"The quality of coastal sea waters: the experience of Regional monitoring in Venetia (Italy)"

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ABSTRACT

A sea water monitoring program, facing VENETIA, in the Northern Adriatic was co-ordinated by Venetia District - "Ecology and Environment Protection Department", and carried out by the Hygiene Institute of Padua University and the Marine Biology Insitute - CNR - of Venice.

Since 1990, 48 sampling stations located along 16 transects in a coastal arch of about 156 Km, have been analyzed. This paper presents the results achieved during the years 1990-92. The controls show that sea water is consistently affected by river water contributions, but has never reached emergency levels according to the parameters fixed for bathing water standards. Monitoring confirmed sporadic bacteriologic and virologic contamination's cases of anthropic origin, in some stations near the mouths of the rivers.

The multivariated analysis (PCA) of the analytical data suggests that a higher number of sampling variables may provide a more exhaustive insight of the dynamics of the phenomenon "afflux of fresh water into salt water".

INTRODUCTION

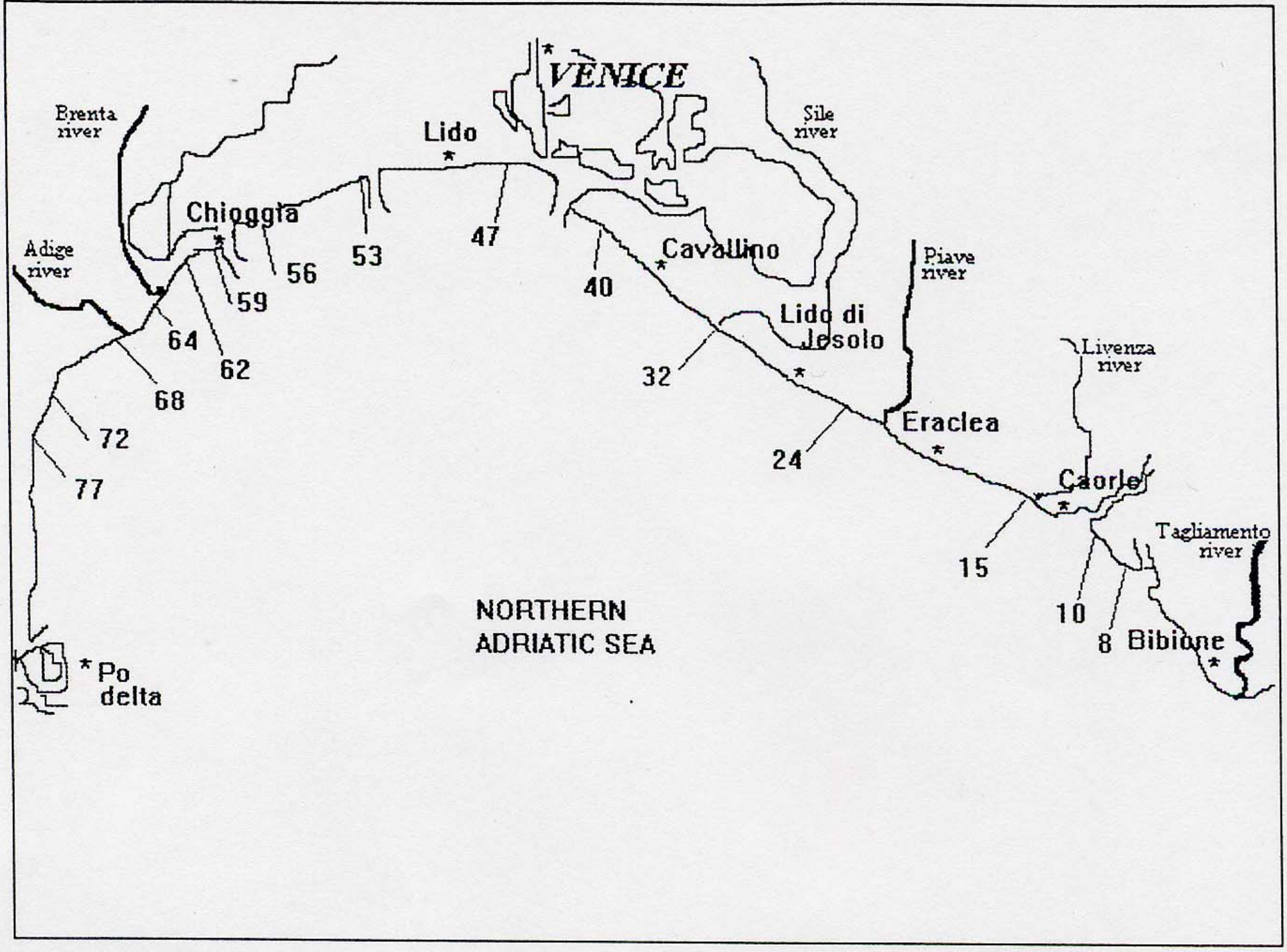
The Northern Adriatic Sea is a basin subject to wide variations both for its water mass features and their circulation on a vast scale "space-time" conditionally the physiografic and morfological features.

