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INVESTIGATION OF INTERTIDAL ZONE MAPPING BY MULTISPECTRAL SCANNER TECHNIQUES

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E. I. Marinello

APRIL 1977

National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Bering Sea-Gulf of Alaska Project Office
P. O. BOX 1808
Juneau, Alaska 99802

Contract 03-6-022-35225
COTR - Dr. Herbert E. Bruce

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PREFACE

This report is submitted by the Environmental Research Institute of Michigan in fulfillment of the requirements specified in Contract 03-6-022-35225 dated June 25, 1976, under sponsorship of the National Oceanic and Atmospheric Administration, Environmental Research Laboratory. The Contracting Officer Technical Representative was Dr. Herbert R. Bruce, Bering Sea-Gulf of Alaska Project Manager. Principal Investigator was F.C. Polcyn.

The analysis of data reported herein was based on data collected in the Gulf of Alaska in June 1976. We greatly appreciate the cooperation of personnel from the Bering Sea-Gulf of Alaska Project Office and from the Auke Bay Laboratories, Juneau, Alaska for their support during the field data collection phase and their evaluation of the initial computer results for the intertidal zone survey. The authors wish to acknowledge the help rendered by Steve Stewart and John Baumler of the Infrared and Optics Division during the installation of the instrumentation used for multi-spectral aerial data collection.

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1

INTRODUCTION

Knowledge” of the distribution of sensitive ecological communities along the Alaskan coastline is a goal of NOAA's Outer Continental Shelf Project now in progress under the direction of Dr. Herbert Bruce, Manager, of the Bering Sea–Gulf of Alaska Project Office in Juneau, Alas ka.

This information will be part of the baseline data set which can be used along with other considerations to determine those shoreline areas most sensitive to changes in the local ecology that might result from man's activities in the development of new resources.

Specifically this report is concerned with the investigation of airborne sensing techniques that would provide an operational capability for mapping and inventorying the intertidal zone along the Alaskan coast-line. The presence or absence of important algal communities and their interrelationship is an aid in the overall interpretations of a given shoreline's importance to the local marine ecology and its subsequent designation for protection.

The objective of the investigation was to collect passive multispectral scanner data at three sites in the Gulf of Alaska selected by Dr. Steven Zimmerman, supervisory oceanography at the Auke Bay Fisheries Laboratories, NOAA.

This data would then be analyzed for spectral signatures and a computer would be used to separate algal communities statistically based on their spectral signature. An inventory of the area of each community could then be made by counting the number of individual picture elements (pixels) containing the algal type. Knowledge of the area of each pixel is known from the altitude of the aircraft and the angular size of the resolution element of the scanner.

As a final graphical display of this information, a computer controlled ink–jet printer is used to color code the algal classes and to form a map-like presentation of the distribution of the communities. Areal statistics for each class was also provided at the same time. The use of narrow band spectral data, stored on magnetic tape, and suitable for computer processing and enhancement, was thought to be preferable to the sole use of color or infrared color photography which had previously been taken in early investigations but had proved unsuitable for this application.

The initial results of the computer processing have been encouraging. Further processing procedures are planned for the second phase of analysis. This report is an interim final report describing the progress made under contract NOAA-03-6-022-35225 and fulfills the objectives of that effort.

2
DATA COLLECTION

The aircraft data collection missions took place in June, 1976. Because of the uncertainties in" the final contract arrangements the ERIM aircraft equipped with the M-7 multispectral scanner originally scheduled to be used for this demonstration was not available for the time period when maximum low tide occurred in the middle of June. Alternatively another multispectral scanner constructed by the Bendix Corporation, Ann Arbor, Michigan was employed. This sensor was installed in a leased twin engined Cessna 310 owned by Walker Associates, based in Seattle, Washington.

2.1 SITE SELECTION

Dr. Steven T. Zimmerman selected three sites for test. (1) Latouche Pointe, Zaikof Bay and Cape Yakataga. The intertidal area at Latouche Point has a gradual slope so the algal zonation is relatively quite broad spatially. The large spatial dimension would help in establishing spectral signatures by the dominant species in each zone. This subtidal area has had several on-site investigations so that a proper evaluation of the computer results could be made.

The Zaikof Bay site is on Montague Island where it represents a "typical" intertidal area with high diversity, hilly topography, and varying slopes.

The Cape Yakataga site is characterized by several large, nearly horizontal benches, each representing almost a mono-specific algal flora.

The presence of the large areas covered with a single dominant algae offered an outstanding opportunity for determining the spectral characteristic of the main intertidal species.

The low tidal periods for these sites were found to fall between June 11–15, 1976 and between June 27 and July 1, 1976, with the earlier period preferred.

Dr. Zimmerman provided expert on–site teams in order to ground truth the Latouche Point and Zaikof Bay sites at the time of the planned over-flights. Because of logistic problems, Cape Yakataga *was to* be in-vestigated within 1 to 2 days of the completion of flights over the first two sites.

The base of operation for the aircraft was Cordova, Alaska. Un-fortunately due to inclement weather enroute between Seattle and Cordova, the aircraft installed with the multispectral scanner was not available during the 11-15 June period when the site teams made their observations.

However, the ground data was collected at all three sites and photography was collected at Zaikof Bay. Markers (aluminum foil) to show separate zones were left at Zaikof Bay on June 12 and were in place two weeks later when the aircraft was available for the next low tide period which took place on June 27 and 28, 1976. The tide conditions for those dates are shown in Table I.

The time of the flights were made so as to be either over the sites at time of maximum low tide or within one half hour of low tide, and the dates chosen were such as to insure sufficient sunlight needed for an adequate signal to noise ratio for the scanner data.

2.2 THE SENSOR CONFIGURATION

The multispectral scanner capable of collecting data in ten spectral bands (as shown in Table II) was installed in a Cessna 310 in Anchorage, Alaska on June 25, 1976. The field team assembled in Cordova on the 26th of June and the first mission was flown on the morning of the 27th of June.

Table III is the complete flight log for the data collection

TABLE I

OCCURRENCE OF LOW TIDES AND MAXIMUM SUNLIGHT

REF. NOAA NATIONAL OCEAN SURVEY

TIDE TABLE FOR 1976 FOR CORDOVA GEOGRAPHIC LOCATION

Date	Time	Tidal Height (ft.)
I. Mid June (Sunrise ≈	0345)	
June 11	0630	-2.9
June 12	0716	-3.3
June 13	0802	-3.2
June 14	0846	-2.8
June 15	0931	-2.0
II. Late June (Sunrise ≈	0345)	
June 27	0712	-1.6
June 28	0750	-1.9
June 29	0827	-1.9
June 30	0906	-1.8
July 1	0948	-1.3
III. Early May (Sunrise ≈	0430)	
May 12	0554	-2.1
May 13	0643	-3.1
May. 14	0729	-3.5
May 15	0817	-3.4
May 16	0903	-2.9
May 17	0952	-2.1
May 18	1041	-1.1
IV. Early July (Sunrise ≈	0400)	
July 10	0620	-2.3
July 11	0703	-2.6
July 12	0744	-2.5
July 13	0825	-2.2
July 14	0903	-1.6

TABLE 11

MULTI SPECTRAL SCANNER CHARACTERISTICS

Spectral Bands	Computer Channel Designation	λc (microns)	Δλ (microns)
Channel 1		0.410	0.06
Channel 2	1	0.465	0.05
Channel 3	2	0.515	0.05
Channel 4	3	0.560	0.04
Channel 5	" 4	0.600	0.04
Channel 6	5	0.640	0.04
Channel 7	6	0.680	0.04
Channel 8	7	0.720	0.04
Channel 9	8	0.815	0.09
Channel 10	9	1.015	0.09
Channel 11	10	11.00" (nominal)	Selectable

Scan Mirror	Rotating optical flat 4 inches diameter Rotation Rate: 10 to 100 rps
Collecting Optics	Dall-Kirkham telescope 65 CM^2 Collecting area (combined with scan mirror)
Field of View (FOV)	100 degrees ± 10 degrees for aircraft roll compensation
Instantaneous Field of View (IFOV)	2.5 milliradians
V/H	Variable .025 to .25 radians per second (10 to 100 scans per second)

TABLE III M^2S FLIGHT LOG

DATE 6-9-76, 6-26-76, 6-27-76 , 6 -2 8- 76

OPERATOR Haeske

A/C N41WA

FLIGHT NO. ______ MISSION ID. ERIM / Alaska TAPE NO. 1

FILM TYPE (S) SO-397

FILTER(S) Hase 500/5.6

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

PAGE 1 OF 4

RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11			
CAL HIGH											070			
CAL LOW											233 / 296			

070 = 35°C
233 = 10°C
296 = 5°C

RUN	LINE ID	T.O.T.	RUN TIME Min	G.S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
1		1020	2.0	180	1.3K	160				70	668	Test Flight 6-9-76 Bremerton, Wash.
2		1245	1.0	140	2.5K	210				70	668	VHF TX During Run Test Flight 6-26-76 Anchorage, Ak.
3	1	0708	.38	140	1.5K	195	0 / 7	7	6	70	668	6-27-76 WX-Very Overcast & Dark Zaikof 8ay
4	2	0712	.45	100	1K	195				70	668	Thermal May Be Clipping Negative
5	3	0715	,50	100	1K	195	17		5	50	450	
6	4	0720	.40	100	1K	120	23		5	70	668	
7	5	0723	.40	90	400	195				70	668	
8	1	0745	.50	150	1.5K	120	32		6	70	668	Latouche Low Black Body 2S6
9	2	0750	1.00	100	1K	120				70	668	
10	3	0753	1.00	100	1K	120				50	450	
11	4	0756	.45	100	1K	010	42		5	70	668	
12	5	0759	1.00	100	400	120				70	663	
13		0809	.50	100	1K	030	47		5	70	668	Needle

TABLE III M²S FLIGHT LOG
(cent 'd)

DATE 6-27-76, 6-28-76

OPERATOR Haeske

FLIGHT NO. ______ MISSION ID. ERIM/ Alaska TAPE NO. 1 FILM TYPE(S) SO-397

FILTER(S) Hase

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

PAGE 2 OF 4

RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11	-	-	-
CAL HIGH											070			
CAL LOW											296			

RUN	LINE ID	T.O.T.	RUN TIME	G. S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
14	1	0845	.40	130	1.5K	090	/ 8		6	70	668	6-27-76 Panels on Gravel at Cordova Airport
15	2	0848	.40	100	1K	090	/			70	668	
16	3	0850	.49	100	1K	090	/ 14		?	50	450	
17	4	0852	.40	100	1K	180	/			70	668	
18	5	0855	.40	100	400	090	/			70	668	
19	1	0800	.45	120	1.5K	170	/ 8		6	70	668	WX-Overcast Some Thin Spots Cape Yakataga Gyro Caged
20	1	0804	.50	120	1.5K	165	/			70	668	
21	2	0808	.50	200	1K	165	/			70	668	
22	3	0811	.50	100	1K	165	/			50	450	
23	4	0815	.50	100	1K	075	/ 17		5	70	668	
24	4	0818	.50	100	1K	255	/			70	668	Opposite Direction Same as above Closer to Shore
25	5	0821	.50	100	400	165	/ 26			70	668	Manual Pictures
26		1410	1.15	100	1K	285	00 / 19			70	668	Nochek Gyro Caged
27		1413	1.05	100	1K	285	/			70	668	Nochek Same As Above Uncaged

TABLE III M²S FLIGHT LOG

(cont'd)

DATE 6-28-76

OPERATOR Haeske

FLIGHT NO. ______ MISSION ID. ERIM/ Alaska TAPE NO. 1 & 2 FILM TYPE(S) SO-397

FILTER(S) Hase

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

PAGE 3 OF 4

RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4		6	7	8	9	10	11			
CAL HIGH											070			
CAL LOW											296			

RUN	LINE ID	T. O.T.	RUN TIME	G. S.	A.G.L.	MAG. HDG.	ACCUM COUNT	FRAME COUNT	f	S/S	DIAL SET	MISSION NOTES
28		1415	.45	100	1K	240	27		5	70	668	Made Extra Run Over Rocks 9 Pictures Porpoise Rocks 6-28-76
29		1425	.45	100	1K	210	36 / 37		5	70	668	Sun Glint Seal Rocks
30		1427	.20	100	1K	190	43		5	70	668	Sun Glint Seal Rocks
31		1430	.30	100	1K	010	50		5	70	668	Sun Glint Small Rocks
32		1432	.30		400	190	56		5	70	668	Sun Gline Seal Rocks
33		1449	.55	130	1.5K	040	60		6	70	668	Wooded Isle
34		1453	1.05	130	1.5K	040	74		6	70	668	Wooded Isle
3s'		1455	.30	100	1K	070	79		6	70	668	Fish Isle
36		1509	.30	100	1K	190	87		6	70	668	Needle
37		1511	.30	100	400	010	90		6	70	668	Needle
38		1646	2.45	170	10K	210				35	250	Start Tape #2 Montaque to Green is Whale △, High Alt.
39		1700	2.30	100	1K	030				70	668	Green to Montique Whale △, Line #1
40		1703	4.54	100	1K	280				70	668	Montique to Seal is #2
41		1709	4.54	100	1K	140						Seal to Green is #3 Sun Glint

TABLE III M^2S FLIGHT LOG

(cont'd)

DATE 6-28-[illegible] OPERATOR Haeske

FLIGHT NO. ______ MISSION ID. ERIM/ Alaska TAPE NO. 2 FILM TYPE(S) SO-397

FILTER(S) Hase

CAMERA(S) Hassalblad

PILOT Byers

CO-PILOT ______

PAGE 4 OF 4

RECORDER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SCANNER	1	2	3	4	5	6	7	8	9	10	11			
CAL HIGH											070			
CAL LOW														

RUN	LINE ID	T.O.T.	RUN TIME	G.S.	AGL	MAG. HDG.	ACCUM COUNT	FRAME COUNT	IV	S/S	DIAL SET	MISSION NOTES
42	1	1735	.30	150	1.5K	090		2		70	668	Manual Pictures Panels
43	2	1739	.40	100	1K	090				70	668	
44	3	1741	.40	100	1K	090				35	250	
45	4	1746	.30	100	1K	180				70	668	
[illegible]	5	1749	.30	100	400	090		3		70	668	Manual Pictures

mission which ended on July 2, 1976. A remotely controlled 70 mm film format, Hasselblad Camera was mounted to collect vertical photography. SO-397 Ektachrome EF xerographic color film was used for all flights. The plan for overflight for each site was as follows:

(1) Pass at 1,000 ft parallel to shore. This mode is likely to be the most operationally suitable in terms of resolution and area covered.

(2) Pass at 1,500 ft parallel to shore. This pass was to insure complete coverage of the intertidal zone especially when some part of the water must be in the picture for reference and to insure coverage of the last exposed algal zone. The resolution element in one dimension is 1 1/2. times larger than that achieved in pass one and knowledge of this effect is important operationally.

