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Final Technical Report - Revised

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INTRODUCTION

The purpose of this study was to investigate the correlation of sensory data obtained from SKYLAB to special sea truth parameters and their relationship in determining productivity in coastal and estuarine waters. Several research vessels from federal, state and private institutions provided ship platforms from which water samples were obtained. Originally, extensive coverage of coastal waters off the northeastern United States was planned to be used. These included cruises of the International Commission for Northwest Atlantic Fisheries (ICNAF) and the Marine Resources Monitoring Assessment and Prediction (MARMAP) programs which were operated under the National Marine Fisheries Service and the U. S. Coast Guard. Each of these programs made available over 100 stations for sampling productivity values during several cruises over the continental shelf. At these stations the phytoplankton composition and density were determined along with other environmental variables. This ground truth information was used to determine the seasonal population densities and distribution patterns for the phytoplankton in relation to specific ecological factors (e.g. temperature, salinity, etc.). The relationship of such high and low phytoplankton concentrations to marine waters of high and low productivity values has been well documented in the literature and was the fundamental premise upon which this investigation was based. The major link between the actual phytoplankton concentrations in the coastal waters and a recordable variable related to the phytoplankton populations that was capable of being detected by the SKYLAB sensors was the total chlorophyll

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in surface waters. The premise followed that if a correlation could be made between the sea truth data collected (which included total chlorophyll and total phytoplankton) and the radiance values detected by SKYLAB, a synoptic mapping for a productivity index could be subsequently determined for the entire area observed.

The major problem was to find coordination of SKYLAB passage to times of ship coverage and suitable weather conditions. The above mentioned ship programs were planned months in advance with courses and schedules that could not be easily altered. The need for suitable weather over the test site as well as having a prime designation of high enough priority granted by the Houston control office for actually obtaining SKYLAB data were other factors. It was apparent that other vessels, and the selection of an area of smaller scope than was originally proposed, would have to be utilized for the project.

METHODS

During SKYLAB II collections were made off Assateague Island, Virginia on June 12, 1973 (Track 61, Pass 9, Rev. 416), on a vessel provided by the U. S. Coast Guard Station at Chincoteague, Virginia and coincided with the overpass period. Nine marine stations were established and extended from the coast seaward 12 miles. With SKYLAB III, two collection dates were utilized. On September 12, 1973, the site selected was the Rappahannock River, Virginia, with 18 mid-water stations distributed from its mouth at the Chesapeake Bay to a station off Smith Mount Landing (Track 43, Pass 25, Rev. 1947). The water samples were taken along the river by several field units to coincide with the overpass period. Another series which included the lower Chesapeake Bay was planned for September 17 (Track 43/44, Pass 35, Rev. 1817/1819). Unfortunately, on this last date, with fifteen stations established, no SKYLAB data were taken. The collections on September 12 were made in cooperation with the Virginia Institute of Marine Science, which provided the vessel, temperature, and salinity data. The U. S. Army Corps of Engineers, Norfolk Division, provided the vessel during the September 17 collections. The only data coverage provided to the investigators during SKYLAB IV was one period over two stations in the Gulf of Mexico, located between Mobile and Key West. These last collections were taken under cloudy conditions and were too limiting in scope to be of any significance to the original intentions of the proposal. In a final attempt to obtain data, an extensive coverage of the lower Chesapeake Bay was planned for 39 stations on January 6, 1974 during a SKYLAB IV overpass. However, no sensory data was taken and the collections aborted. Vessels utilized on this last date were provided by Old Dominion University's Institute of Oceanography and the U. S. Corps of Engineers, Norfolk Division.

At all sampling stations during the study the following information was obtained: composition and density of phytoplankton, total chlorophyll, salinity, and water temperature.

For each of the cruises, the phytoplankton samples were collected in 0.5-liter polyethylene bottles and preserved with a buffered formalin solution. A settling period and siphoning procedure followed, that resulted in a 40-ml concentrate of the original sample. This was placed in a settling chamber for subsequent examination with a Zeiss inverted plankton microscope. Phytoplankters were identified and species concentrations noted in numbers of cells per liter. Separate 1-liter water samples were collected for chlorophyll determinations. These were stored in an ice chest with the chlorophyll subsequently determined according to procedures given in the Unesco publication on the "Determination of Photosynthetic Pigments in Sea Water" (Parsons, 1955). A Gilford Model 240 Spectrophotometer was used for optical density measurements. Isodensity traces were made of the SKYLAB positive transparencies for the various bands. Using a Joyce Lobel Microdensitomer, isodensity traces were then matched with the sea truth data at station points for correlations to actual values determined for chlorophyll at these sites. Since chlorophyll values alone are not considered a valid index for mixed populations of phytoplankters, a more accurate correlation was sought in this investigation by including with the actual chlorophyll values the phytoplankton composition and densities present.

WATER SAMPLE RESULTS

1. Collections off Assateague Island (SKYLAB II)

The phytoplankton population was dominated by <u>Thalassiosira</u> <u>Nordenskioeldi</u>, <u>Melosira</u> spp. and <u>Ceratium</u> <u>tripos</u>. There were 17 diatoms and 8 pyrrhophyceans noted in samples from this area (Table 1). These species are common to the area and do not represent unique populations (Marshall, 1967, 1971). The total numbers of phytocells generally decreased seaward (Table 2). The highest values were noted at Station 2 (96,000 cells/l), with lowest numbers at Station 8 (16,800 cells/l). The salinity range at these 9 stations was between 22.5 and 24.0 $^{o}/oo$ and the temperature range between 17.5 and 20.0°C. The stations were directed offshore for about 12 miles. Upwelling action is characteristic for such near shore waters. In addition to the diatom and pyrrhophycean populations within the samples "other" phytoplankters included cyanophyceans and unidentified nanoplankters having cell sizes below a 5-micron diameter (Table 3).

