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Phytoplankton Composition and Abundance in Southern Lake Huron

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PHYTOPLANKTON COMPOSITION AND ABUNDANCE IN SOUTHERN LAKE HURON

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FOREWORD

Our nation's freshwaters are vital for all animals and plants, yet our diverse uses of water---for recreation, food, energy, transportation, and industry---physically and chemically alter lakes, rivers, and streams. Such alterations threaten terrestrial organisms, as well as those living in water. The Environmental Research Laboratory in Duluth, Minnesota develops methods, conducts laboratory and field studies, and extrapolates research findings

--to determine how physical and chemical pollution affects aquatic life

--to assess the effects of ecosystems on pollutants

--to predict effects of pollutants on large lakes through use of models

--to measure bioaccumulation of pollutants in aquatic organisms that are consumed by other animals, including man

This report, as part of our continuing large lakes study program, details our findings and interpretations of the present conditions of and the interactions between the Southern Lake Huron basin and Saginaw Bay.

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ABSTRACT

Southern Lake Huron contains a diversity of phytoplankton assemblage types ranging from assemblages characteristic of oligotrophic waters to those which usually occur under highly eutrophic conditions. The offshore waters are generally characterized by oligotrophic associations and most eutrophic associations are associated with the Saginaw Bay interface waters. Under certain conditions, populations which are generated within Saginaw Bay are found mixed with offshore assemblages, apparently as a result of passive dispersal. The most widely dispersed populations include nuisance-producing blue-green algae such as Aphanizomenon flos-aquae. During the period of study, floristic modification resulting from inputs from Saginaw Bay was usually found along the Michigan coast south of the bay, but cases were noted where greatest effect was found at stations north of the bay or eastward into the open lake. These differences appear to be related to circulation patterns governed by transient meteorological events. Marked changes in phytoplankton abundance and composition were also noted at stations along the Canadian coastline. This effect was most pronounced during the spring thermal bar period and appeared to result from the stimulation of populations characteristic of oligotrophic to mesotrophic conditions by nutrients from land runoff. Phytoplankton assemblages in this region were qualitatively and quantitatively dissimilar from assemblages in Saginaw Bay. On the basis of our results southern Lake Huron appears to be a somewhat more disturbed region than generally realized. Phytoplankton assemblage modification appears to result from both the influence of nutrients and other materials entering the lake directly and from the dispersal of populations from highly eutrophic Saginaw Bay into the open lake. The wide dispersal of these populations is of special interest since it may furnish a mechanism for transport of nutrients and toxic material from highly impacted Saginaw Bay into the open lake.

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INTRODUCTION

Compared to the other Great Lakes, there has historically been little research on the composition, distribution, and seasonal cycles of phytoplankton assemblages in Lake Huron (Davis, 1966). More recently, Vollenweider *et al.* (1974) have summarized the current status of knowledge in this area and have presented a synthesis based on both previous studies and their own previously unpublished observations. In Appendix II of this report, we have compiled a list of publications dealing with algal populations in Lake Huron that have come to our attention. The majority of these report limited observations from one, or a limited number of sites and are of peripheral interest. There are several recent publications, however, which merit further attention in the context of the present study. Schelske and Roth (1973) found sufficient differences to divide the open waters of Lake Huron into three north-south zones. The types of differences noted could be interpreted as reflecting a higher degree of eutrophication of southern Lake Huron than had previously been suspected. Schelske and Roth emphasized that Saginaw Bay differed drastically from the rest of the lake and imply that materials entering the open lake from Saginaw Bay have measurable effects, particularly on the southern region. Subsequently Schelske *et al.* (1974) demonstrated that there were consistent north-south differences in phytoplankton species composition at stations along the Michigan coast of Lake Huron which could be interpreted as reflecting some degree of eutrophication in the southern part of the lake. This study also showed that certain phytoplankton populations characteristic of highly eutrophic conditions were transported from Saginaw Bay to the open waters of Lake Huron, at least under certain conditions. More recently Schelske *et al.* (1976) have demonstrated the transport of populations developed under severely silica-limited conditions in Lake Michigan into Northern Lake Huron through the Straits of Mackinac. Although this indicates slight eutrophication of northern Lake Huron due to this transport, it should be emphasized that transport from Saginaw Bay presents a much more serious problem in terms of water quality management. While populations transported from Lake Michigan have little or no nuisance potential, those coming from Saginaw Bay are often associated with direct water quality problems. It is also apparent that the total flux of nutrients and conservative contaminants is higher from Saginaw Bay than through the Straits. The same general implication can be derived from Lowe's (1976) study of phytoplankton populations at several nearshore localities along the Michigan coast. Lowe's data additionally show that certain nearshore localities in the northern sector of the lake support large populations of species possibly associated with eutrophied conditions. For instance, Lowe found much higher phytoplankton abundance in Thunder Bay, near Alpena, than at comparable stations in other parts of northern Lake Huron. He, however, pointed out the great differences in assemblages found in Saginaw Bay, compared to the rest of the lake, as well as the effects of the Saginaw Bay discharge on nearshore stations south of the bay. Nicholls *et al.* (1975) have also shown local areas of eutrophication at nearshore localities in Georgian Bay.

In summary, the limited evidence available indicates that certain nearshore areas in Lake Huron are significantly eutrophied. There is also increasing evidence that materials derived from Saginaw Bay are having significant effects on the rest of Lake Huron, particularly the waters of the southern basin. As might be expected, this evidence suggests that the direct effects of the Saginaw Bay discharge are highly dependent on meteorological conditions and resultant circulation patterns.

It should be emphasized here that conditions in Saginaw Bay are exemplary of perhaps the worst water quality degradation found in the Great Lakes system. This region has had a long history of water quality problems including obnoxious blue-green algal blooms, taste and odor problems in municipal water supplies, and fish flesh tainting. The historical context of present problems in Saginaw Bay has been reviewed by Freedman (1974). Vollenweider *et al.* (1974) emphasize that certain regions of Saginaw Bay have the highest phytoplankton standing crop and highest rates of productivity found within the Great Lakes system. While this reflects the high nutrient loading reaching the bay, the qualitative composition of the phytoplankton assemblage also reflects high conservative element loadings (Beeton *et al.*, 1967) and quite possibly the effects of toxic or inhibitory factors. Most significant to this study is that the outputs from Saginaw Bay to the main body of Lake Huron might be expected to be different in character than point source stream discharge entering the lake, in that, nutrients entering the system have already been "processed" through a highly specialized phytoplankton flora, quite different from the assemblage found in most parts of the Great Lakes system. The data of Schelske *et al.* (1974) indicate that most of the nutrients discharged into Saginaw Bay are already sequestered by phytoplankton by the time they reach main Lake Huron. These data also indicate that certain populations generated in Saginaw Bay survive and are dispersed into Lake Huron, while others are apparently lost rapidly through sinking, predation, or cell death and lysis.

This study is part of a general investigation of Saginaw Bay and Southern Lake Huron. Included in the general investigation are studies of chemical conditions in Saginaw Bay (Smith *et al.*, 1976), chemical conditions and productivity in southern Lake Huron (Schelske *et al.*, 1977 in prep.), crustacean zooplankton standing stock and feeding rates (McNaught *et al.*, 1977 in prep.), rotifer standing crop and distribution in southern Lake Huron and Saginaw Bay (Gannon *et al.*, 1977 in prep.), crustacean zooplankton numbers and biomass in Saginaw Bay (Gannon *et al.*, 1977 in prep.), phytoplankton composition and biomass in Saginaw Bay (Stoermer *et al.*, 1977 in prep.) and a general model synthesis of conditions and processes in Saginaw Bay (Bierman *et al.*, 1977 in prep.) and southern Lake Huron (Di Toro *et al.*, 1977 in prep.).

OBJECTIVES

1. A quantitative assessment of phytoplankton standing crop and composition in southern Lake Huron.

2. Provision of a complete set of archival samples which can serve as an objective reference against which possible future changes in the system may be judged.

3. An assessment of the degree to which populations generated in Saginaw Bay are transported to the open waters of Lake Huron and the extent of their subsequent survival and dispersal within the southern portion of the lake.

4. Provision of independent estimates of size fraction, biomass, and qualitative physiological group information to modeling efforts.

CONCLUSIONS AND RECOMMENDATIONS

The phytoplankton flora of southern Lake Huron contains elements characteristic of the entire range of conditions in the Great Lakes from oligotrophic to hypereutrophic.

On the basis of phytoplankton assemblage distribution, it appears that there are three primary input sources which modify the phytoplankton flora of southern Lake Huron.

The most important of these is Saginaw Bay. Most of the eutrophic elements in the flora are apparently generated from this source and its influence is continuous and affects a substantial portion of southern Lake Huron.

Phytoplankton abundance and composition are also modified by inputs from the Canadian shoreline. The effects from these inputs are less drastic and apparently less widespread than the effects of the Saginaw Bay inputs.

Phytoplankton abundance and composition also appear to be modified by input from sources on the U. S. shoreline south of Saginaw Bay. The influence of this source of perturbation is less well defined, partially because in most cases studied the area of effect is also under the influence of the effluent from Saginaw Bay.

The nature of phytoplankton assemblage perturbation resulting from the influence of these sources is different in the three cases.

In the case of Saginaw Bay, floristic modification results from both transport of materials from the bay and from transport of phytoplankton populations generated within the bay to the open lake. In general, the floristic response is characteristic of both high nutrient and high conservative element loadings.

Modification of the phytoplankton assemblage along the Canadian coast appears to result from stimulation of populations characteristic of oligotrophic to mesotrophic conditions within the lake. The primary effect in this case appears to result from nutrient addition.

Phytoplankton assemblages at stations on the southern U. S. coast appear to reflect both secondary stimulation of scenescent populations generated in Saginaw Bay and injection of certain populations unique to this area. Certain of these populations usually find their primary habitat in benthic associations.

The extent of influence of apparent sources is seasonally variable and apparently strongly dependent on physical conditions at the time of sampling.

During the period of study, the influence of Saginaw Bay was most commonly found at stations along the U. S. coast southward from the bay. In some instances, however, the influence of discharges from the bay was widespread in the open lake and in one instance the main effect of materials from Saginaw Bay was found at stations along the U. S. coast north of the bay.

The effect of sources on the Canadian coastline is most pronounced during the spring. This apparently results from the combined effects of the spring peak in runoff and the effects of the spring thermal bar which tends to restrict material entering the lake to the nearshore zone.

Biotic interactions strongly influence the distribution and eventual fates of populations injected into southern Lake Huron from Saginaw Bay. Certain populations, particularly some of the larger diatoms, are lost from the water mass rapidly, apparently through sinking. Other populations, particularly certain species of blue-green algae, have a much longer residence time in the water mass and are dispersed for considerable distances. Our data indicate such populations could reach any part of southern Lake Huron under the proper conditions.

This process should be studied in greater detail since it may be an important mechanism in transporting nutrients and toxic materials from highly impacted areas to the open lake.

MATERIALS AND METHODS

SAMPLING ARRAY

The basic sampling array utilized in this study is shown in Fig. 1. Station locations were chosen to provide greatest sampling density in the Saginaw Bay interface region and less dense coverage over the rest of the region. The constraints of sampling platform availability and the necessity to accomodate the needs of several projects on cruises resulted in compromises which render the design something less than ideal for the purposes of this particular project. Specifically, it would have been highly desirable to have additional stations in the southwestern quadrant of the sampling array (region bounded by stations 14, 60, and 63) and in the northeastern quadrant (area bounded by stations 20, 23, 53, and 56). Depths sampled at each station and the sequence of sampling are given in Table 1. On some occasions weather conditions led to deviations from the planned sampling schedule and, in a limited number of instances, certain stations were not sampled on a particular cruise. Any such omissions are noted on the following data plots.

Samples at all stations were taken as splits from a single 8 ℓ Niskin bottle cast. In the following, we will discuss processing of the samples utilized in this particular investigation. A more complete account of the complete sampling routine can be found in Schelske _et al_. (1977 in prep.).

ARCHIVAL PLANKTON COLLECTIONS

Archival samples were taken from all stations and depths sampled. Samples were drawn as 1ℓ subsamples of the original 8ℓ Niskin bottle sample. Subsamples were immediately filtered onto 47-mm Millipore "AA" cellulose acetate membrane filters and placed in 5-dram amber glass capsule vials. Material was preserved in a mixture of six parts water of collection, three parts 95% ethanol, and one part commercial formalin. Samples were labeled and sealed immediately following preservation.

SAMPLES FOR PHYTOPLANKTON POPULATION ANALYSIS

Samples for phytoplankton population analysis were taken as a 150-ml split of the original 8ℓ Niskin bottle sample. These subsamples were immediately fixed with glutaraldehyde (4% by volume) and stored in the dark at approximately 4°C for at least 4 hr to assure complete fixation. After fixation, sample bottles were gently agitated to assure resuspension of phytoplankton present and a 50-ml volume was withdrawn for further processing. The remaining sample volume of fixed sample was retained as a contingency sample until the subsequent processing steps were successfully completed, then discarded. Material was concentrated by filtration onto 25 mm "AA" Millipore

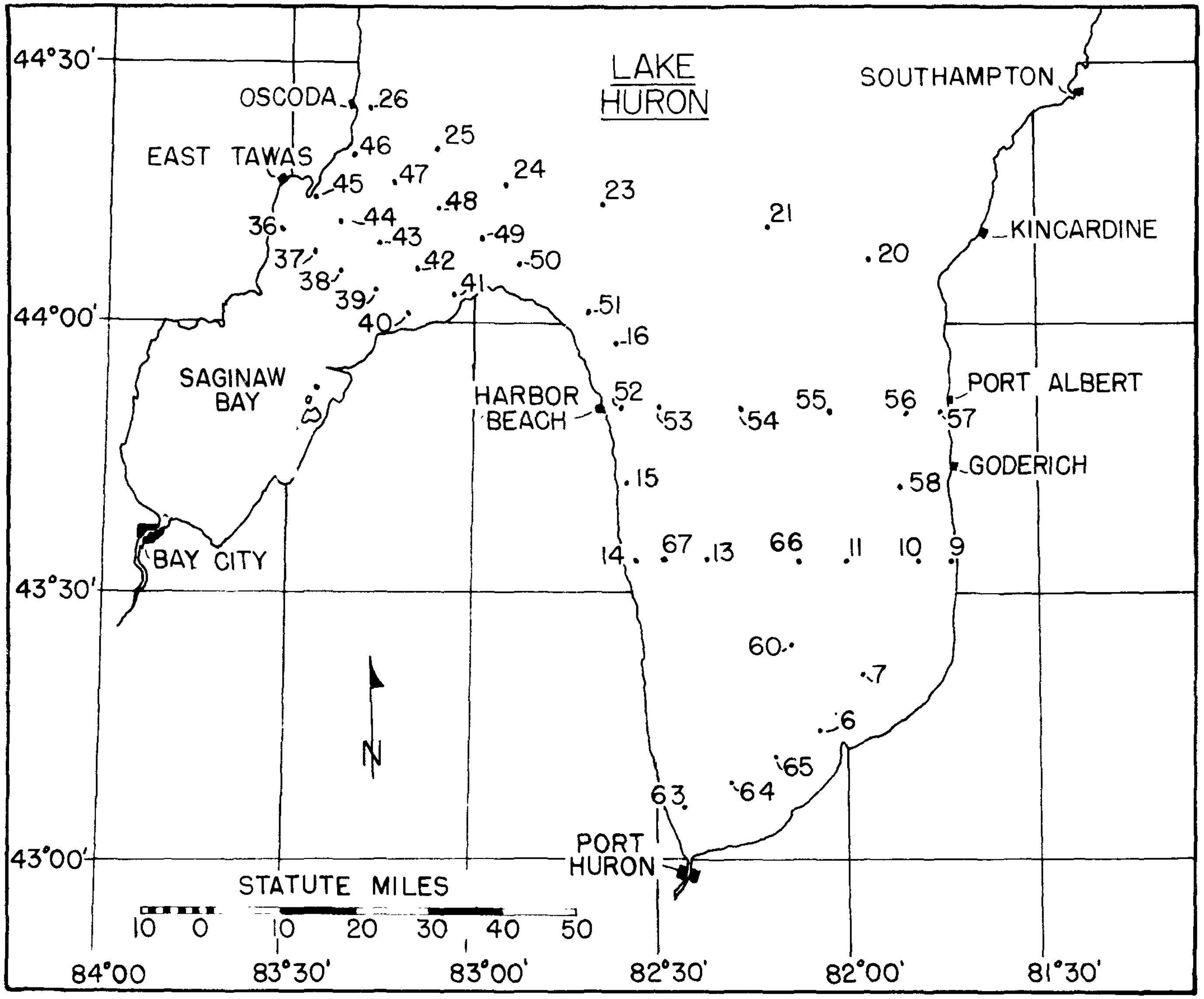


Figure 1. Sampling array, southern Lake Huron, 1974.

TABLE 1. SAMPLING SEQUENCE AND DEPTHS AT ALL STATIONS

Station No.	Sampling Depths	
Day 1		
63	1, 5	
64	1, 5, 10, 15	
65	1, 5, 10, 15	
06	1, 5, 10	
07	1, 5, 10, 15, 20, 25	
09	1, 5	
10	1, 5, 10, 15	
11	1, 5, 10, 15, 20, 30, 40, 50, 60	
58	1, 5, 10, 15, 20, 30	# bottles: 40
Day 2		
57	1, 5	
56	1, 5, 10, 15, 20	
20	1, 5, 10, 15, 20, 30, 40	
21	1, 5, 10, 15, 20, 30, 40, 60, 80, 90	
23	1, 5, 10, 15, 20, 30, 40, 50	
24	1, 5, 10, 15, 20, 30, 40, 50, 60	
25	1, 5, 10, 15, 20, 30, 40, 50	
26	1, 5	# bottles: 51
Day 3		
36	1, 5	
37	1, 5, 10, 15	
38	1, 5, 10	
39	1, 5, 10	
40	1, 5	
41	1, 5, 10	
42	1, 5, 10, 15, 20	
43	1, 5, 10, 15, 20, 25	
44	1, 5, 10, 15, 20	
47	1, 5, 10, 15, 20, 30, 40	
46	1, 5	
45	1, 5, 10	# bottles: 45
Day 4		
48	1, 5, 10, 15, 20, 30, 40	
49	1, 5, 10, 15, 20, 30, 40	
50	1, 5, 10, 15	

(continued)

TABLE 1 (continued).

Station No. Day 1	Sampling Depths	
Day 4		
51	1, 5, 10, 15, 20, 30	
16	1, 5, 10, 15, 20, 30	
55	1, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80	
54	1, 5, 10, 15, 20, 30, 40, 50, 60	
53	1, 5, 10, 15, 20, 30, 40	
52	1, 5, 10, 15, 20	# bottles: 62
Day 5		
15	1, 5	
14	1, 5, 10	
67	1, 5, 10, 15, 20, 25	
13	1, 5, 10, 15, 20, 25	
66	1, 5, 10, 15, 20, 30, 40, 50	
60	1, 5, 10, 15, 20, 30, 40	# bottles: 32

filters, partially dehydrated through an ethanol series and embedded in clove oil. Prepared filters were mounted on 50 x 75-mm glass slides and covered with a 43 x 50-mm, # 1 thickness cover glass. Preparations were kept in a horizontal position and allowed to dry for approximately 2 weeks, during which time the embedding medium lost through volatilization was periodically replaced. The edges of the cover glass were then sealed with paraffin.

Preparations were analyzed by visual counts of phytoplankton cells present using a Leitz "Ortholux" microscope fitted with fluorite immersion objectives with a nominal Numerical Aperature of 1.32. Magnification used for identification and enumeration was approximately 1200 X. Population estimates given are the averaged counts from two 10 mm radial strips, corrected for volume filtered. Effective filtration diameter in the filtration apparatus used is 20 mm.

DATA HANDLING AND PRESENTATION

Reduction and meaningful presentation of the amount of taxonomic data generated by a project of this size present certain problems which are difficult to resolve in a manner completely satisfactory to all potential users. We would like to outline here our approach to this problem and to specify the formats and stages of reduction of the available data.

Raw counts from bench sheets were encoded in computer compatible format on punched cards. Initial card input was machine verified against a master taxonomic code file and card listings were hand verified against bench sheets. After any necessary corrections were made, these cards served as a primary data archive.

First-cut data reduction is in the format shown in Table 2. Summaries include estimates of absolute frequency and estimates of associated error and an estimate of relative abundance for all taxonomic categories. The same information is also provided for data summarized at the level of major physiological division. Assemblage parameters calculated include an estimate of total phytoplankton abundance and a measure of error associated with the estimate, an estimate of assemblage diversity (H), and an estimate of the evenness component of the calculated diversity. These semi-reduced data were reproduced as hard copy for final verification, then reduced to tape file storage. Subsequent data reduction and manipulation routines operated on these files.

Since the semi-reduced data are too extensive to be economically reproduced in standard report format, but may be of interest to other investigators, we have transmitted copies (on tape file) to the project officer and copies can be obtained from that source. Permanent files are also maintained at this institution.

Data display in the results section following is in three main formats:

1. A complete listing of the taxa encountered during the study is given. This summarization includes the number of occurrences of each

TABLE 2. FORMAT OF PHYTOPLANKTON DATA REDUCTION

EPA Southern Lake Huron 05 June 1974

project:	EPA	survey number:	3	slide ID:	453
year:	1974	julian day:	156 (5 Jun)	sample number:	453
station:	21	depth:	5.0 m	volume filtered:	50. ml
latitude:	44° 12.0'	longitude:	82° 13.0'	filter diameter:	2.00 cm
number of cells counted:	289	volume of water scanned:	0.477 ml	field width:	0.0150 cm
				number of half-rows:	2
diversity:	2.743	evenness:	0.832		

division	number of species	cells/ml	SE	CV	% pop.
Cyanophyta (blue-green algae) . .	0	0.0	0.0	****	0.0
Chlorophyta (green algae)	1	25.1	25.1	1.00	4.152
Bacillariophyta (diatoms)	23	534.1	23.0	0.04	88.235
Chrysophyta (chrysophytes). . . .	0	0.0	0.0	****	0.0
Cryptophyta (cryptomonads). . . .	2	16.8	0.0	0.0	2.768
Pyrrophyta (dinoflagellates). . .	0	0.0	0.0	****	0.0
other	0	0.0	0.0	****	0.0
undetermined.	1	29.3	4.2	0.14	4.844
total	27	605.3	6.3	0.01	100.000

species name	cells/ml	SE	CV	% pop.	species code	type code	half-row counts (1)	(2)	(3)	(4)	(5)	(6)
Tabellaria fenestrata	106.8	31.4	0.29	17.647	TAFENEST	DIP1	33	18				
Synedra filiformis.	85.9	2.1	0.02	14.187	SYFILIFO	DIP1	20	21				
Asterionella formosa.	71.2	54.5	0.76	11.765	ASFORMOS	DIP1	4	30				
Cyclotella stelligera	37.7	16.8	0.44	6.228	CYSTELLI	DIR1	13	5				
Melosira islandica.	35.6	18.8	0.53	5.882	MEISLAND	DIR1	13	4				
Rhizosolenia gracilis	33.5	12.6	0.37	5.536	RHGRACIL	DIR1	5	11				
Undetermined flagellate spp..	29.3	4.2	0.14	4.844	FLSPP	UNS3	8	6				
Cyclotella ocellata	27.2	6.3	0.23	4.498	CYOCELLA	DIR1	5	8				
Oocystis questionable spp..	25.1	25.1	1.00	4.152	OOSPP	GRC3	12	0				
Tabellaria flocculosa var. linearis	25.1	8.4	0.33	4.152	TAFLOCVL	DIP1	8	4				
Fragilaria intermedia var. fallax	23.0	14.7	0.64	3.806	FRINTFVF	DIP1	2	9				
Rhodomonas minuta var. nannoplanctica . . .	14.7	2.1	0.14	2.422	RDMINUVN	CRS1	4	3				
Rhizosolenia eriensis	14.7	2.1	0.14	2.422	RHERIENS	DIR1	3	4				
Stephanodiscus minutus.	14.7	2.1	0.14	2.422	STMINUTU	DIR1	4	3				
Fragilaria crotonensis.	12.6	4.2	0.33	2.076	FRCROTON	DIP1	2	4				
Diatoma tenue var. pachycephala	10.5	6.3	0.60	1.730	DITENUVP	DIP1	4	1				
Nitzschia dissipata	8.4	0.0	0.0	1.384	NIDISSIP	DIP1	2	2				
Melosira distans var. alpigena.	6.3	6.3	1.00	1.038	MEDISTVA	DIR1	0	3				
Nitzschia linearis.	4.2	4.2	1.00	0.692	NILINEAR	DIP1	0	2				
Nitzschia questionable spp.	4.2	4.2	1.00	0.692	NISPP	DIP3	2	0				
Cryptomonas ovata	2.1	2.1	1.00	0.346	CROVATA	CRS1	0	1				
Cyclotella spp.	2.1	2.1	1.00	0.346	CYSPP	DIR2	1	0				
Fragilaria vaucheriae	2.1	2.1	1.00	0.346	FRVAUCHE	DIP1	0	1				
Stephanodiscus tenuis	2.1	2.1	1.00	0.346	STTENUIS	DIR1	0	1				
Stephanodiscus transilvanicus	2.1	2.1	1.00	0.346	STTRANSI	DIR1	0	1				
Synedra ostenfeldii	2.1	2.1	1.00	0.346	SYOSTENF	DIP1	1	0				
Synedra ulna var. chaseana.	2.1	2.1	1.00	0.346	SYULNAVC	DIP1	0	1				

and the maximum absolute and relative abundance found in any sample.

2. Since one of the main objectives of this project was to assess the pattern of phytoplankton distribution in Southern Lake Huron, the distribution of many of the more quantitatively important taxa and major physiological groups have been plotted.
3. Finally, we have made a broad scale summarization of abundance of both total phytoplankton and some of the major groups according to the lake segmentation scheme proposed by the International Joint Commission (1976). The segmentation adopted by IJC is shown in Fig. 2. Because some of our stations fall on the Saginaw Bay side of the proposed Lake Huron segmentation, we have added an additional segment, designated as 7A on the figure, which furnishes comparison with conditions found near the mouth of Saginaw Bay.

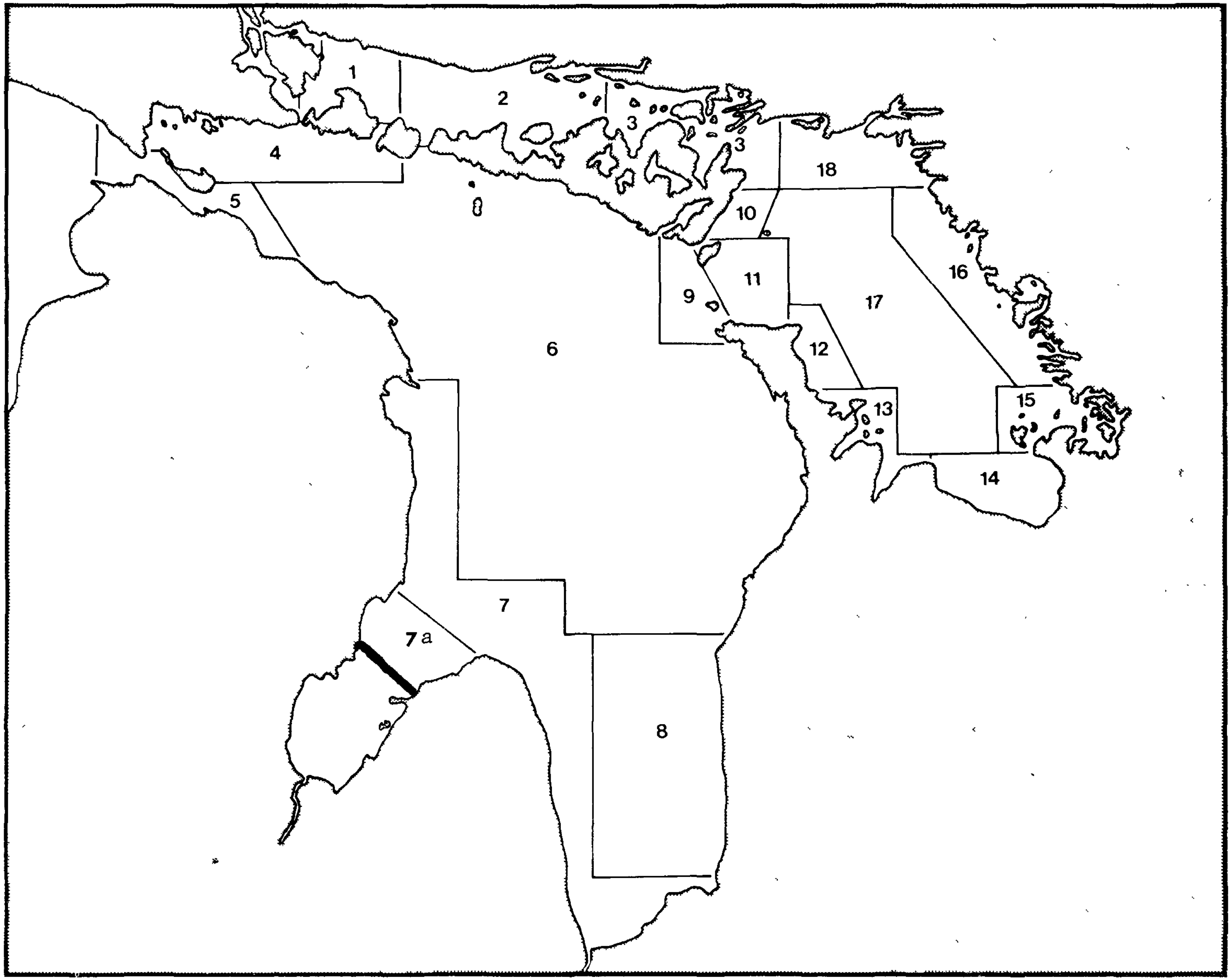


Figure 2. Segmentation scheme as recommended by the International Joint Commission.

RESULTS

OVERALL AVERAGES

The overall abundance of phytoplankton at all stations in all cruises sampled during the study is shown in Table 3. As will be noted from Table 3, total average phytoplankton abundance within the area is moderate. However there is an extreme range in the phytoplankton concentrations which were encountered during the study. Of the major physiological groups present in the phytoplankton, diatoms are most abundant in southern Lake Huron and the green and blue-green algae comprise a lesser but still important part of the flora. Chrysophytes and cryptomonads, although present at nearly all stations sampled, are on the average minor components of the flora. Dinoflagellates constitute a very minor portion of the flora in terms of cell numbers, however due to the very large cells of some species, they may be an important part of the biomass. Euglenoids, although present, comprise a very minor fraction of the phytoplankton standing stock. In Table 3, an undetermined category is indicated. This category is comprised almost entirely of microflagellates which cannot be satisfactorily determined under the light microscope. Many of these organisms probably belong to the algal division Haptophyta (Stoermer and Sicko-Goad, 1977; Sicko-Goad, Stoermer, and Ladewski, 1977).

SEGMENT AVERAGES

In order to inspect regional differences during the reference study, the offshore waters of Lake Huron have been segmented according to the scheme shown in Fig. 2 (Smith et al. 1976). For the purposes of this study, an additional segment labeled segment 7A in Fig. 2 has been designated which includes the waters in the Lake Huron-Saginaw Bay interface. A compilation of the stations sampled during this study according to their segment position is given in Table 4. The yearly average abundance of phytoplankton belonging to the major physiological divisions is given in Table 5. It will be noted that the average standing crop in segment 7A is significantly higher than in the other segments. Segments 7 and 8 have comparable standing crop levels, while segment 6 is significantly lower in phytoplankton abundance. In the case of the major physiological groups, the diatoms, the blue-greens, and particularly the green algae are significantly more abundant in segment 7A than in the other segments. The same trend is exhibited by the minor groups with the exception of the cryptomonads which are slightly more abundant in segment 6. As will be seen later, differences at the major group level are reflective of even larger differences at the specific population level.

The relative abundance of the major physiological groups by segment is shown in Table 6. On average, diatoms are the most important component of the flora, with similar relative abundances in segments 6 and 8, somewhat reduced

TABLE 3. STATISTICAL SUMMARY OF SOUTHERN LAKE HURON PHYTOPLANKTON CRUISES 1-8 AT 5 METER DEPTH

AVE. CELLS/ML 2100.7
RANGE 38221.0 - 293.22
STANDARD DEVIATION 3165.3
MEAN DIVERSITY 2.2923

	Ave. Relative Abundance %	Ave. Cells/ml
Blue-greens	13.46	381.39
Greens	20.17	777.08
Diatoms	55.72	790.52
Chrysophytes	4.72	75.72
Cryptomonads	1.34	16.36
Dinoflagellates	.10	1.31
Euglenoids	.00	.03
Undetermined	4.46	58.18

TABLE 4. SOUTHERN LAKE HURON STATIONS GROUPED ACCORDING TO THE SEGMENTATION SCHEME

Segment	6	7a	7	8
	20	36	6	7
	21	37	13	9
		38	14	10
		39	15	11
		40	16	54
		41	23	55
		42	24	56
		43	25	57
		44	26	58
		45	46	60
			47	66
			48	
			49	
			50	
			51	
			52	
			53	
			63	
			64	
			65	
			67	

TABLE 5. YEARLY AVERAGE ABSOLUTE ABUNDANCE (CELLS/ML) OF ALGAL DIVISIONS BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	BLUE-GREENS	GREENS	DIATOMS	CHRYSOPHYTES	CRYPTOMONADS	DINOFLAGELLATES	UNDETERMINED
6	72.04	222.00	491.55	19.47	26.18	.63	73.31
7a	695.37	2130.48	969.75	120.74	19.43	1.23	83.80
7	294.34	382.12	753.82	74.50	15.47	1.91	51.97
8	214.46	134.31	759.14	34.85	12.49	1.06	41.23

TABLE 6. YEARLY AVERAGE RELATIVE ABUNDANCE (%) OF ALGAL DIVISIONS BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	BLUE-GREENS	GREENS	DIATOMS	CHRYSOPHYTES	CHYPTOMONADS	DINOFLAGELLATES	UNDETERMINED
6	3.19	16.67	66.91	2.74	3.28	.09	7.08
7a	15.01	32.02	41.47	6.05	1.21	.12	4.07
7	13.41	15.88	58.71	5.00	.97	.09	4.43
8	11.44	10.92	67.41	2.73	1.68	.11	4.52

relative abundance in segment 7, and comprise less than 50 percent of the total flora only in segment 7A. Green algae are significantly more abundant in segment 7A than in the other segments. On the other hand, the relative abundance of blue-greens is similar in segments 7, 7A, and 8, but considerably lower in segment 6. Unlike these groups, the cryptomonads and undetermined microflagellates tend to be relatively more abundant in segment 6 than in the other segments.

The seasonal trends of total phytoplankton abundance are shown in Fig. 3. Segment 6 is characterized by having relatively low and stable phytoplankton assemblage abundance during most of the sampling period, with a slight peak during August. Unfortunately stations in this segment were not sampled during the April nor the October and November cruises. The general pattern of phytoplankton abundance is similar in segment 7, although cell densities are considerably larger, particularly during the fall maximum. In segment 8, abundance is on the average somewhat less than in segment 7, and population densities tend to be more stable with a slightly increased spring peak and a markedly decreased fall peak. The situation in segment 7A is markedly different than in the other segments. There is a generally rising trend in phytoplankton density throughout the period sampled with peaks in late May, July, and October. Phytoplankton densities in this segment are significantly larger in all sampling periods than in the other segments. The numerical averages of phytoplankton cell densities found in each segment by cruise are shown in Table 7 and the average diversities of the phytoplankton assemblages at the stations sampled during each cruise is shown in Table 8.

The seasonal trends in major physiological groups are shown in Fig. 4. In segment 6 diatoms are dominant until July, when they are replaced to a significant extent by green and blue-green algae. In segment 7 there is a definite bimodal pattern in diatom abundance with peaks occurring in June and August separated by an assemblage minimum in July. Green algae, on the other hand, undergo a slight increase in average density in June, then reach minimum abundance in July before reaching their seasonal maximum in October. The blue-green algae only reach significant levels of abundance after June, and increase to their seasonal maximum in October together with the green algae. In segment 8, abundance of diatoms is somewhat more erratic, although a definite spring peak is present. The overall abundance of green algae in this segment is less than in segment 7, with only weak population peaks in June and August. Similar to segment 7, the blue-green algae first reach appreciable abundance in June and reach their seasonal population maximum in October. In this segment, the blue-greens attain substantially larger abundance than do the green algae. Segment 7A presents a considerably different picture. Diatom populations exhibit a pronounced bimodal distribution with peaks in May and November with a marked population minimum in July. The green algae are much more abundant in this segment than in the other segments, and show a considerably different pattern of seasonal succession. The populations rise from very low abundances in April to maxima in late May. These are followed by pronounced minima in June. Green algae then increase markedly in abundance to maximum numbers in July, and remain the dominant element of the flora throughout the rest of the season sampled. In this segment the blue-green algae comprise an appreciable part of the phytoplankton assemblage during all of the sampling cruises. However, they are a relatively minor part of the

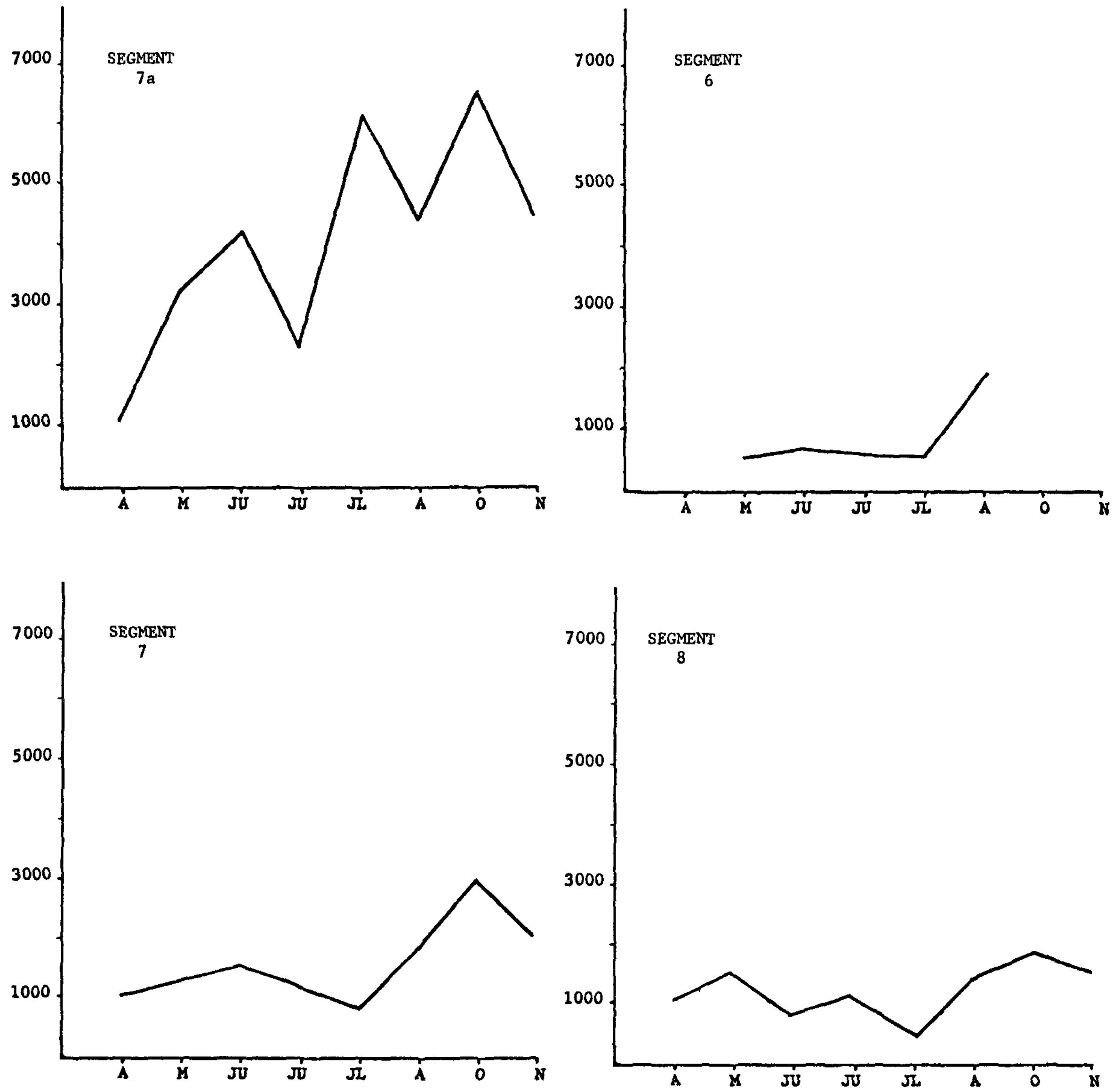


Figure 3. Seasonal trends of total phytoplankton abundance (cells/ml) by segment.

TABLE 7. PHYTOPLANKTON STANDING CROP BY SEGMENT.
MEAN VALUES EXPRESSED AS CELLS/ML
FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave. Total Cells/ml	1	2	3	4	5	6	7	8
6	691.58		670.2	873.4	706.9	686.9	1520.5		
7a	3888.13	1070.9	3169.0	4173.3	2265.9	6150.8	4422.1	6404.0	4519.9
7	1573.87	1014.4	1305.5	1626.7	1187.7	700.1	1815.0	2925.5	2017.0
8	1200.25	1058.9	1417.6	810.1	1045.1	551.7	1364.2	1861.6	1492.7

TABLE 8. AVERAGE DIVERSITY OF PHYTOPLANKTON FOR CRUISES 1-8
AT 5 METER DEPTH BY SEGMENT

	Ave.	1	2	3	4	5	6	7	8
6	2.386		2.948	2.661	2.831	1.736	1.753		
7a	2.273	2.891	2.682	2.060	2.237	1.694	1.969	2.327	2.274
7	2.372	2.899	2.874	2.691	2.556	2.006	1.737	2.334	1.908
8	2.294	2.861	2.869	2.615	2.590	1.864	1.762	1.954	1.825

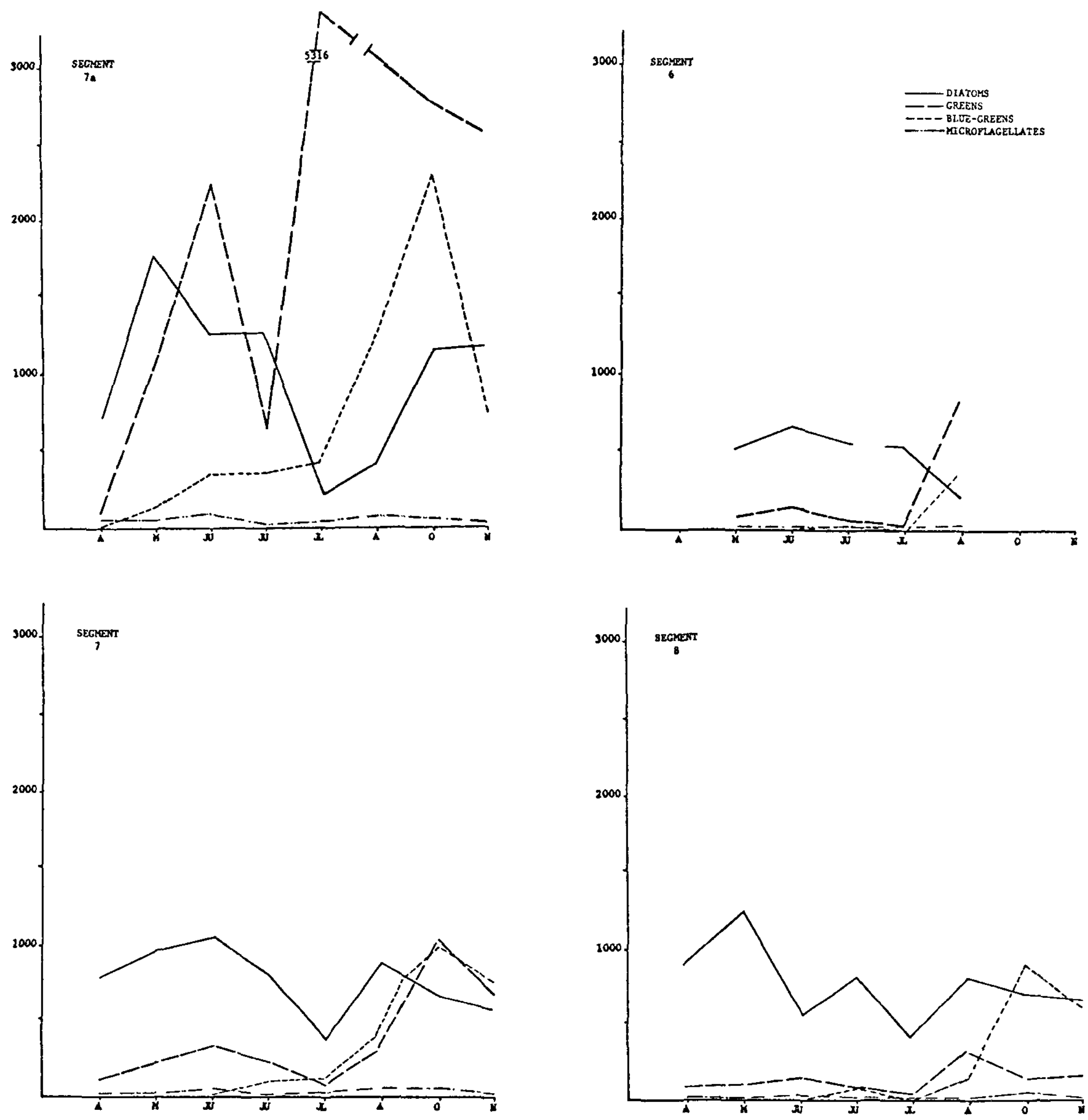


Figure 4. Seasonal abundance (cells/ml) trends of the major algal groups by segment.

total assemblage until July, when they begin a rise to maximum population densities in October. This seasonal peak is followed by a decline in abundance in November. Numerical averages of the absolute abundance of major phytoplankton groups by segment and by cruise are given in Tables 9-12. For comparison, the relative abundances of these groups are given in Tables 13-16.

THE PHYTOPLANKTON FLORA OF SOUTHERN LAKE HURON

A summary compilation of the taxa occurring in samples taken during this project is given in Appendix 1. In the appendix, taxa are arranged alphabetically by genus and by species under the major divisions. In many cases, taxa were encountered which could not be identified with known species. In some cases, this is due to the lack of critical life cycle stages or structures necessary for identification. In other cases, it may be due to the availablity of only a limited number of atypical specimens. There are undoubtedly a certain number of taxa which have not been previously described in the literature. Morphological entities which could only be identified at the generic level are listed with arbitrary numerical designations under the appropriate genera. Entities which could not be satisfactorily determined at the generic level are listed at the end of the divisional classification with some qualifying descriptor, i.e. undetermined blue-green filament; undetermined green individual. Unfortunately, in certain instances taxa which could not be satisfactorily identified are a major element of the phytoplankton flora at certain stations. This is particularly true in the case of the very small filamentous green alga designated as undetermined green filament number 5. As will be seen from the compilation, this taxon is the most abundant entity in terms of cell numbers found in several stations.

In the compilation, the total number of occurrences for each taxon is given, followed by the average population density and relative abundance of the species, which is followed by the maximum level of abundance and percentage of populations attained. A considerable proportion of the species noted during this study are probably pseudoplanktonic. For instance, 22 species of the genus *Achnanthes* were noted in the samples we examined. Most members of this genus are sessile in growth habit and they are probably only secondarily entrained into the plankton. The notable exception to this is *Achnanthes clevei* var. *rostrata* which often grows attached to some of the larger planktonic diatoms and thus, although sessile, is a normal component of phytoplankton assemblages in the Laurentian Great Lakes.

In the compilation, we have also noted the occurrence of particular life cycle stages for certain taxa. Examples of this would be auxospore formation in certain *Cyclotella* species which was quite common at certain of the stations sampled, and statospores formed by genus *Dinobryon*. In a limited number of cases we have also noted the occurrence of populations which are obviously morphologically abnormal and this information is included in the compilation.

TABLE 9. ABUNDANCE OF DIATOMS (CELLS/ML) FOR SOUTHERN LAKE HURON BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	491.55		523.60	640.88	549.78	539.31	204.20		
7a	969.75	763.76	1720.40	1200.50	1222.90	227.66	425.16	1093.70	1104.20
7	753.82	794.05	959.51	1054.50	774.53	389.56	852.22	642.88	565.29
8	759.14	896.10	1250.40	534.49	806.34	441.54	809.58	679.98	654.71

TABLE 10. ABUNDANCE OF GREEN ALGAE (CELLS/ML) FOR SOUTHERN LAKE HURON FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	222.00		73.30	126.71	58.643	20.94	830.43		
7a	2130.00	116.59	1094.70	2256.50	599.210	5316.60	2350.50	2758.50	2551.20
7	382.12	118.96	242.53	356.94	241.350	75.50	321.04	1040.80	659.83
8	134.31	84.37	102.10	153.31	90.060	39.41	330.53	120.78	153.94

TABLE 11. ABUNDANCE OF BLUE-GREEN ALGAE (CELLS/ML) FOR SOUTHERN LAKE HURON CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	72.04		0	1.04	4.19	0	355.00		
7a	695.37	1.75	166.85	358.98	359.19	433.54	1246.60	2272.00	724.03
7	294.34	1.26	5.17	8.38	106.51	117.09	402.32	1009.90	704.12
8	214.46	1.50	8.63	2.51	76.66	0	151.56	879.30	597.53

TABLE 12. ABUNDANCE OF CHRYSOPHYTES (CELLS/ML) FOR SOUTHERN LAKE HURON BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	19.47		27.23	5.24	29.32	29.32	6.28		
7a	120.74	75.75	92.85	83.57	24.71	91.53	330.50	210.49	56.55
7	74.50	37.00	45.38	70.41	24.93	54.55	183.71	166.16	13.86
8	34.85	26.63	18.06	30.37	29.95	22.09	14.28	114.84	22.62

TABLE 13. RELATIVE ABUNDANCE (%) OF DIATOMS IN SOUTHERN LAKE HURON BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	66.91		78.13	76.87	78.77	78.50	22.31		
7a	41.67	69.67	64.60	36.88	60.80	22.38	19.19	27.12	32.73
7	58.71	79.20	75.15	66.13	70.30	60.78	56.75	30.06	31.36
8	67.13	82.55	65.82	79.38	79.38	78.66	58.68	45.07	47.19

TABLE 14. RELATIVE ABUNDANCE (%) OF GREEN ALGAE IN SOUTHERN LAKE HURON BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	16.67		10.94	12.08	7.03	3.06	50.28		
7a	32.02	11.36	22.52	46.43	22.29	52.94	36.14	24.46	40.03
7	15.88	8.85	15.80	19.12	6.68	11.73	15.65	26.88	22.38
8	10.92	.15	10.57	18.80	8.40	7.63	24.99	6.53	10.40

TABLE 15. RELATIVE ABUNDANCE (%) OF BLUE-GREEN ALGAE IN SOUTHERN LAKE HURON BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

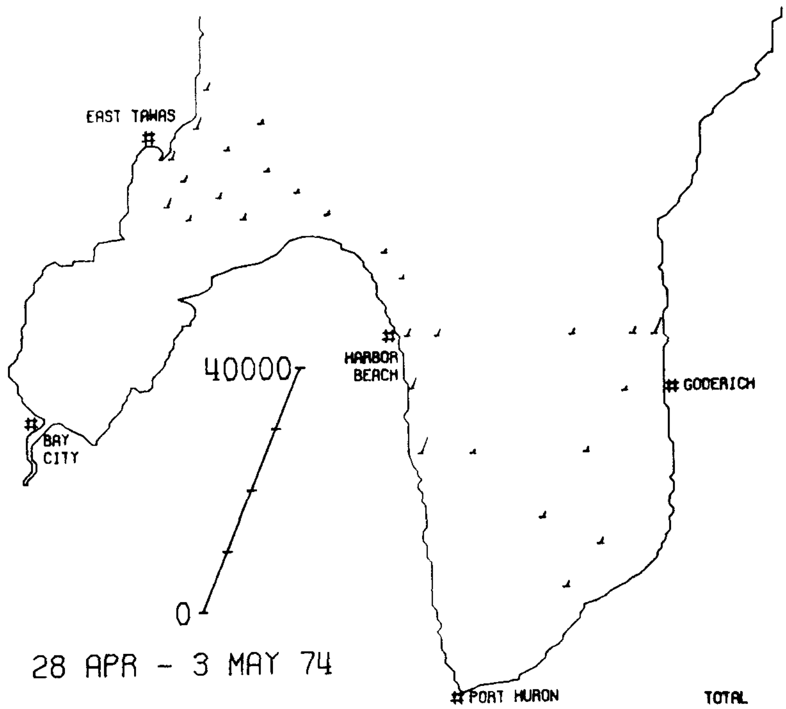
	Ave.	1	2	3	4	5	6	7	8
6	3.19		0	.02	.49	0	15.47		
7a	15.01	.15	4.03	5.86	10.79	12.62	26.54	38.07	22.07
7	13.21	.10	.39	.48	6.69	10.19	16.19	30.79	40.83
8	11.44	.15	1.10	.30	4.61	0	10.43	38.55	36.39

TABLE 16. RELATIVE ABUNDANCE (%) OF CHRYSOPHYTES IN SOUTHERN LAKE HURON BY SEGMENT FOR CRUISES 1-8 AT 5 METER DEPTH

	Ave.	1	2	3	4	5	6	7	8
6	2.74		4.06	.46	4.28	4.34	.56		
7a	6.10	7.34	4.59	2.79	2.41	5.90	15.57	8.50	1.69
7	5.00	4.02	4.22	4.80	2.67	6.94	8.17	8.50	.72
8	2.73	3.39	1.63	1.63	3.06	3.86	.95	5.76	1.52

REGIONAL AND SEASONAL TRENDS IN TOTAL PHYTOPLANKTON ABUNDANCE

In early May (Fig. 5A) phytoplankton density was rather low and uniform in all stations sampled. Slightly increased assemblage abundance was noted at stations nearer shore along both the U.S. and Canadian coasts. By mid-May (Fig. 5B) total phytoplankton abundance had increased markedly at stations in the Saginaw Bay interface and at stations south along the Michigan coast below Saginaw Bay. Slight increases in abundance were also noted along the Canadian shore north and south of Goderich. Phytoplankton abundance during this period was apparently affected by the spring excursion of the thermal bar, and the high population densities noted on the eastern Canadian coast are at least partially reflective of this condition. By early June (Fig. 5C) the effect of the spring thermal bar was largely dissipated and total phytoplankton abundance appeared to be controlled by nutrient input from Saginaw Bay. This is marked by very high phytoplankton densities in the Saginaw Bay interface and somewhat elevated densities southerly along the Michigan coast below the bay. By late June (Fig. 5D) total phytoplankton abundance had declined at most stations sampled. Markedly elevated phytoplankton abundance was noted only at stations in the southerly sector of the Saginaw Bay interface, with slightly elevated levels occurring at nearshore stations north and south of Tawas on the Michigan coast, and north and south of Goderich on the Canadian coast. By mid-July (Fig. 5E), phytoplankton abundance had further declined at most stations sampled. However, very high phytoplankton densities were noted at several stations in the southerly quadrant of the Saginaw Bay interface. During the late August cruise (Fig. 5F) a general increase in phytoplankton cell numbers was found throughout the area of study. It should be noted that this is not necessarily reflective of an increase in biomass of the phytoplankton, since most of the populations dominant during this period of the year are small-celled species. Phytoplankton assemblage distribution during this month is somewhat unusual in that highest cell densities were noted in the northerly sector of the Saginaw Bay interface. This appears to result from Saginaw Bay water being transported northward along the Michigan coast during this time period. In all other cases sampled, it appeared that the dominant transport was southerly along the Michigan coast. This situation appeared to prevail during the early October sampling (Fig. 5G) when particularly elevated phytoplankton cell densities were noted in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast in the vicinity of Harbor Beach. Slightly elevated phytoplankton numbers were found at nearshore stations above Tawas, but these were only on the order of 50 percent or less of the cell densities found in the southern sector. A similar situation apparently prevailed at the time of the mid-November sampling (Fig. 5H) when highest cell densities again occurred in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast. It should be noted that during all except the first cruise the pattern of phytoplankton distribution in southern Lake Huron is strongly dominated by the extremely high cell numbers found in the Saginaw Bay interface waters.



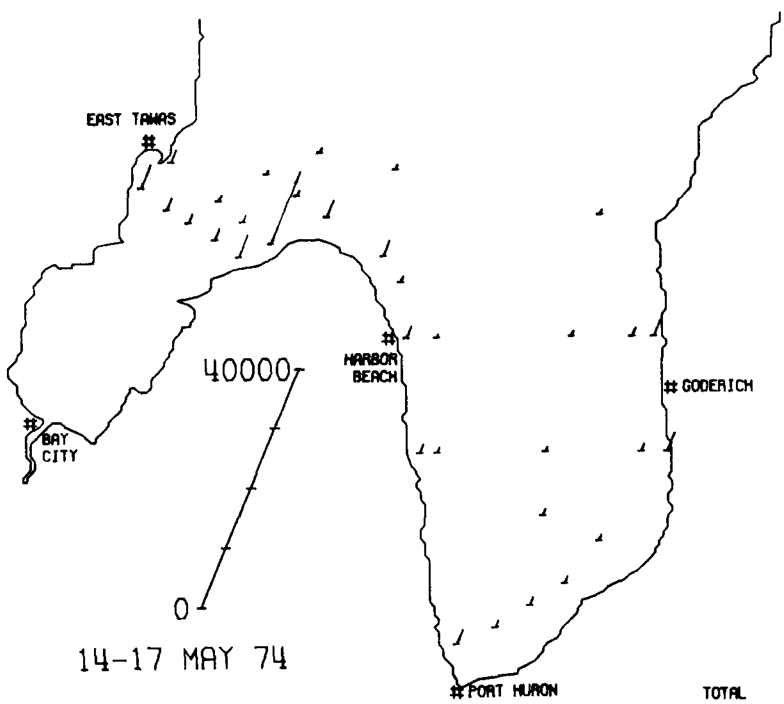
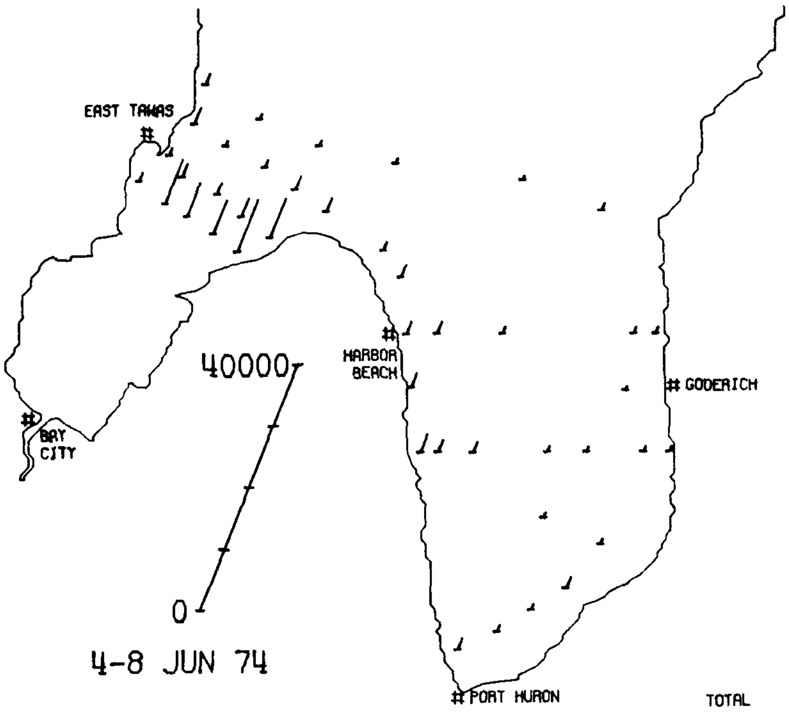
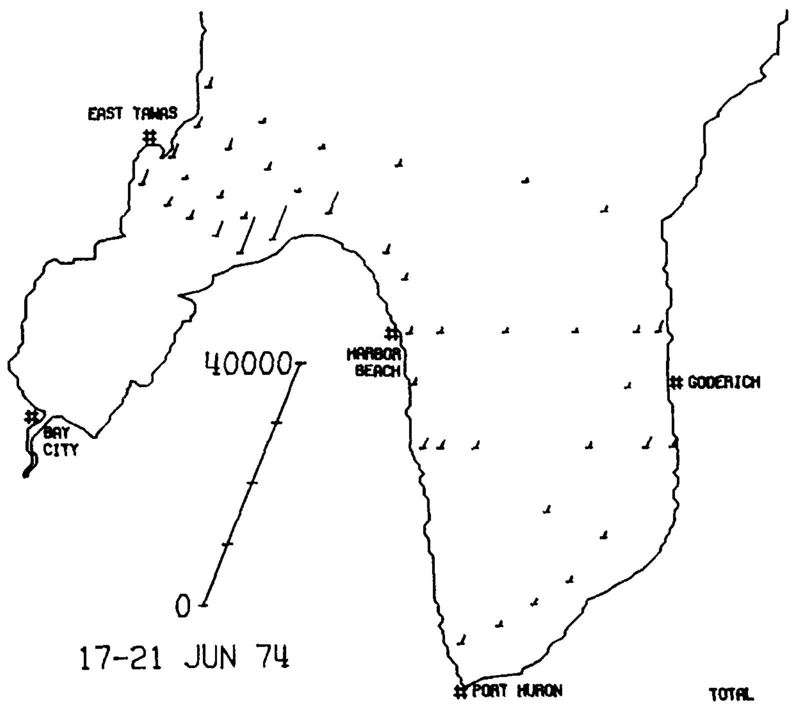


Figure 5. Seasonal distribution and abundance trends of the total phytoplankton assemblage (continued)





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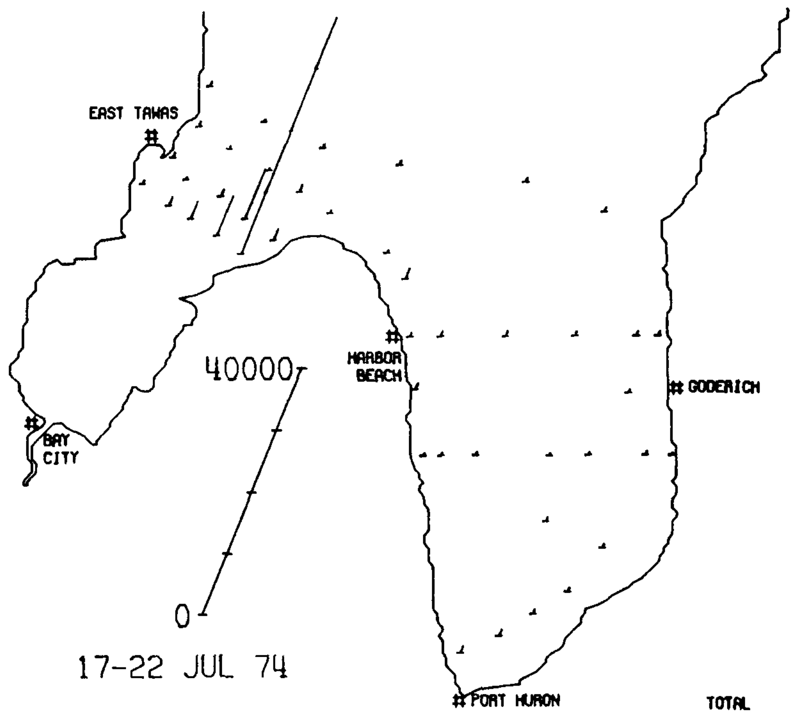

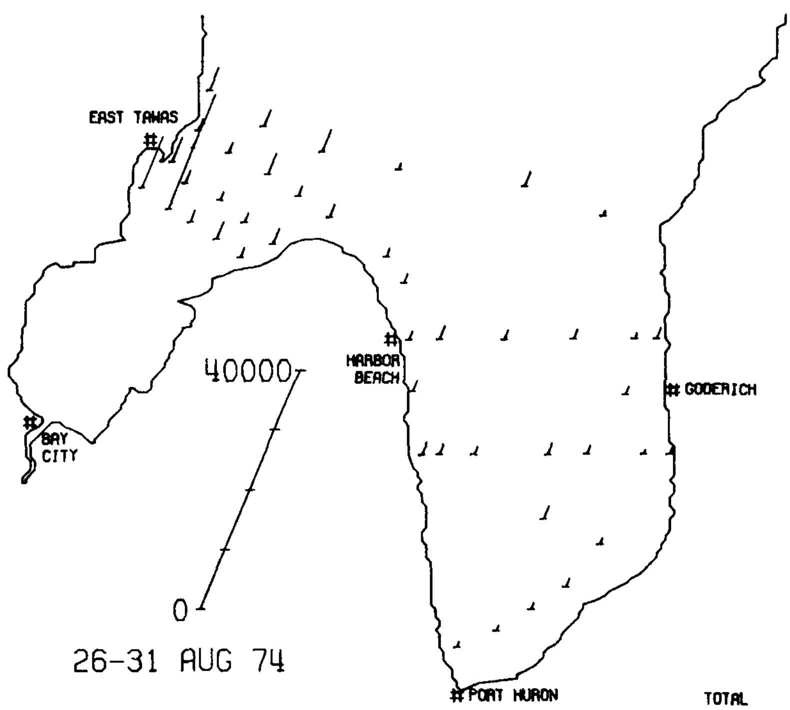

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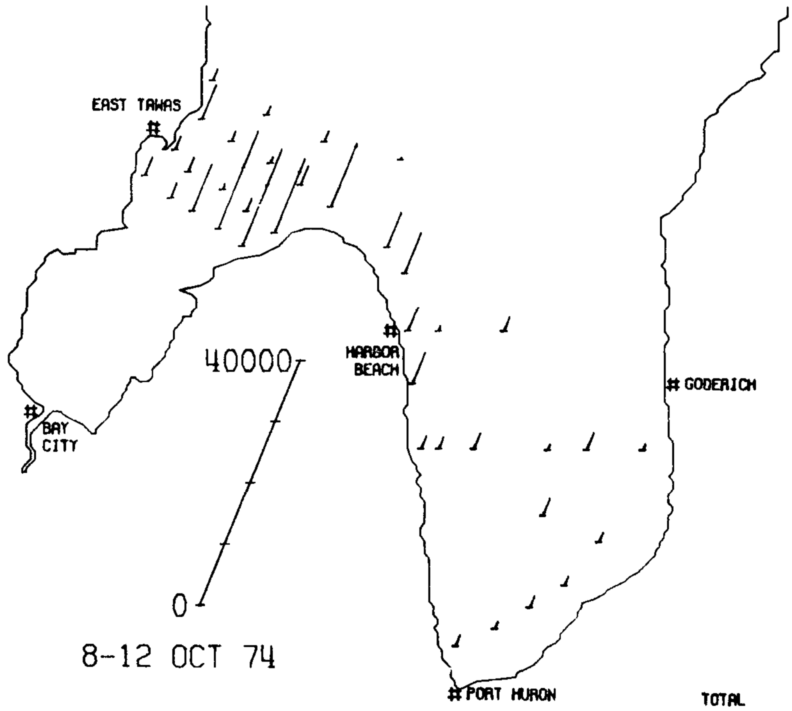


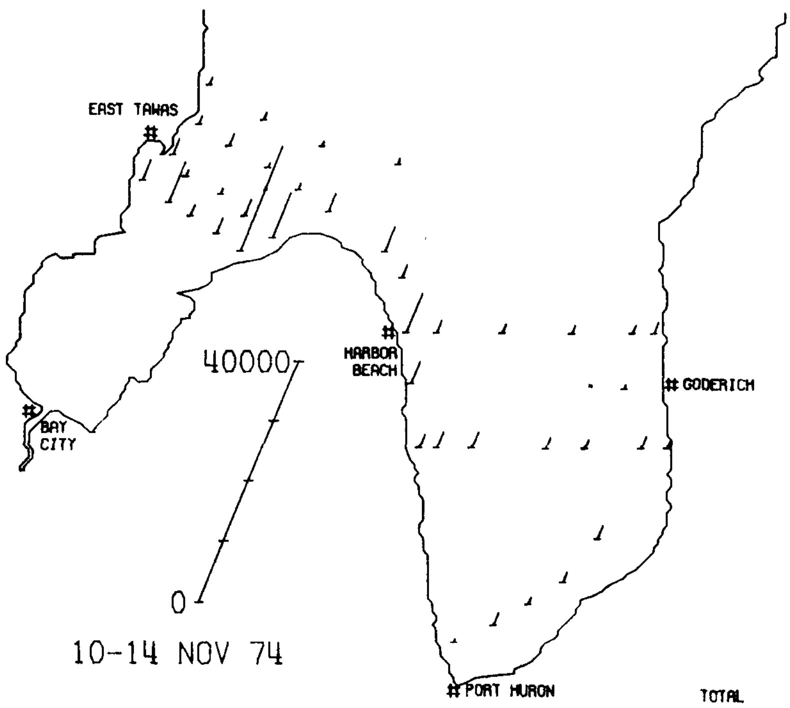


Figure 5. (continued)

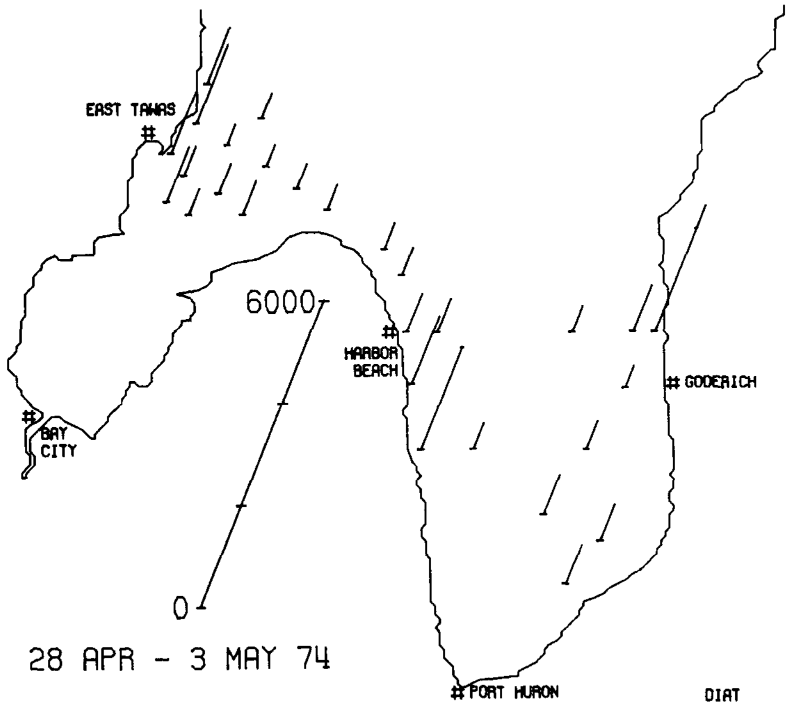
REGIONAL AND SEASONAL TRENDS IN ABUNDANCE OF MAJOR GROUPS AND SELECTED TAXA

Bacillariophyta

Although as will be seen later there are considerable differences in the distribution patterns of individual populations, diatoms are an important component of the phytoplankton assemblages at most stations during all seasons of the year. In early May (Fig. 6A) diatom abundance tends to be highest at nearshore stations, with little obvious pattern at the other stations sampled. This trend is enhanced in the mid-May sampling period (Fig. 6B) when highest diatom abundance is found at nearshore stations and in the Saginaw Bay interface waters. Even in the Saginaw Bay stations, however, there is a considerable increase in diatom abundance in stations nearest shore, particularly in the southern sector. This distribution pattern is probably controlled by the spring thermal bar. By early June (Fig. 6C) the thermal bar has ceased to be an appreciable factor, and diatom abundance is relatively uniform at the stations sampled, with slightly higher population densities in stations in the Saginaw Bay interface and southward along the Michigan coast. Essentially the same situation occurred during the mid-June sampling (Fig. 6D) although there was a visible increase in diatom abundance at nearshore stations along the Canadian shore. In mid-July (Fig. 6E) diatom abundance was low but relatively uniform at most stations sampled. Diatom abundance was strongly reduced in the central and southerly sectors of the Saginaw Bay interface and, to a lesser extent, southerly along the Michigan coast. Population densities similar to those at offshore stations and to nearshore stations on the Canadian coast were found at nearshore stations in the northern sector of the Saginaw Bay interface. By mid-August (Fig. 6F) diatom abundance had increased at most stations south of Saginaw Bay, although the increase was not as large in stations of the Saginaw Bay interface as at stations in the main body of Lake Huron. The exception to this trend of increasing diatom abundance was the relatively low numbers of this group found at stations in the extreme northern part of the sampling area. In early October (Fig. 6G) diatom abundance was quite uniform at stations sampled in the main part of Lake Huron, with slightly increased densities in the Saginaw Bay interface water, particularly at stations nearest shore. This trend towards increased diatom abundance at nearshore stations continued during the mid-November sampling period (Fig. 6H) when diatom abundance was considerably elevated at nearshore stations, possibly as a result of the development of the fall thermal bar situation.

Actinocyclus normanii fo. *subsalsa*

This is one of the species which has increased markedly in abundance in areas of the Great Lakes which have been greatly disturbed (Hohn, 1969). Its correct classification has been a source of considerable argument and confusion and it has been reported variously as *Coscinodiscus radiatus* by Hohn (1969), *C. rothii* var. *subsalsa*, and *C. subsalsa* by Stoermer and Yang (1969). Hasle (1977) has studied this taxon with the scanning electron microscope and confirmed Hustedt's (1957) contention that it should be included in the genus *Actinocyclus*. Its distribution in our study area is relatively limited. One isolated population was found in the Saginaw Bay interface waters in early May (Fig. 7A). Maximum abundance of this species occurred during the October sampling (Fig. 7B) when sizeable populations were found at a group of



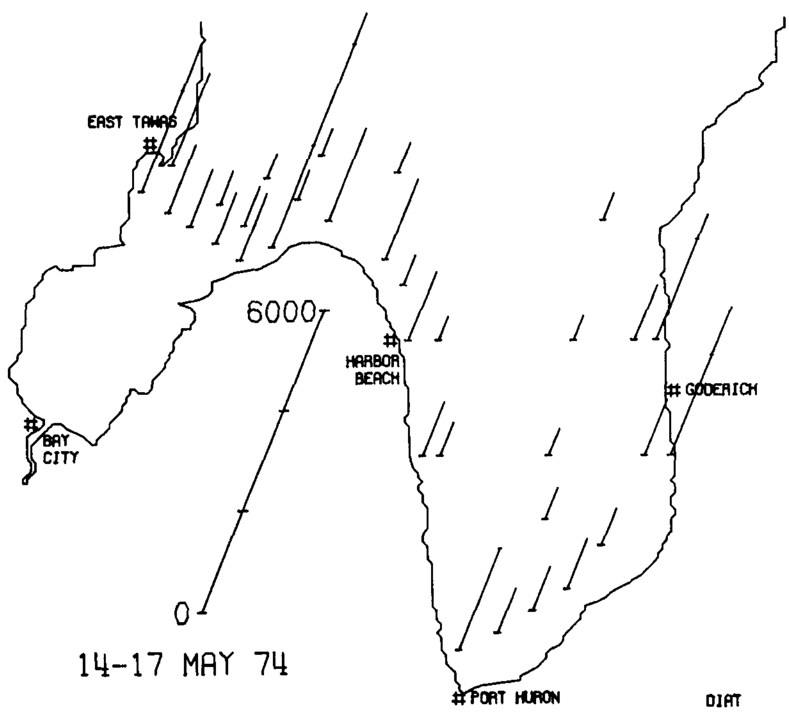
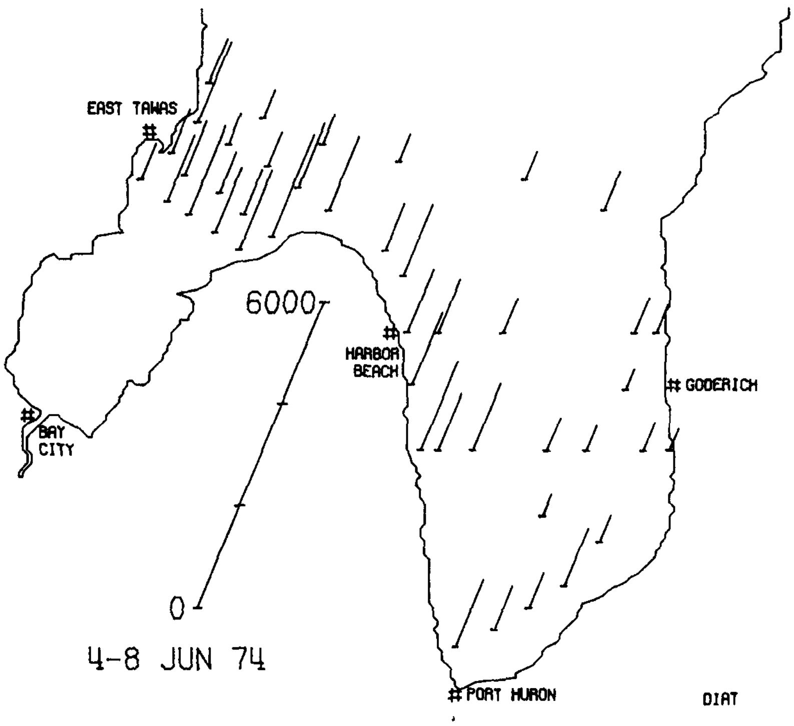
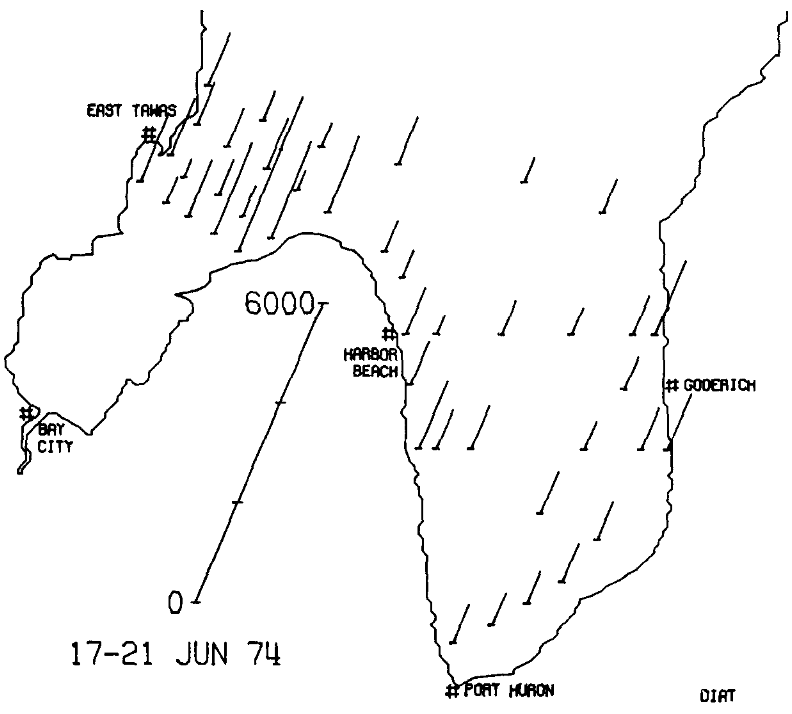


Figure 6. Seasonal abundance and distribution of diatoms. (continued)





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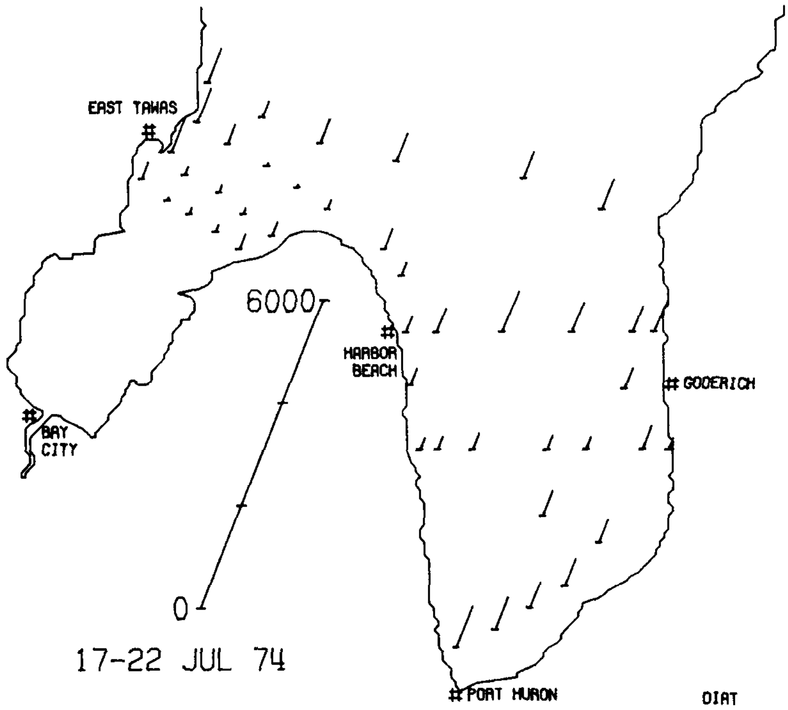

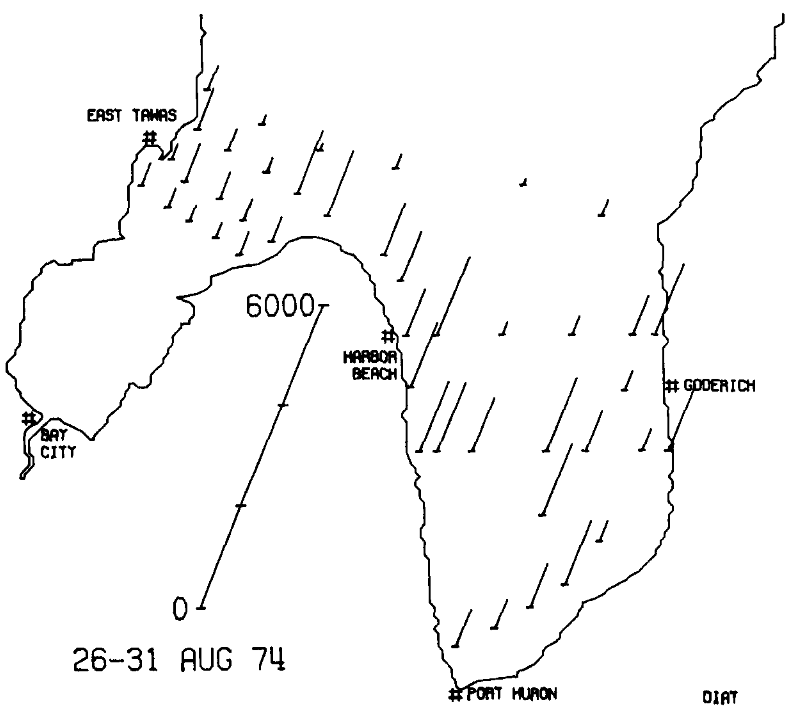

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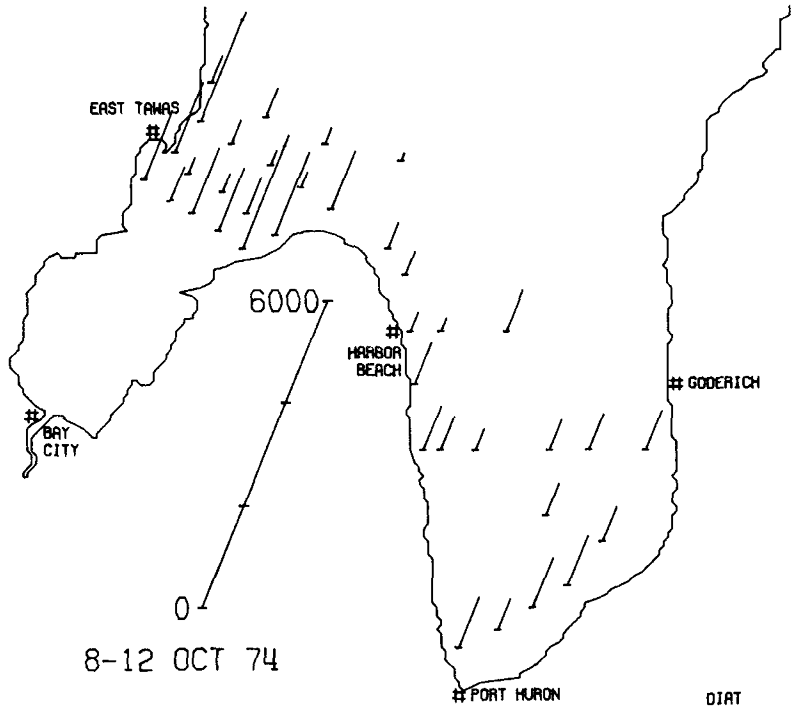

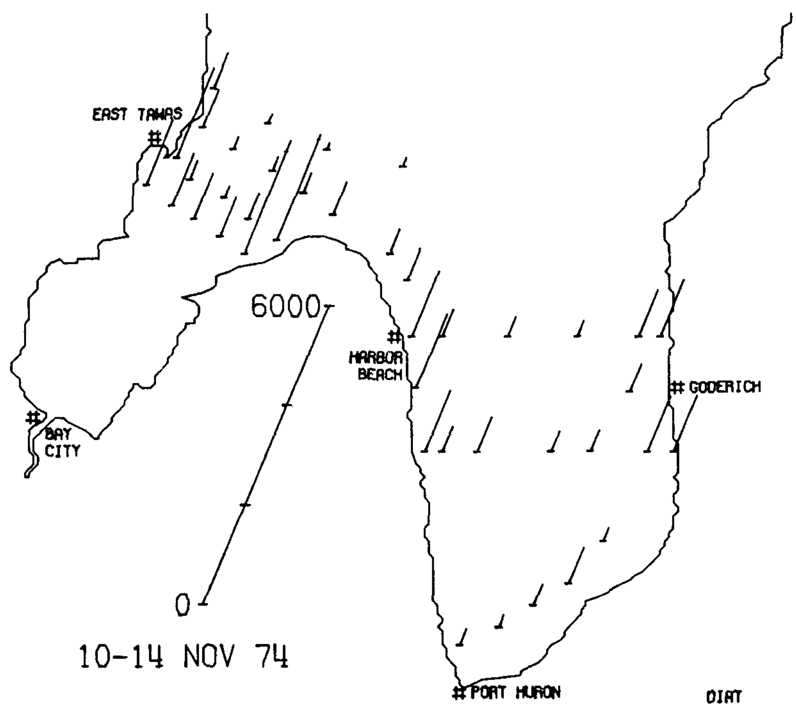

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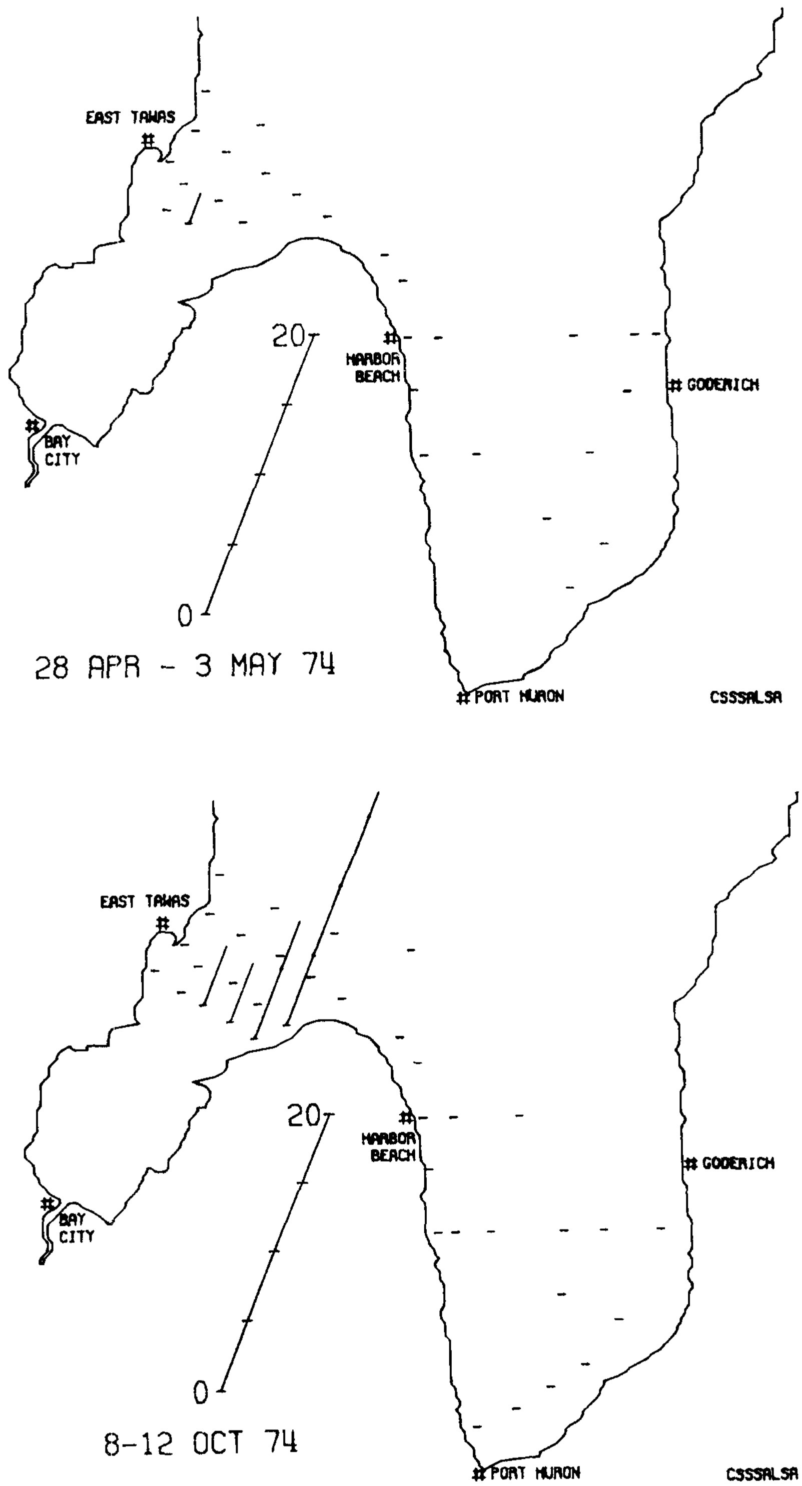
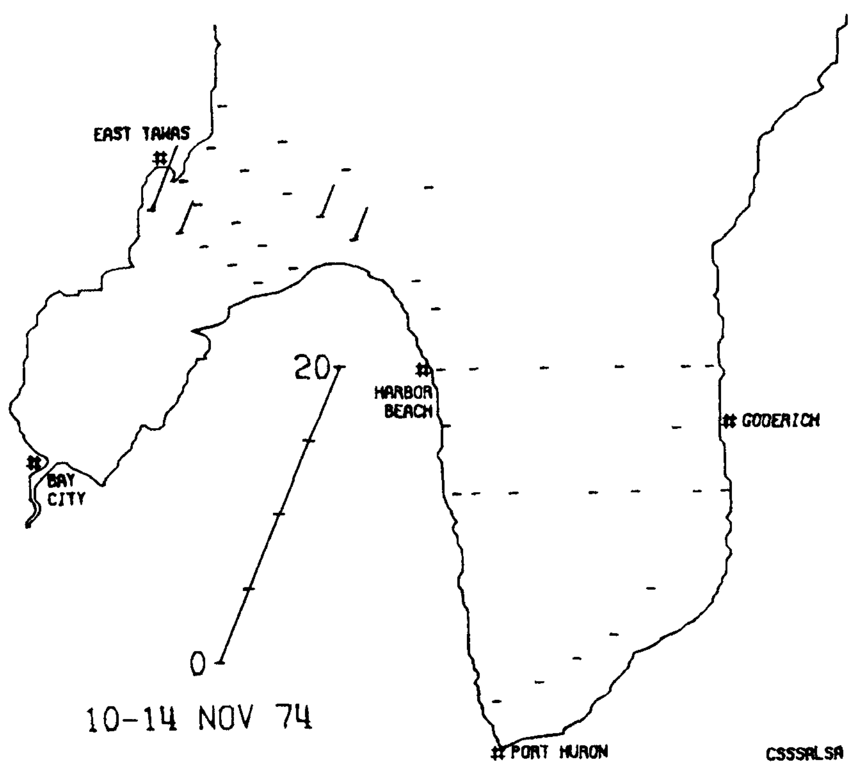


Figure 7. Distribution of Actinocyclus normanii fo. subsalsa. (continued)

stations in the southern sector of the Saginaw Bay interface. Small populations were also found during November (Fig. 7C) at stations in the Saginaw Bay interface. It reaches its greatest abundance in the inner bay during fall.

Asterionella formosa

This well-known and apparently eurytopic phytoplankton dominant occurs in all areas of the Great Lakes under conditions ranging from pristine to highly disturbed. Like many similar "weed" phytoplankton species, it does not appear to respond to other than extreme changes in environmental conditions. In southern Lake Huron its distribution is not as highly patterned as that of some more sensitive species. During early May (Fig. 8A) populations of this species were found at all stations sampled, but no pattern of distribution was evident. During mid-May (Fig. 8B) population levels tended to be highest at nearshore stations along the Canadian shore and, to a lesser extent, at the outer stations in the Saginaw Bay interface and southward along the U.S. shore. During early (Fig. 8C) and late (Fig. 8D) June the distribution of this species was rather erratic, with a slight tendency for higher population levels to occur along the U.S. shore in early June, and in the Saginaw Bay interface and southward along the U.S. shore in late June. In mid-July (Fig. 8E) populations were markedly reduced except at stations in the southern part of main Lake Huron, and in the northerly part of the Saginaw Bay interface. This trend continued in August (Fig. 8F) when A. formosa was absent, or



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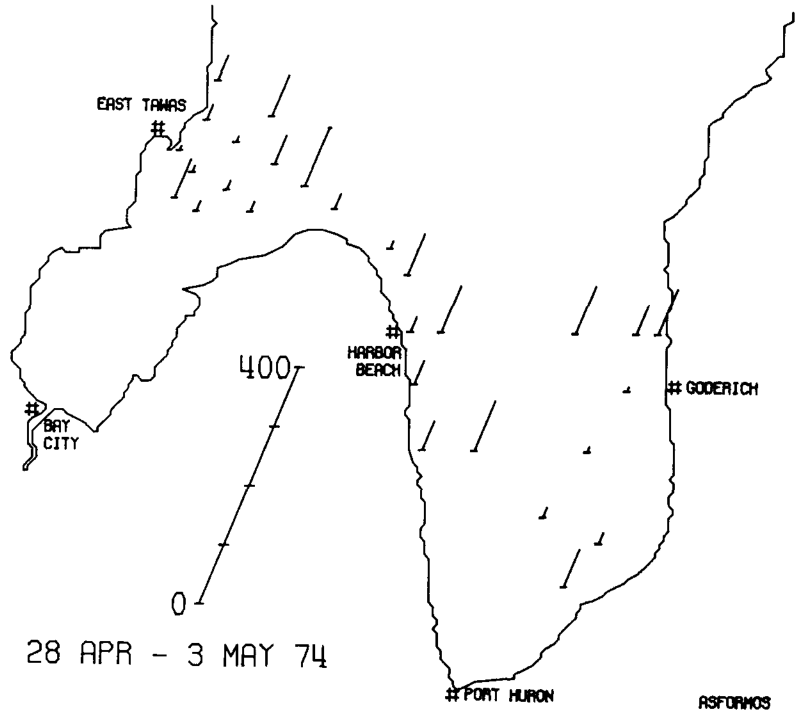


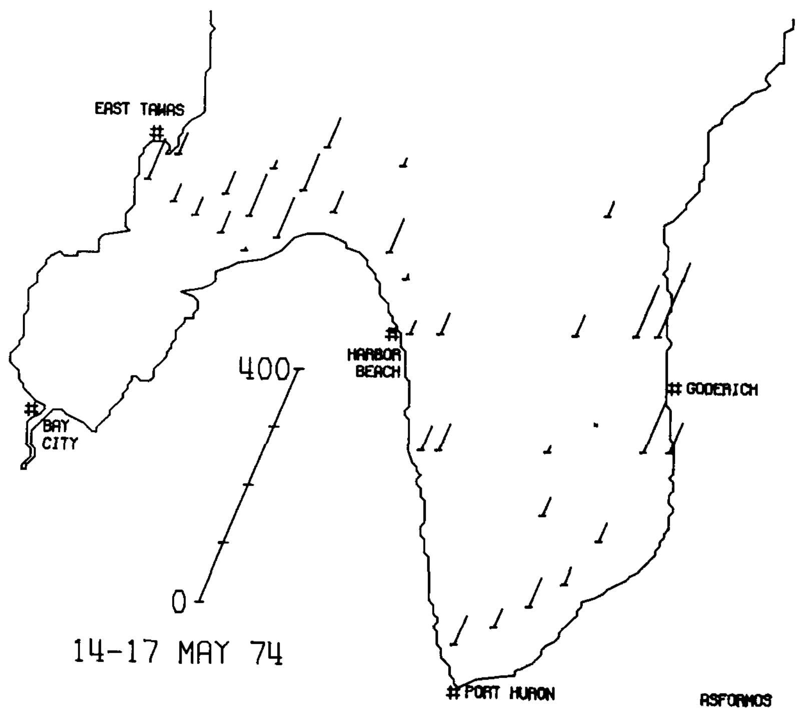
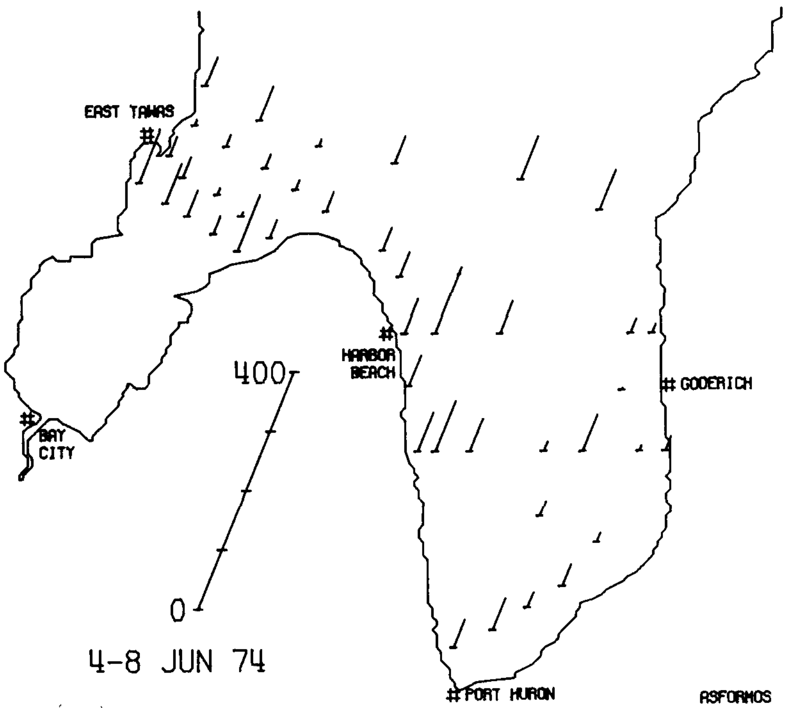


Figure 8. Distribution of *Asterionella formosa*. (continued)



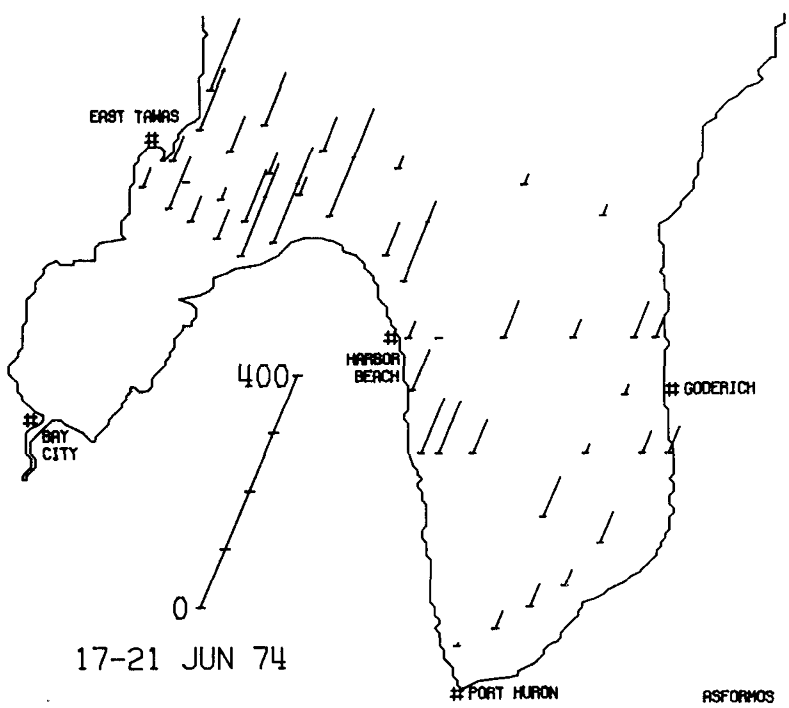
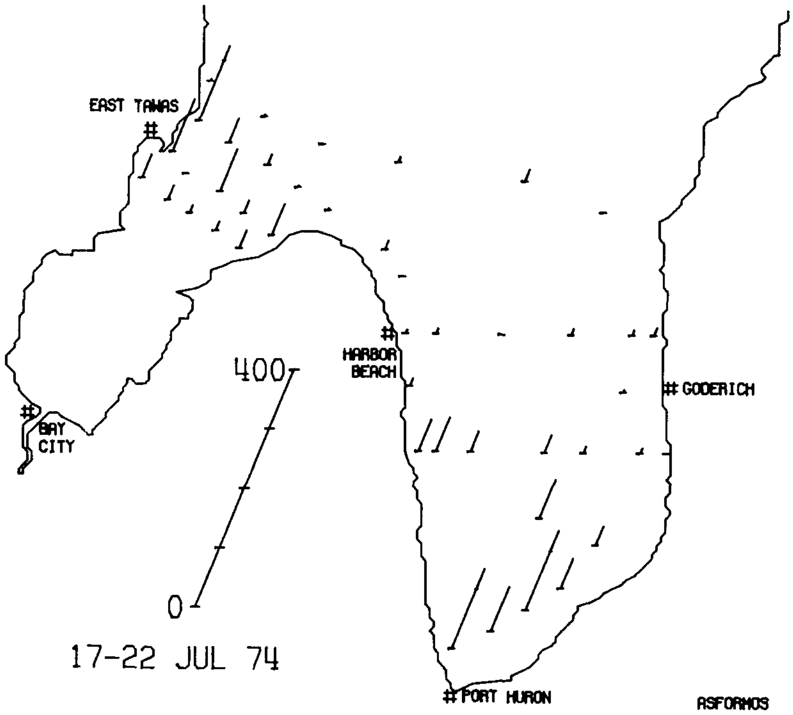


Figure 8. (continued)



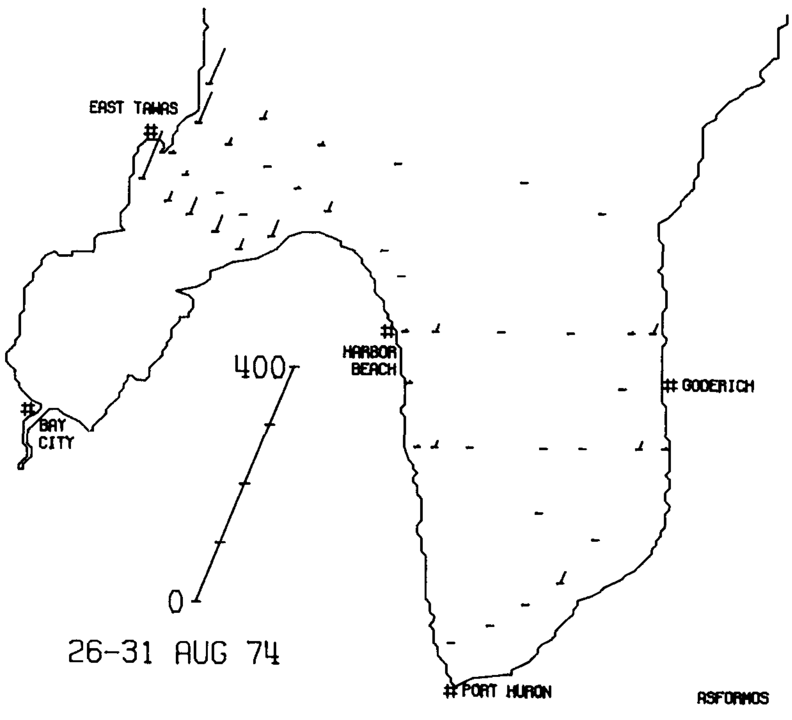


Figure 8. (continued)

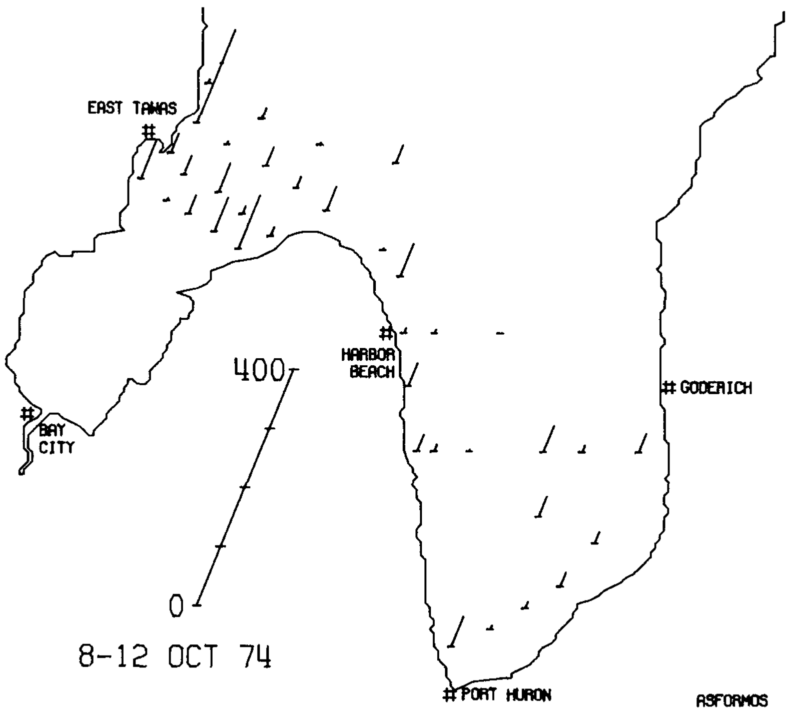
only present in minimal numbers, except at nearshore stations and stations in the Saginaw Bay interface. As is the case for several other taxa during this month, highest population levels were found at nearshore stations along the northerly coast of Saginaw Bay. This species generally increased in abundance by the October sampling period (Fig. 8G) with highest population levels again being found in the Saginaw Bay interface waters. This trend apparently continued into November (Fig. 8H) when maximum population levels were found in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast. Slightly increased abundance was also noted at nearshore stations along the Canadian shoreline.

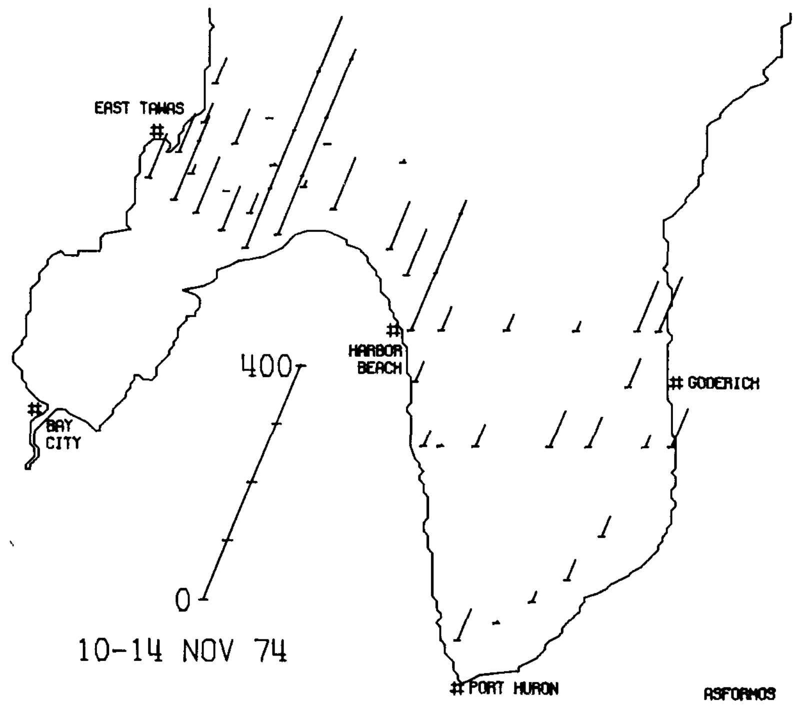
Cyclotella comensis

The seasonal distribution of this species in southern Lake Huron is quite unusual. Although small populations were detected during the April sampling (Fig. 9A) it achieved only very low population densities during May, June, and July (Figs. 9B-E). In August (Fig. 9F) it appeared in bloom quantities at most stations sampled. Population densities were reduced only at stations in the Saginaw Bay interface waters, particularly in the northern sector where other species' populations were generally highest, and conversely at stations in the far northern part of the sampling array where most other species' populations were found in their lowest abundance. Although somewhat less abundant during the October sampling period than it had been the previous month, substantial populations were still found at most stations sampled during October (Fig. 9G), with highest abundance in the northerly sector of the Saginaw Bay interface. Abundance of this species was further reduced during the November sampling period (Fig. 9H) at most offshore stations, although it remained abundant at stations nearshore and stations in the Saginaw Bay interface waters. The ecological affinities of this species are poorly known. It has been previously reported from large alpine lakes in Europe, and it has previously been found in limited abundance in Lake Superior and in northern Lake Huron (Schelske *et al*., 1972, 1974; Lowe, 1976). While it has been reported as being a summer blooming form in large European alpine lakes, the population levels achieved in southern Lake Huron are unprecedented in our experience for the Great Lakes. More recent data (Stoermer, unpublished) indicate that it has also become abundant in Lake Michigan where it was previously unreported despite fairly intensive sampling. The reasons for the apparent expansion of this particular species are not apparent. However its seasonal pattern of occurrence would indicate that it can tolerate very low levels of silicon and is one of the few diatom species which can respond to loadings from Saginaw Bay during the summer and early fall.

Cyclotella comta

This species is a member of the classical oligotrophic *Cyclotella* association (Hutchinson, 1967). It is apparently tolerant of moderate levels of eutrophication, but has been removed from areas of the Great Lakes which have been excessively disturbed (Hohn, 1969; Duthie and Sreenivasa, 1971). In southern Lake Huron scattered low level populations of this species are found particularly in the northwestern sector of our sampling area during April (Fig. 10A) and May (Fig. 10B). It is more abundant during the early June sampling period (Fig. 10C) but high population levels are still largely restricted to the western half of the sampling array. During late June (Fig. 10D) populations are found at most stations sampled, and the species is





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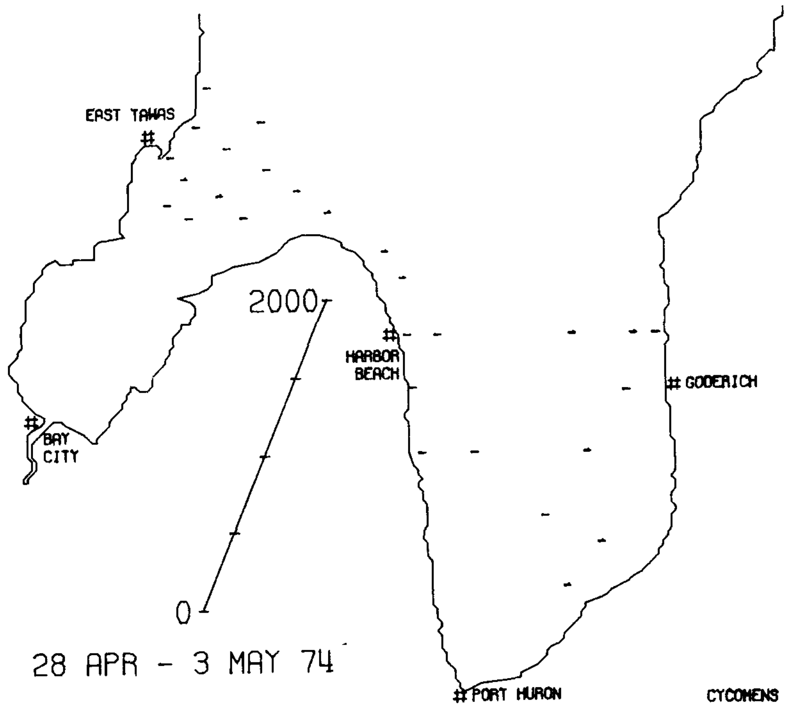


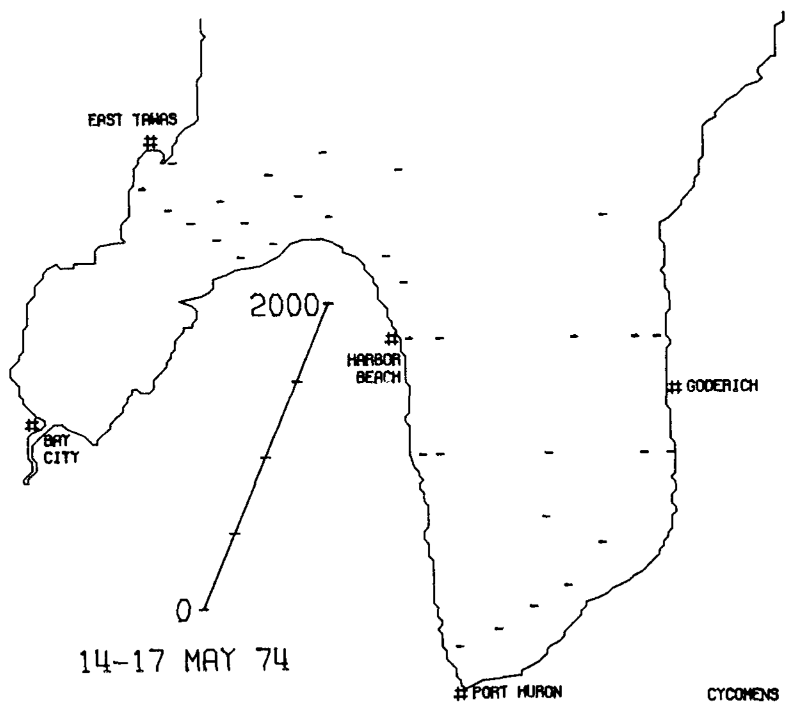
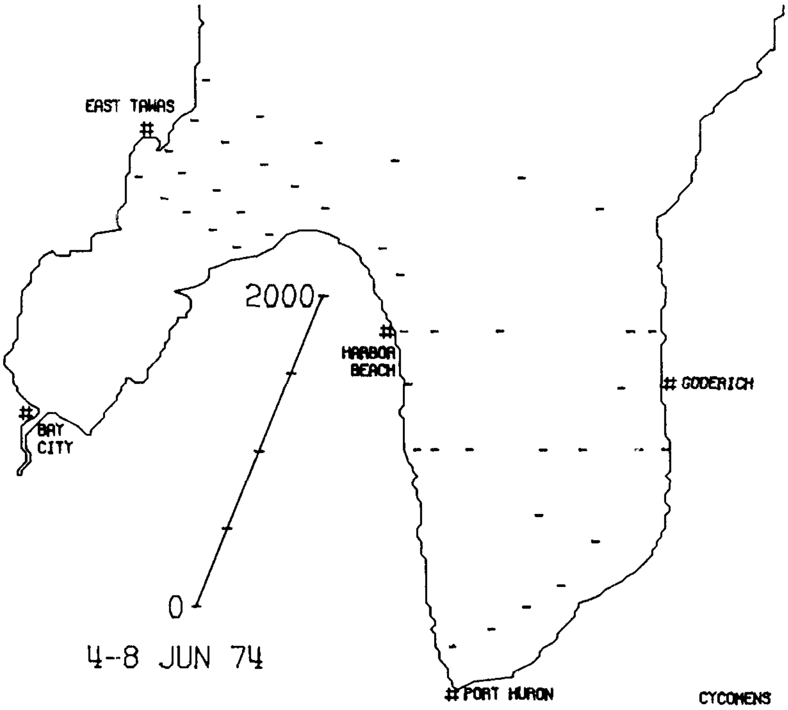
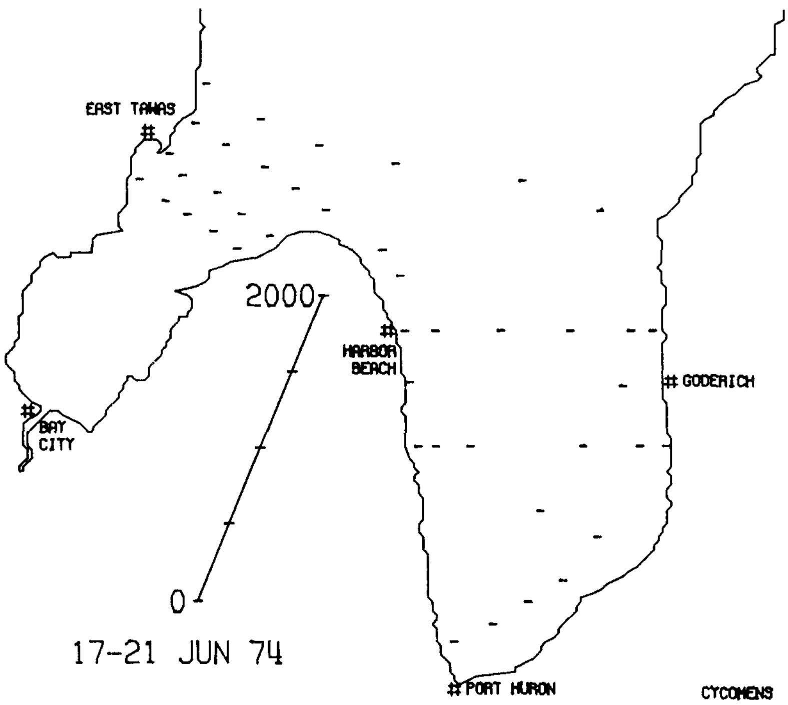


Figure 9. Distribution of *Cyclotella comensis*. (continued)





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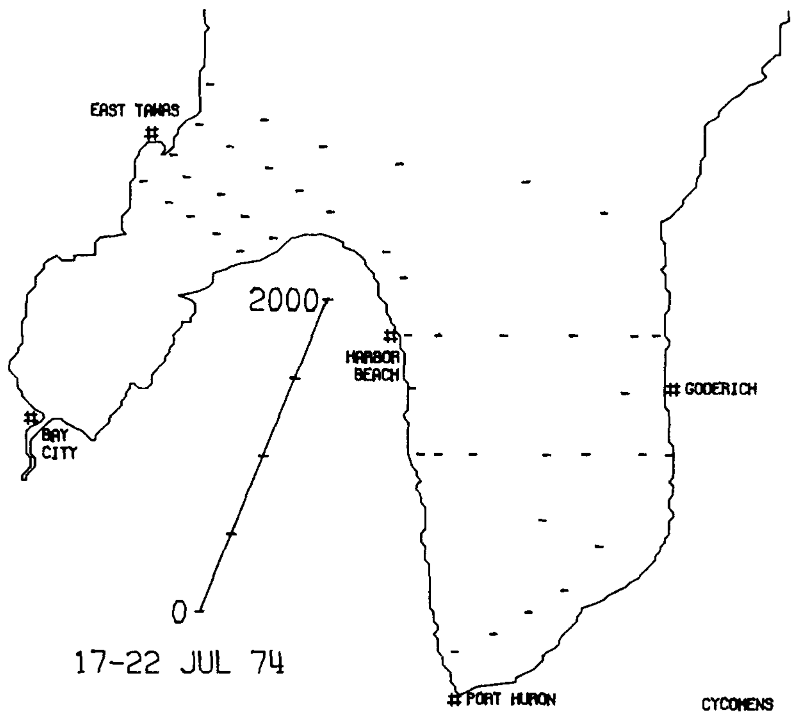

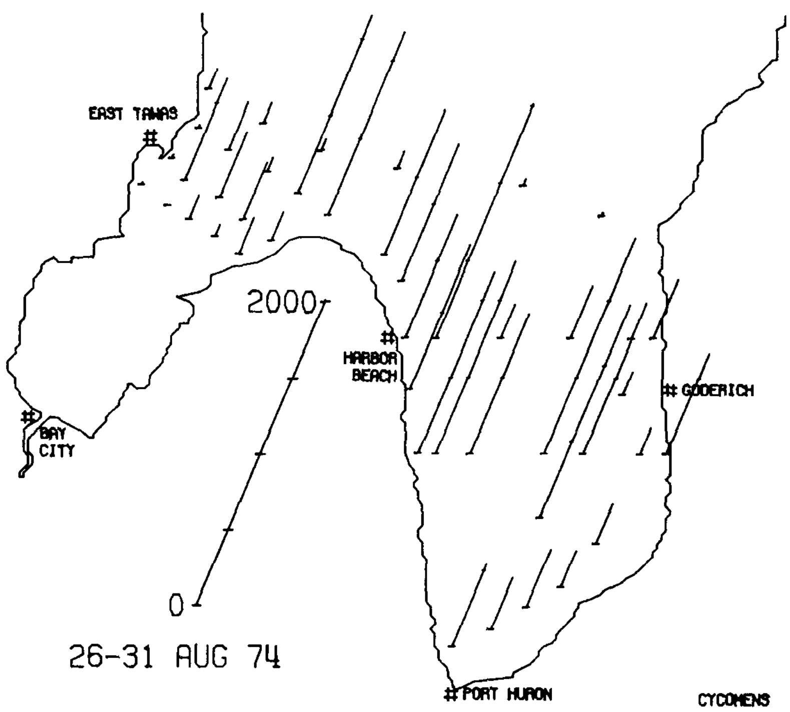

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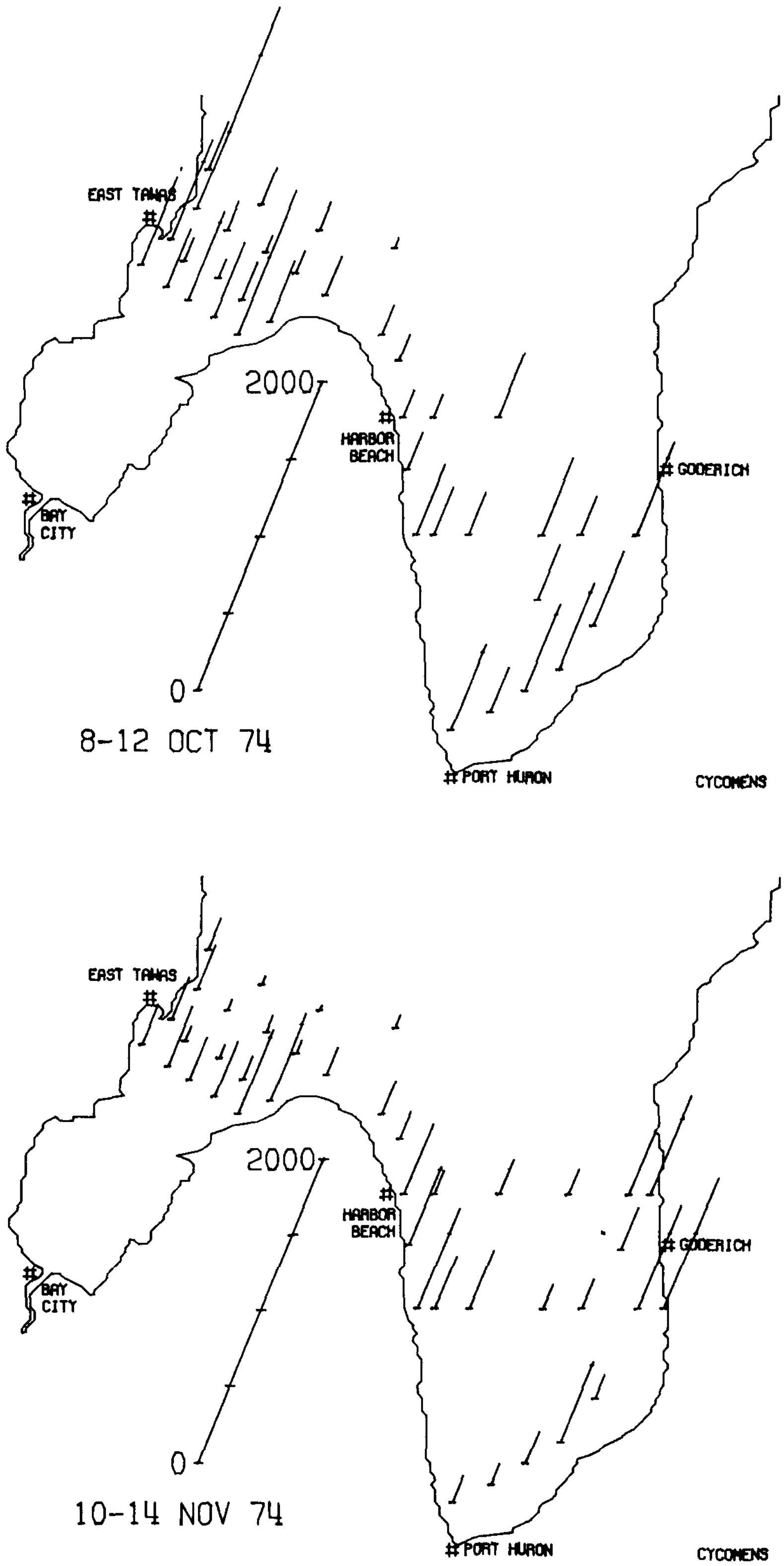

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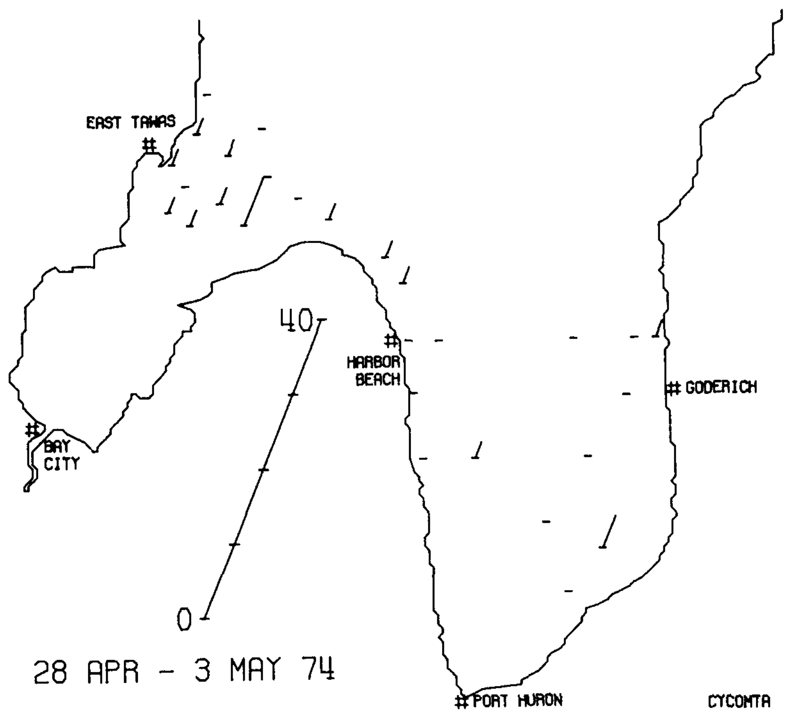


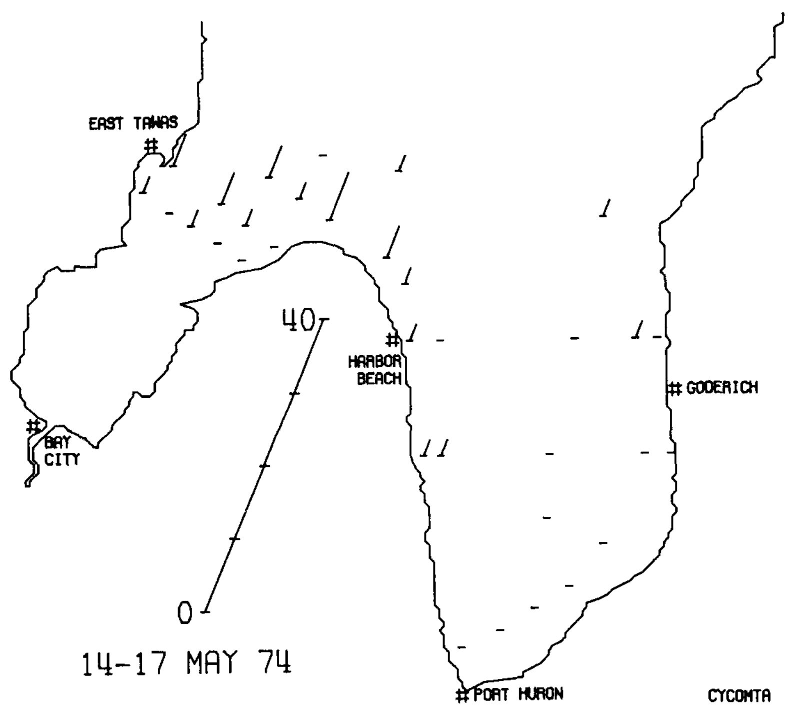
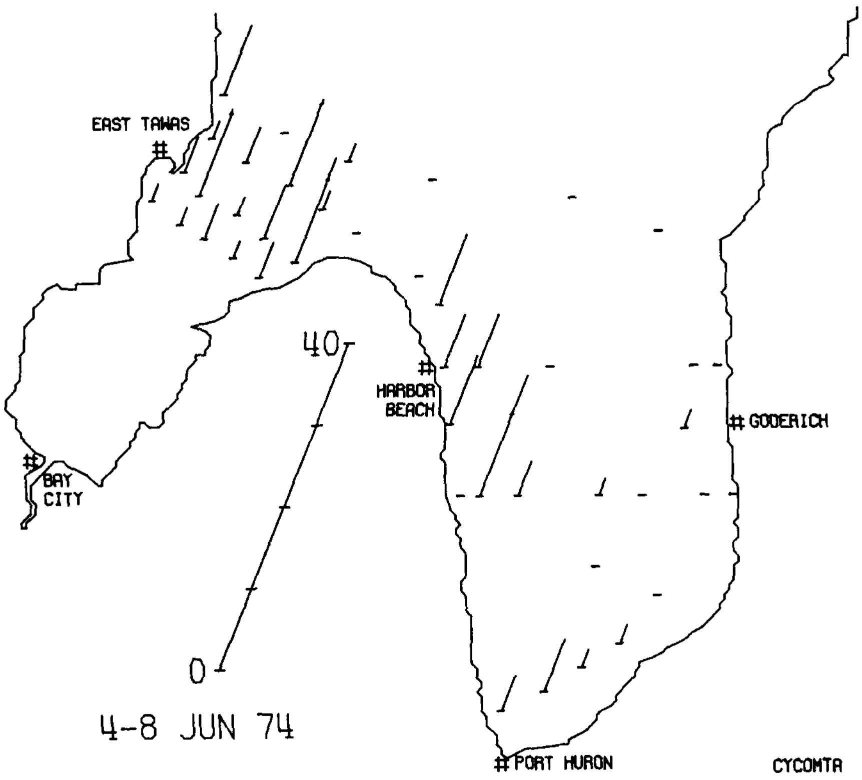


Figure 10. Distribution of *Cyclotella comta*.
(continued)



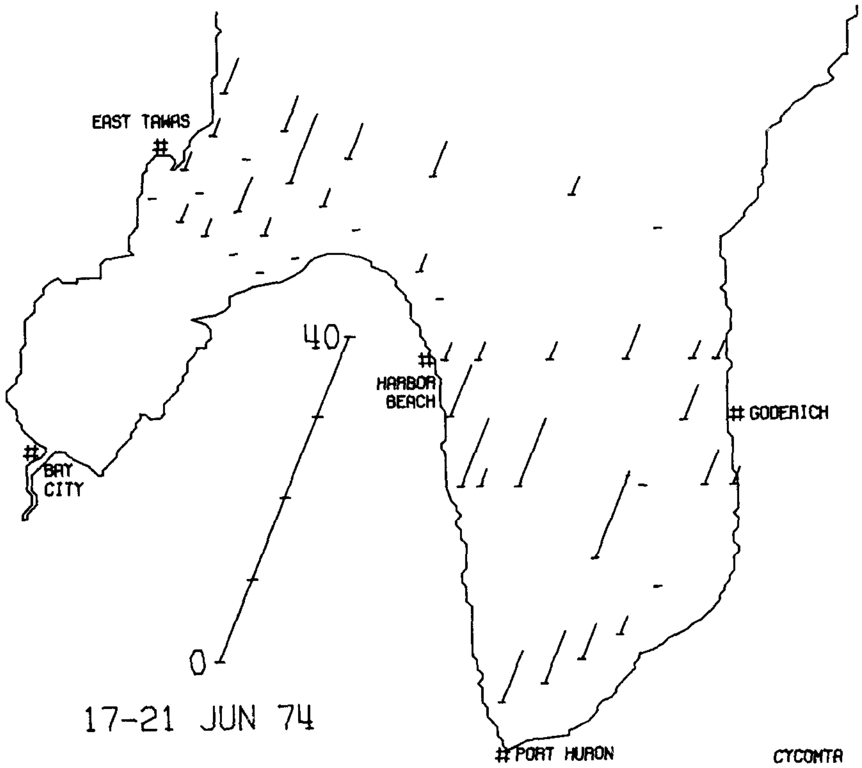


Figure 10. (continued)

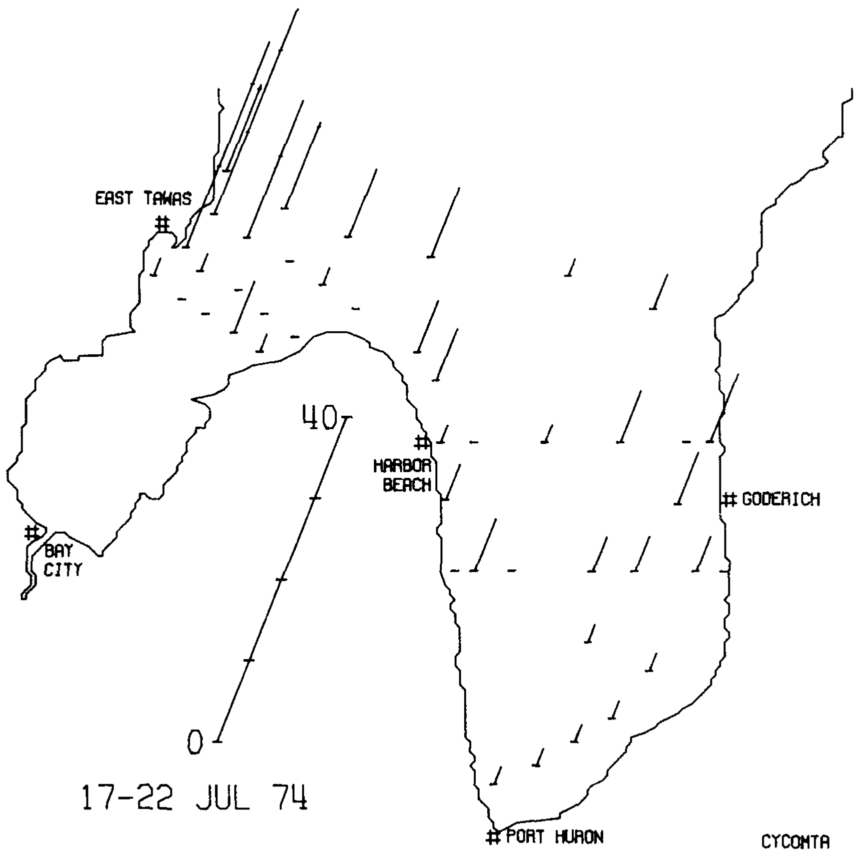
consistently absent only from stations in the southern sector of the Saginaw Bay interface. Essentially the same situation prevailed during the July sampling (Fig. 10E) but large populations were noted at nearshore stations north of Tawas. The species generally increased in abundance by August (Fig. 10F) and was absent only from a few stations in the Saginaw Bay interface water and south along the Michigan coast. It remained abundant during October (Fig. 10G) only to decline in abundance again in November (Fig. 10H).

Cyclotella michiganiana

This species was originally described (Skvortzow, 1937) from the Great Lakes and its recorded distribution is largely restricted to these bodies of water and the inland lakes of Michigan. In southern Lake Huron only small populations of these species were present during the May and June sampling cruises (Fig. 11A-D). During July (Fig. 11E) it underwent an explosive increase in abundance at stations in the western half of the area sampled, although it was more abundant in stations in the main body of Lake Huron than the Saginaw Bay interface waters. During August (Fig. 11F) this pattern was reversed, with highest populations occurring in the eastern half of southern Lake Huron, although appreciable populations were found at most stations sampled. Population levels of this species began to decline during October (Fig. 11G) and reached spring levels by the November cruise (Fig. 11H).

Cyclotella ocellata

This species is an important component of phytoplankton assemblages in northern Lake Huron (Schelske *et al.*, 1974; Schelske *et al.*, 1976) and is generally abundant in areas of the Great Lakes which have not undergone significant eutrophication. In southern Lake Huron it was found at all stations sampled during the April cruise (Fig. 12A) and was reduced in abundance only at a few stations in the Saginaw Bay interface waters and southerly along the Michigan coast. It was slightly more abundant during the May cruise (Fig. 12B) but again its abundance was reduced at a few stations in the Saginaw Bay interface. Its abundance continued to increase at most stations sampled during the early (Fig. 12C) and late (Fig. 12D) June cruises. During both of these cruises the abundance of this species was reduced at stations in the Saginaw Bay interface waters, and at nearshore stations along the Canadian shore. During the July cruise (Fig. 12E) population levels were reduced at stations in the southerly half of the Saginaw Bay interface, and at main lake stations in the southern half of Lake Huron, although it remained abundant at stations in the northern and eastern sectors of the lake. Minimum abundance of *C. ocellata* was found during the August cruise (Fig. 12F) when it was either absent or present in only very small numbers except at station 6 in the far southeast sector of the lake. This isolated abundant occurrence may be indicative of upwelling at this station, as *C. ocellata* is one of the species which has been noted to occur in large numbers at thermocline or sub-thermocline depths. By October (Fig. 12G) this species was again present at most stations sampled, with highest abundance at stations north of Saginaw Bay. It was again present in November (Fig. 12H) although its distribution was irregular, with the only trend being a tendency to decrease in abundance from north to south in the area sampled.



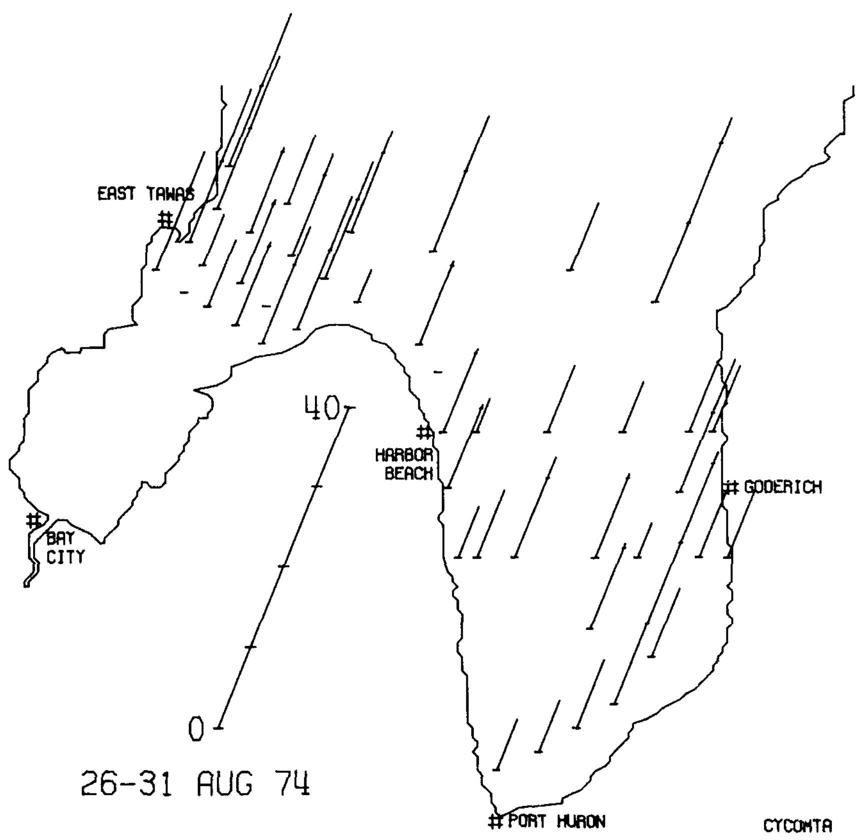
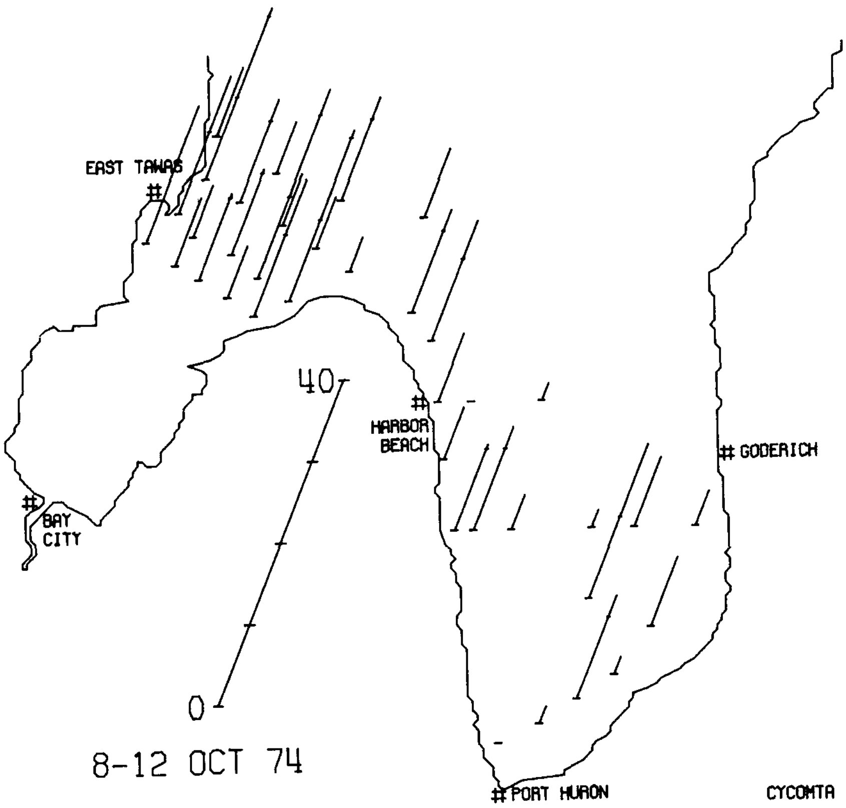
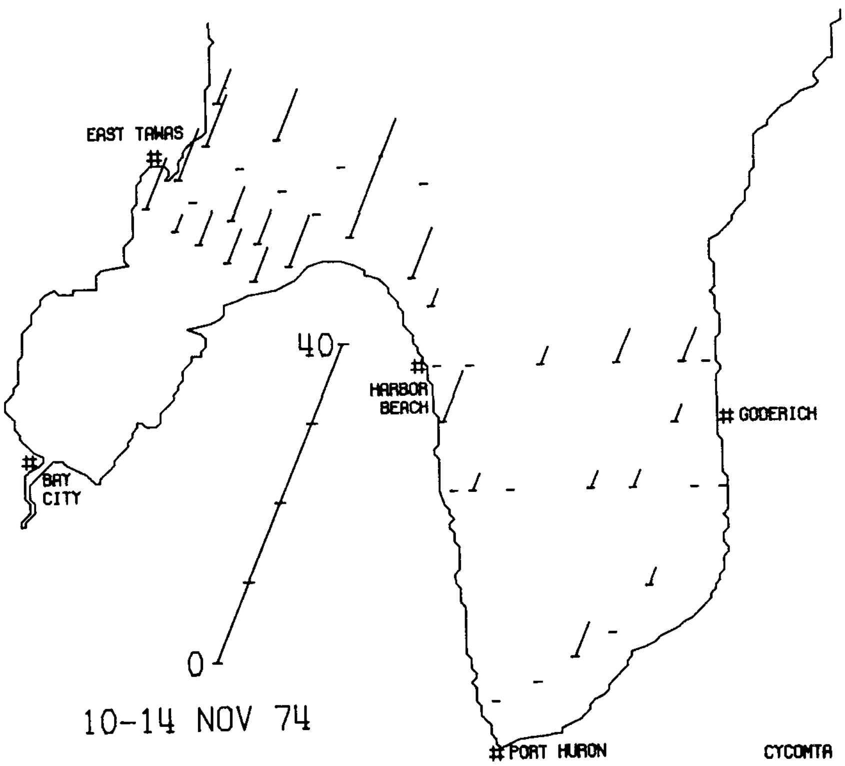


Figure 10. (continued)





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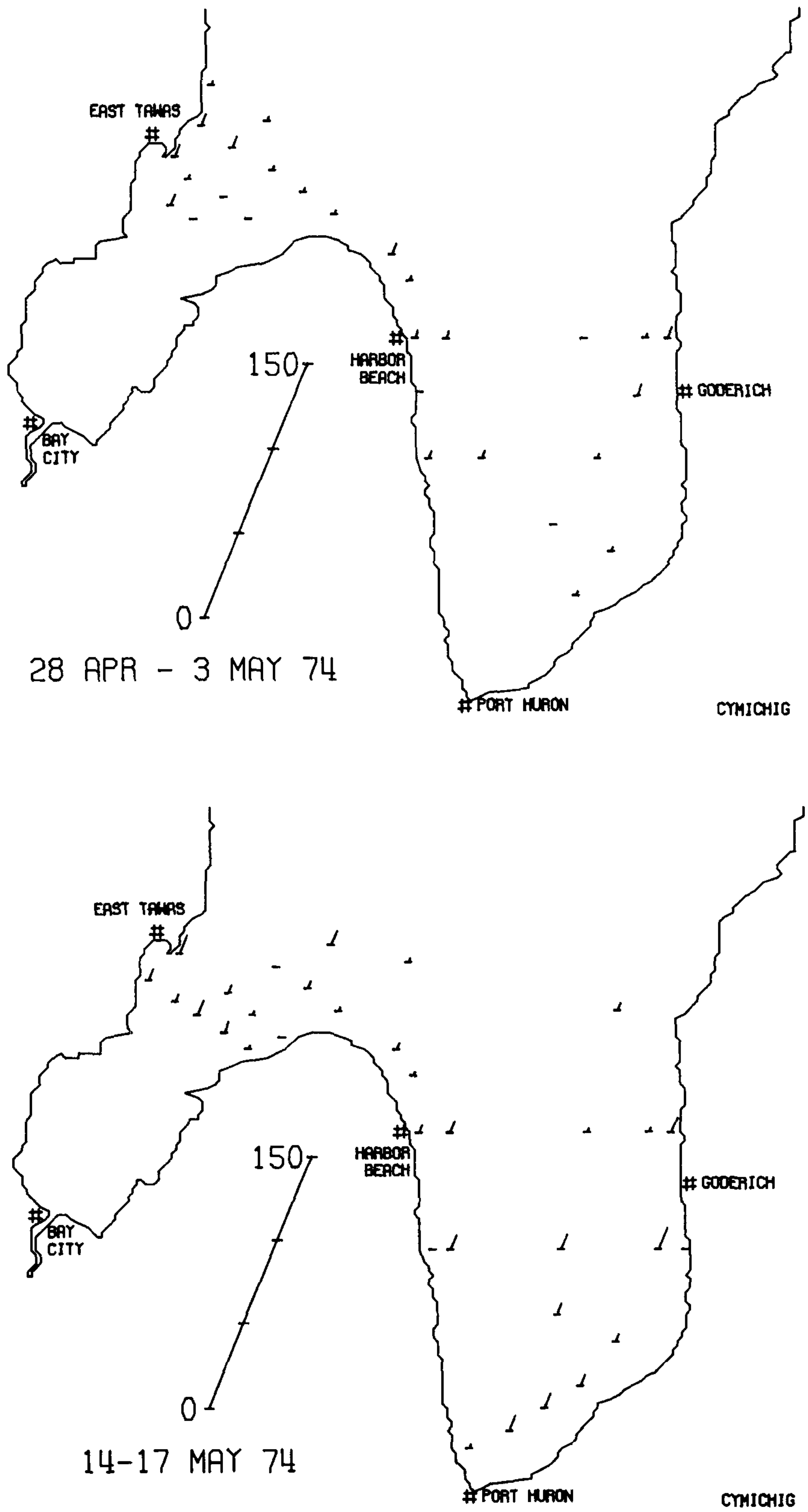
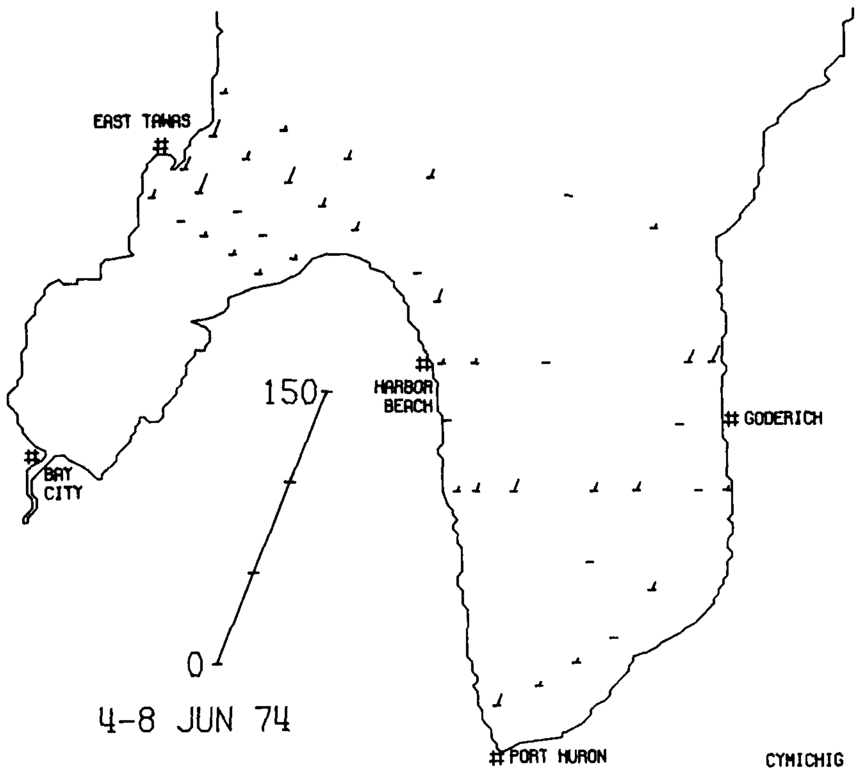
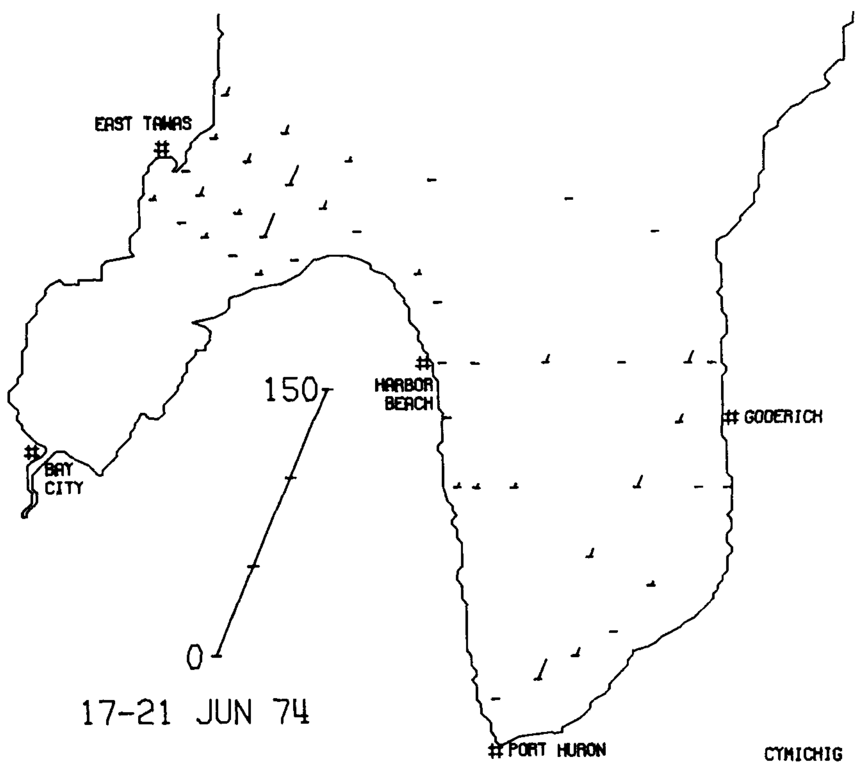


Figure 11. Distribution of *Cyclotella michiganiana*. (continued)





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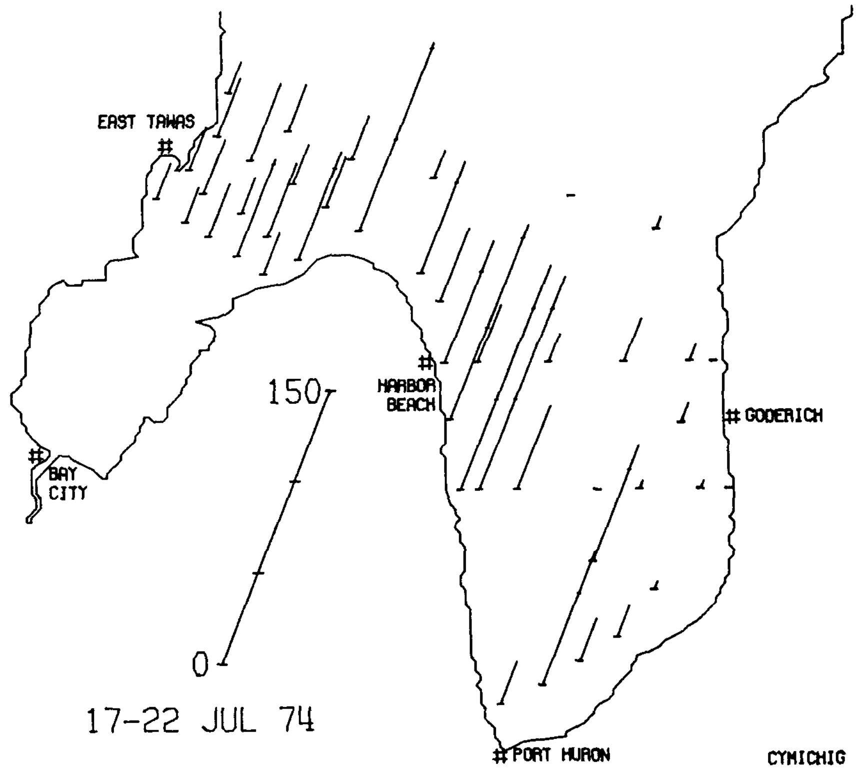

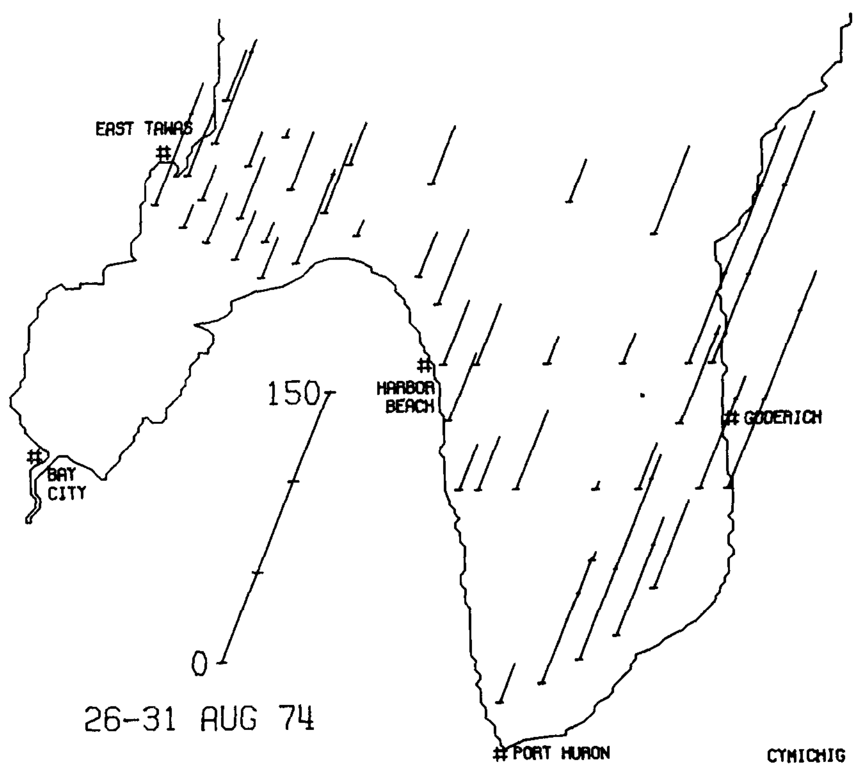

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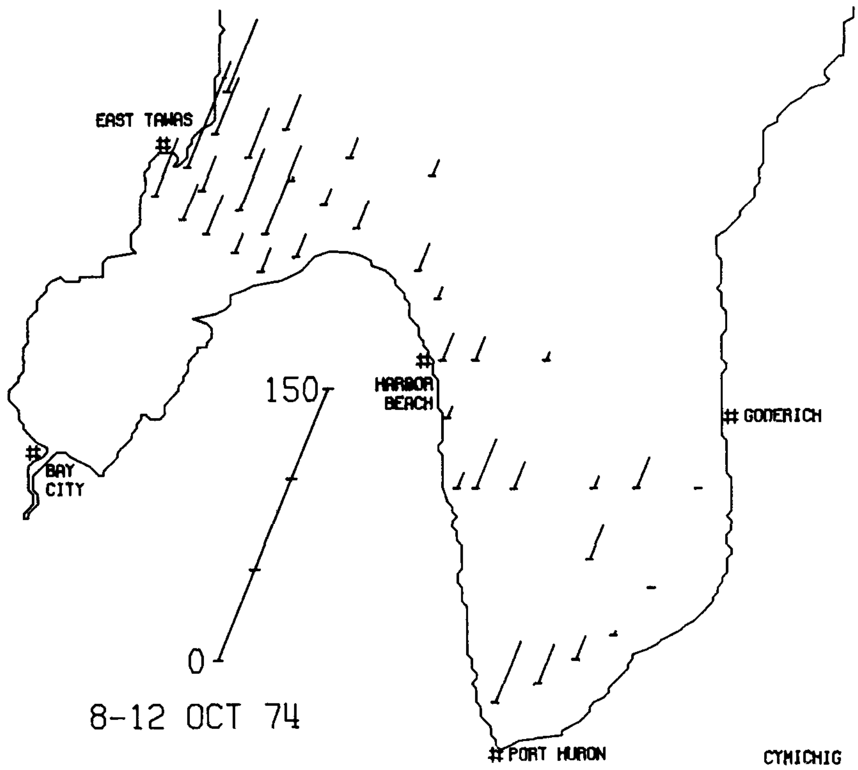

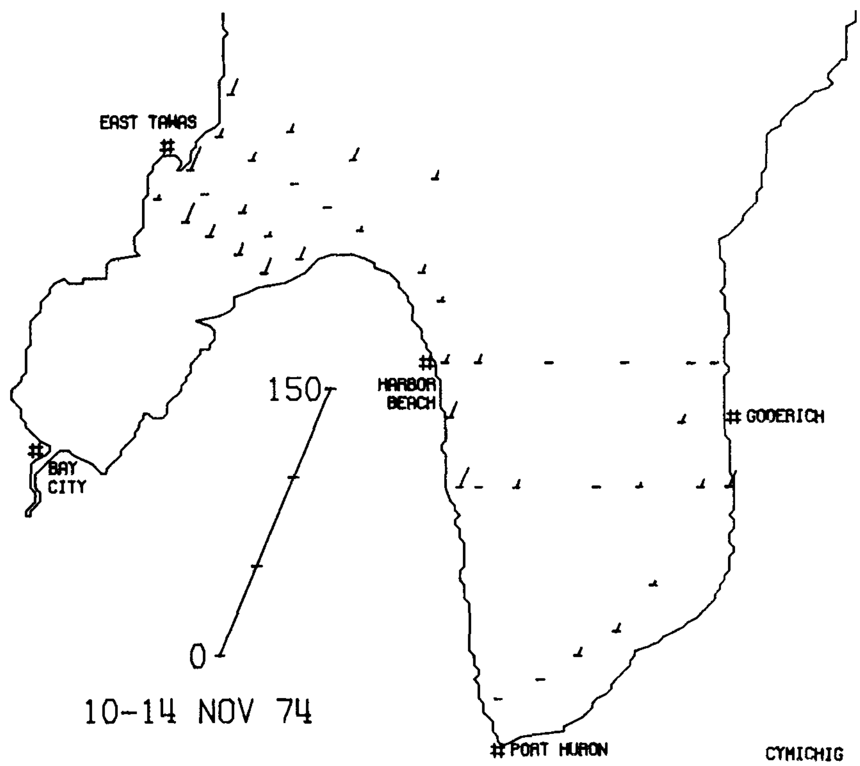

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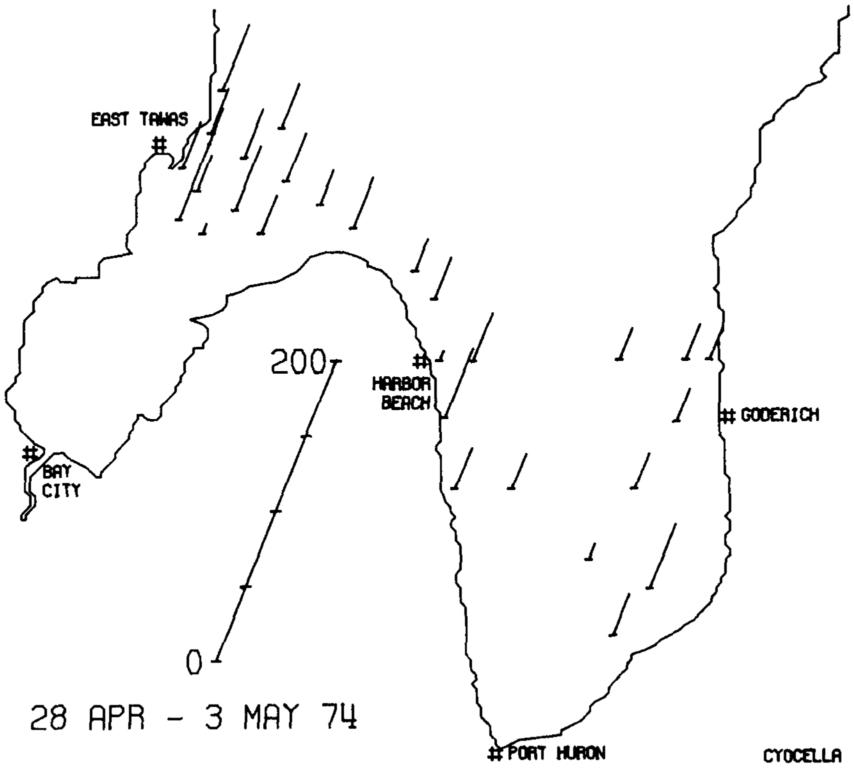


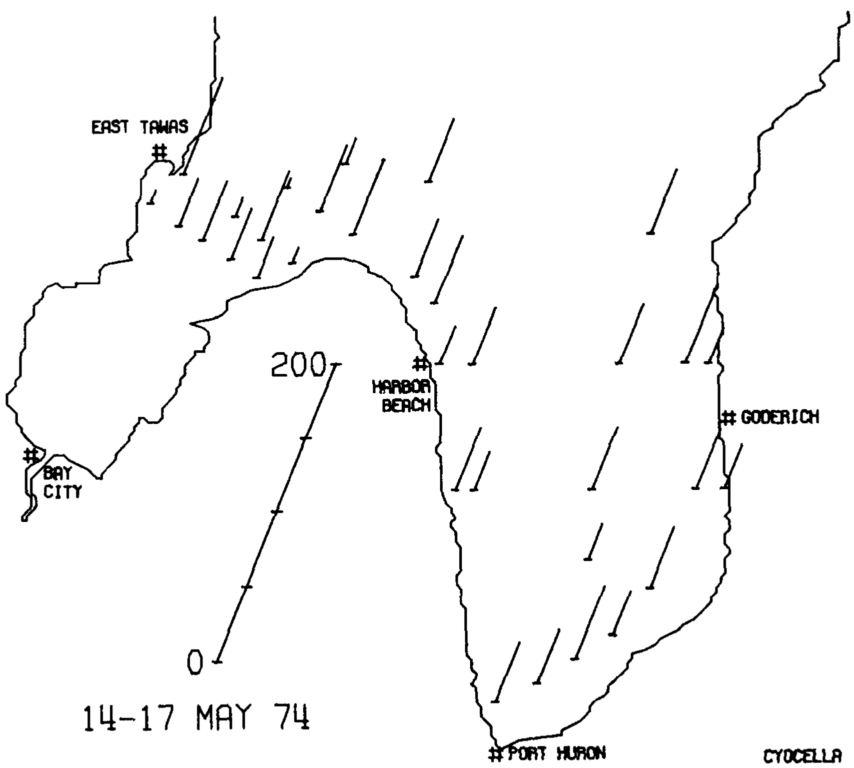
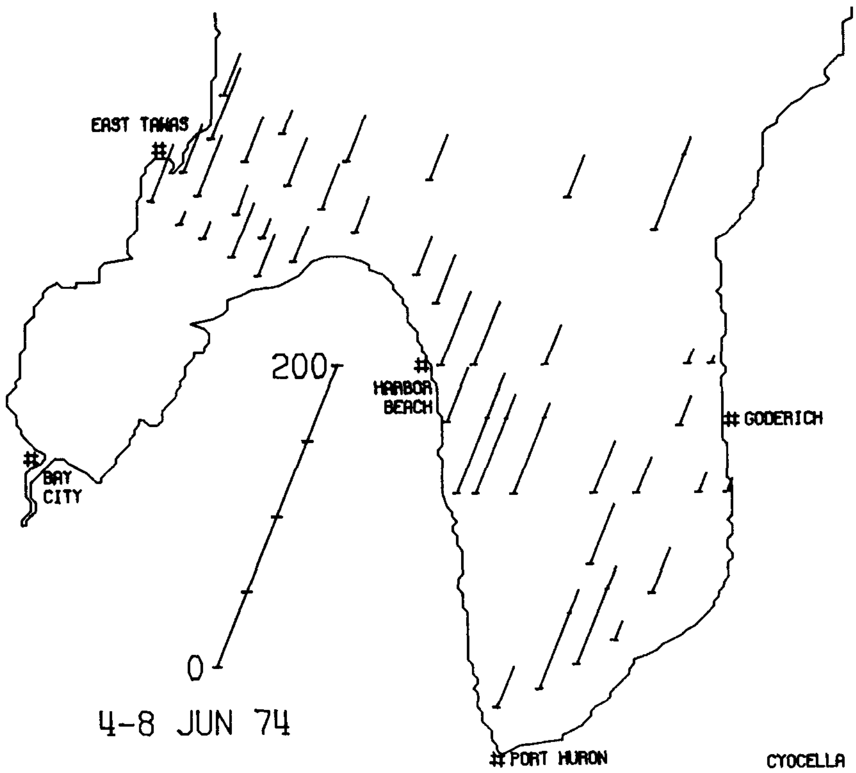


Figure 12. Distribution of *Cyclotella ocellata*.
(continued)



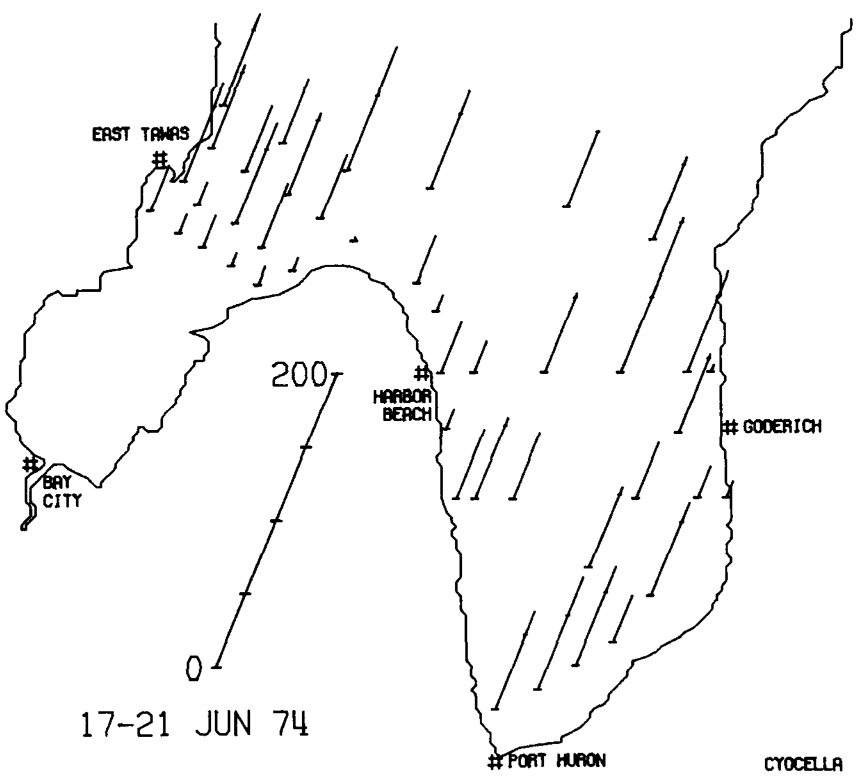
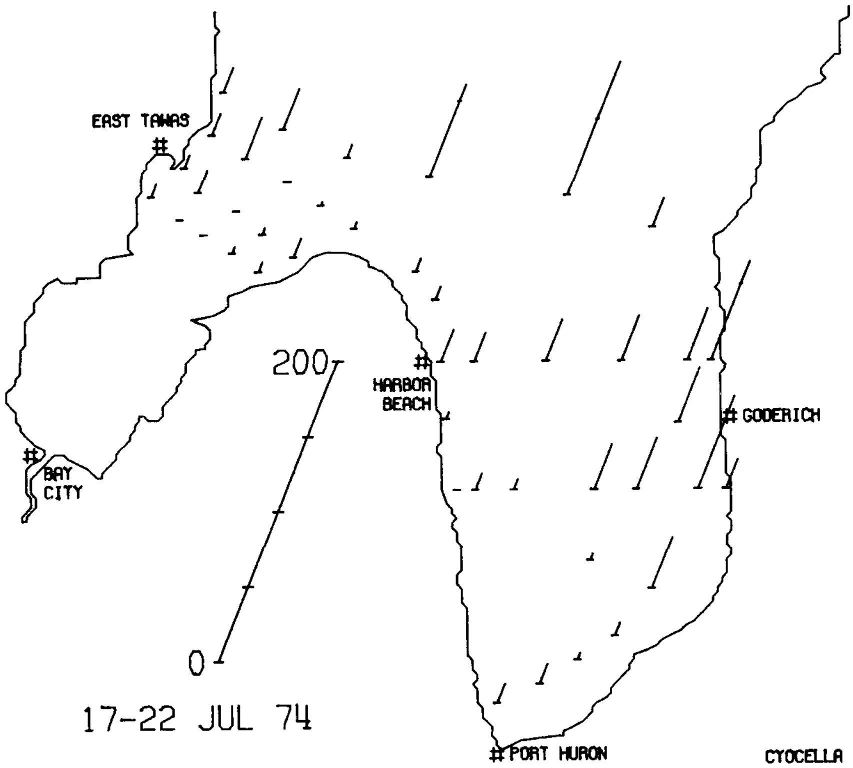
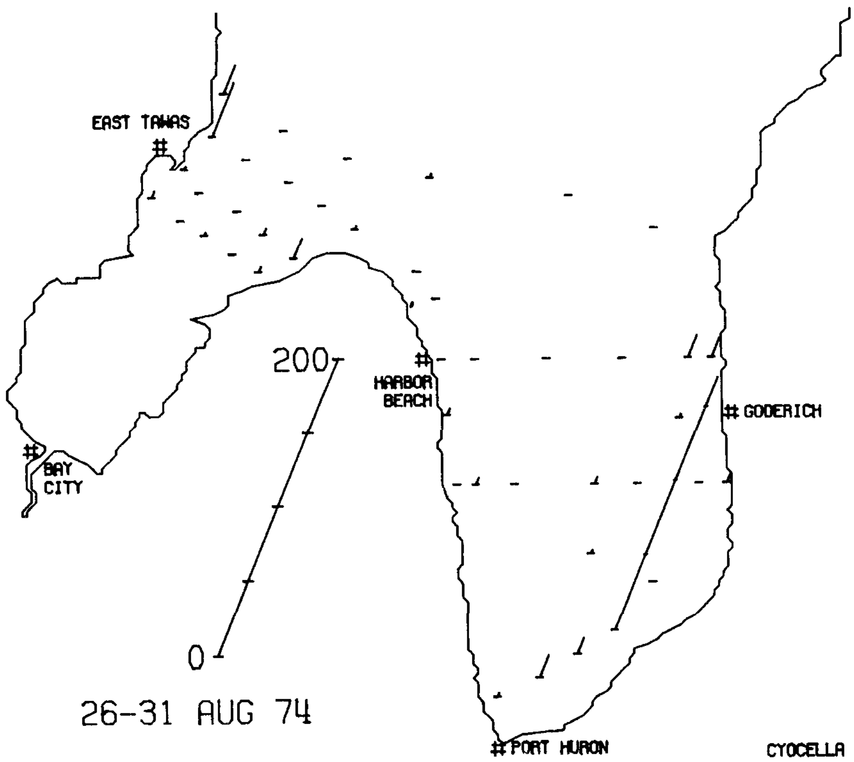


Figure 12. (continued)





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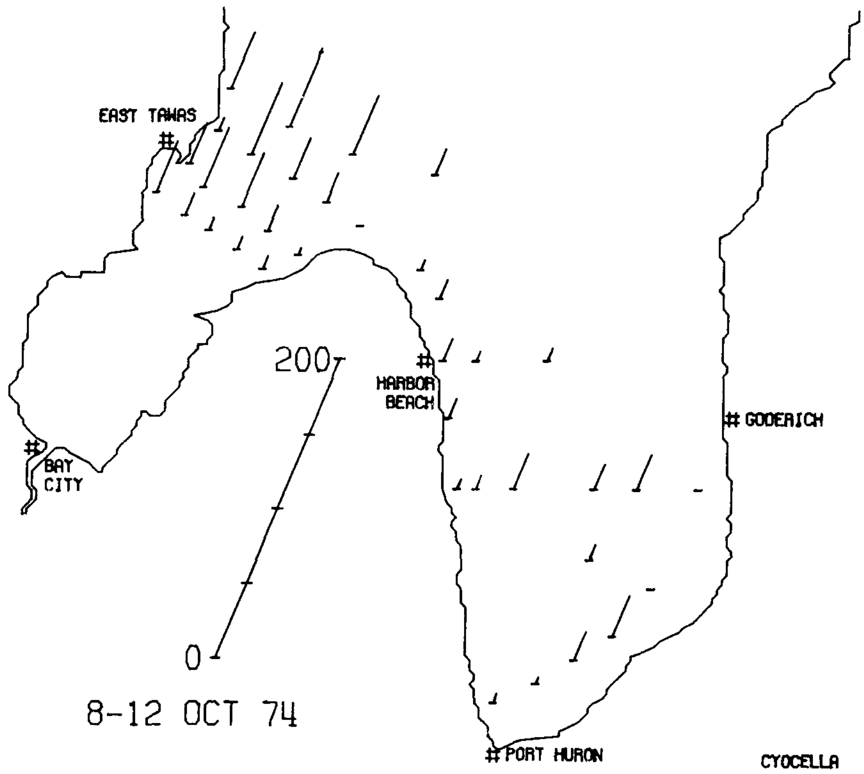


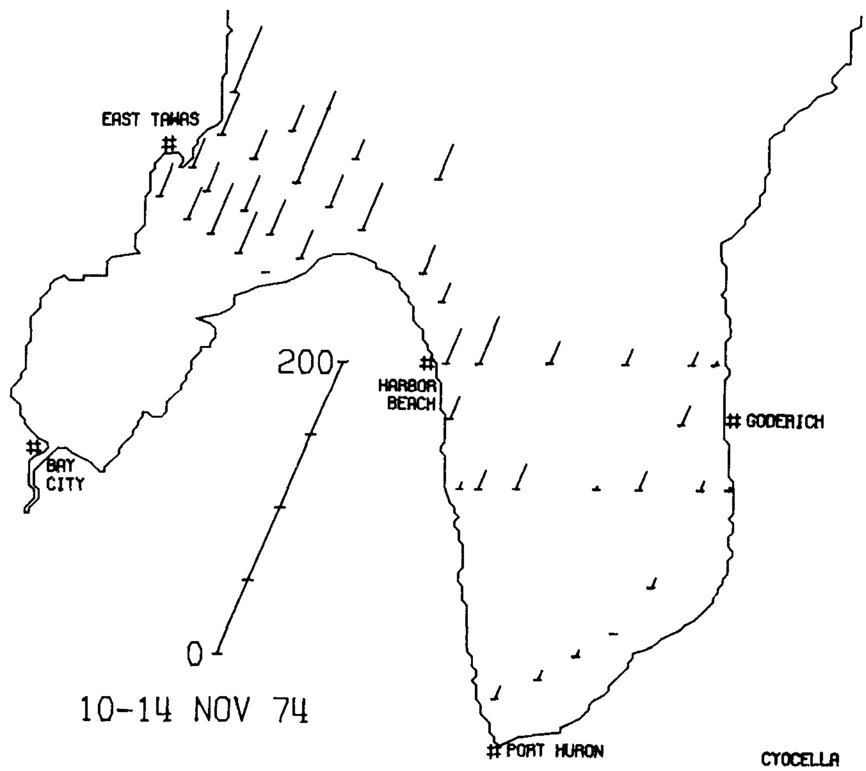


Figure 12. (continued)

Cyclotella operculata

Although this species is generally associated with oligotrophic assemblages in the Great Lakes (Schelske et al., 1976), its distribution is highly erratic in southern Lake Huron. During April, May and June (Figs. 13 A-D) only isolated populations were found at scattered stations throughout the areas sampled. During July (Fig. 13E) it was consistently present at the innermost stations in the Saginaw Bay interface, and isolated populations were found in other areas of the lake. During August (Fig. 13F) its abundance increased somewhat, although its pattern of occurence was still extremely scattered. This species reached its maximum abundance during the October cruise (Fig. 13G) when it was present in significant abundance at most stations sampled, particularly in the northern part of the study area. It however declined drastically by November (Fig. 13H) although populations were still present at most stations sampled except those in the northeasterly sector of the sampling area.

