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Catalogue of phytoplankton pigment images from the Gulf of St. Lawrence: Coastal Zone Color Scanner data from 1979 to 1981

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G5H 3Z4

1995

**Canadian Data Report of
Hydrography and Ocean Sciences 135**



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Canadian Data Report Of Hydrography and Ocean Sciences

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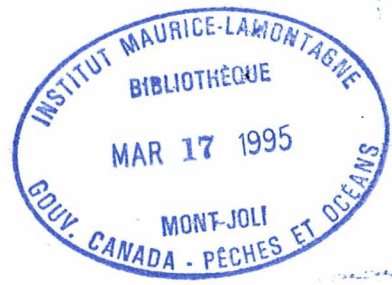
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CATALOGUE OF PHYTOPLANKTON PIGMENT IMAGES FROM
THE GULF OF ST. LAWRENCE: COASTAL ZONE COLOR SCANNER
DATA FROM 1979 TO 1981

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TABLE OF CONTENTS

	Page
ABSTRACT / RÉSUMÉ	iv
PREFACE	v
ACKNOWLEDGEMENTS	v
1.0 INTRODUCTION	1
2.0 METHODS	1
3.0 REFERENCES	3
FIGURE 1. Map of the Gulf of St. Lawrence ecosystem	5
FIGURE 2. Comparison between the <i>in situ</i> and calculated pigments	6
APPENDIX 1. Characteristics of the images used in the project	7
APPENDIX 2. Images of the calculated phytoplankton pigment concentration (mg m^{-3})	11

ABSTRACT

Fuentes-Yaco, C., P. Larouche, A. Vézina, C. Vigneau, and M. Gosselin. 1995. Catalogue of phytoplankton pigment images from the Gulf of St. Lawrence: Coastal Zone Color Scanner data from 1979 to 1981. *Can. Data Rep. Hydrogr. Ocean Sci.* 135: v + 91 p.

This catalogue presents surface phytoplankton pigments concentrations (chlorophyll *a* plus phaeophytin) calculated using Coastal Zone Color Scanner (CZCS) images of the St. Lawrence Gulf. The data set consists of 80 images taken between March and September for the years 1979 to 1981.

RÉSUMÉ

Fuentes-Yaco, C., P. Larouche, A. Vézina, C. Vigneau, and M. Gosselin. 1995. Catalogue of phytoplankton pigment images from the Gulf of St. Lawrence: Coastal Zone Color Scanner data from 1979 to 1981. *Can. Data Rep. Hydrogr. Ocean Sci.* 135: v + 91 p.

Ce catalogue présente les concentrations de pigments de phytoplancton (chlorophylle *a* plus phaeophytin), calculées à partir des images du capteur Coastal Zone Color Scanner (CZCS) du Golfe du Saint-Laurent. Les données consistent en 80 images captées pendant la période comprise entre les mois de mars et septembre, pour les années 1979 à 1981.

PREFACE

This catalogue presents results of satellite remote sensing studies of ocean colour in the Gulf of St. Lawrence. This project was a joint effort between the Maurice Lamontagne Institute of the Canadian Department of Fisheries and Oceans and the Département d'Océanographie of the Université du Québec à Rimouski. This report is part of the program "Recherche multidisciplinaire sur le climat océanique du golfe du Saint-Laurent" of the Maurice Lamontagne Institute. The results are part of Cesar Fuentes-Yaco Ph. D. studies at the Université du Québec à Rimouski.

ACKNOWLEDGEMENTS

Funds for this work were partially provided by a fellowship to Cesar Fuentes-Yaco from the Universidad Nacional Autónoma de México and the Université du Québec à Rimouski. We would like to thank Drs. V. Koutitonsky and J.-C. Therriault for graciously providing the St. Lawrence estuary *in situ* data and for various comments made during the data analysis. Laure Devine improved the edition format.

1.0 INTRODUCTION

The Gulf of St. Lawrence (Fig. 1) is a semi-enclosed coastal sea located between 45-52° N and 56-70° W. Historical data obtained using standard shipboard methods have established that the phytoplankton pigment distribution pattern in the Gulf of St. Lawrence (GSL) is influenced by the local physical and meteorological characteristics as well as by the availability of nutrients. Because of the large spatial and seasonal scales in the GSL, this sea cannot be considered homogeneous (Steven 1975; De Lafontaine *et al.* 1991) but is more accurately characterized as a large atypical estuarine ecosystem (Koutitonsky and Bugden 1991).

To increase our knowledge of the spatio-temporal variability of phytoplankton pigments at intermediate and large synoptic scales, we analyzed remote sensing data from the Coastal Zone Color Scanner (CZCS). This sensor has often been shown to be useful for evaluating phytoplankton pigment distribution (Barale and Schlittenhardt 1993). The main objective of the study was to describe the photosynthetic pigment concentrations (chlorophyll *a* and phaeophytin) in the GSL as imaged by the CZCS. This catalogue presents the complete set of images that were analysed. It is the most extensive number of synoptic views of phytoplankton pigments distribution available for the Gulf of St. Lawrence.

2.0 METHODS

At the beginning of the study, 141 CZCS image files (level 1) of the GSL were selected from NASA's browse data base. They cover the ice-free period extending from March to October, between 1979 and 1981. While the CZCS was operational until 1986, we did not use images after 1981 because the sensor was affected by erratic sensitivity losses. The original set of 141 files was then further reduced to 80 images by eliminating files whose intrinsic noise or errors were too high to allow accurate processing. Furthermore, some images that had been split into two segments were pasted together. The number of images is roughly equal for the three years studied (Table 1); however, the monthly distribution is not homogeneous, with the months of June and July having a greater number of images. Appendix 1 presents the characteristics of the images used in the project.

Corrections of radiometric values were performed by applying the calibration coefficients proposed by Williams *et al.* (1985) and the sensor sensitivity reduction correction factors of Gordon *et al.* (1983b). Ekstein and Simpson's (1991a) method was used to mask clouds and ground, while pixels contaminated by signal overflow were detected using the Mueller (1988) procedure. Molecular scattering (Rayleigh) was evaluated using a single scattering model (Gordon *et al.* 1983a) modified with a solar extraterrestrial radiance coefficient (Ekstein and Simpson 1991b) and an ozone optical depth value (Sturm 1981).

For the aerosol subtraction step, we used an interactive aerosol removal technique (Arnone and LaViolette, 1984) that is based on the fact that aerosol radiances at different wavelengths are well-correlated over large areas while the water and aerosol spatial structures are not. The Rayleigh-corrected CZCS band 4 (670 nm) is weighted by a function of the Angström coefficient and subtracted from each of the three visible Rayleigh-corrected channels until the distinct spatial aerosol structures, if present, disappear. After the atmospheric corrections were completed, the phytoplankton pigments were calculated using the algorithm proposed by Gordon *et al.* (1983a).

Table 1. Time distribution of the final set of images

Year	April	May	June	July	August	Sept.	Total
1979	2	5	7	7	5	2	28
1980	3	3	6	5	6	3	26
1981	2	3	8	7	4	2	26
Total	7	11	21	19	15	7	80

Non-chlorophyll water components (suspended matter and coccoliths) contaminated the phytoplankton pigment calculations to different degrees. To detect these contaminated waters, the atmospherically corrected radiance files (CZCS bands 1, 2 and 3) were converted into reflectances (Holligan *et al.* 1989) and then into Intensity/Hue/Saturation (IHS) (Kruse and Raines 1984). The suspended matter and coccolith spectral signatures in the IHS color space were then used to determine and flag the pixels contaminated by non-phytoplankton material. In itself, this approach was not capable of detecting the dissolved organic matter (DOM) that may be present in the water. However, as most of the DOM is generally of terrestrial origin, we believe that it was probably included in the suspended sediment masking process.

The final processing step was the geometric correction of the images. We used the georeferenced data included in the CZCS level 1 files to produce a first approximation correction. We then precisely adjusted this correction on a stereographic projection using the World Data Bank Feature Codes. The nearest-neighbour method was used as the resampling scheme in order not to distort the pixel's pigment content. The overall location accuracy is better than 1 pixel. We tried as much as possible to retain the original spatial resolution of CZCS throughout the data processing.

To evaluate the precision of the atmospheric correction, a validation of the calculated chlorophyll-like pigments was performed. Simultaneous *in situ* measurements and satellite records were rare for the area and time frame under consideration. Data were only available from the lower St. Lawrence Estuary (J.-C. Therriault, unpublished data; Koutitonsky *et al.* 1980), and from Jacques Cartier Strait and the Esquimalt Channel (P. Larouche, unpublished data). To do the comparison, we calculated the mean chlorophyll *a* plus phaeophytin content measured in the top fifth of the euphotic layer. These values were then compared to the mean value of non-contaminated pigments calculated over a 3x3 tile surrounding the central pixel corresponding to the location of the *in-situ* measurement. Figure 2 shows, the result of a linear regression model applied to the data. The fit between the two sets of measurements appears very good and certainly within the factor of two generally found in similar studies.

Images in appendix 2 show phytoplankton pigment concentrations for specific dates as calculated from CZCS data. Pigment concentrations (mg m^{-3}) are colour-coded from blue and green (low values) to yellow and red (high values). The gray areas represent pixels contaminated by suspended matter (Sed) and/or unavailable data (Ndt). White areas indicate overflow (Ovf) and/or erroneous (Err) areas. The ground (Grd) and/or cloud (Cld) mask is shown in black.

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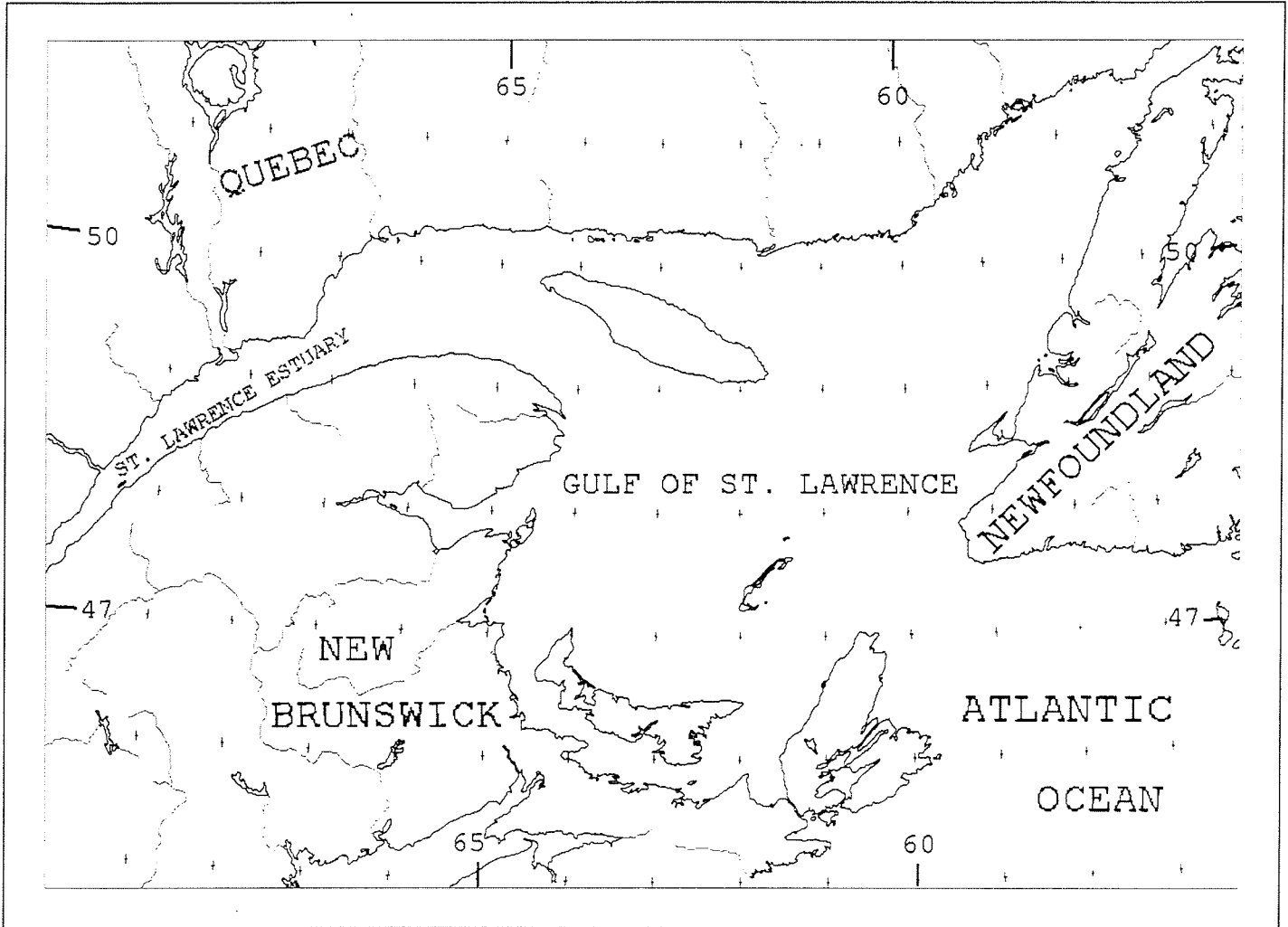


Figure 1. Map of the Gulf of St. Lawrence ecosystem.

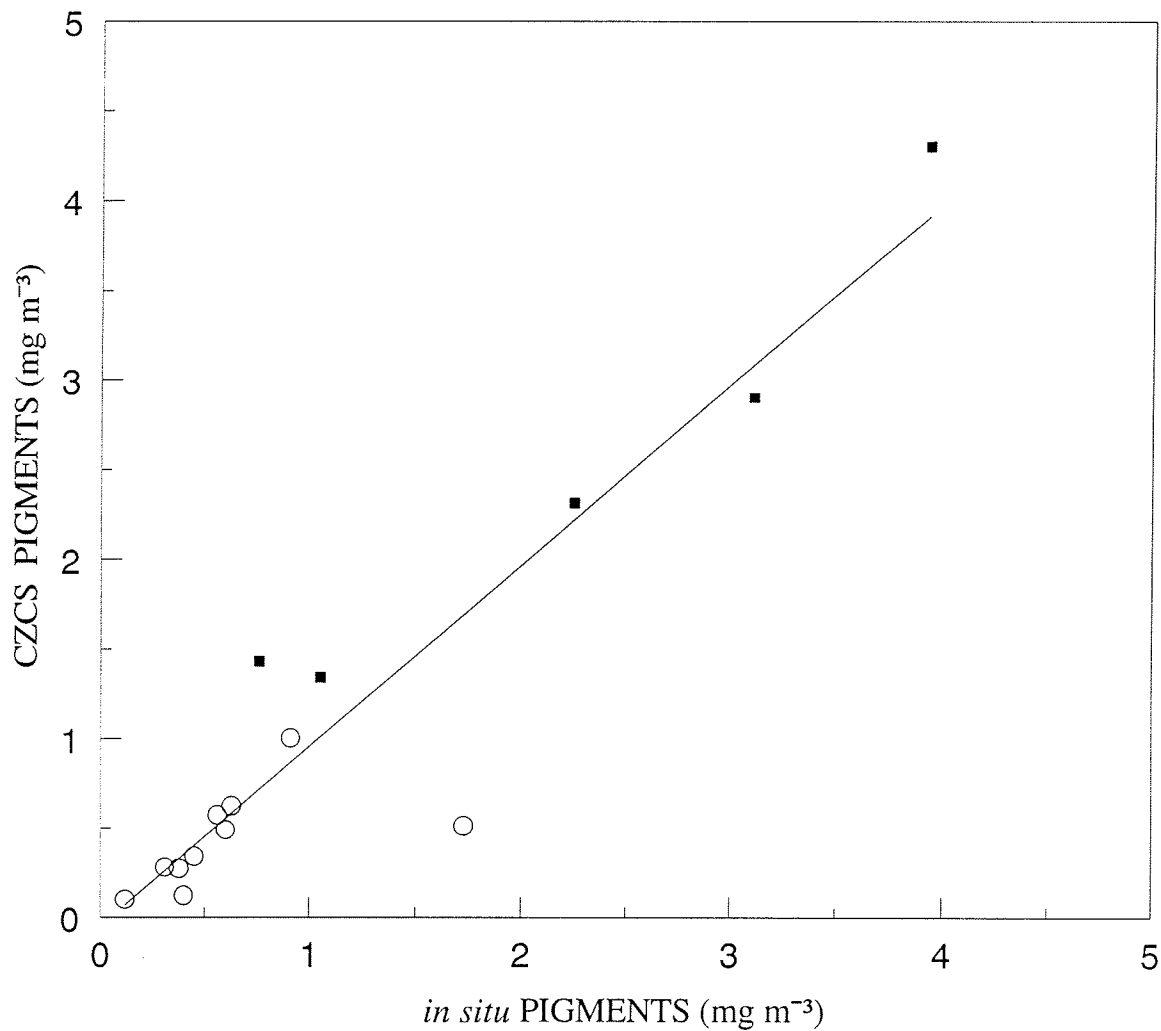


Figure 2. Comparison between pigments measured *in situ* and with the CZCS. Solid squares: St. Lawrence Estuary; open circles: Gulf of St. Lawrence. Regression equation: CZCS pigments=1.007831(*in situ* pigments)-0.04964; $r^2=0.886207$.