A close correlation between the phytoplankton concentrations and total chlorophyll values is indicated by figures presented in Table 2. However, the comparison of total numbers of cells in mixed populations of phytoplankton may be very misleading. There is a wide range of cell sizes (and volumes) found in the diatoms, with the majority of the phytoflagellates being smaller in size. It is feasible to find a single cell of Rhizosolenia alata having a volume a thousand times greater than a common phytoflagellate. Such discrepancies are not always this extreme, with a tendency for several of the smaller sized species to dominate these more "giant" forms.

The concentration of Melosira spp. is noteworthy. This genus, represented by several polymorphic forms, was noted at each station. Most of the cells would be nanoplankton and were found in high concentrations. Marshall (1975) has indicated the significance of this genus to the entire phytoplankton population along the east coast of the United States. The numbers of cells were typically high in upwelling areas over the continental shelf. This genus, even though the individual cells are small, is present in such numbers that it would be significant to the productivity of these waters and certainly influence the surface chlorophyll values.

2. Rappahannock River Sites (SKYLAB III)

Forty-five phytoplankters were identified from the series of samples taken at the Rappahannock River stations. These included 22 diatoms, 12 pyrrhophyceans, and 9 other forms (Table 4). Seventeen stations were distributed along the river, with three of these actually located at its entrance to the Chesapeake Bay (Stations 260, 261, 266). Highest salinity values are recorded at these stations (e.g. $16.94^{o}/oo$), then gradually decrease to station No. 5 sixty miles upstream where the salinity of 0.05 $^{o}/oo$ was recorded (Table 5). The temperature range at these stations was between 25.5 and 27.4°C. The greatest secchi disc reading was 1.5 meters at Station 261, with other station readings mainly less than 1.1 meters.

The phytoplankton composition near the mouth of the river and for about the first one-third of the (lower) river samples indicated a dominance of the diatoms

Cyclotella glomerata and Leptocylindricus danicus, along with a variety of phytoflagellates that are common to open estuary and marine habitats. These included Prorocentrum micans and Ceratium lineatum. Moving up the river the general composition of the phytoplankton changed and accompanied the decrease in saline values (Table 6). The phytoflagellates, chlorophyceans and cyanophyceans increased in numbers upstream, with a decrease in representation of the phytoplankton species noted near the river's mouth. There was definitely a floral change in the phytoplankton populations. The influence of the entry of fresh water phytoplankton from river sections above the fall line, as well as from local tributaries, was evident. Most of these "more" freshwater species have smaller volumes than the "estuarine" species. This situation may be reflected in the comparison of phytoplankton cell numbers to chlorophyll content at stations upstream and downstream (e.g. note Station 266 and Station 3, Table 6). The majority of the cells at Station 266 was composed of pyrrhophyceans, whereas at Station 3, 81% of the cells consisted of blue-green algae (Cyanophyta) and desmids (Chlorophyta).

3. Lower Chesapeake Bay (SKYLAB III)

The collections on the lower Chesapeake Bay were at 15 stations concentrated between the entrance of the James River and the opening of the Bay to the Atlantic Ocean (Table 7). This is a natural estuary setting where the salinity range at the stations was between 15.1 and 22.6 $^{o}/oo$. The temperature range was between 23.6 and 24.3°C. There were 42 diatom and 12 pyrrhophycean species identified at these stations (Table 8). The species were common to the local estuary and are not unique for the region. The dominant forms included the diatoms Skeletonema costatum, Nitzschia pungens atlantica, Rhizosolenia spp. and the phytoflagellates Ceratium lineatum and Prorocentrum micans. Cyanophyceans and chlorophyceans were rare. All the counts were above 100,000 cells per liter (Table 9). The chlorophyll values were all over 1 mg/l with the highest recorded at 5.264 mg/l.

A more direct relationship between cell numbers and chlorophyll values would be expected in uni-algal cultures than in natural water habitats where greater variety of species are common. With an increase or change in species diversity, or when communities located in different habitat types are compared, discrepancies would be more numerous. These conditions are characterized by the different populations found in a river system, estuaries, and marine shore regions. As collections are made more seaward, beyond the influence of upwelling action, estuary outflows, and near shore currents, the species composition becomes more consistent (Marshall, 1975).

4. Lower Chesapeake Bay (SKYLAB IV)

An extensive station base was established for the final series of collections during SKYLAB IV. A concentrated effort was planned for the lower Chesapeake Bay on January 6, 1974 with 39 station sites. Unfortunately the sky was heavily overcast and no SKYLAB data was taken in this area. Another test site was to be utilized in a cooperative effort in the Gulf of Mexico, but again storm conditions cancelled out this attempt for obtaining SKYLAB data. Lastly on January 21, 1974 there was a SKYLAB overpass of two ship stations in the Gulf of Mexico where plankton samples were taken in cooperation with Dr. Robert Boudreaux, Lockheed Electronics Company, Mississippi Testing Facility. There was partially cloudy weather at this time. The two data points and the limited plankton samples did not provide an adequate base for developing significant results on that overpass of that particular area of the Gulf.

CORRELATION OF WATER PARAMETERS

The water sampling station locations are shown in Figure 1. Only 11 of the Rappahannock stations are plotted; not included are the six stations located farthest up the river. Since the phytoplankton populations and other physical data are different for these three areas (the Assateague, Rappahannock and Chesapeake sites) they were analyzed separately.

