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AN INTERDISCIPLINARY STUDY OF THE ESTUARINE AND COASTAL OCEANOGRAPHY OF BLOCK ISLAND SOUND AND ADJACENT NEW YORK COASTAL WATERS

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Interim Report for Period July through December 1972

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16. Abstract

The synoptic repetitive coverage of the multispectral imagery from the ERTS satellite, when photographically reprocessed using the state-of-the-art techniques, has given indication of spectral differences in Block Island and adjacent New England waters which were heretofore unknown. Of particular interest was the possible detection of relatively small amounts of phytoplankton prior to the occurrence of the red tide in Massachusetts waters. Preparation of spatial and temporal hydrographic charts using ERTS imagery and ground truth analysis will hopefully determine the environmental impact of New York coastal waters.

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Preface

The tremendous task of correlating the ERTS image characteristics of coastal waters with the physical, optical, chemical, and biological properties of water has been commenced. The synoptic repetitive coverage of the multispectral imagery from the ERTS satellite, when photographically reprocessed using the state-of-the-art techniques, has given indication of spectral differences in Block Island and adjacent New England waters which were heretofore unknown. Of particular interest was the possible detection of relatively small amounts of phytoplankton prior to the occurrence of the red tide in Massachusetts waters. Significant results from this work depend only on a reduction in cloud cover over the test site at the time of ERTS overflights.

Section 1

Introduction

This report is prepared in regard to NASA contract NAS5-21792 for "An Interdisciplinary Study of the Estuarine and Coastal Oceanography of Block Island Sound and Adjacent New York Coastal Waters". This interim progress report covers the initial preparation, field work, and imagery analysis for the period July through December 31, 1972.

This project was undertaken by Long Island University and New York Ocean Science Laboratory as a joint effort to study the characteristics of the waters of Block Island Sound as they may relate to ERTS-A imagery. Only about ten percent of the received imagery was usable because of the large extent of cloud cover over the New York area.

"First look" analysis of the imagery was performed using a multi-spectral viewer. The additive color analysis revealed that for better contrast and detailed information it was necessary to reprocess the imagery received from NASA. The ground truth experiments were undertaken by the New York Ocean Science Laboratory. Samples were collected in the water column for temperature, salinity, oxygen, nutrients, pigments, organics, phytoplankton, and optical properties. In situ upwelling radiance and downwelling irradiance measurements were taken along with one of the ground truth sampling cruises. The taking of spectra proved unsuccessful due to the instability of the measuring instruments because of the rocking of the research vessel under the sea conditions which were encountered.

A detailed narrative of the work performed by the New York Ocean Science Laboratory in order to analyze the ground truth sampling data for

Block Island Sound is included in the report submitted to Long Island University under the sub-contract. This report is contained herein as an appendix to the subject Type II report.

Section 2

Photogrammetric Analysis of ERTS Imagery

Underflight and ERTS imagery were analyzed in order to determine the hydrologic features of the water mass, including current patterns, particulant in suspension, and the contacts between water masses.

The ERTS imagery exposed on 28 July 1972 for Block Island Sound area was used to determine whether reprocessing of the negatives would be necessary. The spectral bands included the 500-600 nm, 600-700 nm, 700-800 nm, and 800-1100 nm regions.

Figure 1 below shows the general region covered by the frame of ERTS data which has been analyzed using additive color techniques.

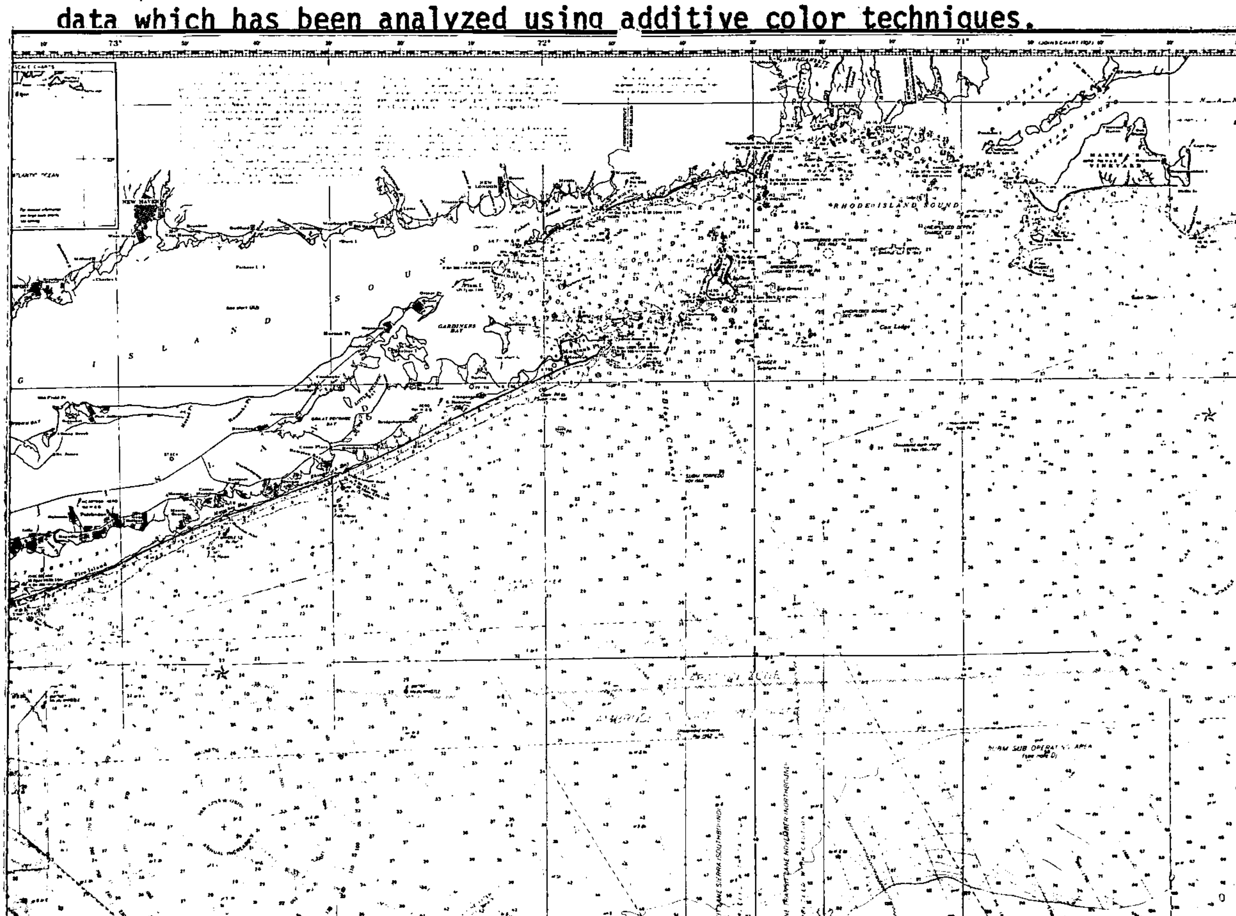


Figure 1. Hydrographic chart of the coastal area between Montauk Point and Block Island Sound.

Quick-look analysis of the NASA second generation negatives indicated that:

- -- The green spectral band lacked contrast, owing perhaps to the presence of some haze; it was also overexposed.
- -- Red spectral band was of acceptable contrast, although somewhat overexposed.
- -- The infrared bands were overexposed for the land areas, but the exposure was good for the water. The land areas fell almost completely on the shoulder of the curve (gray scale number vs. image density), while the water was along the upper toe portion. Almost no areas of interest fell along the straight line region of the curve.

The characteristic curves of the NASA-processed ERTS positive imagery are shown in Figure 2 on the following page. The slopes of the multispectral records are well matched, although the minimum density of both the green and far-infrared images is excessive. These curves were generated plotting the gray scale step number which appears at the bottom of the ERTS chips on the x axis with its density plotted on the y axis. Unfortunately, all the highlights of the scene fall along the toe portion of the curves where the density differences are relatively small for a large change in gray scale number. The darker regions of the imagery lie between the toe and the straight line portion of the curve where the density-brightness gradient is less than optimal.

A visual analysis of the NASA positives indicated the following:

- -- The green spectral band was extremely flat with a high D_{min} due to overexposure.

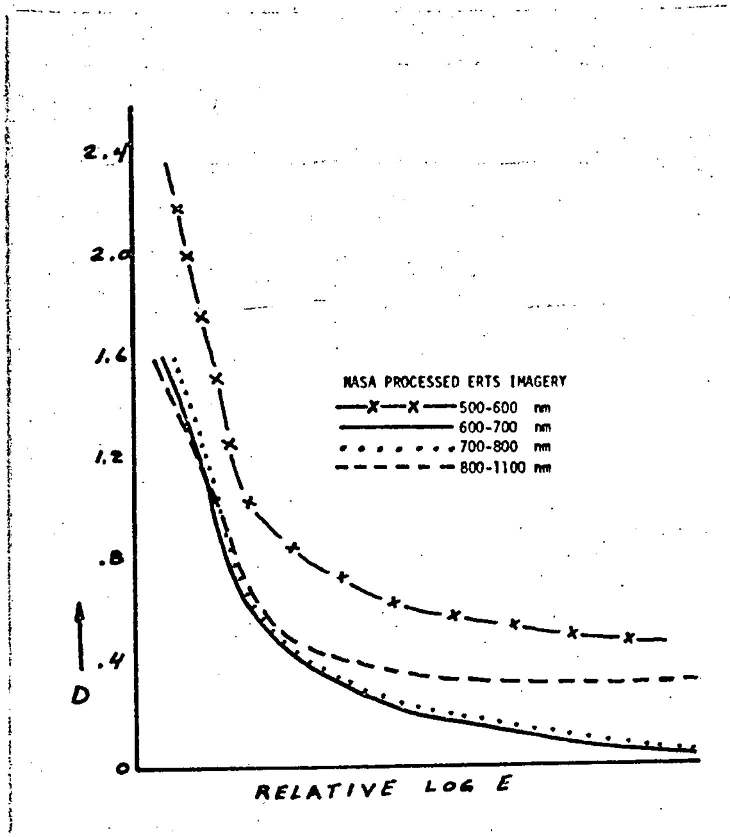


Figure 2. Curve of gray scale number vs. density of the positives supplied by NASA.

-- The red spectral band was of acceptable contrast.

-- The infrared bands lacked detail in both the water and land areas.

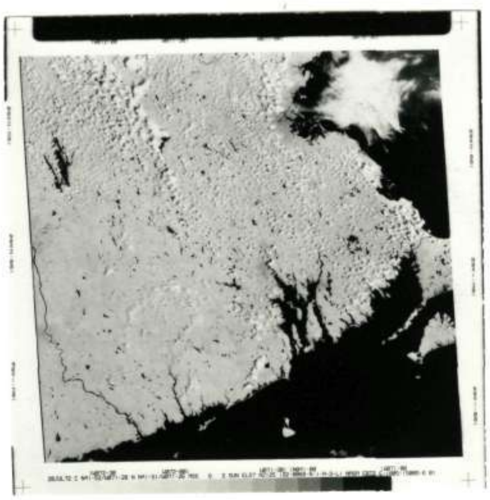
The NASA supplied positive imagery shown in Figure 3 was placed into the Spectral Data Model 64 viewer and the spectral records were projected as follows:

500-600 - Blue	700-800 - Red
600-700 - Green	800-1100 - Red

Only one of the infrared records was projected at a time with the two visible bands. The large urban areas were apparent, although most detail in the land was missing because of the heavy infrared exposure. Of all the records, the red has the most detail in both land and water. No obvious differences in water mass were apparent in this color composite image. Because of the

500 - 600 nm Band

600 - 700 nm Band



700 - 800 nm Band

800 - 1100 nm Band

Figure 3. Four multispectral scanner film transparencies as received from NASA.