Cyclotella pseudostelligera

Unlike other members of this genus previously discussed, populations of this species are usually restricted to significantly eutrophied or disturbed areas. It is often a dominant member of the assemblage in eutrophic small lakes and rivers (Belcher, Swale, and Heron, 1966; Hustedt, 1956). In the Great Lakes large populations are generally restricted to harbor mouths and eutrophied nearshore areas (Stoermer and Yang, 1970) although occasional populations are found in offshore waters. In southern Lake Huron this species was noted only in samples taken during the July, August and October cruises (Figs. 14A-C). All occurrences noted were either at nearshore stations or stations in the Saginaw Bay interface. It was most abundant during August (Fig. 14B) when appreciable populations were found at several nearshore stations in the far northwestern sector of the sampling area and at a nearshore station along the Canadian coast.

Cyclotella stelligera

This species is a common offshore dominant in Great Lakes phytoplankton assemblages. Although it responds strongly to experimental phosphorous enrichment (Stoermer, Schelske, and Feldt, 1971) it is apparently intolerant of highly eutrophied conditions in the natural environment, and tends to be removed from regions of the Great Lakes which have undergone extensive disturbance. It was present during the late April and May southern Lake Huron cruises (Figs. 15A-B) generally in low abundance and no particular distribution pattern was evident. Similar population densities were noted during the June cruises (Figs. 15C-D), however reduced population densities were noted at stations in the Saginaw Bay interface waters and stations along the Canadian coast, particularly later in the month. During July (Fig. 15E) populations increased markedly in the offshore waters of southern Lake Huron, although populations remained at minimal levels at stations in the Saginaw Bay interface waters. During August (Fig. 15H) highest population densities of this species were found in the northern and eastern sectors of the sampling area, with generally reduced populations at the rest of the stations. During October and November (Fig. 15G-H) this species was at minimal levels compared to the previous month, however low level populations were found at most stations sampled.

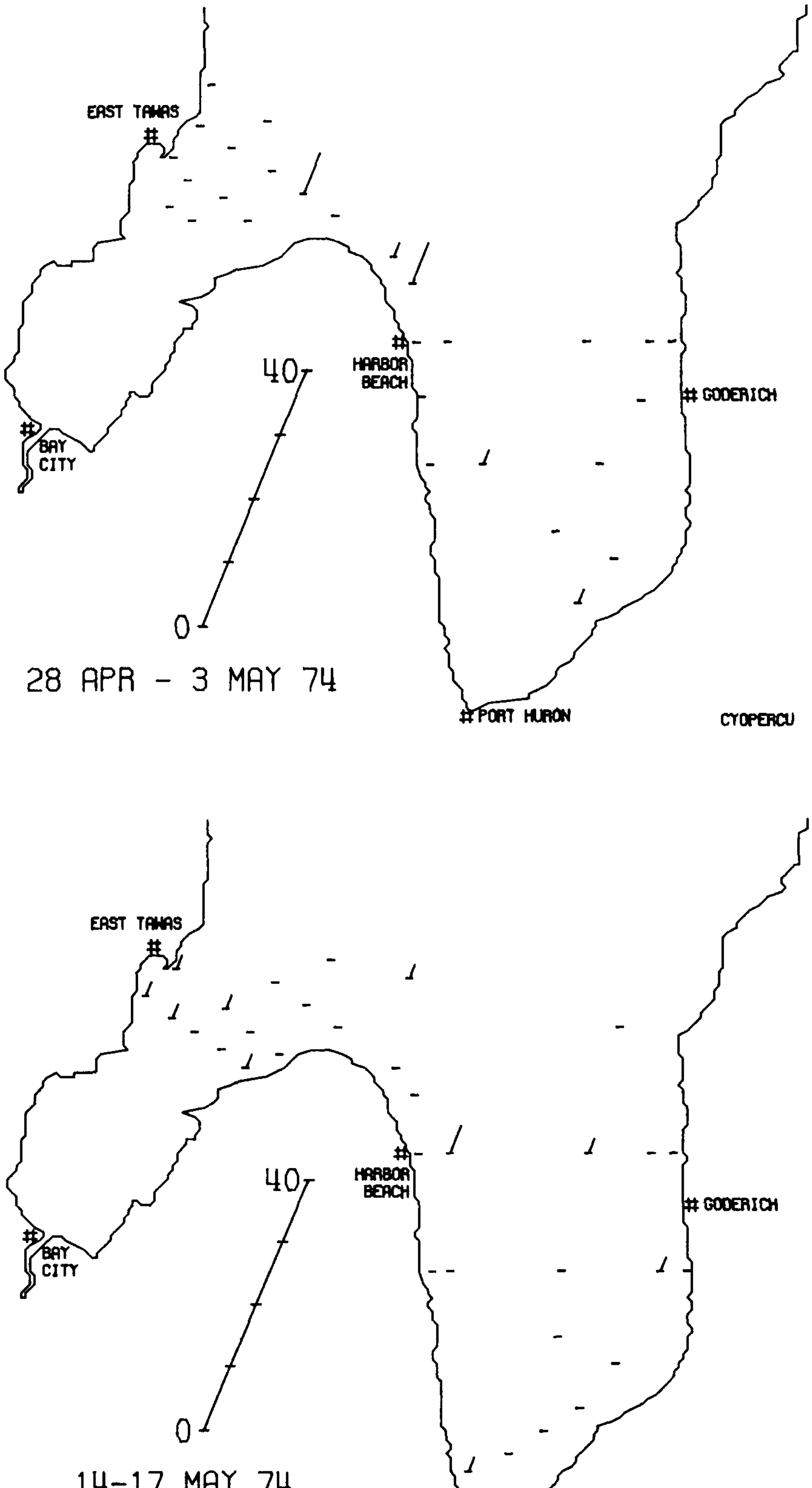
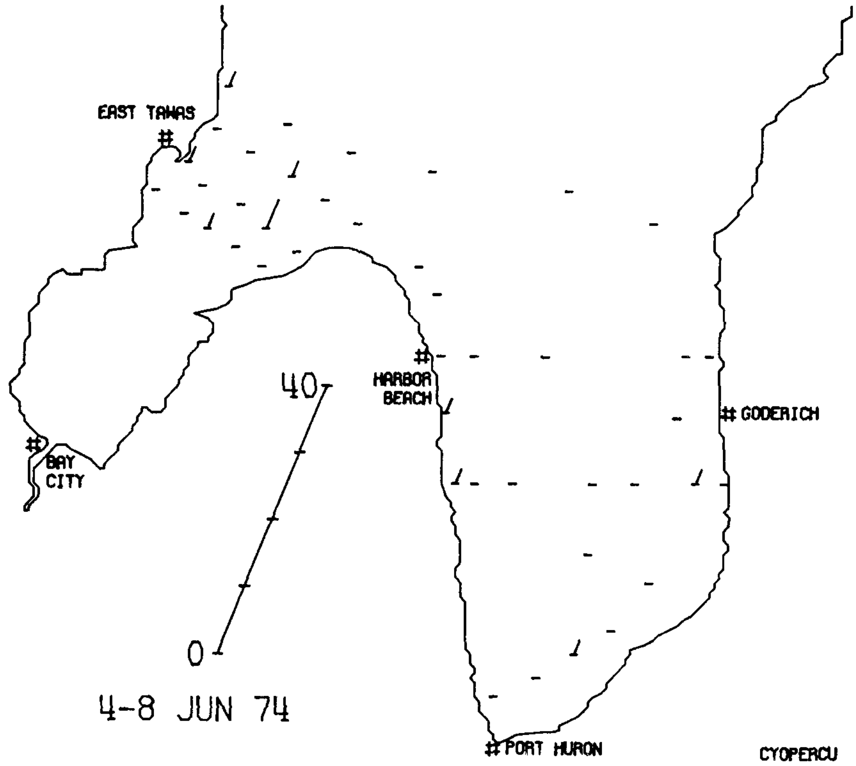


Figure 13. Distribution of *Cyclotella operculata*. (continued)



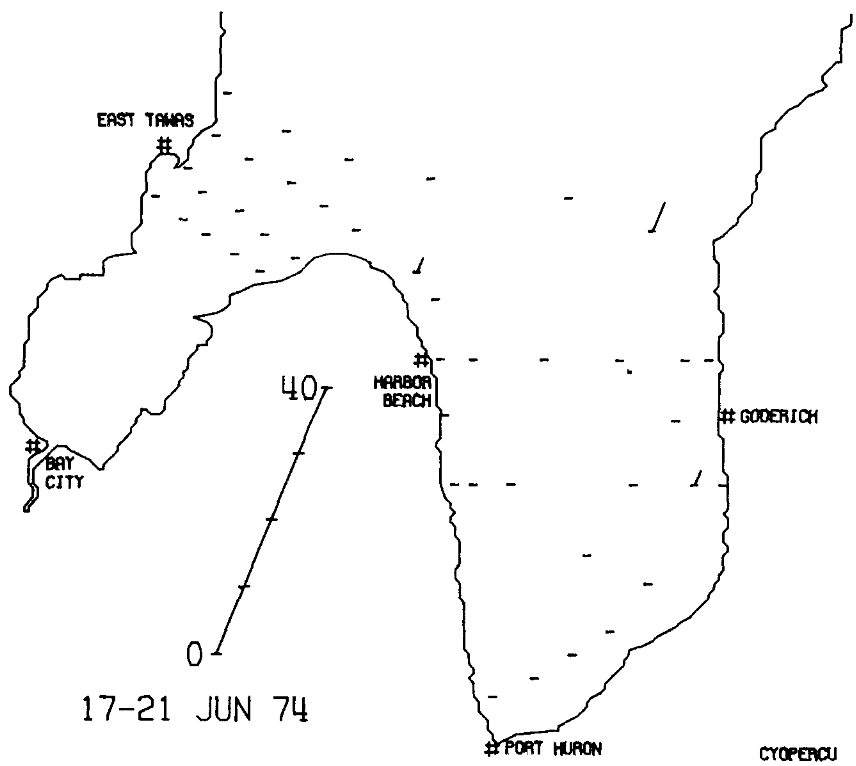
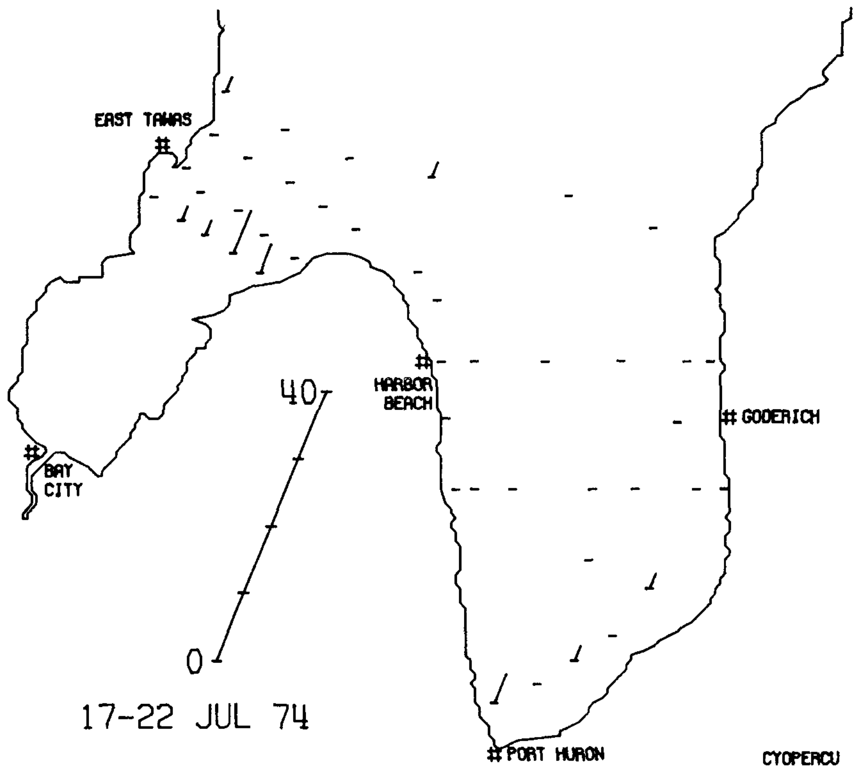


Figure 13. (continued)



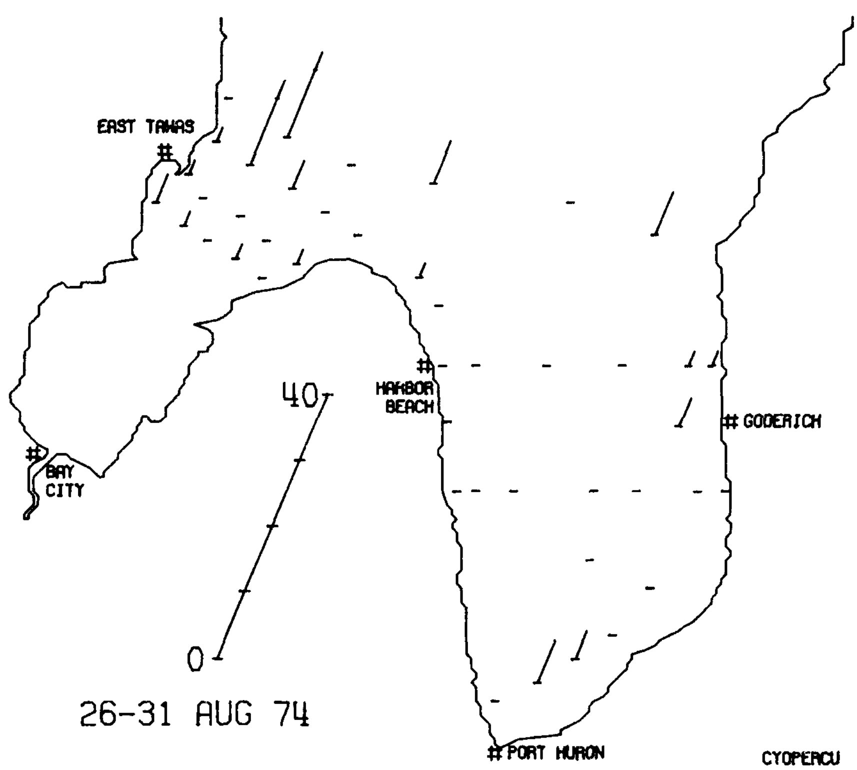
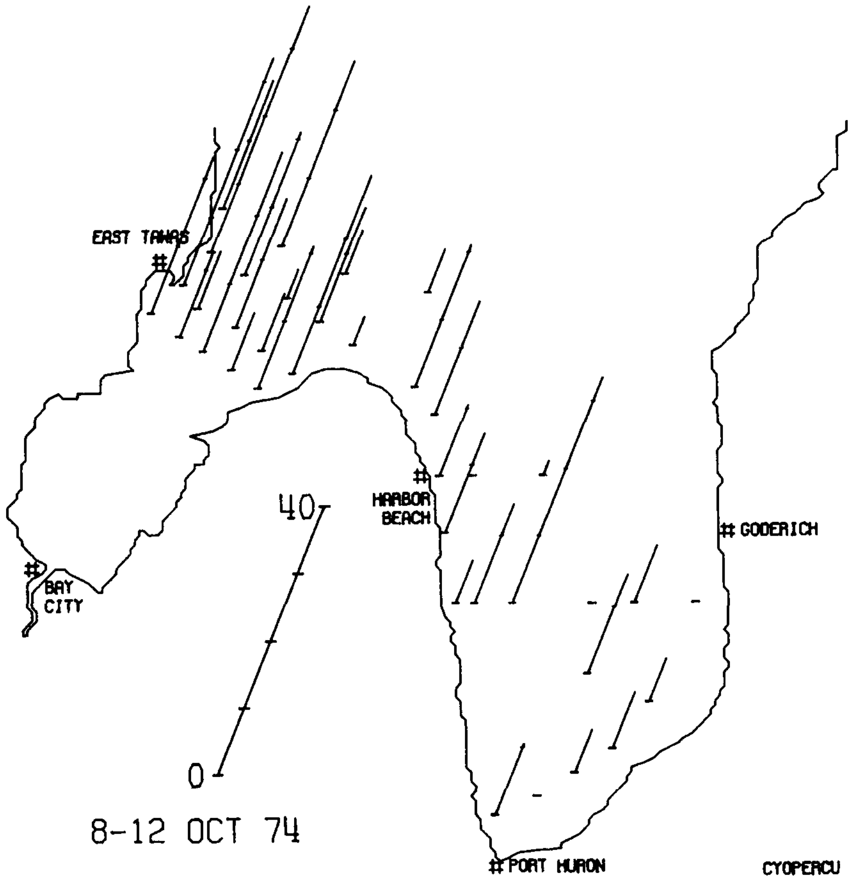
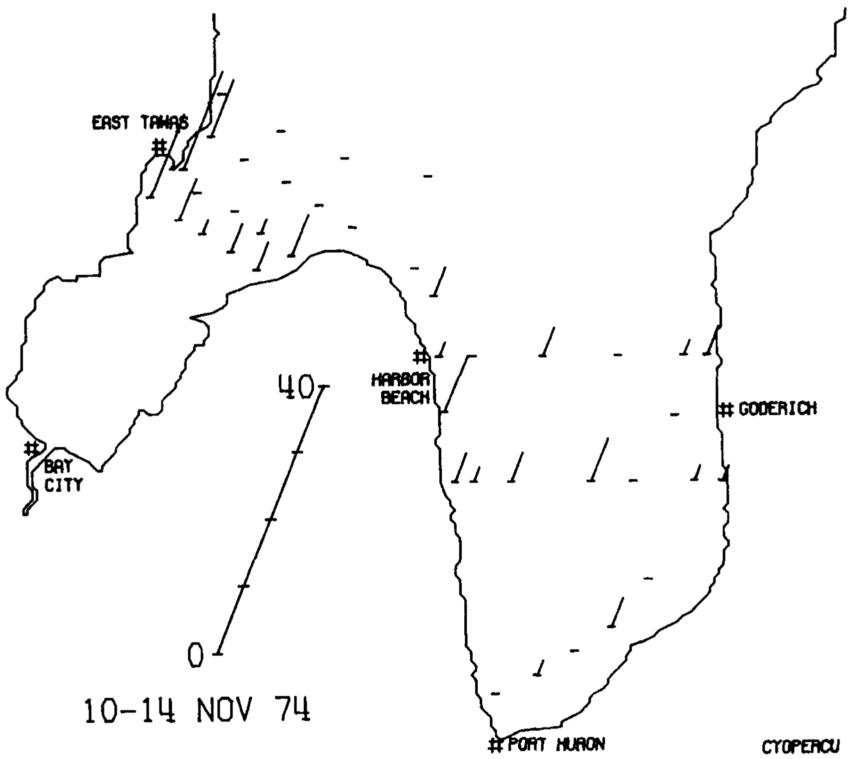


Figure 13. (continued)





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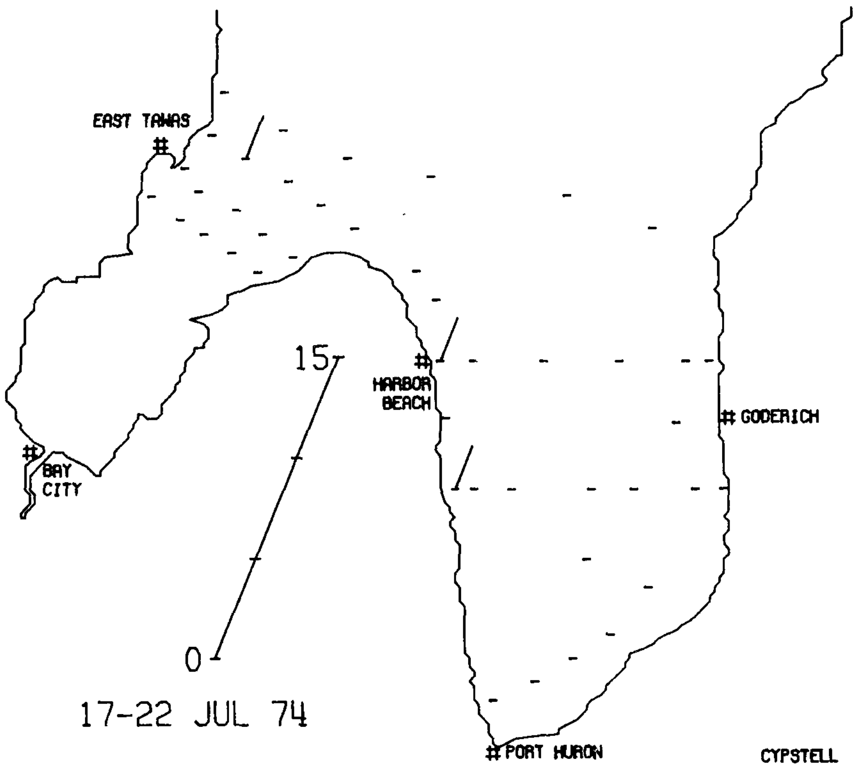


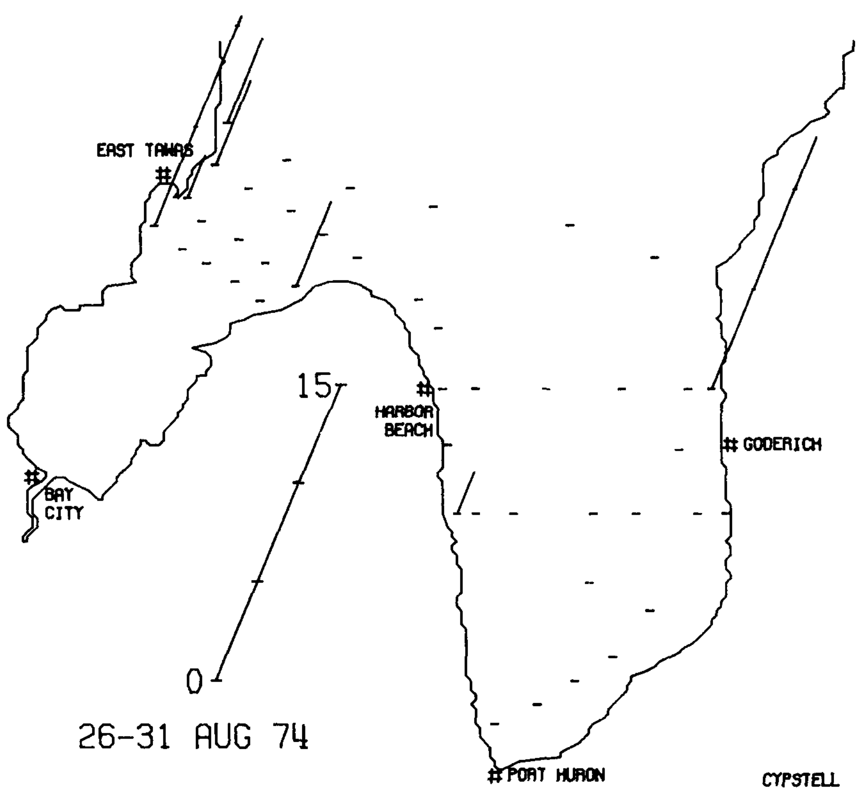


Figure 14. Distribution of *Cyclotella pseudostelligera*. (continued)

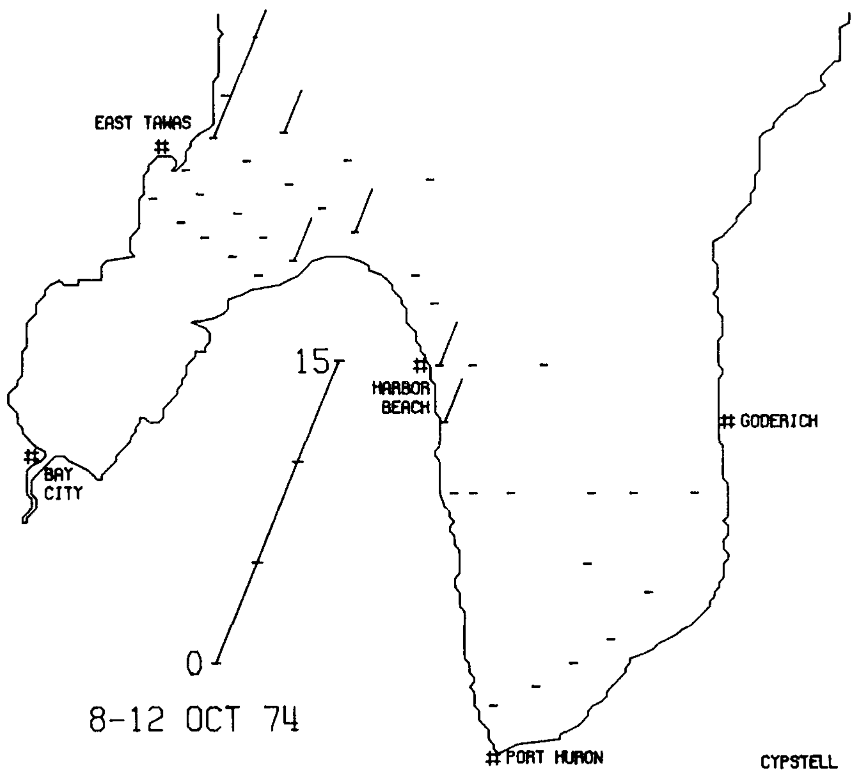


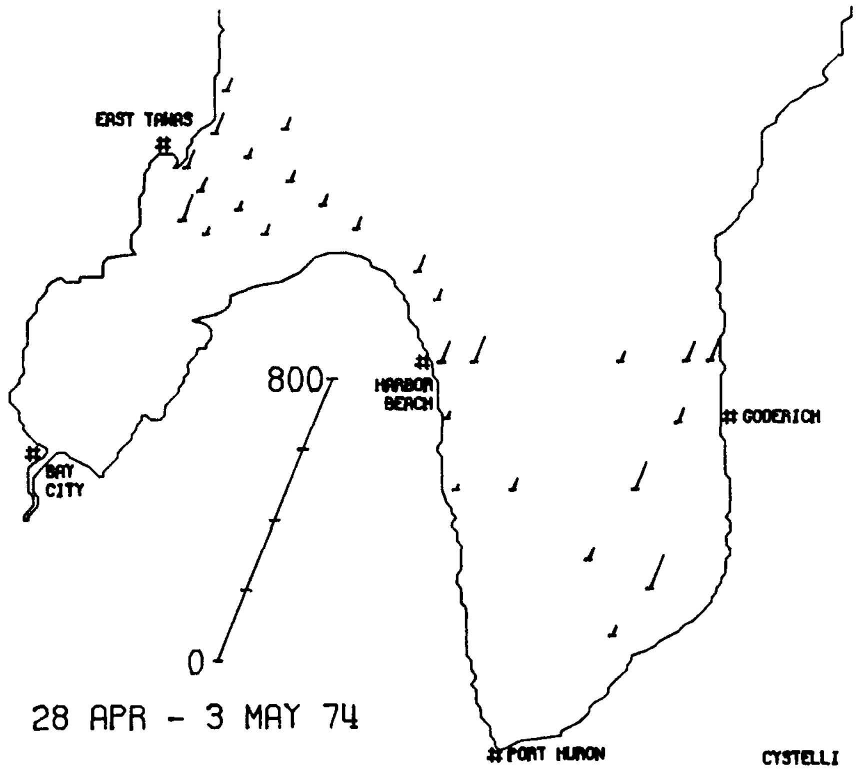
Figure 14. (continued)

<u>Diatoma tenue</u> var. <u>elongatum</u>

This species is widely distributed in the modern Great Lakes, generally reaching its greatest abundance in areas that have undergone significant eutrophication. It was present during all sampling periods in our study (Fig. 16 A-H) but significant population densities were generally restricted to stations in the Saginaw Bay interface waters and stations nearest shore. It reached its greatest abundance during the November cruise (Fig. 16H) at the innermost of the Saginaw Bay interface stations.

<u>Diatoma tenue</u> var. <u>pachycephala</u>

This entity is morphologically quite similar to <u>D. tenue</u> var. <u>elongatum</u> and in the Laurentian Great Lakes appears to have essentially similar distributional affinities. In southern Lake Huron, however, it is both more abundant and has a different temporal and spatial distribution than the previously discussed taxon. It was found at most stations sampled during the early May cruise (Fig. 17A), with maximum population densities occurring at nearshore stations along the Michigan coast. By mid-May (Fig. 17B) it had become quite abundant at nearshore stations in the Saginaw Bay interface and southward along the Michigan coast. During this cruise population densities were generally elevated in nearshore stations, probably as a result of the thermal bar condition. By early June (Fig. 17C) population densities had begun to decline, although it remained relatively abundant at stations in the southerly part of the Saginaw Bay interface and southward along the Michigan coast. Populations apparently continued to decline and, by late June (Fig. 17D), only scattered low level populations were found at the stations sampled. This taxon was rare during the rest of the season with only a few isolated populations being found during November (Fig. 17E).



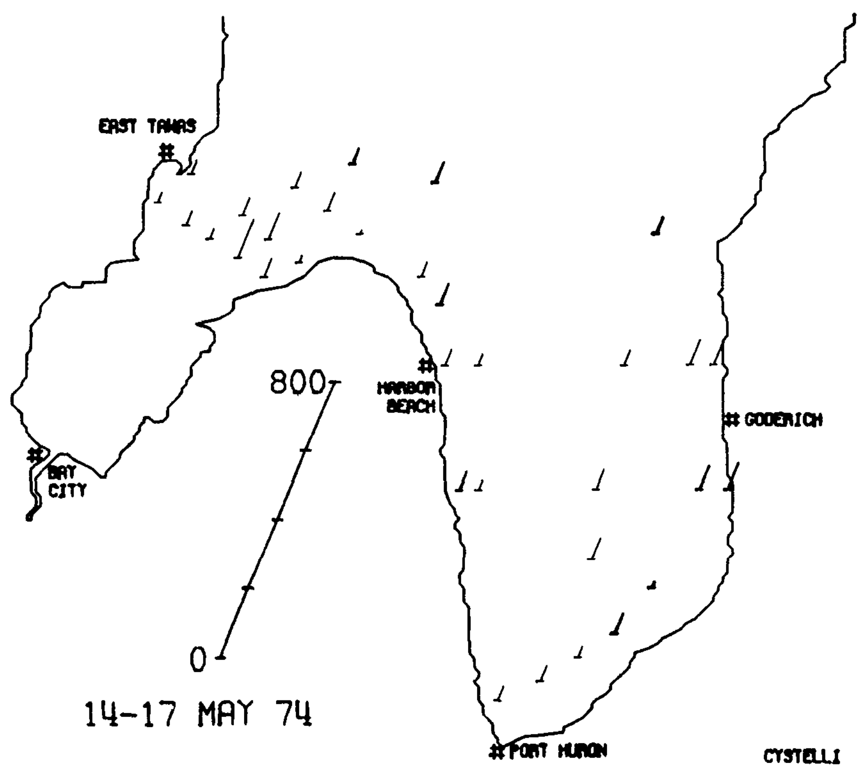
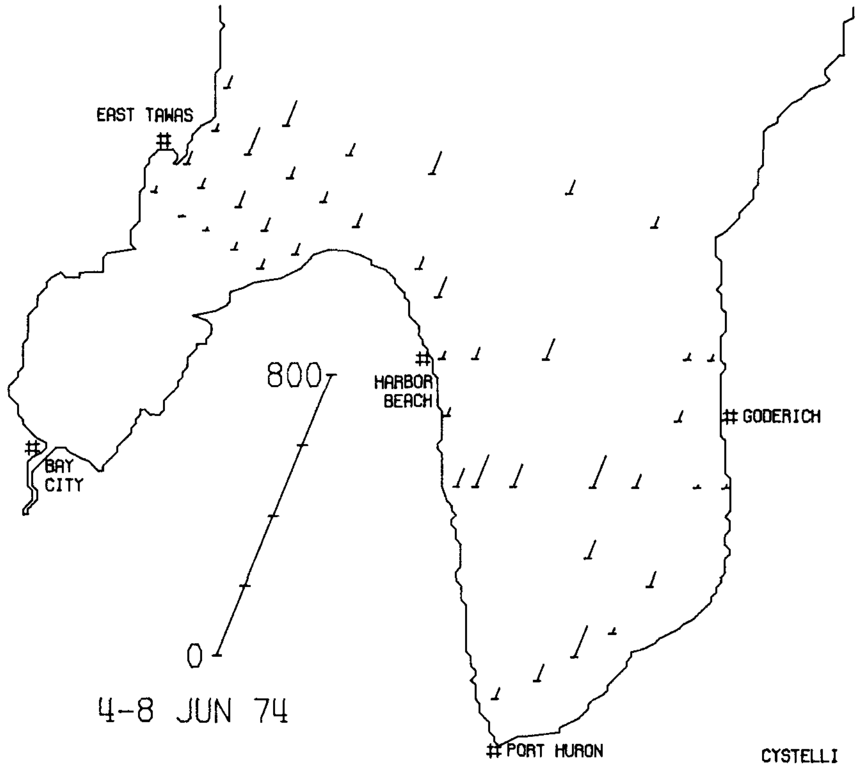
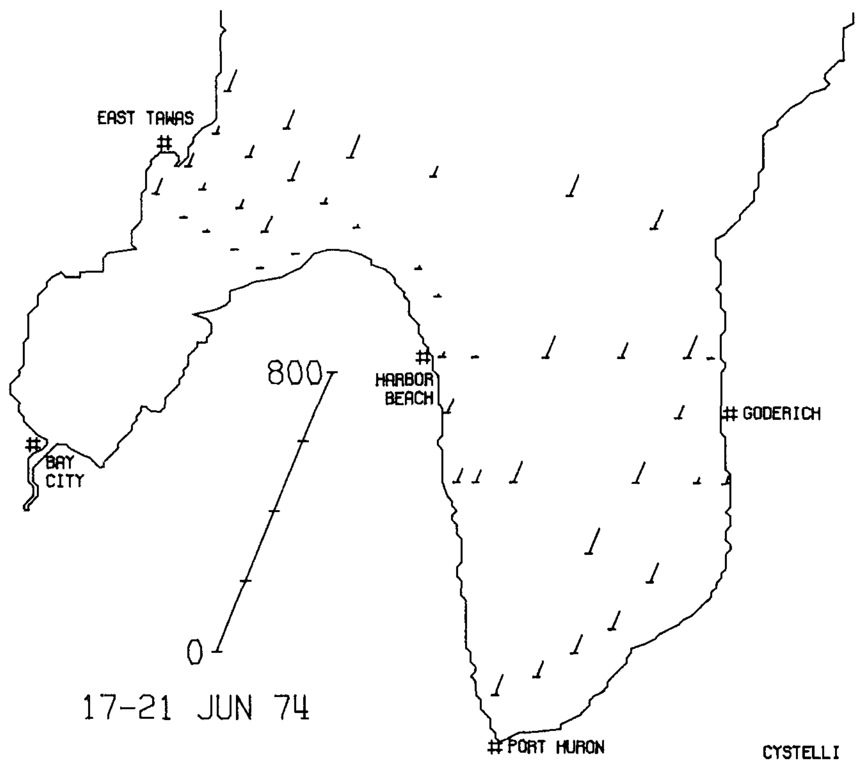


Figure 15. Distribution of Cyclotella stelligera. (continued)





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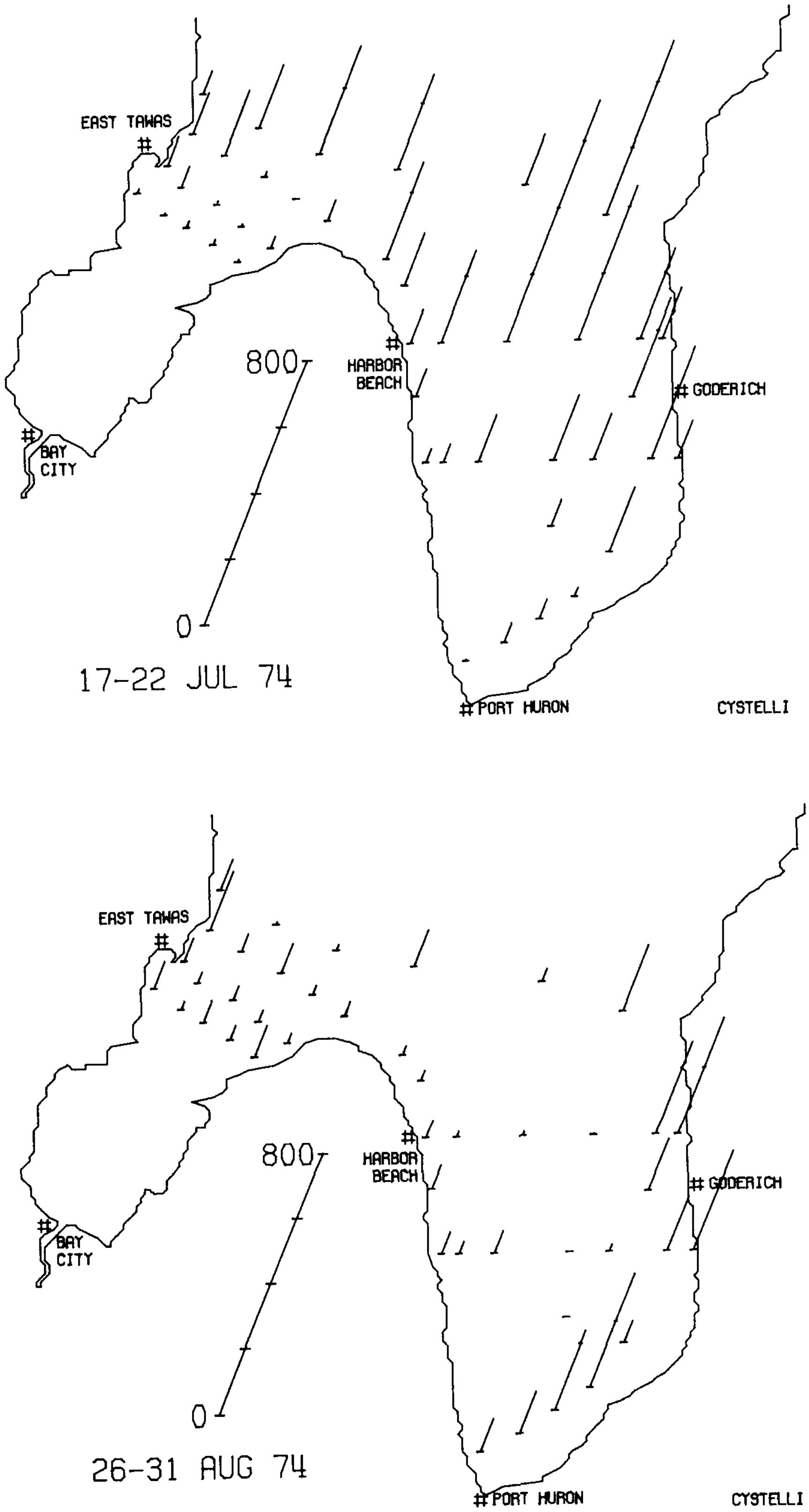
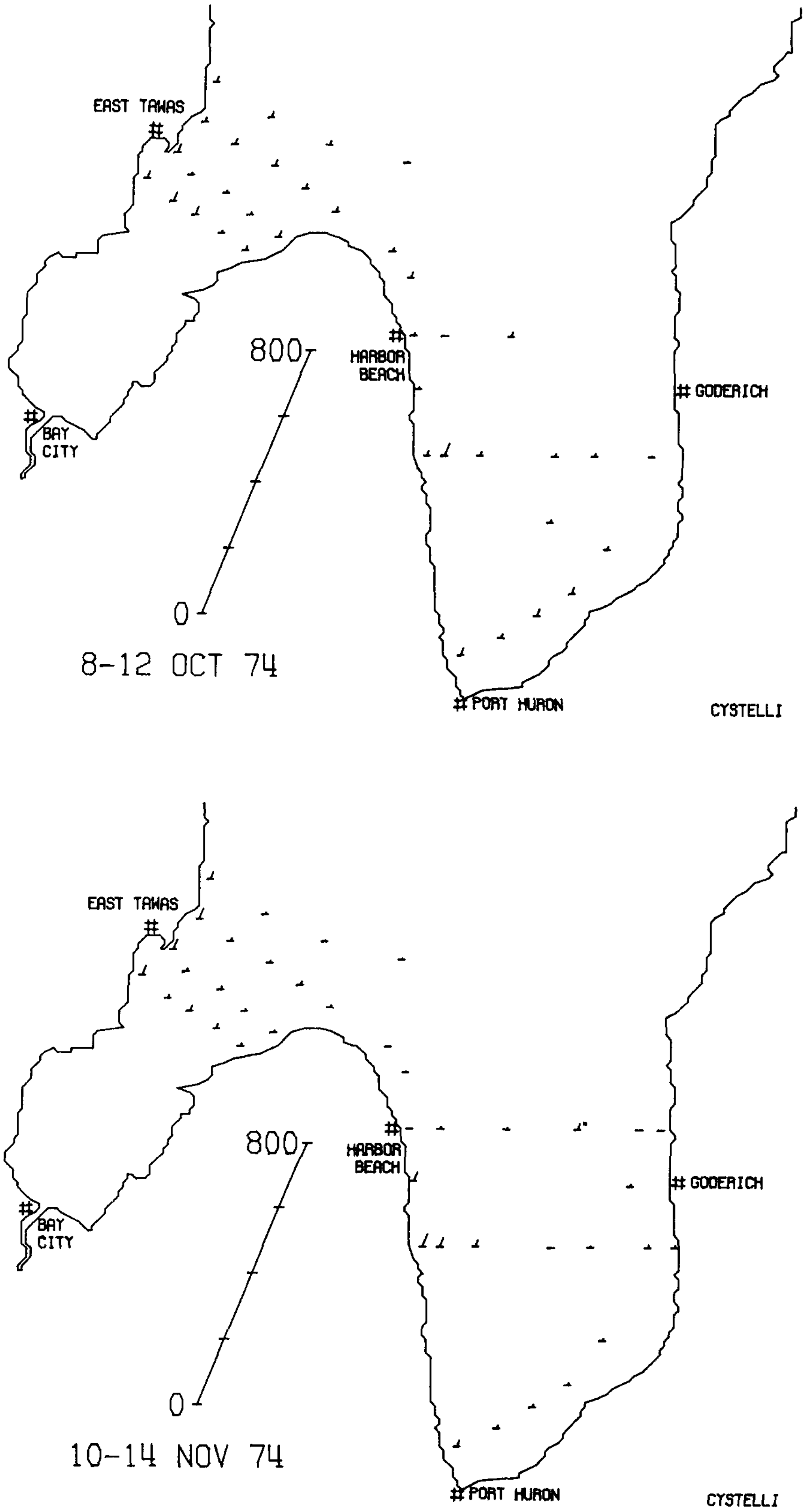


Figure 15. (continued)



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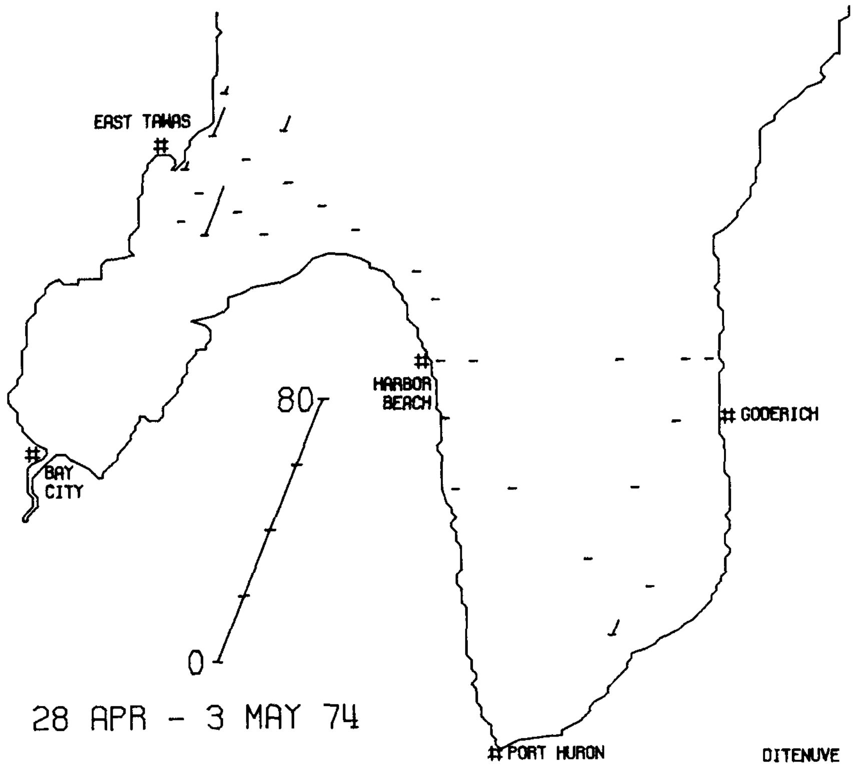


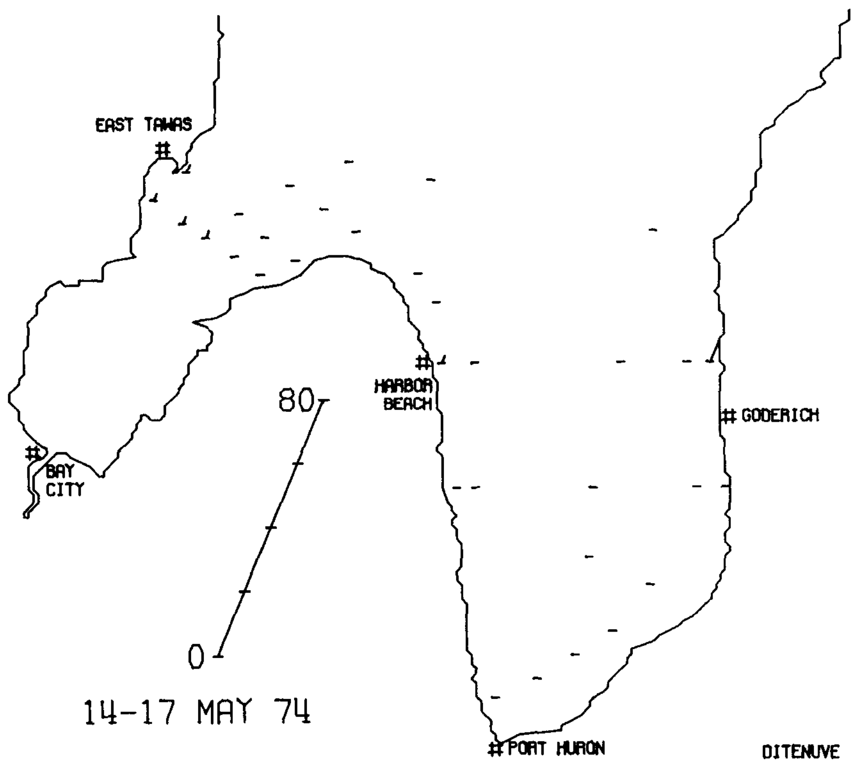
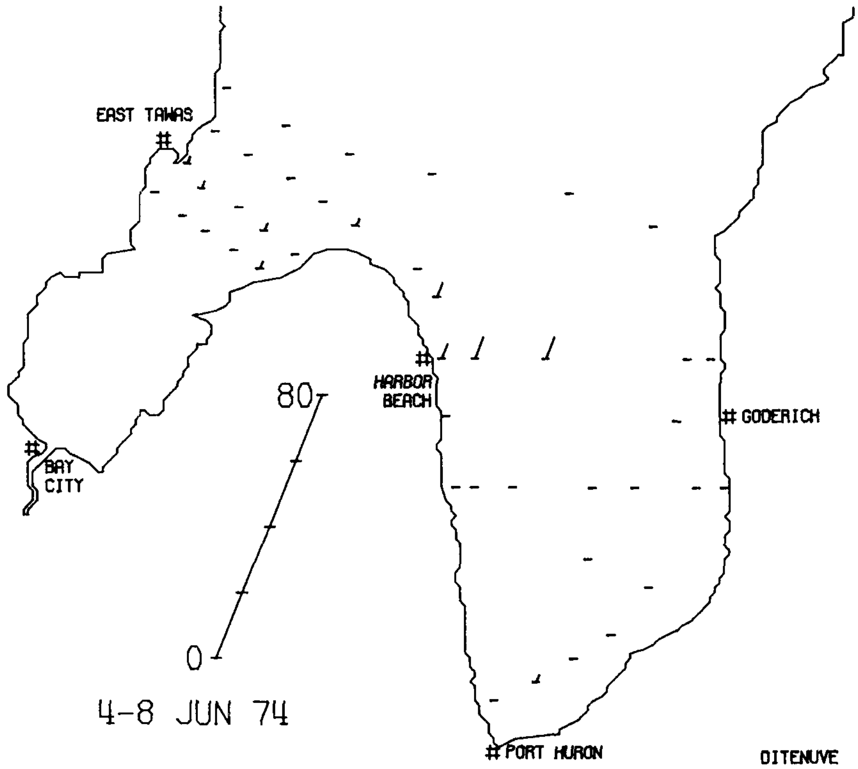
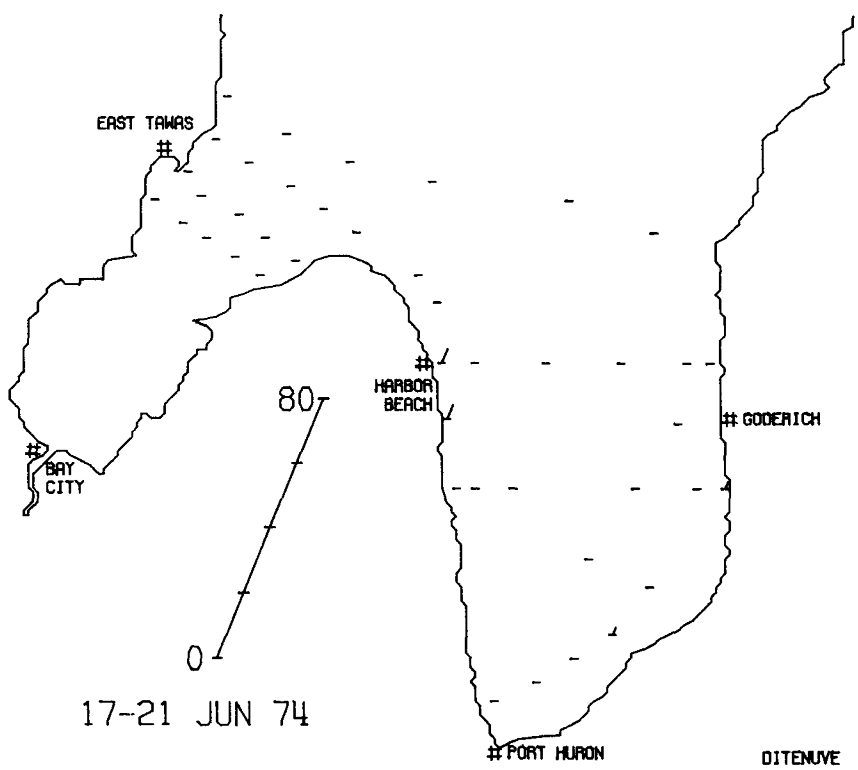


Figure 16. Distribution of Diatoma tenue var. elongatum. (continued)





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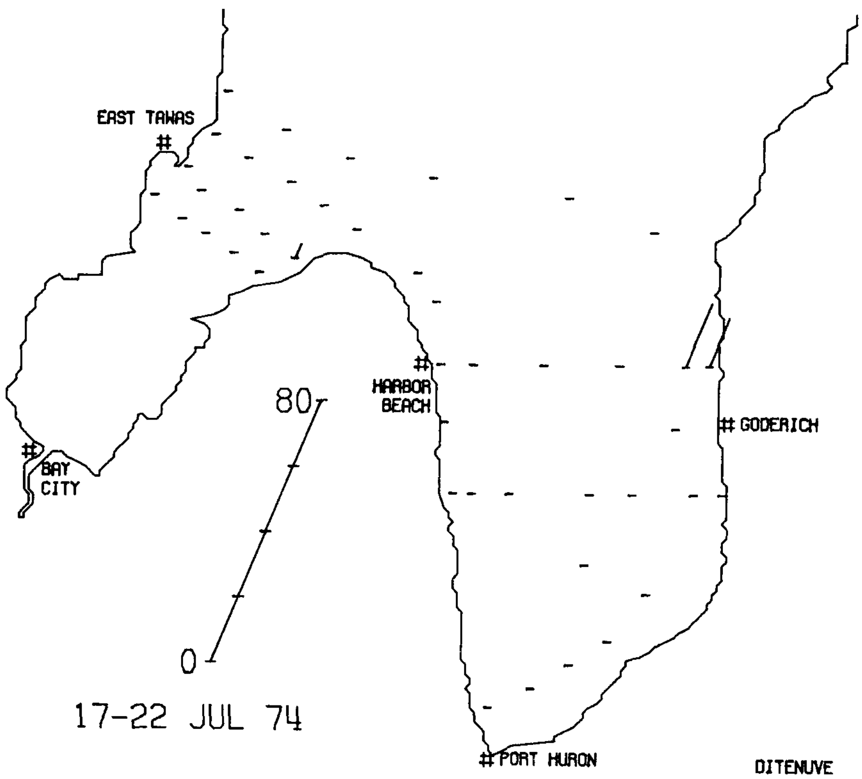

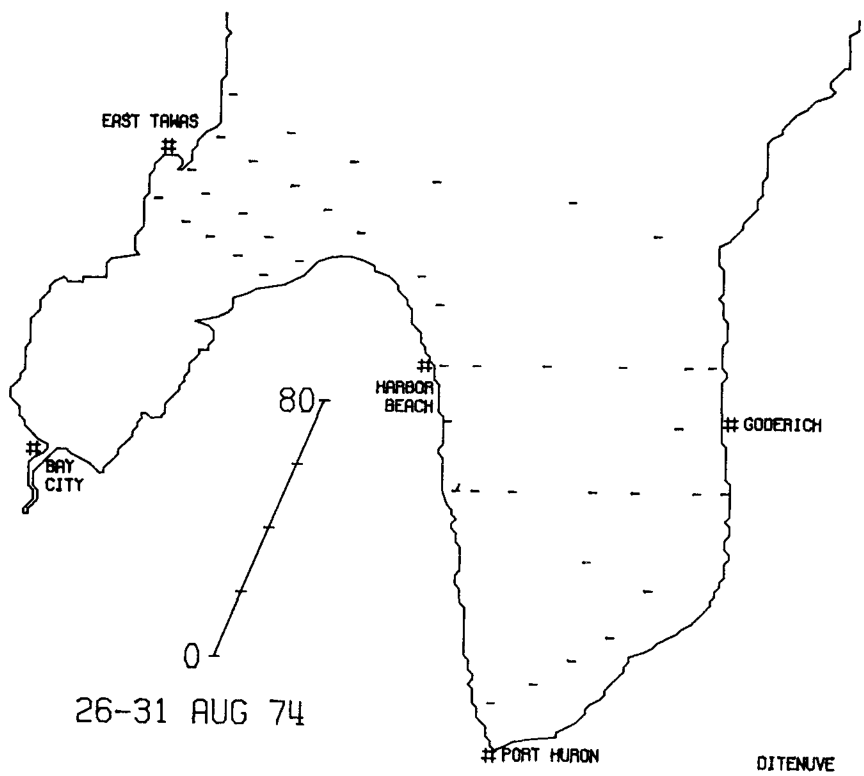

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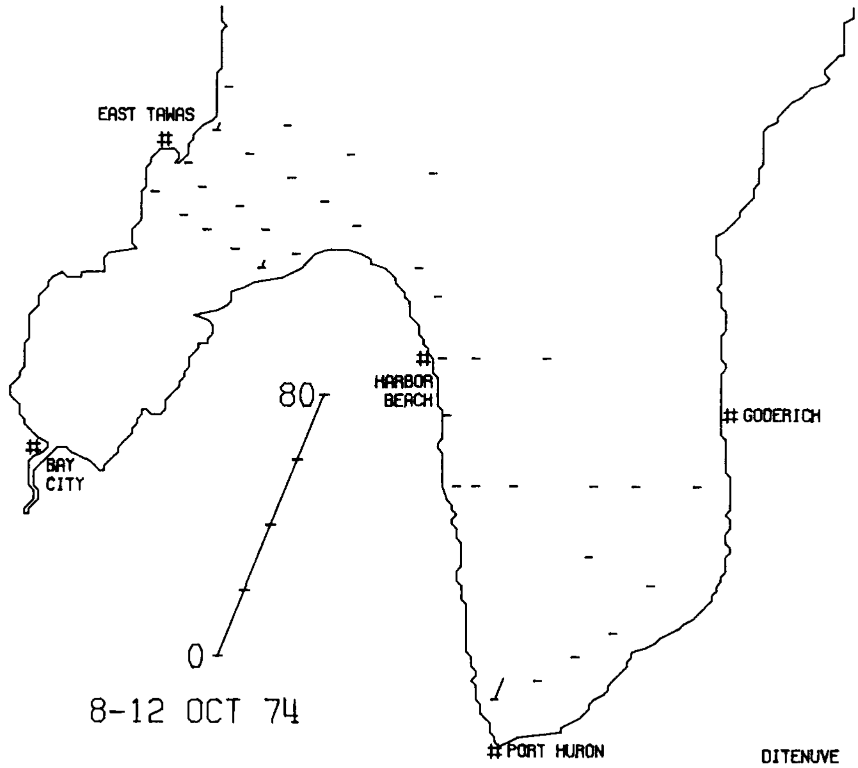

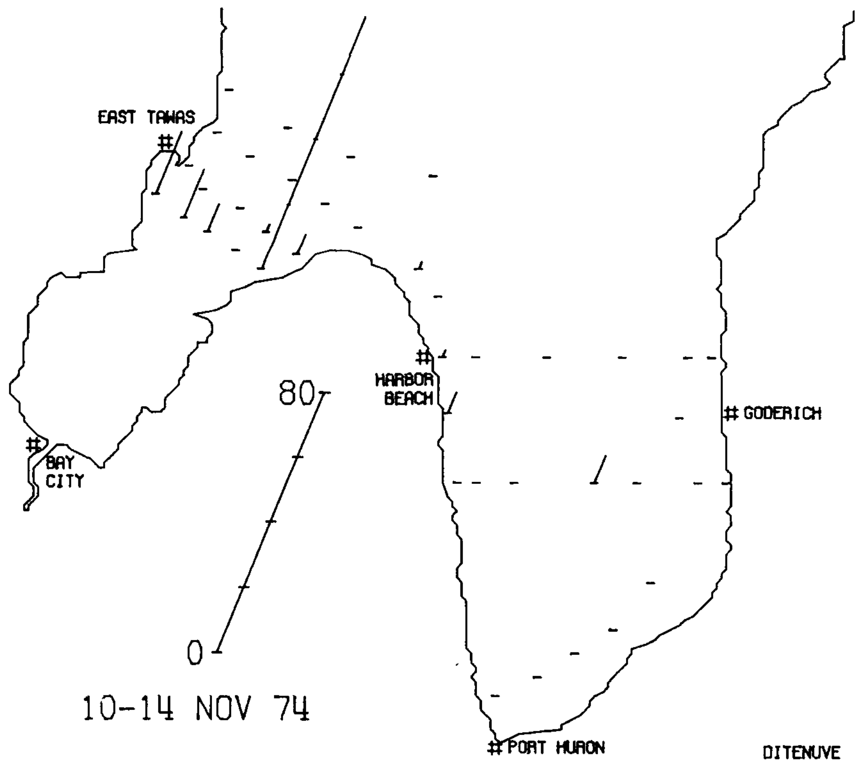

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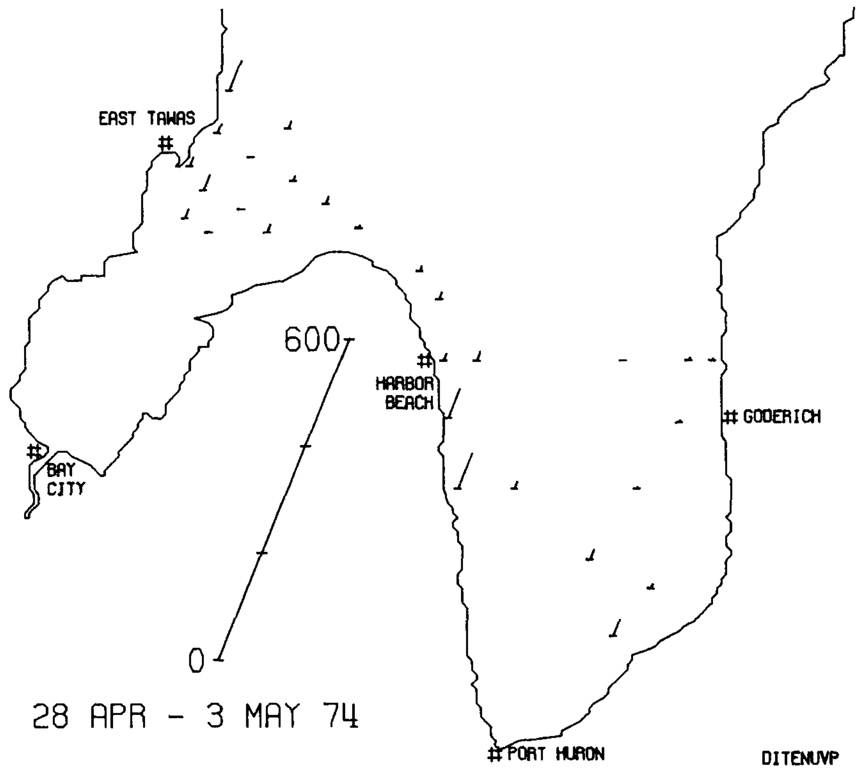


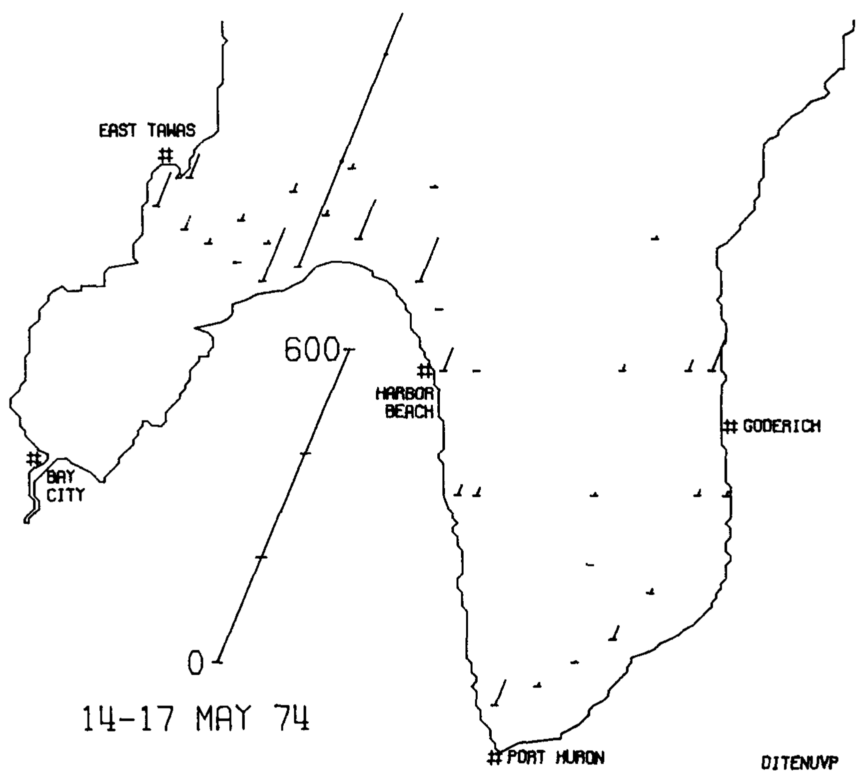
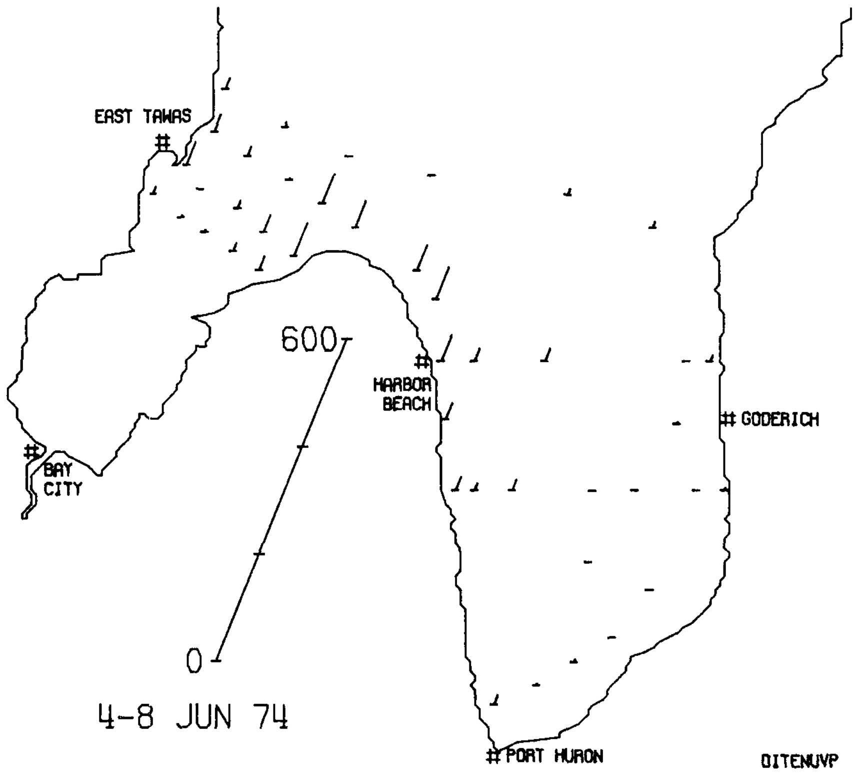


Figure 17. Distribution of *Diatoma tenue* var. *pachycephala*. (continued)



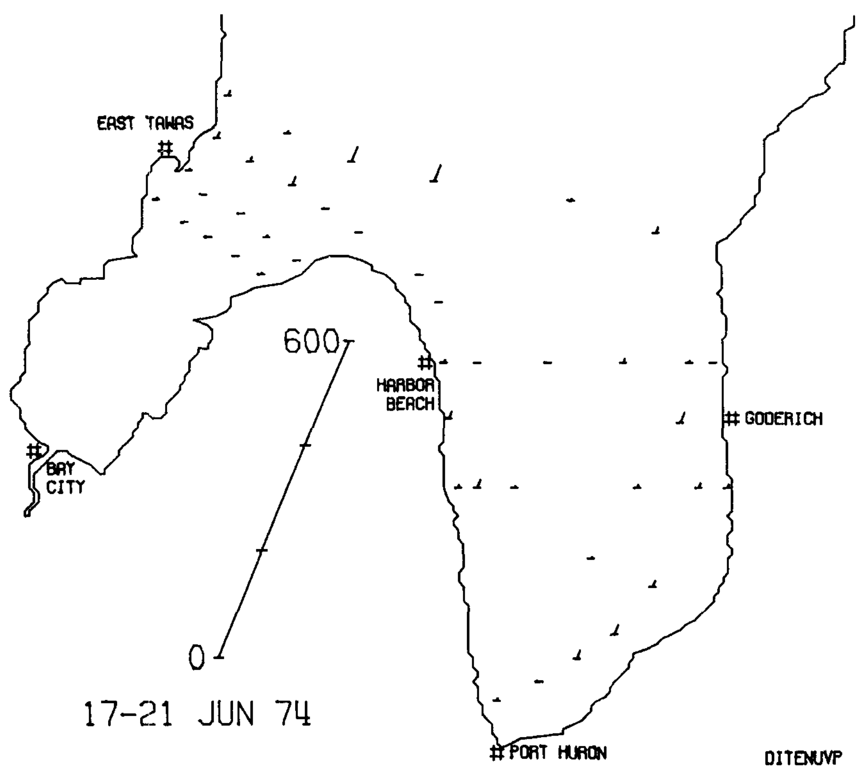


Figure 17. (continued)

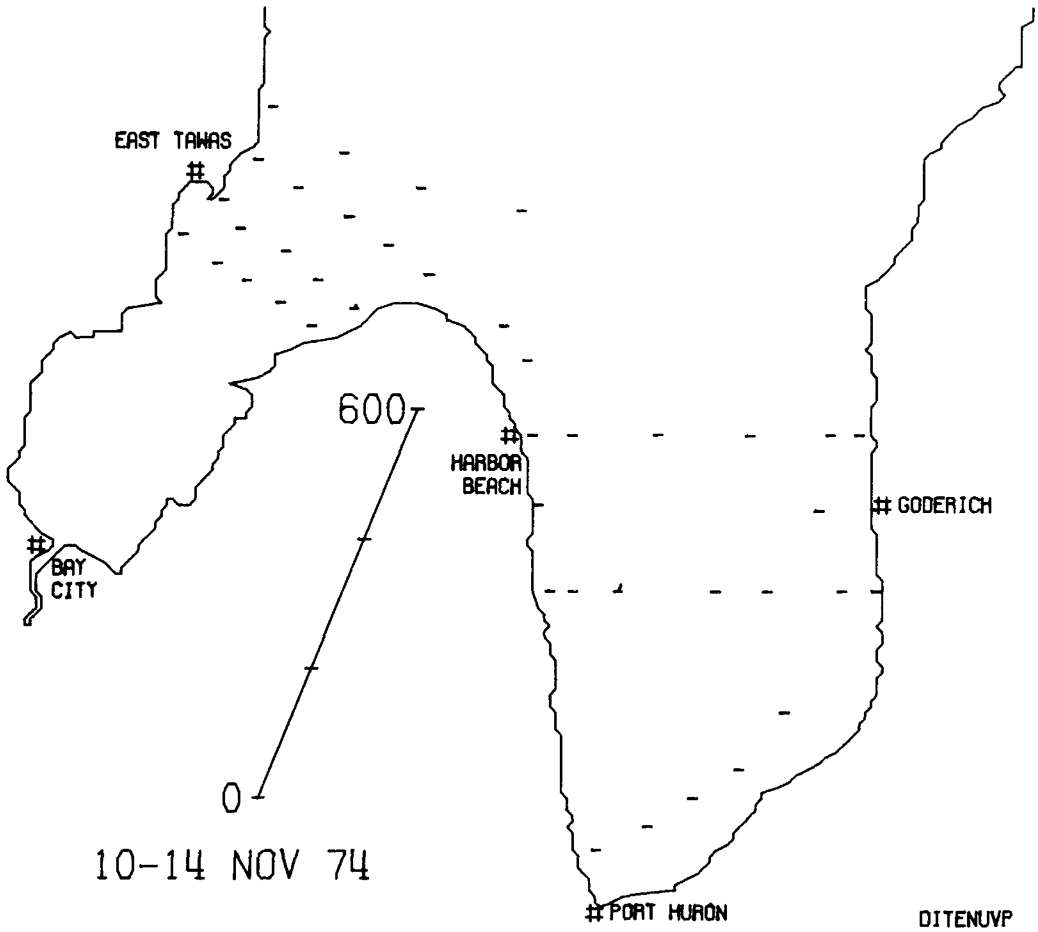
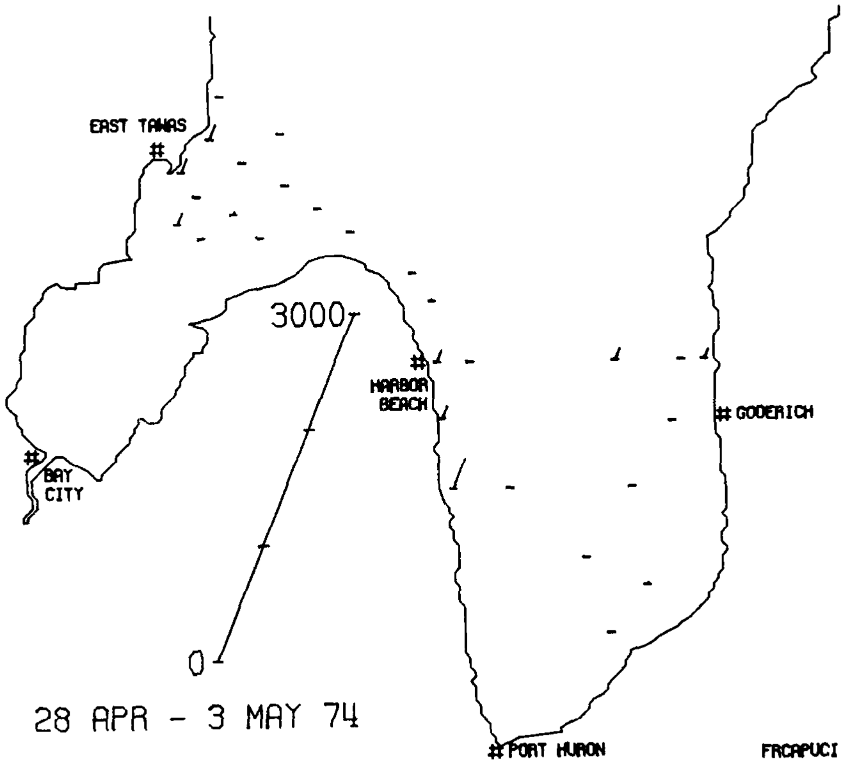


Figure 17. (continued)

Fragilaria capucina

Although this species is most commonly reported from small eutrophic lakes, it is one of the forms which can successfully invade portions of the Great Lakes which become significantly eutrophied (Hohn, 1969) and may become a dominant element of the flora in disturbed parts of the system (Stoermer and Yang, 1970). It is surprisingly abundant in southern Lake Huron. During early May (Fig. 18A) small populations were found in the Saginaw Bay interface waters and at some localities along both the Michigan and Canadian coast. In mid-May (Fig. 18B) it had become very abundant at stations in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast. Small populations were also found at most shoreward stations sampled. It occurs in the nearshore zone at this time with Stephanodiscus binderanus, where their distribution is restricted by the spring thermal bar. During June (Fig. 18C-D) it was abundant at stations in the Saginaw Bay interface and stations running southeastward from this area. During late June (Fig. 18D) significant populations were also found at stations along the Canadian coast. During July and August (Fig. 18E-F) the species declined in abundance although occasional populations were still found in the Saginaw Bay interface and at stations along the Canadian coast. It again increased in abundance during the fall cruises (Fig. 18G-H) but population densities did not approach those found during the spring bloom, and occurrences were restricted to the Saginaw Bay interface waters and a few stations southward along the Michigan coast.



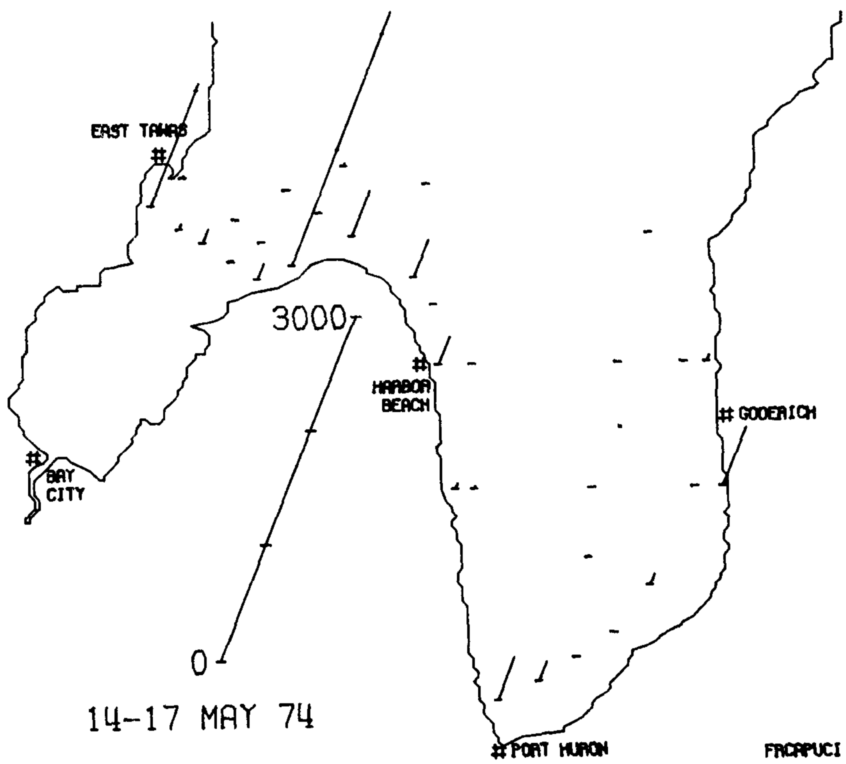
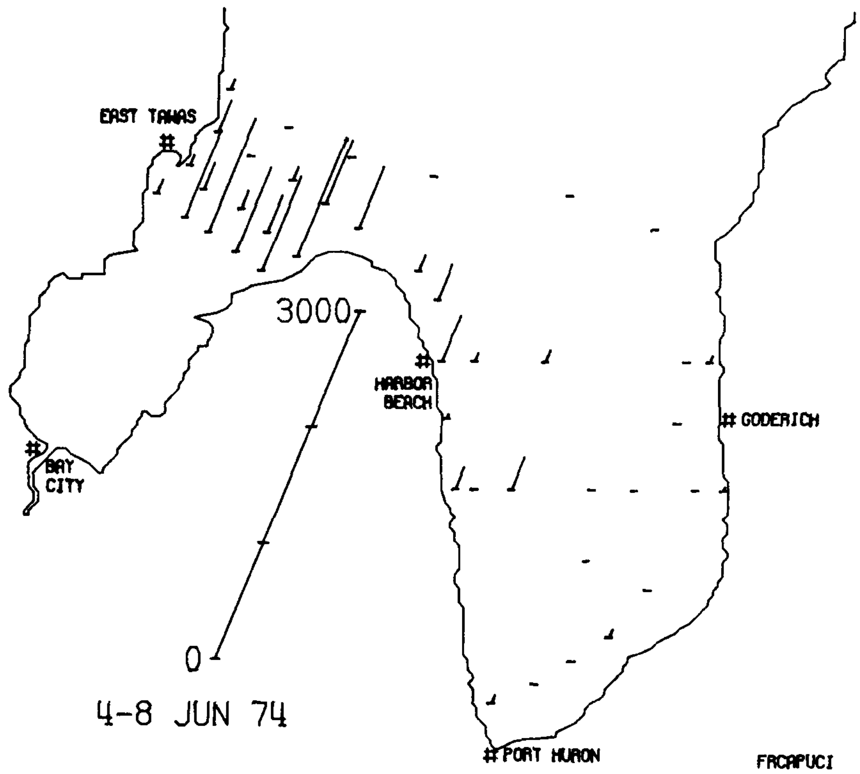


Figure 18. Distribution of _Fragilaria capucina_. (continued)



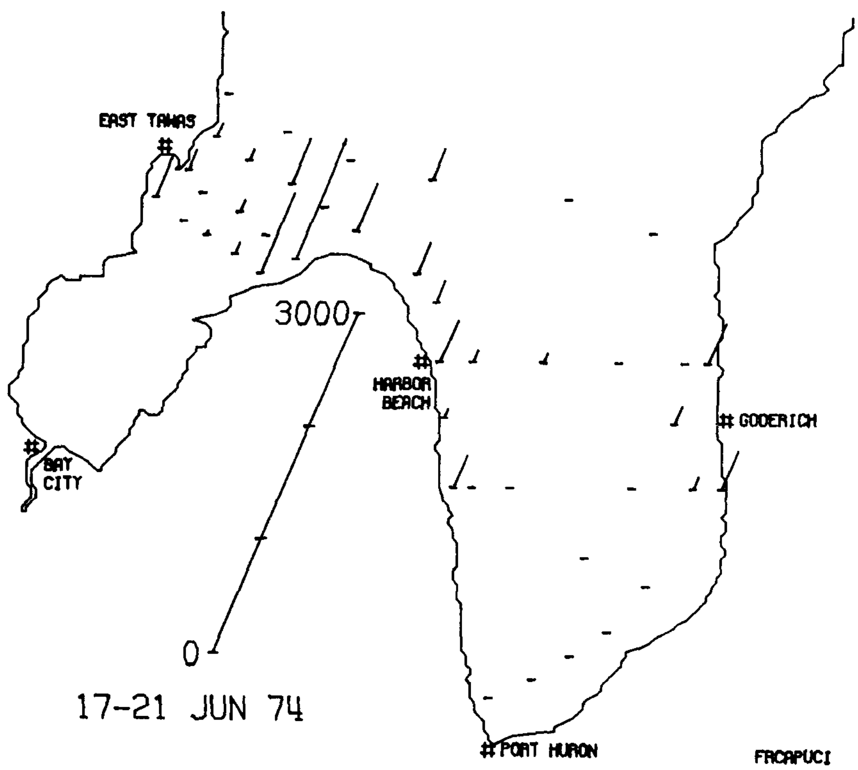
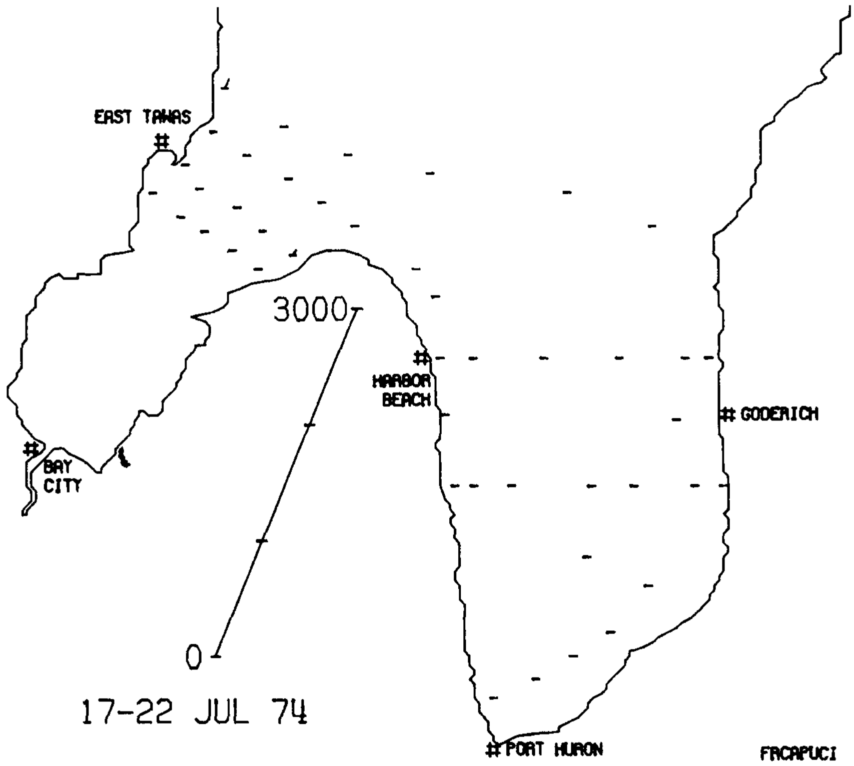


Figure 18. (continued)



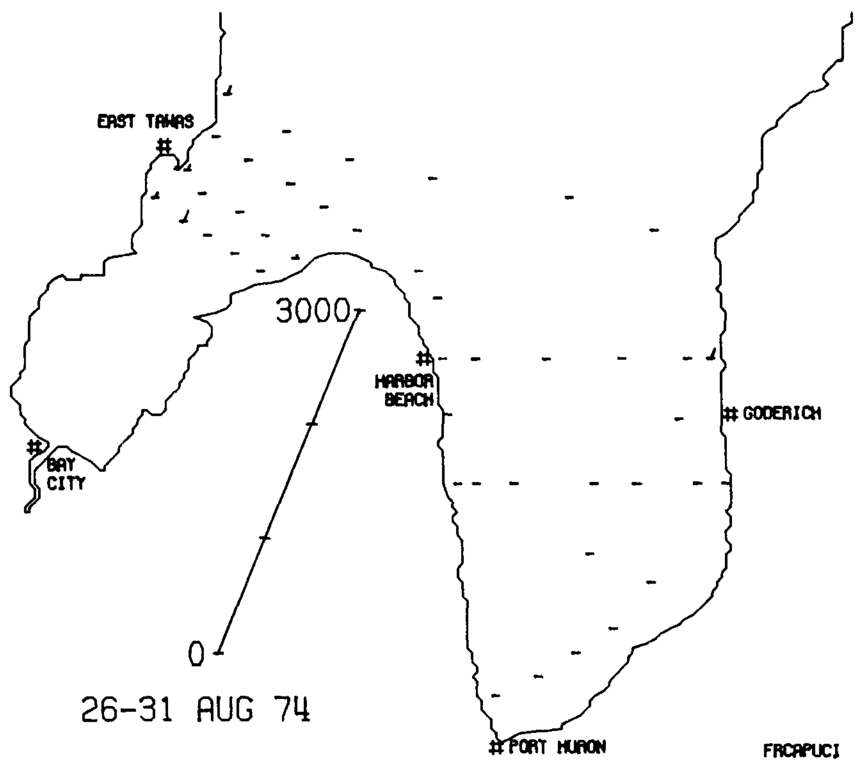
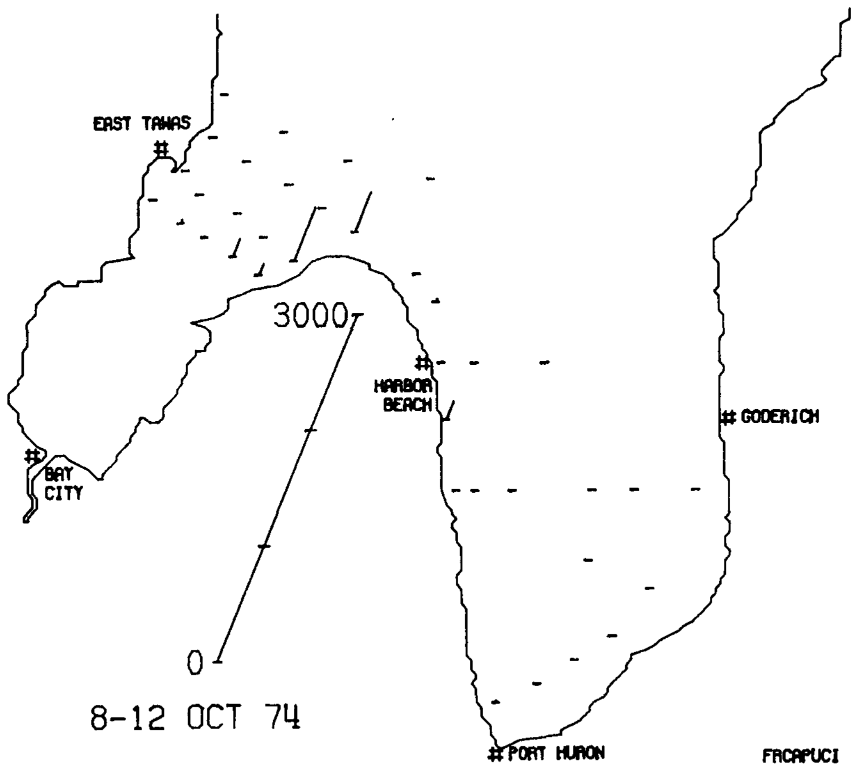


Figure 18. (continued)



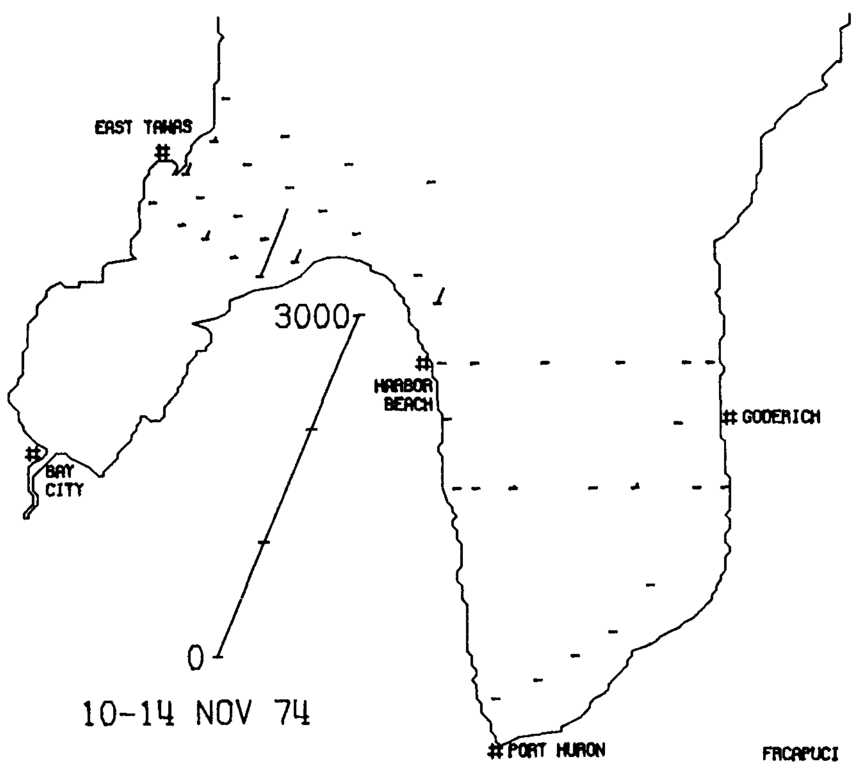


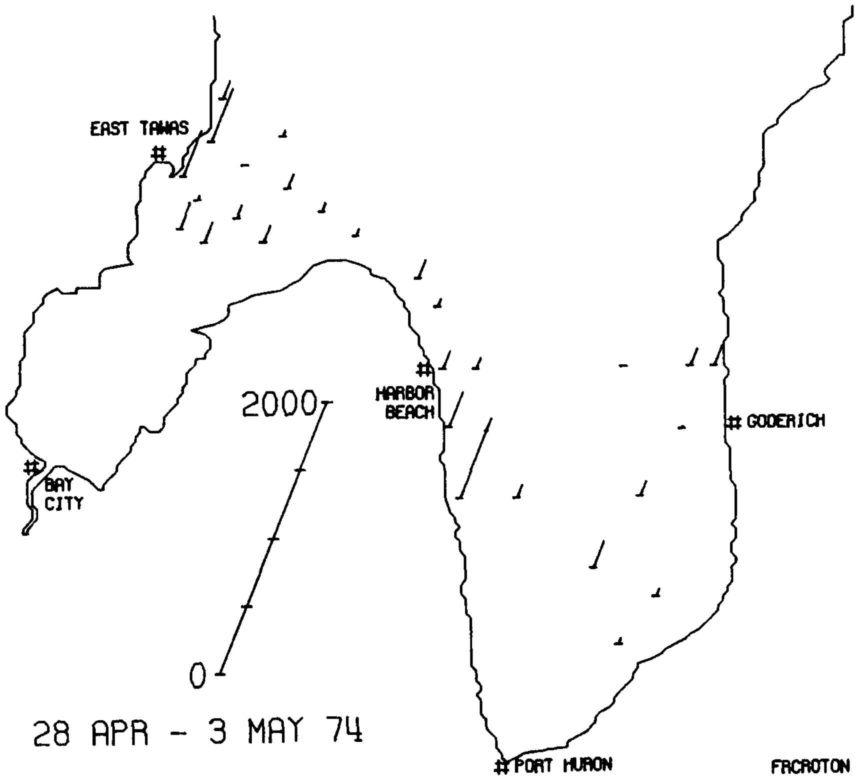
Figure 18. (continued)

Fragilaria crotonensis

This species is one of the most widely distributed and apparently eurytopic of all freshwater planktonic diatoms. It is common throughout the Great Lakes system and apparently tolerant of the full range of conditions found within the system. It responds strongly to experimental phosphorus enrichment (Stoermer, Ladewski and Schelske, 1978) but significant populations may be found in areas of the Great Lakes which have low ambient nutrient concentrations. It was present at most stations sampled during the early May cruise (Fig. 19A) with highest population densities occurring at stations along the Michigan coast. By mid-May (Fig. 19B) populations were highest at stations in the Saginaw Bay interface and nearshore stations around the southern basin. The increase at nearshore stations appeared to be associated with the development of the spring thermal bar. In early June (Fig. 19C) population levels were somewhat reduced, with highest densities occurring at scattered stations in the Saginaw Bay interface. In late June (Fig. 19D) this species bloomed at stations in the southerly portion of the Saginaw Bay interface, and it was present at most stations sampled. These populations had apparently collapsed by the time the mid-July samples (Fig. 19E) were taken and highest population densities were found in the extreme southern portion of the lake. Seasonal minimal abundance of this species occurred during August (Fig. 19F) when only isolated low level populations were found. It increased in abundance again during October (Fig. 19G) when highest population densities were again found in the Saginaw Bay interface waters. Similar population densities were found during the November cruise (Fig. 19H) when this species was most abundant in the Saginaw Bay interface waters southward along the Michigan coast and at certain stations along the Canadian coast.

Fragilaria pinnata

This species is primarily benthic in habitat preference and, although occasional specimens may be found in plankton collections from the Great Lakes, it is rarely a dominant element in phytoplankton assemblages. Its distribution appears to be controlled by both nutrient availability and the availability of suitable benthic substrates. For instance, in Lake Michigan (Stoermer and Yang, 1970), its distribution is largely restricted to stations along the western shore. It appears to be more abundant in southern Lake Huron than in other areas of the Great Lakes so far studied. In May (Fig. 20A-B) occasional populations were noted, particularly at nearshore stations and stations in the Saginaw Bay interface. During early June (Fig. 20C) this species was not abundant but did occur at nearshore localities in Saginaw Bay and north and south along the Michigan coast. Populations were at very low levels during the mid-June and July cruises (Fig. 20D-E). Abundance increased somewhat during August (Fig. 20F) and it had become quite abundant by the time the October (Fig. 20G) samples were taken, with appreciable populations present in the Saginaw Bay interface stations and at most nearshore stations all along the Michigan coast. Population levels of this species were generally reduced during the November cruise (Fig. 20H) at stations south of Saginaw Bay, although it reached seasonal maxima at stations along the Michigan coast north of Tawas.



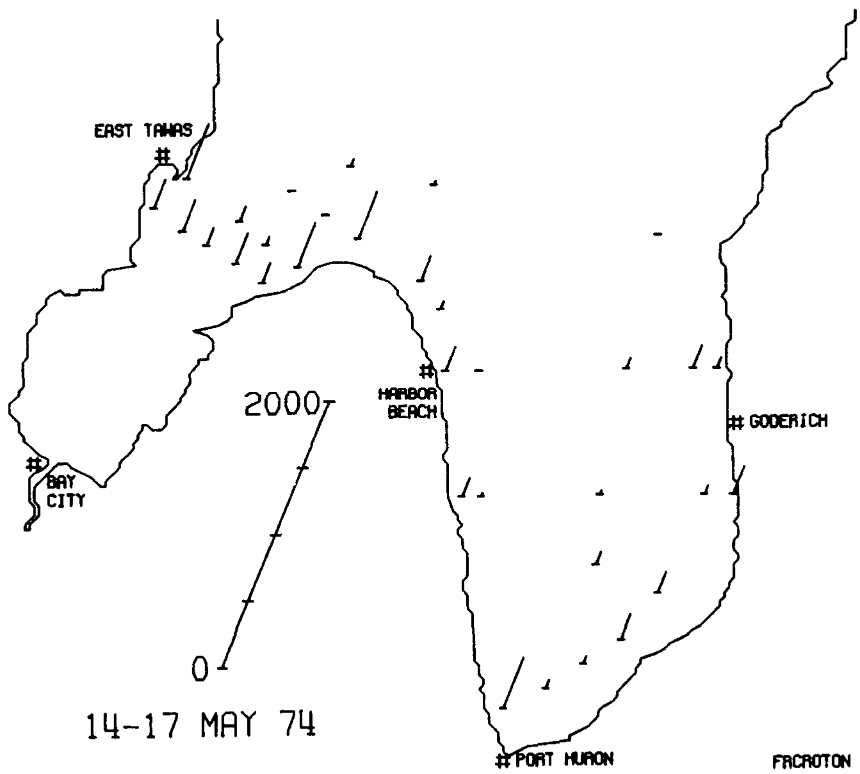
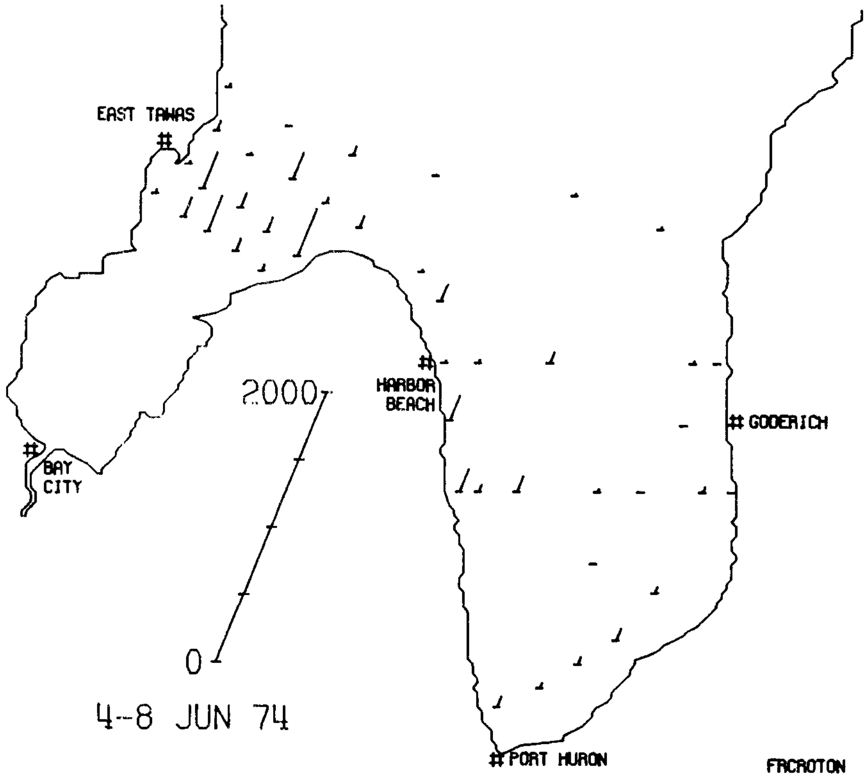


Figure 19. Distribution of *Fragilaria crotonensis*. (continued)



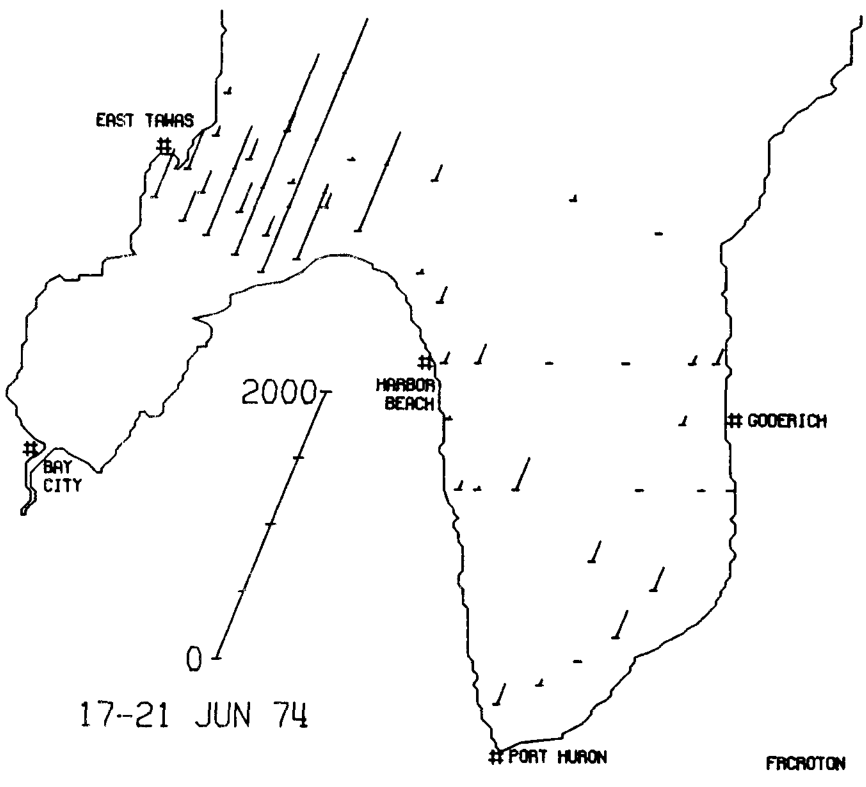
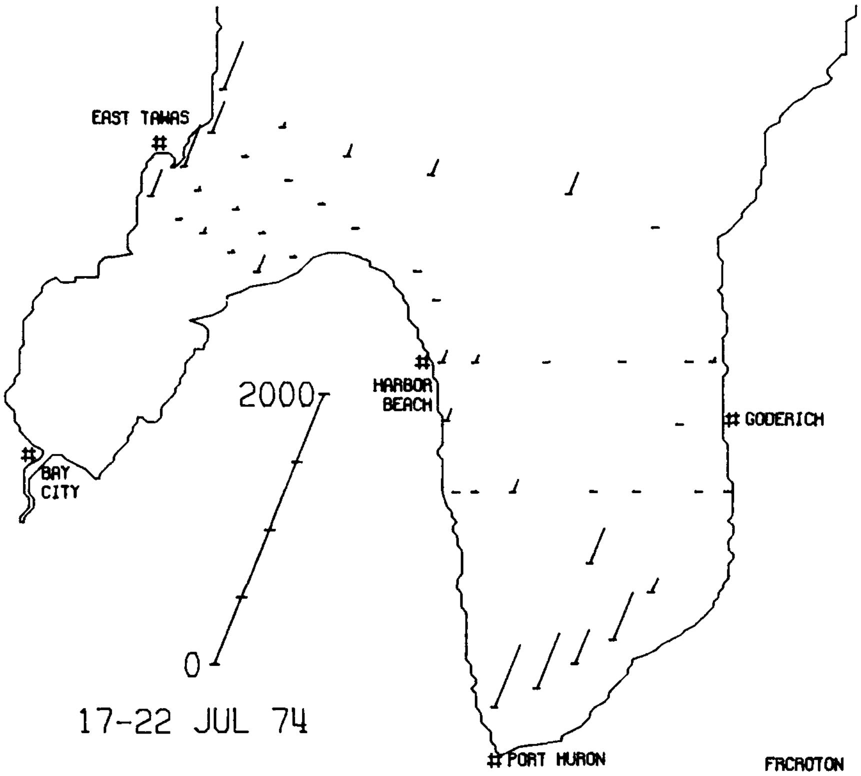


Figure 19. (continued)



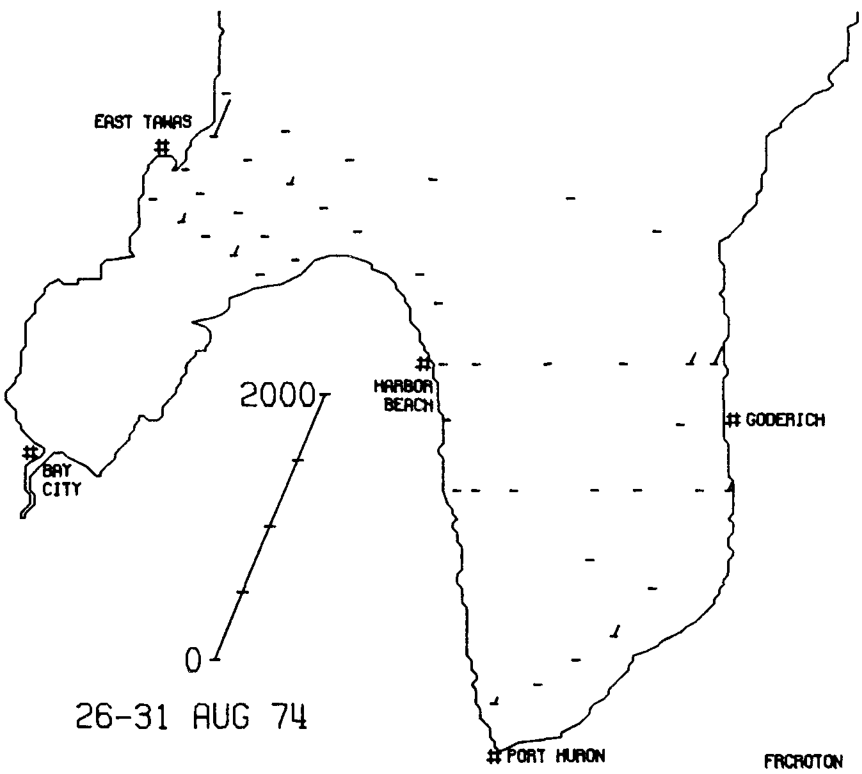
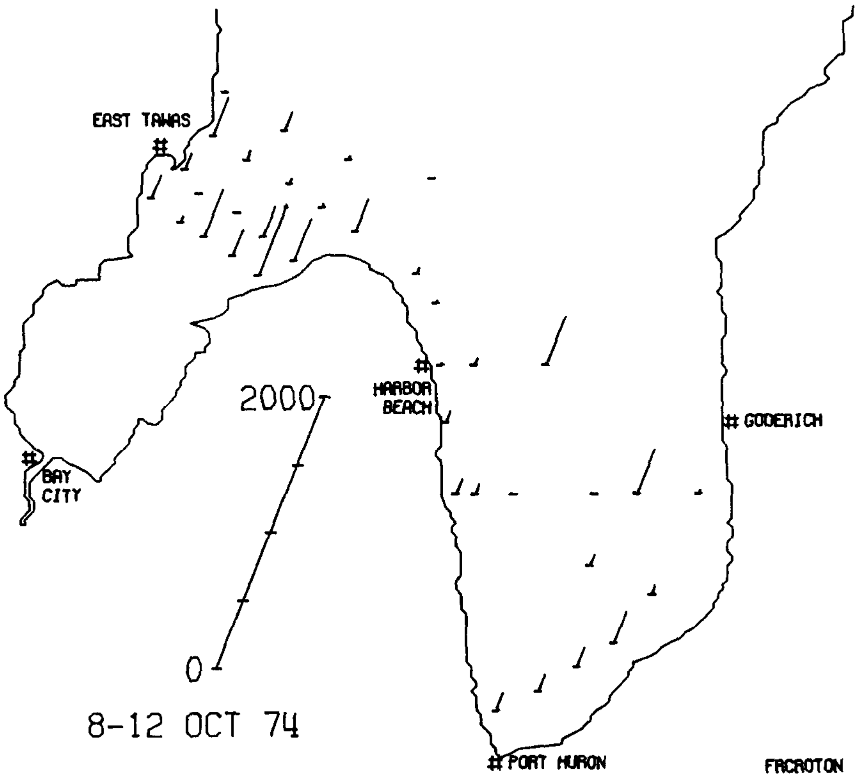


Figure 19. (continued)



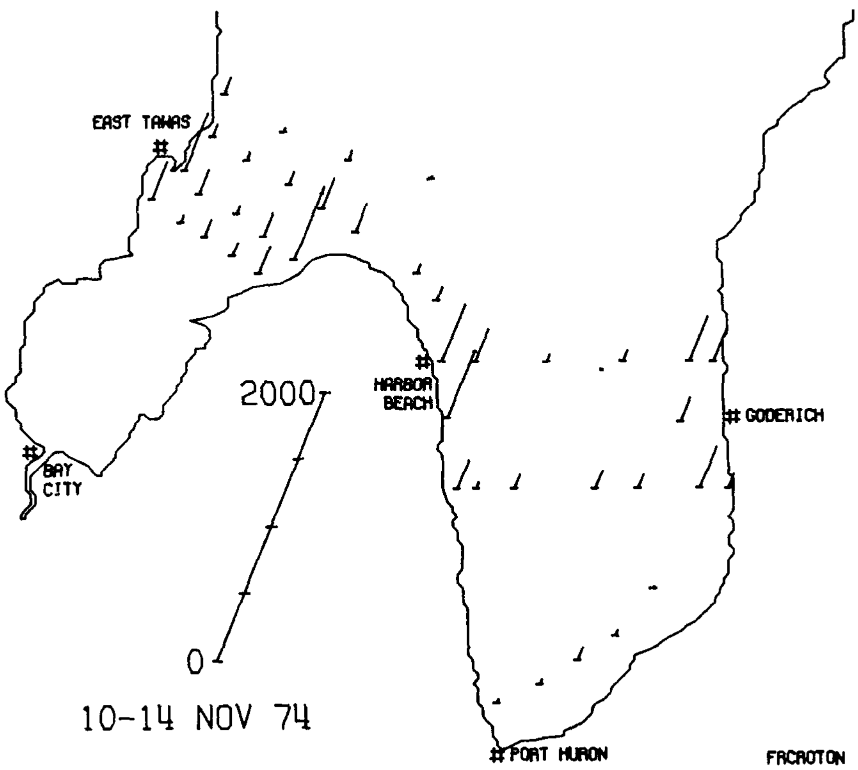
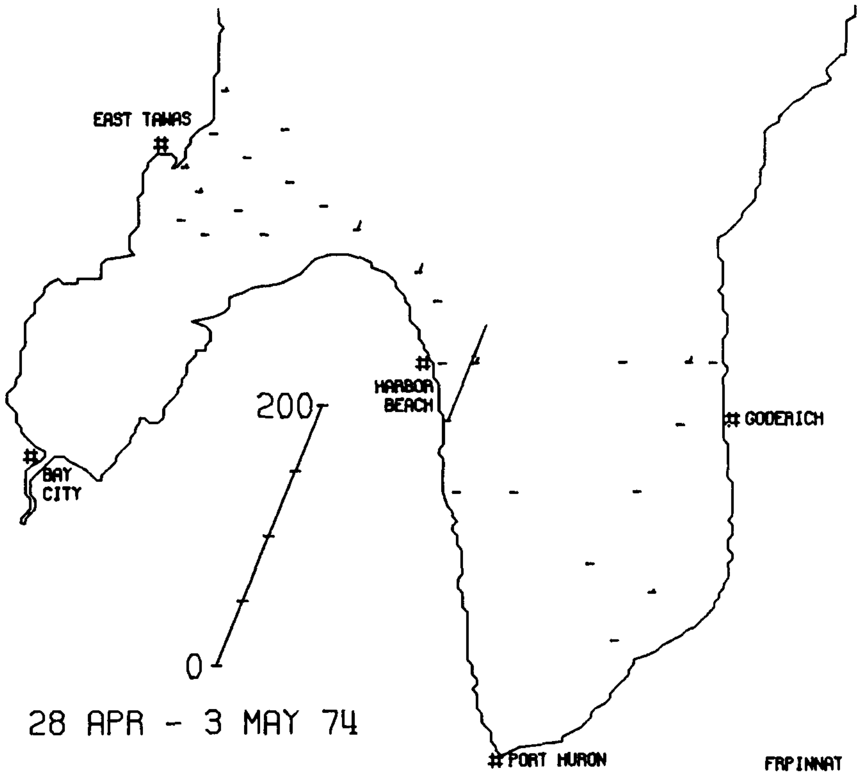


Figure 19. (continued)



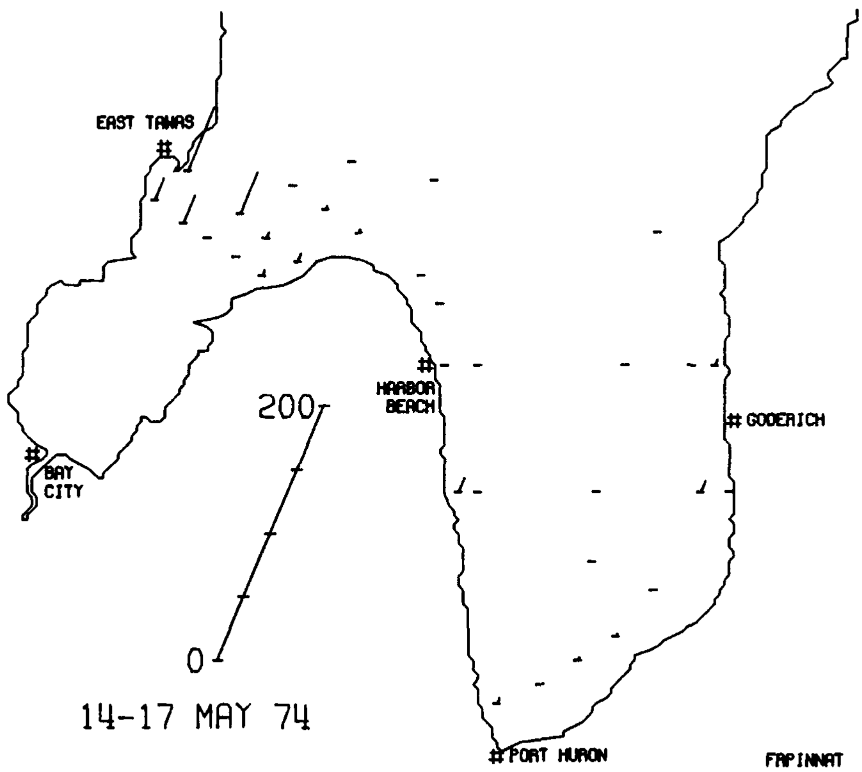
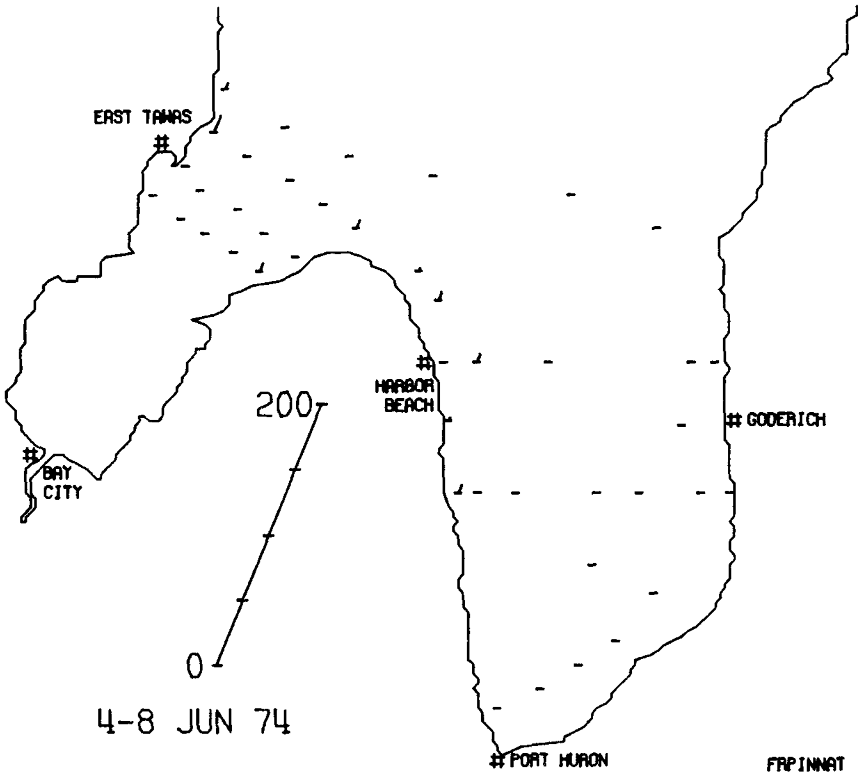


Figure 20. Distribution of *Fragilaria pinnata*. (continued)



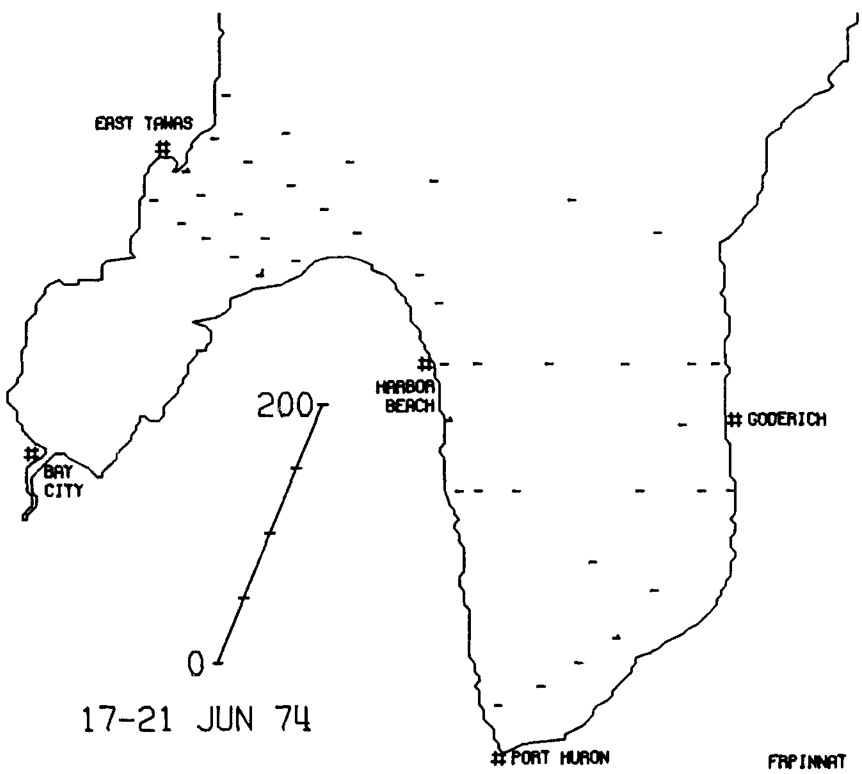
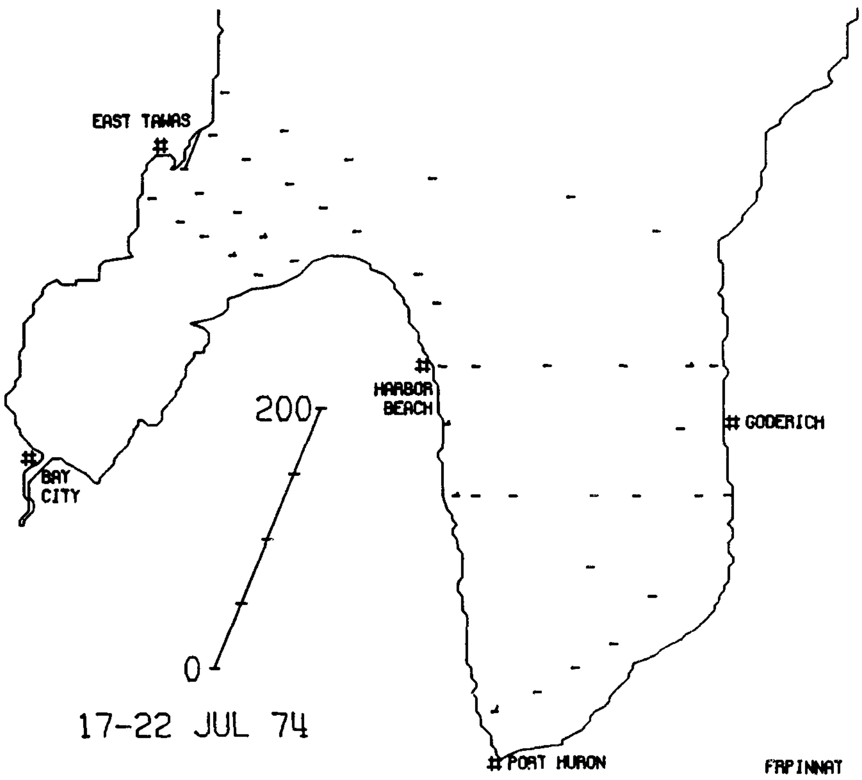


Figure 20. (continued)



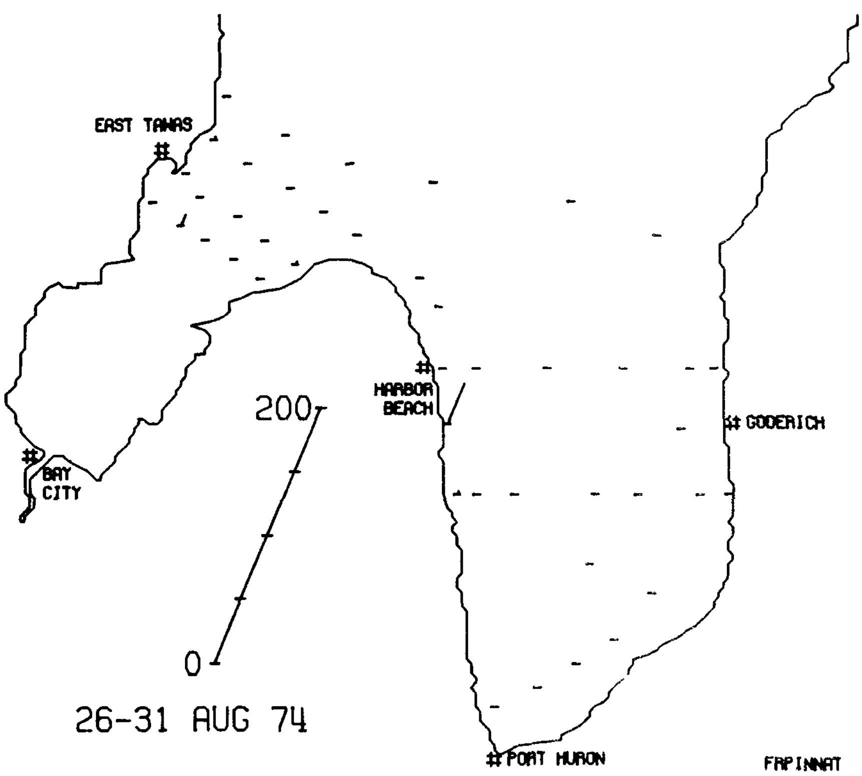


Figure 20. (continued)

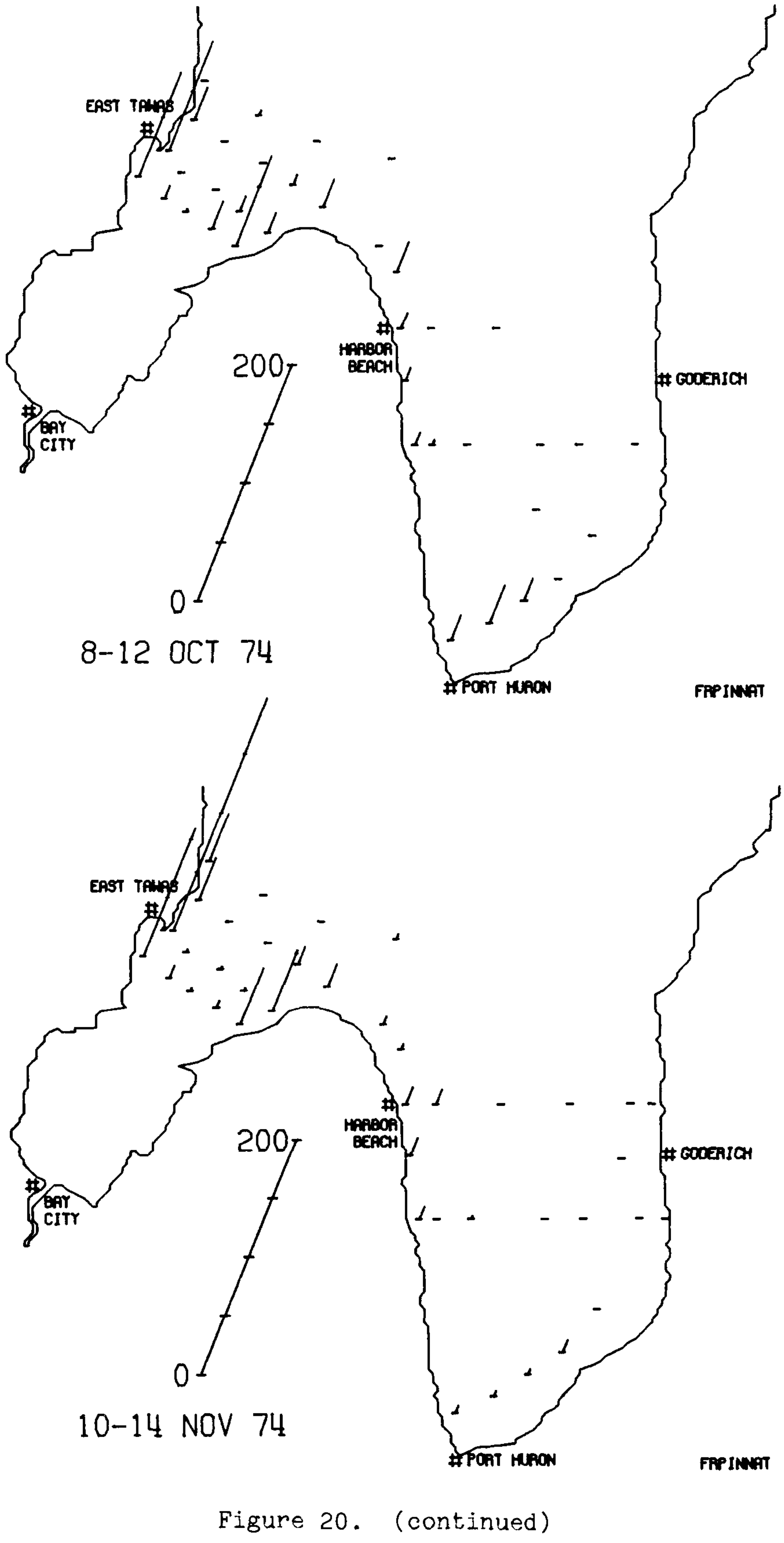


Figure 20. (continued)

Melosira granulata

This species generally reaches its highest abundance in small eutrophic lakes where it often forms sizeable early summer and early fall blooms. It is a common element of phytoplankton assemblages of shallow eutrophied areas in the Laurentian Great Lakes, but rarely, if ever, reaches high population densities in the offshore waters of the lakes other than Lake Erie. It was first noted during the early May sampling cruise at two nearshore stations along the Michigan coast (Fig. 21A). By mid-May (Fig. 21B) it was abundant at certain stations at the Saginaw Bay interface waters, and low level populations were also noted at nearshore stations along the Canadian coast. Population levels of M. granulata declined during June (Fig. 21C-D) although scattered occurrences were noted. This trend continued into July and August (Fig. 21E-F) with only occasional populations found at nearshore stations. During October (Fig. 21G) the abundance of this species again increased, and sizeable populations were noted at stations in the southerly sector of the Saginaw Bay interface and at most nearshore stations sampled. Maximum population levels were noted in November (Fig. 21H) when it was abundant at stations in the Saginaw Bay interface and present at several stations in the southern part of main Lake Huron, including some stations near mid-lake. Two growth forms of this taxon were noted during this study, a very coarsely punctate type with large spines and a finely punctate form with short spines.

Melosira islandica

This species is a common cold season dominant in boreal and alpine lakes worldwide. It is common throughout the Great Lakes system and appears to be favored by moderate levels of nutrient increase although it tends to disappear in areas which are grossly perturbed. It was present at most stations sampled during early May with greatest abundance at stations along the Canadian shoreline. By mid-May populations had somewhat increased and the species was again exceptionally abundant at stations along the Canadian coast north and south of Goderich (Fig. 22A-B). Population levels generally declined during June (Fig. 22C-D) and only occasional low-level occurrences were noted during the rest of the sampling season (Fig. 22E-G).

Nitzschia acicularis

The distribution and ecological affinities of this species are not well known, and it is rarely reported from plankton communities. It is widely distributed in the Laurentian Great Lakes and is a common minor component of phytoplankton assemblages in those areas which have been studied in detail. It may be much more abundant than generally realized because cells may be confused with members of the genus Synedra if observed in wet mounts. Rather uniform populations of this species were present at most stations sampled during May (Fig. 23A-B). In early June (Fig. 23C) distribution of this species was more erratic, and although it was still abundant at many stations, populations were significantly reduced in the Saginaw Bay interface waters and at certain stations offshore. Populations continued to decline in late June (Fig. 23D) although the species remained abundant at nearshore stations north of Tawas and, to a lesser extent, at stations south of Saginaw Bay along both the U.S. and Canadian coasts. Population levels were minimal during July and August (Fig. 23E-F) but the species became more abundant again in October and November (Fig. 23G-H) particularly at stations in the Saginaw Bay interface waters and nearshore stations.

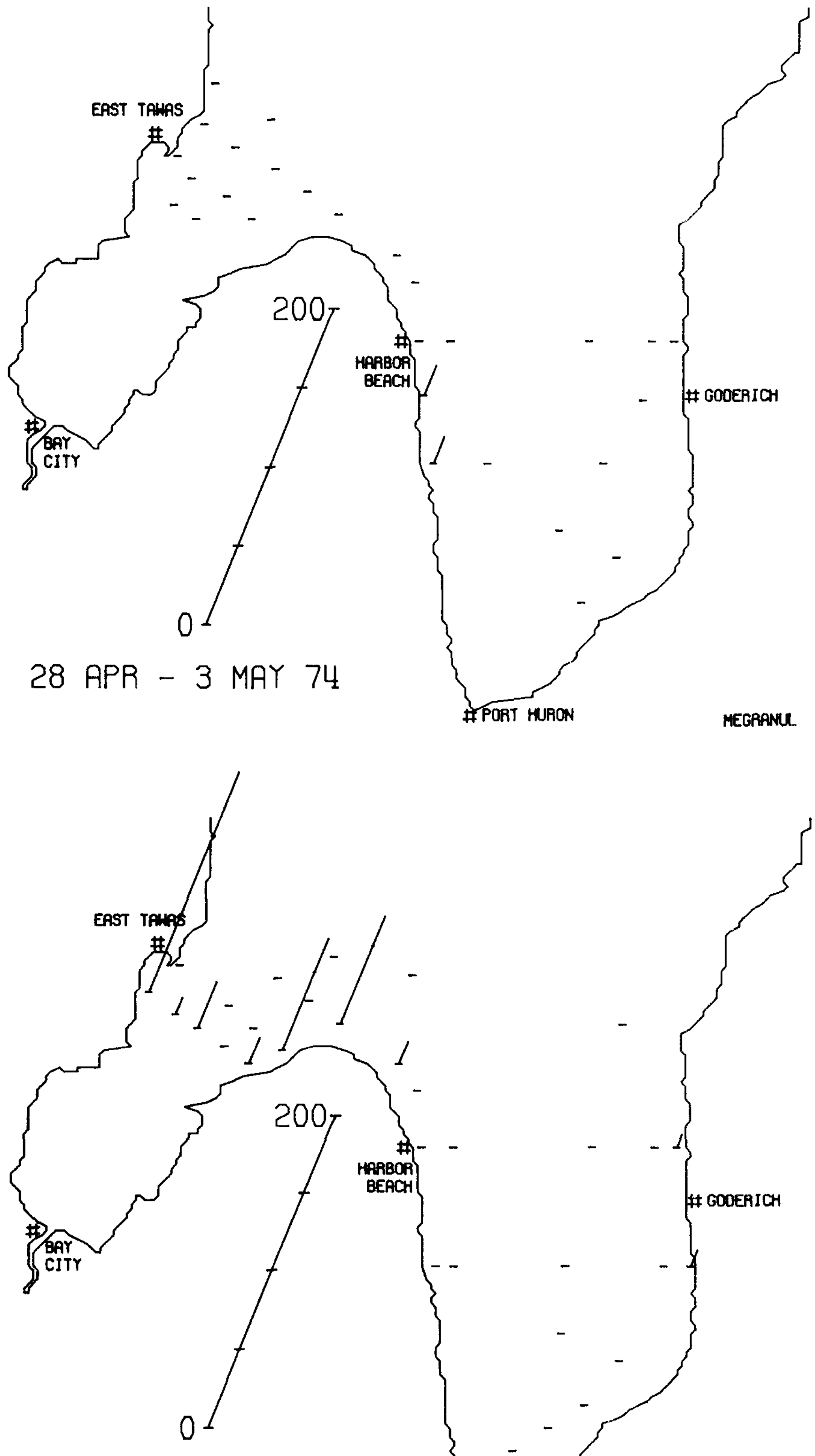
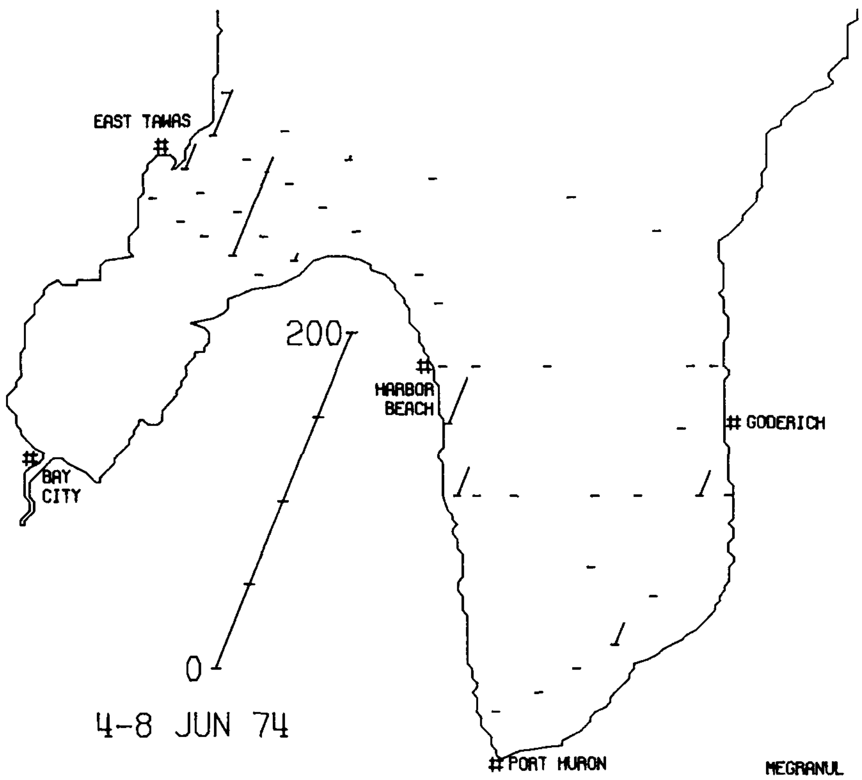


Figure 21. Distribution of Melosira granulata.
(continued)



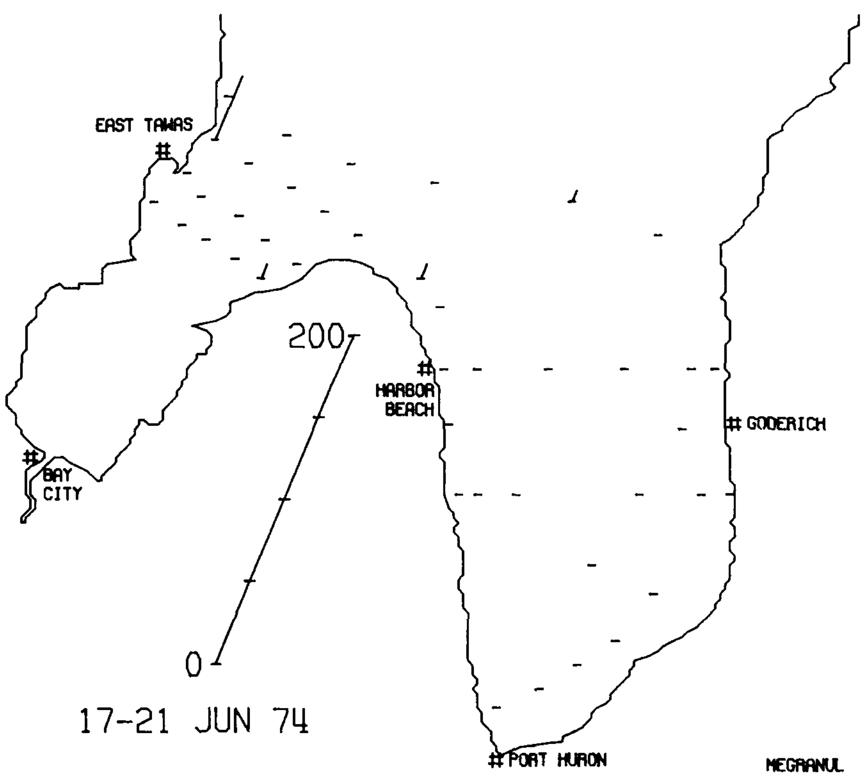
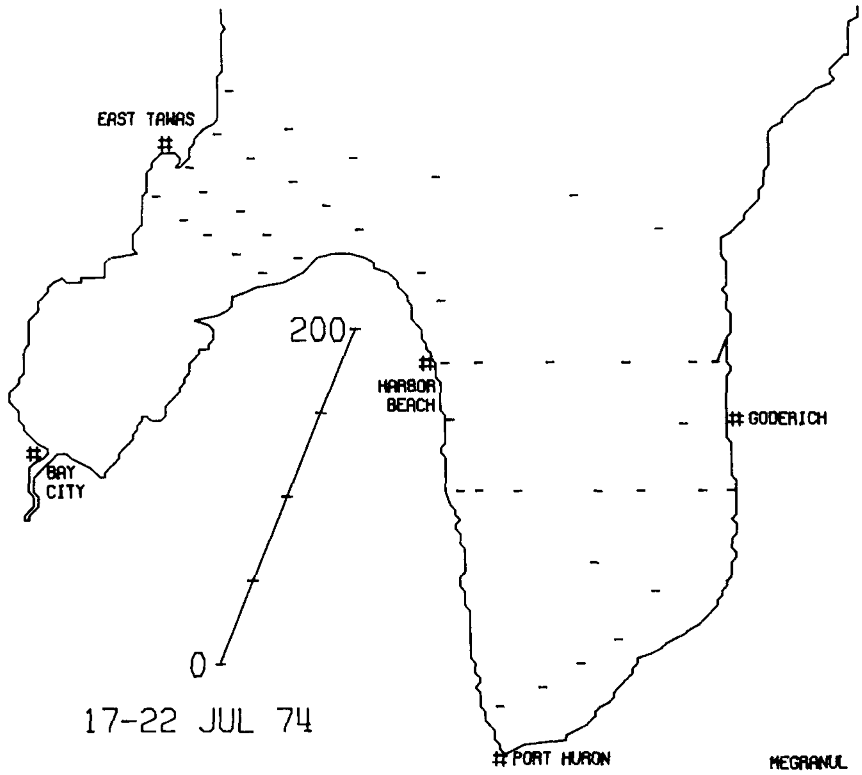


Figure 21. (continued)



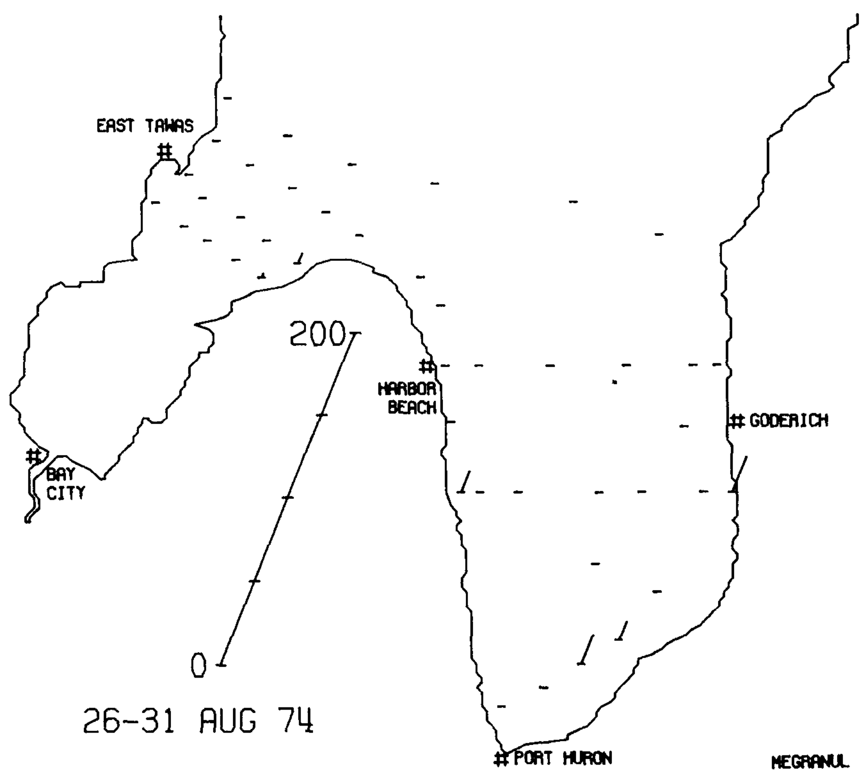
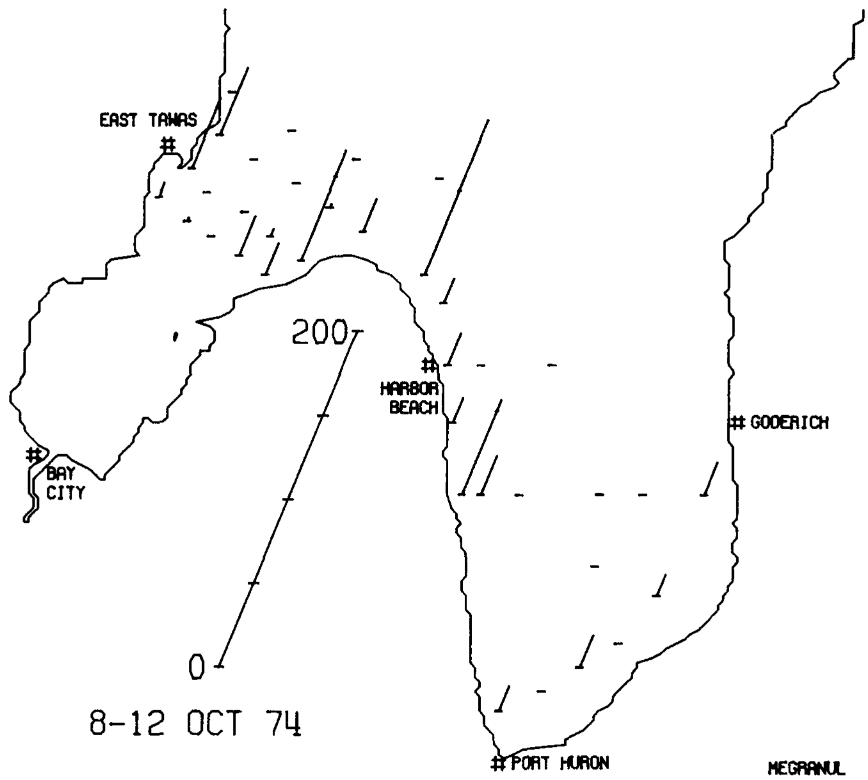
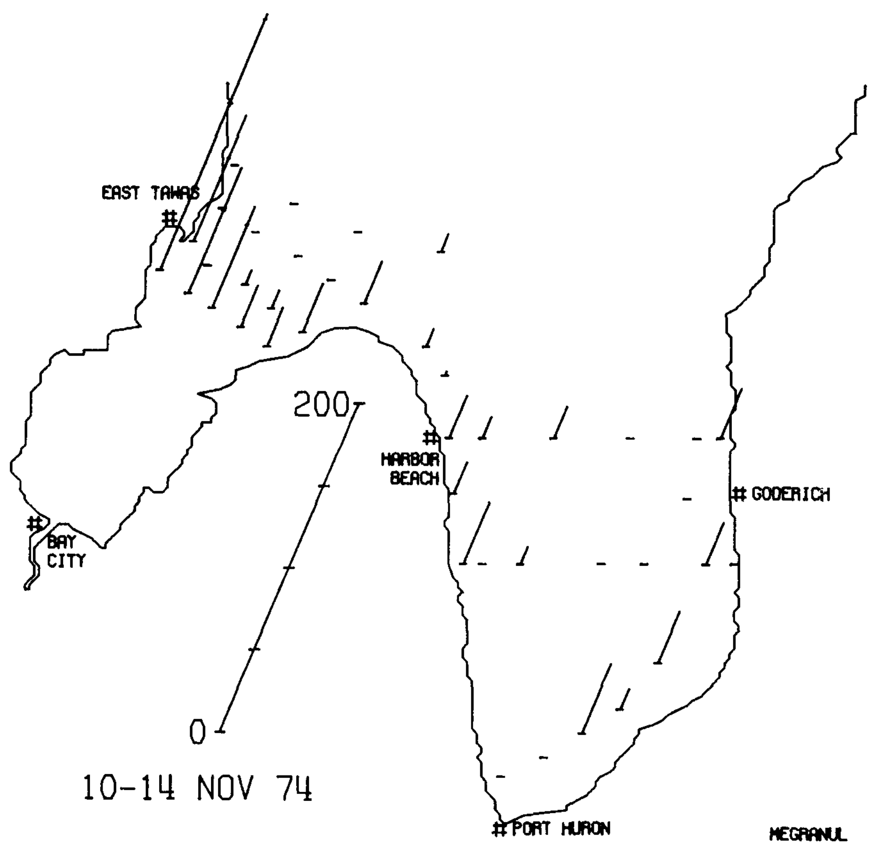


Figure 21. (continued)





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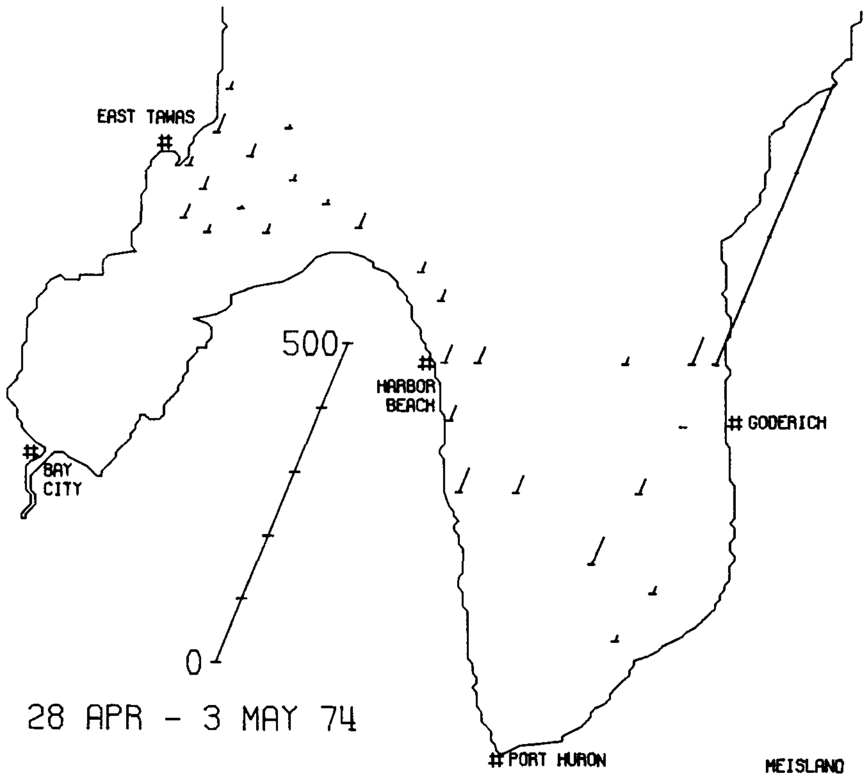


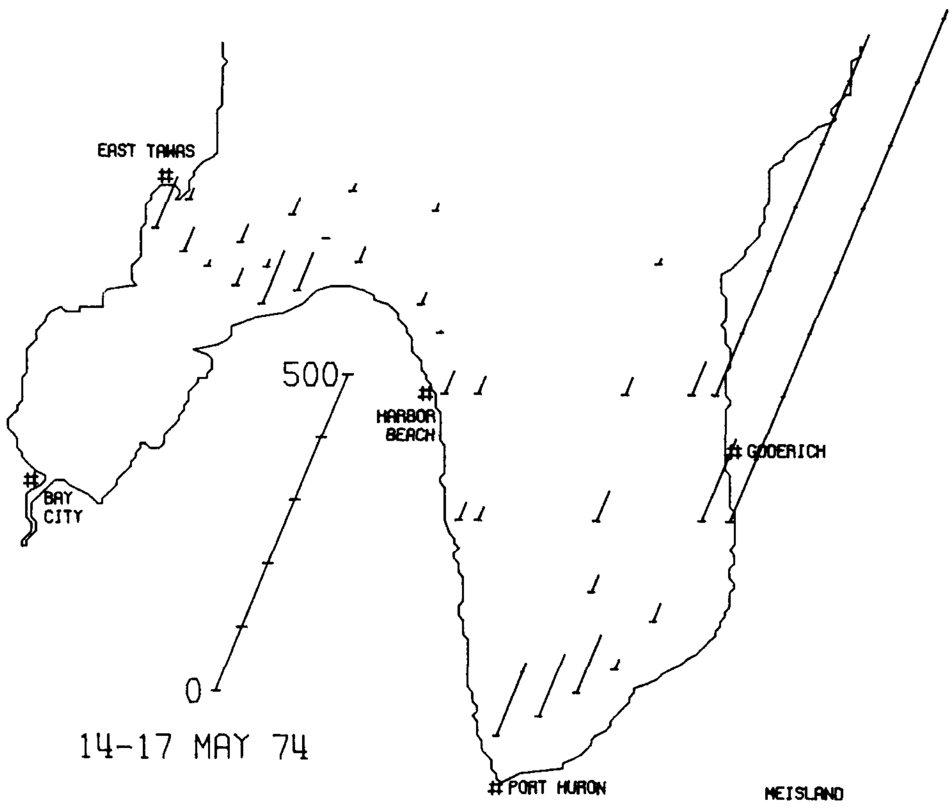
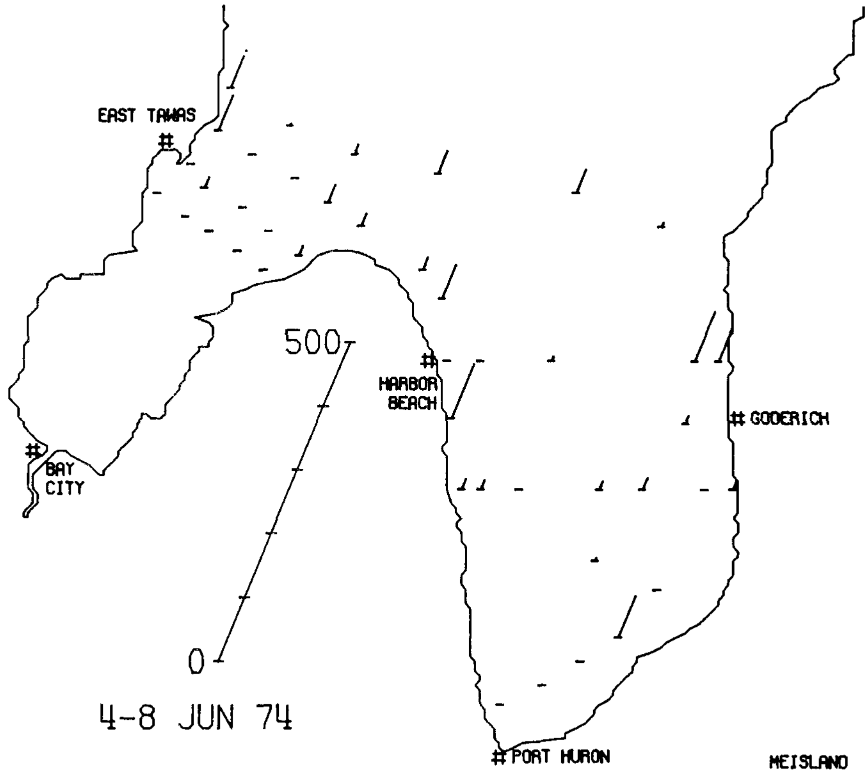
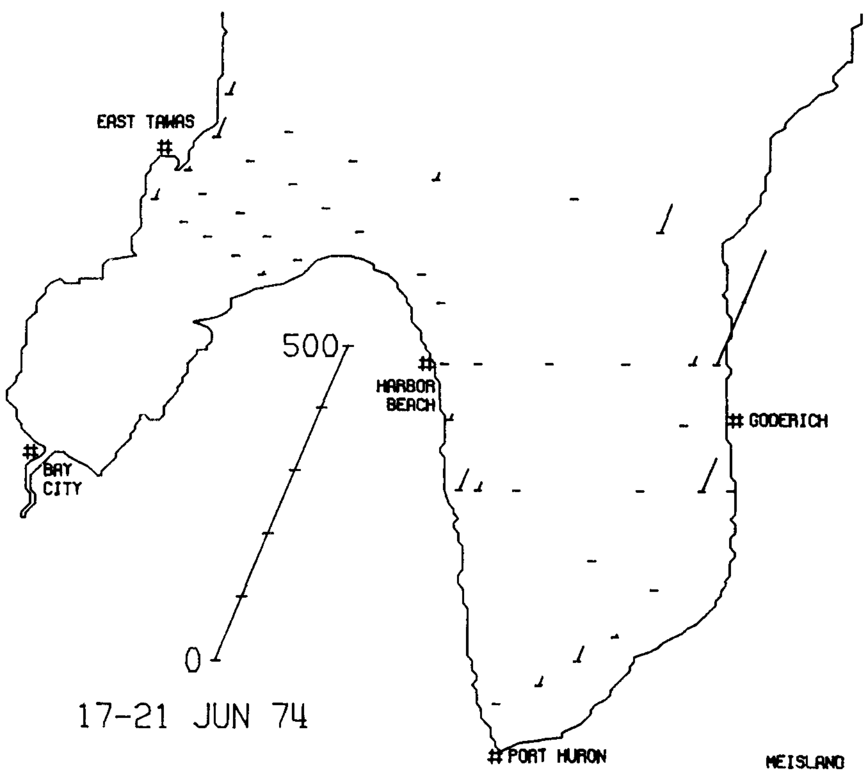


Figure 22. Distribution of *Melosira islandica*. (continued)





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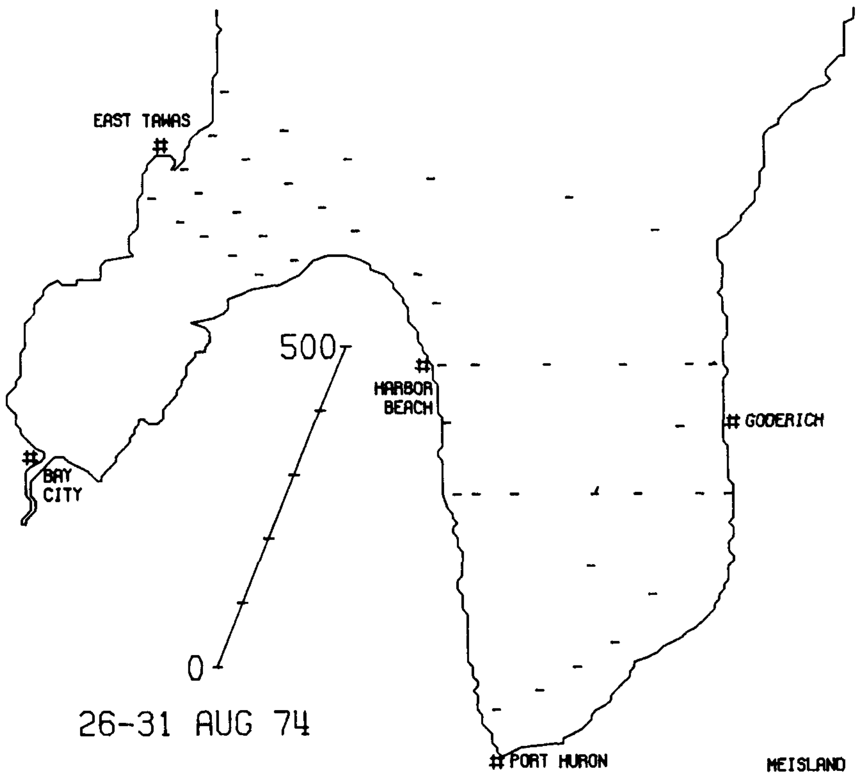

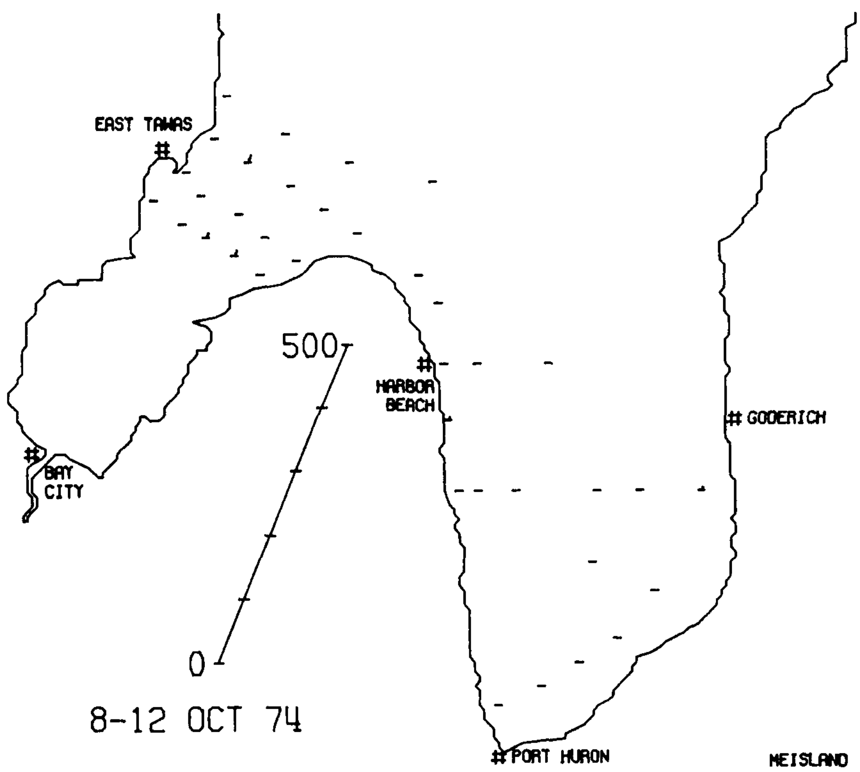

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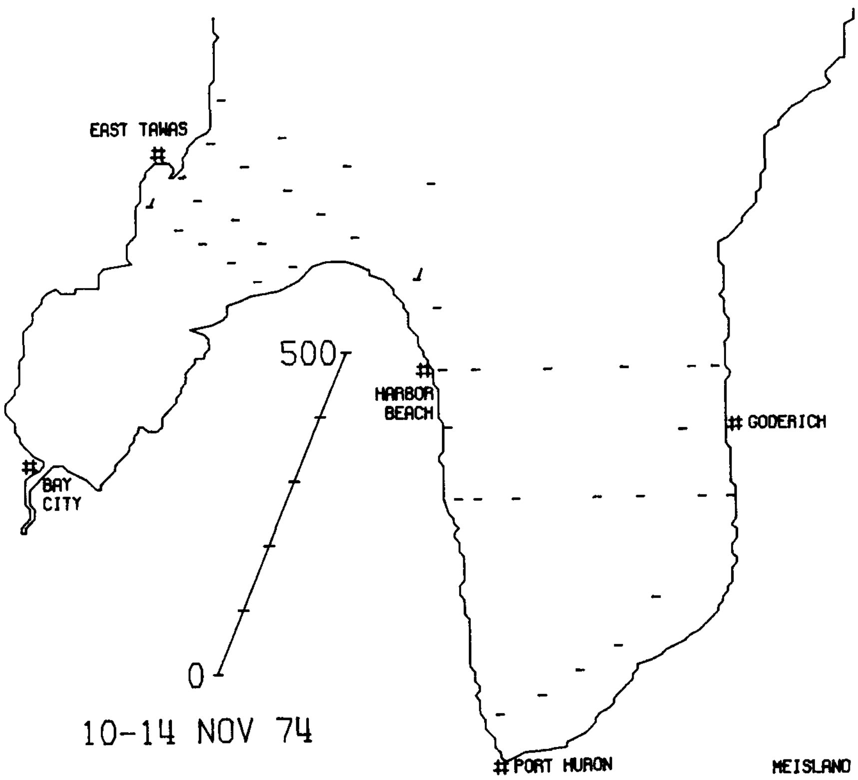


Figure 22. (Continued)

Nitzschia dissipata

This is another member of the genus that is unusually widely distributed and abundant in plankton collections from the Great Lakes. In southern Lake Huron maximum population densities were reached during May (Fig. 24A-B) when this taxon was present at most stations sampled. During June (Fig. 24C-D), population levels declined, particularly at stations in the Saginaw Bay interface waters. Minimum population levels were reached during July (Fig. 24E), when the species was noted at only a few nearshore stations. It increased again slightly in August (Fig. 24F) when sizeable populations were noted at several inshore stations along the Michigan and Canadian coasts of southern Lake Huron. The taxon was more generally distributed in October (Fig. 24G) although population densities were somewhat smaller than in the previous month. Population densities declined again in November (Fig. 24H) when only small populations were found at scattered stations. Unlike the previous month, during November maximum population densities were found at stations in the Saginaw Bay interface waters.

