94-02

The Case For Research on The Effects of Zebra Mussels in Lake Erie: Summary of Information From August and September 1993

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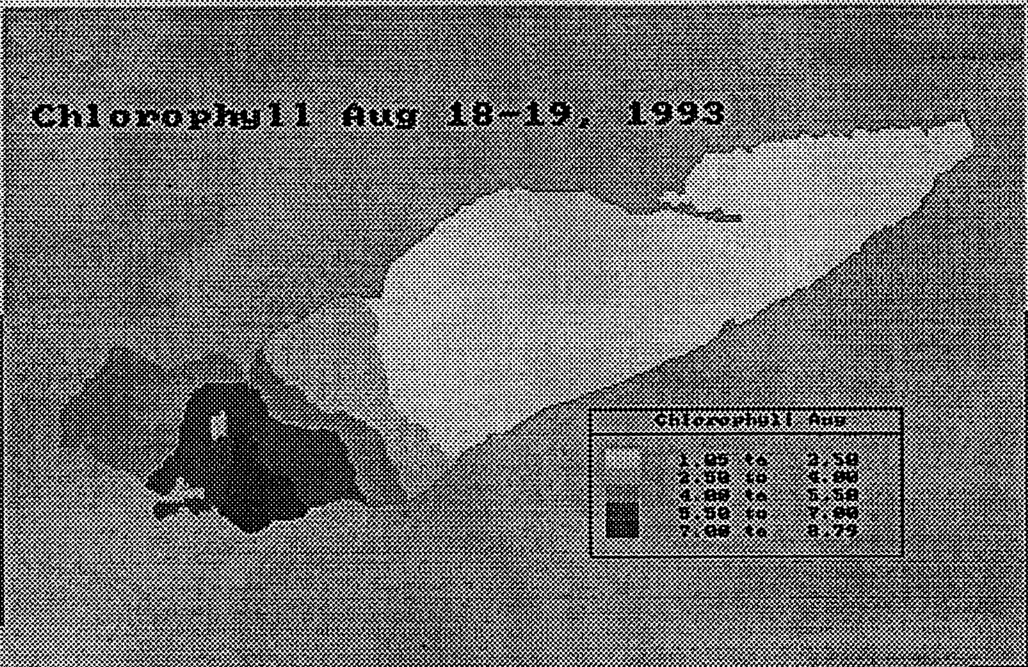
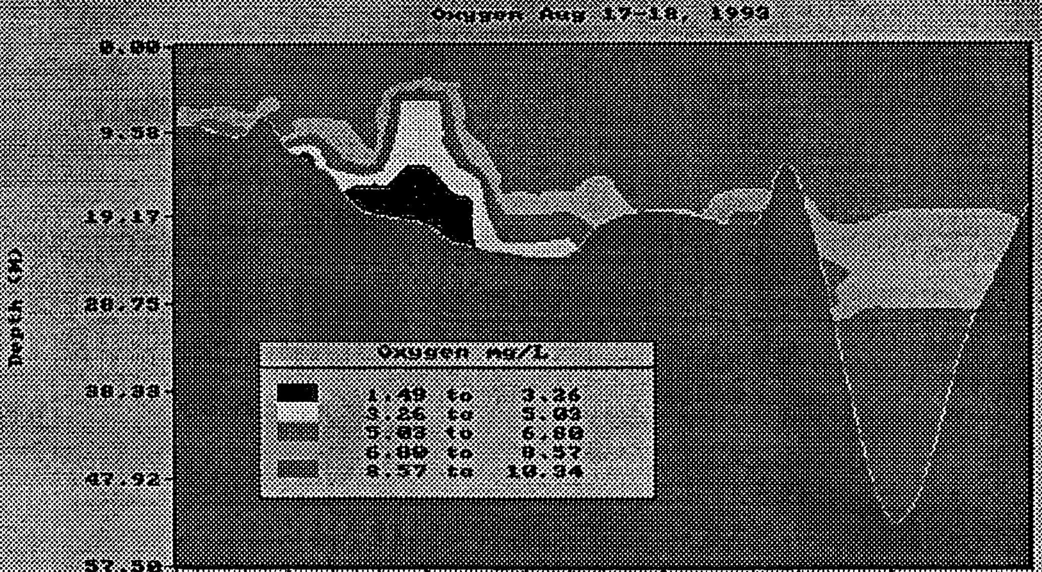
Lakes Research Branch, NWRI. January 18, 1994





NWRI Contribution No. 94-02

Management Perspective

The Case for Research on The Effects of Zebra Mussels in Lake Erie: Summary of Information From August and September 1993

By

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National Water Research Institute
Environment Canada
January 14, 1994

Recent concern about the effects of Zebra mussels has centred on potential loss of fish production and potential loss of fish edibility. The mussels are thought to cause these effects by diversion of energy flow and alteration of contaminant processing. Because management options are limited to controls on nutrients and fish harvest/stocking it is important to determine the extent and degree of Zebra Mussel effects. Some effects of the mussels are obvious in sheltered shallow areas but the effects on the whole ecosystem are not known.