The first step in the analysis was to look for trends in the parameters. Each water parameter has been correlated with the other parameters. The correlation coefficients are given in Table 10 where the numbers referring to the five water parameters in the left column are repeated across the top of each correlation matrix. Thus, the correlation between temperature and salinity, for instance, in the Assateague data is formed by following the fourth item (temperature) across to the third column (salinity) and reading 0.74. The blank data for secchi depth in the Assateague and Chesapeake data are due to the lack of measurements of this parameter in these areas.

The most interesting correlation is between chlorophyll and phytoplankton number. The correlation is high for the Assateague (0.96) and Chesapeake (0.90) areas, but insignificant for the Rappahannock (0.09) area. It was explained earlier that these two parameters were not directly related due to variation in phytoplankton size and chlorophyll content. The Rappahannock area is clearly a mixing zone of fresh and salt water phytoplankton which tends to confuse the chlorophyll-cell number correlation.

There are several other points which can be made concerning the correlation of the water parameters, such as the negative correlation between phytoplankton and salinity. Due to the limited amount of data, however, it is not wise to place too much significance on these results. Their primary usefulness will be in the interpretation of the remote sensing data.

CORRELATION OF WATER PARAMETERS WITH SKYLAB DATA

SKYLAB remote sensing data was available for the Assateague and Rappahannock areas. These two areas are treated separately in the analysis, primarily because the S-190A film data was analyzed for the Assateague area and only the S-192 data for the Rappahannock area.

1. Assateague Area

The four bands of the S-190A multispectral film were available for analysis; although there were some clouds in the area the sampling stations were all visible. The two visible bands, namely the green (.5 - .6 μm) and the red (.6 - .7 μm) bands, were used to extract density data at the station locations. The images were positive transparencies; that is, an increase in radiance from the scene produced a decrease in film density. Thus, to obtain relative radiance the inverse of the antilog of the film density was computed. Figure 2 shows a color density sliced image of the green band positive transparency. The densitometer trace along the station track is given with the grey scale calibration step data supplied along with the film.

In general, radiance levels decrease away from the coastal area in both bands. If any of the water parameters are responsible for producing the radiance variations then these parameters must systematically vary away from the coast also. In Table 2 this is seen to be the case; phytoplankton and chlorophyll decrease going away from the coast, whereas salinity and temperature increase. Table 11 gives the correlation coefficients for the water parameters with the relative radiance values for the green and red band transparencies. As expected, both bands have a positive correlation with chlorophyll and phytoplankton and a negative correlation with salinity and temperature. Further comments on the meaningfulness of the correlations will be reserved until the S-192 data has been presented for the Rappahannock area.

2. Rappahannock Area

Radiance values for each of the water sample stations were extracted from the S-192 tapes by locating the station coordinates on a band 10 (1.2 - 1.3 µm) generated grey level map. The S-192 tapes did not cover station 260 in the Chesapeake Bay. Station BR was covered by a cloud and stations C-19, C-23, P-29, TCB and 1 were obviously degraded by haze. No attempt was made to obtain data for stations two through five due to haze and clouds. The atmospheric interference is clearly visible on the photographic print for band 2 (.46 - .51 µm). In the analysis of the data the first six stations, 261 through 291, were treated separately and in combination with the other five stations. In every instance an analysis with 11 stations gave lower correlations with the data than the six stations alone. Thus, in the following presentation data is included for the six stations only.

In Table 5 the only trends in the data seem to be a decrease in salinity and an increase in temperature going up river. For the stations 261 through 291 the secchi depths basically decrease up river also. In the correlation with radiance, bands 2 (.46 - .51 µm), 3 (.52 - .56 µm), 6 (.68 - .76 µm) and 13 (10.2 - 12.5 µm) were selected for analysis. Band 2 contains part of the chlorophyll absorption band, band 3 is a chlorophyll reference region as well as a sediment indicator, band 6 is useful for algal blooms and band 13 is the thermal band.

The S-192 data was not free of noise, so to minimize its effect on the analysis the radiance values were extracted for a 1×1, 3×3, and 6×6 pixel area centered about the station location. The average radiance for the 6×6 pixel area gave the best correlation and only this data is presented. Averaging more pixels for each station may have improved the correlation further, but is was felt that the 6×6 average was sufficient to eliminate variations due to noise only.

The water parameters were correlated with each of the four bands individually and with all algebraic combinations of two bands. In addition, a stepwise multiple correlation* with all four bands was performed. The correlation

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* The stepwise regression procedure starts with the band most highly correlated with the parameter, and in succession, introduces the next most highly correlated band until all bands have been included. As each new band is included, the previous bands are re-examined as though they had just been introduced into the regression. This provides a judgement on the contribution made by each band, irrespective of its actual entry into the model. A band which may have been the best single band to enter at an early stage may, at a later stage, be superfluous because of the relationships between it and other bands now in the regression.

coefficients are presented in Table 12, where only the combination of bands 2-6, bands 3-6, and bands 6/3 are shown for chlorophyll and the stepwise multiple correlation for all parameters except secchi depth.