Rhizosolenia eriensis

This species was originally described from the Laurentian Great Lakes and is one of the characteristic offshore dominants. It is generally abundant in the offshore plankton of the upper lakes in winter and early spring, but is apparently excluded from areas which have undergone extreme eutrophication (Hohn, 1969). It was present at all stations sampled during May (Fig. 25A-B) and increased in abundance during the course of the month. The increase in

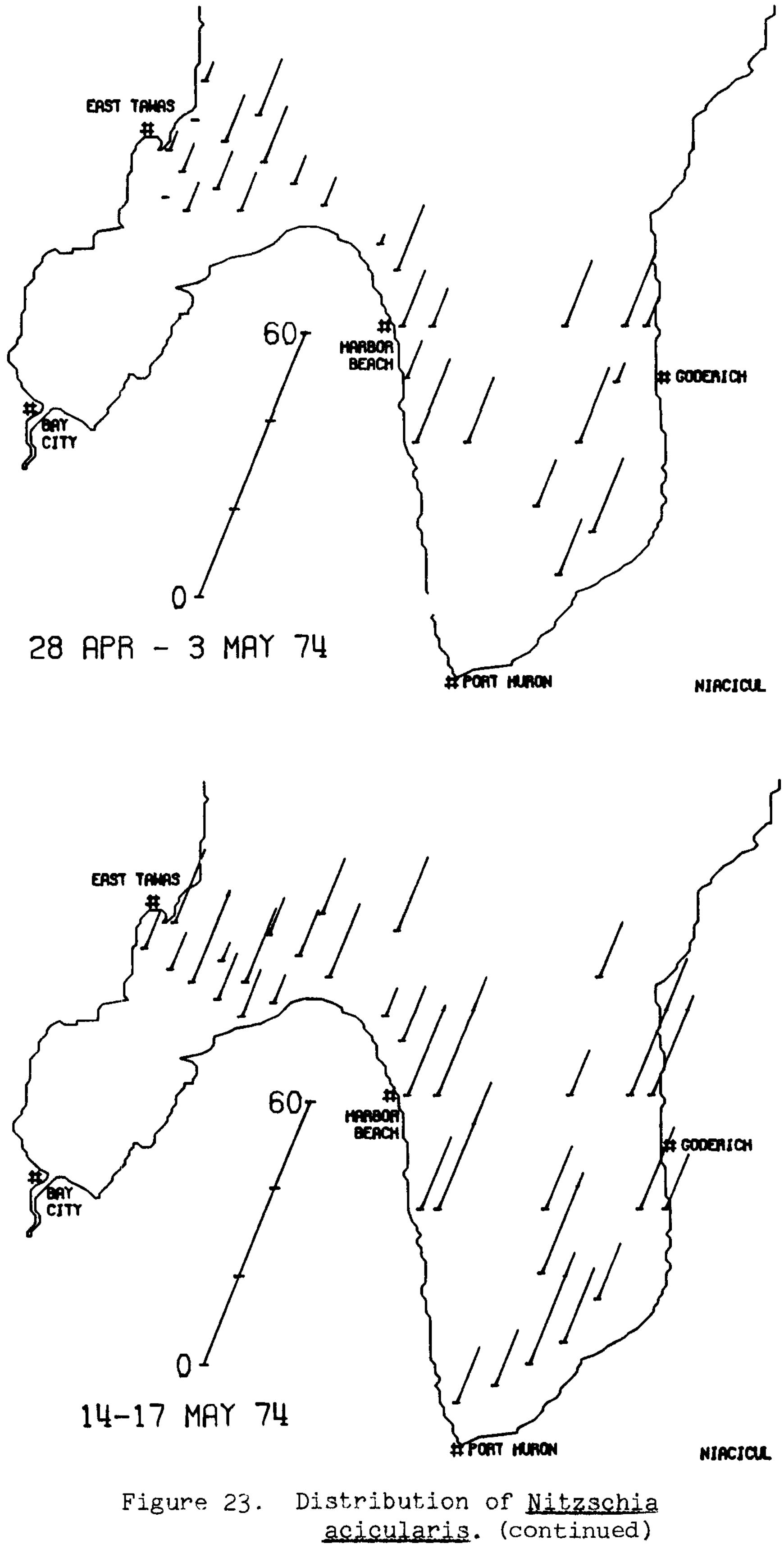


Figure 23. Distribution of *Nitzschia acicularis*. (continued)

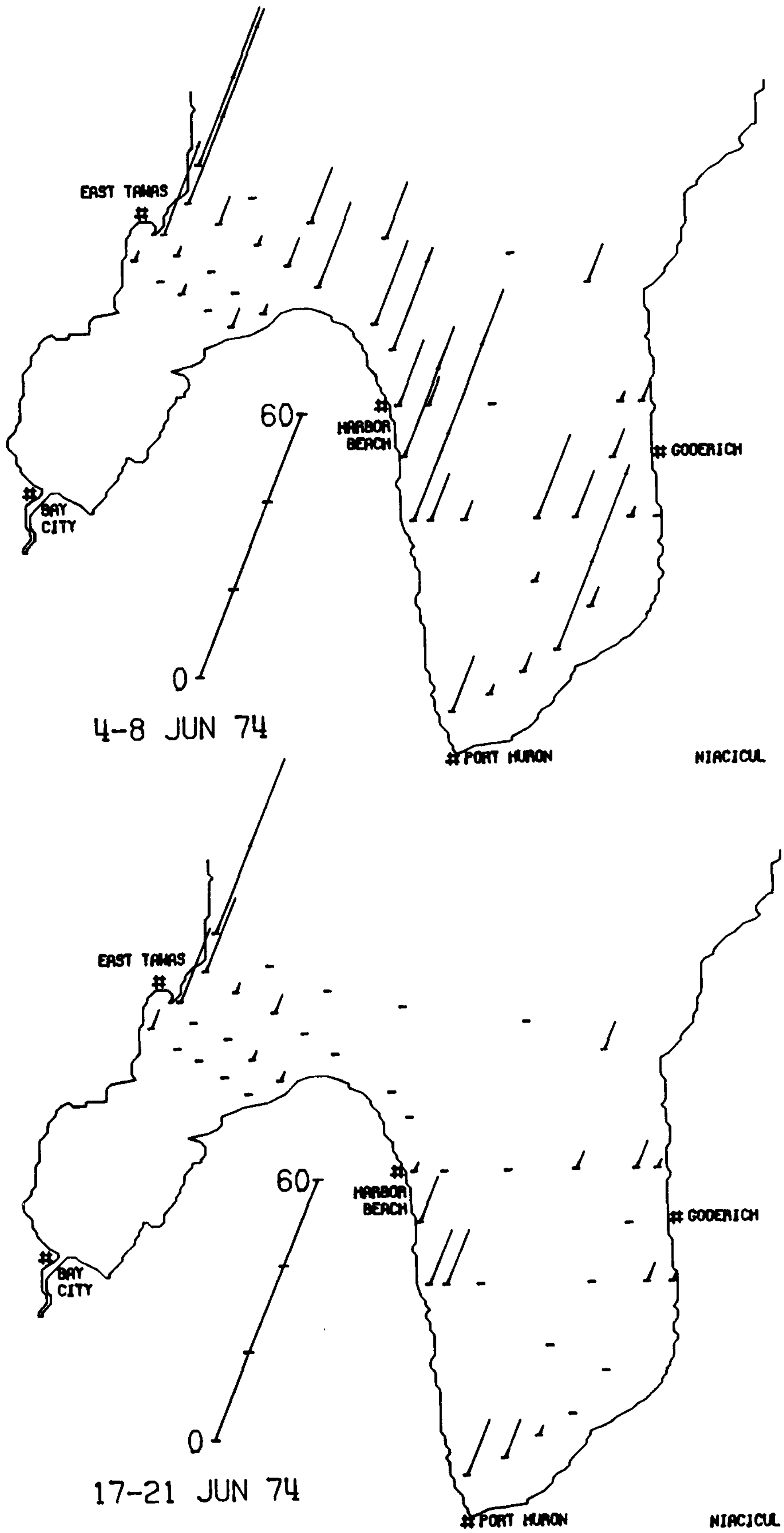
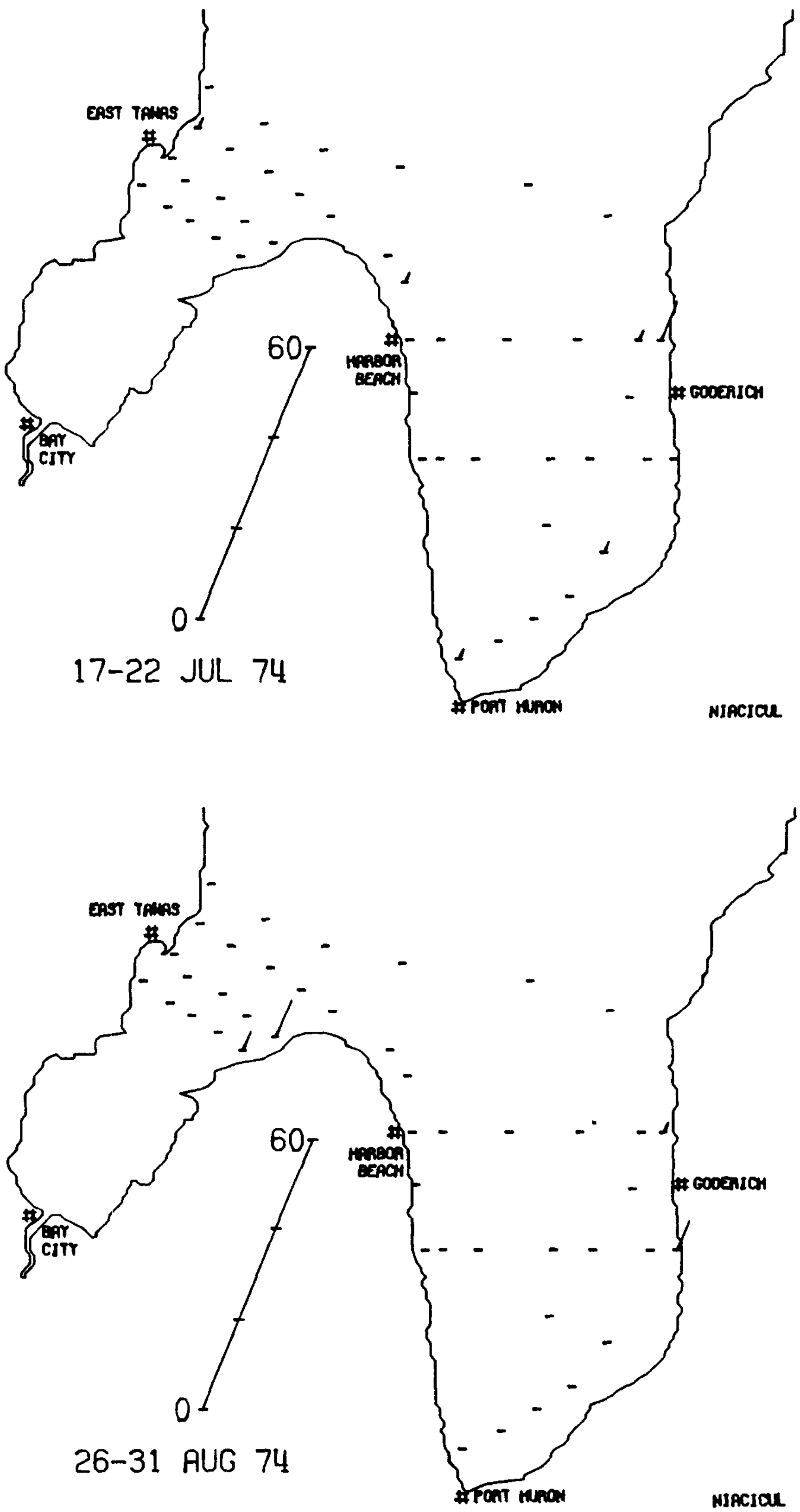


Figure 23. (continued)



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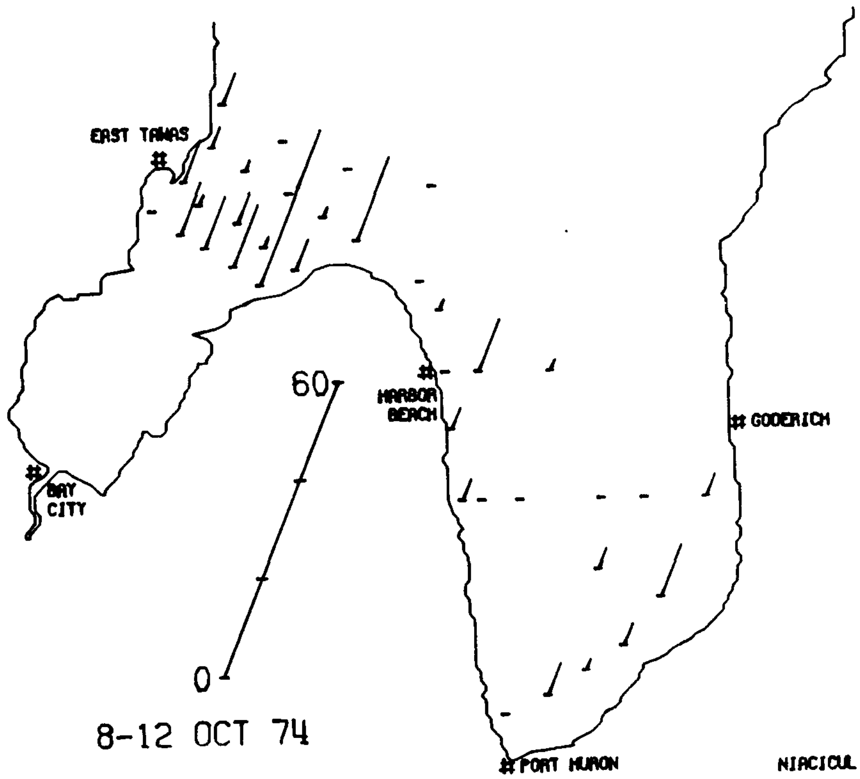

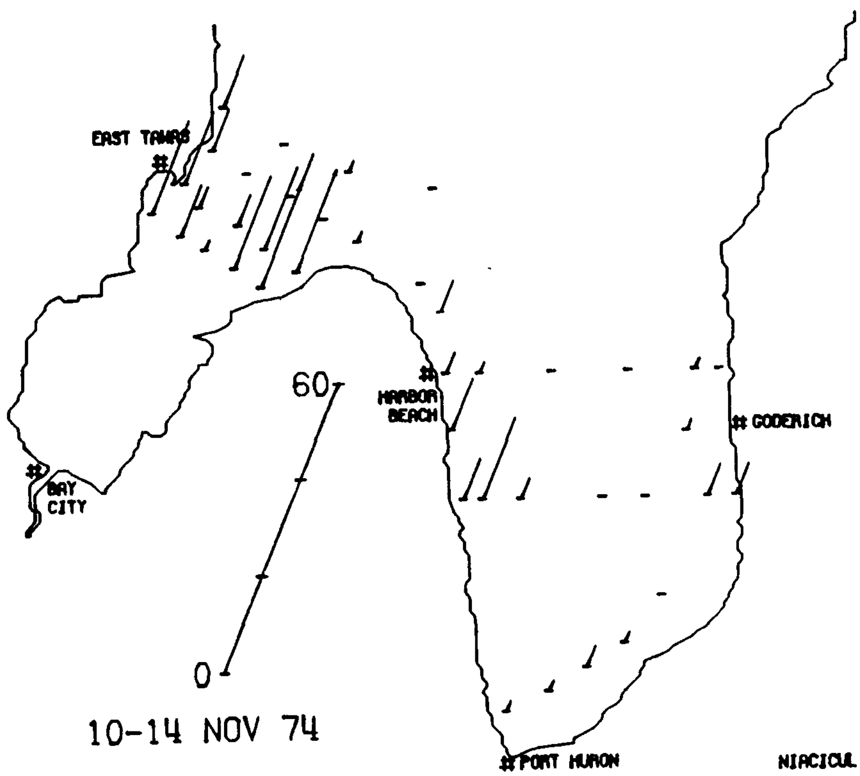

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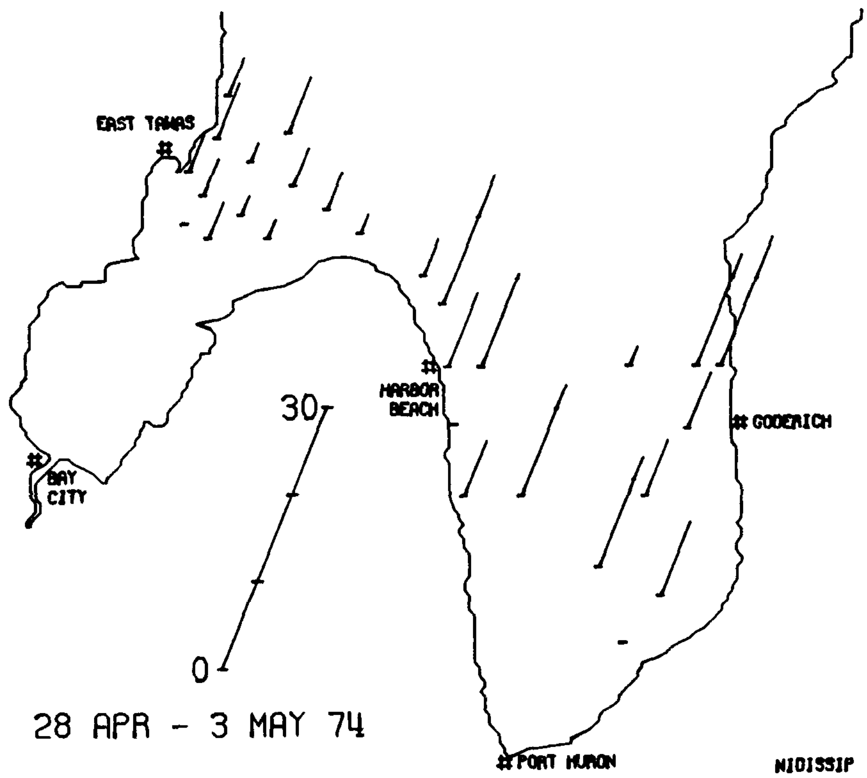


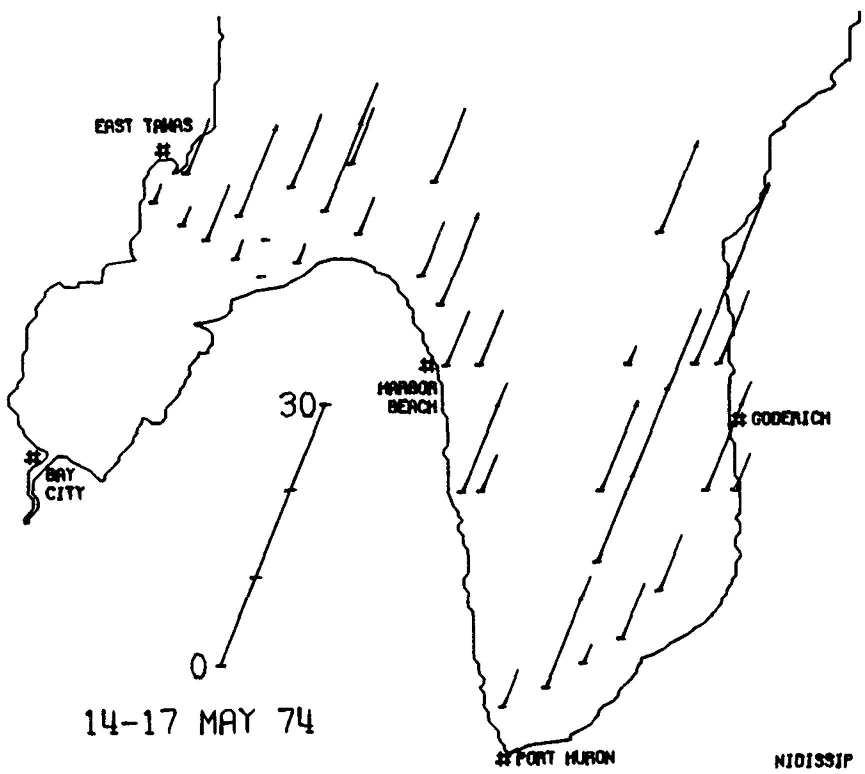
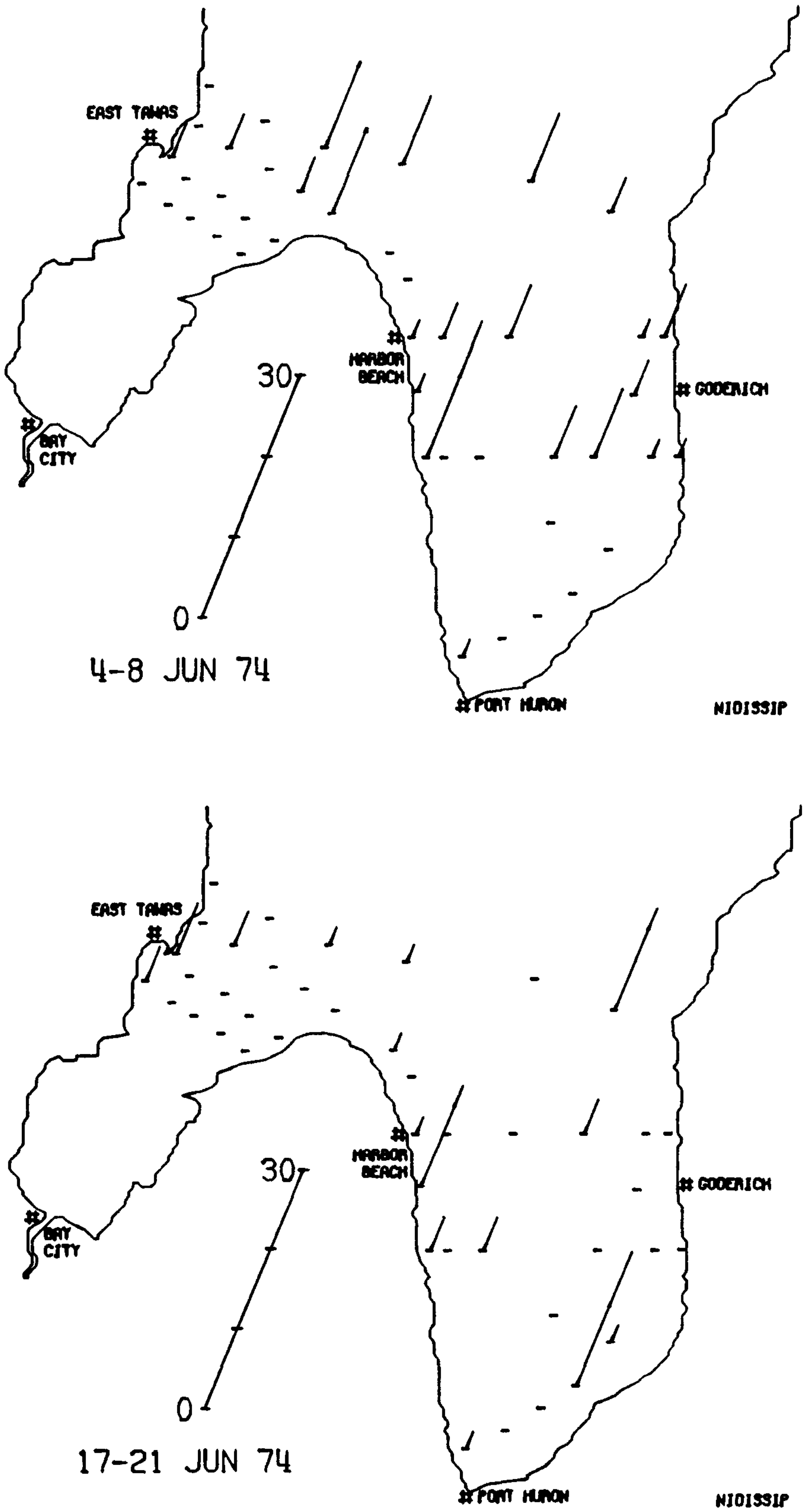


Figure 24. Distribution of Nitzschia dissipata. (continued)



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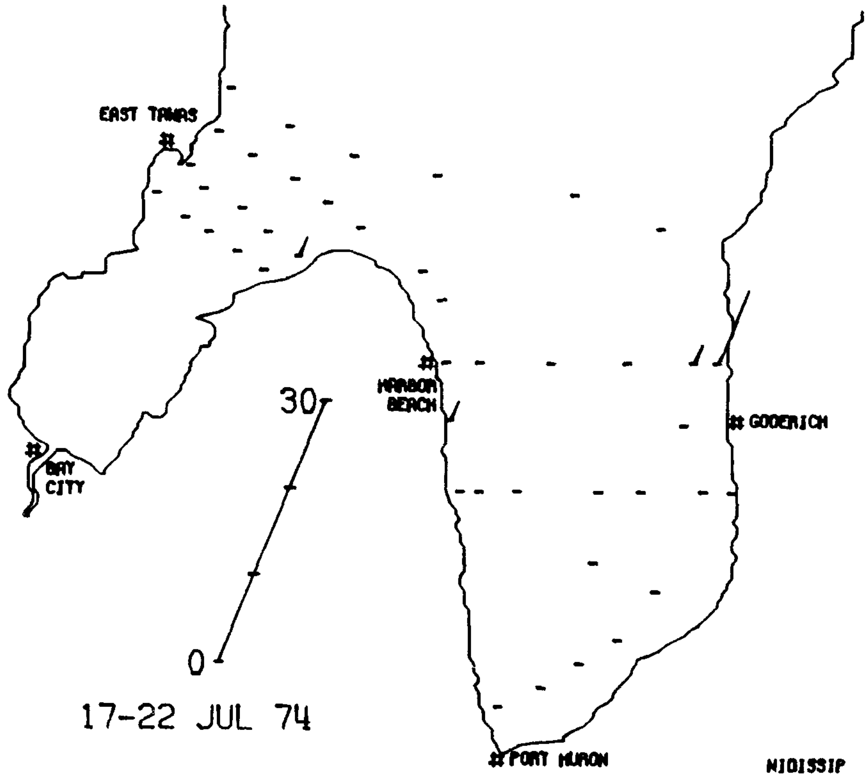

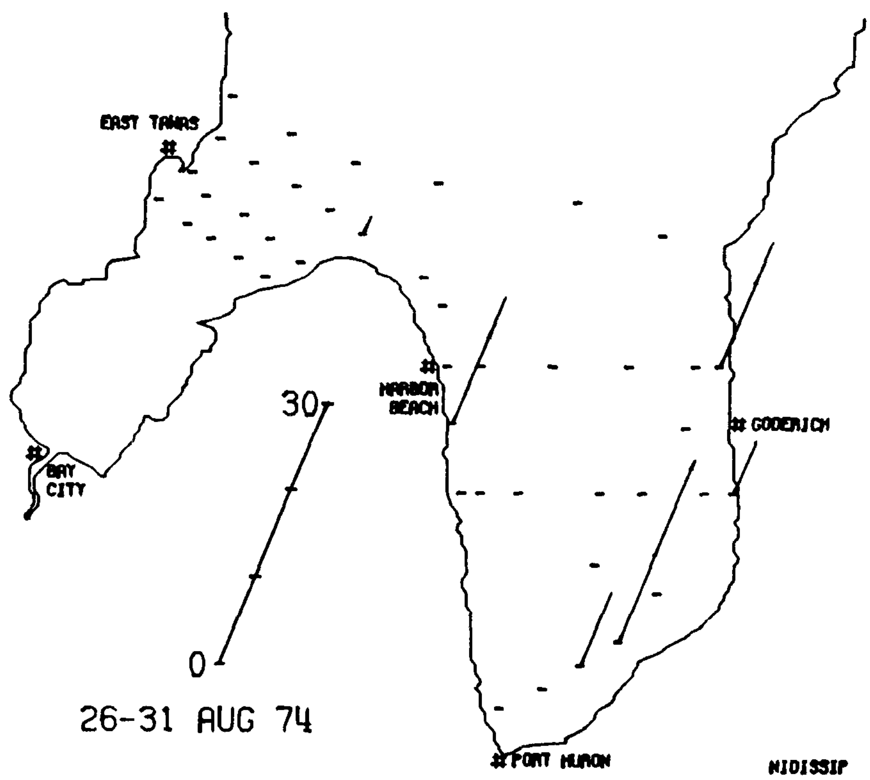

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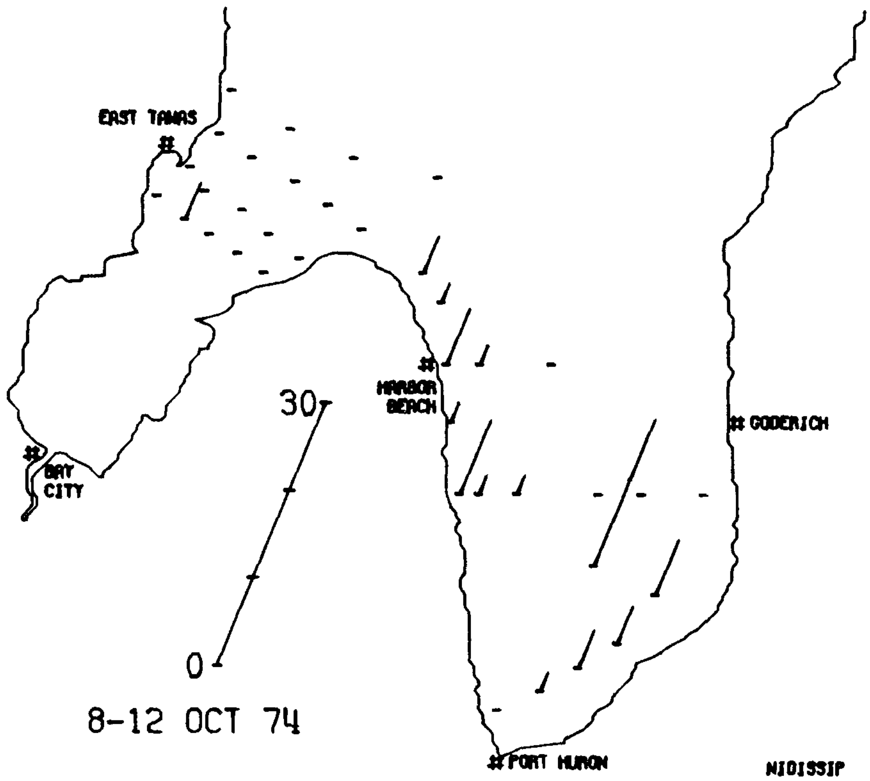

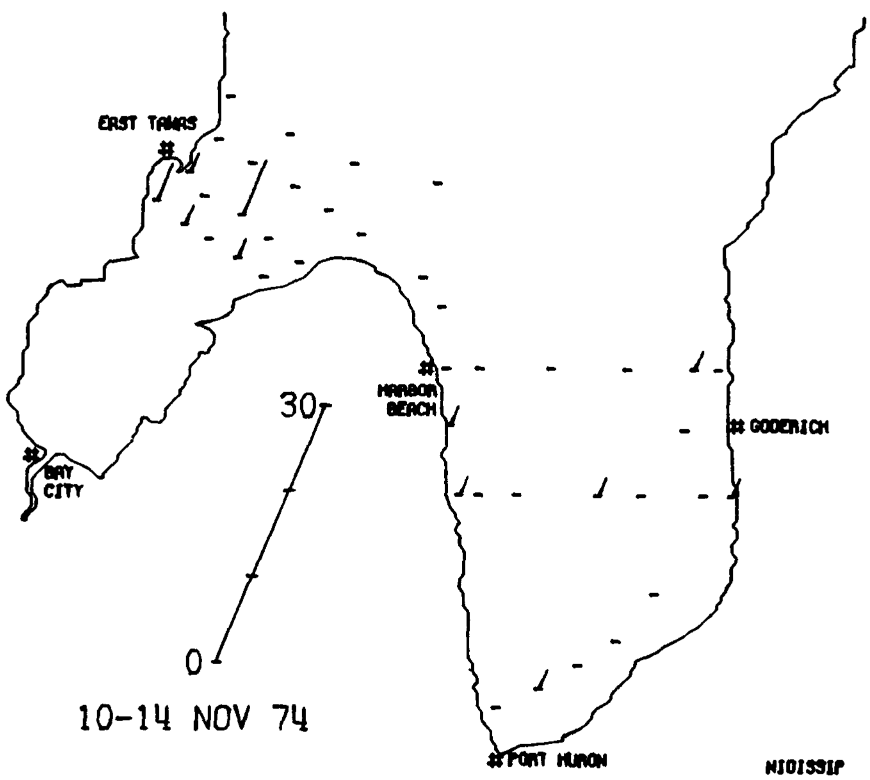

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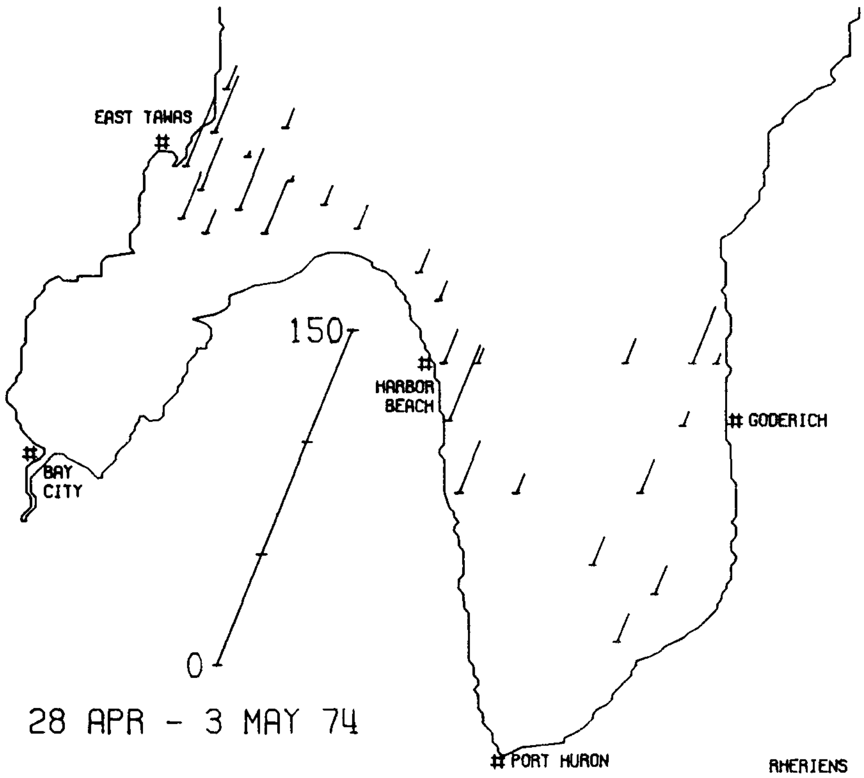


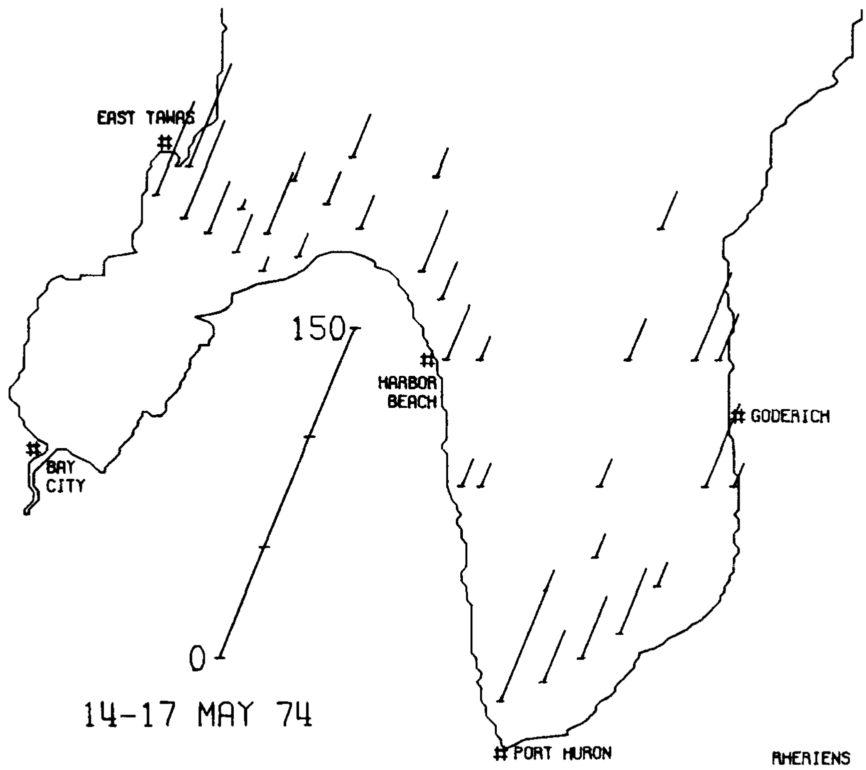


Figure 25. Distribution of Rhizosolenia eriensis. (continued)

population density continued during June (Fig. 25C-D) at offshore stations, but it began to decline in abundance at stations in the Saginaw Bay interface waters, and was absent from several stations in this area by late June. Populations collapsed during July (Fig. 25E) and remained at low levels during August (Fig. 25F). Although population densities were low, this species occurred at a number of stations in the Saginaw Bay interface waters and southward along the Michigan coast in October (Fig. 25G) and appeared to spread southward into the offshore waters of Lake Huron during November (Fig. 25H).

Rhizosolenia gracilis

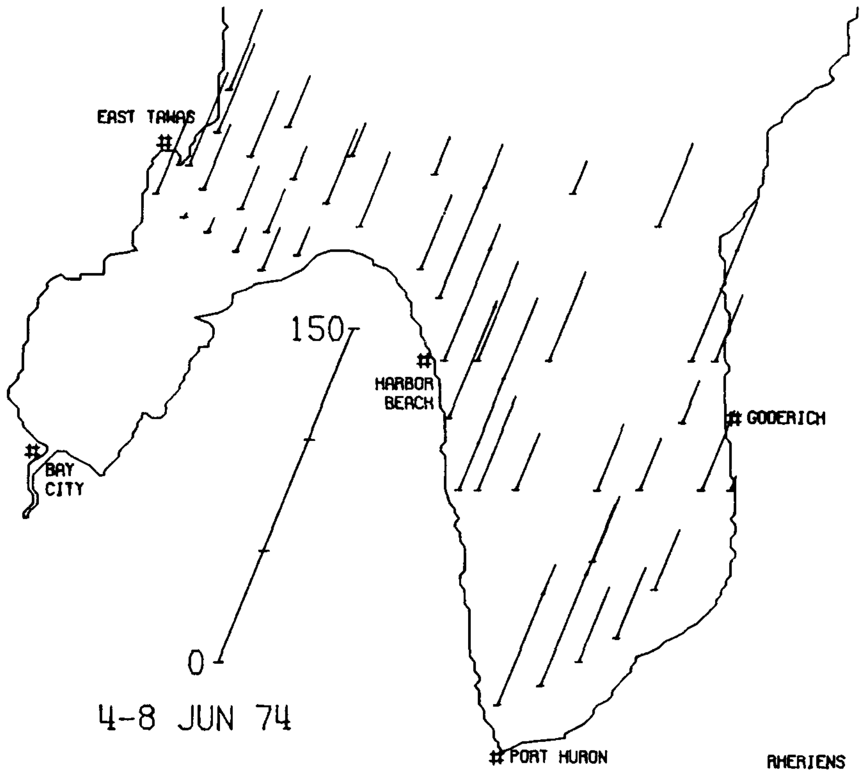
This species was also originally described from the Laurentian Great Lakes and appears to have growth requirements similar to those of *R. eriensis*. It, however, appears to be somewhat more tolerant of eutrophic conditions and is more often reported from small eutrophic lakes. It was present at all stations sampled during May (Fig. 26A-B) and increased during the course of the month, particularly at stations in the Saginaw Bay interface waters and nearshore stations along both the Michigan and Canadian coasts. The trend toward increased abundance continued at offshore stations sampled during June (Fig. 26C-D), although it was reduced in abundance at stations in the Saginaw Bay interface waters early in the month and absent from a few of these stations by the late June sampling cruise. Population densities declined drastically during July (Fig. 26E) and the species was absent from all except a few stations in the Saginaw Bay interface waters and along the Canadian coast during the August (Fig. 26F) sampling period. Small populations were maintained at stations in the Saginaw Bay interface during October and November (Fig. 26G-H) and occasional isolated occurrences were noted at offshore stations.

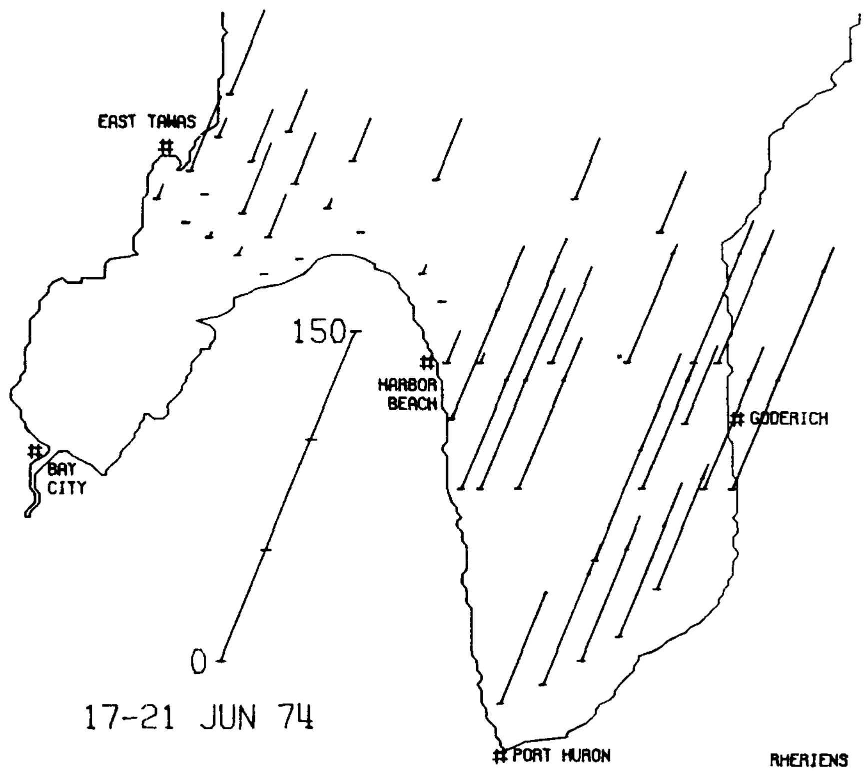
Stephanodiscus alpinus

This species is a common minor component of phytoplankton assemblages in the upper Great Lakes. It appears to be favored by low levels of eutrophication but is not tolerant of extreme levels of perturbation. Although it was present at many stations sampled during early May (Fig. 27A) its distribution pattern was dominated by a massive bloom at station 57 near Port Albert. It was also present at most stations sampled during mid-May (Fig. 27B) with highest population densities occurring in Saginaw Bay interface waters and particularly at nearshore stations along the Canadian coast. Population densities declined during June (Fig. 27C-D) but it was noted at a few scattered stations. Only isolated occurrences were noted during July (Fig. 27E) and August (Fig. 27F). It increased somewhat during October (Fig. 27G) and November (Fig. 27H) with most occurrences in the Saginaw Bay interface waters and at stations southward along the Michigan coast.

Stephanodiscus binderanus

This species was apparently not a part of the indigenous phytoplankton flora of the Laurentian Great Lakes, but has been introduced following eutrophication and is now a dominant element of phytoplankton assemblages in highly disturbed areas (Hohn, 1969; Stoermer and Yang, 1969). It apparently has a restricted temperature tolerance (Stoermer and Ladewski, 1976) and usually reaches its maximum abundance during the spring thermal bar period (Nalewajko, 1967; Loriface and Munawar, 1974). It may reach very high





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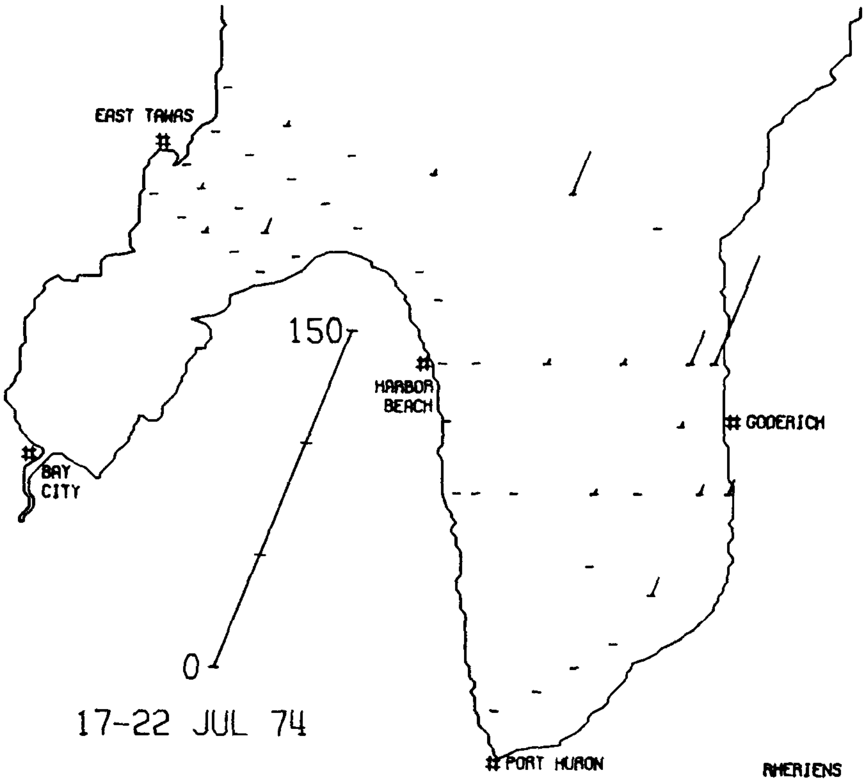

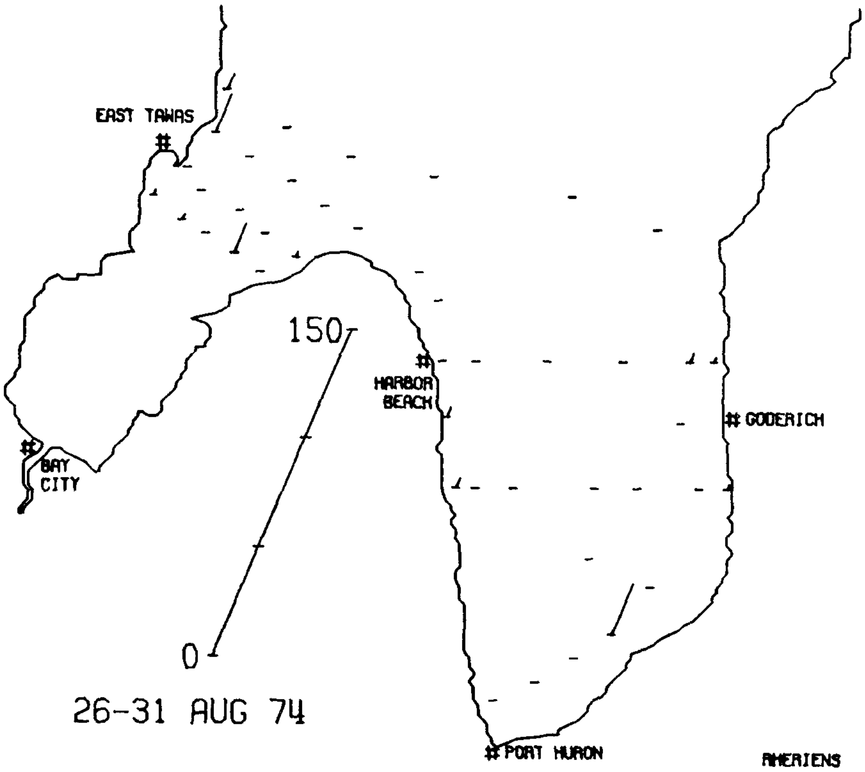

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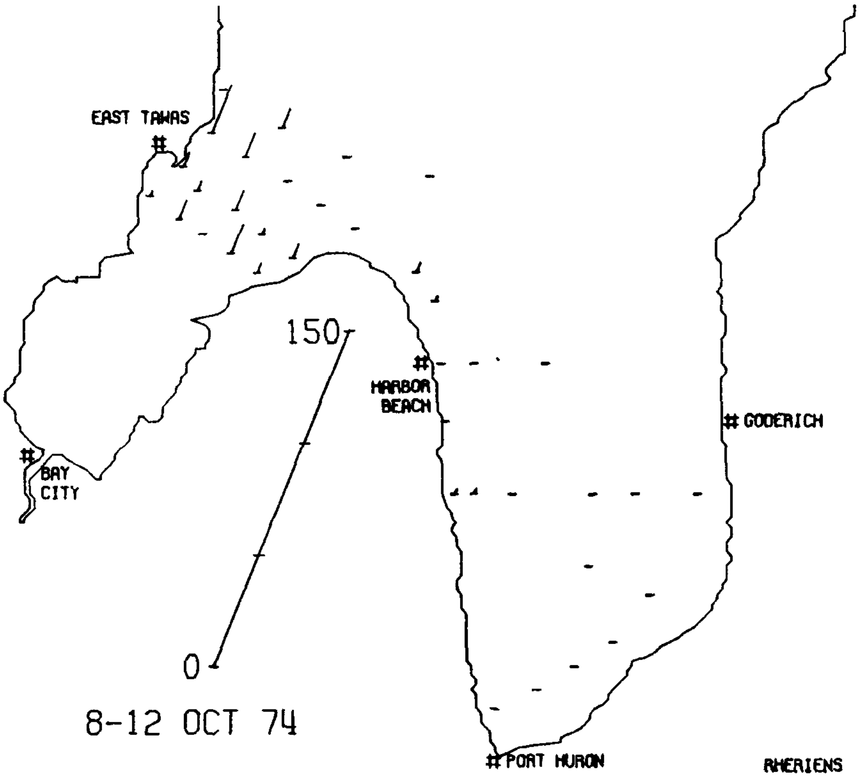

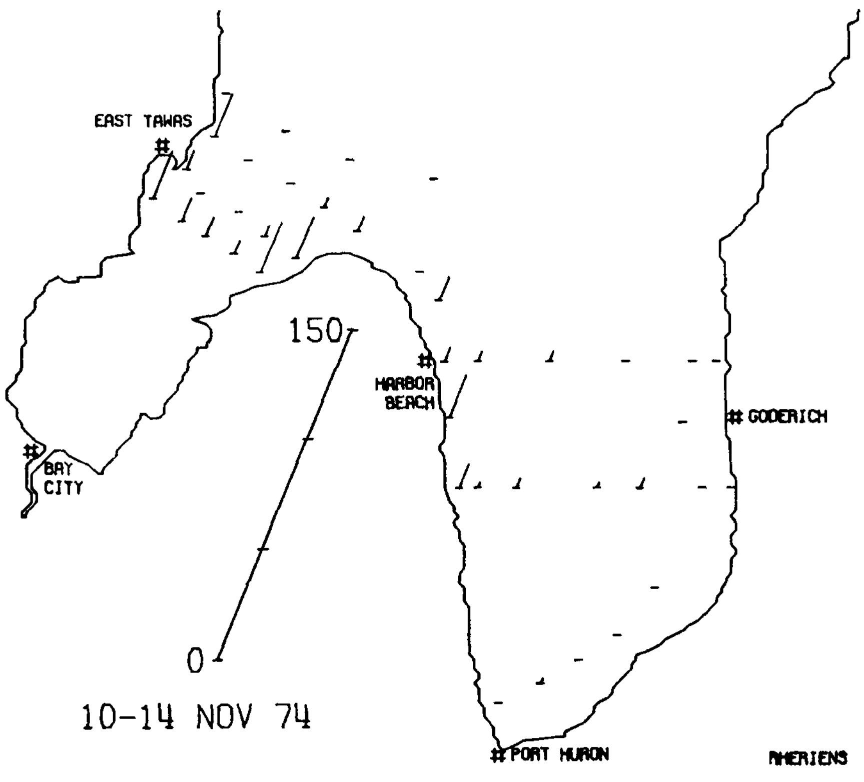

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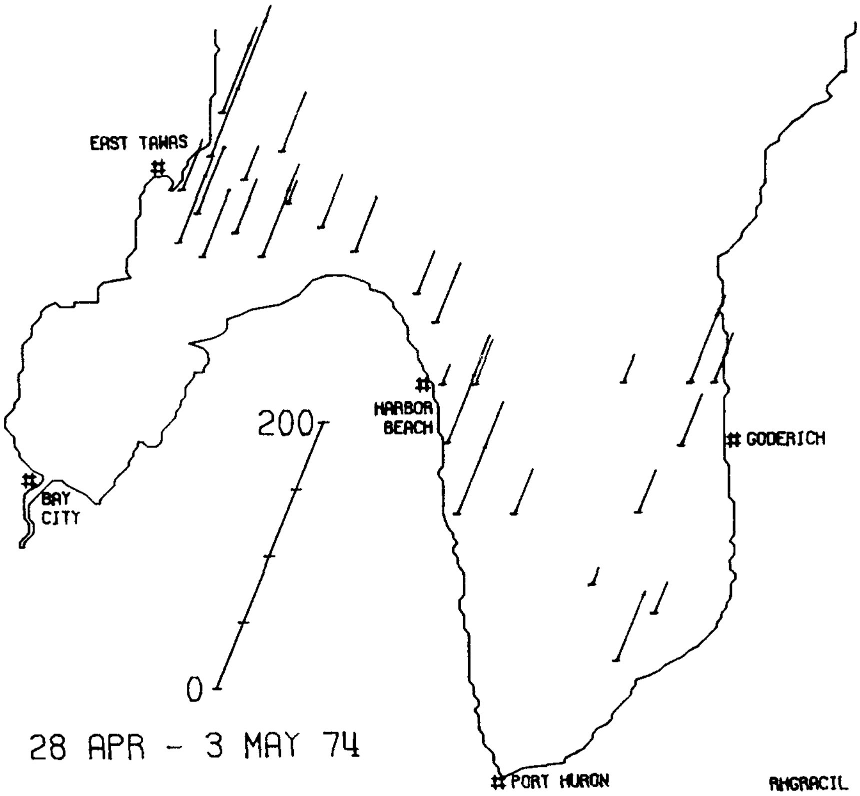


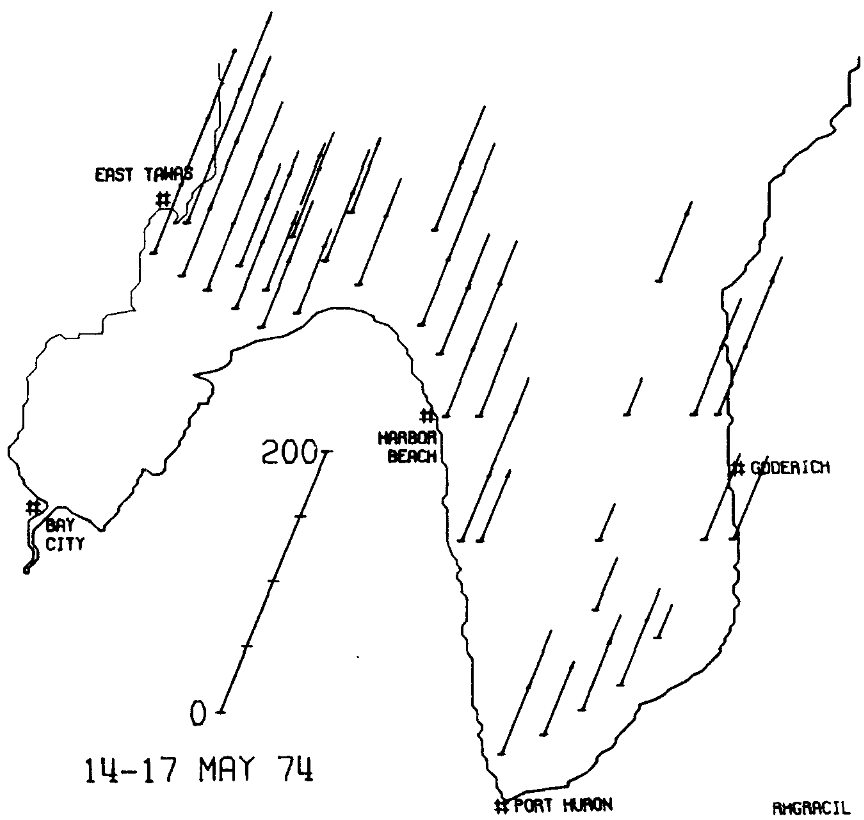
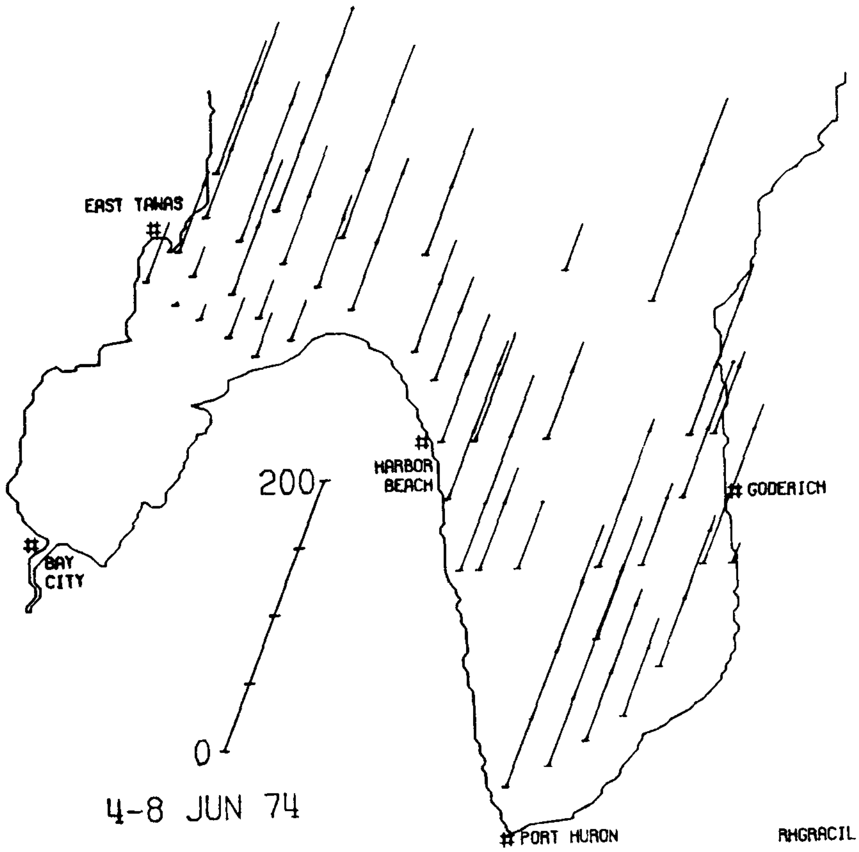
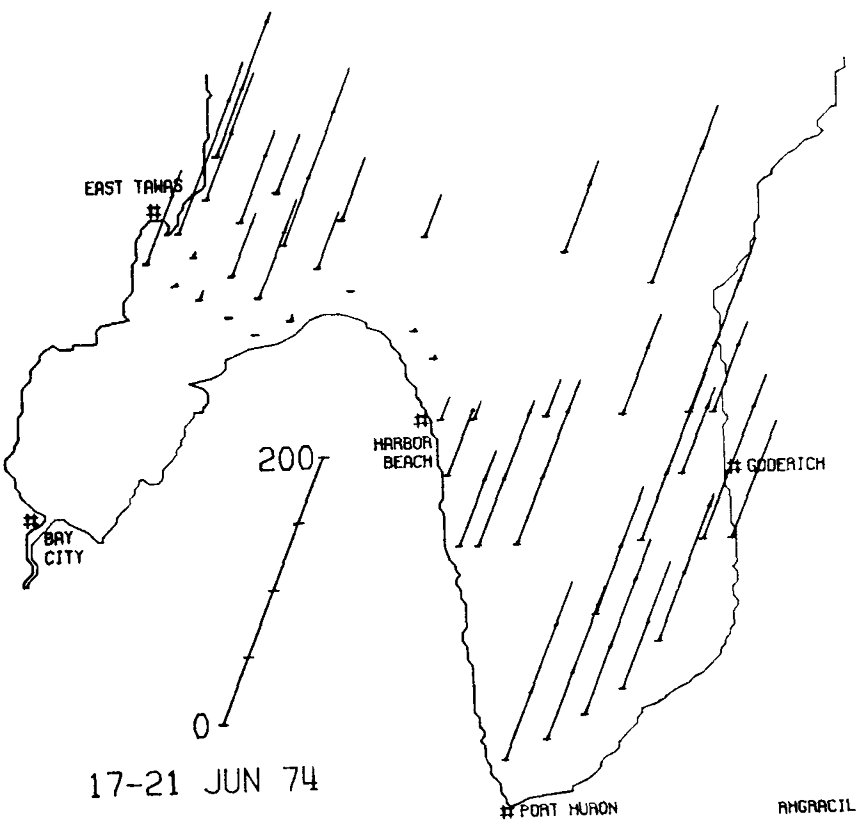


Figure 26. Distribution of <u>Rhizosolenia gracilis</u>.
(continued)





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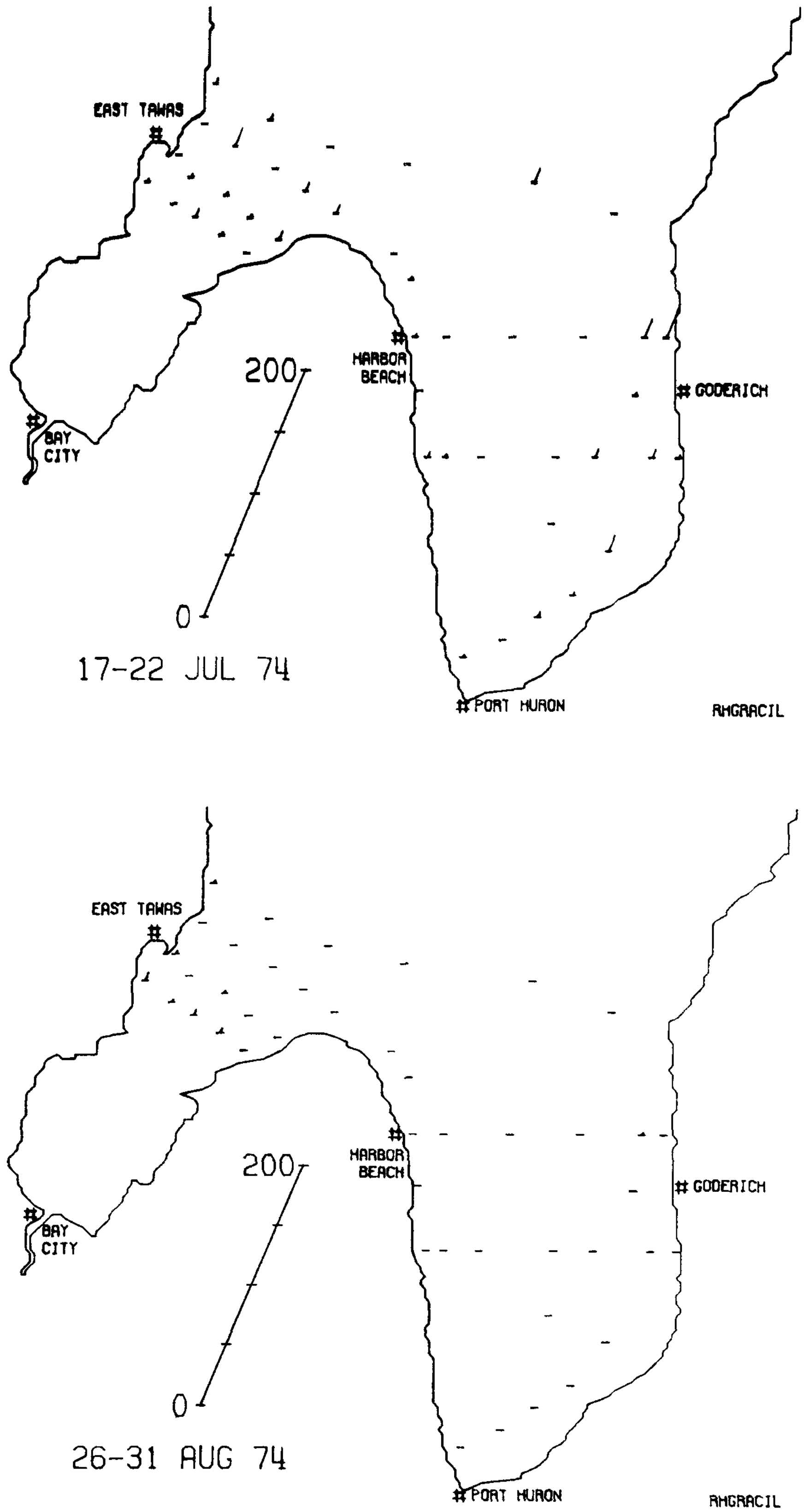

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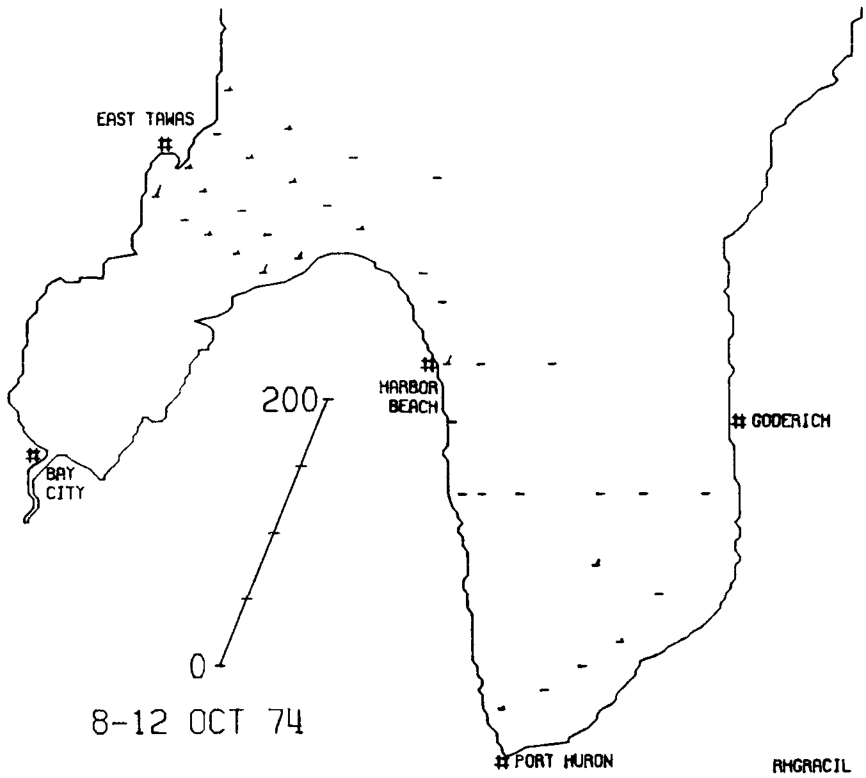


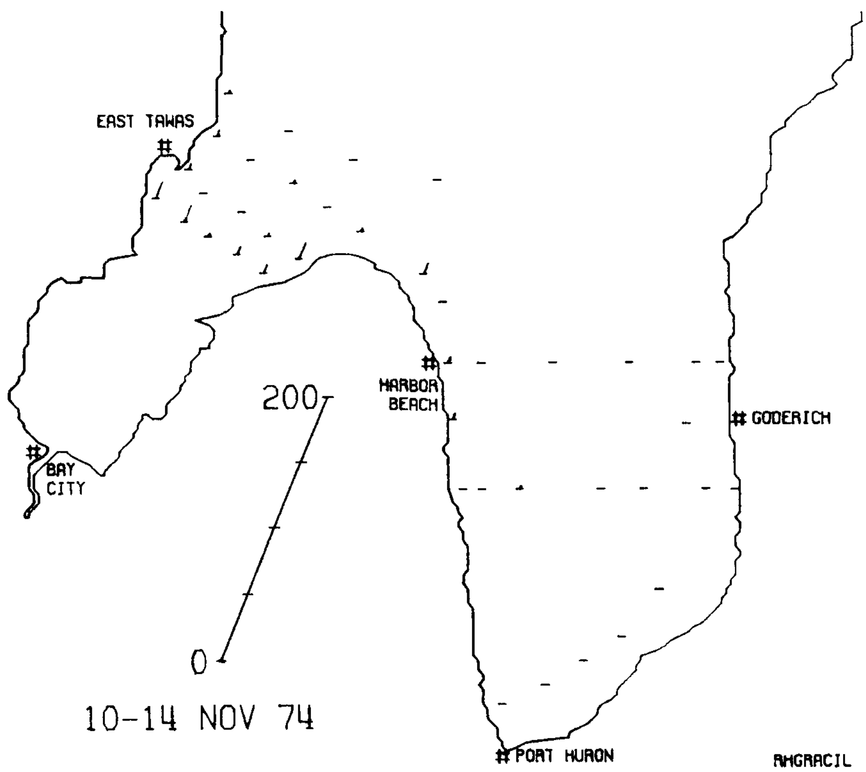


Figure 26. (continued)

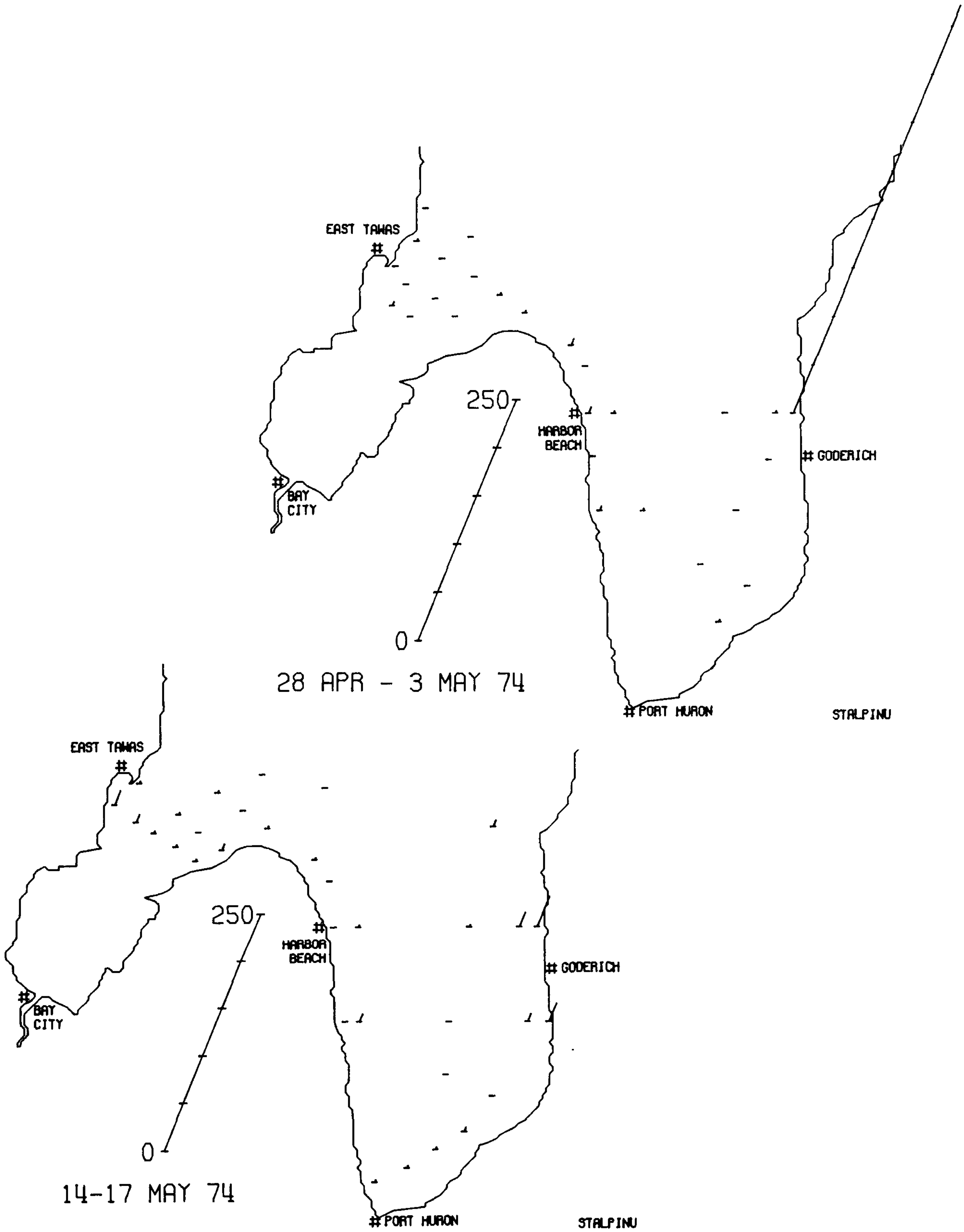
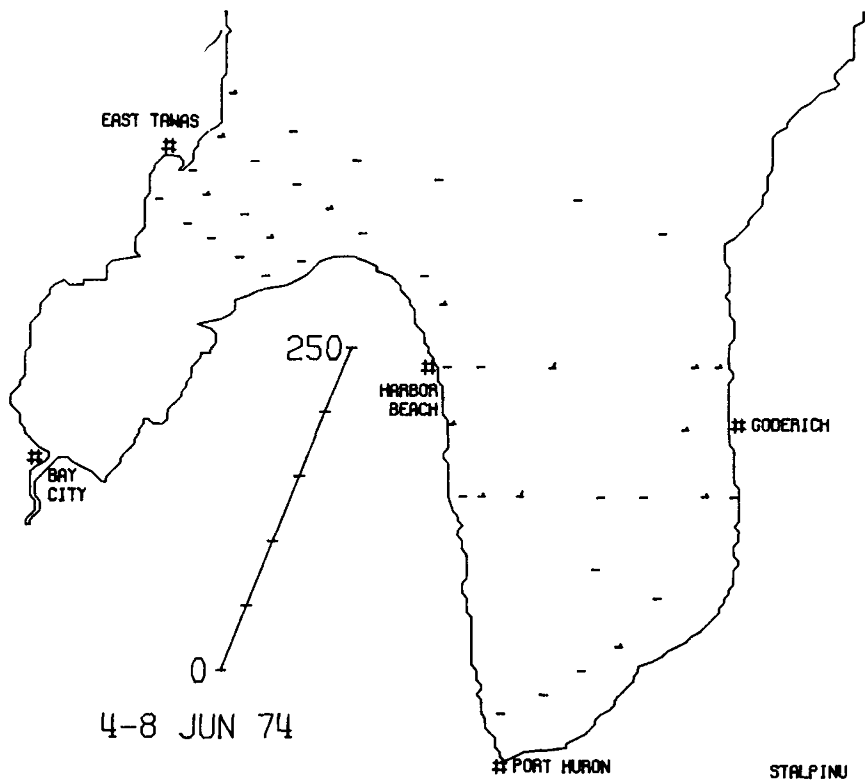


Figure 27. Distribution of Stephanodiscus alpinus. (continued)



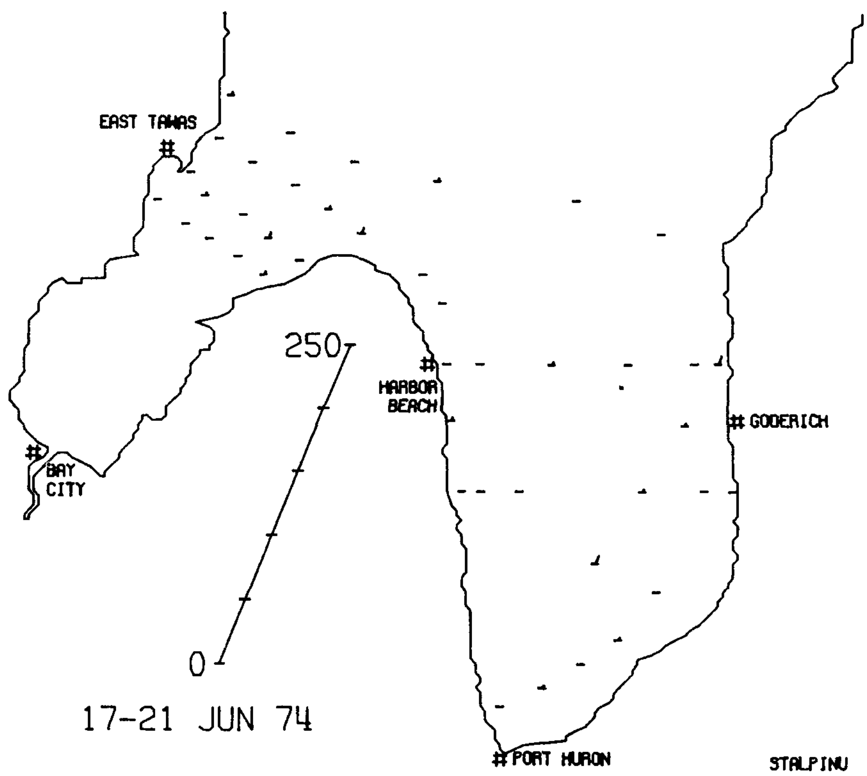
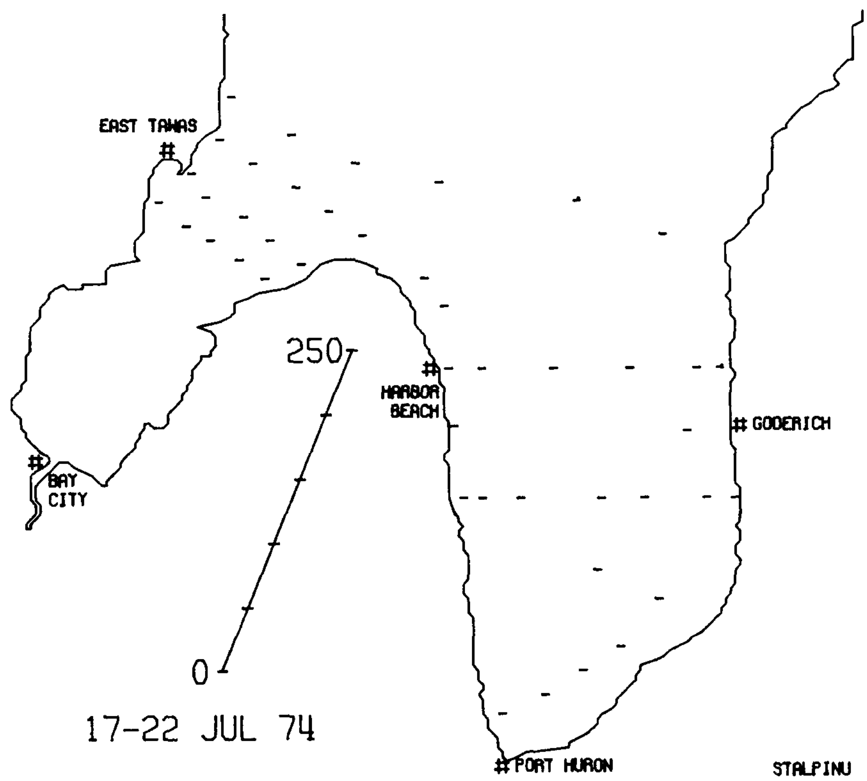


Figure 27. (continued)



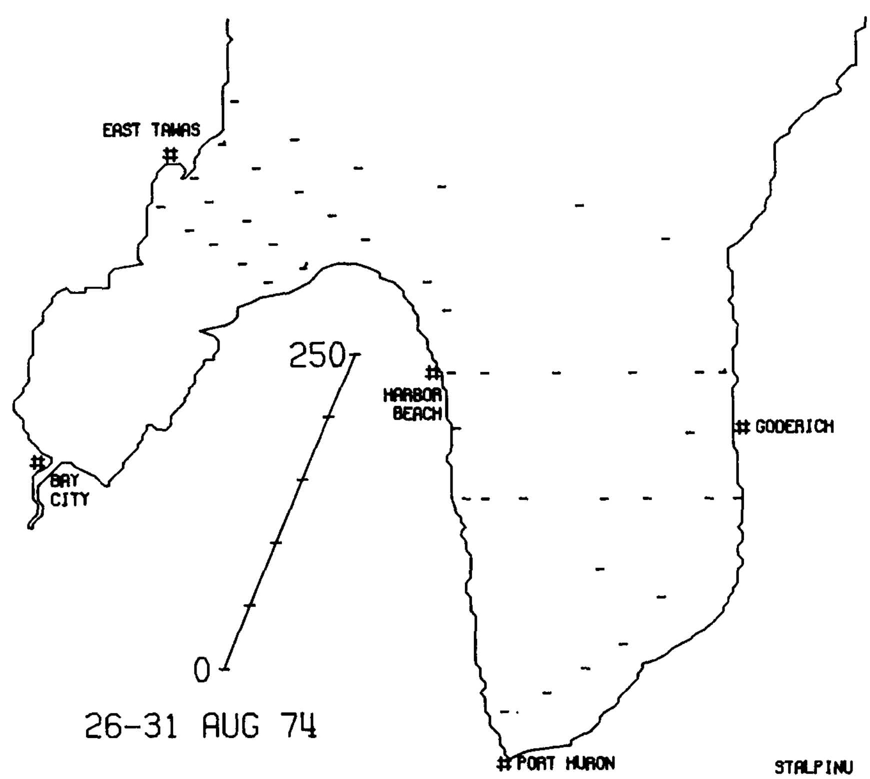
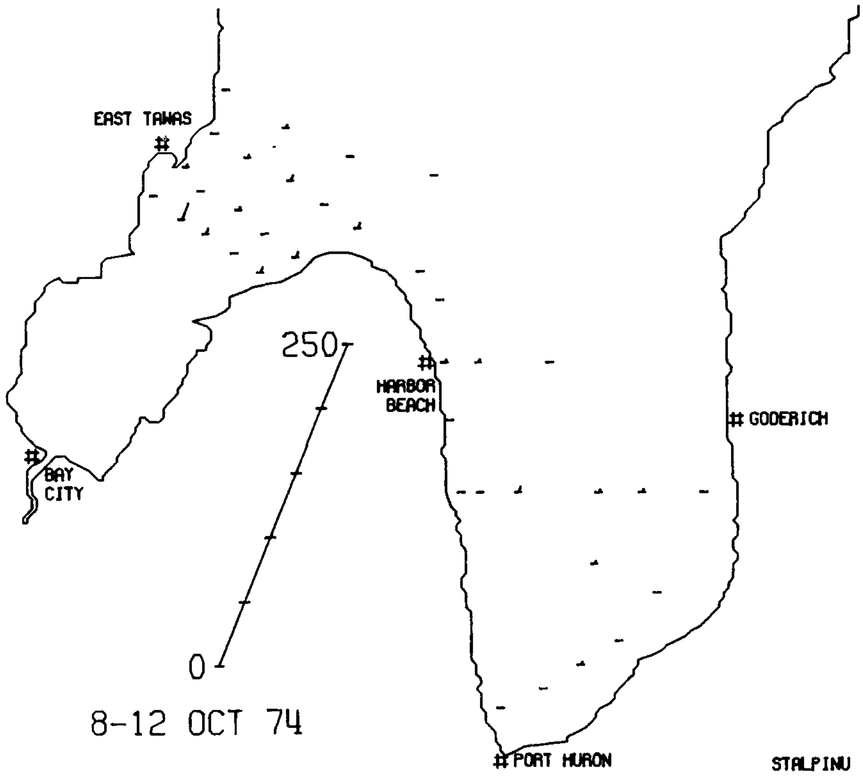


Figure 27. (continued)



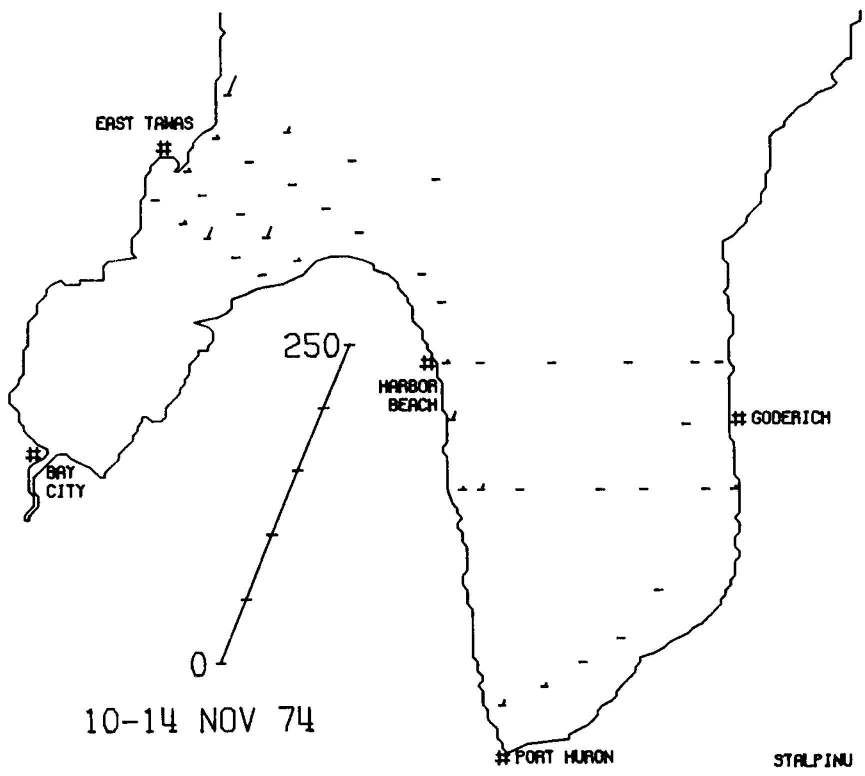


Figure 27. (continued)

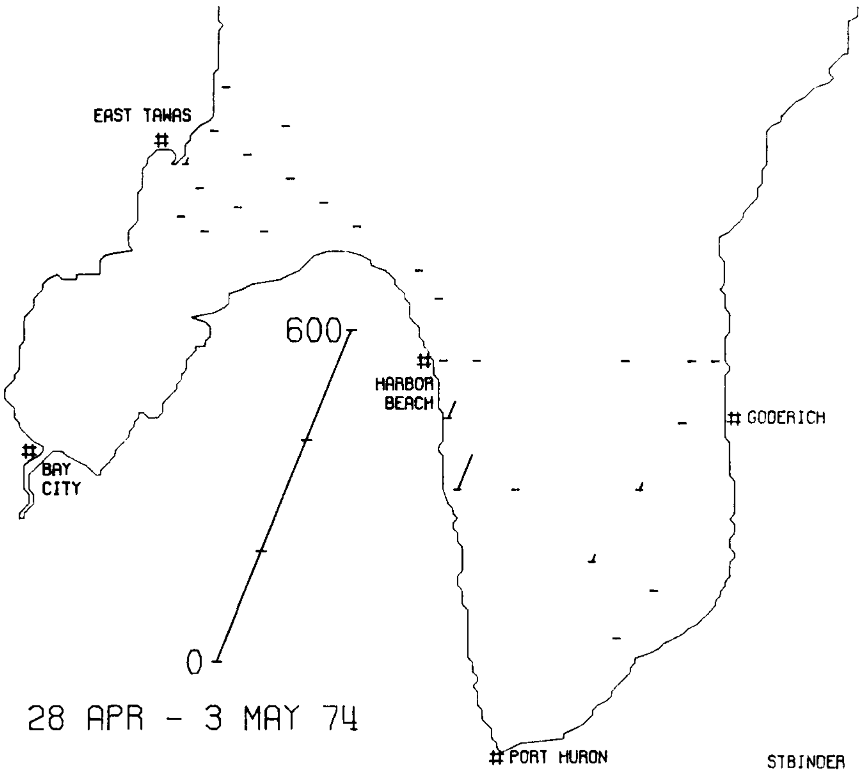
population densities during the spring bloom, and can become a serious nuisance at municipal filtration plants (Vaughn, 1961). In the upper Great Lakes its distribution is largely restricted to eutrophied bays and nearshore areas, but it is abundant in the offshore waters of Lake Erie (Hohn, 1969) and Lake Ontario (Stoermer *et al.*, 1974) as a result of advanced eutrophication. In southern Lake Huron only a few occurrences were noted in the early May samples (Fig. 28A), but it was abundant in samples from the Saginaw Bay interface waters taken during mid-May (Fig. 28B). As is characteristic of this species, maximum population densities were found at nearshore stations. Population densities had been markedly reduced by the time the early June samples were taken (Fig. 28C), and by late June (Fig. 28D), only a few small isolated populations were found. Although a few specimens were noted in fall samples, this species was never a significant part of the flora during the rest of the study.

Stephanodiscus hantzschii

This species is a common element of phytoplankton assemblages in mesotrophic to eutrophic lakes. It is apparently able to respond rapidly to increased nutrient supply and often forms blooms in areas which are significantly enriched. It was present in most of our early May samples from southern Lake Huron but reached very high population densities only at station 57 (Fig. 29A). During mid-May (Fig. 29B) very high population densities were again noted at stations along the Canadian coast and it remained fairly abundant at stations in the Saginaw Bay interface waters and at other nearshore stations, although population densities were somewhat reduced at offshore stations. Populations of this species collapsed during June (Fig. 29C-D) and although isolated specimens were found in a few samples, it was not found in abundance during the rest of the study.

Stephanodiscus minutus

This species is a common element of phytoplankton assemblages in mesotrophic to eutrophic lakes, and often forms winter blooms in large eutrophic lakes (Huber-Pestalozzi, 1942). This taxon is often found in collections from the upper Great Lakes but is generally abundant only in areas which receive elevated nutrient input. Like *Stephanodiscus hantzschii* it responds rapidly to nutrient enrichment (Stoermer, Ladewski, and Schelske, 1978) but is not tolerant of gross pollution. During early May (Fig. 30A) it was present at most stations sampled in southern Lake Huron, but markedly more abundant at nearshore stations along the Canadian coast. During mid-May (Fig. 30B) high population densities of this species were maintained at nearshore stations along the Canadian coast, but had begun to decline particularly at stations in the Saginaw Bay interface waters and nearshore stations along the Michigan coast. Population densities declined and the distribution of the species became more erratic during June (Figs. 30C-D); populations had collapsed by the time the mid-July samples were taken (Fig. 30E). Only a few isolated examples of this species were found in samples taken during August (Fig. 30F) but it became more abundant and widely distributed in the October and November samples (Figs. 30G-H), although it never approached spring population densities.



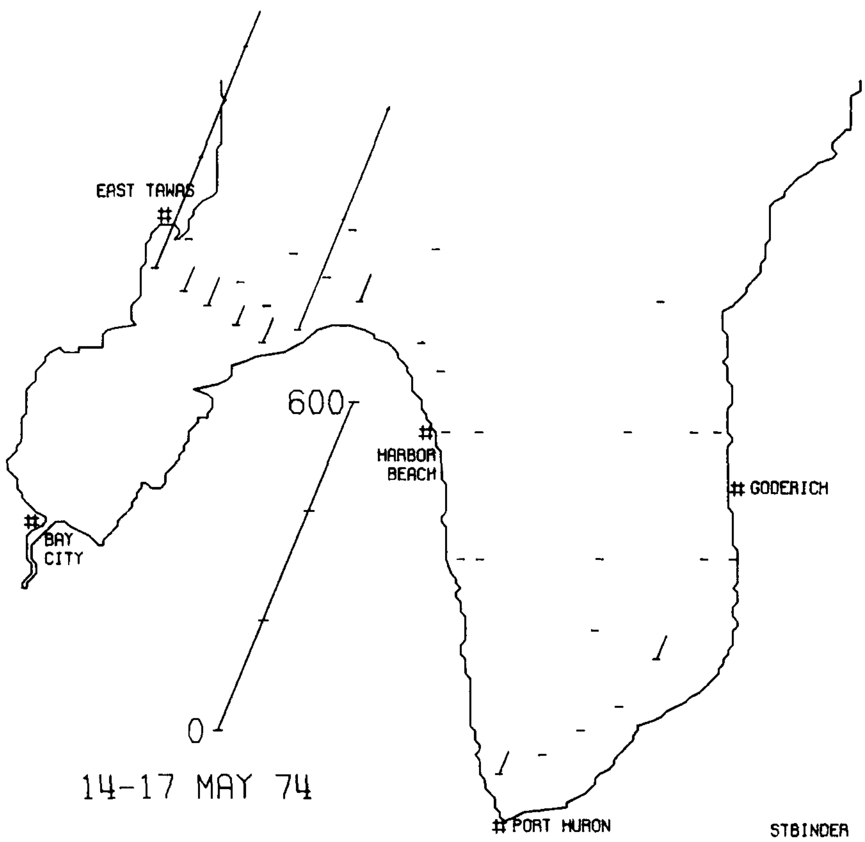
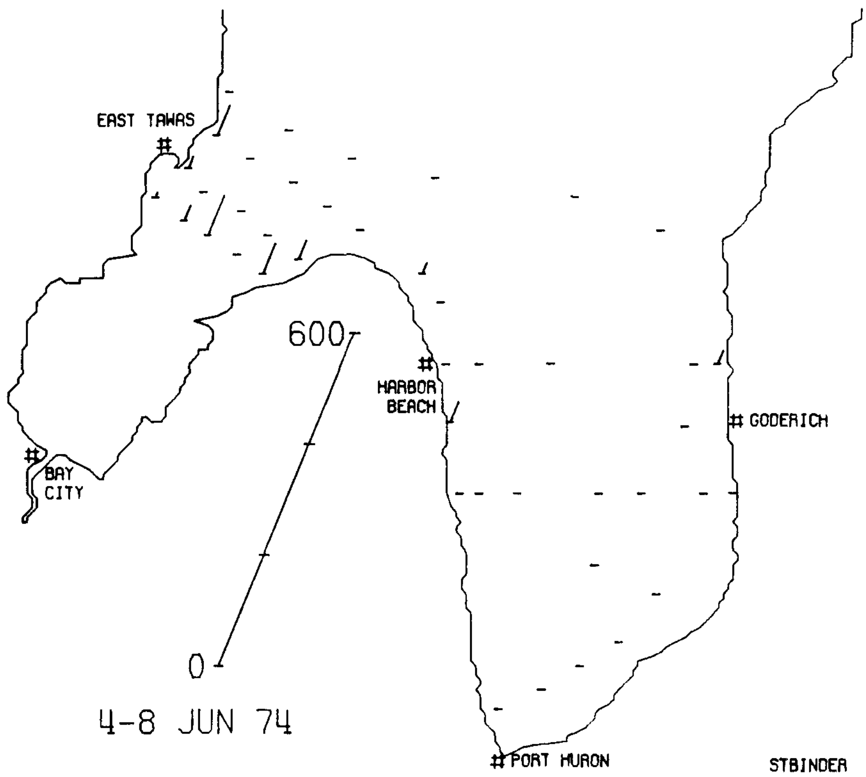


Figure 28. Distribution of *Stephanodiscus binderanus*. (continued)



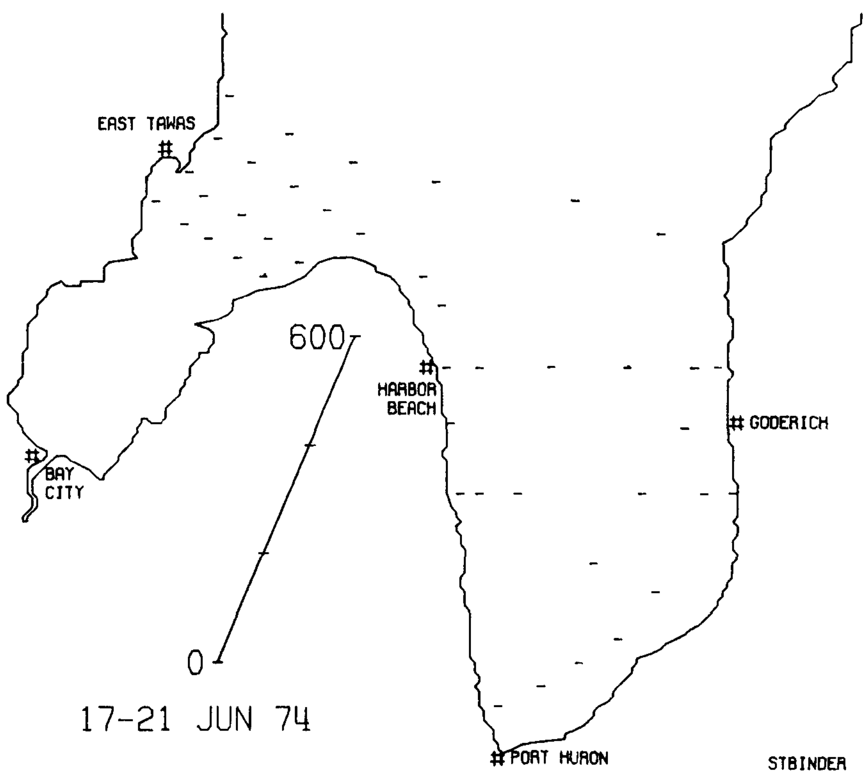
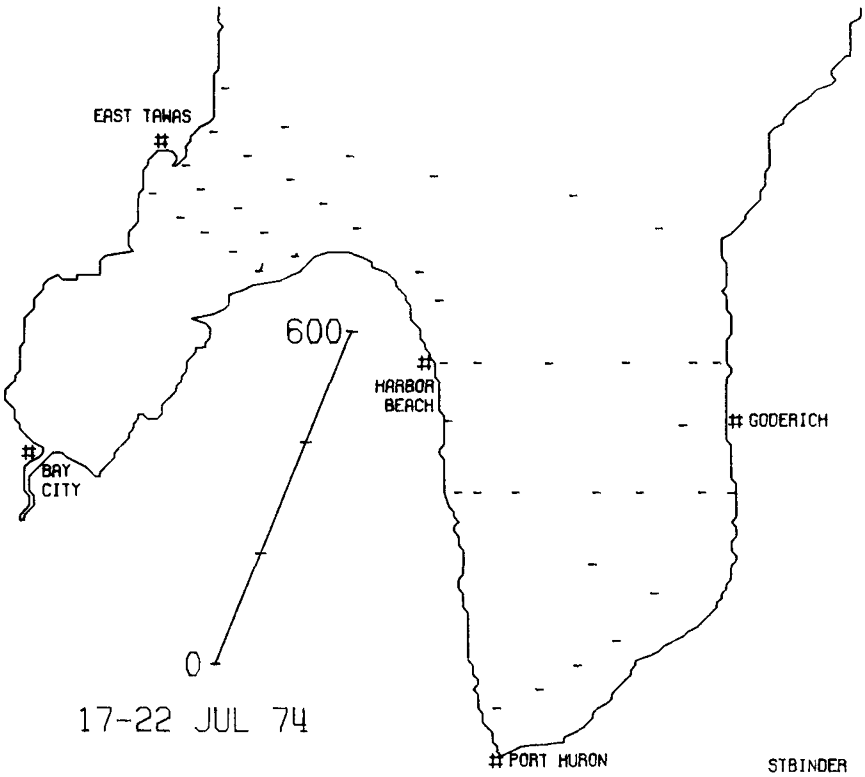


Figure 28. (continued)



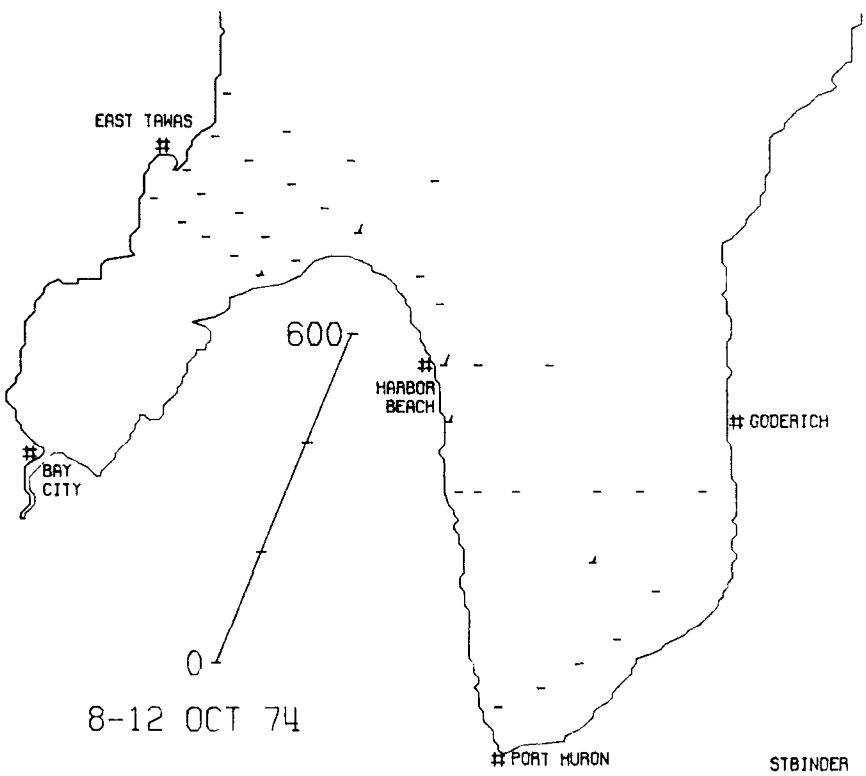


Figure 28. (continued)

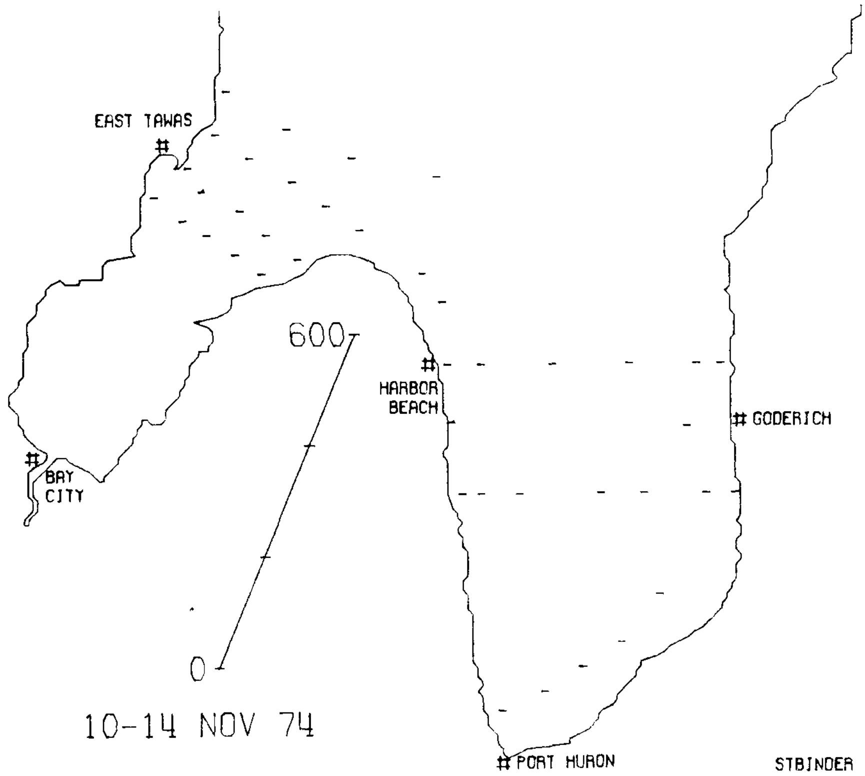


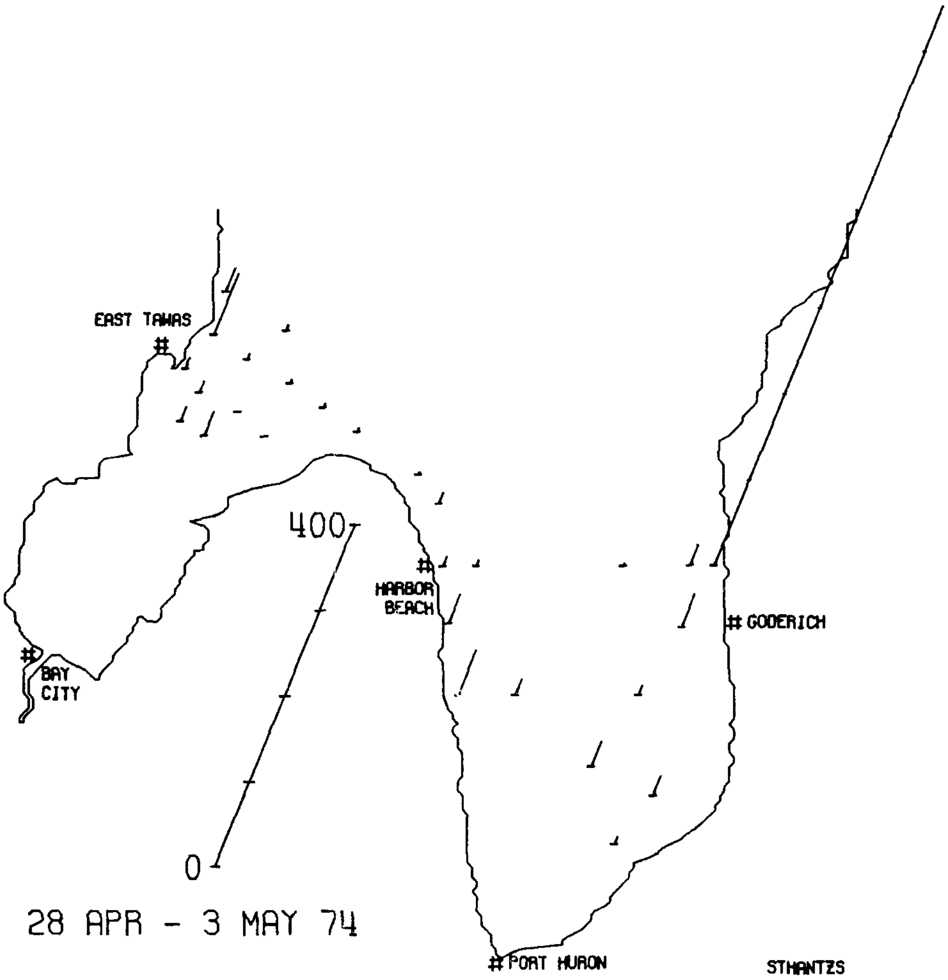
Figure 28. (continued)

Stephanodiscus subtilis

This species is rarely reported in the literature and its ecological affinities are poorly known. It is abundant and widely distributed in Lake Ontario (Stoermer et al., 1974). In Lake Michigan (Stoermer and Yang, 1970) its distribution appears to be restricted almost entirely to harbor entrances and eutrophied nearshore areas. Its distribution in southern Lake Huron is highly unusual in that although it was present during all sampling cruises (Figs. 31A-H), its distribution was almost entirely restricted to nearshore stations along the Canadian coast. These populations may, in fact, be derived from riverine habitats. The only exceptions to this were a few very small populations noted at stations of the Saginaw Bay interface water collected during late June and November.

Synedra filiformis

This species is one of the characteristic forms of the offshore phytoplankton flora of the upper Great Lakes. In southern Lake Huron, large and remarkably uniform populations were found at all stations sampled during May (Figs. 32A-B). Populations remained high at offshore stations sampled during June (Figs. 32C-D); however, population densities were reduced at stations sampled in the Saginaw Bay interface waters during early June. By late June, this species was absent from several stations in the Saginaw Bay interface waters and south along the Michigan coast. Abundance of this species was at a minimum during the July sampling period (Fig. 32E), but by August (Fig. 32F) it had again become abundant at stations in the northerly sector



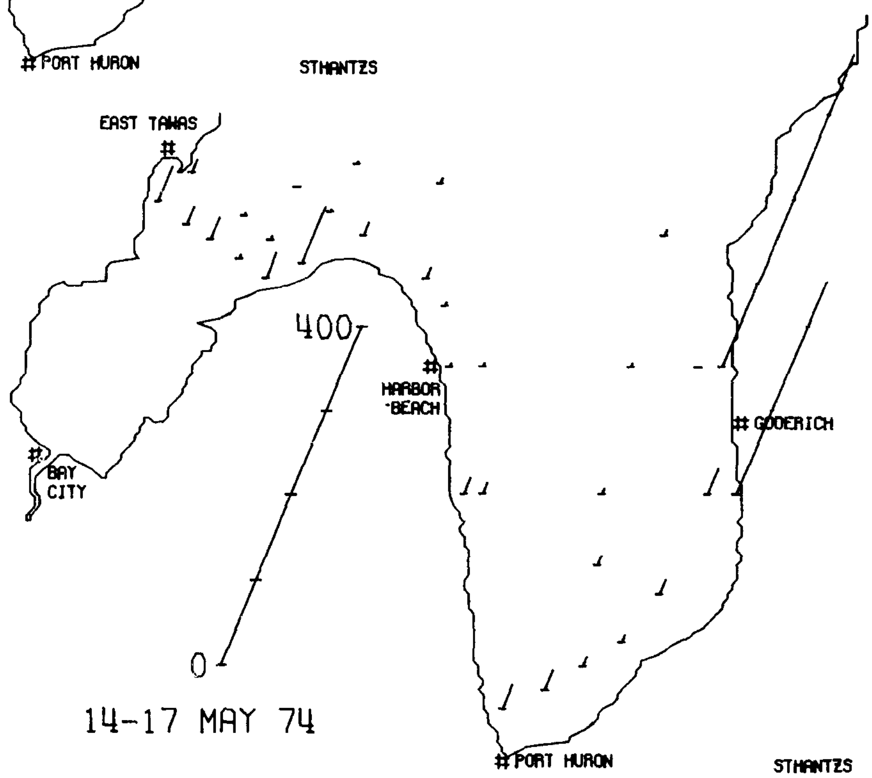
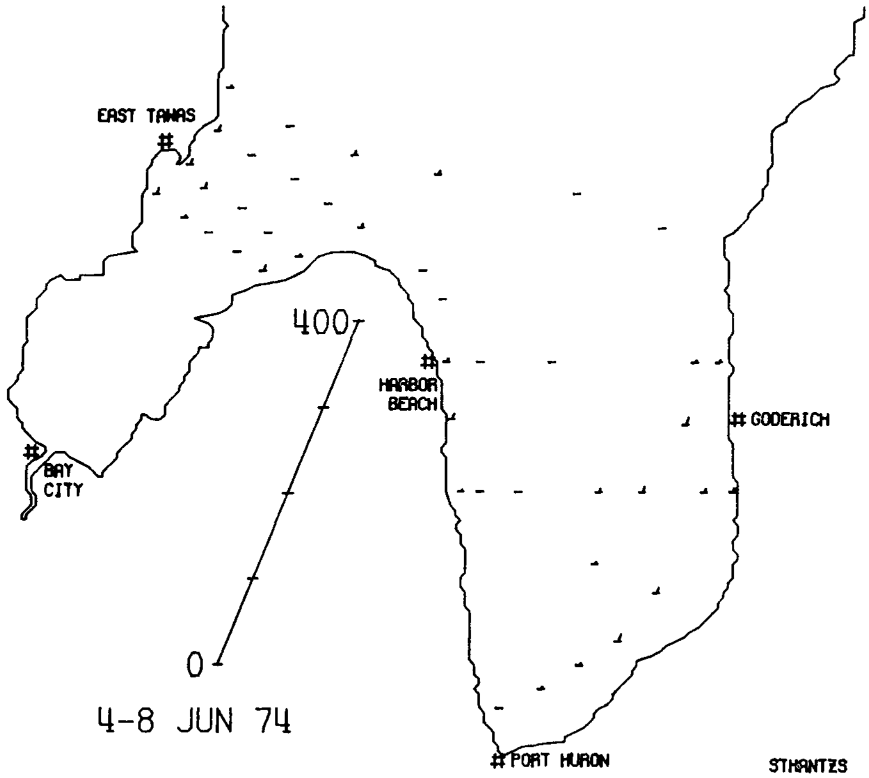


Figure 29. Distribution of Stephanodiscus hantzschii. (continued)



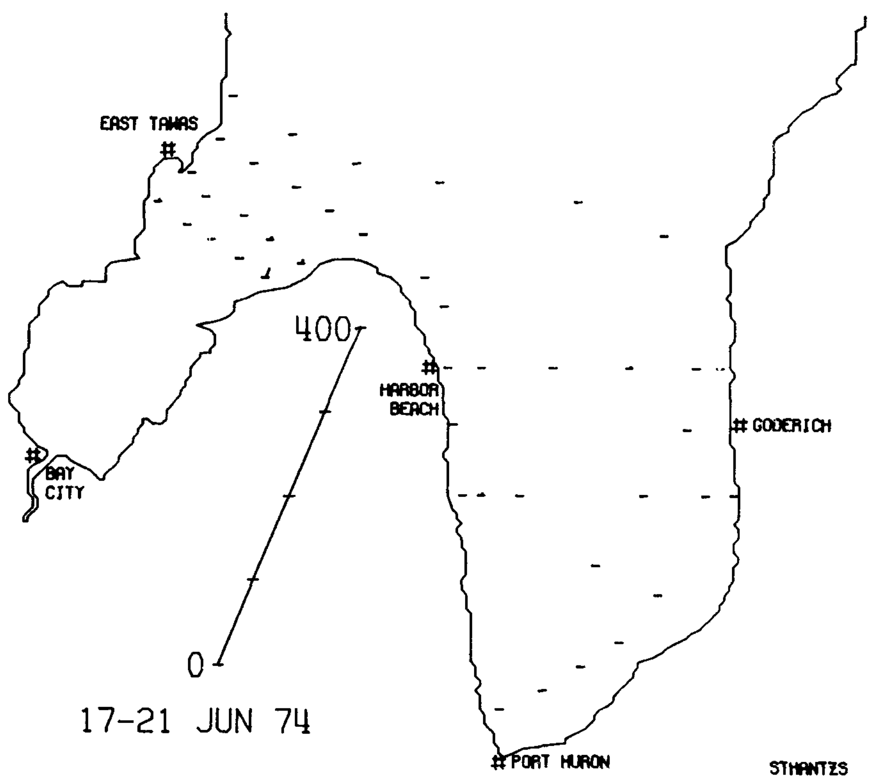
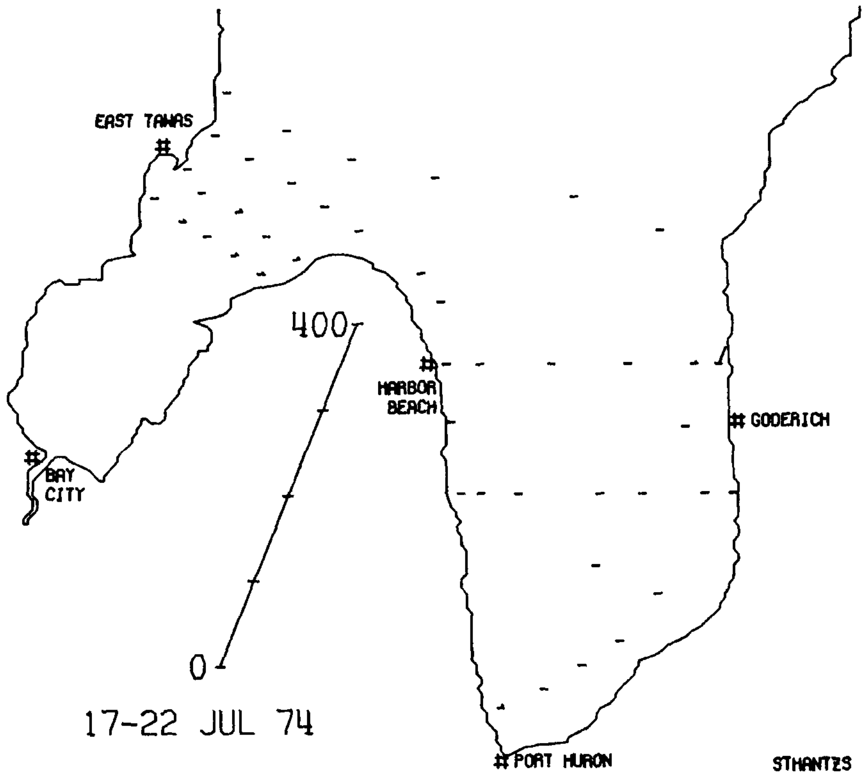
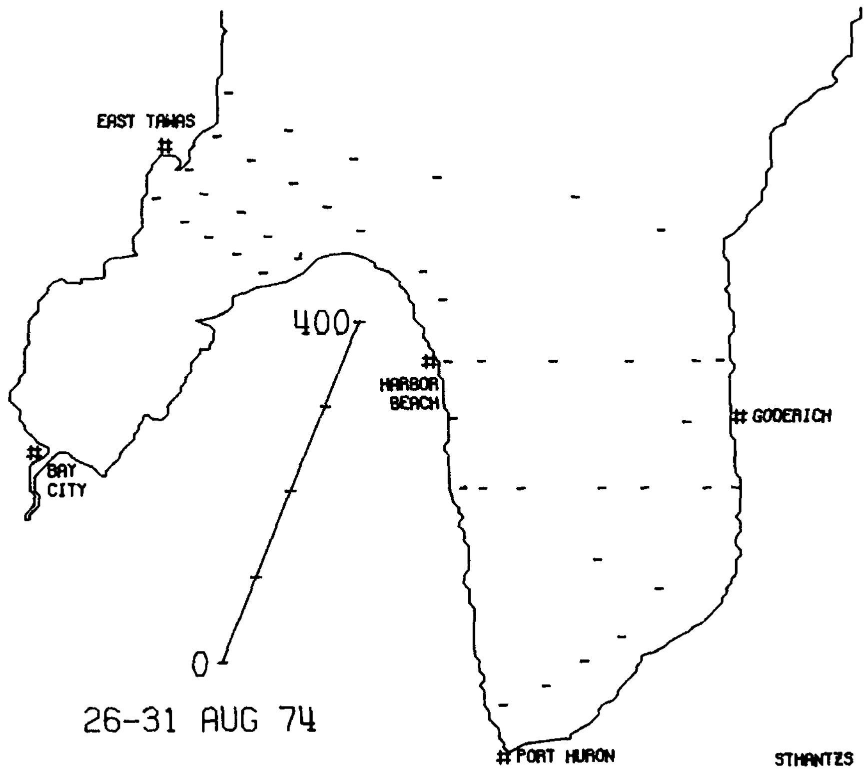


Figure 29. (continued)





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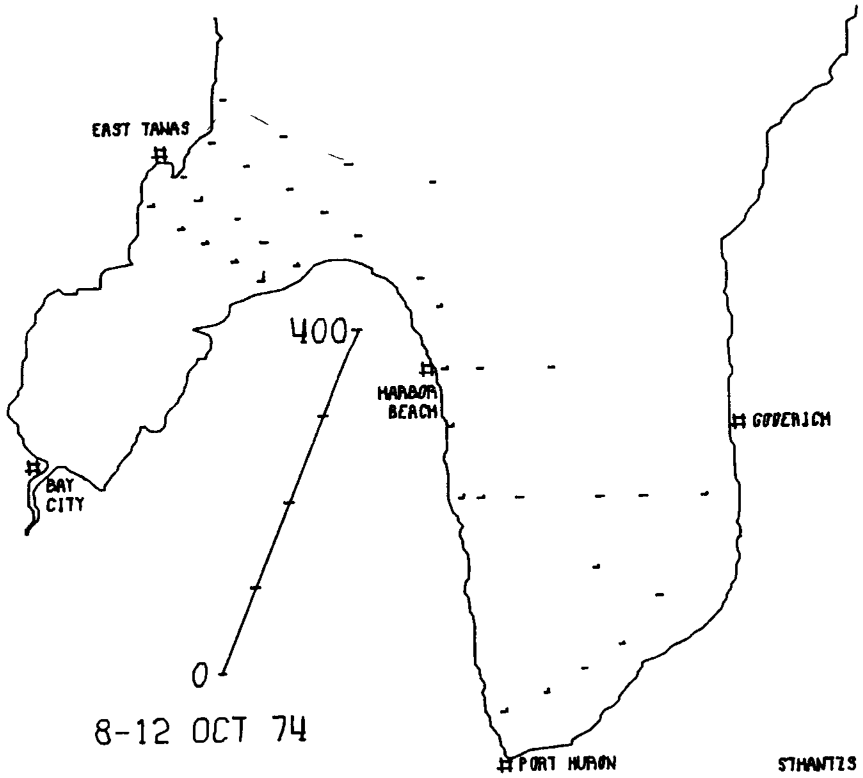


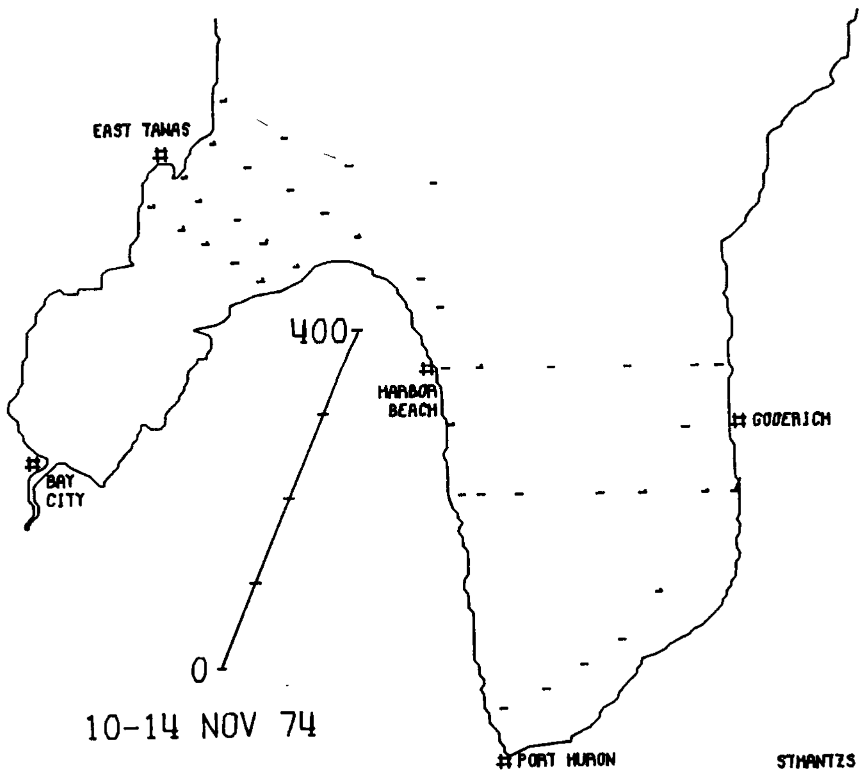
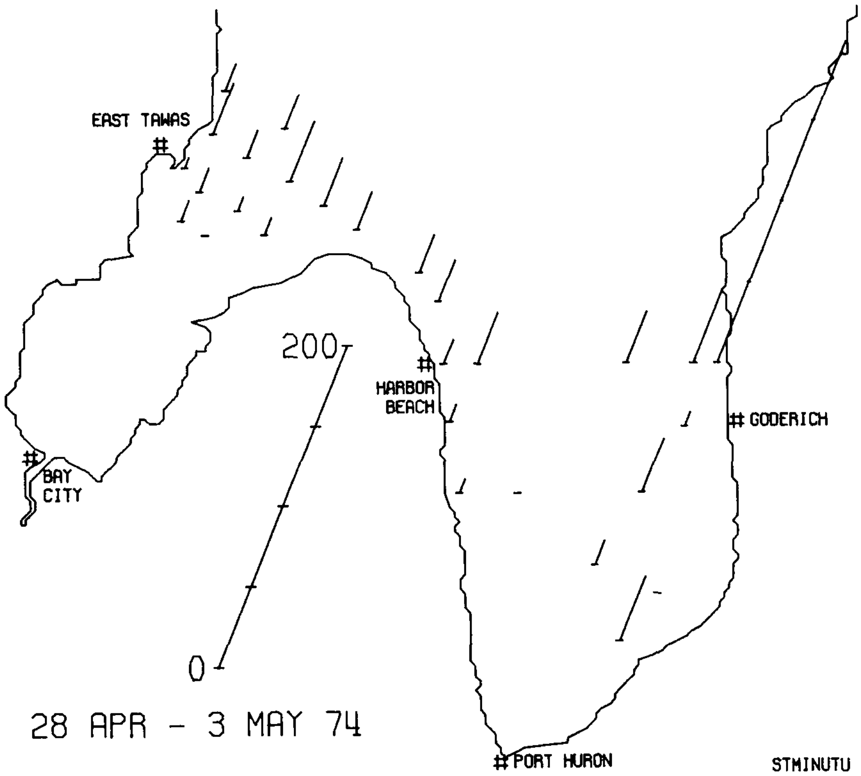


Figure 29. (continued)



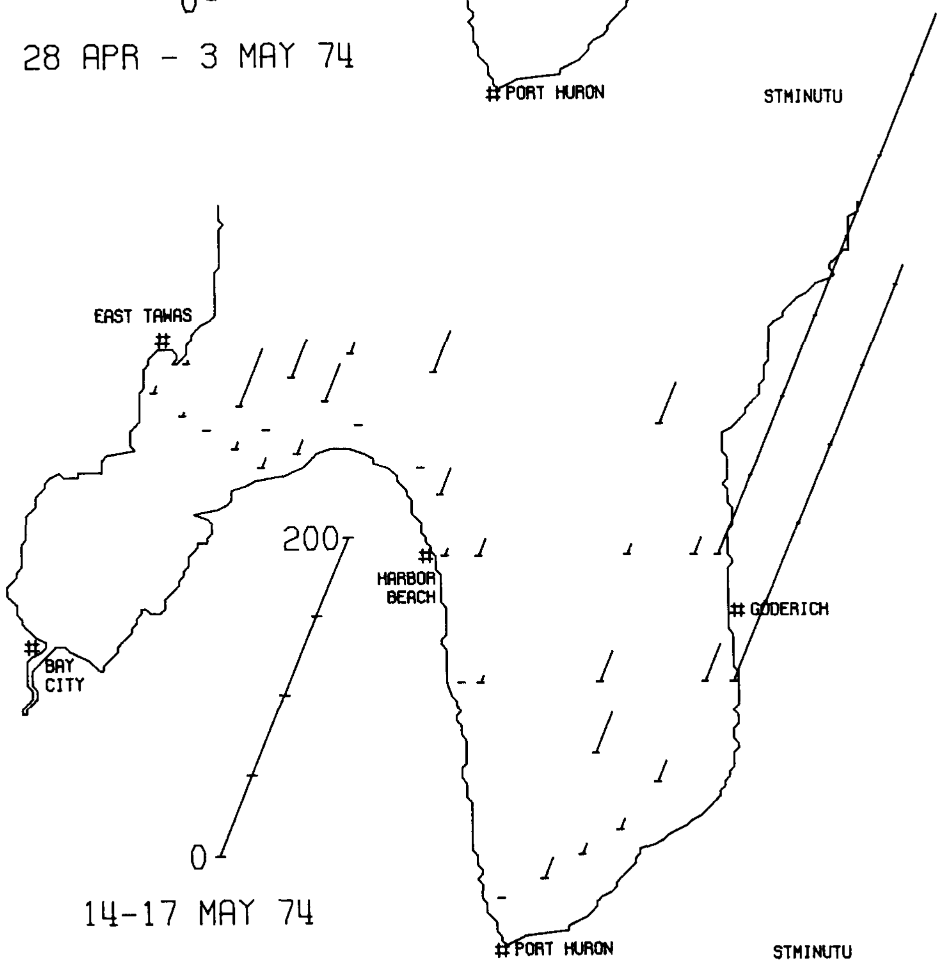
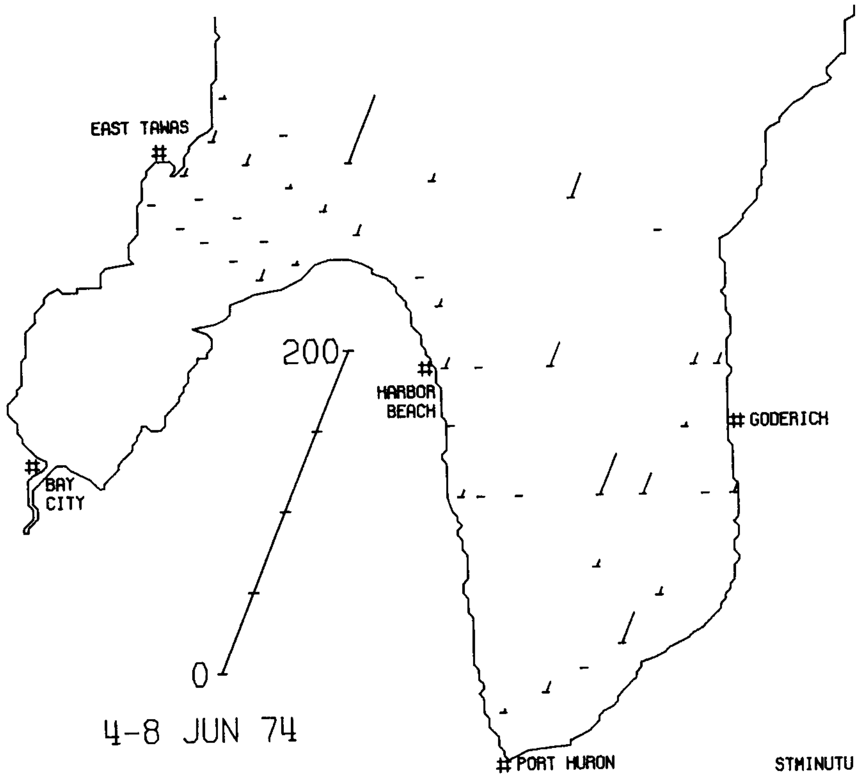


Figure 30. Distribution of Stephanodiscus minutus. (continued)



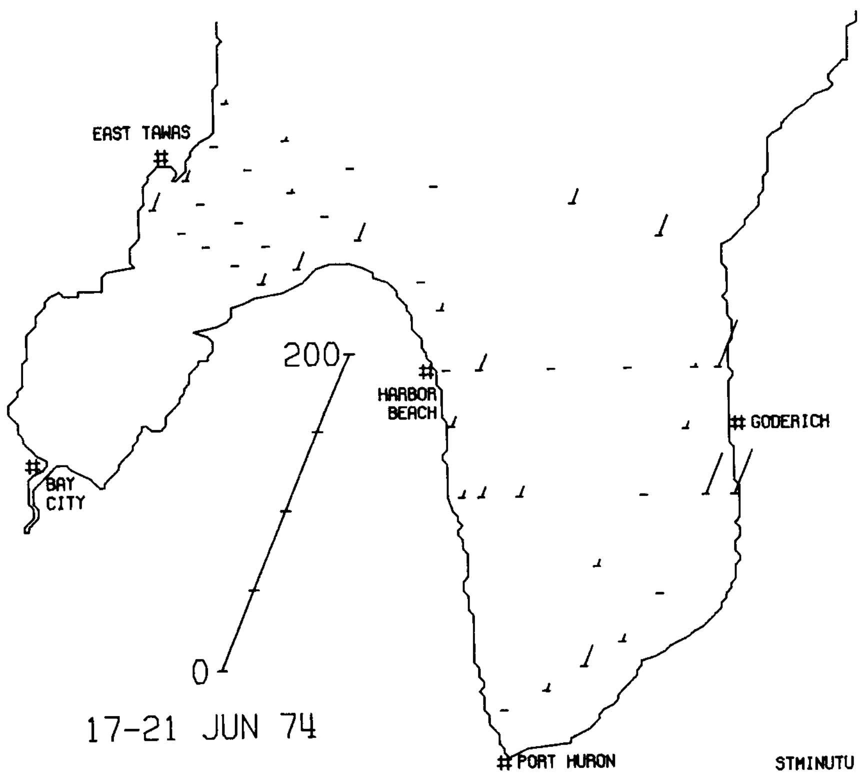
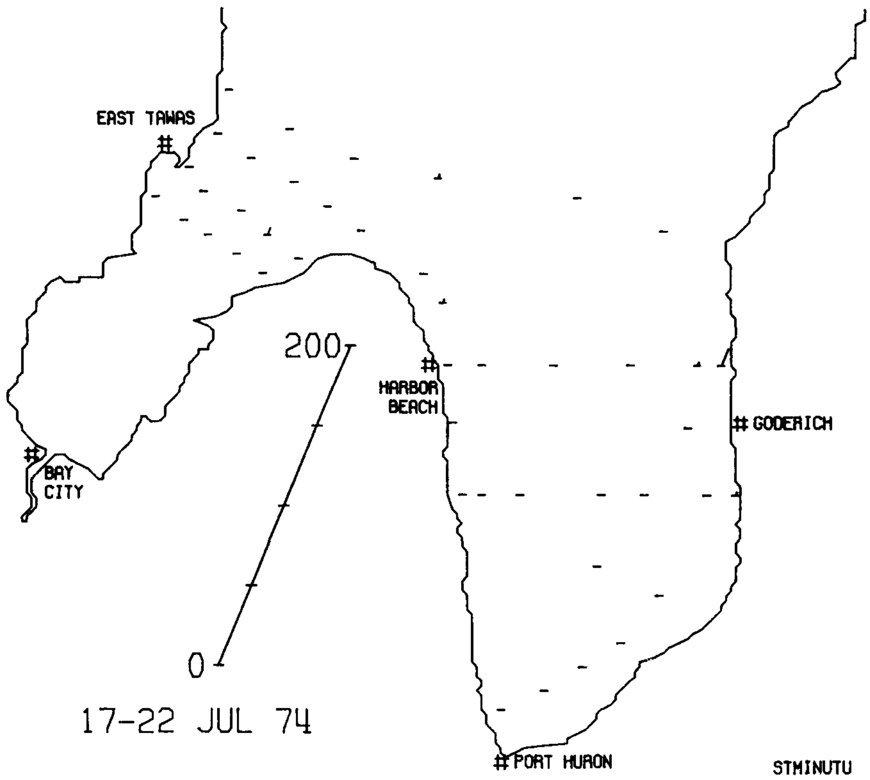


Figure 30. (continued)



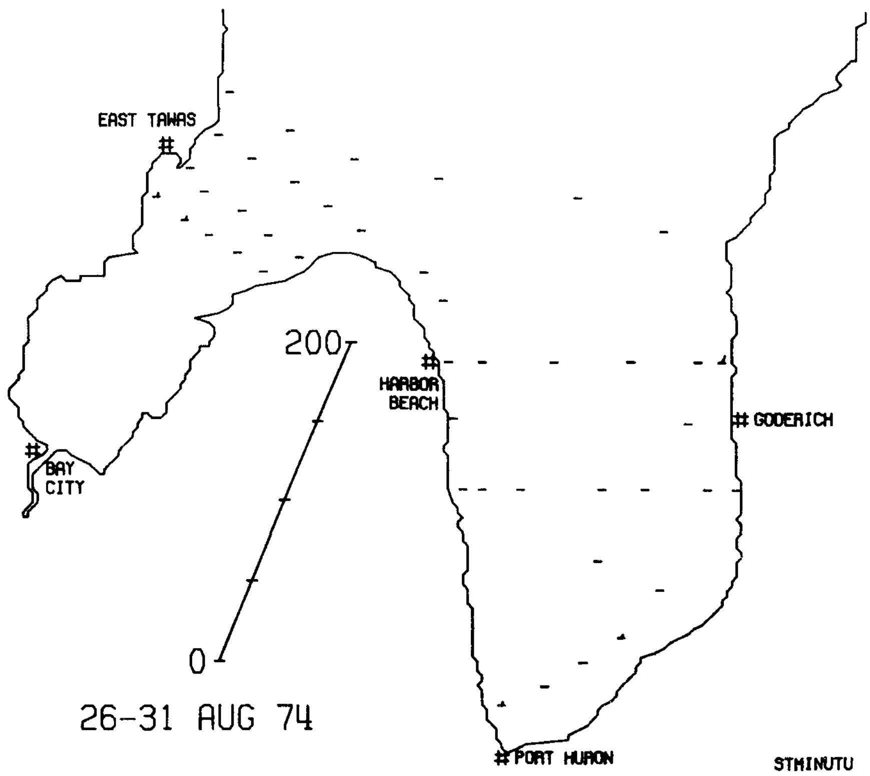
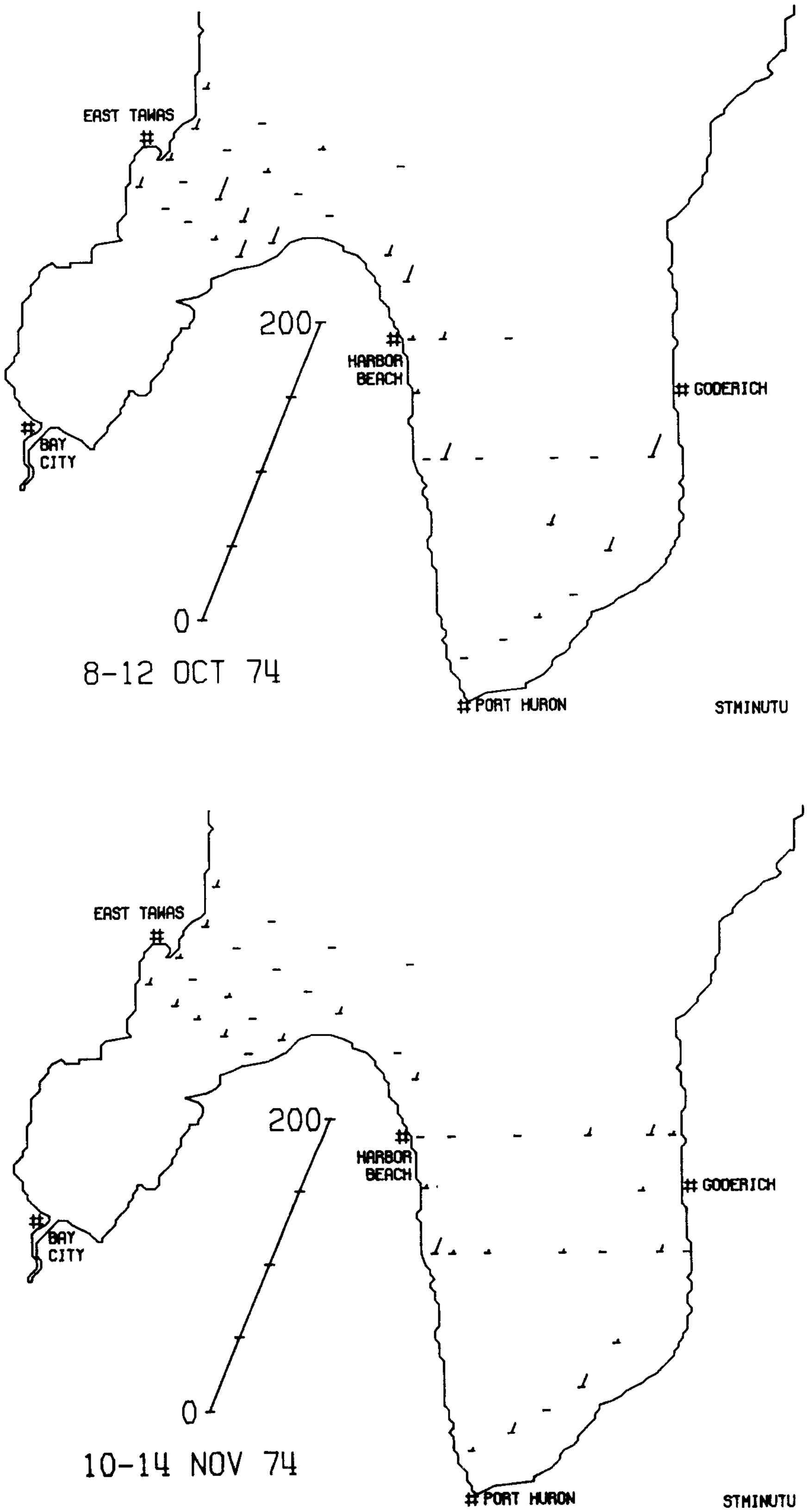


Figure 30. (continued)



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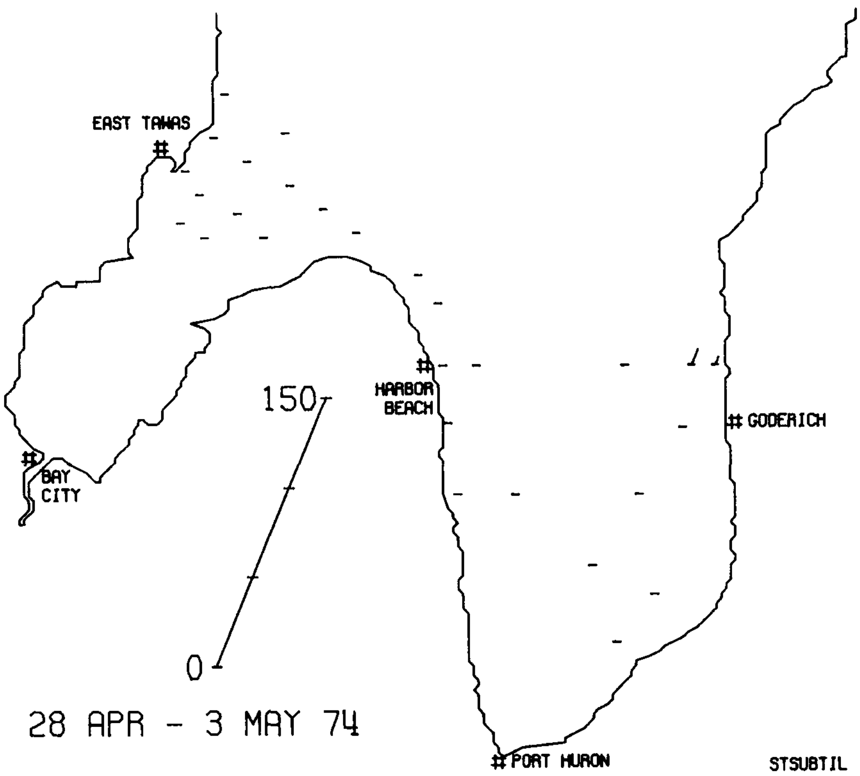


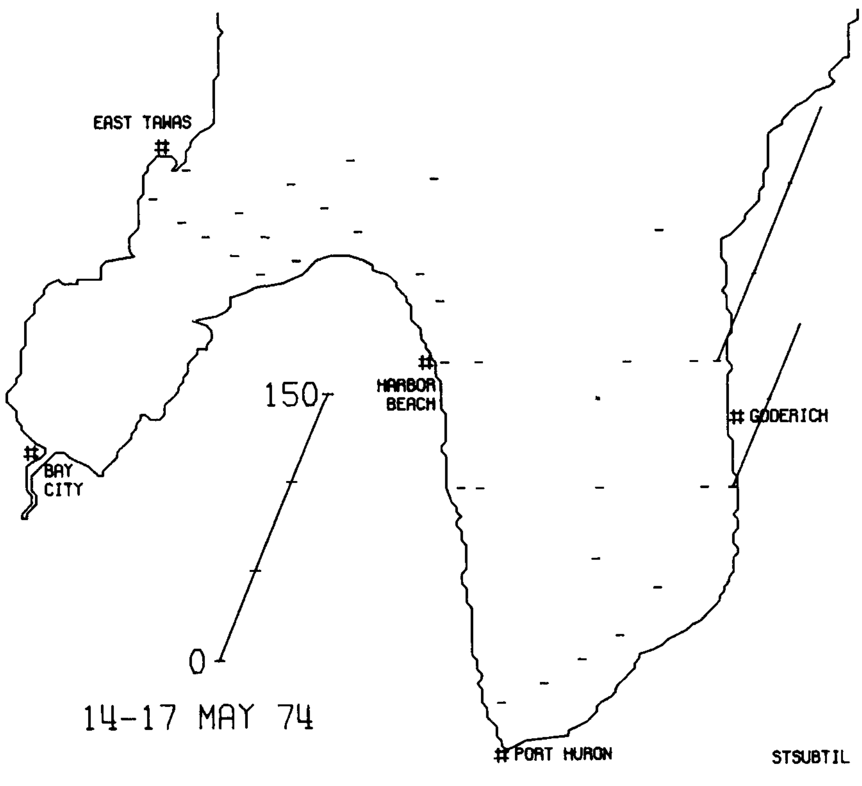
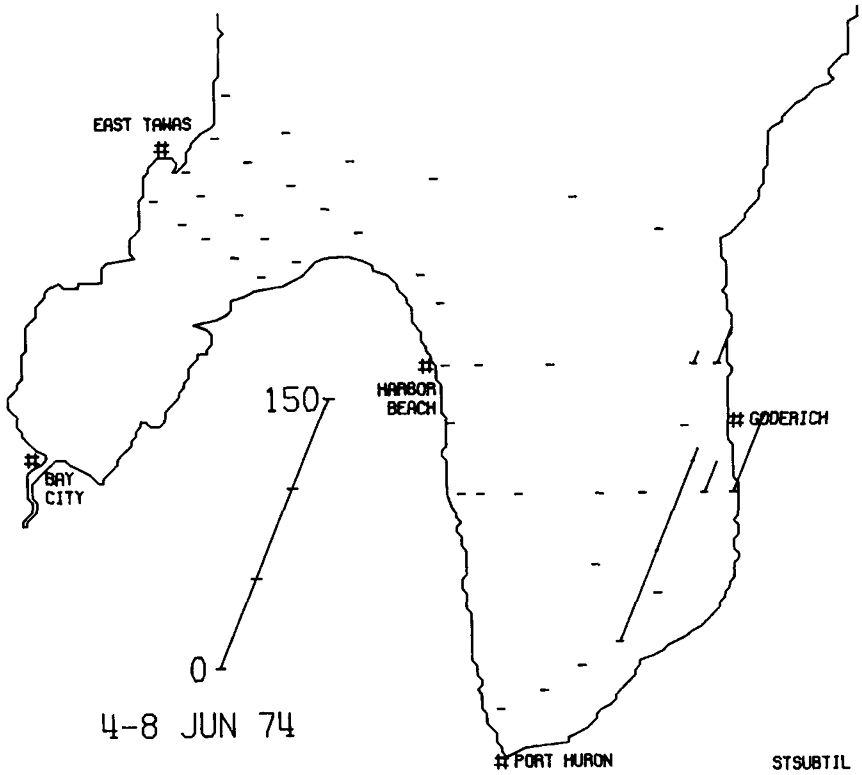


Figure 31. Distribution of *Stephanodiscus subtilis*. (continued)



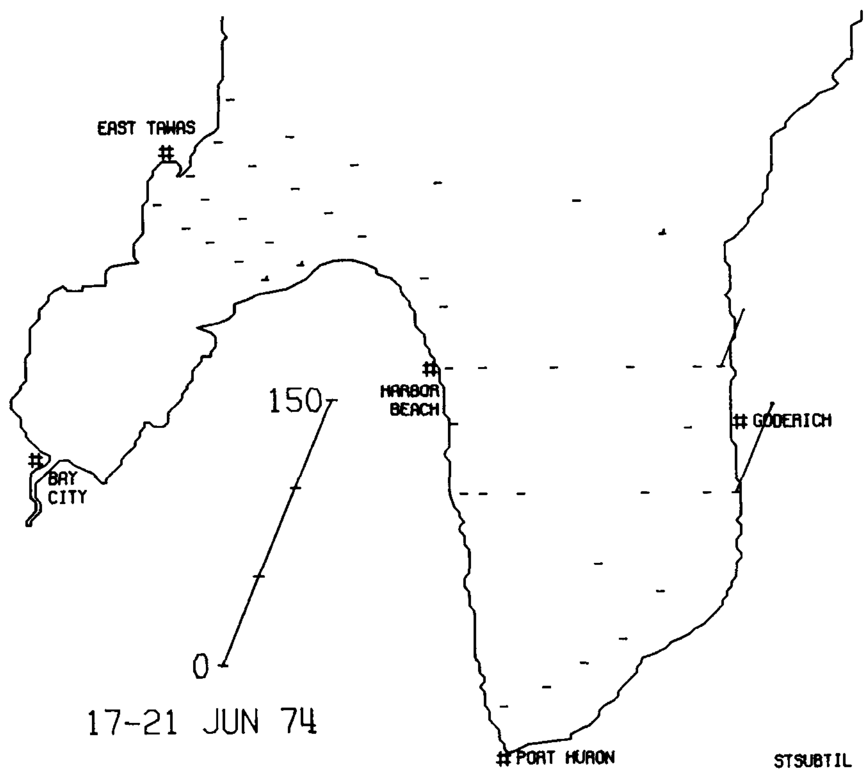
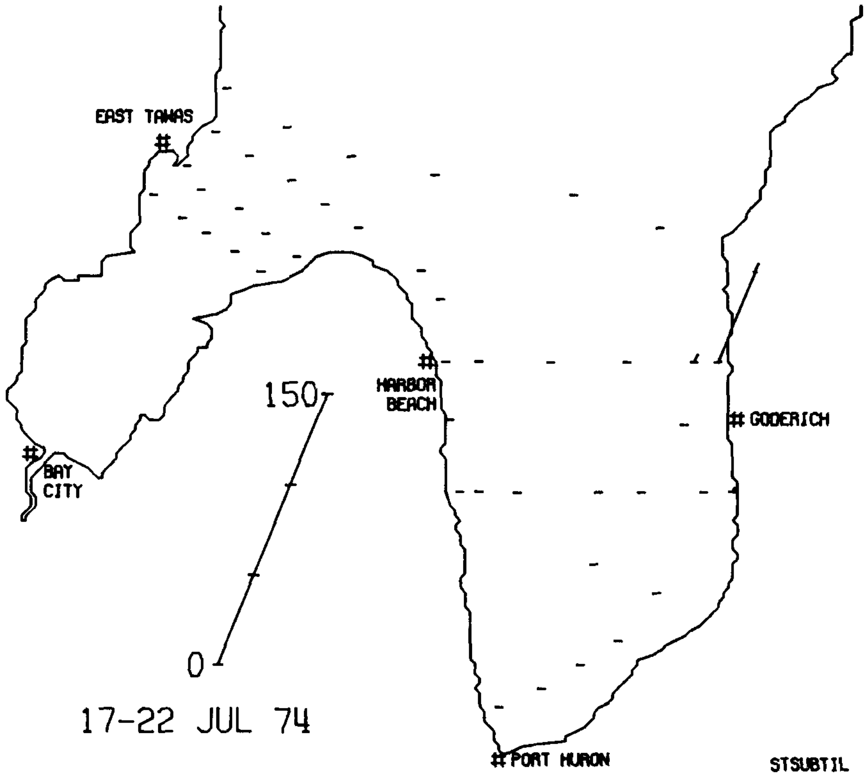
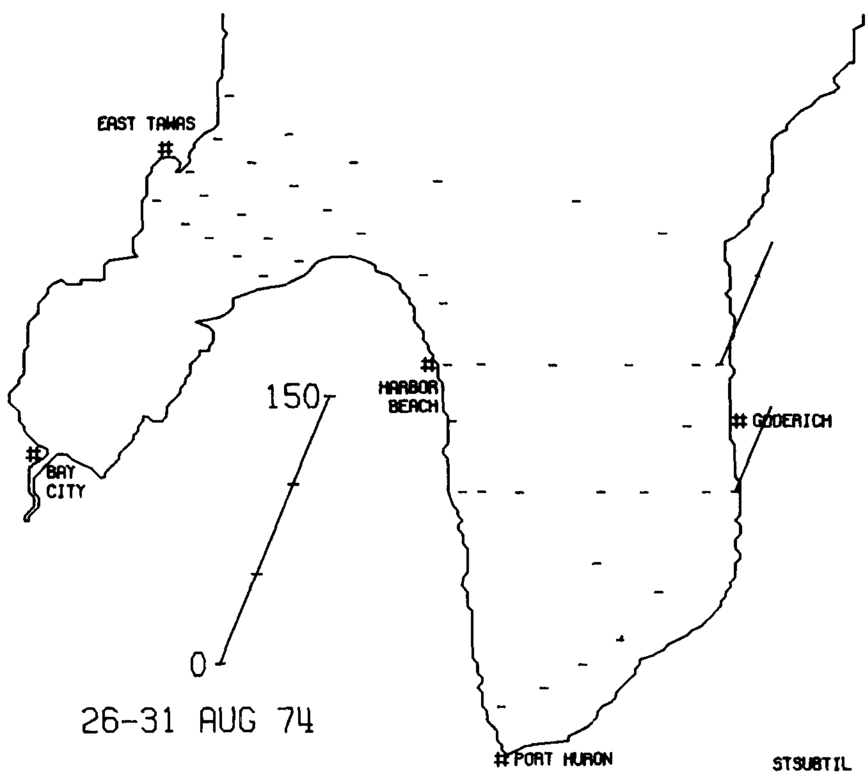


Figure 31. (continued)





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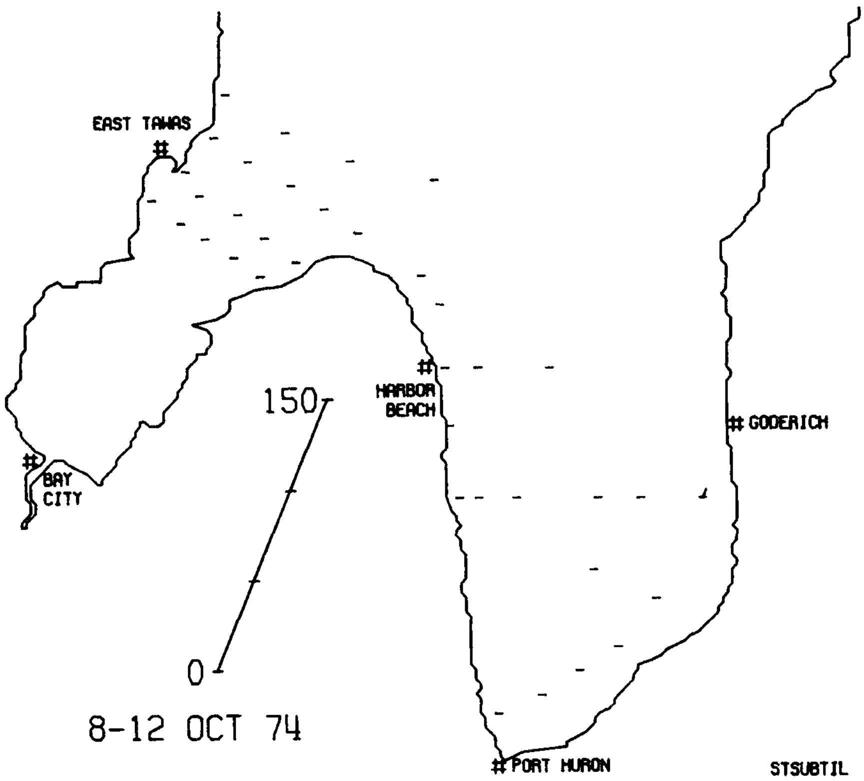

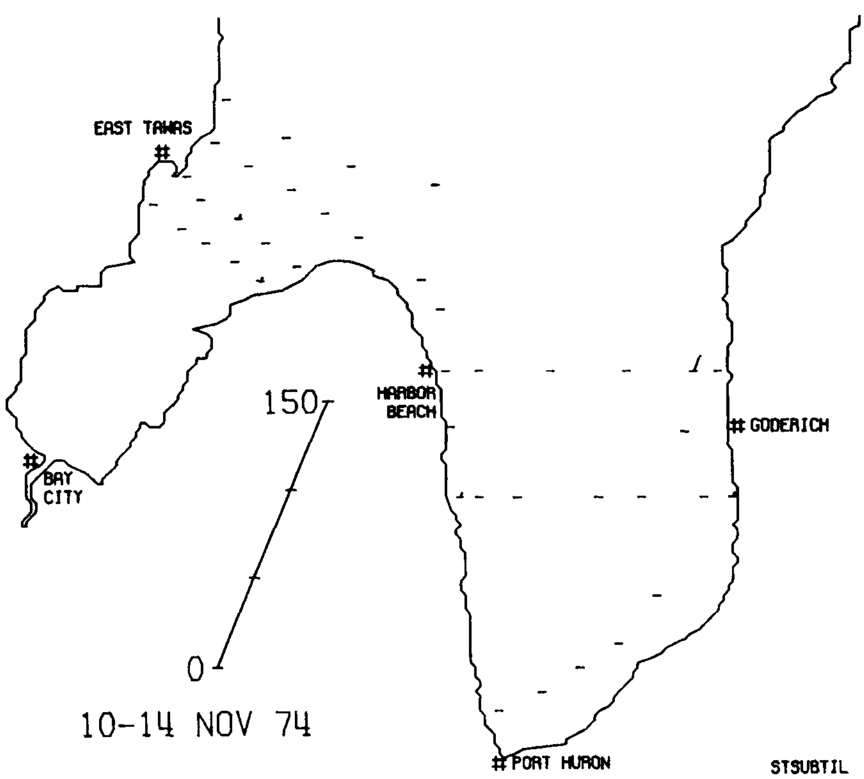

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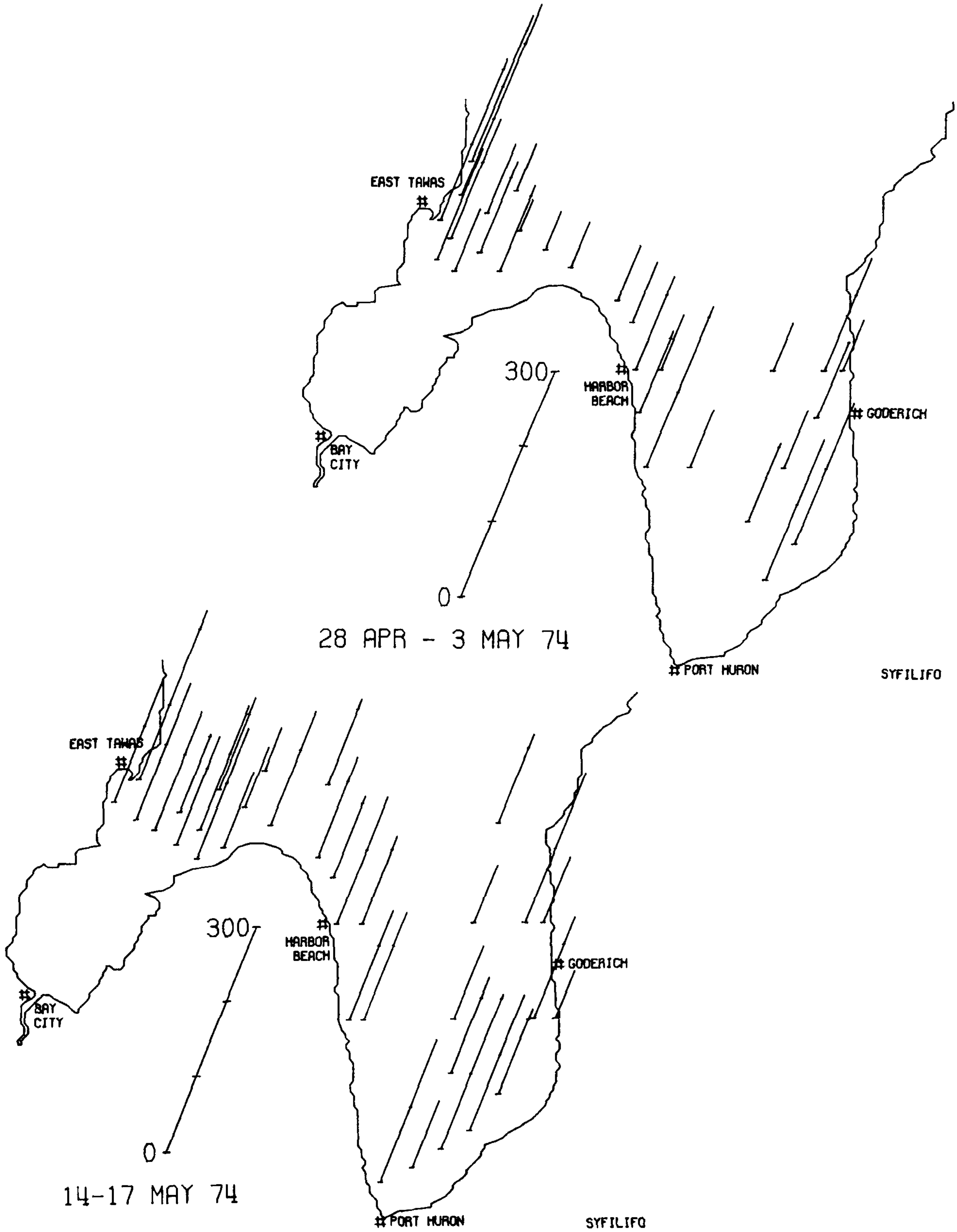
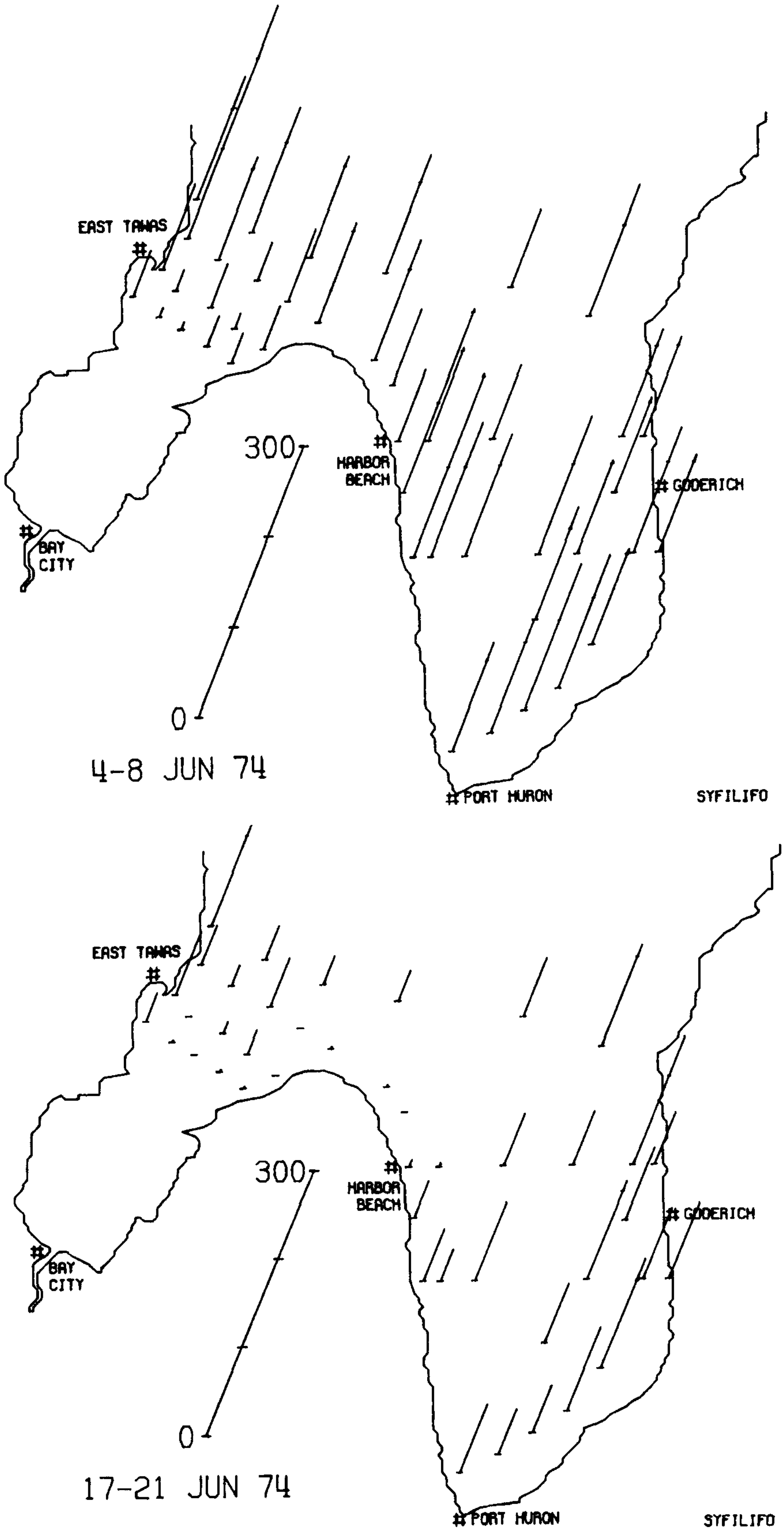


Figure 32. Distribution of *Synedra filiformis*. (continued)



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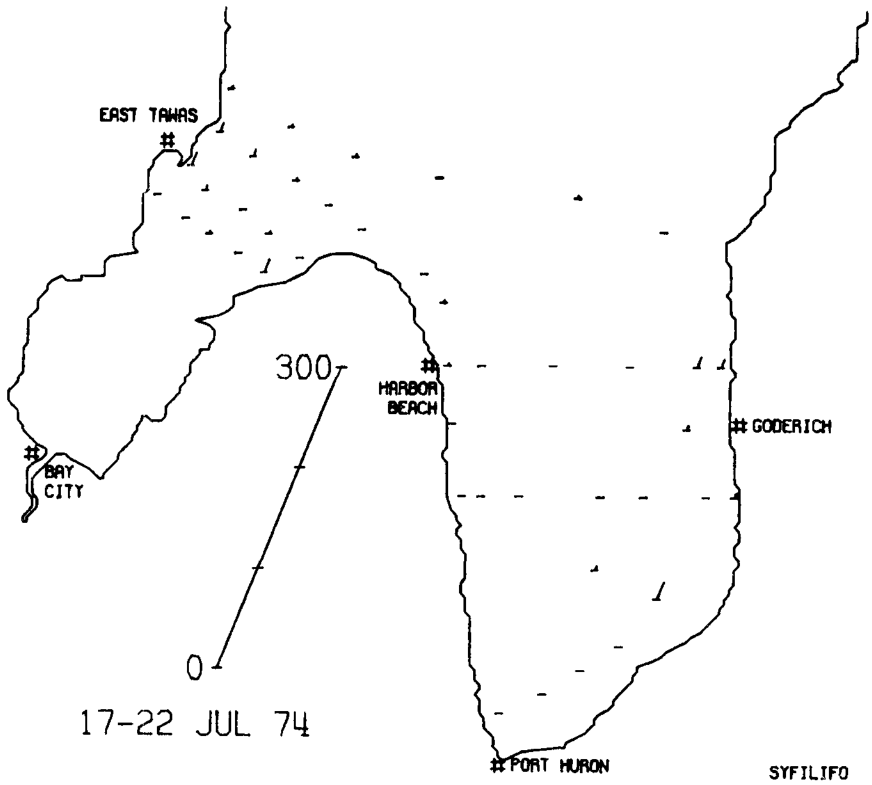


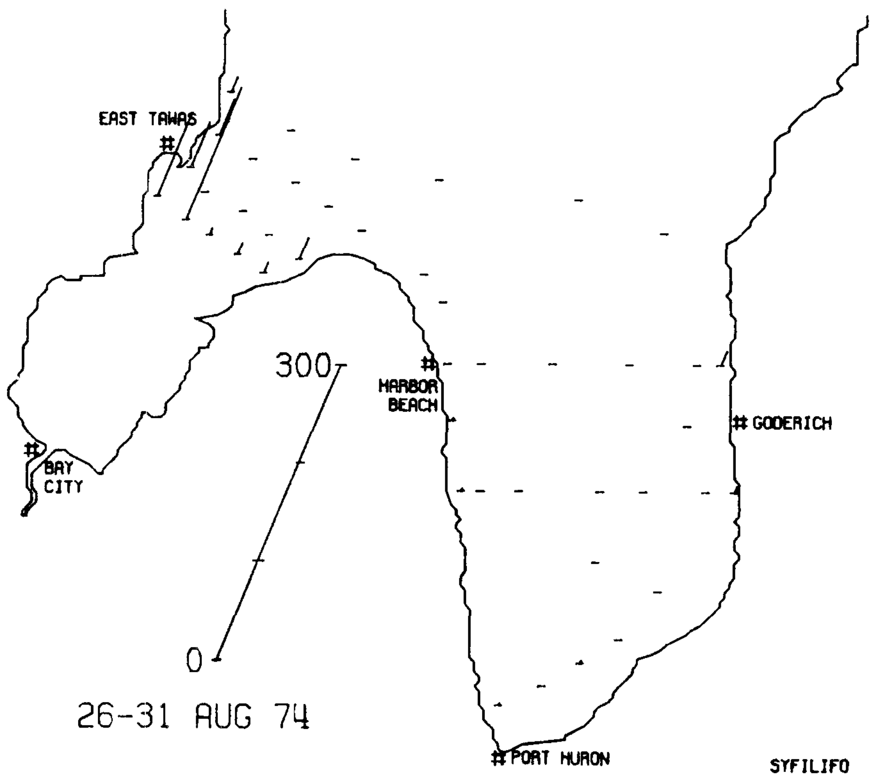


Figure 32. (continued)

of the Saginaw Bay interface waters. It remained abundant at some stations in the Saginaw Bay interface waters during October (Fig. 32G) and appeared to spread southward at stations along the Michigan coast. This trend continued during November (Fig. 32H) and there was a small increase in population densities of this species at offshore stations although it did not approach abundances present in the spring samples.