A series of research surveys done in 1993 is reported in this paper. The effects of the mussels seem to result in a loss of about 25% of the standing algal biomass in some areas. Although an attempt was made to visit many areas of the lake, more extensive work is needed to find whole ecosystem effects. The difficulty in delineating the effects of the mussels is caused by the coincidental achievement of nutrient loading goals. Because the distribution of zebra mussels is uneven their effects may be found through extensive spatial surveys.

A coordinated series of experiments is planned for 1994 encompassing partners in Universities (GLURF) and DFO and Ontario Region of EC and Ontario MNR.

Introduction

Since the discovery of Zebra Mussels in 1988 there has been much speculation about the effect of the mussels on water quality and potential fish production. Lake Erie is afflicted with contaminant loads in the west basin. These loads are largely sedimented out of the water in the west basin. By affecting particle dynamics the mussels may affect the sedimentation of contaminants and therby threaten the edibility of the fish. Effects are expected to be most intense in Lake Erie. Results to date indicate that the mussels filter enough material to cause a marked clearing effect where there are many mussels and the water is shallow. The areal extent of the clearing effect is not known yet. It is important to discern between the water quality improvements caused by the nutrient load reductions begun in the early 70s and the effect of the mussels. This may be done by comparing present conditions with those predicted from nutrient load models but a realistic estimate of present conditions requires an extensive set of surveys. This report presents two preliminary surveys in 1993.

Methods

Water samples were taken from the CSS LIMNOS during Aug-18-19 and Sept 20-24, 1993. Samples collected with a "Rosette" sampler (2m and 1m from bottom) or a 0-10m integrator were either placed in bottles immediately for total phosphorus (TPUF) or filtered immediately for phosphorus forms such as soluble reactive phosphorus (SRP) and chlorophyll (Chla). Chlorophyll samples were frozen and chemical samples were stored at 4°C until analysis. Chemical analyses of samples were conducted at the National Laboratory for Environmental Testing (Environment Canada, 1979). Oxygen, transparency, temperature, and conductivity were measured with a Seabird profiling apparatus (Charlton et al. 1993). Contour maps and vertical profile isopleths were plotted with the "RAISON" GIS system developed at NWRI.

Sampling was conducted at a series of stations (Fig. 1) chosen in consultation with O. Johanssen of Department of Fisheries and Oceans. These stations were chosen to be compatible with ongoing work which will be closely coordinated with Universities and Environment Canada Ontario Region in 1994. Locations of the stations are shown in tables later in this report. A subset of these stations was used to produce isopleth plots of temperature, oxygen, transparency and conductivity along an east west transect.

Results

Analytical results for Chla, Particulate organic carbon (POC), particulate organic nitrogen (PON), Transmission of white light (TRANS %), Soluble reactive phosphorus (SRP), filtered total phosphorus (TPF), (TPUF), ammonia (NH_3), nitrate plus nitrite (NO_3+NO_2) and particulate phosphorus (Part.P) are shown in the following figures and tables. Contour maps provide a visual means to gain an impression of the geographical scale and extent of variability.

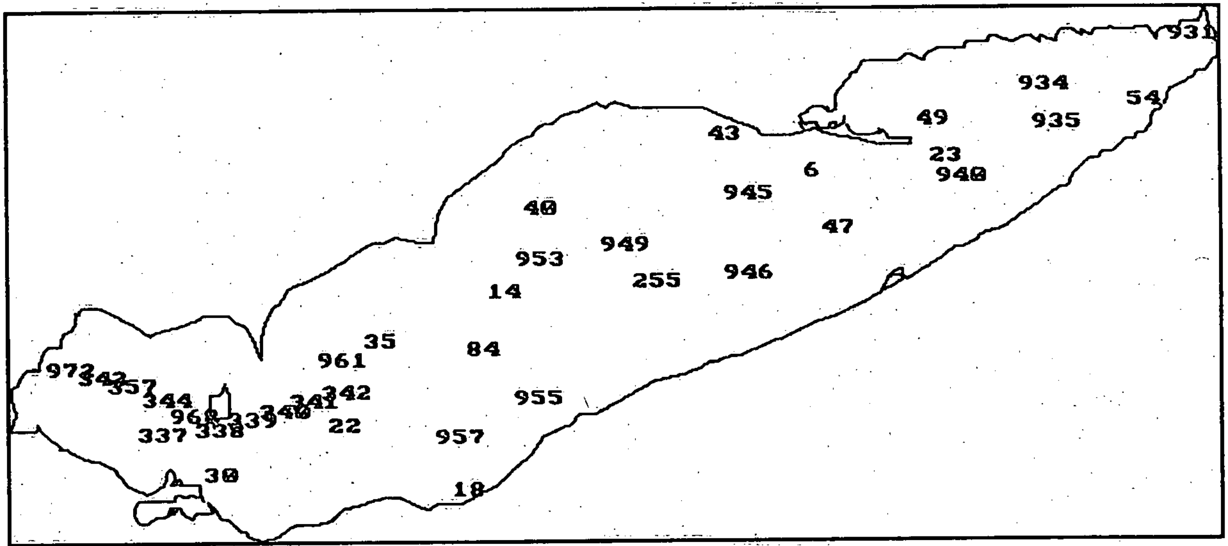

Figure 1: Stations visited in 1993

Contouring programs are dependent on adjustments to the algorithms used and the areal coverage of the station pattern. Therefore, the areal patterns generated are somewhat arbitrary. Although the number of stations visited here is barely adequate for contouring, the derived maps are reasonable representations of the data. The data ranges shown in the map legends are calculated by the contouring algorithm and thus do not present the lowest or the highest values.

