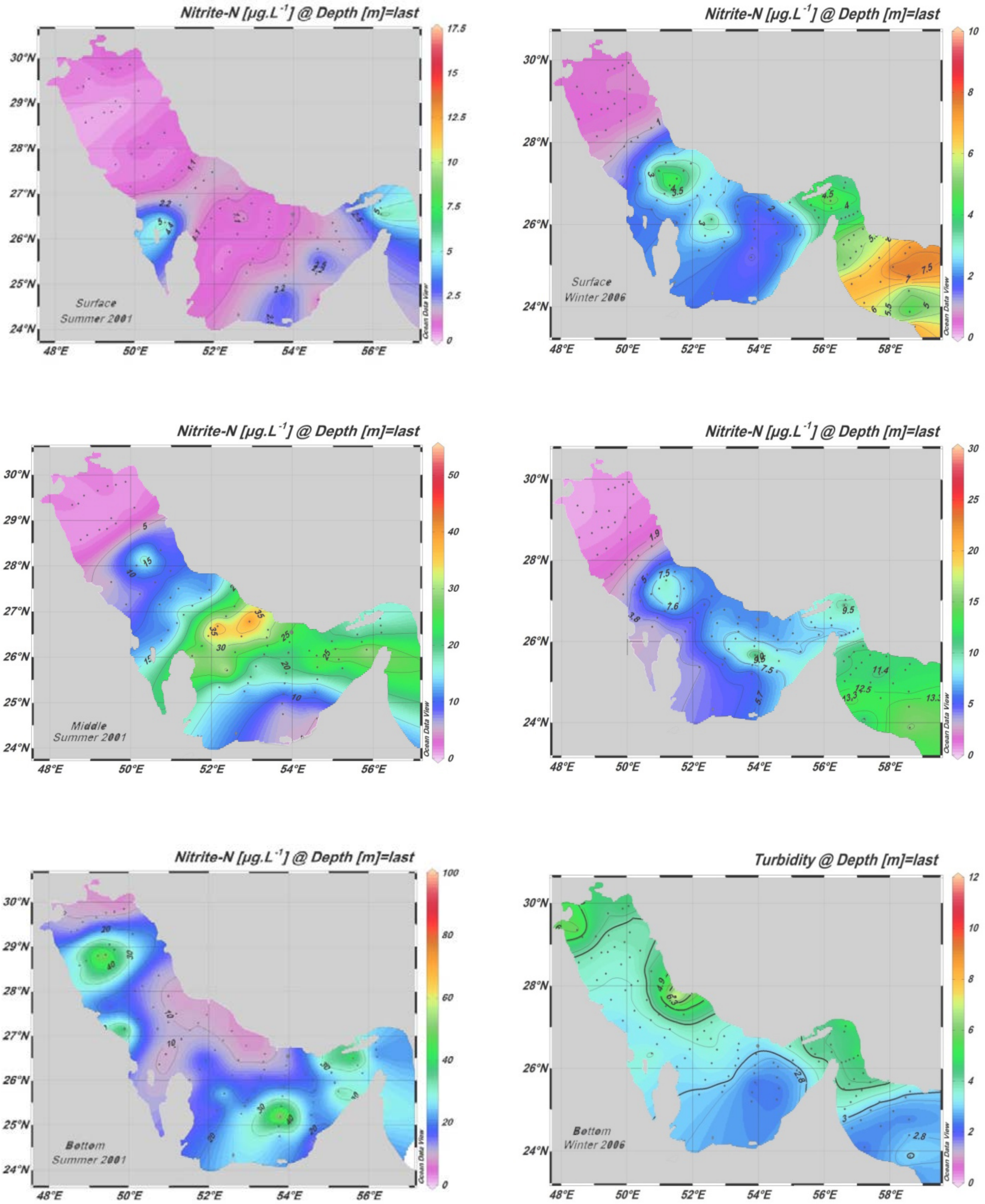


Figure F: Distribution of NO_2 concentrations (2001 and 2006)