Synedra ostenfeldii

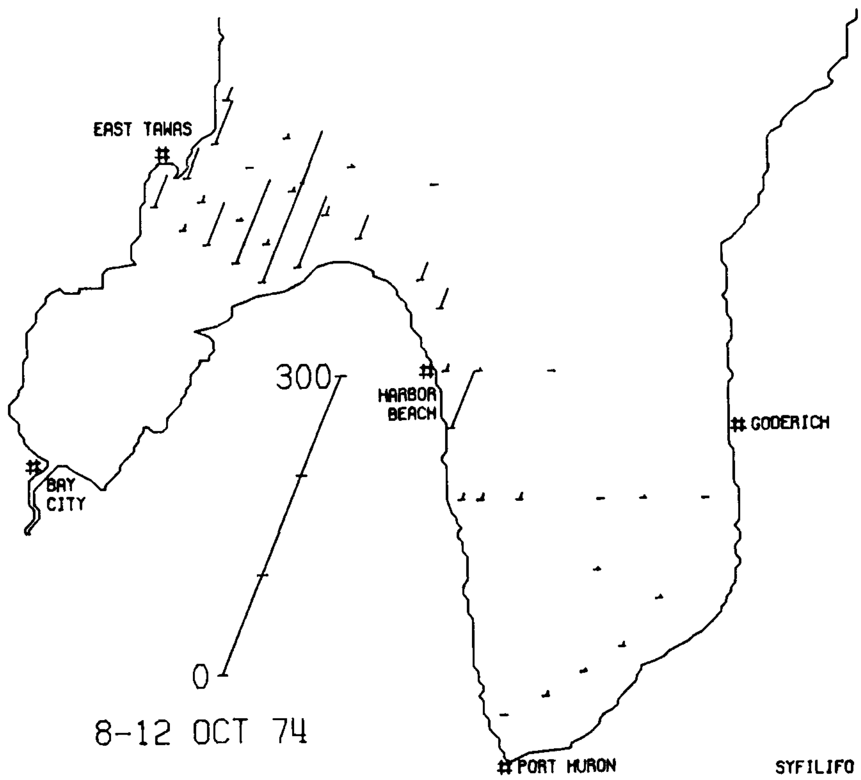
Although this colonial species is not as abundant as *Synedra filiformis*, its areal and temporal distribution in southern Lake Huron are quite similar. It was present at most stations sampled during May (Figs. 33A-B), with highest population densities occurring in stations in the northerly sector of the Saginaw Bay interface waters. During June (Figs. 33C-D), populations began to decline, particularly at stations in the Saginaw Bay interface, and by late June it was absent from several stations in this area and southward along the Michigan coast. Population densities of this species remained low during the rest of the study (Fig. 33E-H), with most occurrences noted in the Saginaw Bay interface waters and at stations southerly along the Michigan coast.

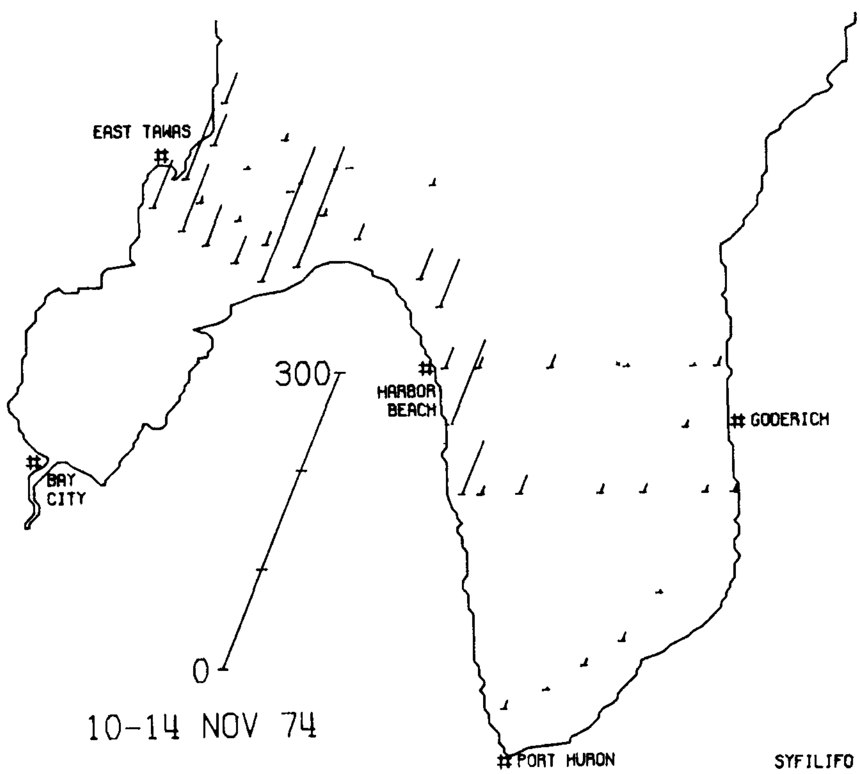
Tabellaria fenestrata

This species is one of the eurytopic plankton dominants which are common to abundant throughout the Great Lakes system. In southern Lake Huron, it was present in all samples taken during early May (Fig. 34A), and population levels increased by the time the mid-May samples were taken (Fig. 34B). Populations remained high in early June (Fig. 34C) but began to decline in late June (Fig. 34D) and had collapsed by the time July (Fig. 34E) samples were taken. Population levels were at a minimum during the August sampling cruise (Fig. 34F) except at station 6 where this species was fairly abundant, perhaps as a result of upwelling. There was a slight increase in abundance of this species during October and November (Figs. 34G-H), although its abundance did not approach spring levels.

Tabellaria flocculosa var. *linearis*

This species was present at most stations sampled during early May (Fig. 35A) and peak population densities were found at nearshore stations north of Saginaw Bay. Increased abundance was noted in the mid-May samples (Fig. 35B) and peak abundance occurred during June (Figs. 35C-D). As was the case with *T. fenestrata* abundance of this species declined during July and August (Figs. 35E-F), but unlike that species occasional abundant occurrences were noted, particularly at nearshore stations. Population densities increased during October and November (Fig. 35G-H) particularly at stations in the Saginaw Bay interface waters and southward along the Michigan coast. Fall abundance of this species however did not approach the levels found in the spring samples.





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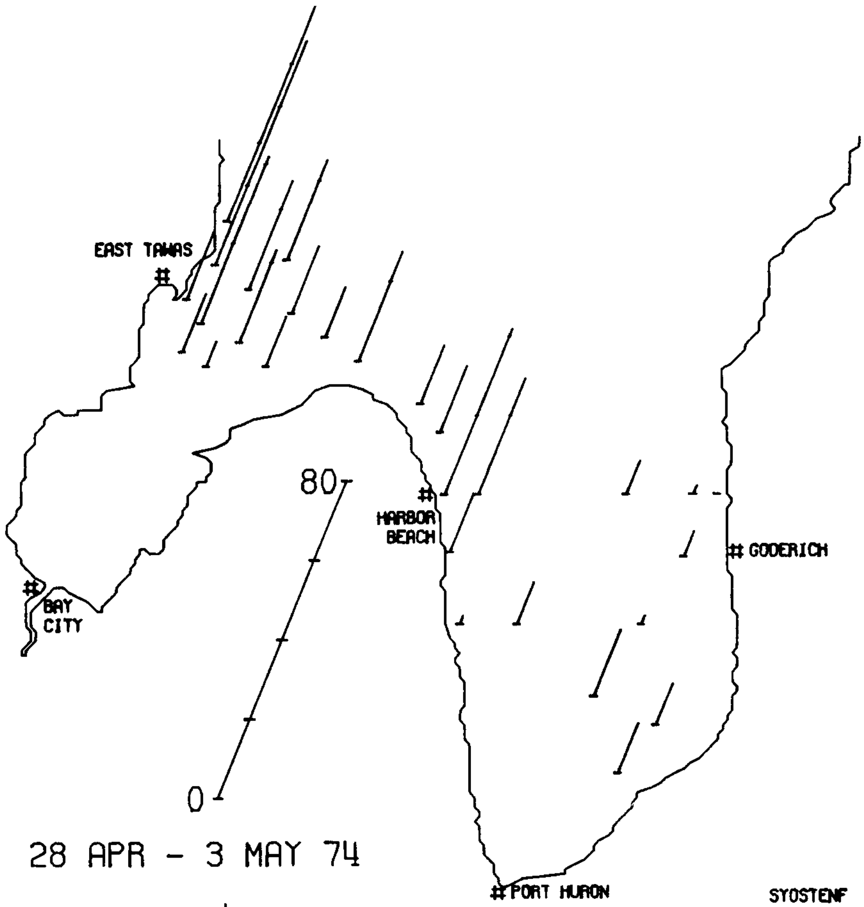


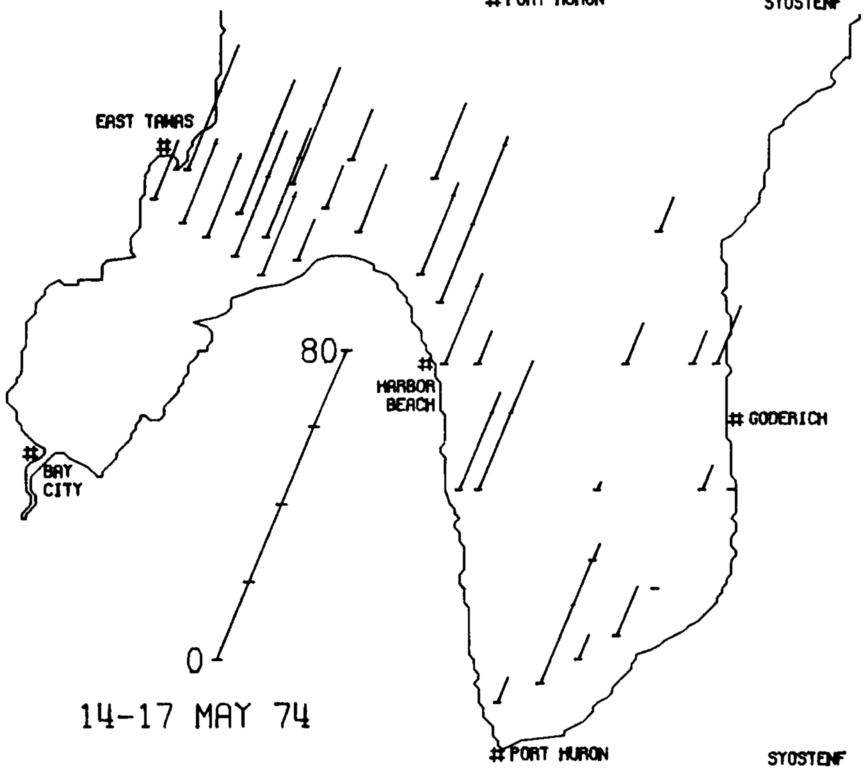
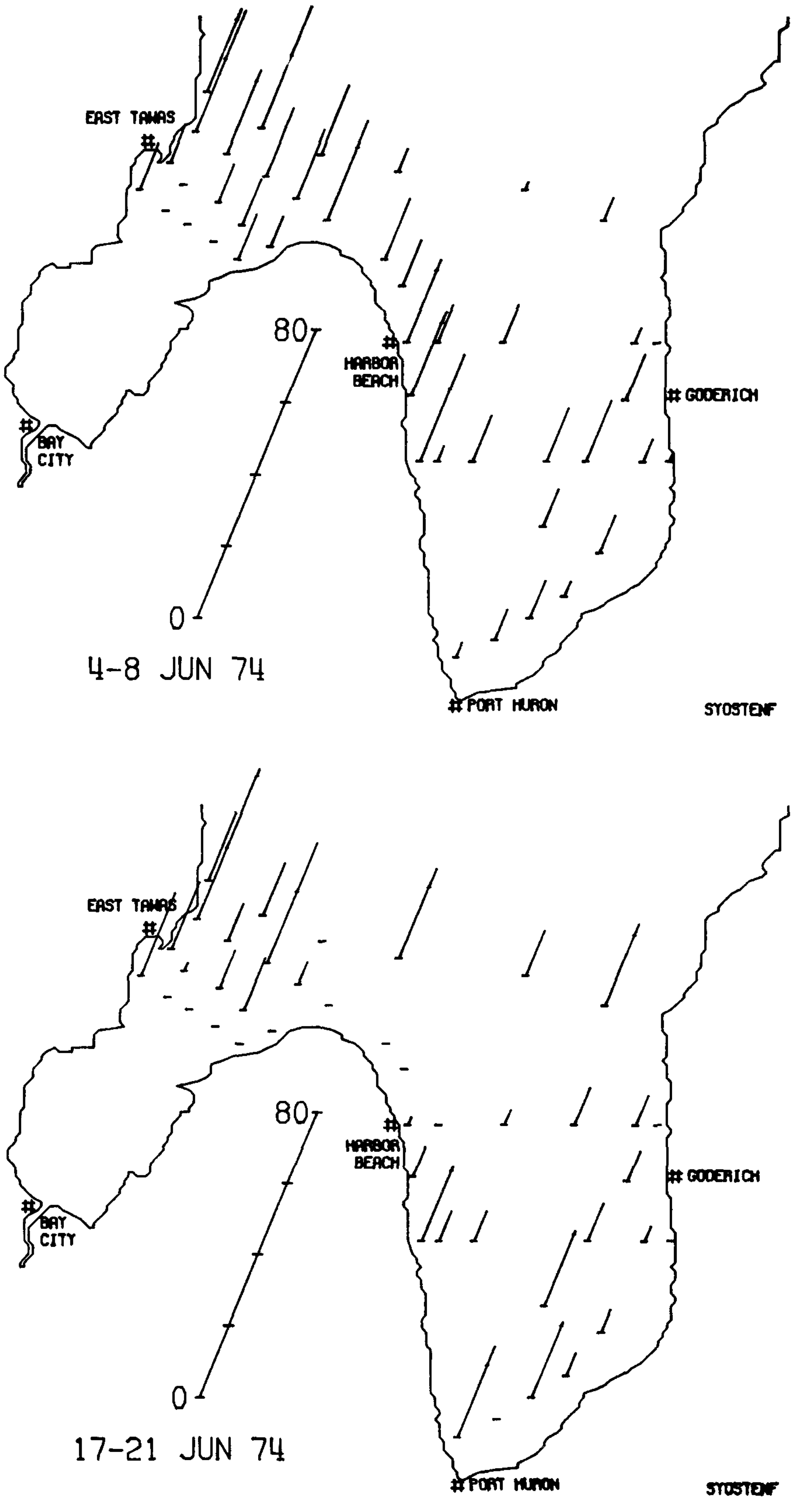


Figure 33. Distribution of *Synedra ostenfeldii*. (continued)



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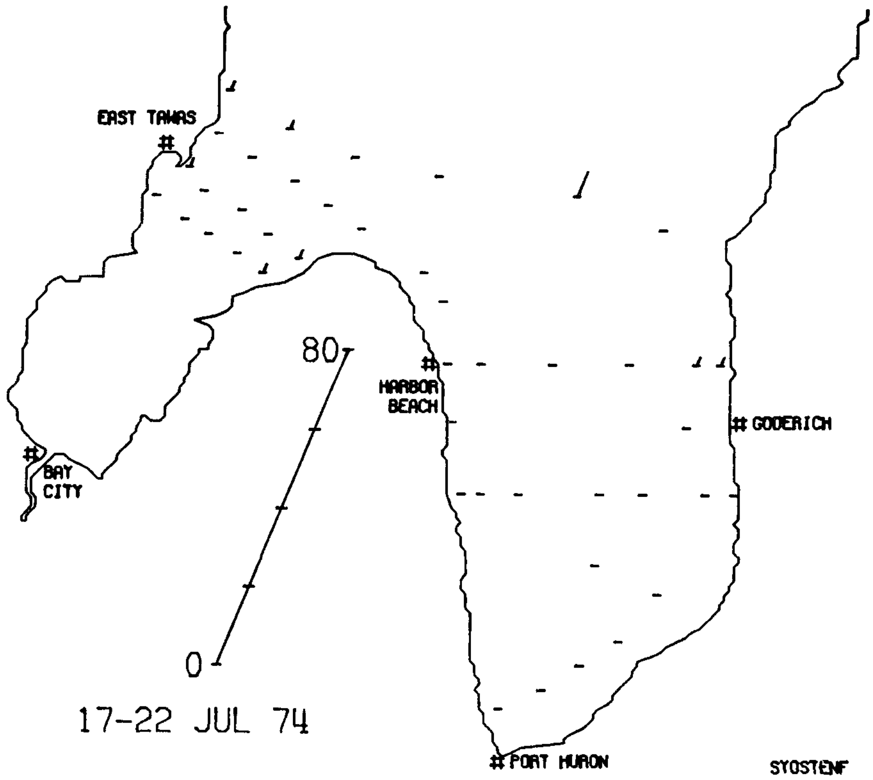


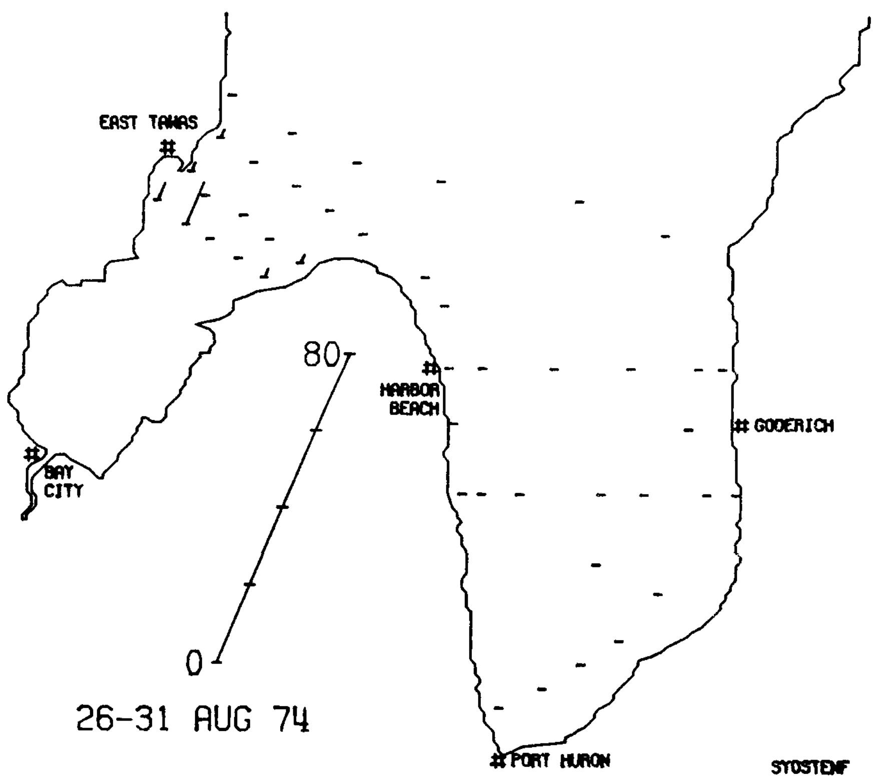
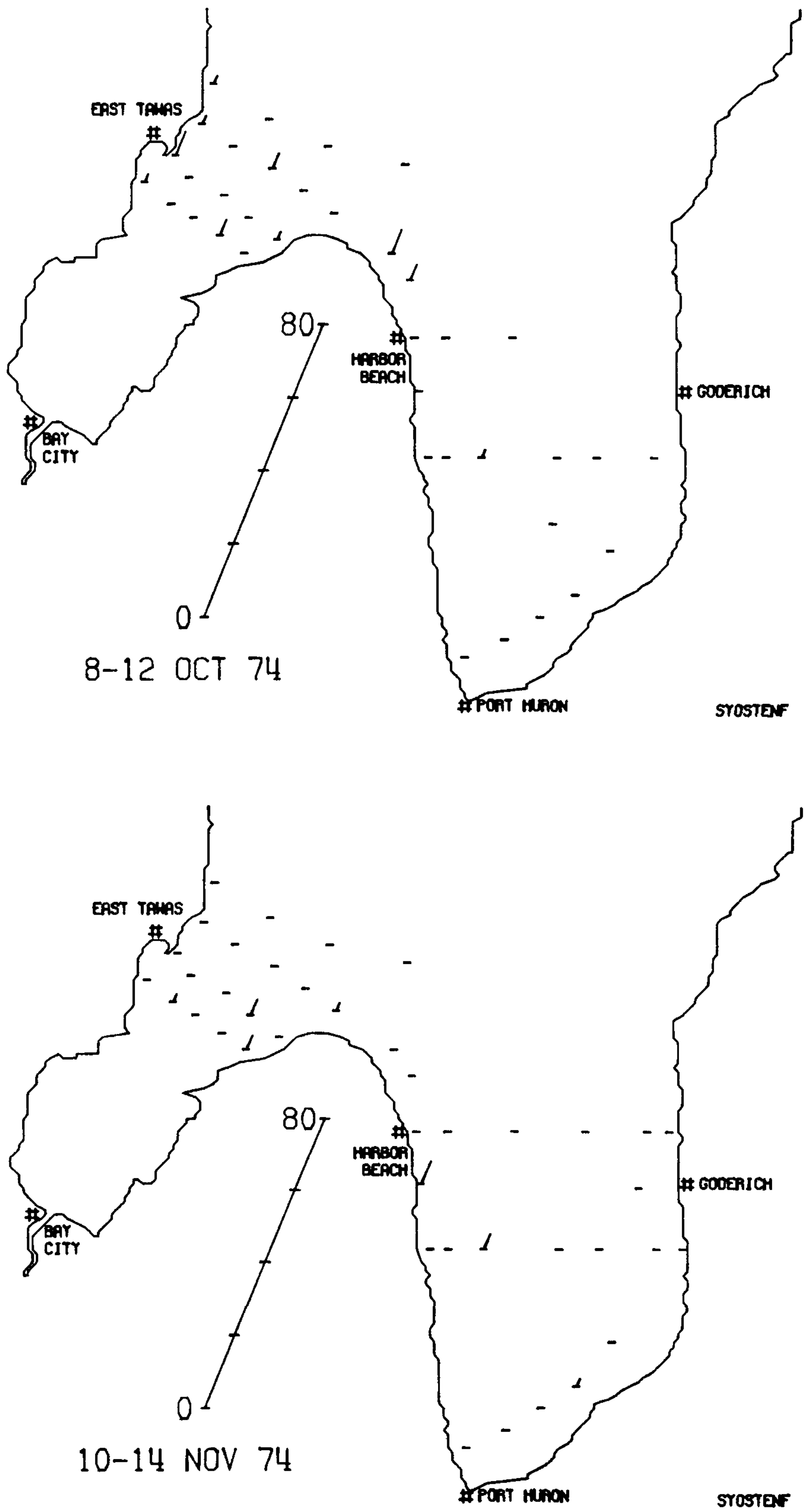


Figure 33. (continued)



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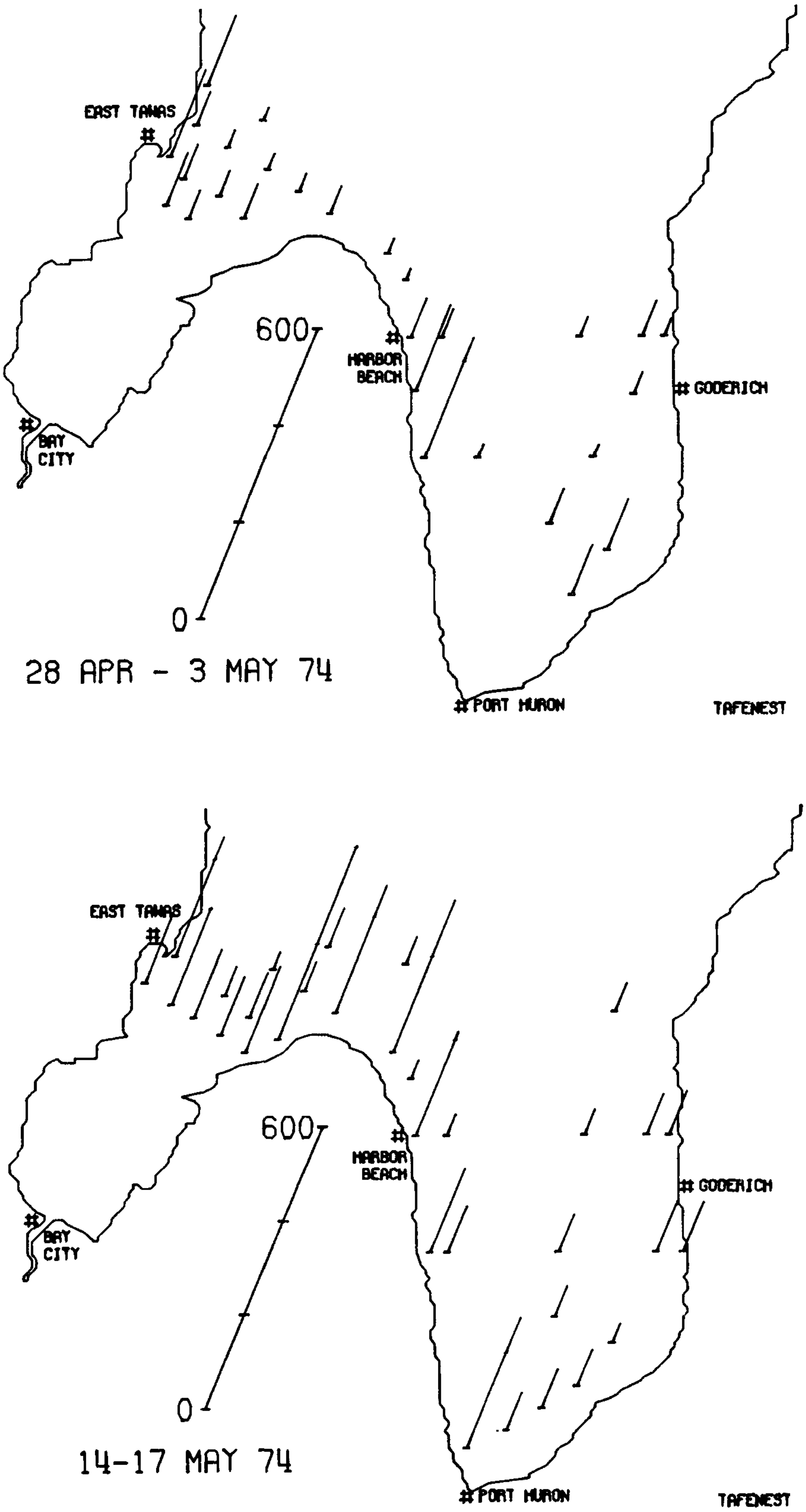
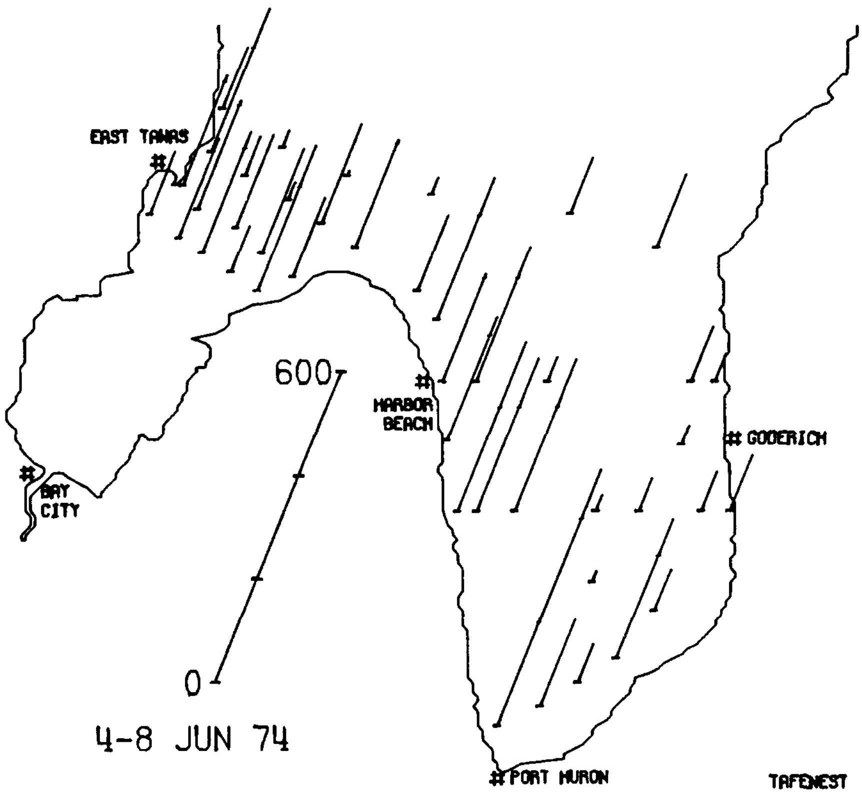
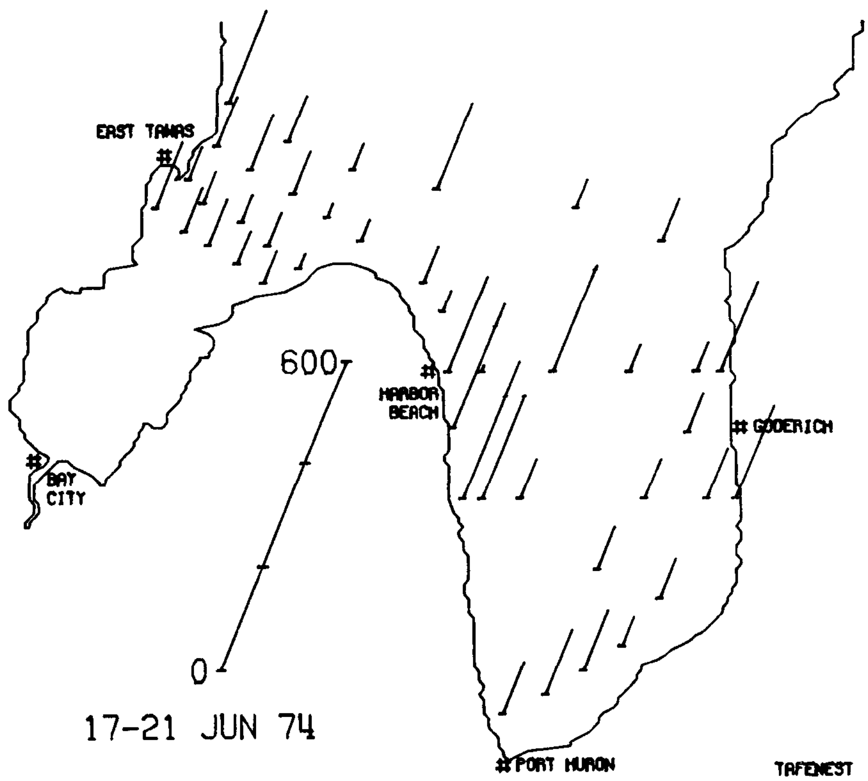


Figure 34. Distribution of *Tabellaria fenestrata*.
(continued)





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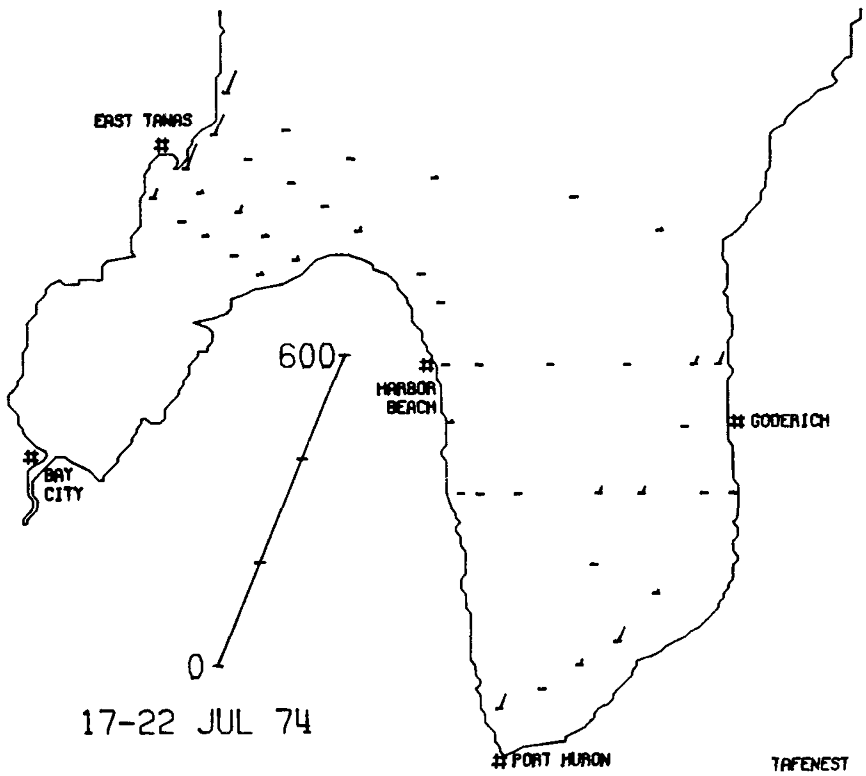

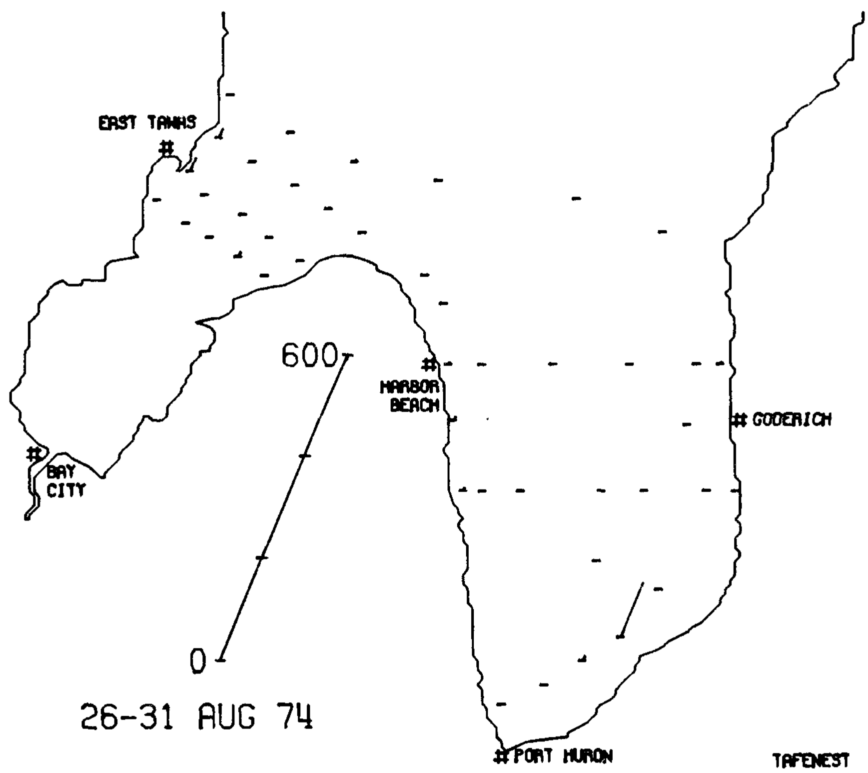

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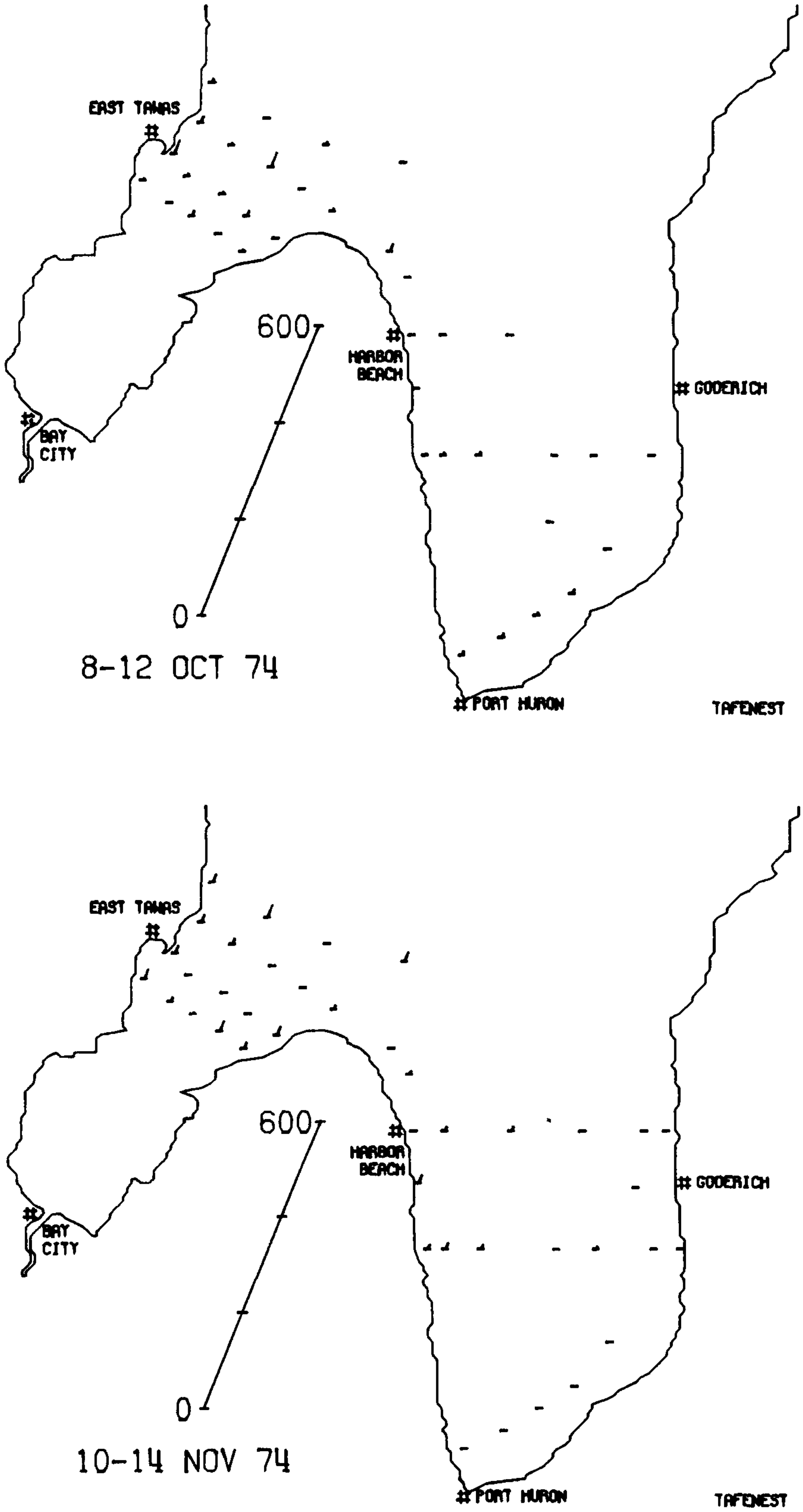

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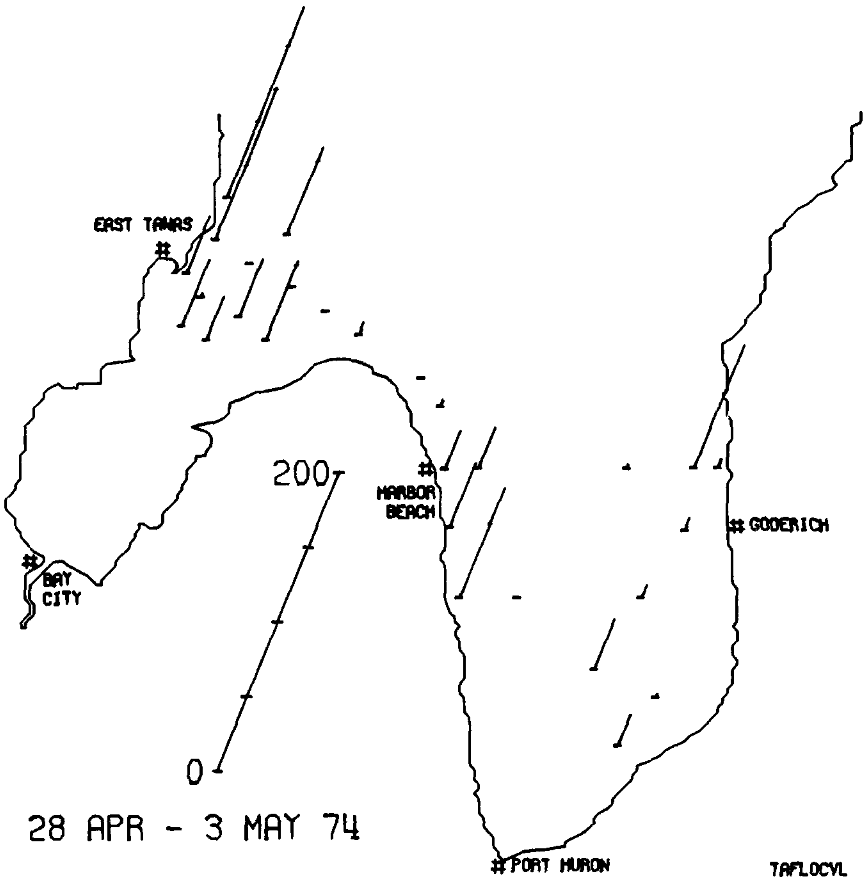


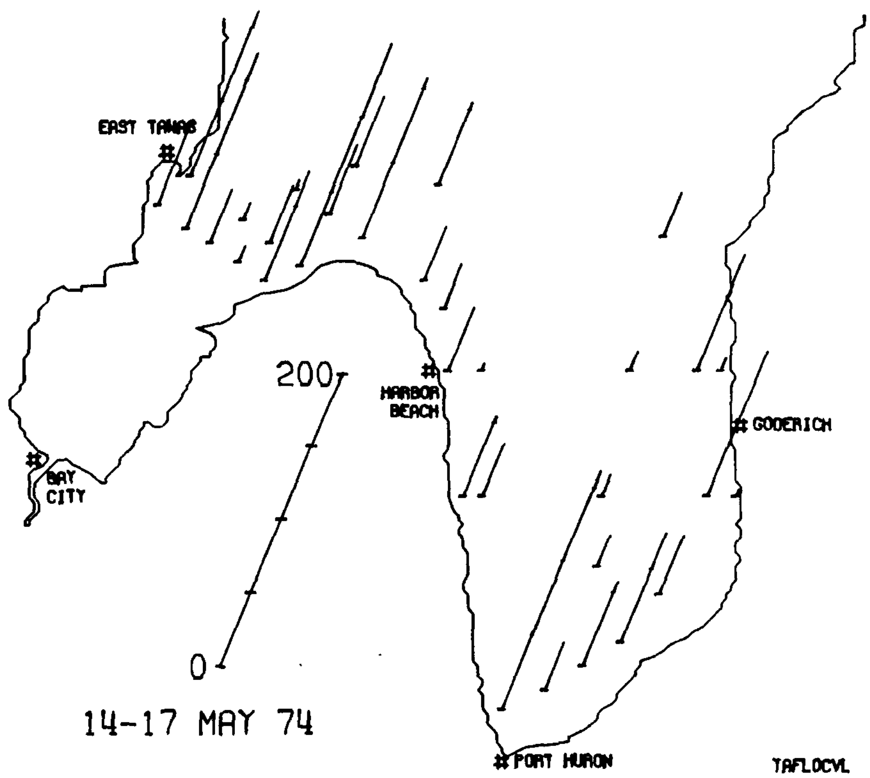
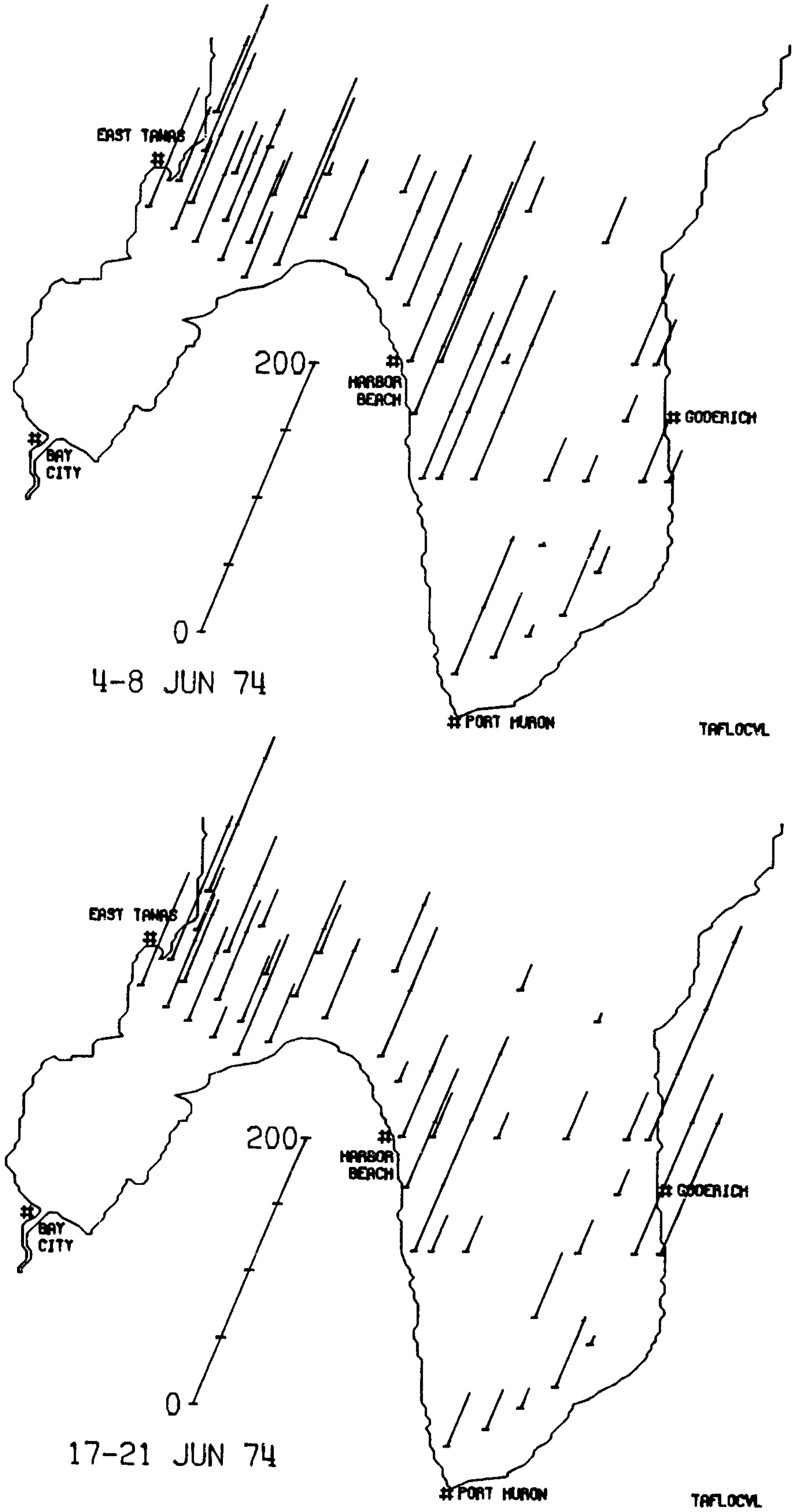


Figure 35. Distribution of *Tabellaria flocculosa* var. *linearis*. (continued)



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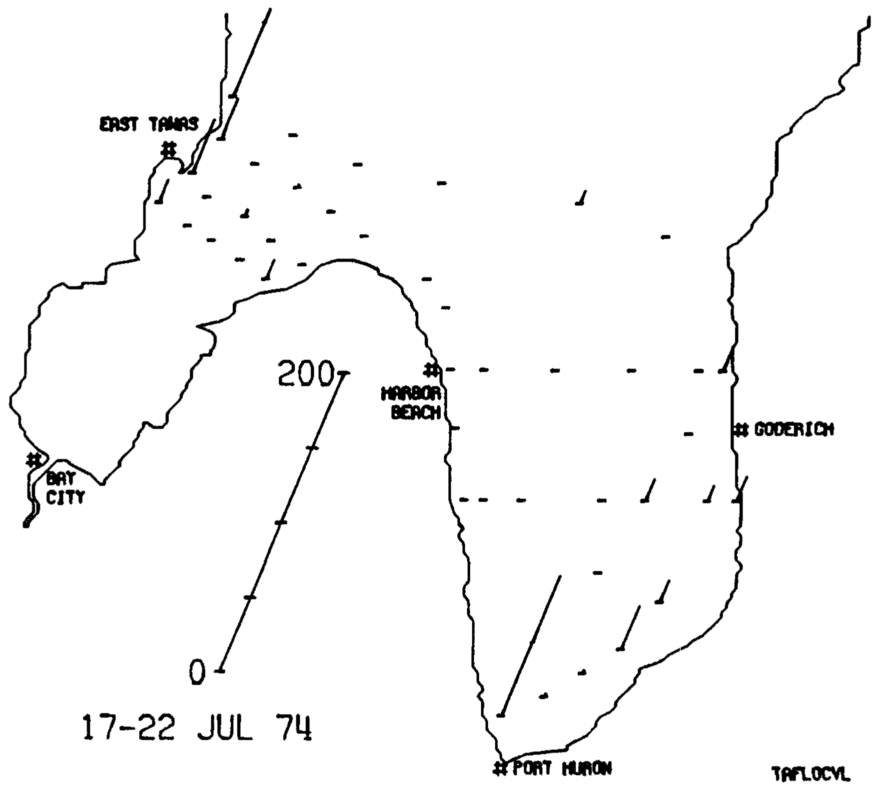

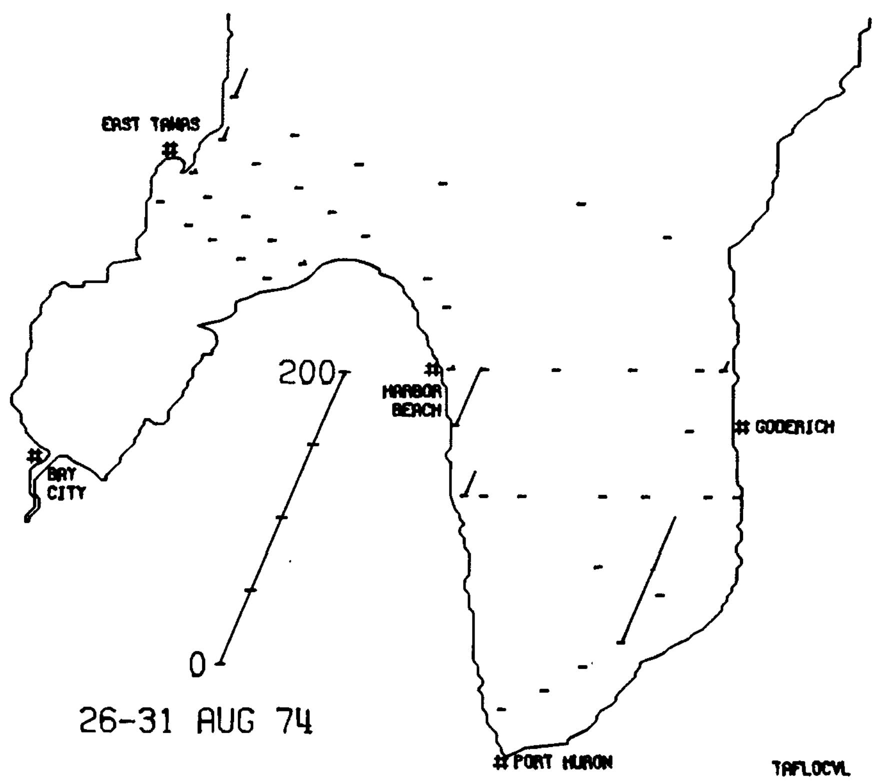

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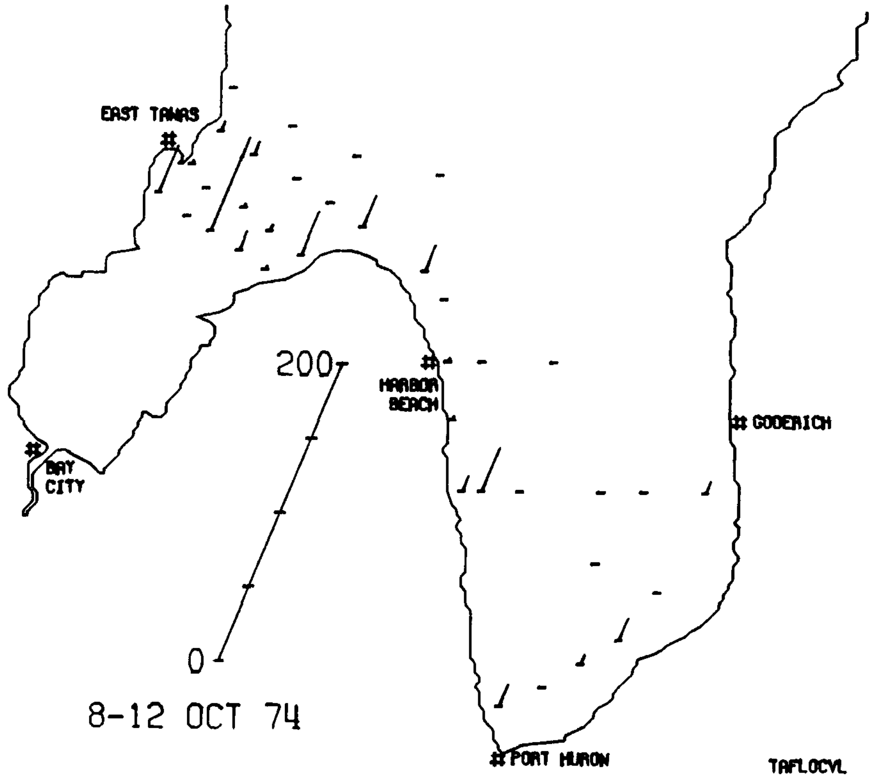


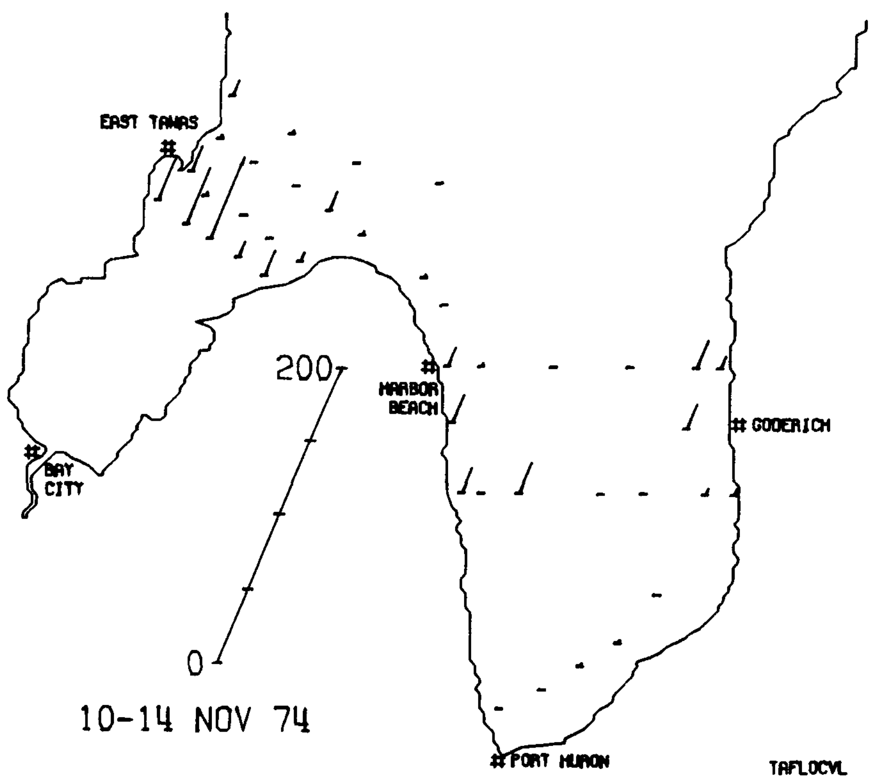


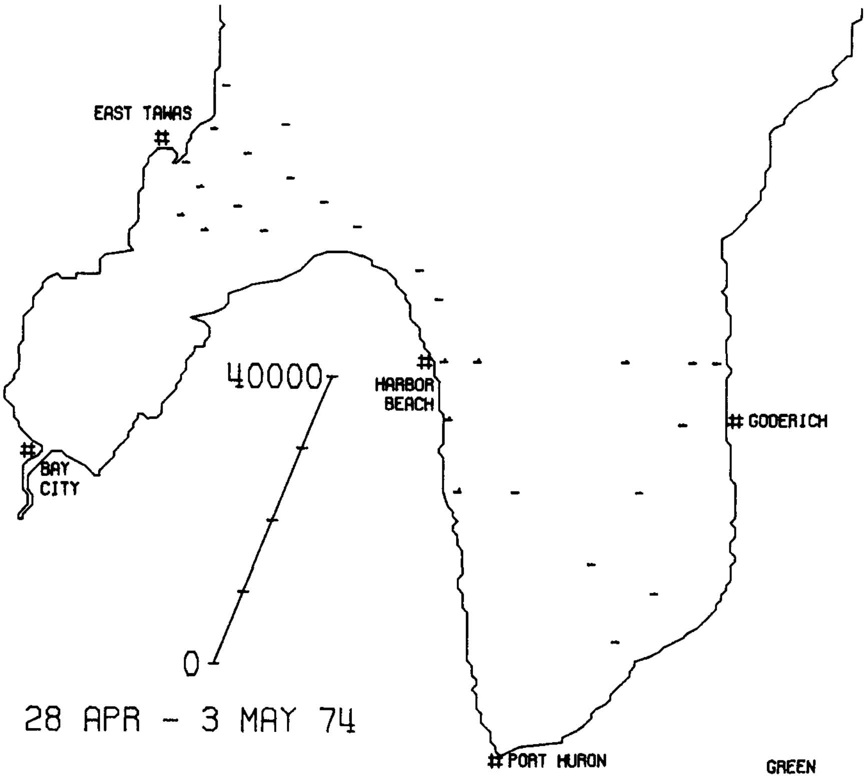
Figure 35. (continued)

Chlorophyta

The green algal flora of southern Lake Huron is more extensive and diverse than most regions of the upper Great Lakes and appears to be dominated by species which originate in Saginaw Bay. Green algae are relatively rare in samples taken in early May (Fig. 36A) but fairly high population densities are present in mid-May samples (Fig. 36B) from the Saginaw Bay interface waters and stations southward along the Michigan coast. The number of green algae present in samples from the Saginaw Bay interface further increases in early June (Fig. 36C) and these populations appear to encroach further into the offshore waters from Lake Huron. Abundance of green algae decreases slightly in late June (Fig. 36D) but appreciable populations were still present in the Saginaw Bay interface waters and southward along the Michigan coast. A large increase from this group is noted in the July samples (Fig. 36E) with maximum abundance in the southern sector of the Saginaw Bay interface waters. In August (Fig. 36F), unlike the previous month, maximum green algal abundance is found in stations in the northerly sector of the Saginaw Bay interface waters. Also during this month, this group reaches its maximum abundance at stations in the offshore waters of Lake Huron. The green algae remain abundant in October (Fig. 36G) and November (Fig. 36H) samples, with maximum abundance in both months being found in the southerly part of the Saginaw Bay interface and southward along the Michigan coast.

Green Filament Number 5 (Gloeotilia sp.?)

This entity is of uncertain systematic position. It rather closely resembles the genus Gloeotilia (Skuja, 1956) but we have been unable to identify it with certainty. Although the individual plants are very small, it sometimes occurs in very large numbers in Saginaw Bay and the adjacent waters of Lake Huron. Its ecological affinities are entirely unknown, although morphologically similar entities occur in Lake Erie and in certain areas of Lake Ontario. It was present in relatively low abundance in early May samples (Fig. 37A) with maximum abundance at nearshore stations along the Michigan coast. By mid-May (Fig. 37B) it reached high population densities at stations in the southerly part of the Saginaw Bay interface and south along the Michigan coast. Smaller populations were also found at a number of offshore stations. In early June (Fig. 37C) this species was abundant at the inner line of stations in the Saginaw Bay interface, and was fairly abundant at nearshore stations southward along the Michigan coast. It was also fairly widely distributed at stations along the Canadian shoreline, but in considerably lower abundance. This entity appeared to decline in abundance in late June (Fig. 37D) but reached very high population densities at stations in the southerly segment of the Saginaw Bay interface during July (Fig. 37E). During this month however it was rarely noted in samples from offshore stations. Unlike the previous month, this entity was most abundant at stations in the northerly sector of the Saginaw Bay interface during August (Fig. 37F) and during this sampling period it was absent from most stations south of Saginaw Bay. Population densities remained high during October (Fig. 37G) and November (Fig. 37H). During both months largest populations were found at stations in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast. During November, significant populations were again found at certain offshore stations.



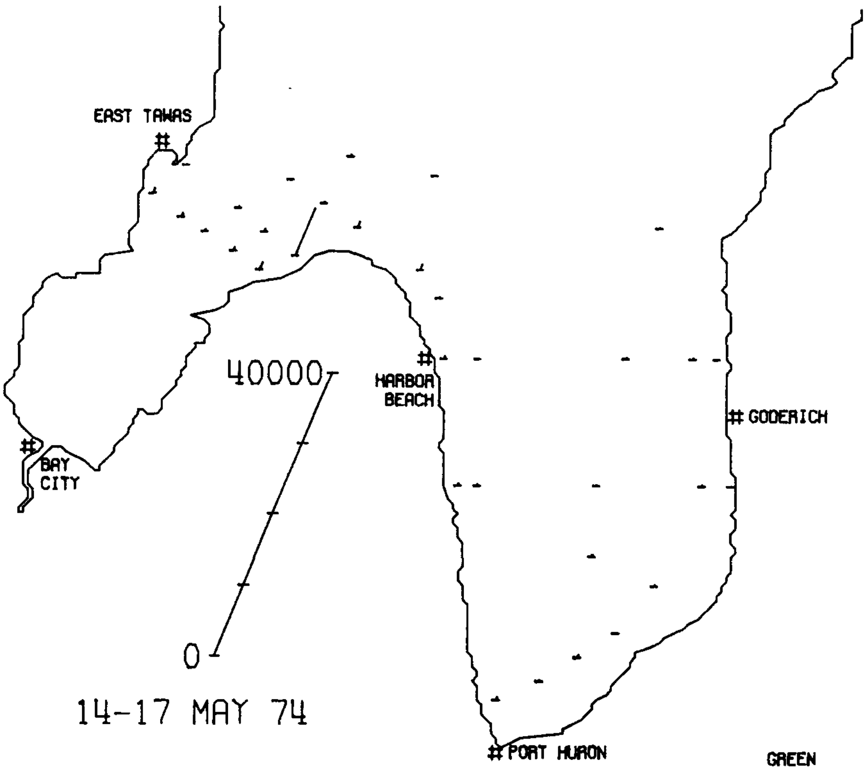
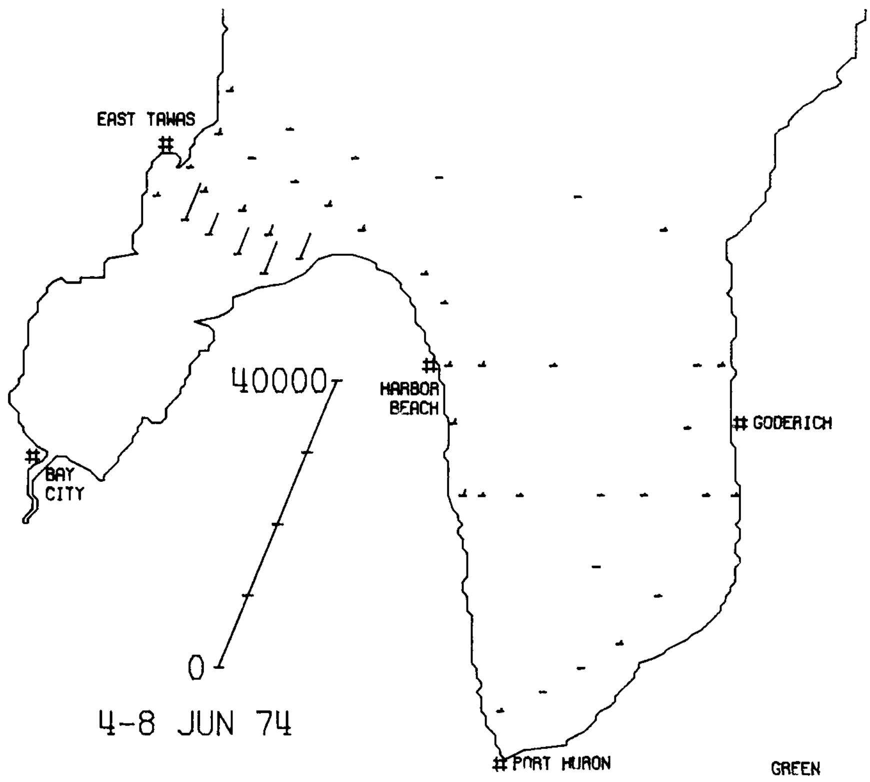
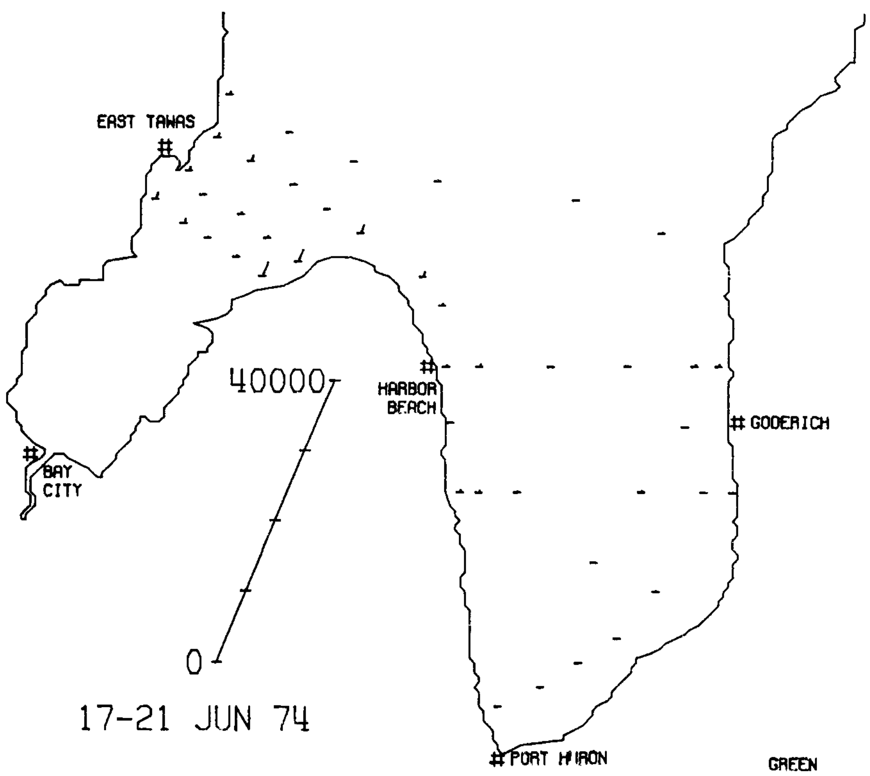


Figure 36. Seasonal abundance and distribution trends of green algae. (continued)





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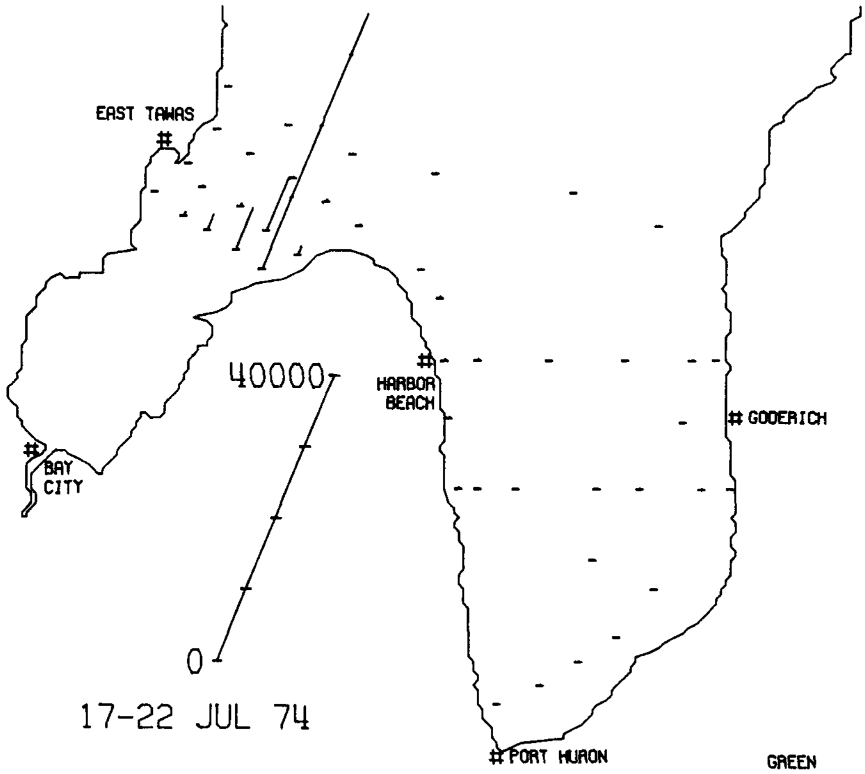

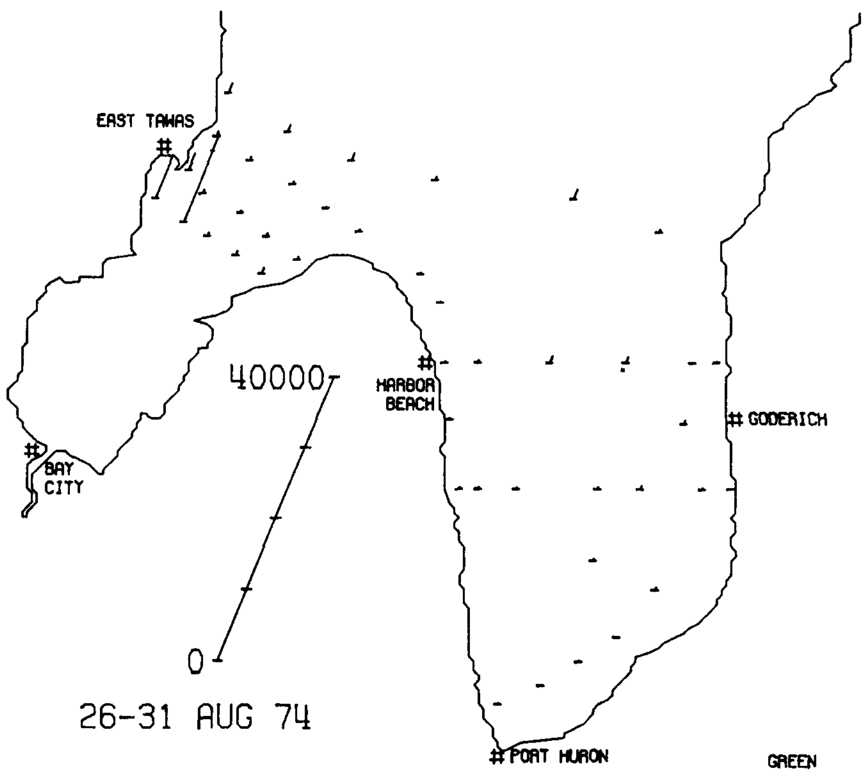

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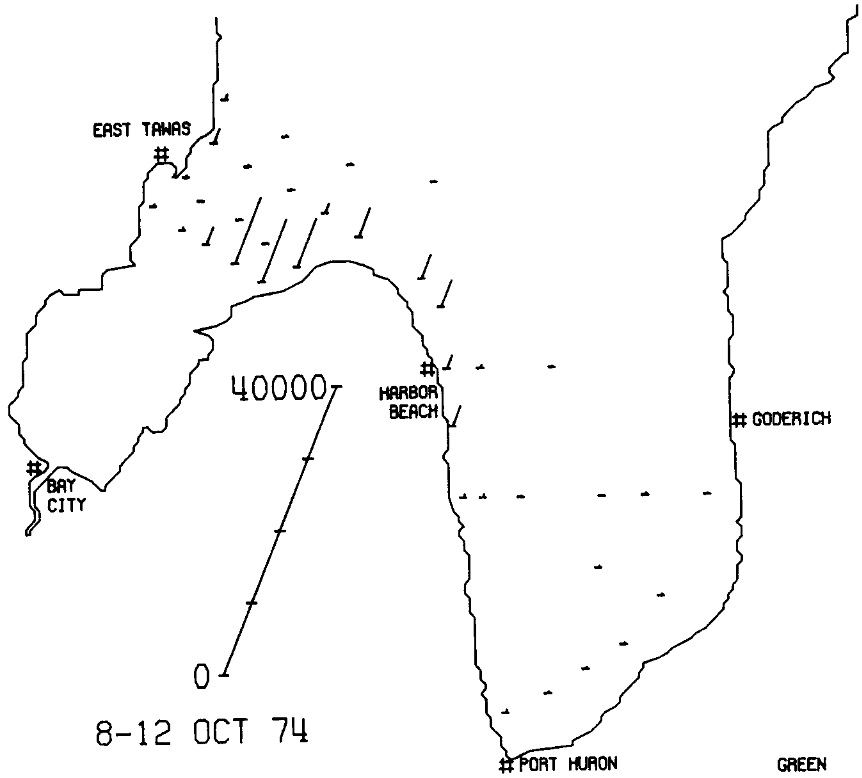


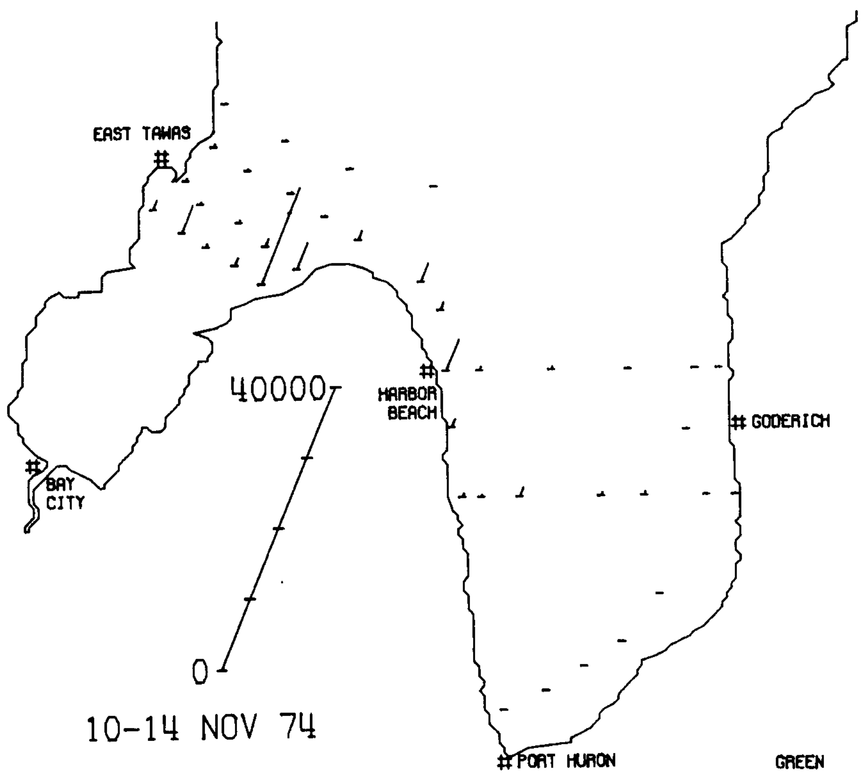
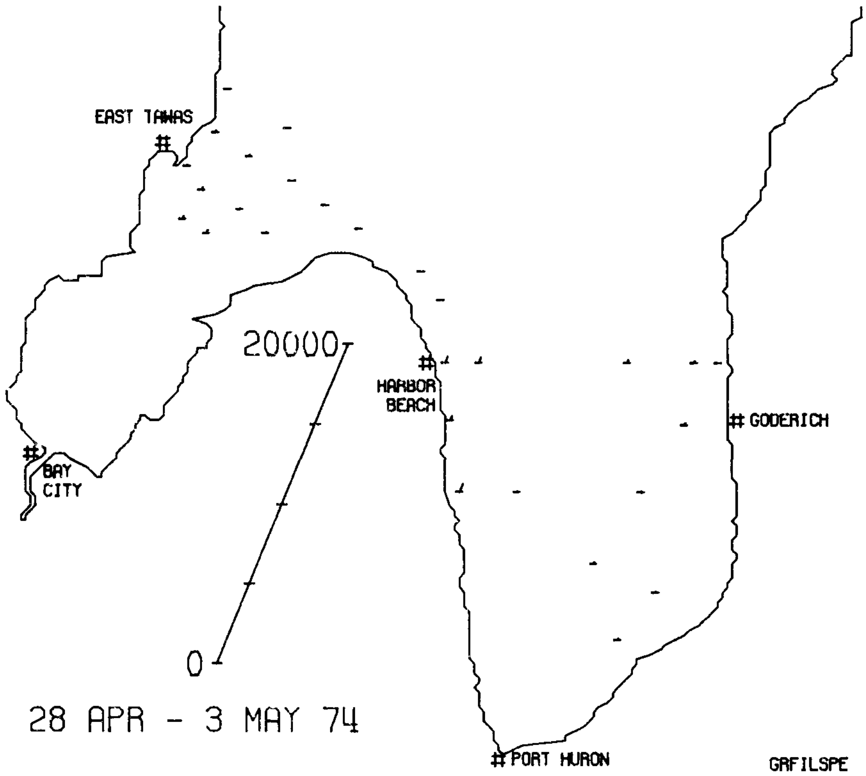


Figure 36. (continued)



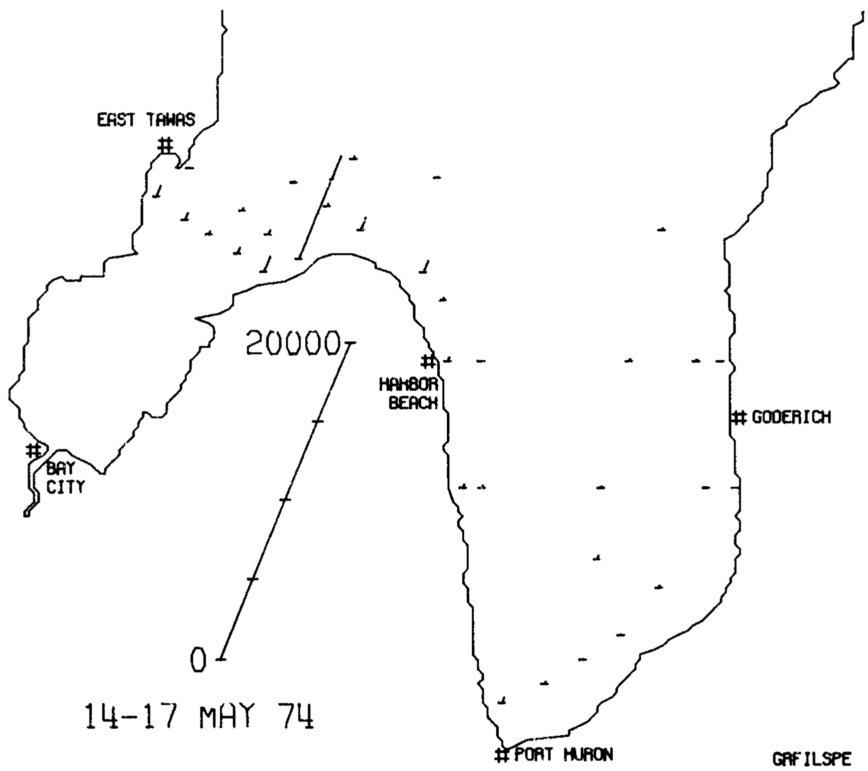


Figure 37. Distribution of green filament sp. #5. (continued)

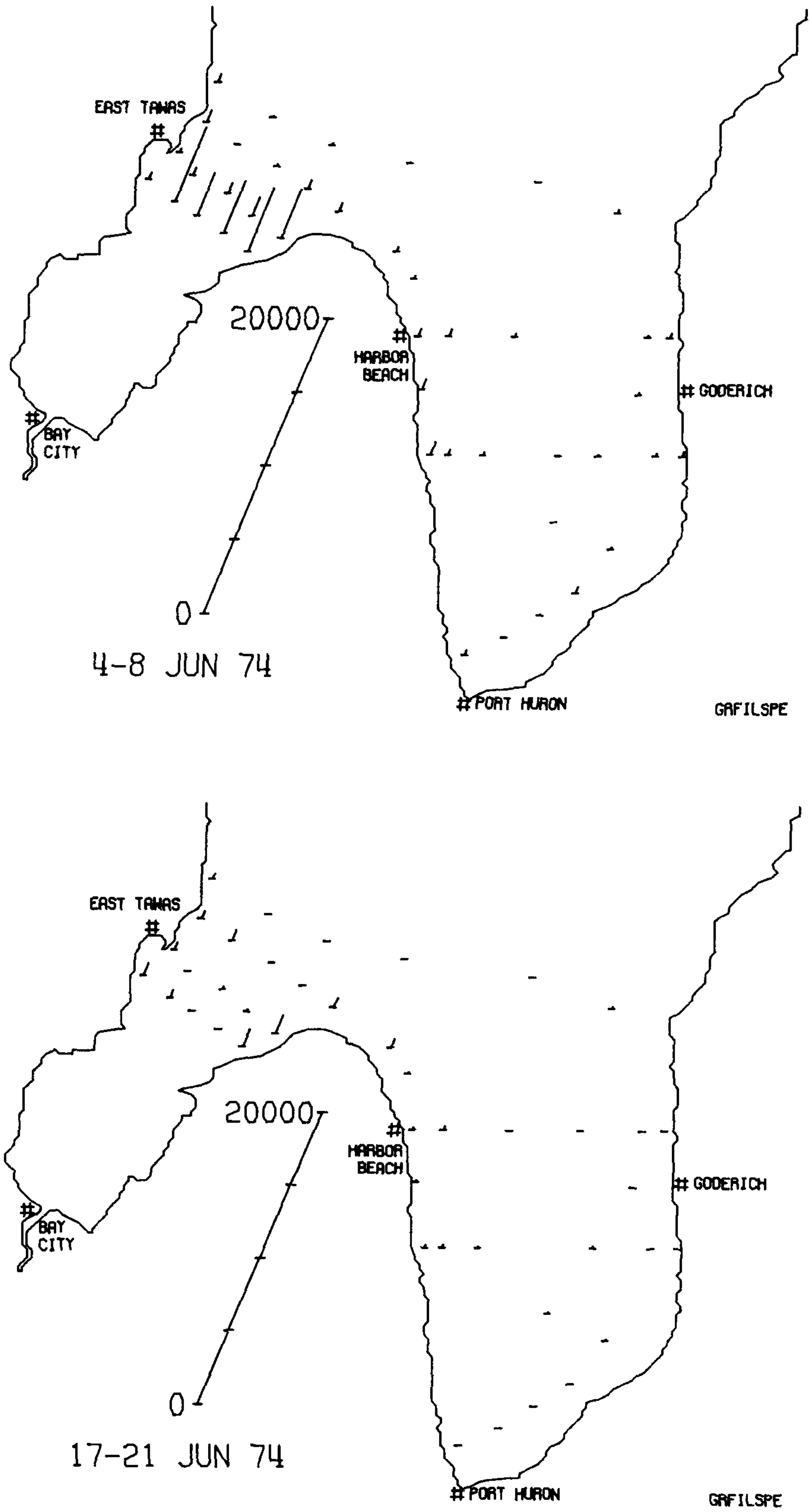
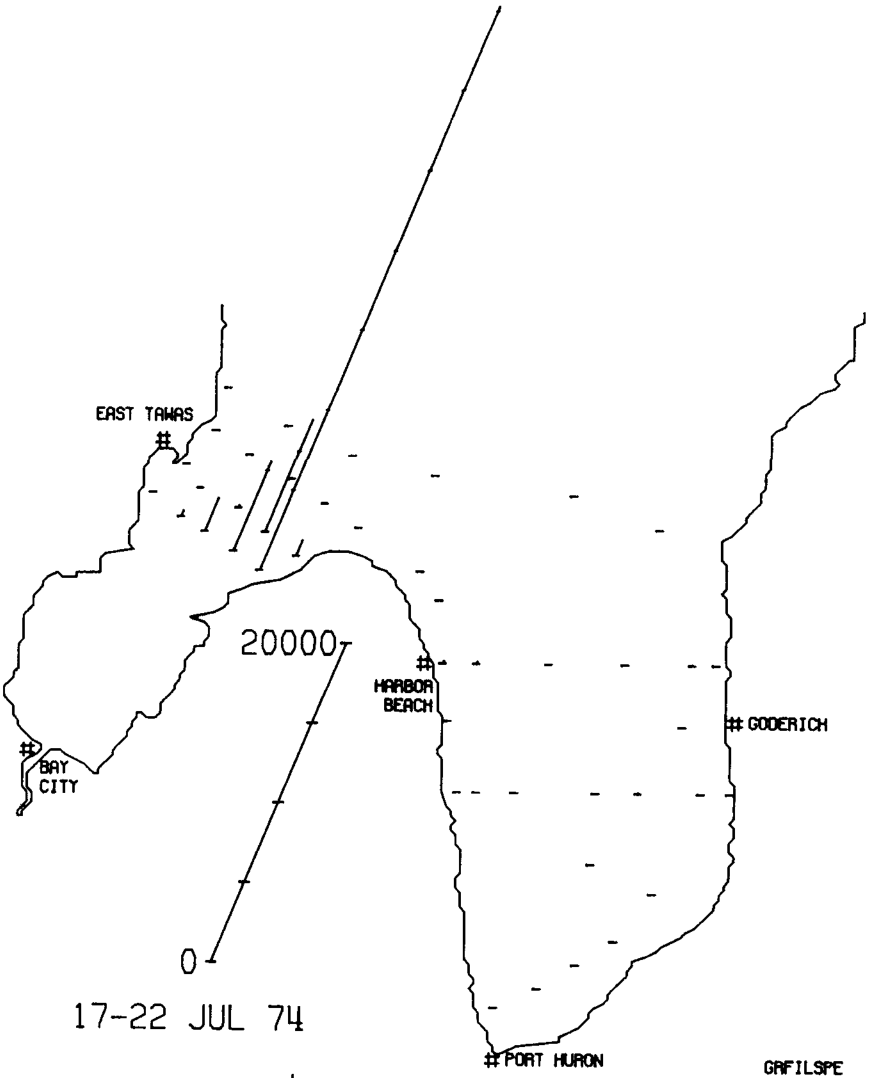


Figure 37. (continued)



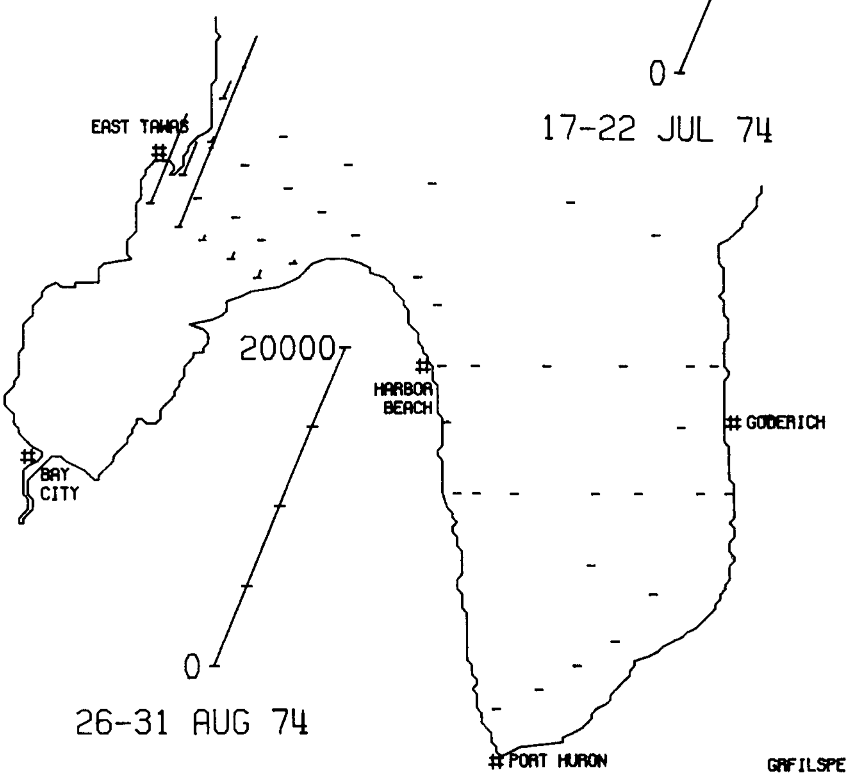
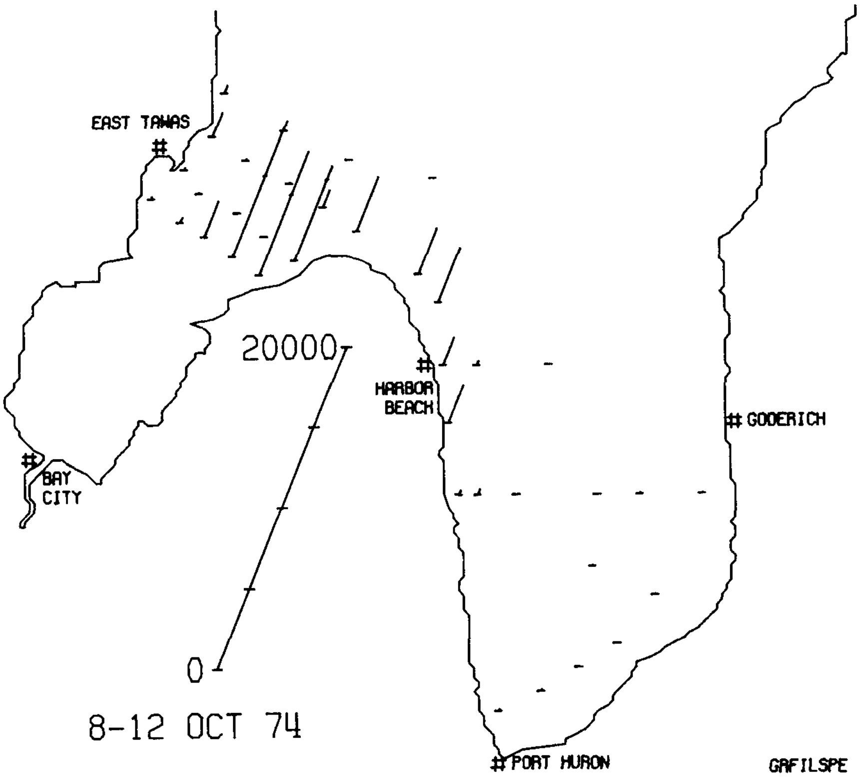


Figure 37. Continued



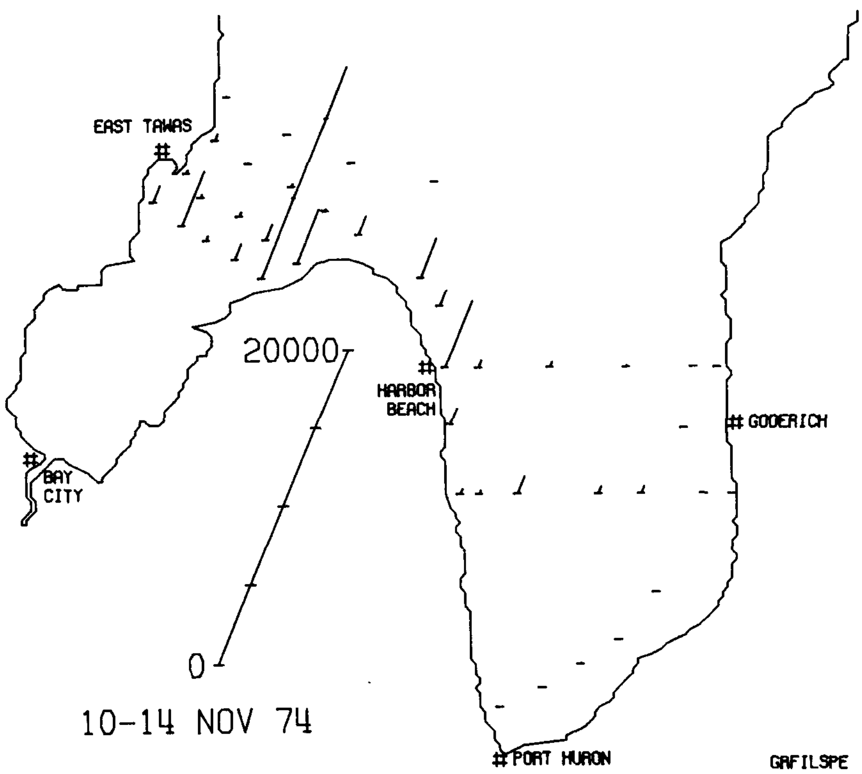


Figure 37. (continued)

Ankistrodesmus sp.

This species is unusual among the green algae, in that significant populations were found at scattered stations in the offshore waters of Lake Huron throughout the period of this study (Fig. 38A-H). It increases slightly in abundance throughout the spring and summer, reaching maximum population densities in the offshore waters during August. Abundance tends to decline during October and November but, as in the previous months, no particular pattern of areal distribution is evident.

Chodatella ciliata

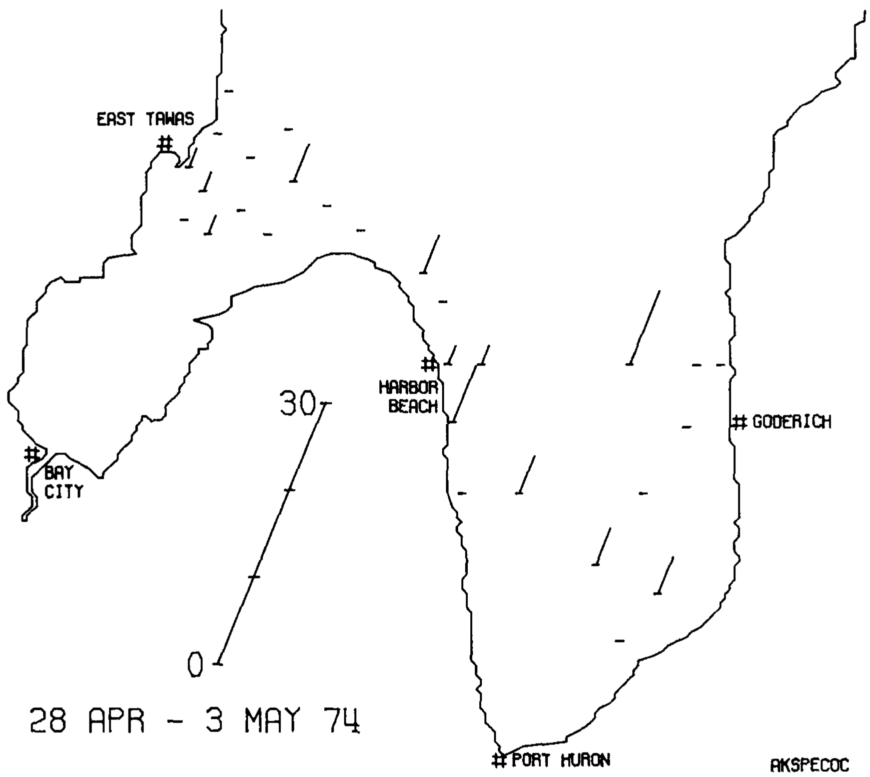
This species is a common element of phytoplankton assemblages in mesotrophic to eutrophic lakes. Occasional individuals are found in plankton collections from all areas of the Laurentian Great Lakes, but it reaches significant abundance only in areas which have been enriched. Unlike the species discussed previously, the areal and temporal distribution of *C. ciliata* in southern Lake Huron is extremely restricted. It was not noted in collections taken during May and June, but was present at stations in the Saginaw Bay interface and southward along the Michigan coast in July (Fig. 39A). These populations apparently collapsed and only isolated occurrences were noted during the August and October cruises (Fig. 39B-C).

Coelastrum microporum

This species is a common element of phytoplankton assemblages in mesotrophic to eutrophic lakes. In the Laurentian Great Lakes it is usually found in significant abundance only in eutrophic areas. In southern Lake Huron it was entirely absent from early May samples, but isolated occurrences were noted at stations in the Saginaw Bay interface waters during mid-May and early June (Fig. 40A-B). In late June (Fig. 40C), it was relatively abundant at stations in the southerly sector of the interface waters, and extended to a few stations in the offshore waters of Lake Huron. In July (Fig. 40D), the species was entirely limited to stations in the Saginaw Bay interface. It was absent from August samples, but occurred again during the October sampling period (Fig. 40E), but again only at stations in the Saginaw Bay interface. It was also present during November (Fig. 40F) at scattered stations in the Saginaw Bay interface and along the U.S. and Canadian coasts.

Crucigenia quadrata

This species is usually a minor component of summer phytoplankton assemblages in the upper Great Lakes. In southern Lake Huron only scattered populations were noted during the May, June and July sampling cruises (Fig. 41A-D). During August (Fig. 41E) the abundance of this species increased considerably, although its distribution remained erratic. Highest population densities were found at offshore stations in the northerly sector of our sampling array. Population densities again declined during the October sampling cruise (Fig. 41F) and this species was absent from a majority of the stations sampled. The decline apparently continued into November (Fig. 41G) although isolated populations were still found, particularly at nearshore stations.



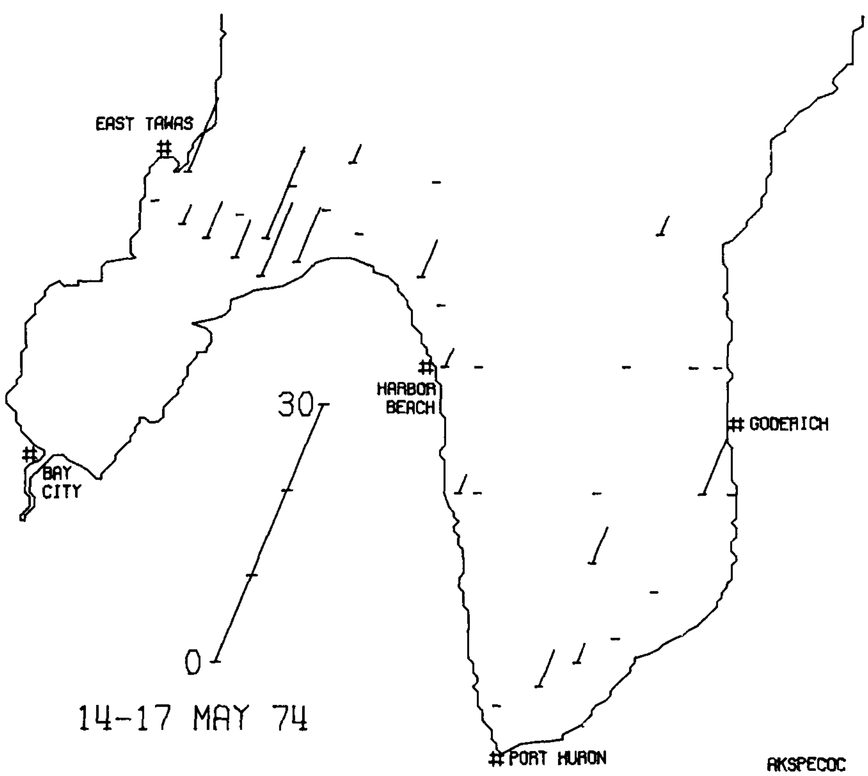
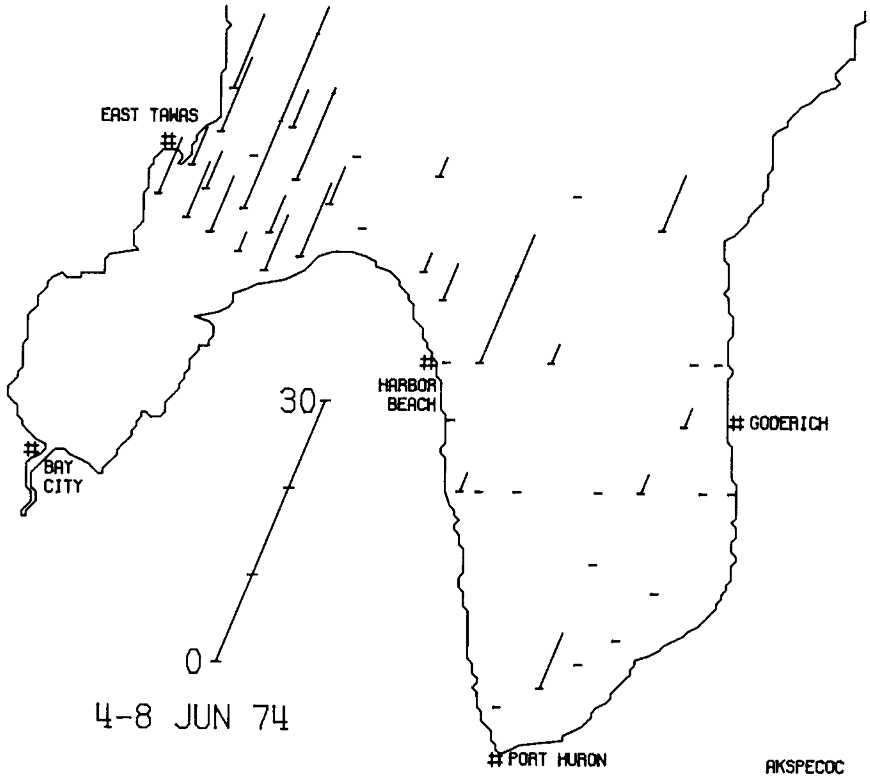


Figure 38. Distribution of Ankistrodesmus sp.. (continued)



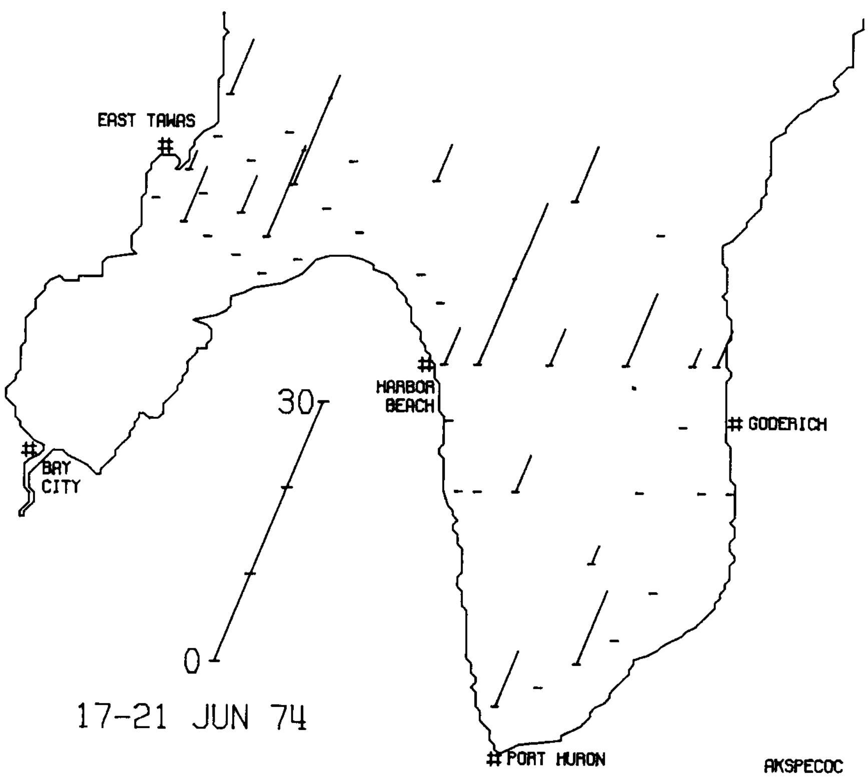
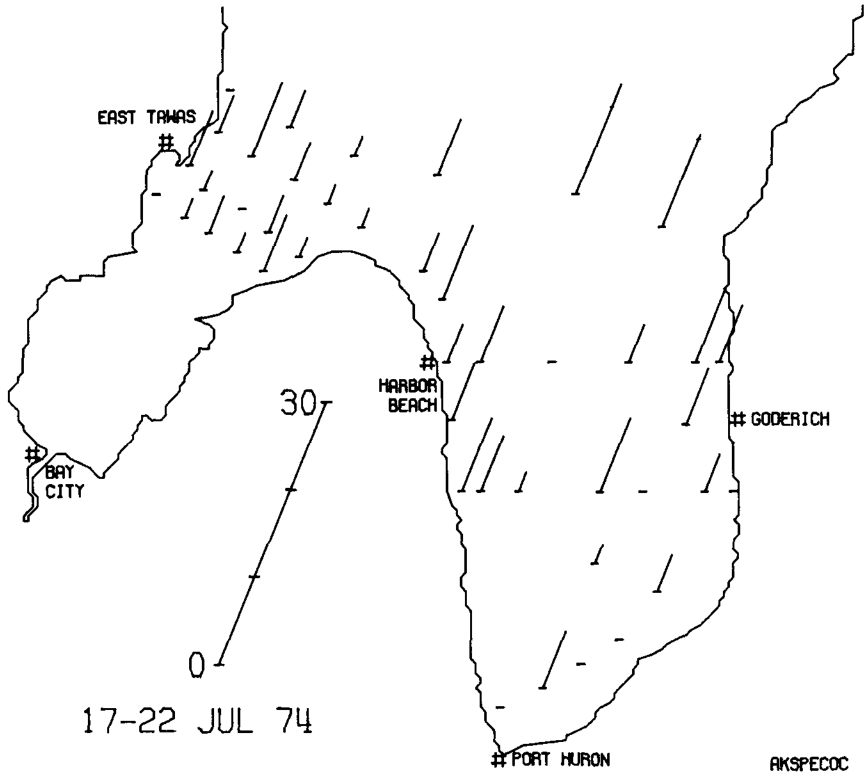
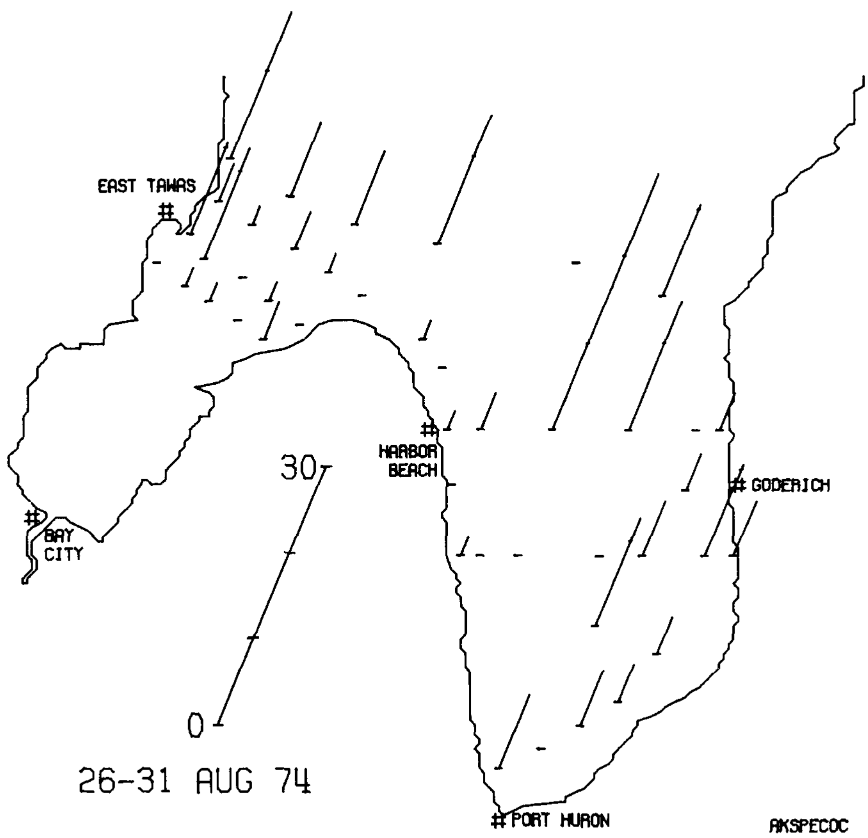


Figure 38. (continued)





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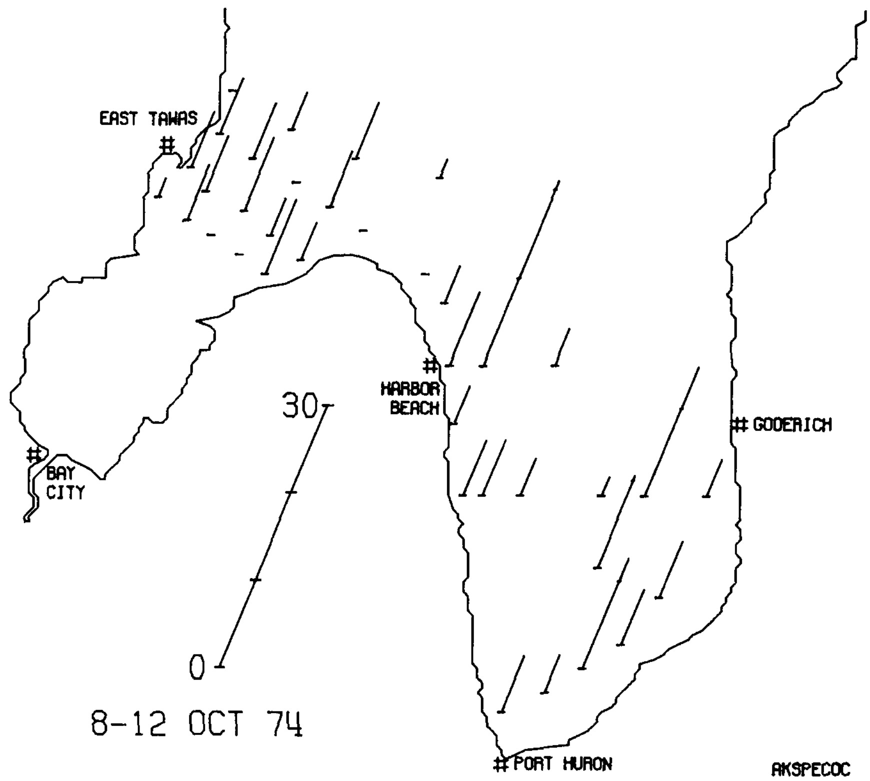

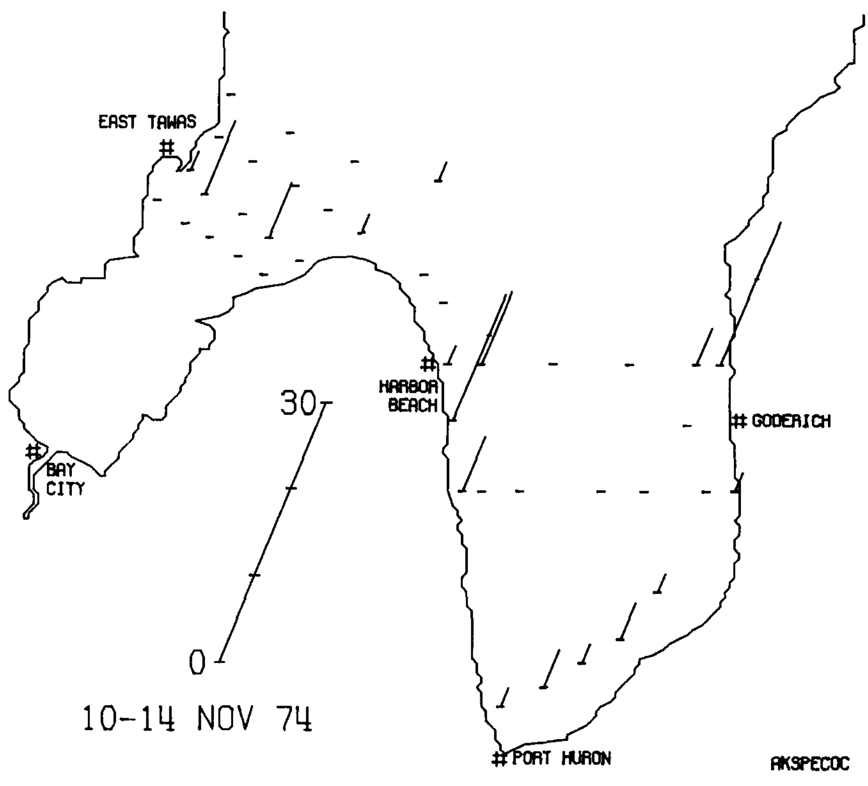

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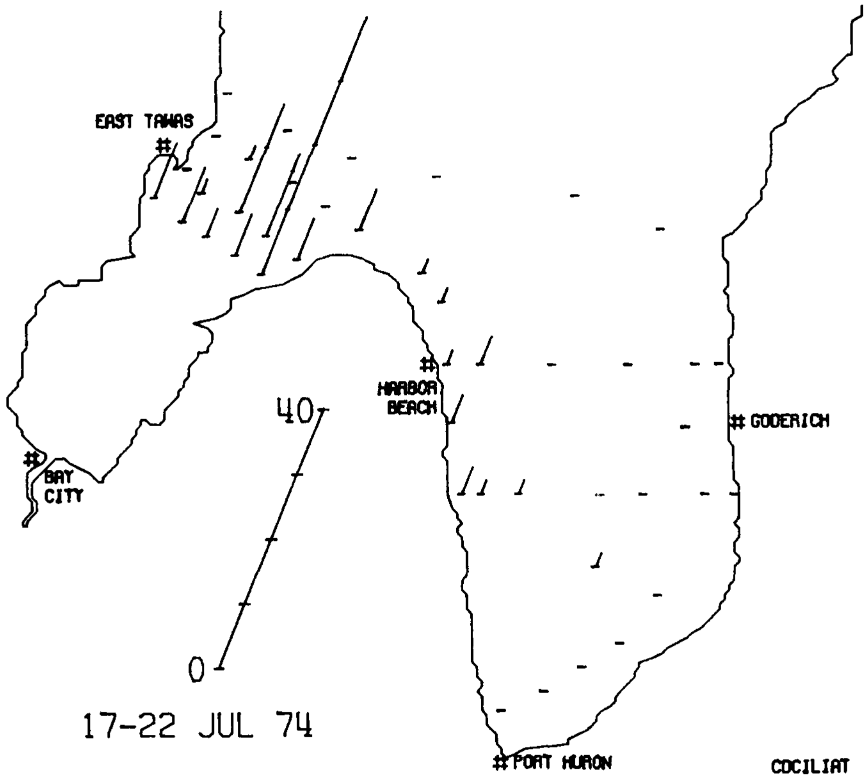


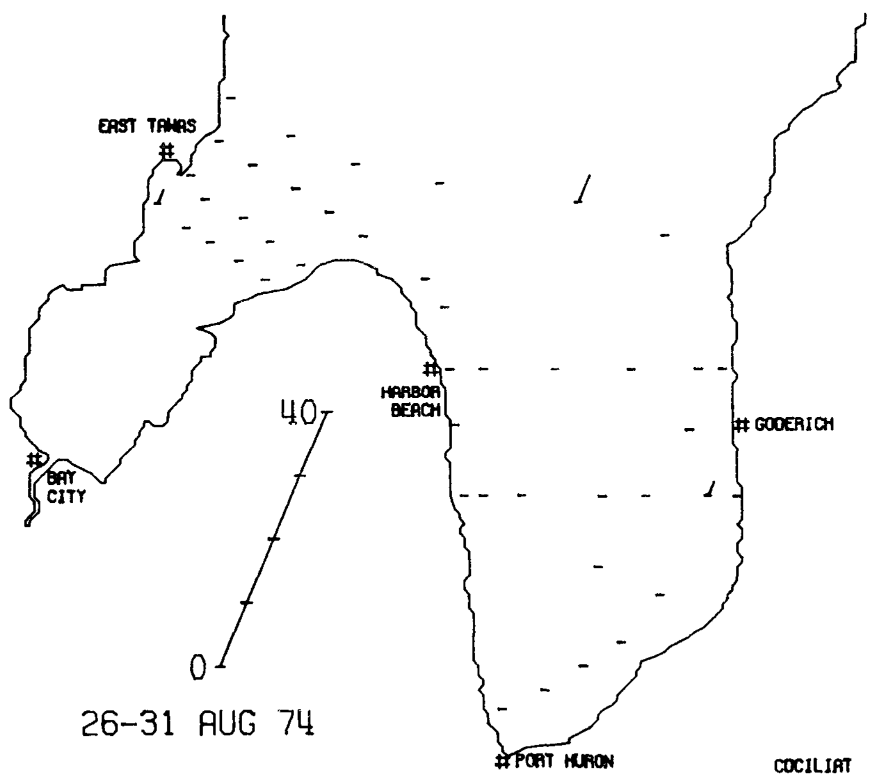


Figure 39. Distribution of *Chodatella ciliata*. (continued)

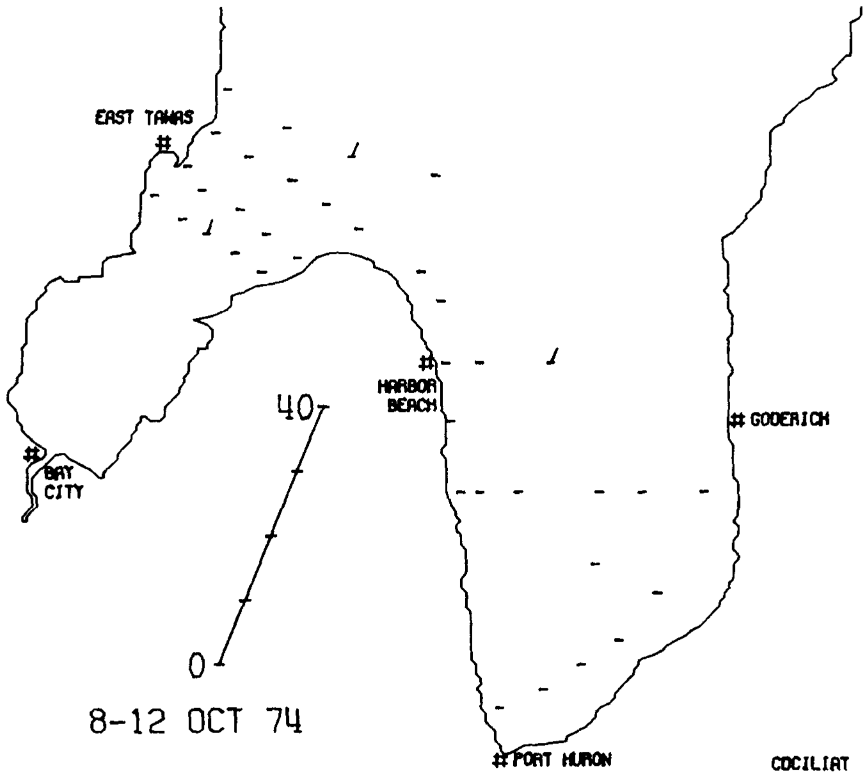
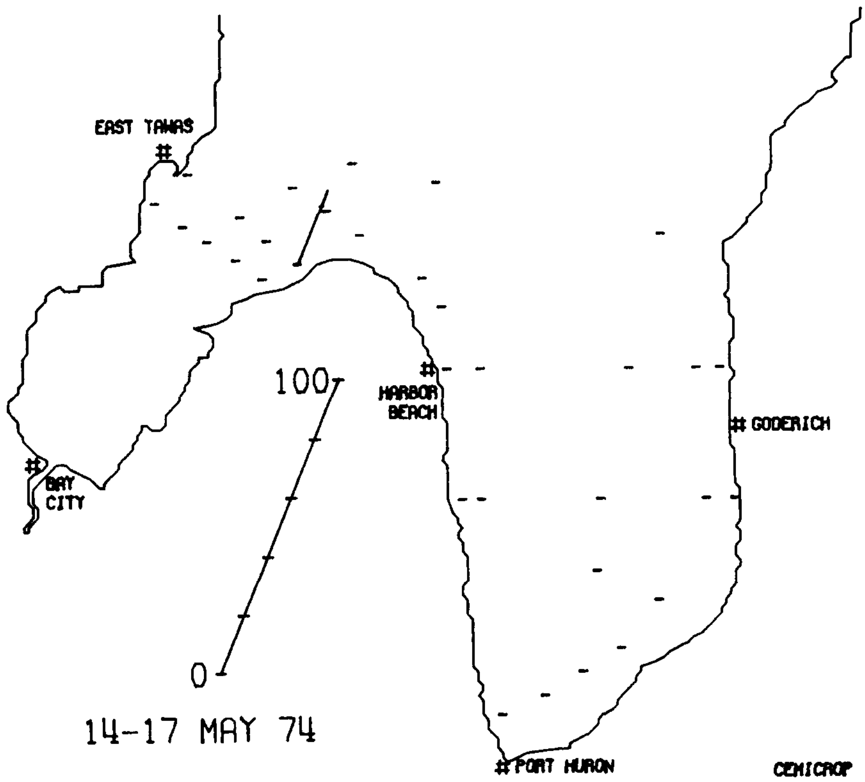


Figure 39. (continued)

Gloeocystis planctonica

Similar to the species previously discussed, G. planctonica reached its highest abundance in the summer phytoplankton assemblages in the upper Great Lakes. It, however, tends to be more abundant, particularly in areas which have been enriched. In southern Lake Huron, only very small populations were found during the early and mid-May sampling periods (Fig. 42A-B) and most occurrences were noted in the Saginaw Bay interface waters and at nearshore stations. During June (Fig. 42C-D), this species became more generally distributed and more abundant particularly at stations in the southerly sector of the Saginaw Bay interface and stations southward along the Michigan coast. A similar distribution pattern was noted during the July cruise (Fig. 42E), although population densities continued to increase and the species became more generally distributed at offshore stations. Similar to the other coccoid green algae, this species reached its maximum abundance during August (Fig. 42F) when it was present in appreciable abundance at nearly all stations sampled. During this cruise, unlike the other sampling cruises, maximum population densities were found at offshore stations in the northerly and easterly sectors of the sampling array. By October (Fig. 42G), population densities were considerably reduced and maximum abundance was again found at nearshore stations, particularly near Saginaw Bay and southerly along the Michigan coast. This decline continued into November (Fig. 42H), when only scattered minor populations were found.



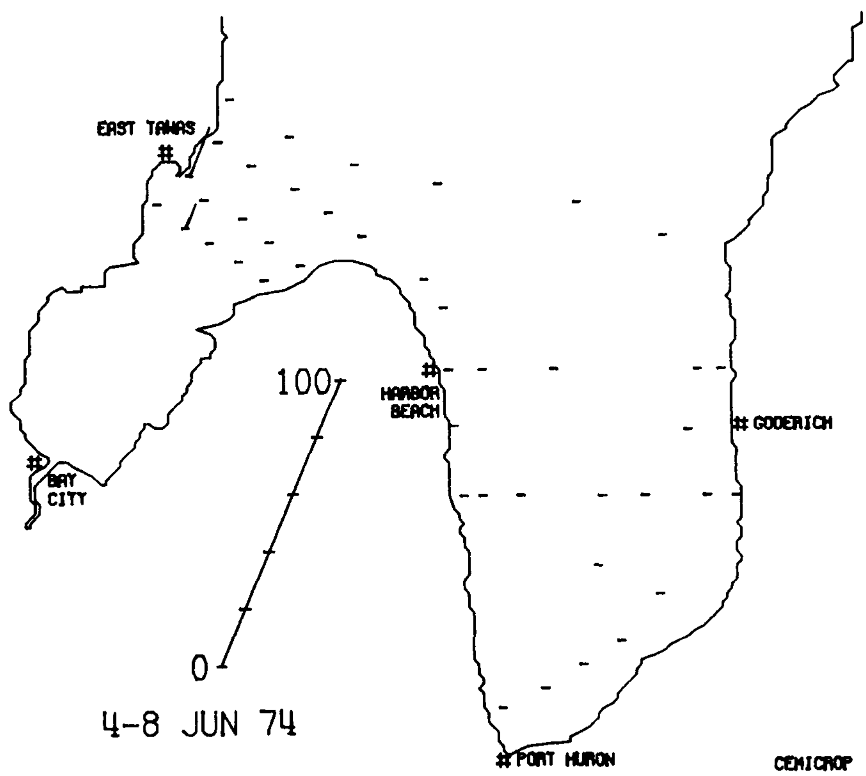
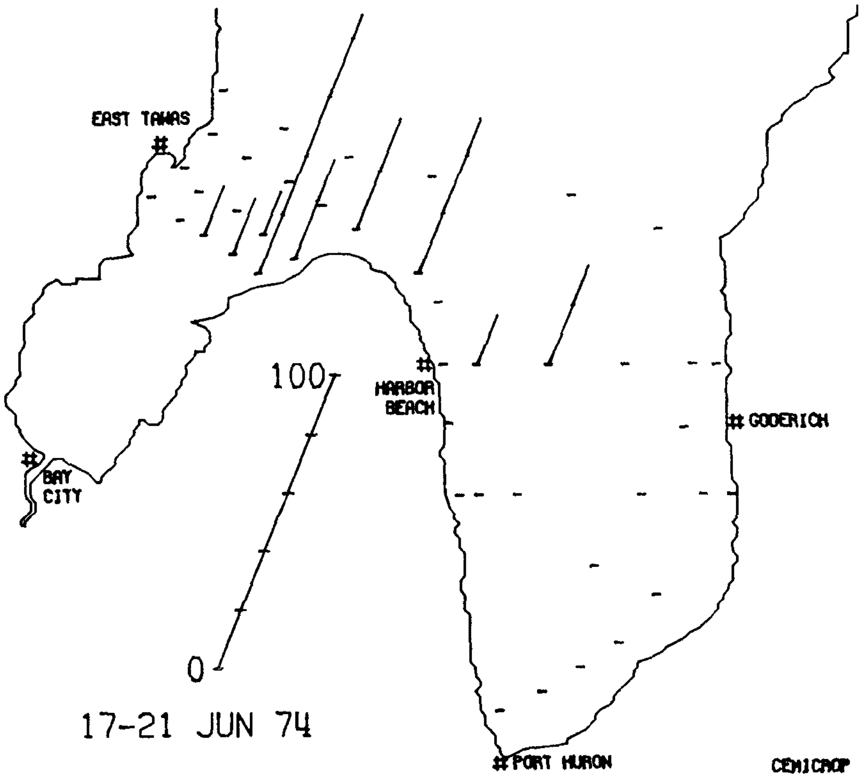


Figure 40. Distribution of *Coelastrum microporum*. (continued)



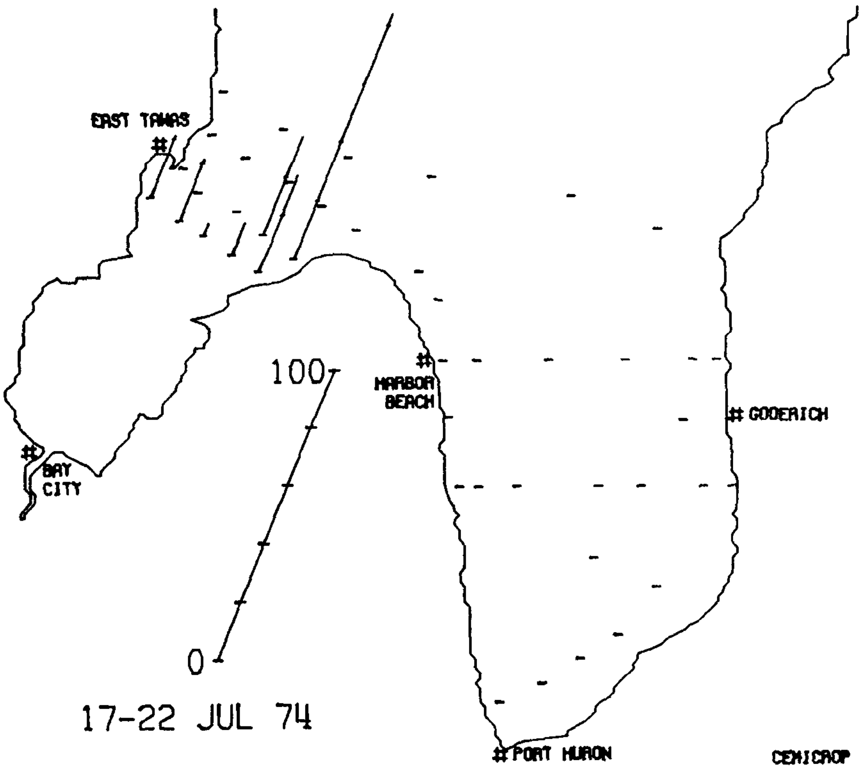


Figure 40. (continued)

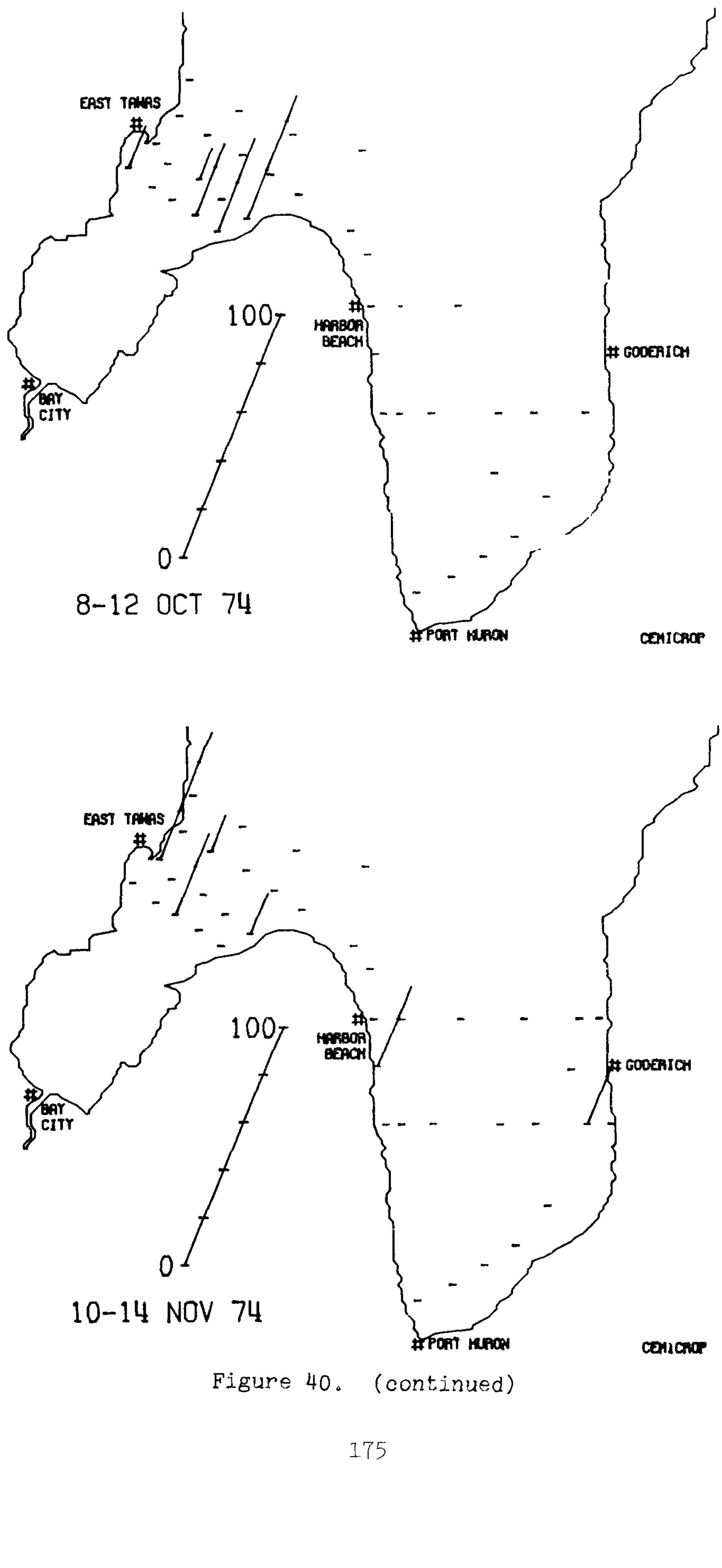


Figure 40. (continued)

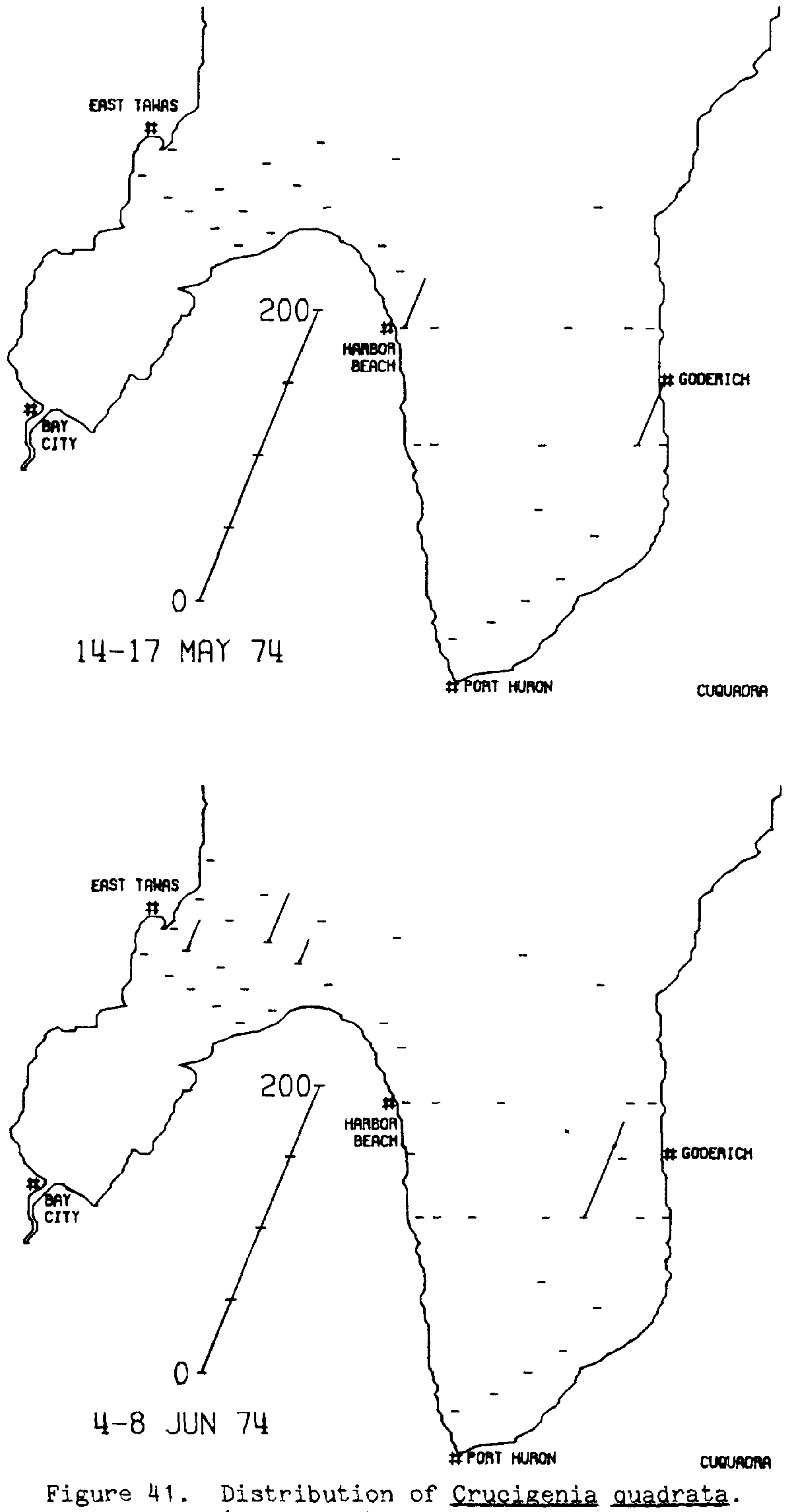
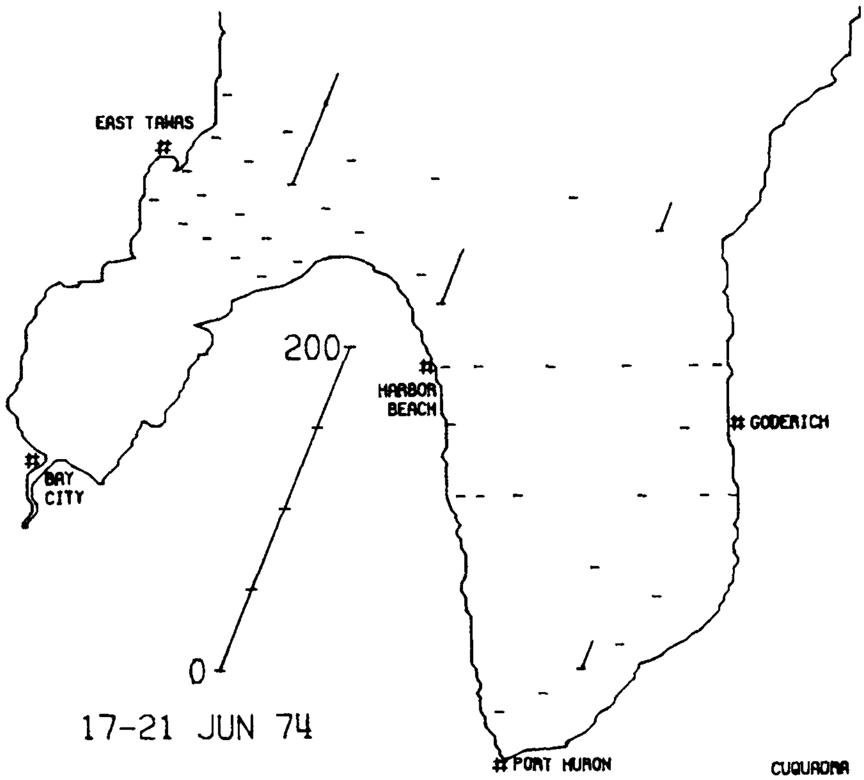


Figure 41. Distribution of *Crucigenia quadrata*. (continued)



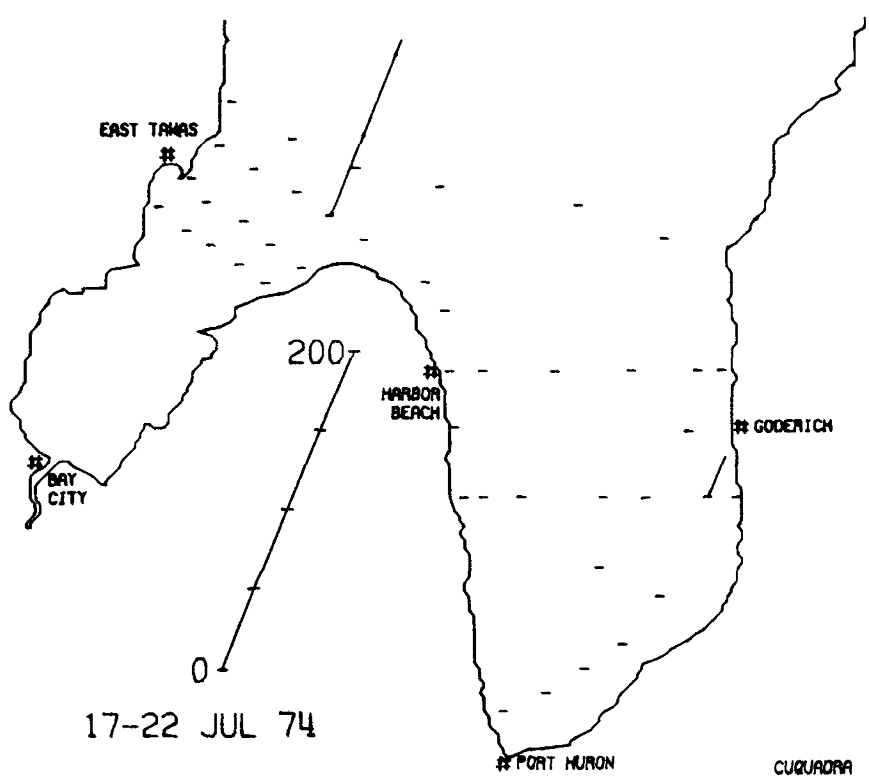
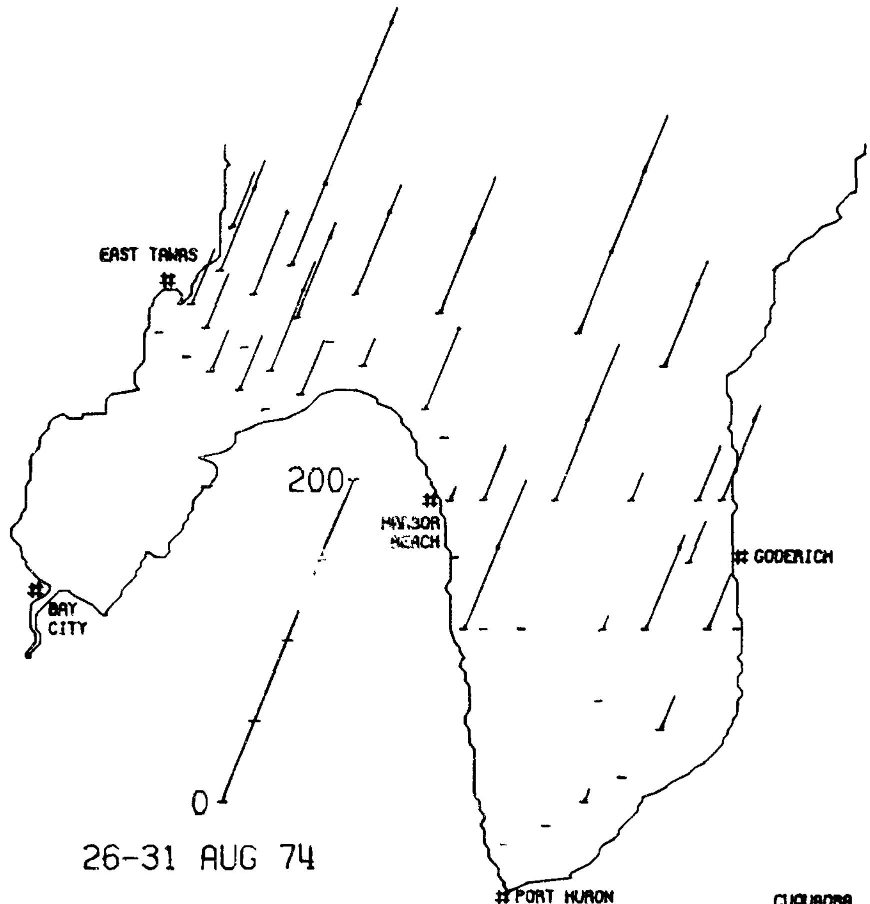


Figure 41. (continued)



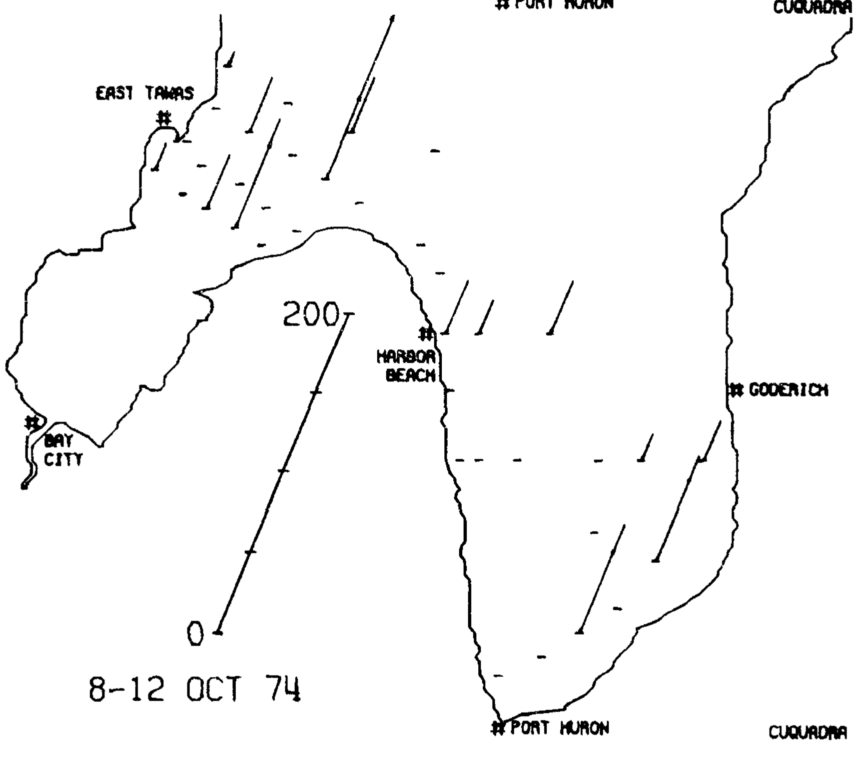


Figure 41. (continued)

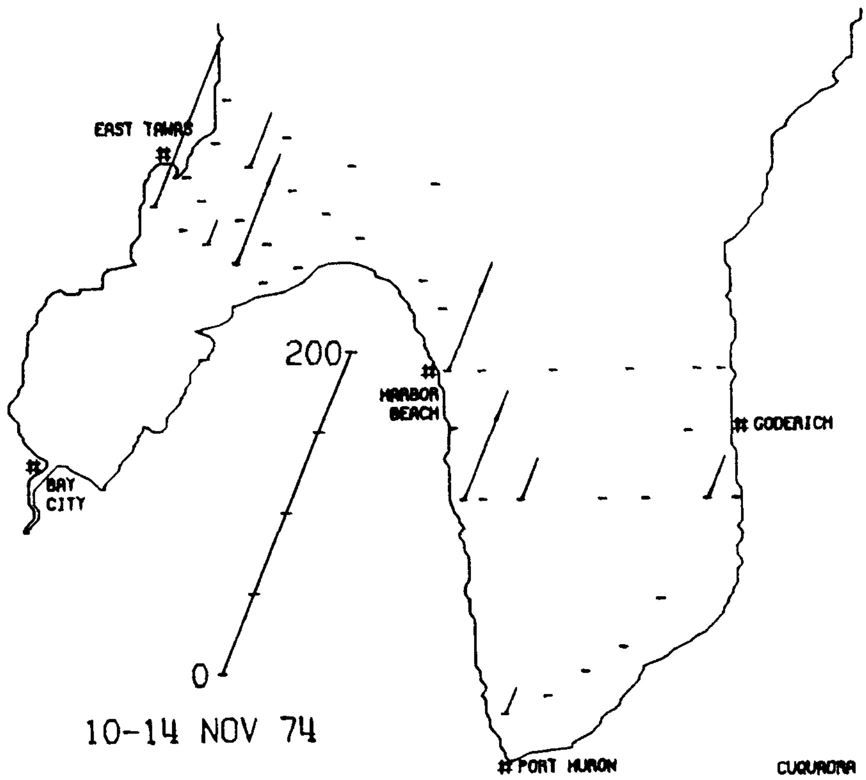
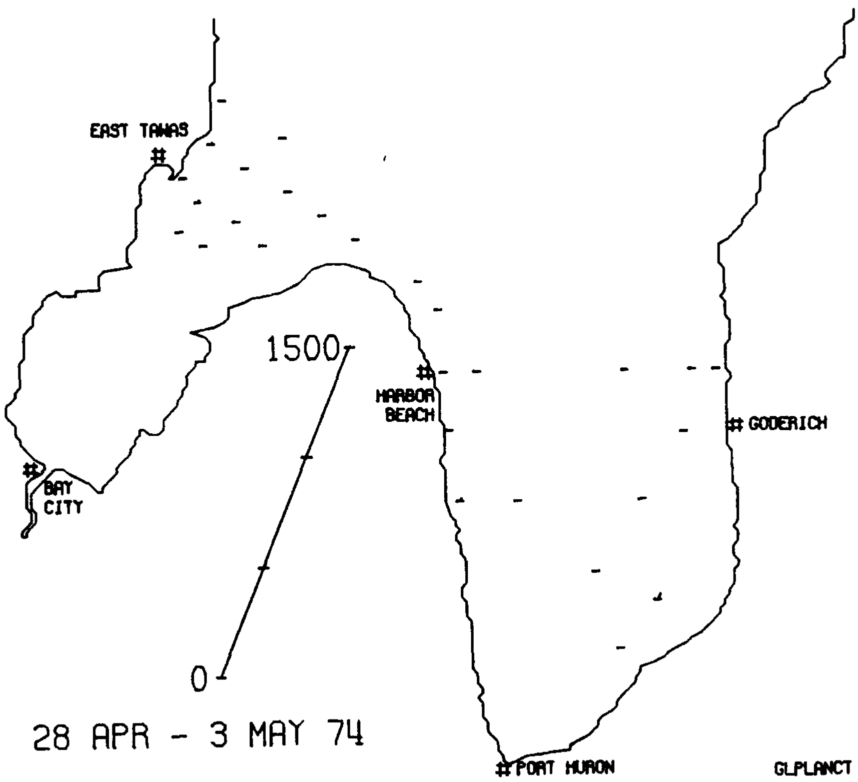


Figure 41. (continued)

Mougeotia sp.

We have been unable to make a satisfactory specific identification of this entity due to the total lack of sexually mature material. It, or morphologically very similar entities, are very abundant in western Lake Erie and certain areas of Lake Ontario. In southern Lake Huron, it was very uncommon during the May sampling cruises (Fig. 43A-B), although small populations were noted at a few scattered stations. During early June (Fig. 43C), populations were noted at stations in the Saginaw Bay interface and at a number of nearshore stations around the basin. Highest population densities were found in the southerly sector of the Saginaw Bay interface waters. By mid-June (Fig. 43D) population densities had increased slightly at stations in the Saginaw Bay interface, particularly in the southern sector, but the species was absent from other stations sampled. A similar pattern was noted during the July sampling (Fig. 43E), although the species was again found at a few nearshore stations along the Michigan coast. In August (Fig. 43F), Mougeotia sp. was again relatively abundant in the Saginaw Bay interface waters, but unlike the previous months, highest population densities were found at stations north of the bay. This species had undergone a considerable increase in abundance by the time the October samples were taken (Fig. 43G), and high population densities were found at stations in the southerly sector of the Saginaw Bay interface and at stations southward along the Michigan coast. A similar pattern was noted during the November cruise (Fig. 43H), although the distribution of this entity had become somewhat more widespread and erratic.



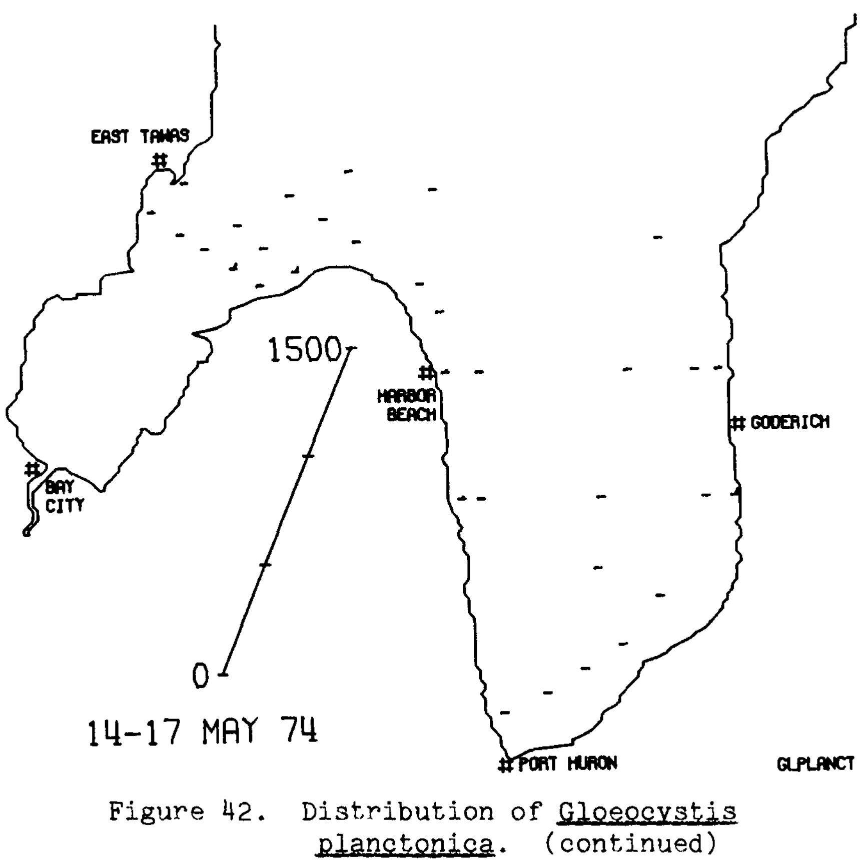
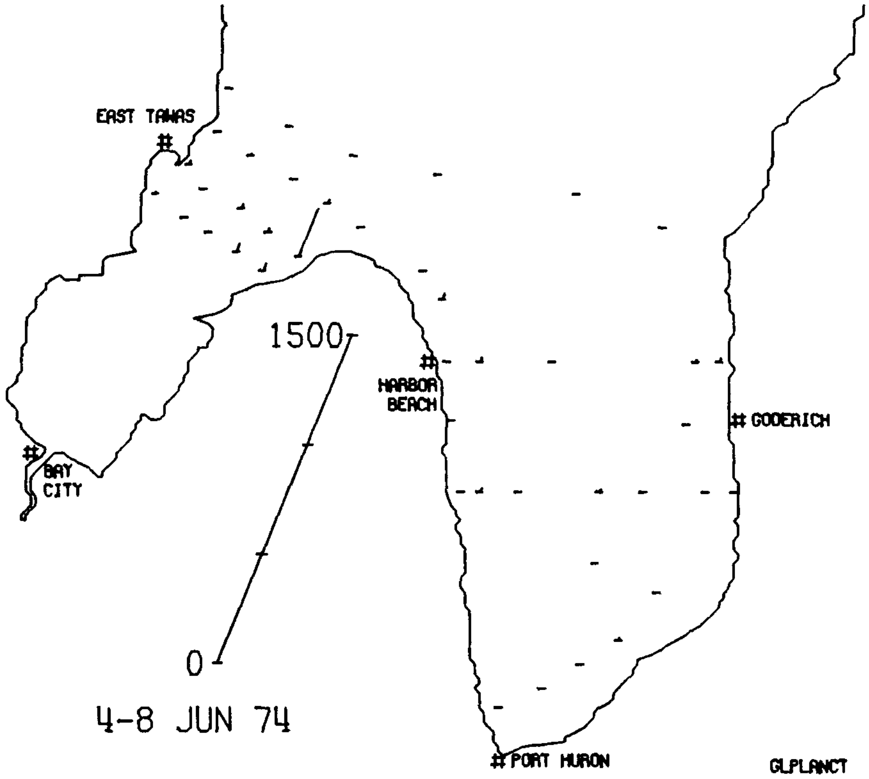


Figure 42. Distribution of _Gloeocystis planctonica_. (continued)



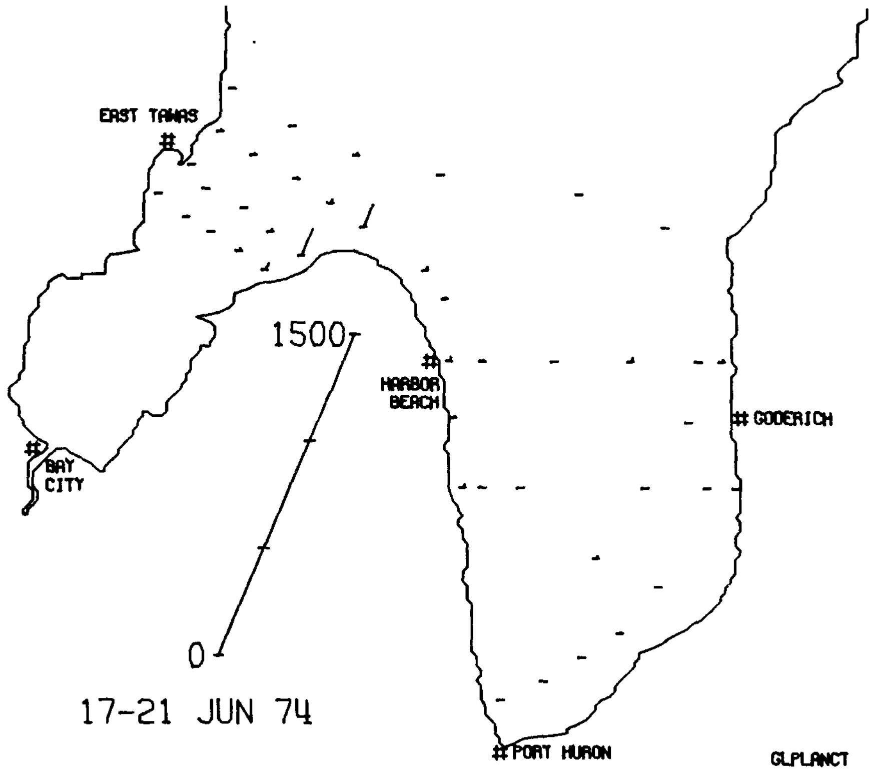
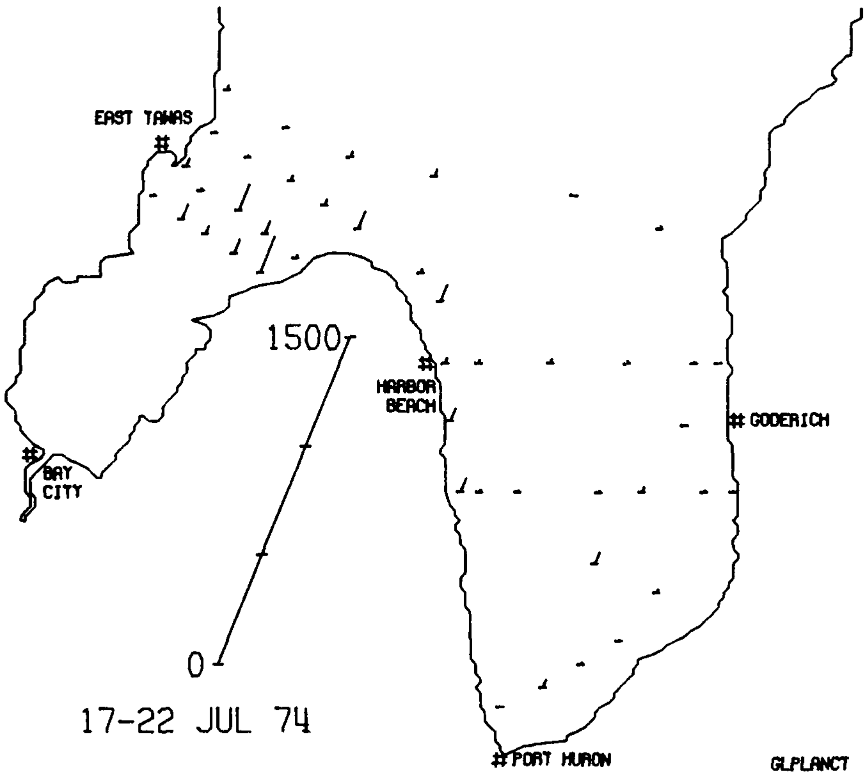


Figure 42. (continued)



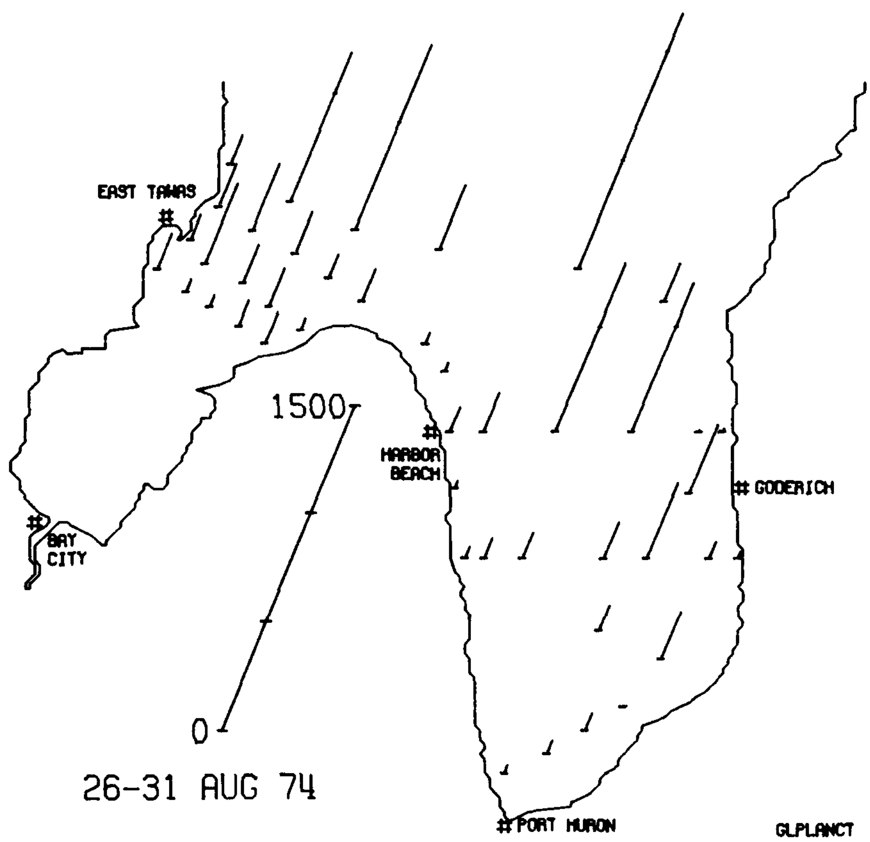
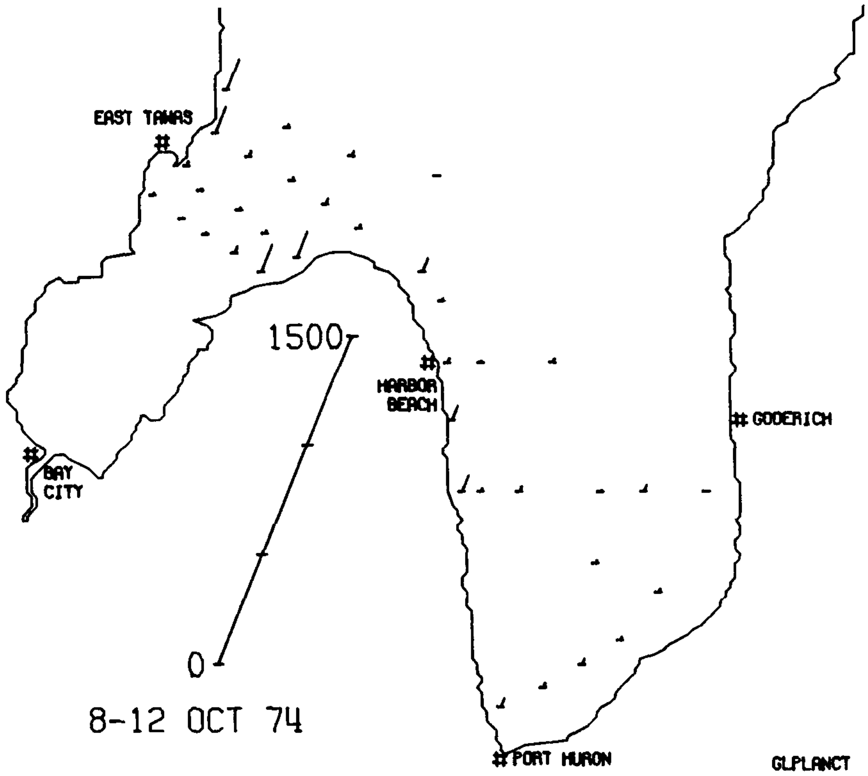


Figure 42. (continued)



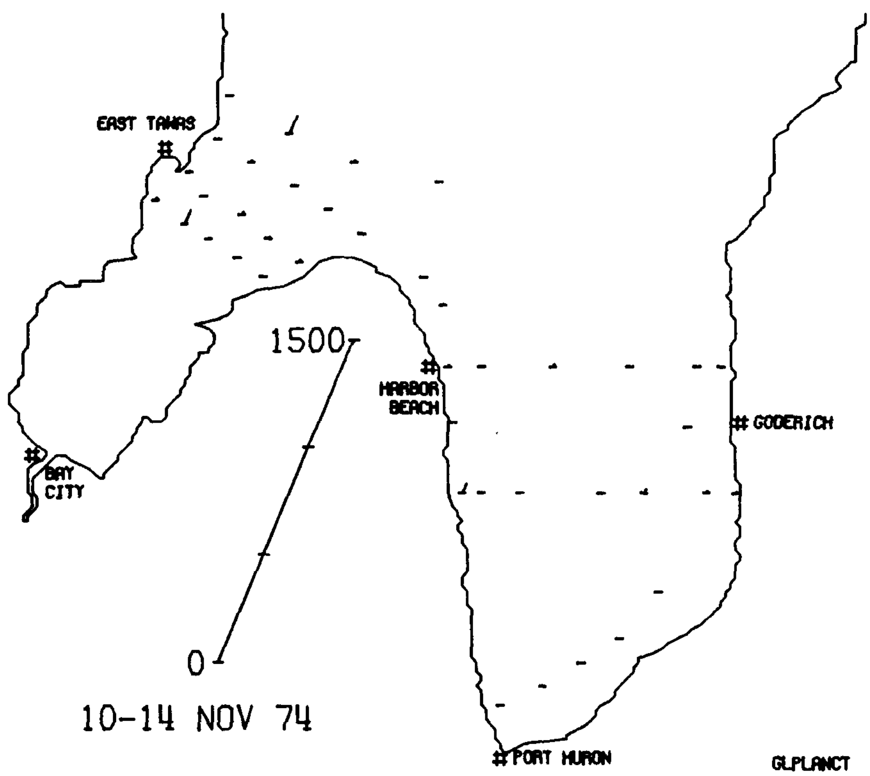
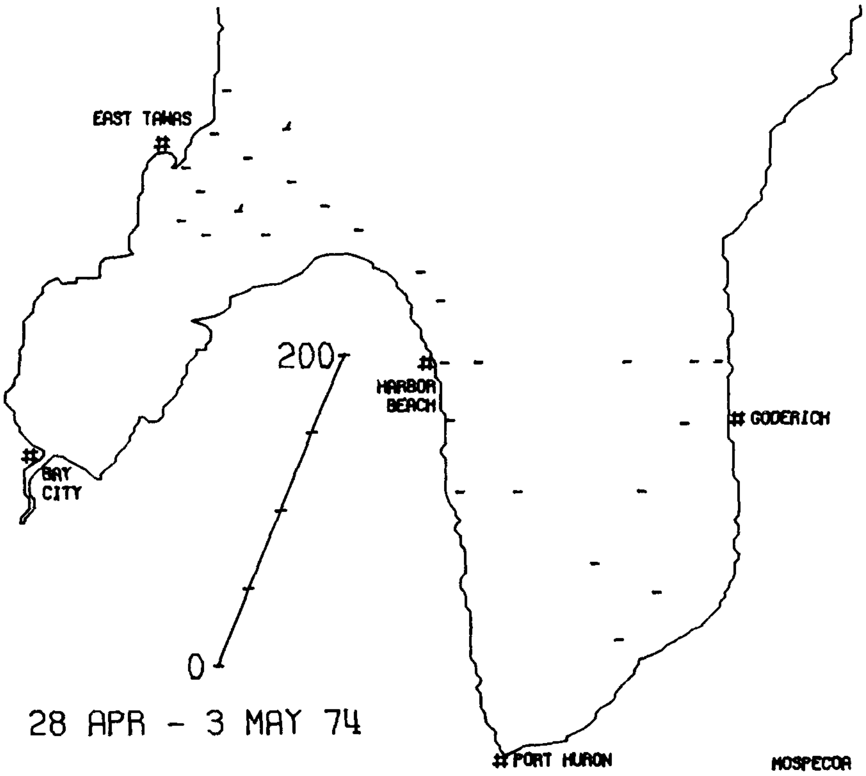


Figure 42. (continued)



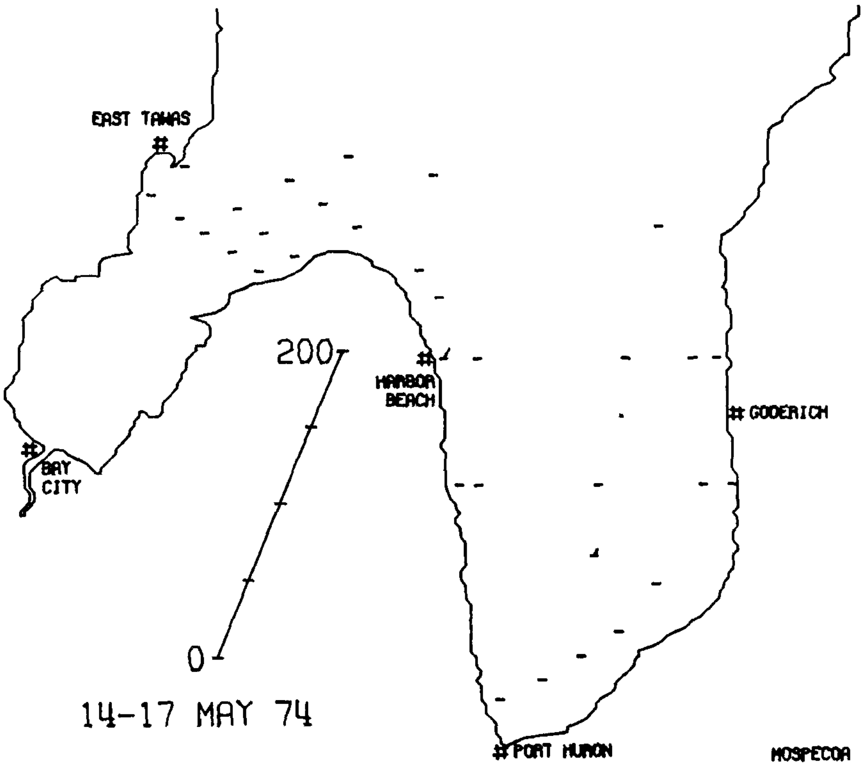
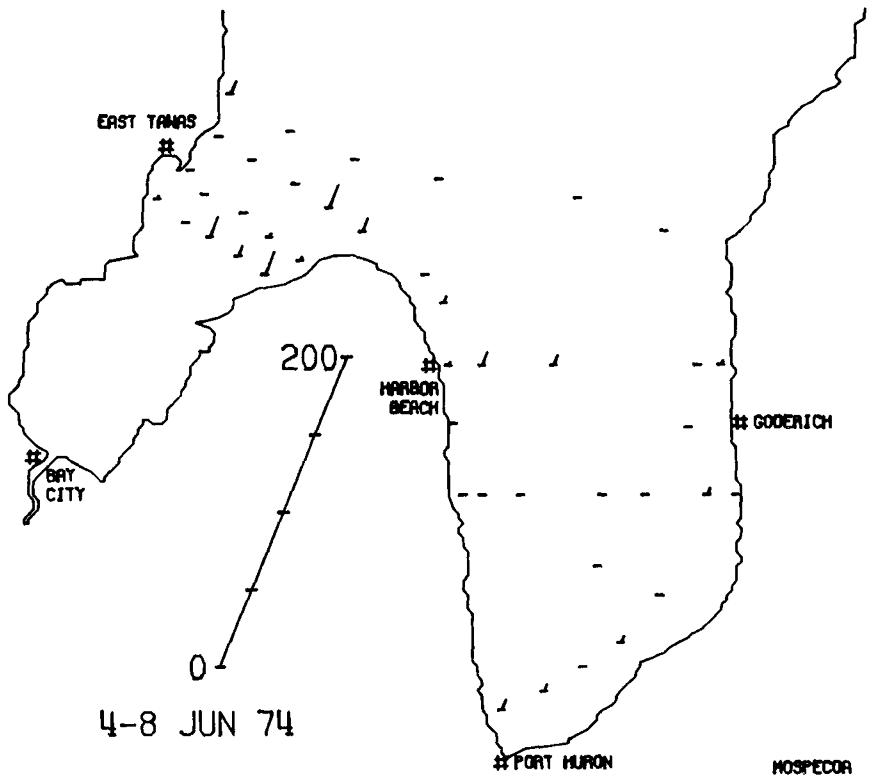


Figure 43. Distribution of Mougeotia sp..
(continued)



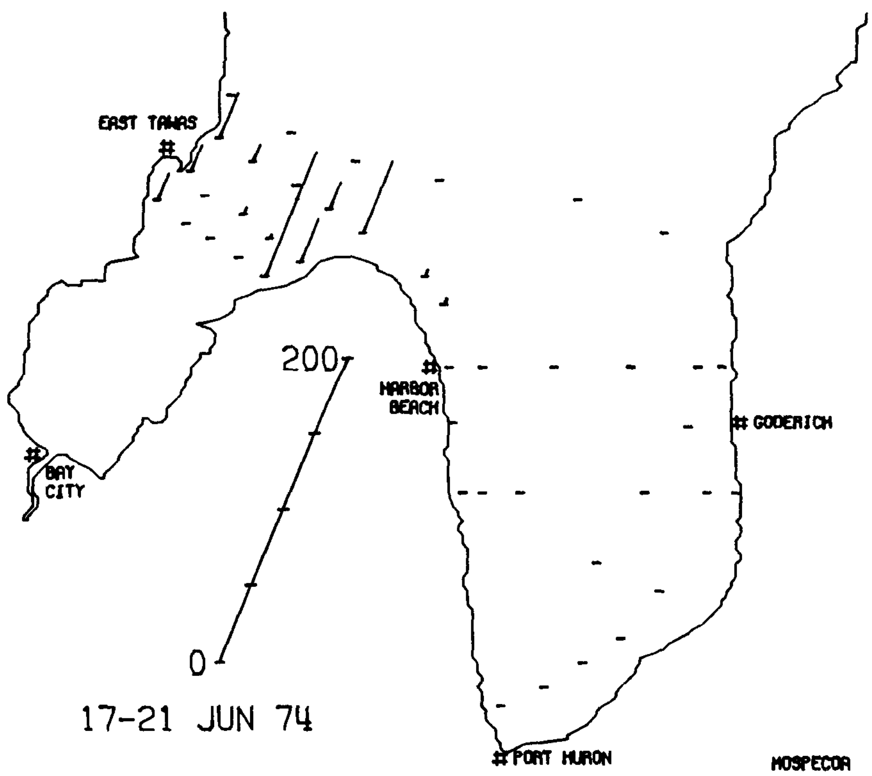
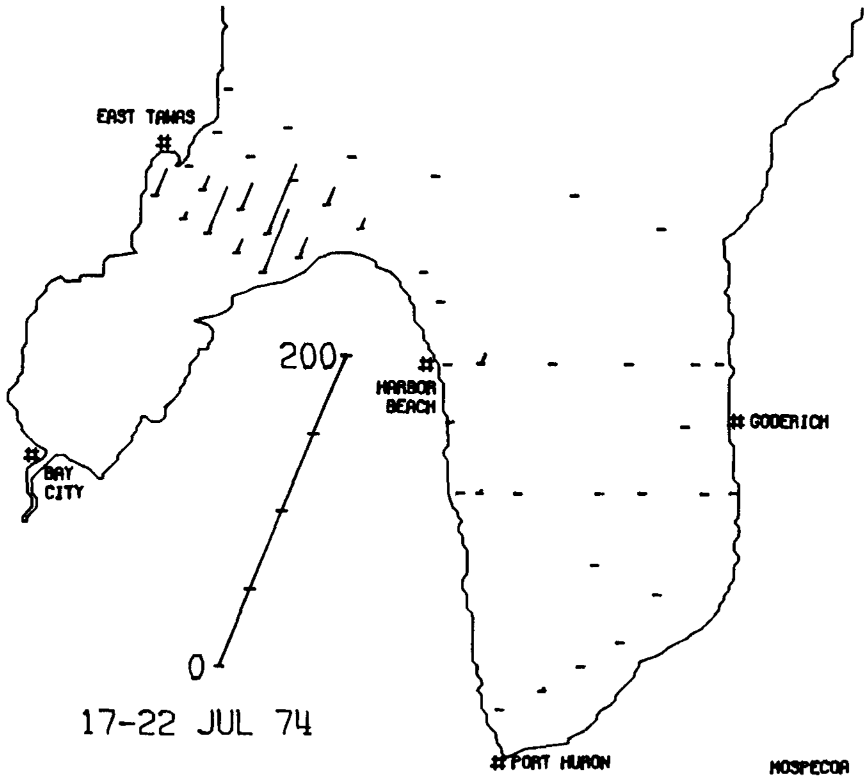


Figure 43. (continued)



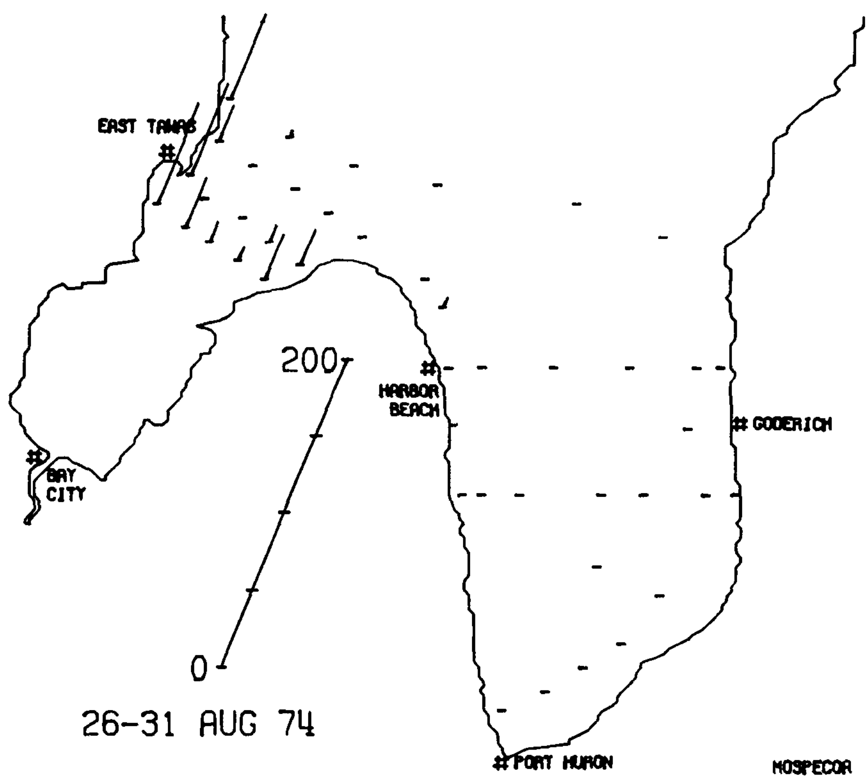


Figure 43. (continued)

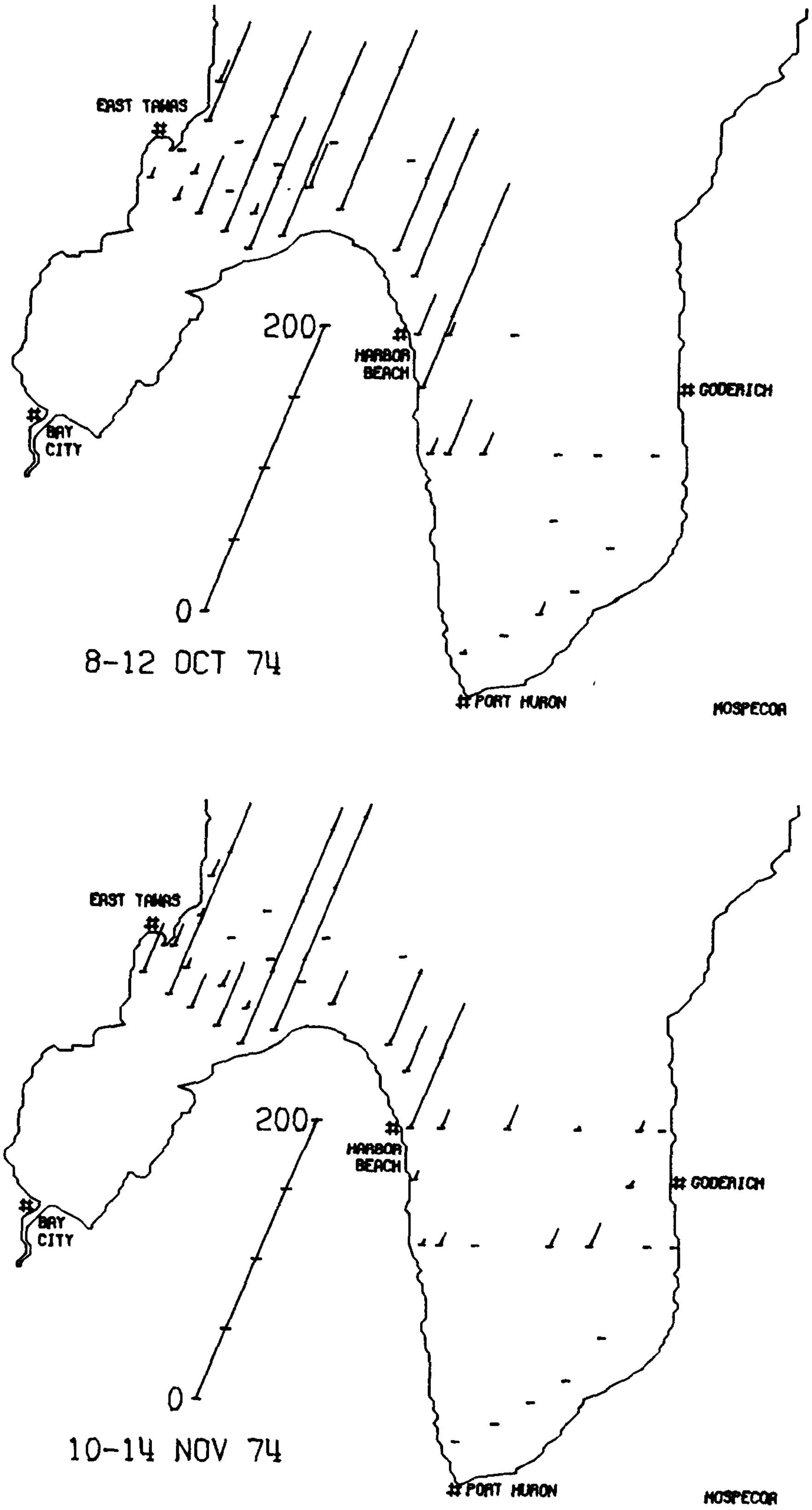


Figure 43. (continued)

Oocystis spp.