APPENDIX 1

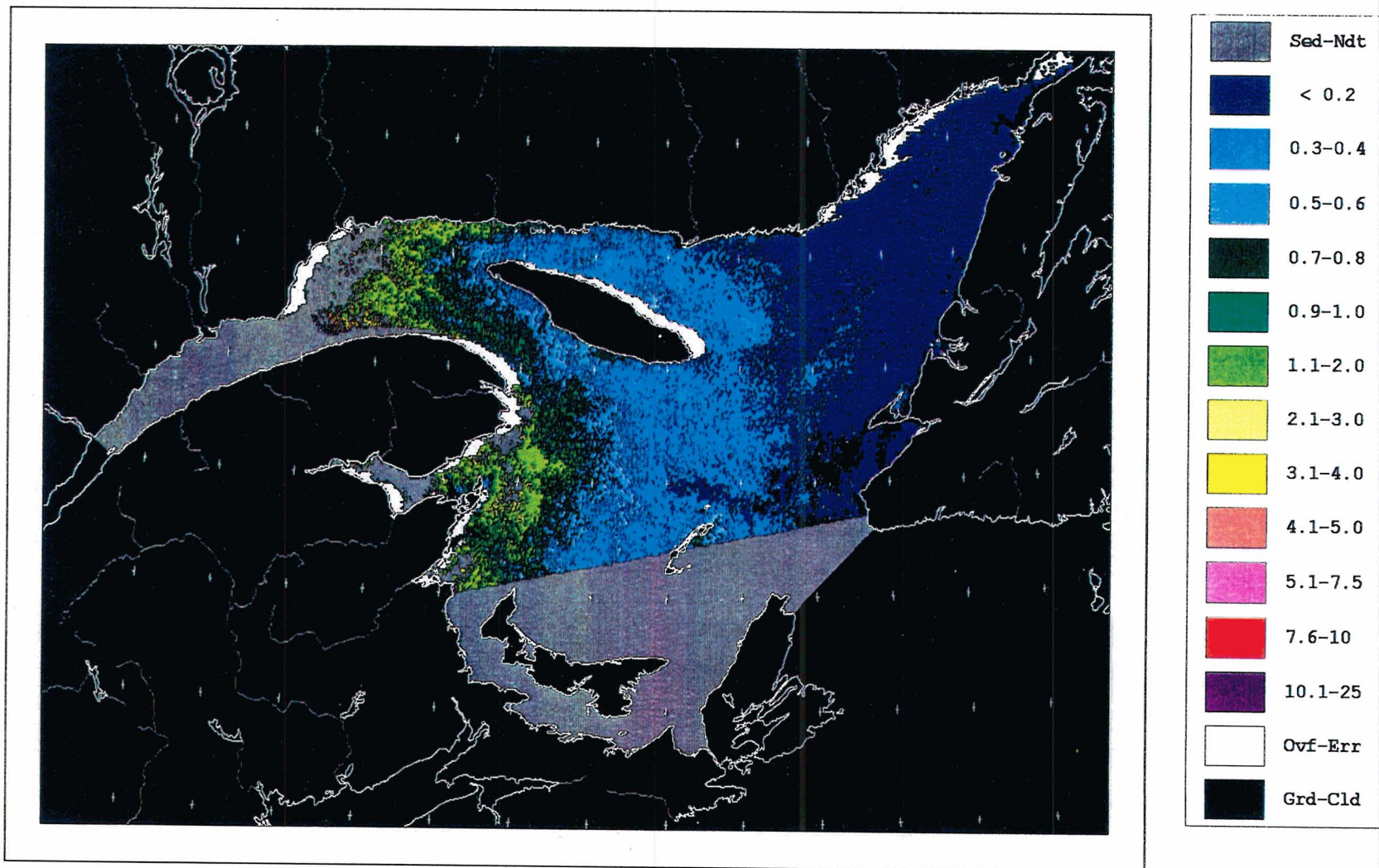
CHARACTERISTICS OF THE IMAGES USED IN THE PROJECT

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30-04-79	15h30	2604	1
19-05-79	16h11	2867	1
20-05-79	14h48	2880	1
23-05-79	15h43	2922	1
25-05-79	14h38	2949	2
26-05-79	14h56	2963	1
02-06-79	15h22	3060	1
08-06-79	15h31	3143	1
17-06-79	14h52	3267	1
19-06-79	15h30	3295	1
20-06-79	15h48	3309	1
21-06-79	16h08	3323	1
26-06-79	15h57	3392	1
04-07-79	15h01	3502	1
07-07-79	15h56	3544	1
10-07-79	15h09	3585	1
16-07-79	15h18	3668	1
19-07-79	16h14	3710	1
21-07-79	15h08	3737	1
22-07-79	15h27	3751	1
02-08-79	15h26	3903	1
03-08-79	15h44	3917	1
07-08-79	15h17	3972	1
18-08-79	15h16	4124	1
31-08-79	15h53	4304	1
05-09-79	15h43	4373	1
16-09-79	15h43	4525	1
02-04-80	15h57	7275	1
04-04-80	14h52	7302	2
19-04-80	16h05	7510	1
20-05-80	15h25	7938	1
21-05-80	15h43	7952	1
30-05-80	15h05	8076	1
06-06-80	15h33	8173	1
07-06-80	15h50	8187	1
13-06-80	15h59	8270	1
22-06-80	15h21	8394	1
23-06-80	15h40	8408	1
29-06-80	15h49	8491	1
01-07-80	14h43	8518	1
04-07-80	15h39	8560	1
05-07-80	14h14	8573	1
18-07-80	14h50	8753	1
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01-08-80	15h45	8947	1
18-08-80	15h52	9182	1

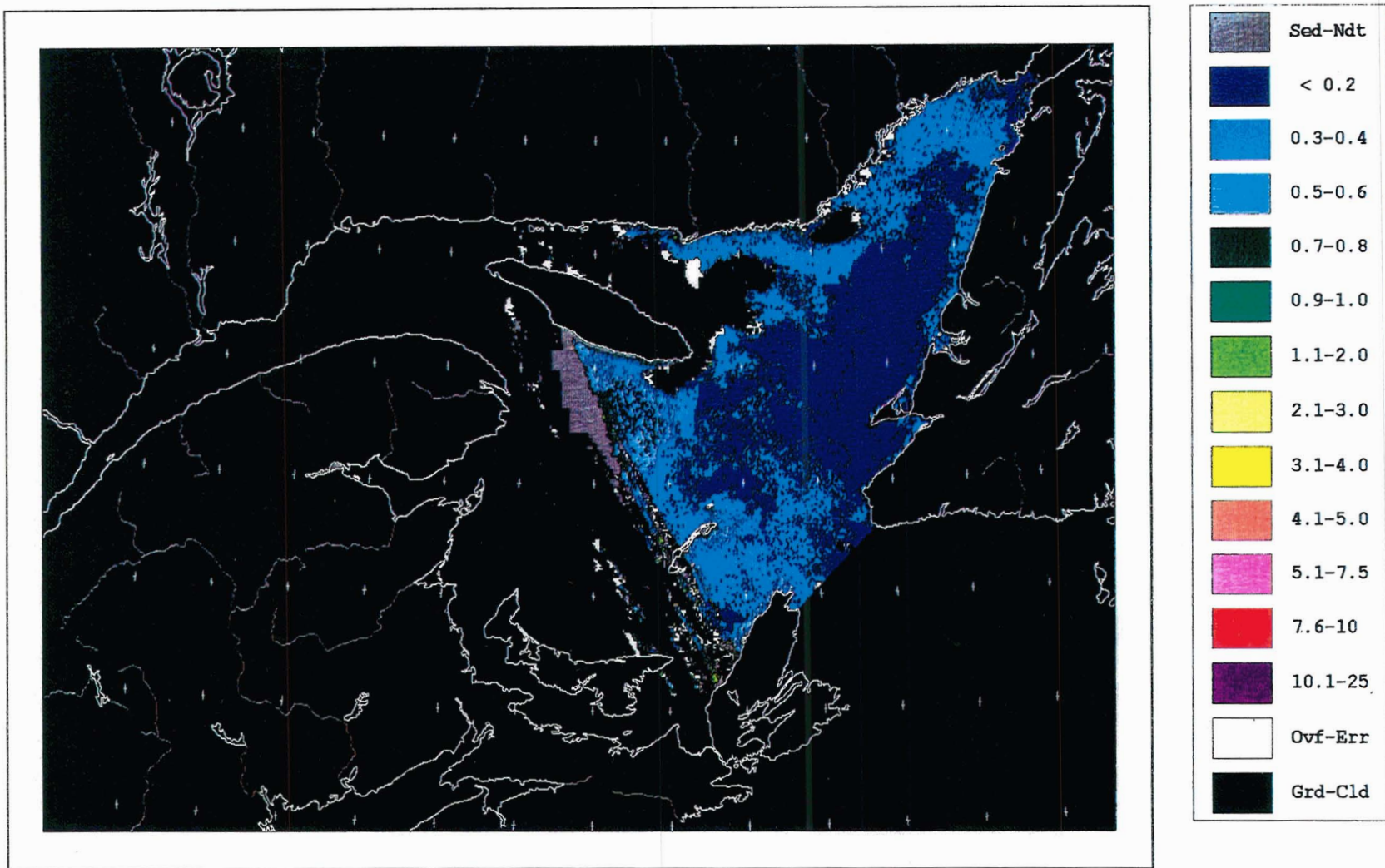
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01-09-80	15h04	9375	2
09-09-80	15h50	9486	2
13-09-80	15h20	9541	1
11-04-81	15h02	12443	2
13-04-81	15h39	12471	2
22-05-81	15h39	13010	1
25-05-81	14h51	13051	1
26-05-81	15h09	13065	1
02-06-81	15h35	13162	1
08-06-81	15h43	13245	1
13-06-81	15h32	13314	1
16-06-81	14h45	13355	1
24-06-81	15h30	13466	1
25-06-81	15h48	13480	1
27-06-81	14h42	13507	1
30-06-80	15h37	13549	1
01-07-81	15h57	13563	1
02-07-81	14h32	13576	1
03-07-81	14h49	13590	1
09-07-81	14h57	13676	1
17-07-81	15h42	13784	1
24-07-81	16h08	13881	1
26-07-81	15h03	13908	1
13-08-81	15h27	14157	1
20-08-81	15h52	14254	1
25-08-81	15h40	14323	1
30-08-81	15h30	14392	1
10-09-81	15h27	14544	1
27-09-81	15h32	14779	1

APPENDIX 2

IMAGES OF THE CALCULATED PHYTOPLANKTON
PIGMENT CONCENTRATION (mg m^{-3})

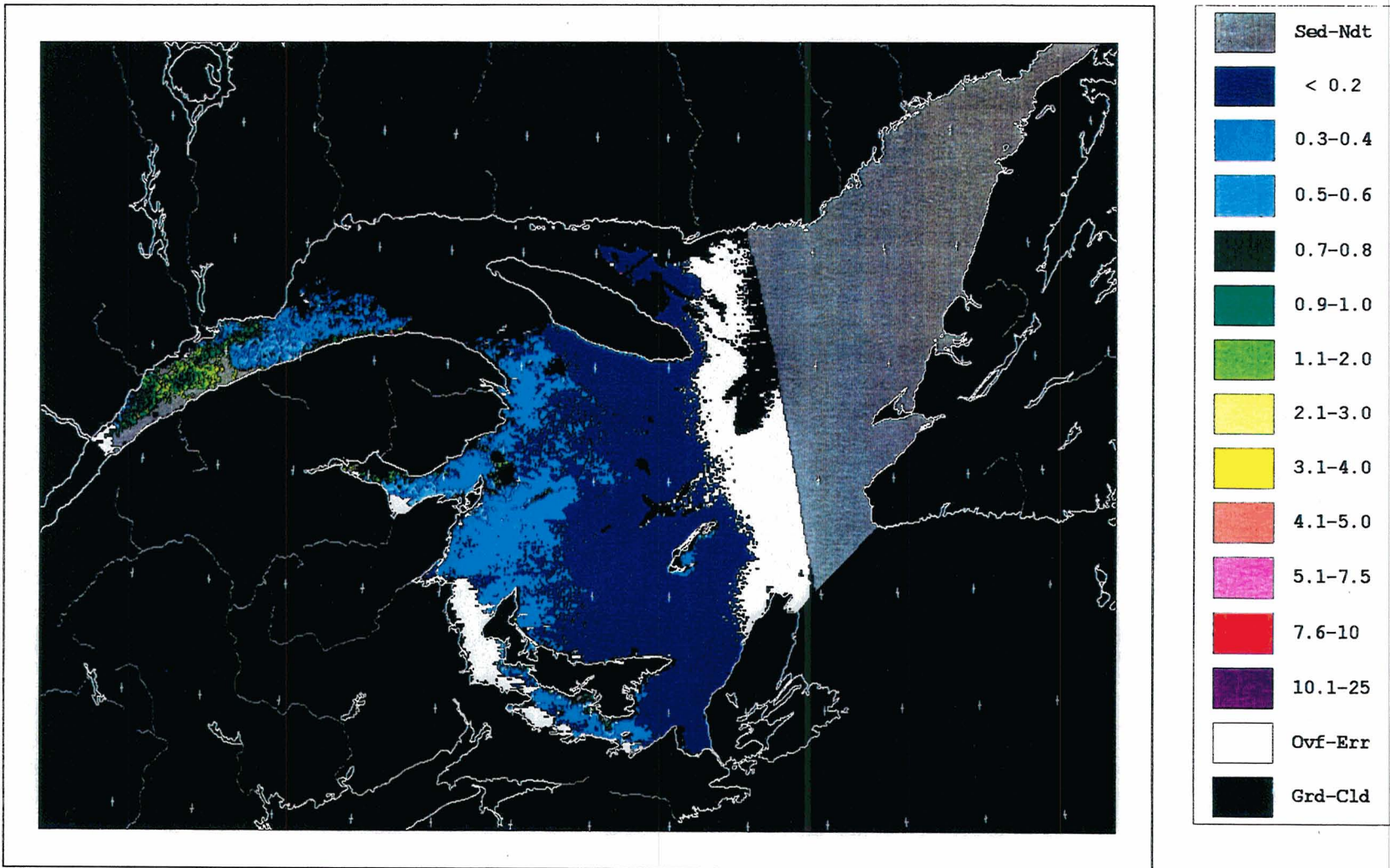


Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (April 25th 1979)

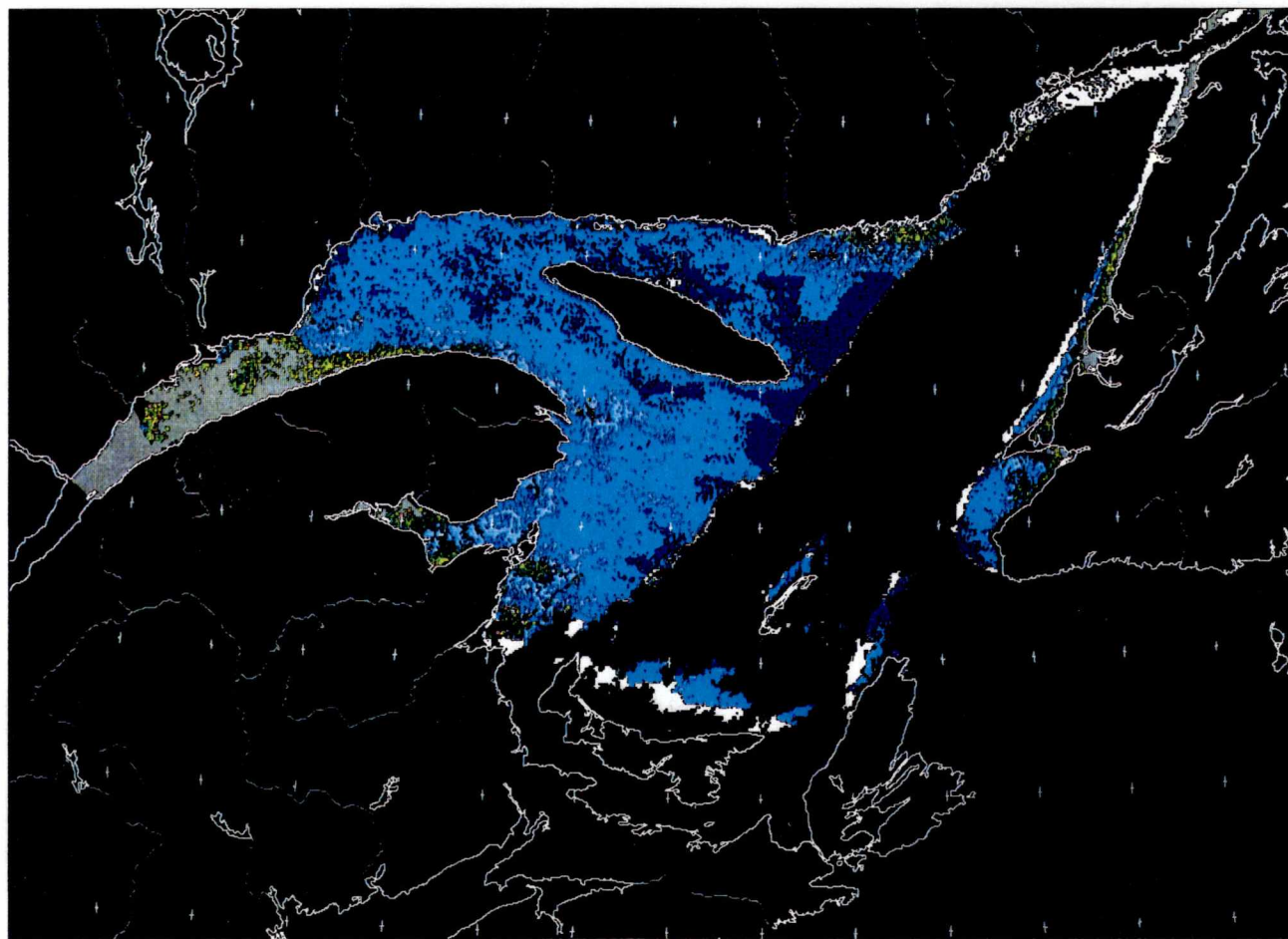


Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (April 30th 1979)