DISCUSSION OF RESULTS

The correlation between chlorophyll and radiance in the Assateague area was positive, whereas in the Rappahannock area the correlations with bands 2, 3, and 6 were negative. This seems to indicate that chlorophyll is not appreciably influencing the radiance in one or both of the areas. Although the spectral bandwidths are not the same for the photography and the S-192 data, the fact that both the green and red band radiances give similar correlation results, and bands 2, 3, and 6 give similar results, make it clear that the spectral signature of chlorophyll is not very dominant. It has been shown (Bowker, et al., 1975) that LANDSAT-1 multispectral radiance values in the lower Chesapeake Bay area are primarily influenced by sediment, or total suspensate weight, and the high correlations between radiance and chlorophyll are due to the association of chlorophyll with sediment. In both the Assateague and Rappahannock series of collections, water samples were taken at times that coincided with the overpass. Thus, there should be no differences resulting from sea truth data being taken at times other than during the overpass period.

Using the bands combinations (2-6), (3-6), and (6/3) improved the correlation with chlorophyll. However, the positive correlation with bands 2-6 means that band 2 radiance is either increasing with increased chlorophyll levels or band 6 radiance is decreasing. The negative correlations with both bands indicate that the decrease in band 6 radiance is dominant. Band 6 would be expected to show a positive correlation when algal levels reached bloom proportion (chlorophyll > 50 μg/l) but for the levels encountered in this data no such response is anticipated (see Bressette and Lear, 1973). The multiple correlation with all four bands does not significantly improve the correlations.

The negative correlations between bands 2 and 3 and secchi depth are perhaps the most meaningful. Secchi depth is expected to decrease when sediment, or turbidity, increase. Thus, it appears that sediment variations are dominating the radiances (also, since the maximum secchi depth was 1.5 m, it is assumed that bottom reflectance is not influencing the data). If plankton count had been a significant contribution to the total suspensate weight it should have a positive correlation with radiance values. Since the correlations with bands

2, 3, and 6 are all negative it is obvious that plankton is not an important parameter in the upwelling radiance at the surface.

Band 13, the thermal channel, actually had a negative correlation with temperature. This can probably be explained by the small variations in surface temperature and the noise in the radiance data. Both temperature and salinity have reasonably high correlations with the other three bands. It was mentioned before that these two parameters show a consistent trend going up river, and since the radiance data may be influenced by atmospheric interference as one approaches the cloud bank up river, it suggests that the data may be biased by atmospheric interference.

The radiance values in band 3 have been plotted as a function of secchi depth in Figure 3. As stated previously, this is probably the only useful relationship in the analysis. For completeness, bands 3-6 are plotted vs. chlorophyll in Figure 4. This relation is probably not valid for areas away from the lower Rappahannock River.

CONCLUDING REMARKS

Radiance values taken from the S-190A positive transparencies have been correlated with water parameters monitored at stations in the Assateague Island area. The S-192 digital tapes were used to correlate radiances from several bands with measurements from the Rappahannock River. In general, it was found that chlorophyll and phytoplankton were not influencing the radiance values directly, although their association with sediment, or turbidity, gave fair correlations between the two parameters and the radiance levels. The S-192 data was complicated by atmospheric interference and instrument noise, and therefore this analysis has not been an adequate test of its capabilities.