The western coastal zone (an elongated coastal land with a high load of nutrients, torbidity but a low salinity) is recognizable and delimitated by fluctuating frontal systems to the open sea. These frontal systems widely fluctuate, on different scales, because they are influenced by different factors (circulation patterns, variability of river water contribution, waring and effects of the wind) produced by water dynamics in the basin (FRANCO P. et al, 1990). The coastal zones, within the global basin dynamics, are marked, in a strictly limited space, by swift variations of their own characteristics.

Since 1986 the Ecology and Environment Protection Department of the Venetia District (Regione Veneto) has been involved in sea water control along coast of Venetia. The monitoring program was co-ordinated by the National Government, which also required us to collect information according to the Health Ministry on 17.06.88, 1.08.90, 1.09.90.
The program was coordinated by the Hygiene Institute of Padua University and the Marine Biology Institute CNR of Venice, and carried out with the collaboration of Bioprogramm s.c.r.l., CAM Idrografica and the Health Organization (ULSS).

Water monitoring programme objectives were:

Fig. 1 - Coastal arch of Northern Adriatic Sea



- to comply with the law
- to characterize the evolution of coastal processes
- to set up a collection of experimental data with automatic filing for programming interventions
- to define the sea water feature variations in the coastal zone
- to control the eutrophication
- to monitor the edible molluscs
- to supply satisfactory and accurate results.

MATERIALS AND METHODS

The coastal waters monitored from 1990 to 1992, are placed in a coastal area including the mouth of the Livenza river and Po delta (Fig. 1).

Several rivers such as Piave, Sile, Brenta, Adige ecc., flow into this area and there are several lagoons.

48 sampling stations were utilized located along 16 lines perpendicular to the coastline (transects) at a mean distance of 10 km along a 156 km coastal stretch from Punta Tagliamento (Ve) to Albarella (Ro). Three stations were set on each line, respectively at 500 mt, 0.5 miles and 2 miles from the coast line. For the molluscs monitoring 10 additional sampling stations were used. The harvesting of samples for the study of numerous data (Tab. 1), was carried out once a month from October to April and from May to September twice-a-month.

Microbiological and mollusc control was carried out seasonally. The samples were collected on waters at all the stations, and in

Tab. 1 - Sampling Variables

- Sampling point and identifyng number
- Geografic coordinates
- Distance from the coast
- Sea depth
- Date and time
- Sampling point depth
- Methereological and oceanographical observations :
air temperature
barometrical pressure
relative humidity
wave height
wind direction and speed
stream direction and speed
(Water)
- temperature (°C)
- salinity (PSU)
- Dissolved Oxygen %
- pH
- Transparency (m)
- Coloration
- Clorophyll a (μg/l)
- N-NH_3 (μM/l)
- N-NO_2 (μM/l)
- N-NO_3 (μM/l)
- Si-SiO_4 (μM/l)
- P-PO_4 (μM/l)
- P (μM/l)
- Tar residuals (presence/absence)
- Oil on surface (presence/absence)
- MBAS
- Phenols (μg/l)
- Total Coliforms (UFC/100 ml)
- Fecal Coliforms (UFC/100 ml)
- Fecal Streptococci (UFC/100 ml)
- Salmonelles (presence/absence)
- Viruses
(Mollusc Edibles)
- Total Coliforms (UFC/100 ml)
- Fecal Coliforms (UFC/100 ml)
- Fecal Streptococci (UFC/100 ml)
- Hg
- Cd
- Pb
- High PM hydrocarbon chlorurate

different depths only in 5 lines perpendicular to the coastline (6 and 12 mt.).