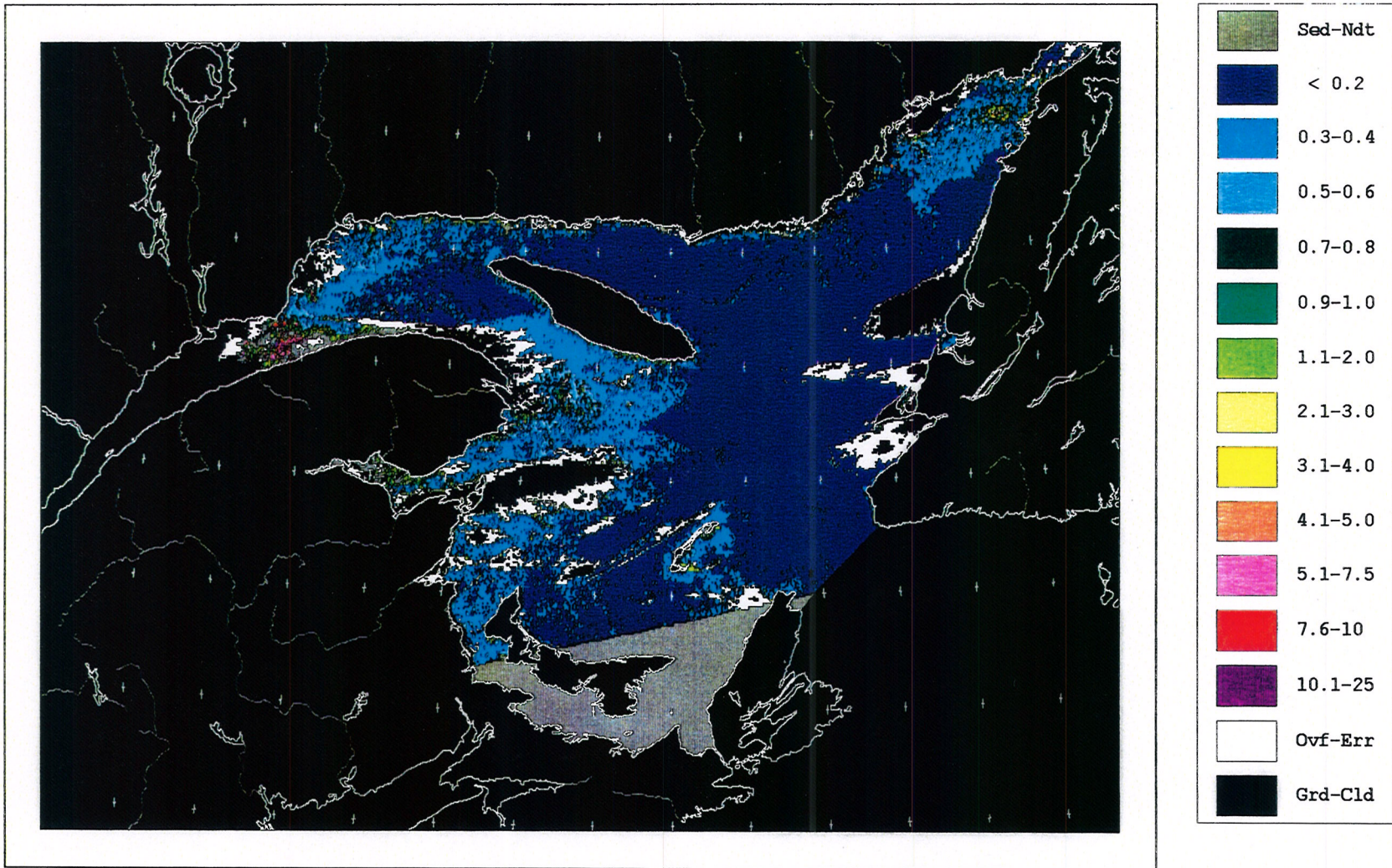


Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (May 19th 1979)

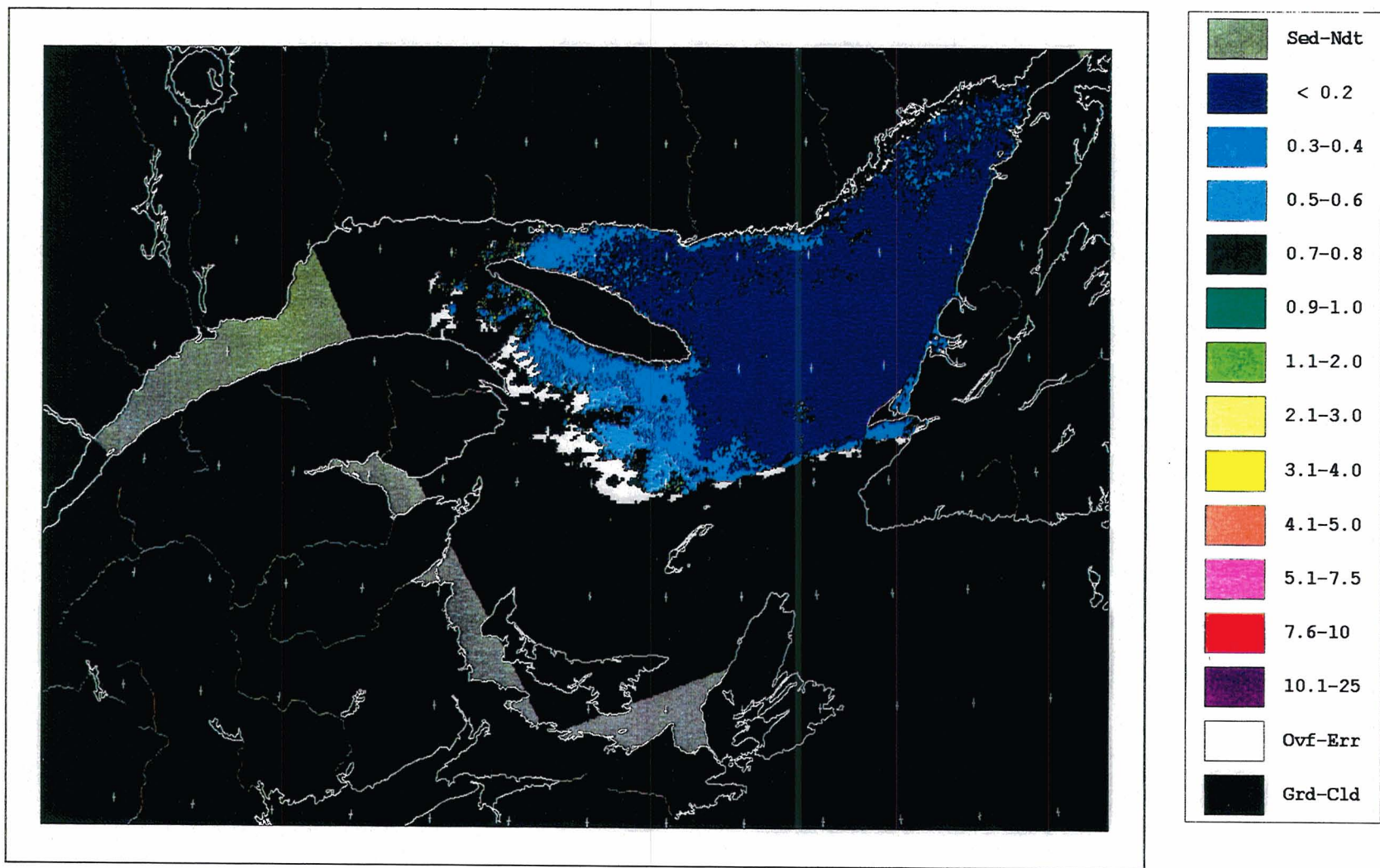


Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (May 20th 1979)

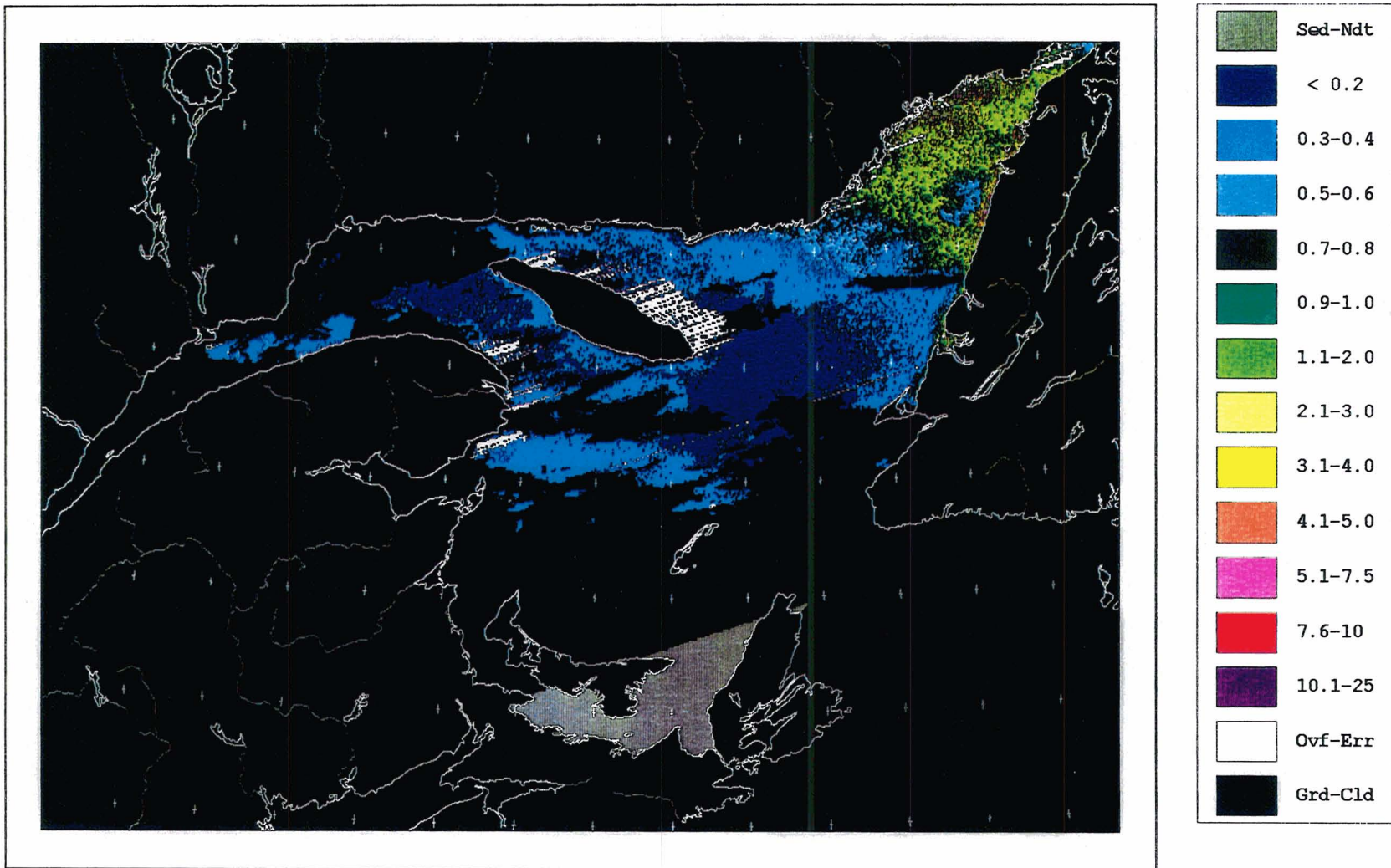


Phytoplankton Pigment Concentration (mg/m**3)
 Gulf of St. Lawrence (May 23th 1979)



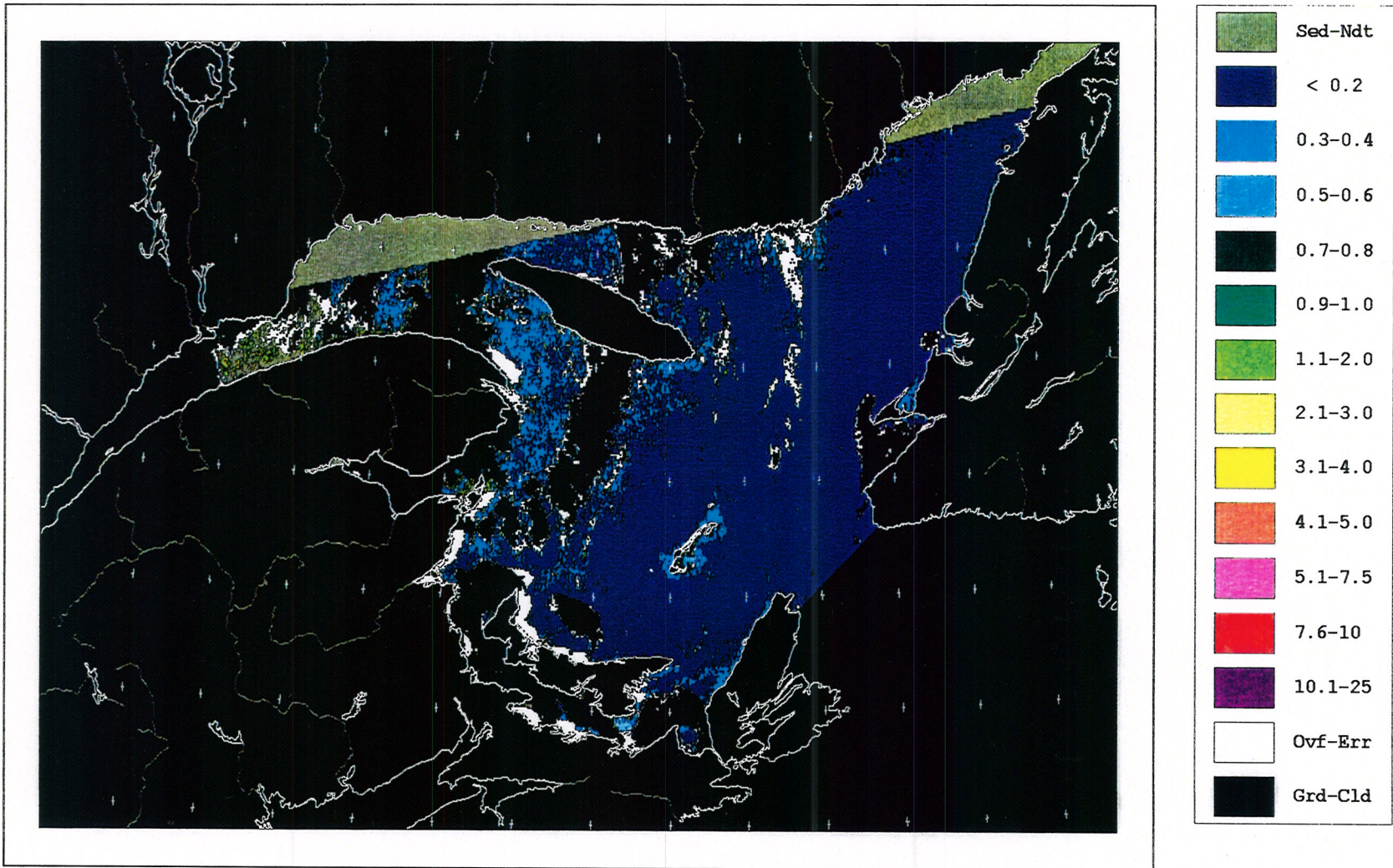
Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (May 25th 1979)