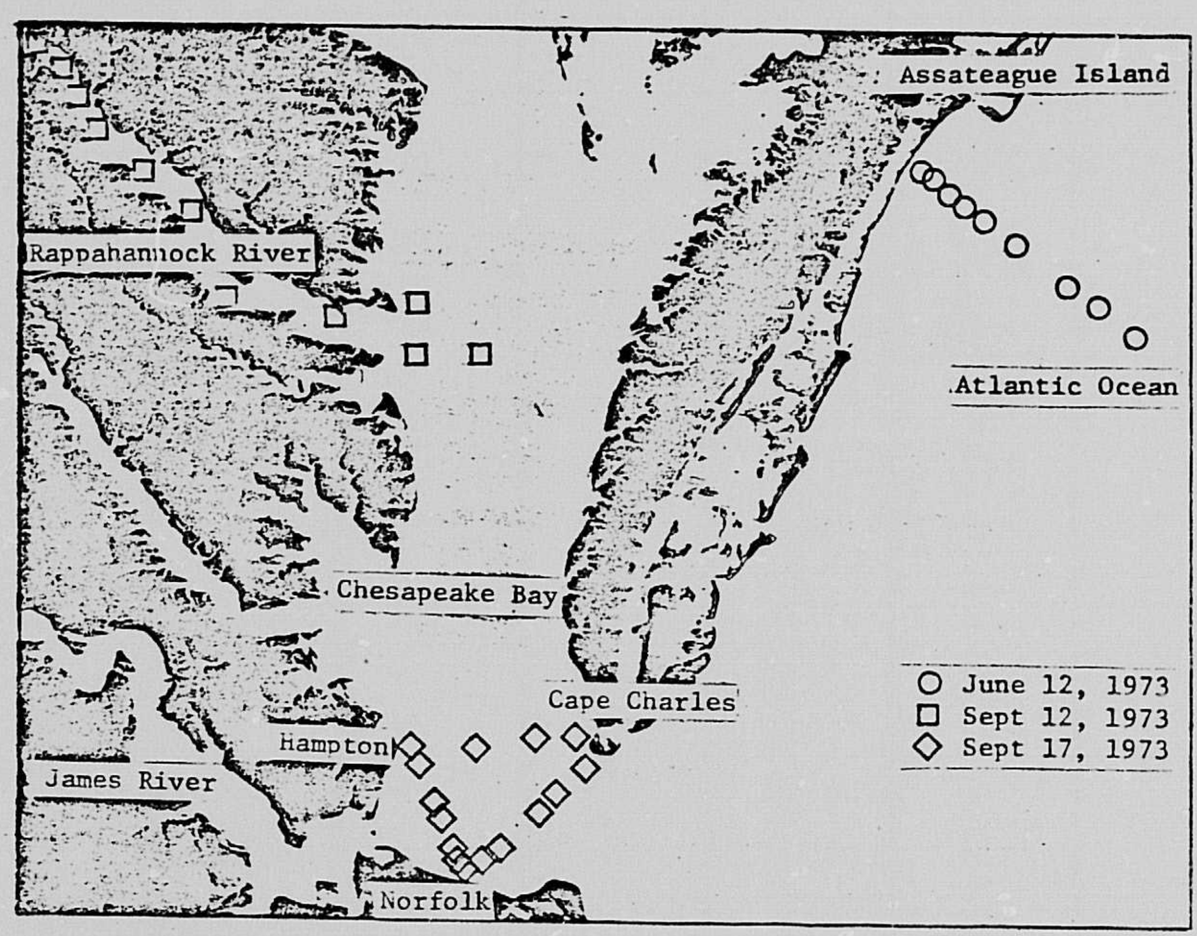
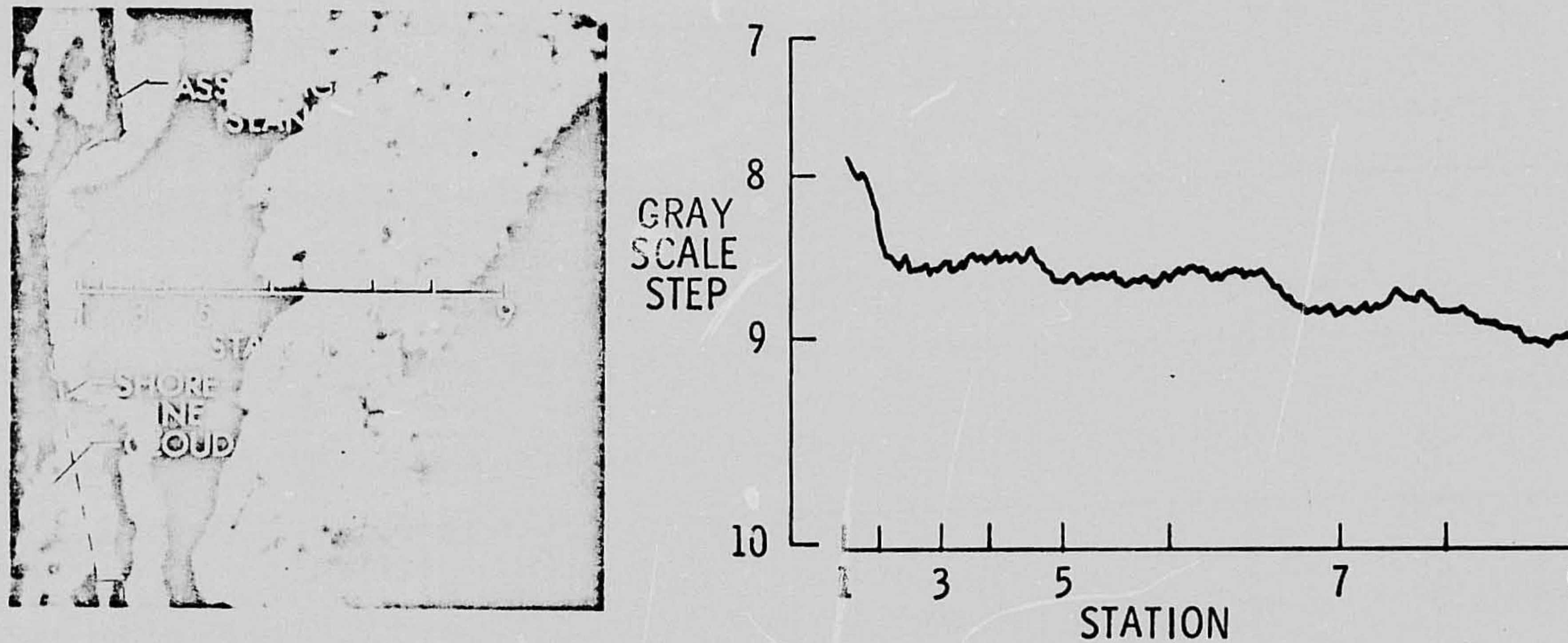


Figure 1. Sketch of lower Chesapeake Bay area showing station locations. Refer to Tables 2, 5, and 7 for station coordinates.



(a) (b)

Figure 2. (a)Color density sliced image of green band positive transparency for Assateague area and (b)densitometer record along station track.