The analytical methods utilized for the study of physical/chemical and chemical analysis were get to NOVA THALASSIA (vol. 11, 1990), and STANDARD METHODS (17° ed.) for microbiological analysis. The elaboration and data studies were carried out with the Principal Component Analysis (PCA) (KLEIN BAUM D.G. et al, 1987).

RESULTS

In all the years 1990, 1991 and 1992 was collected on the whole 2856 samples in 48 stations located along 16 lines perpendicular to the coastline. The chemical, physical and biological variable trend for each year of observations was described in some internal reports (Regional Report 1990, Regional Report 1991, regional report 1992) of the Venetia District (Regione Veneto); in this work only a few considerations about the marine coastal systems were analyzed.

Temperature

The highest superficial water temperatures were recorded both along the coastline and inside 2 miles during the month of August (29°C). The coldest period was verified during February with the lowest temperature ranging from 5°C to 7°C on the surface and from 7°C to 8°C at the bottom.

Salinity

It was characterized by a wide variability caused by the diversity of sampling stations and by the seasonal effects; the absolute values ranged from a minimum of 5 PSU to a maximum of 40 PSU and monthly mean values from 24 PSU to 35 PSU.

pH

Even though it seems stable with values ranging from 8.1 to 8.2; there were extreme values like 7.5 on transect 8 and 8.5 on transects 68, 72, 77.

Theste

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O.D. % (Dissolved Oxygen)

Variations on a small scale CV% on mean monthly values varies from 1% to 24% were present. The recorded values were near saturation point; mean values was near 100%-110% at Station 356, near the seaport of Chioggia; seasonal fluctuations were also recorded with the minimum value corresponding to 60%, and at the stations 164, and 259. Maximum value corresponding to 200% near the mouth of Brenta and Adige rivers was recorded .

During coastal water monitoring, the seasonal trend registered a development of 0_2 percentage during the spring, with the highest values on the surface and in summer (150%-180%) (May, July and August) near Venice and Albarella.

During the autumn of 1991 and 1992 a progressively dissolved oxygen decrease with a minimum value (60%-70%) was registered in the zone between Eraclea and Venice in November.

Probably, this trend is imputable to the persisting summer bedding effect of water masses and to the water stillness caused by climatic situations and by thermoaline coastal presence which separates omogeneus high sea water from the diluited coastal water. This stillness, toghether with the autumn river water infolw, causes an increase in oxydative and respiratory processes, especially in the lagoon areas with a consequent decrease in dissolved oxygen.

N- (NH_3 - NO_2 - NO_3)

Registered monthly mean concentrations show us a decreases trend in this 3 years period with variations that show us the close positive correlation linking these nutritional factors. As reagards N-NO_2 it was noted that during the autumn-winter-spring period it reaches maximum concentration with monthly values between 20-30 µM/l in the superficial layer. The maximum concentration, about 240 µM/l, was registered in the March-April period. In the deep layers monthly mean values fluctuated between 0-9 µM/l.

During the summer the monthly mean values fluctuated between 5-17 µM/l on the surface and in the lower depths the monthly mean fluctuated between 0.5 - 4 µM/l with the minimum top 0.01 µM/l registered in the three months of May, June, July and September in many of the sampling stations 2 miles from the coast line.

Si - SiO4

The maximum values were registered at the sampling stations both along the coastline and in the open-sea, between Chioggia and Albarella. The maximum value was registered in Station 162 during the month of June '90 with a concentration of 67 µM/l but high values up to 40 µM/l were registered even in the open sea. This situation, obviously, was determined by the great river contribution coming from the Adige river and the Po river in these areas. Even the highest values in the depths, were registered in these areas (11 - 25 µM/l) between April-August.

The mean values, throught the sampling period, fluctuated between 3.2 - 24.4 µM/l.

The silicate (SiO_4) concentration resulted tightly correlated with that of N-NO_3 and then, in negative sense, with salinity.