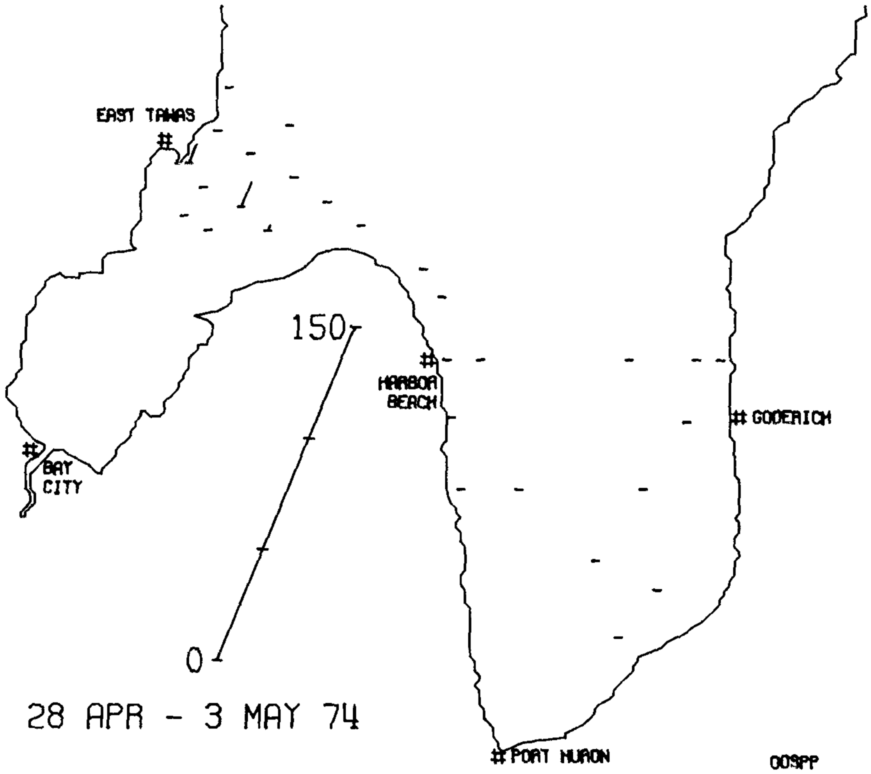
Members of this genus are common minor components of summer assemblages in the offshore waters of the Laurentian Great Lakes; however, they generally reach maximum abundance under slightly eutrophied conditions. In southern Lake Huron, *Oocystis* was rare during the early May sampling period (Fig. 44A) with only a few small populations being noted at stations in the Saginaw Bay interface waters. By mid-May (Fig. 44B), population levels had increased and *Oocystis* was present in significant abundance at stations outside the thermal bar along both Michigan and Canadian coasts, and at a few stations in the Saginaw Bay interface. During June (Fig. 44C-D), *Oocystis* continued to increase in abundance, particularly at stations in the Saginaw Bay interface and southward along the Michigan coast, although significant populations were also found at scattered offshore stations. Its abundance continued to increase during July (Fig. 44E) and August (Fig. 44F), with highest population densities being found at stations in the Saginaw Bay interface waters. The genus reached its maximum abundance during the October sampling period (Fig. 44G) when significant populations were found at nearly all stations sampled. By November (Fig. 44H), population densities were somewhat reduced, and its distribution had become somewhat more erratic.

Scenedesmus quadricauda

This species is generally rare in the offshore waters of the upper Great Lakes, but may become very abundant in Lake Erie and Lake Ontario (Stoermer *et al.*, 1974). In southern Lake Huron, its distribution was largely restricted to a few stations in the Saginaw Bay interface waters during May and early June (Fig. 45A-C). Somewhat increased abundances were noted during the late June sampling cruise (Fig. 45D) but populations were again reduced by July (Fig. 45E) and had increased only slightly by the time the August samples were taken (Fig. 45F). *S. quadricauda* reached its highest abundance during October (Fig. 45G), when large populations were found in the southerly sector of the Saginaw Bay interface water southward along the Michigan coast, and at a few stations in the southern part of the lake. Population levels were again reduced by the time the November samples were taken (Fig. 45H), although the species was still present at a few stations of the Saginaw Bay interface waters southward along the Michigan coast.

Staurastrum paradoxum

Although many members of this genus are restricted to nutrient-poor or dystrophic waters, *S. paradoxum* generally reaches its highest abundance in eutrophic areas. In the Great Lakes, it is relatively abundant in Lake Erie (Vollenweider *et al.*, 1974) and in Lake Ontario (Stoermer *et al.*, 1974). Although it usually does not reach large population densities, it may contribute a significant fraction of the biomass of phytoplankton assemblages because of its very large cell volume (Stoermer and Ladewski, 1978). In southern Lake Huron, first occurrences were noted in early June (Fig. 46A) at the inner line of stations in the Saginaw Bay interface. By late June (Fig. 46B), relatively large populations were found in stations in the southerly sector of the Saginaw Bay interface and at a few stations southward along the Michigan coast. Fewer occurrences were noted during the July sampling (Fig. 46C), when it was again restricted to stations near the Saginaw Bay interface and southerly along the Michigan coast. Unlike the previous month, during the August sampling period (Fig. 46D) the only populations noted were found at



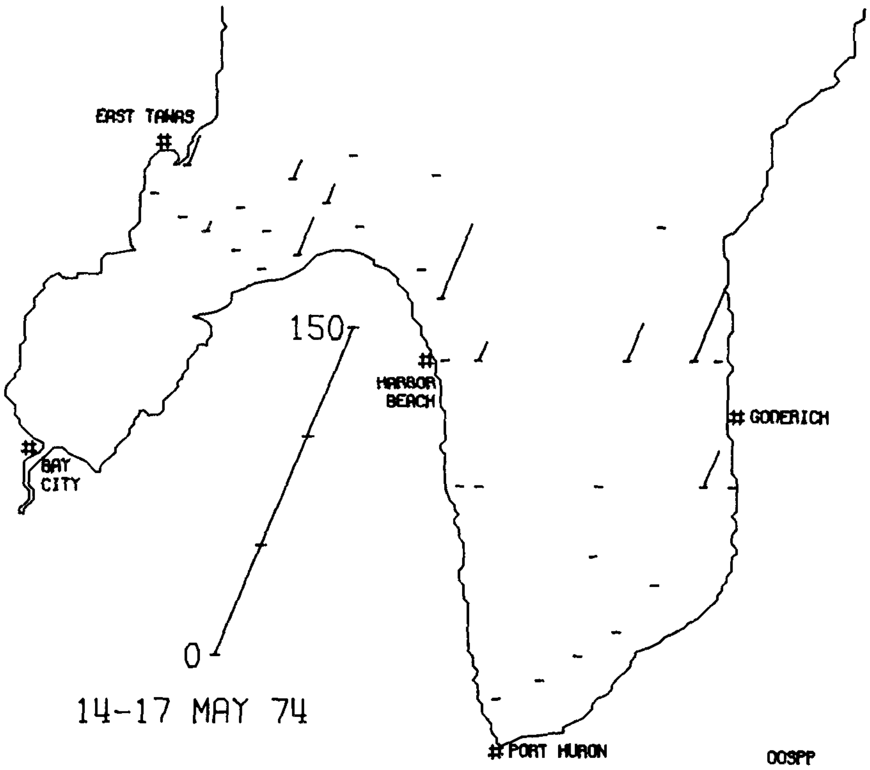
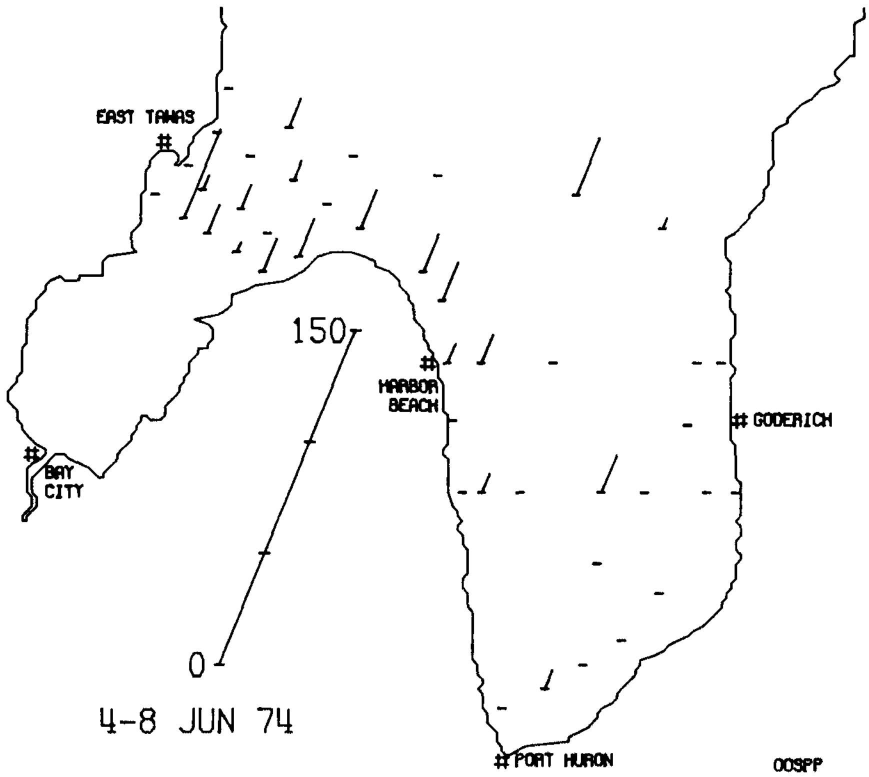


Figure 44. Distribution of <u>Oocystis</u> spp.. (continued)



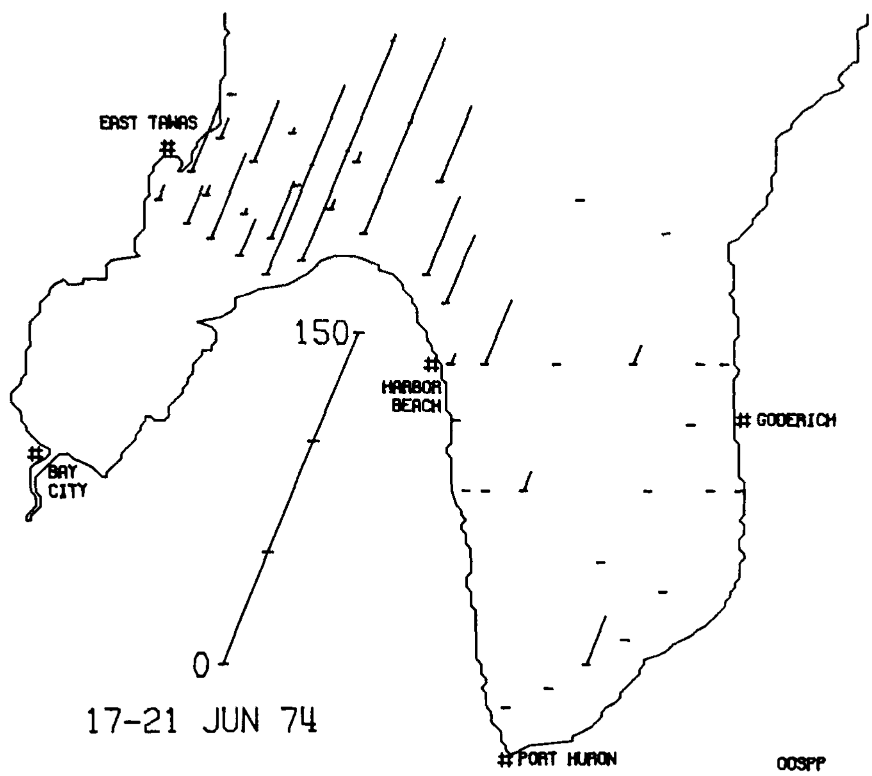
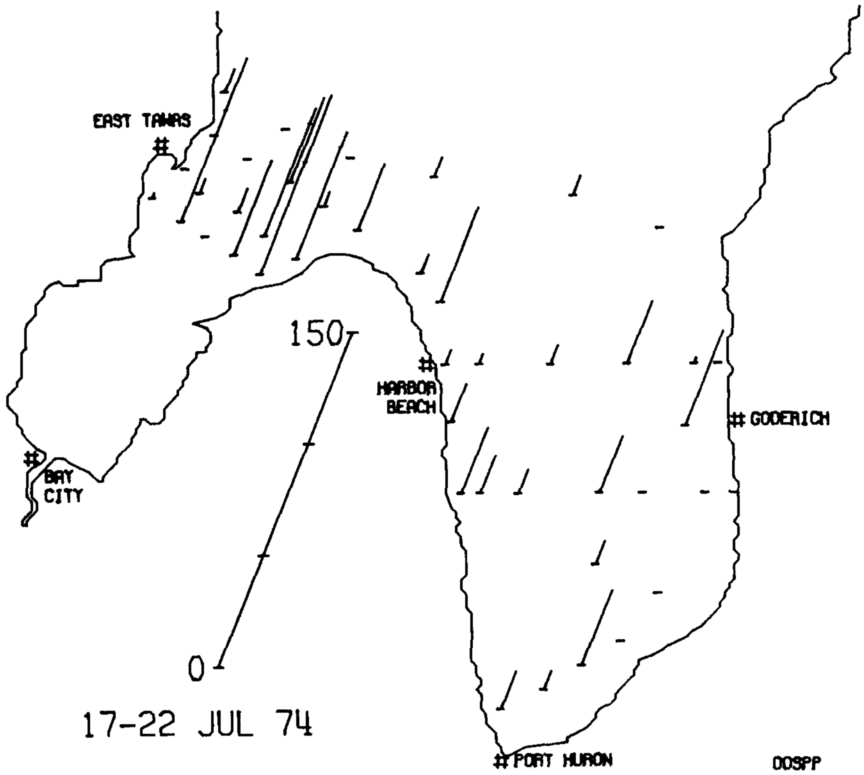


Figure 44. (continued)



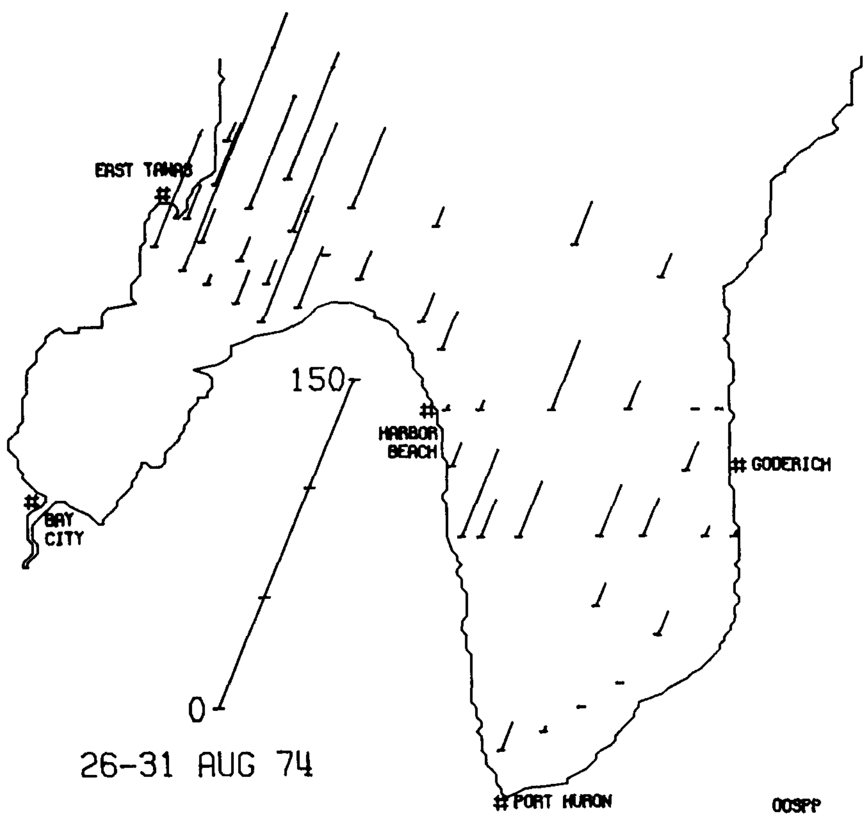
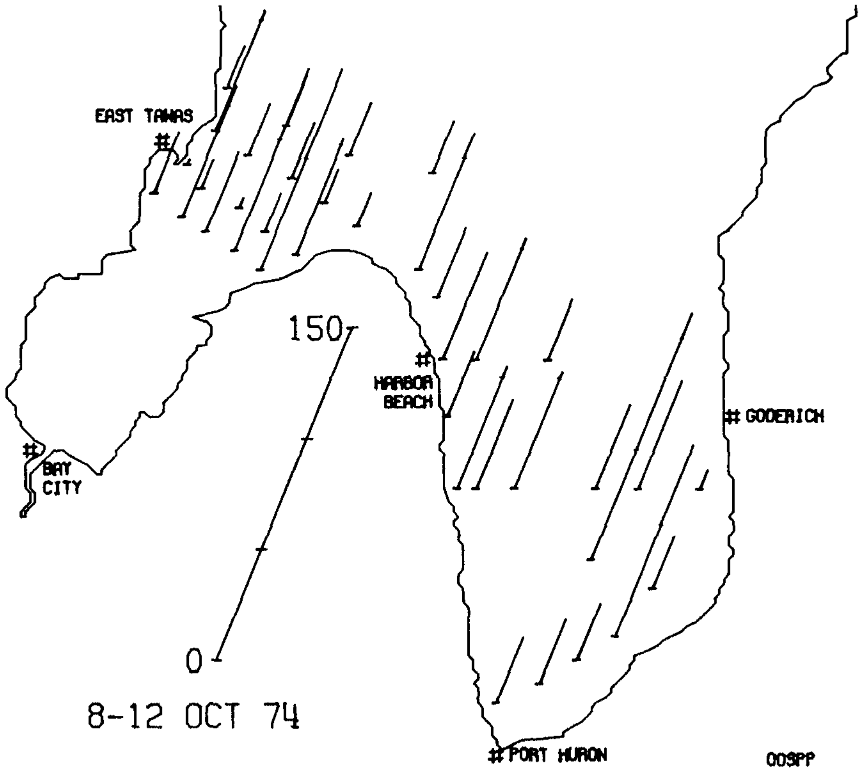


Figure 44. (continued)



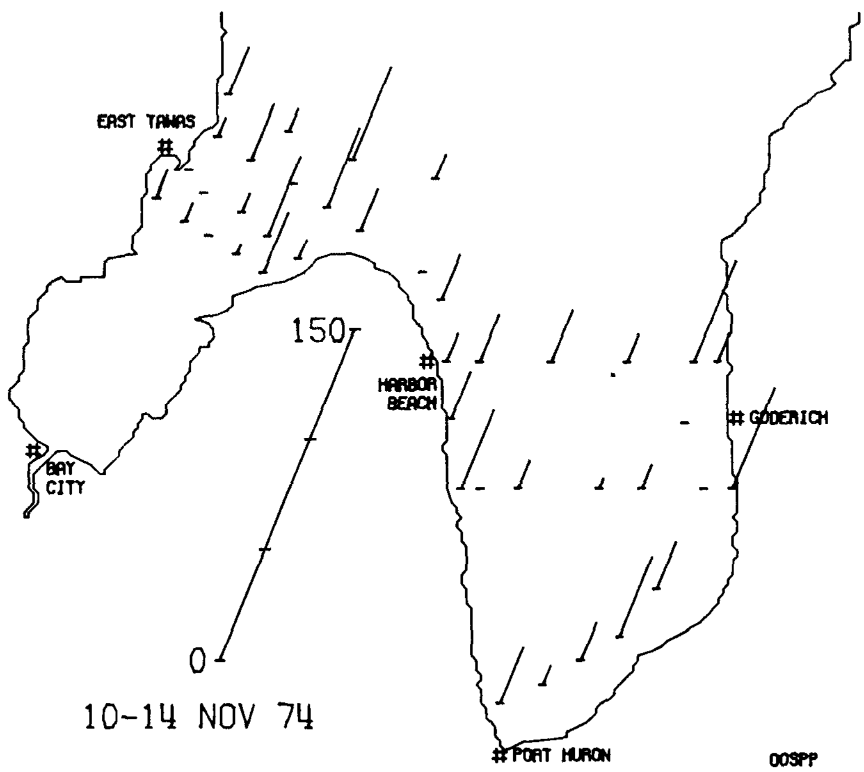
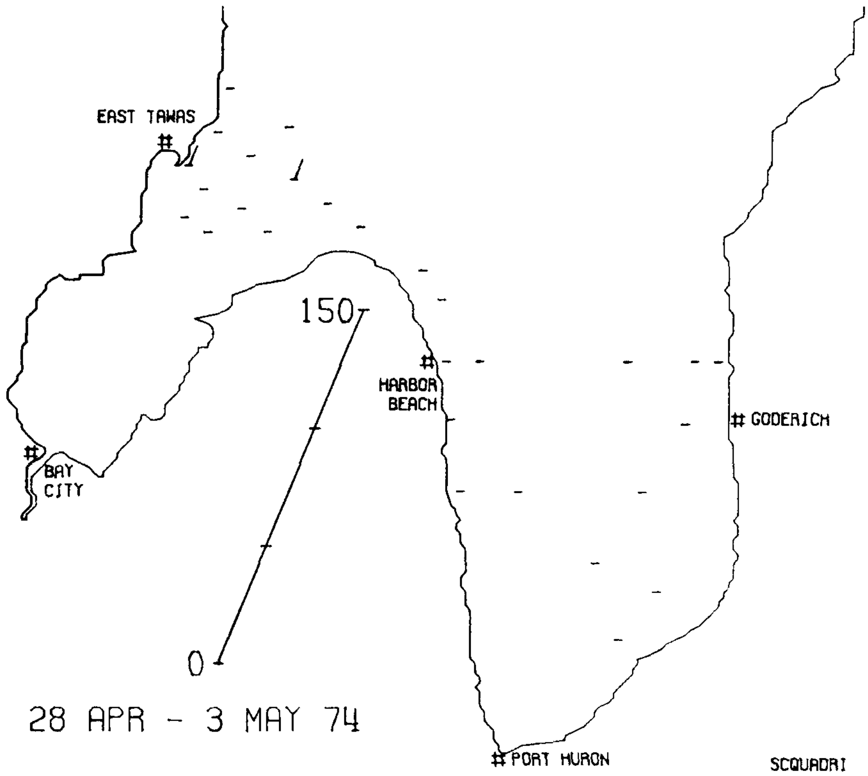


Figure 44. (continued)



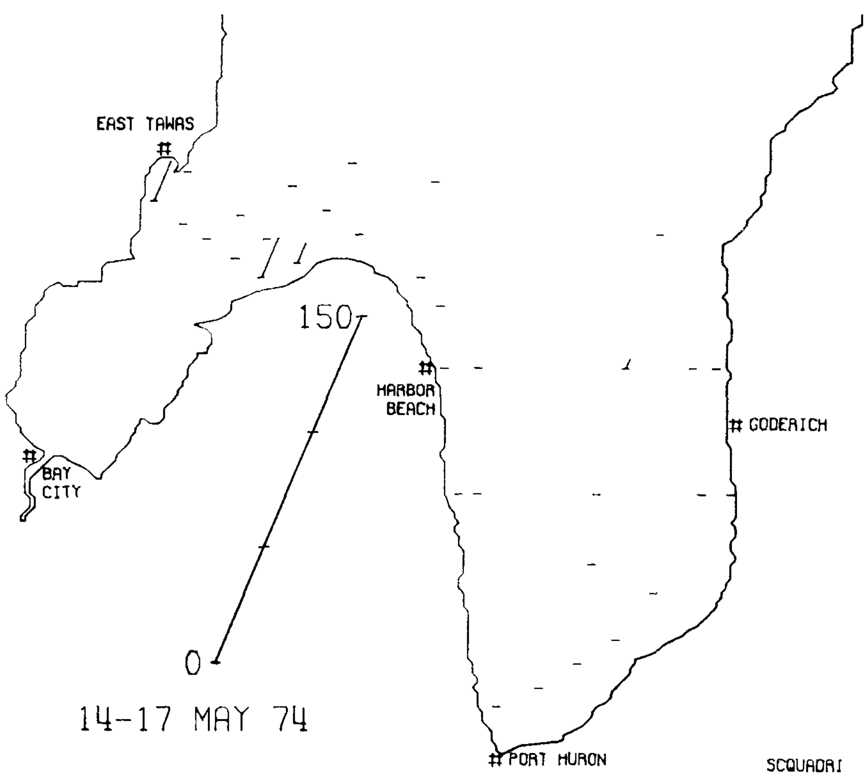
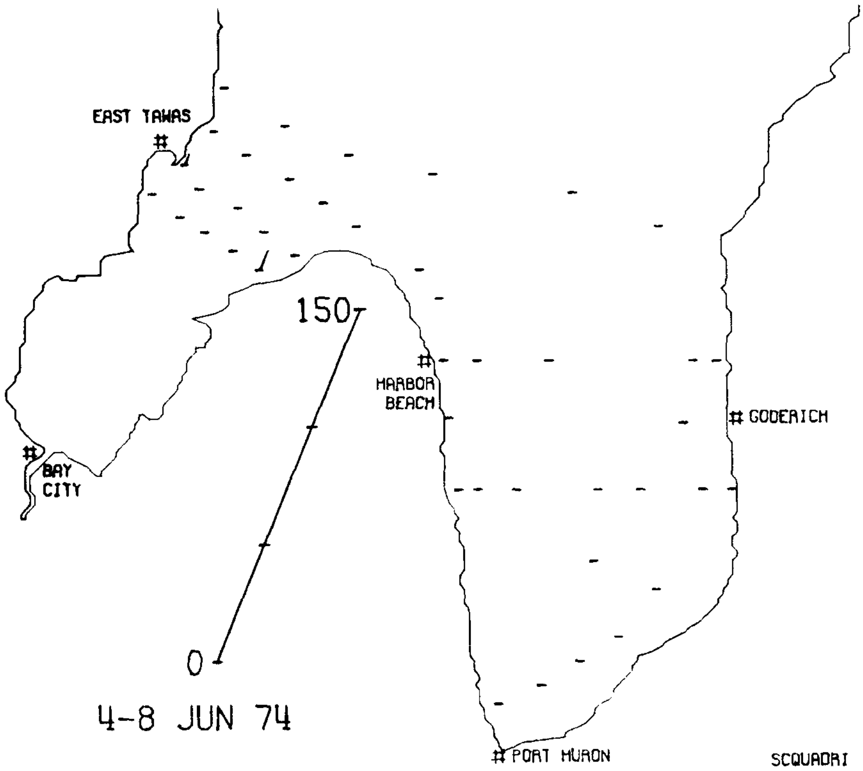


Figure 45. Distribution of Scenedesmus quadricauda. (continued)



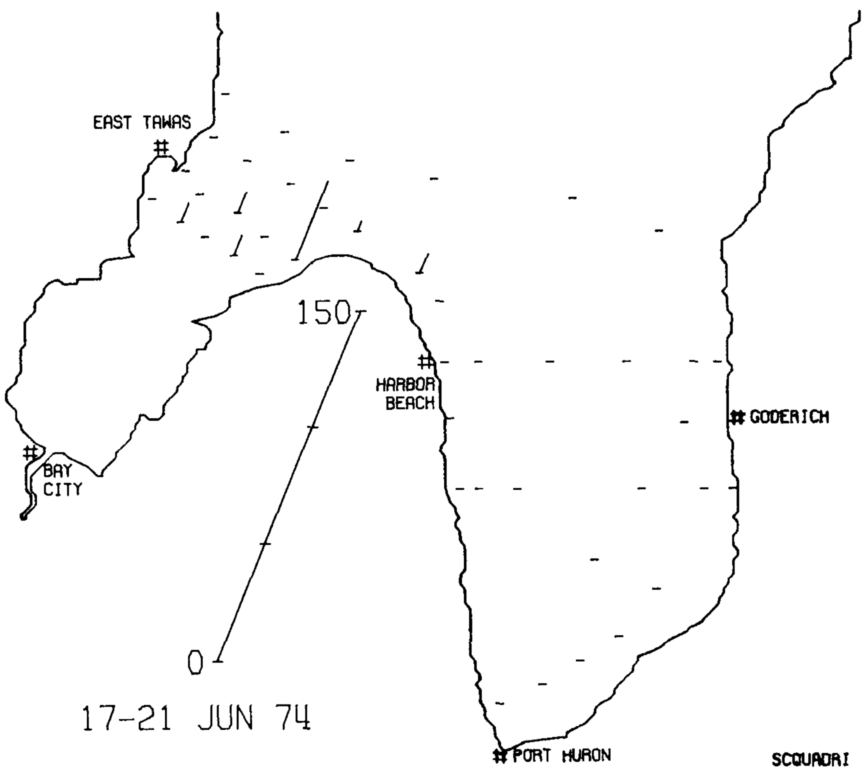
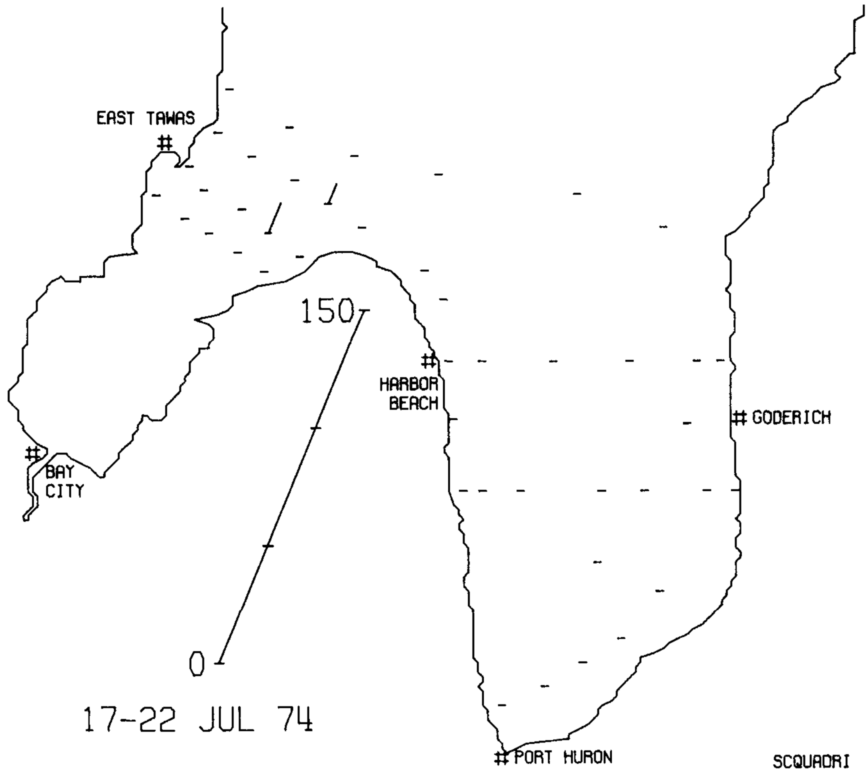


Figure 45. (continued)



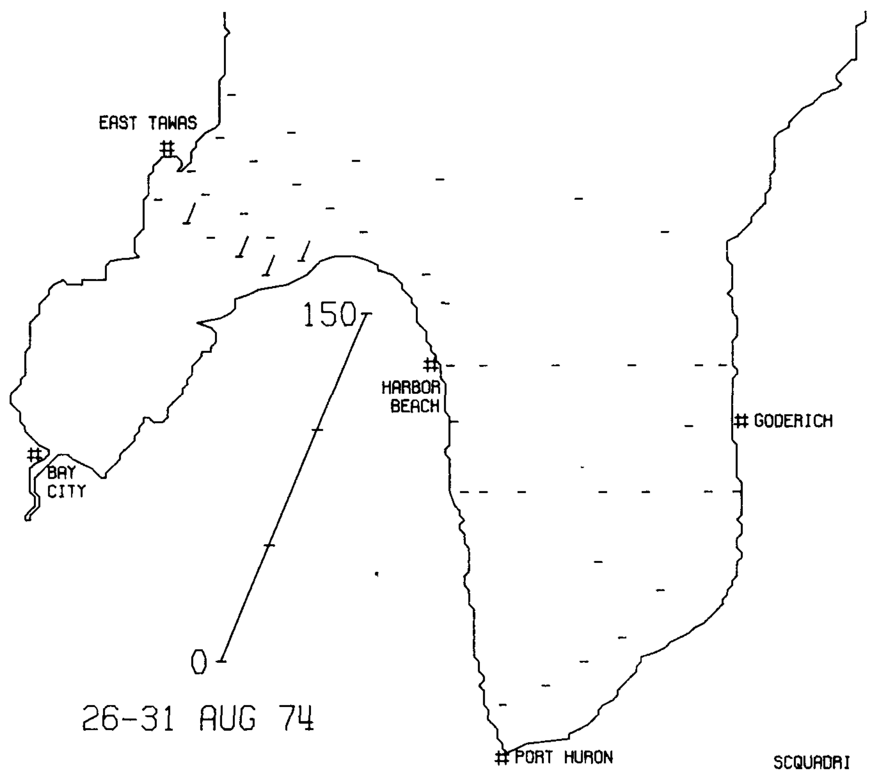
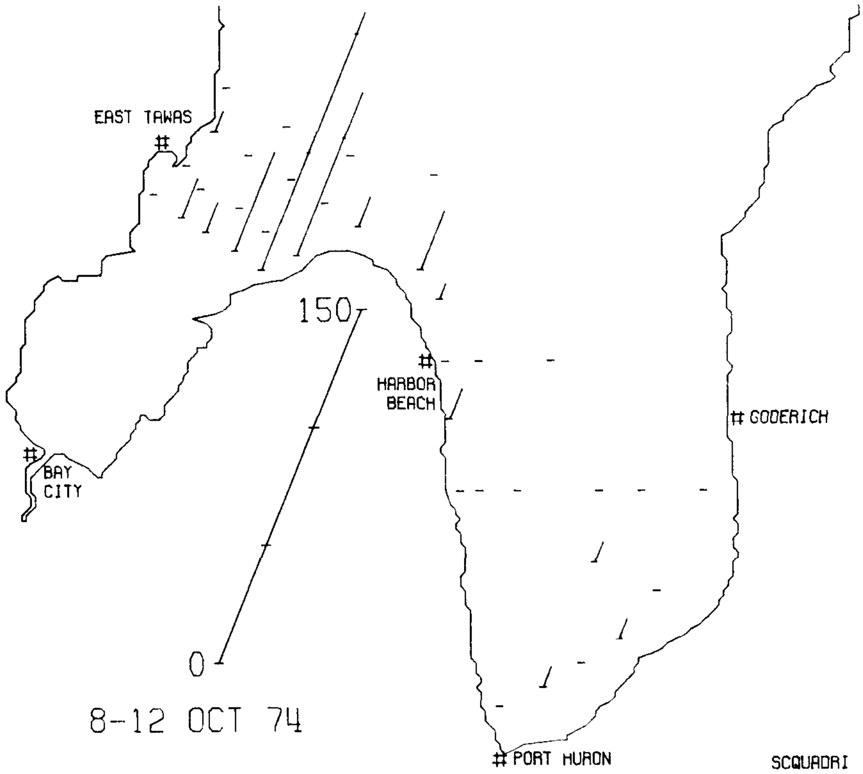


Figure 45. (continued)



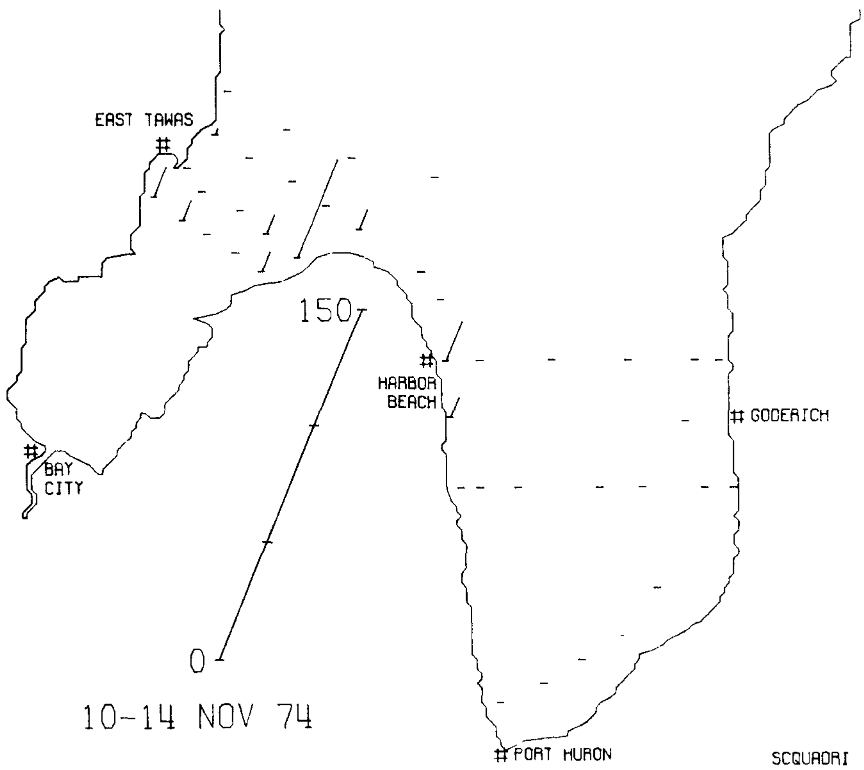
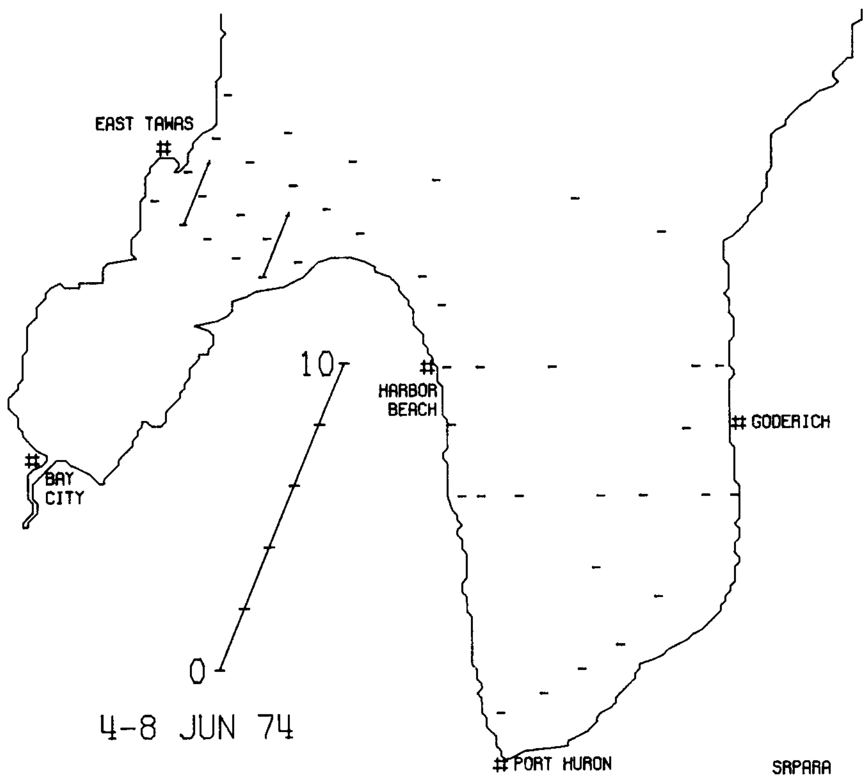


Figure 45. (continued)



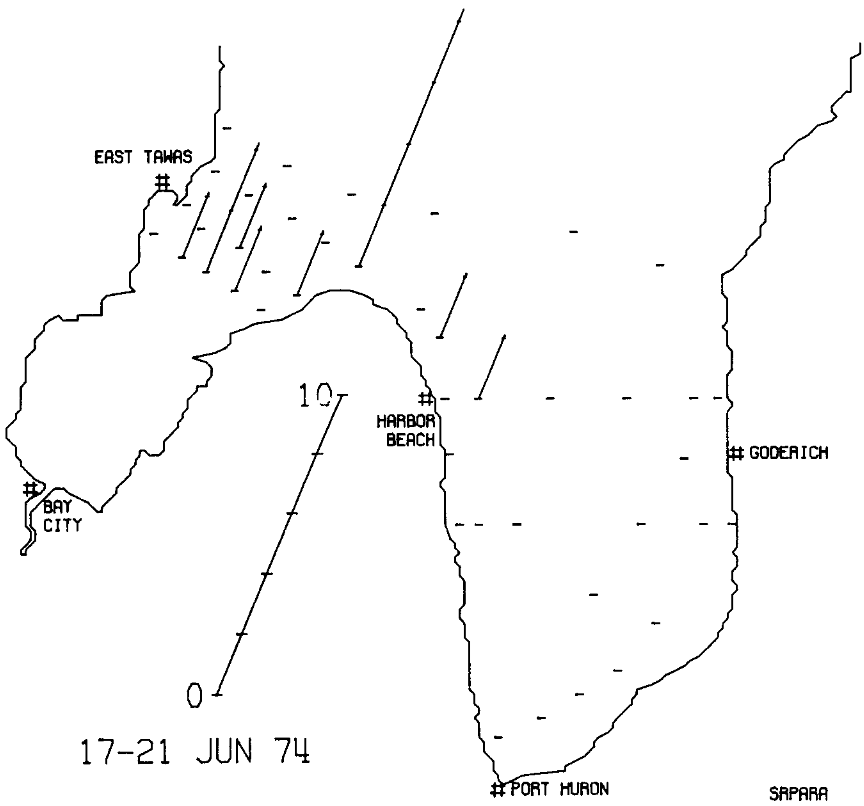
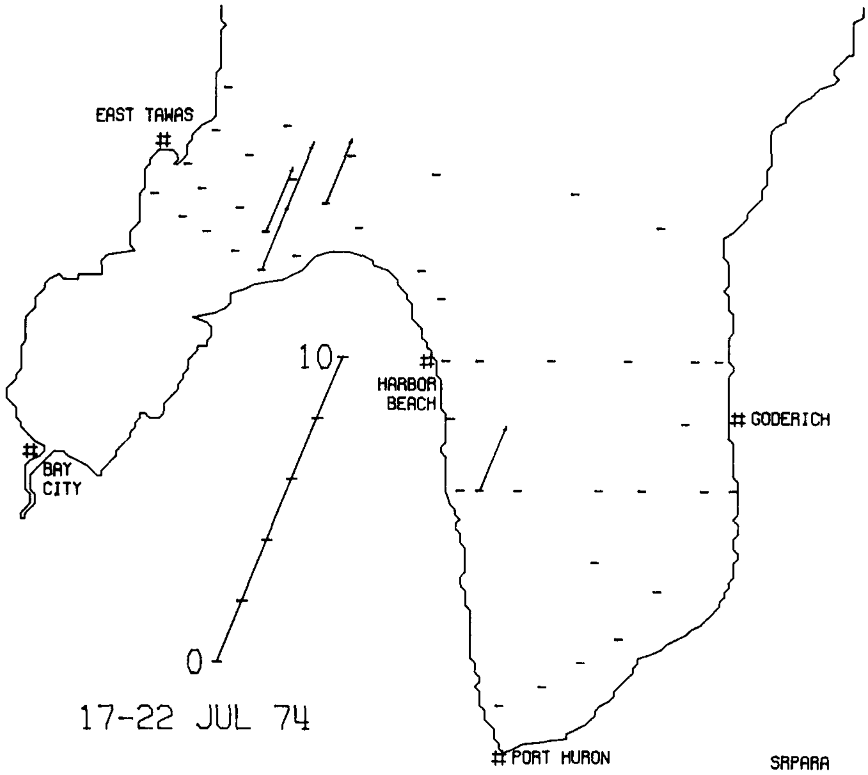


Figure 46. Distribution of *Staurastrum paradoxum*. (contiued)



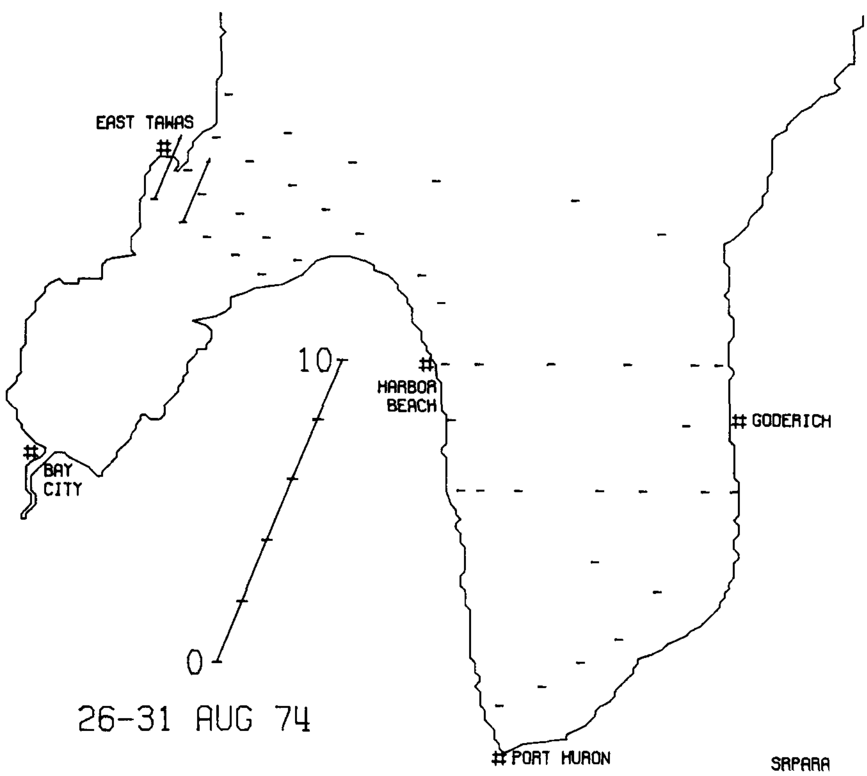


Figure 46. (continued)

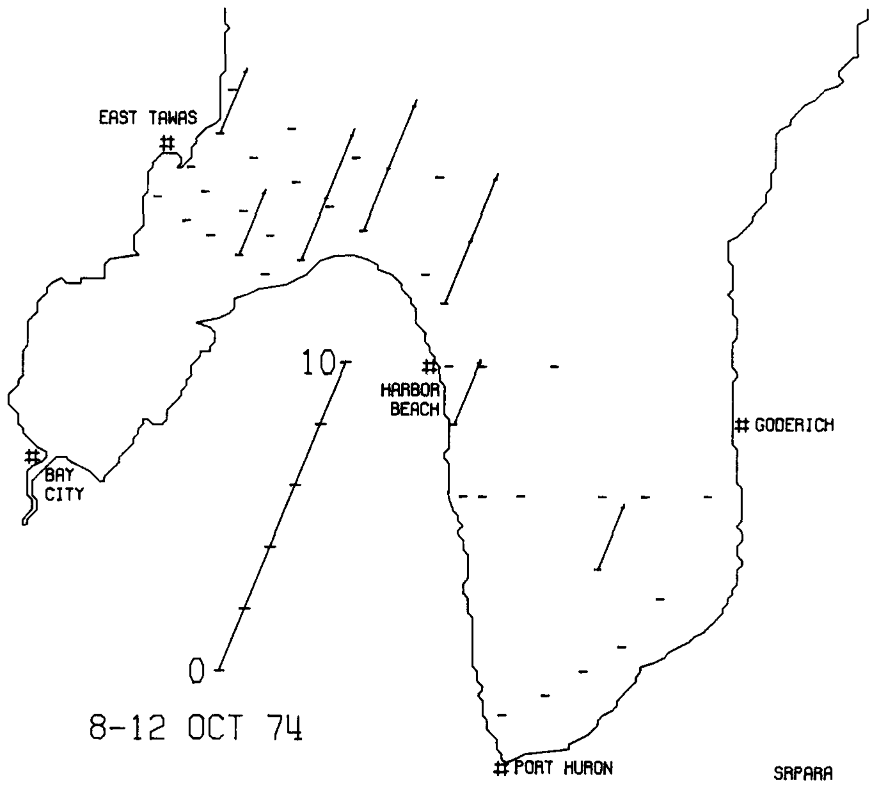
stations in the northerly sector of the Saginaw Bay interface waters. During October (Fig. 46E), most occurrences were found at stations in the southerly part of the Saginaw Bay interface and southward along the Michigan coast although isolated occurrences were found north of Saginaw Bay and at one station in the offshore waters of southern Lake Huron. Abundance was reduced by November (Fig. 46F), although the species occurred at a few stations in the Saginaw Bay interface.

Tetraedron minimum

This species is occasionally found in offshore summer phytoplankton assemblages in the upper Great Lakes, but is generally more abundant in areas that are somewhat eutrophied. In southern Lake Huron, it was first noted in mid-May (Fig. 47A) at a single station in the southern part of the Saginaw Bay interface waters. By early June (Fig. 47B), it was present at most stations in the Saginaw Bay interface and isolated occurrences were noted along the Michigan coast. It appeared to decline in abundance by late June (Fig. 47C), although populations were still found in scattered stations in the Saginaw Bay interface waters and southward along the Michigan coast. It had again increased in abundance by the time mid-July (Fig. 47D) samples were taken. Maximum abundance was found in the southerly sector of the Saginaw Bay interface waters, although occasional populations were found in stations southerly along the Michigan coast. Unlike previous months, T. minimum was found in several of the July samples taken along the Canadian coast. During August (Fig. 47E), only a few occurrences were noted at stations in the Saginaw Bay interface waters and the species remained relatively rare during October (Fig. 47F) and November (Fig. 47G) although populations were still found at stations in the Saginaw Bay interface waters and occasionally at nearshore stations in the main body of Lake Huron.

Cyanophyta

The abundance of blue-green algae is sometimes looked upon as a rough index of eutrophication. The situation in southern Lake Huron is somewhat confounded by the fact that the blue-green algal flora is a mixture of very highly eutrophication-tolerant forms derived from Saginaw Bay and less eutrophication-tolerant species which flourish in the open waters of the lake, particularly during periods of silica limitation. During early May (Fig. 48A), blue-green algae were practically absent from the stations sampled in southern Lake Huron. By mid-May (Fig. 48B), however, significant numbers were found at a few stations in the southerly sector of the Saginaw Bay interface waters. Blue-green abundance increased slightly in early June (Fig. 48C), but distribution was largely restricted to stations in the Saginaw Bay interface. By late June (Fig. 48D), populations had spread to a number of stations along the Michigan coast and a few stations along the Canadian coast. In mid-July (Fig. 48E), the blue-green algae were again largely restricted to stations in the Saginaw Bay interface and southward along the Michigan coast. This situation changed significantly in August (Fig. 48F), when very large populations were found in the Saginaw Bay interface waters and smaller populations were found at most stations sampled throughout the lake. The blue-green algae were most abundant in southern Lake Huron during the October sampling period (Fig. 48G). Very high population densities were found in the southerly sector of the Saginaw Bay interface, and significant populations



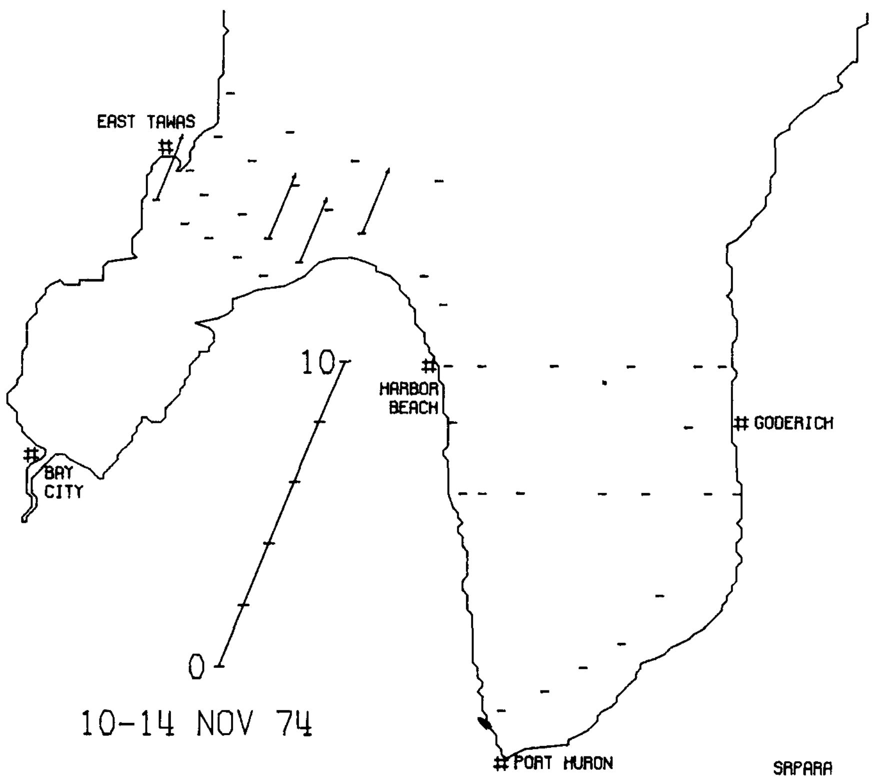
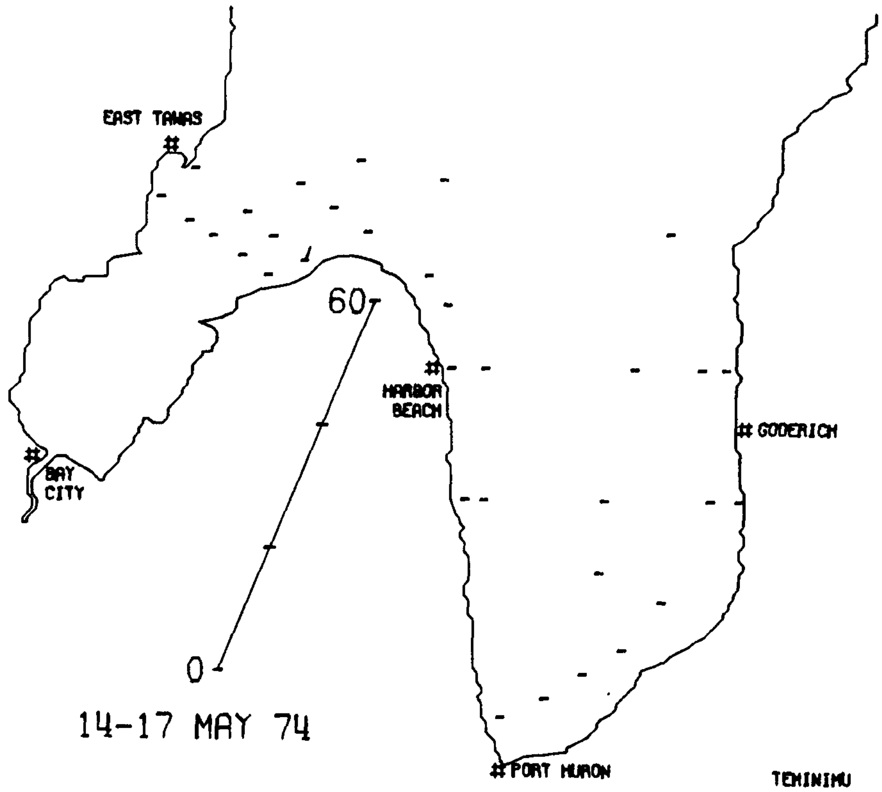


Figure 46. (continued)



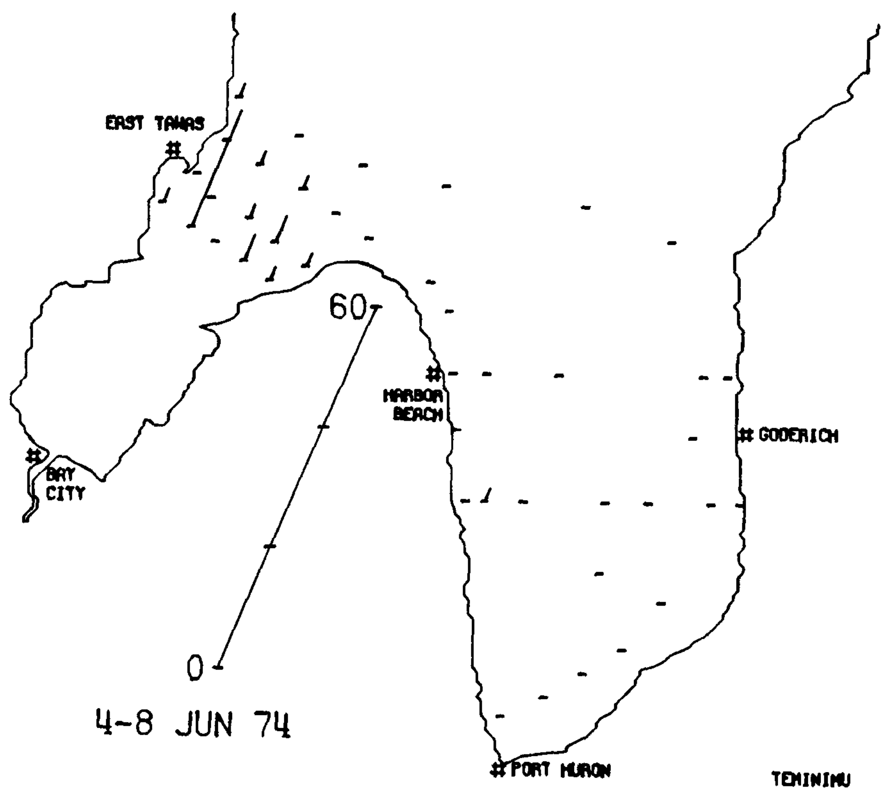
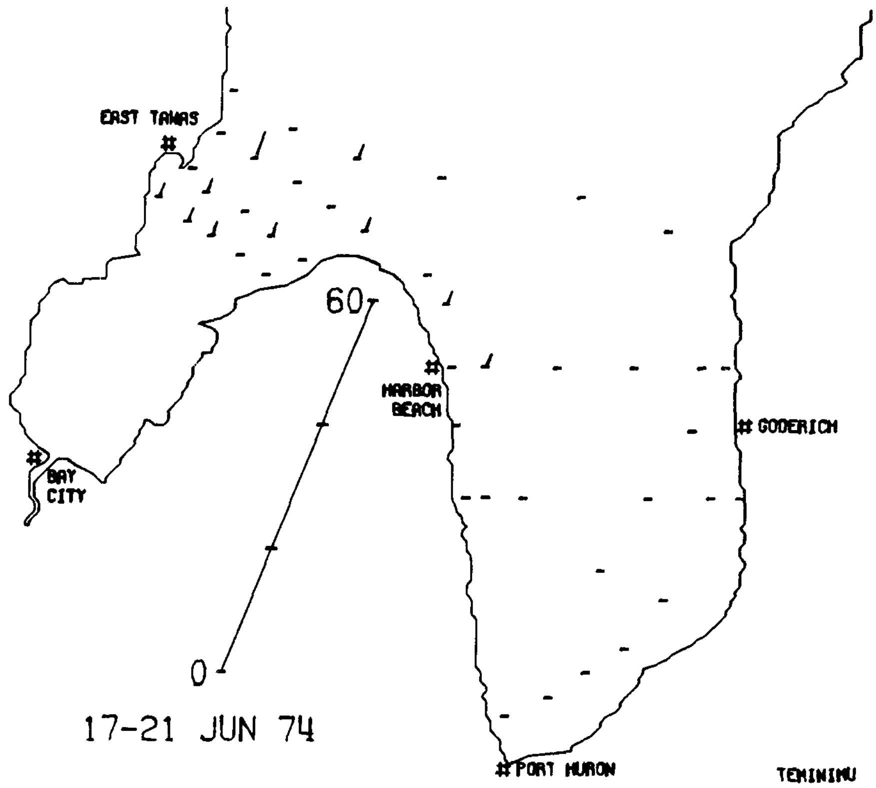
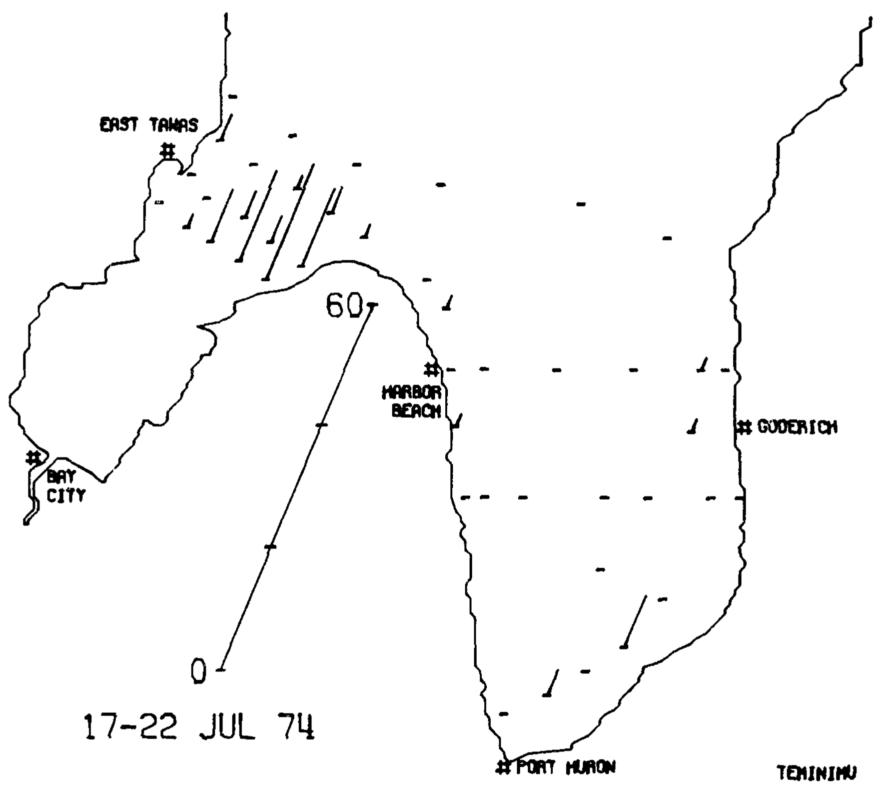


Figure 47. Distribution of _Tetraedron minimum_. (continued)





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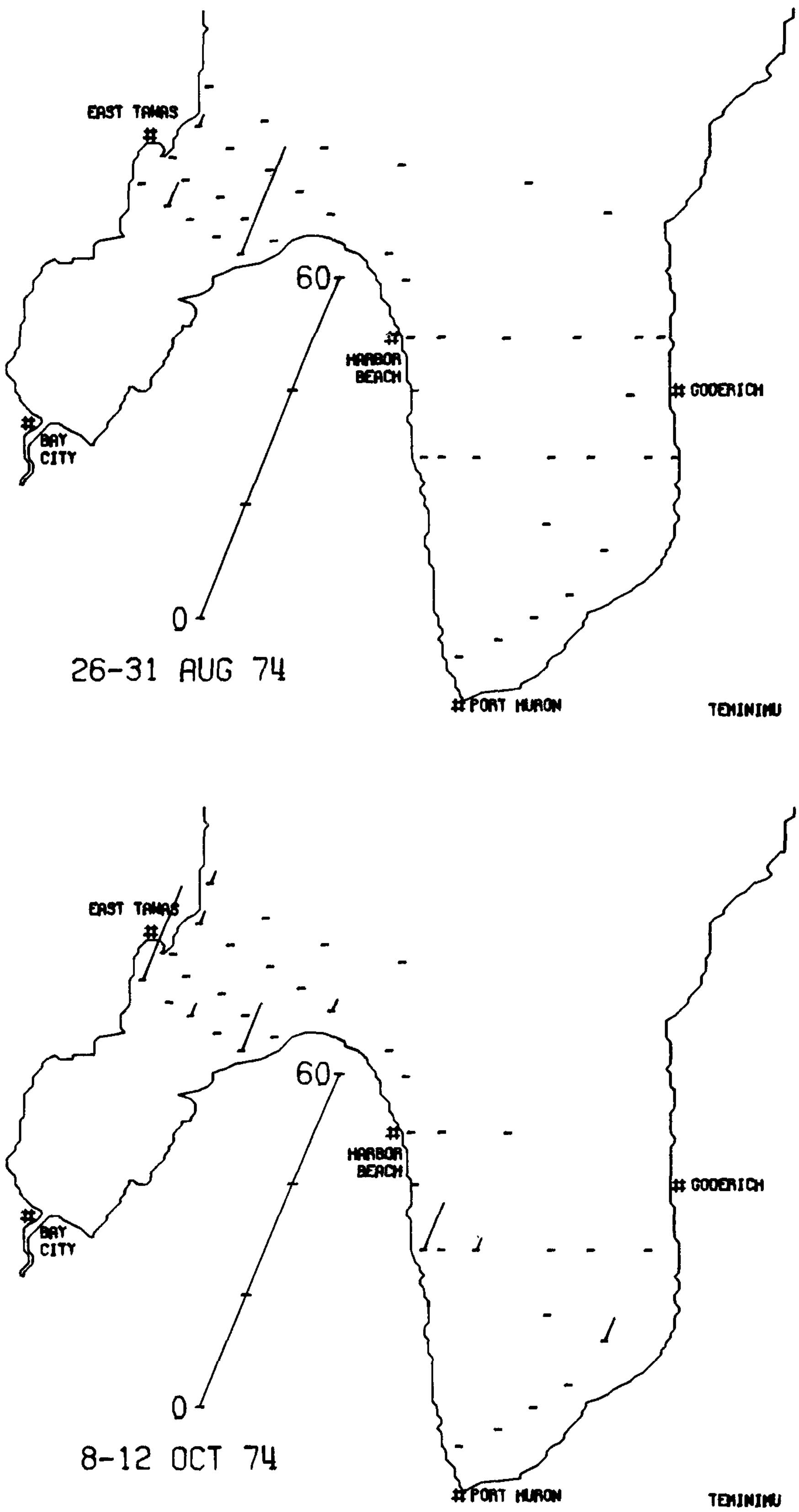

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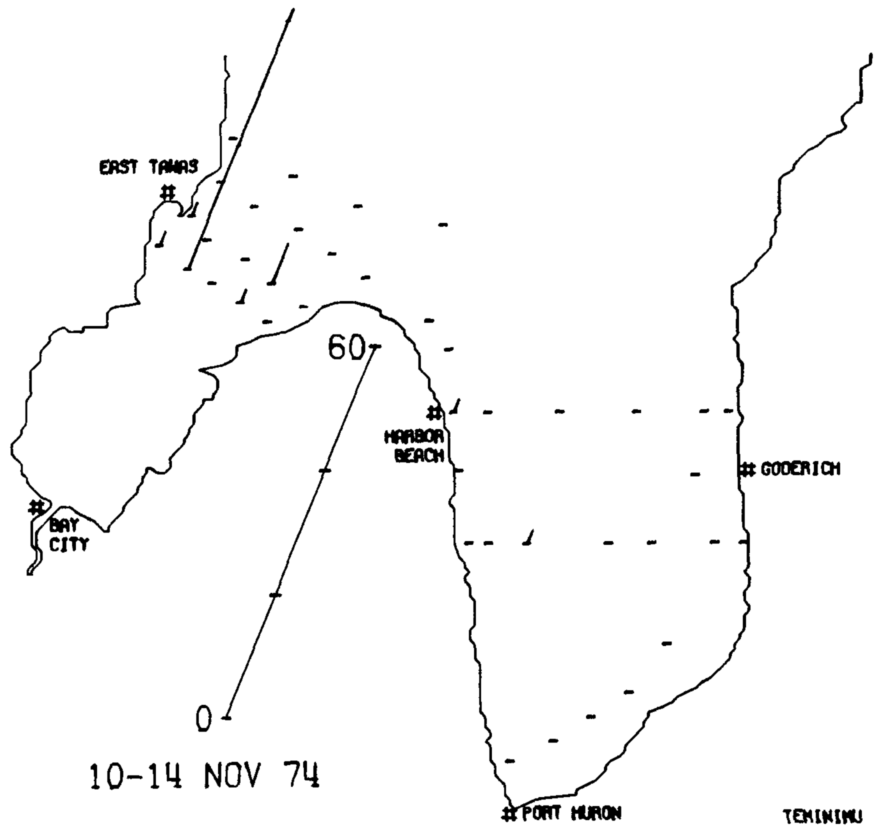
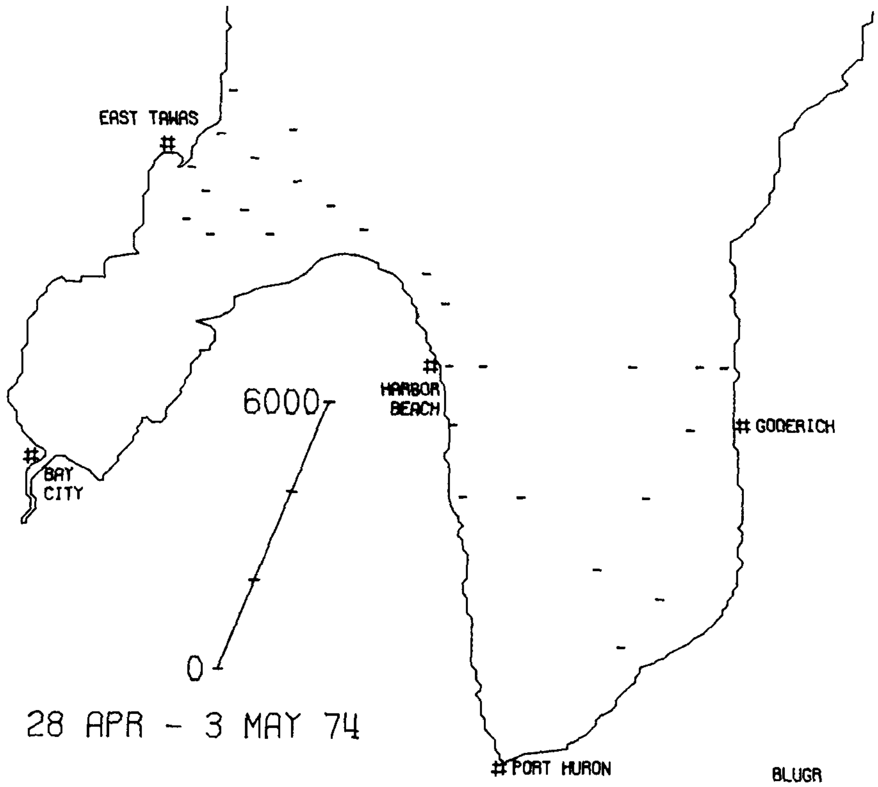


Figure 47. (continued)

were found at most stations sampled throughout the lake. By November (Fig. 48H), blue-green algal abundance was reduced; however, significant populations were still found at most stations sampled.

Anabaena flos-aquae

This species is a common minor component of phytoplankton assemblages in the upper Great Lakes, and generally reaches very high abundance only in areas which have been significantly eutrophied. Estimates of its distribution are somewhat confounded by the fact that it is a gas-vacuole-forming species and often develops in very patchy surface blooms. In southern Lake Huron, it was first noted during the early June sampling cruise (Fig. 49A) when small populations were found at most of the inner stations in the Saginaw Bay interface, and a large bloom was found at station 49. By late June (Fig. 49B), this species was abundant at several stations in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast. Abundance was reduced in the July samples (Fig. 49C), and only small populations were found at a few stations in the Saginaw Bay interface. In August (Fig. 49D), a large bloom occurred at station 48 and smaller populations were found in the Saginaw Bay interface and at a few stations in the southeastern sector of the lake along the Canadian coast. During October (Fig. 49E), abundance of this species was reduced and distribution was erratic; by November (Fig. 49F), it was essentially absent from southern Lake Huron. This species is macroscopic and readily observable in the surface waters of the column. It possibly could be used to visually trace the transport of water from the bay. In an ancillary study, we found amounts in the 1 m samples in excess of four times those of the 5-m samples, demonstrating the species' buoyancy, and its preference for surface waters.



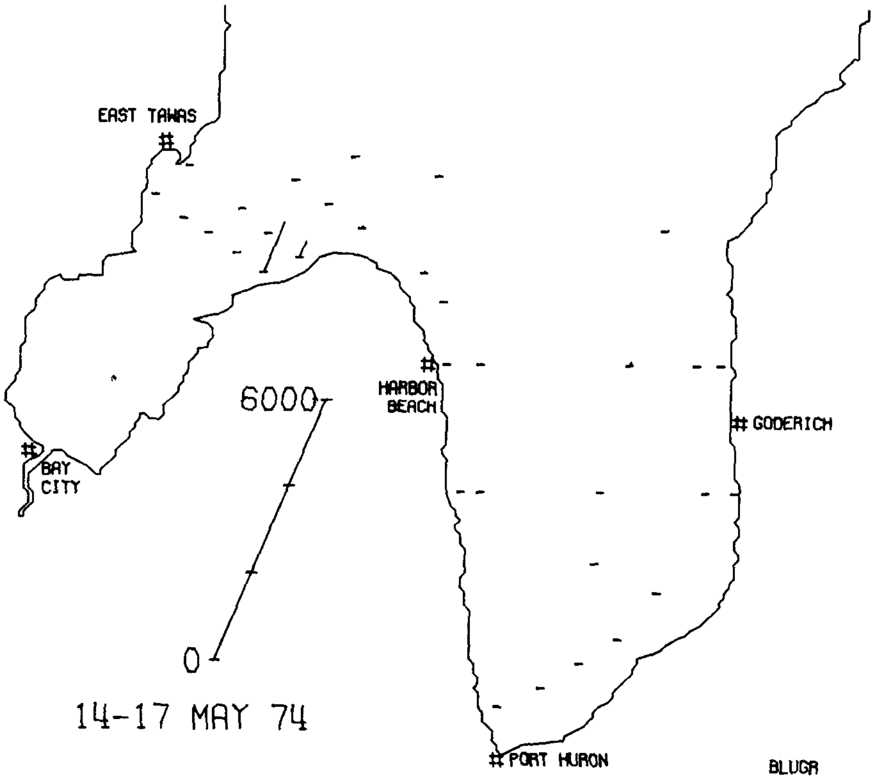
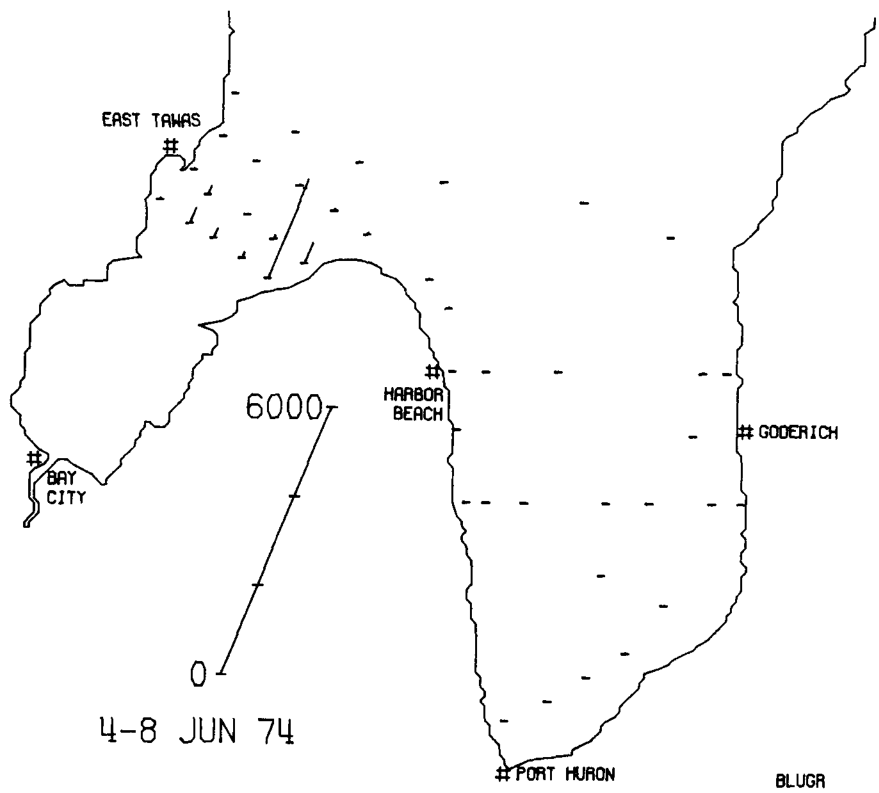


Figure 48. Seasonal abundance and distribution trends of blue-green algae. (continued)



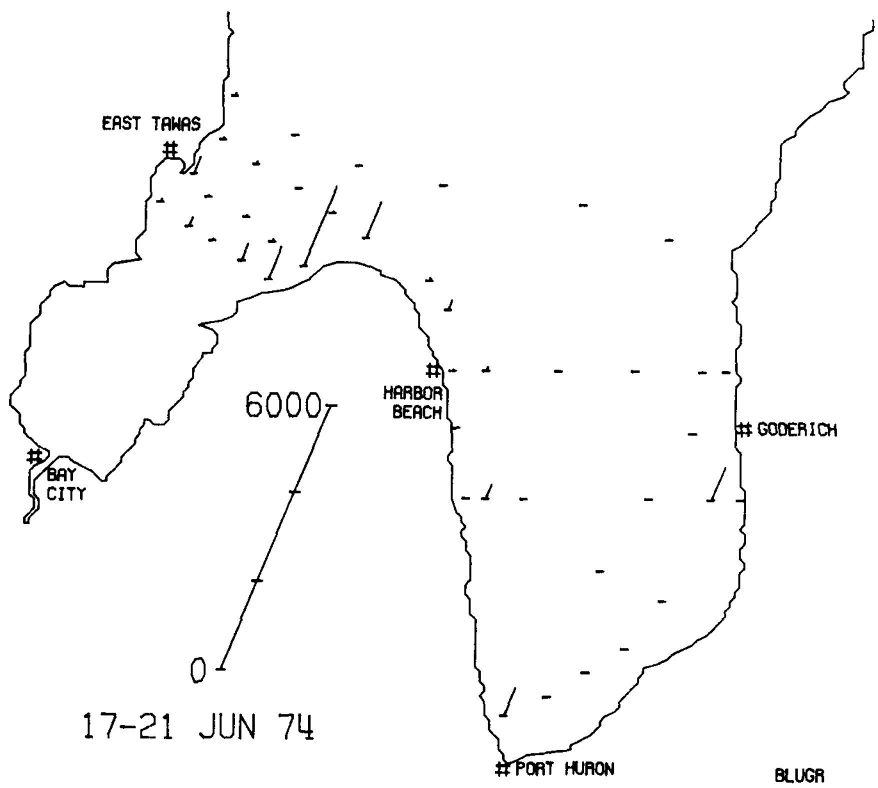


Figure 48. (continued)

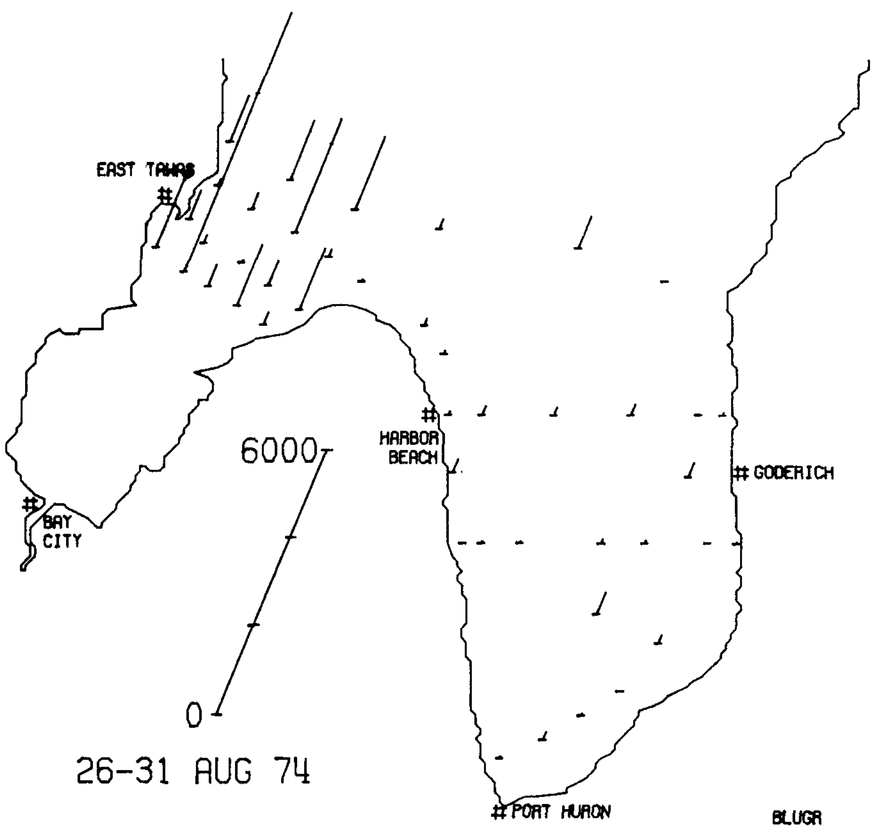
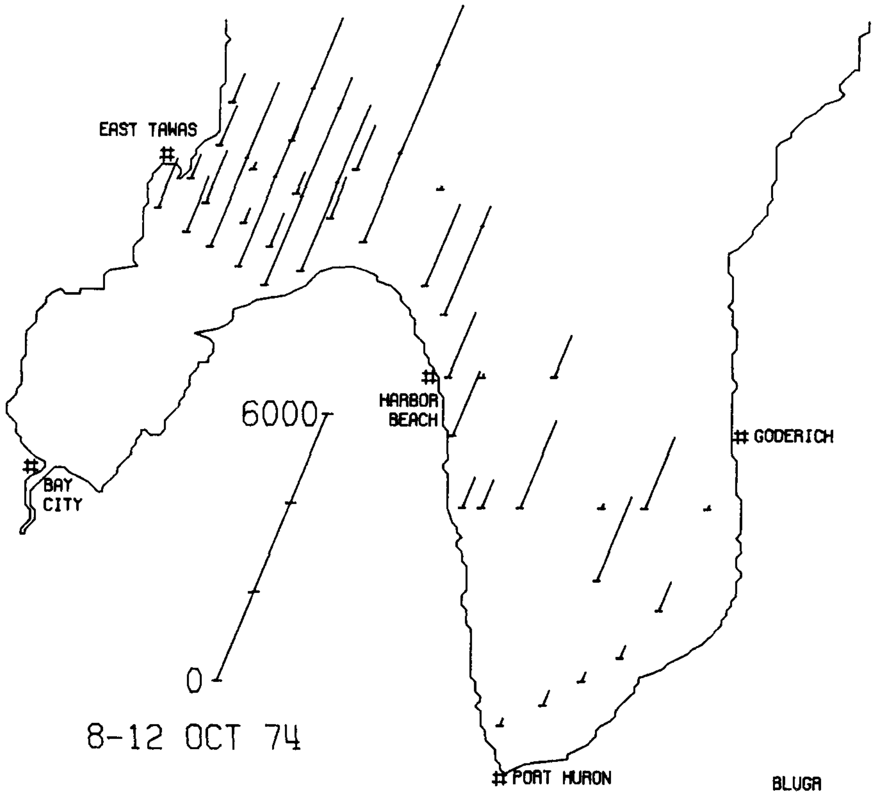


Figure 48. (continued)



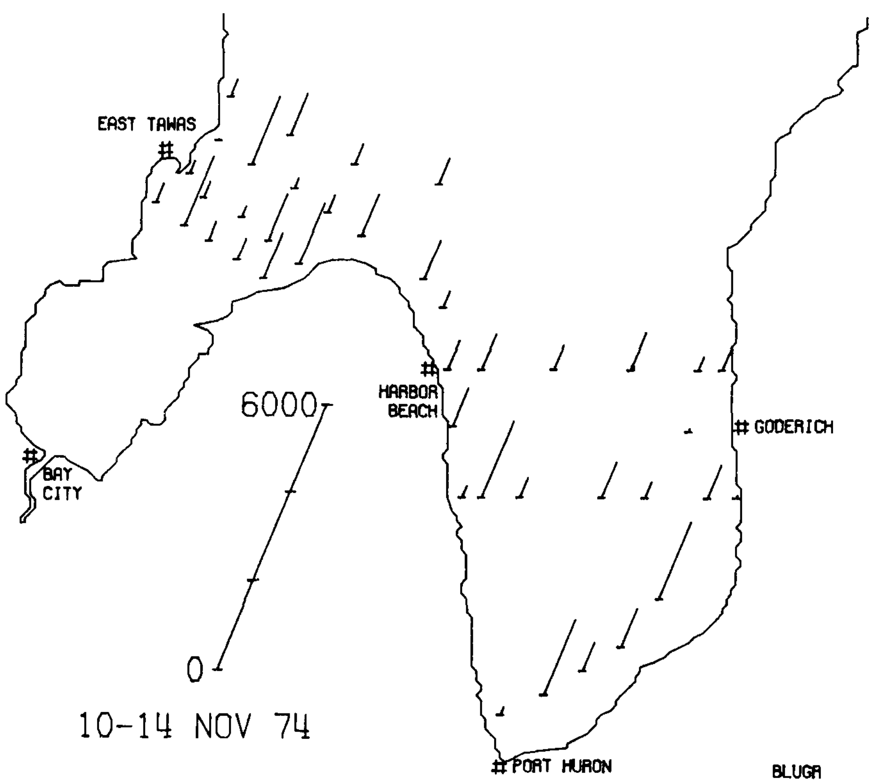
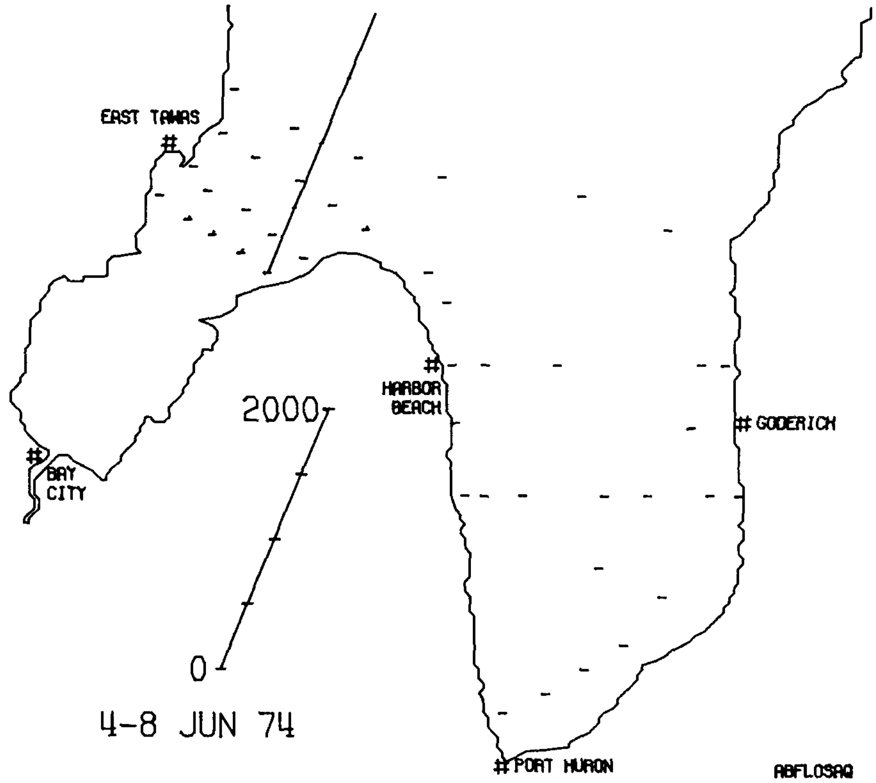


Figure 48. (continued)



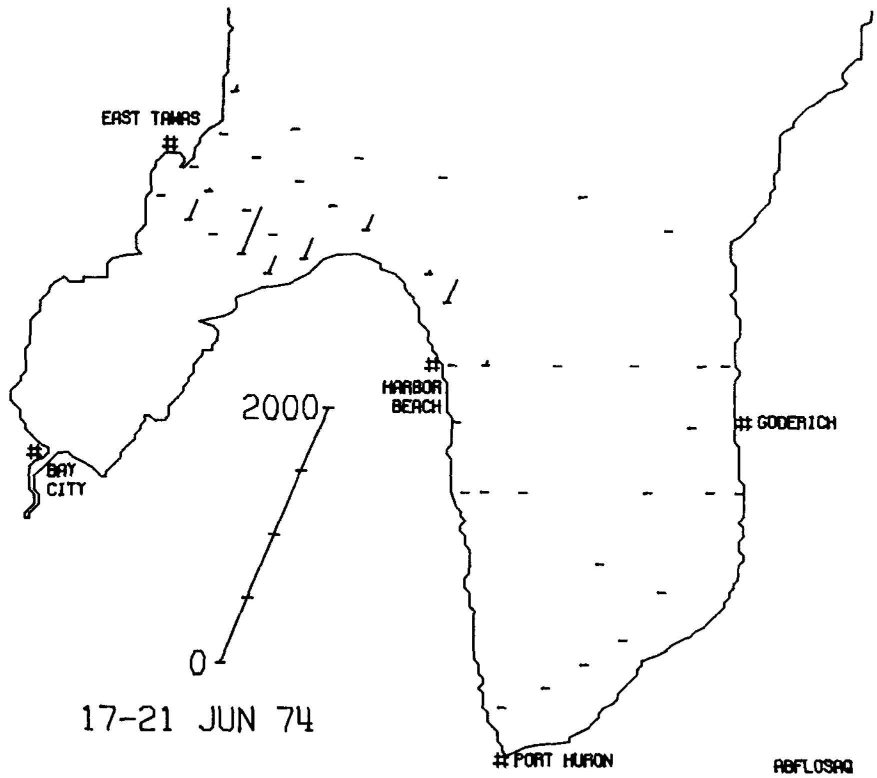


Figure 49. Distribution of <u>Anabaena flos-aquae</u>. (continued)

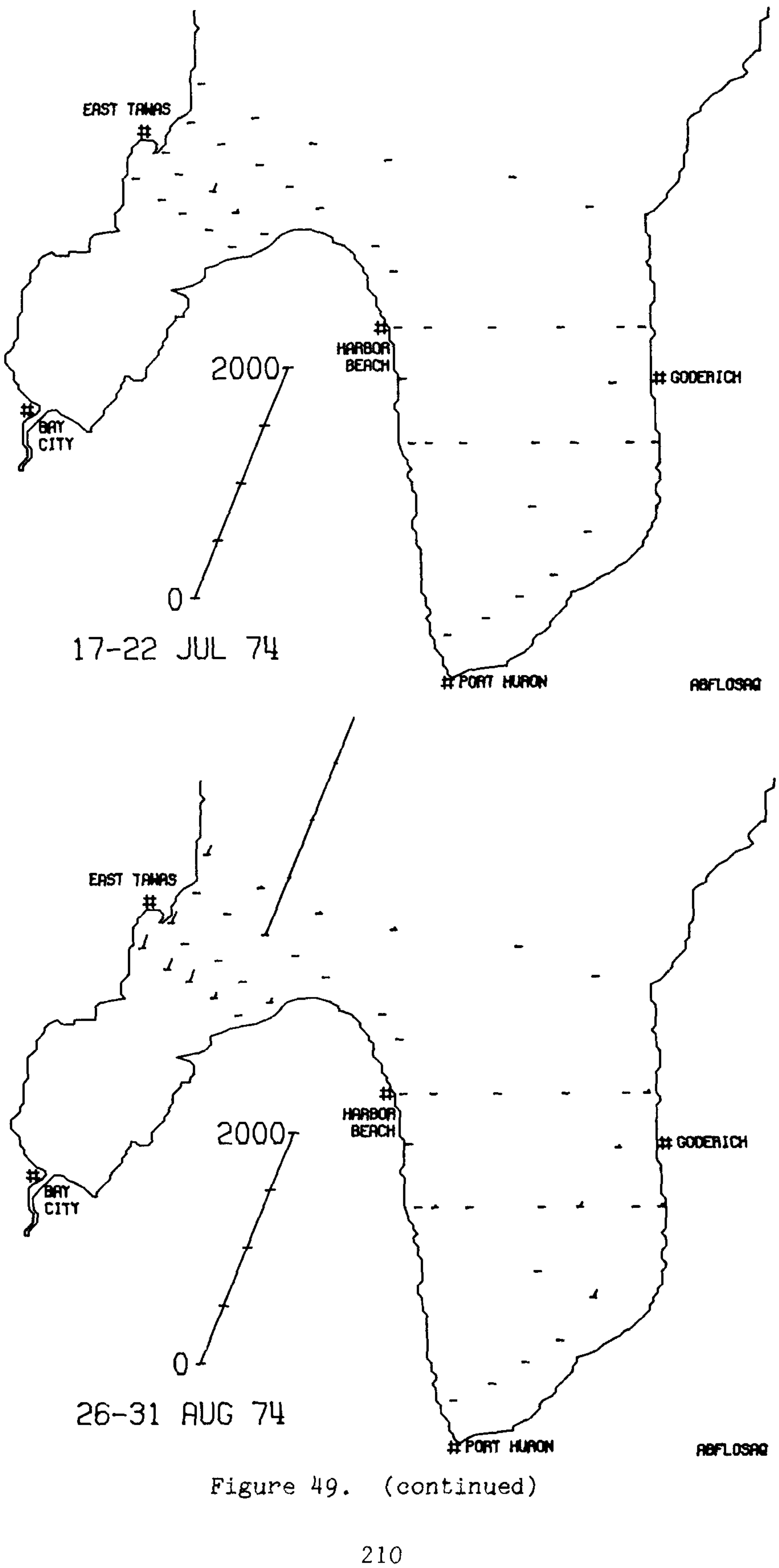
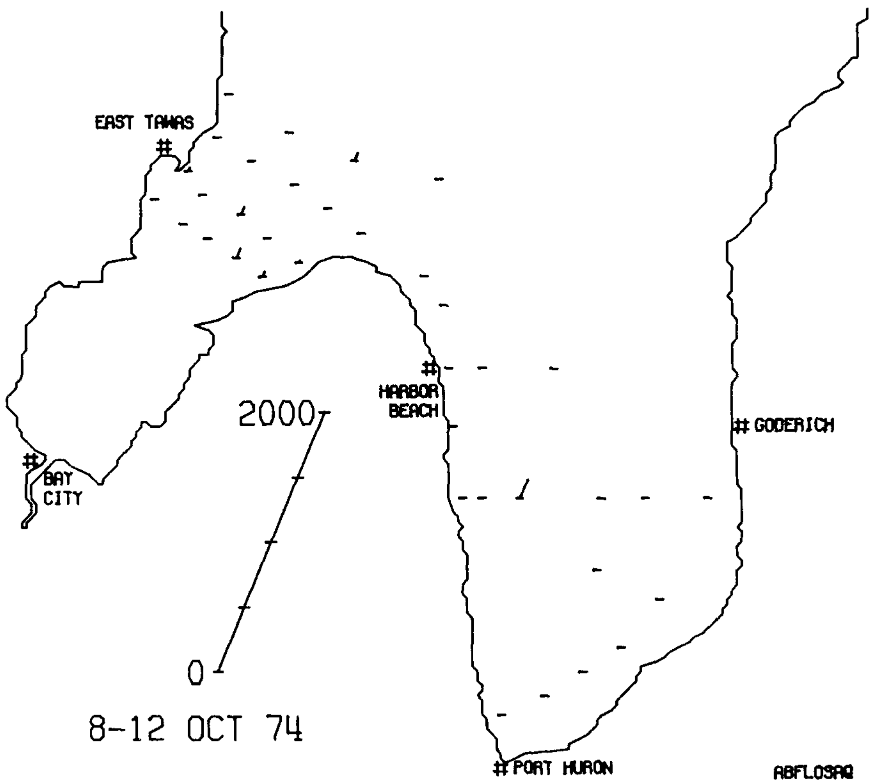


Figure 49. (continued)



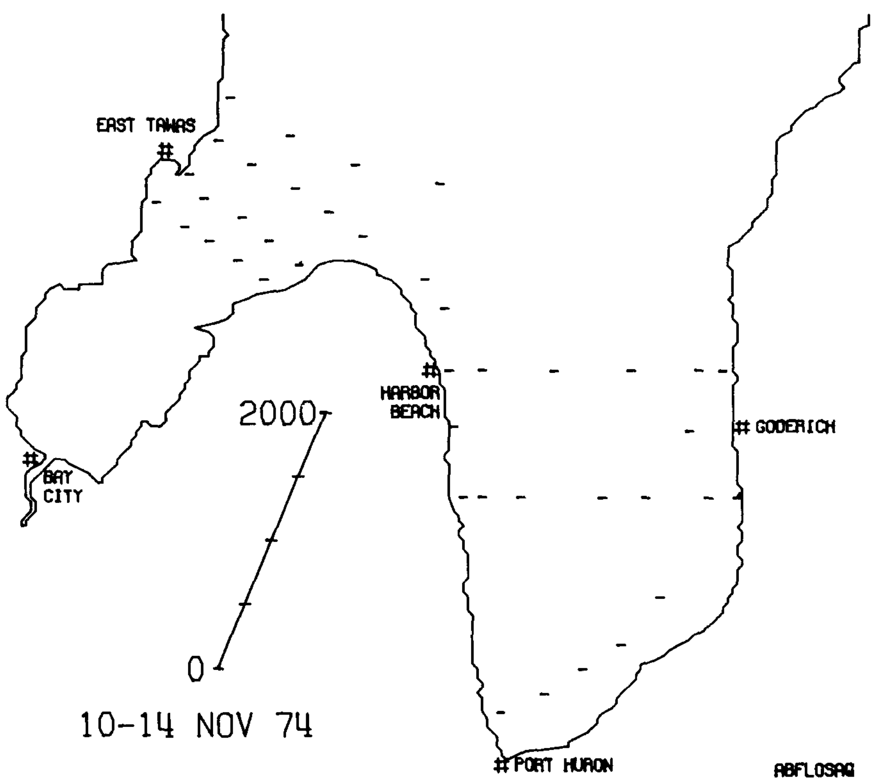


Figure 49. (continued)

Anabaena subcylindrica

The distribution and autecology of this species is very poorly known. However, it has been particularly associated with water masses derived from Saginaw Bay (Schelske et al., 1974). In our samples, it was present in very limited abundance during May (Fig. 50A-B), and only slightly more abundant (although more widely distributed) during early June (Fig. 50C). In July (Fig. 50D), it was present in high abundance at a few stations in the southern sector of the Saginaw Bay interface waters. It was almost equally abundant in August (Fig. 50E), but its highest population densities were found at stations in the northern sector of the Saginaw Bay interface and northward along the Michigan coast. Populations of this species were considerably reduced by the time the October (Fig. 50F) samples were taken; it was essentially absent from samples taken after this date.

Anacystis cyanea

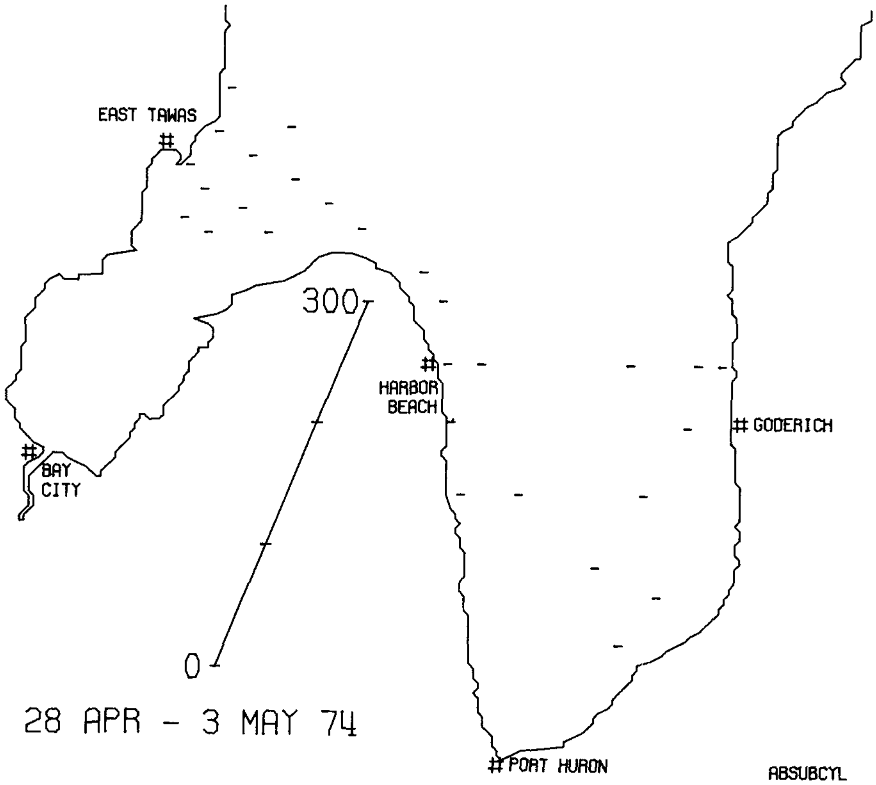
This species is one of the blue-green algae capable of forming the classical nuisance blooms often found in small eutrophic lakes. In the Laurentian Great Lakes, it is rare except in areas which have been highly disturbed. Its distribution in southern Lake Huron is very limited, largely restricted to areas directly affected by the outflow from Saginaw Bay. In July, a large population was found at station 40 (Fig. 51A), and in August a large population was found at station 37 (Fig. 51B). During both of these months, other occurrences were small and limited to stations in the Saginaw Bay interface. Maximum abundance of this species in southern Lake Huron occurred during October (Fig. 51C). It was present in highest abundance at several stations in the southerly sector of the Saginaw Bay interface during that month. By November (Fig. 51D), its distribution was restricted to only two stations, again in the southerly sector of the Saginaw Bay interface waters.

Anacystis incerta

Unlike A. cyanea, this species is not particularly uncommon in the offshore waters of the Great Lakes and may be quite abundant in areas that have been significantly disturbed. Although reported as capable of forming nuisance blooms (Drouet and Daily, 1956), it has not been observed to do so in the Great Lakes. Its seasonal pattern is somewhat unusual for a blue-green alga, in that it generally reaches peak abundance late in the fall, with significant populations surviving into the winter months (Stoermer et al., 1974). In southern Lake Huron, isolated populations were found in mid-May, early June, and late June (Fig. 52A-C), but it was absent from July samples (Fig. 52D). Several large and erratically distributed populations were noted during the August sampling (Fig. 52E), and the species reached its peak abundance during October (Fig. 52F) when significant populations were present at most stations sampled. Abundance was somewhat reduced in the November samples (Fig. 52G), although it was still present in significant abundance at a number of stations.

Anacystis thermalis

This species is a common minor element of phytoplankton assemblages in mesotrophic to marginally eutrophic lakes. It is often quite abundant in regions of the Great Lakes that have been sufficiently eutrophied to induce silica limitation, but is generally not a dominant element of the flora in



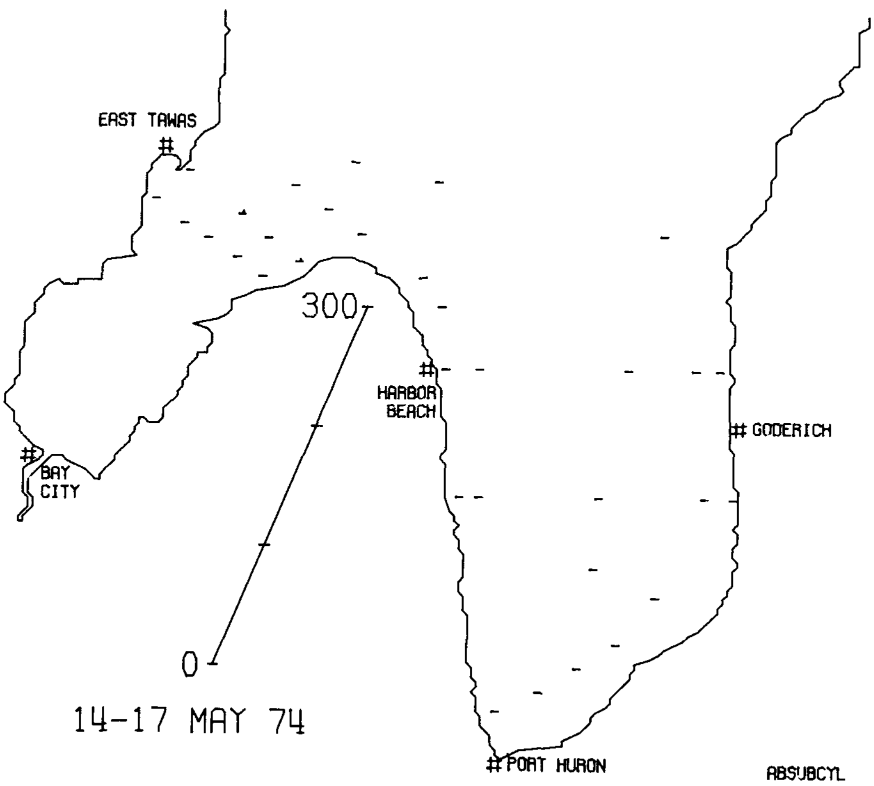
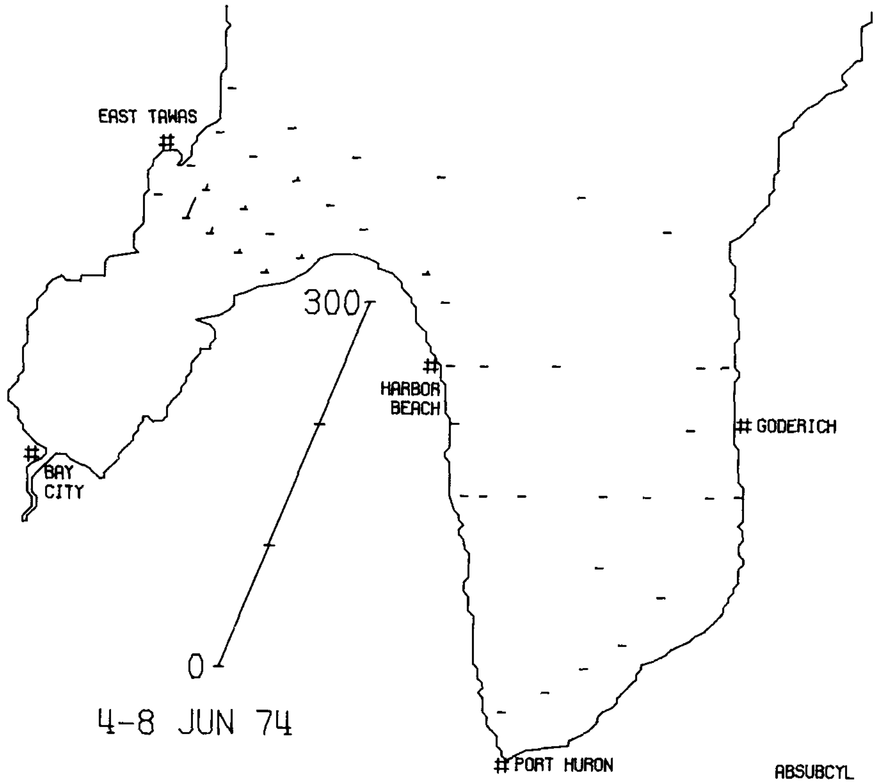


Figure 50. Distribution of *Anabaena subcylindrica*. (continued)



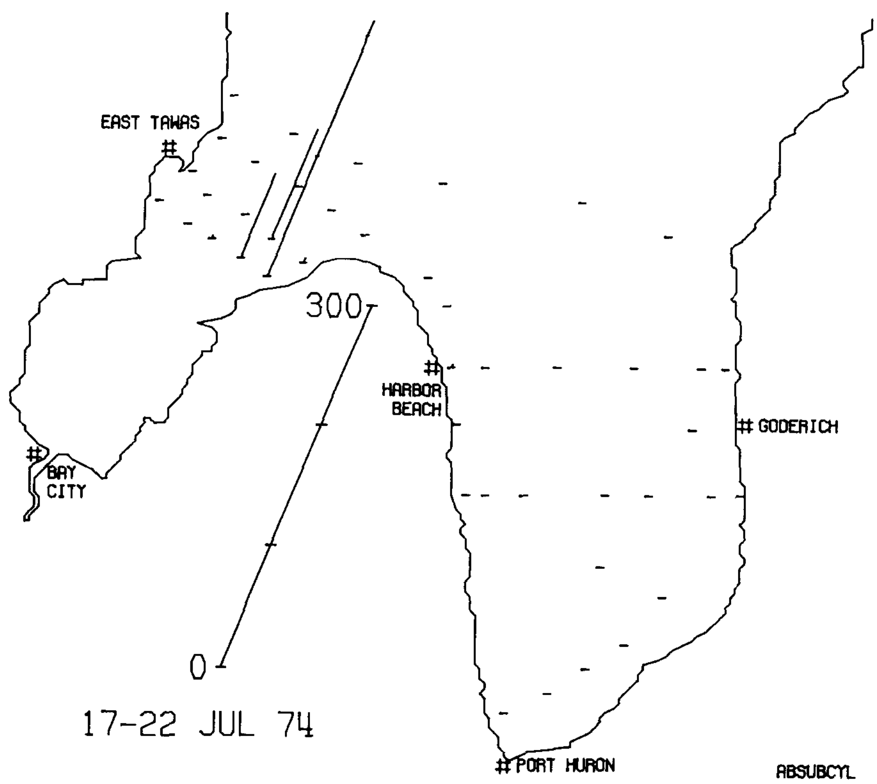
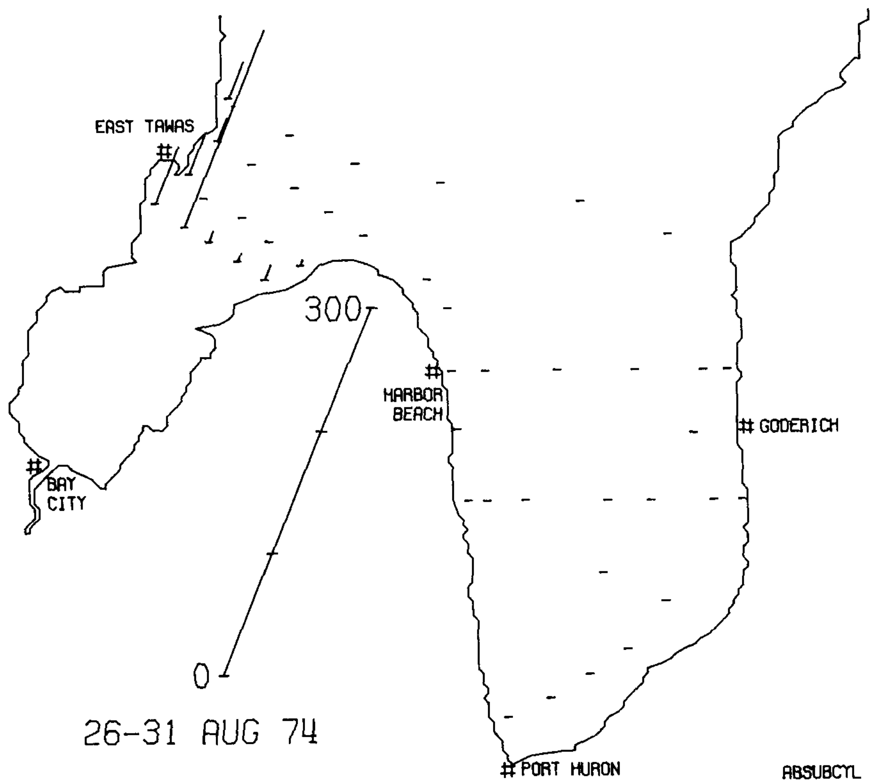


Figure 50. (continued)



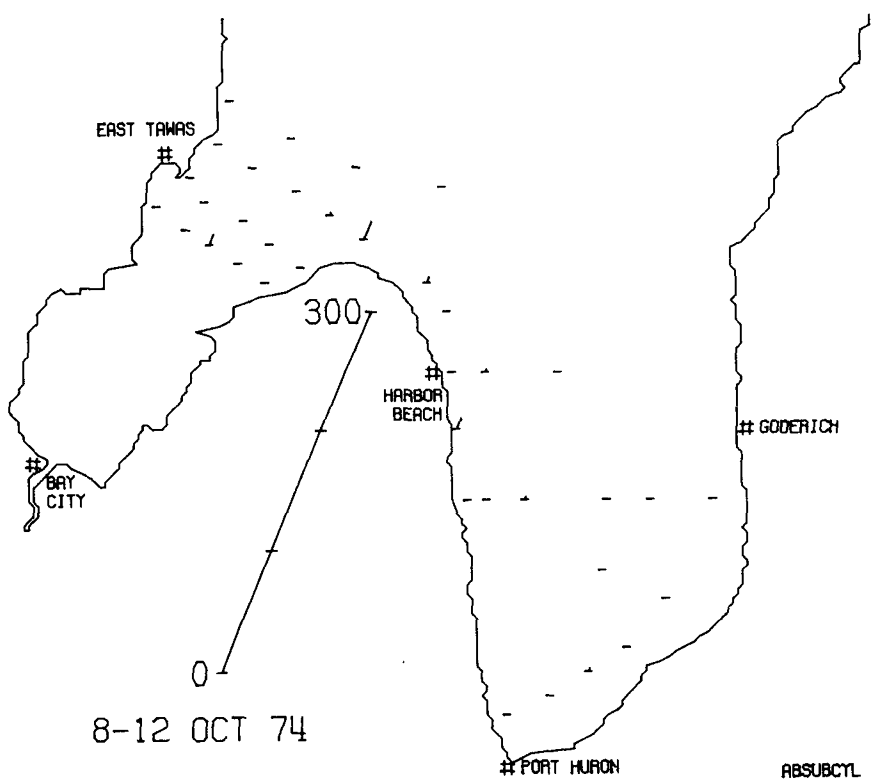
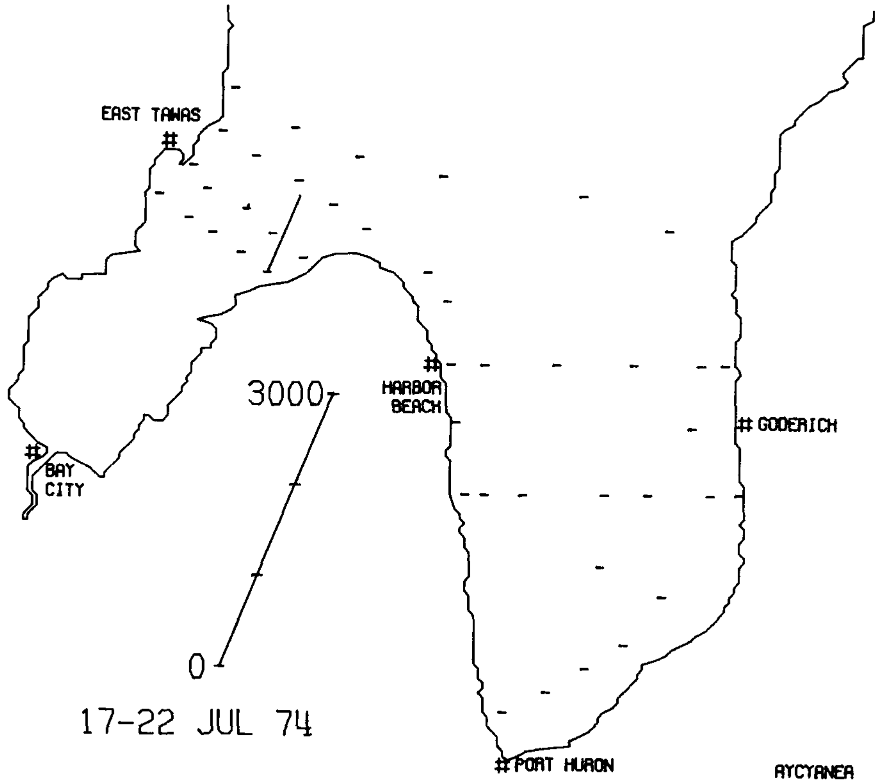


Figure 50. (continued)



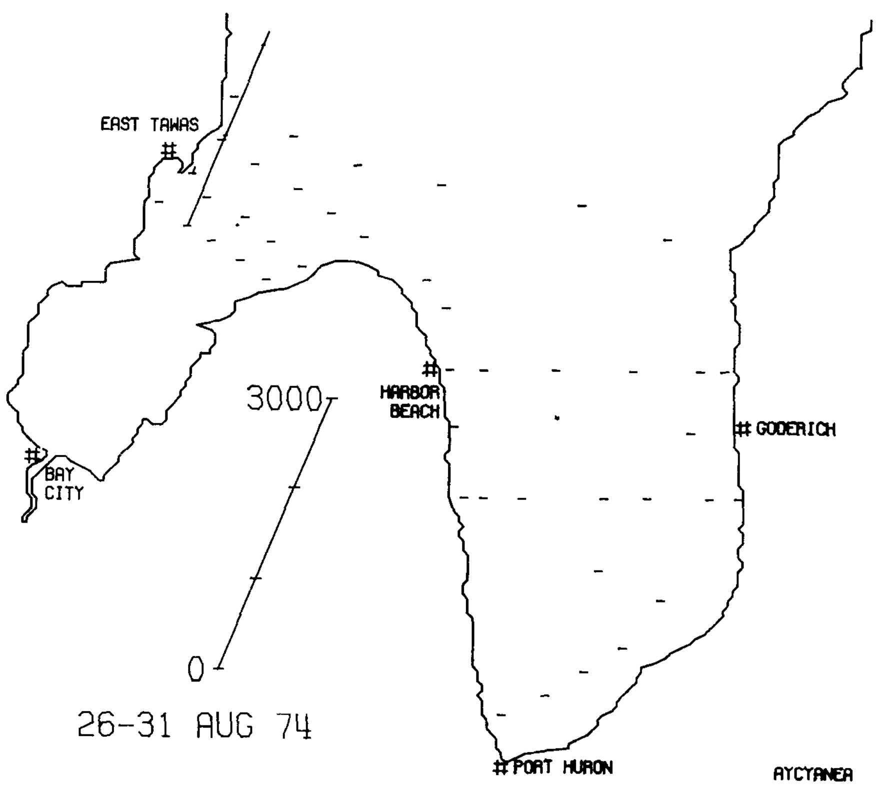
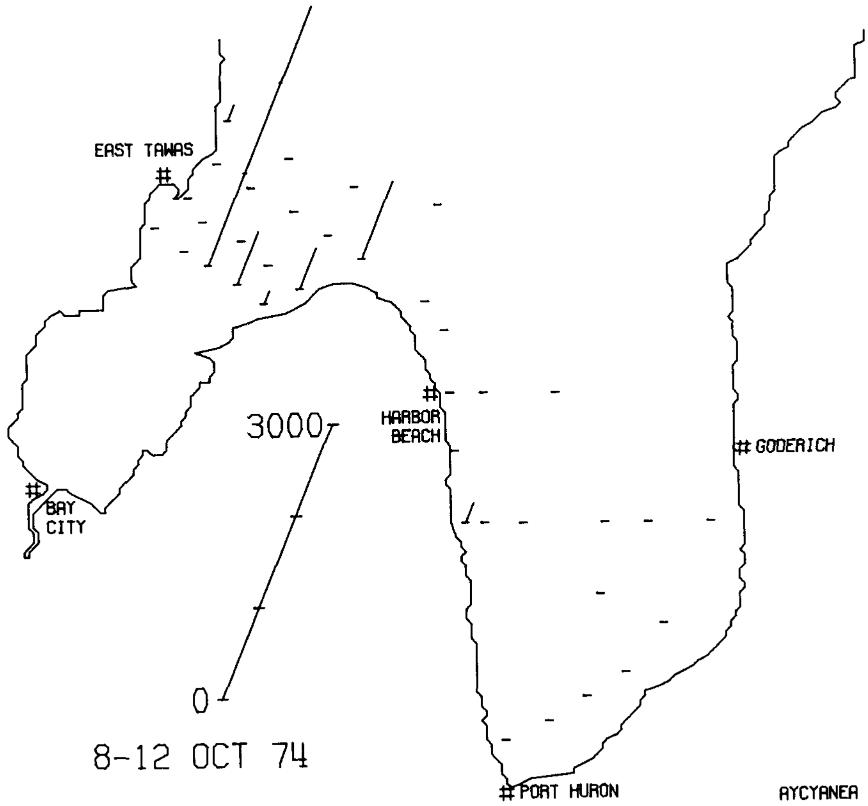


Figure 51. Distribution of *Anacystis cyanea*. (continued)



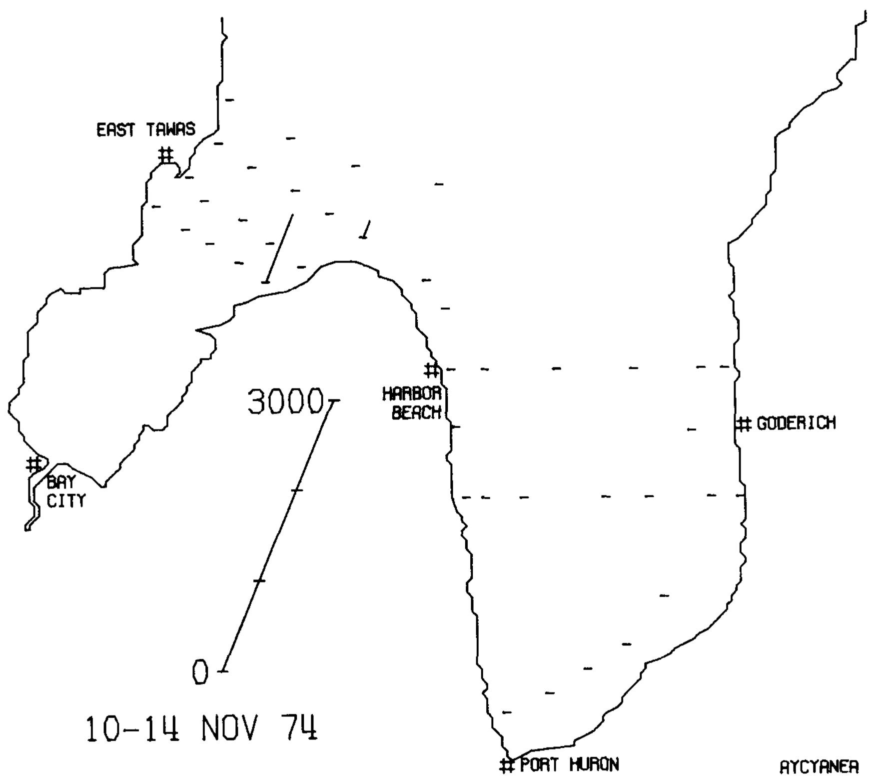
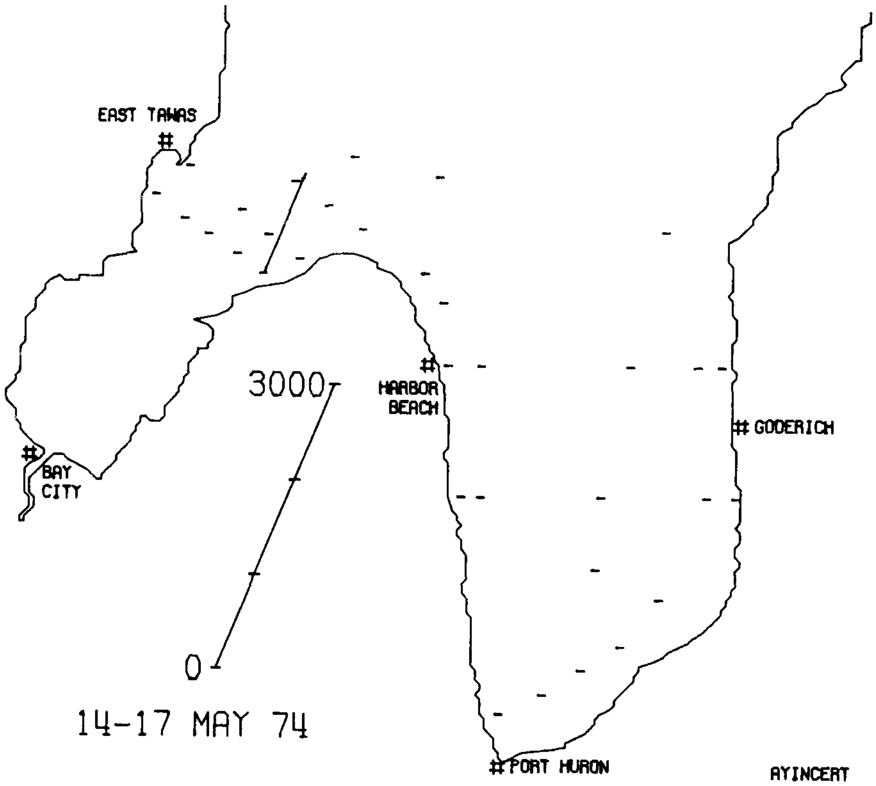


Figure 51. (continued)



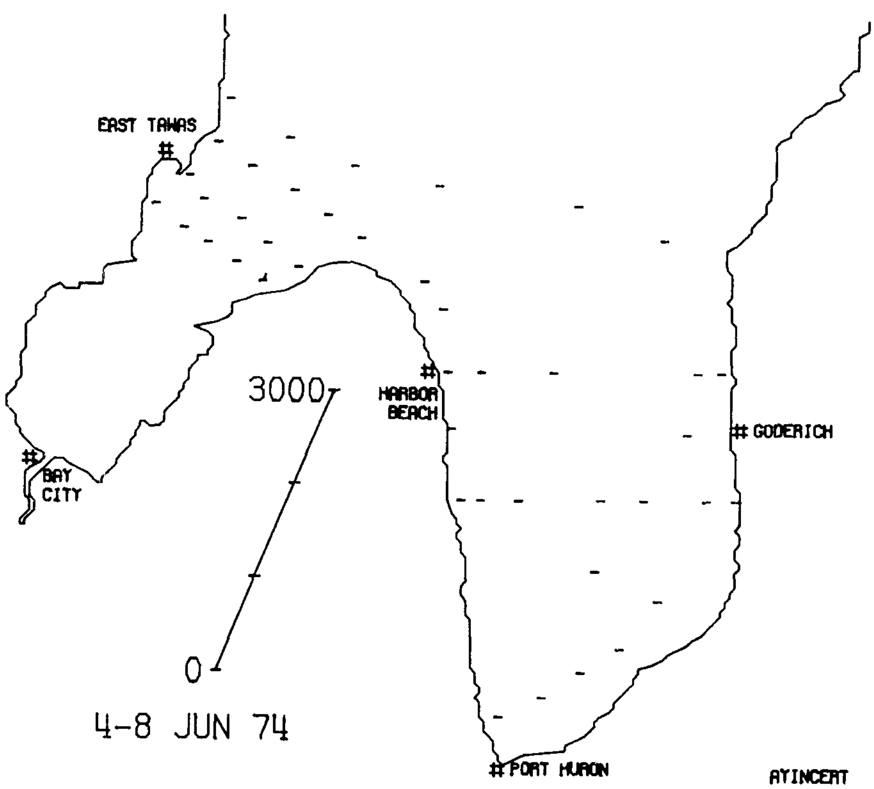
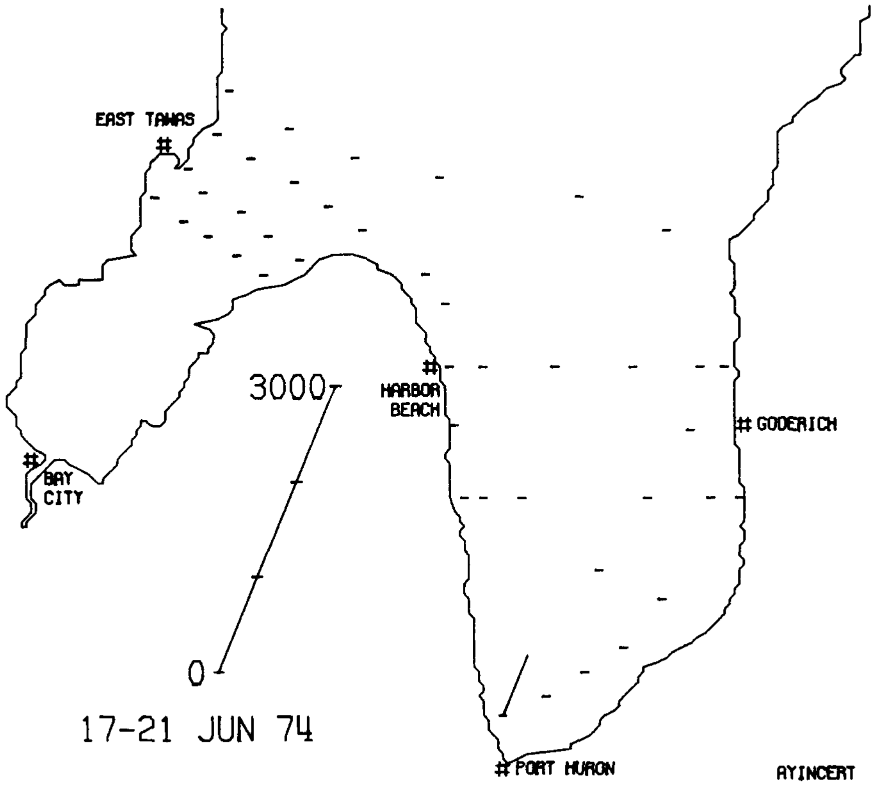
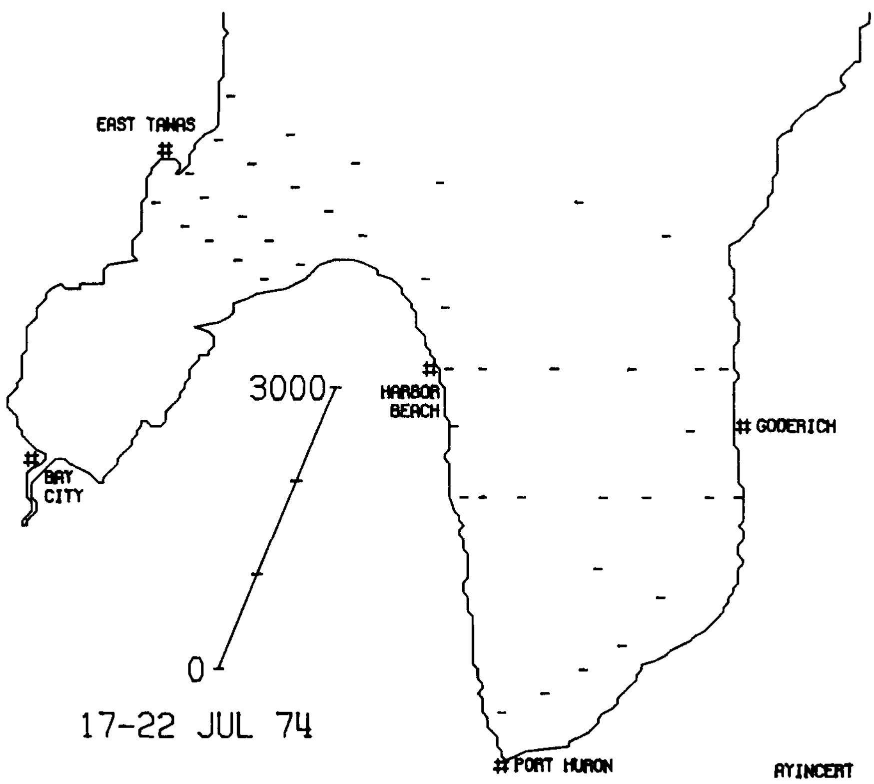


Figure 52. Distribution of Anacystis incerta. (continued)





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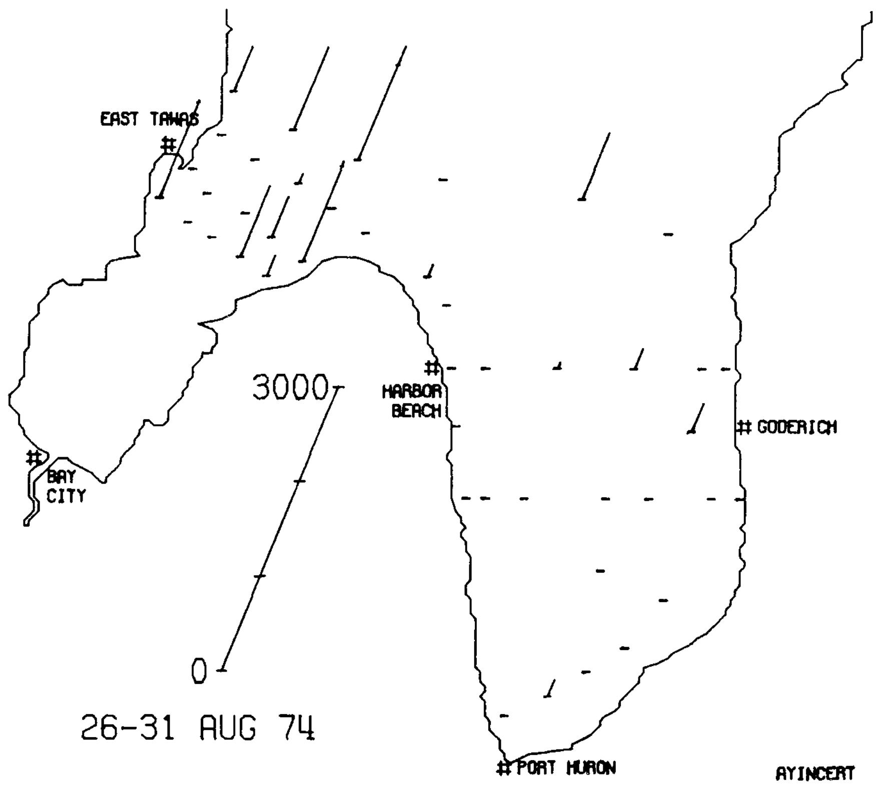

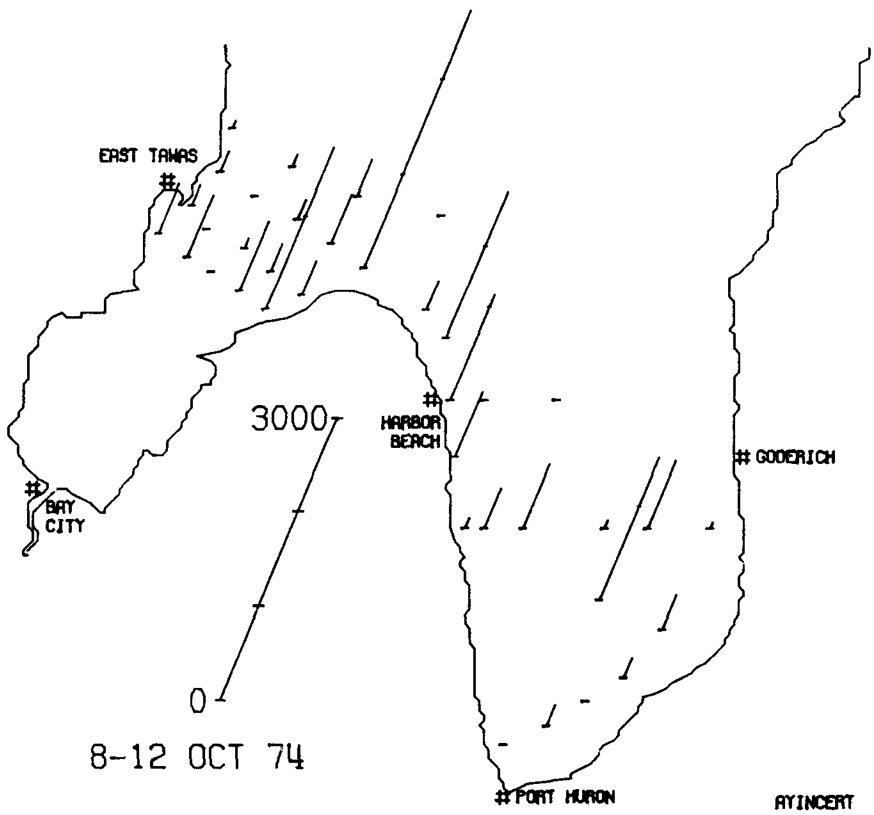

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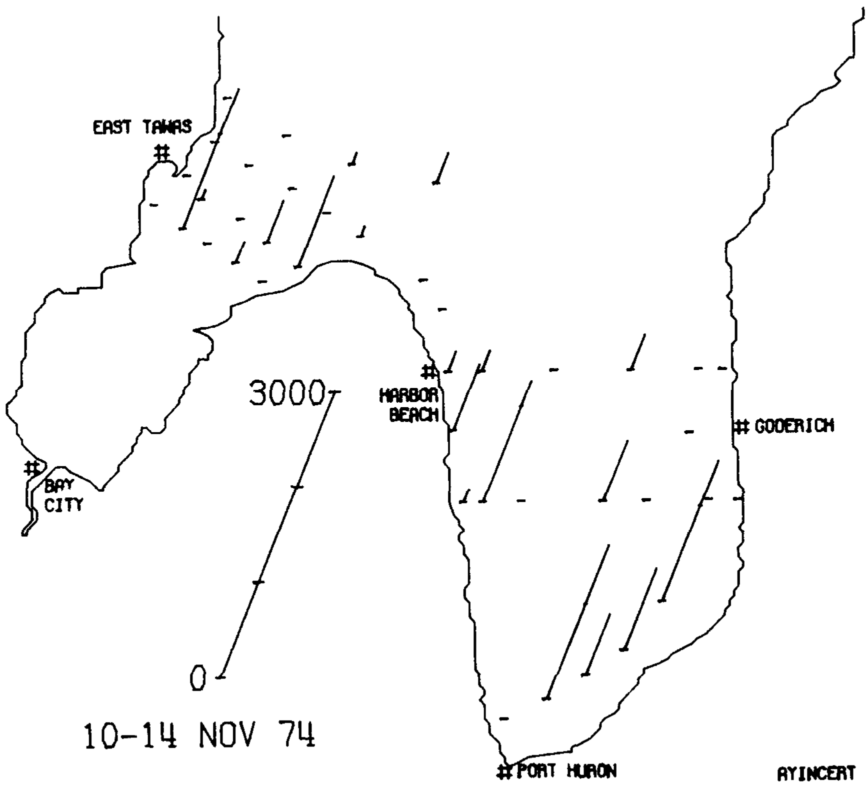
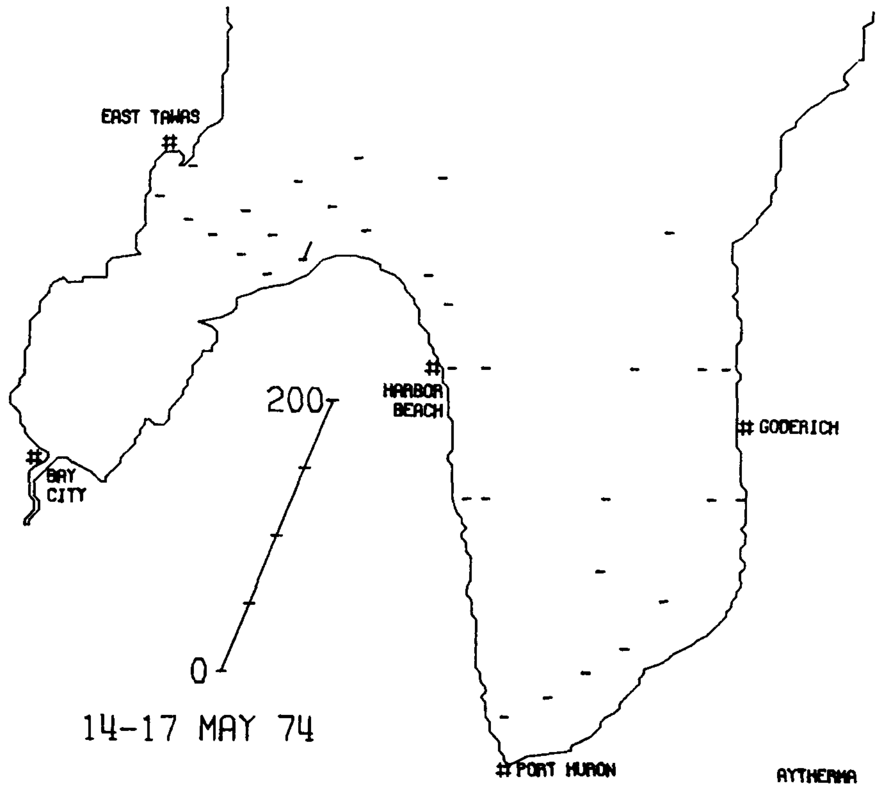


Figure 52. (continued)

regions which have been grossly perturbed. In southern Lake Huron, only scattered isolated populations were found during the mid-May, June, and July cruises (Fig. 53A-D). During August (Fig. 53E), it was present at most stations sampled, and abundant at several stations north of the Saginaw Bay interface. It reached its maximum abundance during October (Fig. 53F) when significant populations were present at most stations sampled throughout the lake. Abundance of this species had been reduced by the time the November samples were taken (Fig. 53G), although it was still present at the majority of the stations sampled, and abundant at some stations in the southern part of the sampling array.

Aphanizomenon flos-aquae

This species is a primary contributor to nuisance blue-green algal blooms in highly eutrophic environments. In the Laurentian Great Lakes, its distribution is restricted to highly disturbed areas. In southern Lake Huron, small populations were found in the Saginaw Bay interface waters during the early and late June cruises (Fig. 54A-B). By the time July samples were taken (Fig. 54C), population densities had increased somewhat at stations in the southerly sector of the Saginaw Bay interface waters. Even higher abundance was found during the August cruise (Fig. 54D); however, at this time, maximum abundance occurred at stations in a northerly sector of the Saginaw Bay interface. Maximum abundance of this species occurred during the August cruise



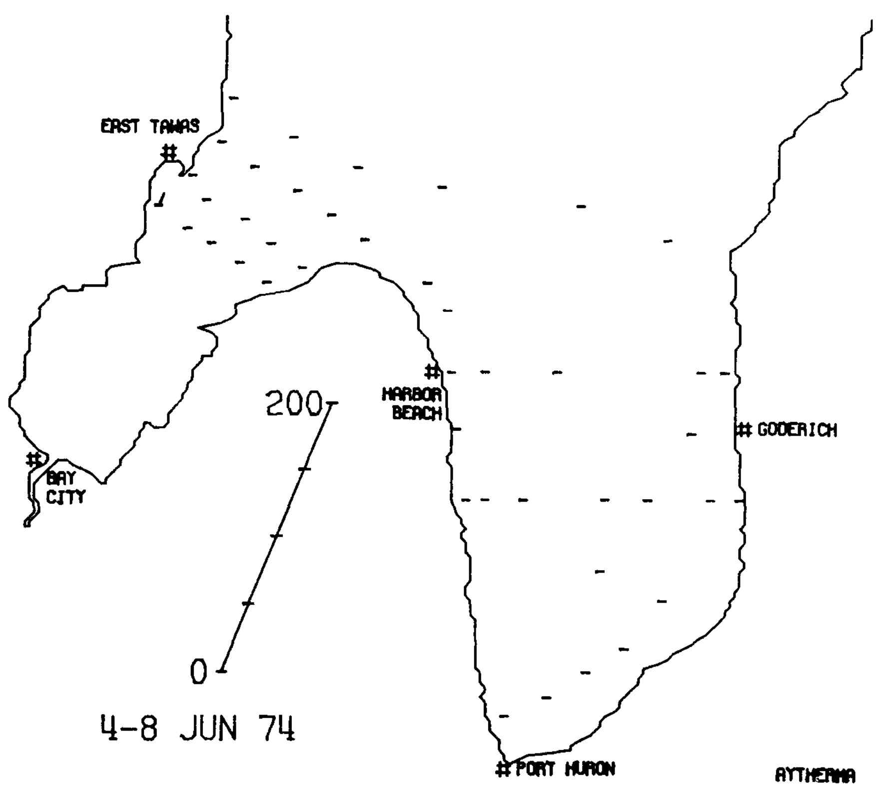
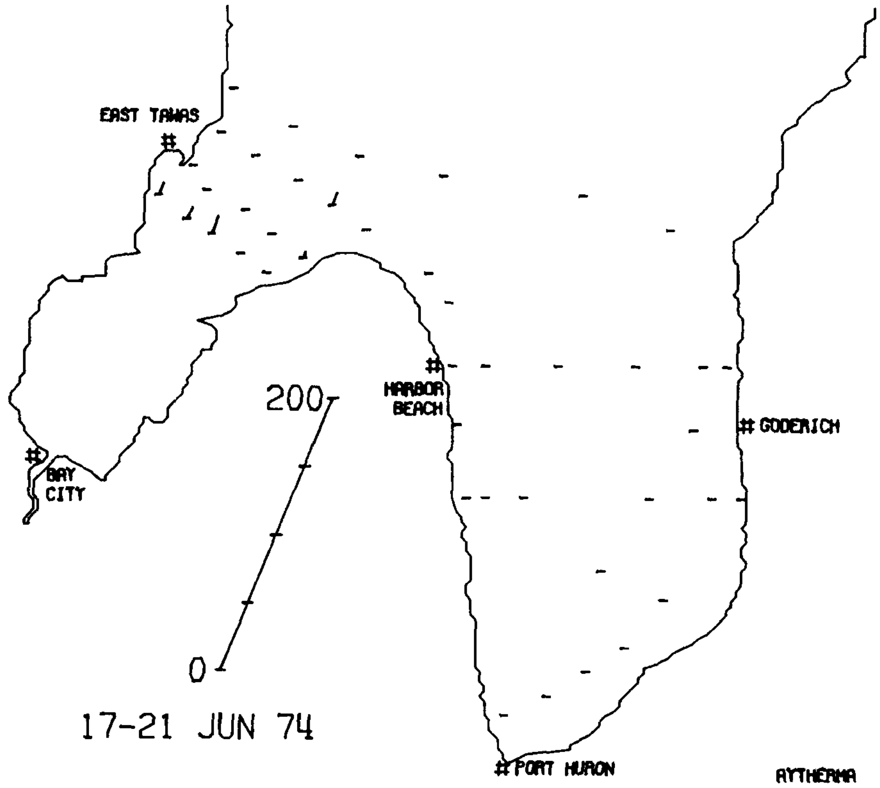


Figure 53. Distribution of *Anacystis thermalis*.
(continued)



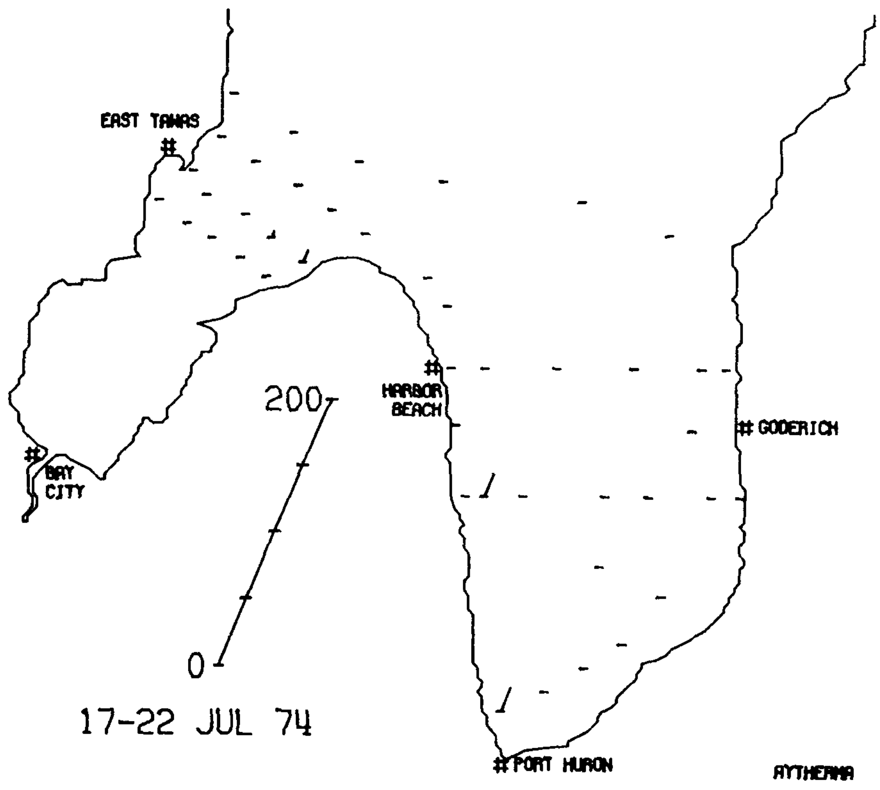
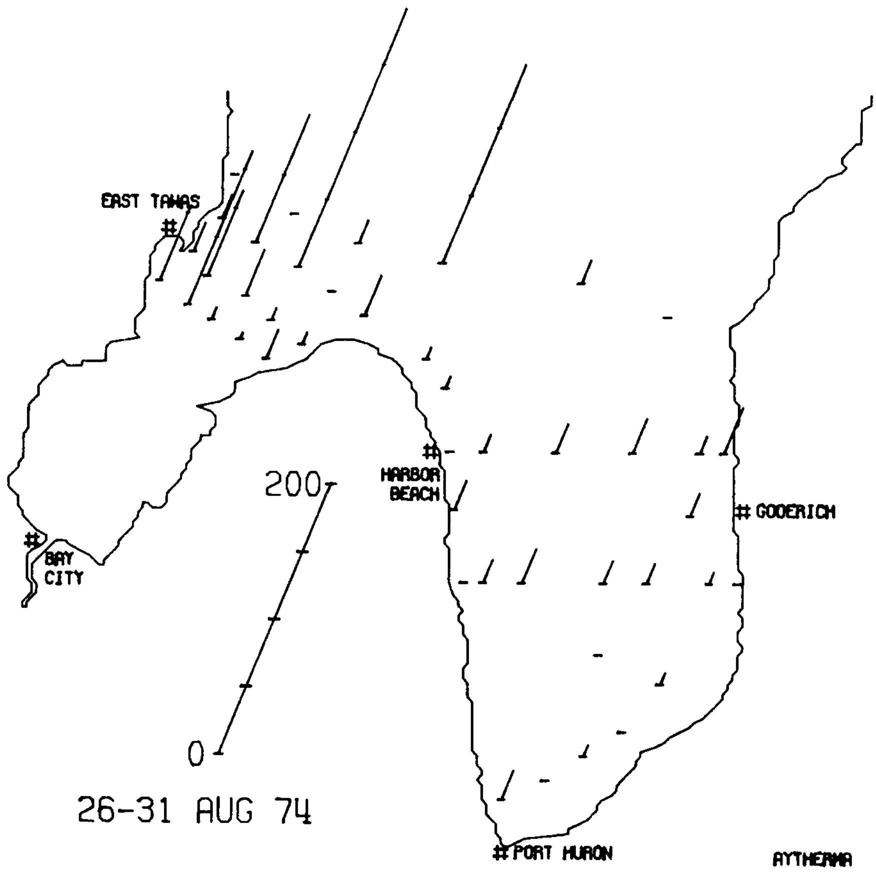
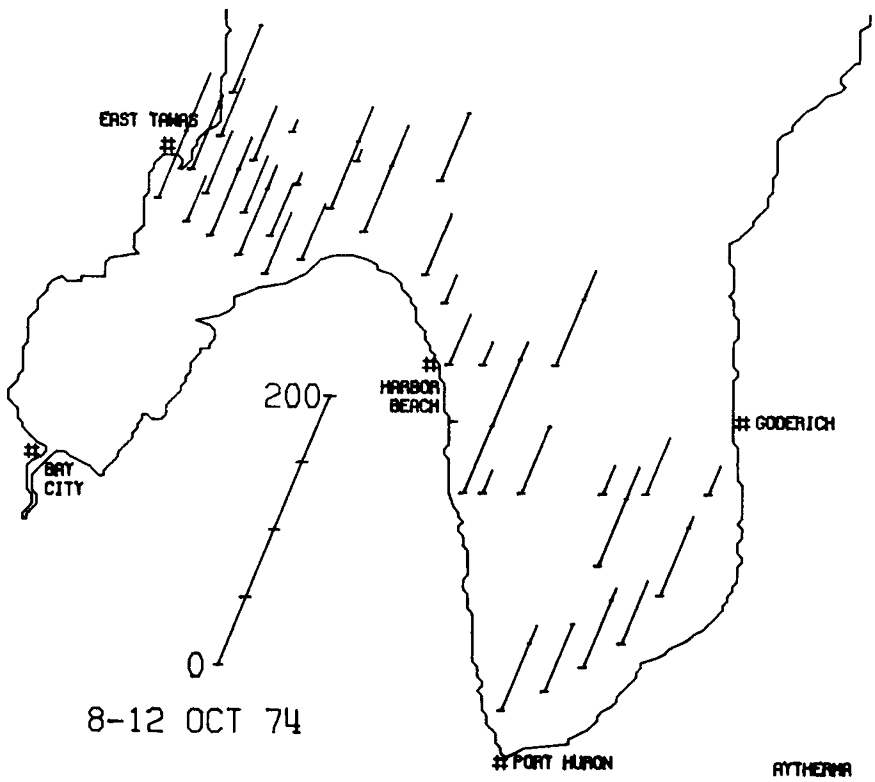


Figure 53. (continued)





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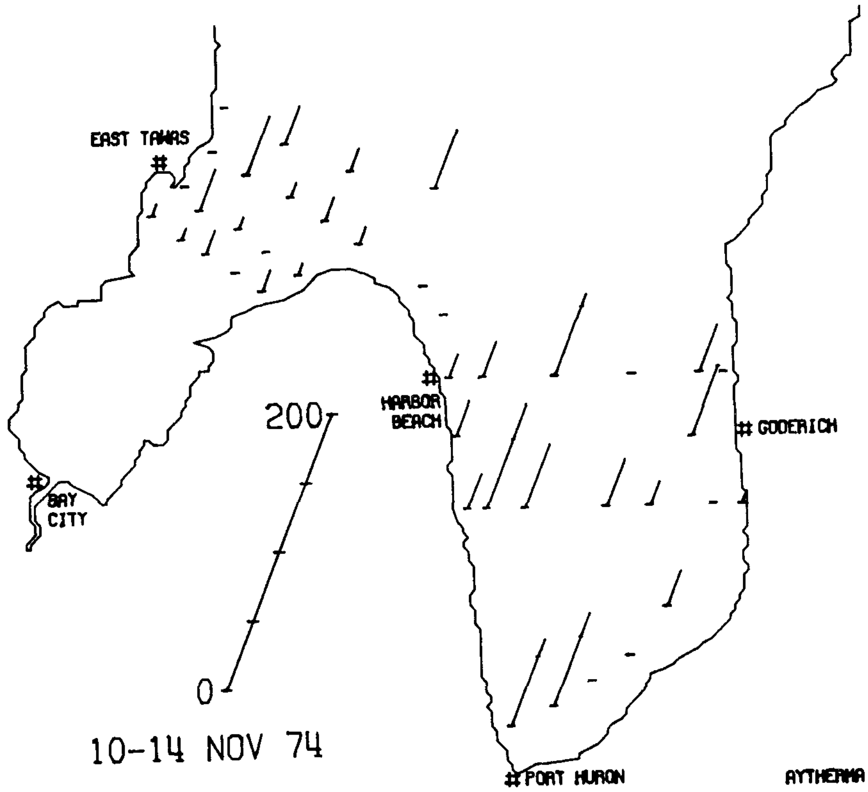


Figure 53. (continued)

(Fig. 54E) when large populations were present in samples in the southerly sector of the Saginaw Bay interface waters and southward along the Michigan coast. Abundance of A. flos-aquae had declined significantly by the time the November samples were taken (Fig. 54F). Small populations were found, however, at offshore stations as far east as Station 11, apparently as a result of dispersion of this organism from Saginaw Bay.