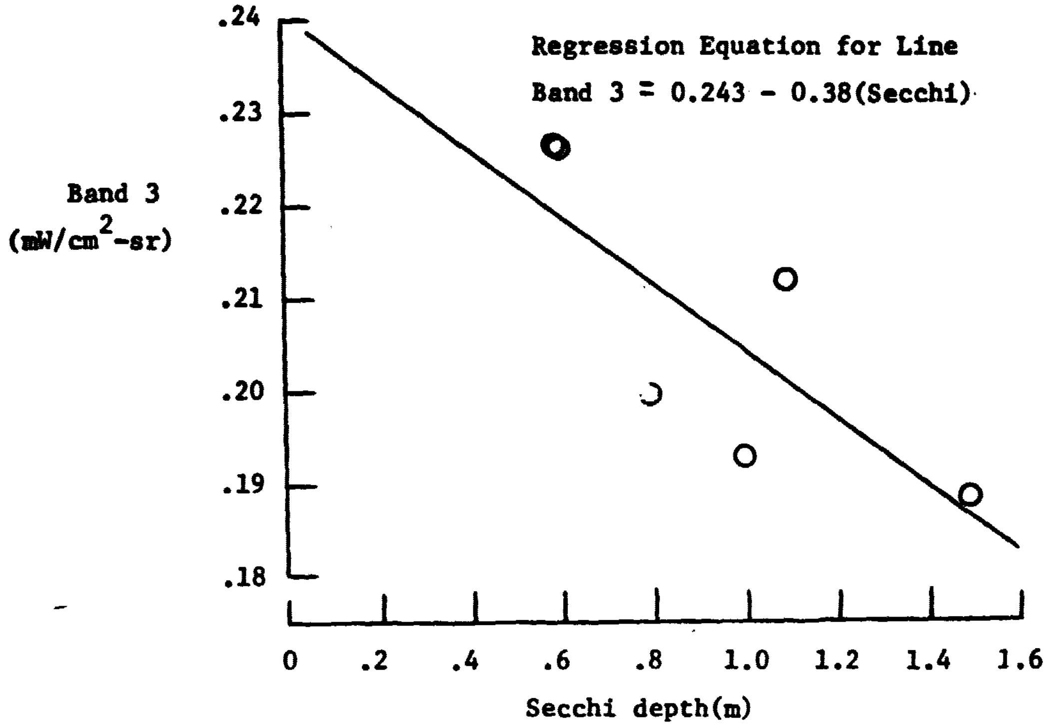


Figure 3. Secchi depth vs. Band 3 for Rappahannock River.

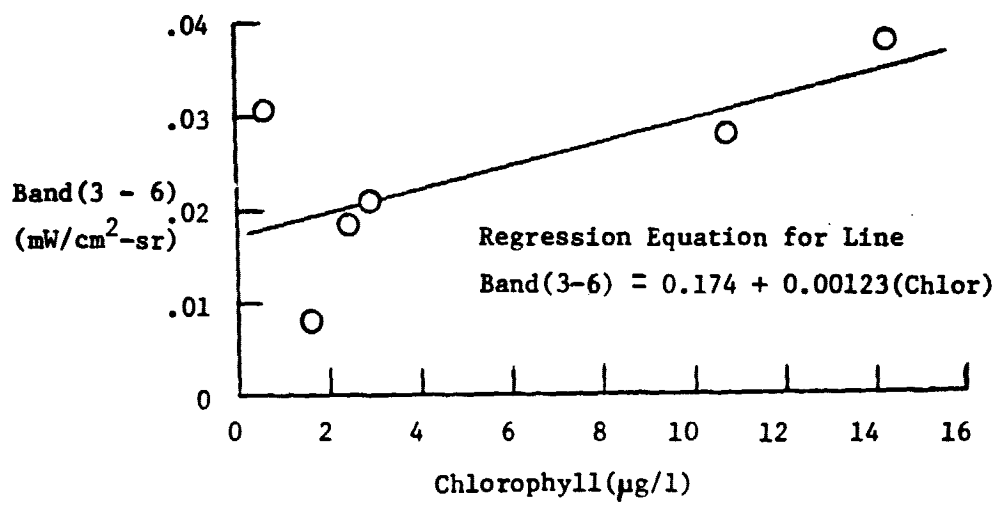


Figure 4. Chlorophyll vs. Band(3 - 6) for Rappahannock River.

TABLE 1. Phytoplankton recorded at stations off Assateague Island on June 12, 1973.

Diatoms	Pyrrhophyta
Chaetoceros affinis	*Amphidinium* sp.
Chaetoceros danicus	*Ceratium fusus*
Chaetoceros decipiens	*Ceratium longipes*
	Ceratium tripos
Coscinodiscus sp.	*Dinophysis acuta*
	Exuviaella marina
Leptocylindrus danicus	*Gymnodinium* sp.
Melosira distans	*Peridinium triquetrum*
Melosira granulata	
Melosira islandica	
Melosira italica	
Melosira sulcata	
Nitzschia closterium	
Nitzschia seriata	
Rhizosolenia alata	
Rhizosolenia delicatula	
Rhizosolenia stolterfothii	
Skeletonema costatum	
Synedra sp.	
Thalassiosira Nordenskioeldi	
Thalassiosira nitzschioides	

TABLE 2. Station locations and results of water analysis during SKYLAB II on June 12, 1973 off Assateague Island.

Station No.	Coordinates Lat N (deg min)	Coordinates Long W (deg min)	Bottom Depth (m)	Phytoplankton (cells/liter)	Total Chlorophyll (mg/liter)	Salinity (^{o}/co)	Temperature (^{o}C)
1	75 29.5	37 49	6.0	94,000	22.01	22.5	17.5
2	75 28.5	37 48	9.0	96,000	23.68	23.0	18.0
3	75 27.5	37 47	11.6	50,800	5.75	23.0	18.5
4	75 26	37 46.5	13.3	45,800	4.97	23.0	19.0
5	75 24	37 45	14.0	42,400	4.42	23.5	19.5
6	75 21	37 43.5	18.3	54,800	5.26	23.5	19.5
7	75 17	37 41	20.0	30,400	1.56	24.0	20.0
8	75 13.5	37 39	22.6	16,800	0.43	23.5	19.0
9	75 10	37 36.5	28.3	18,000	0.83	23.0	20.0

TABLE 3. Composition of phytoplankton at stations, June 12, 1973, off Assateague Island (cell numbers times 10^3 per liter).