(3) Pass at 1,000 ft flown at right angles to shoreline. This pass maintained the same variables as pass one but allowed investigation of scanning parallel to each zone lying along the beach, i.e. (a given scan line would contain the same algal type along the entire line) rather than across the several zones during a given scan line such as is encountered in pass one.

(4) Pass at 500 ft parallel to shore. Because of the suspected small width of algal zones, a flight at 500 ft giving a 1.5 ft resolution element was considered the best spatial resolution that could safely be flown with the particular sensor/aircraft combination used. Thus the effect of resolution could be investigated using passes 1, 2, and 4.

(5) Pass at 1,000 ft with the scan rate adjusted slower. This pass was incorporated to test the sensor detection capability under the lowest noise condition practical. Even though underlap would be present, the signal to noise ratio of the signal

from the scanner would be the best of all passes.

Since the sunlight conditions in future operational missions may be marginal knowledge of the utility of an improved signal to noise ratio would be important. As it happened, data was collected under overcast and mostly cloudly conditions which prevailed at the time. of low tide on June 27 and 28, 1976.

2.3 DATA COLLECTED

The flight logs in Table III give the total flight line miles and time spent in collecting multispectral and multisensory data for the three sites. Five passes were flown at each test site. Scanner data were collected on every pass but color film was collected in general only once per flight except at Cape Yakataga where for each pass at 500 ft color photography was collected.

For each scanner pass, data in ten spectral bands between 0.4 and 12 microns were collected and stored on high density magnetic tape. Subsequently 70 mm wide black and white negative and positive film strips of one channel was reproduced from the tape. This inspection channel was used to designate those areas from which five computer compatible tapes (CCT) were recorded from the high density tapes. The CCTS were used in the performance of the spectral analysis and algal zone mapping on Midas.

As part of the data collection mission the scanner was flown over a set of three calibration panels 40′ x 20′ in size, each representing a known reflectance level. This data taken at the Cordova Airfield provides a reference control for calculating the minimum percent reflectance detectability of the scanner under the illumination condition encountered during the mission.

2.4 ADDITIONAL SITES

After discussions with Dr. K. Pitcher, Game Biologist with the Alaskan State Fish and Game Department, and Dr. Hall of the

Department of the Interior, Fish and Wildlife in Anchorage, Alaska, additional data were collected at nearby sites enroute to the three prime sites chosen for the intertidal study. Table III gives the specific parameters for altitude and locations.

Color photography and scanner data were collected of sea lions and sea bird habitat at such sites as: The Needle, Seal Rocks, Nochek, and Porpoise Rocks, Wooded Isle, Fish Isle. All sites are near Montague Island or near Hinchinbrook Island.

Two sets of color photographs for these areas have been delivered to Dr. Bruce under separate cover. Three lines were flown in a triangle between Montague Island, Green Island and Seal Island in an attempt to sight whales. No photography was collected since no whales were seen. However, scanner data were recorded for future study if deemed necessary since several water parameters can be deduced from the multispectral data (e.g., surface temperature, current patterns, water transparency, and surface chlorophyll). These data were collected on a non-interference basis with the aims of the primary mission and serve to show the multiple disciplinary value of a remote sensing exercise in a given locality.

3

METHODS OF DATA PROCESSING AND ANALYSIS

In order to initiate processing of the multispectral scanner data, it was necessary to convert the initially recorded 9 track tapes into 7 track ERIM format tapes. This was accomplished by running a program on The University of Michigan 470 computer. A total of nine data sets were converted: four over Zaikof Bay (Runs 4-7); three over Latouche Island (Runs 9, 10, and 12); one over Cape Yakataga (Run 21); and one over a set of calibration panels (Run 15). [See Table III] Histograms were made of all channels for each data set, and initial graymaps produced for purposes of orientation, using Channel 9 (0.815μm). Channel wavelengths and scanner characteristics are shown in Table II.

The calibration panels were located on the Run 15 gray-map, and a second histogram was calculated over these panels. This indicated that the data in all of the visible channels was useable.

Of the four runs over Zaikof Bay, the low altitude run (Run 7) was selected for further processing because it had better spatial resolution. Run 9 was chosen for Latouche Island because it appeared to have the best coverage over the study area. For Cape Yakataga, Run 21 was the data set prepared from the high density tape for the initial spectral analysis.

ANALYSIS

The purpose of the computer processing of the multispectral scanner data was to recognize and classify the various types of ground cover appearing in each scene. There are two methods of dealing with this problem.

First, if recognizable examples of each type of ground cover can be located in the scene, signatures can be calculated for each of these areas and used to classify the rest of the scene. Second, a computer program has also been developed to automatically recognize features in the scene and group them into categories on an unsupervised basis, if no prior knowledge of the types of ground cover exist.

The latter method was attempted on one of the data sets, but the results were unsatisfactory due to the relatively poor data quality and to the fact that the program was not optimally designed to use this type of data. As a result, a modified form of supervised classification was chosen.

To this end, the color photographs were examined for color differences associated with algal species in the intertidal zone. Attention was focused on the test areas designated by Dr. Steven Zimmerman on the photographs. Some zonation within the test area was clearly visible on the vertical photographs and scanner images of Zaikof Bay and Latouche Island. Recognition of these zones was aided by the presence of aluminure foil markers in the Zaikof Bay site. No clear color differences were distinguishable in the case of Cape Yakataga, so zones were arbitrarily selected parallel to the shoreline (See Figures 1-3).

Areas within each zone were selected by inspection of signal differences on computer graymaps in locations generally corresponding to those on the photos. Signatures were then calculated for groups of picture elements (pixels) having the same contrast pattern to determine if spectral differences were evident, Signatures were also calculated for trees, water, bare rocks and grass. Spectral differences over the algal species were observed in all channels. Consequently, all channels except the thermal channel were used in calculating the signatures. The thermal channel was not used in this first analysis because it was felt that it would introduce a bias in the results due to temperature differences in the scene. However, this effect may be investigated in the future since tidal exposure and algal species may correlate. Several examples of spectral signatures at each site areshown in figures 4, 5 and 6. In these figures computer channel designation 1 through 9

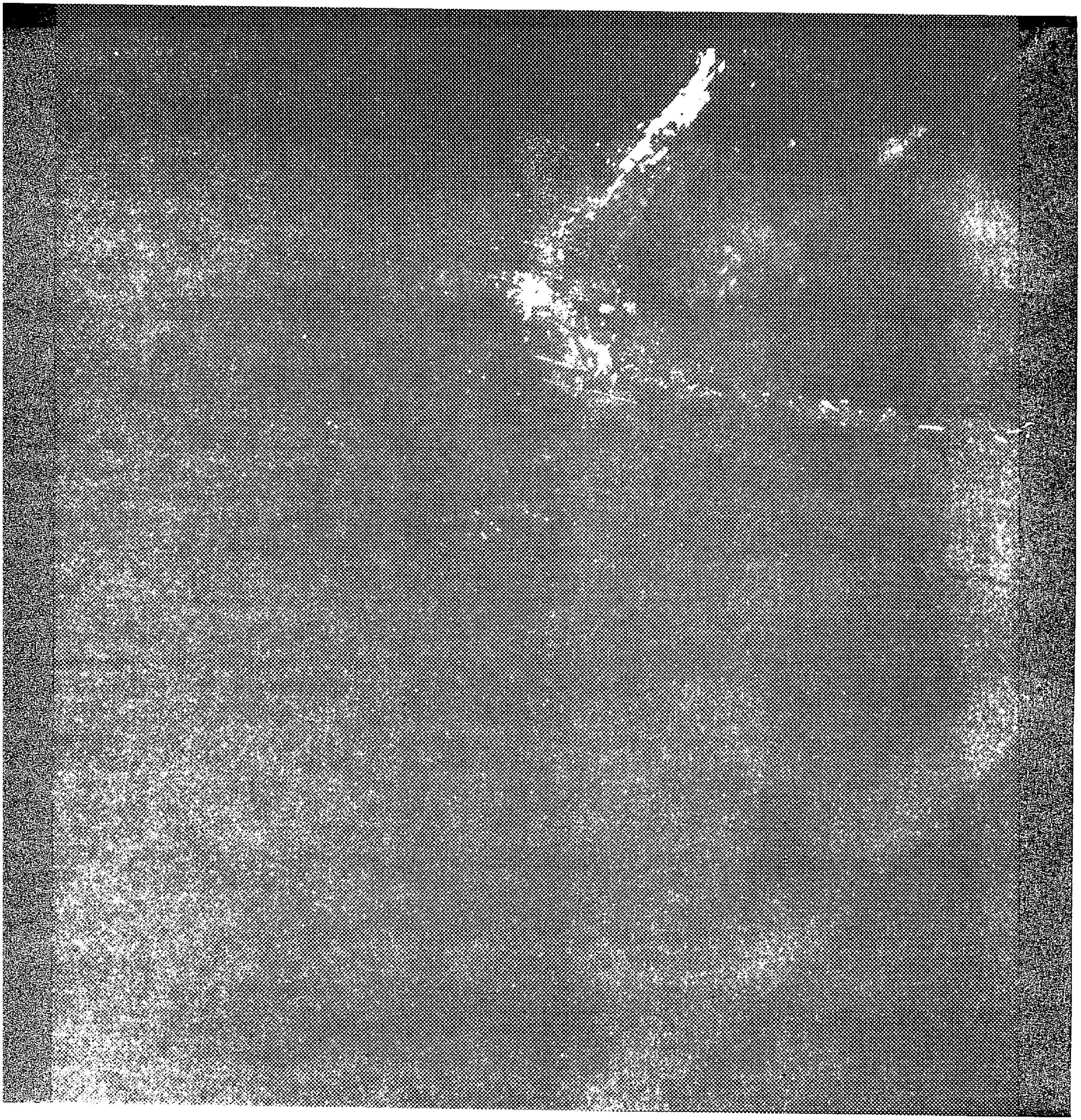
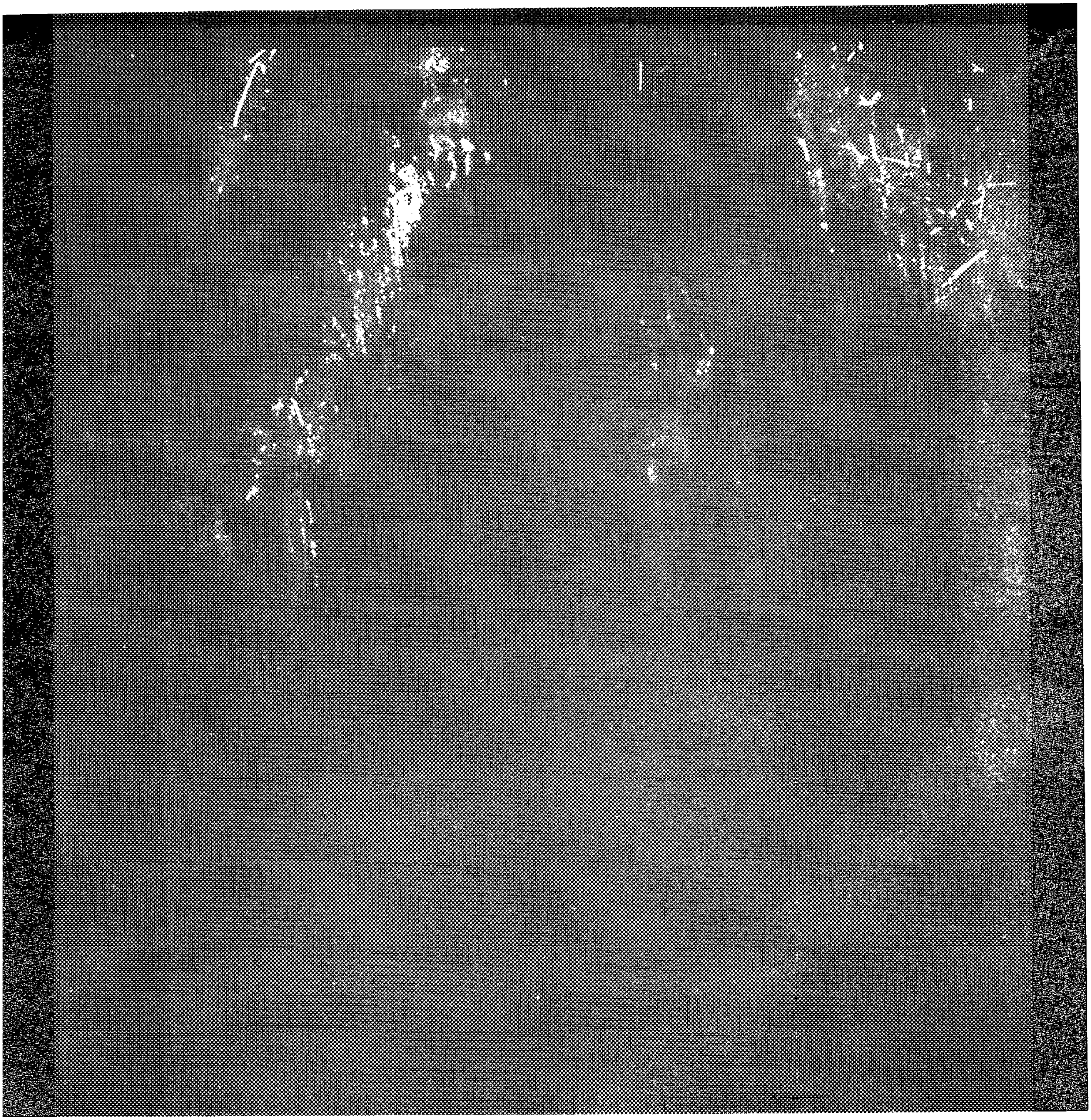


FIGURE 1. COLOR PHOTOGRAPH OF ZAIKOF BAY TEST SITE.
DATA COLLECTED ON JUNE 27, 1976 BETWEEN 0708 to
0723 HOURS AT 1,000 FT ALTITUDE.