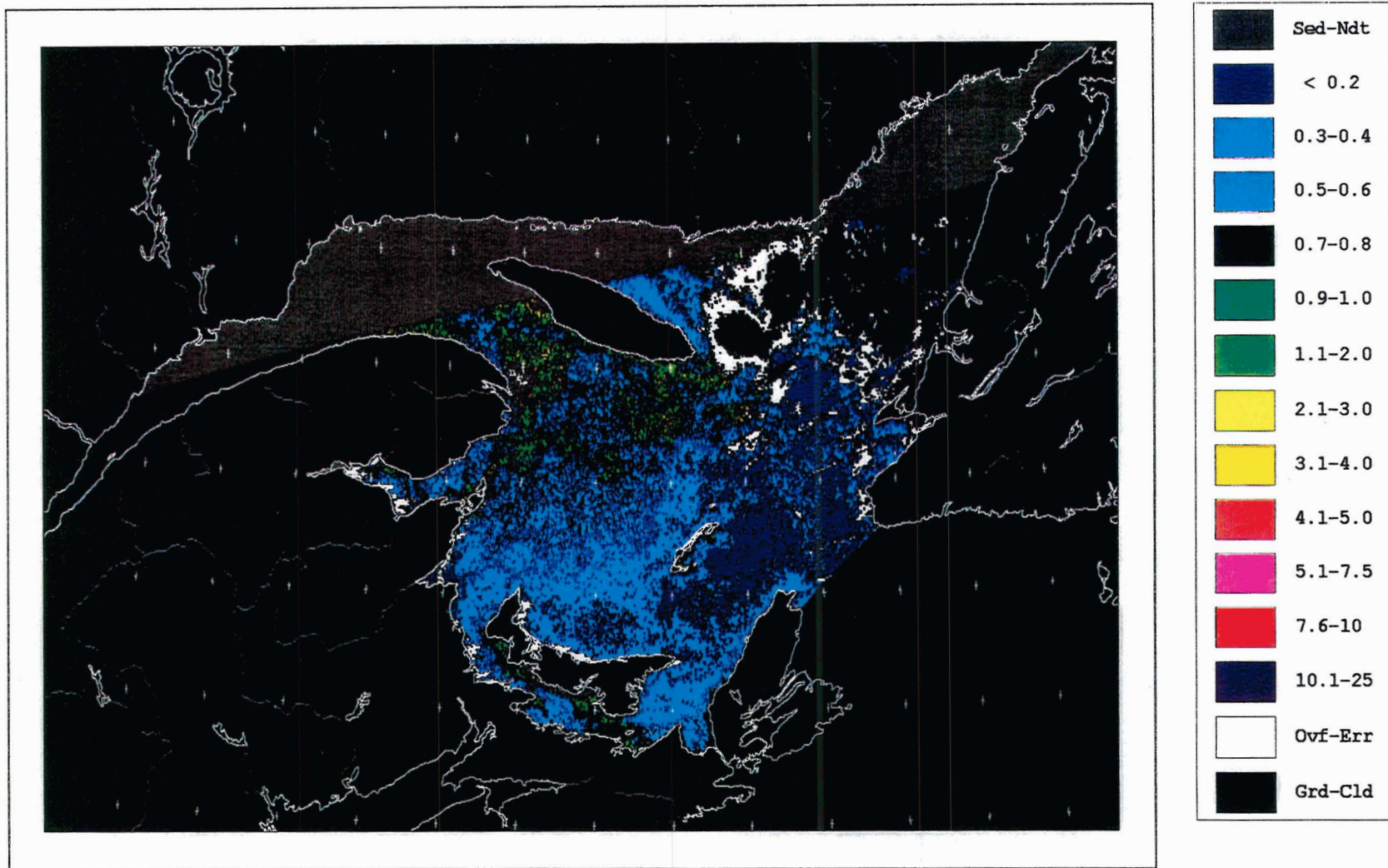
Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (May 26th 1979)



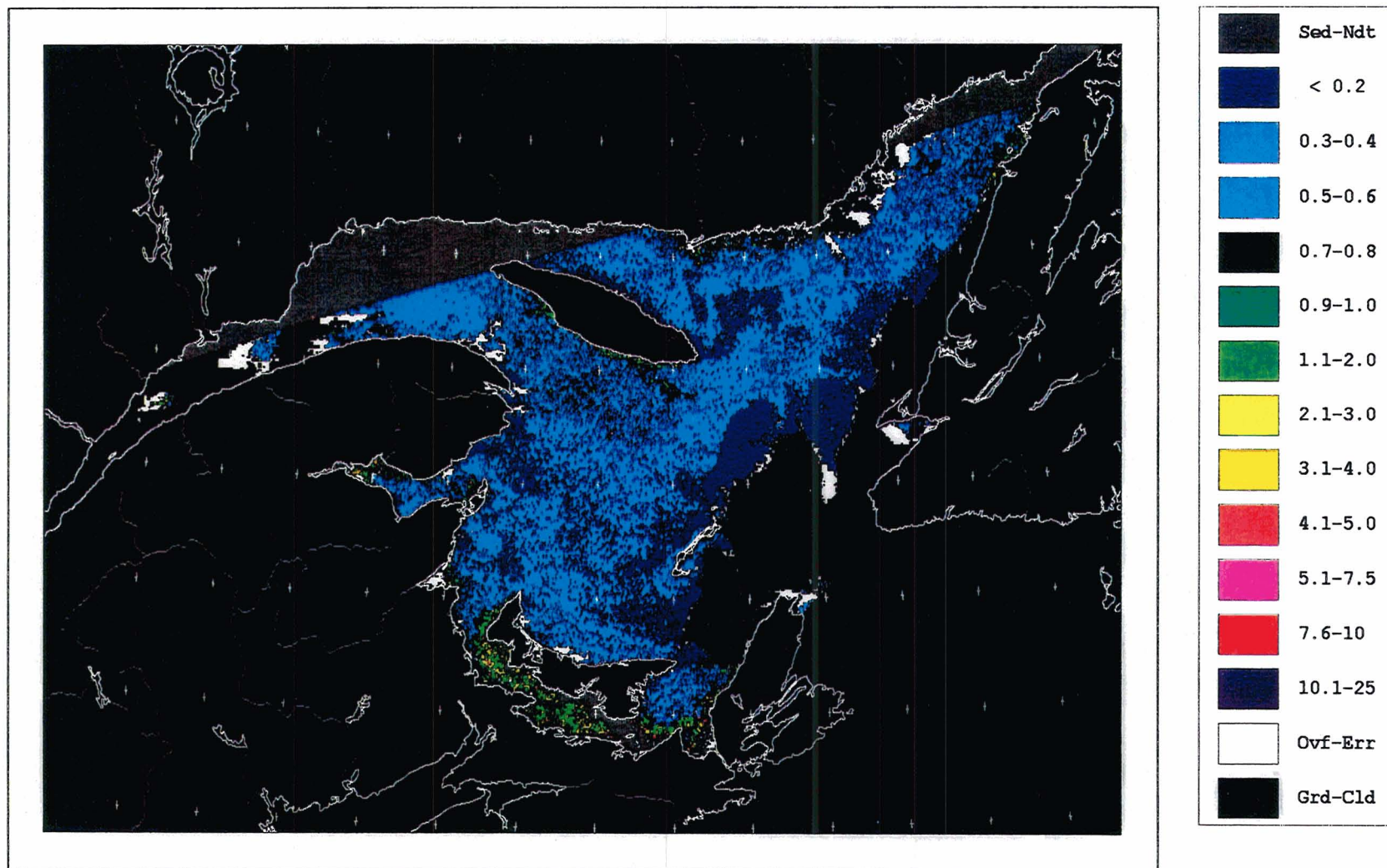
Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (June 2th 1979)

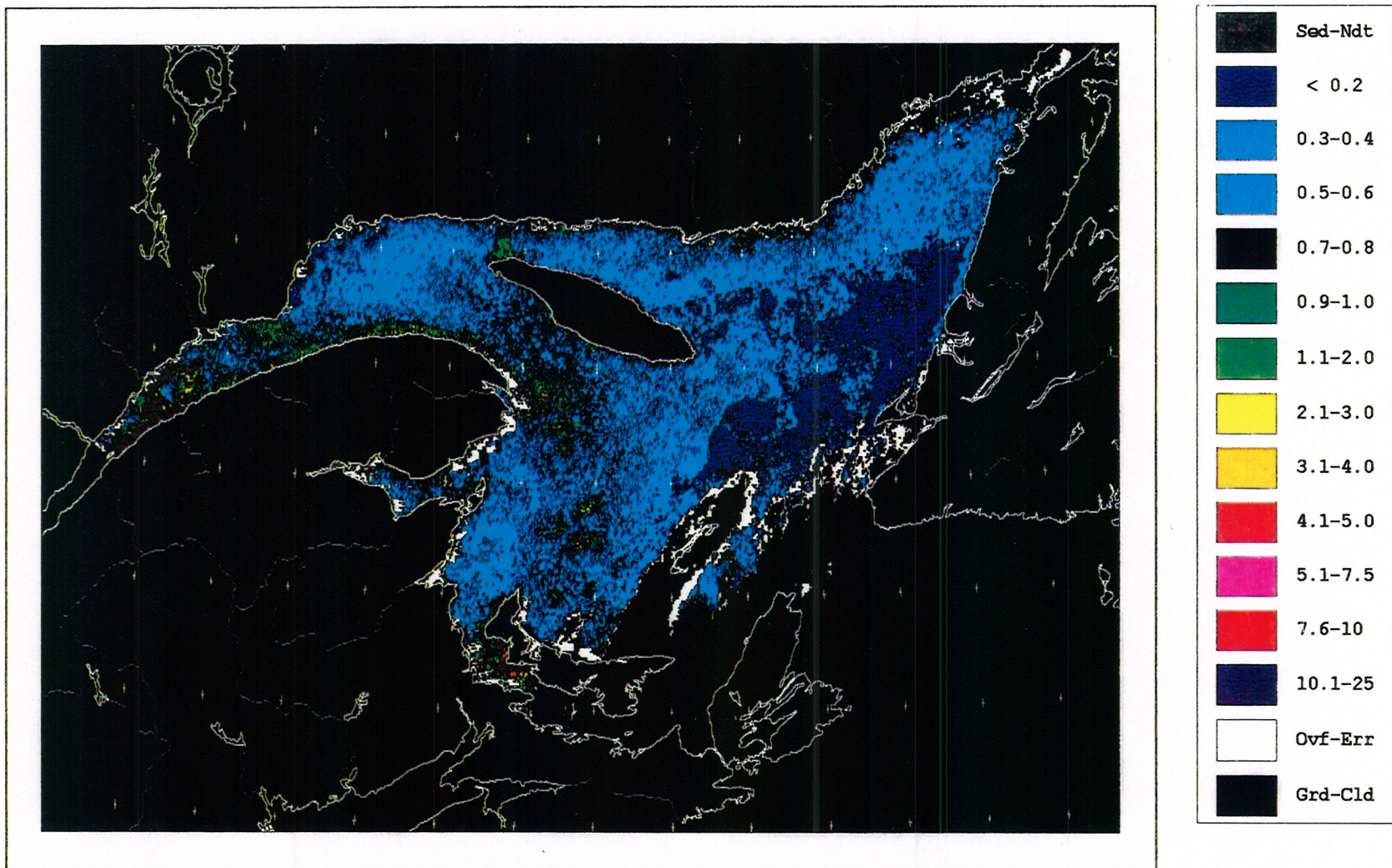


Phytoplankton Pigment Concentration (mg/m³)

Gulf of St. Lawrence (June 8th 1979)

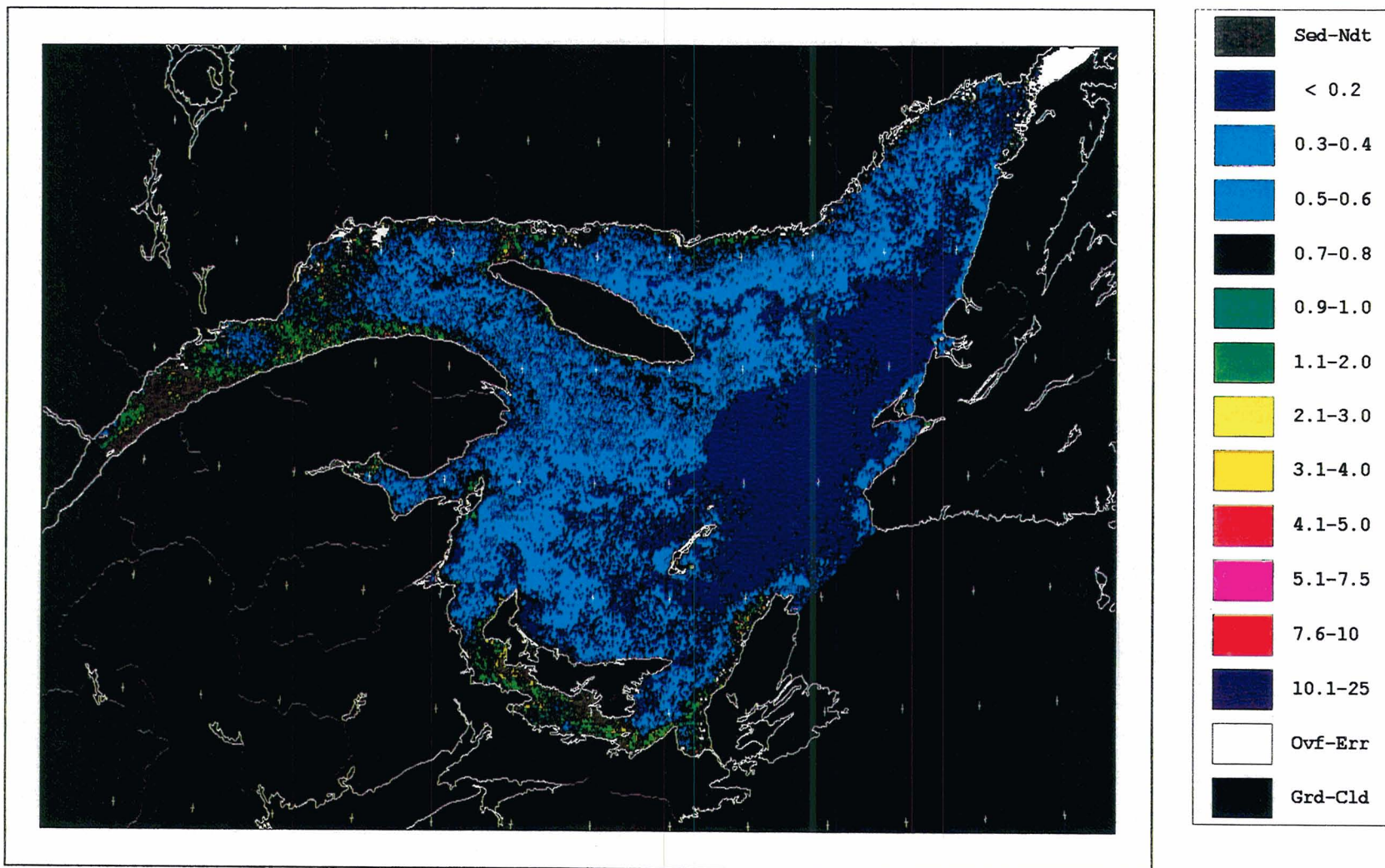


Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (June 17th 1979)



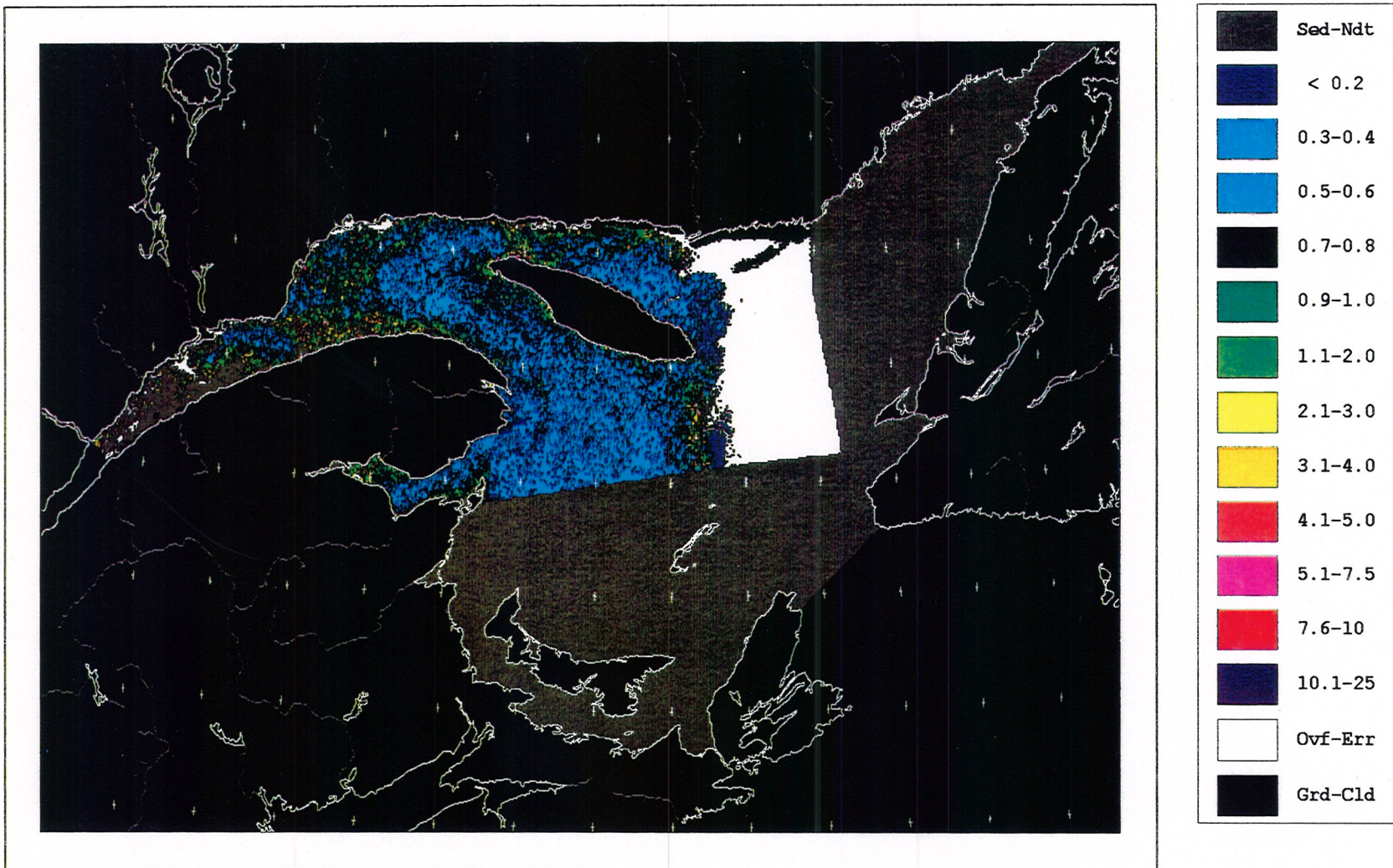
Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (June 19th 1979)