Station	Diatoms	%	Pyrrhophyta	%	Others	%	Total
1	515	55	417	44	10	1	940
2	412	42	536	56	12	2	960
3	292	57	124	24	92	19	508
4	300	63	94	20	64	17	458
5	200	48	74	17	150	35	424
6	120	22	100	19	328	59	548
7	84	41	68	33	52	26	204
8	100	60	14	8	54	32	168
9	164	93	12	6	4	1	180

TABLE 4. Phytoplankton recorded at stations in the Rappahannock River on September 12, 1973.

Diatoms

Amphiprora sp.
Chaetoceros affinis
Chaetoceros compressus
Coscinodiscus radiatus
Cyclotella sp.
Cyclotella glomerata
Diploneis sp.
Ditylum brightwellii
Fragilaria crotonensis
Leptocylindrus danicus
Leptocylindrus minimus
Melosira distans
Melosira granulata
Melosira islandica
Navicula sp.
Nitzschia closterium
Nitzschia longissima
Pleurosigma sp.
Rhizosolenia setigera
Synedra sp.
Thalassionema nitzschioides
Thalassionema aestivalis
Thalassionema Nordenskioeldi

Pyrrhophyta

Amphidinium sp.
Ceratium tripos
Ceratium lineatum
Exuviaella apora
Eutreptia marina
Goniaulax sp.
Gymnodinium splendens
Oxytoxum scolopax
Peridinium divergens
Peridinium minutum
Peridinium steinii
Peridinium triqueta
Prorocentrum micans
Katodinium rotundatum

Others

Anabaena sp.
Ankistrodesmus sp.
Crucigenia sp.
Pediastrum sp.
Scenedesmus sp.
Scenedesmus quadricauda
Staurastrum sp.
Oscillatoria sp.
Merismopedia sp.

TABLE 5. Station locations in the Rappahannock River and results of water analysis during SKYLAB III on September 12, 1973.

Station	Coordinates Lat N (deg min)	Coordinates Long W (deg min)	Bottom Depth (m)	Phytoplankton (cells/liter)	Total Chlorophyll (mg/liter)	Salinity ($^{o}/oo$)	Temperature (^{o}C)	Secchi (m)
260	37 33.6	76 10.6	12.3	500,000	2.453	16.94	25.5	1.3
261	37 33.7	76 16.6	4.0	421,740	2.834	15.67	25.5	1.5
266	37 33.9	76 16.3	5.0	1,110,400	10.970	14.50	25.5	0.8
268	37 35.9	76 22.2	5.6	981,600	12.547	13.78	25.6	1.0
271	37 36.9	76 31.7	4.3	553,600	2.651	12.54	25.6	1.1
284	37 43.2	76 35.3	4.6	273,600	3.000	12.23	25.6	0.6
291	37 46.2	76 39.4	6.6	176,000	2.359	10.97	26.6	0.6
BR	37 50.1	76 43.4	9.6	532,400	2.212	9.24	26.3	-
C-19	37 51.4	76 45.4	7.6	809,600	5.819	8.60	26.8	-
C-23	37 53.6	76 46.9	8.1	364,000	3.370	7.58	26.3	-
P-29	37 55.1	76 49.2	9.0	288,000	1.157	6.19	26.2	-
TCB	37 55.9	76 51.1	5.3	211,200	1.465	3.62	26.1	-
1	36 57.1	76 51.1	3.3	252,000	2.196	3.13	26.1	0.8
2	37 58.8	76 52.9	6.6	933,600	3.002	1.19	26.7	1.0
3	38 00.2	76 54.4	8.0	1,189,600	4.716	0.51	26.7	0.9
4	38 04.9	76 57.1	7.3	8,759,200	3.657	0.06	27.4	0.7
5	38 06.3	77 02.4	11.0	8,772,000	4.499	0.05	26.4	0.6

TABLE 6. Composition of phytoplankton at stations in the Rappahannock River on September 12, 1973. (Cell numbers times 10^3)

Station	Diatoms	%	Pyrrhophyta	%	Others	%	Total
260	207.0	41	270	54.5	24	4.5	500.0
261	243.5	58	147.8	35.5	27	6.5	421.7
266	264.4	24	488	44.0	358	32.0	1,110.4
268	227.2	23	592.8	60.5	161.6	16.6	981.6
271	400.0	72	83.2	15.0	70.4	13.0	553.6
284	46.0	17	215.6	80.0	12.0	3.0	273.6
291	60.4	34	44.8	26.0	70.8	40.0	176.0
BR	42.8	8	395.6	75.0	94.0	17.0	532.4
C-19	84.0	10	151.6	19.0	574.0	71.0	809.6
C-23	121.6	34	150.0	41.0	92.4	25.0	364.0
P-29	108.4	38	62.0	22.0	117.6	40.0	288.0
TCB	117.2	55	20.8	10.0	73.2	35.0	211.2
1	124.4	49	70.4	28.0	57.2	23.0	252.0
2	114.8	12	114.0	12.0	704.8	76.0	933.6
3	218.4	18	8.8	1.0	962.4	81.0	1,189.6
4	1,624.8	19	16.8	1.0	7,117.6	8.0	8,759.2
5	2,659.2	30	18.4	1.0	6,094.4	69.0	8,772.0

TABLE 7. Station locations and results of water analysis during SKYLAB III on September 17, 1973 in the lower Chesapeake Bay.