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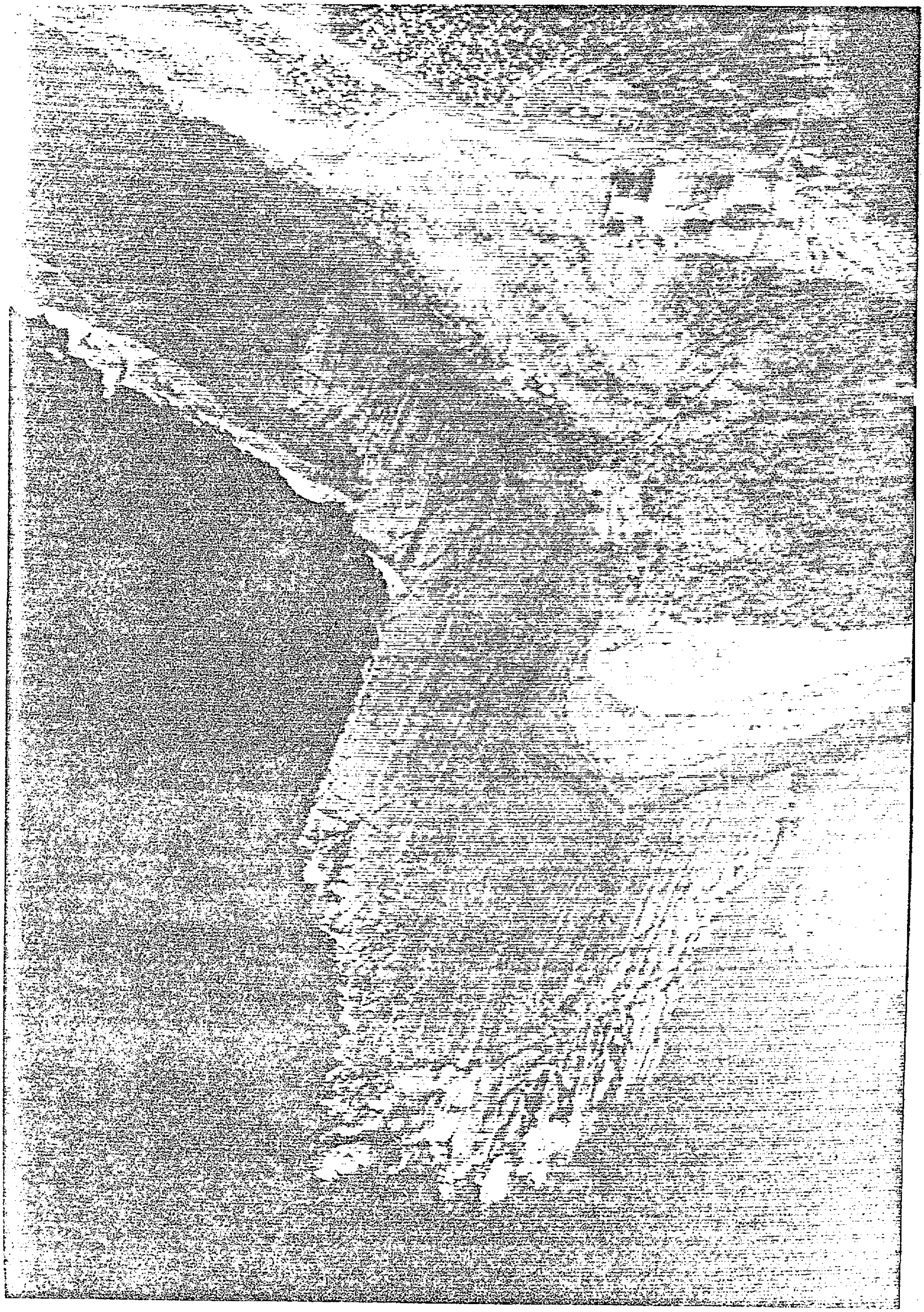


FIGURE 3. SCANNER IMAGE OF CAPE YAKATAGA TEST SITE. DATA COLLECTED ON JUNE 28, 1976 BETWEEN 0800 to 0821 HOURS AT 1,000 FT ALTITUDE.

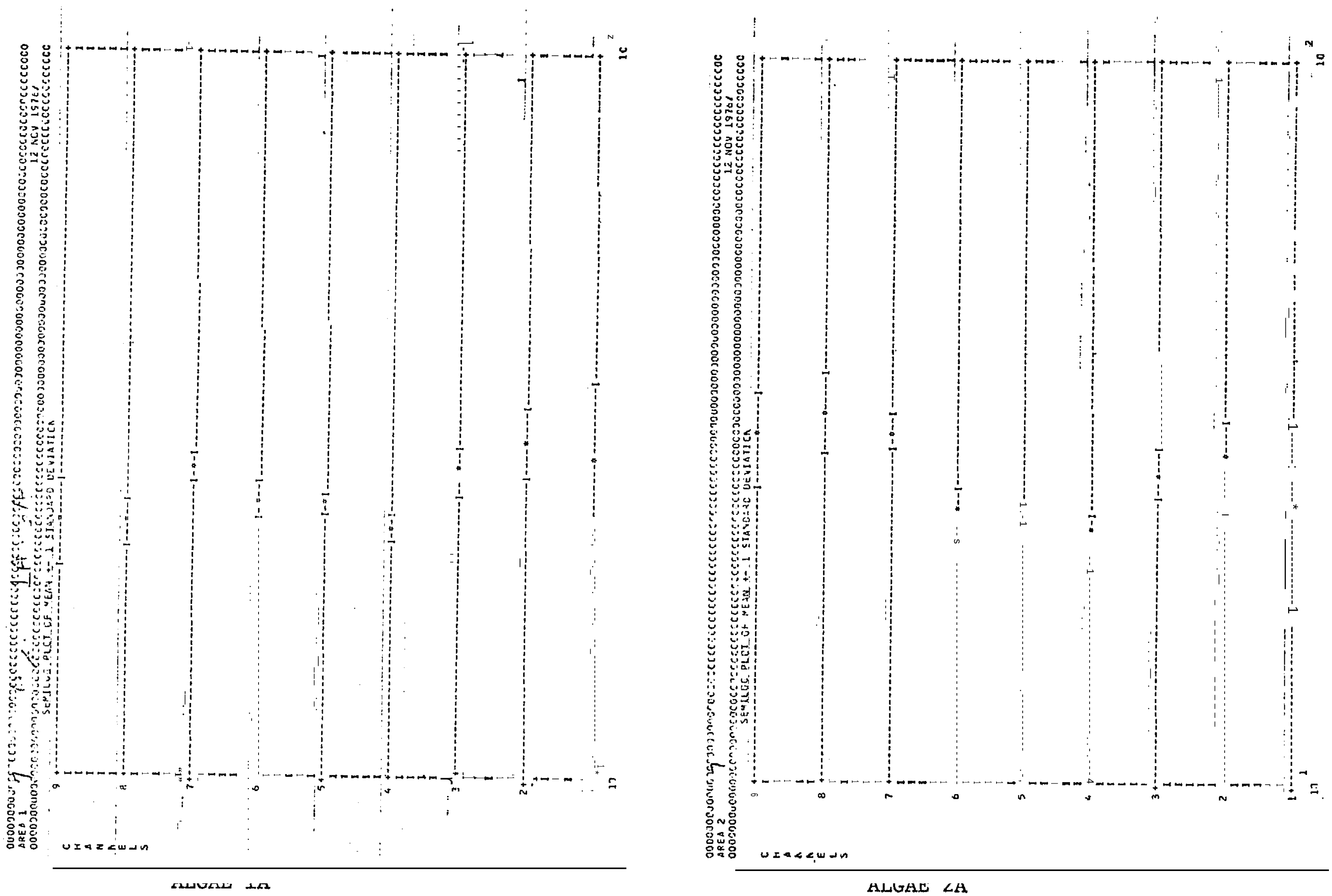
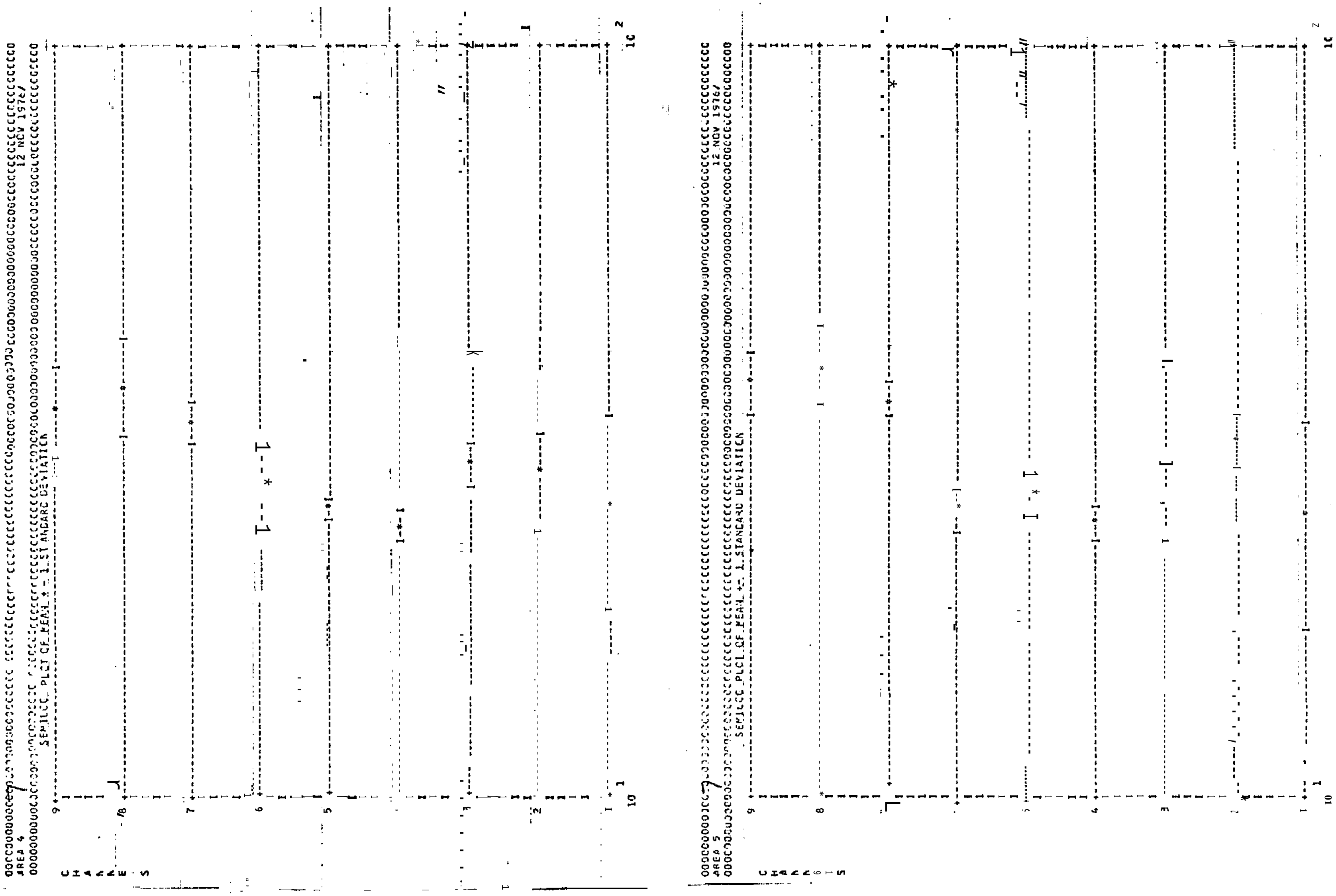


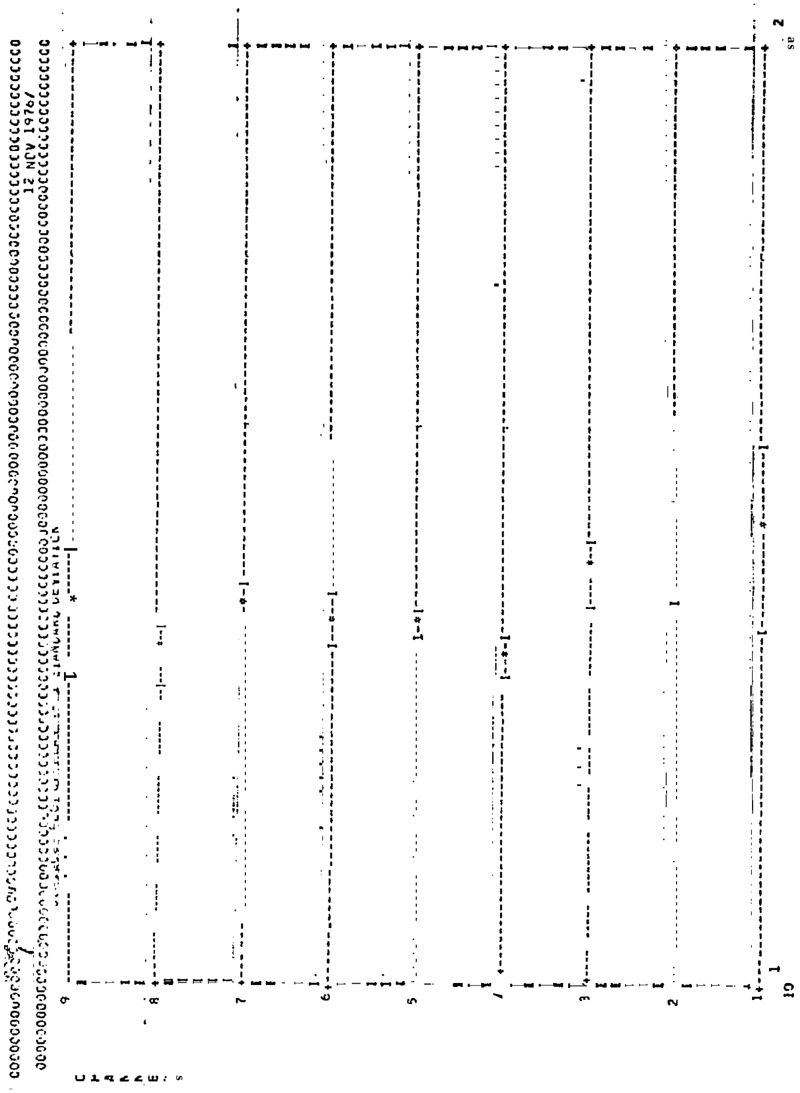
FIGURE 4. SPECTRAL SIGNATURES OF 6 ALGAL COMMUNITIES AT ZAIKOF BAY TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table IV. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)