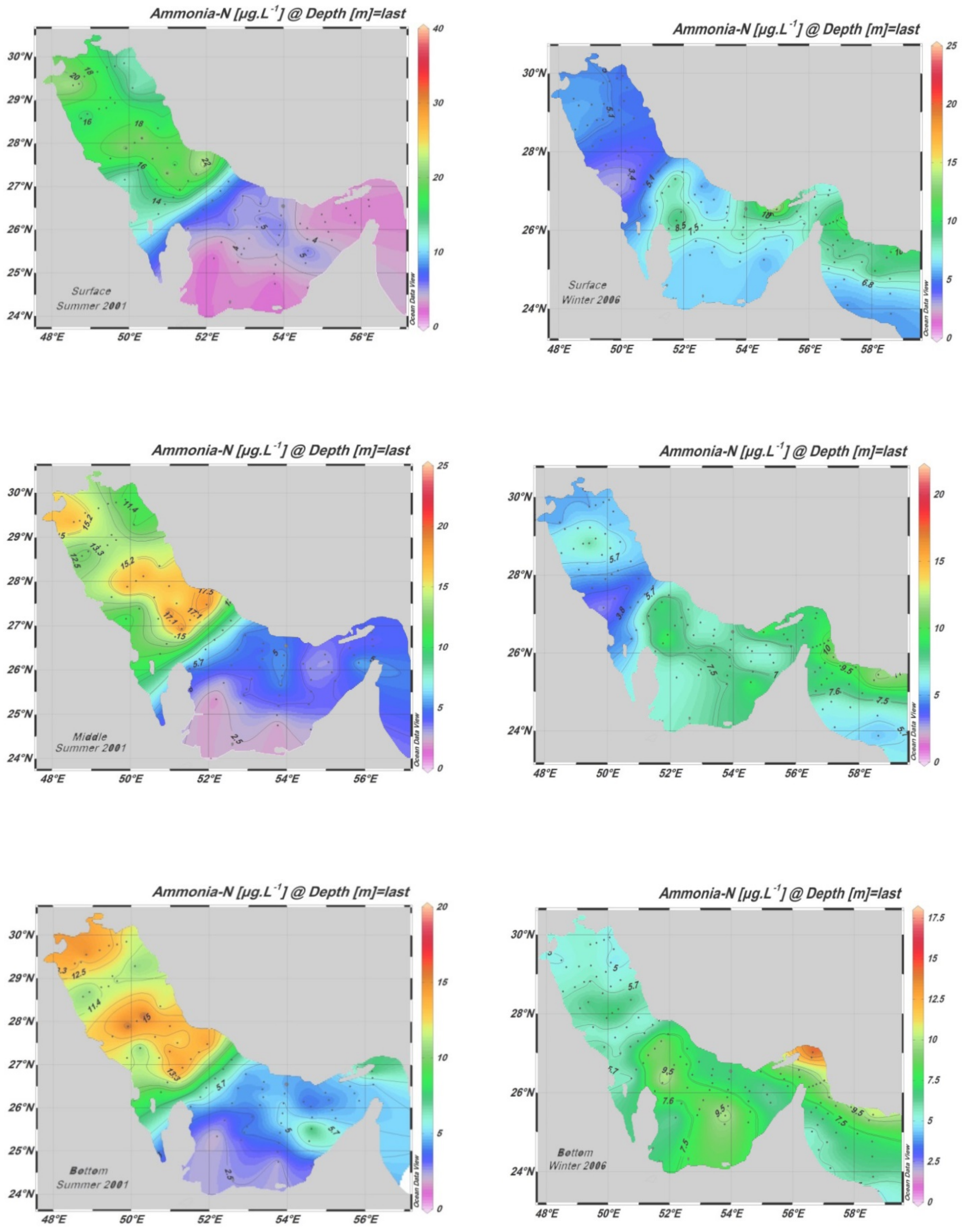


Figure G: Distribution of NH_4 concentrations (2001 and 2006)