Station	Coordinates Lat N (deg min sec)	Coordinates Long W (deg min sec)	Phytoplankton (cells/liter)	Total Chlorophyll (mg/liter)	Salinity ($^{o}/oo$)	Temperature (^{o}C)
1	36 56 02	76 10 00	129,600	1.203	15.1	23.6
2	36 57 04	76 08 01	215,200	1.049	15.2	23.6
3	36 58 04	76 06 04	286,400	1.826	20.2	23.6
4	37 06 06	76 03 09	281,600	1.514	22.6	23.9
5	37 02 03	76 02 00	257,600	1.495	21.2	23.8
6	37 04 03	76 59 05	152,800	1.556	21.2	24.1
7	37 06 04	76 00 03	197,200	2.130	20.2	24.1
8	37 06 01	76 04 07	202,400	2.424	19.0	24.2
9	37 05 08	76 09 02	394,000	3.479	17.2	24.2
10	37 05 06	76 15 00	858,000	4.759	15.7	24.3
11	37 04 03	76 14 05	716,800	5.264	17.2	24.2
12	37 01 07	76 13 03	278,000	2.742	10.0	24.3
13	37 00 00	76 12 05	141,600	1.902	16.9	24.1
14	36 58 03	76 11 08	130,400	1.653	17.2	24.2
15	36 57 00	76 10 08	148,000	1.917	16.8	24.2

TABLE 8. Phytoplankton recorded at stations in the lower Chesapeake Bay on September 17, 1973.

DIATOMS

Biddulphia sp.
Biddulphia longicruris
Cerataulina bergoni
Chaetoceros affinis
Chaetoceros compressus
Chaetoceros borealis
Chaetoceros curvisetus
Chaetoceros decipiens
Chaetoceros didymus
Chaetoceros socialis
Chaetoceros subtilis
Corethron hystrix
Coscinodiscus excentricus
Coscinodiscus radiatus
Cyclotella sp.
Cyclotella glomerata
Climacodium sp.
Ditylum brightwellii
Fragillaria crutonensis
Gyrosigma sp.
Leptocylindrus danicus
Melosira distans
Melosira granulata
Melosira islandica
Melosira sulcata
Navicula sp.
Nitzschia closterium
Nitzschia pungens atlantica
Nitzschia longissima
Pleurosigma sp.
Rhaphoneis sp.
Rhizosolenia alata
Rhizosolenia imbricata
Rhizosolenia calcar avis
Rhizosolenia setigera
Rhizosolenia stolterfothii
Skeletonema costatum
Synedra sp.
Thallassionema nitzschioides
Thalassiosira decipiens
Thalassiosira Nordenskioeldi
Thalassiothrix mediterranea

PYRRHOPHYTA

Amphidinium sp.
Ceratium fusus
Ceratium extensum
Ceratium lineatum
Ceratium tripos
Exuviaella apora
Exuviaella marina
Goniaulax spinifera
Peridinium breve
Peridinium trochoideum
Prurucentrum micans
Prurucentrum compressus

TABLE 9. Composition of phytoplankton at stations in the lower Chesapeake Bay on September 17, 1973 (Cell numbers times 10^3).

Station	Diatoms	%	Pyrrhophyta	%	Others	%	Total
1	53.1	41	67.3	52	9.2	7	129.6
2	94.6	44	118.3	55	2.2	1	215.2
3	151.7	53	123.2	43	11.5	4	286.4
4	140.8	50	135.2	48	5.6	2	281.6
5	216.4	84	18.0	7	23.2	9	257.6
6	84.0	55	59.6	39	9.2	6	152.8
7	153.8	78	41.4	21	2.0	1	197.2
8	89.0	44	107.3	53	6.1	3	202.4
9	118.2	30	264.0	67	11.8	3	394.0
10	368.9	43	437.7	51	51.4	6	858.0
11	265.2	37	422.9	59	28.7	4	716.8
12	125.5	45	133.8	48	19.5	7	278.8
13	73.6	52	63.7	45	4.3	3	141.6
14	56.0	43	71.7	55	2.7	2	130.4
15	65.1	44	75.5	51	7.4	5	148.0

Table 10. Correlation coefficients for water parameters.

		1	2	3	4	5
6-12-73 Assateaque	1 Phytoplankton	1.0				
	2 Chlorophyll	.96	1.0			
	3 Salinity	-.58	-.63	1.0		
	4 Temperature	-.83	-.85	.74	1.0	
	5 Secchi	-	-	-	-	-
		1	**2**	**3**	**4**	**5**
9-12-73 Rappahannock	1	1.0				
	2	.09	1.0			
	3	-.52	.28	1.0		
	4	.49	-.23	-.78	1.0	
	5	-.41	-.06	.49	-.48	1.0
		1	**2**	**3**	**4**	**5**
9-17-73 Chesapeake	1	1.0				
	2	.90	1.0			
	3	-.14	-.25	1.0		
	4	.33	.61	-.24	1.0	
	5	-	-	-	-	-

Table 11. Correlation coefficients for water parameters with S - 190A radiance values for Assateaque area.

	Green band (.5 - .6)	Red band (.6 - .7)
Chlorophyll	.84	.70
Salinity	-.64	-.60
Temperature	-.87	-.76
Phytoplankton	.90	.74

Table 12. Correlation coefficients for Rappahannock water parameters with given S - 192 band combinations.

Band	Chlor.	Sal.	Temp.	Plank.	Secchi
2	-.44	-.93	.88	-.67	-.75
3	-.39	-.92	.89	-.63	-.79
6	-.55	-.92	.76	-.67	-.59
13	.44	.94	-.78	.68	.58
2 - 6	.59				
3 - 6	.66				
6/3	-.65				
2,3,6,13	.71	.98	.96	.72	

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