August

Figure 2 shows the distribution at 2m and 0-10m (Chla, POC, TPUF) of particulates which may relate to potential fish production. There was a general west-east gradient with some tendency for maxima in the south west area of the central basin. The ranges of Chla, Secchi, and TPUF values in the central basin are similar to those found up to ten years ago (Charlton 1993). The ranges of soluble nutrients were relatively less than for particulates and this caused gradients in soluble nutrients to be less pronounced (Fig. 3). West basin total phosphorus seemed to be consistent with an annual mean of about 20 ug/L achieved some years ago. Some Secchi depths (Fig.2) were at or above the upper limit (3m) of historic readings. These values illustrate the problem of finding out just how much effect Zebra Mussels have had. Secchi readings varied 1-2 m between stations only a few km apart (table A1). Thus, it is impossible to support blanket statements about the ecosystem effect of the mussels without more extensive surveys.

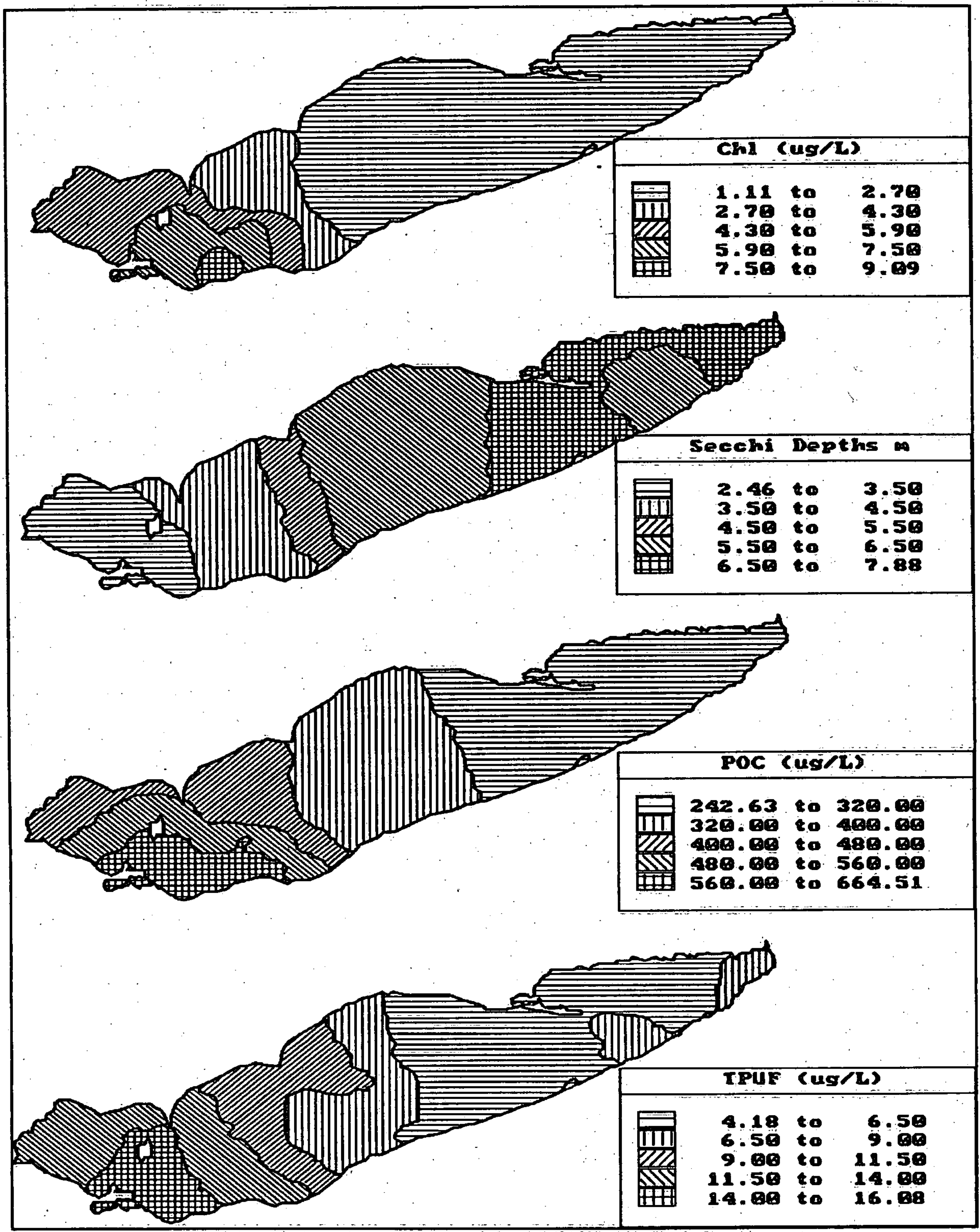

Figure 2 Distribution of Chla, Secchi, POC, and TPUF in August

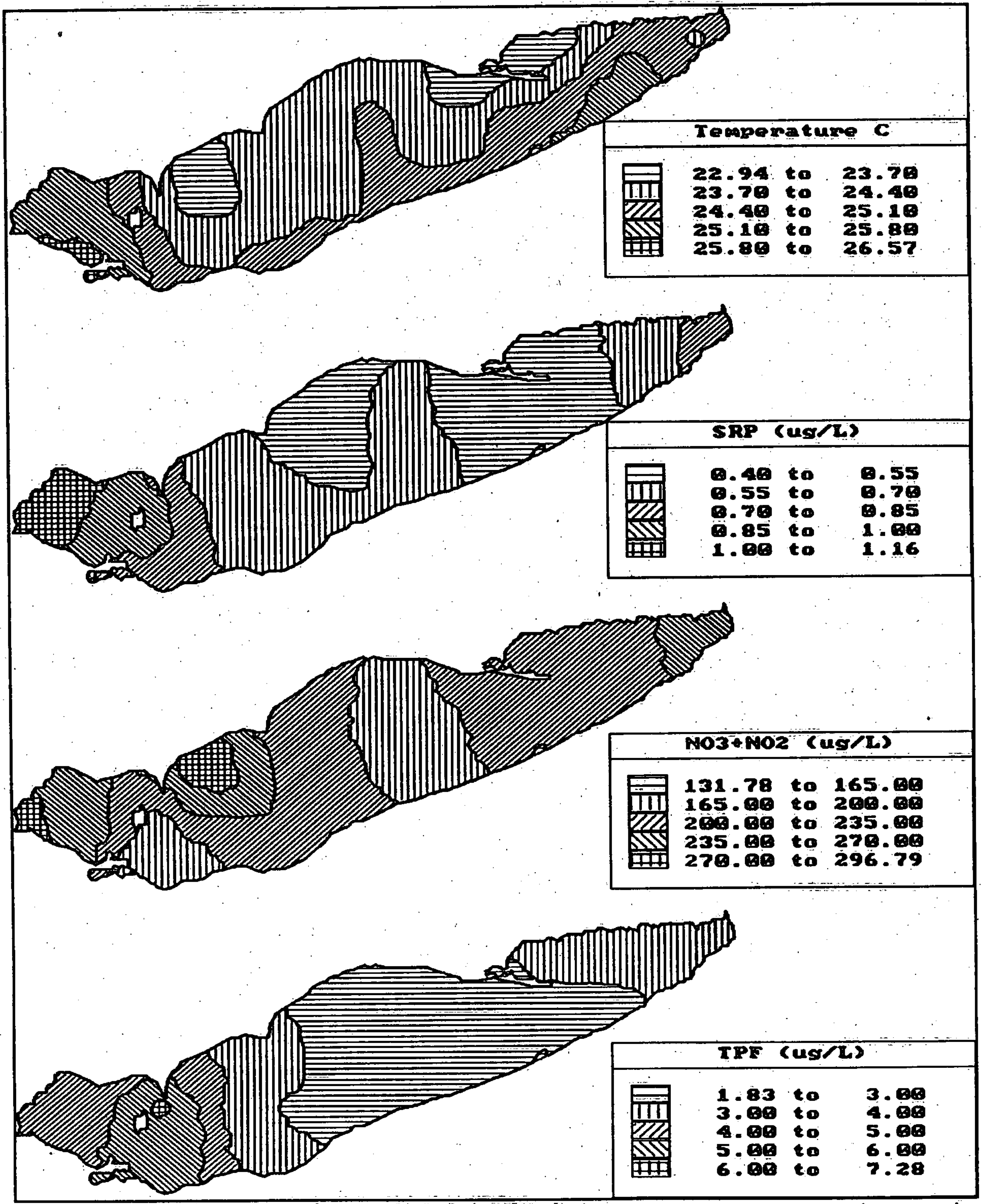

Figure 3 Distribution of temperature and soluble nutrients in August

September

Chlorophyll was lower in the west basin in September compared to August. At the same time, however, Secchi readings were lower and TPUF was higher (Fig.4, table A2). These are symptoms of resuspended sediment which seemed to be prevalent over the entire lake at this time. Chlorophyll increased in the central basin and the position of particulate maxima moved slightly east to be near Cleveland. Soluble reactive phosphorus was generally higher in September and this was reflected in TPF and to some extent NO_3+NO_2 (Fig.5). These results indicate north south gradients as well as east west gradients.

Vertical Profiles

The Raison Limnological plots provide a convenient way to quickly display vertical profile data from a transect of stations. Again, the graphic results are somewhat arbitrary as they depend on the choice of stations and the adjustments to the contouring algorithm.

August

The central and east basins were strongly stratified as usual (Fig.6). There was an upwelling area in the western part of the central basin. The lowest oxygen concentrations were higher then normal but this may have been caused by the thickness of the hypolimnion layer. As expected, transmission was least at shallow stations in the west basin. Although the range of values was not large it is interesting that there was lower conductivity in the west basin than elsewhere. Higher conductivity near the bottom in the central basin may have been due to dissolved nutrients present under low oxygen conditions.