P - PO_4

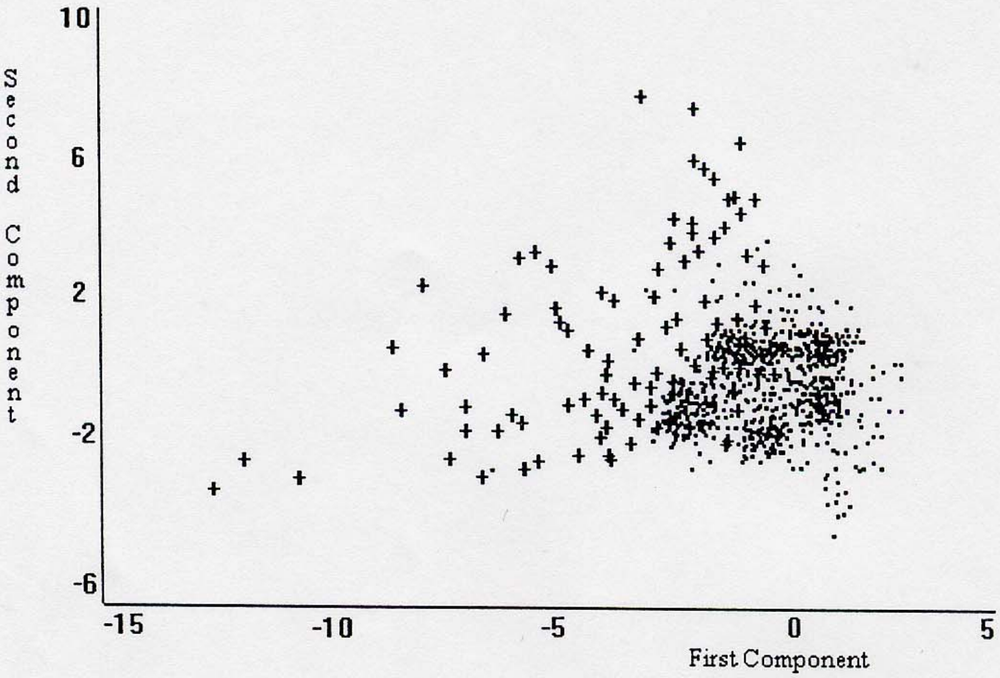
The recorded mean monthly values of concentrations on the surface fluctuated between 0.10 - 0.42 µM/l.

The variation space was between 0 - 9 µM/l. The maximum values on the surface were registered in the summer (June- July) and autumn (October - November).

DISCUSSION AND CONCLUSIONS

The research, carried out over several years, shown us some typical Northern Adriatic

Fig. 5- Distribution of samples collected during 1992 on the plane determined by the first and the second component (Eigenvector) (+ Samples with salinity < 30 μM/l . Samples with salinity > 30 μM/l).



<u>III° component: Chemical-physical factor.</u> This factor shows the ionic variations of temperature on nutrients like N and P.

The multivariate analysis suggests an increase of descriptive variables of sea water (for example Cl- and Na+), in order to describe the flow of river waters into the sea. The controls show that sea water is consistently affected by river water contributions, never reaching emergency levels fixed by the parameters for bathing water standards. Monitoring confirmed some sporadic cases of bacteriologic contamination, of anthropic origin, in some stations near the mouths of the rivers Brenta and Adige.

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Sea characteristics. First the emphasized seasonal variations caused by the shallow sea waters; second, the natural river contribution, which flows into the sea along this part of coastline.

During the annual cycle two heat fronts were registered at sampling stations set up 2 miles from the coastline where there were sampling stations at different depths:
-the first heat front, between March and August, with superficial waters temperatures higher than those in the depths;
- the second heat front between October and February, in which showed an evident thermal inverse stratification, with depth temperatures higher than those at the top.

During the first period (March-August) the superficial waters progressively heated up and the river contribution increased building a horizontal multistratified system that during the summer produces a minimal change between the top and the bottom layers. This situation was also confirmed by the salinity study . The period in which low salinity mean values were often registered on the surface, was June-August. Infact, in the summer months the phenomenon of stratification is rinforced by sun heating on the diluted upper layers which inhibits mixing in the colder saline layers (Fig 2a-2d).

The area in which stratification is greatest is between the Adige and the Po. In this area the effect of continental waters from these important rivers is more evident and its effect is shown even at 2 miles from the coastline. On the other hand the contribution of smaller rivers with less flow, is evident only in the sampling stations on coastline.

In autumn, cold attenuates thermal gradients, and the hydrodinamysm are favored also by the important river contributions.