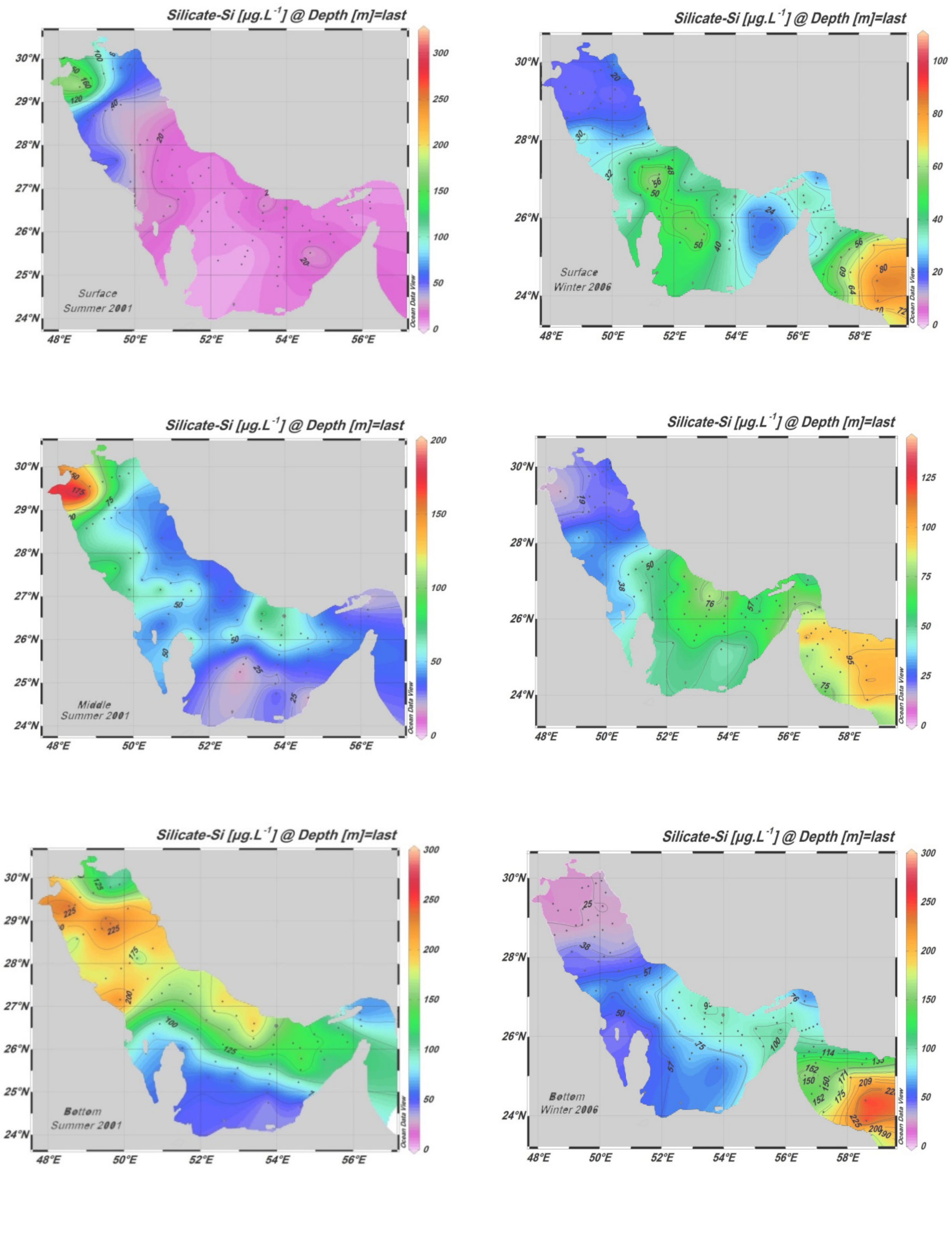


Figure H: Distribution of SiO_2 concentrations (2001 and 2006)