Gomphosphaeria lacustris

This species is a common component of summer phytoplankton assemblages in mesotrophic to slightly eutrophic lakes. It commonly occurs in the offshore waters of the Laurentian Great Lakes in low abundance and may become quite abundant in regions where silica has been depleted during summer stratification. It is quite abundant in southern Lake Huron, although its distribution is temporally and spatially erratic. It was first detected during the early June sampling cruise (Fig. 55A) at a few stations in the Saginaw Bay interface waters. In late June (Fig. 55B), it was abundant at a few stations of the southerly sector of the Saginaw Bay interface and at isolated stations outside the thermal bar along both the U.S. and Canadian coasts. Populations were found at a few stations near the Saginaw Bay interface during both July (Fig. 55C) and August (Fig. 55D); during August, small populations were also found at several nearshore stations along the Michigan coast and in the

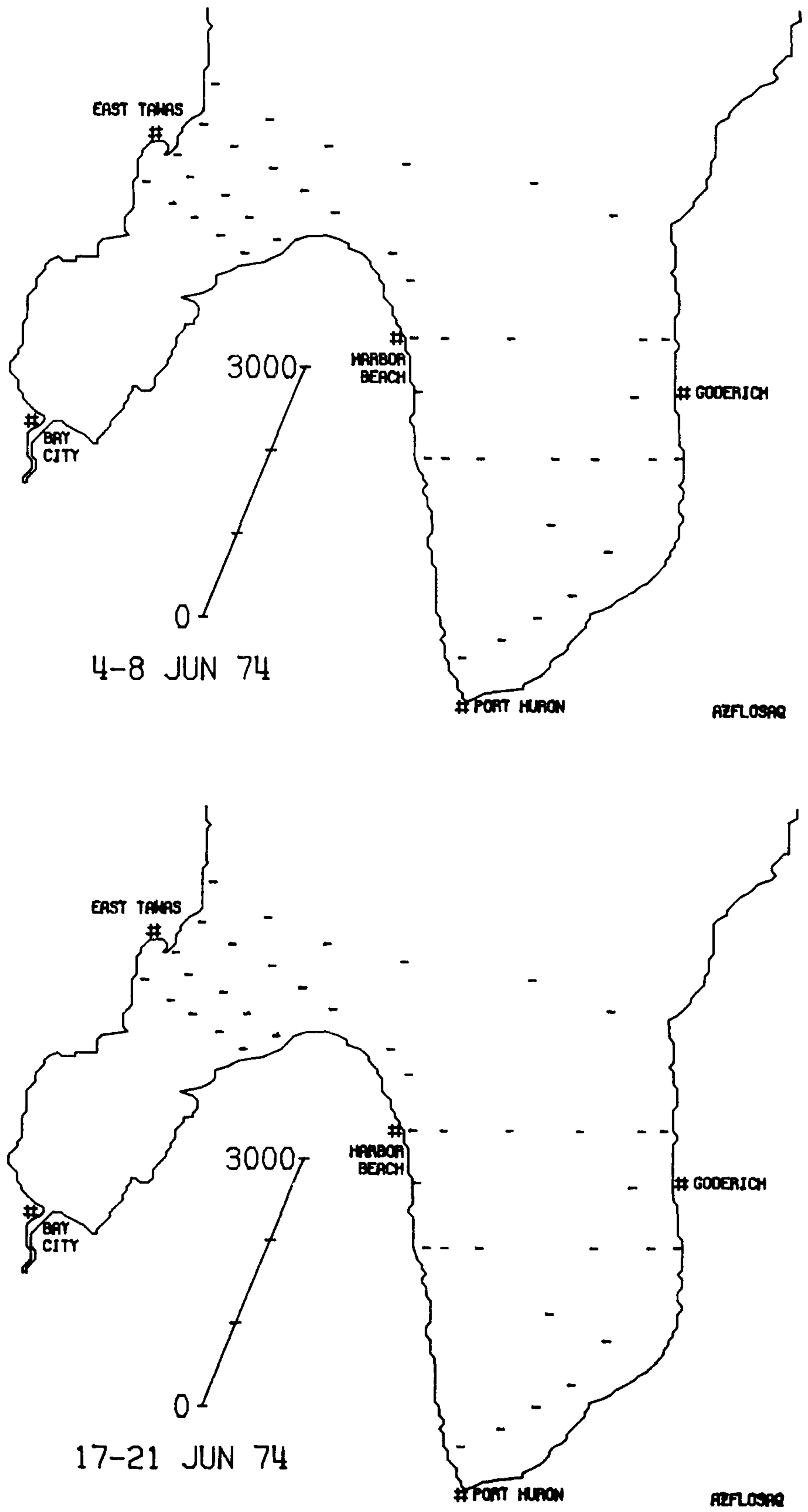
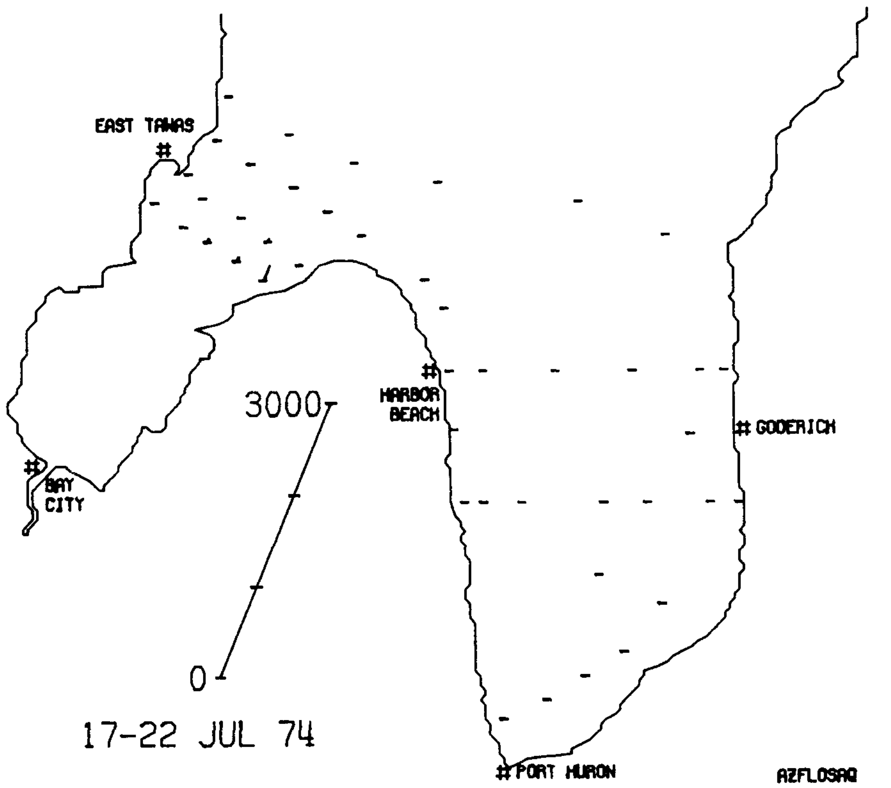


Figure 54. Distribution of Aphanizomenon flos-aquae. (continued)



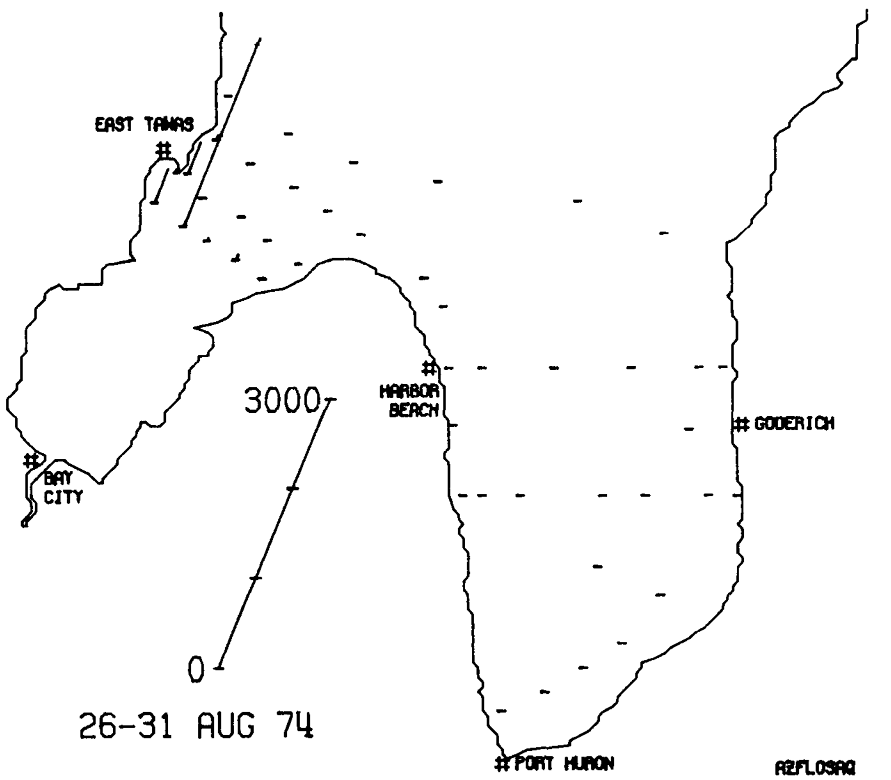
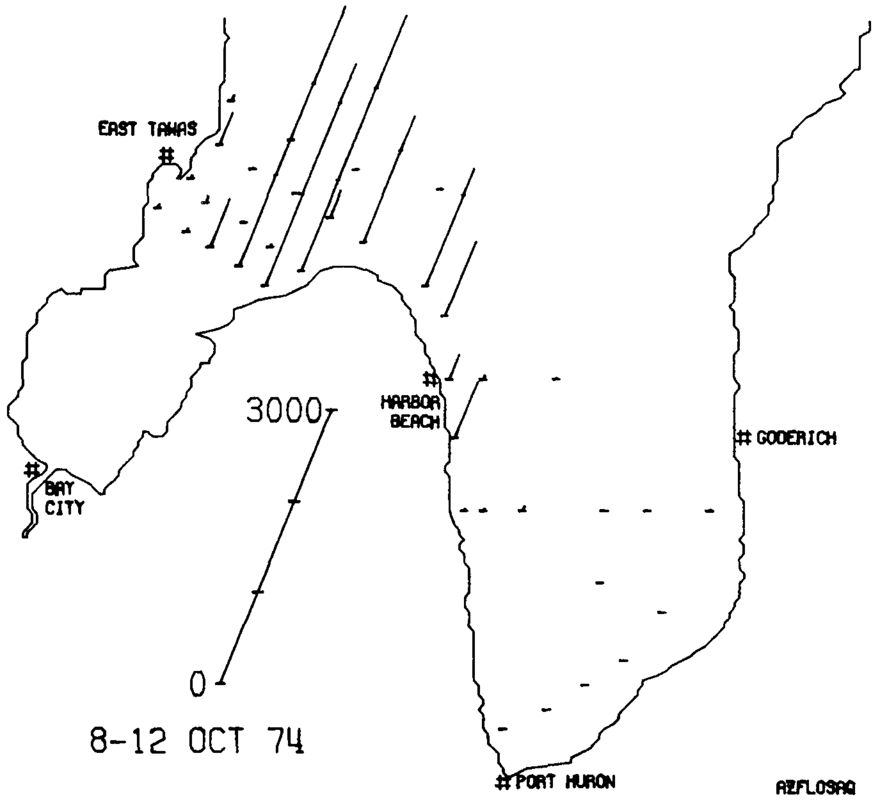


Figure 54. (continued)



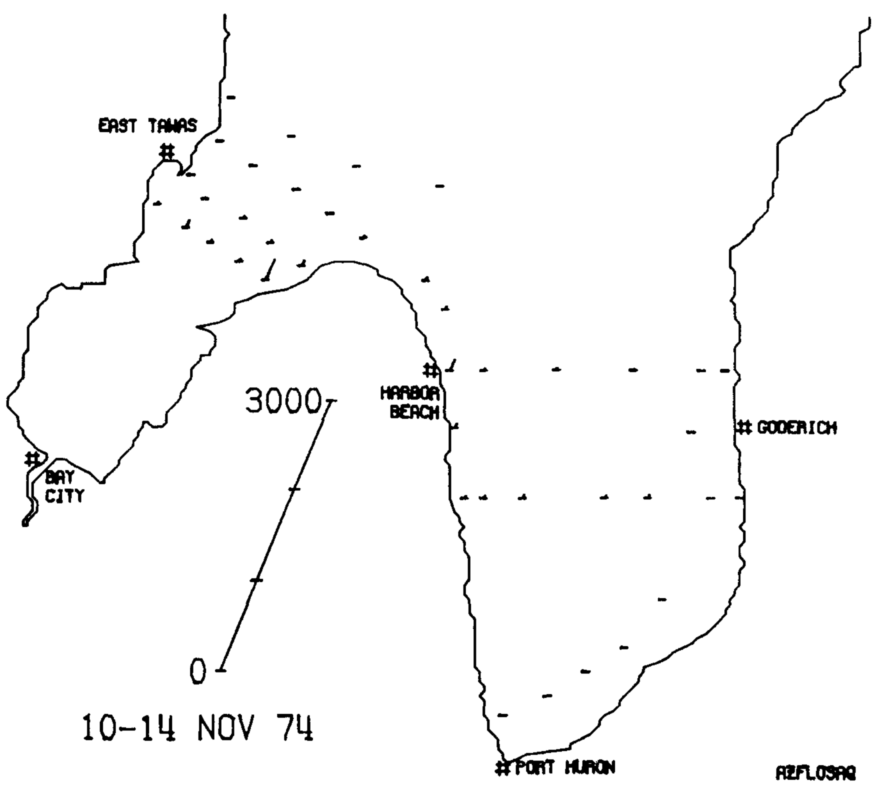
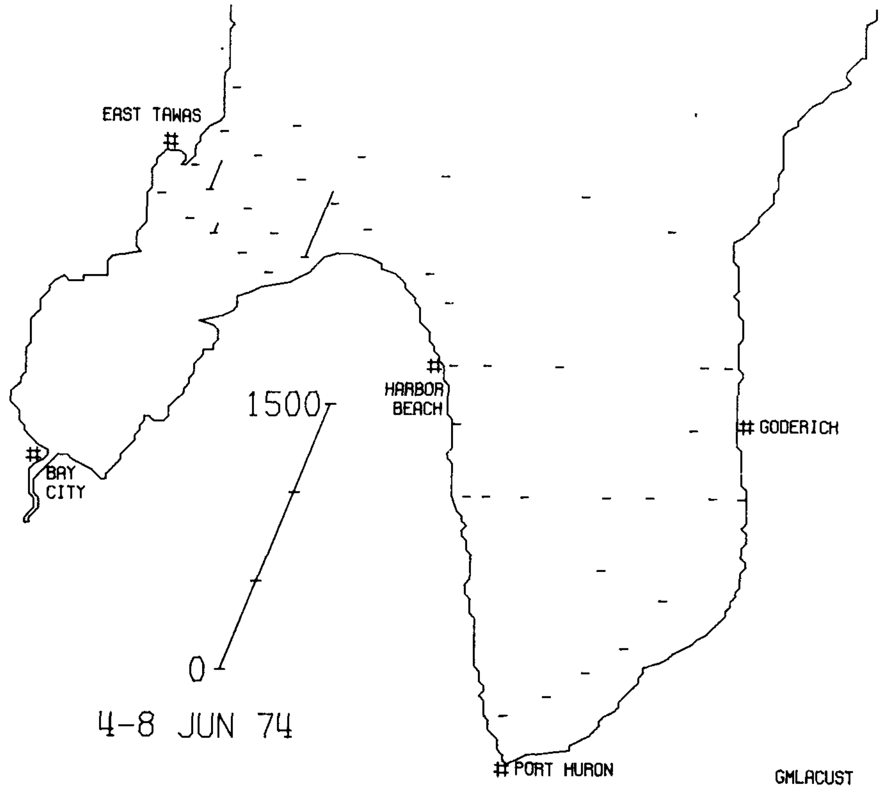


Figure 54. (continued)



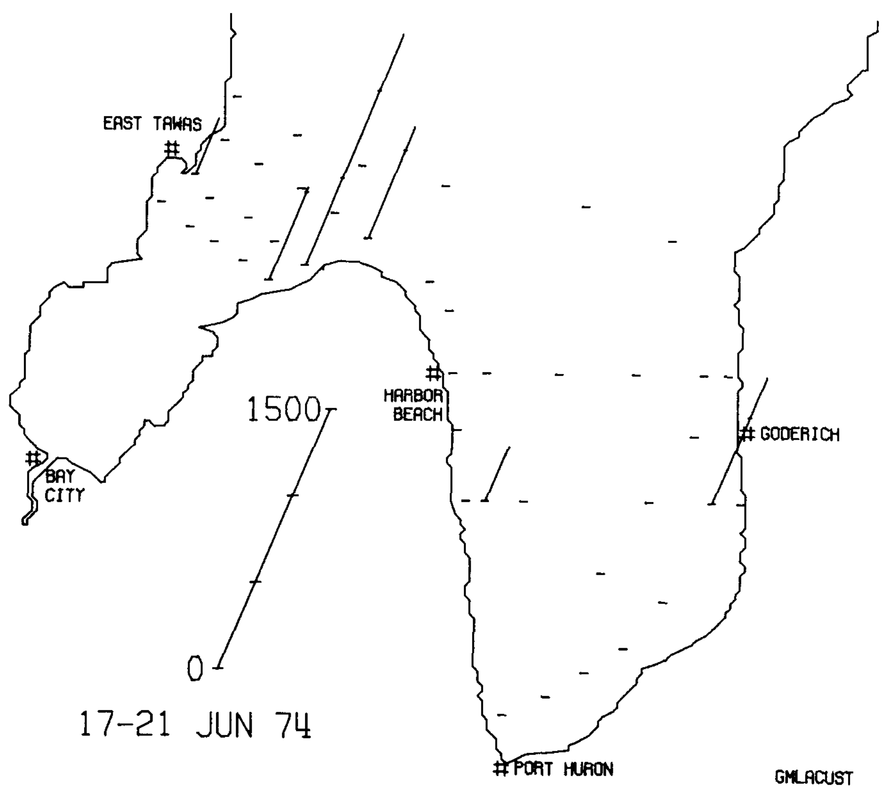
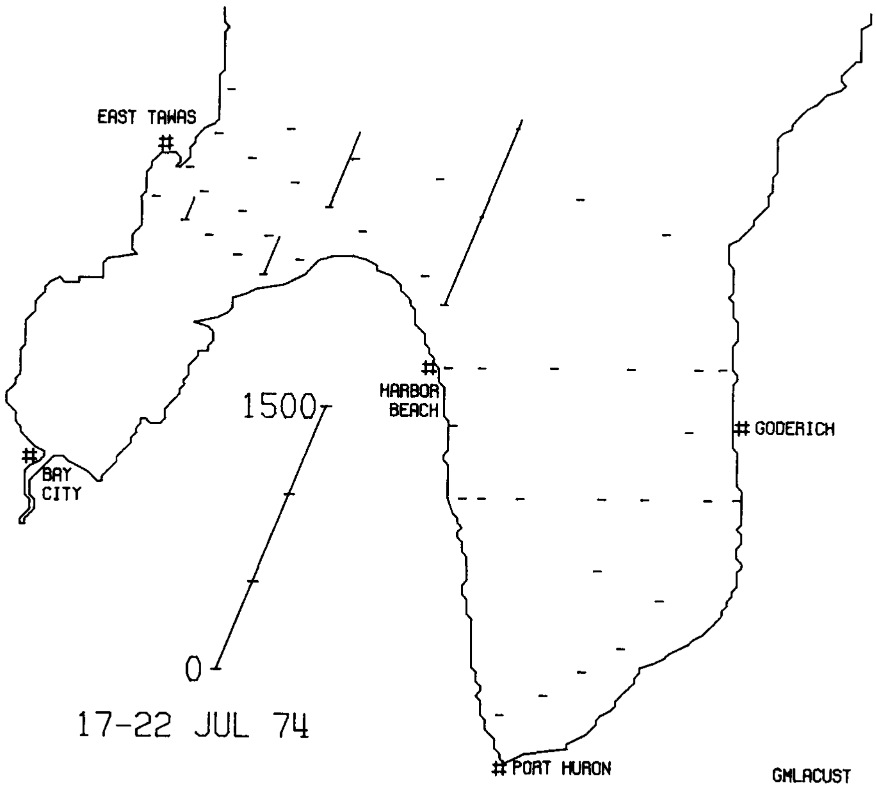


Figure 55. Distribution of Gomphosphaeria lacustris. (continued)



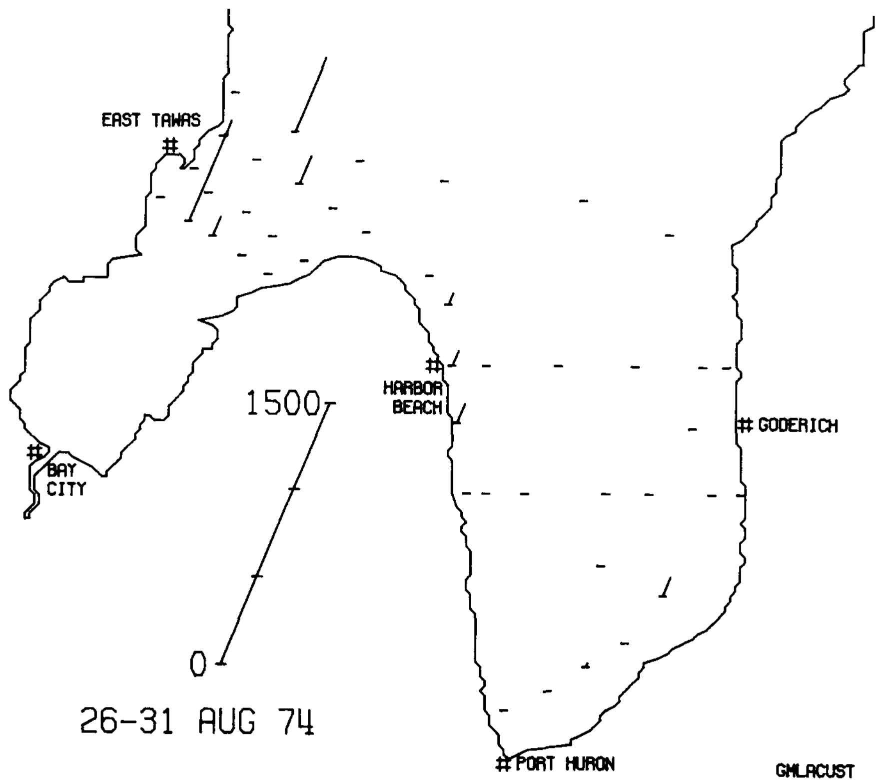
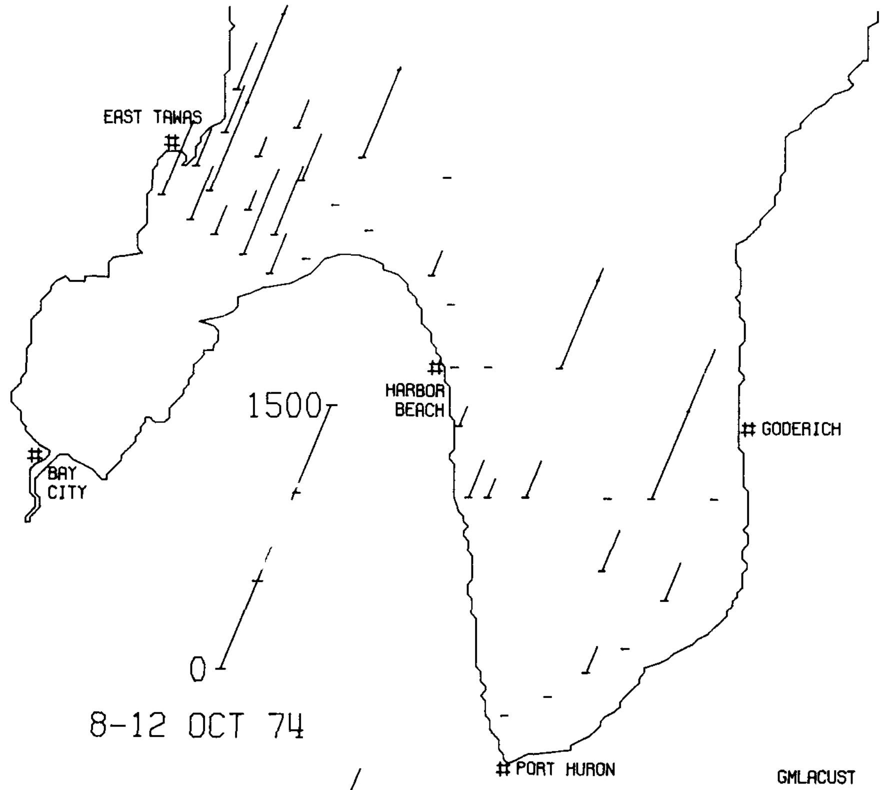


Figure 55. (continued)



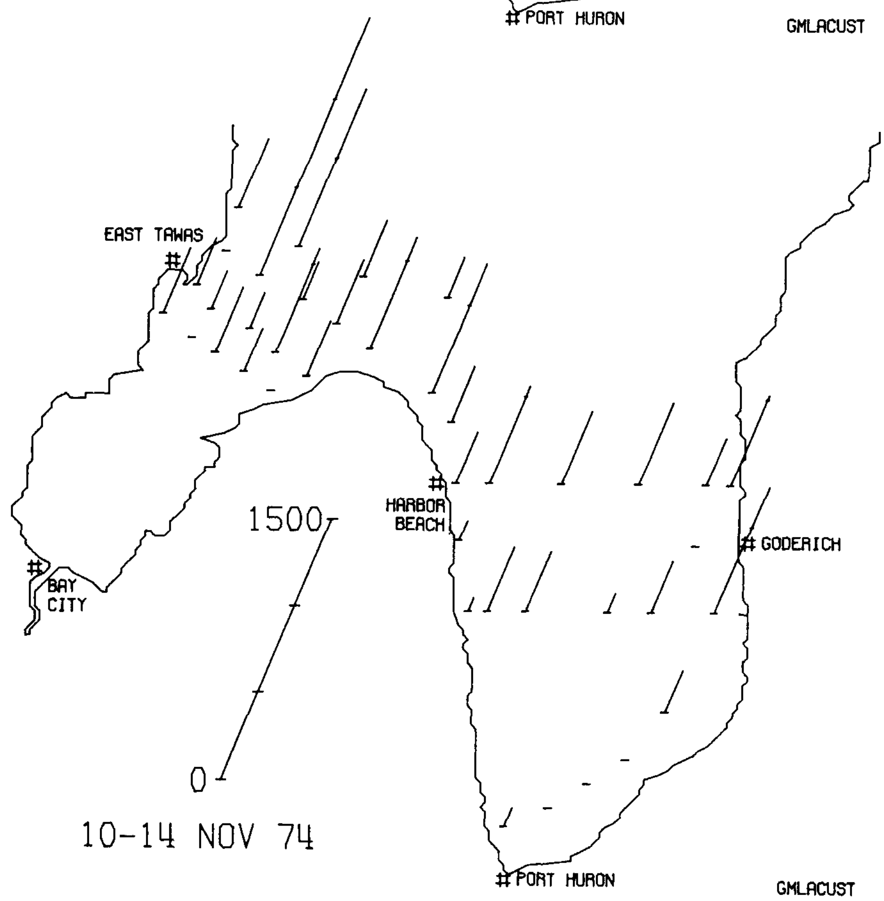


Figure 55. (continued)

southern sector of the lake. This species was present in increased abundance during the October sampling period (Fig. 55E) and, unlike the previous month, it was present in significant abundance at a number of stations in the offshore waters of southern Lake Huron. This trend continued in November (Fig. 55F) when significant populations were present at a majority of the stations sampled.

Oscillatoria bornetii

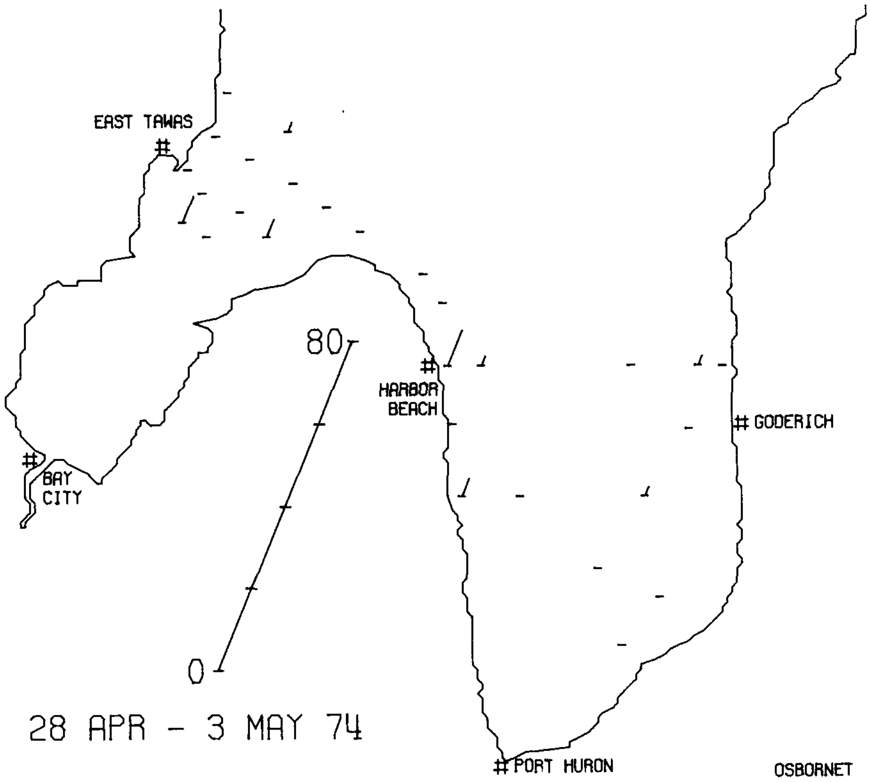
The autecology and distribution of this species is very poorly known. While it is widely distributed in the upper Great Lakes, it is rarely present in abundance. In Lake Michigan, maximum abundance of this species occurs at thermocline depth during summer stratification; however, it is often rare or absent in the surface waters. In southern Lake Huron, occasional small populations of the species were found in samples from early May through late June (Fig. 56A-D) with a slight trend towards increasing abundance throughout this period. Populations apparently collapsed in the surface waters of southern Lake Huron during July and August (Fig. 56E-F) and only isolated small populations were found at a few nearshore stations. This species was again widely distributed in the October samples (Fig. 56G) with maximum abundance occurring at stations 63 and 64 in the extreme southern part of the lake. Relatively small populations were found throughout the area sampled during the November cruise (Fig. 56H), with no apparent pattern to their distribution.

Oscillatoria retzii

This species usually grows in eutrophic environments and has rarely been reported from the upper Great Lakes. In southern Lake Huron, it first appeared in our mid-May samples (Fig. 57A) from the Saginaw Bay interface waters and southward along the Michigan coast. By early June (Fig. 57B) large populations were present at the inner line of stations in Saginaw Bay and small populations were present in most stations southward along the Michigan coast and eastward into the lake as far as stations 54 and 60. By mid-June (Fig. 57C), average abundance of this species had declined somewhat in the Saginaw Bay interface; it was not found in the open lake stations that it had occupied the previous month, although it was still present in nearshore stations north of Harbor Beach. Its abundance was further restricted in July (Fig. 57D) when abundant occurrences were limited to stations in the southerly sector of the Saginaw Bay interface. In August, as was the case with many eutrophication tolerant taxa, highest populations of *O. retzii* were found in the northerly sector of the Saginaw Bay interface waters. In October (Fig. 57F) abundant occurrences were restricted to a few stations in the southerly part of Saginaw Bay interface, even though small populations were found at stations south along the Michigan coast, and at a number of offshore stations. By November (Fig. 57G), abundance of this species was greatly reduced, with only a few small populations found in samples from the Saginaw Bay interface waters.

Filamentous Blue-Green Algae

Since the filamentous forms of blue-green algae perhaps have the greatest potential for producing nuisance conditions, we have plotted the composite abundance of forms described previously, plus the occurrences of several taxa of minor abundance. During early May (Fig. 58A), this group was of very minor importance in southern Lake Huron where only occasional specimens were noted.



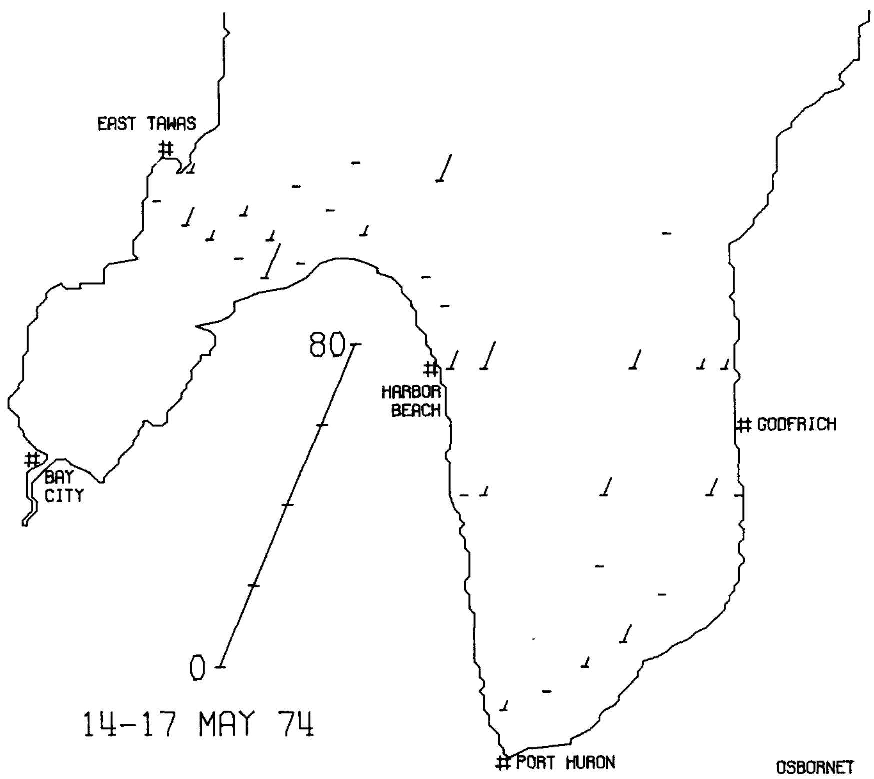
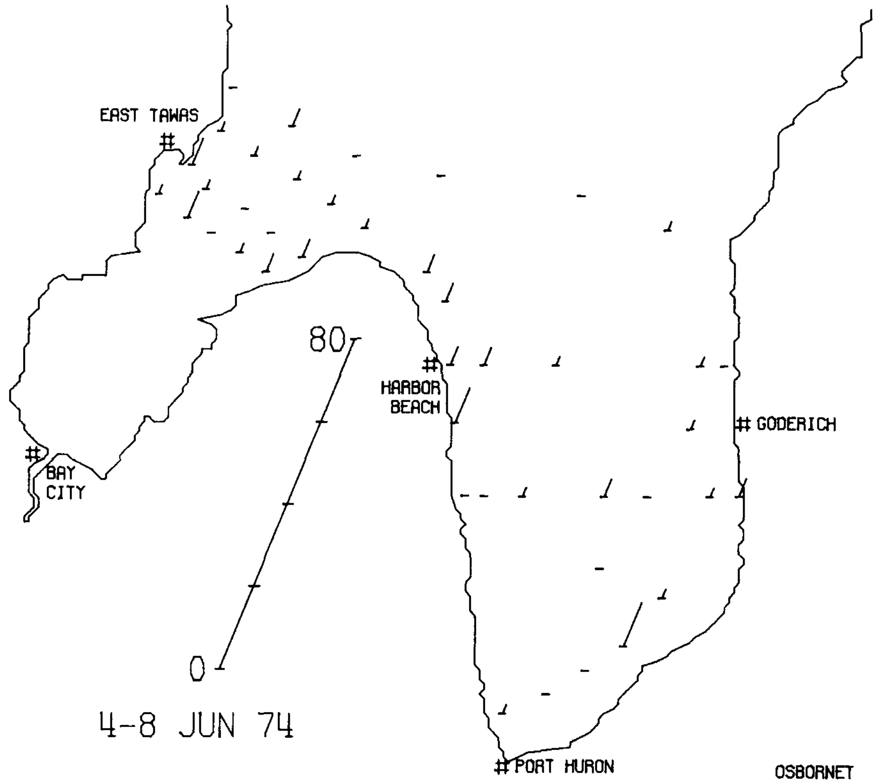


Figure 56. Distribution of *Oscillatoria bornetii*. (continued)



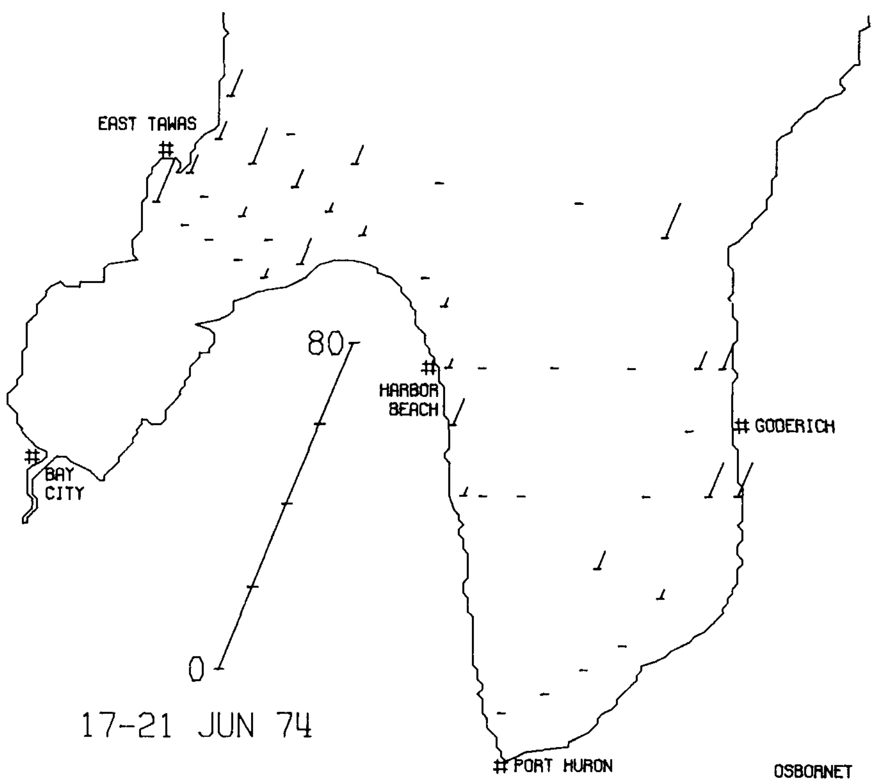


Figure 56. (continued)

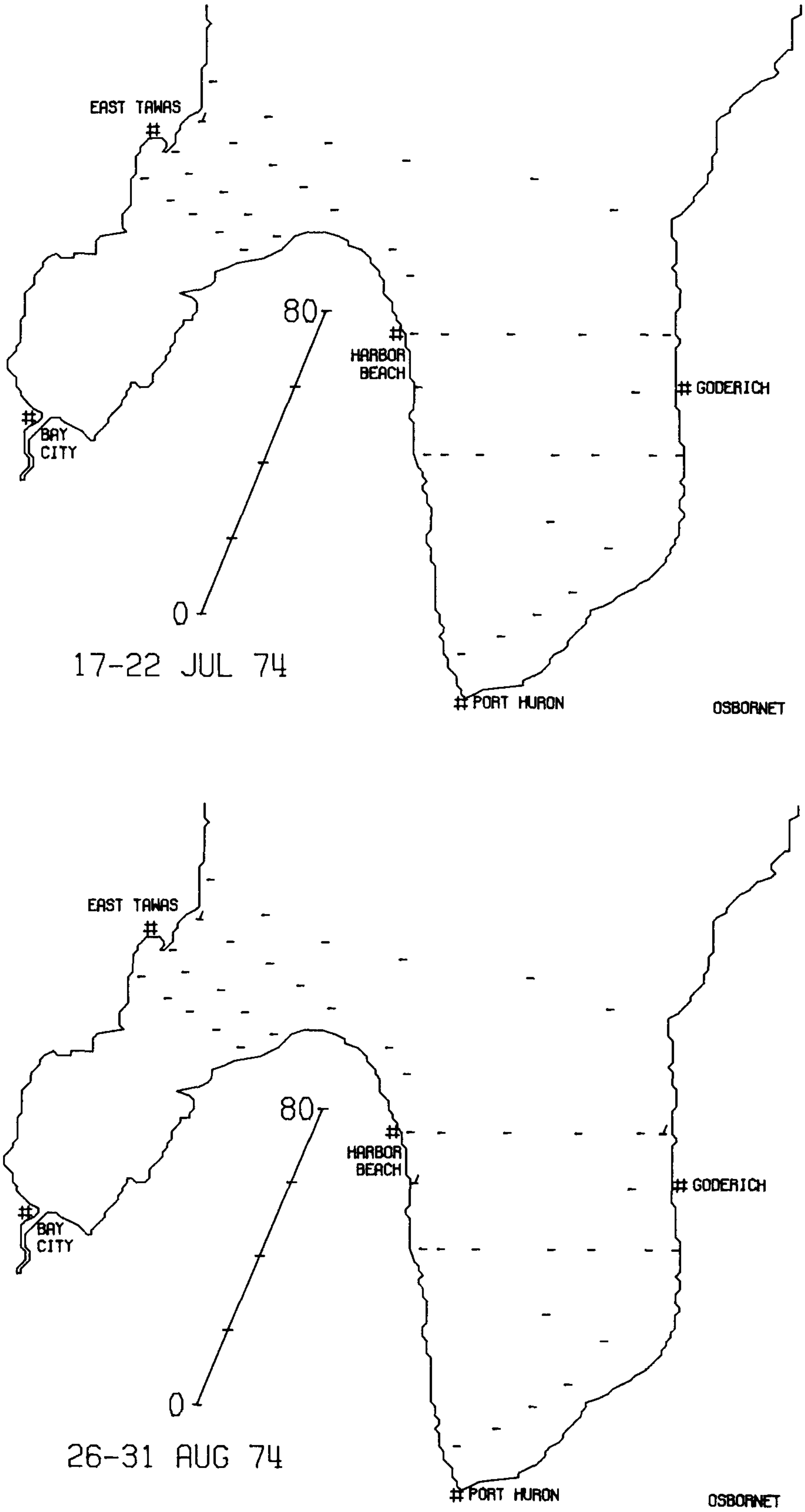


Figure 56. (continued)

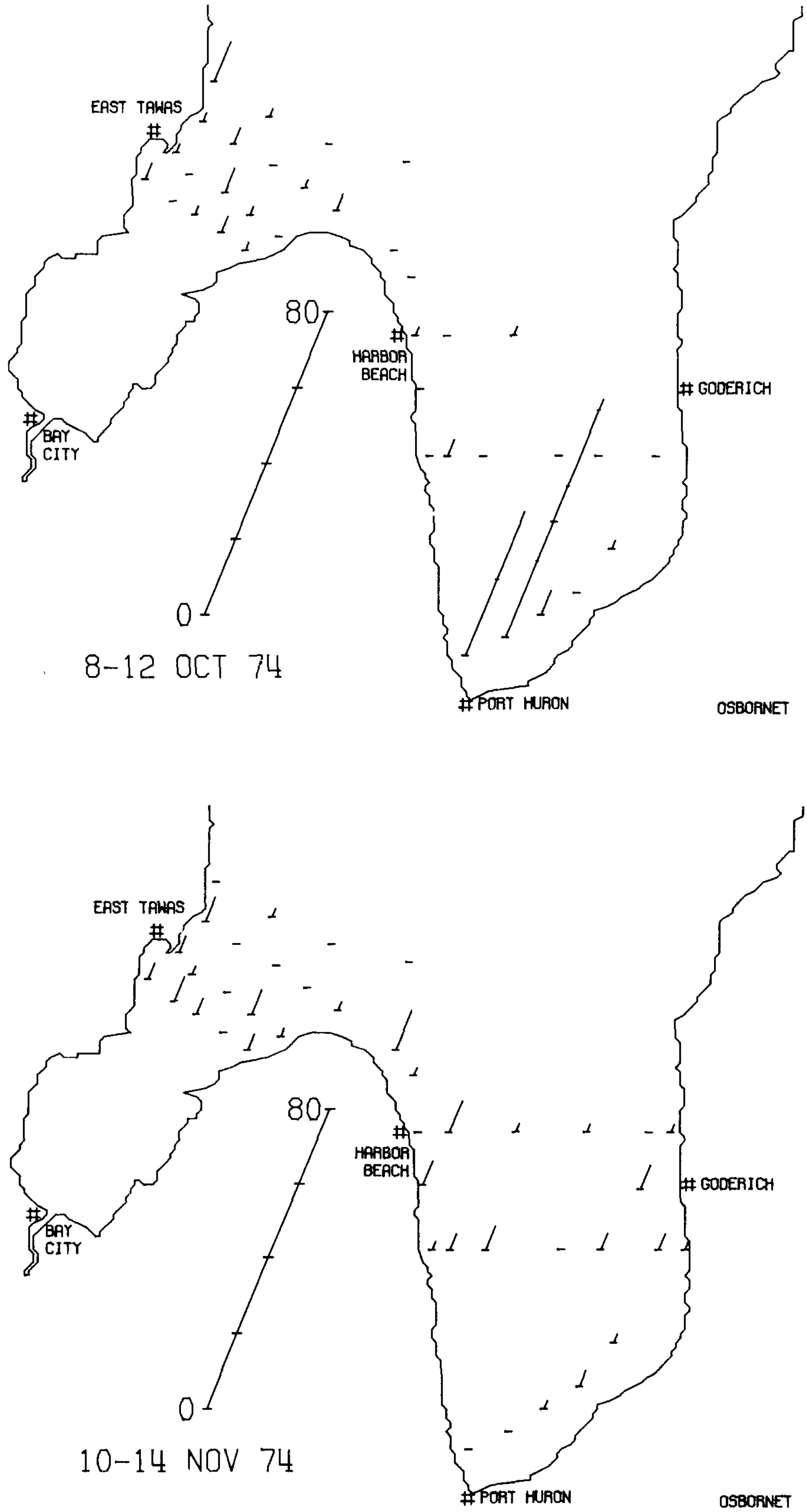
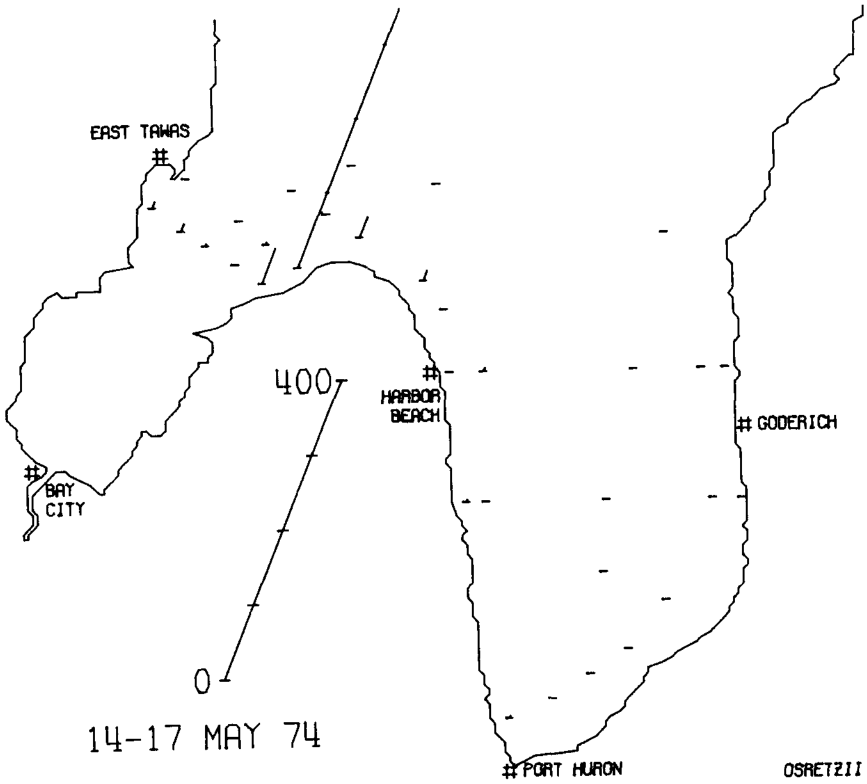


Figure 56. (continued)



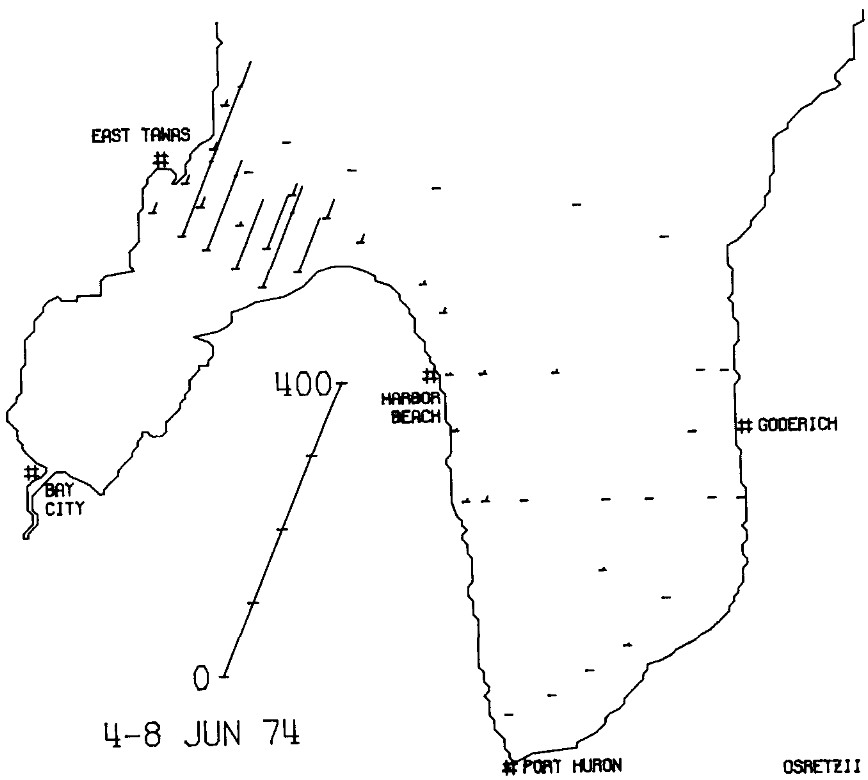
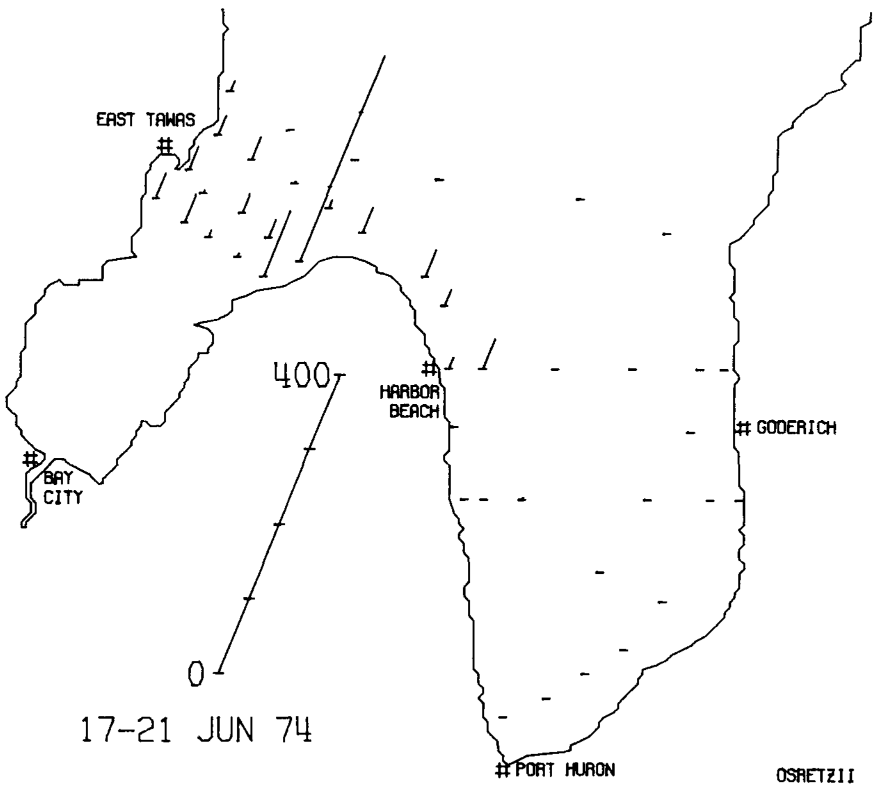


Figure 57. Distribution of _Oscillatoria retzii_.
(continued)



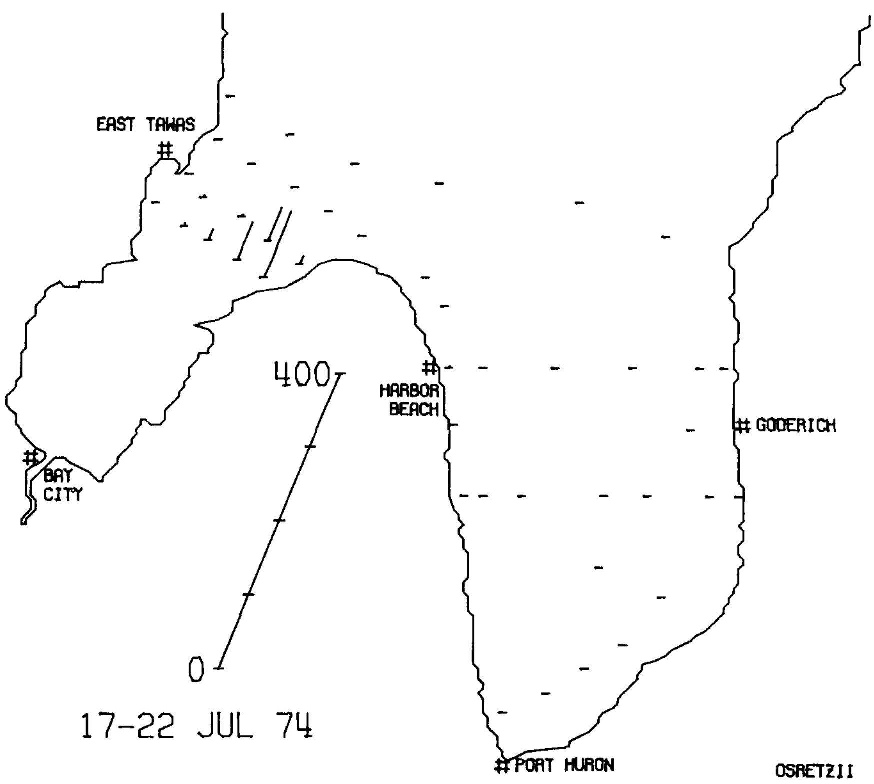
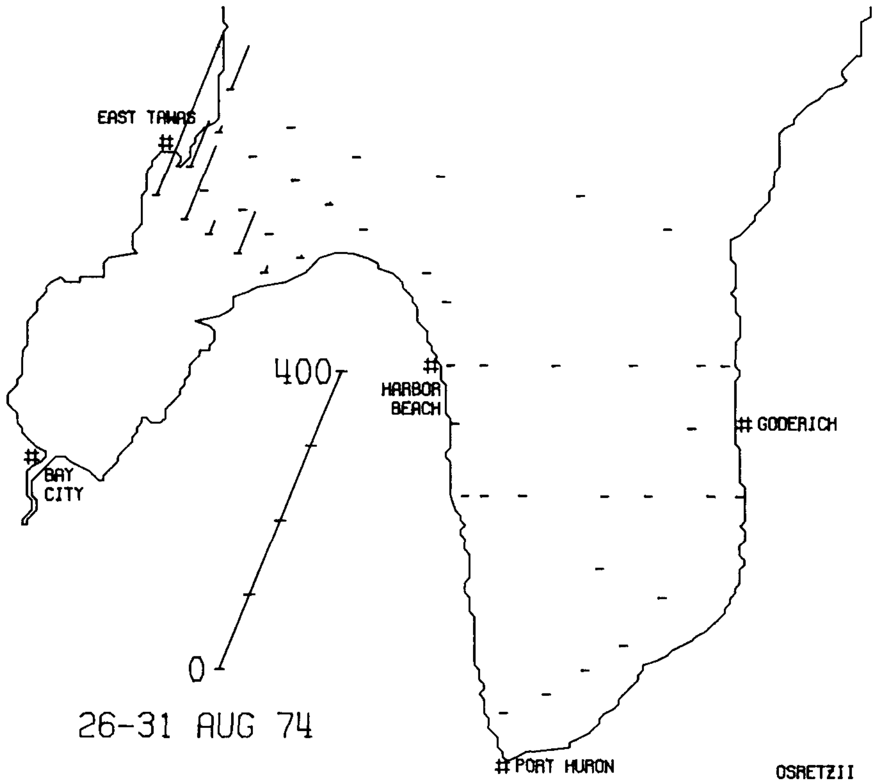


Figure 57. (continued)



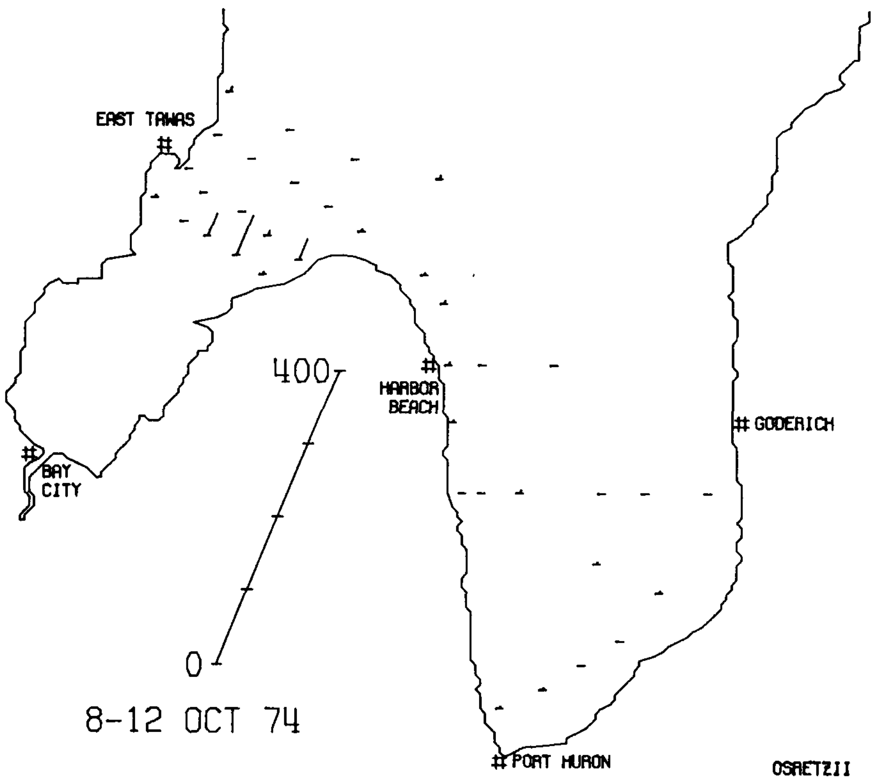


Figure 57. (continued)

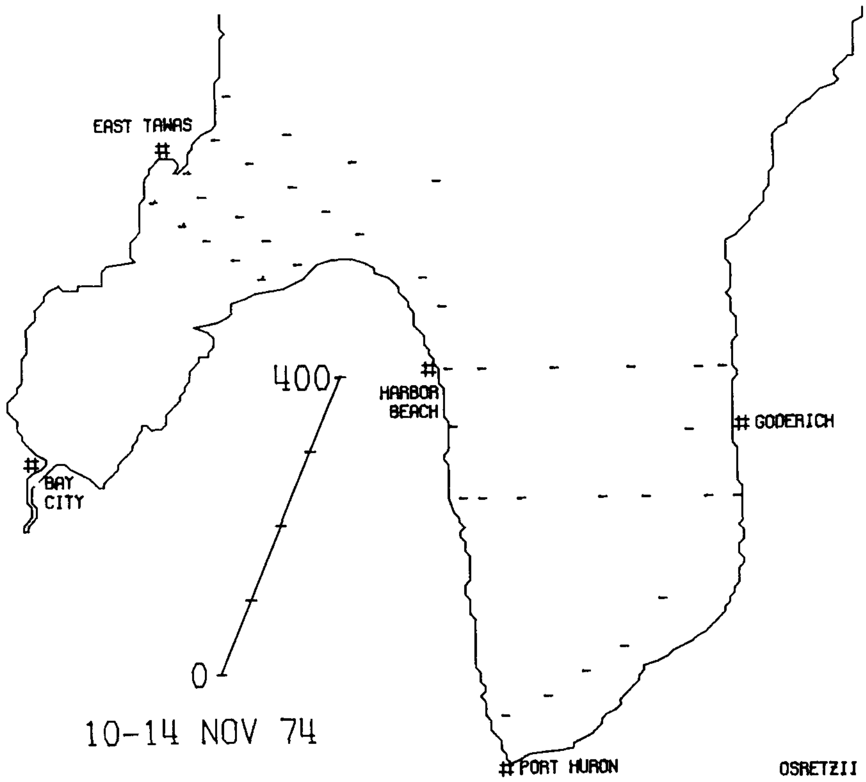
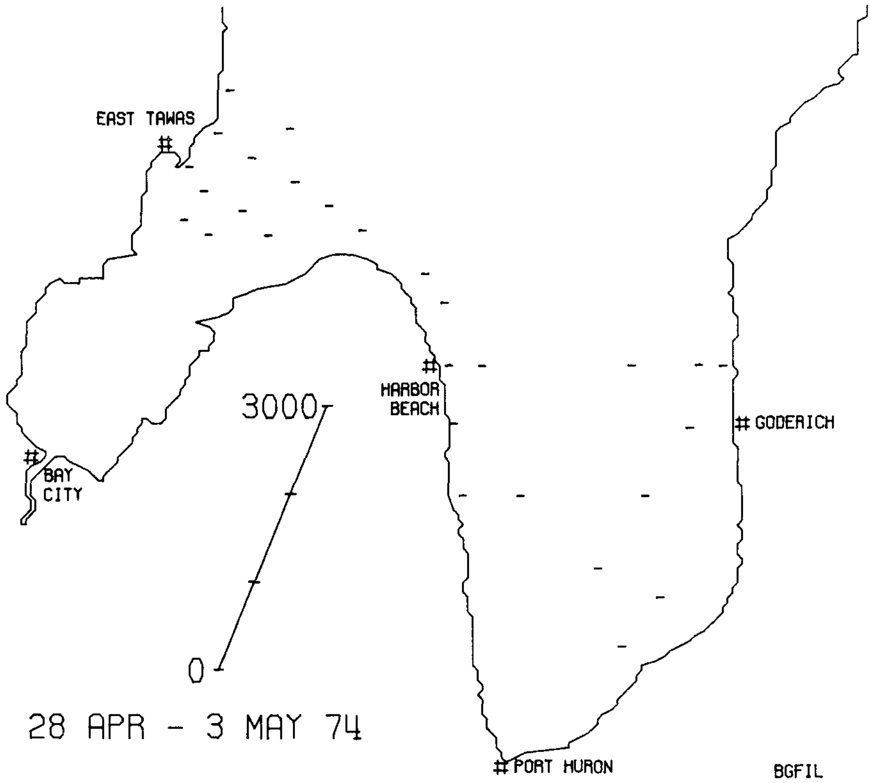


Figure 57. (continued)

By mid-May (Fig. 58B), significant populations were found at stations in the south part of the Saginaw Bay interface waters, and small populations were dispersed southward along the Michigan coast. During June (Fig. 58C-D), members of this group were present at most stations in the Saginaw Bay interface waters, but their dispersion into the open lake was limited largely to stations near the U.S. coast north of Harbor Beach. Somewhat surprisingly, the distribution of these organisms was even more limited in July (Fig. 58E) than it had been in the previous month. In August (Fig. 58F), unlike all other months, maximum abundance of filamentous blue-green algae occurred at stations in the northern part of the Saginaw Bay interface waters, and populations appeared to be dispersed northward along the Michigan coast. These species reached their maximum abundance in October (Fig. 58G), when they were very abundant in the southerly sector of the Saginaw Bay interface and southward along the Michigan coast as far as station 13, and present at detectable levels as far south as stations 63 and 64 above Port Huron. During November (Fig. 58H), the abundance of this group declined, although small populations were widely dispersed in the offshore waters, occurring as far east as stations 11 and 55.

Chrysophyta

In southern Lake Huron, this group is represeted mostly by flagellate forms, the majority of which are colonial. Most of the more abundant species



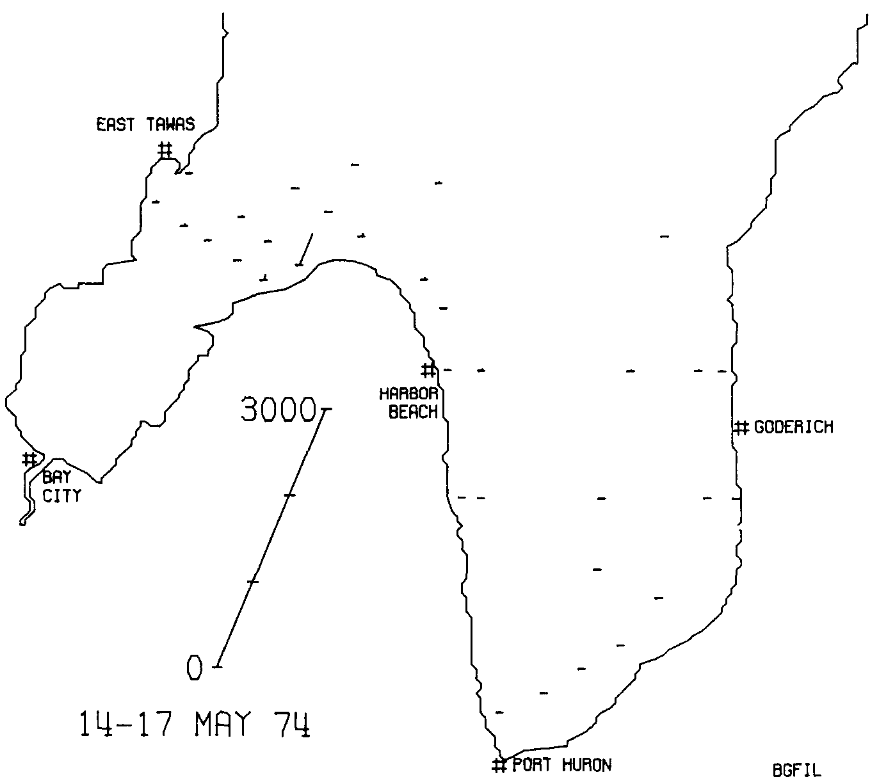
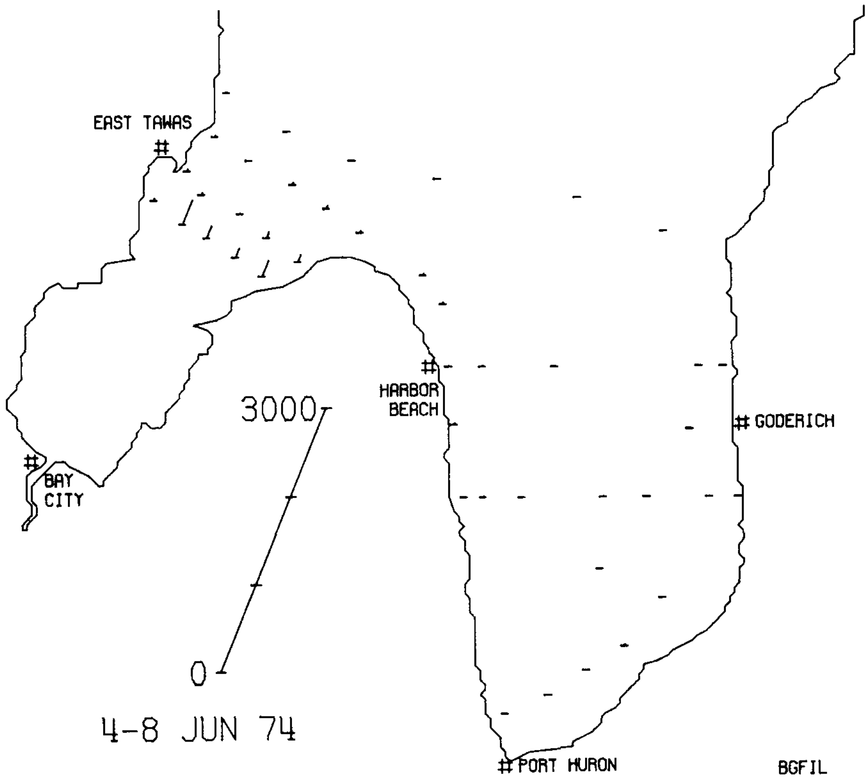


Figure 58. Seasonal abundance and distribution trends of total blue-green filaments. (continued)



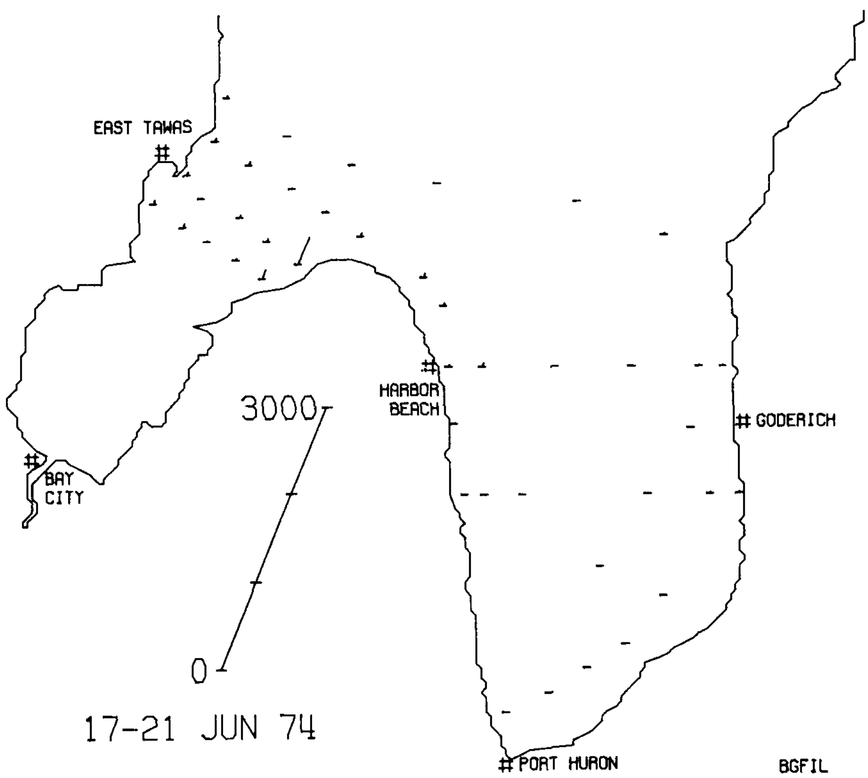
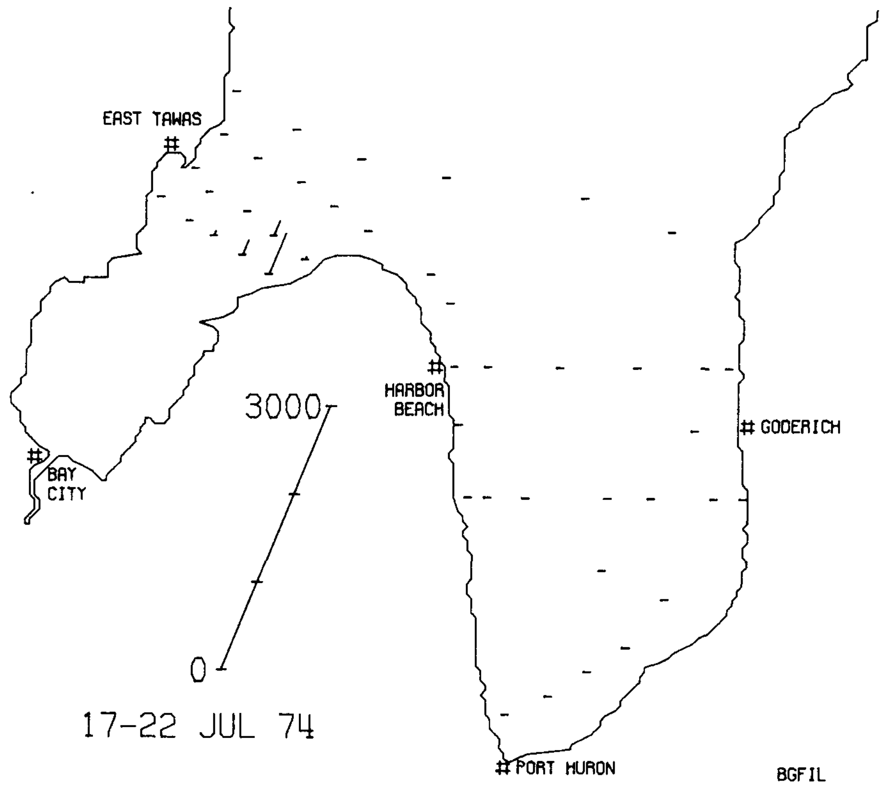


Figure 58. (continued)



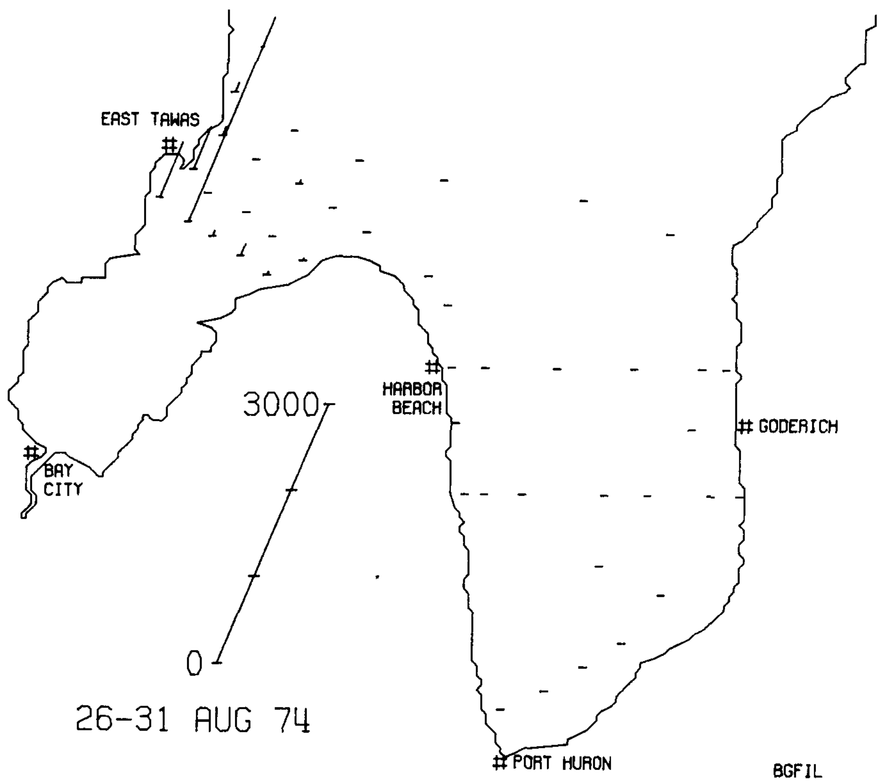


Figure 58. (continued)

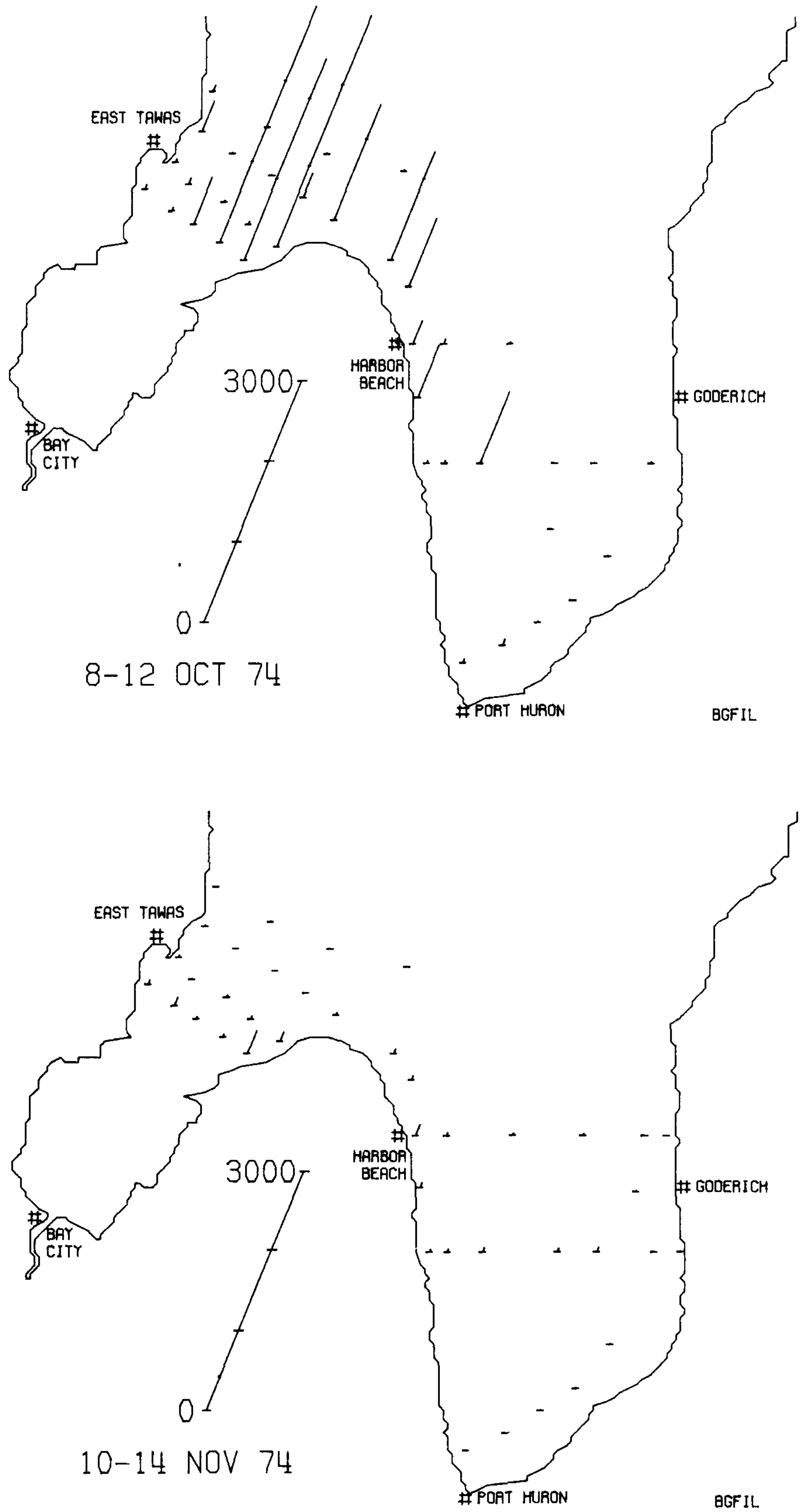


Figure 58. (continued)

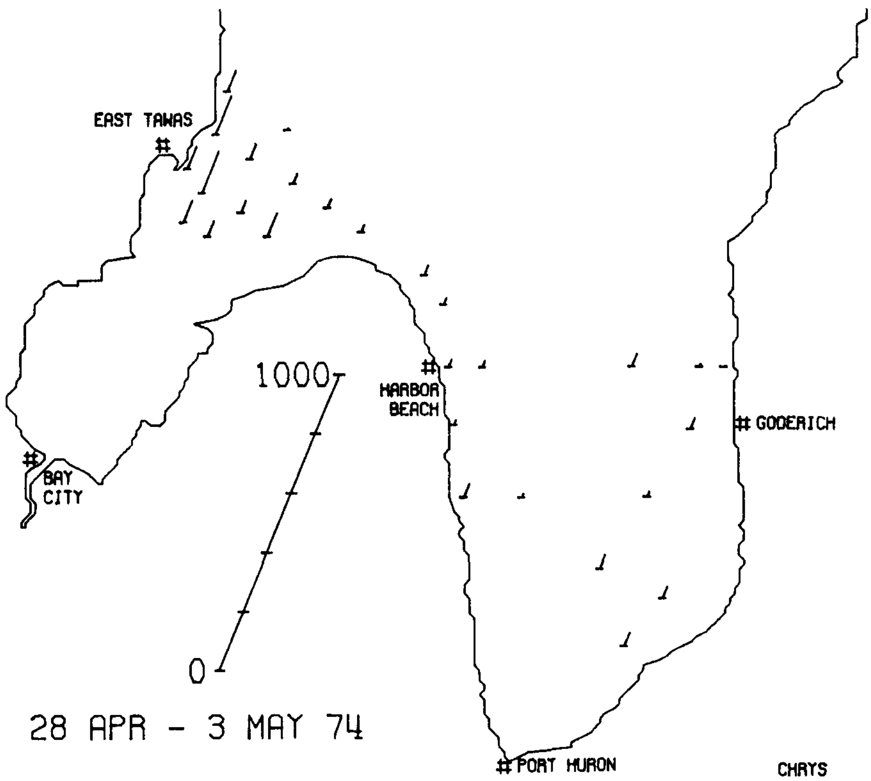
are usually reported from oligotrophic to mesotrophic waters, although they may form ephemeral blooms under a wide variety of conditions. In early May (Fig. 59A), this group was most abundant at a few stations in the northerly sector of the Saginaw Bay interface waters with small and fairly uniform populations occurring over the rest of the regions sampled. Distribution was similar during mid-May (Fig. 59B), although highest abundance during this period was found in the southerly sector of the Saginaw Bay interface waters and southward along the Michigan coast. This trend was accentuated in the early June cruise (Fig. 59C), when fairly high population levels were noted as far southward as station 59. Population levels had been strongly reduced by the time the late June (Fig. 59D) samples were taken; numbers were low and rather uniform throughout the area sampled with a slight trend toward highest population densities occuring at stations where this group had been least abundant in the previous sampling period. In July (Fig. 59E), population levels increased, particularly at the outer stations in the Saginaw Bay interface and at stations in the far southern part of the lake. During August (Fig. 59F), chrysophycean algae were abundant at stations in the central and northerly sector of the Saginaw Bay interface and southward along the Michigan coast, but present in only very small numbers at most offshore stations. In October (Fig. 59G), this group remained abundant at stations north of the Saginaw Bay interface and became quite abundant at a limited number of offshore stations. Numerical abundance of this group was strongly reduced in November (Fig. 59H) when most significant occurrences were found at nearshore stations.

Dinobryon divergens

This species is apparently widely distributed and may occur in waters of significantly different trophic levels. It tends to form ephemeral blooms, particularly following major blooms by other species (Hutchinson, 1967). During May (Fig. 60A-B), only scattered isolated populations were noted. However, in early June (Fig. 60C), this species occurred in significant abundance in a series of stations running southward from the Saginaw Bay interface along the Michigan coast and outward as far as station 60. By late June (Fig. 60D), the population had entirely collapsed, and D. divergens was found only at scattered stations rimming the region where it had been abundant during the previous sampling period. In July (Fig. 60E), D. divergens was again abundant at stations in the Saginaw Bay interface, southward along the Michigan coast, and at stations in the far southerly sector of the lake. Similar to the June sequence, the July populations had apparently collapsed by the time the August samples were taken (Fig. 60F) and only a few scattered populations were noted. Distribution of D. divergens remained scattered during October (Fig. 60G); by November (Fig. 60H), population levels had increased somewhat with abundant occurrences largely restricted to nearshore stations.

Chrysosphaerella longispina

This species is usually a minor component of phytoplankton assemblages in oligotrophic to mesotrophic lakes and small ponds (Huber-Pestalozzi, 1941). It has rarely been reported from the Laurentian Great Lakes. It appears to be particularly abundant in Lake Huron (Schelske et al., 1974). During the present study, only small, isolated populations were found in samples taken from early May through June (Fig. 61A-D). However, during August (Fig. 61E) it



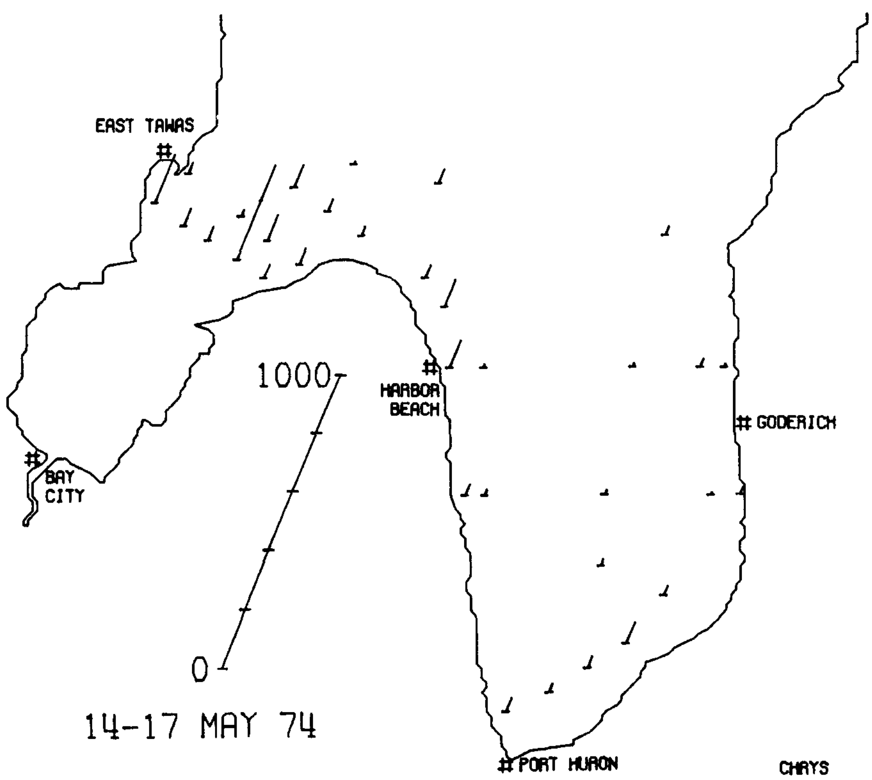
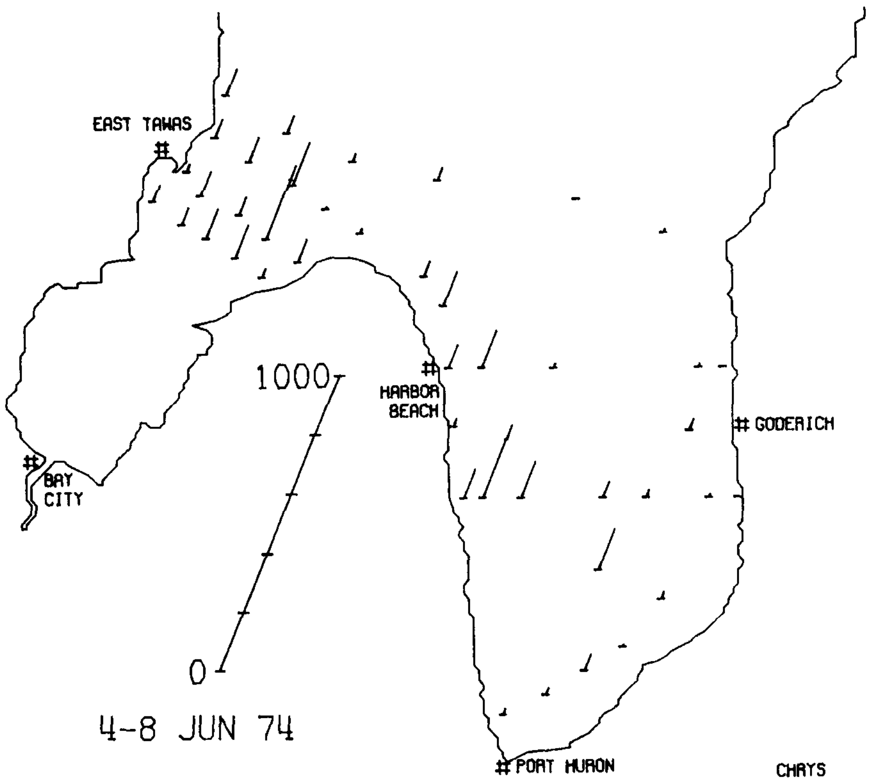


Figure 59. Seasonal abundance and distribution trends of Chrysophytes. (continued)



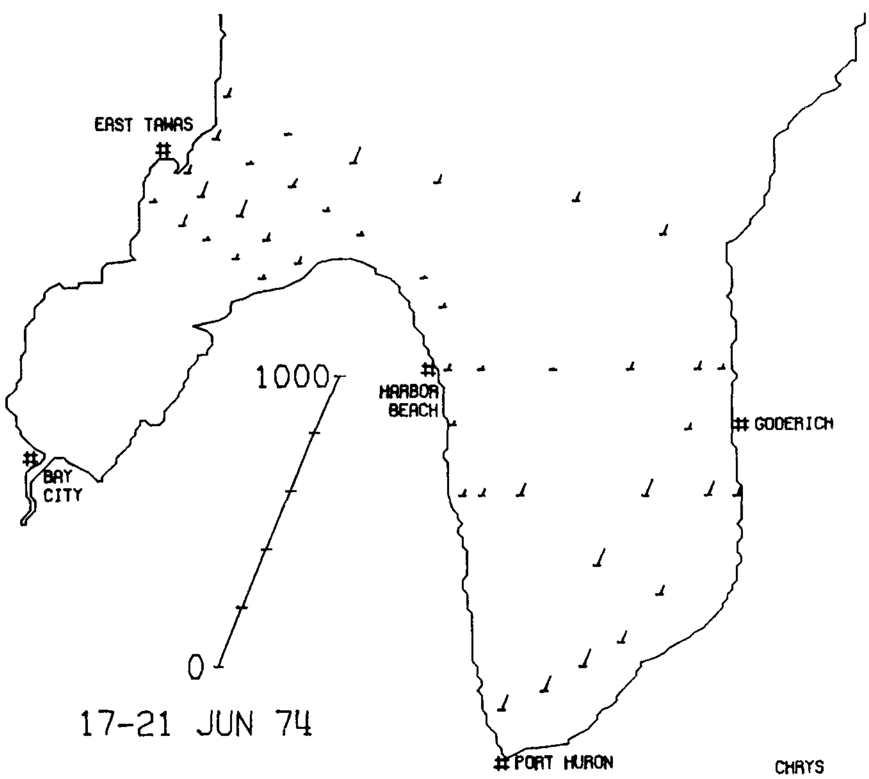


Figure 59. (continued)

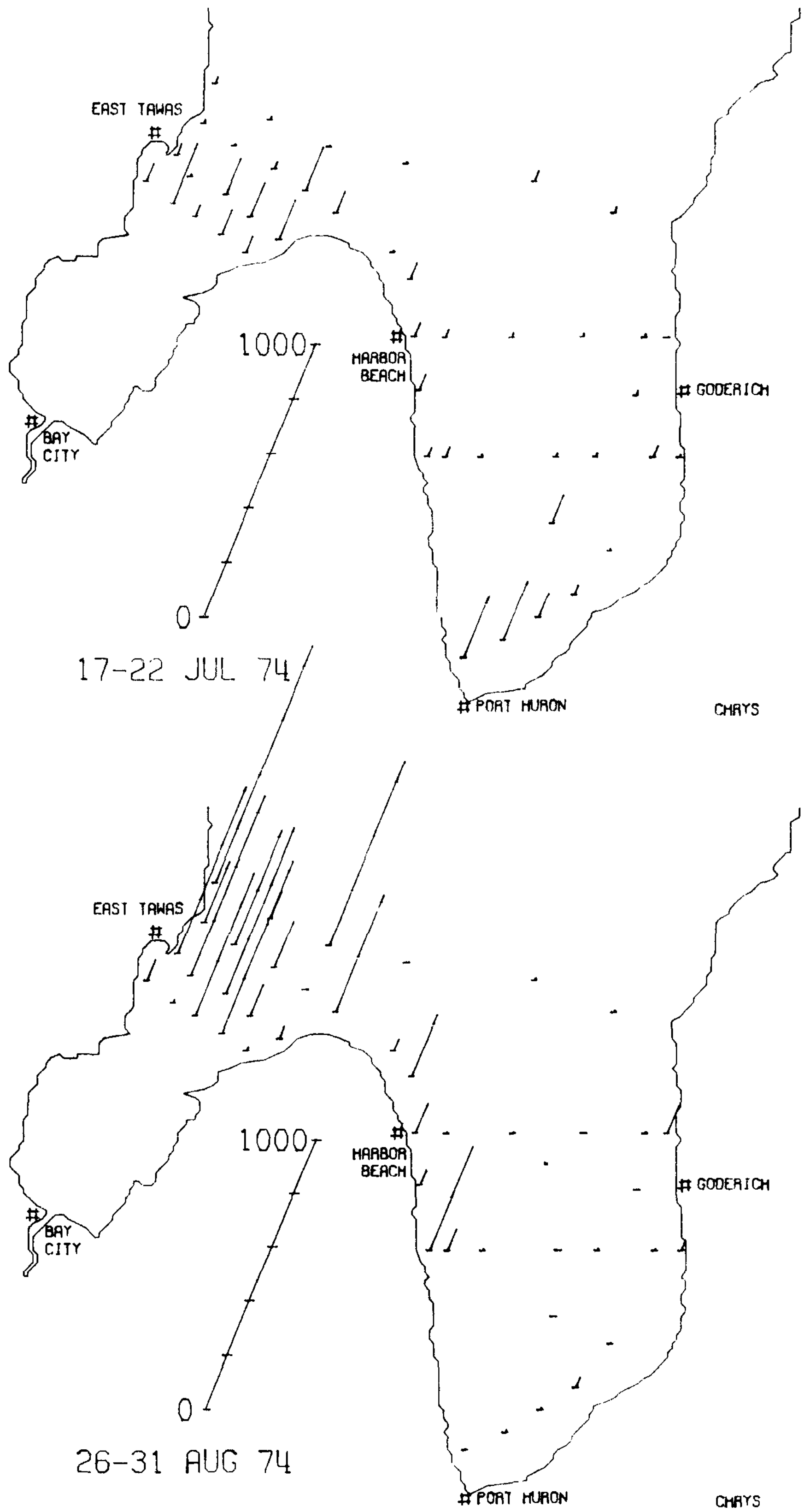
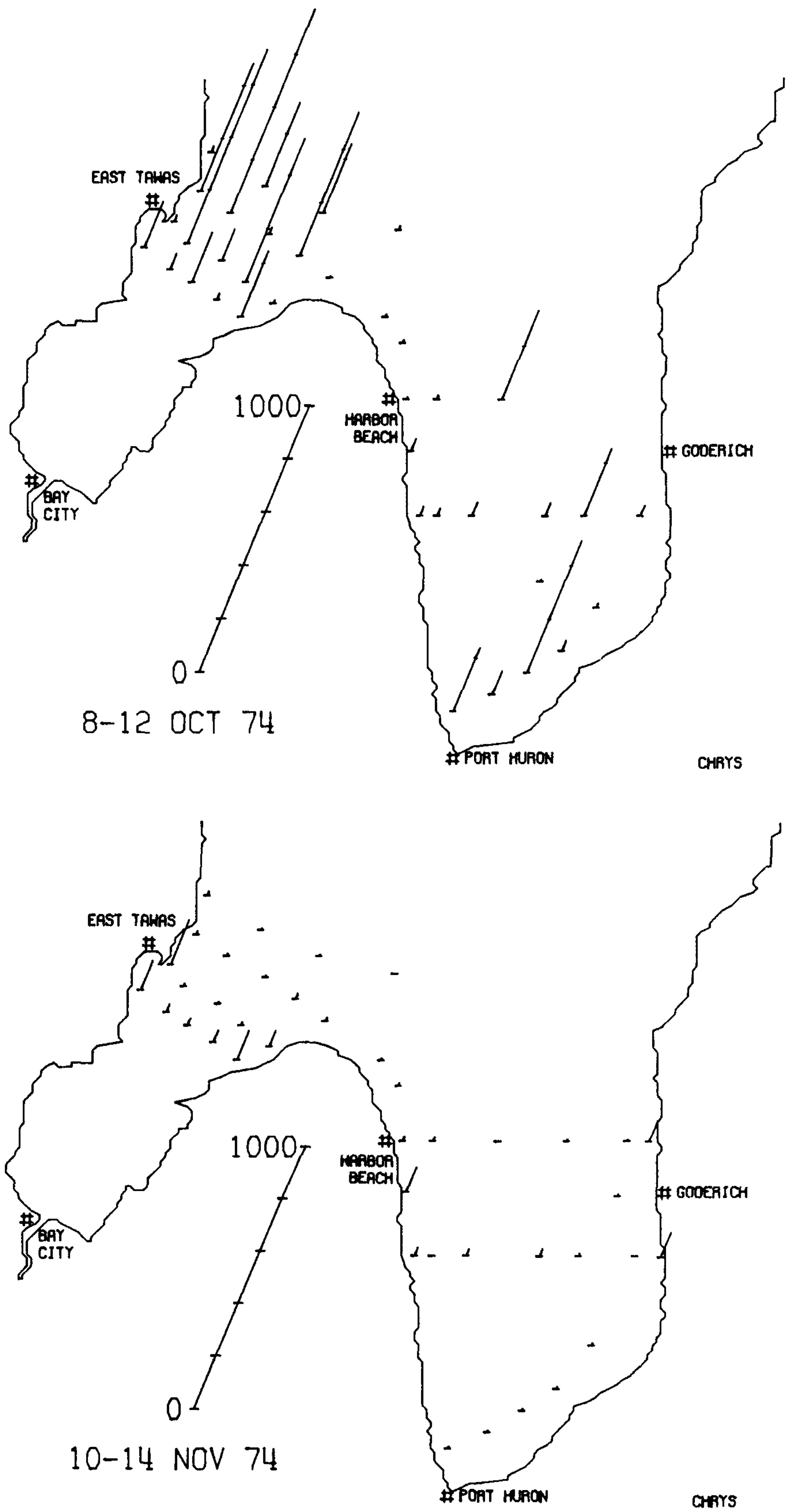


Figure 59. (continued)



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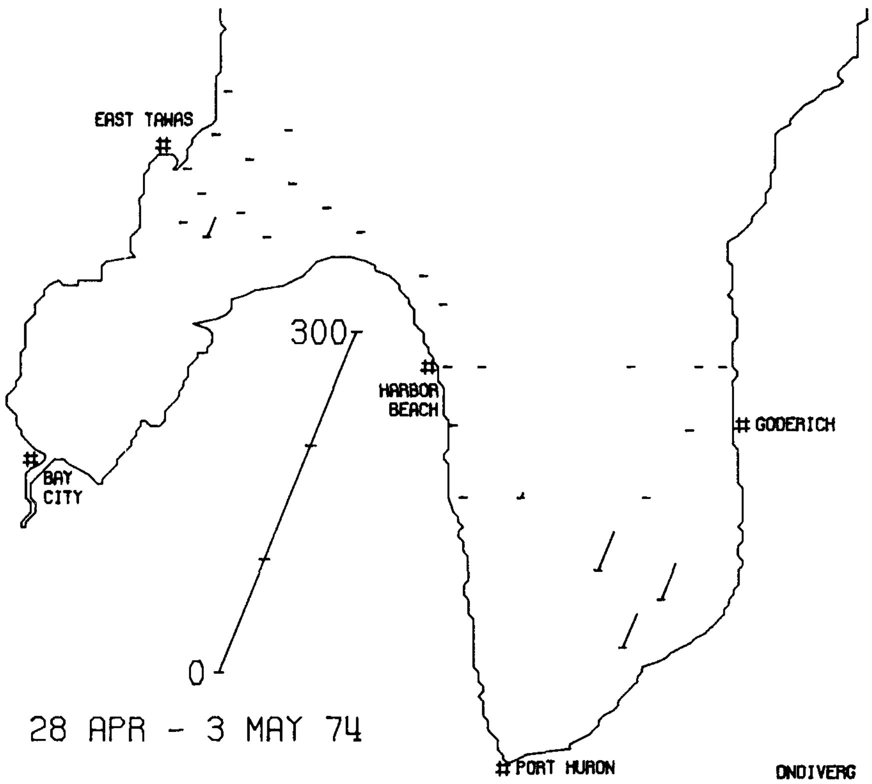


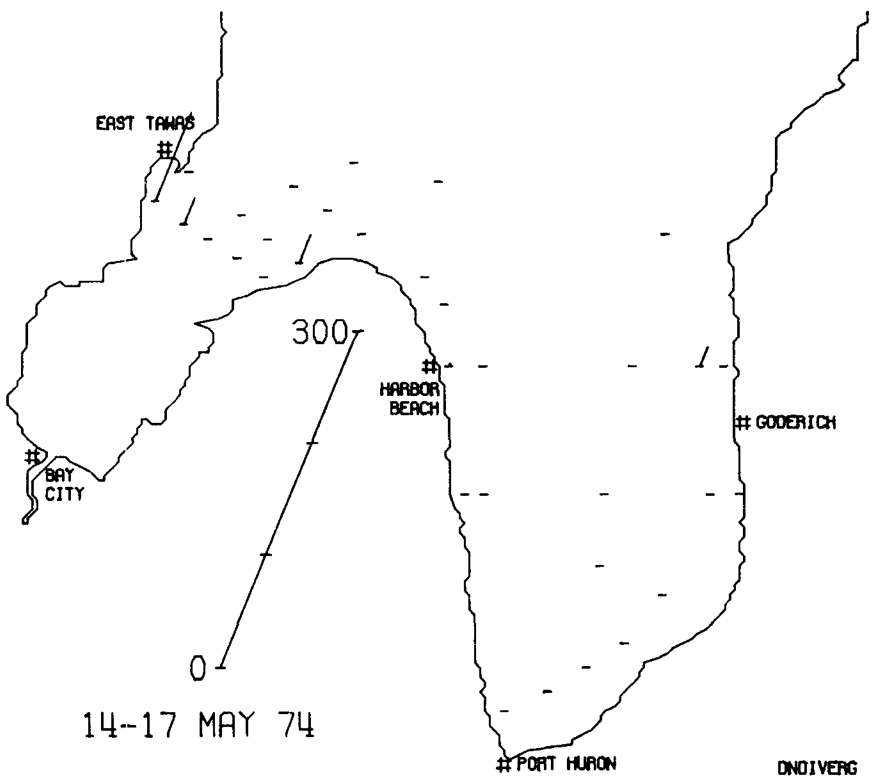
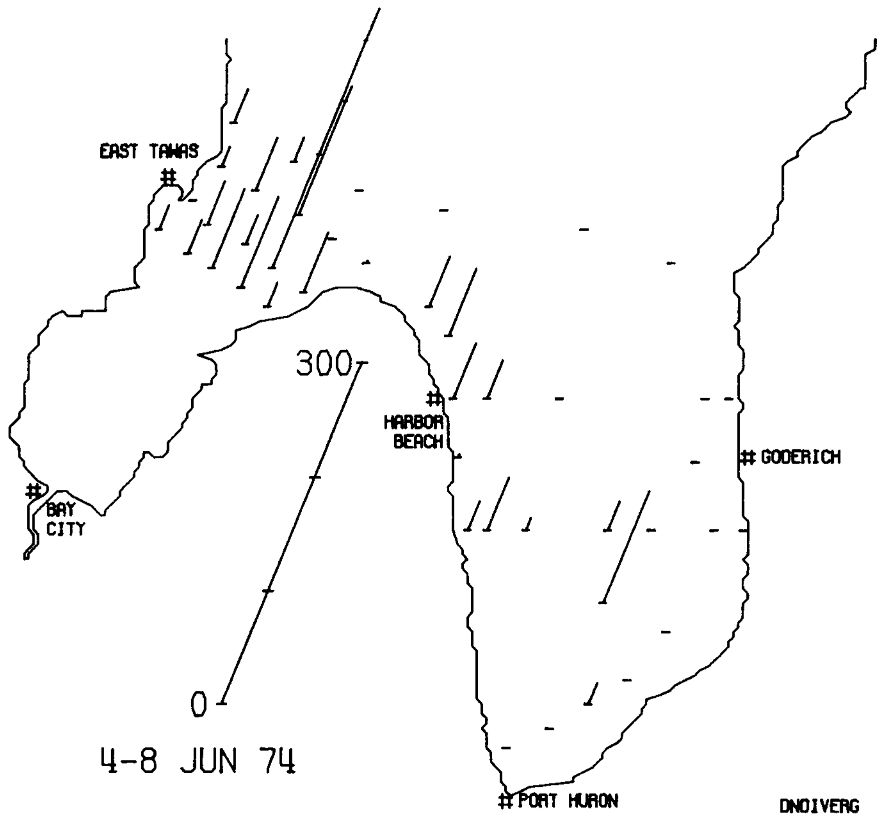


Figure 60. Distribution of Dinobryon divergens. (continued)



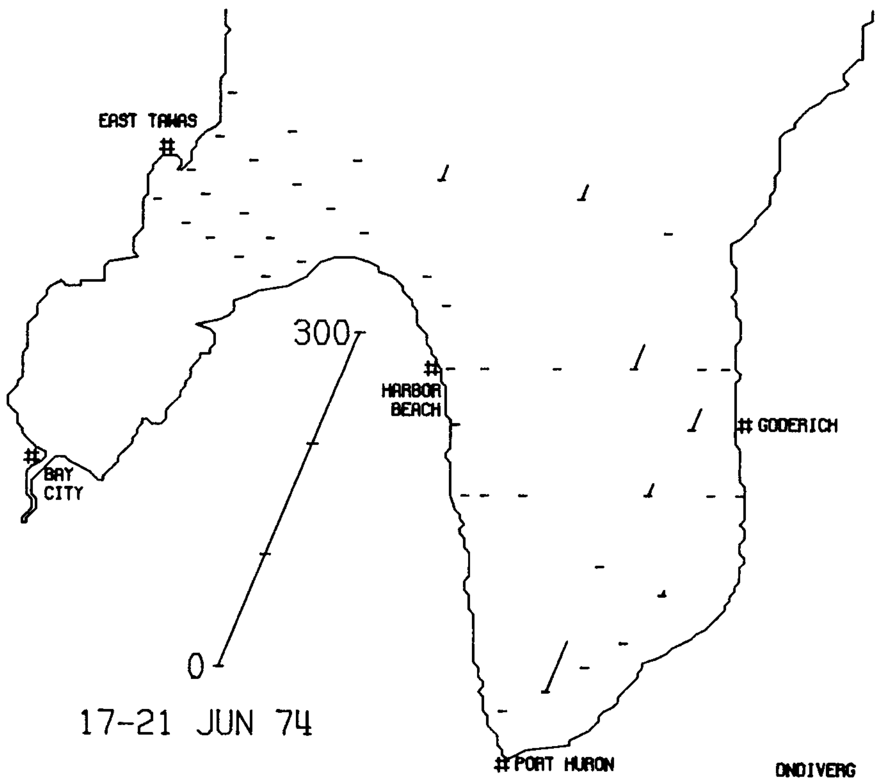


Figure 60. (continued)

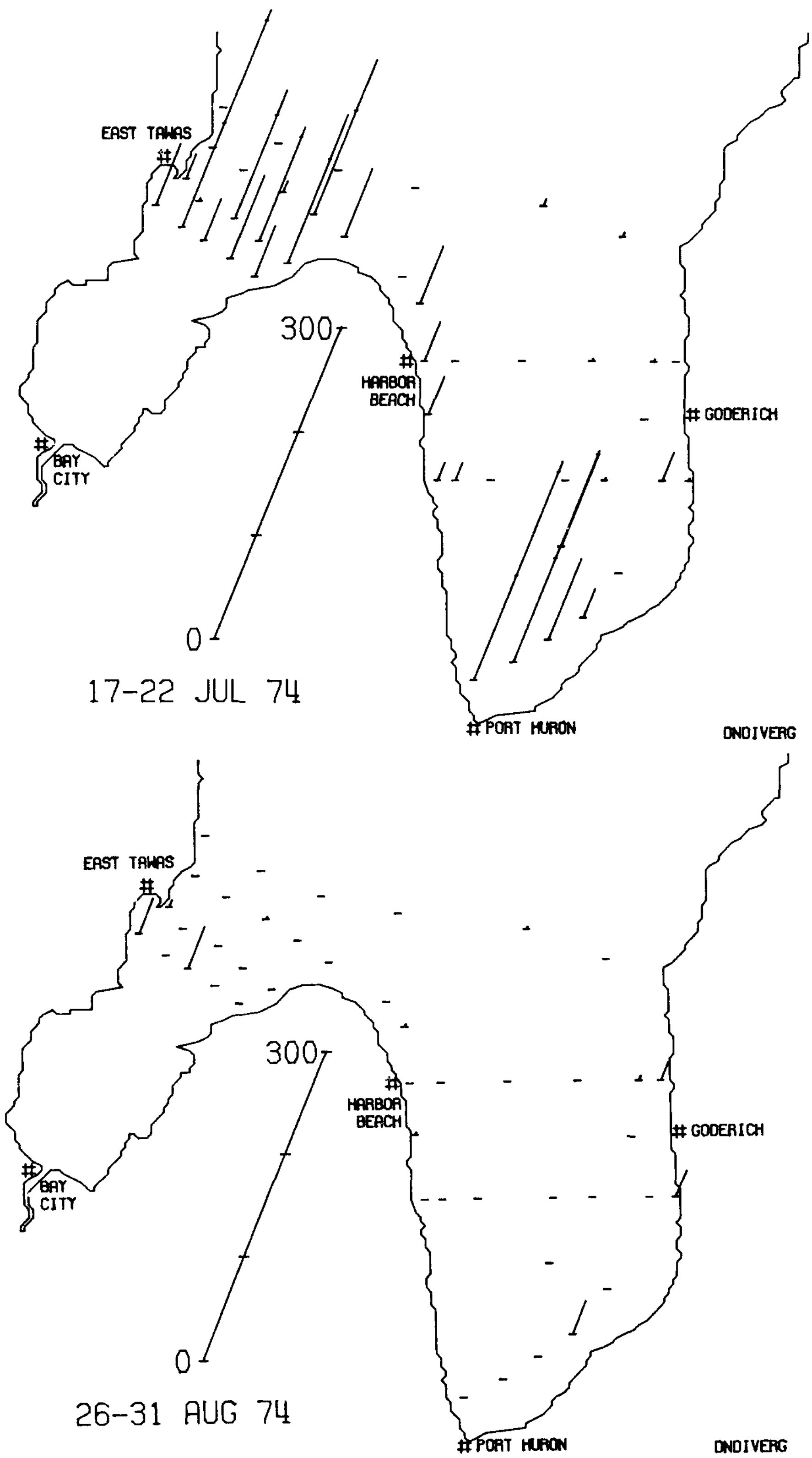
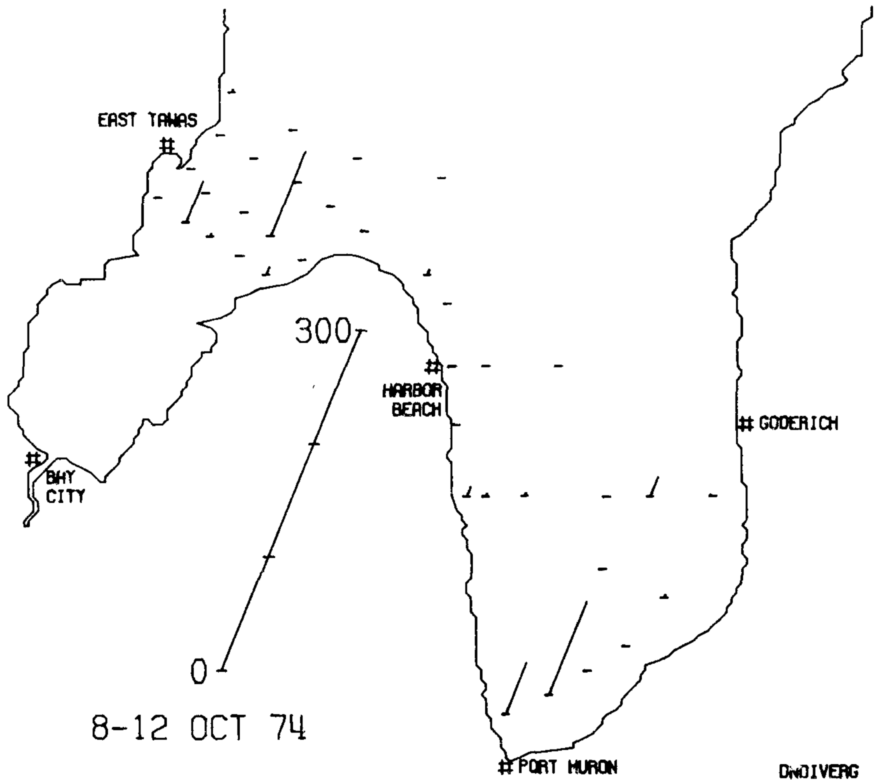


Figure 60. (continued)



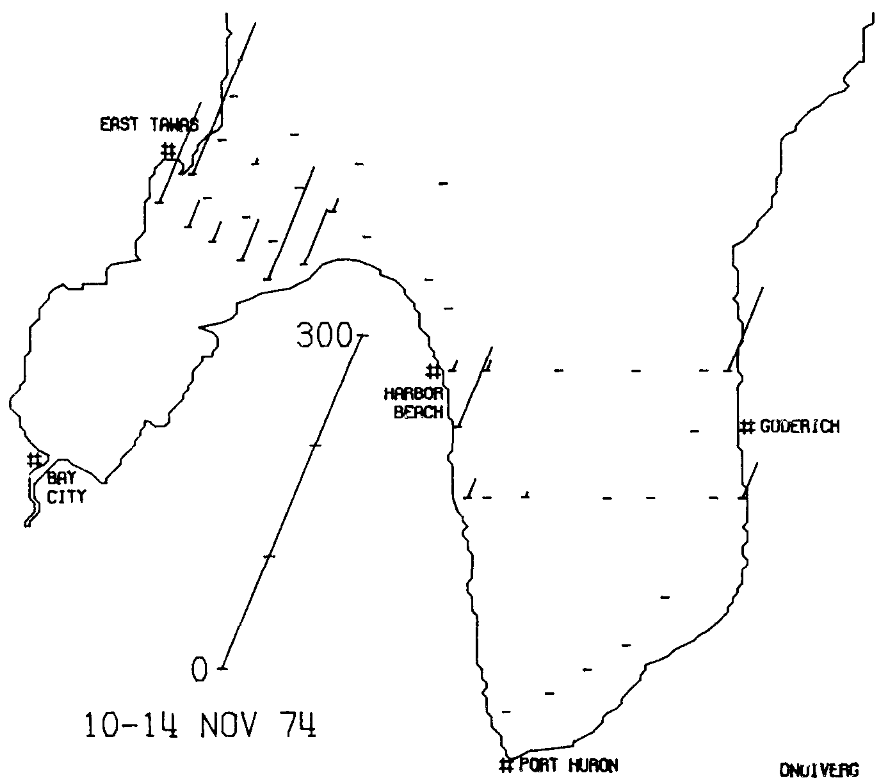
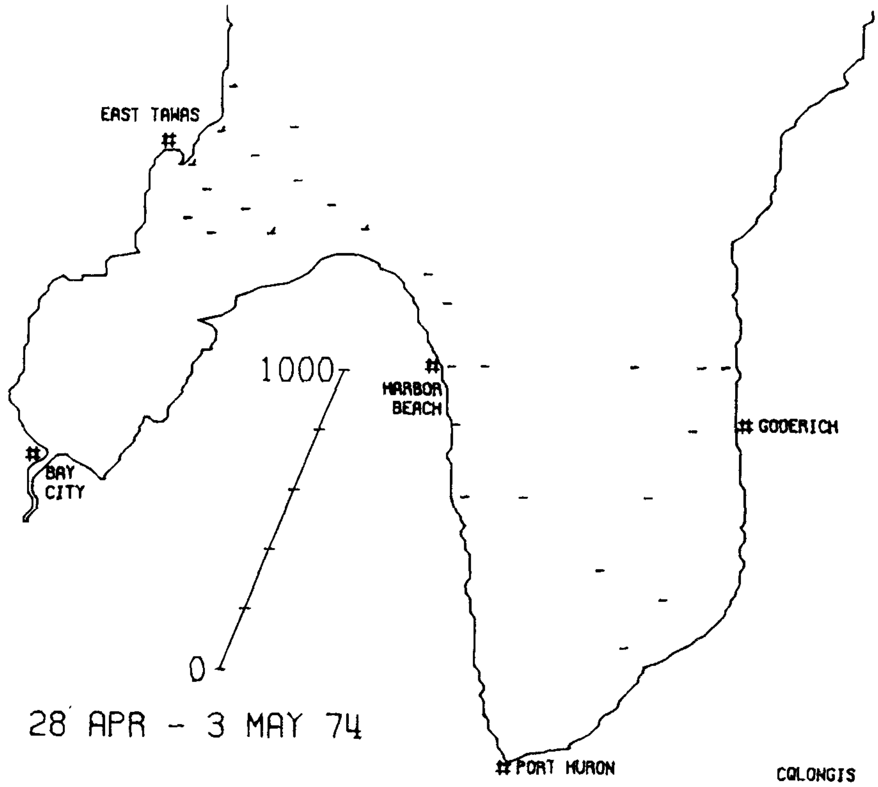


Figure 60. (continued)



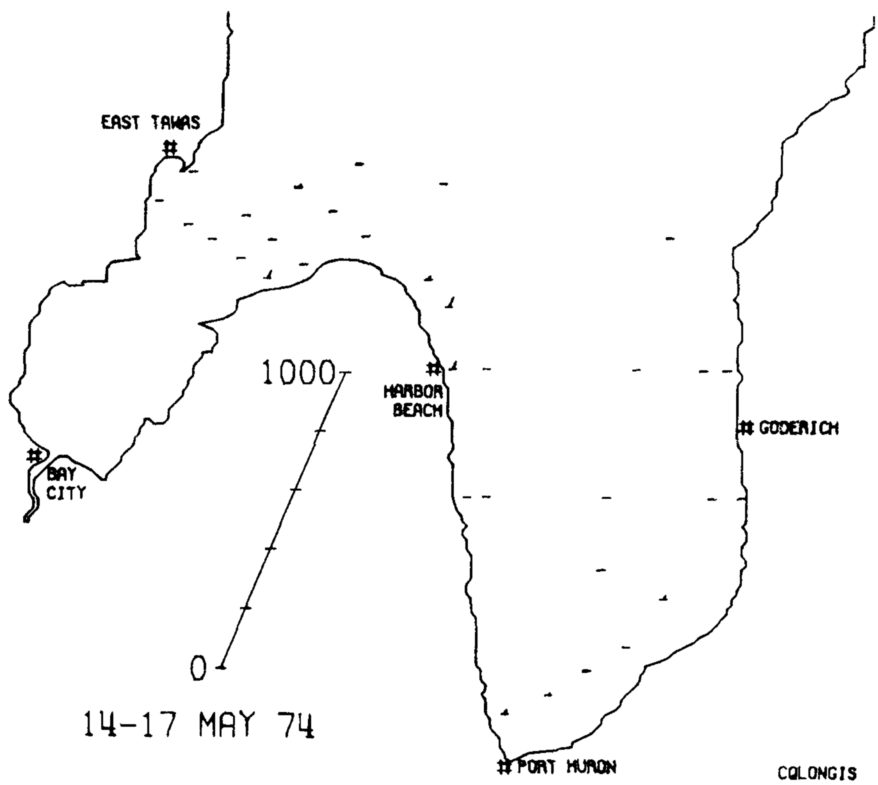
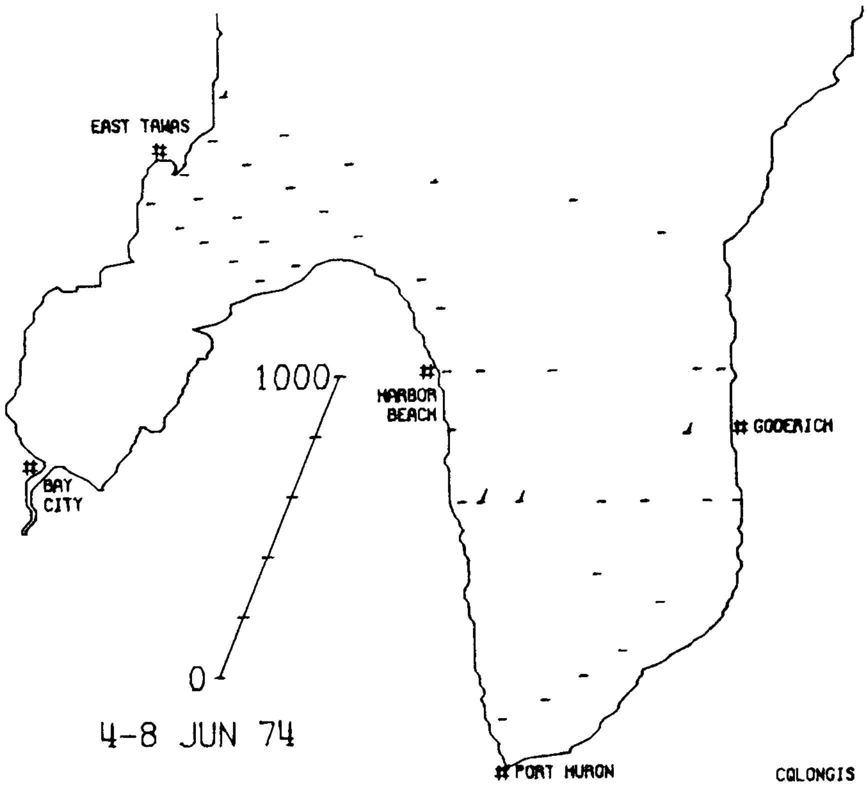
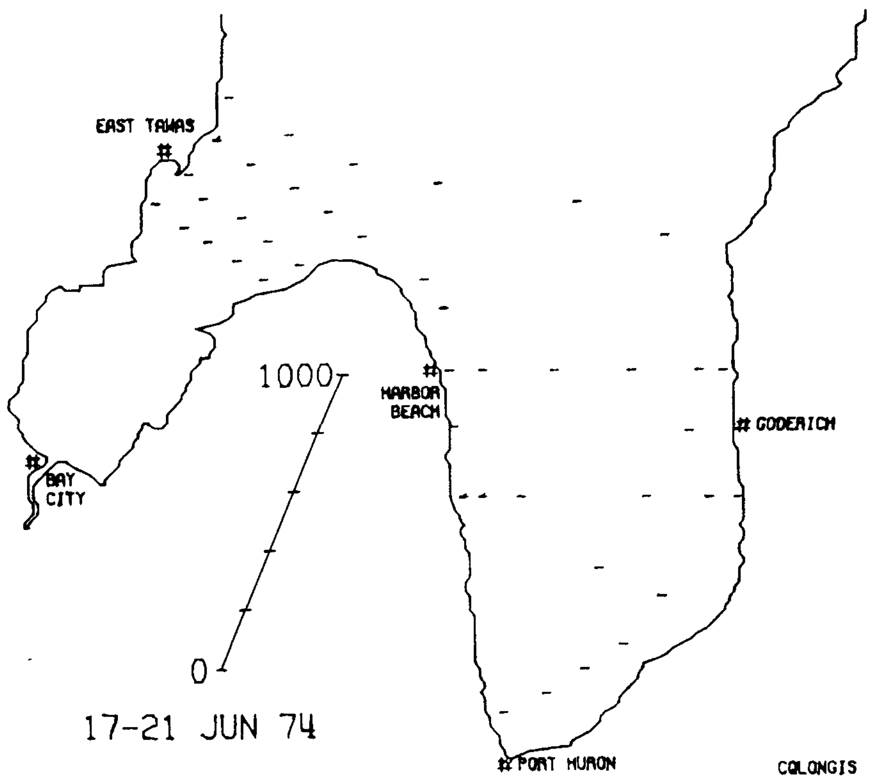


Figure 61. Distribution of <u>Chrysosphaerella longispina</u>. (continued)





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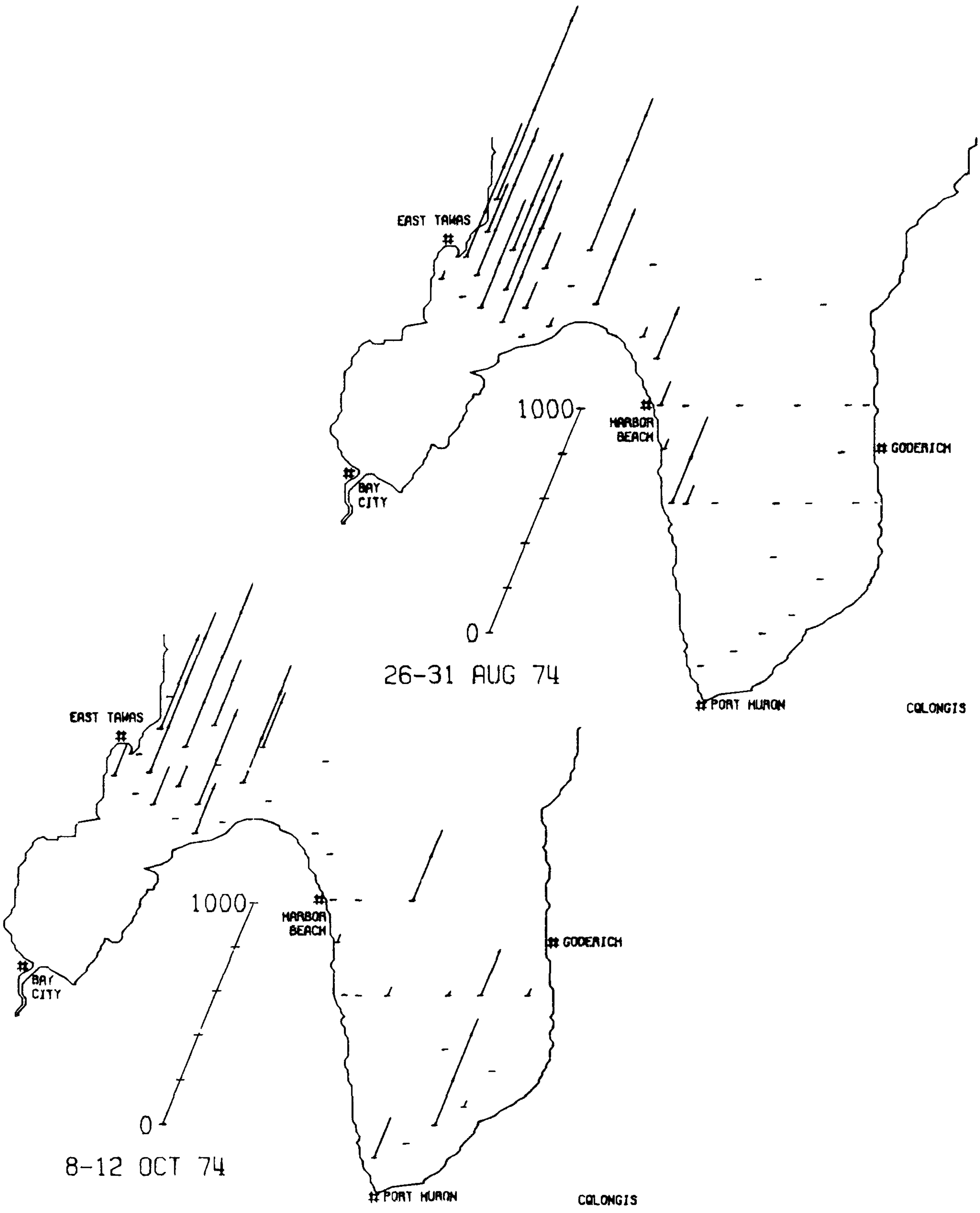

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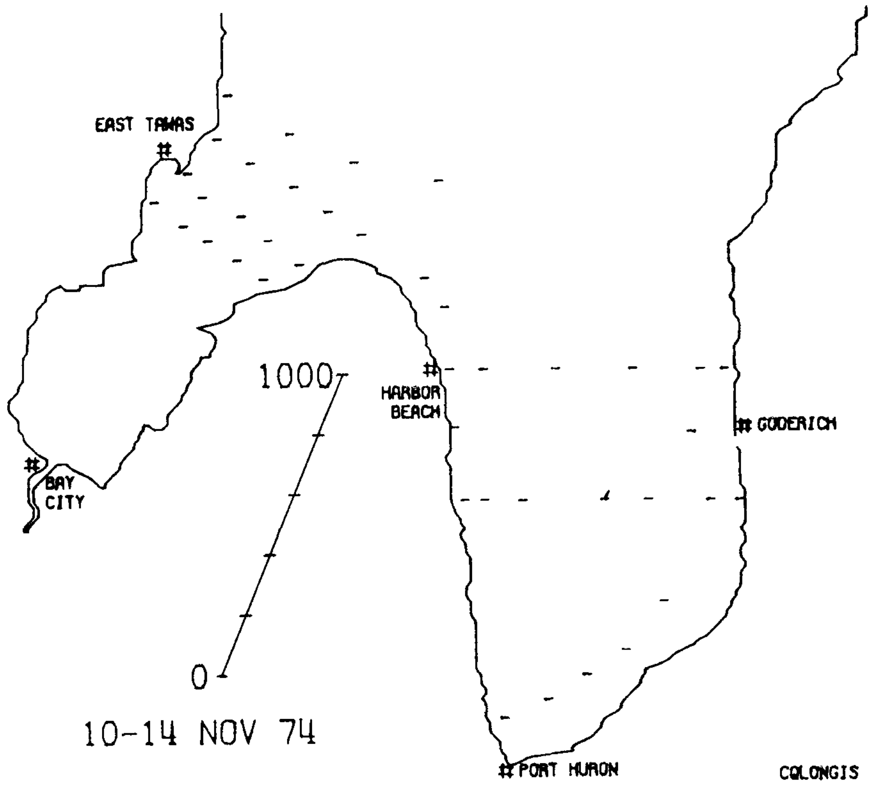


Figure 61. (continued)

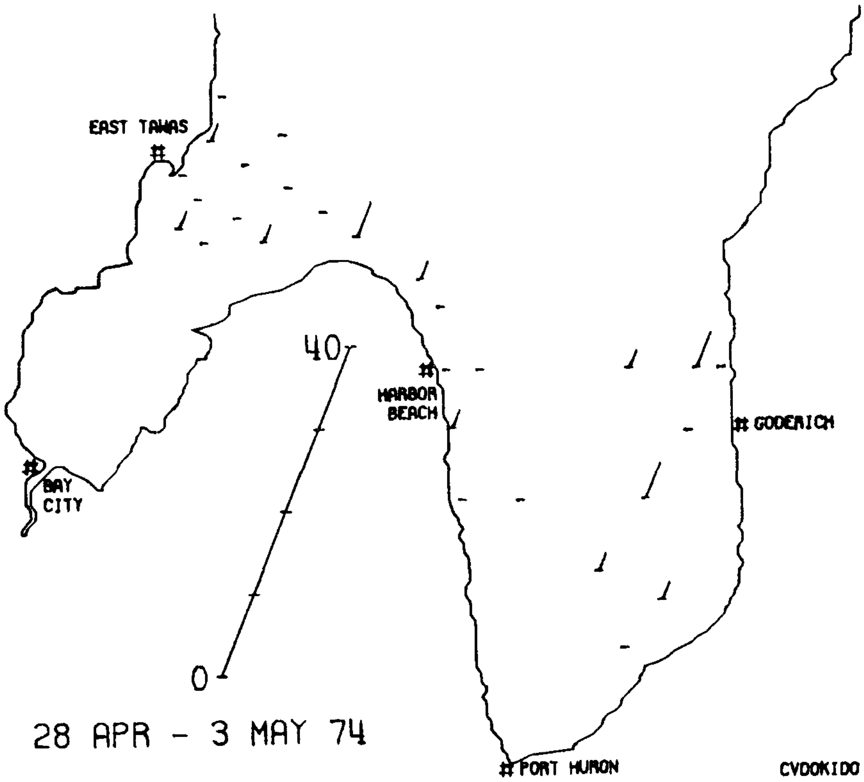
bloomed at stations in the central and northern parts of the Saginaw Bay interface waters and at stations southward along the Michigan coast. During the October sampling period (Fig. 61F), population levels remained high at stations north of the Saginaw Bay interface and at a series of midlake stations surrounding the region in which it had been abundant during August. By November (Fig. 61G), these populations had collapsed, and only isolated minor occurrences were noted.

Chrysococcus dokidophorus

Like the species discussed above, this taxon has rarely been reported from the Laurentian Great Lakes, although it appears to be abundant in Lake Huron. In our samples, its distribution is highly unusual, in that it occurs at all seasons sampled (Fig. 62A-H) but has no readily apparent pattern of distribution. Population maxima occurred during July (Fig. 62E) and October (Fig. 62G). Although highest absolute population densities are reached at stations north of the Saginaw Bay interface during October, population densities at both nearshore and offshore stations tend to be remarkably similar during other sampled months.

Ochromonas sp.

During the early May sampling period (Fig. 63A), this small chrysophycean flagellate was abundant at stations north of Saginaw Bay along the Michigan coast and in the southern portion of the lake, but virtually absent from



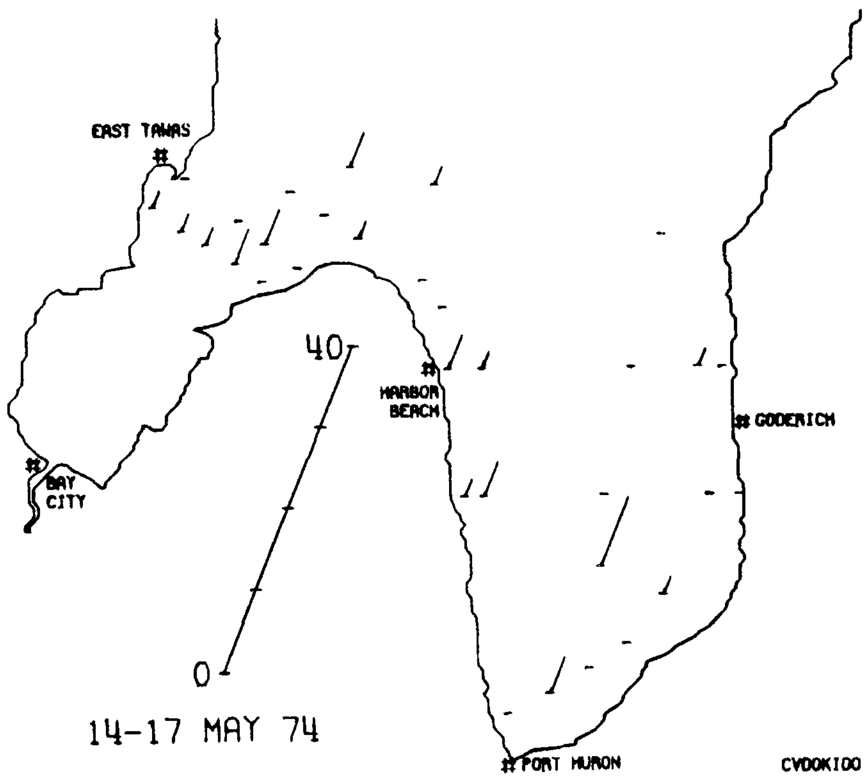
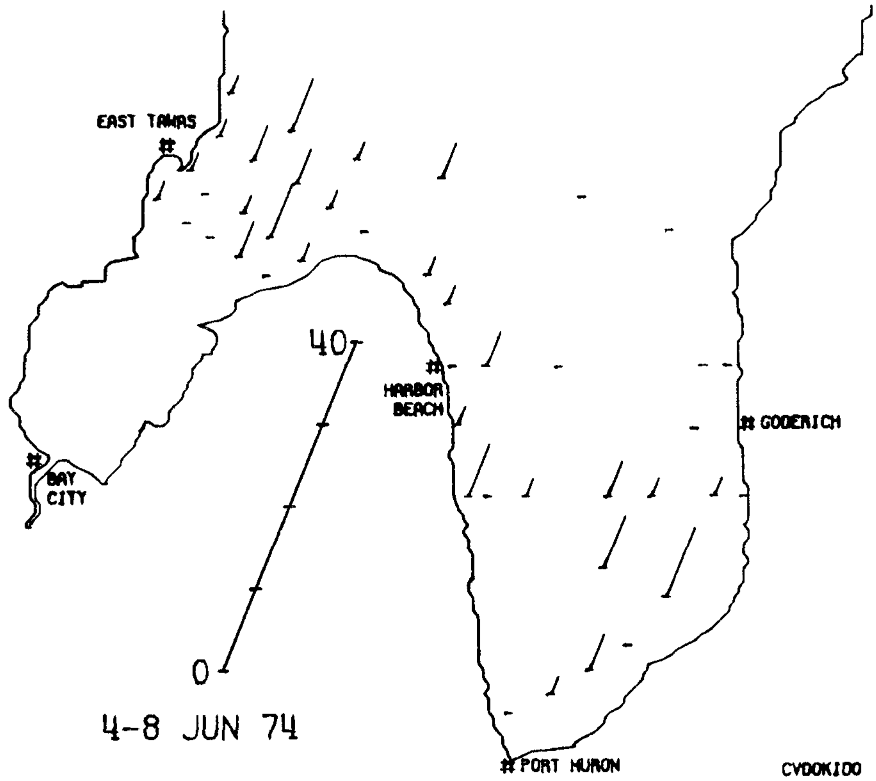


Figure 62. Distribution of *Chrysococcus dokidophorus*. (continued)



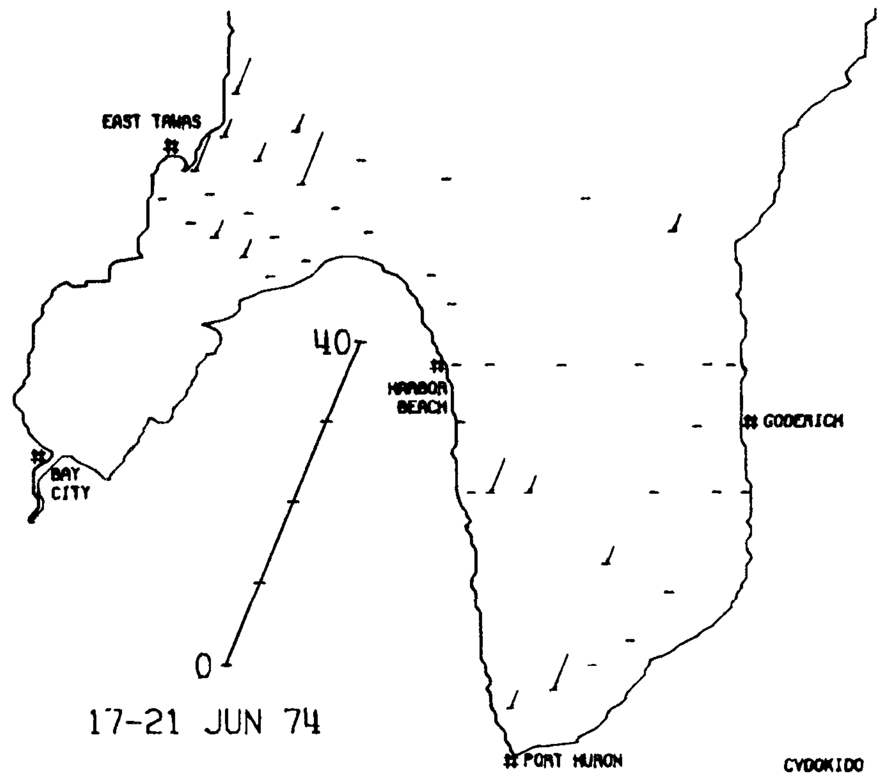
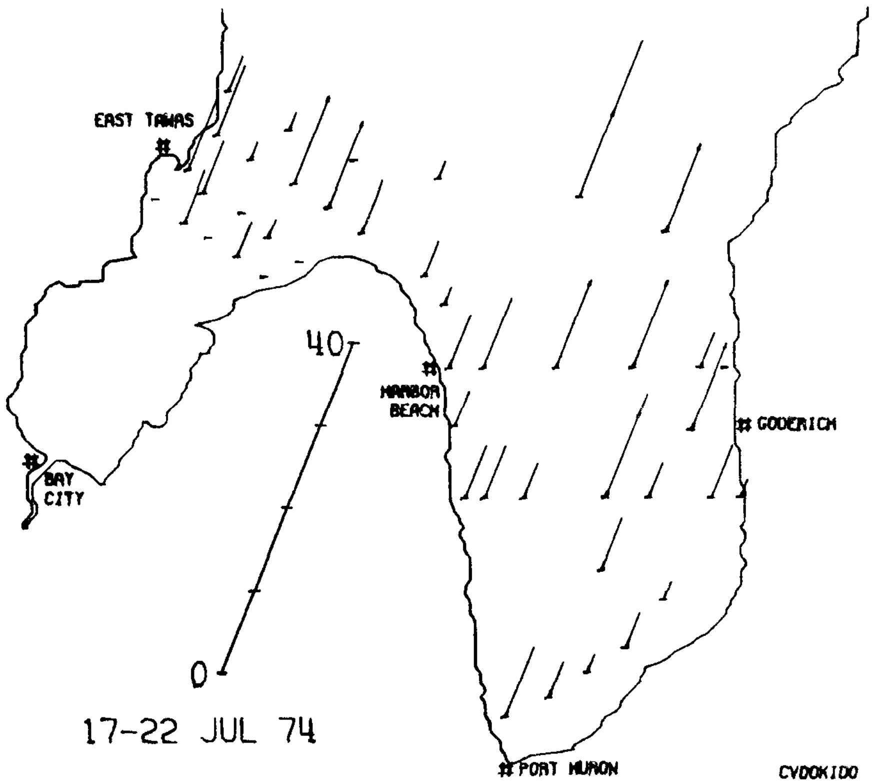


Figure 62. (continued)



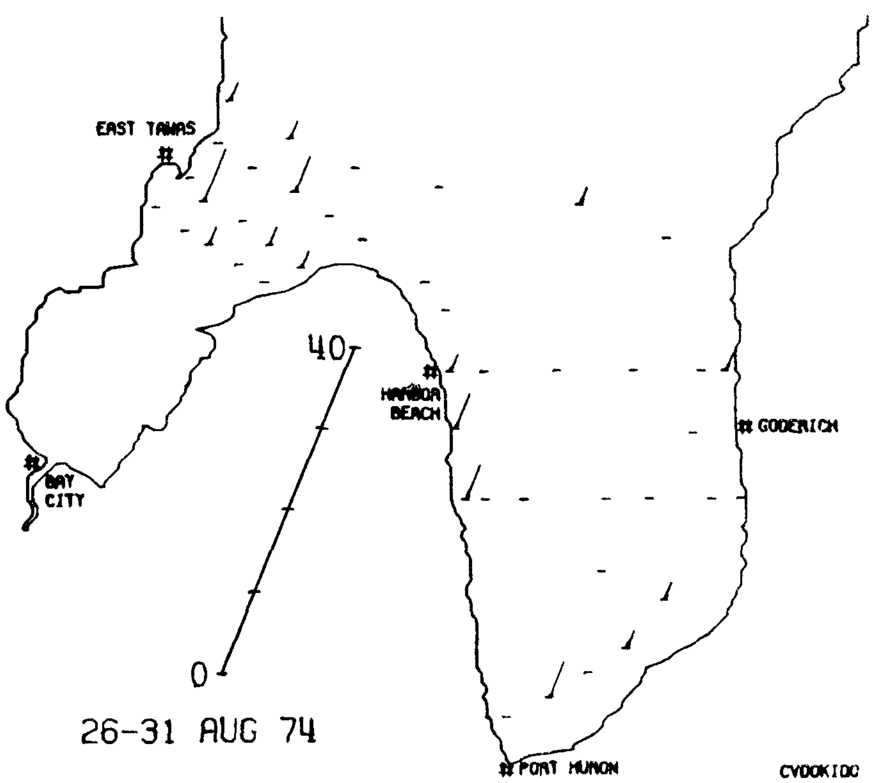
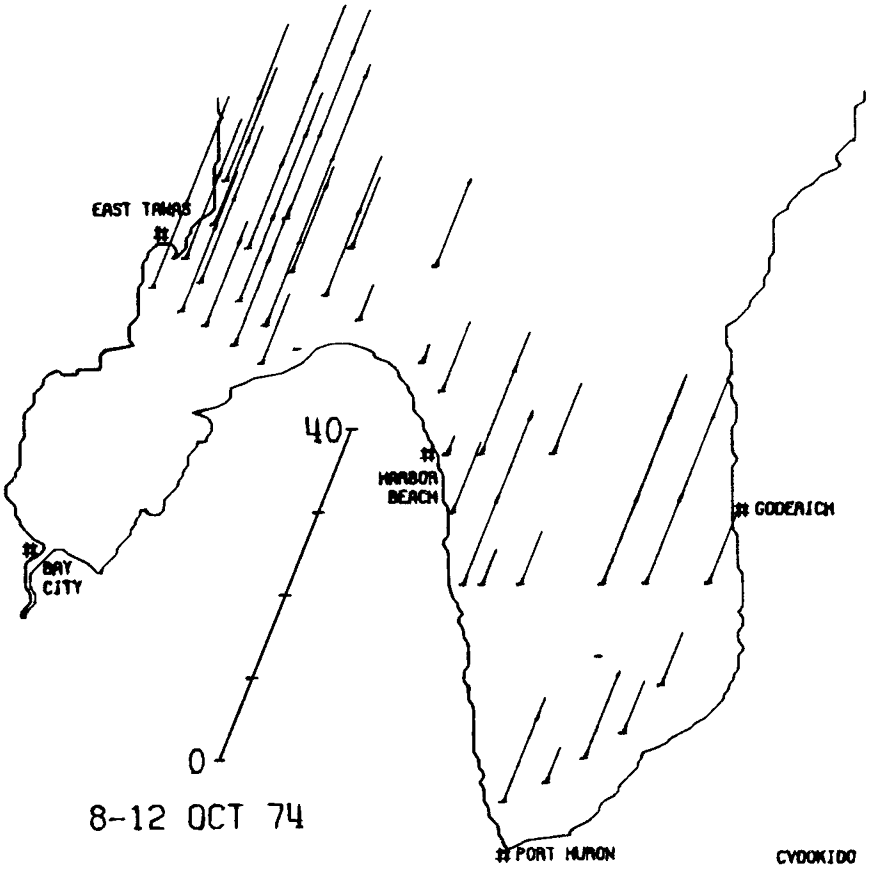


Figure 62. (continued)



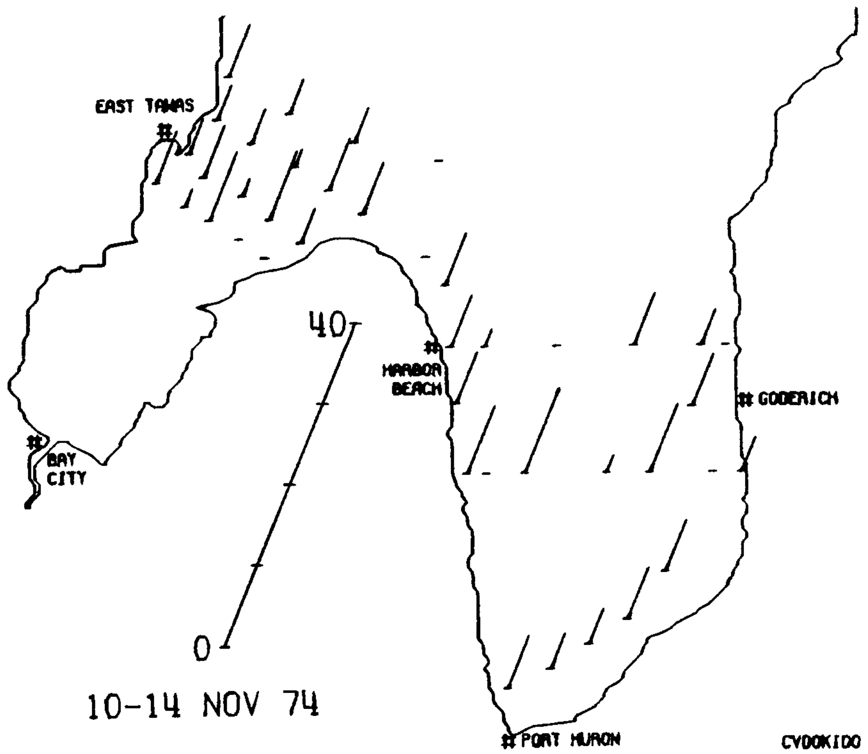
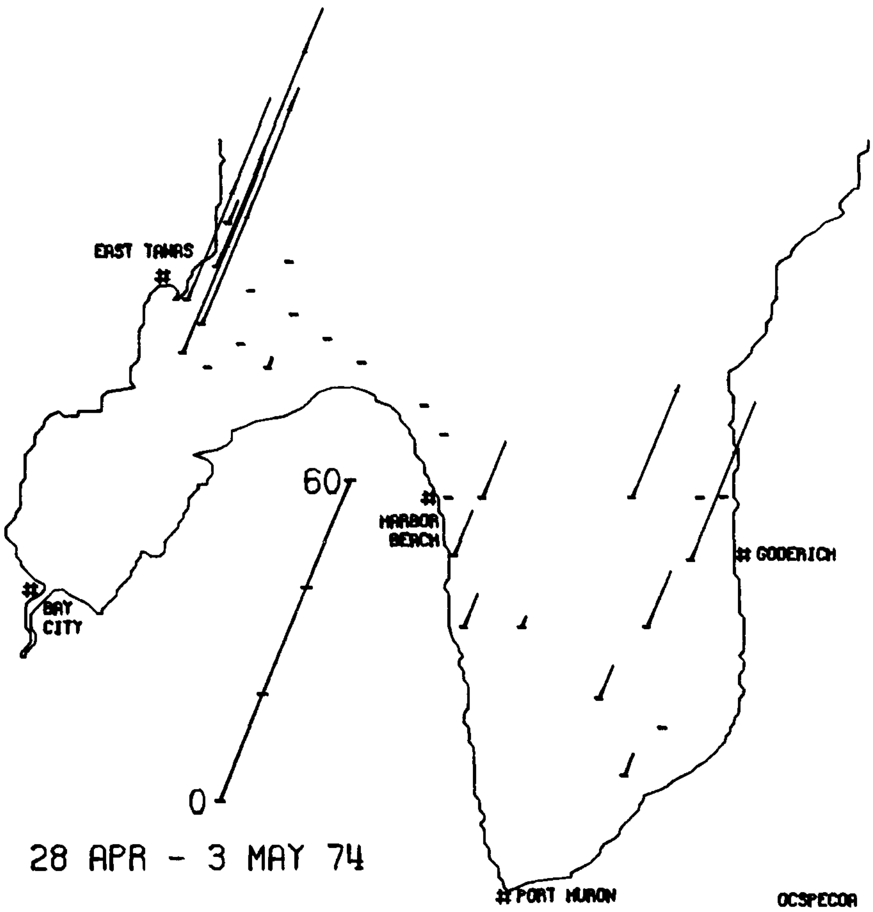


Figure 62. (continued)



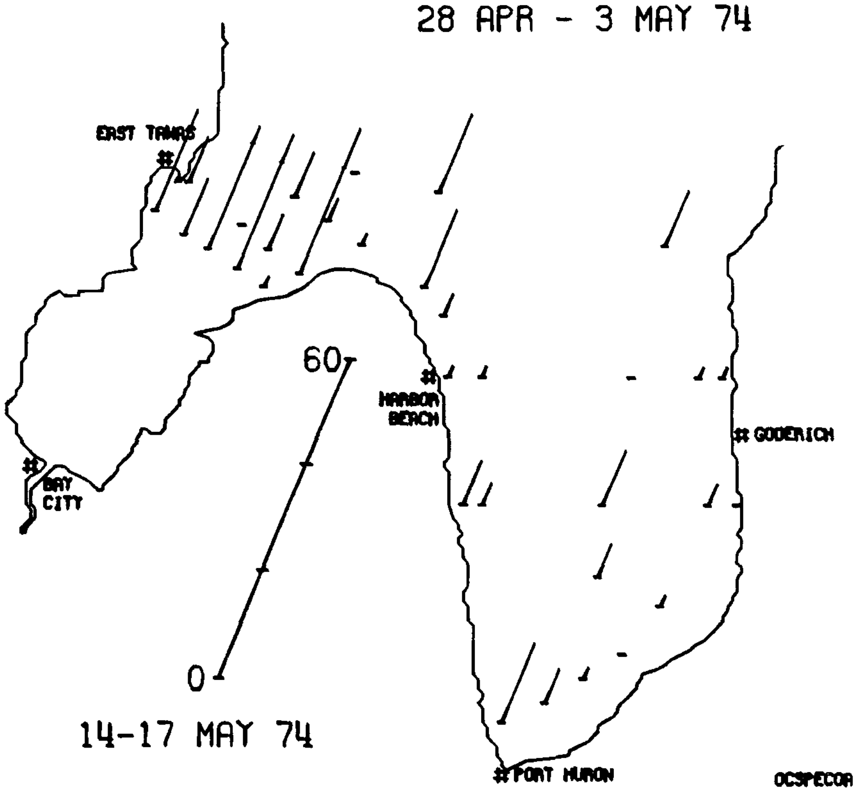
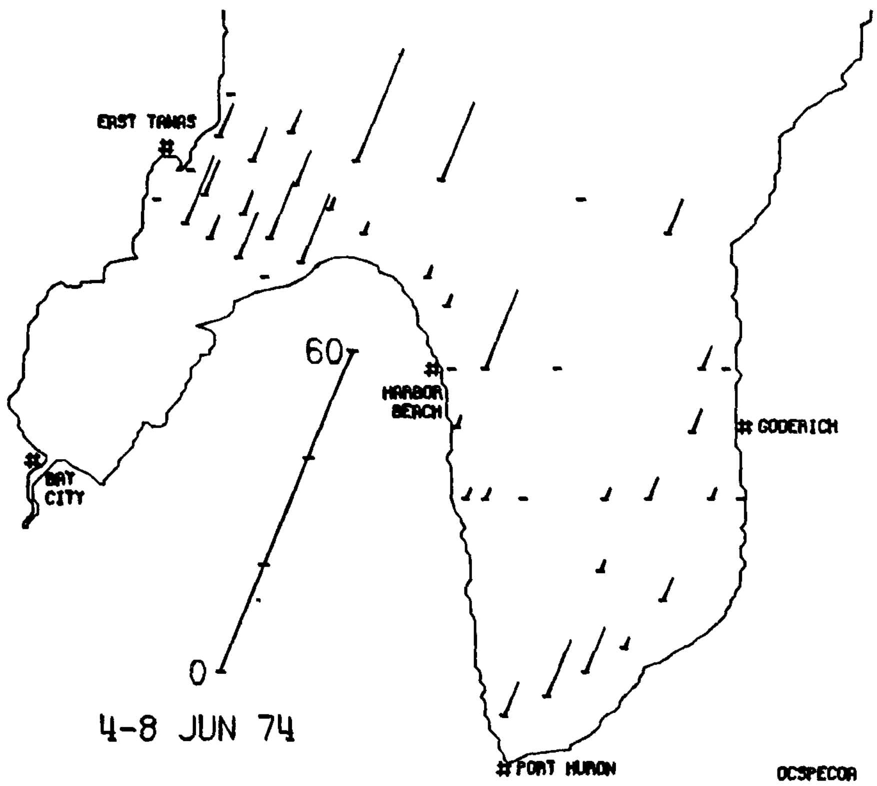


Figure 63. Distribution of Ochromonas sp.. (continued)



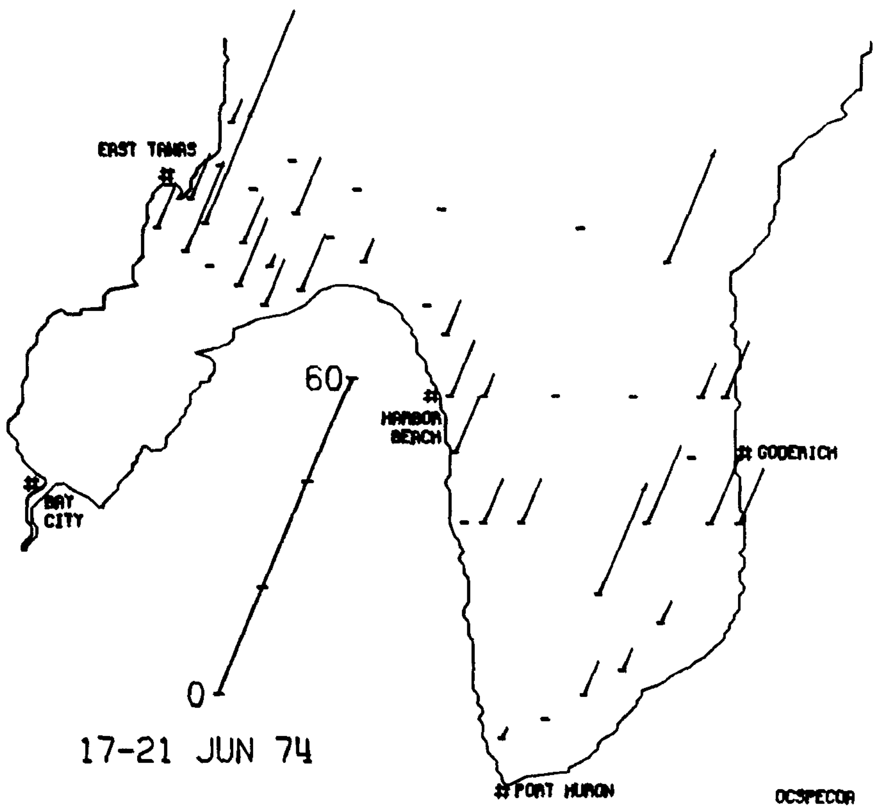


Figure 63. (continued)

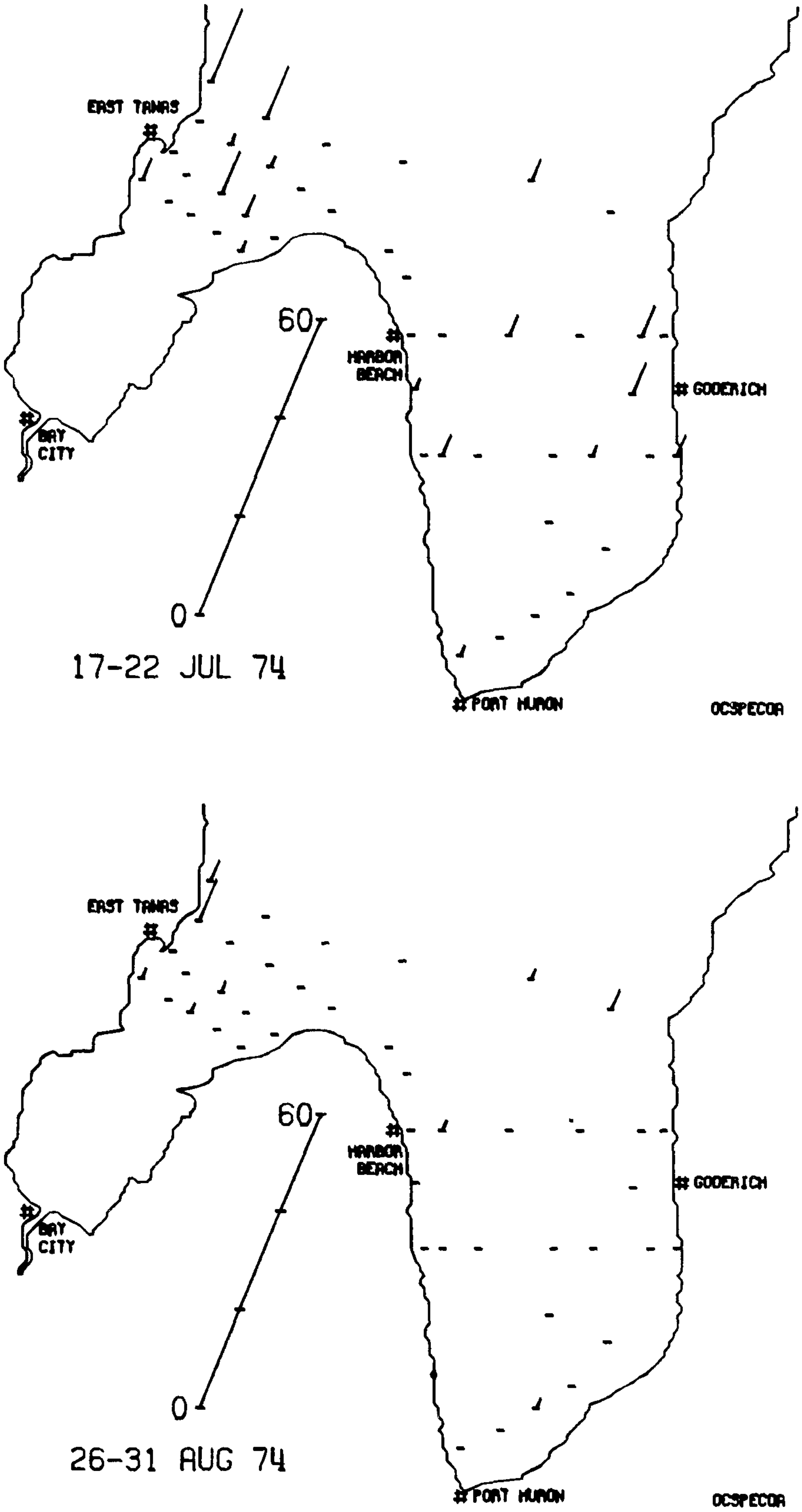
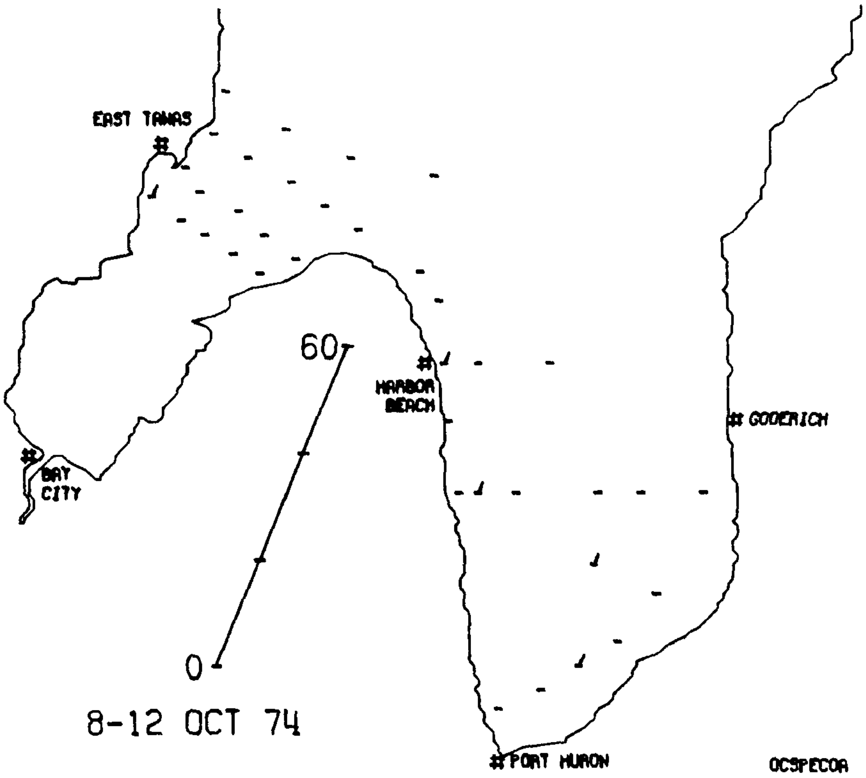


Figure 63. (continued)



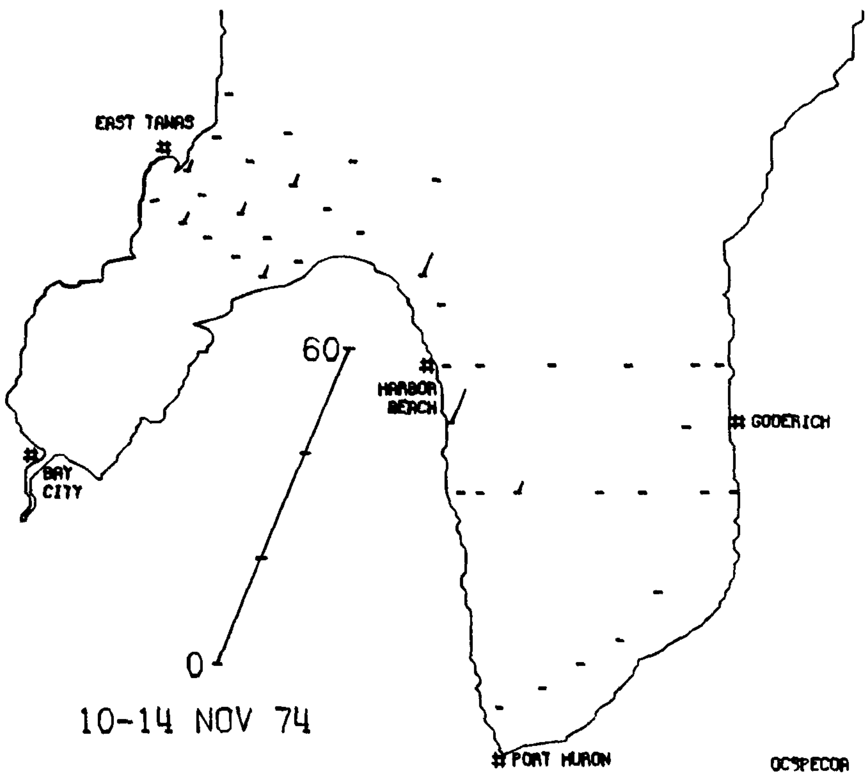


Figure 63. (continued)

stations in the southern sector of the Saginaw Bay interface waters and nearshore stations above Harbor Beach. By mid-May (Fig. 63B), it had become generally distributed and remained so during June (Fig. 63C-D). Population levels were reduced during July and August and reached the seasonal minimum in October, with only slight recovery at stations sampled during the November cruise (Figs. 63E-H).

Cryptophyta

The cryptomonads are a rather enigmatic group of organisms with a number of unusual morphological and physiological characteristics. They are extensively distributed in nearly all fresh and brackish bodies of water. They are generally distributed throughout the Great Lakes system, and unlike most other phytoplankton groups, what appear to be the same species occupy habitats ranging from pristine to highly disturbed. Although highest abundance is usually found in eutrophic areas, members of this group do not usually show the degree of habitat differentiation exhibited by most other phytoplankton organisms. This is illustrated by the abundance of the group in southern Lake Huron (Fig. 64A-H). Although there are seasonal fluctuations in abundance, the group tends to be remarkably evenly distributed throughout the area of study.

Cryptomonas ovata

This species is apparently widely distributed in the upper Great Lakes including northern Lake Huron (Schelske *et al.*, 1974). It was present in most of our early May (Fig. 65A) samples from southern Lake Huron with relatively little variability in abundance from station to station. In late May (Fig. 65B) population levels tended to increase in the inner Saginaw Bay stations and at nearshore stations particularly in the western and southern sides of the lake. A similar pattern was noted in the early June (Fig. 65C) samples with the trend towards increase in nearshore stations extended to the Canadian coast. This pattern had been somewhat modified by late June (Fig. 65D) when high population levels were found in the southern sector of the Saginaw Bay interface and southward along the Michigan coast, but only very low populations at other stations sampled. This species had been reduced to a seasonal minimum in abundance by the time the mid-July samples were taken (Fig. 65E) and remained present in low and relatively uniform numbers throughout the rest of the season (Figs. 65F-H).

Rhodomonas minuta var. *nannoplanctica*

Like *Cryptomonas ovata* this species is generally distributed throughout the Great Lakes system. Although less abundant than *C. ovata* it too was present at most stations sampled thoughout the year in southern Lake Huron (Fig. 66A-H). The primary distinction in their distribution pattern is the fact that *R. minuta* var. *nannoplanctica* showed a consistent tendency to be least abundant in the Saginaw Bay interface waters and nearshore stations on the Michigan coast and the most abundant particularly during June (Fig. 66D) at offshore stations and stations near the Canadian coast.