For its conformation the Northern Adriatic Sea can be considered a "close-sea" in certain given times of the year and its continental waters are the most important influencing factor. (92 x 10^6 m^3 yearly) (CAVAZZONI GALAVERNI, 1972). Many of the nutrients (N, P, S), taken by biological-phytozoo-planktons cycles flow into the sea with these waters (DEGOBBIS G et al., 1990), conditioning the biological productivity in this area. Consequently the Northern Adriatic Sea is an ecosystem which is very sensitive to the territorial anthropological pressure which sourround it, above all in summer when there is a minimum water movement due to stratification.

Figures n°3a-3i, show the concentrations of nutritional factors, registered during the summer sampling period (in the figures transects are rappresented with progressive numbers starting form 1=transect n°8). The stations near the river mouths are evident and generally are indicative of continental water contribution. In fact we can see there the highest silicate concentrations. The maximum values correspond to the 59-77 transects near the Adige and Po mouths.

The nutrient redistributionis helped by the ecosystem dynamism with dilution and diffusion mechanisms. Indicator variables (nutrients) confirm their concervation trend as already seen in Tab. 2 from 1992 data. The nutritional factors (N-NH4, N-NO2, N-NO3, Si-SiO4 and P-PO4), present mean concentrations

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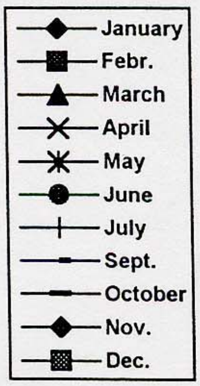
Legend of following Figures 2a-2d rappresenting variations of Si-SiO_4 at different deph (y-axis) in some transects during 1992.



Tab.3-Mean annual concentrations of nutrients

	N-NH_3	N-NO_2	N-NO_3	Si-SiO_4	P-PO_4
1990	3.45	0.79	20.41	9.53	0.17
1991	2.72	0.57	16.31	9.80	0.35
1992	1.60	0.39	11.74	7.89	0.22

decreasing from the coastline to the open sea and from the top to the bottom. This trend was confirmed over the three years even if in 1992 lower concentrations than those in the previous periods were registered (Tab. 3).
On the other hand, biomass phytoplanktonic concentration, registered in 1992, resulted generally higher than those of 1991, with monthly mean values higher than 1.5 μg/l even during the autumn period both on the surface and at the bottom. The sampling percentage in 1992 which was more than 5 μM/l, at the upper limit, was similar to the previous years (Fig.4). To the south of the transect n° 59 the area presented frequently high concentrations of chlorophyll a.

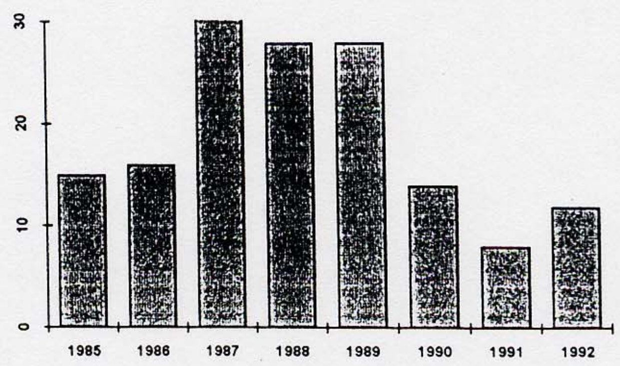
It is evident that during the period 1990-1992 no mucillageneous blooms were at any of the stations.

The findings of the mathematical and statistical analysis of analytic sampling data collected between 91-92 show that 58% of total variance is explained sufficiently by the first three extacted components (Eigenvectors) (Tab. 4).

I° component: Mixture of river water and sea water factor. It shows two kinds of variables : salinity and transparence with positive signe; and N-NO2, N-NO3, SiO4, N-NH4 with negative signs; these component shows the change that the nutrients of river waters create on the sea and then the great changes that river contribute producing diluition and organic arrichment.

The variance (30%) shows the fundamental character on which are classified the sampling stations (Fig. 5), particularly the stations to

Fig 4. Yearly percentage of samples with concentration of clorophyll a >5 μ



south of Chioggia, between the Brenta, Adige and Po mouths, which present lower salinity values than the others.

II° component: Biophisic factor. This factor is defined by chlorophyl a, O_2%, pH and temperature. It defines the role of the photosynthetic process, its sensibility to temperature variations and oxygen production.
In this component there are no contributions to the nutrients deriving from the river water.