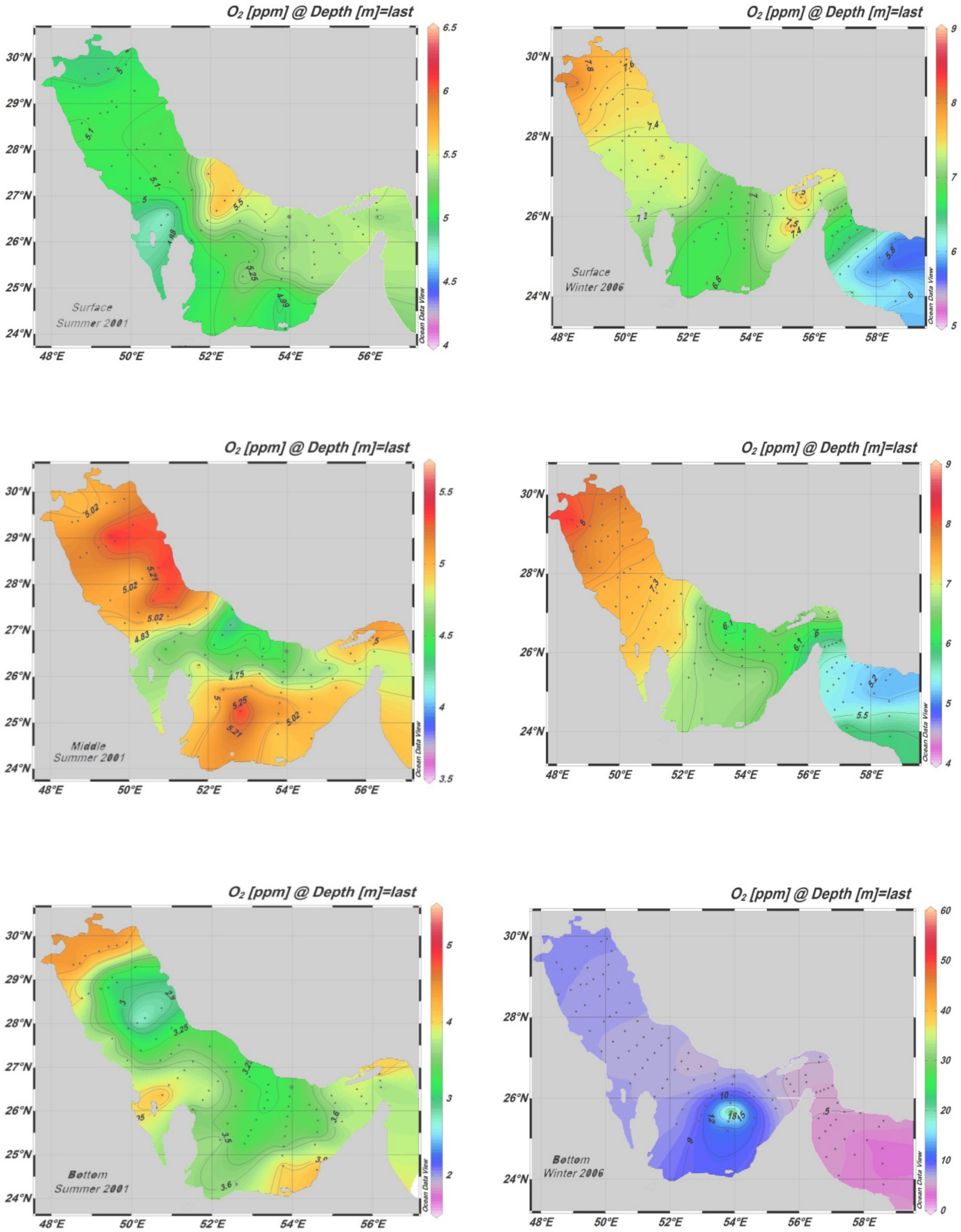


Figure I: Distribution of Dissolved Oxygen concentrations (2001 and 2006)