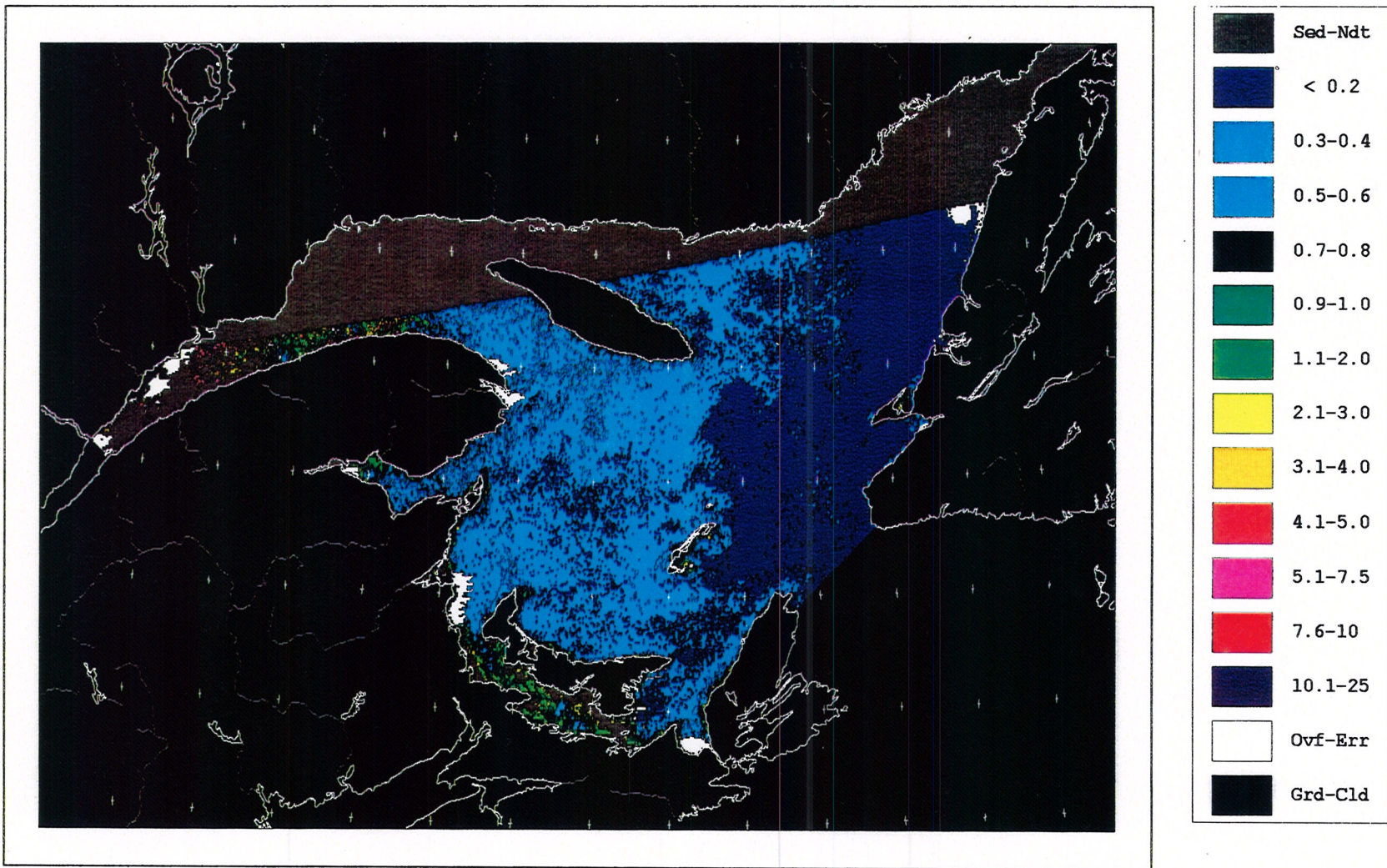
Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (June 20th 1979)



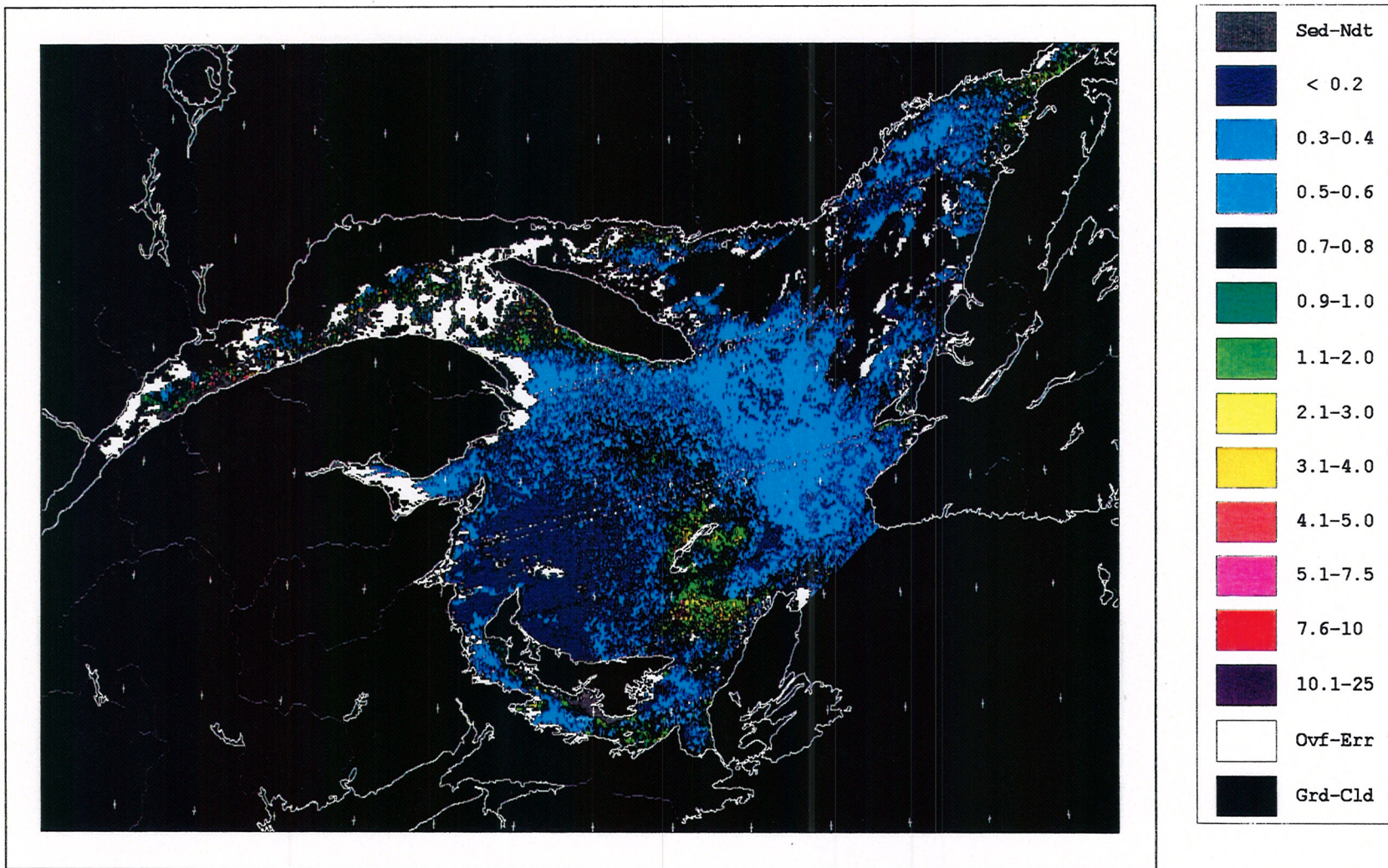
Phytoplankton Pigment Concentration (mg/m³)

Gulf of St. Lawrence (June 21th 1979)

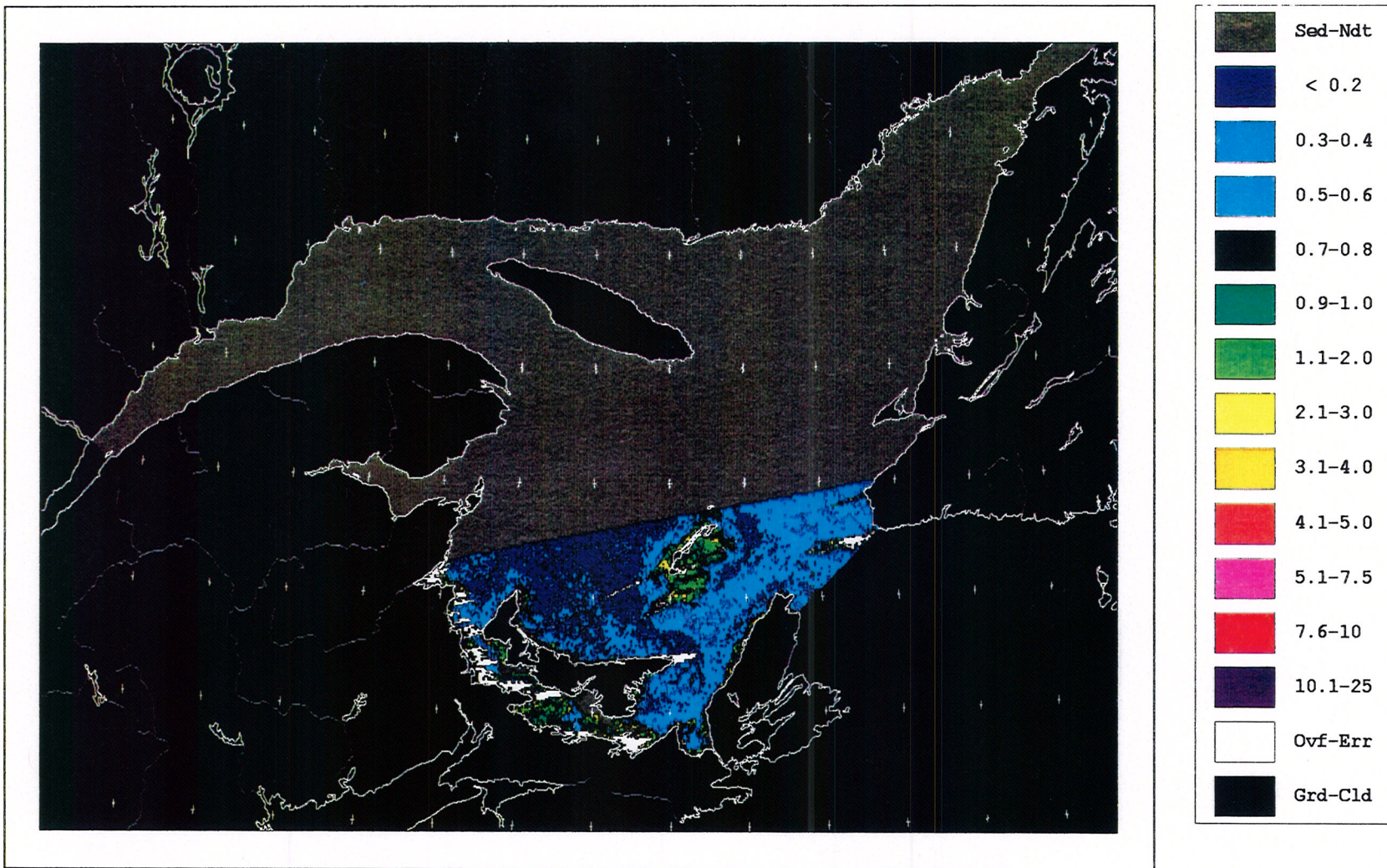


Phytoplankton Pigment Concentration (mg/m³)

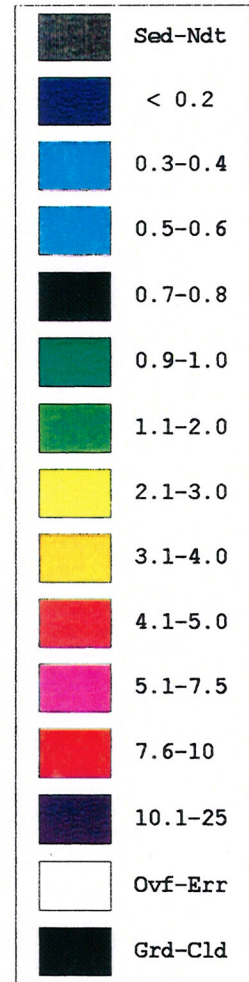
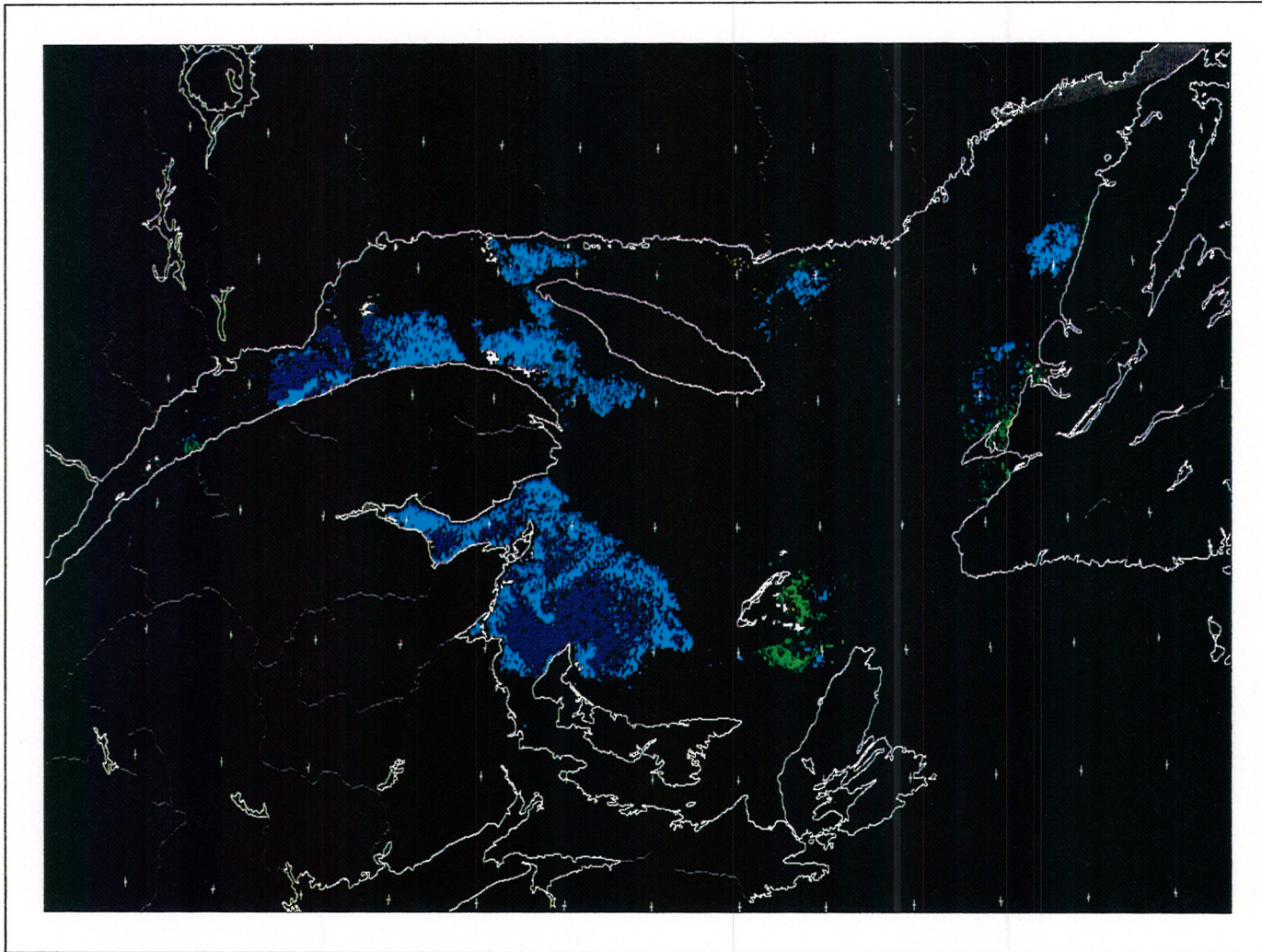
Gulf of St. Lawrence (June 26th 1979)