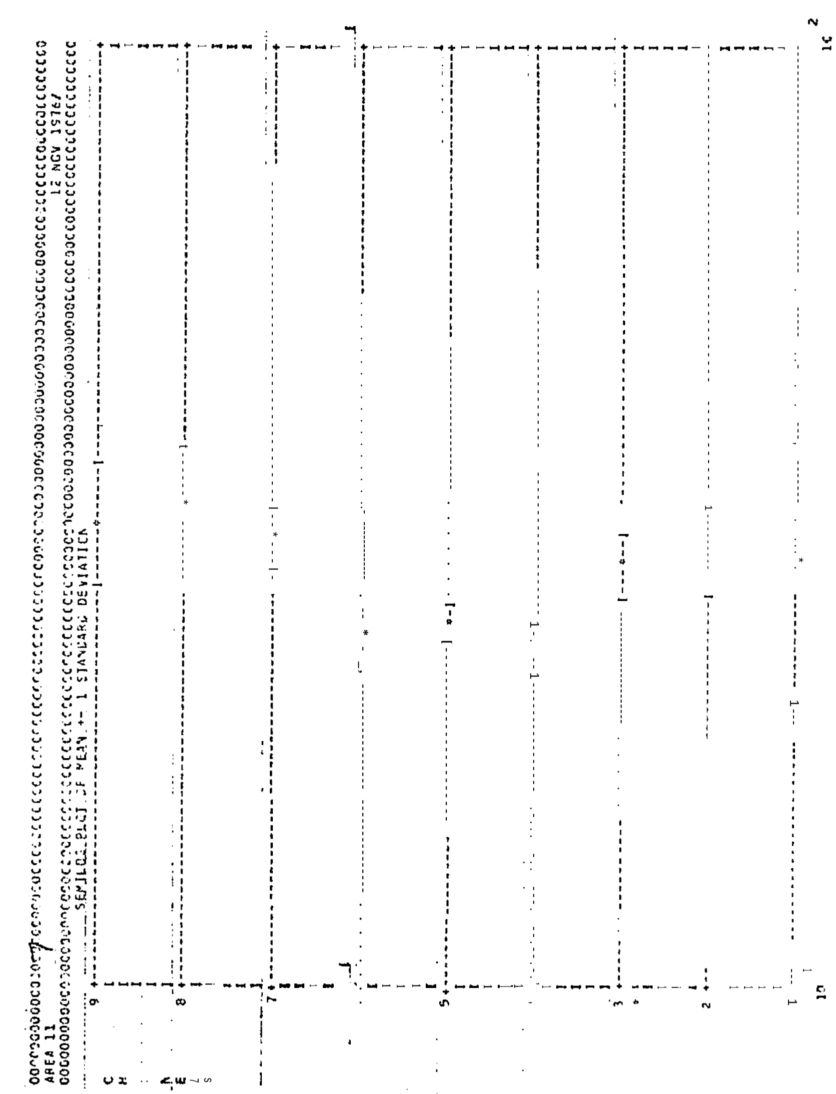
ALGAE 3A

ALGAE 4A

FIGURE 4. (continued) SPECTRAL SIGNATURES OF 6 ALGAL COMMUNITIES AT ZAIKOF BAY TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table IV. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)

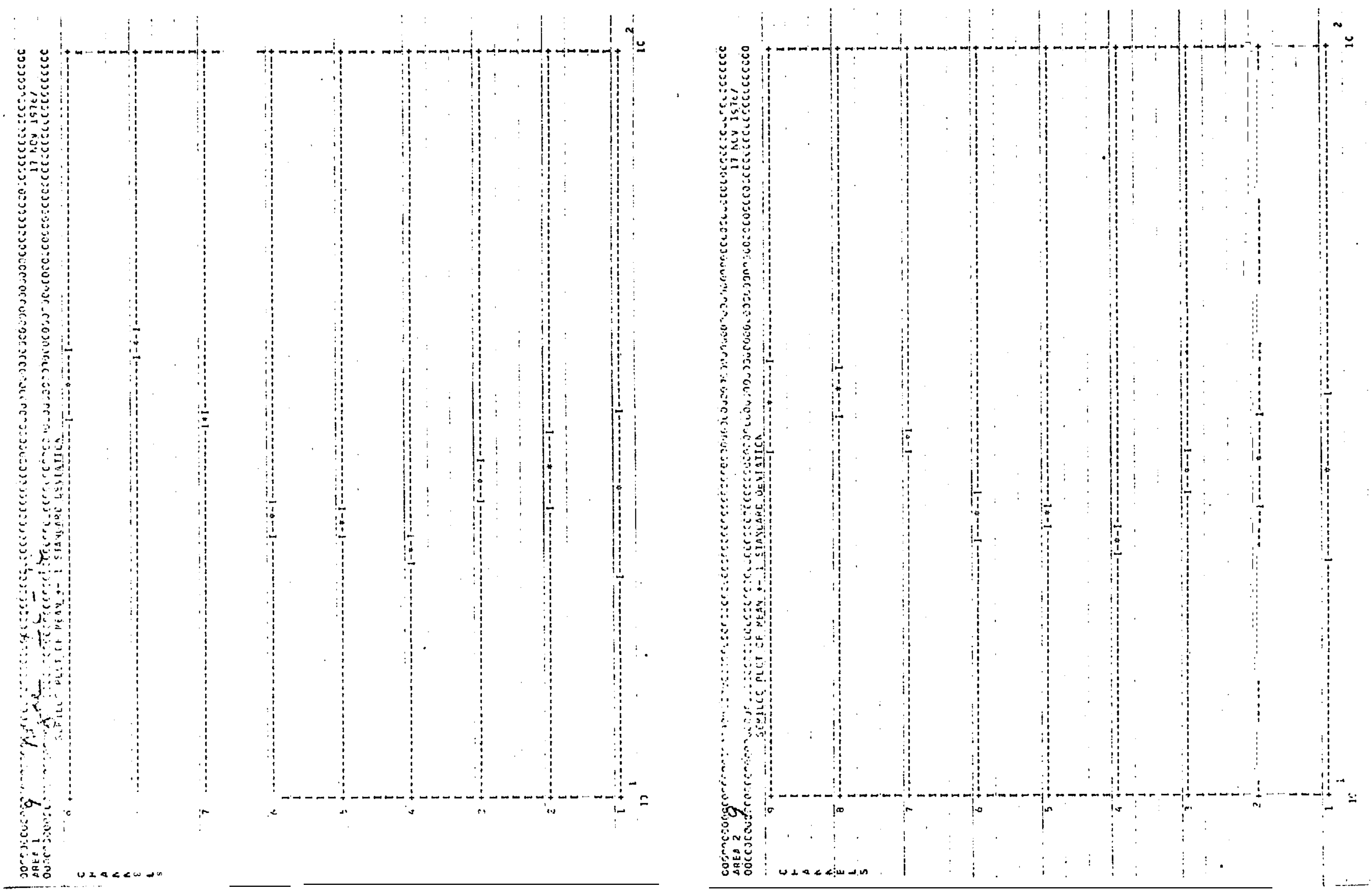


ALGAE 5A



ALGAE 6A

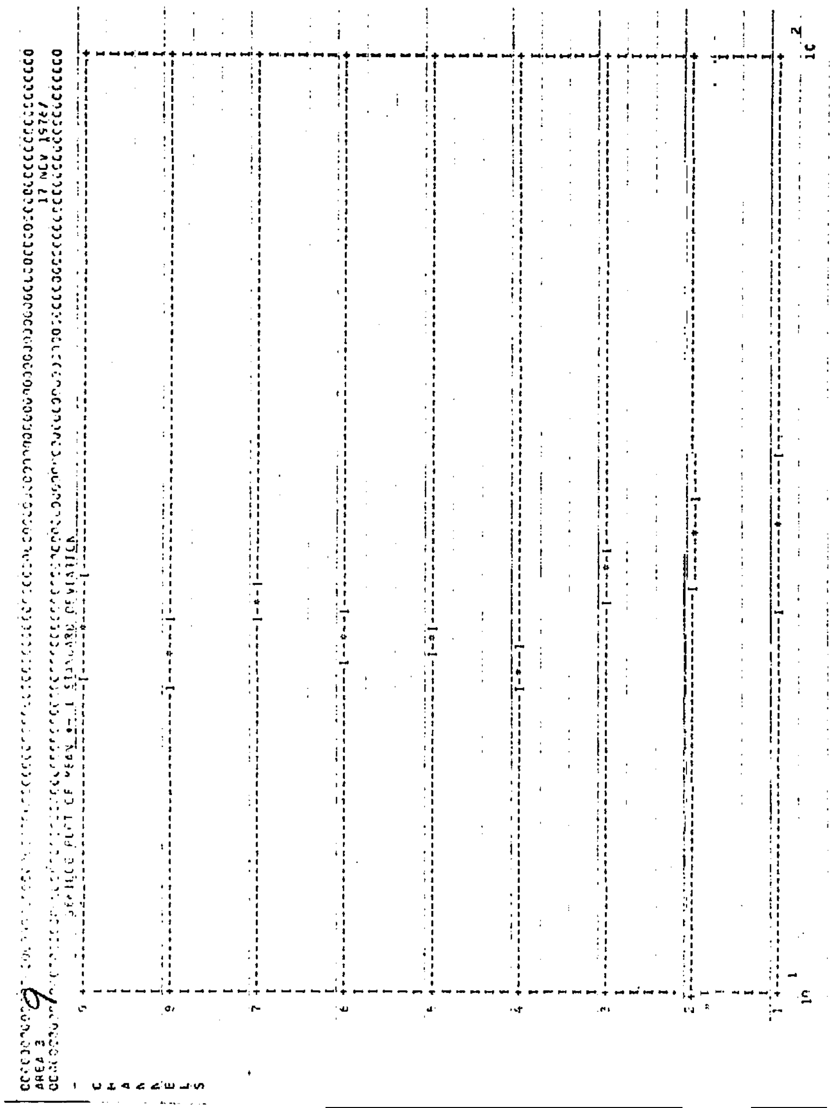
FIGURE 4. (continued) SPECTRAL SIGNATURES OF 6 ALGAL COMMUNITIES AT ZAIKOF BAY TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table IV. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)



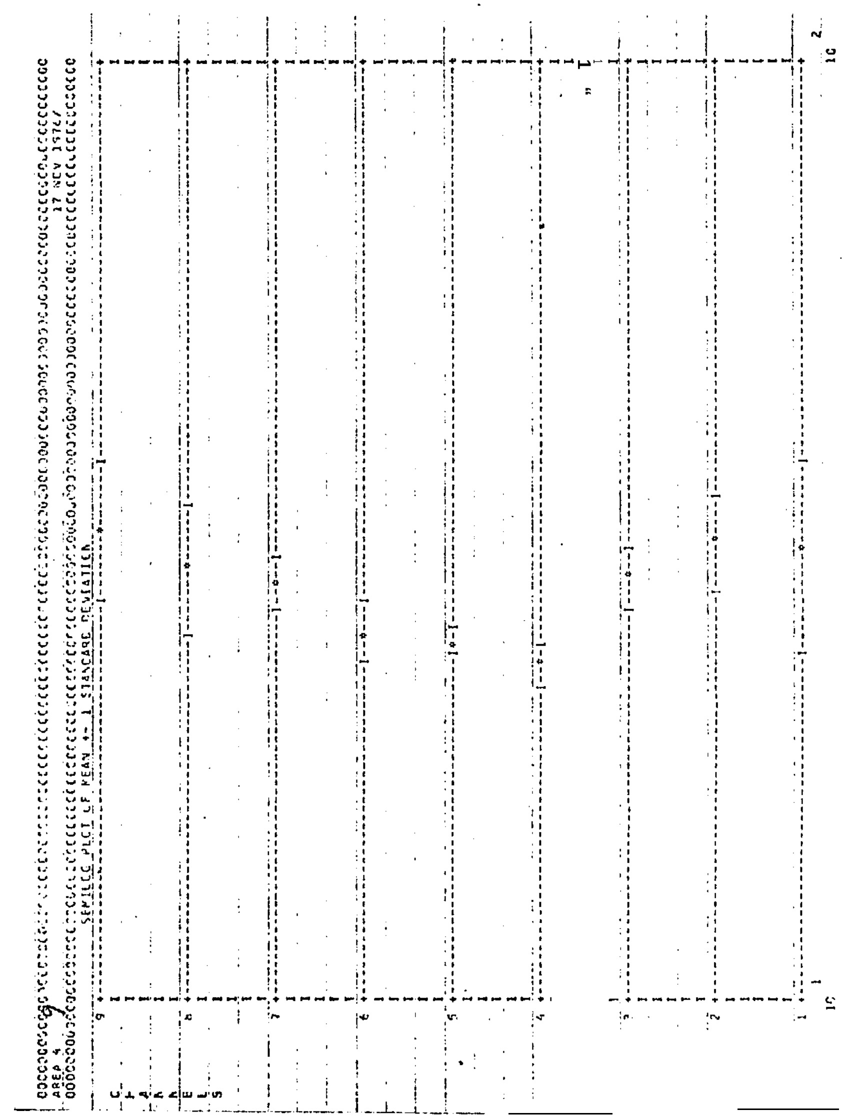
ALGAE 1C

ALGAE 2C

FIGURE 5. SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT LATOUCHE TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table V. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)