500 - 600 nm Band

600 - 700 nm Band

700 - 800 nm Band

800 - 1100 nm Band

Figure 4. Four multispectral scanner positives reprocessed to enhance water detail.

non-optimal development of the MSS data for either the highlights (land) or the shadows (water), the NASA imagery was reprocessed at Long Island University.

The negatives supplied by NASA were used to generate a second set of positives which would enhance any small detail in the water mass. Both the exposure and processing were altered to place the low brightness regions on the straight line portion of the characteristic curve shown in Figure 5. Notice that those regions which existed between the toe and straight line of Figure 2 are now imaged along the straight line portions of Figure 5. The minimum density has also been reduced on the red and near-infrared records. Due to the poor exposure of the green band, little could be done to create any significant change in the high minimum density without losing the little detail which the image contained. Contrast increased by using EK 2420 duplicating film and processing in D-19. The scene brightness range for both water and land is small so that a single reproduction of the green record has been used for the enhancement of both water and land areas. A more accurate comparison of the effects of reprocessing can be made by noting the density differences in the water between NASA and Long Island University processing. The water mass is represented by step wedge steps #14-16. The Δ density between these steps for NASA processed infra-red positives is .7, while the Δ density of the water for the reprocessed infrared positives is 1.35. The Δ density in the red region is .6 for NASA processed film and .8 for Long Island University reprocessed images. It should also be noted that the lower D_{min} makes the water differences more obvious when projected by increasing the brightness level on the viewer screen.

Figure 6 is a composite color rendition of the positive imagery

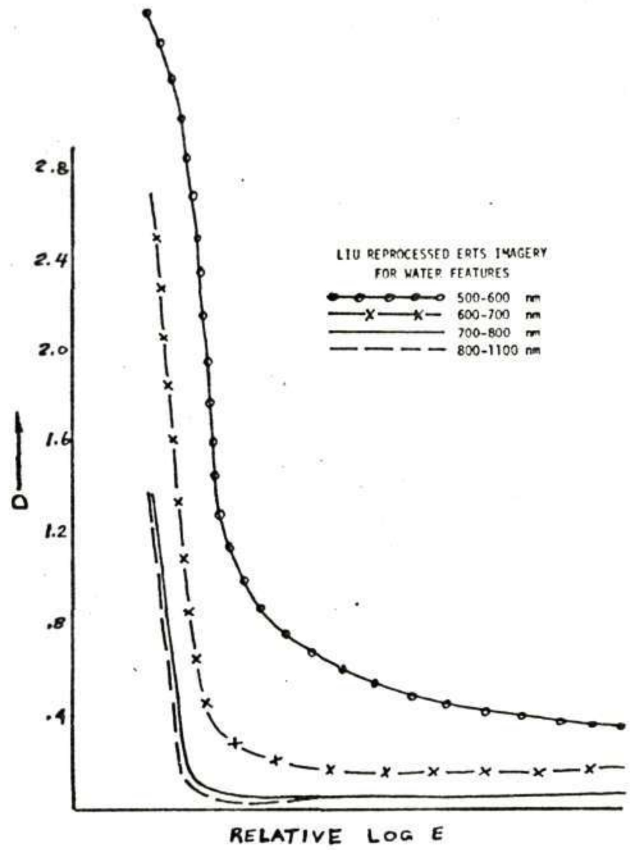


Figure 5. Curve of gray scale number vs. density for positives reprocessed to enhance water detail.

Figure 6. Additive color image of MSS bands 4, 5, and 6 reprocessed to enhance water detail.

reprocessed to enhance water detail. Notice that all detail in the land areas has been lost since highlights have been placed along the toe of the curve of Figure 5. Distinct outpourings from the Connecticut and Thames Rivers are apparent as a cyan color. Some turbidity also exists in the vicinity of Newport, as well as between Martha's Vineyard and Cape Cod. Attention is called to the water mass south of Martha's Vineyard. The light grayish-purple hue is indicative of the high reflectance of the water in the red spectral region. We believe that this image could be related to the infestation of poisonous algae that invaded the New England coast from Cape Cod to upper Maine known as the "red tide".

The analyses indicate that it is necessary to expose and process the multispectral imagery for the scene brightness range under con id-eration. Unfortunately, some of the reprocessed film is grainy, which is a natural consequence of trying to develop the film to a sufficiently high contrast in order to get good projected color.

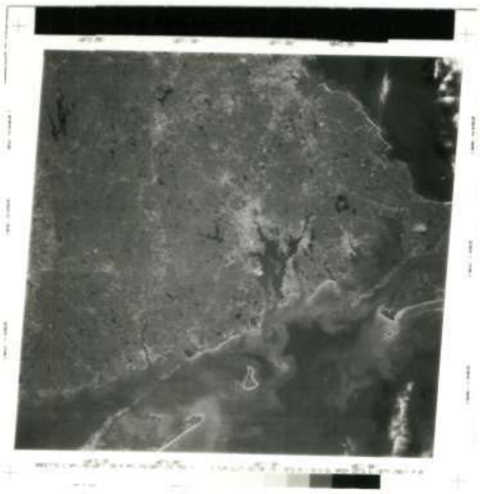
Optical Properties of the Water

An attempt was made to measure the upwelling radiance of the water in the visible portion of the spectrum. The measurements obtained could not be utilized for a scientific analysis due to the inaccuracy and large variations in the data. These inconsistencies in the data were caused by the vibrations in the measuring instruments due to the rocking of the research vessel on a fairly calm sea surface.

However, the downwelling irradiance of the total visible spectrum, together with spectral bands in the red, blue, and green regions, were measured during the cruises using an upward facing irradiance meter. Reference is made to the interim report submitted by the New York Science

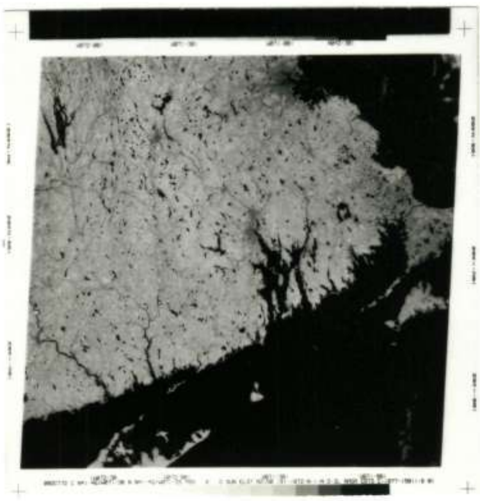
Laboratory in Appendix A for detailed information. The extinction coefficient, an index of the turbidity, was calculated and, as such, relates to the suspended and dissolved material in the water. No measurements were attempted under overcast skies.

The sampling stations closest to shore generally show the highest extinction values as would be expected. Indications are that these stations also contain the largest number of particles per liter and phytoplankton in the water. Examination of October 8, 1972, satellite imagery shows that the area closest to Montauk Point is marked by what appears to be a comparatively heavy concentration of suspended material that is dominating everything in the 500-600 nm band as shown in Figure 7. The variations in the imaged water densities are apparent in MSS bands 4 and 5 representing the different concentrations of suspended materials at different locations. Similar inferences can be observed for the area by the northern tip of Block Island and the northern end of Rhode Island by Point Judith. The broad band assessments of the spectral downwelling irradiance do serve to show the general bands wherein the greatest transmission can be expected and thereby also an index of the band wherein the emission might also be expected to be greatest.

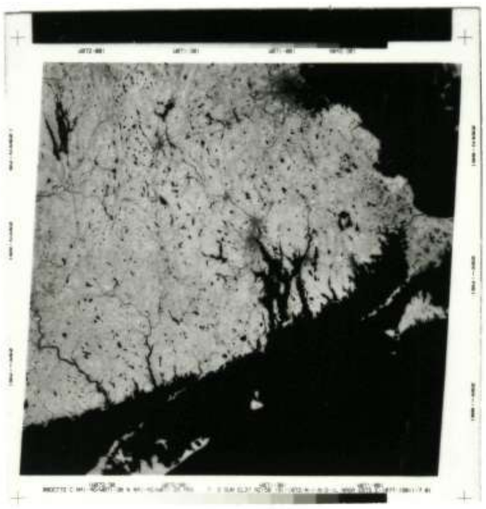


500 - 600 nm Band

600 - 700 nm Band



700 - 800 nm Band



800 - 1100 nm Band

Figure 7. Four multispectral scanner positives of October 8, 1972, satellite imagery showing heavy concentrations of suspended material in water near Montauk Point.

Section 3

New Technology

The "Interdisciplinary Study of the Estuarine and Coastal Oceanography of Block Island Sound and Adjacent New York Coastal Waters" constitutes the ground truth experiments on site and correlation with the ERTS imagery. No innovations were made and there are no data available for new technology section.

Section 4

Program for Next Reporting Interval

The sampling cruises for the year 1973 to collect ground truth in the New York Bight and Block Island Sound area will be planned and acted upon. A sampling program is being designed that will survey the entire Block Island Sound region concentrating on the surface waters only. Intervalometer systems are now being readied that will continuously monitor pigments by means of a continuous flow fluorometer, and temperature, both in the surface layer. The vessel, however, will be stopped at positions where pigment concentrations indicate, for spectral irradiance measurements within the water column and for drawing water samples for biological analysis.

In situ upwelling radiance measurements will be obtained with modified instrumentation so as to minimize the inaccuracy in the obtained data due to the rocking of the research vessel. The data would be correlated with the image characteristics of ERTS imagery and with chemical, biological, and physical parameters of ocean waters.

The received usable ERTS imagery will be analyzed for detailed information by using an additive color viewer. Additive color, density slicing, and isoluminous analysis will be performed to achieve the maximum information regarding the spatial location and probable composition of the water masses.

The relationship between the in situ water sample and spectra with the analyzed ERTS imagery will be established to determine the spatial and temporal changes of water masses.

Section 5

Conclusions

ERTS multispectral scanner imagery of the New York coastal waters can be photographically reprocessed to show the presence of subtle spectral differences in the water when viewed using an additive color viewer. In Block Island Sound and Rhode Island Sound suspended materials, most probably organic in nature, were permanent in the 600-700 nm and 700-800 nm spectral bands.

Only about ten percent of the received ERTS imagery is usable due to the extent of cloud cover over the New York area on satellite days. It is evident from the photometric analysis that the ERTS imagery received from NASA must be reprocessed to enhance water detail. This implies, in fact, that the imagery should be reprocessed to maximize the information depending upon the area of interest.

Photographic reprocessing techniques have been developed which when applied to the NASA multispectral imagery supplied to investigators yields greatly improved detectability of subtle water and land phenomena. These techniques have been related to the gray scale supplied with each of the four multispectral images in order to provide quantified data on the photographic transformations applied to the imagery.

In order to collect water sample data which is relevant to the characteristics being detected on the multispectral imagery, a revision of the "ground truth" collection plan is required. Rather than concentrating on "in depth" sampling at a relatively small number of stations, surface collection of data at a large number of stations is required.

Section 6

Recommendations for Further Action

A modification of the "ground truth" data collection plan is required. During the period reported upon, concentrated "in depth" sampling at selected stations in Block Island Sound was performed. Since the satellite imagery shows predominantly surface effects over a large area, this data collection plan has been modified. This modified data collection plan includes predominantly surface sampling of physical, chemical, and biological water characteristics at a large number of randomly located stations.

New techniques and instrumentation are being tested to obtain statistically repeatable measurements of the upwelling radiance of water at the sampling stations. During the reporting period repeatable results of upwelling water spectra could not be obtained due to the inability to maintain the instrumentation in a constant orientation simultaneously with vessel motion under the sea conditions encountered.