September

By mid September the central basin was unstratified but stratification remained in the east basin (Fig. 7). Oxygen values in the east basin reflect the typical degree of oxygen depletion from 12-13 mg/L in the spring. Light transmission distribution was influenced strongly by high turbidity at station 255. High turbidity was also apparent at shallow stations in the east and west basins. Conductivity was also lowest again in the west basin. The west-east gradient in conductivity was larger than can be expected from any errors in the profiling system.

Spatial/Temporal

Contour maps portray well the spatial variations in a survey but for graphical trend displays a consistent set of category ranges is needed. An example of this is the August-September comparison of light transmission at 2M in Fig. 8. Although the two maps show quickly the difference between the surveys, the spatial variation shown in Fig. 7 is lost in the August map in Fig. 8. The variation shown in the September survey is likely related to sediment resuspension and increased chlorophyll.

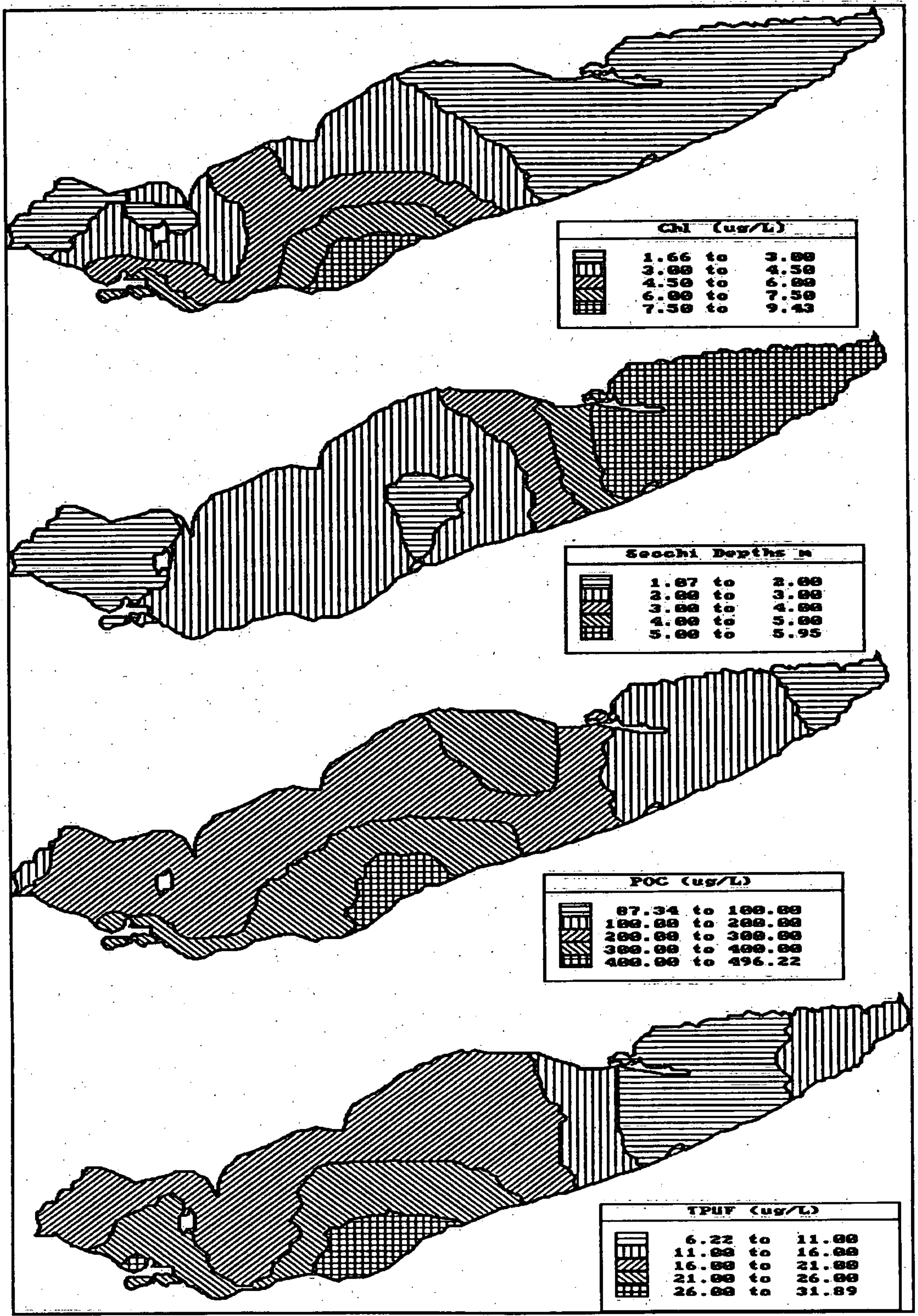

Figure 4 Distribution of Chla, Secchi, POC, and TPUF in September

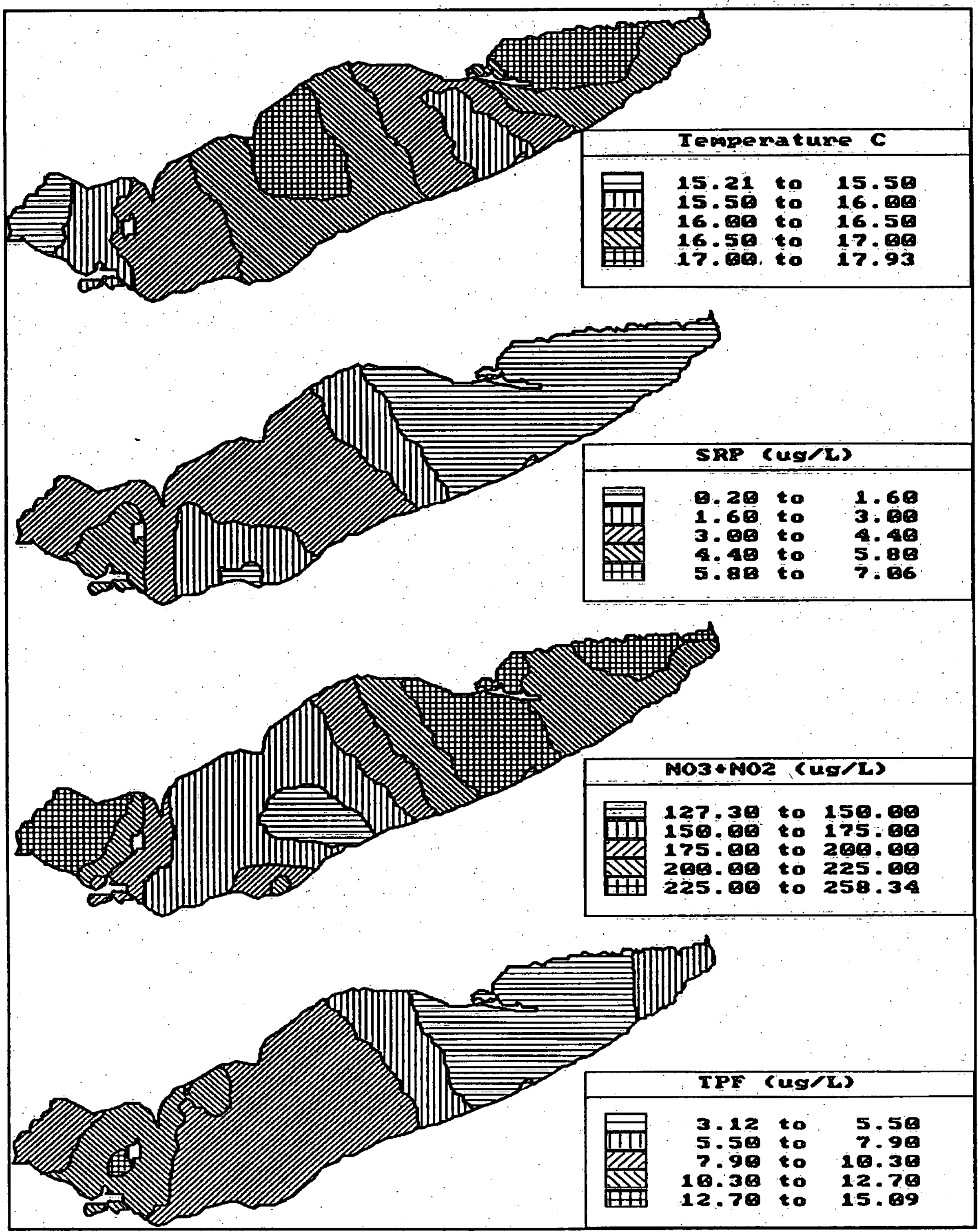

Figure 5 Distribution of temperature and soluble nutrients in September

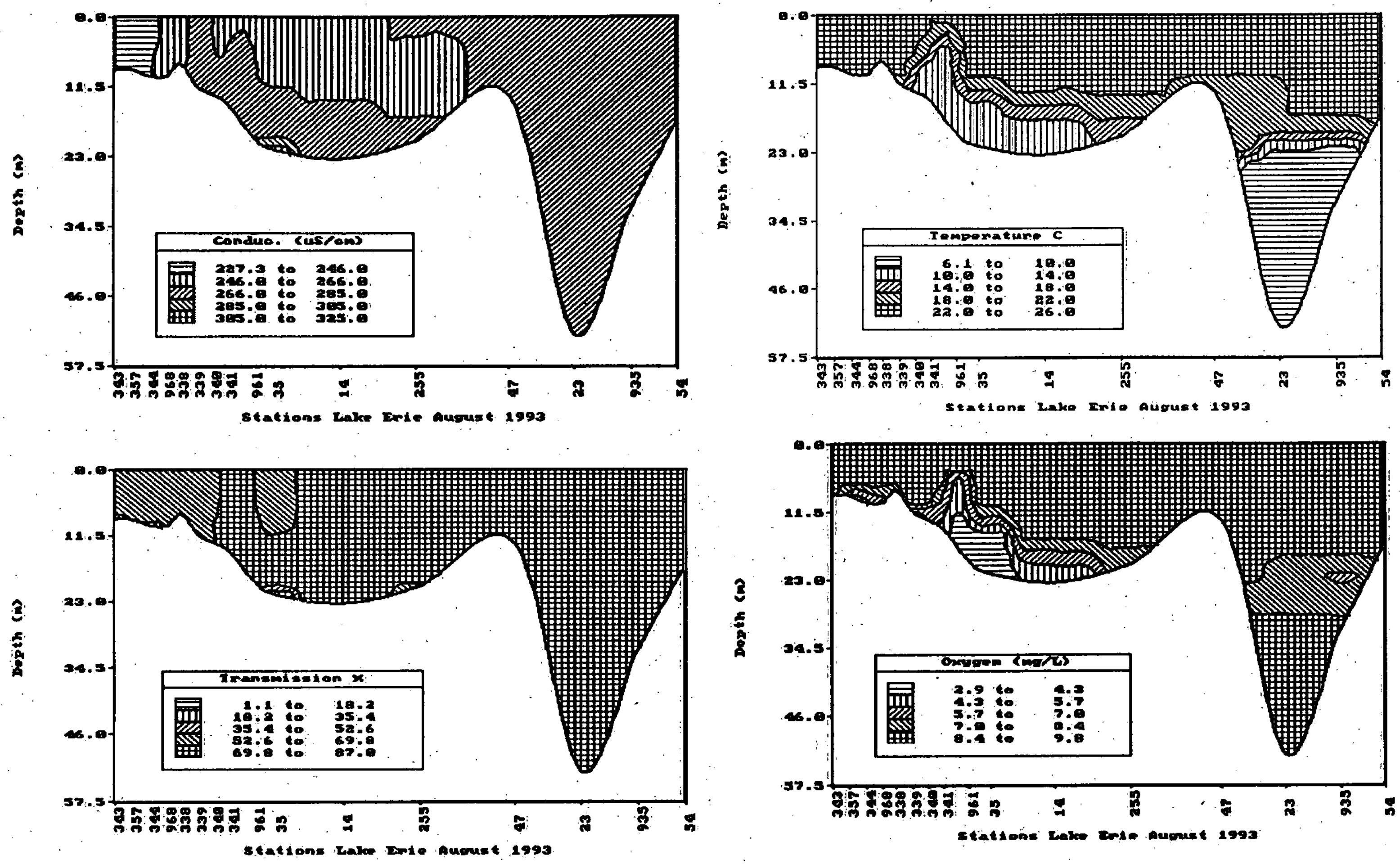

Figure 6 Vertical profile isopleths of conductivity, temperature, dissolved oxygen, and light transmission in August.