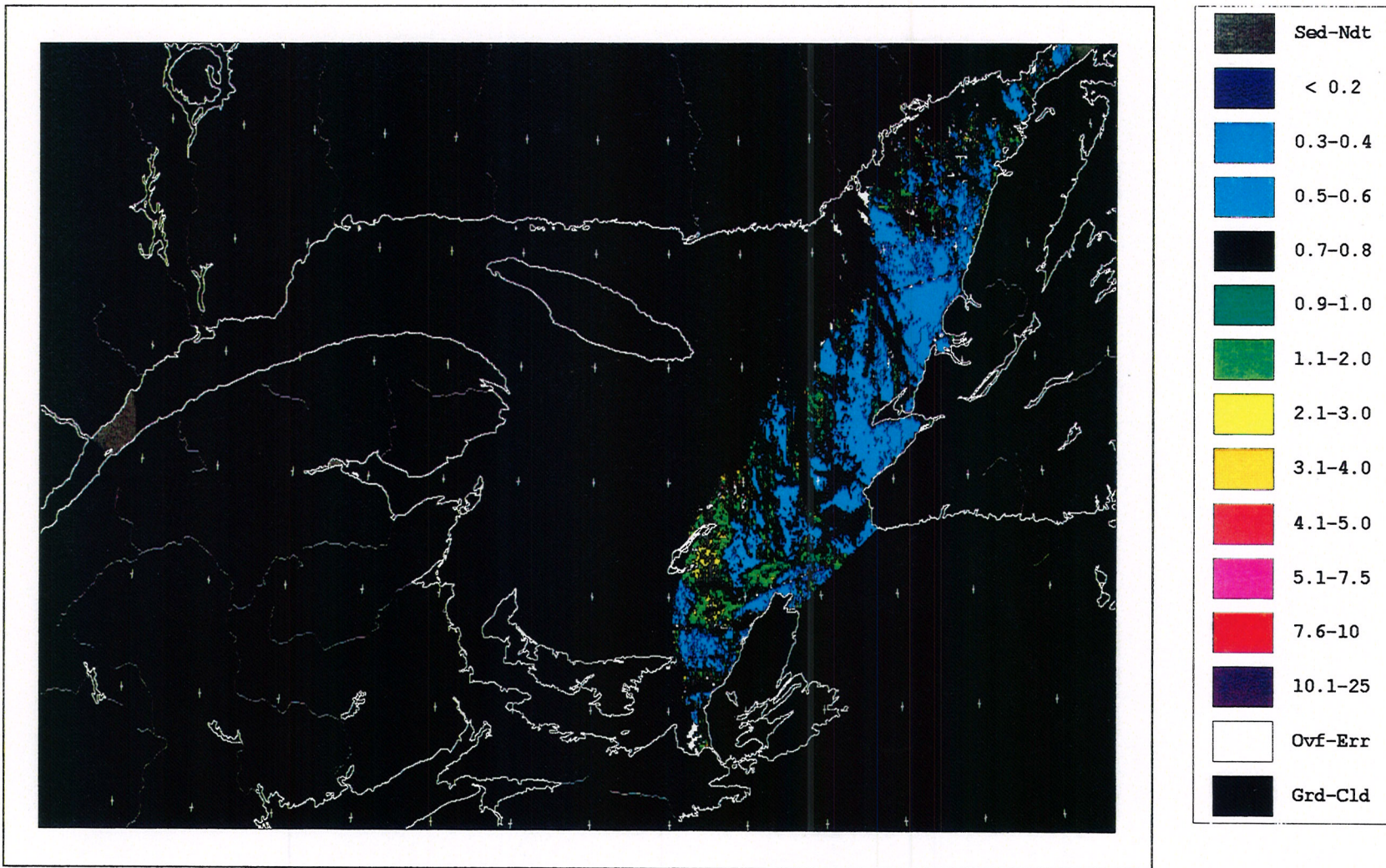
Phytoplankton Pigment Concentration (mg/m**3)
Gulf of St. Lawrence (July 4th 1979)



Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (July 7th 1979)

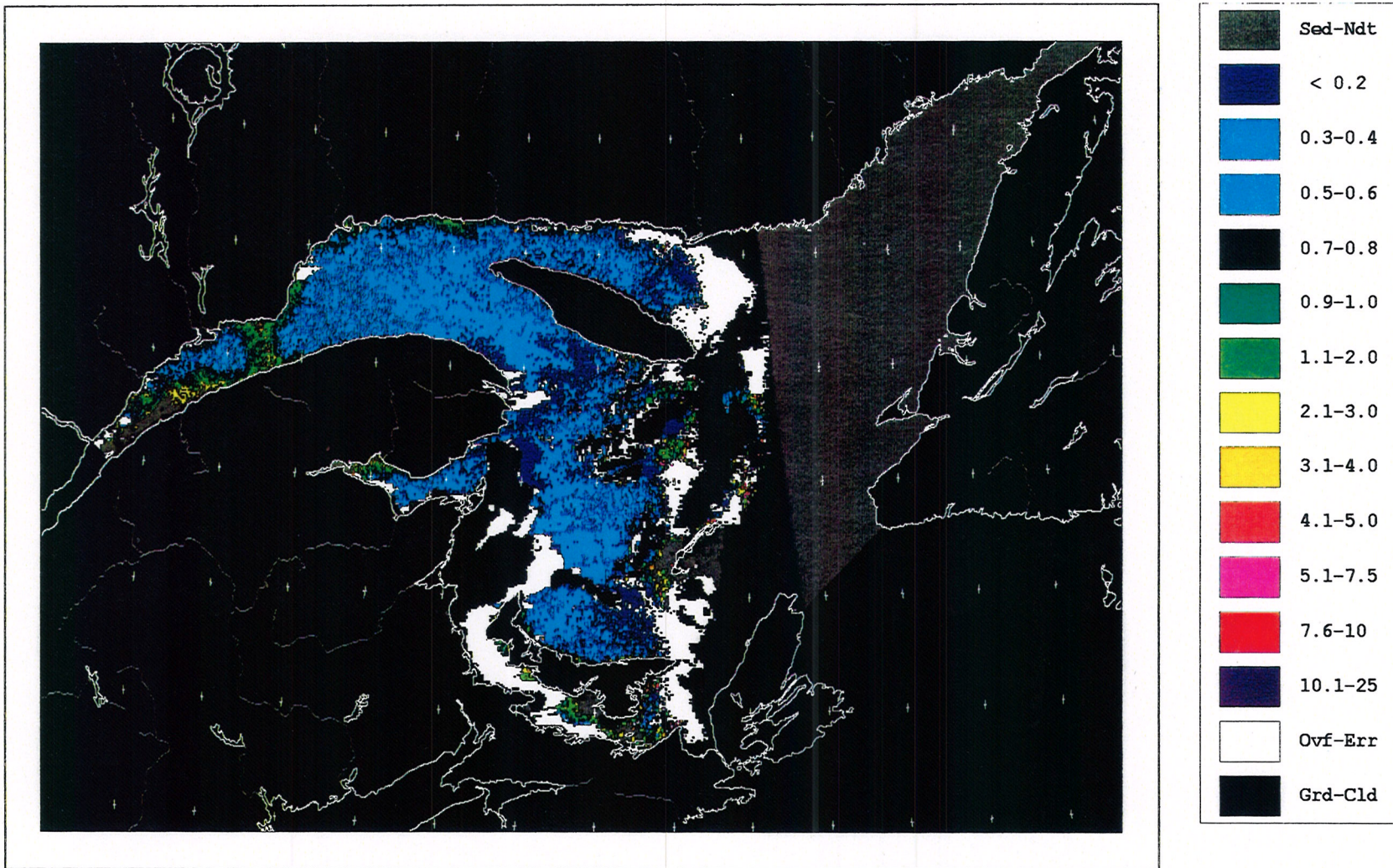


Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (July 10th 1979)

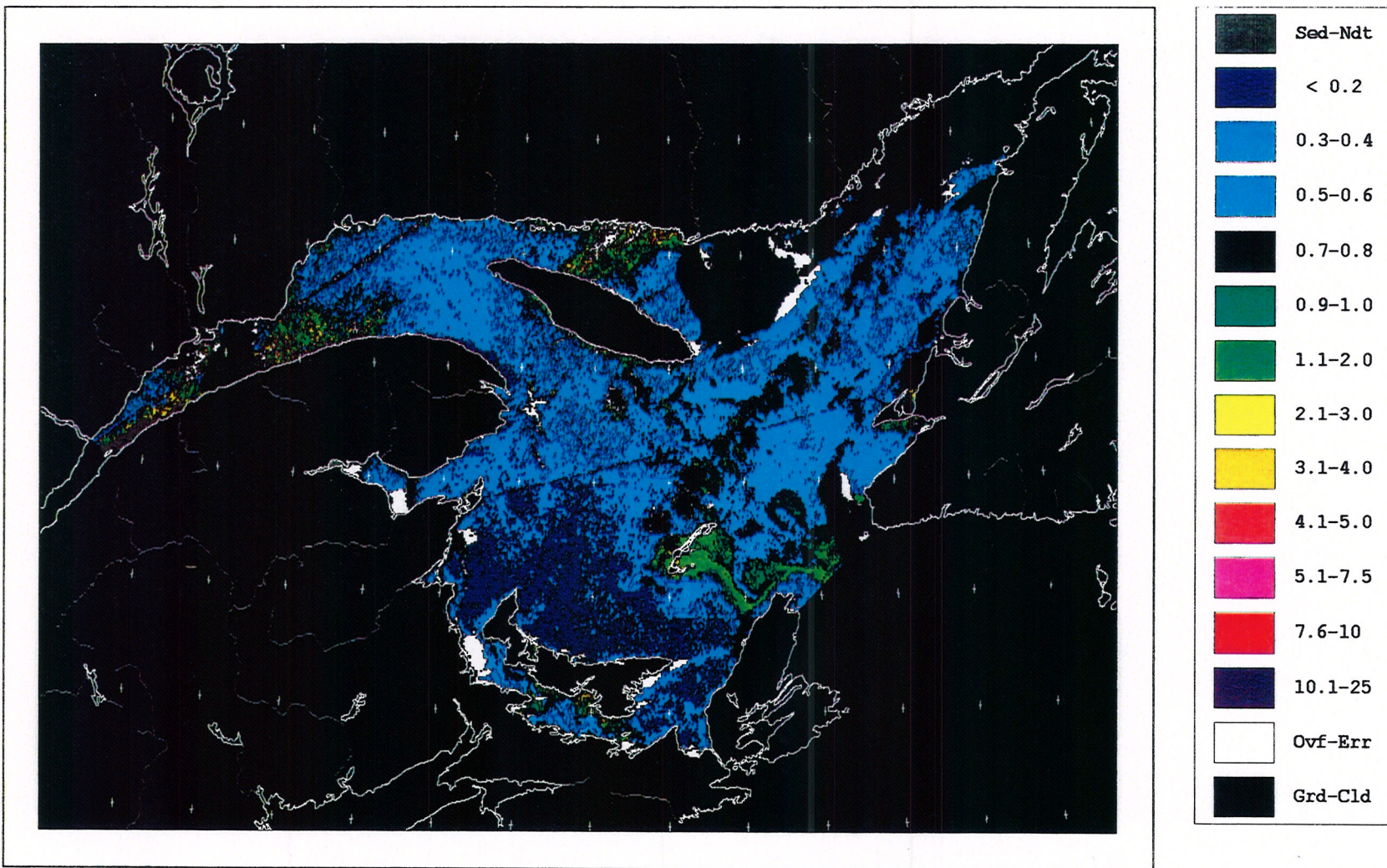


Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (July 16th 1979)

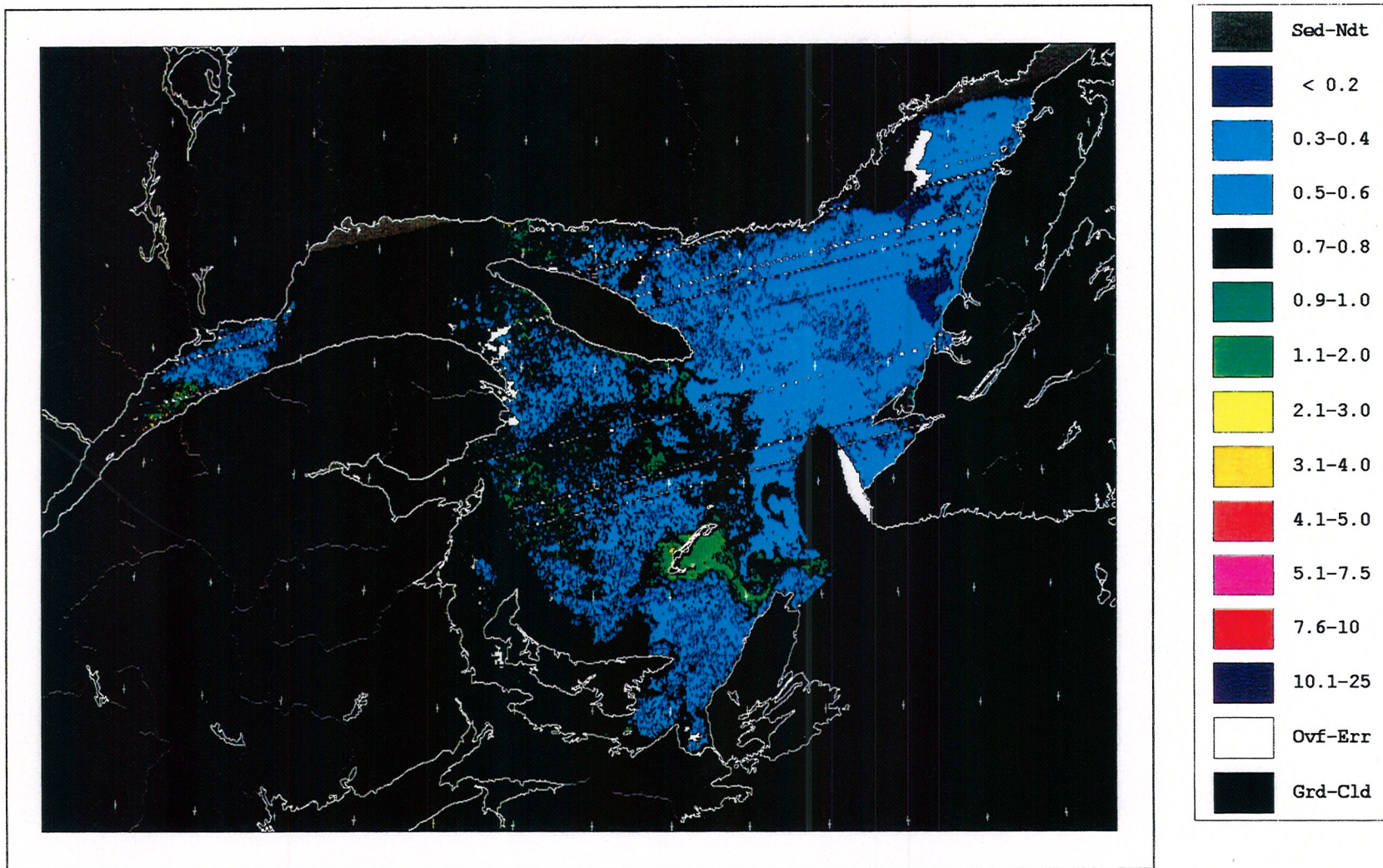


Phytoplankton Pigment Concentration (mg/m³)
 Gulf of St. Lawrence (July 19th 1979)