The photographic reprocessing techniques which have been developed will be further refined to maximize the detection of subtle water spectral reflectance differences. It is planned to perform an additive color and density slicing analysis on enlargements of the 70 mm ERTS imagery.

Anticipating that additional ERTS imagery will be obtained when cloud cover does not obscure the test area, correlation of water sample data with the imagery in the form of thematic charts will be accomplished in the next reporting period.

APPENDIX

Interim Progress Report

for the Period July through December 1972

in reference to

"An Interdisciplinary Study

of the Estuarine and Coastal Oceanography

of Block Island Sound and Adjacent New York Coastal Waters"

submitted by

Dr. R. Hollman

Dr. J.E. Alexander

Dr. R. Nuzzi

under sub-contract between

Long Island University

and

New York Ocean Science Laboratory

INTRODUCTION

A program has been established to study the characteristics of the waters of Block Island Sound as they may relate to ERTS 'A' imagery.

This report covers the initial preparation and field work for the period of August through November, 1972. Data for December are currently being acquired and analyzed.

Six satellite passes of the Block Island Sound area are involved in the period from August through November, these being: August 15 (16, 17), September 2 (3, 4), September 20 (21, 22), October 8 (9, 10), October 26 (27, 28) and November 13 (14, 15). Data reported on herein were largely acquired during 7 cruises in the area as tabulated in Table 1 along with the station positions that are located in the map of Block Island Sound shown in Figure 1. Six cruises that were planned were either cancelled or aborted due to mechanical problems with ship equipment or bad weather. Cruises were also rescheduled due to these weather problems. An attempt to obtain data in the New York Bight toward the end of October was also cancelled due to poor weather conditions.

The report itself is divided into three sections: Section 1, Physical Oceanography, Section 2, Chemical Oceanography and, Section 3, Biological Oceanography.

TABLE 1. Cruise Dates and Station Locations in Block Island Sound.

Transect	Station	Latitude (North)	Longitude (West)	Dates 1972
"H"	H1	41°06.8'	71°51.5'	24 Aug. 10 Oct. 14 Nov. 4 Dec.
	H2	41°10.4'	"	
	H3	41°13.8'	"	
	H4	41°16.5'	"	
"HB"	HB1	41°04.8'	71°49.4'	29 Aug. 10 Nov. 6 Dec.
	HB2	41°05.8'	71°46.3'	
	HB3	41°06.7'	71°43.3'	
	HB4	41°07.5'	71°40.2'	
	HB5	41°08.4'	71°37.3'	
"BR"	BR1	41°15.7'	71°34.8'	5 Sept. 16 Nov. 8 Dec.
	BR2	41°18.0'	71°33.0'	
	BR3	41°20.8'	71°30.5'	

METHODS

Each transect is occupied for a complete tidal cycle by continually sailing back and forth so that each station of a transect is sampled from 4 to 6 times during the tidal cycle. Samples at each station from within the water column, generally at 6 depths, are collected in 5 liter Niskin bottles for chemical and biological analysis. Temperatures are measured with bathythermographs and thermometers.

Salinities are obtained using a laboratory conductivity cell (Beckman RS-7), chlorophylls and nutrients using the methods as described in Strickland and Parsons (1968).[1]

The phytoplankton in a liter of seawater are concentrated with a continuous plankton centrifuge (Kahl Scientific) to a volume of approximately 10 ml, then buffered with neutralized formalin (3% final concentration). Counting is done in a Palmer nannoplankton counting chamber under 100x and 400x magnification. From the raw seawater, 50 ml are collected for particle size analysis with the Counter counter.

[1] Strickland, J.D.H., and T.R. Parsons, 1968. A practical handbook of seawater analysis. Bull. 167, Fish. Res. Bd., Canada.

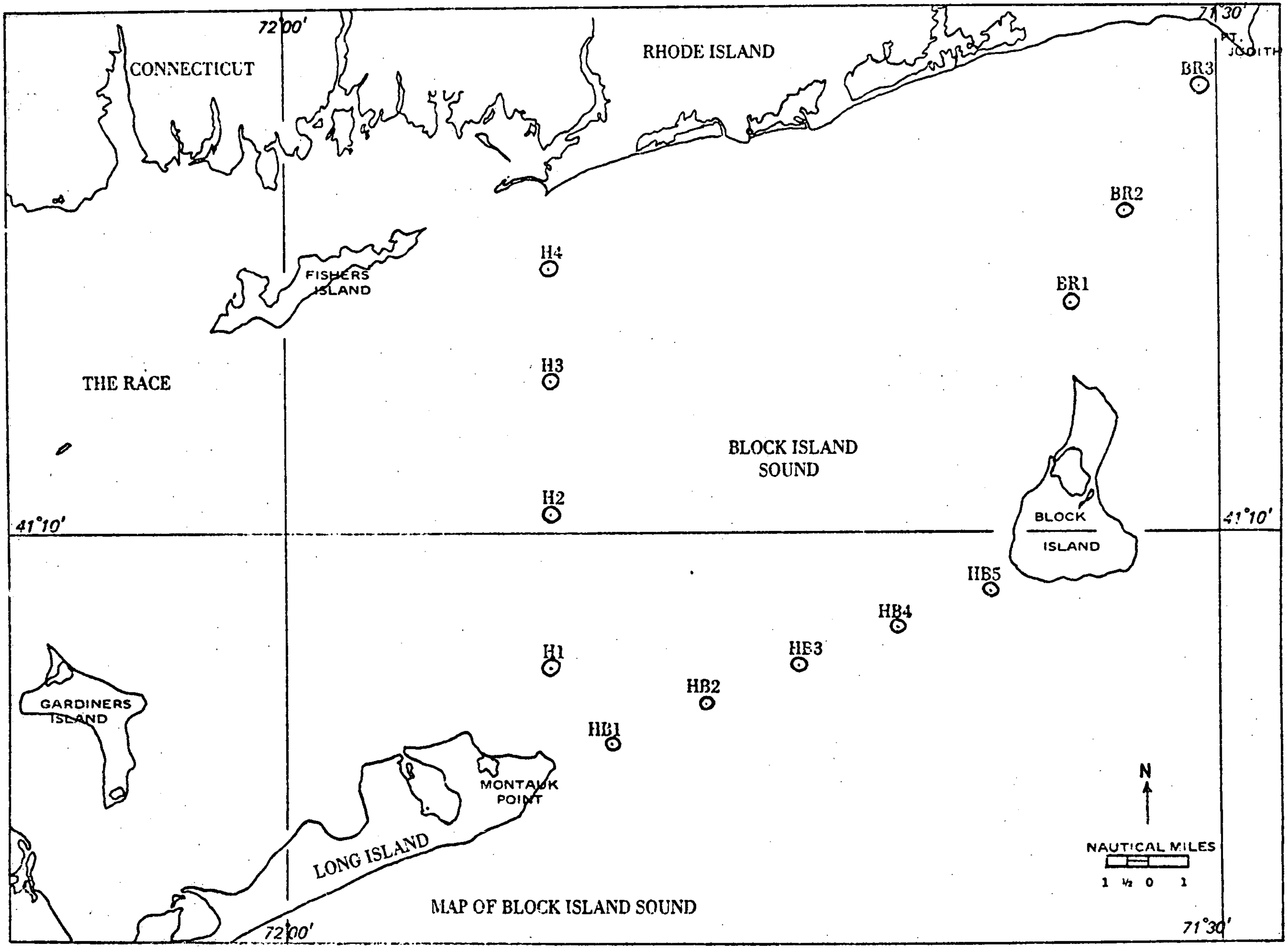


FIGURE 1: Map of Block Island Sound showing transects and station locations.

3-a

1. PHYSICAL OCEANOGRAPHY (R. Hollman)

A. Temperature and Salinity

A typical example of the temperature and salinity fields across the H Transect as a function of time is chown in Figure 1-2. The temperature and salinity distributions to the left in the figure represent the conditions as function of depth across the transect when the tidal flow was at maximum flood, that is, the currents were flowing approximately west near maximum speed at each station. Similarly, the temperature and salinity distributions to the right in the figure represent the conditions under maximum ebb conditions when the flows are to the east. The first distributions were measured during the second crossing of the transect and the last distributions during the sixth crossing during that tidal cycle.

Table 1-1. Representative average surface temperatures and salinities for the three transects in Block Island Sound.

a) H Transect

Date	Variate	H1	H2	H3	H4
24 Aug	$\overline{S‰}$	30.27	30.24	30.62	30.54
	$\overline{t°c}$	19.33	18.77	20.07	19.70
10 Oct	$\overline{S‰}$	31.14	31.10	31.39	31.71
	$\overline{t°c}$	17.30	17.68	17.48	17.40

b) HB Transect

Date	Variate	HB1	HB2	HB3	HB4	HB5
29 Aug	$\overline{S‰}$	30.70	30.77	30.86	31.15	31.29
	$\overline{t°c}$	17.93	17.83	18.02	18.64	18.00

c) BR Transect

Date	Variate	BR1	BR2	BR3
5 Sept	$\overline{S‰}$	31.40	31.57	31.56
	$\overline{t°c}$	18.70	19.20	19.23

At first glance, conditions appear to be more homogeneous during the flood conditions than during ebb when conditions appear more stratified. Similar results have been observed along the other two transects, HB and BR. A more detailed analysis is in progress to study the significance that these variations with depth and time may have on the surface distributions that can be detected in the satellite imagery.

These extensive data have been averaged for each tidal cycle at each station in order to produce a more efficient first glance at surface conditions. The values have been tabulated in Table 1-2 and appear in Figure 1-3.

In general, the stations close to Montauk Point are less saline than at any of the other stations thereby indicating the presence of the more brackish estuarine waters. The source of this water type appears to be the Peconic Bay System to the west. The waters around Block Island and the Rhode Island shore are mixtures of Coastal water, Rhode Island Sound waters, and Long Island Sound waters. Data from recent cruises are being processed and analyzed.

B. Optical Properties of the Water

The downwelling irradiance of the total visible spectrum, together with spectral bands in the red, blue and green regions were measured during the cruises using an upward facing irradiance meter ("submarine photometer") comprising a photo-cell and cosine collector. "Extinction" coefficients, k, were calculated from these data where k is defined by

$$I(z) = I(z=0)\ \exp{-kz}$$

where I(z=0) is the visible light energy incident at the naviface and I(z) is the remaining light energy at at the depth z, in meters. The units of k are therefore per meter (m^{-1}).

The extinction coefficient k is thereby an index of the turbidity and as such, is related to the suspended and dissolved material in the water. The data for these coefficients in the total visible spectrum are tabulated in Table 1-2 for each station. No measurements were attempted under overcast skies.

The average values for k for each station from Table 1-2 are plotted as a function of distance for each transect in Figure 1-2. As shown in the figure, stations closest to shore (H1, H4, HB1, HB5, BR1, BR3) generally show the highest extinction values as would be expected. Indications are that these stations also contain the largest number of particles per liter as will be discussedin a following section dealing with phytoplankton and particles in the water. Examination of the available satellite imagery, particularly for the October 8 Satellite Day shows that the area closest to Montauk Point, Stations H1 and HB1, also is marked by what appears to be a comparatively heavy concentration of suspended material that is dominantly emitting in the 400-500 nm as determined from the MSS 4 imagery. Similarly for the area by the northern tip of Block Island and the northern end of Rhode Island by Point Judith.