Tab. 4 - Eigenvectors and Eigenvalues

Component	1	2	3
VARIABLE	λ%= 30	λ%= 18	λ%= 10
Depth	0.21	-0.22	0.15
Transparency	0.23	-0.05	-0.05
Temperature	0.10	0.36	-0.22
Salinity	0.40	-0.14	0.15
pH	0.07	0.51	-0.04
O_2%	-0.01	0.57	-0.01
N-NH_3	-0.27	-0.11	-0.12
N-NO2	-0.41	-0.08	-0.10
N-NO3	-0.44	-0.04	0.06
Si-SiO4	-0.39	-0.07	-0.20
P-PO4	-0.18	-0.07	-0.29
N inorg. T	-0.25	0.01	0.54
N/P	-0.13	0.07	0.67
Clorofyll a	-0.15	0.42	0.08

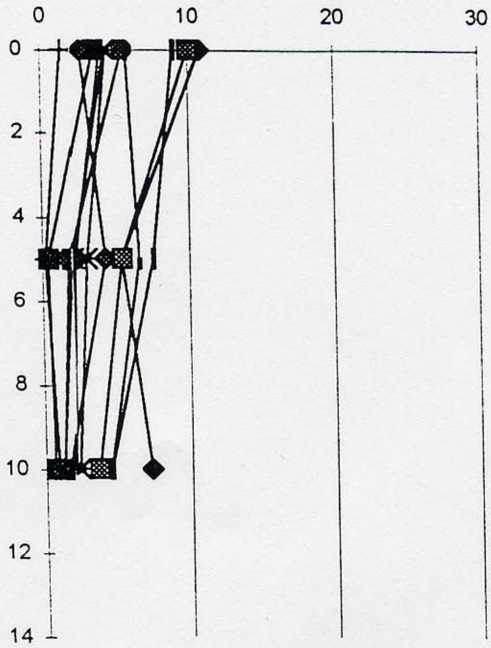


Fig.2a - Transect 8
Si-SiO4 (µM/l) by Depth (m)

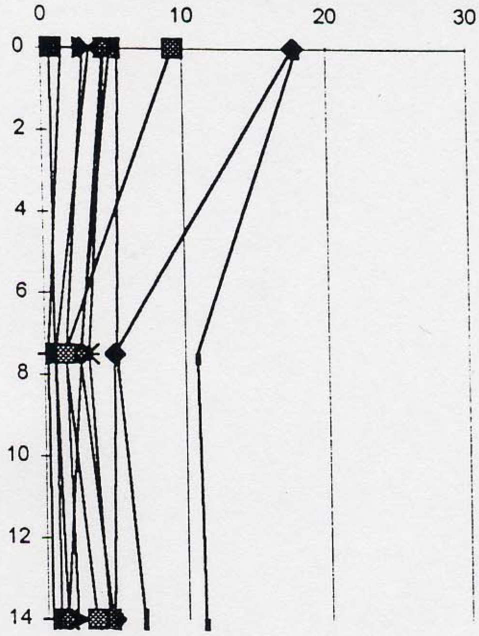


Fig.2 b - Transect 24
Si-SiO4 (µM/l) by Depth (m)

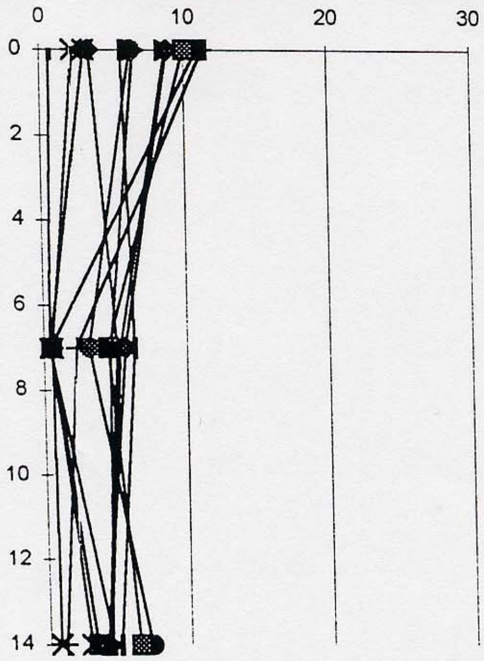


Fig.2c - Transect 40
Si-SiO4 (µM/l) by Depth (m)