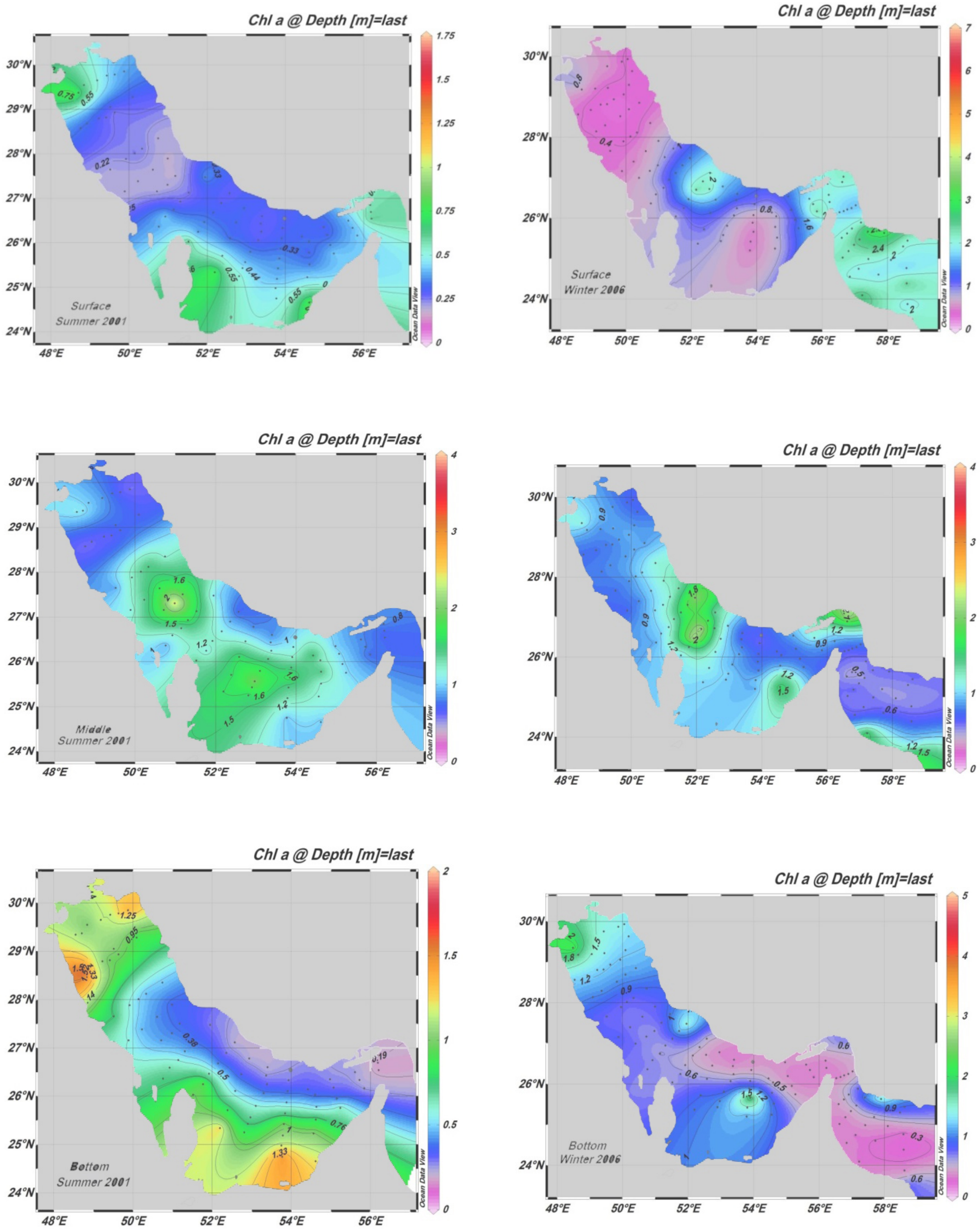


Figure J: Distribution of chl-a concentrations (2001 and 2006)