Table 1-2. Extinction coefficients calculated from downwelling irradiance measurements for the visible spectrum acquired in Block Island Sound.

a) H Transect

Date	Cruise	H1	H2	H3	H4
22 Aug.	K7215	0.61	0.47	0.29	0.33
24 Aug.	K7217	0.44	0.41	0.33	0.31
Averages		0.52	0.44	0.31	0.32

b) HB Transect

Date	Cruise	HB1	HB2	HB3	HB4	HB5
22 Aug.	K7215	0.47	0.47	0.29	-	-
29 Aug.	K7218	0.39	0.29	0.31	0.29	0.34
10 Nov.	K7230	0.85	0.56	0.37	0.52	0.63
Averages		0.57	0.44	0.32	0.40	0.48

c) BR Transect

Date	Cruise	BR1	BR2	BR3
22 Aug.	K7215	0.31	0.26	0.27
5 Sept.	K7219	0.32	0.34	0.47
Averages		0.32	0.30	0.37

The measurement of the spectral characteristics of the downwelling irradiance within these waters are now being carried out on a routing basis. The first successful series of measurements are tabulated in Table 1-3. The glass filters employed are broad band where the green filter has a 65% maximum transmission over a range of 460 to 660 nm, the blue filter has a maximum transmission of 87% over the range of approximately 300 to 550 nm, and the red filter with 85% maximum transmission over the range of 500 to 720 nm. These broad bands invalidate any detailed quantitative assessments of the spectral downwelling irradiance, however, they do serve to show the general bands wherein the greatest transmission can be expected, and thereby, also an index of the band wherein the emission might also be expected to be greatest. This is certainly indicated in imagery on October 8th.

Table 1-3. Spectral extinction coefficients for BR Transect, 16 Nov. 1972.

Color	BRI	BR2	BR3
Visible	0.45	0.48	0.62
Green	0.39	0.38	0.48
Blue	0.60	0.64	0.75
Red	0.77	0.66	0.76

The high level of attenuation of the blue and red bands in Table 1-3 compared to the relatively low attenuation of the green indicates a very turbid coastal water (type No. 9, Jerlov (1968) Chap. 10). Burt (1968) has shown that there is reason to believe that attenuance caused by a mixture of suspended particles of various sizes and composition would increase toward shorter wavelengths, that is, toward the blue region.

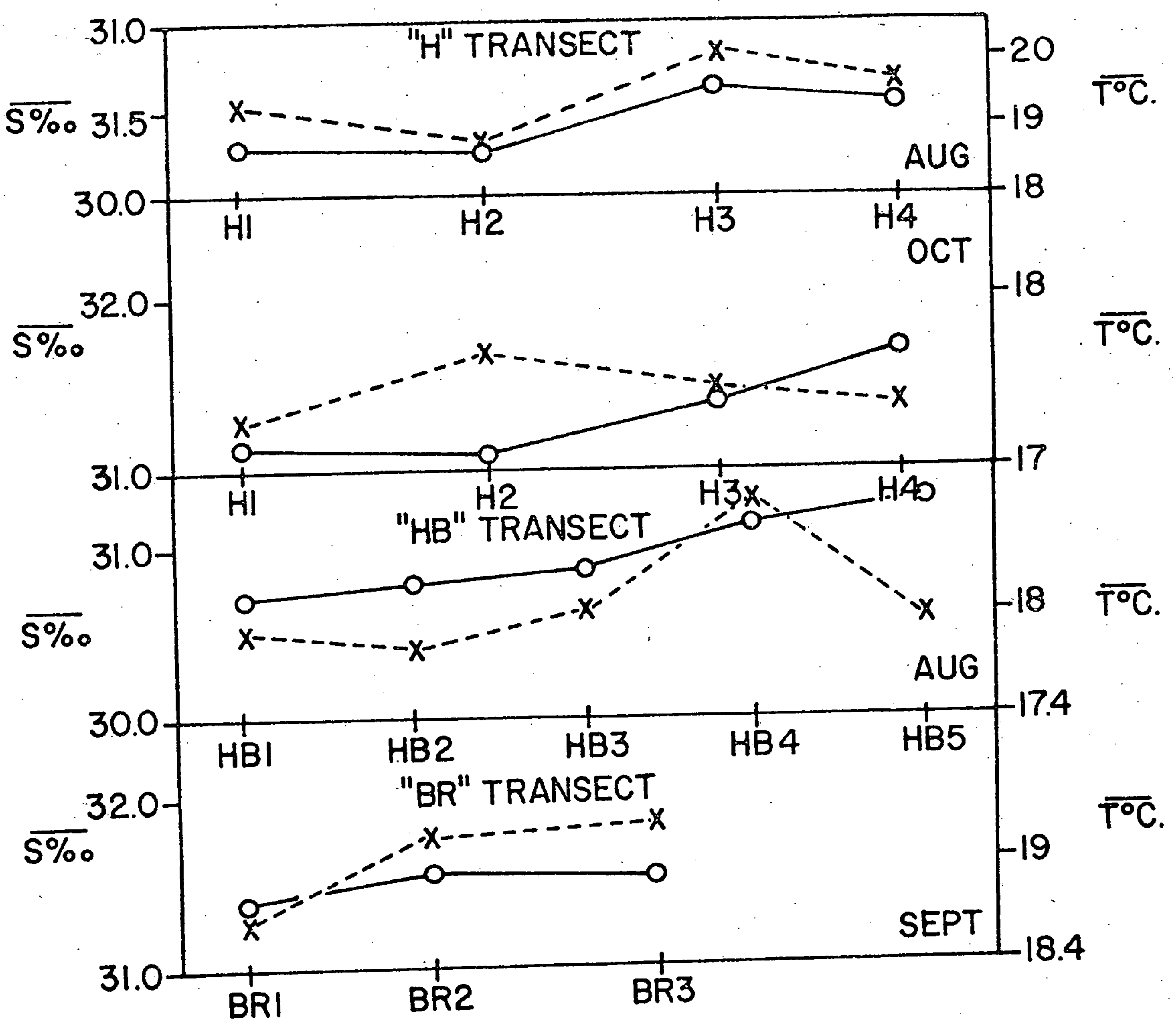


FIGURE 1-1: Average surface salinities and temperatures along the three transects in Block Island Sound.

a) Average salinities ——O——

b) Average temperatures ---X---

8-a

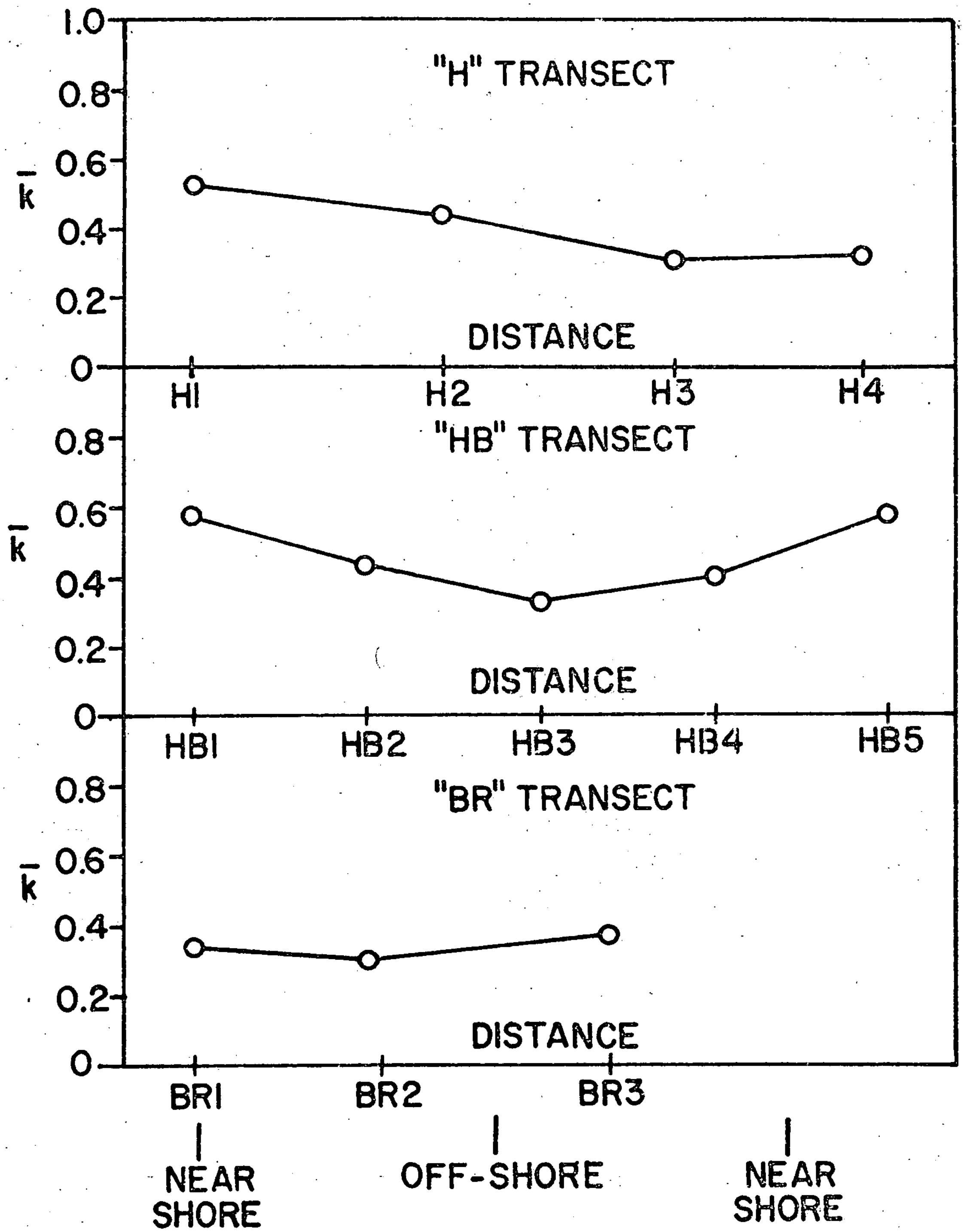


FIGURE 1-2: Average extinction coefficients along the transects in Block Island Sound.

2. CHEMICAL OCEANOGRAPHY (J.E. Alexander)

The parameters being monitored are salinity, oxygen, reactive, total soluble and particulate phosphate, nitrite and nitrate nitrogen, silica and chlorophyll a and c. As noted previously a minimum of three samples (maximum six) are collected from the water column at each station over the tidal cycle.

In these early stages of the study, the data is treated in two ways. To obtain a representative concentration for the parameter on a given day all data collected from a particular station on that day is averaged. These data are then plotted as in Figures 1, 3 and 5. In the second treatment data from each transect completed during the day is plotted in a time series similar to that shown in Figures 2a, 2b, 4a, 4b, 6a and 6b.

Transect H

Chlorophyll a and c

The average chlorophyll a and c concentration at each of the stations on H1, 2, 3, and 4 is shown in Figure 2-1. In general the chlorophyll content of the water ranged between 2-3 mg/m^3 for chlorophyll a and between 1-2 mg/m^3 for chlorophyll c. Figures 2-2a and b show the concentration for each of the pigments on 24 August and 10 October for each of the transects completed. On 14 November only one transect was completed (inclement weather) and these data are shown in Figure 1.

Transect BR

The average concentration of chlorophyll a and c for 24 August and 10 November is shown in Figure 2-3. These data are similar to those found for the H Transect.

Short term variations in the pigment content of the waters along the HB transect are shown in Figures 2-4a and b. The water close to Montauk Point contained more pigment than those further offshore on 29 August while the opposite situation was found on 10 November, 1972.

Transect BR

Figure 2-5 depicts the average concentration of chlorophyll *a* and *c* along the BR transect for each of the three sampling periods. Mechanical problems prevented us from collecting additional data on 12 October. The average concentrations encountered along this transect in September and November are similar to those found for the other transects. The effect of the tides was more pronounced in September (Figure 2-6a) than in November (Figure 2-6b).