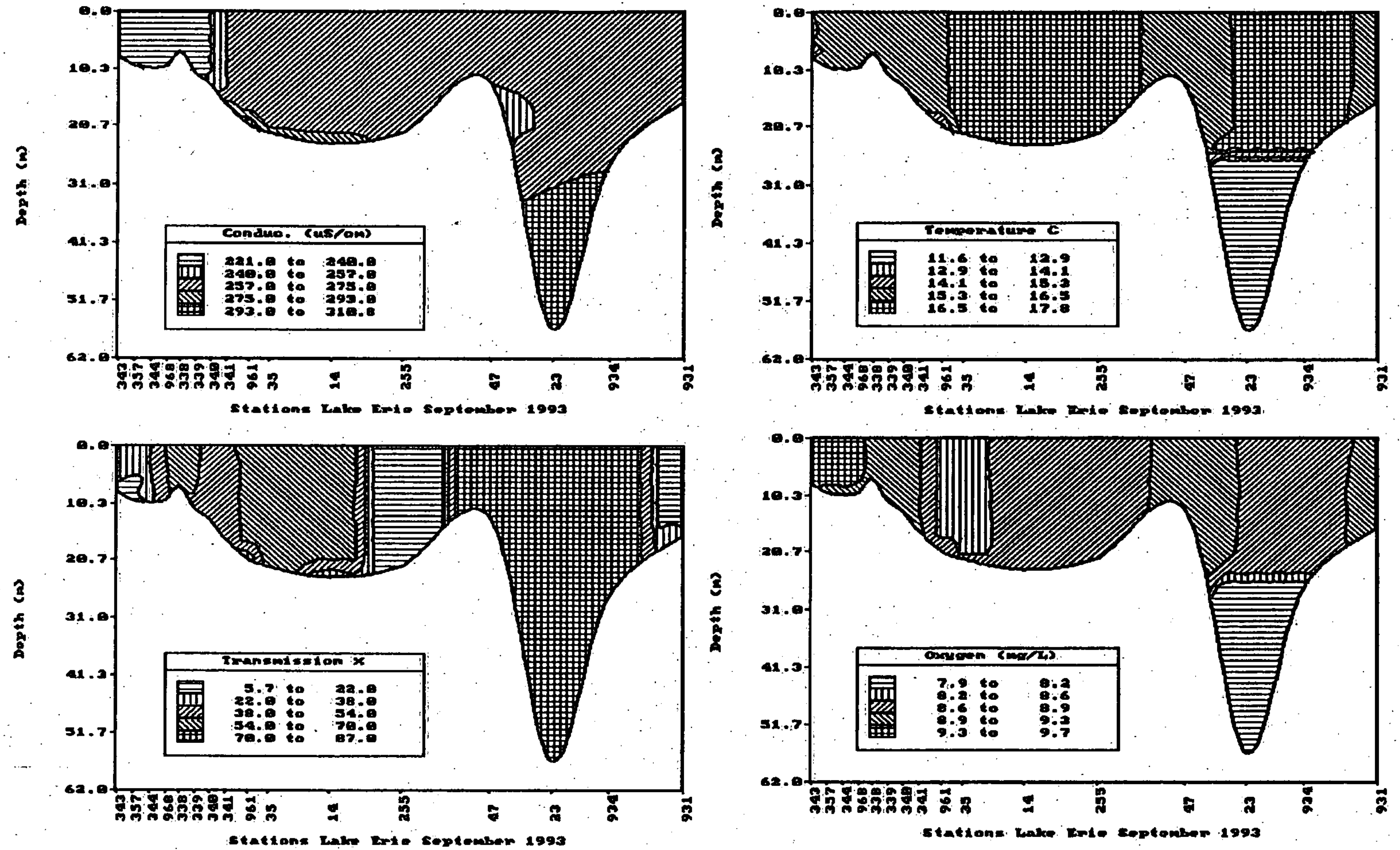

Figure 7 Vertical profile isopleths of conductivity, temperature, dissolved