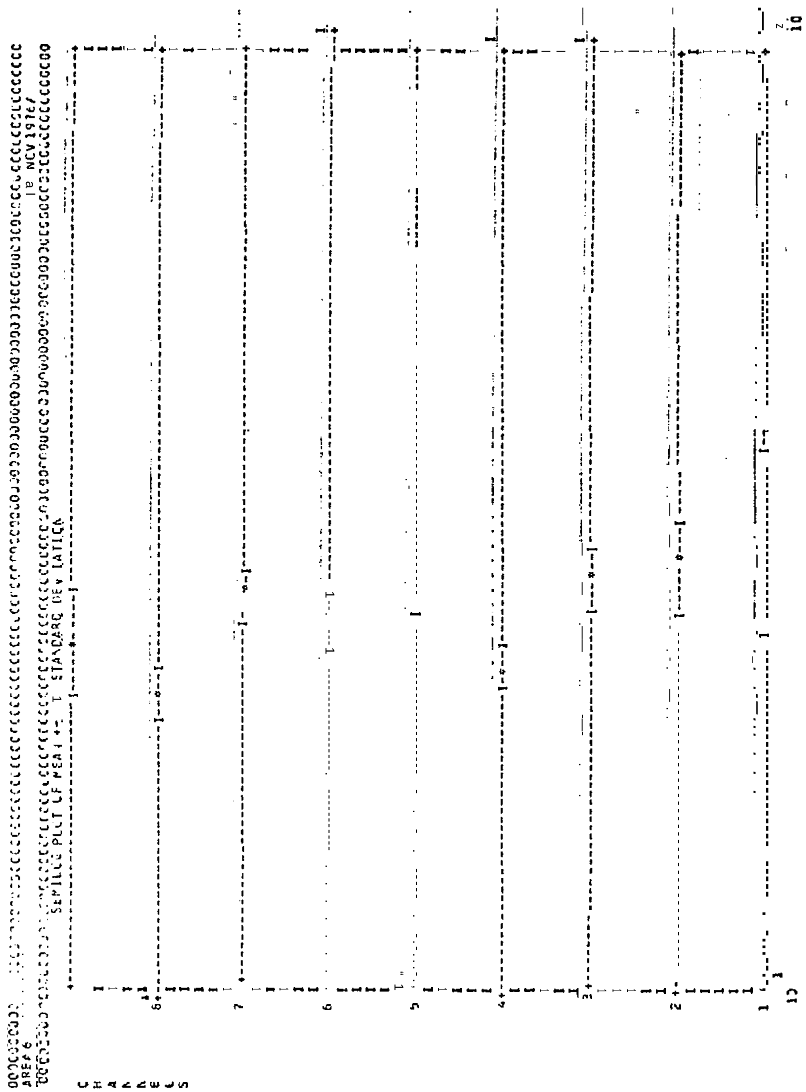


ALGAE 3C

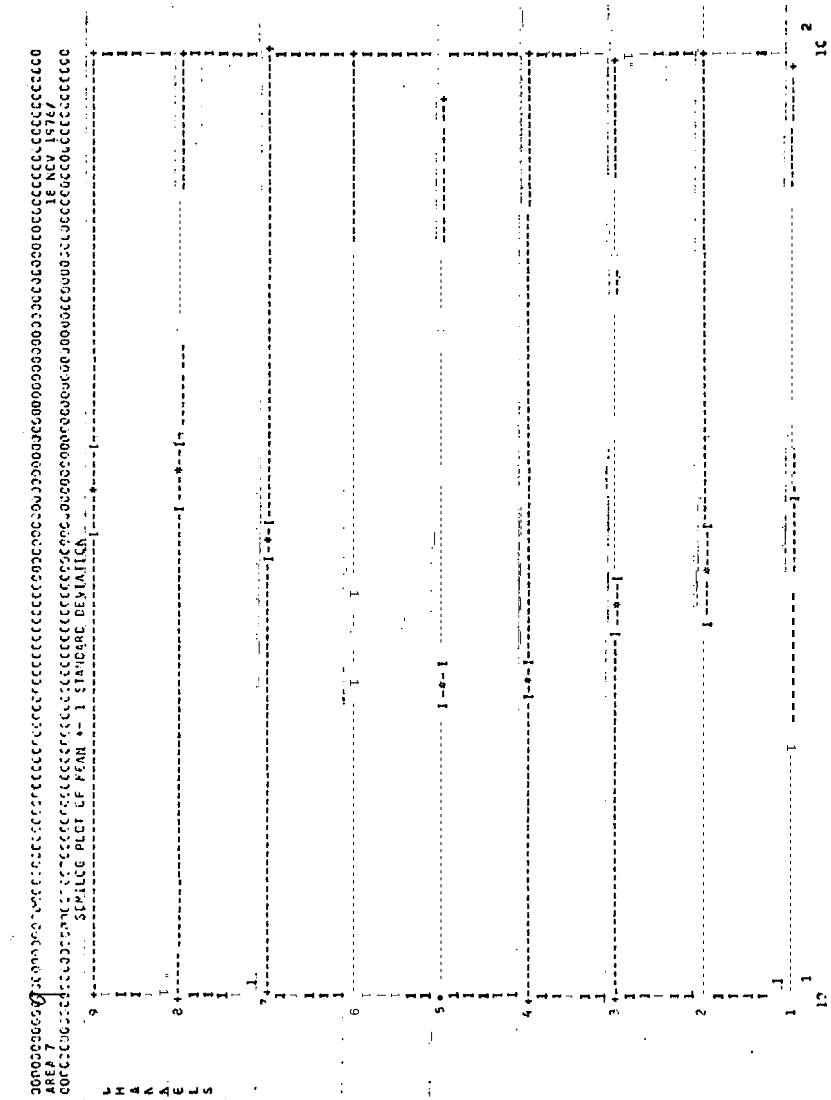


ALGAE 4C

FIGURE 5. continued) SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITES AT LATOUCHE TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table V. Each semilog graph shows signal means $\pm$ one standard deviation as a function of wavelength (channel no.)

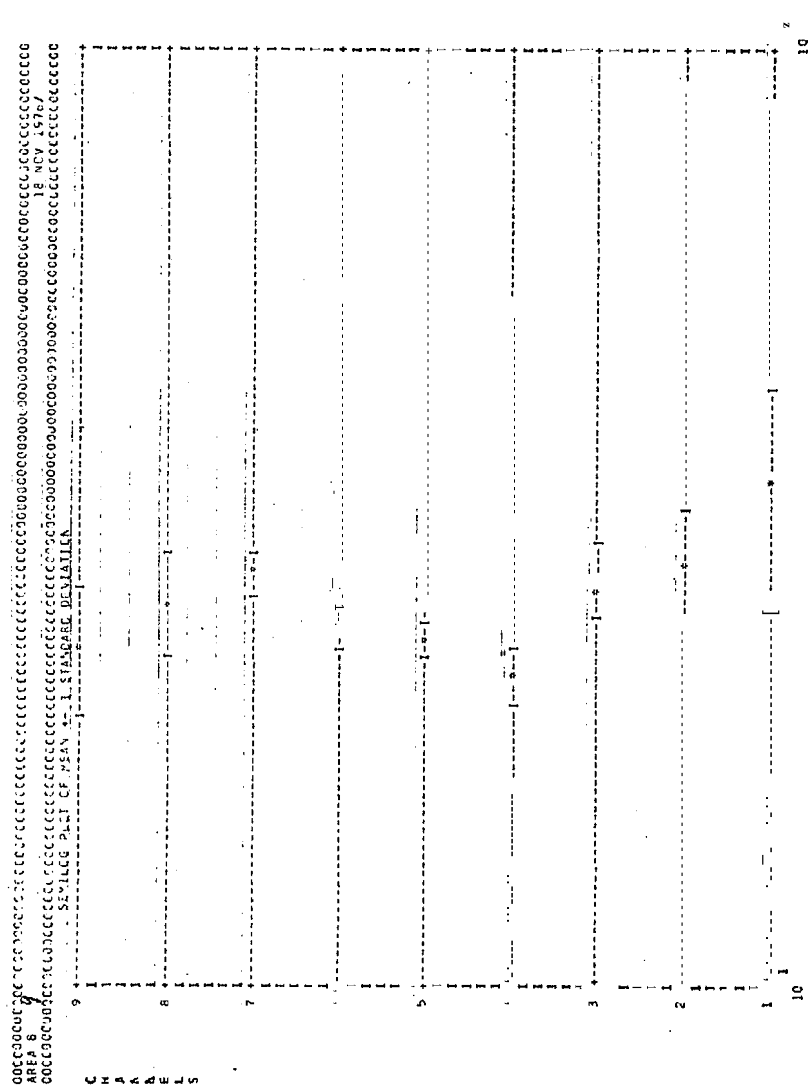


ALGAE 5C

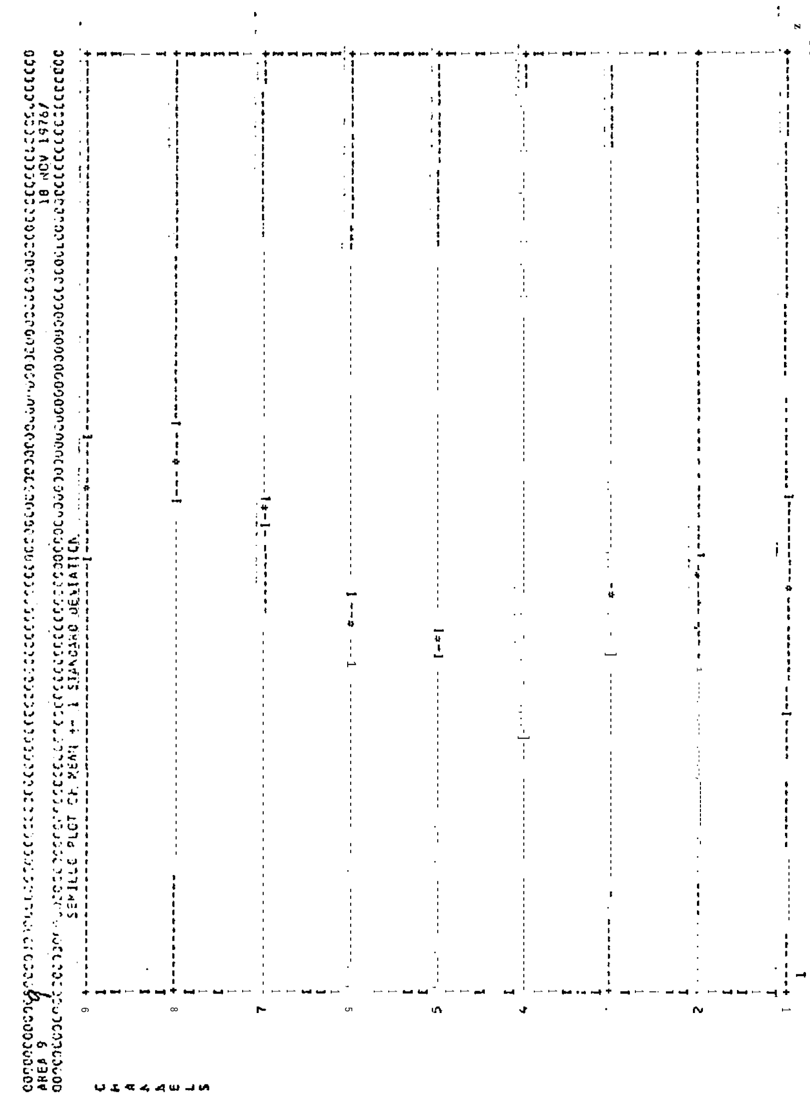


ALGAE 6C

FIGURE 5. (continued) SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT LATOUCHE TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table V. Each semilog graph shows signal means $\pm$ one standard deviation as a function of wavelength (channel no.)

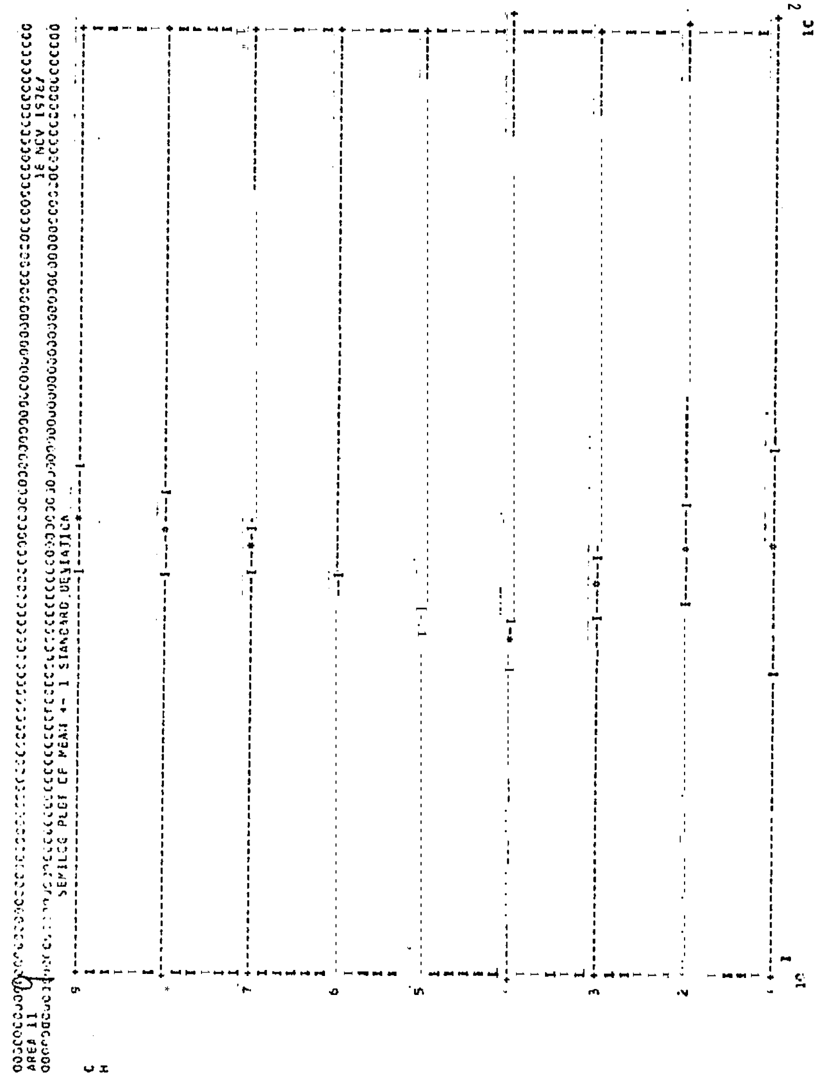


ALGAE 7C



ALGAE 8C

FIGURE 5. (continued) SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT LATOUCHE TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table V. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)



ALGAE C

FIGURE 5. (SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT LATOUCHE TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table V. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)