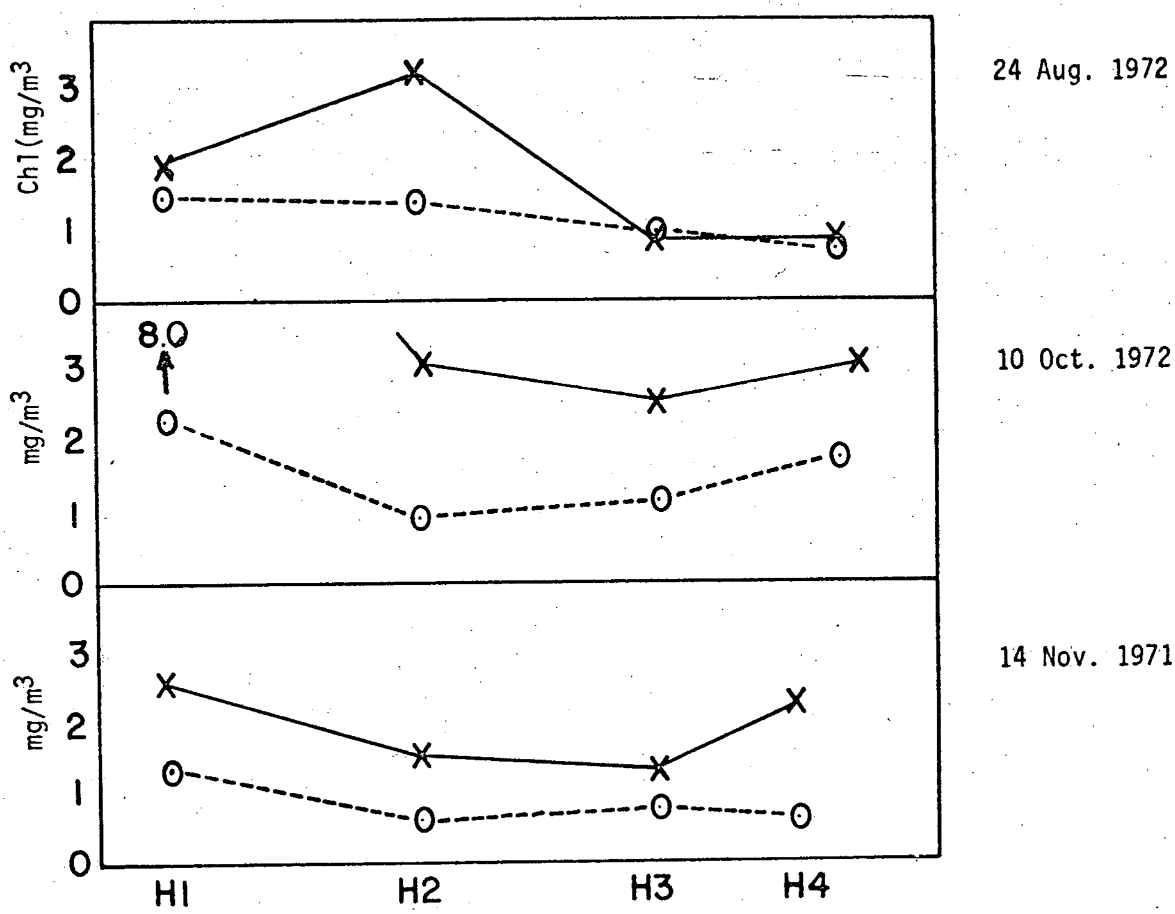


FIGURE 2-1: The average concentration of chlorophyll a (X——X) and c (O----O) along the H transect for each of the sampling periods (K7231 - one transect only.

10a

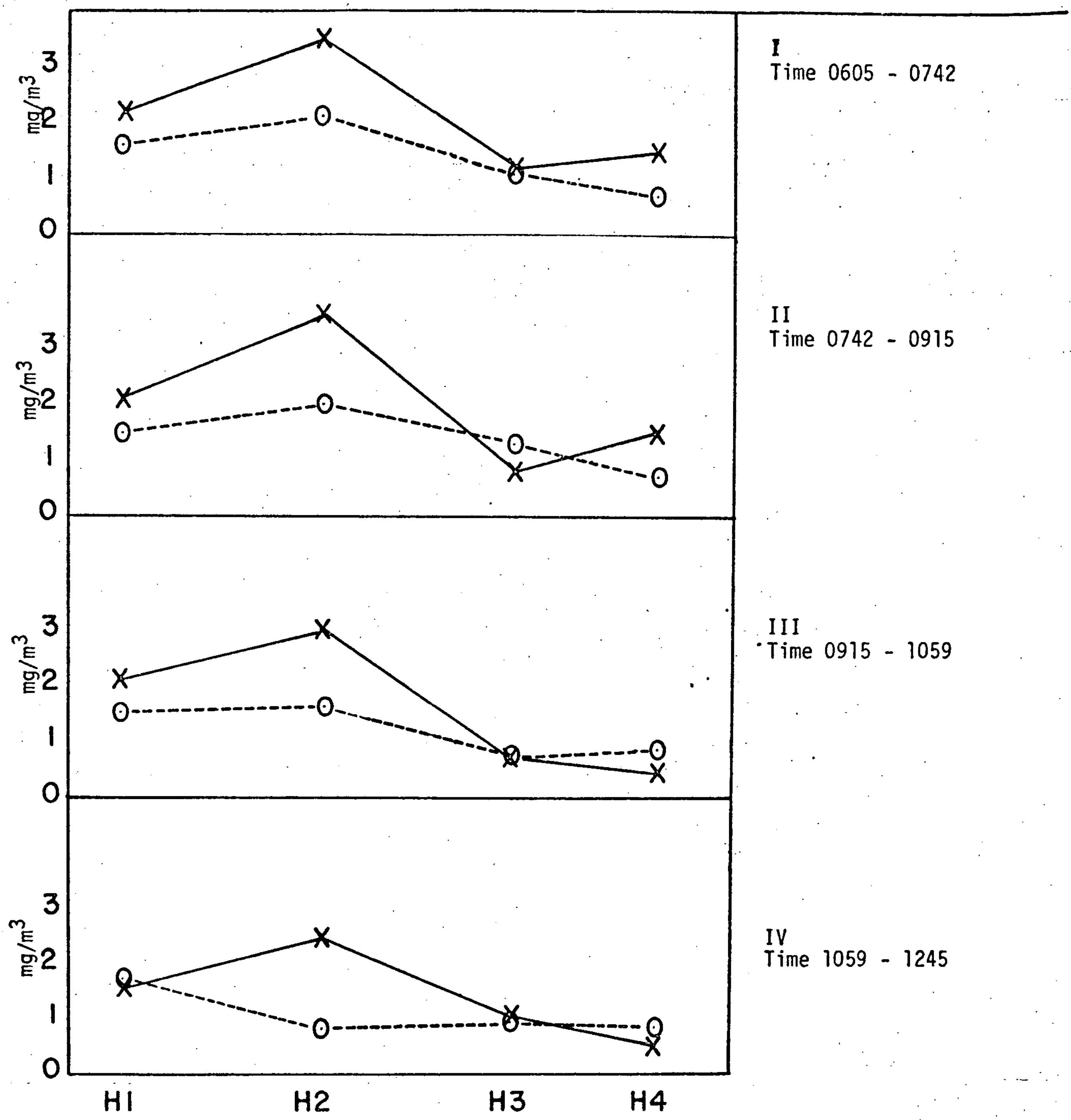


FIGURE 2-2a: Temporal and spatial variations in the chlorophyll a (X——X) and c (0------0) contents of the waters along the H transect, 24 August 1972.

10-6

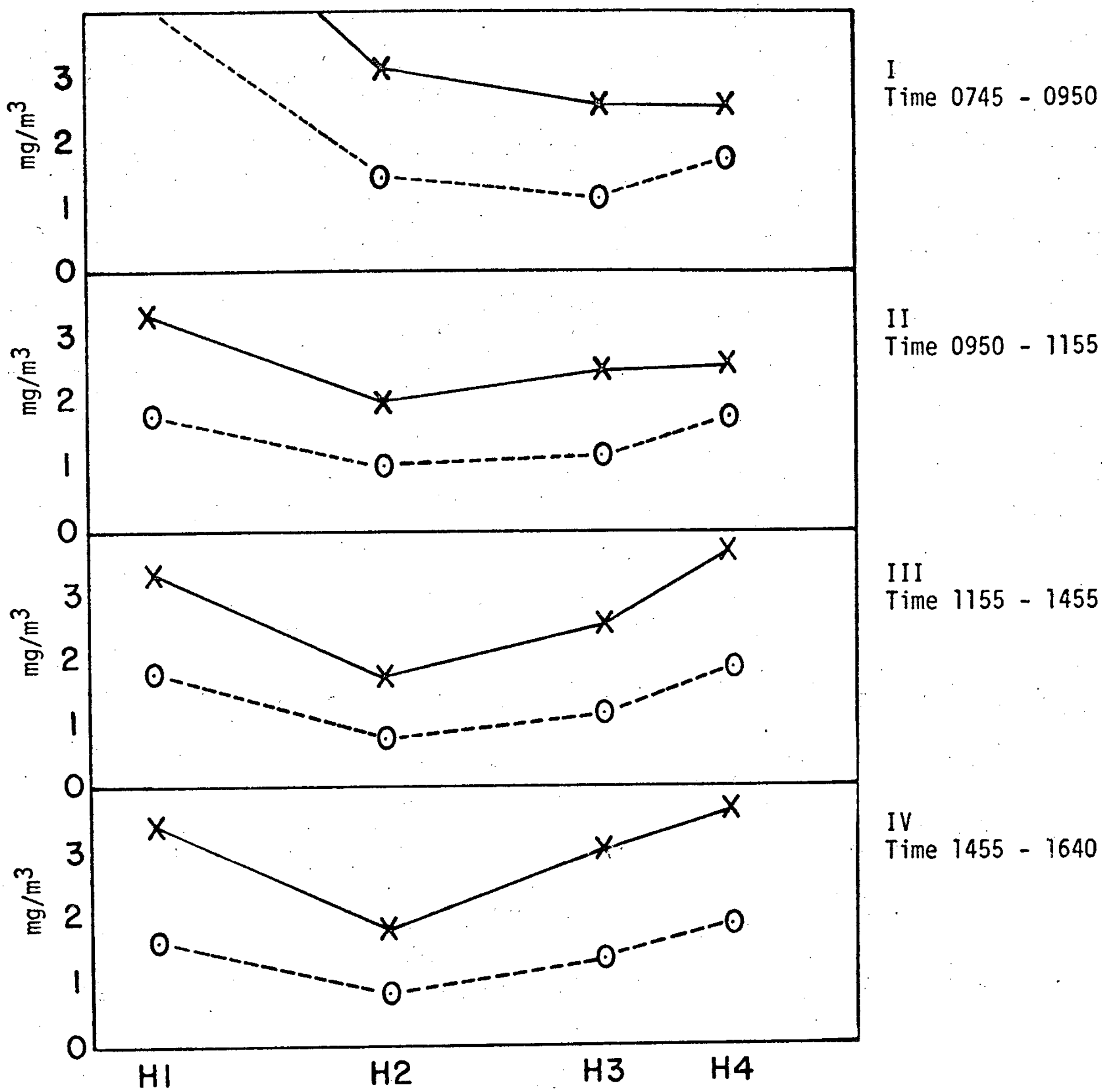


FIGURE 2-2b: Temporal and spatial variations in the chlorophyll a (X———X) and c (0--------0) content of the waters along the H transect, 10 October 1972.