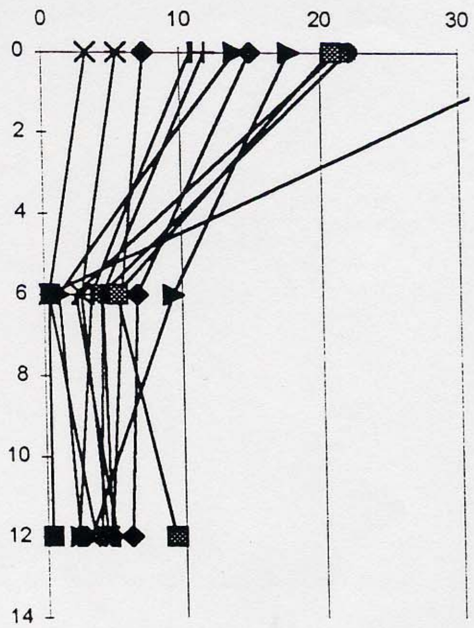


Fig 2d - Transect 72
Si-SiO4 (µM/l) by Depth (m)

Fig. 2 - Mean values of T°, salinity, O.D. (%), N-NO2, N-NO3, Si-SiO4, P-PO4, chlorophyll a of samples collected during 1992.

	Miles to the costline		
Depth (m)	0.5	1	to 2
≤ 0.5	17.6	17.6	17.7
0.6 - 7.5	-	17.7	17.8
7.6 - 15	-	16.5	16.3

Mean values of Temperature (°C)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0.5	16.22	14.20	12.87
0.6 - 7.5	-	4.93	3.24
7.6 - 15	-	1.79	1.68

Mean values of Nitrates (μM/l)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0,5	30.9	31.3	32.4
0.6 - 7.5	-	34.8	35.7
7.6 - 15	-	36.6	36.7

Mean values of Salinity (PSU)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0.5	9.87	9.45	8.41
0.6 - 7.5	-	4.40	2.91
7.6 - 15	-	2.84	3.66

Mean values of Silicates (μM/l)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0.5	109.5	110.1	110.0
0.6 - 7.5	-	106.5	108.1
7.6 - 15	-	101.6	98.0

Mean values of Dissolved oxygen (%)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0.5	0.26	0.25	0.24
0.6 - 7.5	-	0.18	0.17
7.6 - 15	-	0.17	0.19

Mean values of Phosphates (μM/l)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0.5	0.47	0.46	0.38
0.6 - 7.5	-	0.26	0.19
7.6 - 15	-	0.40	0.22

Mean values of Nitrites (μM/l)

	Miles to the coastline		
Depth (m)	0.5	1	to 2
≤ 0.5	3.05	2.78	2.42
0.6 - 7.5	-	2.42	1.75
7.6 - 15	-	1.30	1.57

Mean values of Chlorophyll a (μM/l)