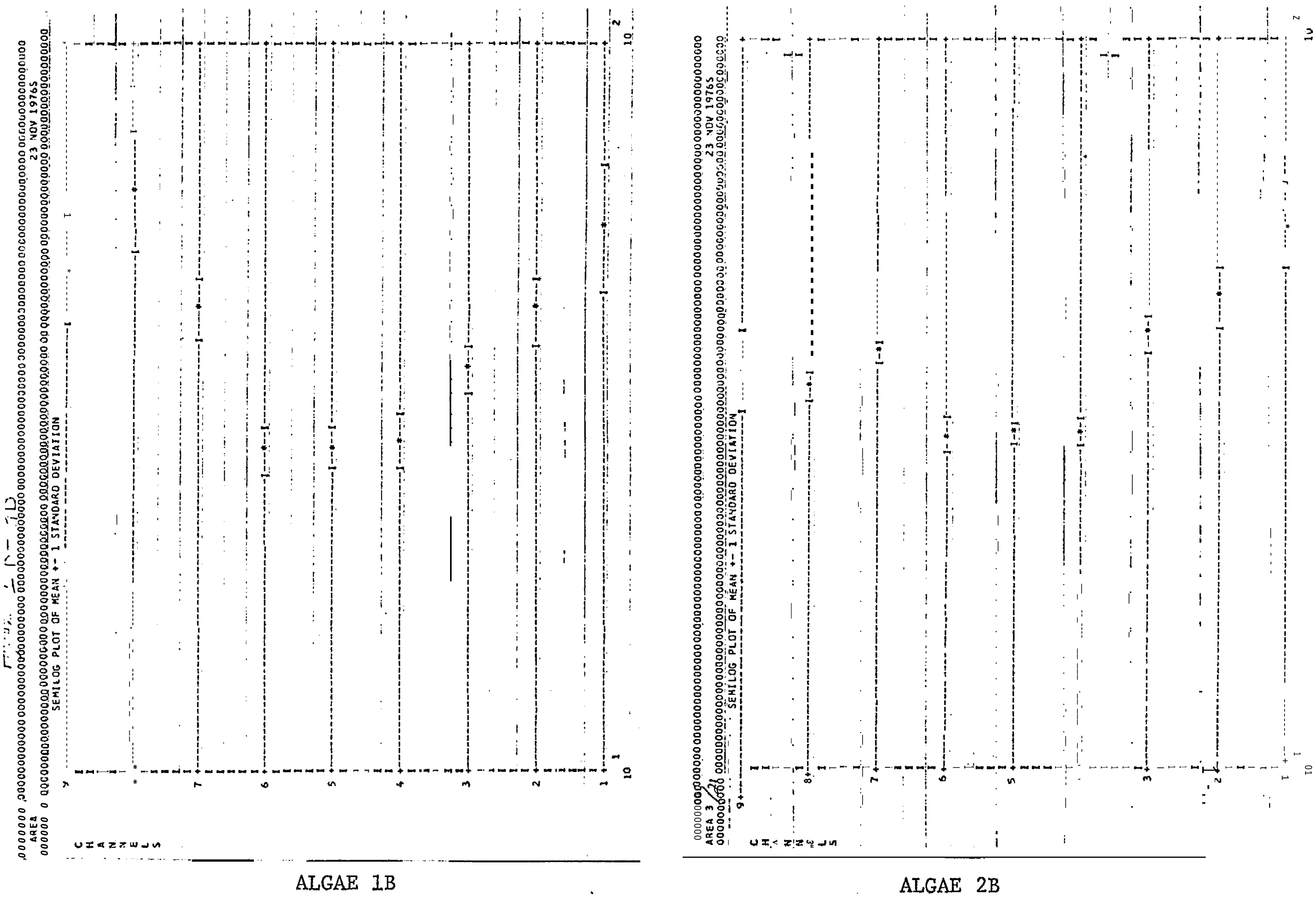
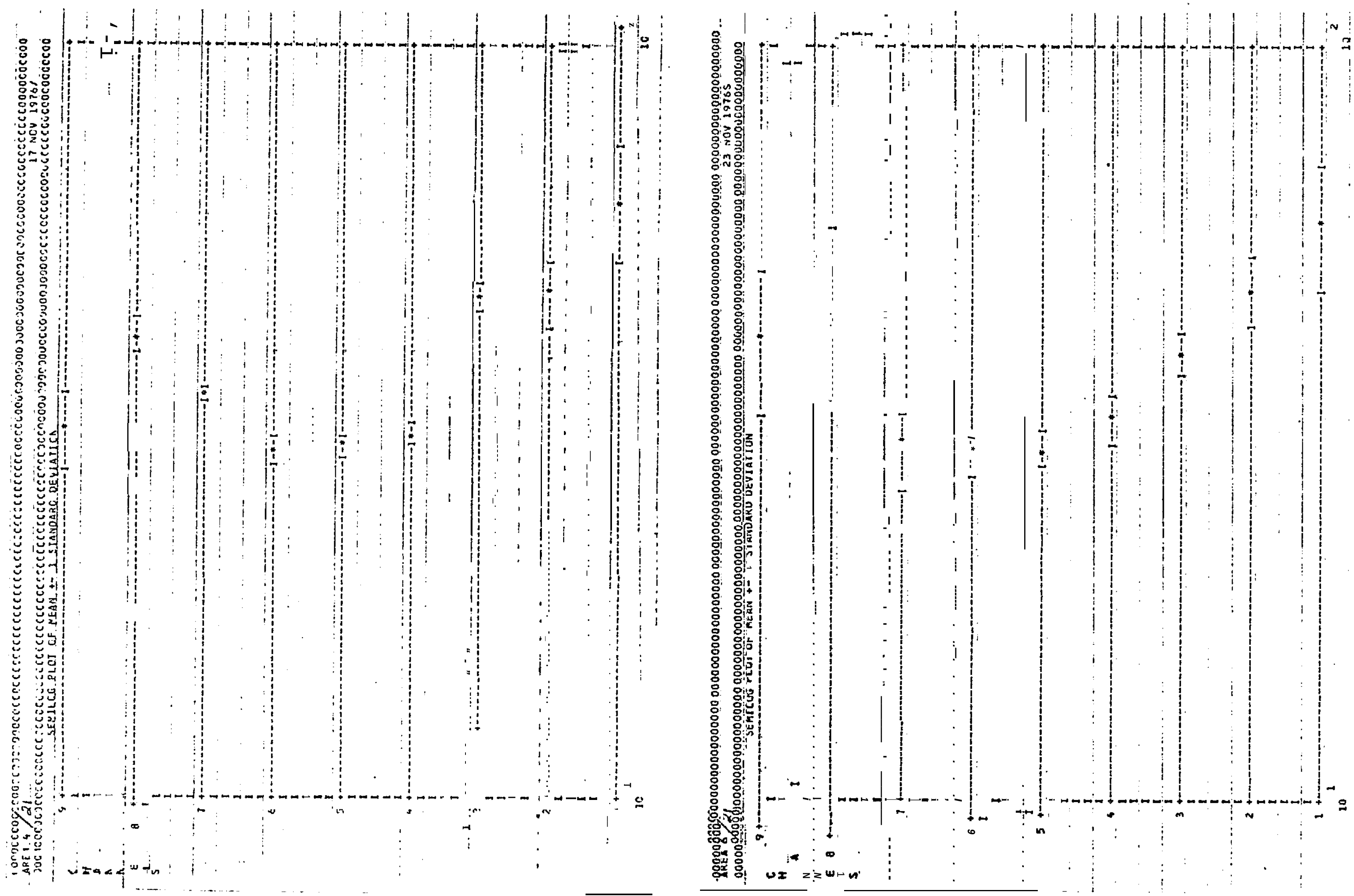


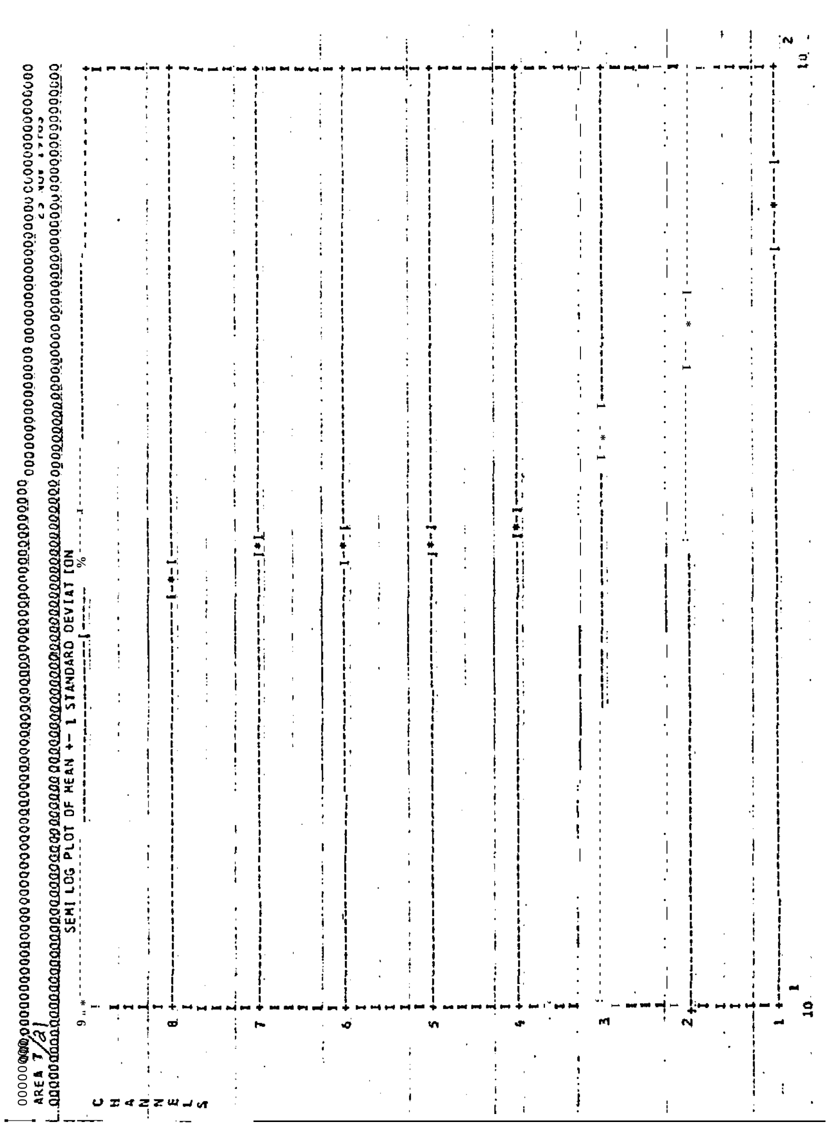
FIGURE 6. SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT CAPE YAKATAGA TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table VI. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)



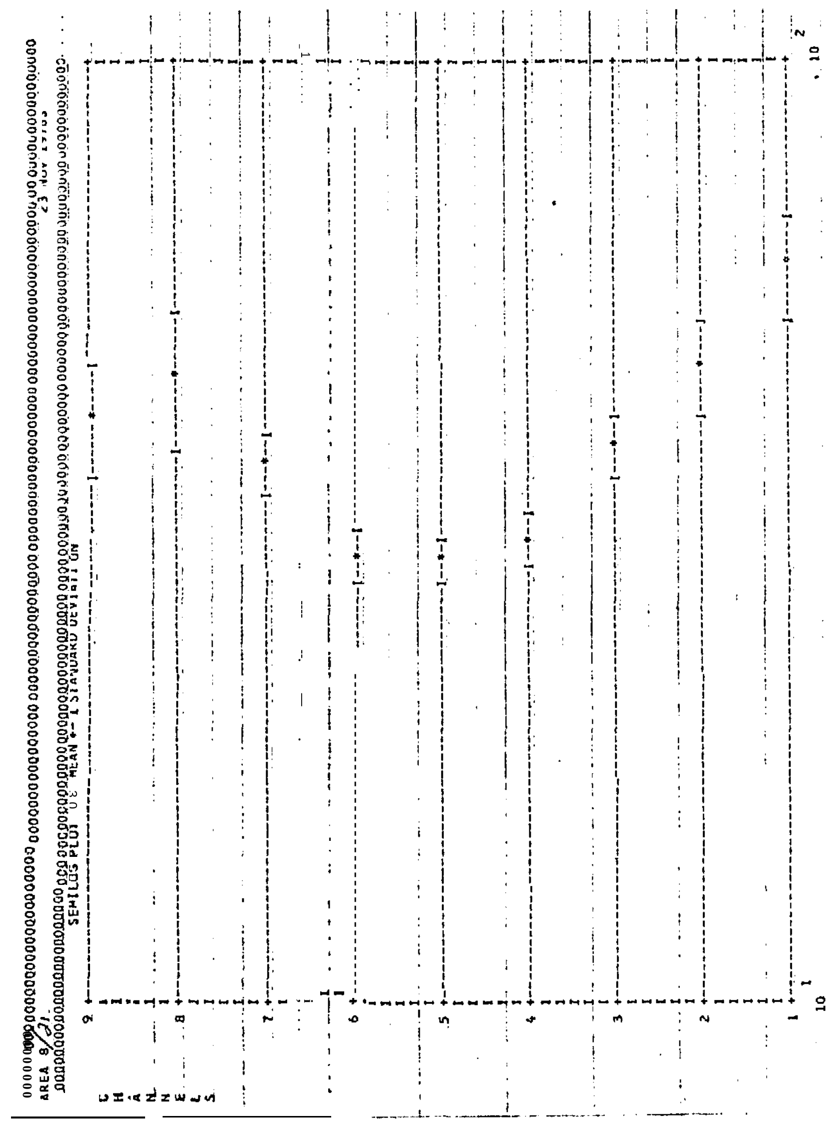
ALGAE 3B

ALGAE 4B

FIGURE 6. (continued) SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT CAPE YAKATAGA TEST SITE. Channels numbers are defined in Table II, while map color codes for each algal group are defined in Table VI. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)