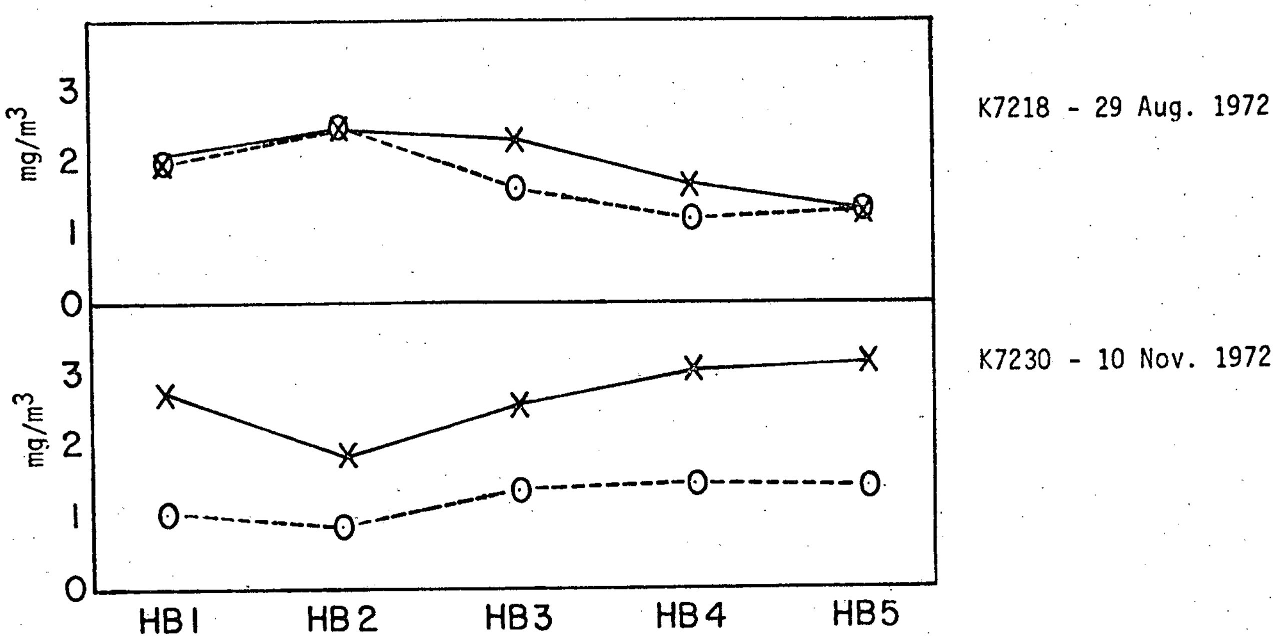


FIGURE 2-3: The average concentration of chlorophyll a (X———X) and c (O--------O) along the HB transect for each of the sampling periods.

10-e

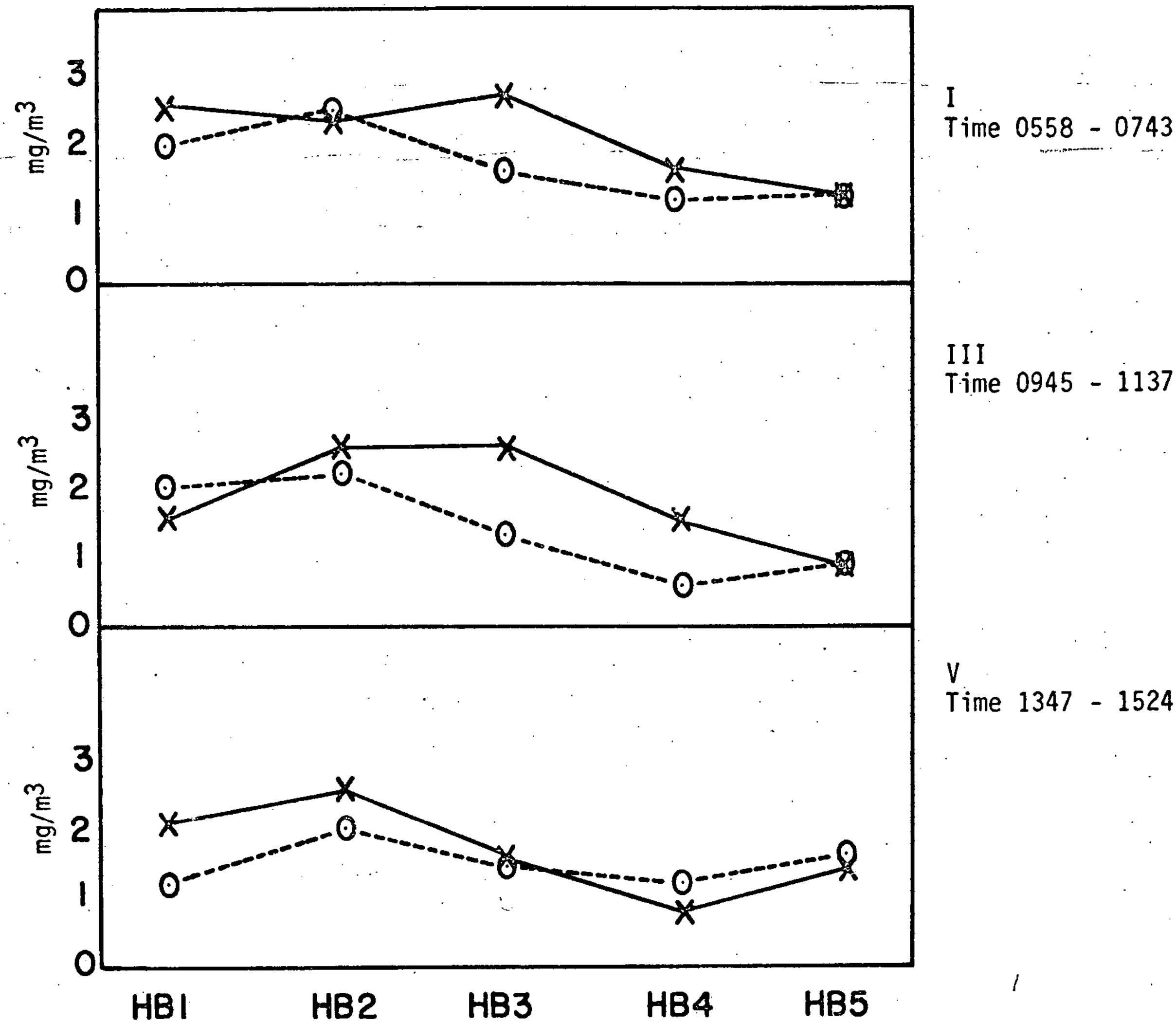


FIGURE 2-4a: Temporal and spatial variations in the chlorophyll a (X———X) and c (O------O) content of the waters along the HB transect, 29 August, 1972.

10f

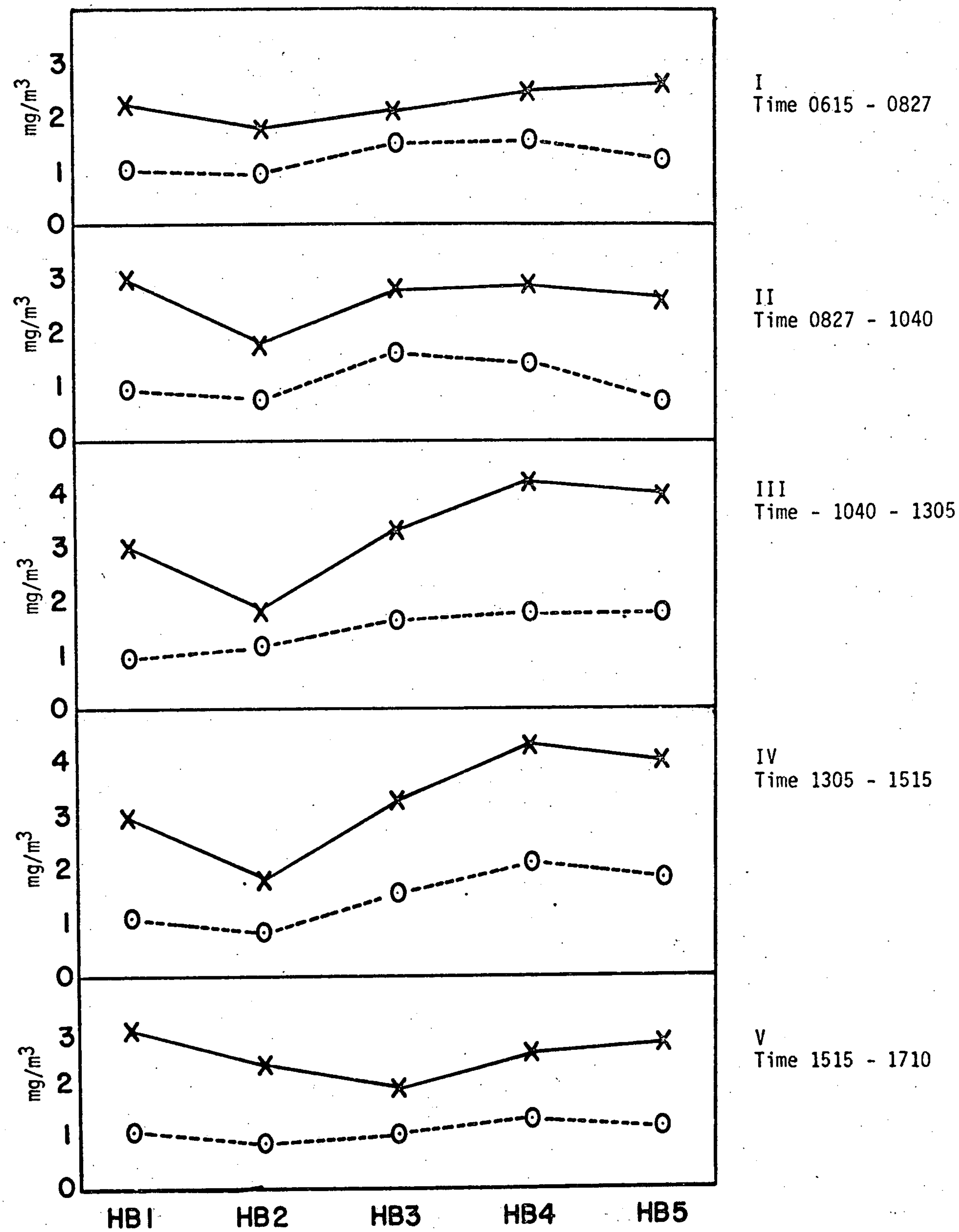
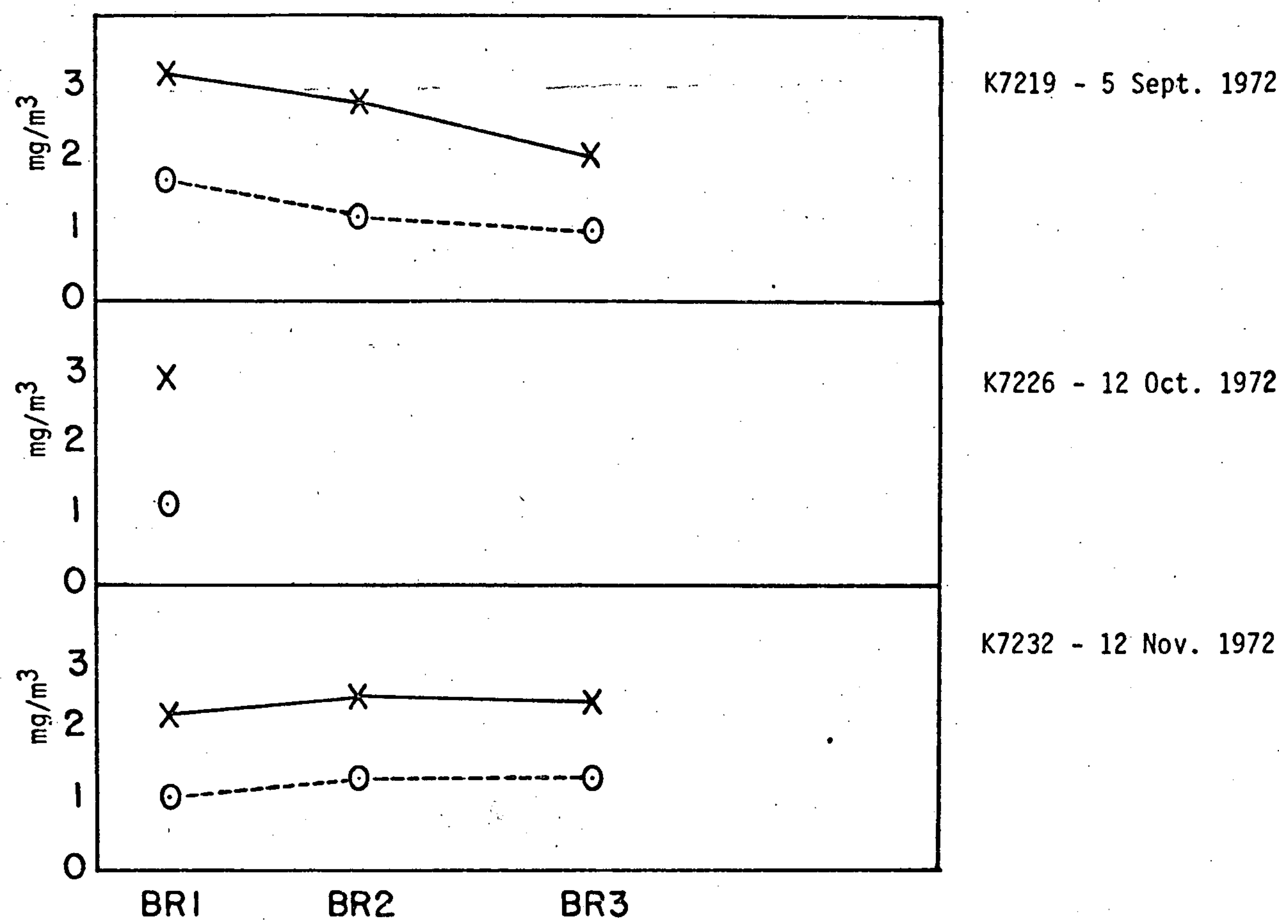