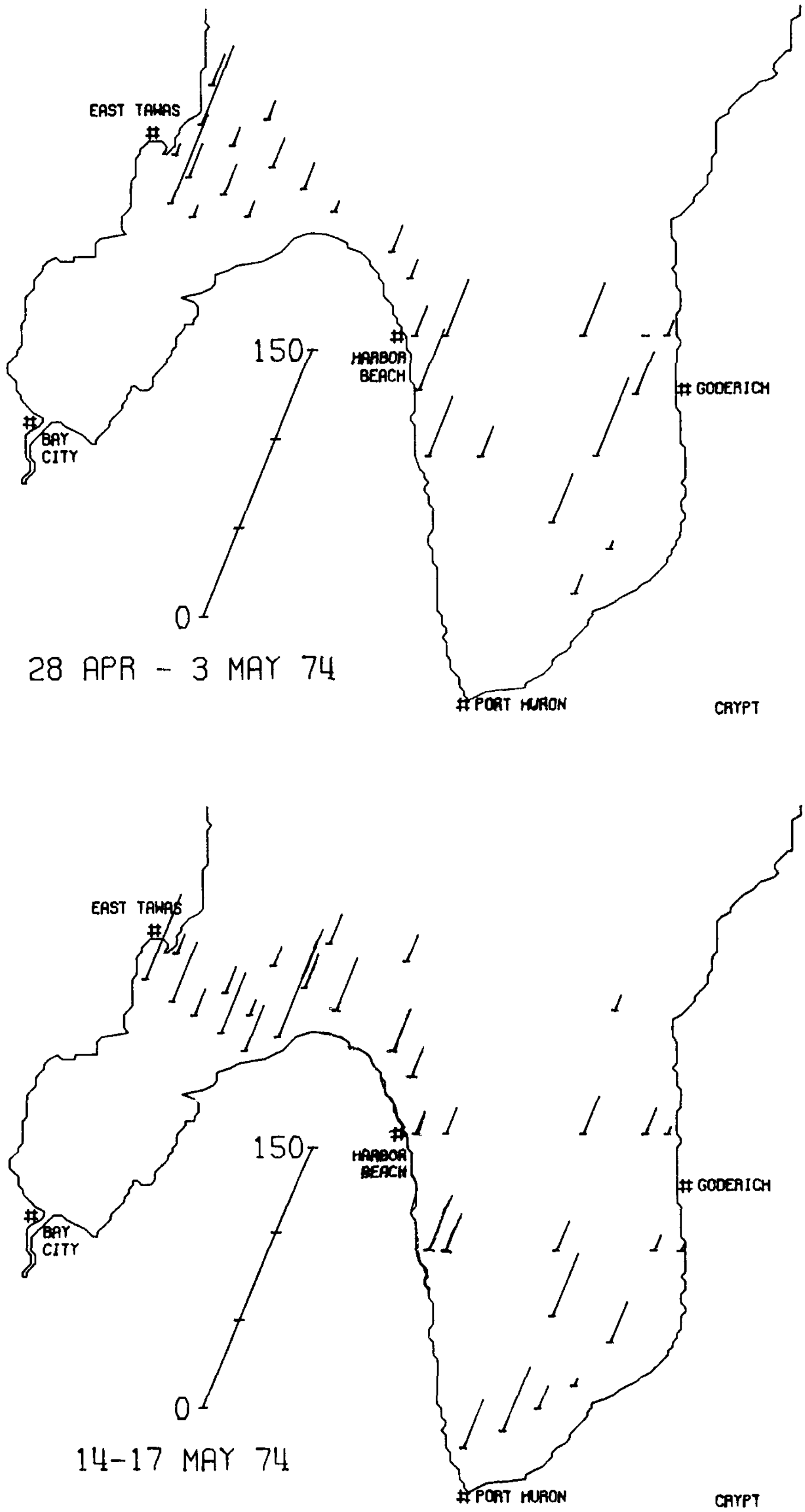
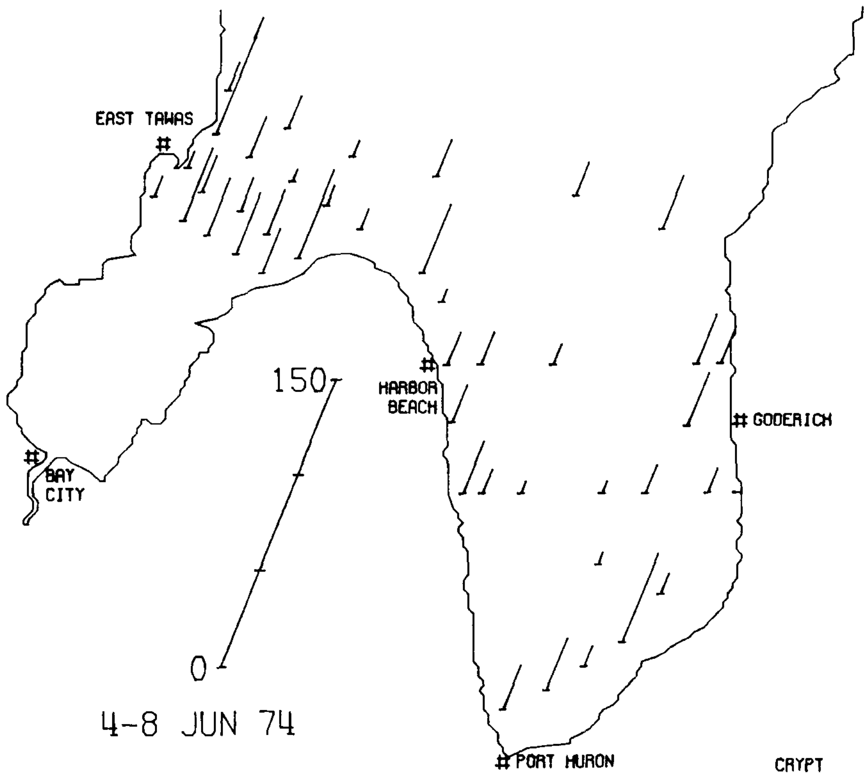
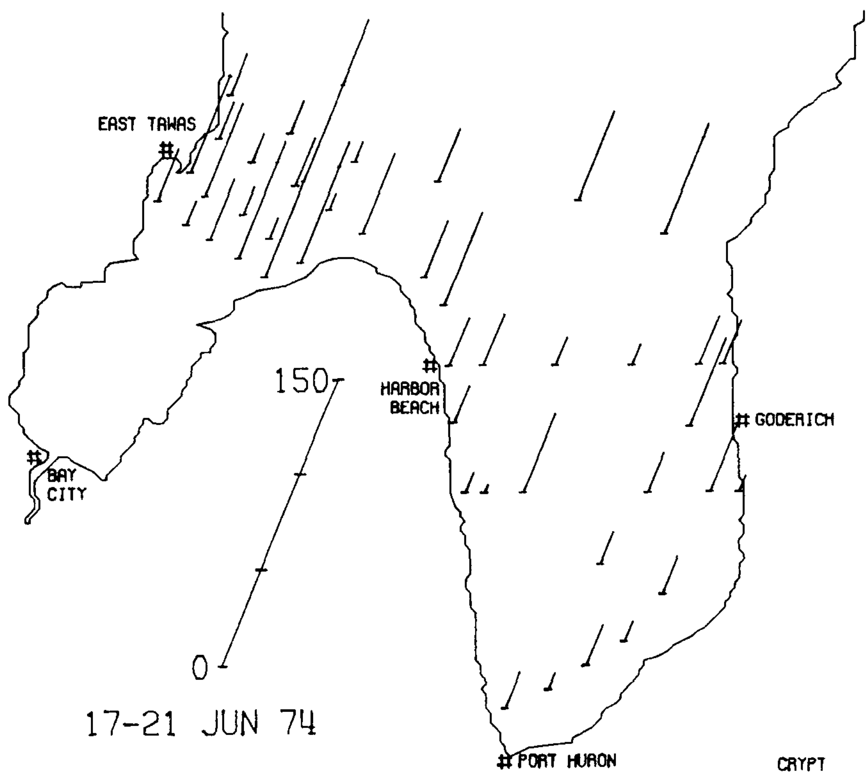


Figure 64. Seasonal abundance and distribution trends of Cryptomonads. (continued)





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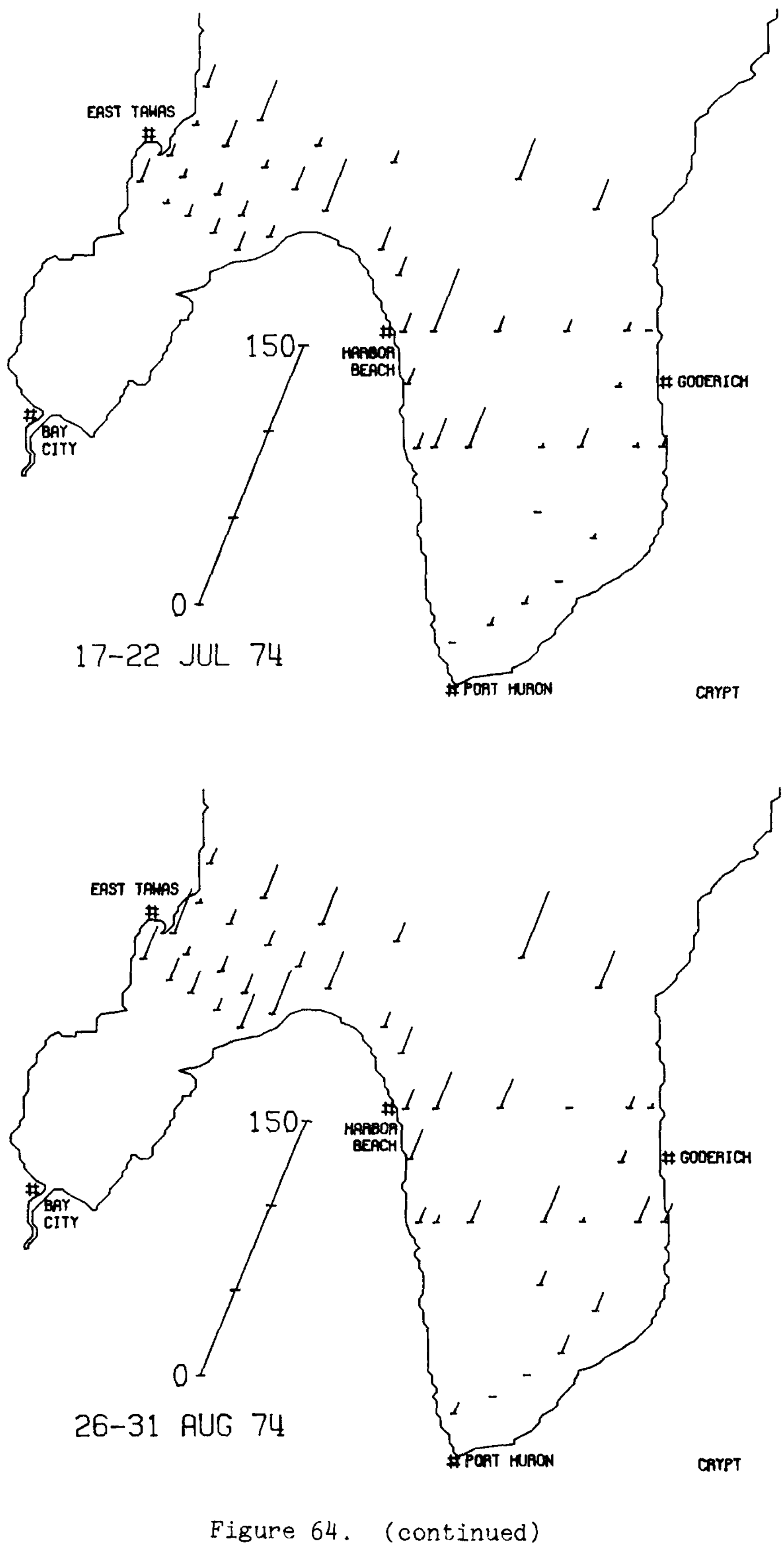

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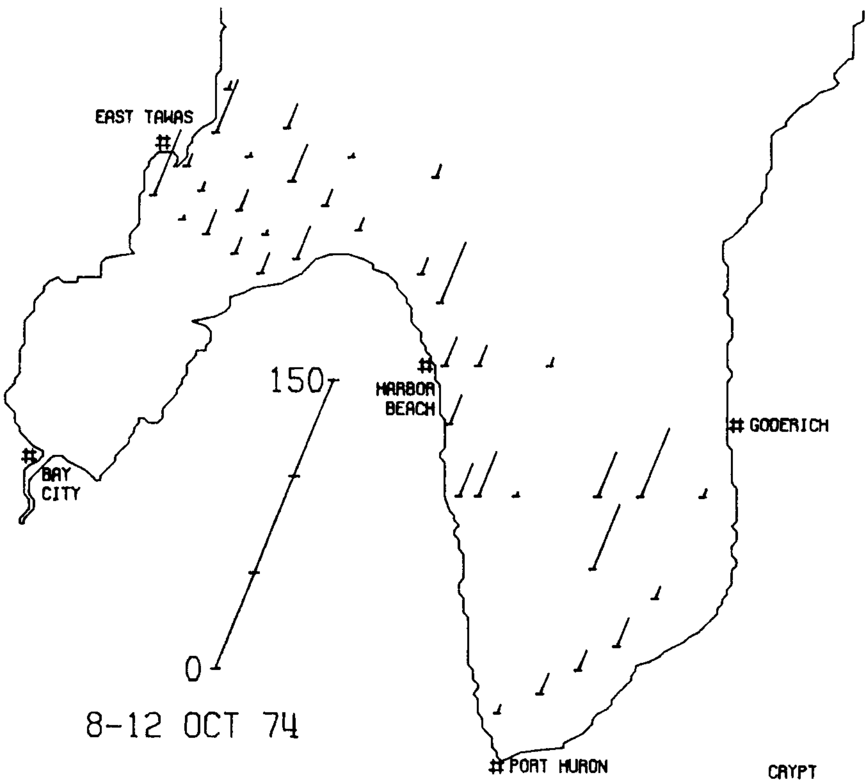

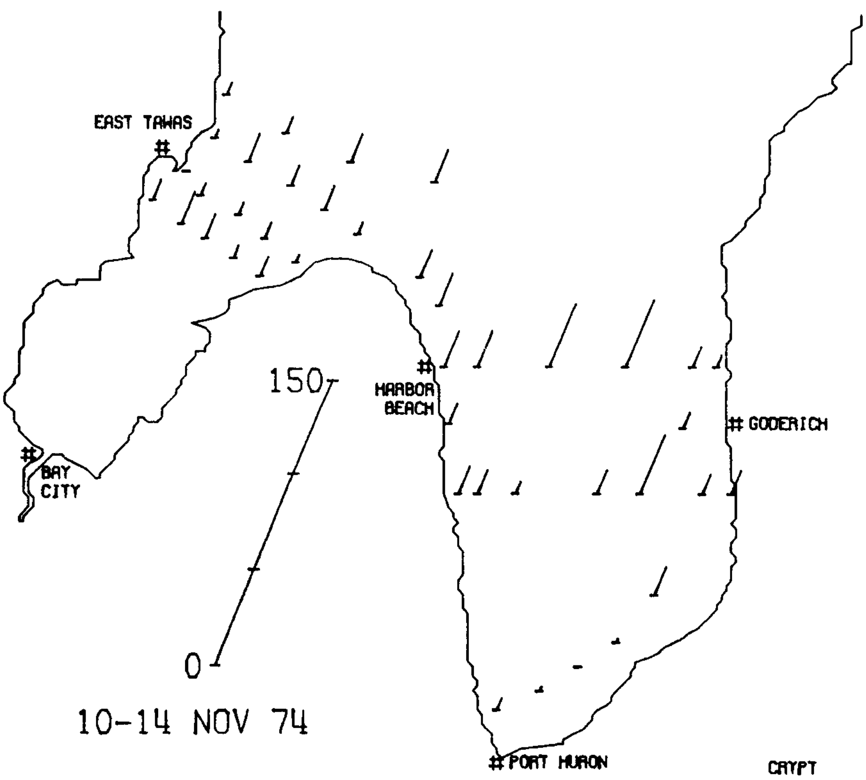

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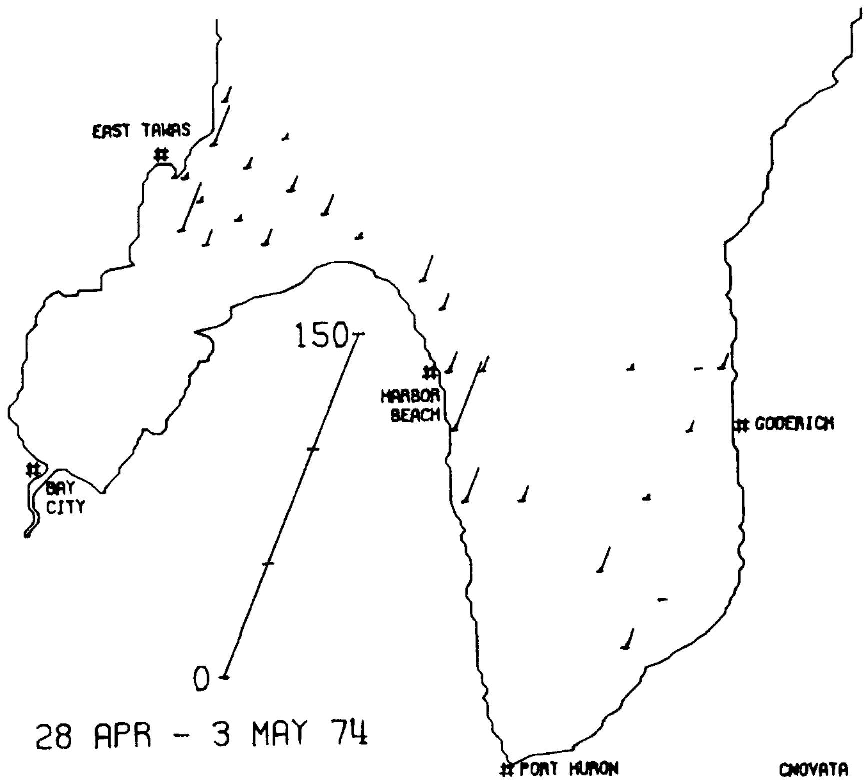


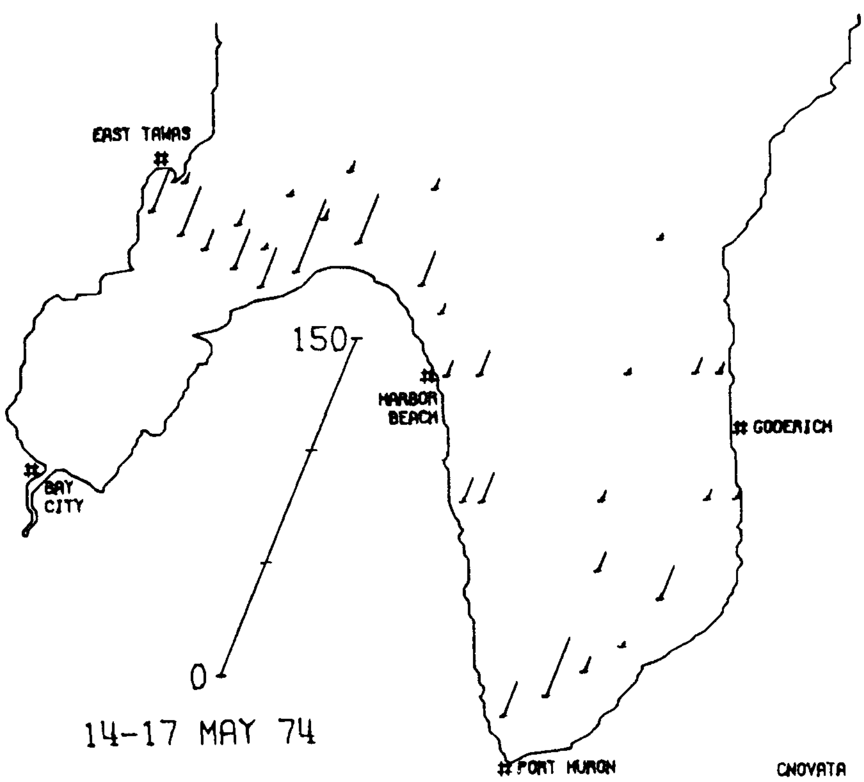
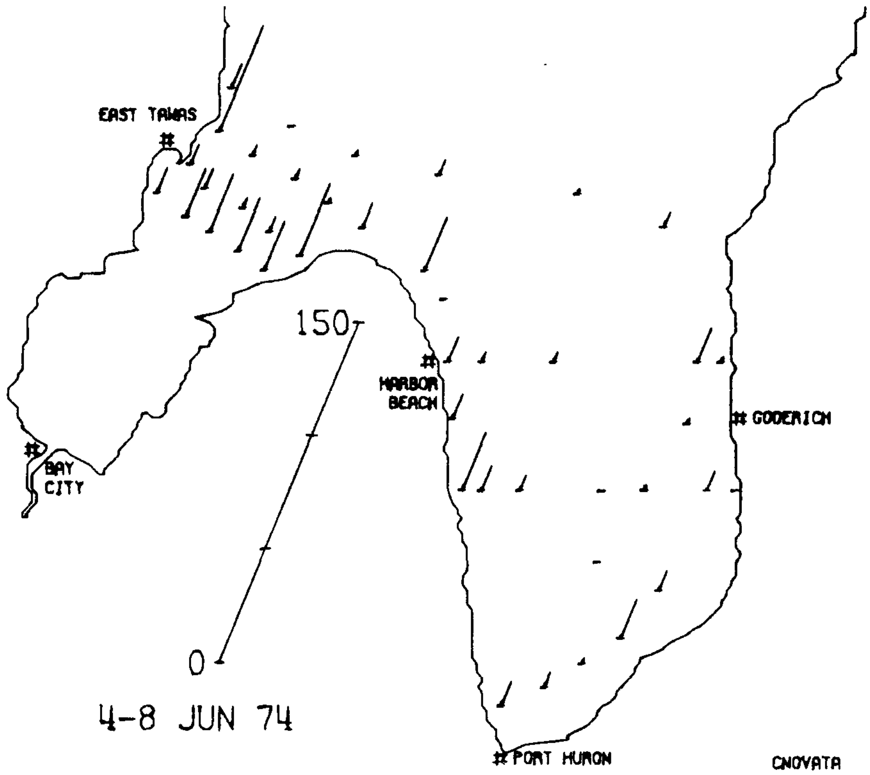
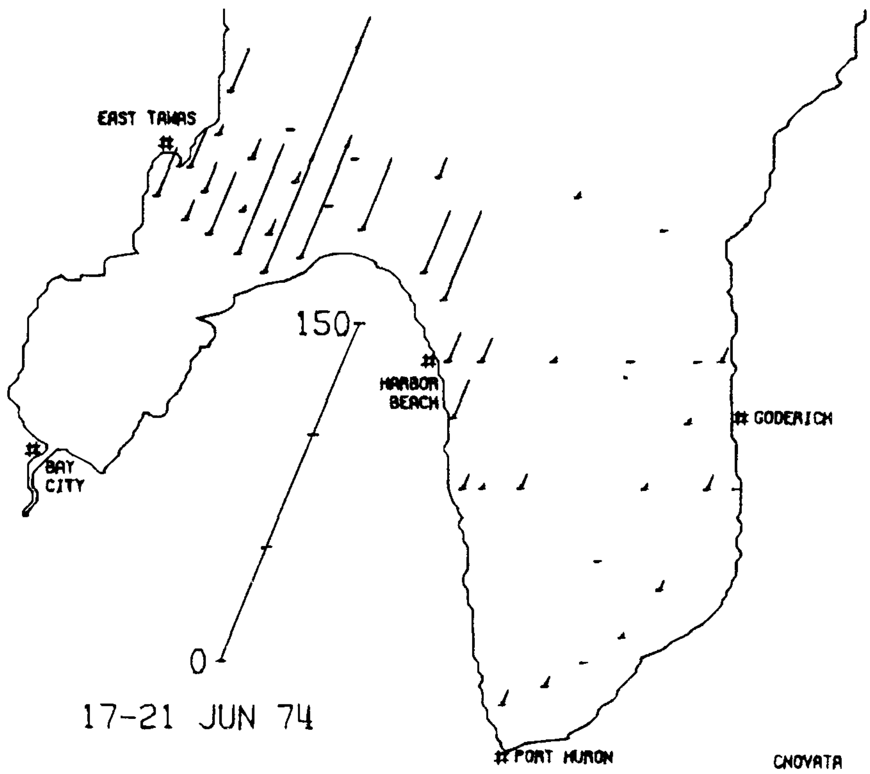


Figure 65. Distribution of *Cryptomonas ovata*. (continued)





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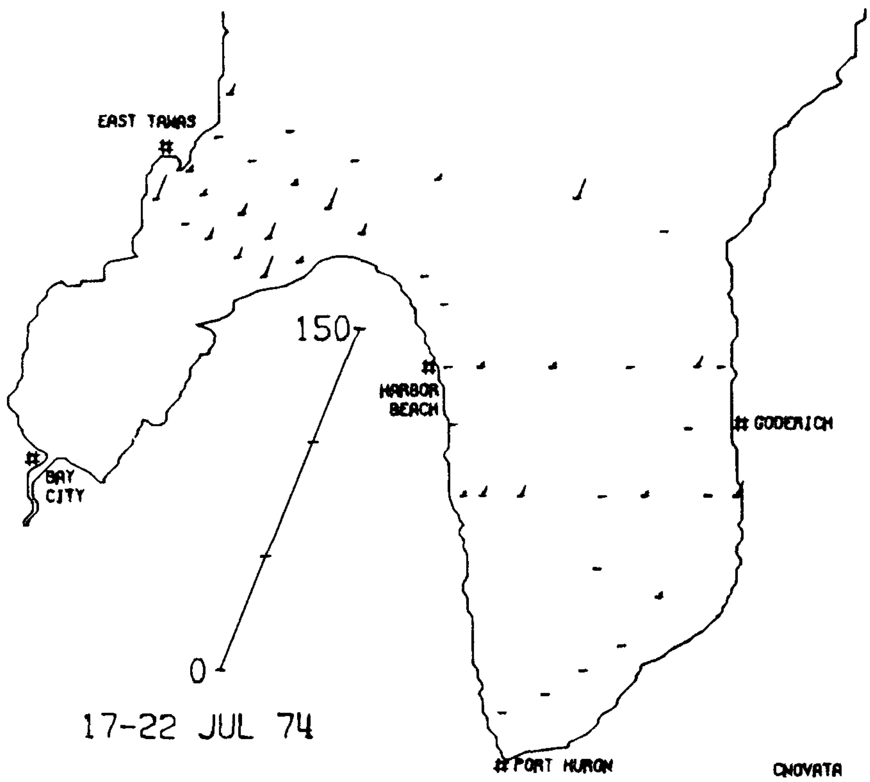

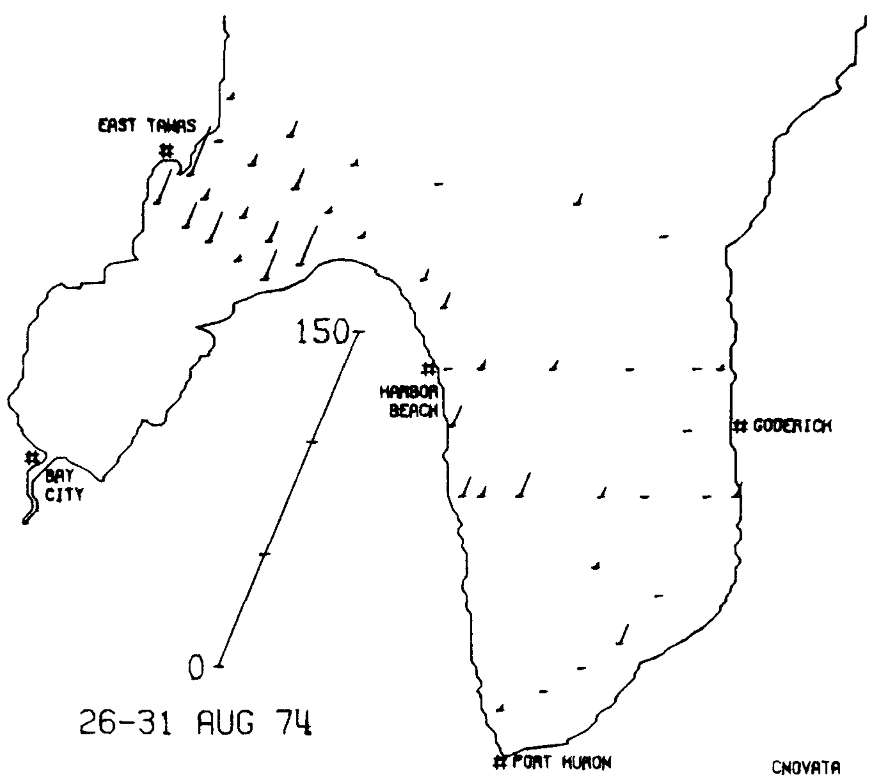

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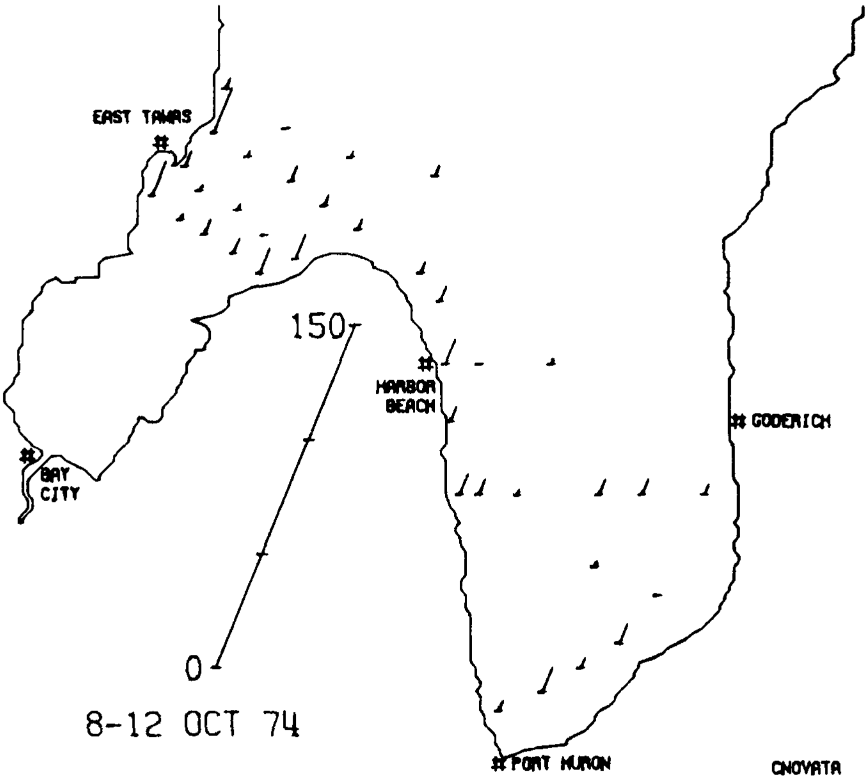

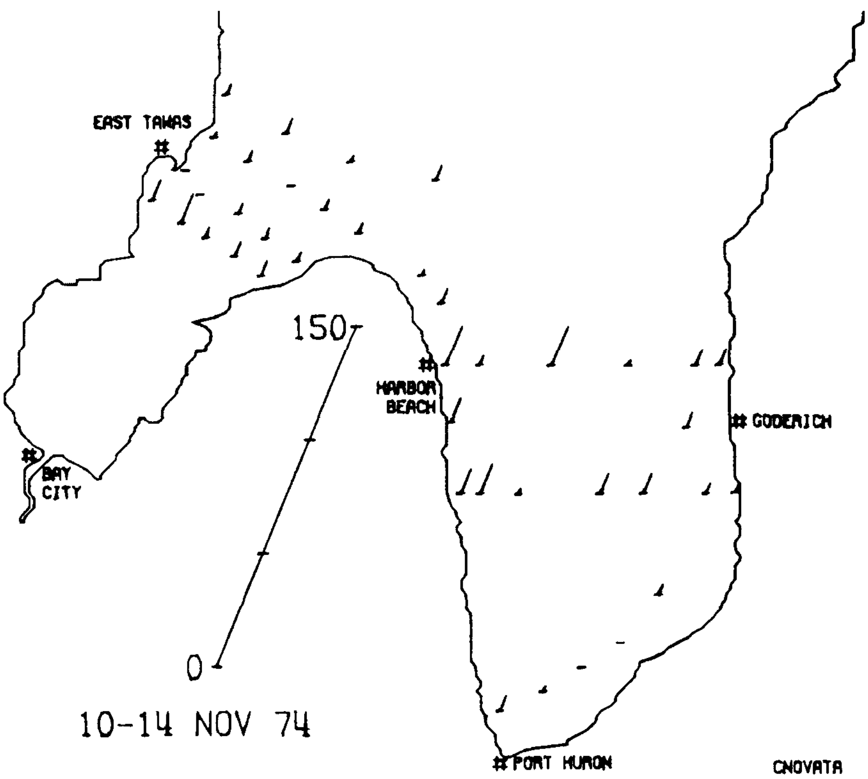

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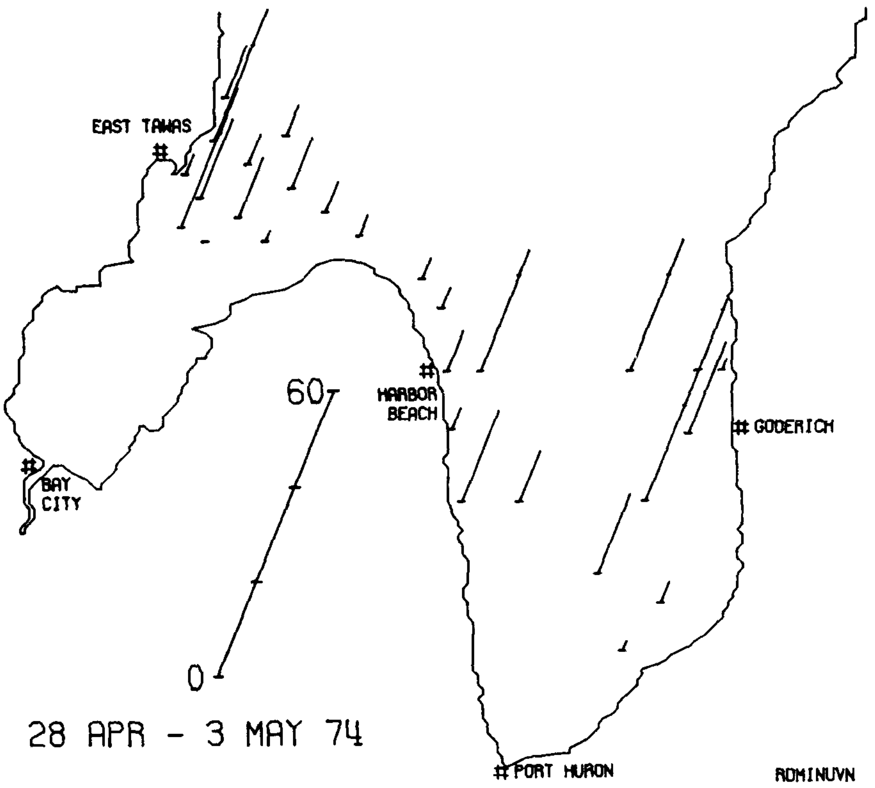


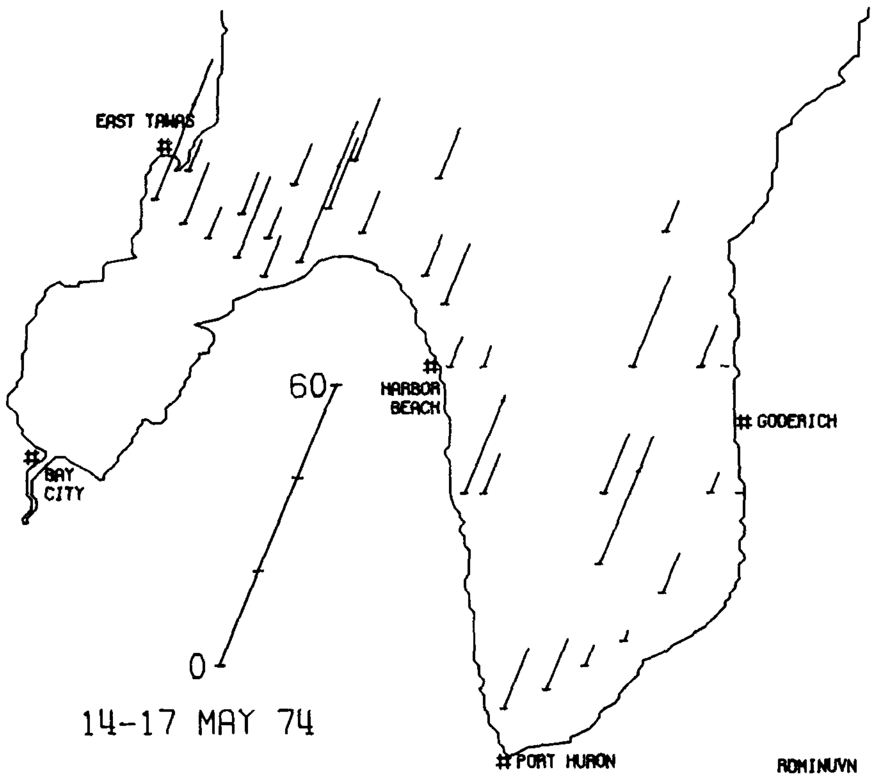
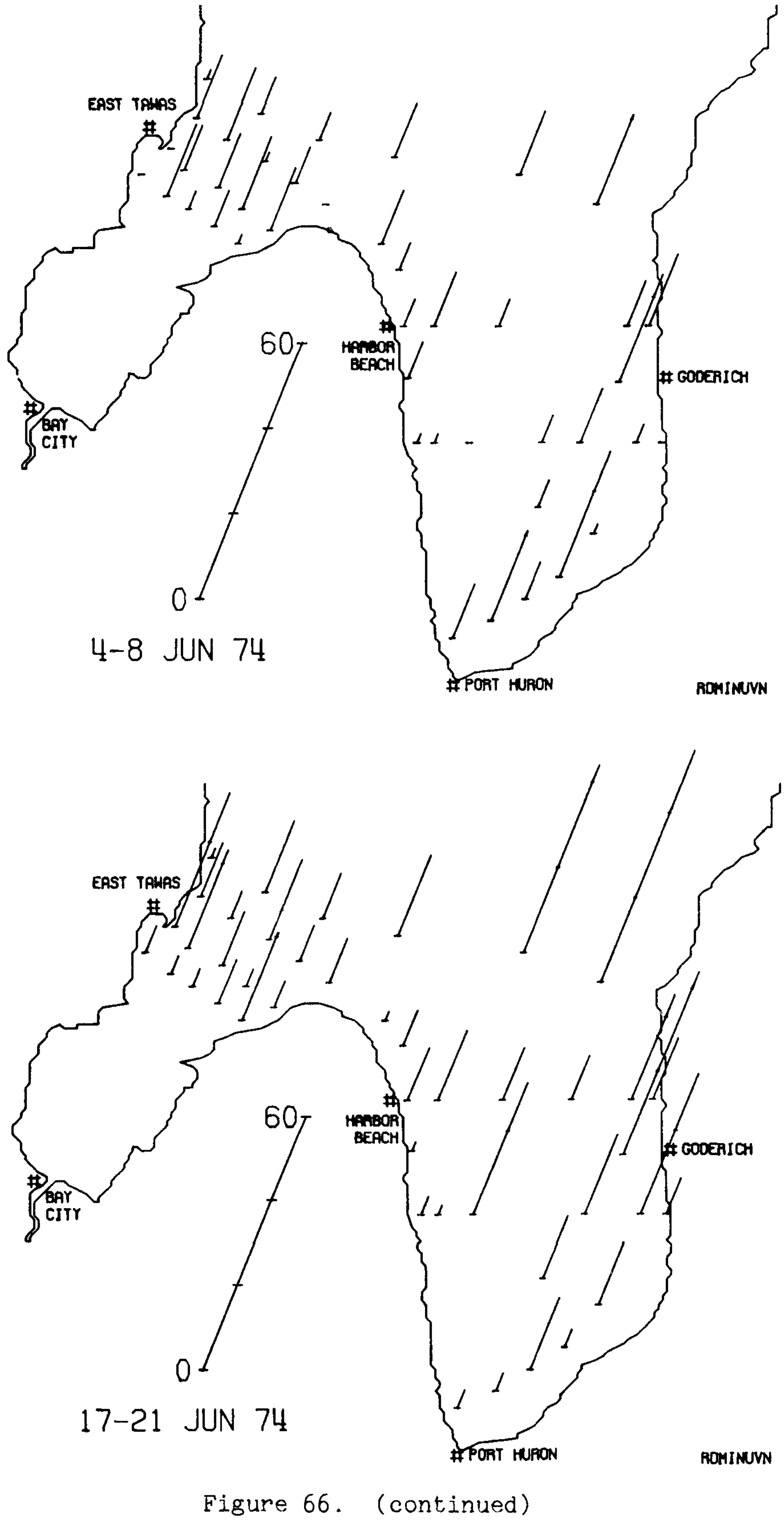


Figure 66. Distribution of *Rhodomonas minuta* var. *nannoplanctica*. (continued)



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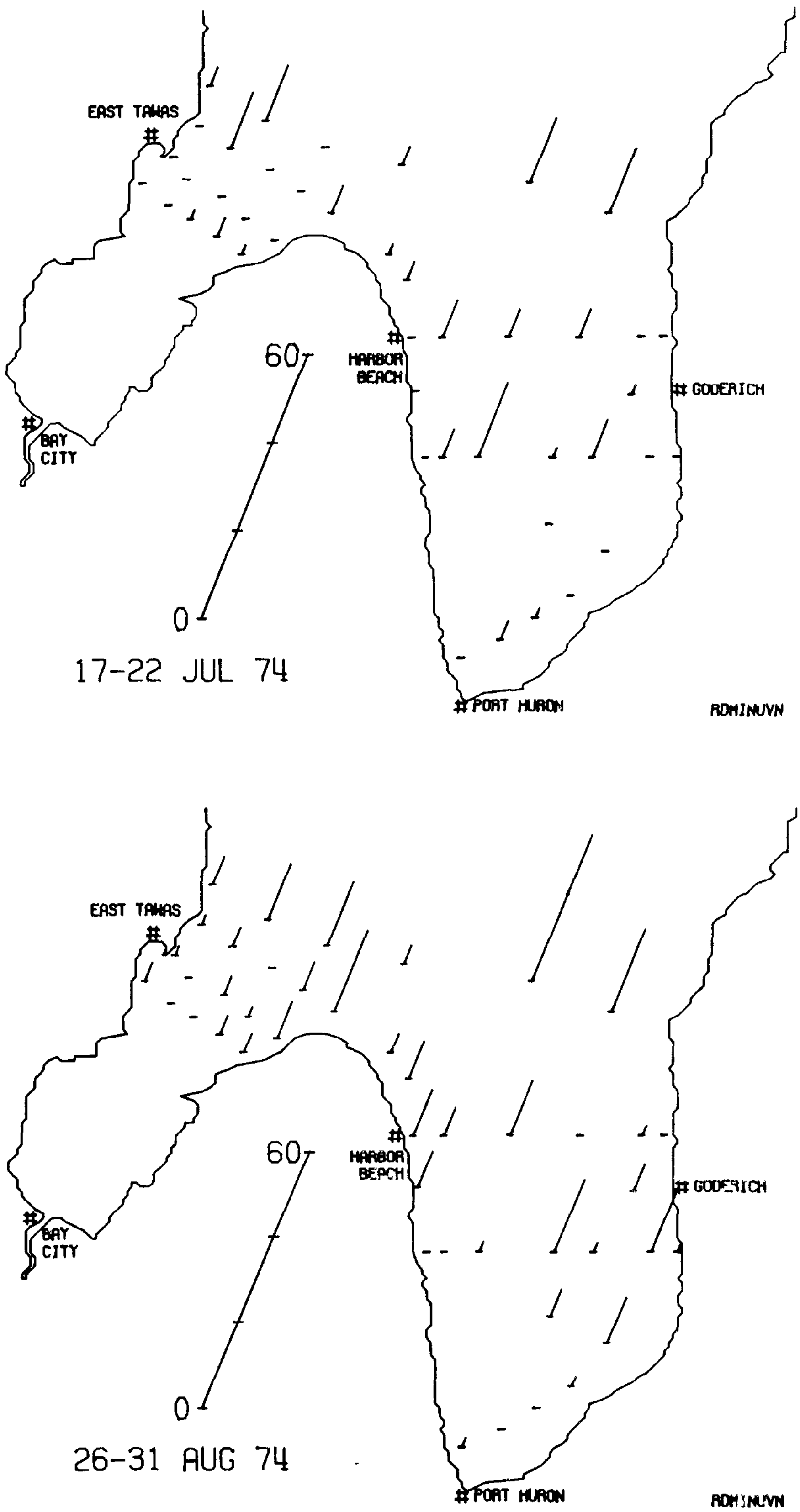

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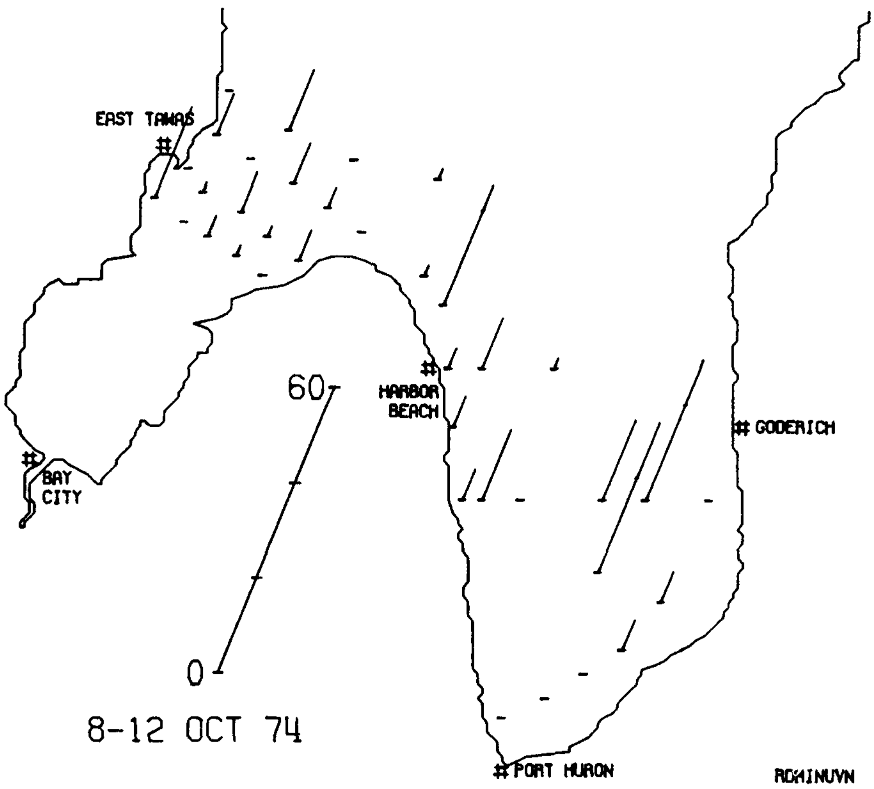


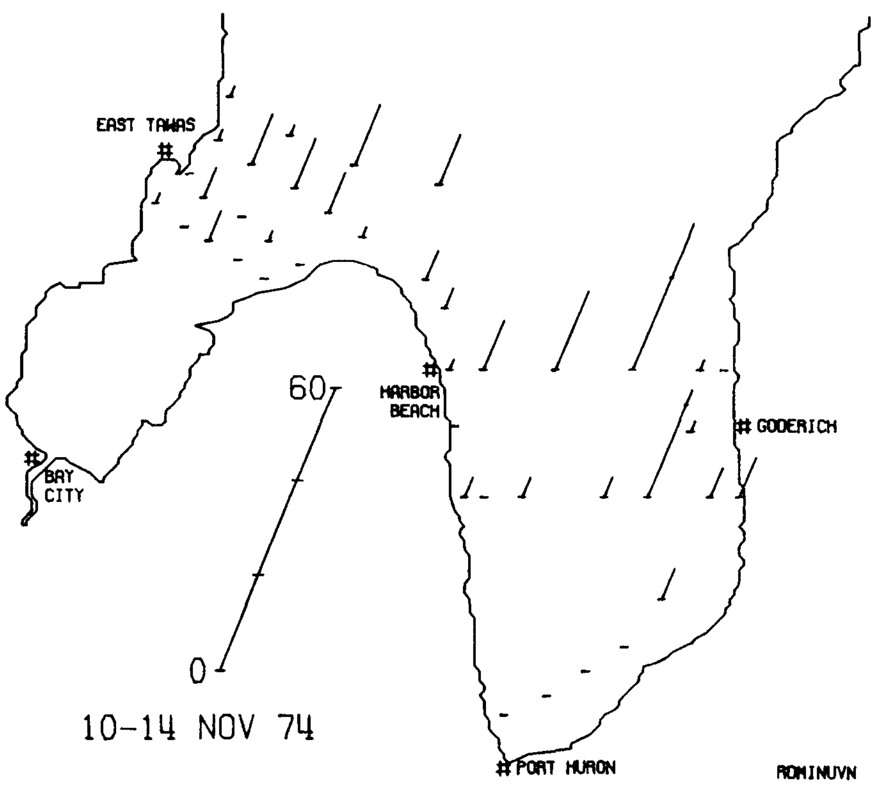
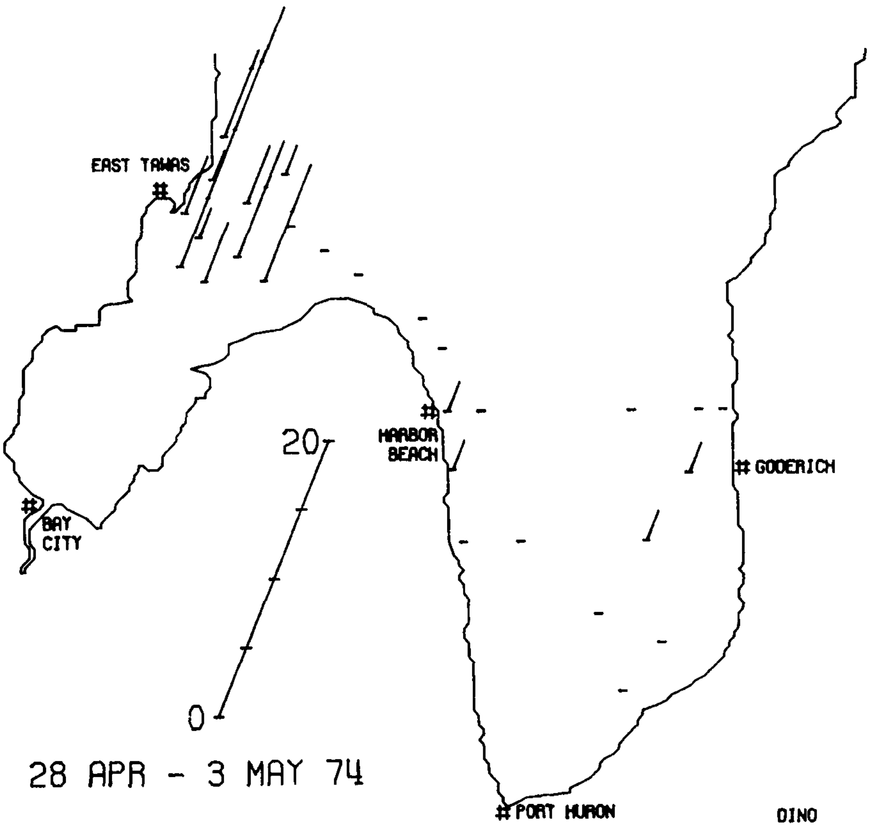


Figure 66. (continued)



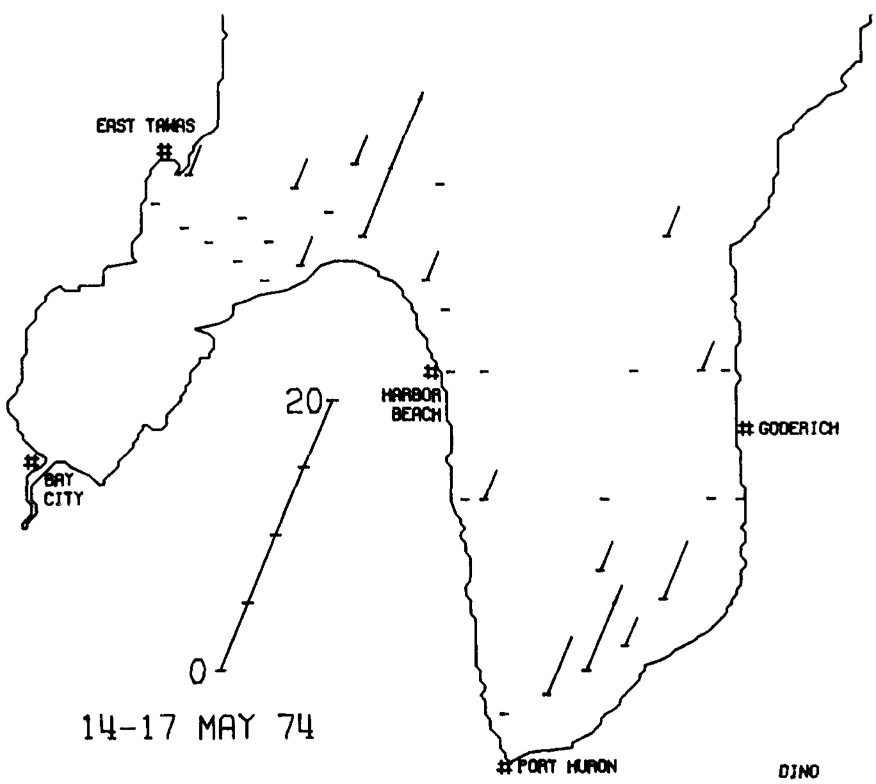


Figure 67. Seasonal abundance and distribution trends of dinoflagellates. (continued)

Pyrrophyta

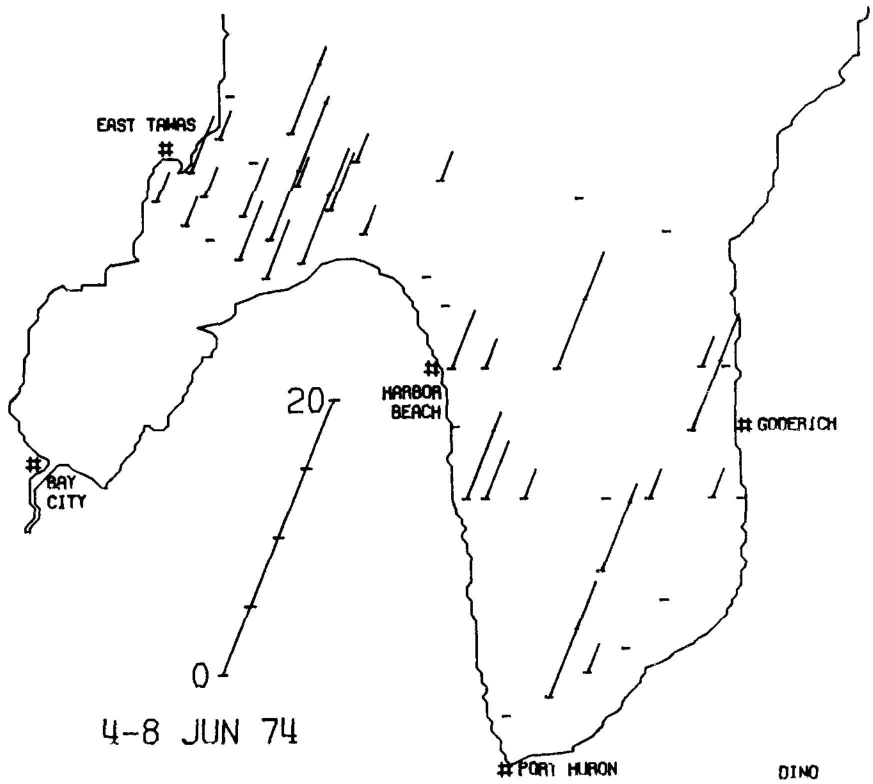
Although the dinoflagellates are relatively rare in the Great Lakes phytoplankton assemblages they may, because of the large size of certain species, constitute a significant portion of the biomass. The ecological affinities of most species is very poorly known and most appear to be erratic in their distribution, although this may be complicated by their relative rarity in most phytoplankton assemblages. In southern Lake Huron dinoflagellates were relatively abundant at a group of stations in the northerly sector of the Saginaw Bay interface during early May (Fig. 67A) but were noted at only a few stations south of Saginaw Bay. By mid-May (Fig. 67B) this pattern had changed in that the group was absent from most of the inner stations in the Saginaw Bay interface, but found at scattered stations throughout the rest of the area sampled. The group reached its greatest abundance and widest distribution during early June (Fig. 67C) but was reduced in abundance by late June (Fig. 67D) and remained at relatively low abundance throughout the rest of the sampling period (Fig. 67E-H). During July (Fig. 67E) dinoflagellates were consistently present at stations in the southerly sector of the Saginaw Bay interface but this pattern was not repeated in succeeding months.

Peridinium spp.

During most months sampled (Figs. 68A-H) members of this genus reached detectable levels of abundance at stations in or near the Saginaw Bay interface waters, with sporadic occurrences at stations or clusters of stations in the rest of the lake. Maximum levels of abundance were reached in the early spring and the primary species involved was Peridinium aciculiferum which may become quite abundant in eutrophic areas. Although its numbers are relatively low in Saginaw Bay it may contribute an appreciable part of the total biomass because of its very large cells.

Spirodinium spp.

This unusual small form greatly resembles Spirodinium pusillum var. minor (Skuja, 1956). So far as we have been able to determine, this species has not been reported from the Great Lakes and most previous reports of its occurrence come from small lakes and ponds. The entity we are dealing with here is widely distributed in southern Lake Huron. During early May (Fig. 69A) sizeable populations were present at stations in the northerly sector of the Saginaw Bay interface waters and at isolated stations along the U.S. and Canadian coasts. By mid-May (Fig. 69B) abundance had been reduced and the only occurrences noted were at stations in the northerly and easterly sectors of the area sampled. During early June (Fig. 69C), however, relatively large abundances of this species were found at scattered stations throughout southern Lake Huron. These populations had apparently collapsed by late June (Fig. 69D) and this taxon is found only at occasional scattered stations during the rest of the study (Fig. 69E-H).



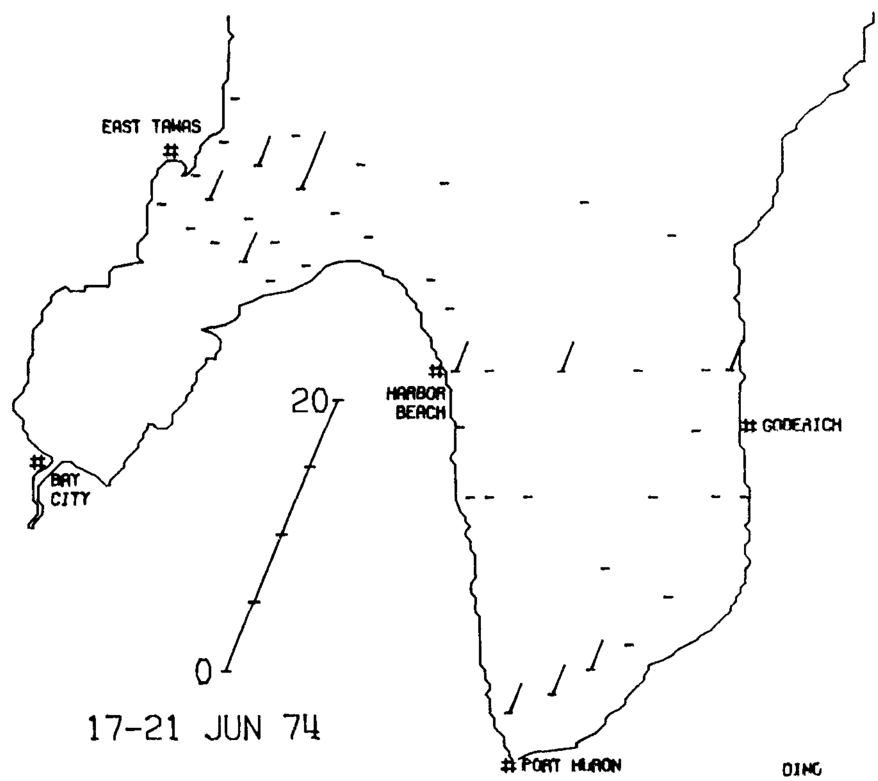
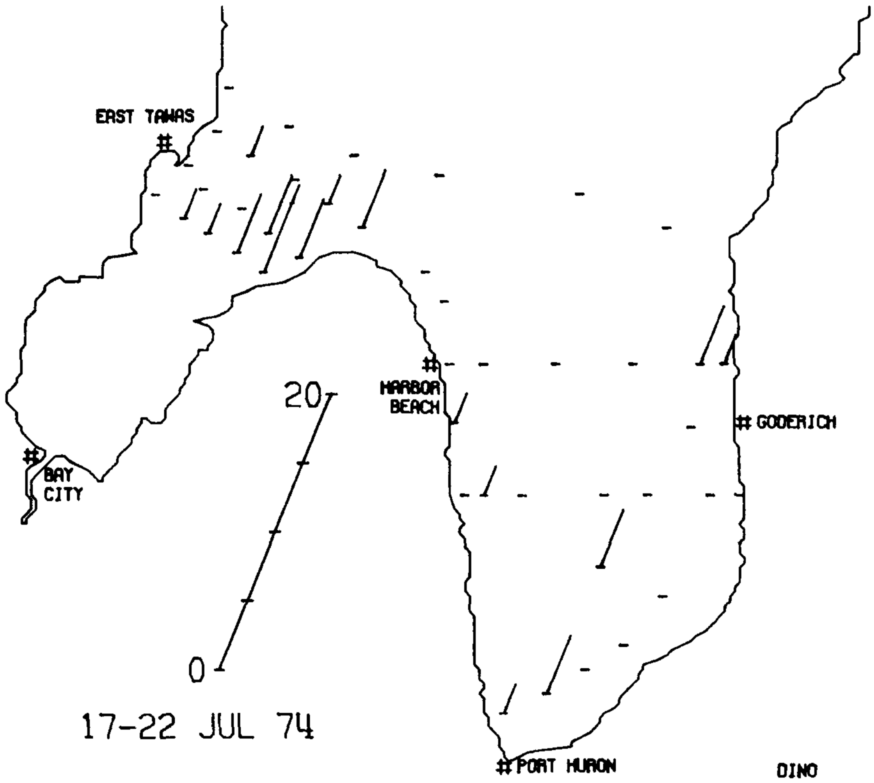


Figure 67. (continued)



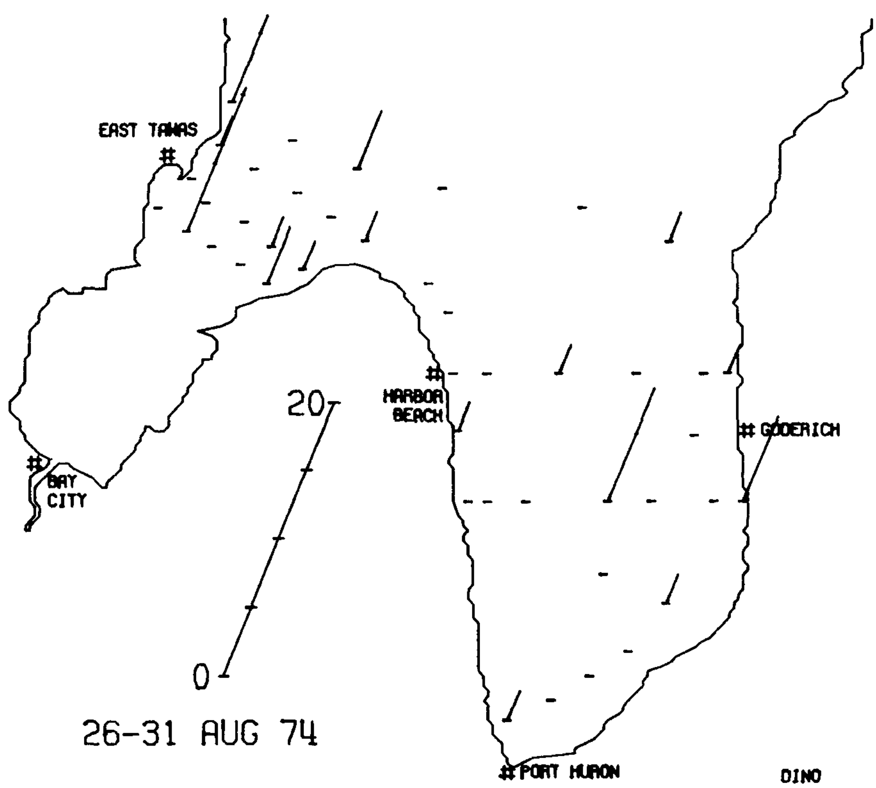


Figure 67. (continued)

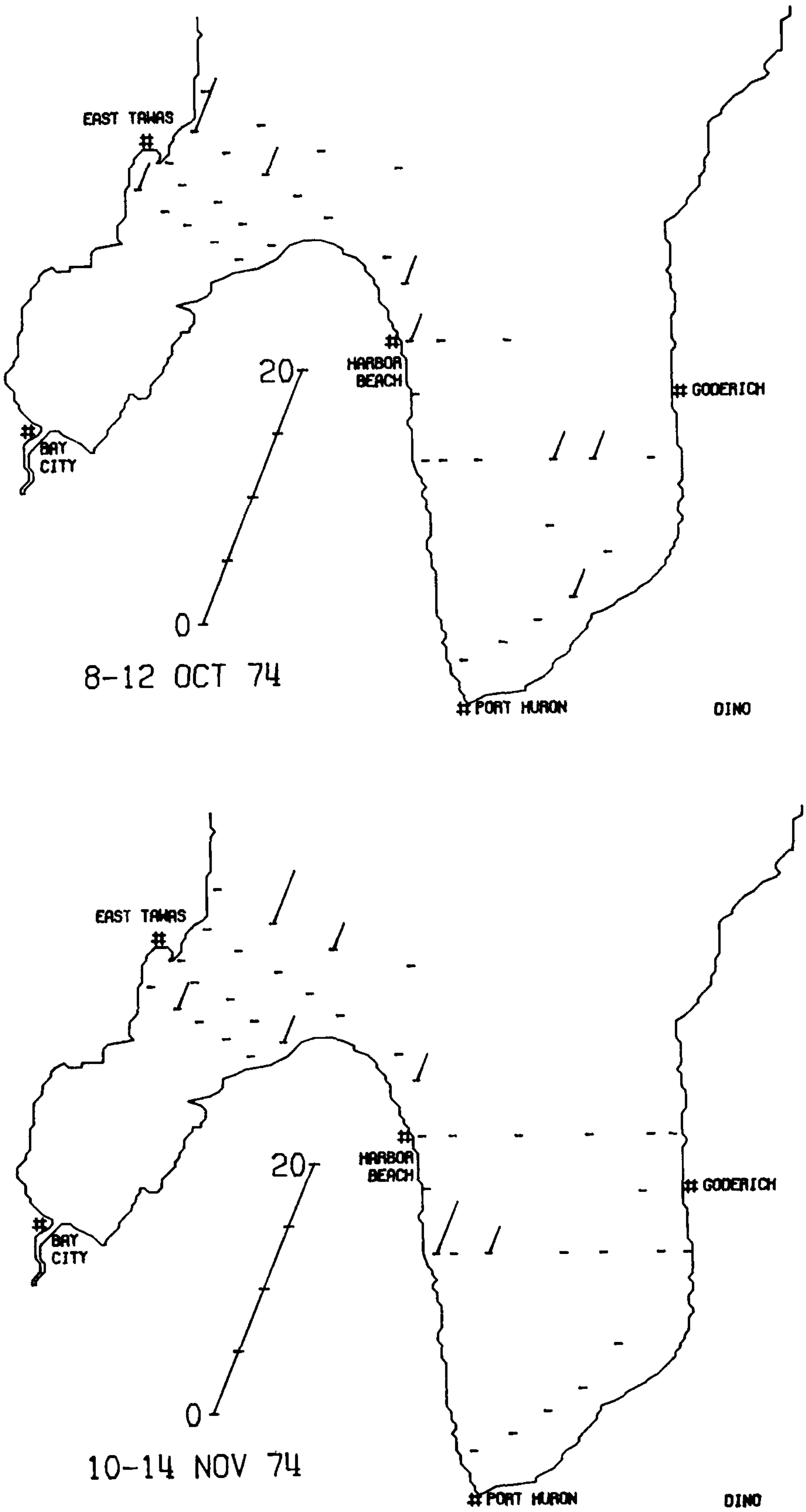


Figure 67. (continued)

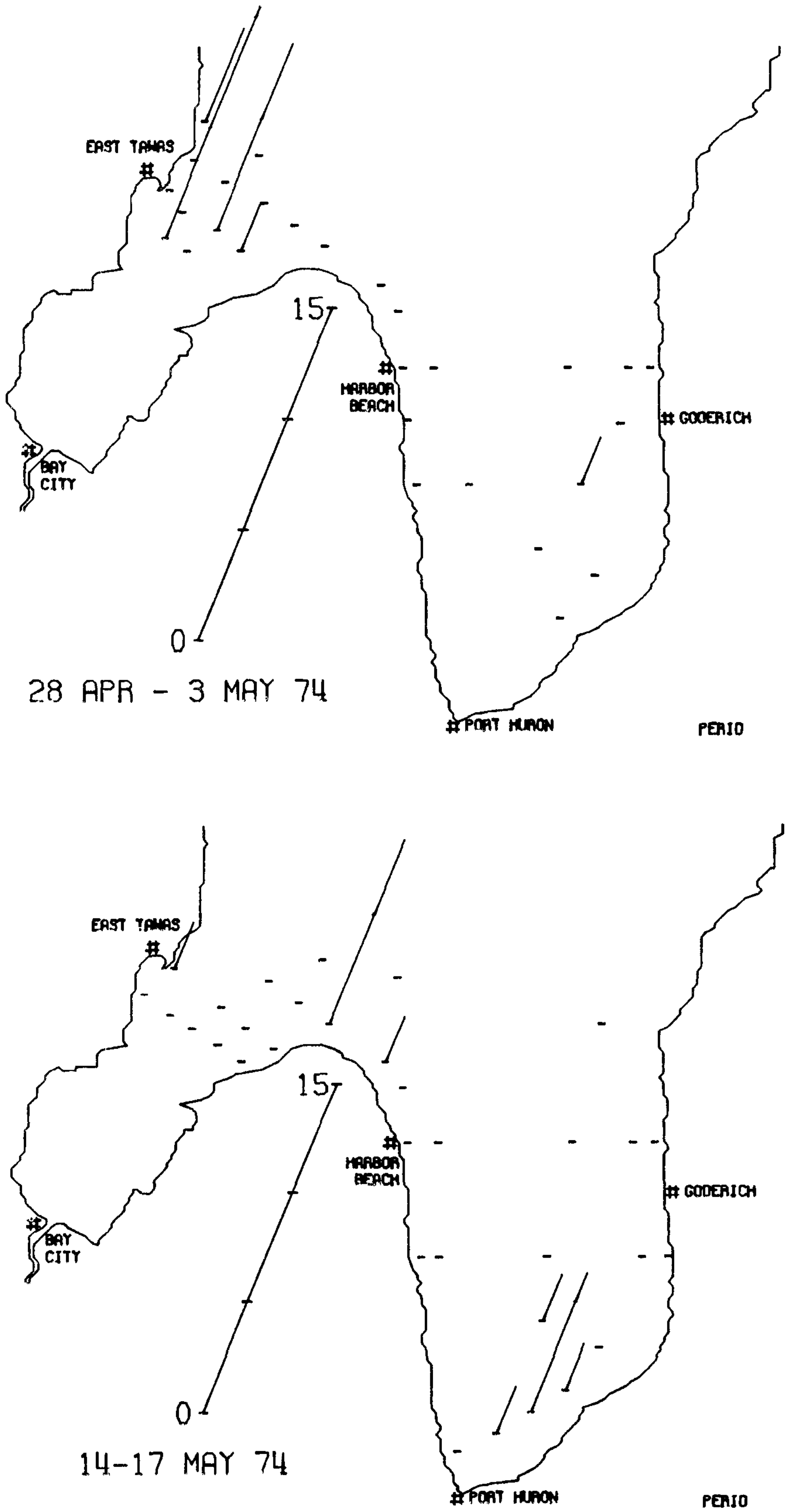
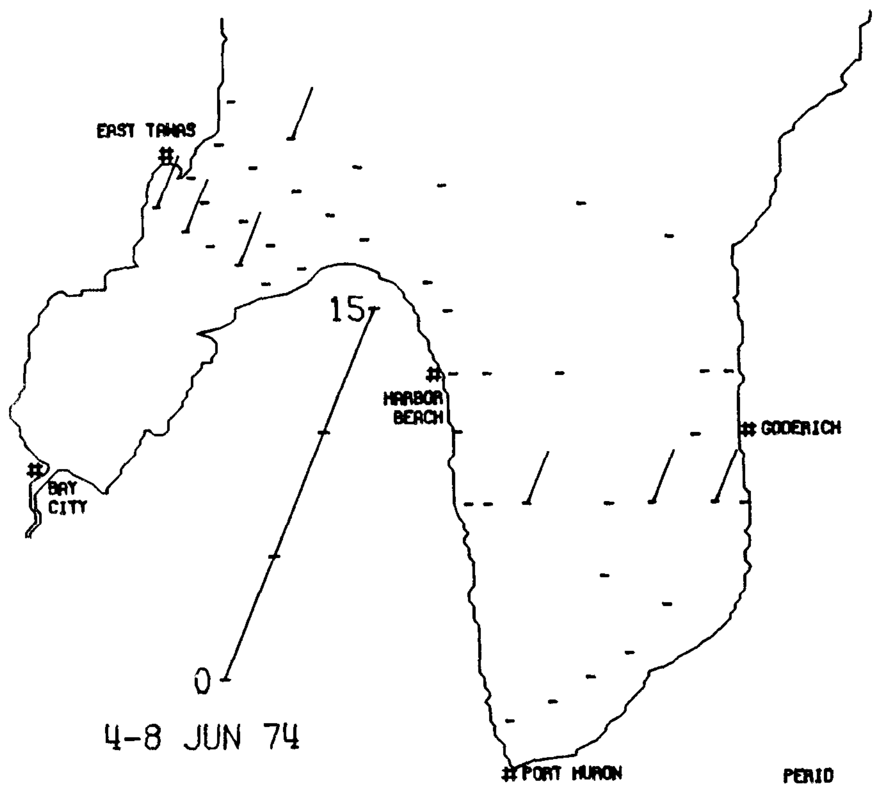


Figure 68. Distribution of Peridinium spp.. (continued)



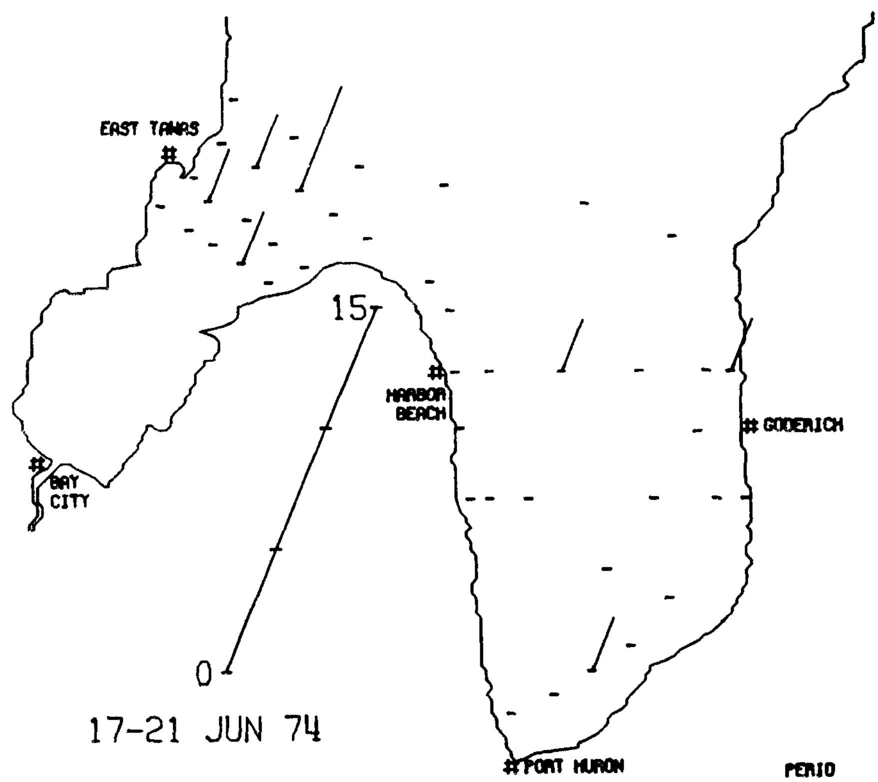
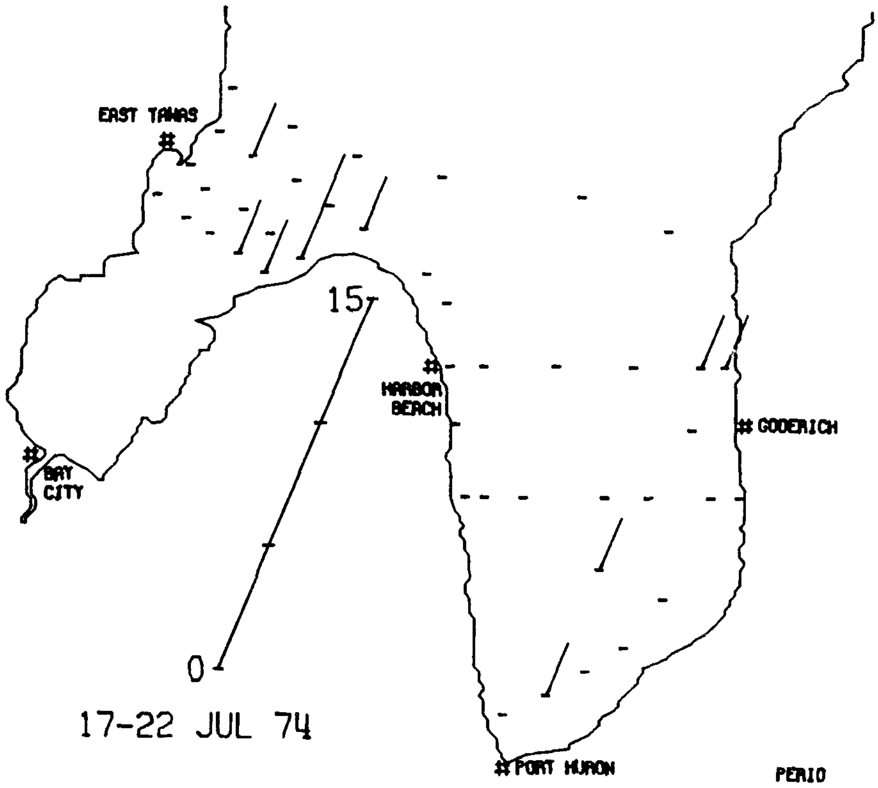


Figure 68. (continued)



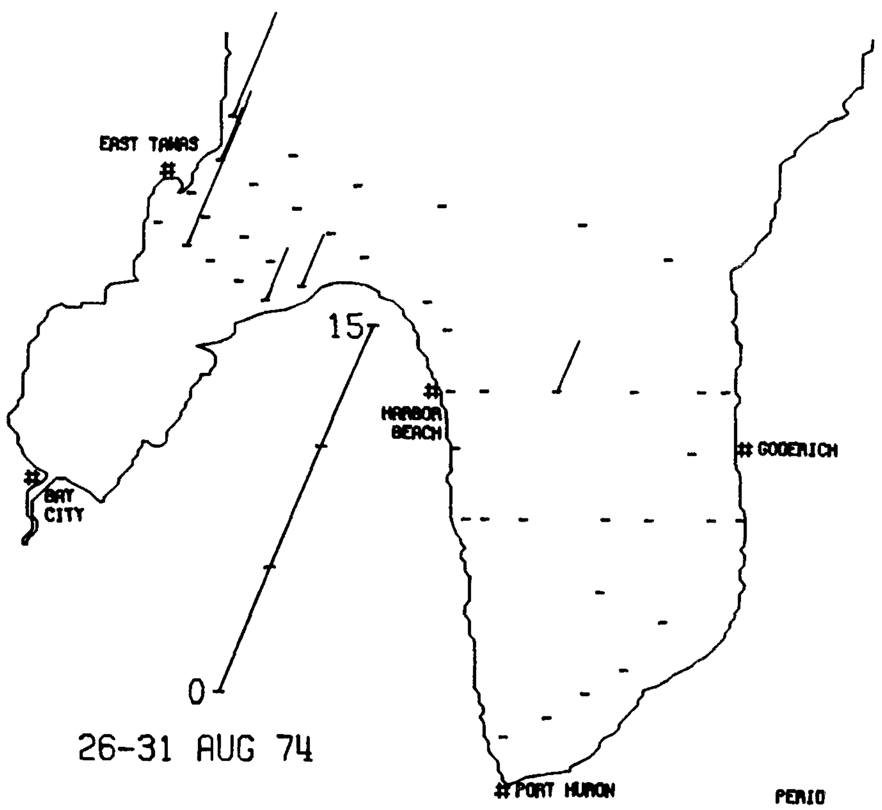
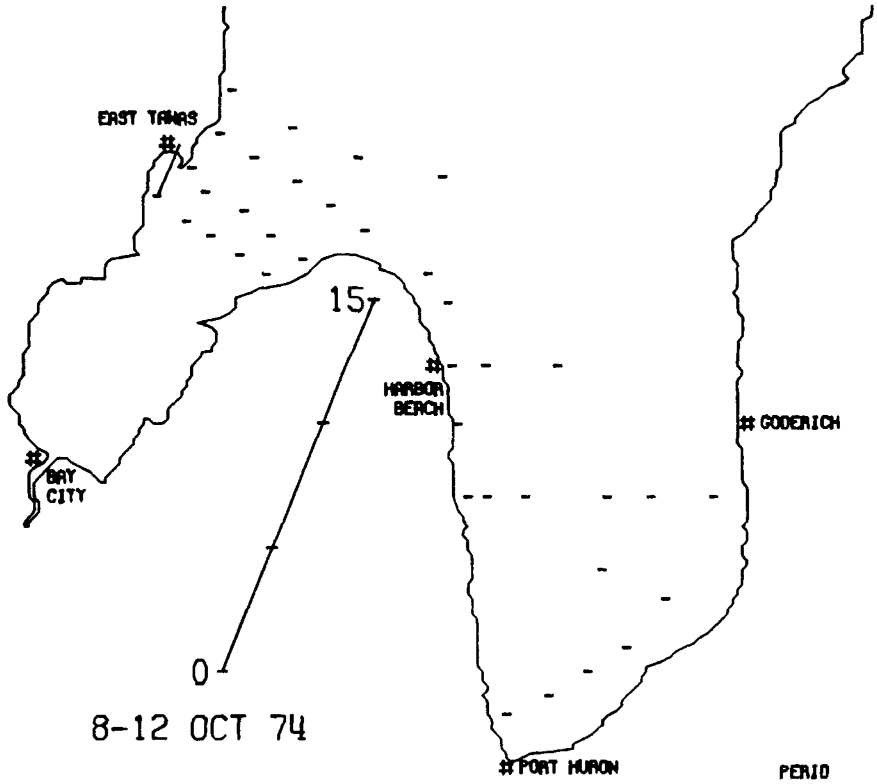
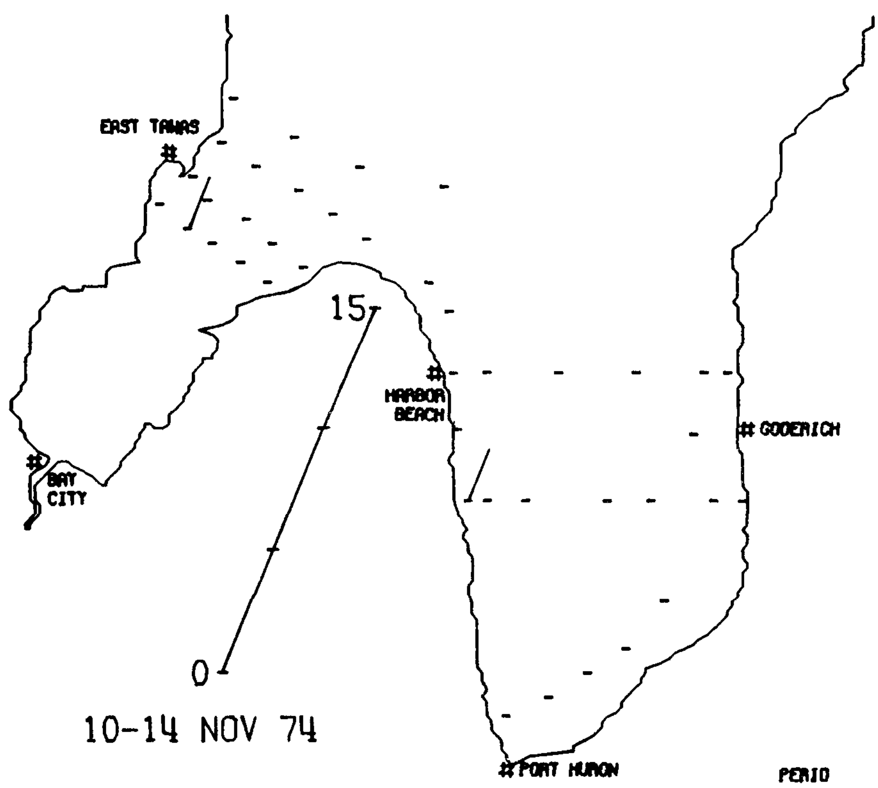


Figure 68. (continued)





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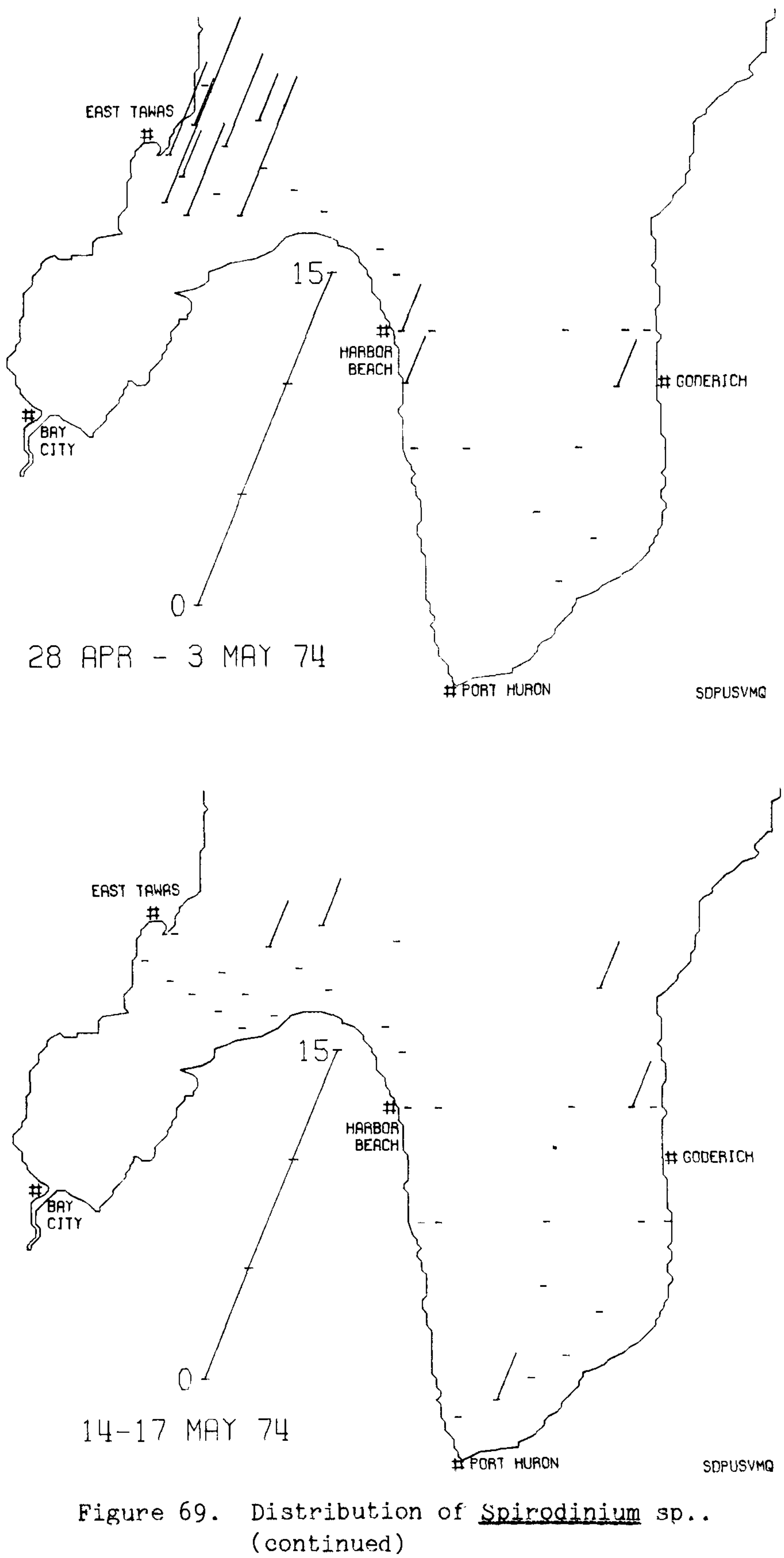
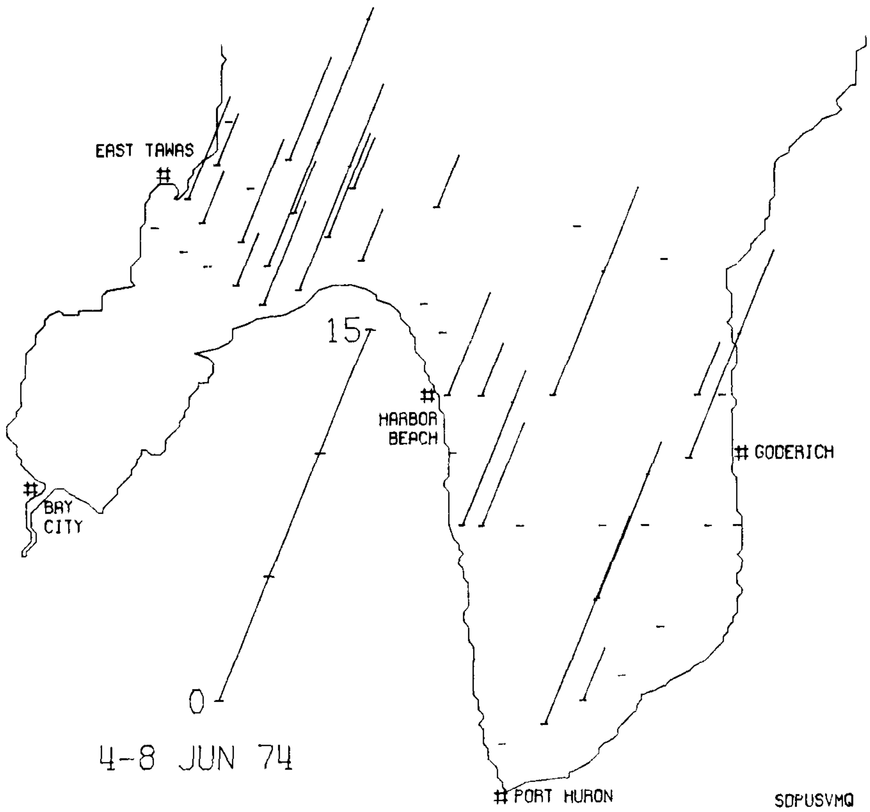
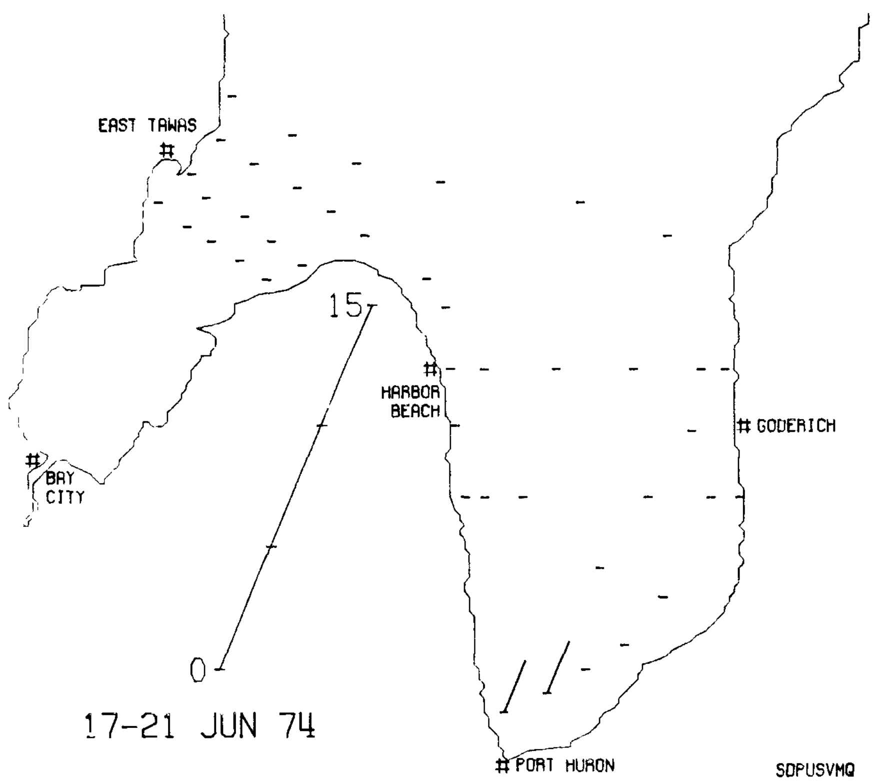


Figure 69. Distribution of *Spirodinium* sp..
(continued)





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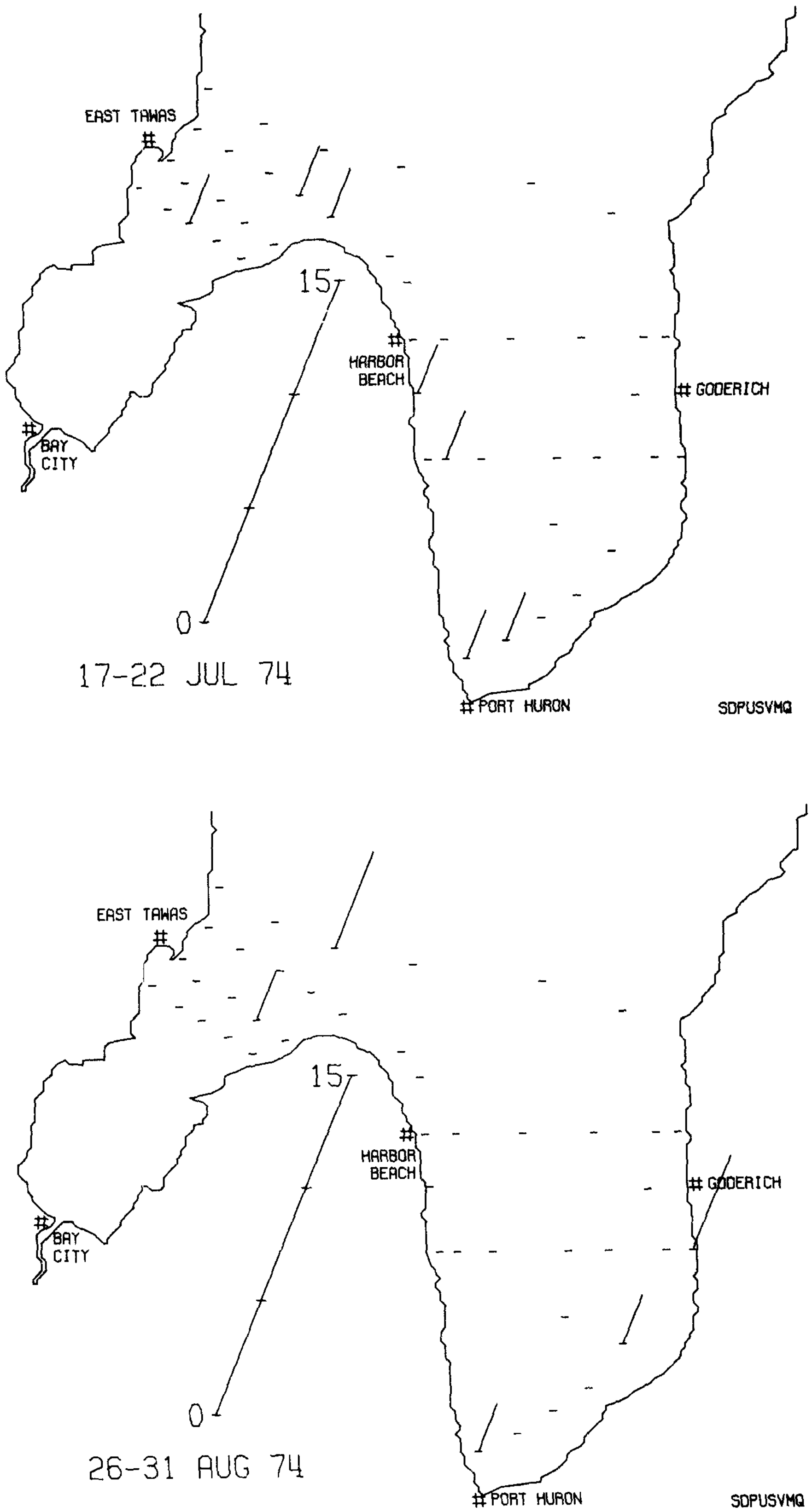

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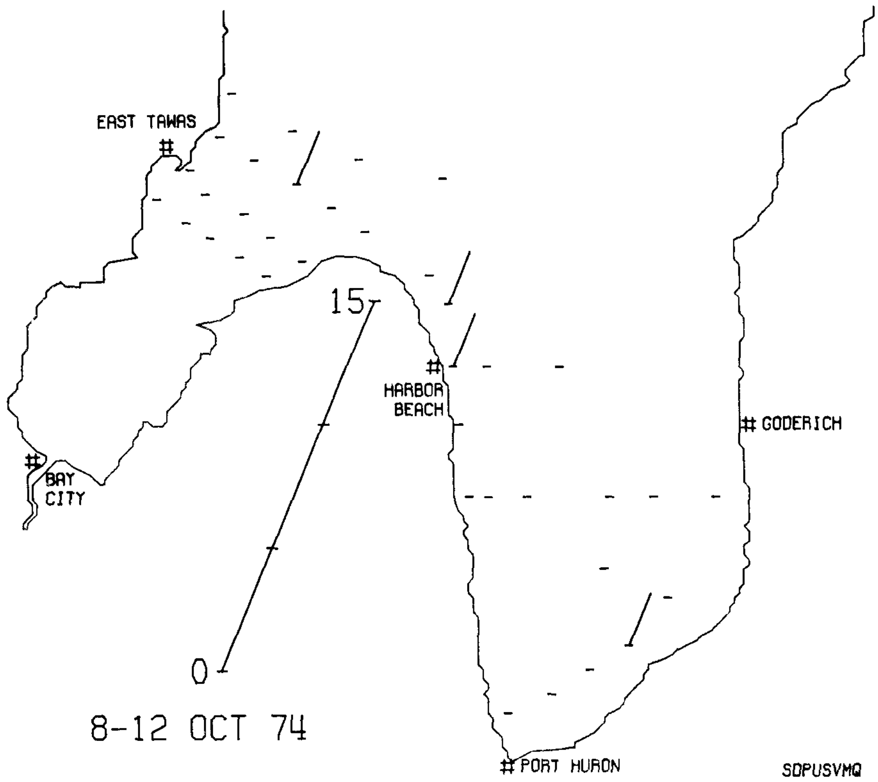

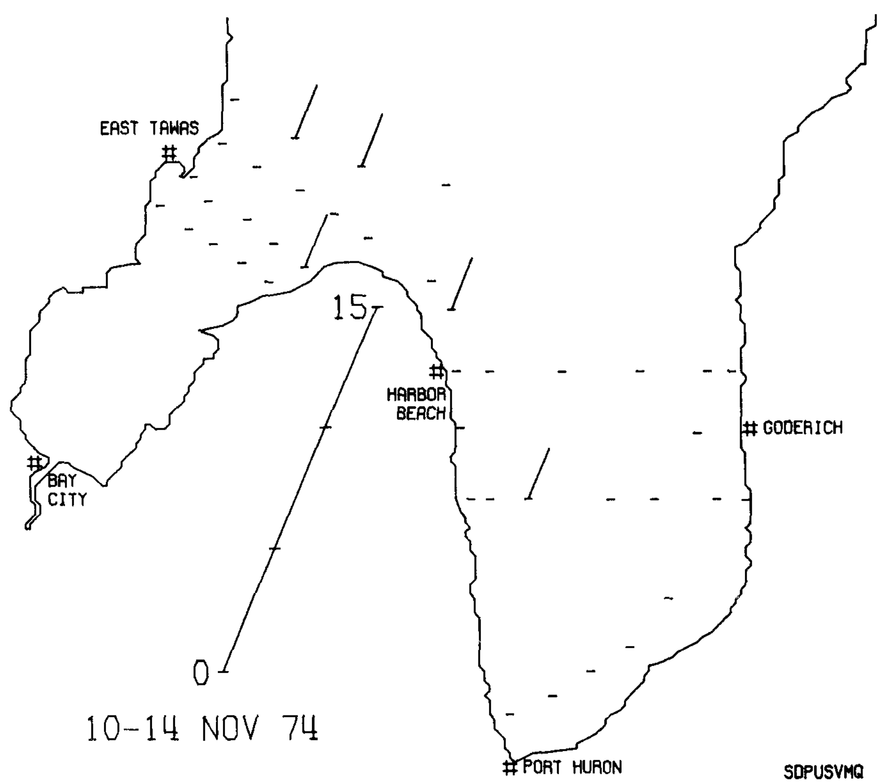

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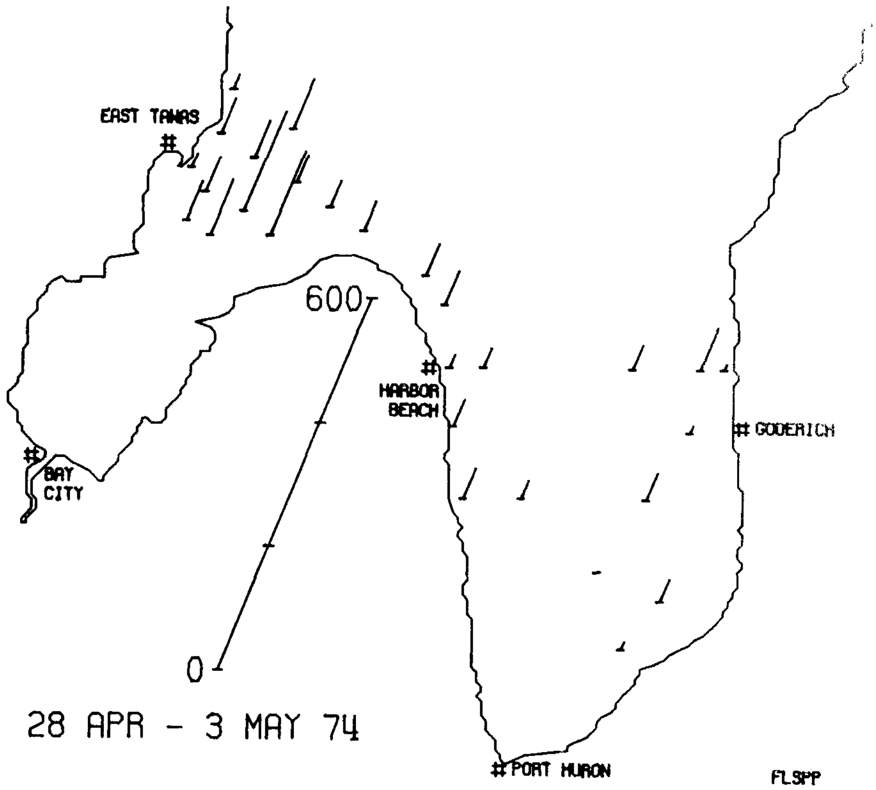


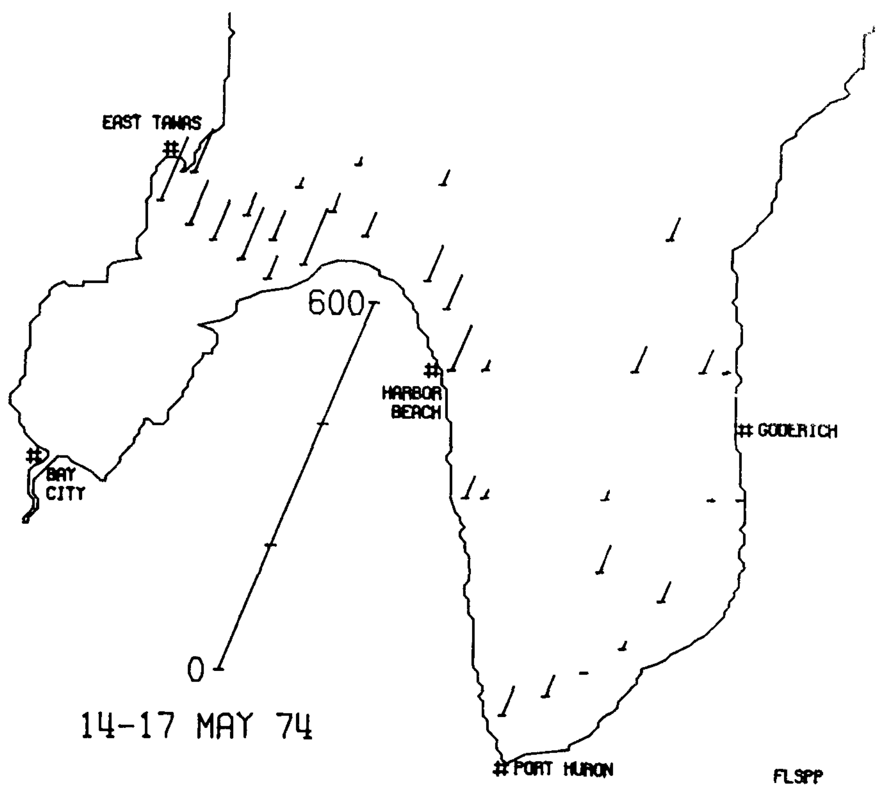
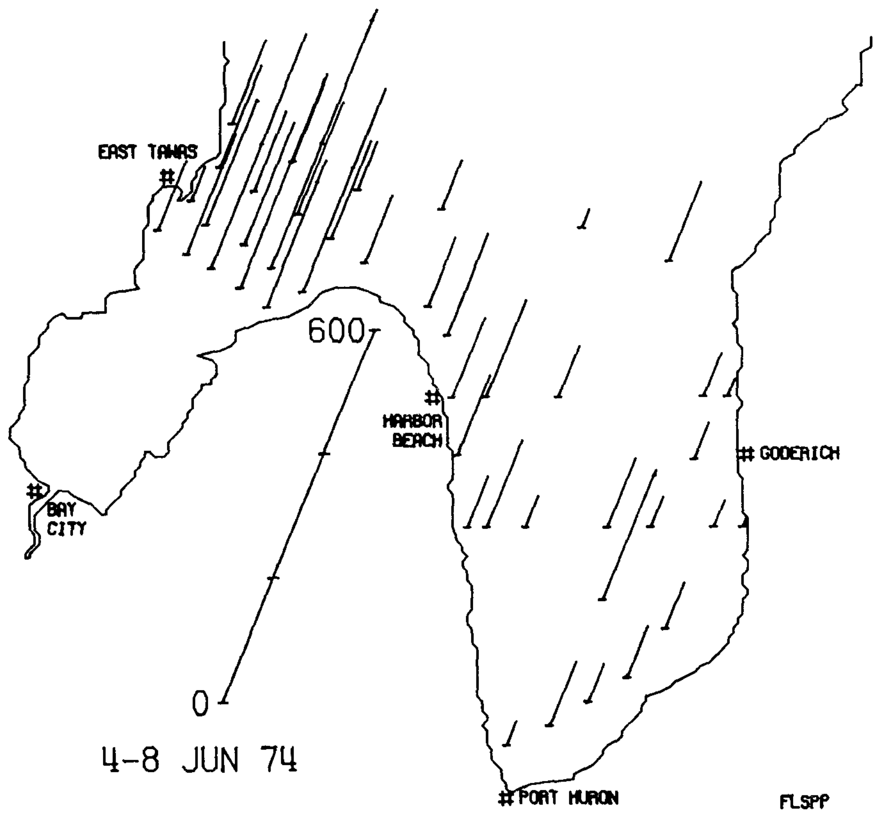


Figure 70. Seasonal abundance and distribution trends of microflagellates. (continued)



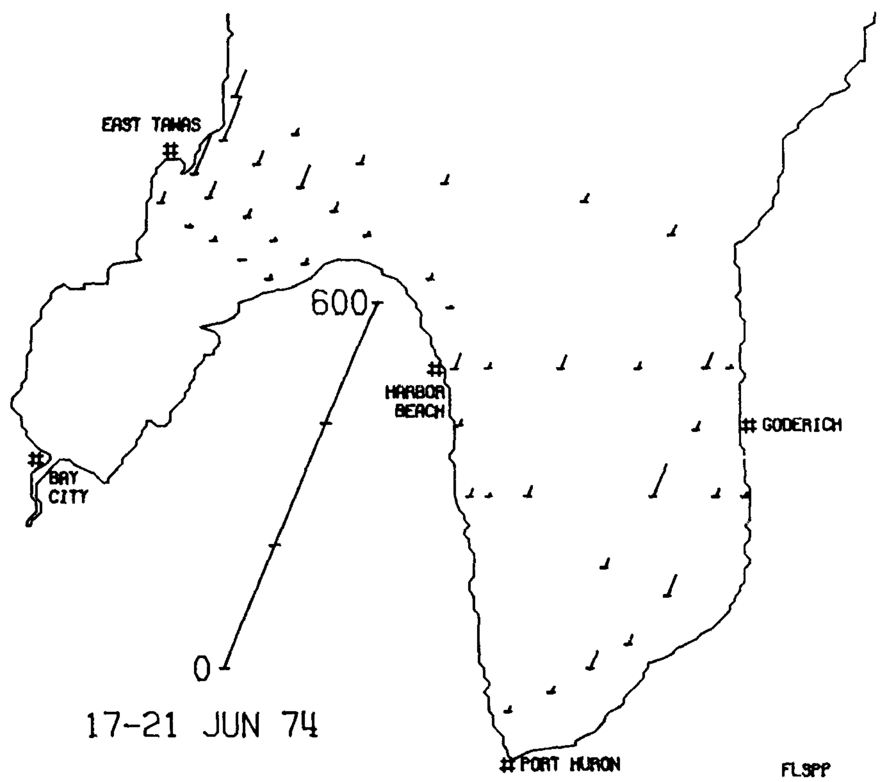
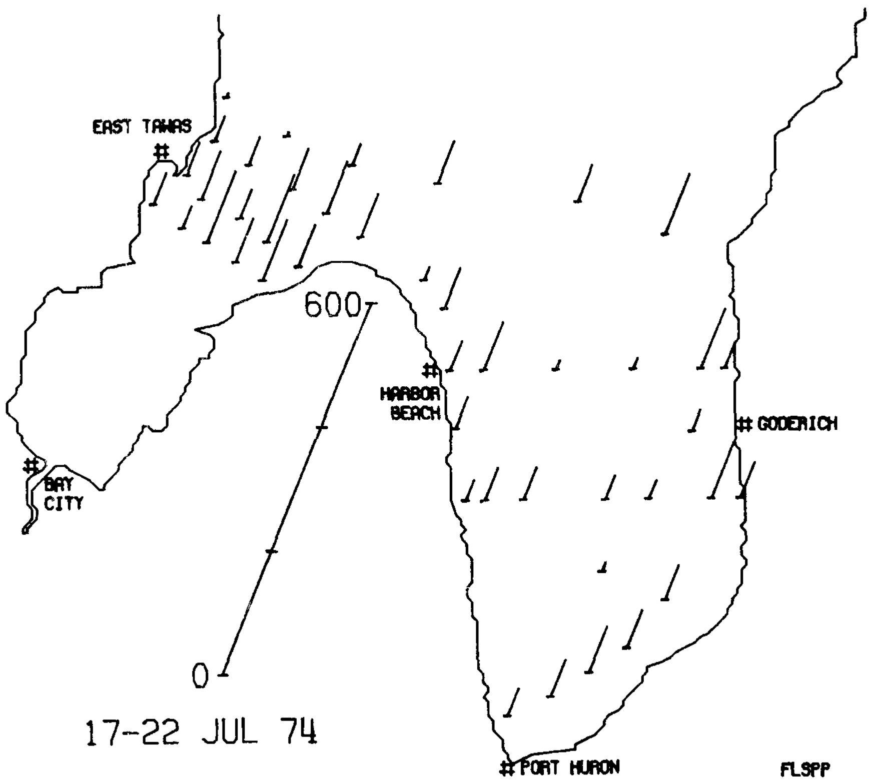


Figure 70. (continued)



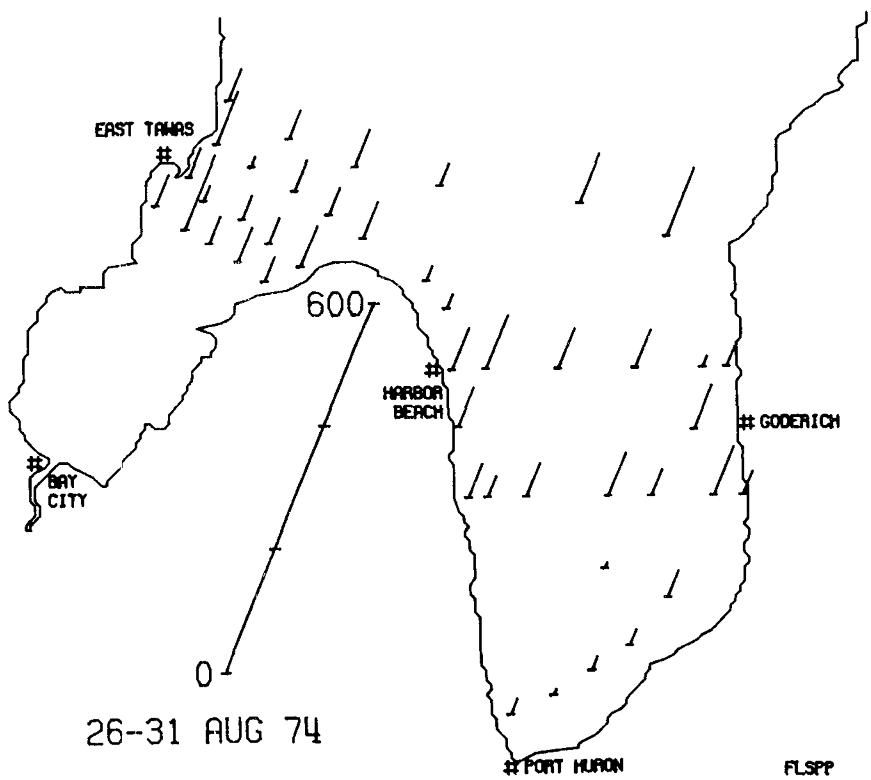
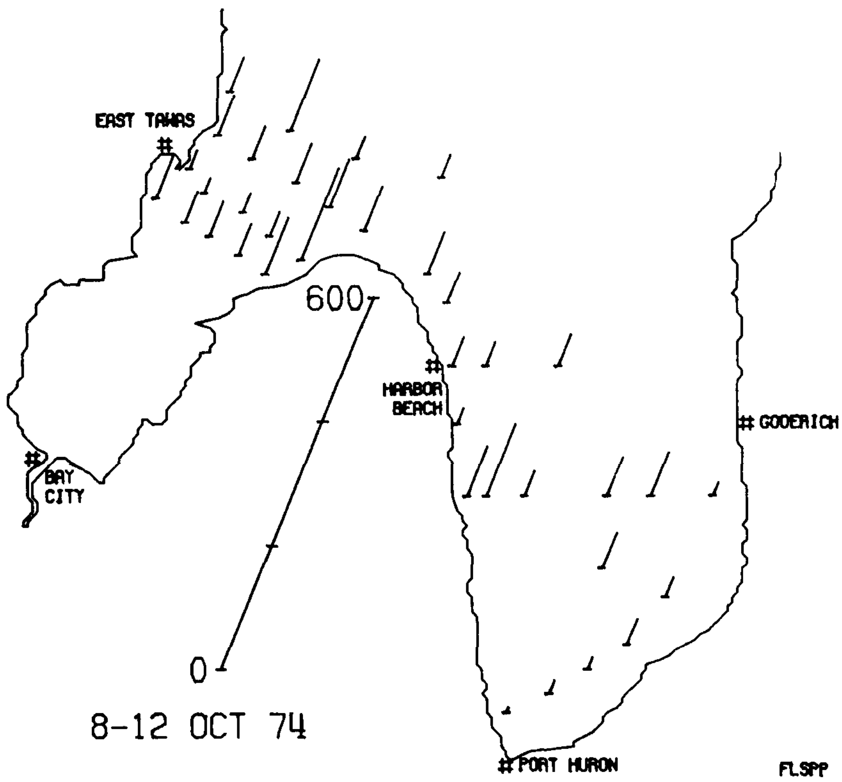


Figure 70. (continued)



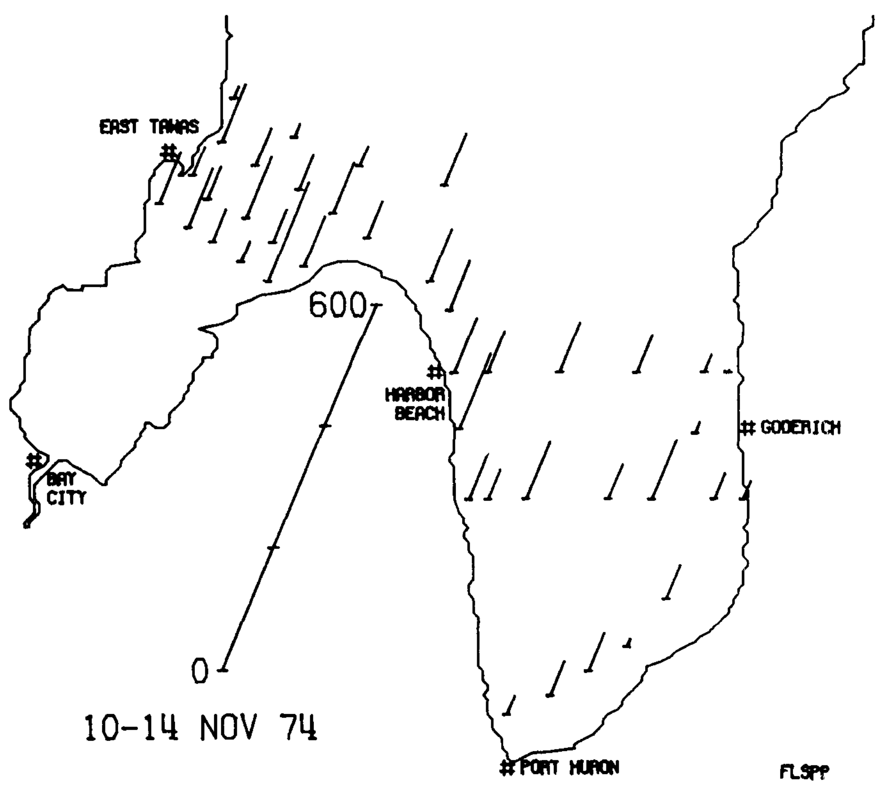


Figure 70. (continued)

Microflagellates

This is a composite category comprised of small haptophytes and chrysophytes which cannot be satisfactorily identified at the specific level. Although relatively abundant in southern Lake Huron it is probably quantitatively less important than some of the other flagellate groups such as much larger dinoflagellates and cryptomonads. The overall distribution of this group was remarkably stable during the period of our study. Appreciable populations were found in most stations sampled during May (Fig. 70A-B). Maximum abundance was found during early June (Fig. 70C) and this was followed by an apparent collapse in late June (Fig. 70D). Population levels recovered by mid-July (Fig. 70E) and remained quite stable during the rest of the study (Fig. 70F-H).

VERTICAL DISTRIBUTION OF PHYTOPLANKTON AT MASTER STATIONS

In general, there was remarkably little consistency in the vertical distribution of phytoplankton at the southern Lake Huron master stations studied either at the given station over time or between stations during a given cruise. In most cases (Fig. 71) greatest phytoplankton abundance was found at some depth below the surface, however, there appeared to be relatively poor correlation with the thermal structure. Pronounced subsurface peaks occurred during homothermous conditions particularly during cruises 7 and 8, and during thermal stratification. At station 25 the spring assemblage maximum appeared to move downward through the water column to thermocline depths by the initiation of stratification but no such trend was observed in the other stations studied. Interpretations of the vertical distribution information is considerably complicated by the possible presence of senescent populations from Saginaw Bay sinking through the column.

Of the major physiological groups, diatoms (Fig. 72) tended to have the most uniform vertical distribution, particularly during periods of homothermous conditions. During stratification highest diatom abundance was generally found at or below the thermocline, although very high population densities found at station 60 during cruise 6 were restricted to the epilimnion.

Somewhat surprisingly the vertical distribution of green algae (Fig. 73) was markedly discontinuous prior to stratification. Although the abundance of green algae was uniformly low during cruise 5, following the initiation of stratification, large populations had developed in the surface waters at stations 23 and 25 by the time cruise 6 samples were taken but remained low and relatively uniform at station 60.

Although it might be expected that blue-green algae would concentrate near the surface, this was clearly not the case in southern Lake Huron (Fig. 74). Maximum abundance of this group occurred in the fall under isothermal conditions and in only one case (station 23, cruise 7) was maximum abundance found at the surface.

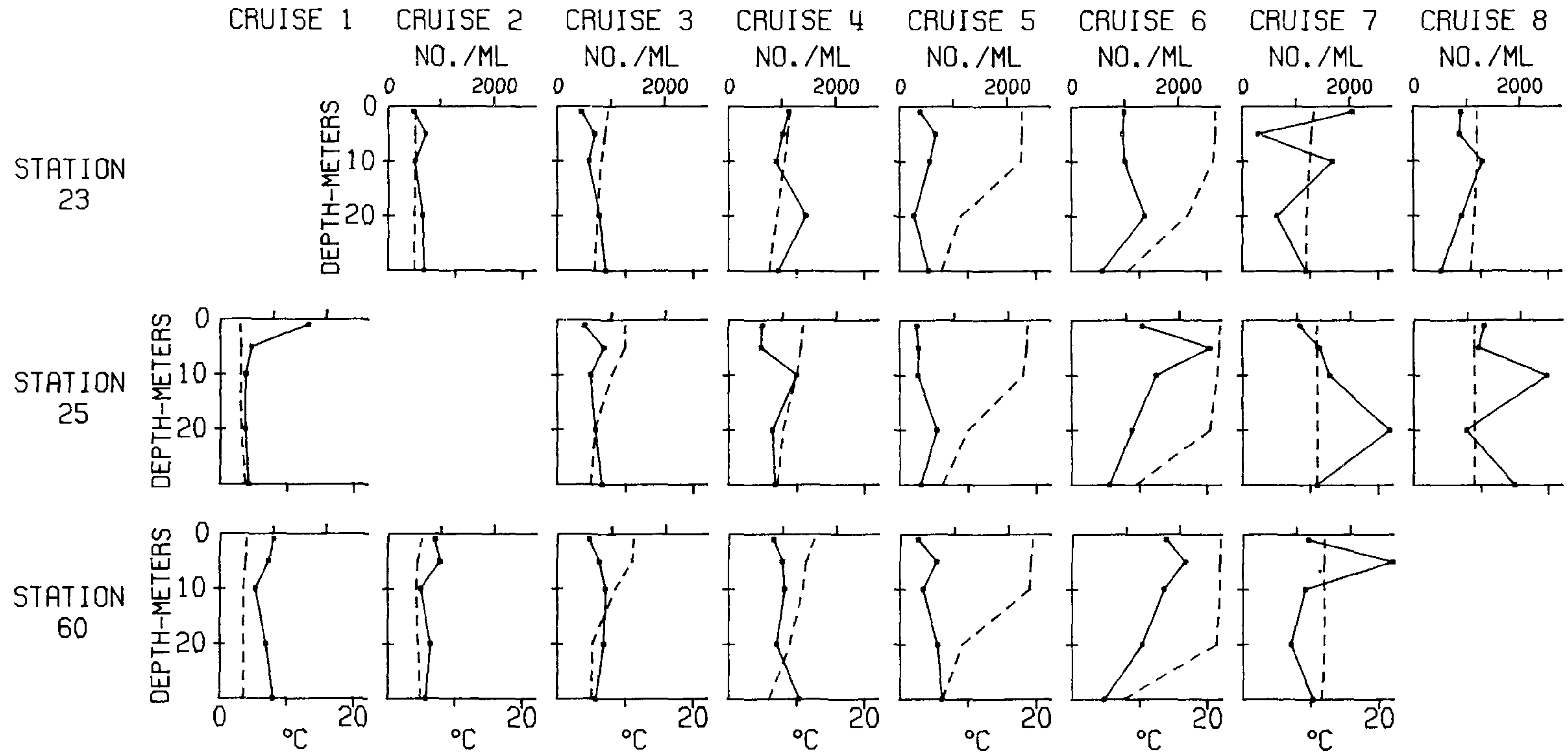


Figure 71. Vertical distribution of total phytoplankton cell densities at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

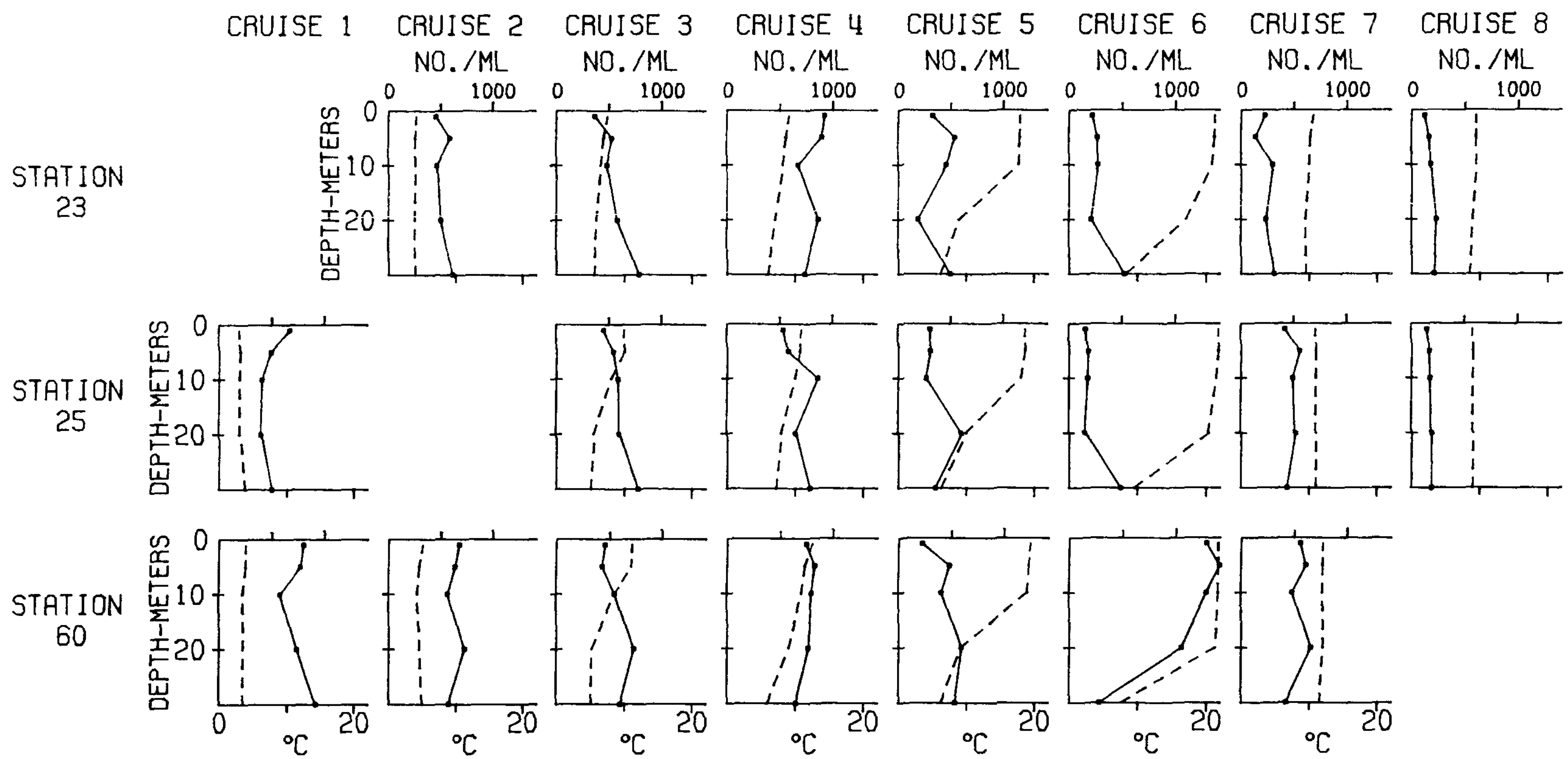


Figure 72. Vertical distribution of diatoms at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (^{o}C).

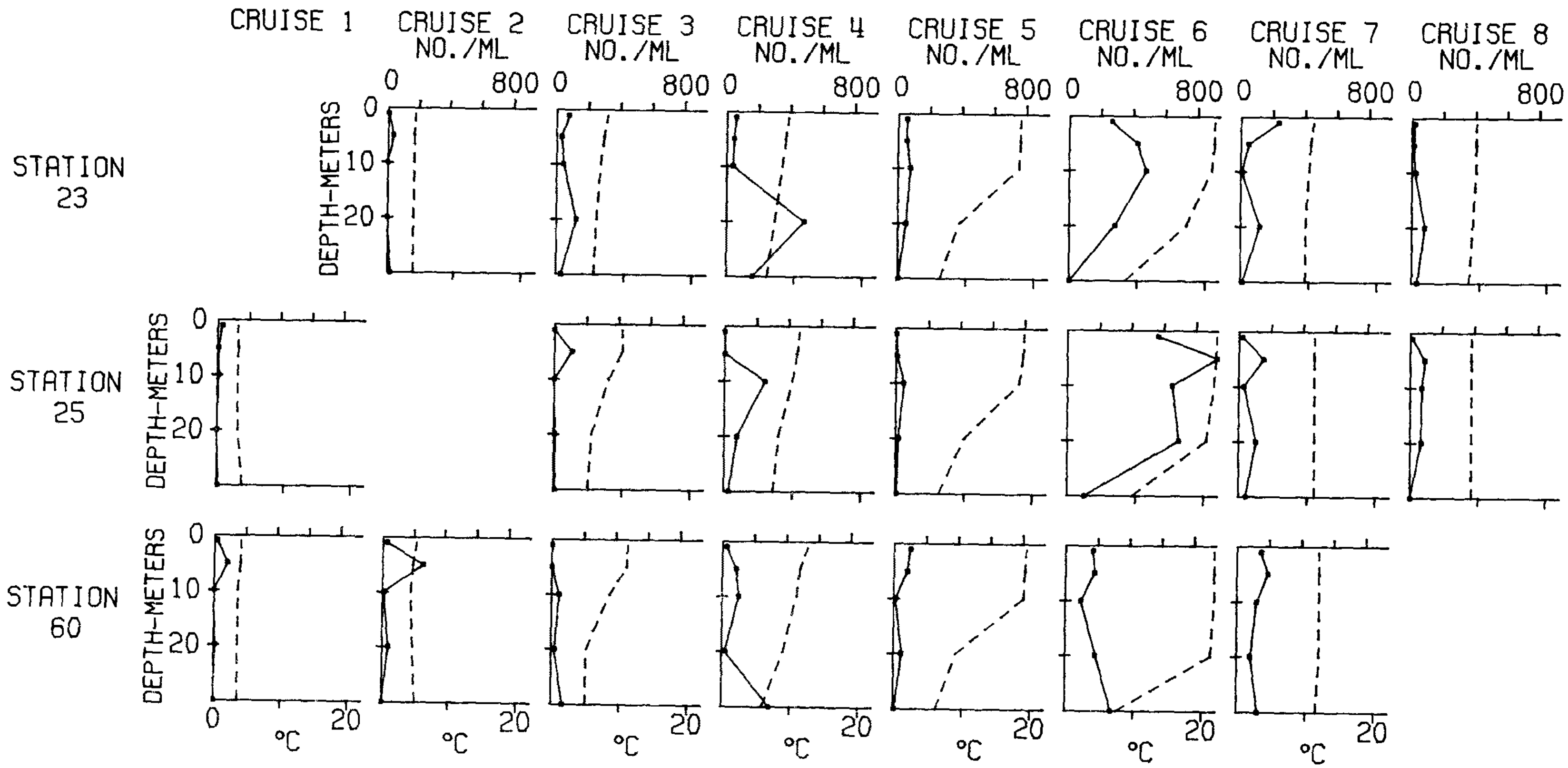


Figure 73. Vertical distribution of green algae at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

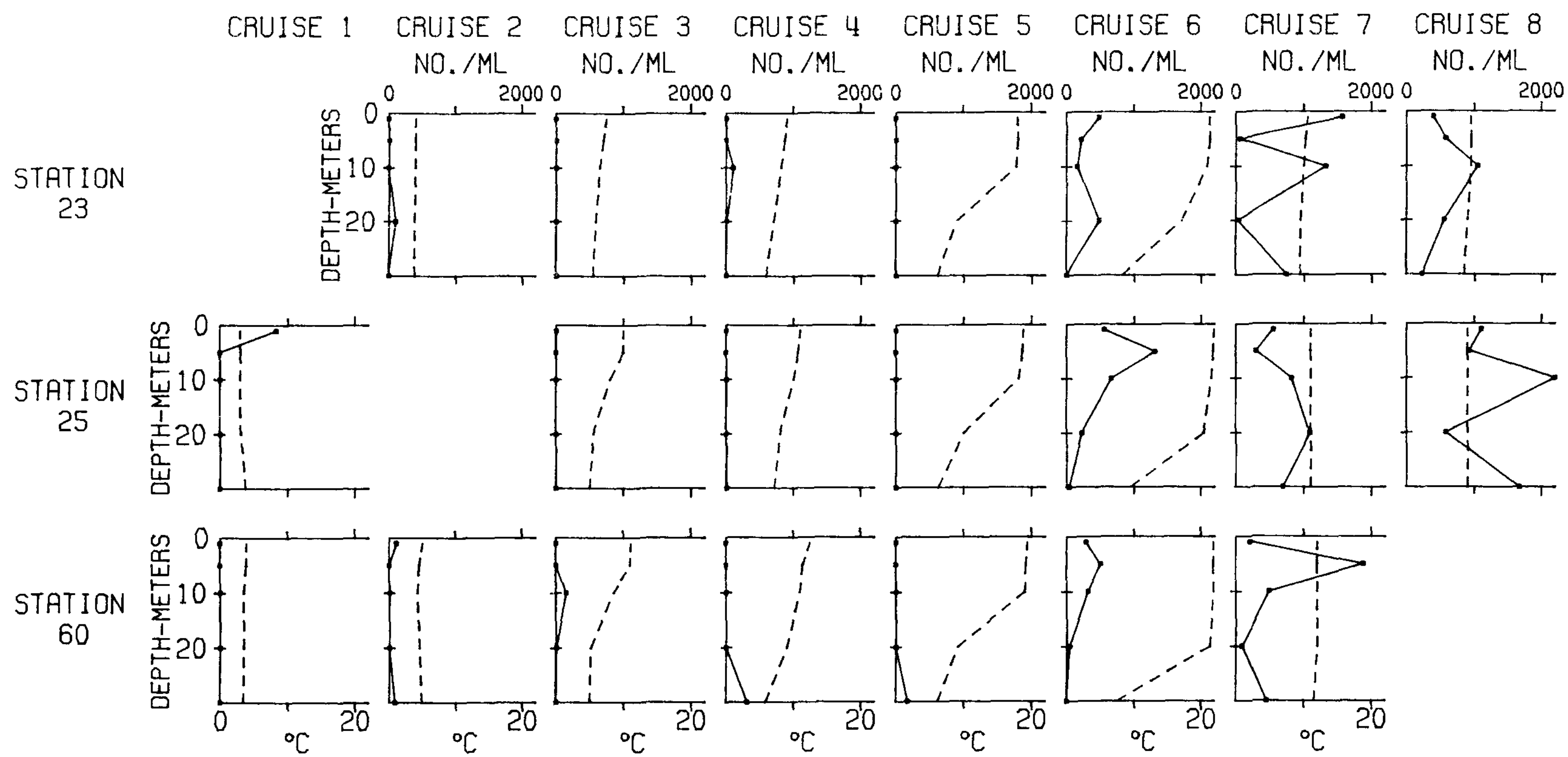


Figure 74. Vertical distribution of blue-green algae at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

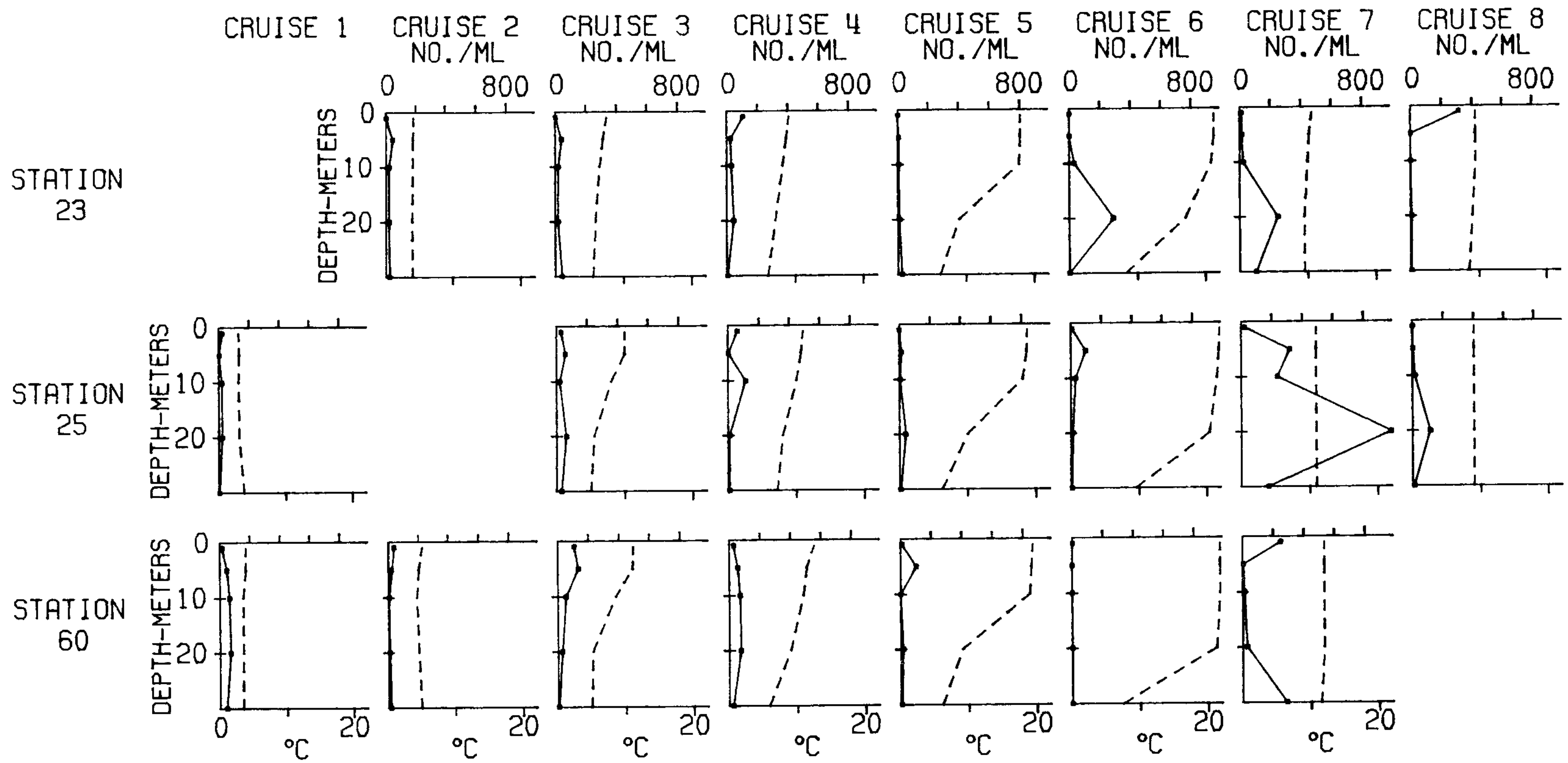


Figure 75. Vertical distribution of chrysophytes at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

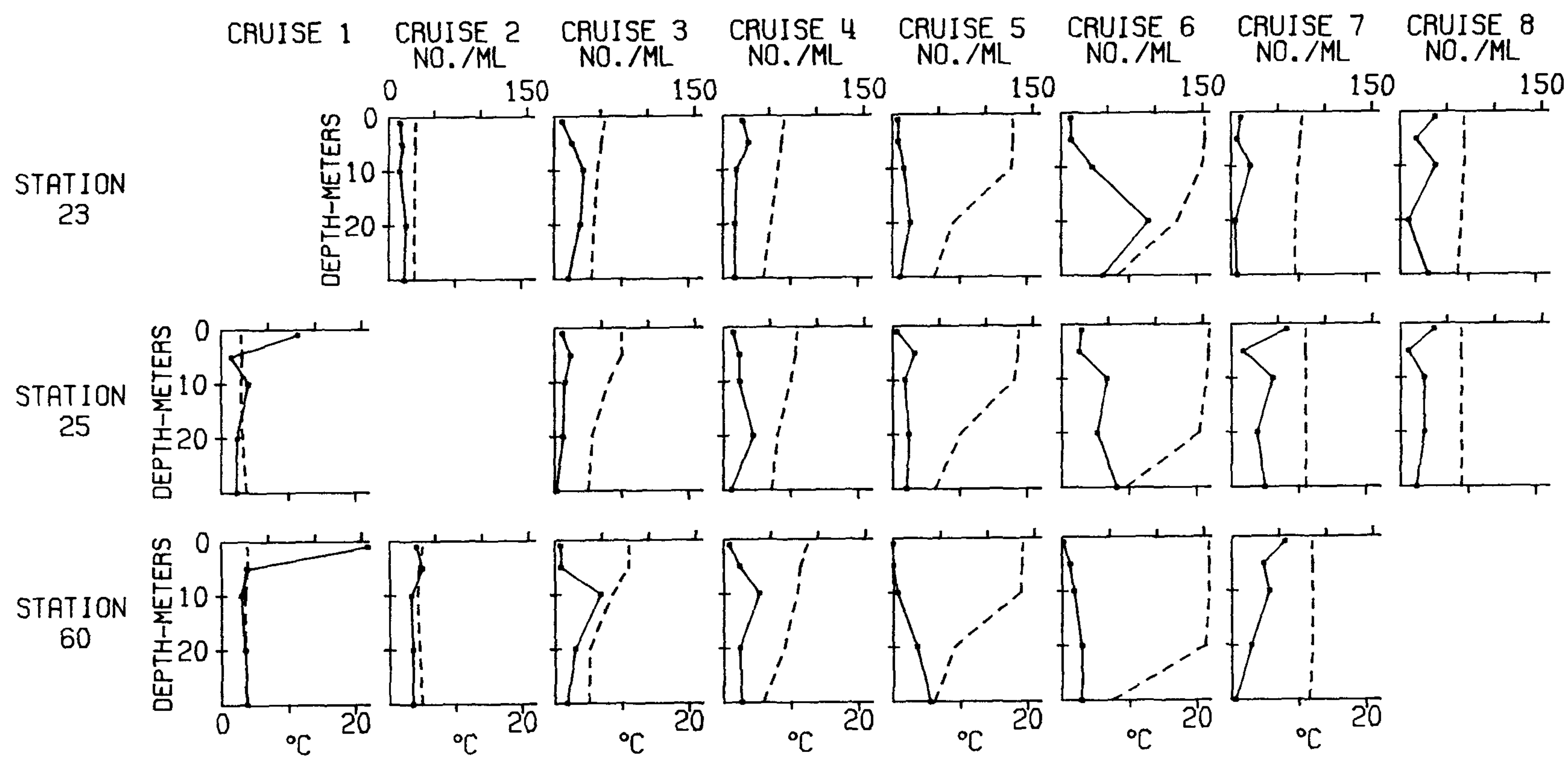


Figure 76. Vertical distribution of cryptomonads at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

Prior to the establishment of stratification, population densities of phytoplankters in the division Chrysophyta were remarkably uniform with depth (Fig. 75). Population densities of this group reached their minimum during cruise 5 following the establishment of a stable stratification. During cruise 6 maximum population densities were found in the thermocline regions at station 23, but this group was present only in small numbers at station 25 and virtually absent at station 60. During cruise 7, although the water column sampled was essentially isothermal, peak abundance of chrysophytes was found at 20 m depth at stations 23 and 25, with a remarkably large peak at station 25 being composed almost exclusively of *Chrysosphaerella longispina*.

During cruise 1 cryptomonads (Fig. 76) were strikingly more abundant in near surface waters than other depths sampled. Population densities of this group were remarkably similar at all depths sampled during cruise 2. During cruises 3, 4 and 5 minimum population densities usually occurred at the surface at the master station sampled with maximum densities occurring at depths of either 5 or 10 m. During cruise 6, a large population maximum was found at the depth of 20 m at station 23, although the other stations sampled did not show this trend. During cruises 7 and 8, the population densities of this group were again relatively uniform with depth. During these cruises, maximum abundance was again generally found in the surface samples although these peaks were not as pronounced as they had been during the spring.

Due to the low population densities found in the offshore waters from Lake Huron detectable quantities of dinoflagellates (Fig. 77) were generally found only at 5 and 10 m depths at the stations sampled.

Considering the composite nature of the group the distribution of microflagellates (Fig. 78) was remarkably similar at all the stations and dates sampled in southern Lake Huron. In the majority of instances these organisms tended to be strongly concentrated at a depth of 5 m. The main exception to this was at all stations sampled during cruise 4, and at stations 25 and 60 sampled during cruise 5. Although population densities varied in most other samples these organisms were several times more abundant at the 5 m depth than the other depths sampled. The reasons for this highly unusual depth distribution pattern are obscure although some active type of depth regulation is suggested by such remarkably stable patterns.

INTEGRATED FLORISTIC EFFECTS

Relation of Selected Species to Specific Chemical Parameters

It is evident that the phytoplankton flora of southern Lake Huron reacts to various chemical and physical conditions and gradients within the environment in a complex manner. While nutrient control of phytoplankton growth is an undeniably important factor in controlling the patterns of distribution observed, it is also clear that certain populations react to the conservative ion content of their environment and the temperature regime. The effects of these directly observable parameters, although complicated by

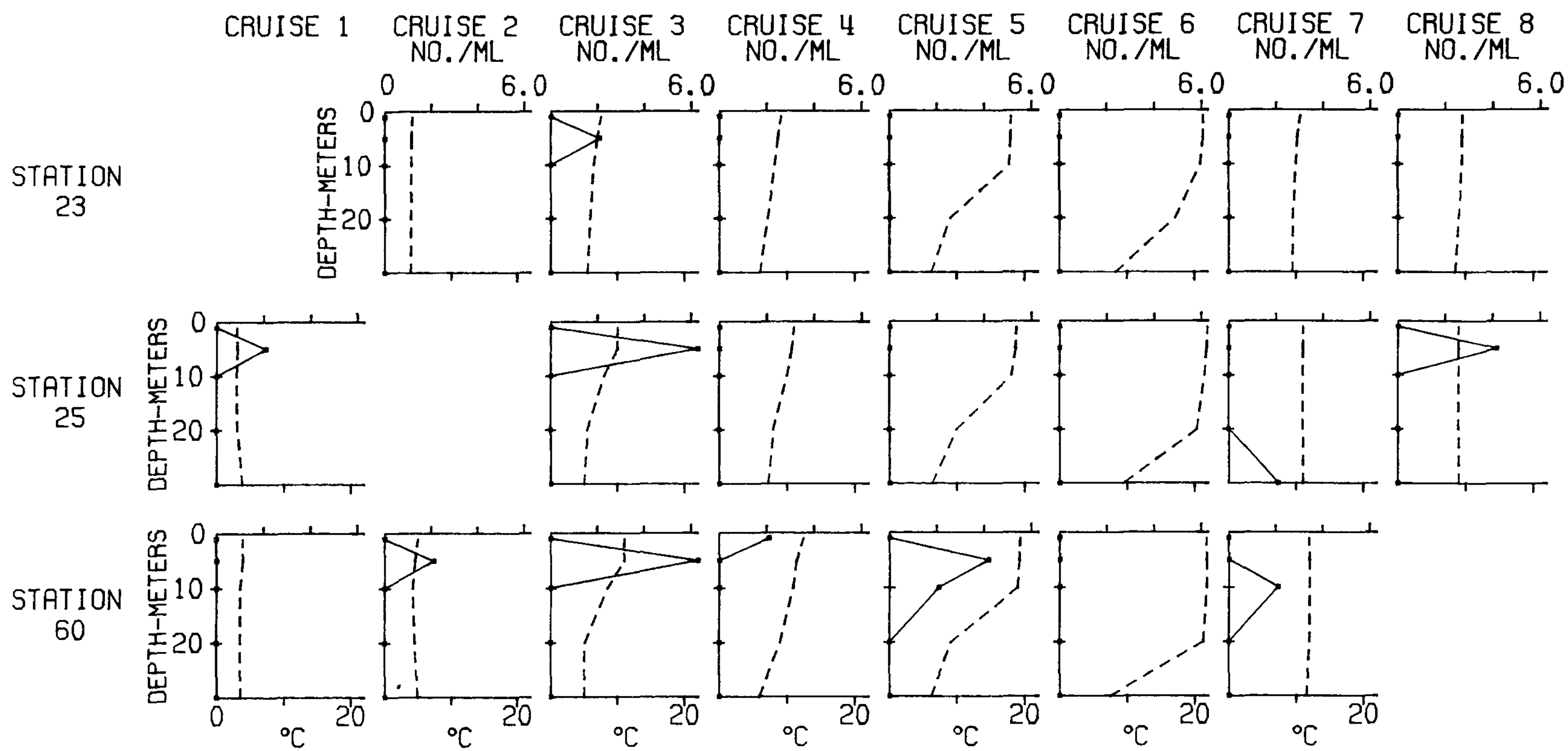


Figure 77. Vertical distribution of dinoflagellates at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

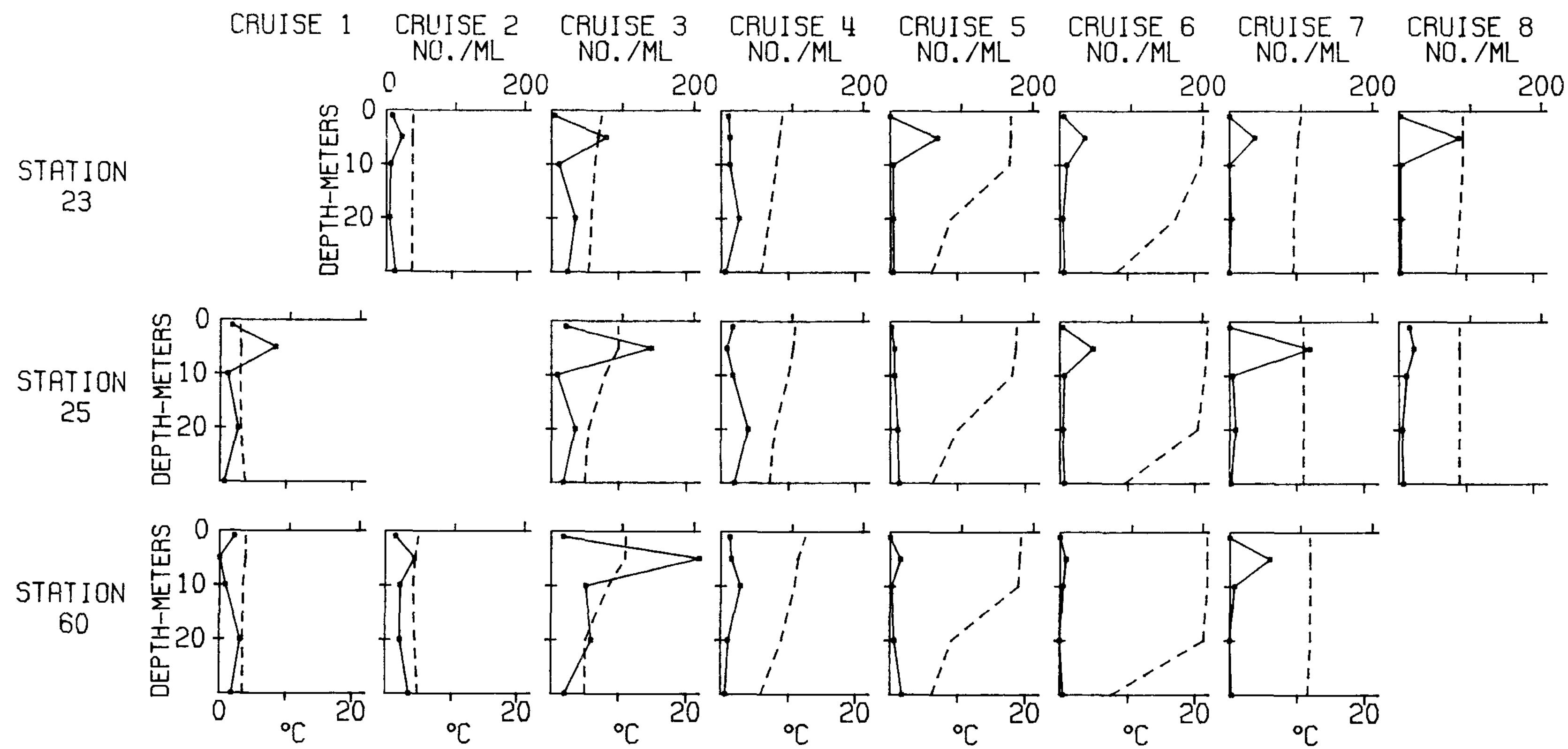


Figure 78. Vertical distribution of microflagellates at master stations. Three master station profiles are presented for each cruise when sampled. The solid line (____) represents absolute abundance (cells/ml), the dashed line (----) represents temperature (°C).

TABLE 17. CORRELATION MATRIX OF *APHANIZOMENON FLOS-AQUAE* AND MACRONUTRIENT VALUES FOR CRUISE 7 AT 5 METER DEPTH. N = 37.

Cond.	1.0000					
Cl	.7260	1.0000				
NO_3	-.7579	-.9062	1.0000			
SIO_2	-.3993	-.4705	.3879	1.0000		
TPO_4	.6943	.8388	-.8319	-.4140	1.0000	
AZFLOS	.7405	.9201	-.9306	-.4325	.9142	1.0000
	Cond.	Cl	NO_3	SIO_2	TPO_4	AZFLOS

<SCATTER V=11,47,59,73:95,96,99 ST=V100:7>

SCATTER PLOT STRAT=CRUISE:7
N= 37 OUT OF 37 11.AZFLOSAQ VS. 95.CL

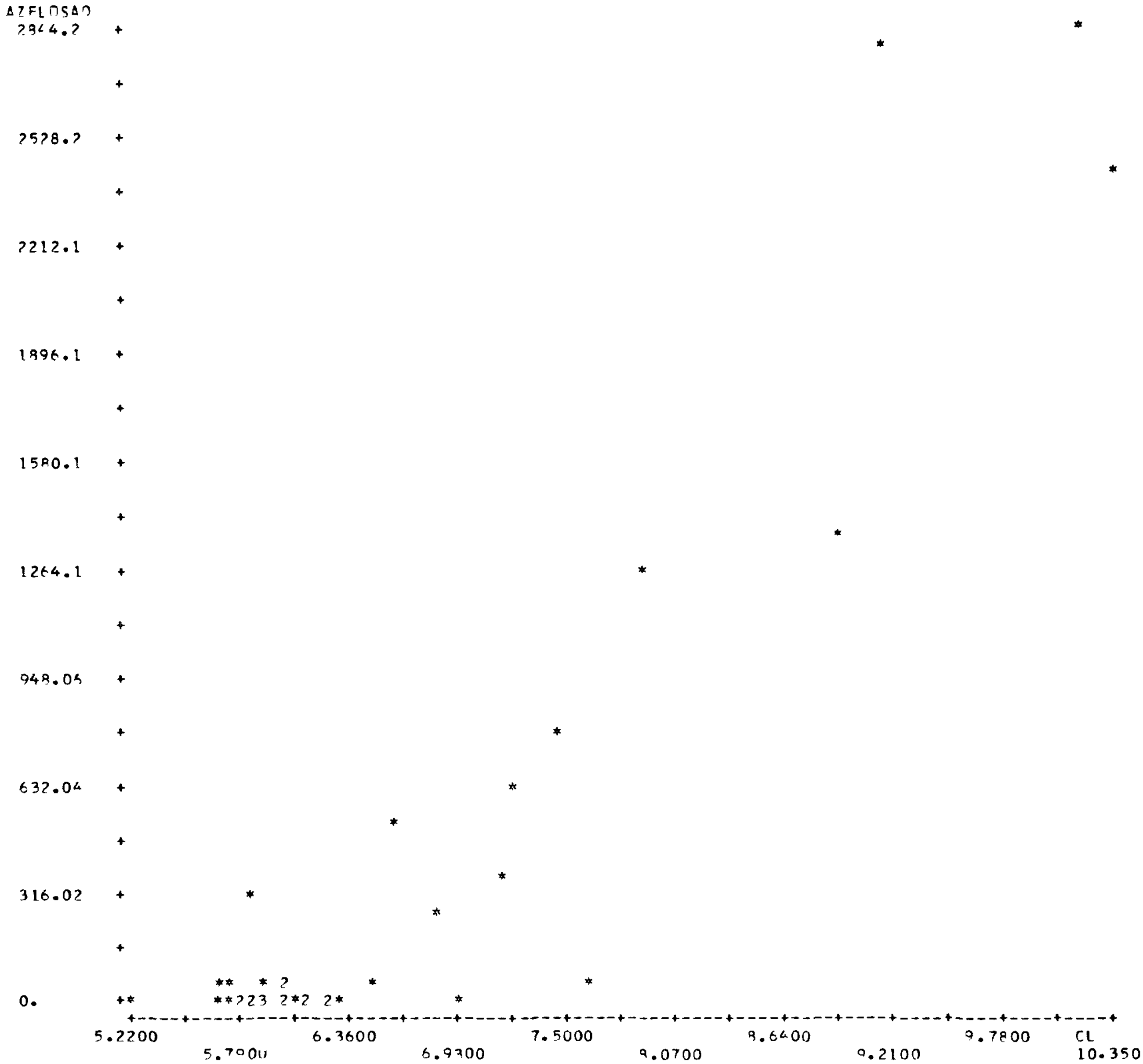


Figure 79. Correlation plots of absolute abundance (cells/ml) of *Aphanizomenon flos-aquae* vs. chloride (mg/l).

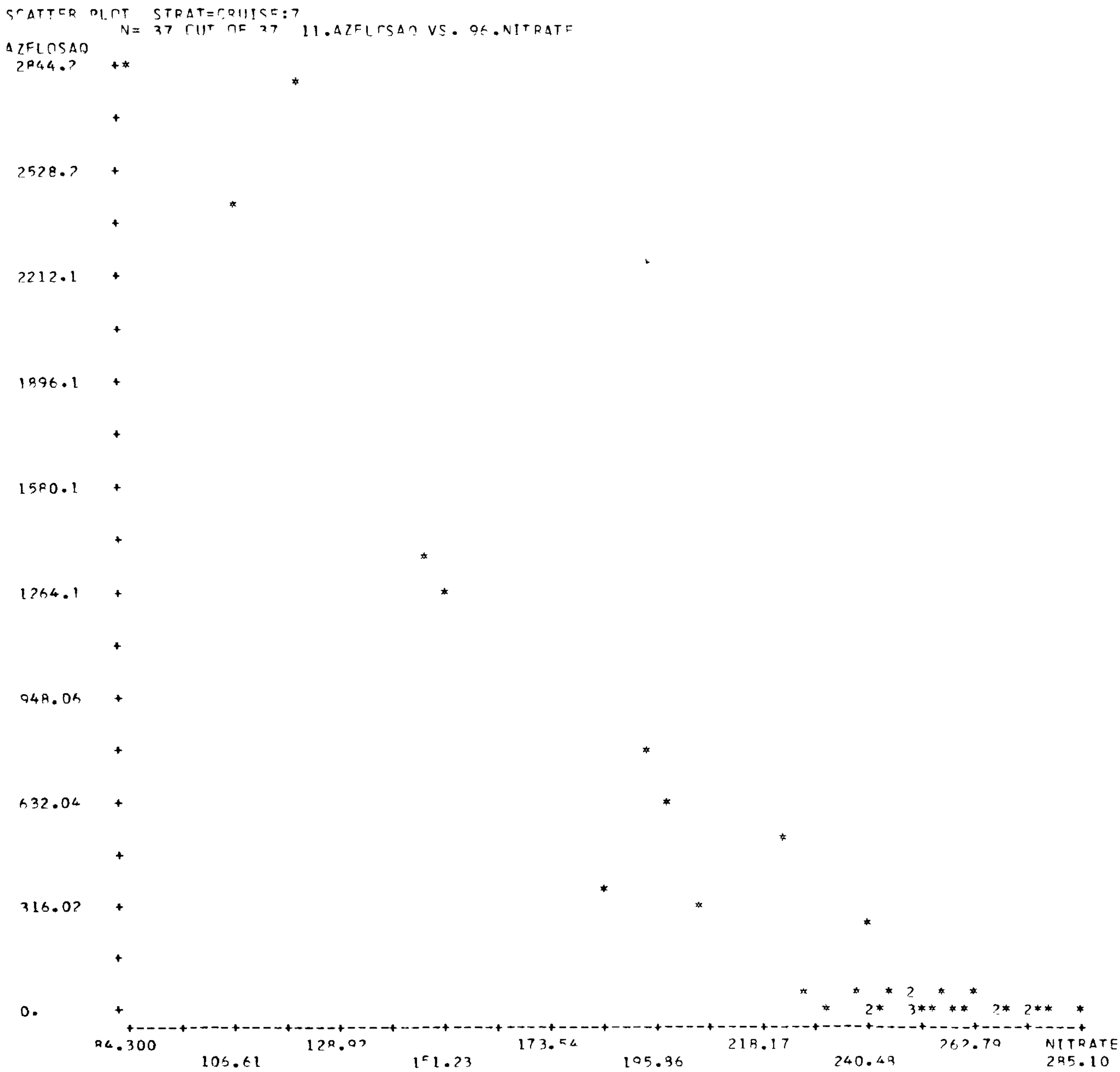


Figure 80. Correlation plots of absolute abundance (cells/ml) of <u>Aphanizomenon flos-aquae</u> vs. nitrate (mg/l).

historesis effects, usually can be evaluated by relatively straightforward objective analysis if sufficient data is available. In most instances it is much more difficult to evaluate more subtle biotic interactions, particularly the characteristics of certain populations which render them more or less subject to losses through sinking, predation or parasitism.

In the case of certain populations abundant in southern Lake Huron the factors controlling distribution appear to be relatively straightforward. For instance, Aphanizomenon flos-aquae is a population which appears to be largely restricted to water masses derived from Saginaw Bay. As would be expected its abundance is highly correlated with high levels of chloride and total phosphorus, and negatively with nitrate concentration (Table 17; Fig. 79, 80). In the case of this species it may be speculated that it has competitive advantage in waters rich in phosphorus and relatively depleted in nitrate and silicon, since it is known to be capable of fixing atmospheric nitrogen and does not require silicon for growth. It is also quite possible that the growth of this species is in some way facilitated by relatively high conservative ion levels, as might be inferred from the high correlation with chloride. Such causality arguments are somewhat weakened by inspection of similar data for the same cruise for undetermined green filament number 5 (Table 18; Fig. 81, 82). Although the physiological capabilities of this entity are entirely unknown, it is extremely doubtful that it is capable of fixing atmospheric nitrogen. It however shows nearly identical high positive correlations with chloride and total phosphorus and negative correlation with inorganic nitrogen concentration. It may well be that apparent similarity in response of these two species evolves from the fact that they are both generated under the conditions present in Saginaw Bay, and that neither population is subject to significant sinking or grazing losses as they are transported into southern Lake Huron. Hence their behavior is essentially similar to that of the conservative chemical ion species. In this case it is entirely possible that the apparently high negative correlation with nitrate values of these two entities may result from opposite causality (i.e. the growth of green filament number 5 and similar populations may result in the depletion of nitrate in water masses where they are abundant and this, in turn, may confer competitive advantage on nitrogen-fixing poulations such as Aphanizomenon flos-aquae).

The situation with other populations may be even more complex. For instance, Fragilaria capucina is a species which has been observed to increase greatly in abundance in shallow embayments and nearshore areas which have been significantly eutrophied. However it apparently does not invade the offshore waters of the Great Lakes to any significant extent. On the basis of data from cruise 3 (Table 19; Fig. 83) populations of this species show moderately high positive correlation with the chloride level, although positive correlation to total phosphorus and low negative correlations with inorganic nitrogen and soluble silicon. Goad et al. (1977) have shown that this species has a relatively thick siliceous wall compared to taxa which are euplanktonic in the Great Lakes. It may well be that the apparently weak correlation of the occurrence of this species with chemical factors results from high sinking loss rates inherent in its morphology and cellular constitution.

TABLE 18. CORRELATION MATRIX OF GREEN FILAMENT SP. #5 AND MACRONUTRIENT VALUES FOR CRUISE 7 AT 5 METER DEPTH. N = 37

Cond.	1.0000					
Cl	.7260	1.0000				
NO_3	-.7579	-.9062	1.0000			
SIO_2	-.3993	-.4705	.3879	1.0000		
TPO_4	.6943	.8388	-.8319	-.4140	1.0000	
GRFILS	.7629	.9229	-.9295	-.4316	.8765	1.0000
	Cond.	Cl	NO_3	SIO_2	TPO_4	GRFILS

TABLE 19. CORRELATION MATRIX OF *FRAGILARIA CAPUCINA* AND MACRONUTRIENT VALUES FOR CRUISE 3 AT 5 METER DEPTH. N = 43

Cond.	1.0000					
Cl	.8209	1.0000				
NO_3	.3625	.0771	1.0000			
SIO_2	-.3001	-.2538	-.1382	1.0000		
TPO_4	.4562	.4857	.0994	-.1174	1.0000	
FRCAPU	.5773	.7350	-.1034	-.1203	.2963	1.0000
	Cond.	Cl	NO_3	SIO_2	TPO_4	FRCAPU

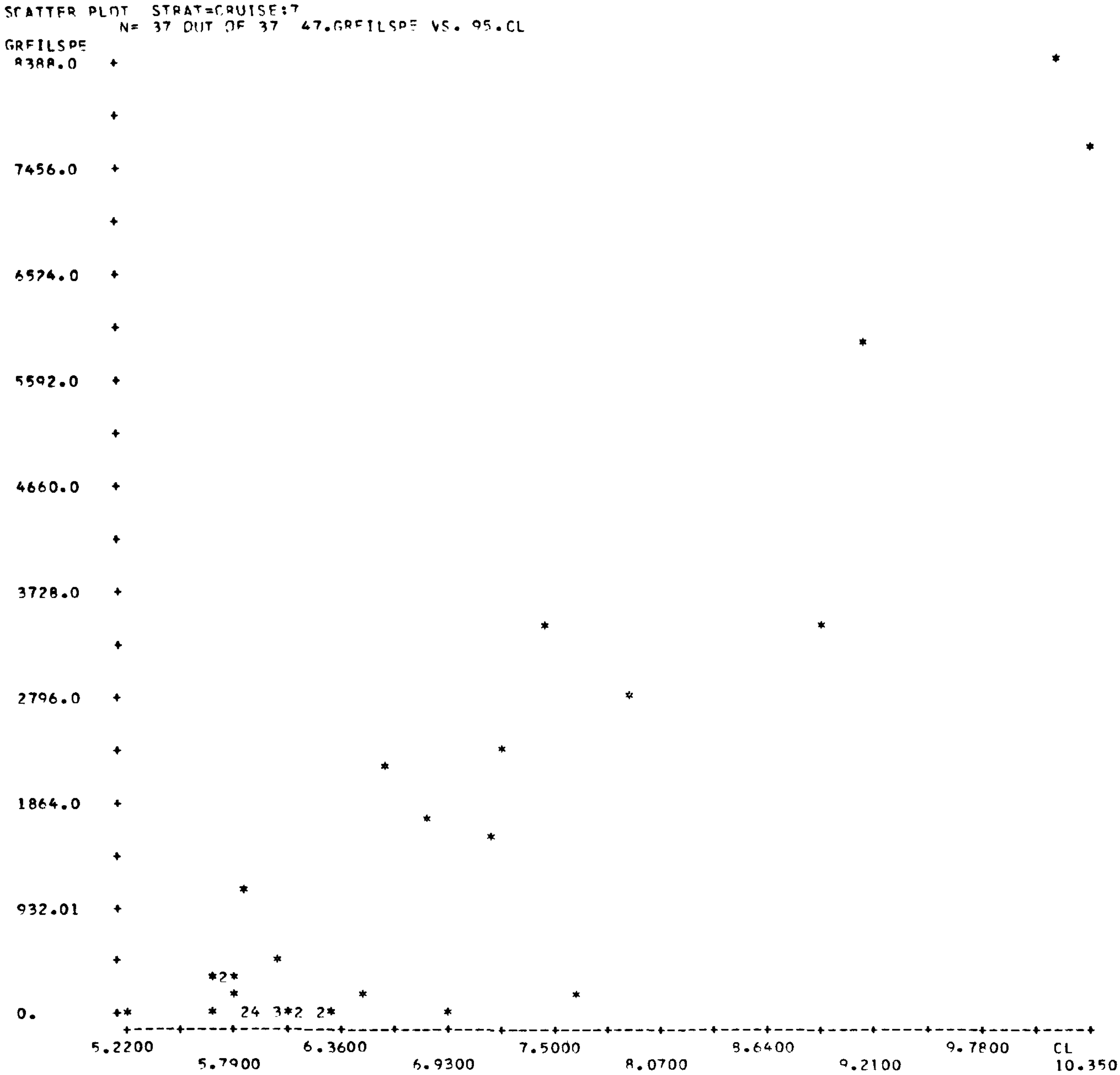


Figure 81. Correlation plots of absolute abundance (cells/ml) of green filament sp. #5 vs. chloride (mg/l).