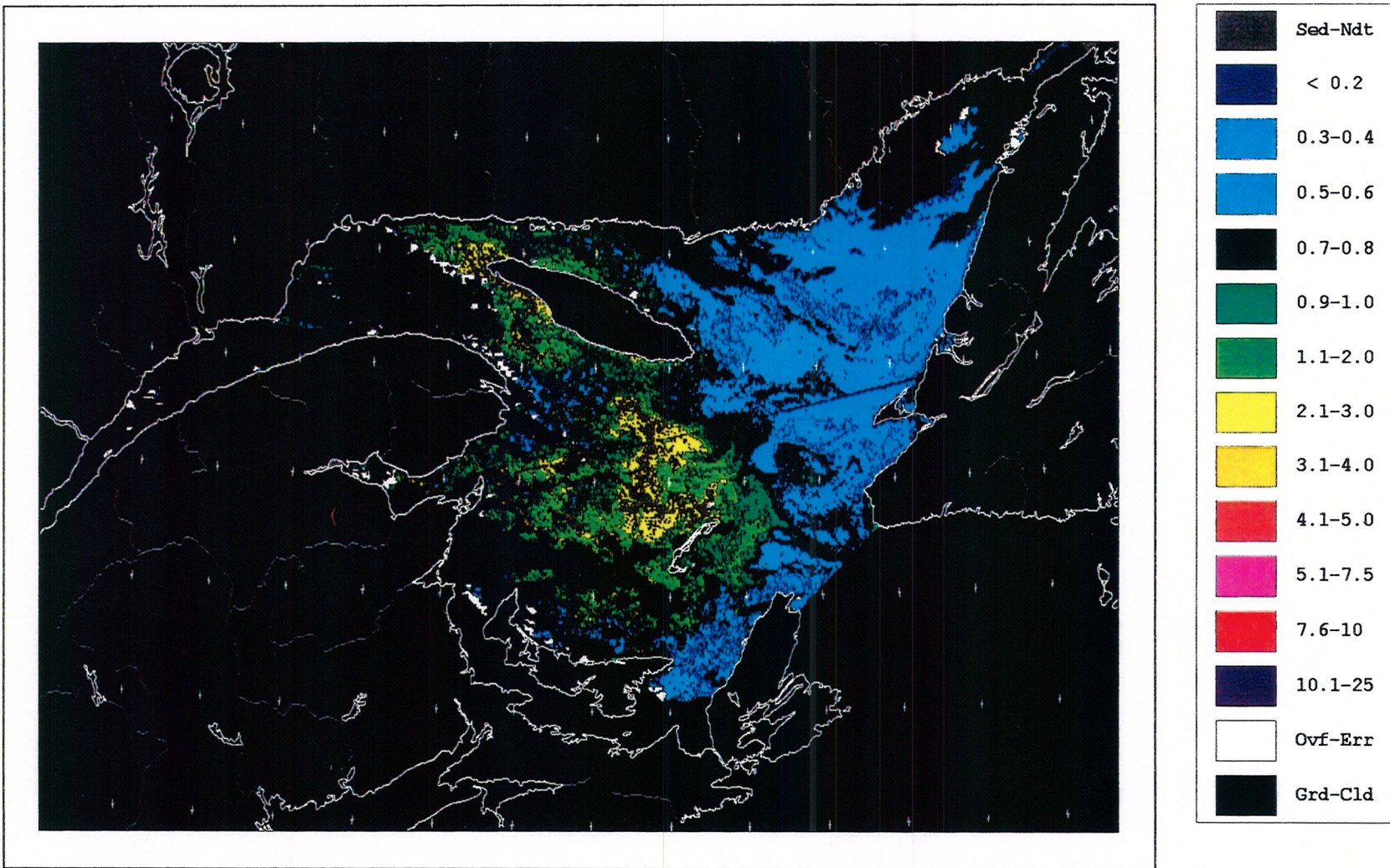
Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (July 21th 1979)



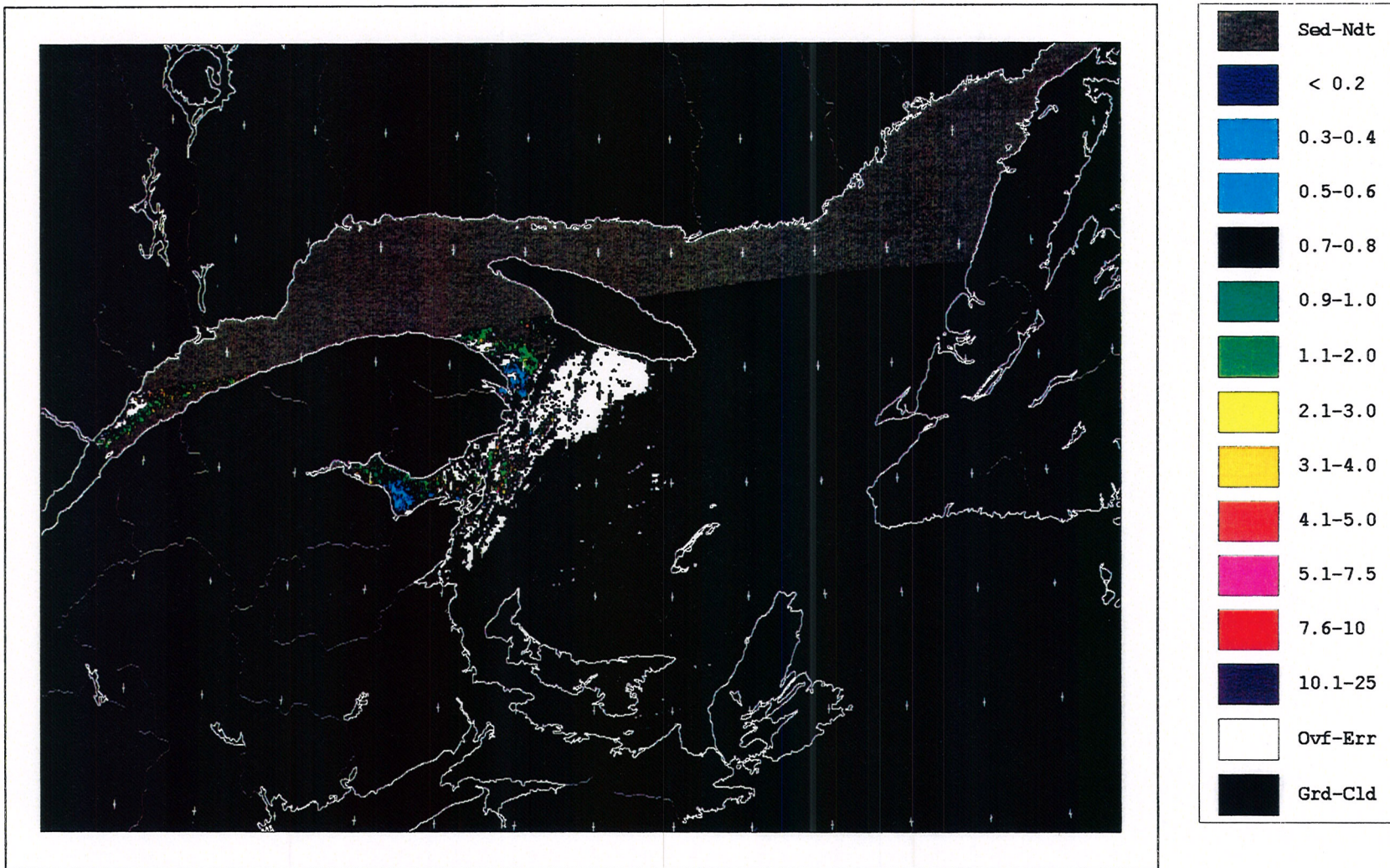
Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (July 22th 1979)



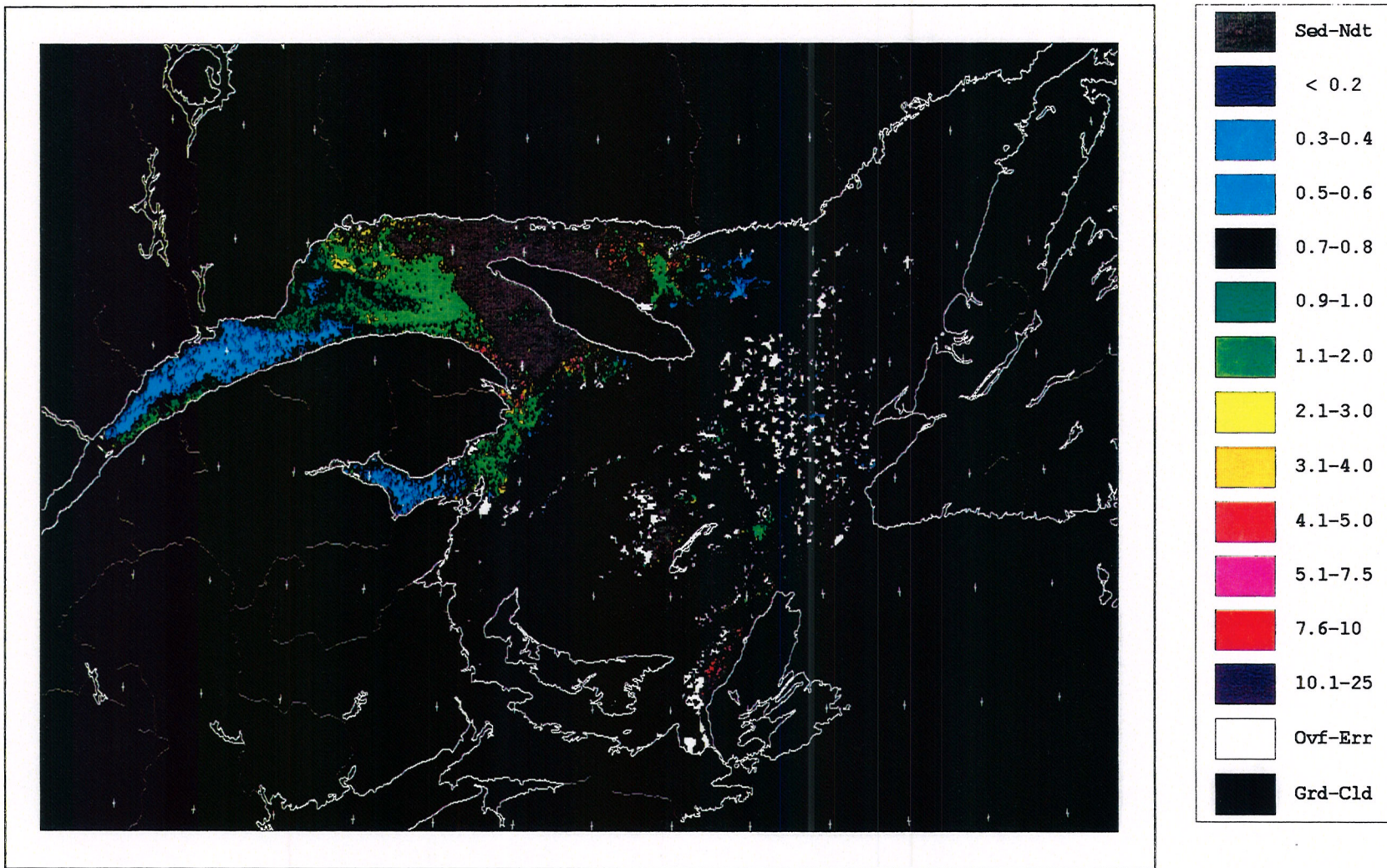
Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (August 2th 1979)



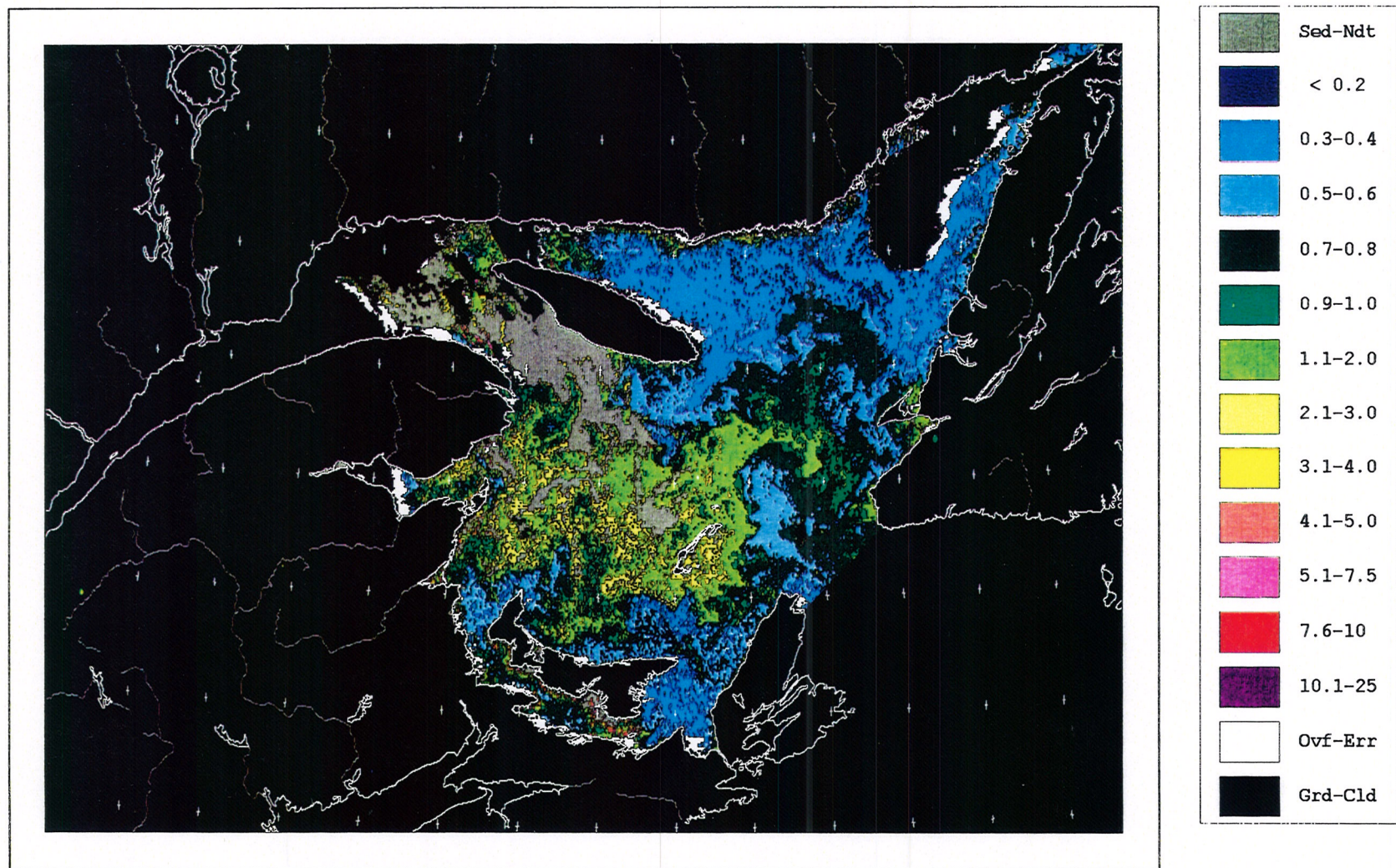
Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (August 3th 1979)



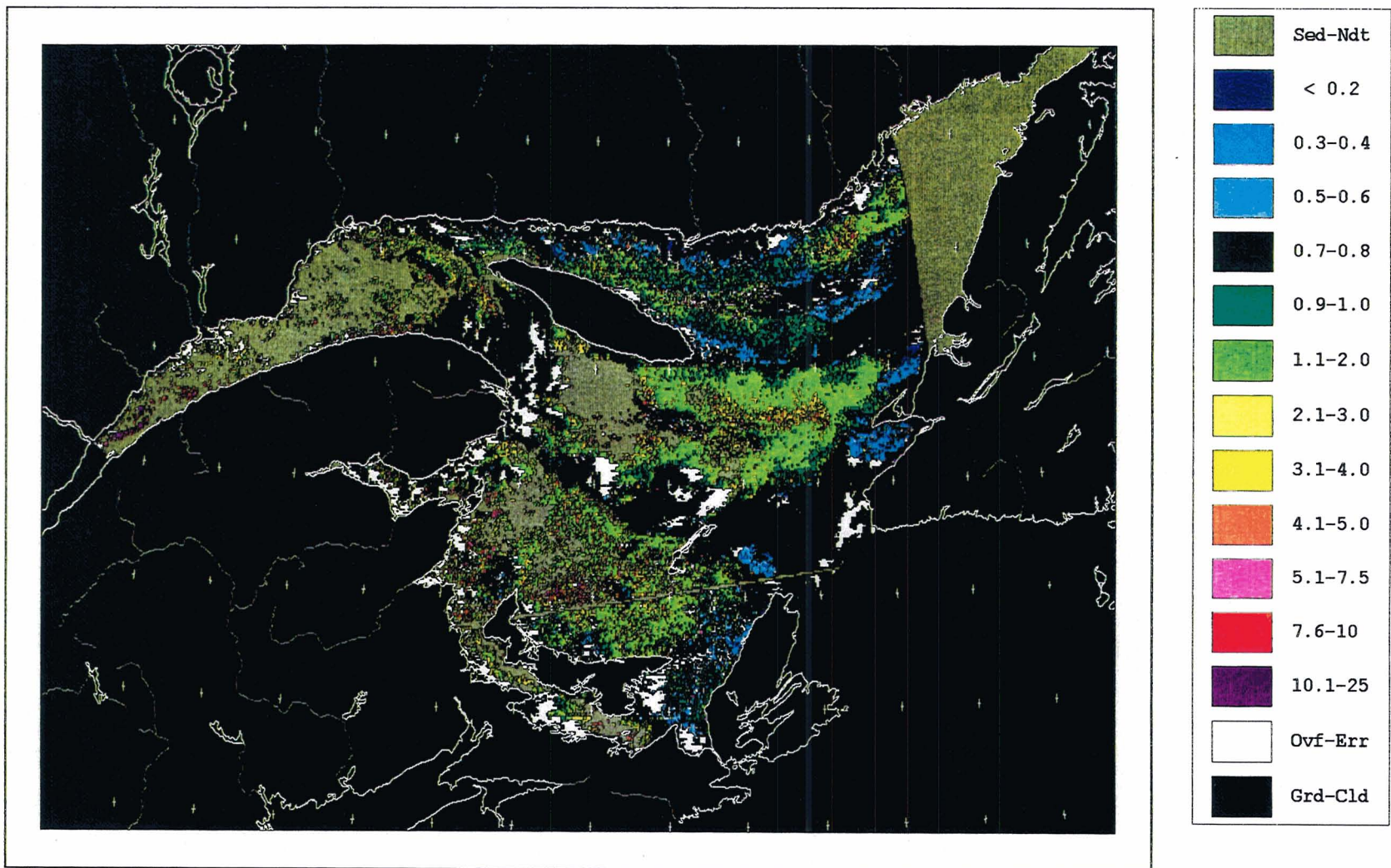
Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (August 7th 1979)