FIGURE 2-4b: Temporal and spatial variations in the chlorophyll a (X———X) and c (0----0) content of the waters along the HB transect, 10 November, 1972.



<u>FIGURE 2-5:</u> The average concentration of chlorophyll <u>a</u> (X———X) and <u>c</u> (O-------O) along the BR transect for each of the sampling periods.

10-h

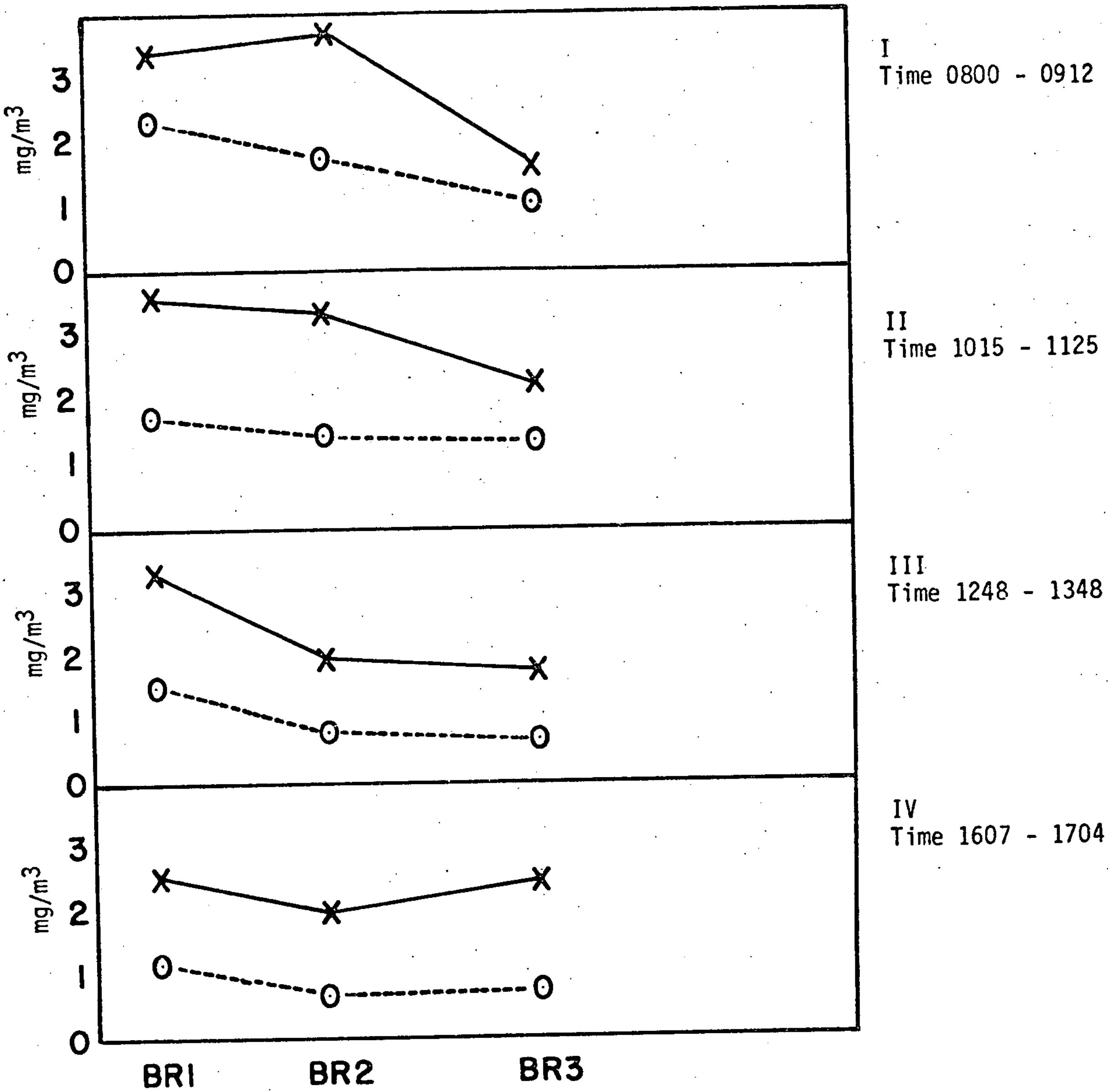


FIGURE 2-6a: Temporal and spatial variations in the chlorophyll a (X———X) and c (0------0) content of the waters along the BR transect, 5 September, 1972.

10 i

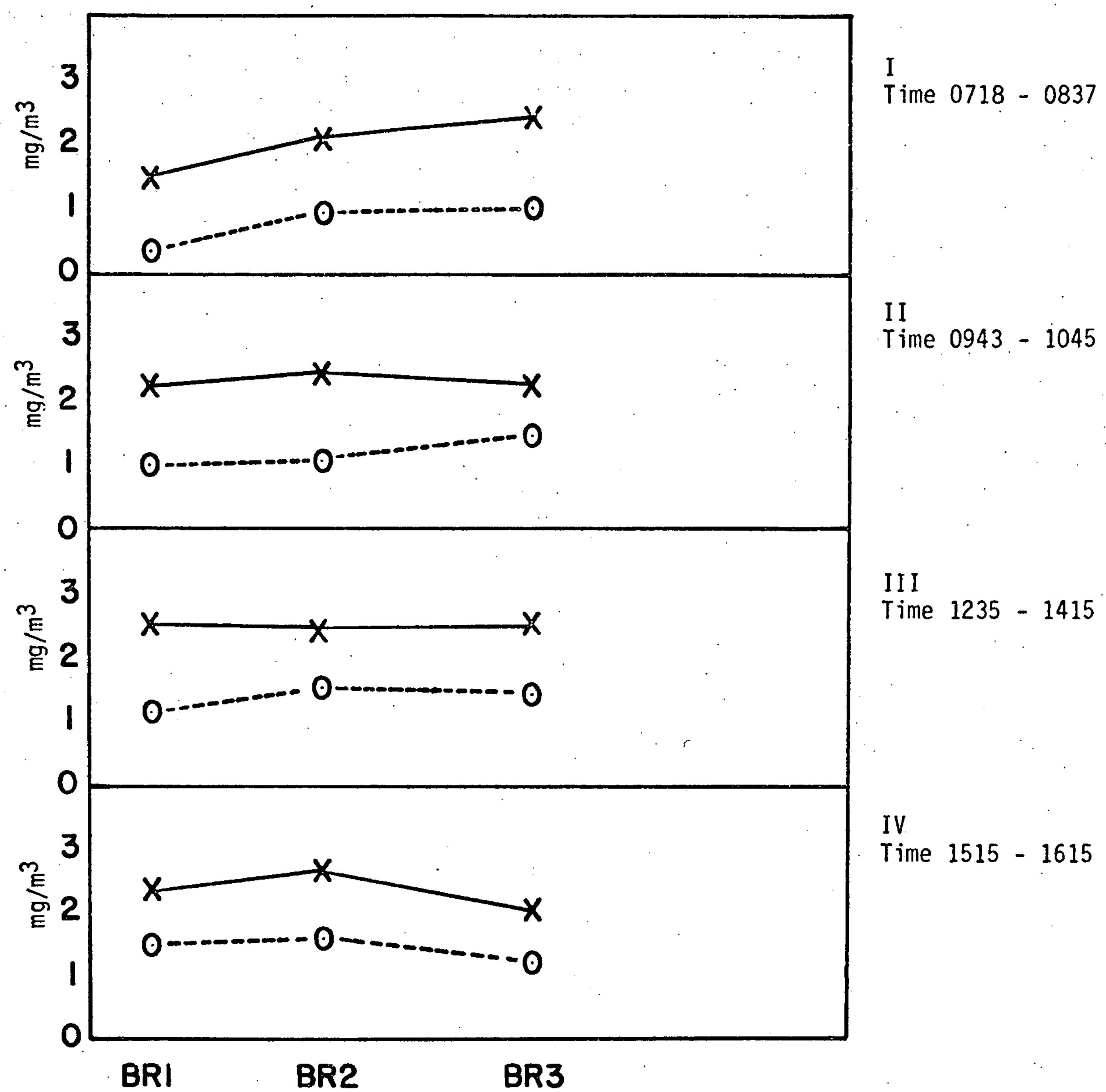


FIGURE 2-6b: Temporal and spatial variations in the chlorophyll a (X———X) and c (O------O) of the waters along the BR transect, 16 November, 1972.

10-J

3. PHYTOPLANKTON AND SUSPENDED PARTICLES (R. Nuzzi)

A. Phytoplankton

Differential phytoplankton cell counts have been performed on samples collected from the surface waters of the Block Island Sound study area (Figure I-1) during five separate cruises. Table III-1 presents the total cells per liter found at each station. The number of cells found at each station varies with time of sampling but in general, the population along the H transect, for which the most data is available, is highest at stations H1 and H4 (Figure III-1). Figure III-1 also presents the averages for the HB and BR transects but we have not yet collected enough data to consider these points significant.