Fig. 3a - June '90

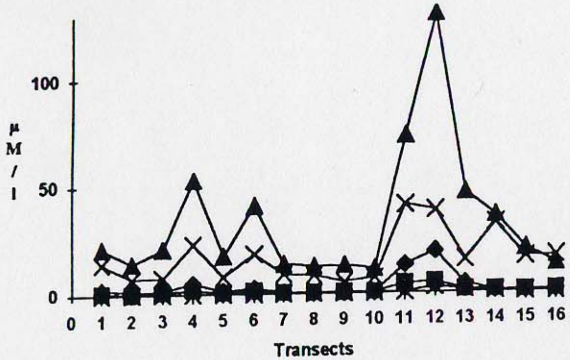


Fig. 3 d - July '90

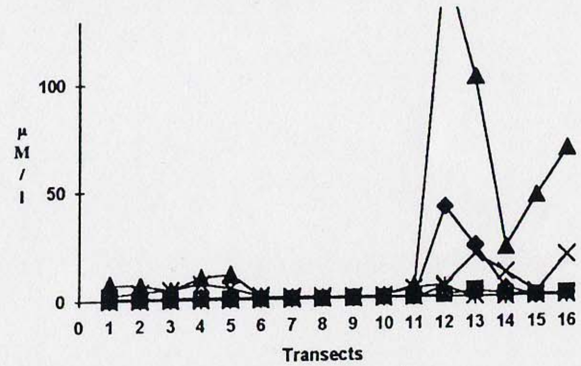


Fig. 3g - August '90

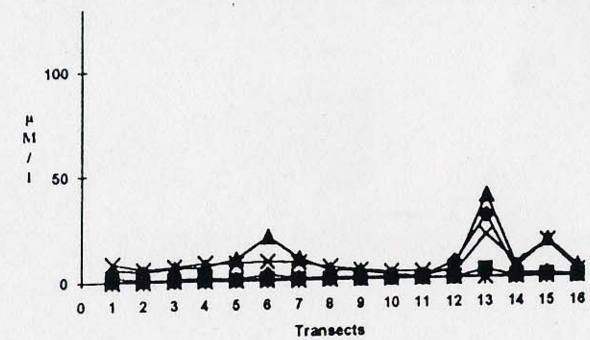


Fig3 b - June '91

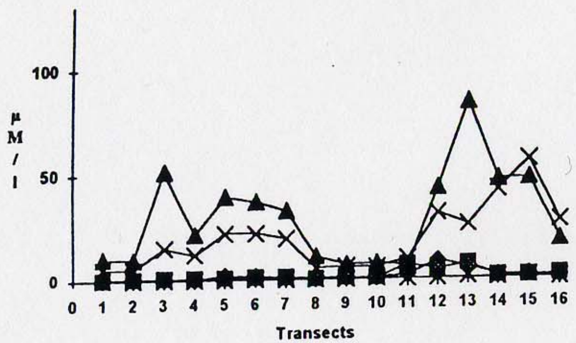


Fig.3e -July '91

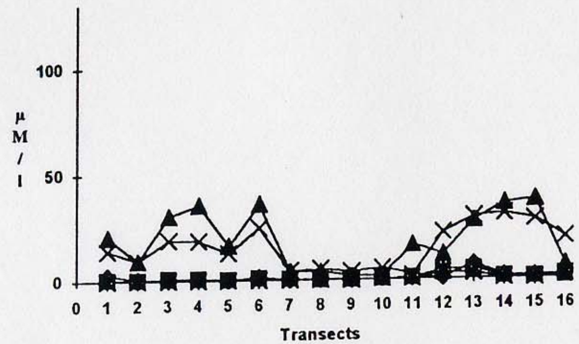
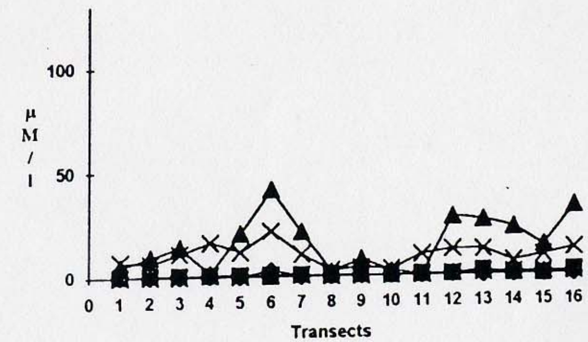


Fig.3h -August '91



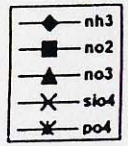


Fig 3c - June '92

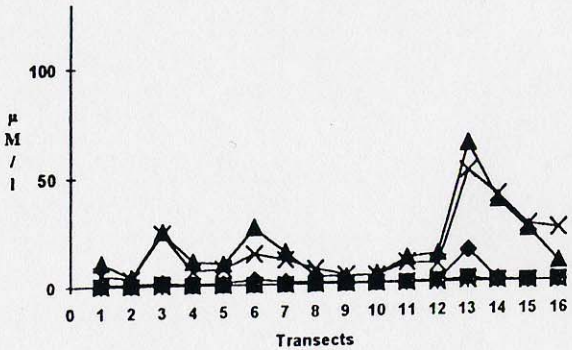


Fig.3f -July '92

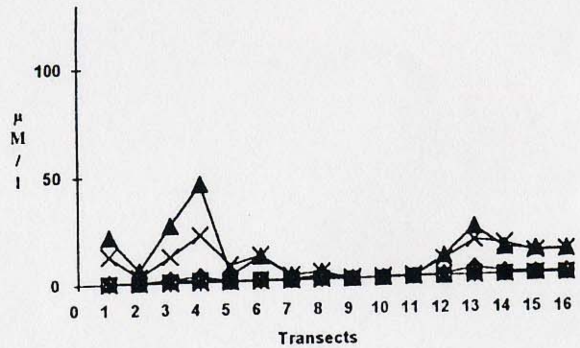


Fig 3i - August '92