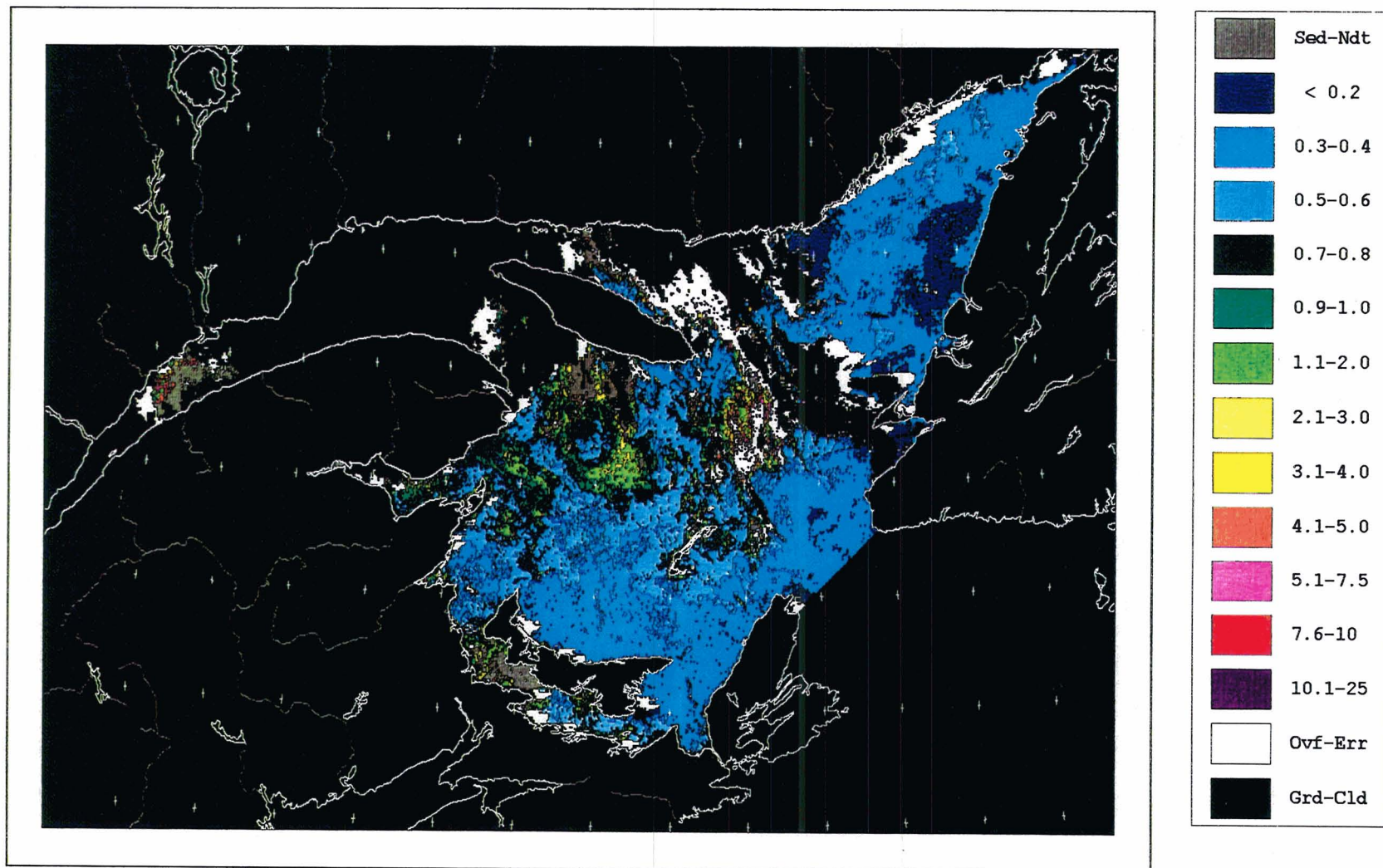


Phytoplankton Pigment Concentration (mg/m**3)

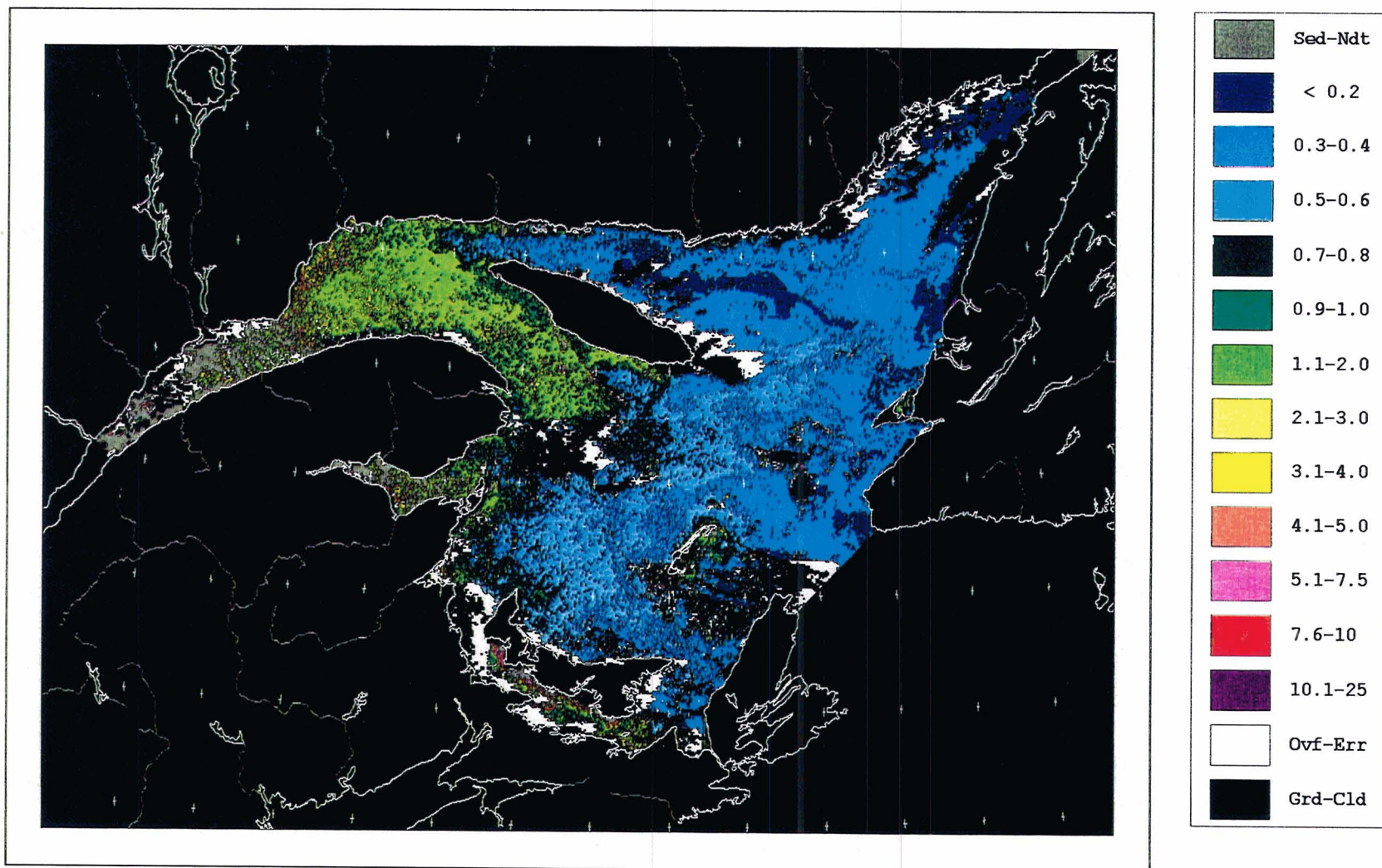
Gulf of St. Lawrence (August 18th 1979)



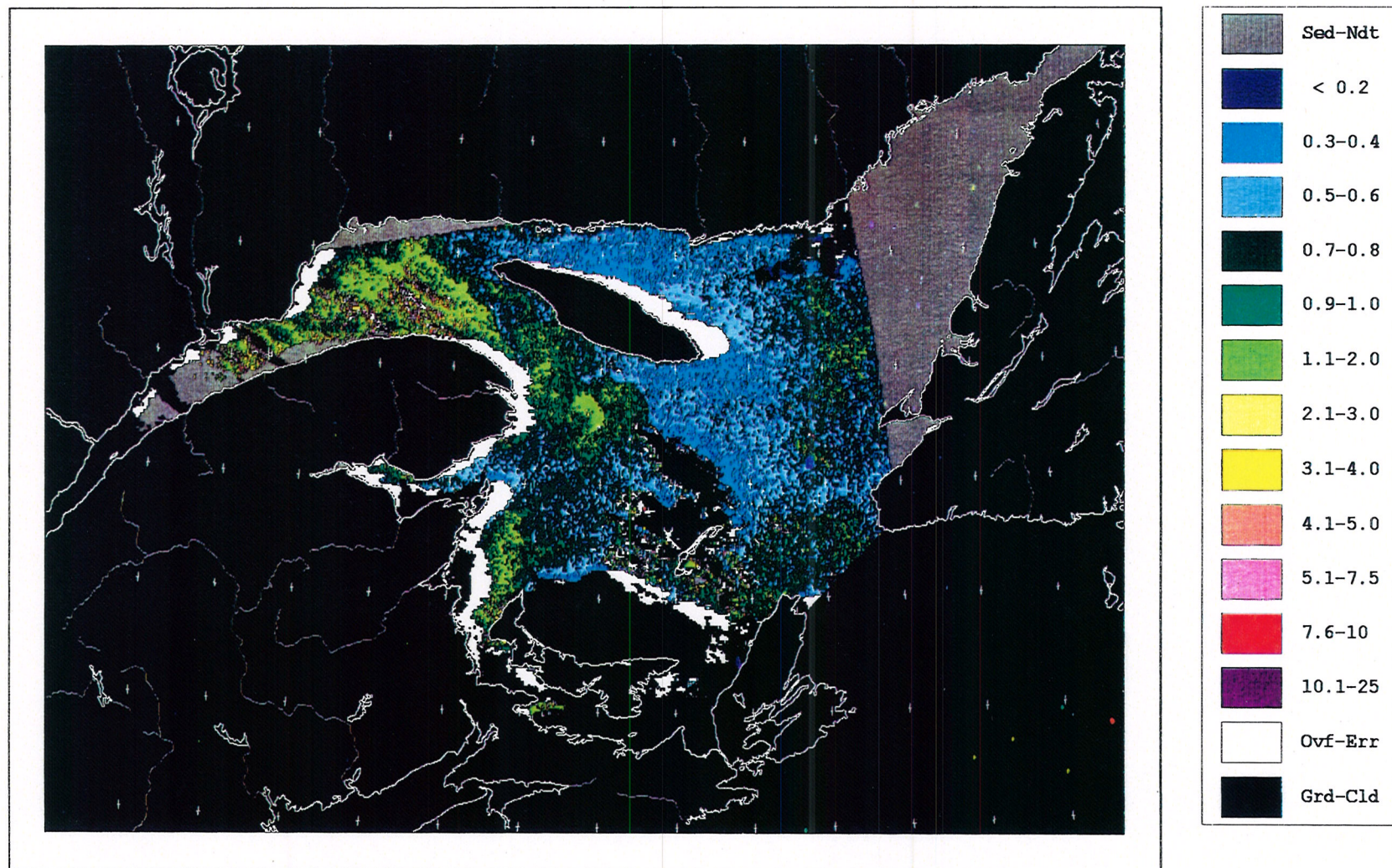
Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (August 31th 1979)



Phytoplankton Pigment Concentration (mg/m**3)
 Gulf of St. Lawrence (September 5th 1979)

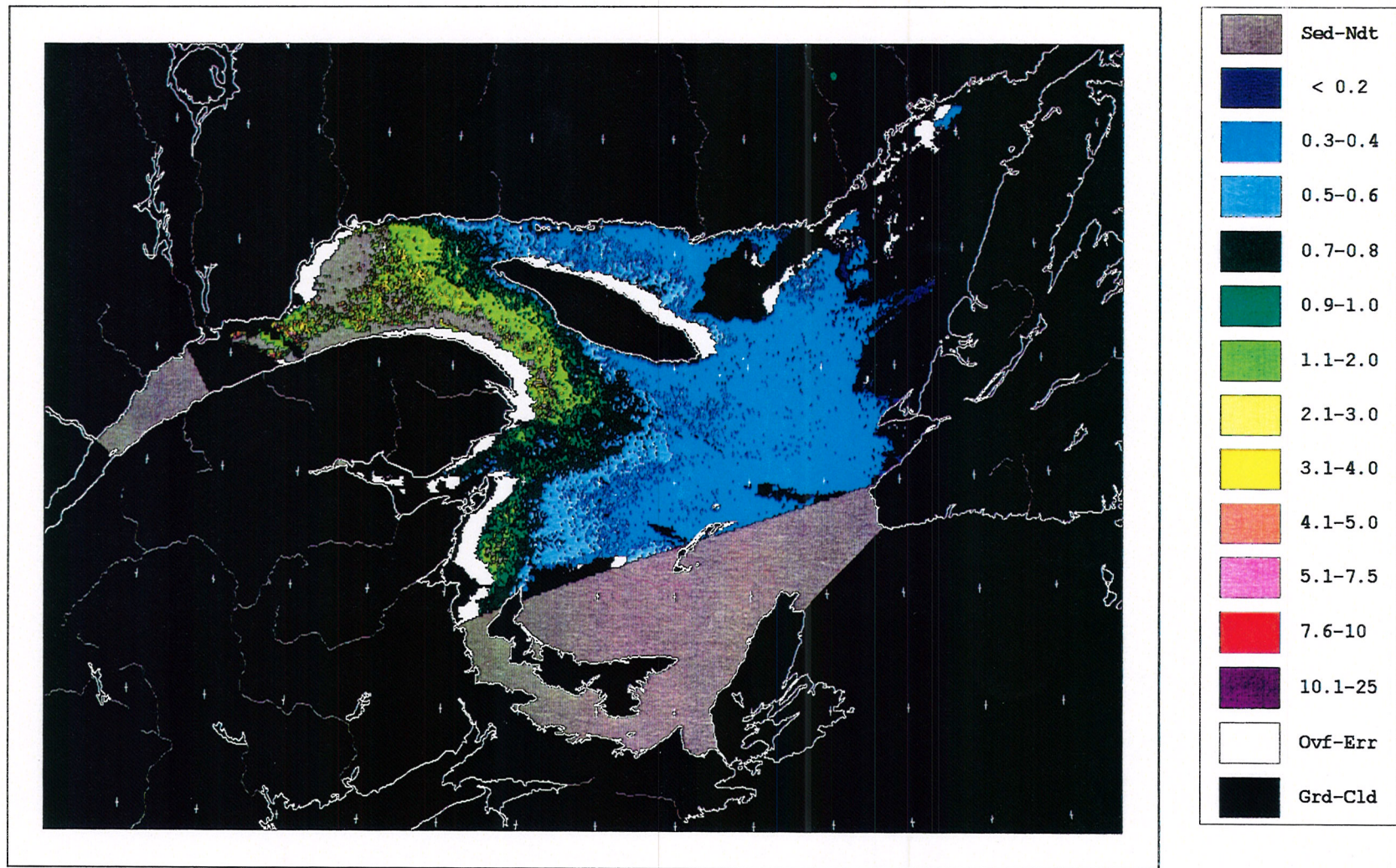


Phytoplankton Pigment Concentration (mg/m^3)
 Gulf of St. Lawrence (September 16th 1979)



Phytoplankton Pigment Concentration (mg/m^3)

Gulf of St. Lawrence (April 2th 1980)



Phytoplankton Pigment Concentration (mg/m**3)

Gulf of St. Lawrence (April 4th 1980)