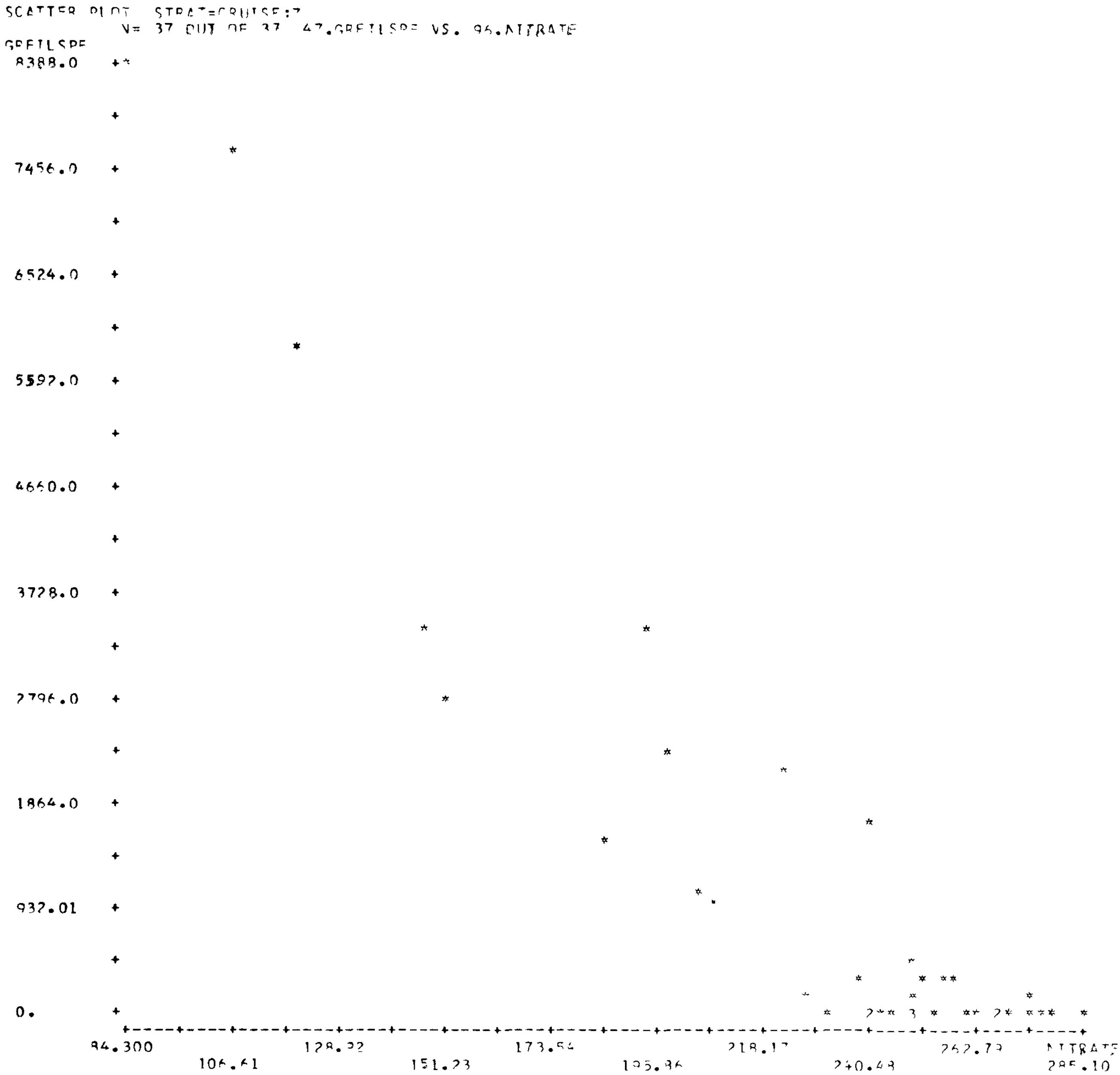


Figure 82. Correlation plots of absolute abundance (cells/ml) of green filament sp. #5 vs. nitrate (mg/l).

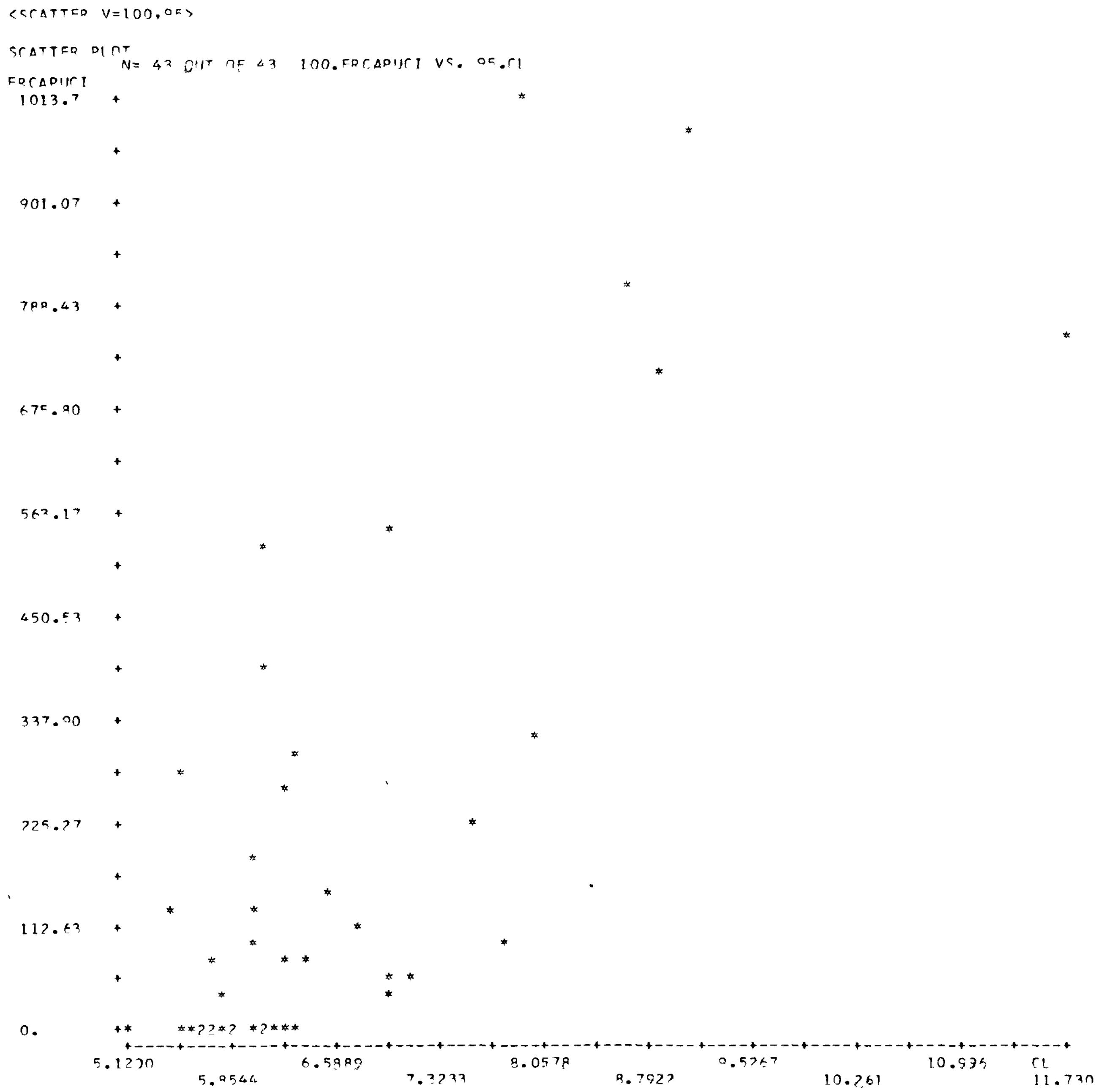


Figure 83. Correlation plots of absolute abundance (cells/ml) of *Fragilaria capucina* vs. chloride (mg/l).

TABLE 20. CORRELATION MATRIX OF *CYCLOTELLA COMENSIS* AND MACRONUTRIENT VALUES FOR CRUISE 6 AT 5 METER DEPTH
N = 44

Cond.	1.0000					
Cl	.3763	1.0000				
NO_3	-.1006	.0044	1.0000			
SIO_2	.1177	.0663	-.4415	1.0000		
TPO_4	.5926	.7326	-.0793	.1417	1.0000	
CYCOME	-.2507	-.2172	.6194	-.7871	-.2430	1.0000
	Cond.	Cl	NO_3	SIO_2	TPO_4	CYCOME

TABLE 21. CORRELATION MATRIX OF *CYCLOTELLA OCELLATA* AND MACRONUTRIENT VALUES FOR CRUISE 4 AT 5 METER DEPTH
N = 42

Cond.	1.0000					
Cl	.9189	1.0000				
NO_3	.3894	.5044	1.0000			
SIO_2	-.7769	-.7649	-.4989	1.0000		
TPO_4	.8672	.8746	.3283	-.7795	1.0000	
CYOCEL	-.6319	-.5403	-.3780	.7328	-.5595	1.0000
	Cond.	Cl	NO_3	SIO_2	TPO_4	CYOCEL

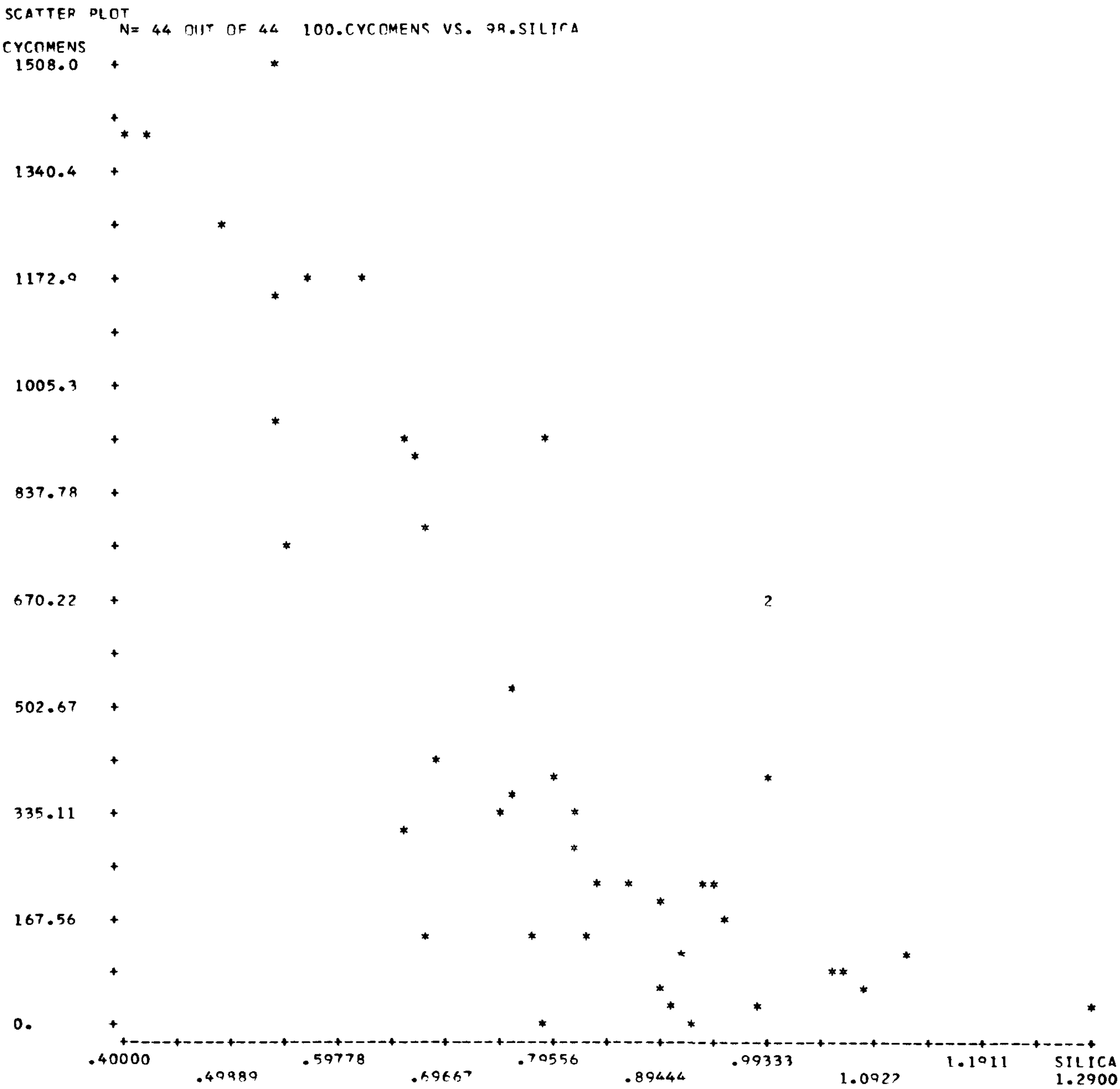


Figure 84. Correlation plots of absolute abundance (cells/ml) of *Cyclotella comensis* vs. silica (mg/l).

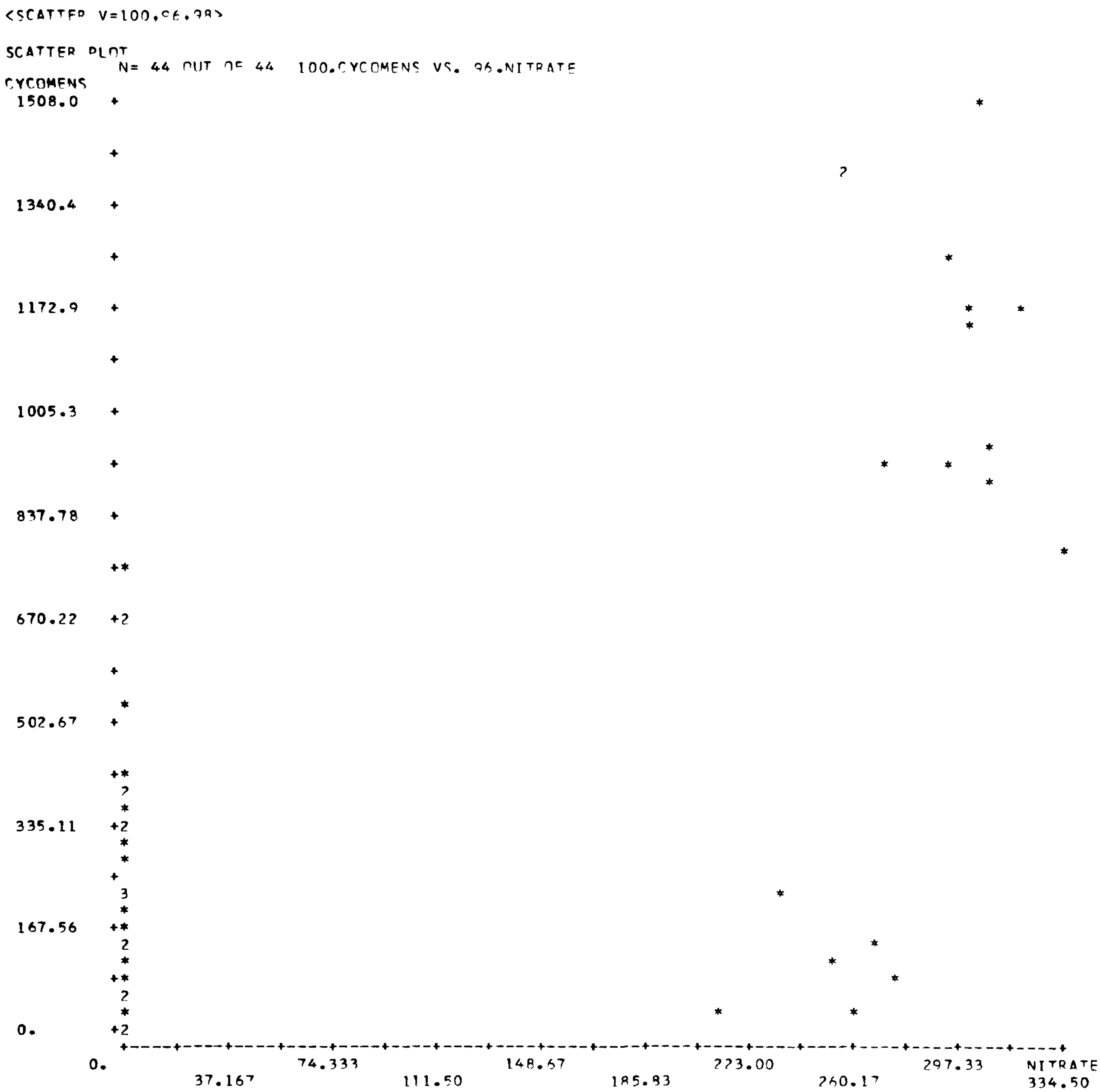


Figure 85. Correlation plots of absolute abundance (cells/ml) of *Cyclotella comensis* vs. nitrate (mg/l).

The occurrence pattern of Cyclotella comensis in the Great Lakes is something of an enigma. Although this species was previously recorded from the offshore waters of Lake Superior (Schelske et al., 1972) and northern Lake Huron (Schelske et al., 1974; Lowe, 1976) its distribution range and abundance has apparently increased considerably in recent years. It is now present in Lake Michigan, where it was previously either absent or present in only very small abundance (Stoermer & Yang, 1969), and during our study occurred in bloom proportion at several stations in southern Lake Huron. In southern Lake Huron blooms of this species were usually associated with auxospore formation during the late summer which in our experience is highly unusual for most planktonic diatoms. Inspection of data from cruise 6 (Table 20; Fig. 84, 85) shows that this species has a relatively strong positive correlation with nitrate level. Conversely it shows negative correlation with other nutrient and conservative ions. It is particularly interesting that this species shows a high negative correlation with dissolved silicon, although this nutrient is known to be an essential requirement for its growth. These data, plus the highly unusual occurrence pattern of this species in the Great Lakes in recent years, lend some credence to the hypothesis that inorganic nitrogen levels in the offshore waters of the upper Great Lakes are in fact increasing. It would also tend to indicate that this species is particularly efficient in its utilization of silicon at low levels and may become an increasingly important element of summer phytoplankton assemblages in the upper lakes. Our data (Fig. 85) suggest that this species has an absolute requirement for nitrate levels in excess of 200 $\mu g/\ell$, but when this requirement is supplied, it can tolerate silica levels of less than .5 mg/ℓ (Fig. 84).

The distribution of Cyclotella ocellata, another species with apparent oligotrophic affinites, is quite different with respect to major conservative and nutrient ions (Table 21; Fig.86). Unlike C. comensis this species shows relatively high positive correlation with increasing levels of dissolved silicon, but it is negatively correlated with other major nutrients and with chloride. Previous studies in northern Lake Huron (Schelske et al., 1976) suggest that C. ocellata is most abundant at or below the thermocline. This suggests that it has a relatively high silicon requirement but is able to fulfill this limitation by adaptation to growth under low light conditions. As will be discussed later, significant occurrences of this species in southern Lake Huron during stratification appear to be associated with upwelling incidents.

Dimensional Ordination Analysis Utilizing Principal Components

A number of multivariate statistical procedures are available to aid in evaluating properties, in this case floristic associations, emergent from the complex interactions of the basic physical and chemical properties of the given system. In this case, we have chosen to utilize principal components analysis. For each cruise, we have plotted the regions of floristic similarity in southern Lake Huron derived from this analysis, and in addition have prepared a tabular listing of the species particularly characteristic of the regions defined. The analytical procedures used are essentially similar to those utilized by Schelske et al. (1976) and Stoermer and Ladewski (1978).

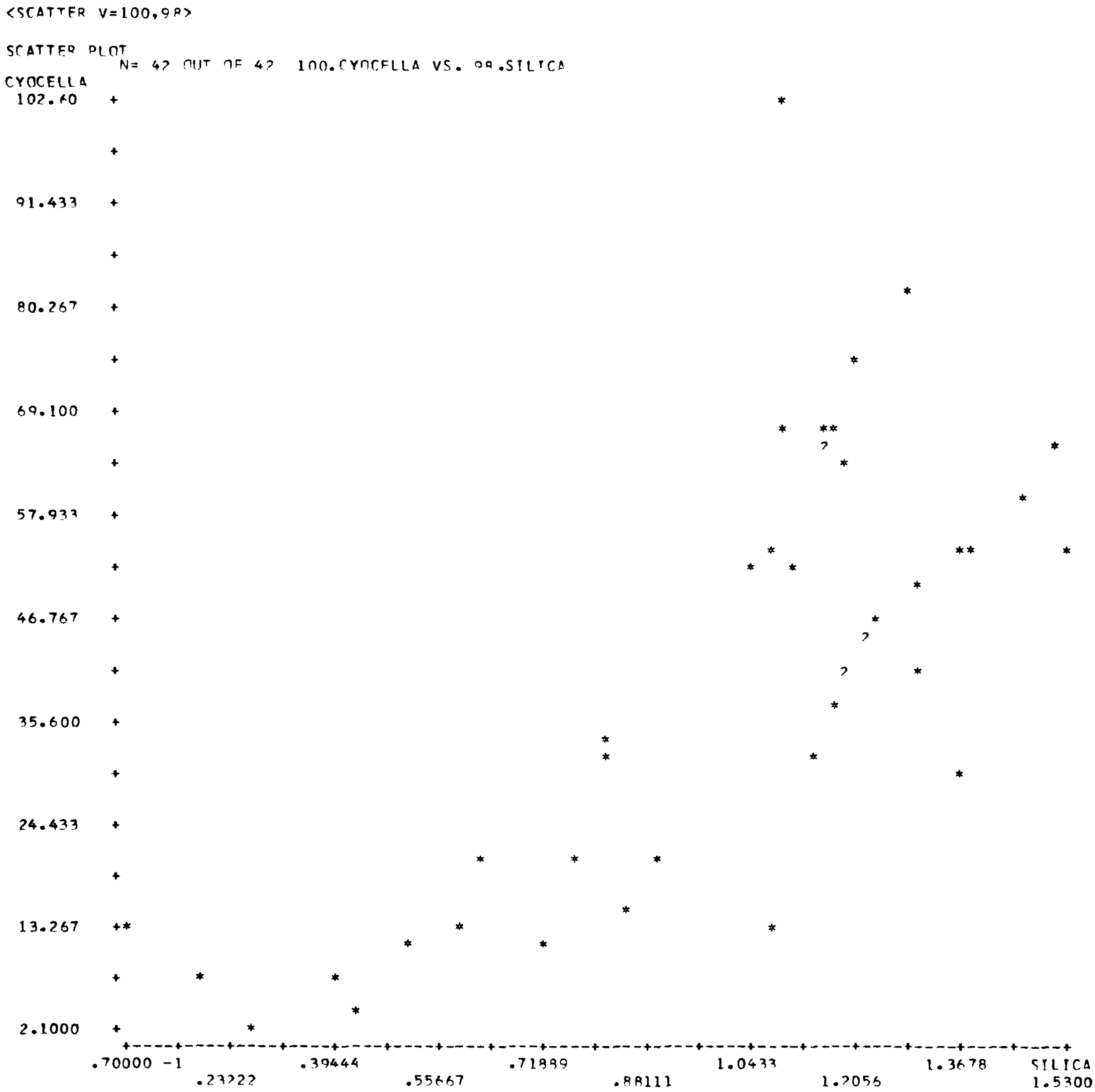


Figure 86. Correlation plots of absolute abundance (cells/ml) of *Cyclotella ocellata* vs. silica (mg/l).

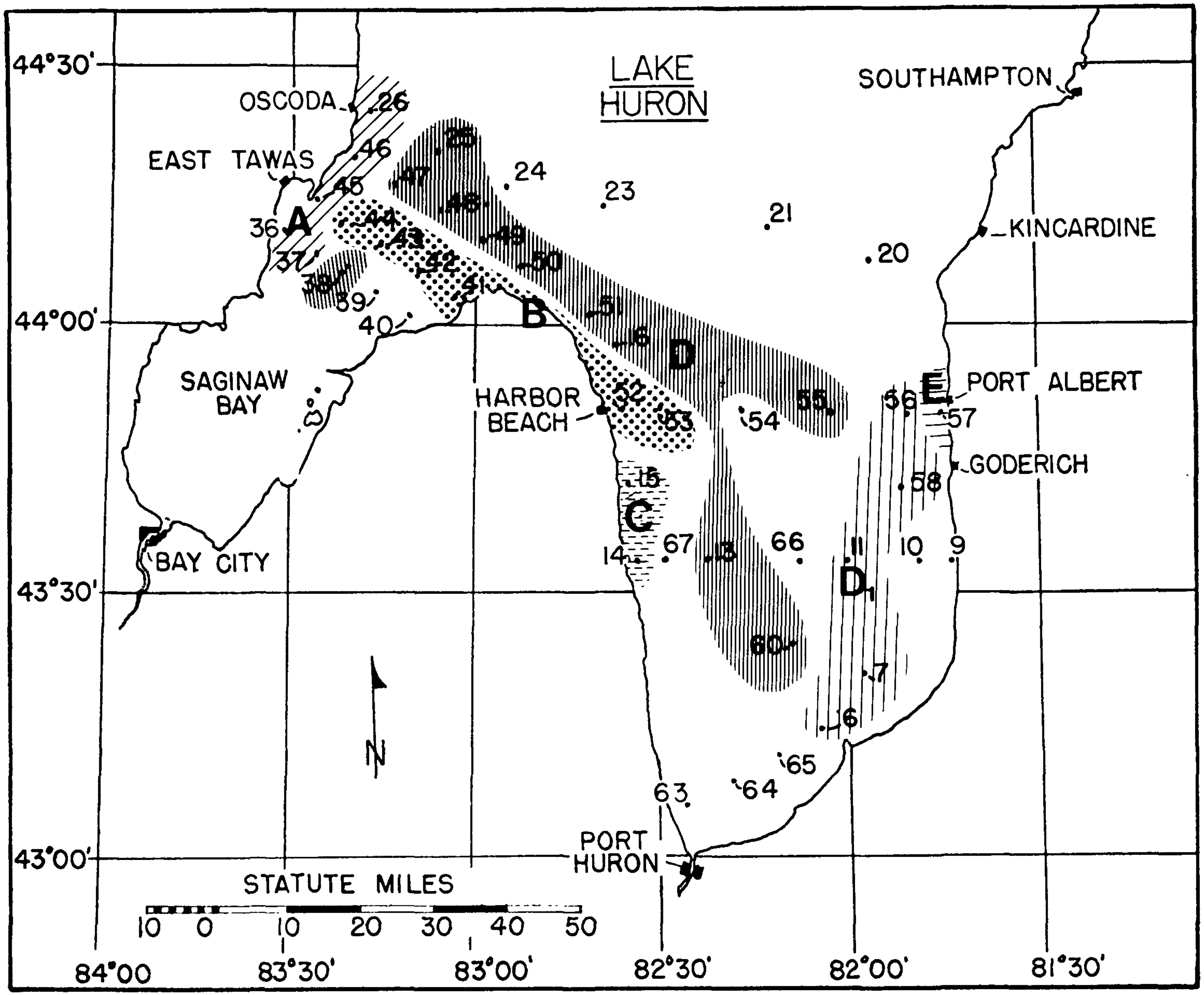


Figure 87. Cruise 1- April 28 - May 3, 1974. Phytoplankton asociations as determined by dimensional ordination and principal components analysis.

TABLE 22. CRUISE 1 - APRIL 28-MAY 3, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 87) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Species / Region:	Grand	A	B	C	D	D_1	E	Apparent Trend High	Apparent Trend Low
N =	28	4	5	2	11	5	1		
Amphora ovalis var. pediculus**	1.57 2.83	7.33 3.63	.84 1.15	1.04 1.48	.19 .63	.84 1.15	2.09	A	D
Cryptomonas ovata** +	7.18 6.56	11.51 8.80	5.03 2.81	21.99 10.37	5.90 3.08	2.93 3.50	6.28	C	D_1
Cyclotella ocellata +	28.27 13.15	43.98 20.73	25.55 13.03	36.65 13.33	23.42 8.68	27.23 8.51	20.94	A	E
Cyclotella stelligera* +	40.32 19.69	52.88 14.95	42.30 19.78	15.71 4.44	29.89 6.00	57.39 27.41	58.64	E	C
Diatoma tenue var. pachycephala**	15.48 17.03	26.18 18.50	14.24 9.76	59.69 10.37	8.19 6.38	9.22 11.53	2.09	C	E
Fragilaria capucina**	36.05 61.71	85.87 58.69	24.30 44.54	176.98 102.19	9.52 28.86	1.68 3.75	77.49	C	D_1
Fragilaria crotonensis**	132.55 128.26	261.80 119.34	89.64 41.19	420.97 236.95	80.73 60.94	68.28 46.40	144.51	C	D_1
Fragilaria pinnata*	3.67 13.78	1.05 1.21	1.26 1.87	36.65 51.83	1.14 2.54	1.26 1.87	0	C	E
Fragilaria vaucheriae** +	2.77 5.29	5.24 4.99	1.26 1.87	16.76 11.85	1.14 1.72	0 0	4.19	C	D_1
Undetermined green filament sp. #5** +	99.93 125.24	71.21 76.91	181.79 148.79	373.85 176.23	57.22 70.32	67.44 31.67	0	C	E
Melosira islandica** +	32.99 80.12	17.80 7.73	17.17 10.20	30.37 10.37	16.76 11.47	16.76 16.29	437.73	E	D, D_1

Legend: * ≤ .02; ** ≤ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for 5 m samples for respective cruise.

(continued)

TABLE 22 (continued)

Species / Region: N =	Grand 28	A 4	B 5	C 2	D 11	D_1 5	E 1	Apparent Trend High	Apparent Trend Low
Nitzschia acicularis *	9.42 5.24	2.09 2.42	8.80 2.29	13.61 7.40	10.09 4.27	13.40 5.46	6.28	C	A
Ochromonas sp. #1 +	9.65 14.97	31.41 18.97	11.31 18.77	7.33 1.48	2.67 6.36	8.80 12.25	0	A	E
Rhodomonas minuta var. *nannoplanctica* +	11.59 10.60	17.80 12.39	12.99 8.69	11.52 10.37	8.76 7.54	13.40 17.56	2.09	A	E
Rhizosolenia eriensis ** +	14.51 8.79	21.99 8.80	18.85 8.38	28.27 7.40	8.38 3.38	14.24 6.85	4.19	C	E
Rhizosolenia gracilis * +	44.58 22.70	69.59 30.66	41.47 20.17	81.68 2.96	32.56 12.33	41.89 16.76	35.61	C	D
Stephanodiscus alpinus ** +	16.31 79.33	1.57 2.01	1.68 2.73	2.09 2.96	1.14 1.96	.84 1.15	420.97	E	D_1
Stephanodiscus binderanus **	4.56 13.12	2.62 5.24	0 0	46.08 23.70	1.14 3.79	2.51 5.62	0	C	B, E
Stephanodiscus hantzschii ** +	39.79 120.99	31.94 26.90	5.86 5.81	42.94 13.33	10.66 10.02	20.53 11.79	651.36	E	B
Staphanodiscus minutus ** +	25.43 36.17	16.76 10.68	15.92 9.08	9.42 1.48	20.18 11.90	25.13 19.70	198.97	E	C
Surirella angusta *	.82 1.65	.52 1.05	0 0	1.05 1.48	.95 1.72	.42 .94	6.28	E	B
Synedra filiformis ** +	116.61 57.50	202.11 44.35	117.29 29.91	161.27 74.05	71.21 17.97	139.49 50.28	67.02	A	E
Synedra minuscula ** +	9.65 17.61	8.90 6.71	5.45 4.34	68.07 10.37	1.90 3.31	5.03 2.39	25.13	C	D
Synedra ostenfeldii * +	19.07 15.94	38.22 26.24	29.74 12.60	8.38 8.89	16.56 7.28	6.70 4.78	0	A	E

(continued)

TABLE 22 (continued)

Species	Region: N =	Grand 28	A 4	B 5	C 2	D 11	D_1 5	E 1	Apparent Trend High	Apparent Trend Low
Tabellaria fenestrata * +		74.50	125.66	67.02	212.58	39.98	69.53	35.61	C	E
		54.74	47.61	11.57	48.87	15.52	35.92			
Tabellaria flocculosa var. linearis * +		29.70	76.97	28.90	57.60	12.38	24.30	6.28	A	E
		33.36	43.04	18.46	22.21	19.57	32.80			

During cruise 1 (Fig. 87; Table 22) six fairly well defined phytoplankton associations were present in southern Lake Huron. Three of these associations, labeled A, C, and E, were associated with nearshore stations sampled. Although these stations had in common relatively high abundance of certain predominately benthic taxa such as Amphora ovalis var. pediculus, the predominant planktonic taxa present were different in each region. Region A was dominated by oligotrophic to mesotrophic species such as Rhodomonas minuta var. nannoplanctica, Stephanodiscus transilvanicus, Synedra filiformis, and Tabellaria flocculosa. Region C, on the other hand, was characterized by much greater abundance of species with eutrophic affinities such as Diatoma tenue var. pachycephala, Fragilaria capucina, Melosira granulata, and Stephanodiscus binderanus. Region E was dominated by a different set of taxa with mesotrophic to eutrophic affinites including very high abundances of Melosira islandica, Nitzschia dissipata, several of the smaller species of Stephanodiscus, and Surirella angustata. Region B, which encompasses a number of stations in the Saginaw Bay interface waters and southward along the Michigan coast, contained a mixture of species with primarily eutrophic affinities but was mostly distinguished by a very high abundance of microflagellates. Region D was characterized primarily by the occurrence of a number of species with oligotrophic or mesotrophic affinities, generally in low abundance. This region is distinguished from Region D1 primarily by the greater abundance of species such as Dinobryon divergens and Fragilaria intermedia var. fallax in Region D1.

During cruise 2 (Fig. 88, Table 23) a somewhat different floristic pattern was present. A large number of stations in the Saginaw Bay interface waters and southward along the Michigan coast had floras dominated by species with eutrophic affinities such as Diatoma tenue var. pachycephala, Fragilaria crotonensis, Gloeocystis planktonica, Melosira granulata, Oscillatoria retzii, Scenedesmus quadricauda, and Stephanodiscus binderanus. Region A was particularly characterized by very high populations of Diatoma tenue var. pachycephala, and maximum abundance of microflagellates and Fragilaria capucina. Region A1 contained similar species but had a greater admixture of primarily benthic taxa such as Fragilaria pinnata, and more mesotrophic euplankters such as Anacystis incerta, Rhizosolenia gracilis, and Synedra ostenfeldii. At this time most offshore stations labeled as Region B on the map were characterized by relatively low abundance of oligotrophic and mesotrophic populations. Region C, along the Canadian coast, was characterized by high abundance of some of the more eurytopic plankton dominants such as Asterionella formosa, Cyclotella stelligera, Melosira islandica, and Stephanodiscus alpinus, together with certain species such as Cyclotella meneghiniana, Stephanodiscus hantzschii, Stephanodiscus minutus, S. subtilis, and Surirella angustata, which usually occur under more eutrophic conditions. Stations in the area labeled C1 had a qualitiatively similar flora to Region C, but certain species such as Crucigenia quadrata, Cyclotella ocellata, Rhizosolenia gracilis, and Synedra filiformis were relatively more abundant. This flora tended to grade into that found in Region B in the area labelled BC1, but this region was also distinguished by relatively high population densities of Chrysosphaerella longispina and Chrysococcus dokidophorus.

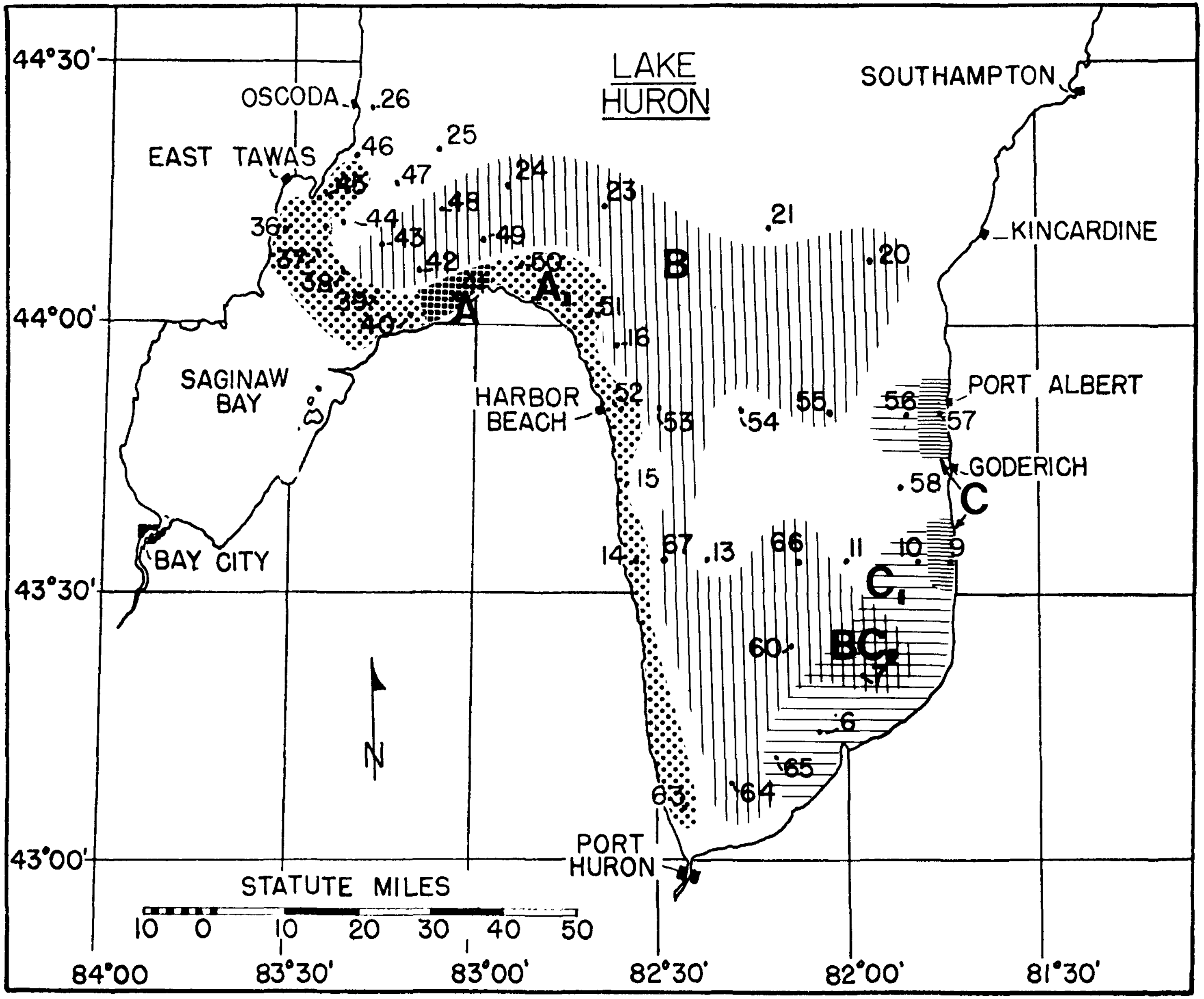


Figure 88. Cruise 2- 14-17 May, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

TABLE 23. CRUISE 2 - MAY 14-17, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 88) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5M SAMPLES. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES.

Species	Region:	Grand	A	A_1	B	C	BC_1	C_1	Apparent Trend	
	N =	33	1	11	14	2	1	4	High	Low
Anabaena subcylindrica **		.13	2.09	0	.15	0	0	0	A	A, C, BC_1, C
		.51		0	.56	0		0		
Asterionella formosa *		42.52	67.02	36.94	33.21	89.01	31.42	63.88	C	BC_1
		25.99		17.15	18.69	54.80		30.04		
Cosmarium sp. #1 **		.38	4.19	.57	.15	0	0	0	A	C, BC_1, C
		.97		.98	.56	0		0		
Cryptomonas ovata ** +		9.65	31.42	13.90	6.58	4.19	14.66	4.71	A	C
		7.59		5.80	6.25	0		2.00		
Cyclotella meneghiniana *		.19	0	.19	0	2.09	0	0	C	A, B, BC_1, C
		.80		.63	0	2.97		0		
Cyclotella ocellata +		34.27	10.47	36.37	32.76	26.18	39.79	42.41	BC_1	A
		13.49		14.46	13.39	4.44		10.17		
Cyclotella stelligera +		47.66	18.85	43.60	48.62	75.40	16.76	56.55	C	BC_1
		20.14		25.03	11.80	2.96		18.81		
Diatoma tenue var. *pachycephala* ** +		36.24	475.43	45.70	6.28	32.46	8.38	14.14	A	B
		83.01		31.62	5.06	34.06		10.03		
Undetermined flagellate species **		38.14	90.06	61.19	29.32	1.05	31.42	13.09	A	C
		26.88		21.36	14.56	1.48		17.30		
Fragilaria capucina ** +		174.72	2184.5	248.47	14.66	277.51	87.97	0	A	C_1
		420.27		303.53	40.38	318.41		0		

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for 5 m samples for respective cruise.

(continued)

TABLE 23 (continued)

Species / Region: N =	Grand 33	A 1	A_1 11	B 14	C 2	BC_1 1	C_1 4	Apparent Trend High	Apparent Trend Low
Fragilaria pinnata +	5.077 10.43	6.28	9.71 14.67	2.69 8.35	2.09 2.96	0	3.14 3.63	A_1	BC_1
Gloeocystis planctonica **	3.11 7.18	25.13	4.57 6.87	0 0	13.61 16.29	0	0 0	A	B, BC_1, C_1
Undetermined green filament sp. #5 ** +	403.92 1112.10	6444.40	449.91 300.55	116.99 75.76	0 0	106.81	44.51 17.80	A	C
Melosira granulata	11.23 29.06	71.21	25.51 43.33	0 0	9.42 1.48	0	0 0	A	B, BC_1, C_1
Melosira islandica ** +	77.81 164.62	58.64	42.46 33.38	24.39 24.36	692.0 170.31	27.23	72.26 50.31	C	B
Nitzschia acicularis +	15.36 6.80	6.28	13.52 5.16	15.11 7.08	17.80 7.40	12.57	23.04 6.62	C_1	A
Nitzschia dissipata +	7.55 6.04	2.09	4.76 3.39	9.57 6.96	6.28 2.96	6.28	10.47 8.20	A	C_1
Ochromonas sp. #1 ** +	7.49 7.53	27.23	11.81 8.23	5.54 4.39	1.05 1.48	2.09	2.09 1.71	A	C
Oscillatoria retzii **	14.09 60.61	347.67	10.09 14.48	.45 1.21	0 0	0	0 0	A	C, BC_1, C_1
Rhodomonas minuta var. *nannoplanctica* * +	10.73 7.46	29.32	12.38 7.34	11.52 5.91	0 0	8.38	4.71 2.64	A	C
Rhizosolenia eriensis * +	21.58 13.03	10.47	28.75 16.60	14.96 5.86	15.71 7.40	10.47	33.51 6.17	C_1	A, BC_1
Rhizosolenia gracilis ** +	86.70 37.90	62.83	126.04 28.11	65.08 24.36	90.06 38.51	25.13	73.83 8.78	A_1	BC_1

(continued)

TABLE 23 (continued)

Species	Region: N =	Grand 33	A 1	A_1 11	B 14	C 2	BC_1 1	C_1 4	Apparent Trend High	Apparent Trend Low
Stephanodiscus alpinus ** +		4.51 6.77	6.28	3.43 4.32	1.80 2.58	25.13 8.89	0	7.33 5.54	C	BC_1
Stephanodiscus hantzschii ** +		31.99 74.69	67.02	19.42 10.97	6.28 5.86	311.02 81.45	16.76	12.04 12.38	C	B
Stephanodiscus subtilis **		7.11 29.11	0 0	0 0	0 0	117.29 35.54	0	0 0	C	all others
Surirella angusta *		.89 1.66	0	.76 1.41	.45 1.21	5.24 1.48	0	1.05 1.21	C	A, BC
Synedra filiformis ** +		134.10 42.37	98.44	166.03 25.57	108.31 27.84	75.40 17.77	113.10	180.12 31.21	C_1	C
Synedra minuscula +		8.89 7.80	12.57	12.76 9.62	5.09 5.31	7.33 7.40	4.19	12.57 6.84	A_1	BC_1
Synedra ostenfeldii +		17.14 11.10	10.47	21.33 7.18	19.45 12.97	7.33 10.37	0	8.38 2.96	A_1	BC_1
Synedra ulna var. *chaseana* ** +		7.43 7.22	20.94	11.61 7.22	2.24 2.66	14.66 5.92	2.09	8.38 6.62	A	BC_1
Tabellaria fenestrata ** +		126.55 90.55	402.12	208.11 61.77	64.33 19.43	97.39 10.37	39.80	87.44 13.17	A	BC_1
Tabellaria flocculosa var. *linearis* ** +		51.34 41.46	148.70	73.49 45.79	27.08 15.98	6.28 2.96	38.79	76.45 17.23	A	C

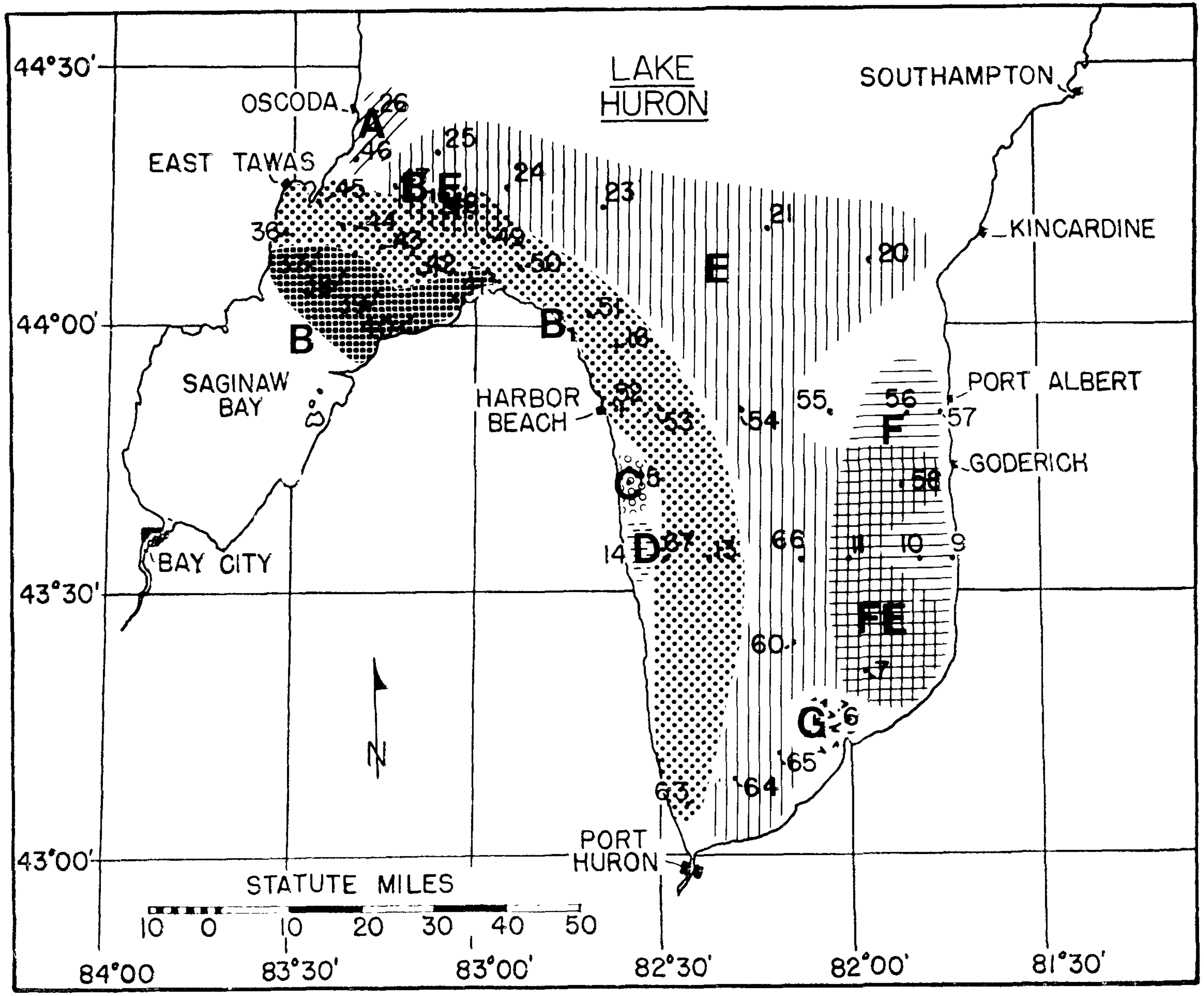


Figure 89. Cruise 3- June 4-8, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

TABLE 24. CRUISE 3 - JUNE 4-8, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 89) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5 M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Region:	Grand	A	B	B_1	C	D	E	B_1E	F	FE	G	Apparent Trend	
Species N =	43	2	5	14	1	1	11	1	4	3	1	High	others
Aphanizomenon flos-aquae *	.83 3.51	0 0	7.12 8.58	0 0	0	0	0 0	0	0 0	0 0	0	B	
Cryptomonas ovata ** +	9.79 9.82	28.27 25.18	24.30 4.34	8.23 5.48	10.47	25.13	3.05 2.54	4.19	6.28 6.23	4.19 3.63	16.76	A	E
Cyclotella ocellata ** +	31.42 17.55	36.65 13.33	20.94 11.47	35.01 14.75	35.61	79.59	38.08 17.44	31.42	8.38 3.42	23.74 5.27	12.57	D	F
Cyclotella stelligera ** +	36.43 21.95	24.09 10.37	16.76 11.38	38.45 18.94	20.94	50.27	57.12 20.86	29.32	11.52 4.99	35.61 6.28	14.66	E	F
Diatoma tenue var. pachycephala *	16.95 18.15	25.13 8.89	20.94 24.24	30.37 18.89	29.32	25.13	6.85 7.79	2.09	3.67 4.95	.70 1.21	0	B_1	G
Undetermined flagellate species	133.36 92.68	148.70 20.73	293.22 76.55	144.66 93.22	127.76	81.68	103.77 47.37	180.12	38.22 23.41	60.04 12.62	81.68	B	F
Fragilaria capucina ** +	195.31 280.80	173.83 130.32	851.58 133.76	228.89 170.25	31.42	184.31	9.71 30.84	113.10	21.99 27.38	0 0	64.93	B	FE

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for 5 m samples for respective cruise.

(continued)

TABLE 24 (continued)

Species	Region: N =	Grand 43	A 2	B 5	B_1 14	C 1	D 1	E 11	B_1E 1	F 4	FE 3	G 1	Apparent Trend High	others
Fragilaria crotonensis **		72.43 79.83	47.12 28.14	175.93 125.48	77.19 67.07	180.12	169.65	28.37 28.62	192.68	16.76 21.90	16.06 27.81	90.06	B_1E	FE
Fragilaria pinnata **		1.22 2.75	8.38 5.92	1.27 2.81	1.50 2.65	2.09	6.28	0 0	0	0 0	0 0	0	A	E, B_1E, F, FE, G
Fragilaria vaucheriae **		.58 1.32	1.05 1.48	.84 1.15	.30 .76	6.28	0	.38 .85	0	0 0	1.40 2.42	0	C	D, B_1E, F, G
Gloeocystis planctonica +		10.72 33.09	0 0	56.55 89.50	9.43 9.47	0	0	1.33 3.28	0	5.76 7.13	0 0	8.38	B	A, C, D, B_1E, FE
Undetermined green filament sp. #5 ** +		707.39 1175.1	636.70 133.29	3746.0 859.65	460.77 261.33	638.79	858.70	69.16 74.14	108.91	224.62 96.86	90.06 17.90	427.26	B	E
Melosira islandica ** +		17.05 23.28	56.55 2.96	2.93 6.56	10.62 15.47	83.78	16.76	10.66 13.26	0	35.61 35.75	10.47 9.60	64.93	C	B_1E
Nitzschia acicularis ** +		10.47 13.04	39.79 5.92	1.68 1.75	10.23 8.14	29.32	52.36	6.09 6.31	2.09	2.09 1.71	6.98 3.20	41.89	D	B
Nitzschia dissipata **		2.78 3.87	0 0	0 0	1.94 3.01	2.09	16.76	4.38 3.91	0	3.14 2.09	4.19 4.19	0	B_1	A, B, B_1E, G

(continued)

TABLE 24 (continued)

Species / Region: N =	Grand 43	A 2	B 5	B_1 14	C 1	D 1	E 11	B_1E 1	F 4	FE 3	G 1	Apparent Trend High	Apparent Trend low
Oscillatoria bornetii **	2.39 2.40	1.05 1.48	3.35 2.39	2.54 1.87	8.38	0	1.33 1.69	2.09	2.09 1.71	1.40 1.21	10.47	G	D
Oscillatoria retzii ** +	20.02 46.05	7.33 1.48	129.85 62.26	11.97 17.70	2.09	4.19	.57 1.35	14.66	0 0	0 0	2.09	B	F,FE
Rhodomonas minuta var. nannoplanctica +	9.40 7.16	8.38 8.89	9.22 6.39	7.18 5.91	8.38	2.09	11.61 5.88	2.09	7.85 7.33	13.26 11.54	29.32	G	D,B_1E
Rhizosolenia eriensis ** +	33.07 19.60	37.70 2.96	10.05 6.35	39.35 15.63	52.36	85.87	31.80 18.71	14.66	35.61 26.88	23.04 4.19	31.42	D	B
Rhizosolenia gracilis * +	84.80 44.93	121.47 32.58	20.53 13.36	76.89 42.24	117.29	144.51	110.43 37.20	85.87	79.59 52.01	90.76 26.52	71.21	D	B
Stephanodiscus binderanus **	8.04 17.27	26.18 37.02	37.28 27.16	3.44 7.33	35.61	0	0 0	0	5.76 11.52	0 0 0	0	B	D,E,B_1E, FE,G
Stephanodiscus hantzschii *	2.68 2.72	4.19 2.96	2.09 2.57	1.94 2.78	6.28	2.09	1.71 1.83	0	3.14 1.21	6.98 1.21	8.38	G	B_1E
Stephanodiscus minutus +	5.21 7.96	4.19 2.96	1.68 2.73	1.94 2.52	0	4.19	10.66 12.96	2.09	4.71 3.14	6.28 5.54	18.85	G	C
Stephanodiscus subtilis **	4.48 17.70	0 0	0 0	0 0	0	0	0 0	0	21.47 15.99	0 0	106.81	G	all others but F

(continued)

TABLE 24 (continued)

Species	Region: Grand N = 43	A 2	B 5	B_1 14	C 1	D 1	E 11	B_1E 1	F 4	FE 3	G 1	Apparent Trend High	 low
Synedra filiformis ** +	104.48 52.22	196.87 85.90	26.81 16.98	87.22 41.01	203.16	203.16	124.14 25.33	41.89	117.81 14.35	104.02 1.21	146.61	C,D	B
Synedra miniscula ** +	5.55 8.39	8.38 5.92	.84 1.15	4.34 5.23	12.57	50.27	4.00 2.88	2.09	3.14 3.63	5.59 1.21	18.85	D	B
Synedra ostenfeldii ** +	12.23 9.05	28.27 7.40	4.19 5.92	12.57 7.30	23.04	29.32	13.14 8.99	18.85	3.14 2.70	13.26 3.20	4.19	D	F
Tabellaria fenestrata ** +	156.11 105.08	196.87 112.55	187.24 73.85	233.82 90.49	234.57	324.63	66.45 52.08	33.51	84.82 25.96	58.64	270.18	D	B_1E
Tabellaria flocculosa *	1.41 3.59	0 0	0 0	.60 2.24	12.57	4.19	2.09 4.68	10.46	.52 1.05	0 0	0	C	A,B, FE,G
Tabellaria flocculosa var. *linearis* ** +	65.41 46.30	82.73 37.02	88.80 36.08	97.09 34.98	171.74	123.57	20.75 16.34	31.42	42.11 18.92	18.85 0	62.83	C	FE

During cruise 3 (Fig. 89; Table 24) the floristic pattern in southern Lake Huron was essentially similar to that found during cruise 2 but somewhat more complex. Stations within Region A were characterized by the presence of relatively high numbers of benthic taxa, such as Amphora ovalis var. pediculus, and Fragilaria pinnata, together with certain flagellate species such as Cryptomonas ovata and Chrysosphaerella longispina. Region B was characterized by relatively high abundance of species usually associated with eutrophic conditions such as Anabaena flos-aquae, A. subcylindrica, Aphanizomenon flos-aquae, Fragilaria capucina, Gloeocystis planctonica, and Mougeotia sp.. Region B1 was floristically similar, however it had a greater abundance of species such as Diatoma tenue var. pachycephala and Ulothrix sp.. Region C was characterized by relatively high abundance of certain benthic species such as Achnanthes minutissima together with some of the more eutrophic plankton dominants such as Melosira granulata and Oscillatoria bornetii. Immediately adjacent Region D had a markedly different flora which was dominated by eurytopic or oligotrophic species such as Asterionella formosa, Cyclotella ocellata, Rhizosolenia eriensis, Synedra filiformis, and Tabellaria fenestrata. At this time, offshore stations within region E were mainly characterized by the presence of populations of small diatoms such as Cyclotella stelligera and small flagellates such as Rhodomonas minuta var. nannoplanctica. The region labeled BE was apparently a mixing zone between the open Lake Huron and Saginaw Bay water masses, as it contains a mixture of the species found in Region B1 plus substantial quantities of species such as Crucigenia quadrata, Cyclotella comta, Cyclotella michiganiana, Dinobryon divergens, and Fragilaria crotonensis which were also found in Region E. Region F was defined primarily on negative characteristics and lacked species dominance patterns displayed by any of the other regions. The region labeled FE appeared to be a mixture of floristic associations found at nearshore stations along the Canadian shoreline and populations found in the open waters of Lake Huron. It was additionally characterized by relatively high abundance of Chrysosphaerella longispina. Station 6, labeled G on the map, was distinguished from adjacent stations by high abundance of some of the small Stephanodiscus species such as S. minutus and S. subtilis.

During cruise 4 (Fig. 90; Table 25), the influence of the Saginaw Bay water mass was apparently less extensive than it had been during the previous sampling period. The region labeled A contained a very high abundance of species associated with highly eutrophic conditions such as Anabaena flos-aquae, Aphanizomenon flos-aquae, Fragilaria capucina, Oscillatoria retzii, and Pediastrum boryanum. The region labeled A1 had a substantially similar flora but with a greater admixture of more mesotrophic taxa such as Anacystis thermalis. Region A2 was likewise similar to Regions A and A1 but had a greater abundance of more eurytopic diatom species such as Synedra ostenfeldii. Region B contained certain elements of the eutrophication-tolerant flora found in Region A such as Anabaena flos-aquae. These species however were present in low abundance and the flora of Region B was dominated by more eurytopic taxa such as Cyclotella stelligera, Synedra filiformis, and Tabellaria flocculosa var. linearis. Unlike Region B, Region C contained practically none of the species associated with the Saginaw Bay water mass, and the flora of this region was

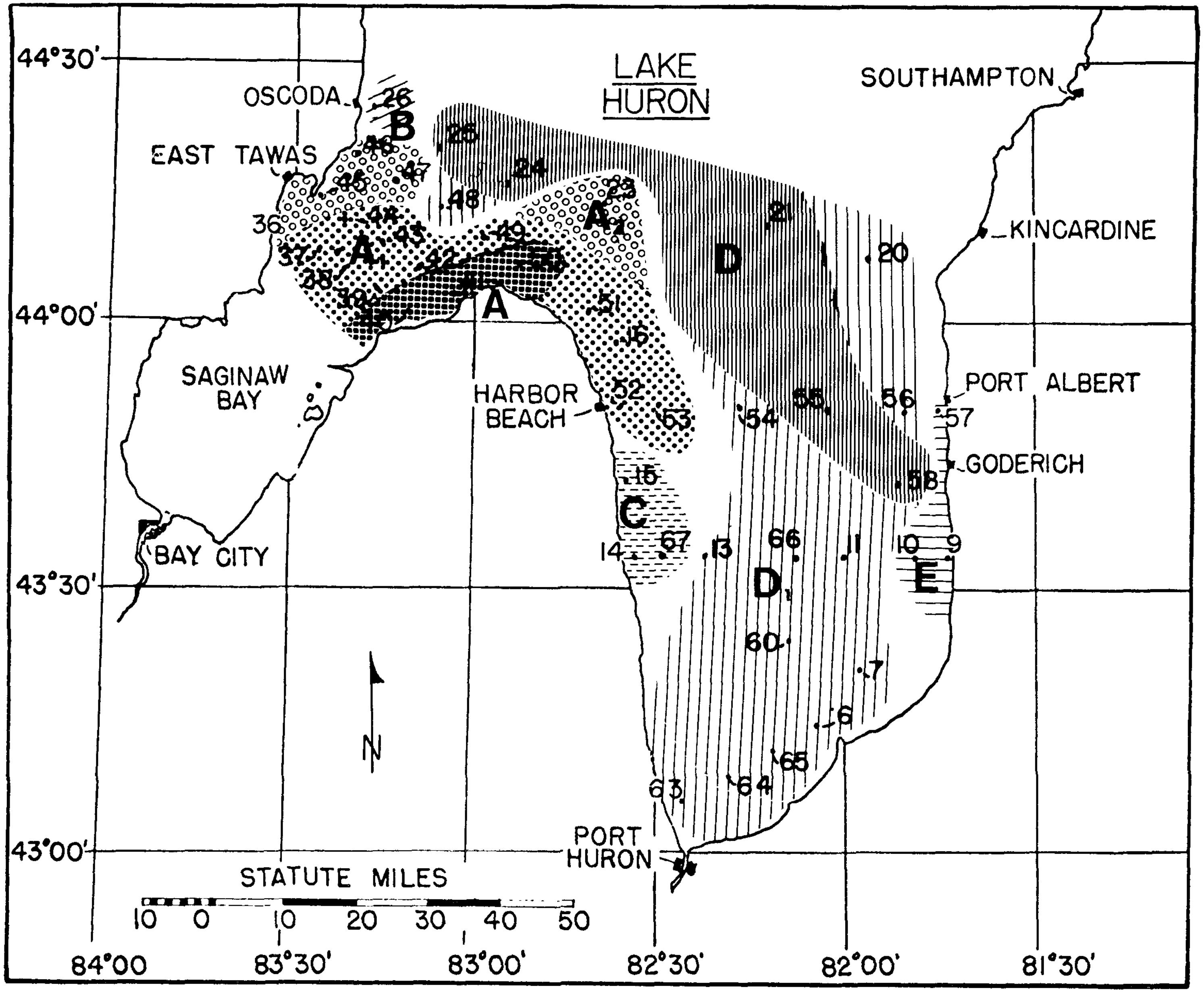


Figure 90. Cruise 4-June 17-21, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

TABLE 25. CRUISE 4 - JUNE 17-21, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 90) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Region:	Grand	A	A_1	A_2	B	C	D	D_1	E	Apparent Trend	
Species / N =	43	3	11	5	1	3	5	12	3	High	Low
Aphanizomenon flos-aquae *	1.32 5.58	13.26 17.81	1.33 4.42	.42 .94	0	0 0	0 0	0 0	0 0	A	B,C,D,D_1,E
Coelastrum microporum **	7.26 17.60	53.06 30.30	10.85 16.06	0 0	0	0 0	0 0	2.79 9.67	0 0	A	A_2,B,C,D,E
Cryptomonas ovata **	12.66 20.45	66.32 42.11	17.71 15.74	11.73 6.88	18.85	8.38 7.55	.84 1.15	2.62 2.38	4.19 3.63	A	D
Chrysosphaerella longispina *	.68 2.57	0 0	0 0	2.51 5.62	0	5.59 4.84	0 0	0 0	0 0	C	
Cyclotella ocellata ** +	41.60 23.96	7.68 5.27	27.61 17.77	51.52 15.15	60.74	37.70 22.17	65.76 25.51	55.50 12.96	11.87 8.46	D	A
Cyclotella stelligera ** +	32.93 22.17	2.79 3.20	11.61 12.40	31.42 9.37	58.64	36.30 2.42	49.85 11.32	55.85 7.16	11.87 8.72	B	A
Undetermined flagellate spp. **	16.90 15.30	6.98 1.21	9.71 8.40	36.02 26.72	41.89	8.38 4.19	11.31 1.87	22.69 12.91	7.68 4.36	B	A
Fragilaria capucina ** +	142.08 213.78	714.19 312.59	105.10 123.68	201.48 116.66	0	120.78 144.72	30.58 68.38	39.79 113.52	270.18 142.03	A_2	
Fragilaria construens var. minuta **	1.12 2.48	0 0	0 0	.84 1.15	8.38	0 0	4.19 4.44	1.05 2.09	.70 1.21	B	A,A_1,C

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for 5 m samples for respective cruise.

(continued)

TABLE 25 (continued)

Species	Region: N =	Grand 43	A 3	A_1 11	A_2 5	B 1	C 3	D 5	D_1 12	E 3	Apparent Trend High	Low
Fragilaria crotonensis ** +		215.09 378.74	1066.0 725.82	318.92 442.14	196.45 123.63	39.79	34.91 26.19	49.01 54.18	87.62 89.06	39.79 65.33	A	C
Gloeocystis planctonica ** +		9.70 23.77	84.47 46.71	7.62 7.33	1.68 2.29	0	6.98 7.36	5.03 7.49	1.40 2.87	2.79 4.84	A	B
Gomphosphaeria lacustris **		89.09 258.10	823.10 431.25	0 0	62.83 140.50	0 0	104.72 181.38	0 0	0 0	244.35 423.22	A	A_1 ,B,D,D_1
Undetermined green filament sp. #5 ** +		199.84 312.07	1008.1 318.85	161.65 199.99	496.79 313.35	324.63	154.29 74.12	0 0	43.28 53.06	0 0	A	D,E
Melosira islandica **		10.81 29.23	1.40 2.42	0 0	11.73 11.34	18.85	18.15 13.47	0 0	8.03 13.57	77.49 92.65	E	A_1,D
Mougeotia sp. #1 **		5.99 15.06	50.96 26.52	2.86 4.98	14.66 10.68	0	0 0	0 0	0 0	0 0	A	
Nitzschia acicularis ** +		4.04 7.36	.70 1.21	.38 .85	7.96 8.17	39.79	11.87 1.21	.84 1.87	3.32 4.23	2.80 1.21	B	A_1
Ochromonas sp. #1 +		6.96 7.82	7.68 3.20	9.14 11.60	3.35 4.59	4.19	6.28 5.54	0 0	8.20 7.28	11.87 2.42	E	D
Oocystis spp. ** +		14.76 24.70	92.15 9.13	18.85 13.70	21.36 13.03	0	0 0	2.93 3.50	2.44 6.30	0 0	A	B, C,E
Oscillatoria bornetii **		2.58 3.09	3.49 2.42	.76 1.06	5.44 4.08	6.28	2.79 3.20	.84 1.87	1.92 2.75	7.68 1.21	E	A_1

(continued)

TABLE 25 (continued)

Species	Region: N =	Grand 43	A 3	A_1 11	A_2 5	B 1	C 3	D 5	D_1 12	E 3	Apparent Trend High	Apparent Trend Low
Oscillatoria retzii ** +		17.53	131.25	20.37	23.46	14.66	0	0	.35	0	A	C,D,D_1,E
		43.79	126.68	13.18	13.44		0	0	.82	0		
Rhodomonas minuta var. nannoplanctica +		14.71	12.57	9.71	15.08	2.09	2.79	25.13	18.33	18.85	D	B
		12.27	7.55	6.30	10.51		1.21	17.40	14.10	13.08		
Rhizosolenia eriensis ** +		36.82	0	7.62	19.69	37.70	95.64	31.00	57.07	78.89	C	A
		32.53	0	9.97	11.90		18.06	14.84	19.30	27.89		
Rhizosolenia gracilis ** +		66.63	1.40	18.85	78.33	106.81	76.79	59.48	112.40	92.85	D_1	A
		47.11	2.42	24.19	35.59		29.72	13.78	30.43	28.59		
Stephanodiscus hantzschii **		.54	4.89	.19	.42	0	.70	.42	0	0	A	B,D_1,E
		1.78	5.27	.63	.94		1.21	.94	0	0		
Stephanodiscus minutus ** +		5.16	9.08	1.33	3.35	2.09	5.59	2.93	4.01	27.23	E	A_1
		7.29	2.42	3.28	4.82		1.21	3.50	4.51	2.09		
Stephanodiscus subtilis ** +		2.05	1.40	0	0	0	0	0	.17	27.23	E	
		8.93	1.21	0	0		0	0	.60	25.39		
Surirella angusta **		.15	0	0	0	2.09	1.40	0	0	0	B	
		.71	0	0	0		2.42	0	0	0		
Synedra filiformis ** +		47.78	1.40	5.33	40.63	119.38	45.38	55.29	86.05	74.70	B	A
		39.96	1.21	8.29	18.65		11.91	20.61	31.47	14.26		

(continued)

TABLE 25 (continued)

Species	Region: N =	Grand 43	A 3	A_1 11	A_2 5	B 1	C 3	D 5	D_1 12	E 3	Apparent Trend High	Apparent Trend Low
Synedra ostenfeldii ** +		9.98 10.33	0 0	3.24 5.08	23.88 11.53	18.85	12.57 7.26	9.22 5.66	13.96 10.31	1.40 2.42	A_2	A
Synedra ulna var. *chaseana* **		2.92 3.77	0 0	.38 .85	4.61 2.29	0	11.87 5.27	1.68 1.75	3.49 2.87	4.19 4.19	C	A,B
Tabellaria fenestrata ** +		98.68 60.20	44.68 16.93	68.73 45.47	111.42 38.29	180.12	238.06 34.05	64.09 16.73	94.07 41.00	150.80 47.21	C	A
Tabellaria flocculosa var. *linearis* ** +		58.25 39.88	64.23 23.54	60.55 27.17	76.24 24.00	115.19	93.55 68.14	27.23 8.38	27.40 14.82	134.74 27.25	E	D

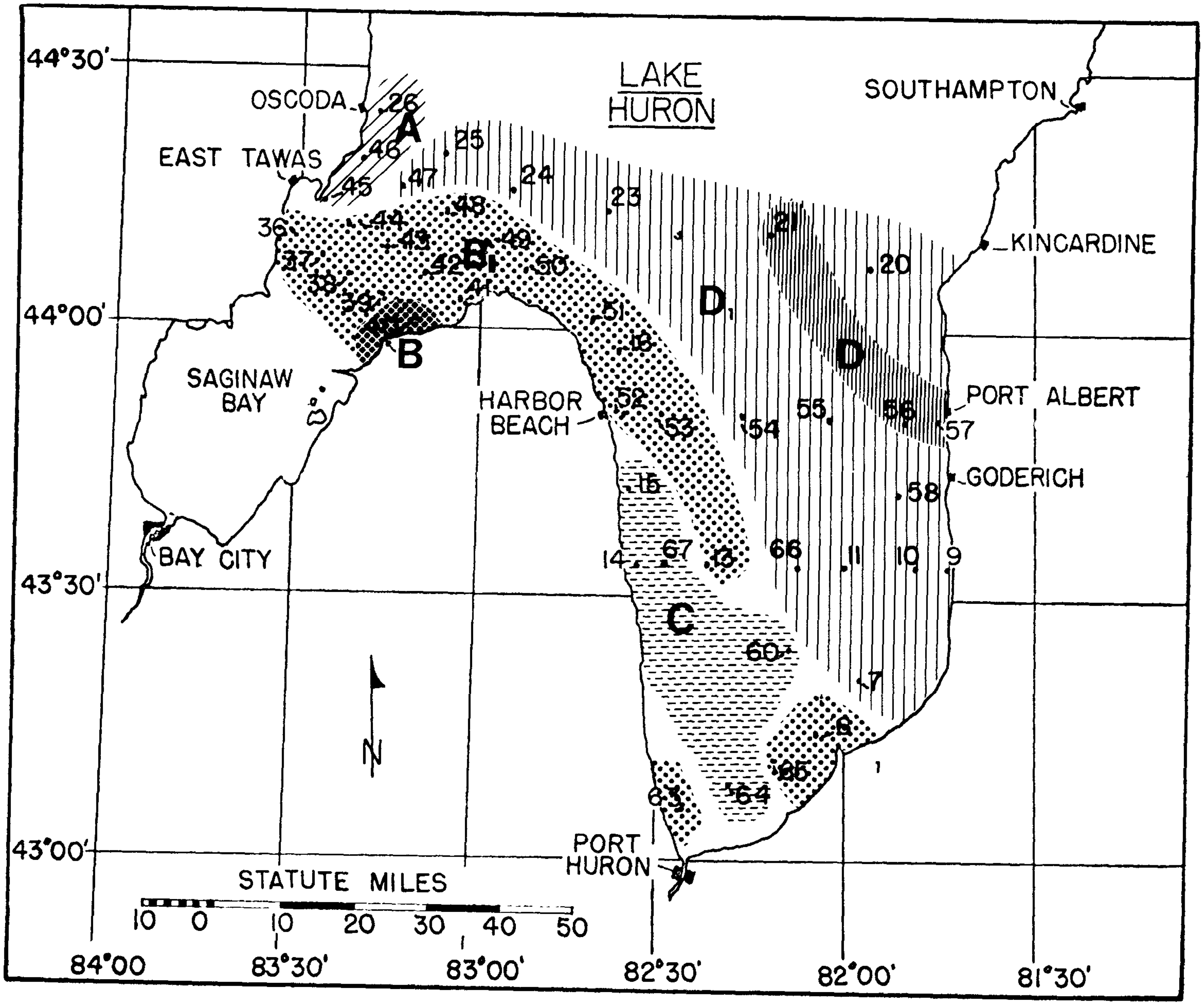


Figure 91. Cruise 5-July 17-22, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

TABLE 26. CRUISE 5 - JULY 17-22, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 91) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5 M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Species	Region:	Grand	A	B	B_1	C	D	D_1	Apparent Trend	
	N =	44	3	1	19	5	3	13	High	Low
Anabaena subcylindrica ** +		8.62	0	211.53	8.82	0	0	0	B	A,C,D,D_1
		35.57	0		25.21	0	0	0		
Achnanthes minutissima **		.38	4.19	4.19	0	0	0	0	A,B	B_1,C,D,D_1
		1.71	5.54		0	0	0	0		
Ankistrodesmus sp. #3 *		4.14	3.49	6.28	2.65	5.84	9.08	4.51	D	B_1
		3.18	3.20		2.30	2.29	3.20	3.40		
Anacystis cyanea **		19.99	0	837.76	2.20	0	0	0	B	A,C,D,D_1
		126.31	0		9.61	0	0	0		
Aphanizomenon flos-aquae **		5.95	0	157.08	5.51	0	0	0	B	A,C,D,D_1
		24.81	0		12.40	0	0	0		
Chodatella ciliata ** +		3.14	0	39.79	4.41	2.51	0	.16	B	A,D
		6.74	0		4.63	1.75	0	.58		
Cyclotella comta ** +		4.52	20.25	2.09	1.76	2.93	3.50	5.96	A	B_1
		5.82	8.46		2.24	2.39	4.36	4.35		
Cyclotella michiganiana ** +		33.70	23.74	23.04	38.14	96.76	2.79	13.21	C	D
		31.53	7.36		22.16	27.12	4.84	12.28		
Cyclotella ocellata ** +		18.47	13.26	6.28	7.28	6.28	62.13	31.58	D	B,C
		19.48	4.36		6.30	5.13	27.33	14.87		
Cyclotella sp. #5 **		7.66	4.19	0	.88	.42	42.59	13.69	D	B
		12.66	7.26		1.61	.94	3.20	10.63		
Cyclotella stelligera ** +		146.04	92.85	6.28	67.90	62.83	190.59	304.98	D_1	B
		154.52	27.89		88.48	17.21	68.92	173.32		
Fragilaria pinnata *		1.00	9.77	0	.45	.84	.70	0	A	B,D_1
		4.46	16.93		1.12	1.15	1.21	0		

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for respective cruise.

(continued)

TABLE 26 (continued)

Species	Region: N =	Grand 44	A 3	B 1	B_1 19	C 5	D 3	D_1 13	Apparent Trend High	Low
Fragilaria pinnata var. lancettula **		.29	2.79	0	.22	0	0	0	A	B,C,D,D_1
		1.07	2.42		.96	0	0	0		
Gloeocystis planctonica ** +		27.23	19.55	159.17	32.74	42.31	1.40	10.96	B	D
		33.32	15.72		33.07	21.38	2.42	9.06		
Undetermined green filament sp. #5 ** +		1176.0	0	35309.0	860.91	0	10.74	3.83	B	A,C
		5436.4	0		1984.0	0	18.14	12.20		
Melosira granulata *		.29	0	0	0	0	4.19	0	D	all others
		1.89	0		0	0	7.26	0		
Mallomonas pseudocoronata **		2.28	2.09	2.09	2.20	8.38	0	.64	C	D
		3.22	0		2.56	4.19	0	1.32		
Mougeotia sp. #1 **		4.71	0	39.79	8.60	.84	0	0	B	A,D,D_1
		10.20	0		11.63	1.15	0	0		
Nitzschia acicularis **		.43	.70	0	.22	0	3.49	.16	D	B,C
		1.40	1.21		.66	0	4.36	.58		
Nitzschia dissipata **		.33	0	0	.11	.42	3.49	0	D	A,B,D_1
		1.35	0		.48	.94	4.36	0		
Oocystis spp. *		16.71	3.49	79.59	23.26	16.34	3.49	8.54	B	A,D
		20.74	6.05		22.50	8.17	4.36	13.91		
Oscillatoria bornetii *		.05	.70	0	0	0	0	0	A	all others
		.32	1.21		0	0	0	0		
Oscillatoria retzii **		5.00	0	90.06	6.83	0	0	0	B	A,C,D,D_1
		16.59	0		14.77	0	0	0		
Rhizosolenia eriensis ** +		2.81	0	0	.55	0	27.23	2.42	D	A,B,C
		7.99	0		1.54	0	18.26	2.54		
Rhizosolenia gracilis ** +		3.62	1.40	0	2.54	1.26	17.45	3.71	D	B
		5.33	2.42		2.27	1.87	8.72	5.00		

(continued)

TABLE 26 (continued)

Species	Region: N =	Grand 44	A 3	B 1	B_1 19	C 5	D 3	D_1 13	Apparent Trend High	Apparent Trend Low
Scenedesmus bijuga **		2.33 5.91	4.89 4.36	29.32	3.09 5.73	0 0	0 C	0 0	B	D,D,D_1
Stephanodiscus alpinus **		.10 44	0 0	0	0 0	0 0	1.40 1.21	0 0	D	all others
Stephanodiscus binderanus **		.38 1.98	0 0	12.57	.22 .96	0 0	C 0	0 0	B	A,C,D,D_1
Stephanodiscus hantzschii **		.81 2.93	0 0	2.09	.66 1.22	0 0	6.98 10.33	0 0	D	A,C,D_1
Stephanodiscus subtilis **		1.38 8.22	0 0	0	0 0	0 0	19.55 30.30	.16 .58	D	A,B,B_1,C
Synedra filiformis **		2.52 4.08	7.68 5.27	12.57	.77 1.25	.84 1.87	6.98 4.36	2.74 4.71	B	B_1
Synedra ostenfeldii **		.48 1.18	1.40 1.21	2.09	.11 .48	0 0	3.49 2.42	.16 .58	D	C
Synedra ulna var. *chaseana* *		.05 .32	.70 1.21	0	0 0	0 0	0 0	0 0	A	all others
Tabellaria fenestrata **		7.52 12.11	42.59 3.20	4.19	6.17 8.95	.84 1.87	12.57 11.66	3.06 4.65	A	C
Tetraedron minimum **		2.24 4.22	1.40 2.42	18.85	3.42 4.48	1.26 1.87	.70 1.21	.16 .58	B	D_1

dominated by species such as Chrysosphaerella longispina, Rhizosolenia eriensis, Synedra ulna var. chaseana, and Tabellaria fenestrata, none of which is particularly tolerant of eutrophied conditions. Regions D and D1 were characterized by low population densities and assemblages of species usually intolerant of eutrophic conditions. Some of the characteristic populations in Region D were species such as Crucigenia quadrata, Cyclotella ocellata, Cyclotella stelligera, Dinobryon divergens, and Rhodomonas minuta var. nannoplanctica. Region D1 was distinguished from Region D primarily by the greater abundance of species such as Anacystis incerta, Cyclotella comensis, and Rhizosolenia gracilis. As in the previous sampling period, during this cruise a series of stations along the Canadian coastline labeled E in the diagram had a substantially different flora than the rest of the lake. Diatoms were particularly abundant, and the flora at these stations contained both significant quantities of primarily benthic taxa such as Achnanthes minutissima and Amphora ovalis var. pediculus, as well as euplanktonic species tolerant of elevated nutrient levels such as Melosira islandica, Stephanodiscus minutus, and S. subtilis.

During cruise 5 (Fig. 91, Table 26), a number of stations along the north Michigan coast labeled A in the diagram had a diatom dominated assemblage containing primarily eurytopic species such as Asterionella formosa, Cyclotella comta, Fragilaria crotonensis, and Tabellaria fenestrata, together with a number of species having more eutrophic affinities such as Fragilaria capucina, and usually benthic taxa such as Fragilaria pinnata. The hypereutrophic assemblage characteristic of Saginaw Bay dominated Region B where species such as Anabaena subcylindrica, Anacystis cyanea, and Aphanizomenon flos-aquae were particularly abundant. Certain elements of this flora were also found in the region labeled B1, but this region also contained less eutrophication-tolerant taxa such as Anabaena flos-aquae, Crucigenia quadrata, and Dinobryon divergens. Region C likewise had certain affinities to Region B1 since it contained species in common such as Chodatella ciliata and Dinobryon divergens, but the flora of this region was dominated more by typical offshore summer forms such as Anacystis thermalis and Cyclotella michiganiana. Stations within the region labeled D appeared to reflect the influence of some nutrient enrichment, possibly resulting either from upwelling or shoreline nutrient discharge, since their floras contained both some of the typical offshore phytoplankton dominants and species such as Melosira granulata, Stephanodiscus minutus and S. subtilis, which generally occur under more enriched conditions. The region labeled D1 contained a typical offshore assemblage dominated by species such as Cyclotella stelligera and Rhodomonas minuta var. nannoplanctica.

Unlike the other cruises, during cruise 6 (Fig. 92, Table 27) the immediate influence of Saginaw Bay appeared to extend northward. The flora of Region A was dominated by blue-green algae such as Anabaena subcylindrica, Anacystis cyanea and Aphanizomenon flos-aquae, characteristic of hypereutrophic conditions. This influence extended into Region A1 with the assemblages at these stations containing more species with benthic affinities, and eurytopic taxa such as Asterionella formosa and Chrysosphaerella longispina. A large sector of the lake labelled Region B contained an unusual assemblage dominated by high abundance of Cyclotella comensis, but also containing certain species

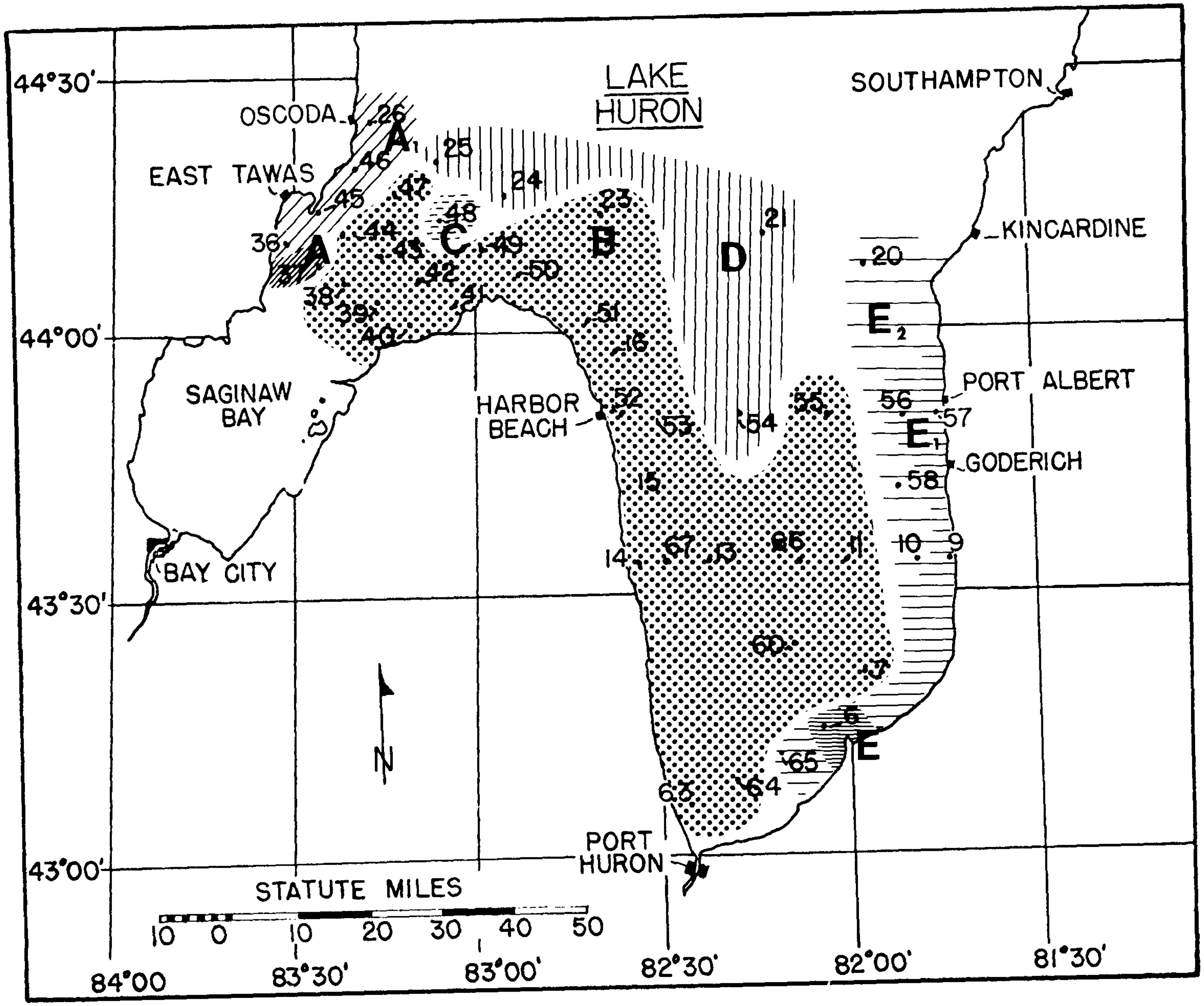


Figure 92. Cruise 6-August 26-31, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

TABLE 27. CRUISE 6 - AUGUST 26-31, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 92) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5 M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Region:	Grand	A	A_1	B	C	D	E	E_1	E_2	Apparent Trend	
Species N =	44	1	4	26	1	4	1	4	3	High	Low
Anabaena flos-aquae ** +	60.36 283.23	94.25	68.59 48.53	12.41 25.74	1885.0	5.24 6.05	0	11.00 12.73	4.89 8.46	C	E
Anabaena subcylindrica ** +	7.28 25.71	161.27	31.94 11.26	1.21 3.14	0	0 0	0	0 0	0 0	A	D,D,E,E_1, E_2
Ankistrodesmus sp. #3 +	5.14 6.02	2.09	7.85 7.33	3.71 4.82	4.19	11.52 12.51	4.19	4.19 2.96	8.38 3.63	D	A
Asterionella formosa **	9.90 16.94	14.66	47.65 32.78	6.20 9.28	0	4.19 5.92	18.85	5.24 7.74	4.19 7.26	E	C
Anacystis cyanea **	49.89 321.97	2136.3	14.66 29.32	0 0	0	0 0	0	0 0	0 0	A	B,C,D,E, E_1, E_2
Anacystis thermalis ** +	25.56 39.48	113.10	23.04 22.82	22.88 32.65	190.59	13.61 9.29	0	13.61 14.26	8.38 8.38	C	E
Aphanizomenon flos-aquae **	65.93 317.20	2065.1	186.92 191.57	3.83 11.19	0	0 0	0	0 0	0 0	A	C,D,E, E_1,E_2

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for 5 m samples for respective cruise.

(continued)

TABLE 27 (continued)

Species	Region: Grand	A	A_1	B	C	D	E	E_1	E_2	Apparent Trend	
	N = 44	1	4	26	1	4	1	4	3	High	Low
Cosmarium depressum **	.33 1.35	8.38	.52 1.05	.08 .41	0	.52 1.05	0	0 0	0 0	A	C,E,E_1, E_2
Crucigenia quadrata ** +	34.22 37.69	0	33.51 27.36	24.33 27.84	58.64	114.14 40.67	0	25.13 26.49	41.19 20.98	D	A,E
Cyclotella comensis * +	481.00 451.36	0	42.41 54.36	701.54 454.92	90.06	114.14 75.56	230.38	411.02 180.93	111.00 78.84	B	A
Cyclotella comta ** +	10.52 6.05	0	17.80 2.09	8.87 4.39	12.57	9.42 2.09	31.42	8.38 0	16.06 7.36	E	A
Cyclotella michiganiana ** +	40.56 32.46	12.57	47.12 17.98	28.84 15.05	31.42	16.23 8.95	64.93	126.71 11.91	55.15 7.36	E_1	A
Cyclotella ocellata ** +	7.62 25.92	0	15.18 15.52	2.26 3.74	0	0 0	169.65	11.00 3.58	.70 1.21	E	A,C,D
Cyclotella sp. #5 **	.76 1.87	0	1.57 2.01	.56 1.62	0	0 0	8.38	1.05 1.21	0 0	E	A,C,D,E_2
Cyclotella stelligera ** +	88.20 92.14	25.13	104.72 48.40	47.69 32.81	87.97	17.80 13.95	345.57	292.69 46.50	173.83 22.17	E	A
Undetermined flagellate spp. **	49.41 24.73	121.47	58.12 17.13	43.42 19.96	50.27	62.83 13.79	25.13	26.70 9.58	85.87 20.20	A	E

(continued)

TABLE 27 (continued)

Species / Region: N =	Grand 44	A 1	A_1 4	B 26	C 1	D 4	E 1	E_1 4	E_2 3	Apparent Trend High	Apparent Trend Low
Gloeocystis planctonica **	211.20 252.31	58.64	150.80 35.67	163.28 145.66	192.68	875.46 210.02	2.09	30.89 32.87	188.50 121.10	D	E
Gomphosphaeria lacustris **	37.13 109.49	575.96	0 0	17.72 37.79	157.08	104.72 209.44	0	5.24 10.47	0 0	A	A_1,E,E_2
Undetermined green fimilment sp. #5 ** +	504.80 1975.5	11921.0	2227.9 2349.5	53.00 129.01	0	0 0	0	0 0	0 0	A	C,D,E,E_1, E_2
Mougeotia sp. #1 **	7.43 16.35	31.42	50.27 18.66	3.46 7.63	0	1.05 2.09	0	0 0	0 0	A_1	C,E,E_1, E_2
Nitzschia dissipata **	1.52 4.53	0	0 0	.64 2.89	0	0 0	20.94	7.33 6.05	0 0	E	A,C,D,E_2
Oocystis spp. ** +	19.61 21.73	115.19	25.66 19.45	16.35 13.89	48.17	35.61 15.67	0	.52 1.05	9.08 4.36	A	E
Oscillatoria retzii **	11.95 37.50	98.44	85.87 89.89	3.22 11.05	0	0 0	0	0 0	0 0	A	C,D,E, E_1,E_2
Oscillatoria sp. #4 *	.81 2.22	0	5.24 4.01	.56 1.73	0	0 0	0	0 0	0 0	A_1	A,C,D, E,E_1,E_2

(continued)

TABLE 27 (continued)

Species / Region:	Grand	A	A_1	B	C	D	E	E_1	E_2	Apparent Trend High	Apparent Trend Low
N =	44	1	4	26	1	4	1	4	3		
Phacotus lenticularis **	.86 4.77	31.42	1.57 2.01	0 0	0	0 0	0	0 0	0 0	A	B,C,D,E, E_1,E_2
Rhodomonas minuta var. *nannoplanctonica* **+	6.09 6.85	0	3.67 2.01	5.16 4.96	0	18.33 10.17	2.09	1.05 1.21	13.26 6.40	D	A,C
Rhizosolenia eriensis **	1.86 4.66	2.09	6.28 7.45	.89 2.66	0	0 0	23.04	2.09 1.71	0 0	E	C,D,E_2
Scenedesmus bijuga **	2.19 5.60	25.13	2.09 4.19	1.77 5.05	0	4.19 4.84	0	0 0	0 0	A	C,E,E_1, E_2
Stephanodiscus subtilis **	2.71 12.55	0	0 0	0 0	0	0 0	2.09	29.32 34.92	0 0	E_1	all others except E
Synedra filiformis **	8.90 24.63	134.04	45.03 28.95	2.09 4.88	0	0 0	0	5.76 6.48	0 0	A	C,D,E_1, E_2
Synedra ostenfeldii **	.52 1.76	10.47	2.09 1.71	.16 .57	0	0 0	0	0 0	0 0	A	C,D,E,E_1, E_2
Tabellaria fenestrata **	4.09 16.25	0	10.47 12.57	.81 2.14	0	.52 1.05	104.72	2.62 3.96	0 0	E	A,C,E_2

(continued)

TABLE 27 (continued)

Species	Region: N =	Grand 44	A 1	A_1 4	B 26	C 1	D 4	E 1	E_1 4	E_2 3	Apparent Trend High	Low
Tabellaria flocculosa var. *linearis* **		4.14	0	7.33	2.34	0	0	85.87	1.57	0	E	A,C,D, E_2
		14.44		8.46	8.32		0		3.14	0		

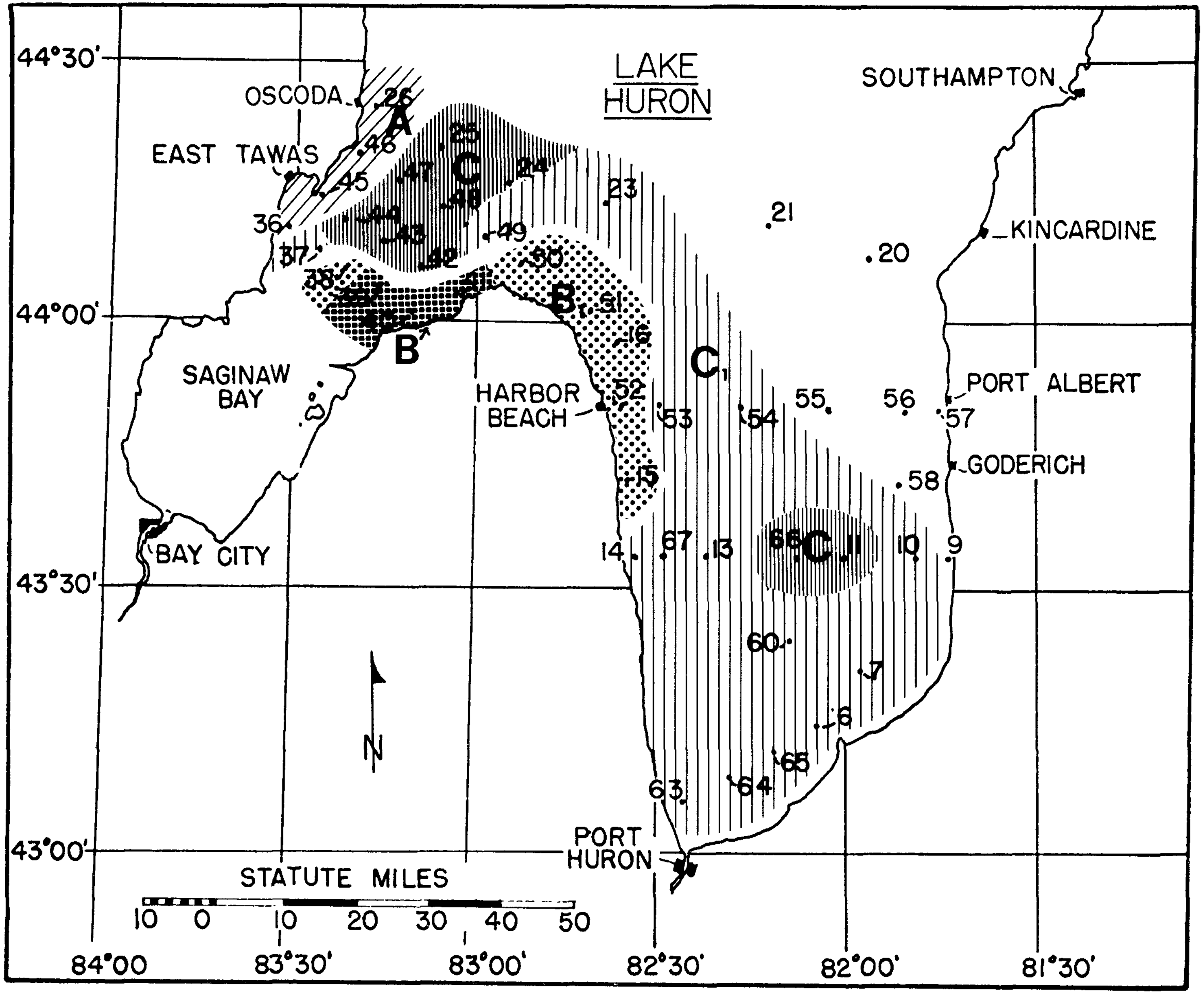


Figure 93. Cruise 7-October 8-12, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

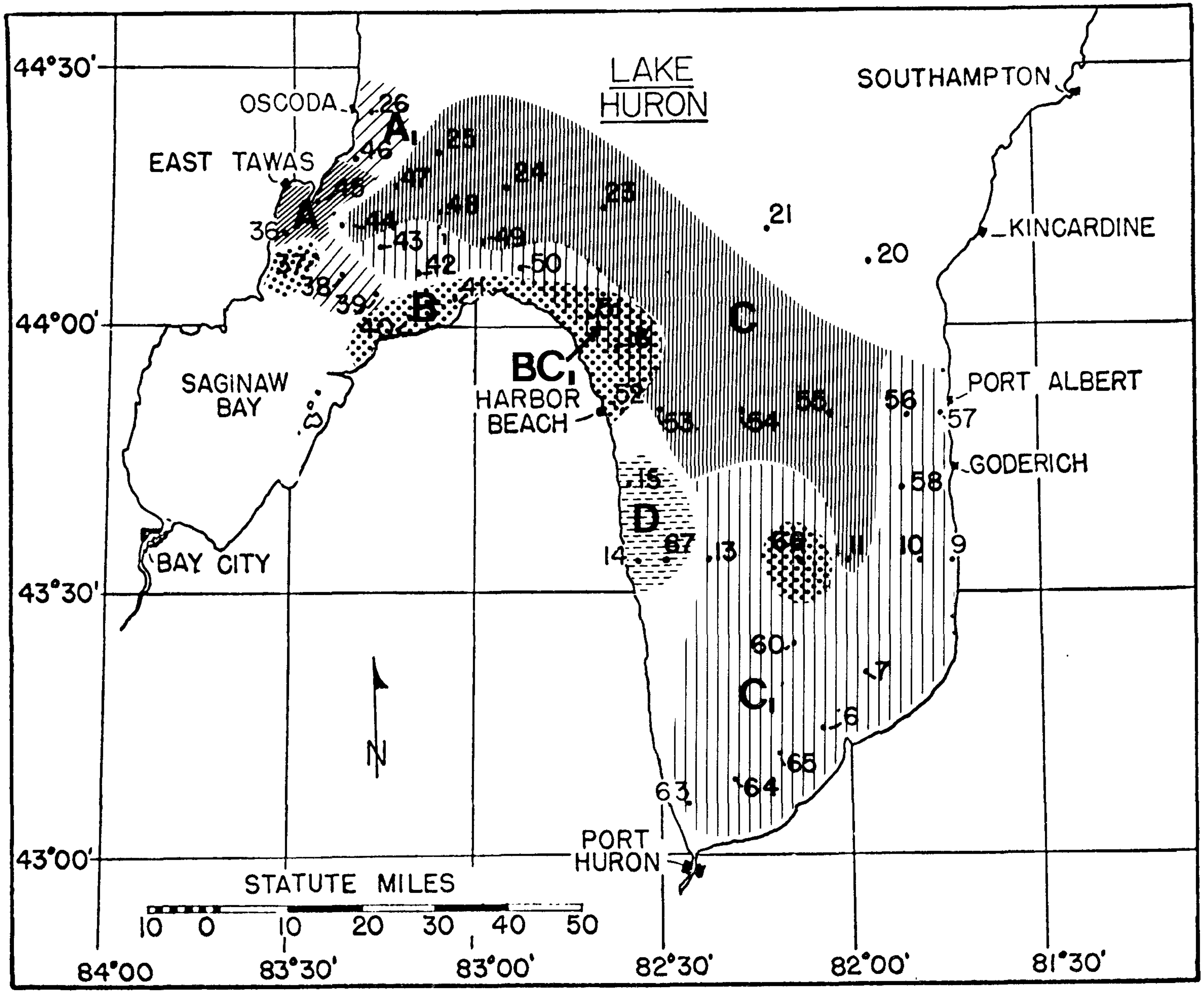


Figure 94. Cruise 8-November 10-14, 1974. Phytoplankton associations as determined by dimensional ordination and principal components analysis.

TABLE 28. CRUISE 7 - OCTOBER 8-12, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 93) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5 M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Species	Region:	Grand	A	B	B_1	C	C_1	Apparent Trend	
	N =	37	4	3	6	9	15	High	Low
Amphora ovalis var. pediculus ** +		2.83	11.00	1.40	5.24	.23	1.54	A	C
		5.11	10.03	2.42	5.74	.70	2.16		
Anacystis incerta * +		458.22	253.95	942.48	1071.6	214.09	316.95	B_1	C
		594.38	190.88	704.43	984.45	230.03	412.65		
Anacystis thermalis +		46.02	59.69	51.66	42.94	28.16	53.20	A	C
		24.89	22.26	13.47	30.43	16.40	25.53		
Aphanizomenon flos-aquae ** +		377.78	118.33	2688.5	807.74	12.10	32.25	B	C
		774.92	151.85	230.90	440.07	22.36	75.17		
Coelastrum microporum **		3.96	4.19	39.10	0	1.40	0	B	B_1, C_1
		11.38	8.38	10.54	0	4.19	0		
Cryptomonas ovata **		5.38	11.00	9.08	6.28	3.03	4.19	A	C
		3.07	6.92	2.42	2.29	2.59	3.07		
Coscinodiscus subsalsa **		.91	0	9.77	.70	0	0	B	A,C,C_1
		3.14	0	6.40	1.71	0	0		
Chrysococcus dokidophorus ** +		13.19	19.37	8.38	6.28	22.34	9.77	C	B_1
		8.51	2.64	8.38	4.19	7.62	5.69		
Cyclotella comensis ** +		373.71	724.66	601.09	264.94	218.28	371.41	A	C
		250.51	421.70	290.26	153.42	116.85	167.76		

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = mean value for 5 m samples for respective cruise.

(continued)

TABLE 28 (continued)

Species / Region: N =	Grand 37	A 4	B 3	B_1 6	C 9	C_1 15	Apparent Trend High	Apparent Trend Low
Cyclotella michiganiana ** +	17.49	40.32	11.87	12.92	20.25	12.71	A	B
	13.30	12.84	1.21	5.68	14.32	9.84		
Cyclotella ocellata ** +	17.60	26.70	6.98	9.08	33.28	11.31	C	B
	13.83	12.95	2.42	5.41	13.06	8.22		
Cyclotella operculata * +	13.76	28.27	19.55	16.06	11.40	9.22	A	C_1
	10.35	8.80	10.54	8.65	8.89	8.70		
Cyclotella stelligera +	12.45	16.76	10.47	11.87	10.24	13.26	A	C
	7.44	5.41	6.28	7.09	4.74	9.46		
Fragilaria capucina **	33.96	0	232.48	86.92	0	2.51	B	A, C
	95.64	0	192.24	133.89	0	7.72		
Fragilaria pinnata ** +	13.98	51.84	38.40	12.22	1.86	6.98	A	C
	23.53	45.55	32.20	10.38	4.25	9.84		
Gloeocystis planctonica ** +	30.85	71.21	88.66	28.97	15.13	18.71	B	C
	36.62	66.05	51.49	26.11	8.87	18.61		
Undetermined green filament sp. #5 ** +	1150.0	544.02	7297.6	2626.7	30.02	163.50	B	C
	2120.6	652.18	1306.4	678.92	28.27	276.75		
Melosira granulata * +	13.76	22.52	35.61	26.53	.47	9.91	B	C
	15.46	21.45	25.48	32.89	1.40	15.46		
Melosira granulata alpha status **	1.98	.52	21.64	1.05	0	0	B	C,C_1
	7.69	1.05	20.34	2.57	0	0		
Mallomonas pseudocoronata **	.57	1.57	2.79	0	.47	.14	B	B_1
	1.06	1.05	1.21	0	.92	.54		
Mougeotia sp. #1 ** +	30.28	22.52	122.87	88.31	1.40	7.96	B	C
	46.59	31.64	26.69	46.10	2.77	11.56		

(continued)

TABLE 28 (continued)

Species / Region: N =	Grand 37	A 4	B 3	B_1 6	C 9	C_1 15	Apparent Trend High	Apparent Trend Low
Nitzschia acicularis ** +	4.75	4.71	16.76	5.86	1.40	4.05	B	C
	6.22	3.58	13.08	6.71	2.09	3.83		
Oocystis spp. * +	37.76	25.66	74.70	36.65	23.74	42.45	B	C
	24.97	21.86	19.80	15.99	13.00	27.78		
Oscillatoria bornetii +	4.47	4.71	2.09	1.40	1.63	7.82	C_1	B_1
	11.73	3.96	2.01	1.71	2.29	17.97		
Oscillatoria retzii ** +	4.25	2.09	27.23	7.33	.70	1.12	B	C
	10.36	2.96	25.13	10.82	2.09	1.56		
Oscillatoria sp. #4 ** +	5.32	6.28	27.23	11.52	.70	.98	B	C
	11.34	9.82	27.39	11.14	1.48	1.92		
Phacotus lenticularis *	.06	0	.70	0	0	0	B	all others
	.34	0	1.21	0	0	0		
Rhodomonas minuta var. nannoplanctonica +	6.51	6.81	2.79	6.98	8.84	5.59	C	B
	8.35	8.95	3.20	9.15	9.64	8.40		
Rhizosolenia eriensis *	2.83	7.33	7.68	1.05	3.72	.84	B	C_1
	4.64	9.44	4.36	1.75	4.29	2.21		
Rhizosolenia gracilis *	1.42	3.14	4.19	1.75	.93	.56	B	C_1
	2.10	3.63	2.09	2.45	1.10	1.24		
Scenedesmus bijuga **	3.17	1.05	19.55	4.89	0	1.68	B	C
	6.28	2.09	6.40	6.71	0	3.09		
Scenedesmus quadricauda **	9.17	2.09	73.30	11.52	0	2.79	B	C
	21.72	4.19	33.71	8.35	0	5.17		
Stephanodiscus binderanus *	1.64	0	2.09	7.33	0	.70	B_1	A, C
	4.50	0	3.63	8.46	0	2.70		

(continued)

TABLE 28 (continued)

Species	Region: Grand	A	B	B_1	C	C_1	Apparent Trend	
N =	37	4	3	6	9	15	High	Low
Stephanodiscus hantzschii *	1.42	.52	4.89	1.40	.47	1.54	B	C
	2.10	1.05	4.84	1.08	1.40	1.67		
Synedra filiformis ** +	17.83	28.80	101.93	27.23	2.79	3.35	B	C
	30.45	12.14	42.79	18.50	2.09	2.83		
Synedra ostenfeldii *	.96	3.14	2.09	1.75	.47	.14	A	C_1
	1.82	2.09	2.09	2.78	1.40	.54		
Schizothrix calcicola **	2.04	.52	15.36	2.79	0	.70	B	C
	5.53	1.05	13.47	4.12	0	1.71		

such as Pediastrum boryanum generally associated with eutrophied conditions in the Great Lakes. Region C had certain similarities to Regions A1 and B but contained a greater abundance of mesotrophic blue-green species such as Anabaena flos-aquae and Anacystis thermalis. Region D also contained a flora characteristic of silica depletion under midsummer conditions, but with a greater abundance of species such as Anacystis incerta, Crucigenia quadrata, and Rhodomonas minuta var. nannoplanctica. During this cruise Region E appeared to reflect the influence of upwelling. The flora within the primary region was dominated by species such as Cyclotella ocellata, Dinobryon divergens, Fragilaria crotonensis, Rhizosolenia eriensis, Tabellaria fenestrata, and Tabellaria flocculosa var. linearis. Region E1 contained a greater abundance of species such as Cyclotella comta, C. michiganiana, and C. stelligera, while Region E2 was distinguished primarily on the basis of high population densities of microflagellates.

A somewhat more simple floristic pattern was present during cruise 7 (Fig. 93, Table 28). In this case the region labeled A contained the diatom-dominated assemblage with species such as Asterionella formosa, Cyclotella comta, C. michiganiana, and C. stelligera being prominent. As had been the case at these stations in previous months, the flora also contained a substantial number of primarily benthic species such as Amphora ovalis var. pediculus, Fragilaria pinnata, and F. vaucheriae. Region B contained a typical hypereutrophic assemblage. Although certain blue-green species such as Aphanizomenon flos-aquae were still prominent, by this time a number of fall-blooming diatom species, such as Actinocyclus normanii fo. subsalsa, Fragilaria capucina, and Melosira granulata had also become prominent.

These elements in the flora were reduced in abundance at the stations in Region B1 and blue-green algae such as Anabaena subcylindrica and Anabaena cyanea were particularly abundant. All during this cruise assemblages at offshore stations in Region C contained relatively large populations of species like Chrysosphaerella longispina, Chrysococcus dokidophorus, Cyclotella ocellata, and Gomphosphaeria lacustris. Stations in Region C1 were distinguished from those in Region C primarily by having larger populations of Dinobryon divergens.

During cruise 8 (Fig. 94, Table 29) a very complex pattern was present. Region A contained assemblages composed of several primarily benthic diatoms, a number of euplanktonic species tolerant of moderate nutrient enrichment, such as Fragilaria crotonensis, Melosira islandica, and Tabellaria fenestrata, plus a few green algae such as Crucigenia quadrata and Golenkinia radiata, plus Dinobryon divergens. Region A1 was distinguished from Region A primarily by the greater abundance of species such as Cyclotella ocellata and Stephanodiscus alpinus. The flora of Region B was dominated by species usually occurring under highly eutrophic conditions, such as Anacystis cyanea, Aphanizomenon flos-aquae, and Fragilaria capucina. Assemblages at stations in Region C were fairly typical of moderately disturbed offshore regions in the upper Great Lakes, containing species such as Anacystis thermalis, Gomphosphaeria lacustris, and Rhodomonas minutus, in moderate abundance. Region C1 was distinguished from Region C primarily through the greater abundance of Oocystis spp. The region labeled BC appeared to be a mixture of the floristic assemblages found in the two primary regions. As had been the case in several previous sampling periods, the region of the Michigan coast labeled D in the diagram had a unique floristic composition. Assemblages in this region were relatively rich in species like *Cyclotella comensis* and *C. stelligera*, together with *Cryptomonas ovata* and *Anacystis incerta*, and benthic diatoms such as *Fragilaria vaucheriae*.

TABLE 29. CRUISE 8 - NOVEMBER 10-14, 1974. AVERAGE PHYTOPLANKTON CELL DENSITIES (CELLS/ML) BY REGION (FIG. 94) AS DETERMINED BY PCA AND ORDINATION ANALYSIS FOR 5 M SAMPLES. MEAN VALUES ARE LISTED ABOVE THE STANDARD DEVIATION. STANDARD DEVIATION VALUES ARE OMITTED FOR REGIONS REPRESENTED BY ONLY (1) ONE STATION. APPARENT TREND INDICATES THE REGIONS WITH THE MAXIMUM AND MINIMUM AVERAGE DENSITIES

Region:	Grand	A	A_1	B	BC_1	C	C_1	D	Apparent Trend	
Species	41	2	4	4	3	11	14	3	High	Low
Achnanthes minutissima **	1.17	11.52	2.62	1.05	0	0	.15	2.79	A	BC_1,C
	3.18	10.37	2.01	1.21	0	0	.56	2.41		
Amphora ovalis var. pediculus **	2.61	25.13	4.19	5.24	0	.19	.45	3.49	A	BC_1
	6.33	14.81	4.52	2.70	0	.63	1.21	6.05		
Asterionella formosa ** +	62.53	70.16	60.21	268.61	72.61	20.37	43.23	20.25	B	D
	80.06	7.40	28.84	109.58	10.33	20.86	30.69	16.27		
Aphanizomenon flos-aquae ** +	22.02	7.33	9.95	125.14	29.32	7.24	6.58	29.32	B	C_1
	42.00	10.37	10.87	75.77	7.55	11.06	11.11	12.74		
Cosmarium botrytis **	.10	0	0	1.05	0	0	0	0	B	
	.46	0	0	1.21	0	0	0	0		
Cosmarium depressum *	.10	1.05	0	.52	0	0	0	0	A	
	.46	1.48	0	1.05	0	0	0	0		
Cyclotella comensis ** +	288.46	267.04	279.08	492.18	185.70	114.05	348.57	505.45	D	C
	202.13	7.40	61.88	81.60	24.27	61.08	246.78	158.27		
Cyclotella michiganiana *	3.88	7.33	6.28	7.33	2.09	2.28	2.84	6.28	A,B	BC_1
	3.36	7.40	1.71	2.70	2.09	2.38	2.41	5.54		
Cyclotella ocellata * +	16.86	19.90	32.99	15.71	11.17	21.90	10.77	10.47	A_1	D
	12.21	1.48	7.91	10.61	8.46	14.15	9.39	5.54		
Cyclotella operculata **	2.76	13.61	3.67	4.71	3.49	.38	1.65	4.89	A	C
	3.52	1.48	3.58	2.01	3.20	1.26	1.68	3.20		

Legend: * $\leq$ .02; ** $\leq$ .005; + = species selected for ordination analysis. N = total number of 5 m samples for respective cruise. Grand = Mean value for 5 m samples for respective cruise.

(continued)

TABLE 29 (continued)

Species	Region: N =	Grand 41	A 2	A_1 4	B 4	BC_1 3	C 11	C_1 14	D 3	Apparent Trend High	Apparent Trend Low
Cyclotella stelligera ** +		10.11	28.27	19.90	4.71	.70	6.09	7.03	30.72	D	BC_1
		9.81	1.48	7.15	3.58	1.21	4.54	5.30	6.05		
Dinobryon divergens **		16.35	109.96	13.09	44.51	0	2.09	7.78	29.32	A	BC_1
		31.73	31.10	·16.96	39.53	0	3.86	20.63	37.23		
Fragilaria intermedia var. fallax **		.87	7.33	2.62	0	.70	.76	0	0	A	
		2.73	10.37	2.01	0	1.21	2.53	0	0		
Fragilaria pinnata ** +		15.48	152.89	20.94	31.42	3.49	3.05	3.59	8.38	A	C
		35.50	62.20	19.50	21.90	3.20	5.41	5.35	57.02		
Fragilaria vaucheriae *		.97	1.05	1.05	1.05	3.49	.38	0	4.89	D	C_1
		2.35	1.48	1.21	1.21	6.05	1.26	0	4.36		
Undetermined green filament sp. #5 ** +		911.73	630.41	417.31	6024.0	1260.8	151.18	244.30	496.37	B	C
		2199.6	589.42	391.62	4771.5	1028.6	171.10	439.36	416.34		
Melosira granulata **		18.85	114.14	21.47	38.22	4.19	3.81	13.91	18.85	A	C
		29.30	54.80	28.74	24.92	5.54	6.81	14.15	18.85		
Melosira islandica **		.77	7.33	0	0	5.59	0	0	0	A	
		3.24	7.40	0	0	9.67	0	0	0		
Mougeotia sp. #1 ** +		21.81	24.09	20.42	136.66	32.11	4.95	3.44	6.28	B	C_1
		41.33	13.33	17.55	35.19	19.91	7.03	6.50	2.09		
Nitzschia acicularis ** +		5.93	16.76	9.95	15.71	2.09	.76	4.04	11.87	A	C
		7.01	2.96	6.92	10.33	3.63	1.41	4.23	4.36		
Nitzschia fonticola **		1.17	9.42	.52	2.62	0	0	.60	2.79	A	BC_1,C
		2.85	7.40	1.05	3.96	0	0	1.28	3.20		
Oscillatoria retzii **		.31	2.09	0	2.09	0	0	0	0	A,B	all others
		1.00	0	0	2.42	0	0	0	0		

(continued)

TABLE 29 (continued)

Species	Region: N =	Grand 41	A 2	A_1 4	B 4	BC_1 3	C 11	C_1 14	D 3	Apparent Trend High	Low
Oscillatoria sp. #4 ** +		4.50 6.97	6.28 5.92	1.05 1.21	19.37 11.26	13.26 2.42	1.90 1.98	1.20 2.28	4.19 2.09	B	A_1
Rhodomonas minuta var. nannoplanctica ** +		5.11 6.66	1.05 1.48	2.62 2.64	.52 1.05	4.89 1.21	12.95 8.16	2.39 2.83	1.40 2.42	C	B
Rhizosolenia eriensis **		4.85 6.66	14.66 8.89	8.38 7.84	14.66 7.65	4.19 5.54	1.52 2.11	1.20 2.13	10.47 8.38	A, B,	C_1
Scenedesmus quadricauda **		2.81 7.46	6.28 8.89	.52 1.05	18.85 15.86	0 0	0 0	1.20 3.04	2.79 4.84	B	BC_1, C
Stephanodiscus alpinus *		1.63 3.05	1.05 1.48	6.28 6.62	1.57 1.05	0 0	.38 1.26	1.20 2.43	4.19 2.09	A_1	BC_1
Surirella angusta *		.10 .46	1.05 1.48	0 0	0 0	0 0	0 0	0 0	.70 1.21	A	
Synedra filiformis ** +		24.37 31.97	59.69 16.29	31.94 5.51	86.39 52.80	29.32 19.98	5.52 4.11	7.78 4.89	49.57 38.98	B	C
Synedra minuscula **		.77 1.61	6.28 0	1.05 1.21	0 0	0 0	0 0	.60 .98	2.09 2.09	A	B, BC_1, C
Synedra ulna var. chaseana *		.36 .93	1.05 1.48	.52 1.05	.52 1.05	0 0	0 0	.15 .56	2.09 2.09	D	BC_1, C
Schizothrix calcicola **		1.33 4.13	1.05 1.48	.52 1.05	9.42 10.88	0 0	.38 .85	.15 .56	2.09 2.09	B	BC_1
Tabellaria fenestrata **		6.44 7.64	16.76 2.96	13.61 8.11	9.95 7.91	2.09 3.63	6.85 8.59	1.20 3.04	12.57 4.19	A	C_1
Tabellaria flocculosa var. linearis *		8.07 11.67	21.99 7.40	19.37 23.72	18.33 13.61	.70 1.21	1.71 3.73	5.68 7.55	11.87 10.33	A	BC_1

DISCUSSION

Based on the results of this study, it appears that the phytoplankton flora of southern Lake Huron has been modified by anthropogenic inputs to a greater extent than is generally realized. Although at any given sampling period phytoplankton assemblages at offshore stations are generally dominated by populations which develop under oligotrophic conditions, there is evidence of nutrient stimulation of more tolerant populations, and the injection of populations tolerant of extremely eutrophic conditions into the offshore waters. Our results indicate that the areal extent of these effects is highly seasonal, and it may well be that certain of the patterns observed during this study result from transient meteorological events (Schelske *et al.*, 1974). Unfortunately, the present data base does not allow evaluation of this source of variability.

Because of the limited number of studies of the openwater phytoplankton flora of southern Lake Huron, there is also a limited basis for evaluating long-term chronic floristic effects of eutrophication. Those studies available (Nichols *et al.*, 1975, 1977; Schelske *et al.*, 1972, 1974) indicate that the waters of northern Lake Huron and Georgian Bay generally contain phytoplankton assemblages more indicative of oligotrophic conditions. While local regions in the northern part of the lake may show the effects of nutrient stress, they do not appear to develop the populations tolerant of highly eutrophic conditions, except in very local regions of southern Georgian Bay (Nichols *et al.*, 1977). While some effect of chronic nutrient stress on southern Lake Huron may be inferred from these apparent differences, direct comparison with historic samples as has been done in Lake Erie (Hohn, 1969) and Lake Michigan (Stoermer and Yang, 1969) is not possible.

In terms of the quasi-instantaneous effects directly addressable from our study, it is clear that there are three primary areas of floristic modification which have significantly different characteristics, and which vary appreciably in the area of the lake effects. The floristic characteristics of these areas are variable over the time period sampled in this study due to seasonal succession of the species involved. Although the apparent source regions are consistent from cruise to cruise, the area of the effect is highly variable, depending apparently on both the amount of input of nutrients and other factors which may affect phytoplankton composition, and on the physical factors which determine the subsequent dispersion of these materials into the main body of Lake Huron.

As might be expected, most extensive and intensive modifications are associated with Saginaw Bay. Populations developed within this area are characteristic of extreme eutrophication and salinification, and are thus quite clearly distinguished from assemblages developed in the open waters of Lake Huron. As alluded to previously, the flora of this region contains a mixture of populations, including those developed within Saginaw Bay proper and dispersed into Lake Huron, and certain populations which develop in the mixing zone between Saginaw Bay and Lake Huron proper. The areal extent and direction of the Saginaw Bay influence is highly variable, and apparently dependent on the circulation patterns in the bay and in main Lake Huron (Allender, 1975; Danek and Saylor, 1977). Due to the rapid response of circulation patterns in Saginaw Bay to wind stress, the dispersion of biological populations and chemical materials from this source may be highly dependent on transient meteorological events (Schelske et al., 1974). For this reason the limited number of sampling cruises undertaken during the course of this project may not furnish a very complete assessment of the possible effects of this source on southern Lake Huron. On the basis of the data available however, it appears that the region most consistently affected is the area running southward from Saginaw Bay along the Michigan coast. Only during the August cruise (Fig. 92) did phytoplankton assemblages characteristic of Saginaw Bay extend northward from the bay. The area of the affect appeared to extend beyond our sampling array so that the full extent of northward excursion cannot be determined. Nonetheless it would appear that most of the influences of discharge from Saginaw Bay are found in southern Lake Huron rather than being distributed over the entire lake. The areal extent of the Saginaw Bay influence in southern Lake Huron is quite variable from cruise to cruise. During the mid-May and early June cruises (Fig. 88, 89) while the lake is still under the influence of the thermal bar, phytoplankton assemblage modification resulting from Saginaw Bay discharge is restricted to stations along the Michigan coast, and appears to move lakeward following the excursion of the spring thermal bar. The furthest dispersal of material and populations from the bay appeared to occur during July (Fig. 91) when the influence of the Saginaw Bay water mass extended southeastward as far as stations 6 and 65 near the southern Canadian coast. Somewhat surprisingly during November (Fig. 94) senescent populations characteristic of the Saginaw Bay water mass were found at midlake station 66.

The influences of nutrient discharge on the Canadian coastline are both less extensive and more seasonally variable. The largest area of affect was found during the May and early June cruises (Fig. 88, 89) and appeared to be controlled by a combination of maximum spring runoff from land sources and the effects of the spring thermal bar. Phytoplankton assemblages at stations along the Canadian coast were also quite strikingly different during the August cruise (Fig. 92). This effect however appeared to be associated with upwelling along the Canadian coastline during this period rather than the influence of nutrients from shoreline sources. As discussed previously, the general pattern of phytoplankton distribution during this cruise was different than all other cases examined. The apparent excursion of the Saginaw Bay plume northward combined with the apparent upwelling at stations along the Canadian coast indicates that the surface waters of southern Lake Huron were being transported in a northwesterly direction during this sampling period which is atypical of the average case. It should also be noted that phytoplankton populations most characteristic of the oligotrophic openwater stations in Lake Huron were restricted to stations 21, 24, 25, and 54 during this cruise.

The other area of floristic modification noted during the study was in the region of stations 14, 15 and 67. Although this pattern was less striking and less consistent than those discussed previously, it was recurrent, which tends to indicate a source of nutrient addition in this region. The greatest apparent effect appeared during July (Fig. 91) when populations characteristic of this region extended as far south as station 64. This region was not detectable during the mid-May cruise (Fig. 88) when any influence with sources in this region were apparently overwhelmed by materials exiting Saginaw Bay landward of the spring thermal bar and during August (Fig. 92) when, as discussed previously, these stations were occupied by a water mass more characteristic of the offshore waters of southern Lake Huron. The influence of sources in this area thus appears to be less than the sources discussed previously. The phytoplankton assemblages of southern Lake Huron are thus reflective of an oligotrophic environment which is variably modified by eutrophication. The primary difference between southern Lake Huron and other areas of the Great Lakes which are undergoing eutrophication is in the nature of perturbations arising from Saginaw Bay. In most areas of the Great Lakes, changes in phytoplankton composition and abundance result directly from the addition of nutrients and other materials. In southern Lake Huron this appears to be the case at stations along the Canadian coast. The effects of materials entering Saginaw Bay, on the other hand, are strongly modified by biotic interactions within the bay. It appears that most of the nutrients entering southern Lake Huron from Saginaw Bay are contained in phytoplankton cells. The subsequent effect of this loading in southern Lake Huron is thus strongly dependent on both the load carried by these populations and their subsequent dispersal and fate in the lake. Our data indicate that certain of the populations generated within Saginaw Bay are quite persistent and thus may be transported over considerable distances in southern Lake Huron before they die and the materials they contain are released. This is particularly true of certain of the blue-green algal populations generated within Saginaw Bay. These populations are apparently not subject to large losses from sinking and/or grazing and persist in the near-surface waters for considerable periods of time. The dispersion of these populations into the open waters of the lake would appear to be of importance since they may store large quantities of phosphorus as polyphosphate bodies. Many other populations, particularly some of the larger diatoms, are apparently lost from water masses exiting Saginaw Bay quite rapidly, and thus the materials entrained are either lost through sinking or fairly rapidly recycled. Thus the ultimate effects of pollution sources within Saginaw Bay on Lake Huron may be a function of not only the biological productivity within the bay but also of the types of populations which are produced. Our results indicate that it is conceivable, given the right circulation conditions, that certain populations generated in Saginaw Bay could reach nearly any part of southern Lake Huron. Under the specific conditions examined in this study, it was demonstrated that these populations do in fact reach midlake stations and stations along the southern Canadian coast. Management strategies which minimize the loadings to Saginaw Bay thus may be especially effective since they will not only reduce the total loading to Lake Huron, but if sufficient to limit blue-green algal blooms, they may also limit the dispersion of materials entering Saginaw Bay to the open lake.

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APPENDIX I

SUMMARY OF PHYTOPLANKTON SPECIES OCCURRENCE IN THE NEAR-SURFACE WATERS OF SOUTHERN LAKE HURON DURING 1974 SAMPLING SEASON*.

	#	Average		Maximum	
	Slides	Cells/ml	% Pop	Cells/ml	% Pop
CYANOPHYTA					
Agmenellum quadruplicatum (Menegh.) Bréb.	2	0.870	0.033	238.761	9.794
Anabaena flos-aquae (Lyngb.) Bréb.	45	20.636	0.656	1989.674	55.901
Anabaena sp. #1	2	0.013	0.001	2.094	0.263
Anabaena sp. #2	1	0.007	0.000	2.094	0.028
Anabaena sp. #4	1	0.020	0.000	6.283	0.034
Anabaena subcylindrica Borge	35	2.516	0.037	211.534	1.125
Anacystis cyanea (Kütz.) Dr. and Daily	13	29.328	0.326	2827.431	37.303
A. dimidiata (Kütz.) Dr. and Daily	2	0.087	0.006	18.850	1.111
A. incerta (Lemm.) Dr. and Daily	67	121.508	4.498	2722.712	80.967
A. thermalis (Menegh.) Dr. and Daily	110	12.038	0.713	190.590	16.667
Aphanizomenon flos-aquae (L.) Ralfs	75	57.940	0.744	2844.187	23.122
Chroococcus dispersus var. *minor* G.M. Smith	45	28.645	1.311	722.566	50.607
Coccochloris sp. #1	2	0.314	0.014	50.265	3.625
Gomphosphaeria lacustris Chod.	80	90.882	4.541	1466.075	75.594
Oscillatoria bornetii Zukal	131	1.920	0.133	62.832	5.310
O. limnetica Lemm.	7	0.080	0.002	10.472	0.222
O. retzii Ag.	98	9.569	0.274	347.669	5.109
Oscillatoria sp. #1	2	0.013	0.001	2.094	0.177
Oscillatoria sp. #2	1	0.114	0.001	35.605	0.342
Oscillatoria sp. #3	1	0.007	0.000	2.094	0.013
Oscillatoria sp. #4	50	1.345	0.038	58.643	0.846
Oscillatoria sp. #5	13	2.891	0.112	816.813	31.733
Oscillatoria sp. #6	2	0.047	0.001	12.566	0.337
Schizothrix calcicola (Ag.) Gom.	21	0.435	0.012	25.133	0.694
Undetermined blue-green filament #1	5	0.161	0.005	20.944	0.653
Undetermined blue-green filament #2	1	0.007	0.001	2.094	0.218
Total for Division (26 species)		381.390	13.461		
CHLOROPHYTA					
Actinastrum hantzschii Lag.	1	0.027	0.000	8.378	0.069
Ankistrodesmus falcatus (Corda) Ralfs	4	0.040	0.003	6.283	0.353
A. gelifactum (Chod.) Bourr.	11	0.314	0.024	25.133	2.160
Ankistrodesmus questionable sp.	2	0.027	0.003	4.189	0.556
Ankistrodesmus questionable sp. #1	1	0.027	0.003	8.378	0.844
Ankistrodesmus sp. #1	1	0.020	0.000	6.283	0.096
Ankistrodesmus sp. #2	8	0.167	0.018	12.566	1.695
Ankistrodesmus sp. #3	185	3.473	0.297	29.322	2.778
Ankistrodesmus sp. #4	4	0.067	0.006	6.283	0.625
Ankistrodesmus sp. #5	5	0.067	0.005	4.189	0.501
Binuclearia eriensis Tiffany	2	0.054	0.004	10.472	1.389
Borodinella polytetras Miller	1	0.161	0.003	50.265	0.943

*Summary is based on all 5-m samples analyzed. Summary includes the total number of samples in which a given taxon was noted, the average population density (cells/ml), the average relative abundance (% of assemblage), the maximum population density encountered (cells/ml), and the maximum relative abundance (% of assemblage) encountered. (continued)

APPENDIX I (continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Botryococcus brauniı Kütz.	5	2.978	0.127	335.103	26.144
Characium limneticum Lemm.	2	0.013	0.001	2.094	0.242
Chodatella ciliata (Lag.) Chod.	26	0.488	0.038	39.793	1.597
C. citriformis Snow	4	0.040	0.004	4.189	0.893
C. subsalsa Lemm.	1	0.007	0.000	2.094	0.139
Closterium aciculare T. West	2	0.013	0.001	2.094	0.258
Closterium sp. #1	2	0.013	0.001	2.094	0.177
Coelastrum microporum Näg.	30	2.851	0.128	87.965	4.614
C. reticulatum (Dang.) Senn	1	0.375	0.007	117.286	2.042
Coelastrum sp. #1	1	0.054	0.000	16.755	0.106
Cosmarium bioculatum Bréb.	14	0.134	0.013	8.378	1.429
C. botrytis Menegh.	9	0.120	0.003	12.566	0.242
C. depressum (Näg.) Lundell	18	0.154	0.008	8.378	0.568
C. geometricum var. *suecicum* Borge	9	0.074	0.005	4.189	0.714
C. laeve var. *distentum* G. S. West	1	0.007	0.000	2.094	0.080
Cosmarium questionable sp. #1	1	0.007	0.000	2.094	0.017
Cosmarium sp. #1	13	0.107	0.006	4.189	0.367
Crucigenia irregularis Wille	15	1.586	0.115	134.041	10.440
C. quadrata Morren	65	9.555	0.586	159.174	9.302
Elakatothrix gelatinosa Wille	1	0.013	0.001	4.189	0.236
Eutetramorus questionable sp. #1	24	1.084	0.080	29.322	7.639
Franceia droescheri (Lemm.) G. M. Smith	2	0.013	0.001	2.094	0.220
Gloeocystis planctonica (W. and W.) Lemm.	190	41.339	2.487	1172.860	54.310
Golenkinia radiata (Chod.) Wille	63	0.629	0.064	8.378	2.424
Kirchneriella lunaris (Kirchn.) Moebius	1	0.007	0.000	2.094	0.065
Kirchneriella sp. #1	2	0.120	0.001	33.510	0.211
Mougeotia sp. #1	108	9.388	0.280	165.457	3.571
Nephrocytium agardhianum Näg.	7	0.268	0.048	33.510	9.697
Oocystis questionable spp.	196	15.109	0.990	115.192	10.976
Pediastrum biradiatum Meyen	2	0.120	0.004	25.133	0.988
P. boryanum (Turp.) Menegh.	9	2.101	0.034	259.705	4.038
P. duplex Meyen	6	0.937	0.024	83.776	3.396
P. duplex var. *clathratum* (A. Braun) Lag.	3	0.803	0.036	142.419	4.219
P. duplex var. *reticulatum* Lag.	1	0.087	0.003	27.227	1.080
Pediastrum sp. #1	1	0.020	0.000	6.283	0.126
Pediastrum spp.	1	0.054	0.000	16.755	0.142
Pediastrum tetras (Ehr.) Ralfs	3	0.161	0.005	33.510	1.602
Phacotus lenticularis (Ehr.) Stein	7	0.147	0.003	31.416	0.220
Quadrigula lacustris (Chod.) G. M. Smith	2	0.080	0.005	16.755	1.416
Scenedesmus abundans (Kirch.) Chod.	1	0.027	0.001	8.378	0.287
S. acuminatus (Lag.) Chod.	3	0.107	0.002	16.755	0.450
S. acutus fo. *alternans* Hortob.	1	0.054	0.001	16.755	0.292
S. acutus fo. *costulatus* (Chod.) Uherkov.	1	0.054	0.003	16.755	0.977

(continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Scenedesmus armatus (Chod.) G. M. Smith	6	0.161	0.007	8.378	0.572
S. armatus var. *boglariensis* Hortob.	1	0.027	0.001	8.378	0.168
S. bijuga (Turp.) Lag.	35	1.258	0.051	29.322	1.852
S. carinatus (Lemm.) Chod.	1	0.027	0.001	8.378	0.344
S. denticulatus var. *linearis* fo. *costato-granulatus* (Hortob.) Uherkov.	1	0.107	0.001	33.510	0.211
S. denticulatus Lag.	8	0.375	0.016	25.133	1.597
S. dimorphus (Turp.) Kützing.	1	0.027	0.000	8.378	0.156
S. longus Meyen	1	0.054	0.002	16.755	0.664
S. opoliensis var. *aculeatus* Hortob.	1	0.027	0.000	8.378	0.053
S. opoliensis P. Richt.	7	0.468	0.005	37.699	0.362
S. quadricauda var. *longispina* fo. *granulatus* Uherkov.	1	0.013	0.000	4.189	0.026
S. quadricauda (Turp.) Bréb.	42	2.094	0.054	108.908	1.575
S. quadricauda var. *longispina* (Chod.) G. M. Smith	1	0.054	0.001	16.755	0.292
S. quadricauda var. *quadrispina* (Chod.) G. M. Smith.	20	0.763	0.014	46.077	0.840
S. sempervirens Chod.	1	0.013	0.000	4.189	0.035
S. serratus (Chod.) Bohn.	14	0.535	0.012	33.510	0.798
Scenedesmus sp. #1	1	0.040	0.000	12.566	0.080
Scenedesmus spinosus Chod.	12	0.348	0.007	20.944	0.858
Scenedesmus spp.	25	1.191	0.030	52.360	1.043
Selenastrum sp. #1	1	0.007	0.000	2.094	0.012
Sphaerocystis schroeteri Chod.	1	0.248	0.004	77.493	1.386
Staurastrum paradoxum Meyen	27	0.234	0.009	8.378	0.446
Staurastrum sp. #1	7	0.067	0.001	6.283	0.075
Staurastrum sp. #3	2	0.013	0.001	2.094	0.153
Staurastrum sp. #4	1	0.013	0.000	4.189	0.057
Tetraedron minimum var. *apiculato-scorbiculatum* (Reinsch, Lag.) Skuja	10	0.074	0.005	4.189	0.508
Tetraëdron minimum (A. Br.) Hansg.	58	0.957	0.047	41.888	1.338
T. regulare Kütz.	2	0.013	0.001	2.094	0.247
Tetraëdron sp. #1	1	0.007	0.000	2.094	0.017
Tetrallantos lagerheimii Teiling	1	0.107	0.015	33.510	4.611
Tetrastrum staurogeniaeforme (Schroeder) Lemm.	1	0.054	0.002	16.755	0.679
Ulothrix sp. #1	5	0.937	0.035	142.419	8.028
Undetermined green colony	11	0.803	0.066	67.021	8.036
Undetermined green colony sp. #1	1	0.027	0.004	8.378	1.278
Undetermined green filament #1	1	0.047	0.003	14.661	0.826
Undetermined green filament #2	2	0.261	0.015	71.209	4.014
Undetermined green filament #3	4	1.566	0.115	257.610	17.706
Undetermined green filament #4	1	0.013	0.002	4.189	0.525
Undetermined green filament #5	198	667.756	14.139	35309.383	92.383
Undetermined green filament spp.	1	0.033	0.001	10.472	0.430
Undetermined green individual	8	0.261	0.019	43.982	2.178
Total for Division (96 species)		777.071	20.172		

(continued)

APPENDIX I (continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
BACILLARIOPHYTA					
Achnanthes affinis Grun.	1	0.007	0.000	2.094	0.054
A. biasolettiana (Kütz.) Grun.	8	0.060	0.003	4.189	0.197
A. clevei Grun.	6	0.040	0.002	2.094	0.165
A. clevei var. *rostrata* Hust.	25	0.214	0.012	6.283	0.348
A. exigua Grun.	4	0.027	0.001	2.094	0.165
A. exigua var. *heterovalva* Krasske	1	0.007	0.000	2.094	0.057
A. hauckiana var. *rostrata* Schulz	1	0.007	0.001	2.094	0.175
A. lanceolata (Breb.) Grun.	4	0.040	0.002	6.283	0.320
A. lanceolata var. *dubia* Grun.	4	0.040	0.003	6.283	0.494
A. lanceolata var. *elliptica* Cl.	1	0.007	0.000	2.094	0.054
A. linearis (Wm. Smith) Grun.	6	0.047	0.002	4.189	0.172
A. linearis fo. *curta* H. L. Smith	3	0.020	0.001	2.094	0.115
A. microcephala (Kütz.) Grun.	2	0.013	0.001	2.094	0.111
A. minutissima var. *cryptocephala* Grun.	3	0.020	0.001	2.094	0.174
A. minutissima (Kütz.)	56	0.843	0.072	58.643	10.370
A. oestrupi (A. Cl.) Hust.	1	0.007	0.000	2.094	0.118
A. pinnata Hust.	5	0.033	0.002	2.094	0.124
Achnanthes questionable sp. #1	1	0.027	0.003	8.378	0.926
Achnanthes sp. #1	1	0.007	0.000	2.094	0.117
Achnanthes sp. #10	1	0.013	0.001	4.189	0.213
Achnanthes sp. #16	1	0.007	0.000	2.094	0.025
Achnanthes sp. #17	1	0.007	0.001	2.094	0.231
Achnanthes spp.	85	1.345	0.076	50.265	1.958
Amphipleura pellucida Kütz.	14	0.120	0.007	4.189	0.390
Amphora fonticola Maill.	1	0.007	0.000	2.094	0.102
A. neglecta Stoerm. and Yang	1	0.007	0.001	2.094	0.195
A. ovalis var. *constricta* Skv.	8	0.087	0.004	10.472	0.366
A. ovalis var. *gracilis* (Ehr.) V. H.	28	0.241	0.013	6.283	0.714
A. ovalis var. *libyca* (Ehr.) Cl.	5	0.040	0.002	4.189	0.200
A. ovalis var. *pediculus* (Kütz.) V. H.	80	1.258	0.069	35.605	1.387
Amphora questionable sp. #1	8	0.074	0.004	6.283	0.531
Amphora veneta var. *capitata* Haworth	1	0.007	0.000	2.094	0.082
Anomoeoneis vitrea (Grun.) Ross	5	0.040	0.003	4.189	0.234
Asterionella formosa Hass.	282	38.501	2.941	393.746	18.444
Caloneis bacillum (Grun.) Cl.	1	0.007	0.000	2.094	0.032
C. bacillum var. *lancettula* (Schulz) Hust.	2	0.013	0.000	2.094	0.106
Caloneis sp. #1	1	0.007	0.000	2.094	0.143
Caloneis ventricosa var. #2	1	0.007	0.000	2.094	0.013
C. ventricosa var. *truncatula* (Grun.) Meist.	1	0.007	0.000	2.094	0.037
Cocconeis diminuta Pant.	28	0.241	0.010	6.283	0.341
C. pediculus Ehr.	2	0.013	0.001	2.094	0.183
C. placentula var. *euglypta* (Ehr.) Cl.	2	0.013	0.002	2.094	0.341
C. placentula var. *lineata* (Ehr.) V. H.	6	0.040	0.002	2.094	0.278

(continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Cocconeis sp. #1	1	0.007	0.001	2.094	0.165
Coscinodiscus subsalsa Juhl-Dannf.	9	0.147	0.003	16.755	0.242
Cyclotella atomus Hust.	1	0.007	0.000	2.094	0.056
C. comensis Grun.	154	150.126	8.555	1507.963	76.250
C. comensis auxospore	49	0.716	0.036	18.850	1.288
C. comta (Ehr.) Kütz.	222	4.724	0.365	31.416	3.704
C. comta (abnormal)	2	0.013	0.001	2.094	0.249
C. comta auxospore	2	0.027	0.004	4.189	0.738
C. comta var. *glabriuscula* Grun.	1	0.007	0.001	2.094	0.260
C. comta var. *oligactis* (Ehr.) Grun.	3	0.020	0.001	2.094	0.121
C. cryptica Reimann, Lewin, and Guillard	1	0.007	0.000	2.094	0.138
C. kutzingiana Thw.	3	0.020	0.003	2.094	0.377
C. meneghiniana Kütz.	14	0.161	0.008	10.472	0.694
C. meneghiniana var. *plana* Fricke	1	0.007	0.000	2.094	0.042
C. michiganiana Skv.	257	14.567	1.431	140.324	29.949
C. michiganiana auxospore	2	0.013	0.001	2.094	0.211
C. ocellata Pant.	281	24.128	2.370	169.646	17.438
C. ocellata auxospore	23	0.194	0.016	6.283	0.647
C. operculata (Ag.) Kütz.	109	2.549	0.131	37.699	2.179
C. pseudostelligera Hust.	16	0.201	0.010	12.566	0.733
Cyclotella questionable sp. #1	1	0.013	0.002	4.189	0.763
Cyclotella sp. #1	1	0.007	0.001	2.094	0.158
Cyclotella sp. #2	1	0.007	0.001	2.094	0.231
Cyclotella sp. #3	7	0.187	0.018	14.661	1.984
Cyclotella sp. #5	105	2.262	0.285	46.077	7.143
Cyclotella sp. auxospore	9	0.047	0.004	2.094	0.377
Cyclotella spp.	2	0.013	0.002	2.094	0.346
Cyclotella stelligera (Cl. and Grun.) V. H.	302	53.884	6.406	720.471	86.216
C. stelligera auxospore	4	0.033	0.003	4.189	0.763
Cymatopleura elliptica (Bréb. and Godey) Wm. Smith	1	0.007	0.000	2.094	0.054
C. solea var. *apiculata* (Wm. Smith) Ralfs	4	0.027	0.002	2.094	0.394
C. solea (Bréb. and Godey) Wm. Smith	1	0.007	0.000	2.094	0.146
Cymbella aspera (Ehr.) H. Perag.	1	0.007	0.000	2.094	0.012
C. cesatii (Rabh.) Grun.	3	0.020	0.001	2.094	0.099
C. cistula (Ehr.) Kirchn.	1	0.007	0.001	2.094	0.174
C. delicatula Kütz.	6	0.040	0.002	2.094	0.158
C. hustedtii Krasske	1	0.007	0.000	2.094	0.029
C. hybrida Grun.	2	0.020	0.001	4.189	0.197
C. laevis Näg.	1	0.007	0.000	2.094	0.115
C. leptoceros var. *rostrata* Hust.	1	0.007	0.000	2.094	0.121
C. microcephala Grun.	47	0.502	0.030	12.566	0.927
C. minuta Hilse	5	0.060	0.005	6.283	0.634
C. minuta fo. *latens* (Krasske) Reim.	7	0.100	0.004	10.472	0.348
C. minuta var. *silesiaca* (Bleisch and Rabh.) Reim.	11	0.120	0.007	10.472	0.566

(continued)

APPENDIX I (continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Cymbella parvula Krasske	2	0.013	0.00.	2.094	0.223
C. prostrata var. *auerswaldii* (Rabh.) Reim.	3	0.020	0.000	2.094	0.115
C. prostrata (Berk.) Cl.	4	0.333	0.002	4.189	0.213
Cymbella questionable sp. #1	2	0.013	0.001	2.094	0.231
Cymbella sp. #14	1	0.007	0.000	2.094	0.074
Cymbella sp. #2	1	0.007	0.000	2.094	0.093
Cymbella sp. #6	1	0.007	0.001	2.094	0.240
Cymbella spp.	29	0.301	0.018	8.378	0.427
Cymbella subventricosa Cholnoky	2	0.013	0.002	2.094	0.295
C. triangulum (Ehr.) Cl.	2	0.013	0.002	2.094	0.446
C. ventricosa (Ag.) Ag.	1	0.007	0.000	2.094	0.124
Denticula tenuis Kütz.	1	0.007	0.000	2.094	0.124
D. tenuis var. *crassula* (Näg. and Kütz.) W. and G. S. West	20	0.201	0.012	8.378	0.692
Diatoma tenue Ag.	1	0.007	0.000	2.094	0.099
D. tenue var. *elongatum* Lyngb.	43	0.943	0.052	77.493	2.922
D. tenue var. *pachycephala* Grun.	117	8.398	0.487	475.427	4.962
D. vulgare Bory	1	0.007	0.000	2.094	0.107
Diploneis boldtiana Cl.	2	0.013	0.001	2.094	0.145
D. elliptica var. *pygmaea* A. Cl.	1	0.007	0.000	2.094	0.139
D. oculata (Bréb.) Cl.	4	0.027	0.004	2.094	0.714
D. parma Cl.	4	0.027	0.002	2.094	0.211
Diploneis sp. #1	1	0.007	0.000	2.094	0.145
Entomoneis ornata (J. W. Bail.) Reim.	2	0.013	0.001	2.094	0.243
Eucocconeis flexella Kütz.	1	0.007	0.000	2.094	0.072
E. flexella var. *alpestris* (Brun) Hust.	1	0.007	0.000	2.094	0.114
Eucocconeis questionable sp. #1	2	0.181	0.021	37.699	5.294
Fragilaria brevistriata Grun.	1	0.007	0.000	2.094	0.083
F. brevistriata var. *inflata* (Pant.) Hust.	5	0.094	0.006	12.566	0.696
F. capucina Desm.	117	77.010	3.007	2184.453	32.541
F. capucina var. *mesolepta* Rabh.	1	0.013	0.001	4.189	0.423
F. construens (Ehr.) Grun.	27	1.024	0.038	60.737	2.365
F. construens var. *binodis* (Ehr.) Grun.	1	0.013	0.001	4.189	0.231
F. construens var. *capitata* Hérib.	1	0.007	0.001	2.094	0.218
F. construens var. *minuta* Temp. and Per.	108	1.720	0.163	18.850	2.264
F. construens var. *pumila* Grun.	7	0.067	0.003	8.378	0.165
F. construens var. *venter* (Ehr.) Grun.	6	0.167	0.013	33.510	2.832
F. crotonensis Kitton	247	115.679	7.577	1897.521	65.986
F. intermedia Grun.	10	0.074	0.004	4.189	0.369
F. intermedia var. *fallax* (Grun.) A. Cl.	45	3.165	0.234	278.554	9.262
F. lapponica Grun.	2	0.020	0.002	4.189	0.369
F. leptostauron (Ehr.) Hust.	18	0.442	0.022	23.038	1.250
F. leptostauron var. *dubia* (Grun.) Hust.	1	0.013	0.002	4.189	0.738
F. pinnata var. *intercedens* (Grun.) Hust.	1	0.007	0.001	2.094	0.195

(continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Fragilaria pinnata var. *lancettula* (Schum.) Hust.	31	0.816	0.034	69.115	2.692
F. pinnata Ehr.	95	5.032	0.229	196.873	7.667
Fragilaria questionable sp. #1	2	0.134	0.015	31.416	3.472
Fragilaria sp. #10	1	0.007	0.001	2.094	0.173
Fragilaria spp.	59	1.760	0.105	56.549	4.515
Fragilaria vaucheriae (Kütz.) Peters.	58	0.830	0.053	25.133	1.493
F. vaucheriae var. *capitellata* (Grun.) Patr.	38	0.589	0.033	27.227	1.937
F. vaucheriae var. *truncata* (Grev.) Grun.	3	0.020	0.001	2.094	0.117
Gomphonema intricatum Kütz.	1	0.007	0.000	2.094	0.072
G. olivaceum (Lyngb.) Kütz.	7	0.094	0.005	8.378	0.279
Gomphonema questionable sp. #1	1	0.013	0.001	4.189	0.463
Gomphonema spp.	12	0.134	0.007	12.566	0.418
Gomphonema truncatum Ehr.	1	0.007	0.000	2.094	0.085
Gyrosigma attenuatum (Kütz.) Rabh.	2	0.013	0.001	2.094	0.155
Melosira distans var. *alpigena* Grun.	29	0.689	0.058	33.510	3.612
M. granulata alpha status (Ehr.) Ralfs	7	0.308	0.005	43.982	0.539
M. granulata var. *angustissima* O. Müll.	8	0.381	0.018	35.605	2.024
M. granulata (Ehr.) Ralfs	75	6.417	0.254	152.891	4.768
M. islandica auxospore	1	0.007	0.001	2.094	0.370
M. islandica O. Müll.	110	15.236	0.972	812.625	27.019
M. italica (Ehr.) Kütz.	7	0.355	0.014	27.227	1.190
Meridion circulare (Grev.) Ag.	5	0.094	0.004	12.566	0.502
Navicula anglica var. *signata* Hust.	1	0.013	0.001	4.189	0.422
N. capitata Ehr.	5	0.033	0.002	2.094	0.143
N. capitata var. *hungarica* (Grun.) Ross	6	0.060	0.003	4.189	0.348
N. capitata var. *luneburgensis* (Grun.) Patr.	4	0.027	0.002	2.094	0.174
N. cryptocephala var. *intermedia* Grun.	1	0.007	0.000	2.094	0.116
N. cryptocephala var. *veneta* (Kütz.) Rabh.	14	0.120	0.008	4.189	0.658
N. cryptocephala Kütz.	14	0.134	0.007	6.283	0.429
N. cuspidata (Kütz.) Kütz.	1	0.007	0.001	2.094	0.246
N. decussis Østr.	5	0.033	0.001	2.094	0.126
N. gottlandica Grun.	1	0.007	0.001	2.094	0.172
N. lanceolata (Ag.) Kütz.	3	0.020	0.002	2.094	0.299
N. latens Krasske	2	0.013	0.001	2.094	0.118
N. menisculus var. *upsaliensis* Grun.	4	0.027	0.002	2.094	0.190
N. minuscula Grun.	1	0.007	0.000	2.094	0.120
N. neoventricosa Hust.	1	0.007	0.000	2.094	0.085
N. nyassensis fo. *minor* O. Müll.	5	0.033	0.002	2.094	0.211
N. placentula (Ehr.) Kütz.	1	0.007	0.001	2.094	0.211
N. pupula Kütz.	5	0.040	0.001	4.189	0.163
N. pupula var. *capitata* Skv. and Meyer	3	0.020	0.001	2.094	0.278
N. pupula var. *elliptica* Hust.	2	0.013	0.001	2.094	0.189
N. pupula var. *rectangularis* (Greg.) Grun.	1	0.007	0.000	2.094	0.151
Navicula questionable sp. #1	2	0.020	0.002	4.189	0.491

(continued)

APPENDIX I (continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Navicula spp.	79	1.037	0.060	23.038	1.174
Navicula radiosa var. *tenella* (Bréb.) Grun.	4	0.040	0.002	4.189	0.348
N. radiosa Kütz.	8	0.067	0.004	4.189	0.313
N. rhynchocephala Kütz.	6	0.047	0.002	4.189	0.282
N. rotunda Hust.	1	0.007	0.000	2.094	0.089
Navicula sp. #44	25	0.274	0.013	8.378	0.352
Navicula stroesei A. Cl.	1	0.007	0.000	2.094	0.118
N. subrhynchocephala Hust.	2	0.013	0.000	2.094	0.120
N. tripunctata var. *schizonemoides* (V. H.) Patr.	1	0.007	0.000	2.094	0.084
N. tuscula Ehr.	3	0.020	0.001	2.094	0.124
N. viridula (Kütz.) Kütz.	1	0.007	0.000	2.094	0.107
N. vulpina Kütz.	1	0.007	0.001	2.094	0.216
Neidium dubium fo. *constrictum* Hust.	1	0.007	0.001	2.094	0.329
N. dubium var. #1	1	0.007	0.000	2.094	0.124
N. iridis var. *vernalis* Reich.	1	0.007	0.001	2.094	0.240
Neidium sp. #1	1	0.007	0.000	2.094	0.082
Nitzschia acicularis (Kütz.) Wm. Smith	179	5.922	0.454	52.360	5.159
N. acuta Hantz.	33	0.268	0.016	6.283	0.647
N. angustata var. *acuta* (abnormal)	1	0.007	0.001	2.094	0.329
N. angustata var. *acuta* Grun.	17	0.161	0.009	6.283	0.463
N. bacata Hust.	25	0.288	0.018	10.472	1.502
N. capitellata Hust.	4	0.033	0.002	4.189	0.277
N. confinis Hust.	3	0.027	0.001	4.189	0.197
N. denticula Grun.	1	0.007	0.000	2.094	0.084
N. dissipata (Kütz.) Grun.	127	2.536	0.238	29.322	2.947
N. dissipata var. *media* (Hantz.) Grun.	1	0.007	0.000	2.094	0.113
N. fonticola Grun.	57	0.596	0.038	14.661	1.384
N. fonticola var. *pelagica* Hust.	1	0.007	0.000	2.094	0.107
N. interrupta (Reich.) Hust.	1	0.007	0.000	2.094	0.154
N. kutzingiana Hilse	3	0.020	0.001	2.094	0.162
N. linearis Wm. Smith	18	0.214	0.017	18.850	0.961
N. longissima var. *reversa* Grun.	1	0.007	0.000	2.094	0.029
N. luzonensis Hust.	12	0.154	0.009	23.038	1.343
N. palea (Kütz.) Wm. Smith	37	0.294	0.025	4.189	1.429
N. pseudoatomus Stoerm.	1	0.007	0.000	2.094	0.107
Nitzschia questionable sp. #1	1	0.027	0.003	8.378	0.926
Nitzschia questionable spp.	153	3.546	0.218	58.643	3.419
Nitzschia recta Hantz.	1	0.007	0.001	2.094	0.175
N. romana Grun.	1	0.007	0.000	2.094	0.119
N. sigmoidea (Nitz.) Wm. Smith	8	0.060	0.004	4.189	0.254
N. sinuata var. *tabellaria* (Grun.) Grun.	1	0.007	0.000	2.094	0.070
Nitzschia sp. #1	7	0.060	0.004	4.189	0.319
Nitzschia sp. #19	21	0.201	0.013	6.283	0.494
Nitzschia sp. #2	34	0.375	0.027	16.755	1.527

(continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Nitzschia sp. #32	49	0.602	0.058	12.566	1.592
Nitzschia sp. #6	17	0.141	0.009	8.378	0.780
Nitzschia sp. #7	1	0.007	0.001	2.094	0.242
Nitzschia sp. #9	1	0.007	0.000	2.094	0.122
Nitzschia spiculoides Hust.	32	0.348	0.021	8.378	0.903
N. sublinearis Hust.	2	0.013	0.001	2.094	0.139
N. tryblionella var. *levidensis* (Wm. Smith) Grun.	1	0.007	0.000	2.094	0.113
Oestrupia zachariasi (Reich.) Stoerm. and Yang	1	0.007	0.001	2.094	0.175
O. zachariasi var. *undulata* (Schulz) Stoerm. and Yang	1	0.007	0.000	2.094	0.059
Opephora martyi Hérib.	5	0.060	0.003	6.283	0.633
Pinnularia brebissonii (Kütz.) Rabh.	1	0.007	0.000	2.094	0.114
Rhizosolenia eriensis H. L. Smith	206	14.801	1.273	115.192	9.395
R. gracilis H. L. Smith	211	34.968	3.125	192.684	17.895
Rhoicosphenia curvata (Kütz.) Grun.	1	0.007	0.001	2.094	0.377
Stephanodiscus alpinus Hust.	102	2.630	0.144	420.973	17.121
S. astraea (Ehr.) Grun.	1	0.007	0.001	2.094	0.313
S. binderanus (Kütz.) Krieger	36	5.547	0.177	462.861	11.914
S. hantzschii Grun.	133	7.862	0.451	651.356	26.491
S. minutus Grun.	161	7.508	0.602	337.197	13.473
S. niagarae Ehr.	12	0.120	0.006	6.283	0.661
Stephanodiscus questionable sp. #1	8	0.080	0.005	4.189	0.276
Stephanodiscus sp. #1	1	0.013	0.001	4.189	0.163
Stephanodiscus sp. #5	1	0.007	0.000	2.094	0.083
Stephanodiscus sp. auxospore	1	0.007	0.001	2.094	0.329
S. subtilis (Van Goor) A. Cl.	26	2.329	0.166	142.419	8.553
S. tenuis Hust.	10	0.087	0.006	6.283	0.394
S. transilvanicus Pant.	37	0.308	0.022	6.283	0.489
Surirella angusta (Kütz.)	23	0.221	0.016	6.283	0.738
S. biseriata var. *bifrons* (Ehr.) Hust.	1	0.007	0.000	2.094	0.017
S. ovata (Kütz.)	6	0.047	0.002	4.189	0.353
S. ovata var. *pinnata* (Wm. Smith) Hust.	5	0.033	0.001	2.094	0.165
Surirella questionable sp. #1	1	0.007	0.001	2.094	0.211
Surirella sp. #1	1	0.007	0.000	2.094	0.148
Synedra acus Kütz.	8	0.067	0.003	4.189	0.196
S. cyclopum Brutschy	20	0.167	0.015	6.283	0.862
S. delicatissima Wm. Smith	1	0.007	0.001	2.094	0.369
S. delicatissima var. *angustissima* Grun.	8	0.067	0.004	4.189	0.422
S. filiformis Grun.	247	52.392	4.350	257.610	22.222
S. incisa Boyer	1	0.007	0.000	2.094	0.117
S. minuscula Grun.	124	3.118	0.224	75.398	4.478
S. ostenfeldii (Krieger) A. Cl.	157	6.899	0.625	64.926	5.363
S. ostenfeldii (abnormal)	2	0.013	0.002	2.094	0.353
S. parasitica (Wm. Smith) Hust.	10	0.107	0.007	8.378	0.467
Synedra sp. (abnormal)	1	0.007	0.000	2.094	0.145

(continued)

APPENDIX I (continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
Synedra spp.	26	0.388	0.037	16.755	3.019
Synedra ulna var. *chaseana* Thomas	111	2.201	0.158	25.133	1.757
S. ulna var. *claviceps* Hust.	1	0.007	0.001	2.094	0.377
S. ulna var. *danica* (Kütz.) V. H.	2	0.047	0.003	12.566	0.714
S. ulna (Nitz.) Ehr.	40	0.442	0.026	8.378	0.846
Tabellaria fenestrata (Lyngb.) Kütz.	222	58.040	4.292	494.277	28.710
T. fenestrata var. *geniculata* A. Cl.	12	0.408	0.017	54.454	0.911
T. flocculosa (Roth) Kütz.	30	1.071	0.090	35.605	3.390
T. flocculosa var. *linearis* Koppen	213	28.772	2.095	171.740	18.304
Total for Division (271 species)		790.488	55.726		
CHRYSOPHYTA					
Chrysophyte cyst	31	0.462	0.073	18.850	3.782
Chrysococcus dokidophorus Pasch	188	3.707	0.330	31.416	3.472
Chrysosphaerella longispina Lautb.	64	40.114	1.872	862.890	45.632
Dinobryon bavaricum Imhof	11	0.448	0.029	56.549	4.147
D. cylindricum Imhof	1	0.040	0.008	12.566	2.362
D. cylindricum statospore	1	0.040	0.005	12.566	1.467
Dinobryon spp. statospores	183	6.665	0.511	150.796	7.886
Dinobryon divergens Imhof	113	14.614	1.054	228.289	21.087
D. divergens statospore	2	0.020	0.001	4.189	0.146
D. sociale Ehr.	4	0.515	0.057	83.776	9.542
D. sociale var. *americanum* (Brunn.) Bach.	4	0.094	0.006	12.566	1.502
Dinobryon spp.	56	3.566	0.354	64.926	8.148
Kephyrion spirale (Lackey) Conrad	1	0.007	0.001	2.094	0.244
Mallomonas elongata Reverdin	13	0.087	0.006	2.094	0.347
M. pseudocoronata Presc.	57	0.629	0.063	12.566	2.538
Mallomonas sp. #3	9	0.060	0.002	2.094	0.107
Mallomonas sp. #4	3	0.020	0.000	2.094	0.060
Mallomonas statospore	17	0.134	0.010	4.189	0.446
M. tonsurata var. *alpina* (Pasch. and Ruttn.) Krieger	41	0.335	0.024	6.283	0.435
Ochromonas sp. #1	144	3.720	0.337	48.171	8.051
Ochromonas sp. #2	2	0.020	0.000	4.189	0.117
Ochromonas spp.	1	0.013	0.002	4.189	0.491
Rhizochrysis limnetica G. M. Smith	3	0.033	0.003	4.189	0.533
Rhizochrysis sp. #1	1	0.007	0.001	2.094	0.249
Uroglenopsis americana (Calkins) Lemm.	1	0.836	0.046	261.799	14.468
Total for Division (25 species)		75.725	4.722		

(continued)

APPENDIX I (continued)

	# Slides	Average Cells/ml	Average % Pop	Maximum Cells/ml	Maximum % Pop
CRYPTOPHYTA					
Cryptomonas erosa Ehr.	4	0.027	0.000	2.094	0.054
C. ovata Ehr.	256	7.106	0.458	113.097	4.008
Cryptomonas sp. #1	1	0.007	0.001	2.094	0.244
Rhodomonas minuta Skuja	46	0.522	0.048	12.566	2.542
R. minuta var. *nannoplanctica* Skuja	247	8.244	0.765	54.454	7.925
Total for Division (5 species)		16.367	1.345		
PYRROPHYTA					
Ceratium hirundinella (O.F. Müll.) Shrank	19	0.161	0.009	6.283	0.341
Gymnodinium helveticum Penard	1	0.007	0.000	2.094	0.100
Gymnodinium sp.	8	0.060	0.004	4.189	0.456
Peridinium aciculiferum (Lemm.) Lemm.	18	0.161	0.014	8.378	0.490
P. lindemanni Lef.	3	0.033	0.003	4.189	0.489
Peridinium sp. #1	5	0.033	0.003	2.094	0.287
Peridinium spp.	20	0.187	0.012	6.283	0.489
Spirodinium pusillum var. *minor?* Skuja	63	0.669	0.056	10.472	1.303
Total for Division (8 species)		1.312	0.102		
EUGLENOPHYTA					
Phacus sp. #1	1	0.007	0.000	2.094	0.025
Trachelomonas volvacina Ehr.	3	0.027	0.001	4.189	0.154
Total for Division (2 species)		0.033	0.001		
MYXOPHYTA					
Beggiatoa alba (Vauch.) Trev.	6	0.094	0.006	8.378	0.725
Total for Division (1 species)		0.094	0.006		
Undetermined flagellates sp. #1	1	0.060	0.011	18.850	3.422
Undetermined flagellate spp.	309	58.120	4.452	416.784	26.400
Total for Division "Un" (2 species)		58.180	4.463		

APPENDIX II

CHRONOLOGY OF LAKE HURON ALGAL RESEARCH

Date	Author	Divisional Group	Site
1842	Bailey, J.W.	D	Mackinaw Is.-Lake Huron
1845	Ehrenberg, C.G.	D	Mackinaw Is.-Lake Huron
1847	Bailey, J.W.	G	Lake Huron
1849	Kützing, F.T.	D	Mackinaw Is.-Lake Huron
1872	Briggs, S.A.	D	Mackinaw Is.-Lake Huron
1911	Baker, H.B. In: Ruthven, A.G.	G	Saginaw Bay
1911	Coons, G.H. In: Ruthven, A.G.	G	Saginaw Bay
1911	Klugh, A.B.	G	Georgian Bay
1912	Klugh, A.B.	G	Georgian Bay
1913	Klugh, A.B.	G,B-G	Georgian Bay
1913	Klugh, A.B.	G,B-G	Georgian Bay
1915	MacClement, W.T.	D,G,B-G	Georgian Bay
1915	Boyer, C.S. In: MacClement, W.T.	D	Go Home Bay-Georgian Bay
1915	Klugh, A.B. In: MacClement, W.T.	G,B-G	Georgian Bay
1921	Bailey, L.W. and A.H. Mackay	D	Parry Sound-Georgian Bay
1924	Bailey, L.W.	D	Georgian Bay
1927	Boyer, C.S.	D	Mackinaw Is.-Lake Huron
1928	Collins, F.S.	G	Georgian Bay
1961	Schlichting, H., Jr.	D,G,B-G	Port Sanilac, Mi.-Lake Huron
1962	Fenwick, M.	D,G	Lake Huron
1964	Neil, J.H. and G.E. Owen	G	Lake Huron
1965	Beeton, A.M.	D	Lake Huron
1966	Davis, C.C.	D,G	Lake Huron
1966	Patrick, R. and C.W. Reimer	D	Mackinaw Is.-Lake Huron
1967	Bellis, V.J. and D.A. McLarty	G	Port Franks, Ont.-Lake Huron
1967	Fetteroff, C. and J. Robinson	G	Lake Huron
1967	Fetteroff, C. et. al.	D	Thunder Bay-Lake Huron
1967	Michigan Water Res. Commission	G	Lake Huron
1968	Fenwick, M.	D,G	Lake Huron
1968	Stoermer, E.F. and J.J. Yang	D	Lake Huron
1969	Herbst, R.P.	G	Lake Huron
1969	Michalski, M.F.P. In: Anderson, D.V.	D,G,Ch,Cr,B-G,E,Dn,X	Lake Huron
1969	Parkos, W.G. et. al.	D,G,Ch,B-G,Dn	Lake Huron
1970	Beeton, A.M. In: Swain, W.R. et. al.	D,G,Ch,B-G,Dn	Lake Huron
1970	Robinson, J.	D,G,Ch,B-G	Lake Huron
1971	Veal, D.M. and M.F.P. Michalski	D,G,Ch,Cr,B-G	Georgian Bay
1972	Berst, A.H. and G.R. Sprangler	D	Lake Huron
1973	Hohn, M.H. In: Batchelder, T.L.	D,G,Ch,B-G,Dn	Saginaw Bay
1973	Chartrand, T.A.	D,Ch,B-G	Whitestone Pt.-Saginaw Bay
1973	Munawar, M. and I.F. Munawar	D,Ch,Cr,Dn	Lake Huron
1973	Neil, J.H. In: Ont. Water Res. Comm.	G	Georgian Bay, Lake Huron
1973	Schelske, C.L. and J.C. Roth	D,G,Ch,B-G,Dn	Saginaw Bay, Lake Huron
1974	Freedman, P.	G,B-G,Dn	Sagianw Bay
1974	Limnetics, Inc.	D	Lake Huron
1974	Robinson, J.	G	Harbor Beach, Mi.-Lake Huron
1974	Schelske, C.L. et. al.	D,B-G	Saginaw Bay, Lake Huron
1974	Vollenweider, R.A. et. al.	D,Cr,B-G,Dn	Saginaw Bay, Lake Huron
1974	Young, D.C.	D	Georgian Bay
1975	Great Lakes Water Quality Board	G	Lake Huron
1975	Lowe, R.L.	D	Lake Huron
1975	Munawar, M. and I.F. Munawar	D,Ch,Cr,B-G,Dn	Lake Huron
1975	Neil, J.H. In: Shear, H.	G	Saginaw Bay, Lake Huron
1975	Nicholls, K.H. et. al.	D,G,Cr,B-G,E,Dn	Georgian Bay
1975	Patrick, R. and C.W. Reimer	D	Mackinaw Is.-Lake Huron
1975	Stoermer, E.F.	D,G,Cr,B-G,Dn	Sagianw Bay, Lake Huron
1976	Lowe, R.L.	D,G,Chl,Ch,Cr,B-G,E,Dn	Lake Huron
1976	Stoermer, E.F. et. al. In: Schelske, C.L. et. al.	D,G,Ch,Cr,B-G,Dn	Mackinac Straits-Lake Huron
1977	Friedrich, P.D. and C.K. Lin	D	Lake Huron

Legend

D	diatoms	Bacillariophyta	B-G	blue-green algae	Cyanophyta
Chl	chloromonads	Chloromonophyta	E	euglenoids	Euglenophyta
G	green algae	Chlorophyta	Dn	dinoflagellates	Pyrrhophyta
Ch	chrysophyts	Chrysophyta	X	yellow-green algae	Xanthophyta
Cr	cryptomonads	Cryptophyta			

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15. SUPPLEMENTARY NOTES

16. ABSTRACT Southern Lake Huron contains a diversity of phytoplankton assemblage types ranging from assemblages characteristic of oligotrophic waters to those which usually occur under highly eutrophic conditions. The offshore waters are generally characterized by oligotrophic associations and most eutrophic associations are associated with the Saginaw Bay interface waters. Under certain conditions, populations which are generated within Saginaw Bay are found mixed with offshore assemblages, apparently as a result of passive dispersal. The most widely dispersed populations include nuisance-producing blue-green algae such as Aphanizomenon flos-aquae. During the period of study, floristic modification resulting from inputs from Saginaw Bay was usually found along the Michigan coast south of the bay, but cases were noted where greatest effect was found at stations north of the bay or eastward into the open lake. Along the Canadian shore assemblages were qualitatively and quantitively dissimilar from assemblages in Saginaw Bay. On the basis of our results southern Lake Huron appears to be a somewhat more disturbed region than generally realized. Phytoplankton assemblage modification appears to result from both the influence of nutrients and other materials entering the lake directly and from the dispersal of populations from highly eutrophic Saginaw Bay into the open lake. The wide dispersal of these populations is of special interest since it may furnish a mechanism for transport of nutrients and toxic material from highly impacted Saginaw Bay into the open lake.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Algae, Lakes, Nutrients	Lake Huron	06/C

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