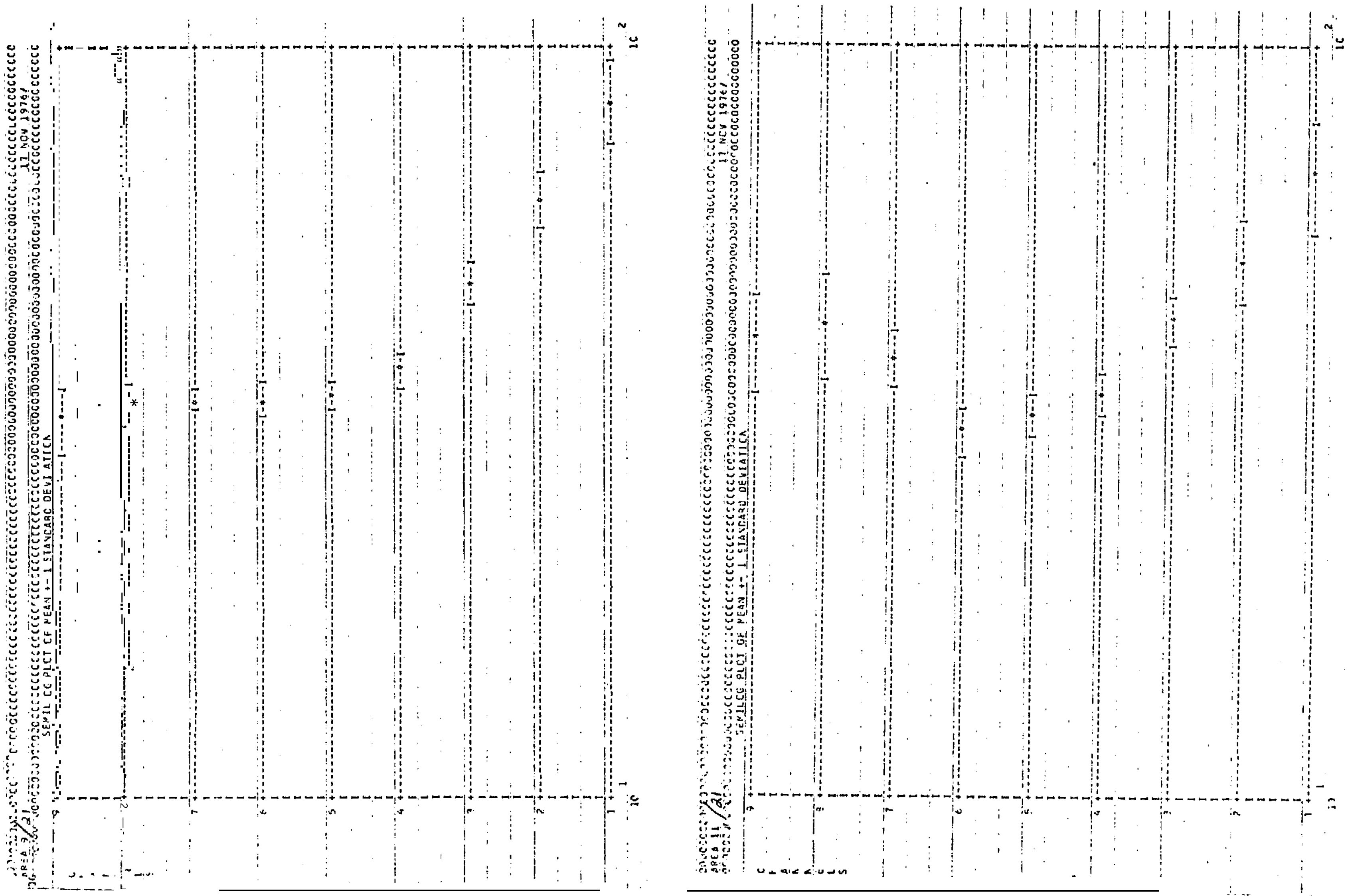


ALGAE 5B



ALGAE 6B

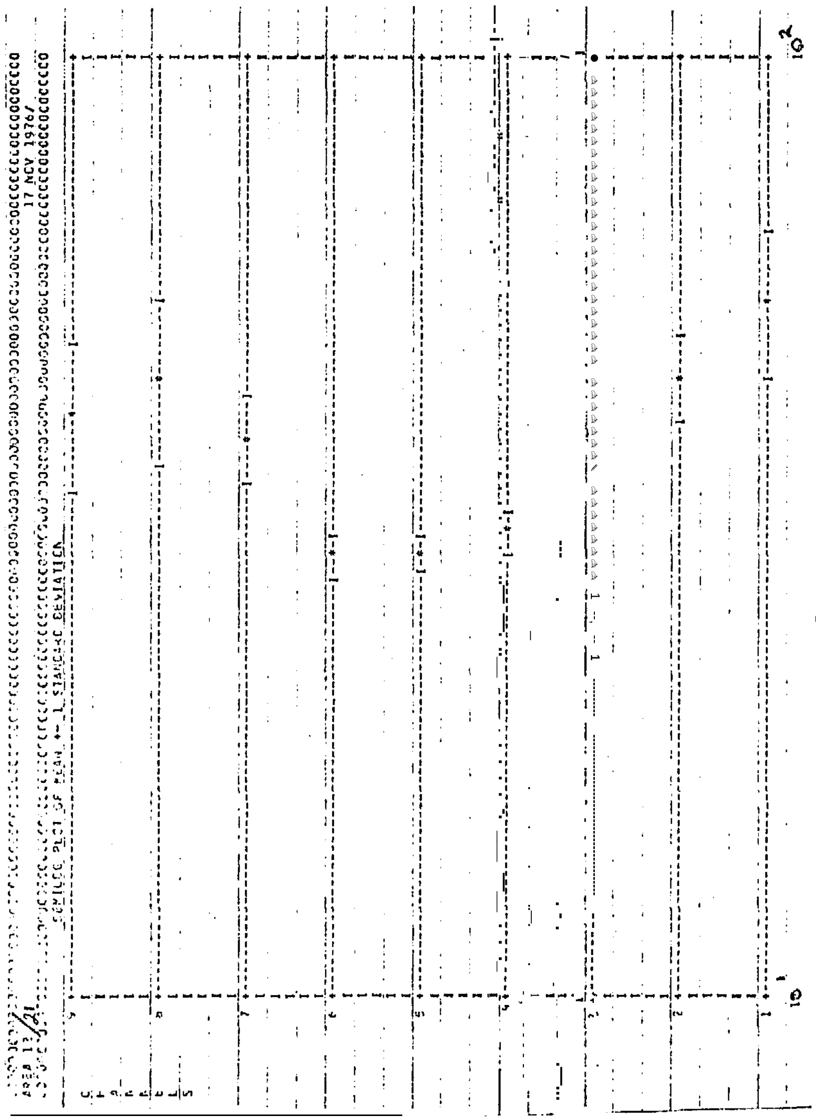
FIGURE 6. (continued) SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITES AT CAPE YAKATAGA TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table VI. Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)



ALGAE 7B

ALGAE 8B

FIGURE 6. (continued) SPECTRAL SIGNATURES OF 9 ALGAL OMMUNITIES AT CAPE YAKATAGA TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table VI, Each semilog graph shows signal means ± one standard deviation as a function of wavelength (channel no.)



ALGAE 9B

FIGURE 6. (continued) SPECTRAL SIGNATURES OF 9 ALGAL COMMUNITIES AT CAPE YAKATAGA TEST SITE. Channel numbers are defined in Table II, while map color codes for each algal group are defined in Table VI. Each semilog graph shows signal means $\pm$ one standard deviation as a function of wavelength (channel no.)

corresponds to scanner channels 2 through 10 respectively as listed in Table II. The semilog plot shows the mean signal level plus or minus one standard.deviation in each spectral band. By comparing the relative "shape" of the spectral mean signals between algal type, a quick insight into their separability can be developed. Through a statistical test of maximum likelihood processing each pixel in the scene is tested as to which spectral class it should be assigned. The general theory of spectral recognition is given in the appendix.

These signatures were used to classify the remainder of the scene using a previously developed computer program. This program compares each pixel in the scene with each signature and assigns each pixel a number corresponding to the signature which it most closely resembles. The total number of pixels recognized in each category can be compiled and area statistics for each algae class can be computed. Area results are shown in Tables IV, V and VI.

In Table VII, a color bar chart is supplied which defines the shades of colors listed for each algal class referred. to in Tables IV, V, and VI and subsequently used in the computer graphics shown in Figures 7, 8, and 9.

TABLE IV

ZAIKOF BAY
Run 7
Algae

LEVEL	SCENE CLASS	COLOR	NUMBER OF PIXELS	AREA (m^2)
1	Algae 1A	light red	22591	4498
2	Algae 2A	olive brown	23439	4666
3	Algae 3A	dark green	11482	2286
4	Algae 4A	light green	24534	4885
5	Algae 5A	orange	15720	3130
6	Rock 1A	dark gray		
7	Rock 2A	black		
8	Grass	yellow		
9	Trees	light orange		
10	Algae 6A	light purple	21131	4207
11	Water	blue		
255	Unclassified	white		

2.143 ft^2/pixel   0.1990912147 m^2/pixel

TOTAL AREA

pixels = 437,660 @ 0.1990912147 m^2/pixel

Total Area = 87,134.261 m^2

TABLE V

LATOUCHE ISLAND
Run 9
Algae

LEVEL	SCENE CLASS	COLOR	NUMBER OF PIXELS	AREA (m^2)
1	Algae 1C	light red	22258	12304
2	Algae 2C	olive brown	15987	8837
3	Algae 3C	dark green	14251	7878
4	Algae 4C	light green	10693	5911
5	Algae 5C	dark orange	36872	20382
6	Algae 6c	violet	8864	4900
7	Algae 7C	dark red	16939	9363
8	Algae 8c	light blue	18407	10175
9	Algae 9C	black	12237	6764
10	Water	blue		
11	Trees	light orange		
12	Grass	yellow		
13	Rock	gray		
255	Unclassified	white		

5.95 ft^2/pixel about 0.552773088 m^2/pixel

TOTAL AREA

pixels = 300,600 @ 0.552773088 m^2/pixel

Total Area = 166,163,590 m^2

TABLE VI

CAPE YAKATAGA
Run 21
Algae

LEVEL	SCENE CLASS	COLOR	NUMBER OF PIXELS	AREA (m^2)
1	Algae 1B	light red	15761	8712
2	Algae 2B	olive brown	14389	7954
3	Algae 3B	dark green	5862	3240
4	Algae 4B	light green	18402	10172
5	Algae 5B	dark orange	9828	5433
6	Algae 6B	violet	12380	6843
7	Algae 7B	dark red	33773	18669
8	Rock 1B	gray		
9	Algae 8B	black	43470	24029
10	Rock 2B	light blue		
11	Algae 9B	light orange	18238	10081
12	Water	blue		
13	Grass	yellow		
255	Unclassified	whit-e		

5.95 ft^2/pixel about 0.552773088 m^2/pixel

TOTAL AREA

pixels = 259,201 @ 0.552773088 m^2/pixel

Total Area = 143,279.337 m^2

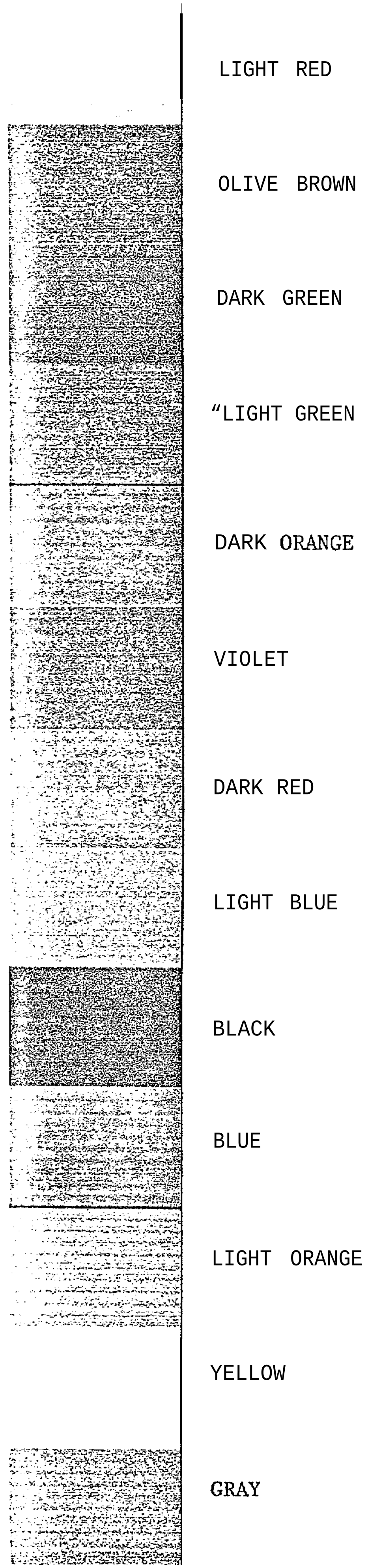


TABLE VII. DEFINITION OF COLOR LEGEND AS USED IN TABLES IV, V, AND VI FOR ALGAL DISTRIBUTION MAPS SHOWN IN FIGURES 7, 8, 9.

4
RESULTS

A set of color photographs and scanner imagery were sent to both Dr. Herbert Bruce and Dr. Zimmerman on 22 September 1976. They consisted of the following items:

set of Zaikof Bay data for both June 14 and June 27, 1976
set of Latouche Island data for June 27, 1976
set of Cape Yakataga data for June 28, 1976
set of color photographs of the Needle, West of Montague, taken on June 12, 1976

These data covered three sites for which ground truth had been taken and which were used in subsequent computer analysis. The results of the classification program were written on magnetic tape which was used on the Midas" computer to generate color displays. Figures 7A, 8A and 9A show the color coded algal zones for the three areas. The color legend giving the area of each algal type is given in Tables IV, V and VI. Figures 7B, 8B, and 9B show a section enlarged either by 3x3 or 3x6 picture elements per element for each the the three sites. Enlargements are possible during construction of the image by programming the computer to repeat pixels in both dimensions in the appropriate ratio in order to maintain proper geometric aspect or to delineate different zones easier. These results were evaluated by Dr. Zimmerman" during the fall of 1976. The color code is the same for figures A and B. Color assignments are arbitrary.