B. Suspended Particles

Suspended particulate material is being analyzed with a Coulter Counter Model B. By using two aperture tubes (30μ and 100μ) and varying the threshold controls it has been possible to count particles between 0.16-635μ^3 in volume (equivalent diameter = 0.68μ - 10.66μ). Separate counts are performed at one micron intervals except for the lower and upper ends of the scale (Tables III-2 and III-3).

A problem encountered has been the handling of samples after collection. The procedure currently followed is to collect the raw seawater samples in 50 ml vials and immediately refrigerate. The samples are then returned to the laboratory and kept under refrigeration until analysis, generally within two days of collection.

Table III-2 presents a comparison of counts performed immediately after collection with counts performed after one and two days refrigeration. The differences in the counts of the total number of particles between 0.7 and 3μ is negligible (1%). However, other counts range from a difference of 6% to 26% and this must be considered when interpreting the data.

It is obvious from Table III-3 that the number of particles decreases with size with the most particles generally being found at the shoreward stations H1, HB1, and BR1 (Figure III-1). As with the phytoplankton, the number of suspended particles found varies with the time of sampling.

Table III-1

Phytoplankton Total Cells per Liter (x 10^3)

Date	Transect	Sampling Period	Station 1	2	3	4	5
24 August, 1972	H	0609-0742	2,141	1,703	975	1,426	-
	H	0915-1059	774	1,397	216	330	-
29 August, 1972	HB	0558-0743	437	347	467	869	585
5 September, 1972	BR	0800-0912	980	1,675	194	-	-
10 October, 1972	H	0745-0950	4,410	226	120	165	-
10 November, 1972	HB	0615-0827	153	80	8	40	32

Table III-2

A Comparison of Initial Particle Count (immediately after collection) with Counts Performed after One and Two Days Refrigeration

Particle Diameter (μ)	Initial Count	1 Day Refrigeration	Percent Difference	2 Days Refrigeration	Percent Difference
0.7-3	15643	15728	+1%	15772	+1%
0.7-1	12869	13560	+5%	13964	+7%
1-2	5524	5199	-4%	6665	+18%
2-3	1048	1066	-4%	1215	+14%
3-10.7	7125	7097	-0.4%	8889	+20%
3-4	3294	3177	-4%	4479	+26%
4-5	1695	1642	-3%	2269	+26%
5-6	908	892	-2%	1142	+20%
6-7	495	486	-2%	602	+18%
7-8	293	319	+8%	339	+14%
8-9	162	196	+17%	208	+22%
9-10	112	127	+12%	122	+8%
10-10.7	56	56	0	53	-6%

Table III-3

Particle Size Distribution as Determined by Coulter Counter Model B
(Surface Samples)

		Particle Diameter (μ)											
Date	Station	0.7-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-10.7	Total
10 Nov.'72	HB1-1	79660	42580	8560	5420	3948	2048	1110	570	372	230	94	144592
	HB2-1	84660	38320	6920	4104	2214	810	692	420	238	138	46	138562
	HB3-1	95860	67660	9640	4726	4946	1602	836	414	244	168	68	186164
	HB4-1	118940	53320	8440	5376	3316	1892	944	458	212	184	*	193082
	HB5-1	134180	74300	5260	5834	3152	1840	902	498	258	162	74	226460
	HB1-2	344420	75720	11400	6134	3730	1960	1452	960	592	382	124	443144
	HB5-2	130300	35200	7880	6208	3370	2294	1214	708	426	208	72	187380
	HB1-3	157600	65480	12080	7310	4518	2946	1854	1196	702	324	140	254150
	HB2-3	249580	52100	7040	4854	2600	1584	938	594	356	228	84	319958
	HB3-3	171440	43860	8420	5664	3668	2410	1030	486	242	128	54	237402
	HB5-3	137980	52560	7400	4814	2910	1852	936	572	304	194	74	209596
	HB2-5	142300	48680	5000	6634	4092	2376	1280	762	442	266	124	211956
	HB3-5	122120	44340	6200	2986	1680	978	576	346	218	142	54	179640
	HB4-5	168760	48460	7000	4784	2868	2078	1082	498	254	166	62	236012
14 Nov.'72	H1-1	839280	232380	11020	10232	2512	1392	734	408	232	146	52	1098388
	H2-1	376140	90560	8180	3352	1648	766	348	218	102	68	24	481406
	H3-1	201860	62480	6980	4056	1676	808	386	226	110	56	12	278650
	H4-1	168240	68100	8080	4450	2060	930	470	268	152	78	26	252854
16 Nov.'72	BR1-1	360240	67720	5520	4184	2238	1288	696	404	188	88	30	442596
	BR2-1	160620	42340	5920	6386	3334	1808	920	456	262	120	60	222226
	BR3-1	122580	51080	9800	7660	4224	2342	1278	754	398	242	90	200448

* No sample

Table III-3 (Cont'd.)

Date	Station	Particle Diameter (μ) 0.7-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-10.7	Total
16 Nov.'72	BR1-2	98040	38020	4700	5166	2590	1384	730	386	210	108	28	151362
	BR2-2	89920	37980	6480	5848	3214	1562	782	410	184	112	50	146542
	BR3-2	99380	47760	7720	7602	4212	1996	1042	546	280	124	60	170722
	BR1-3	*	*	*	3024	1874	1066	628	378	262	132	42	-
	BR2-3	*	*	*	5894	3180	1716	826	406	222	124	44	-
	BR3-3	95720	44380	6620	9890	5428	2730	1366	788	476	264	114	167776
	BR1-4	*	*	*	1764	1104	788	538	336	228	126	60	-
	BR2-4	*	*	*	4700	2518	1366	738	416	210	126	56	-
	BR3-4	*	*	*	9736	4720	2492	1348	666	396	228	116	-

* No sample

Table III-3 (cont'd.)

Date	Station	Particle Diameter (μ) 0.7-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-10.7	>10.7	Total
4 Dec.'72	H1-1	262940	95080	17200	6620	4094	2590	1522	904	514	304	150	*	391614
	H2-1	203960	78940	13240	3964	2554	1054	416	280	134	58	34	37	304671
	H3-1	196620	72780	11560	4814	2424	1278	466	320	136	92	26	80	290596
	H4-1	203020	68840	11200	3792	1836	1004	470	294	252	124	40	81	290953
	H1-2	174080	81660	16580	5210	3110	1918	702	376	200	148	80	*	284064
	H2-3	163840	77300	11760	5508	2796	1448	776	422	212	124	48	124	264358
	H3-3	161540	87300	13360	4278	2136	1090	592	340	186	114	52	102	271090
	H4-2	188680	89880	14000	4698	2154	1182	664	400	260	138	62	178	302296
	H1-3	162720	85780	20360	7984	4364	2302	1372	800	422	286	100	230	286720
	H2-5	252900	103500	20100	6488	3524	1744	972	562	290	164	62	130	390436
	H3-5	300700	86180	4740	5694	2794	1310	770	378	208	98	38	100	403010
	H4-3	400840	104120	9000	3066	1662	976	646	352	202	118	48	140	521170
6 Dec.'72	HB1-1	308080	81480	12640	4534	2666	1542	840	516	378	188	80	196	413140
	HB2-1	142360	52940	7040	3816	1996	1008	528	294	146	102	34	110	210374
	HB3-1	180300	61820	8260	3454	1768	984	494	276	164	100	34	120	257774
	HB4-1	211900	80180	10320	3688	1826	988	468	288	178	98	30	122	310086
	HB5-1	159600	52320	8380	3042	1444	712	386	212	132	90	38	96	226452

* No sample

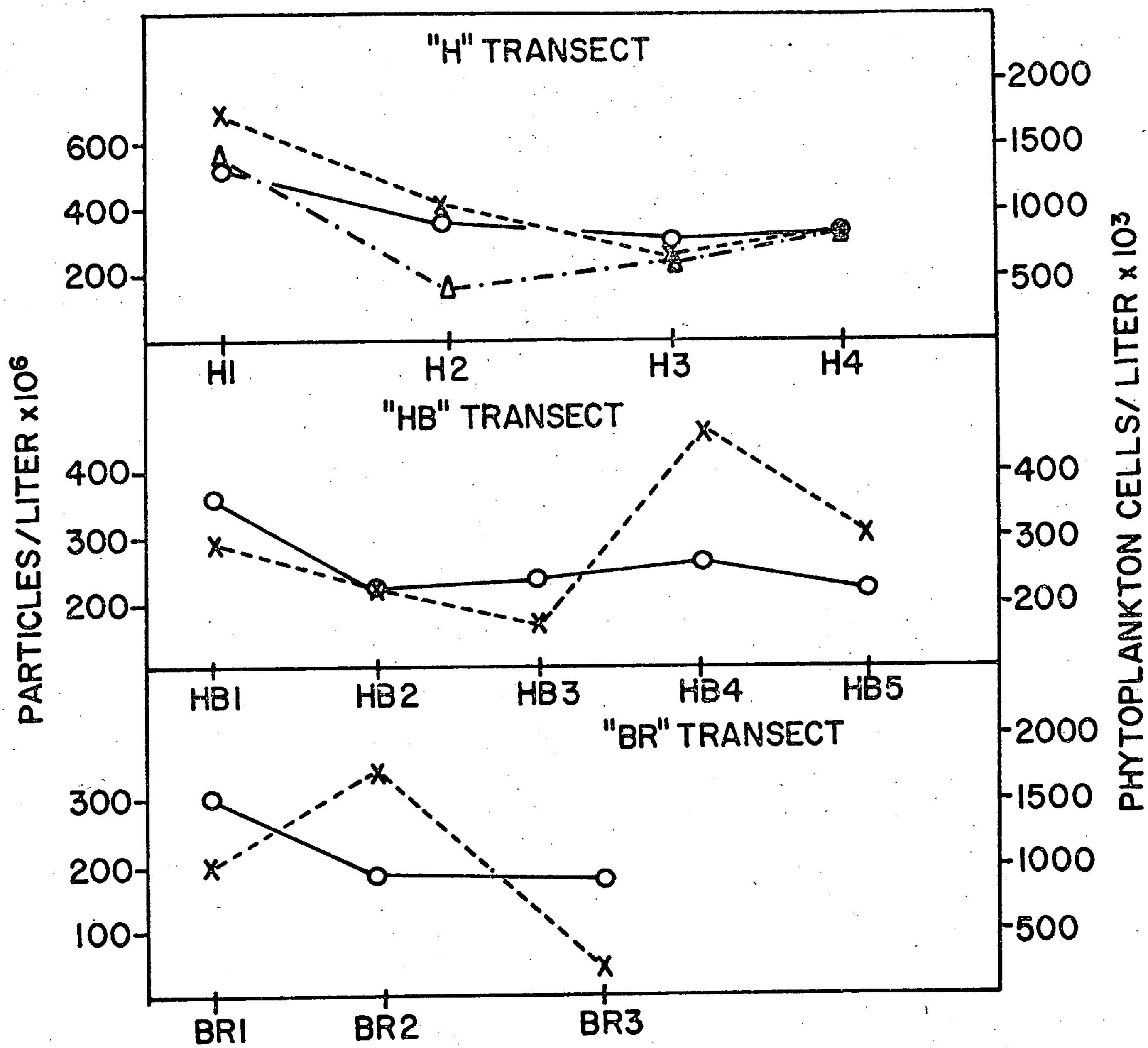


FIGURE III-1: Average counts of phytoplankton and suspended particles at each station.

O———O	= Particles	H Transect - Average of 3 samples HB Transect - Average of 2 samples BR Transect - 1 sample
X------X	= Phytoplankton	
Δ-·-·-Δ	= Phytoplankton	H Transect - Average of 12 samples (Sept. 1970 - Aug. 1971)