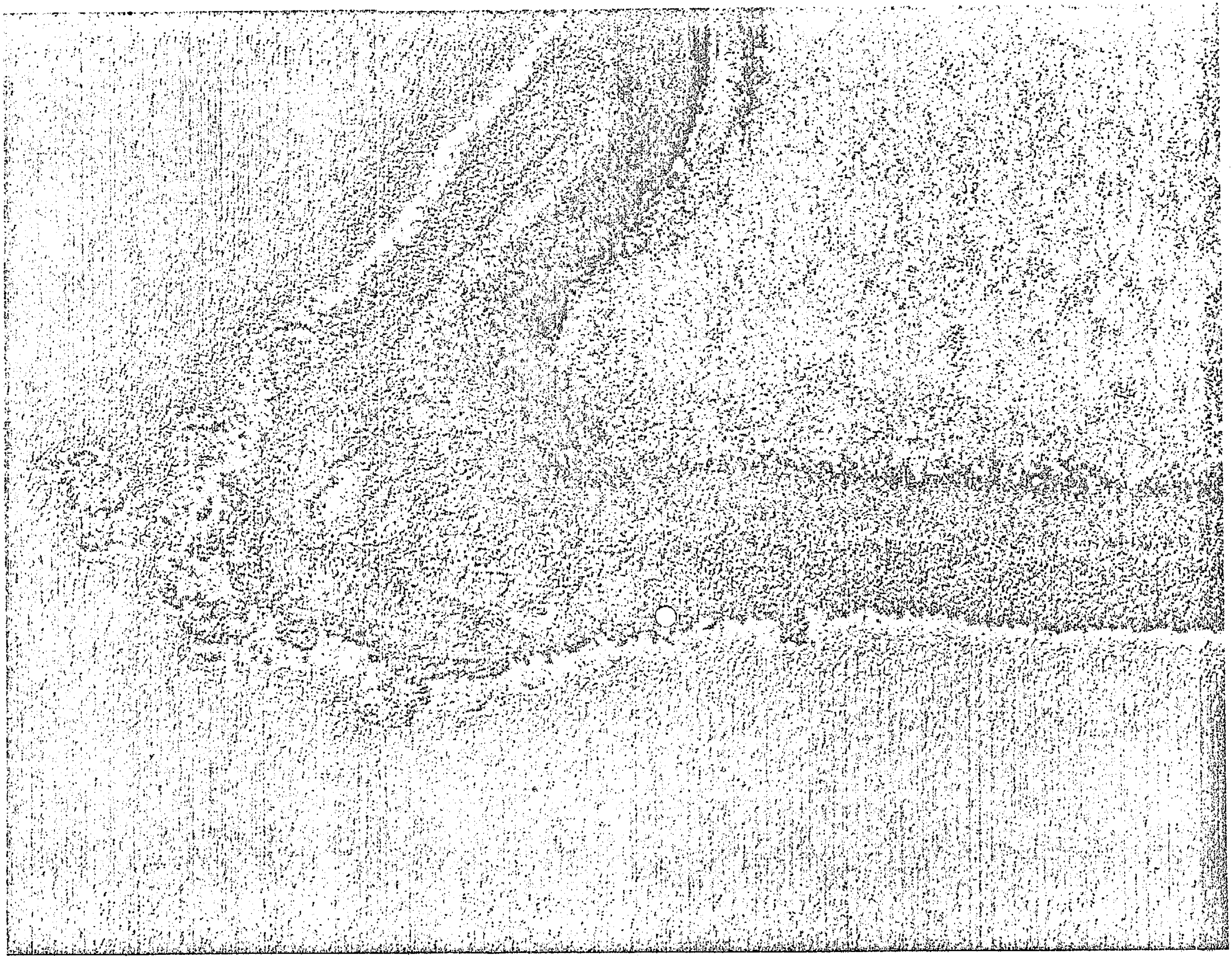


FIGURE 7A. COLOR CODED ALGAL DISTRIBUTION
MAP FOR ZAIKOF BAY TEST SITE - SEE TABLE IV

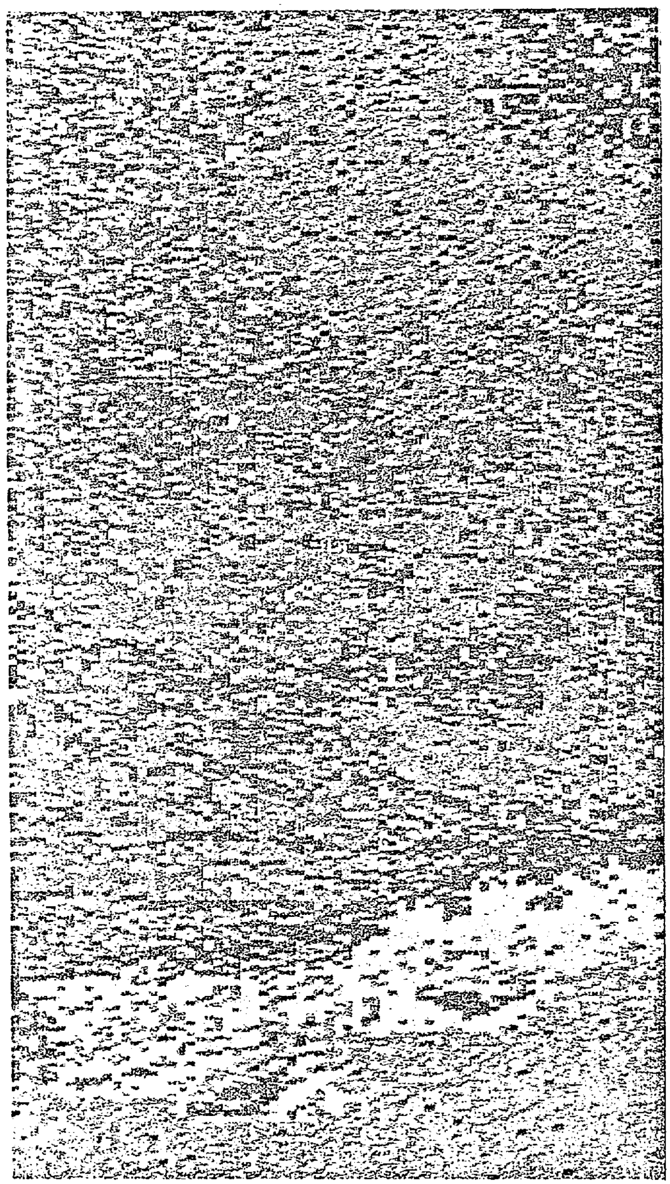


FIGURE 7B. SECTION OF FIGURE 7A ENLARGED BY COMPUTER DISPLAYING 3 X 6 PICTURE ELEMENTS

FIGURE 9A. COLOR CODED ALGAL DISTRIBUTION MAP
FOR CAPE YAKATAGA TEST SITE - SEE TABLE VI

FIGURE 8A. COLOR CODED ALGAL DISTRIBUTION
MAP FOR LATOUCHE TEST SITE - SEE TABLE V

FIGURE 8B. SECTION OF FIGURE 8A ENLARGED
BY COMPUTER DISPLAYING 3 X 3 PICTURE ELEMENTS

FIGURE 9B. SECTION OF FIGURE 9A ENLARGED
BY COMPUTER DISPLAYING 3 X 3 PICTURE ELEMENTS

5
PRELIMINARY ASSESSMENT

The first maps generated were evaluated by Dr. Zimmerman and his staff. While preliminary at this time, their initial reactions were favorable. The technique holds promise for a broad scale description of the distribution of littoral communities. It appears that the different algal communities may have distinguishable signatures. Zaikof Bay was found to be the most dramatic and appeared to follow the known real distribution.

The technique must be careful to avoid choosing too many classes especially if the computer method is able to detect differences that are more subtle within a community as compared to differences between communities. Cape Yakataga must be reevaluated with respect to carefully choosing biologically distinct communities.

6
RECOMMENDATIONS

For the first analysis, the method chosen was deliberately the most difficult in order to avoid using as much prior information as possible. However, from previous experience with the technique of computer spectral analysis the use of known training sites for each algal community will improve the final classification map. The data obtained during the mission was collected under a variety of operational variables such as altitude, direction of flight scan, rate and local site conditions, as described in section 2.2. It is recommended that further processing of the data be made with the objectives defined as follows:

1. Classify by computer spectral techniques the intertidal algal communities for Latouche, Zaikof Bay and Cape Yakataga test sites using the specific algal training areas designated by Dr. Zimmerman. Develop area statistics for each algal community reported, and optimum scale for computer graphics.

2. Test extension of signatures developed at one site to other areas to determine need for retraining. Test special algorithms such as mixtures and clustering if appropriate.

3. Test classification accuracies of algal classes for other conditions referenced in data set by altitude, scan rate, or flight direction for at least one test area.

4. Prepare recommendations for a cost effective operational approach to an intertidal algal survey for designated coastlines in Alaska.

APPENDIX

AN INTRODUCTION TO MULTISPECTRAL CLASSIFICATION AND RECOGNITION PROCESSING

Multispectral classification essentially consists of deciding the class of the object being observed on the basis of its color. While the human eye utilizes three dimensions of color - value, hue, and intensity - for classification, other multispectral classification systems may use as many dimensions as the number of spectral bands observed. In the following paragraphs a brief description of an airborne scanning spectrometer is given. This is followed by a discussion of the theory of multispectral classification and recognition processing as it relates to the outputs of the scanning device.

Environmental Research Institute of Michigan's airborne scanning spectrometer is configured to sense radiation simultaneously in several spectral bands ranging from 0.4 μ m (blue) to 13.0 μ m. The scanning spectrometer, which is mounted in the belly of an airplane, accomplishes the scanning function by means of a rotating mirror. The mirror rotates about an axis parallel to the aircraft heading, and the forward motion of the aircraft causes succeeding scans to view different portions of the scene below. Thus, by appropriately setting the aircraft velocity and mirror rotation rate, each point in the ground scene that is within the total system field of view may be scanned.

The visible radiation from each point of the scan is collected and directed through a spectral dispersing element (a prism). Radiation in different portions of the spectrum are then picked off by up to 12 fiber optic bundles each of which directs the radiation to a different photo-multiplier. Separate focal positions serve the thermal infrared wave-length bands. The voltages produced in each of the detectors are then amplified and recorded on magnetic tape by a multichannel tape recorder. Thus the data recorded on tape, which is used as an input to the recog-nition processor, consists of 12 multispectral scanner signals, each signal corresponding to information gathered over a different spectral band.

In order to simplify the explanation of the recognition processing, much of the discussion will be presented first in terms of two channels, and the extension to many channels will be explained at appropriate points in the development. Also, for simplification, we assume that only three materials are being scanned.

First, then, let us consider the nature of two-channel scanner data which would be obtainable from each of three separate materials: suppose that the spectral radiation intensity received at the scanner from each of the three materials, A, B, and C, is as shown by figures 1a, b, and c, respectively.

The specific wavelengths λ_1 and λ_2 indicated on each of the three figure parts correspond to the centers of the respective wavelength bands covered by the two channels of the scanner, and therfore, for each material, the response of a given scanner channel will be proportional. to the height of the material's spectral curve at the wavelength corresponding to that channel. Thus, if u_1 and u_2 is the signal from channel 1 and u_2 is the signal from channel 2, the relative magnitudes of u_1 and u_2 for each of the three materials will be as indicated in figures a, b, and c.

The scanner responses for the three materials may be presented in a more compact form by considering u_1 and u_2 as the two components of a two-dimensional vector and plotting the coordinates for each material as shown in figure 2.

The u_1, u_2 plane shown in figure 2 will be referred to as signal space or "u" space. If the scanner had three channels instead of two, this space would be three dimensional, with the response of the third channel corresponding to the third dimension. If the scanner had n channels, the corresponding "u" space would be n-dimensional. Although an n-dimensional space for n greater than 3 is difficult to visualize.

from material B, and let DC (u_1, u_2) the the density of sample points from material C. The "maximum likelihood" decision rule is to decide that point e belongs to the material with the largest density at e. The maximum likelihood principle is highly respected in its own right. It can also be justified as a Bayesian decision with equal prior probabilities and equal costs of misclassification.

In a target-background type of decision rule, the density of one material, say A, is compared with a composite density of the other materials, and the rule is

$$\text{decide on A if } \frac{K_A D_A}{K_B D_B + K_C D_C} > 1$$

where K_A, K_B, and KC are the relative frequencies (prior probabilities) of A, B, and C, respectively.

The recognition processor can be implemented such that it decides that a sample belongs to a given material (A, for example) if the "A" likelihood ratio for the sample is greater than some constant, K. Thus, if

$$\frac{D_A(e)}{D_B(e) + D_C(e)} \geq K$$

then the processor decides that the sample is material A. The value of the constant K in equation III-1 depends upon the estimated costs for false alarms and missed detection and upon the particular optimal decision criterion which is to be employed. For recognition of various crops, a value of unity has been used for K. In this case, the identified material must have a point density at point e of at least 50% of the total point density for all materials at e.

In order to implement equation 1, it is necessary to generate mathematical expressions which accurately describe DA (u_1, U_2) and DC (U_1, U^*). It is assumed that these densities of points on the u_1, u_2

plane may be represented in terms of bivariate Gaussian probability density functions in this plane, if the latter are fitted to the measured statistical properties of actual data. Thus, if $f_A(u_1, u_2)$ is the bivariate Gaussian probability density function which represents the relative density distribution of points from material A in the u_1, u_2 plane (fig. 2), the actual density as a function of u_1 and u_2 will be given by

$$D_A(u_1, u_2) = P(A) f_A(u_1, u_2) \qquad 2$$

where P(A) is the probability of occurrence of material A in the scanned area. Similarly,

$$D_B(u_1, u_2) = P(B) f_B(u_1, u_2) \qquad 3$$

and

$$D_C(u_1, u_2) = P(C) f_C(u_1, u_2) \qquad 4$$

Substituting 3, 4 and 5 into 2 gives

$$\frac{D_A(e)}{D_B(e)+D_C(e)} \cdot \frac{P(A) f_A(e)}{P(B) f_B(e) + P(C) f_C(e)} \geqq K \qquad 5$$

if point e is to be classified as belonging to material A.

Inequality 5 is the relationship which is implemented on the recognition processors, both digital and analog. Instead of working on two channels, the processors can accept information from many channels and hence the recognition space is a multi-dimensional space instead of the two-dimensional plane shown in figure 2.

For processing signals from an unknown area, the probabilities of occurrence of the various materials (ie., P(A), P(B), and P(C) in eq. 5 must be estimated, since they are not known. Experience has shown, however, that these estimates can be very crude without appreciably

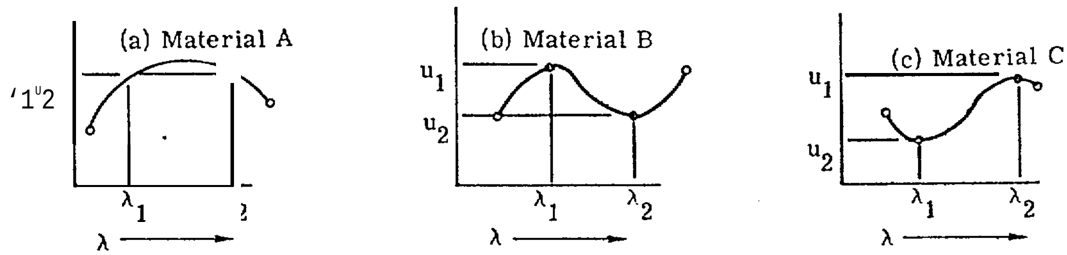


FIGURE 1. SPECTRAL CURVES AND SCANNER RESPONSES FOR THREE MATERIALS

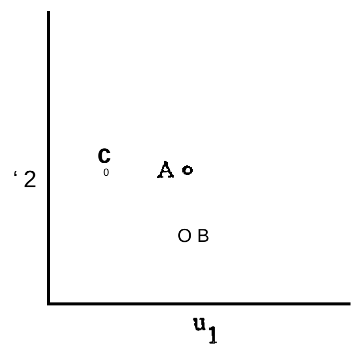


FIGURE 2. RESPONSES OF TWO CHANNELS FOR MATERIALS A, B, AND C

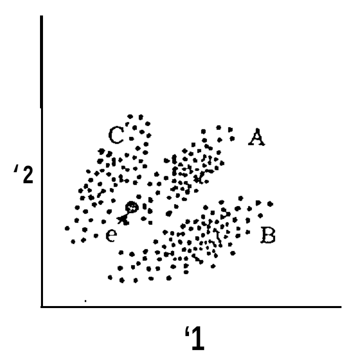


FIGURE 3. RESPONSES TO MANY SAMPLES OF MATERIALS A, B, AND C

Actually, because of various statistical fluctuations in the properties of the materials being scanned, the intensity and spectral properties of the illumination, the scanner's look angle and other factors, the plot of u_1 vs. u_2 will not generally be distinct points as indicated in figure 2. Instead, if points for a large number of samples of these materials are plotted in u space, the points will tend to form three clusters as shown in figure 3 with each cluster corresponding to one of the three materials, A, B, or C.

In general, the density of points will be greater near the center of each cluster and will become very low near the edge. Also, the clusters will tend to be elliptical rather than circular because of correlation between changes in u_1 and changes in u_2 for a given material. This means, simply, that if u_1 increases because of some natural occurrence, such as in increase of illumination on the scene being scanned, u_2 will probably increase also.

The problem to be solved by the processor may be stated as follows: "Given any sample point on the u_1, u_2 plane, from what type of material A, B, or C, was the sample obtained?" If the sample point falls near the centroid of one of the clusters of points for A, B, or C, the decision is obvious; the material belongs to the class indicated by the group near whose centroid the sample point is located.

Suppose, however, that the sample point is located at e in figure 3. and thus does not clearly belong to either A, B, or C. A decision can still be made by comparing the densities (also called "likelihoods") of points from material A, from material B, and from material C in the neighborhood of point e.

Assume that a large strip of terrain has been scanned, and that the resulting large number of sample points has been plotted in the u_1, u_2 plane as in figure 3.

Let $D_A(u_1, u_2)$ be the density of sample points from material A as a function of u_1 and u_2, let $D_B(u_1, u_2)$ be the density of sample points affecting the processor operation. In fact, the processor usually operates quite satisfactorily with P(A) = P(B) = P(C).

Having determined which of many materials the unknown sample is most 1 ike, the question still remains whether the sample is to be classified as that material. It is possible that although the inequality 5 for that material was satisfied, the magnitude of the probability density function at point "e" was extremely small. This indicates that the sample at "e" might better be classified as not belonging to any material whose probability distribution functions was included in the classification. Therefore, the final classification or lack of classification of a sample is based on its existence within a fixed region of the probability function. This region is very often defined as that region which includes 99.9% of the points in the distribution function.

DISTRIBUTION

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Dr. Steven Zimmerman NOAA Auke Bay Laboratories P.O. Box 155 Auke Bay, Alaska 99821	copy