oxygen, and light transmission in September.

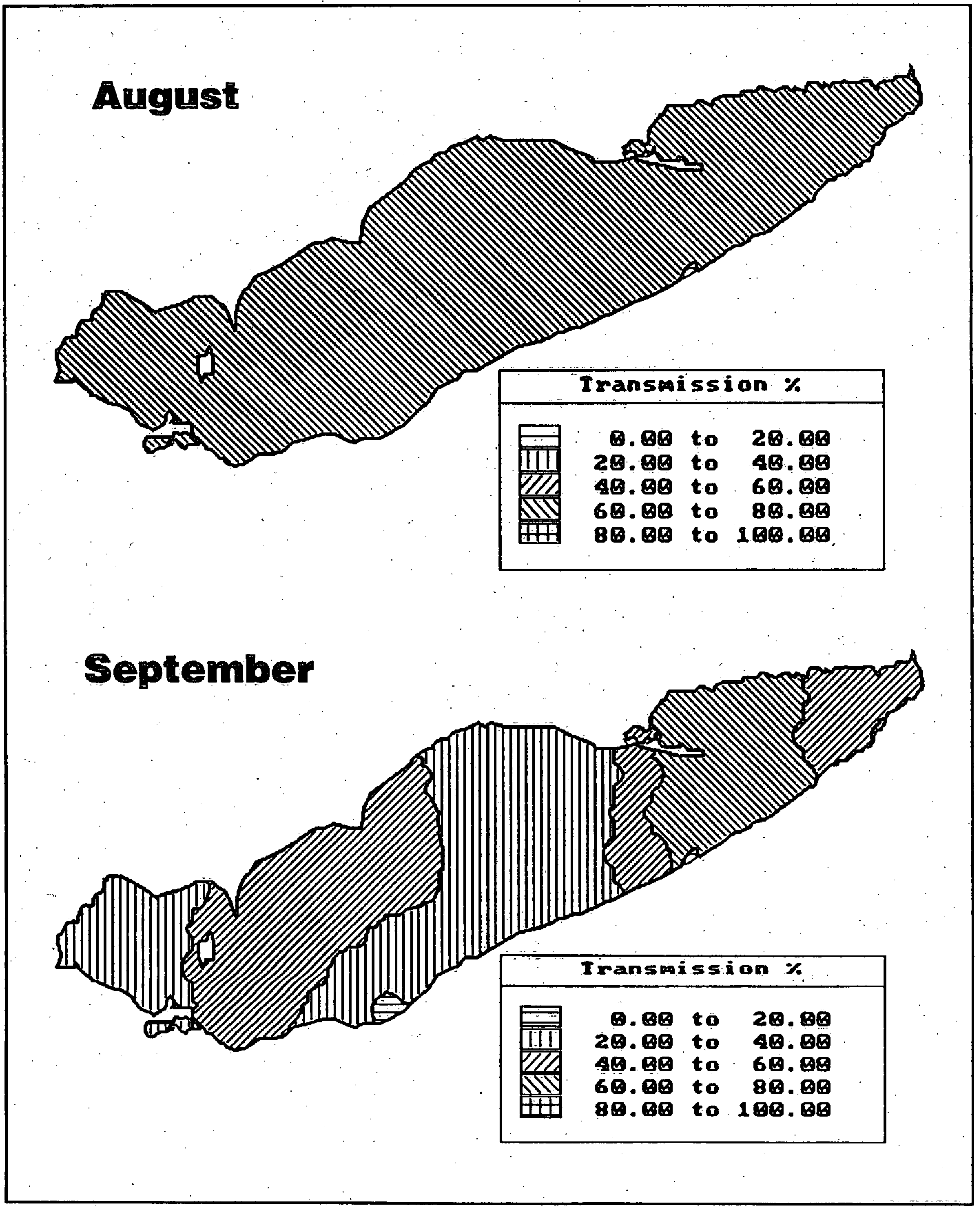

Figure 8 Distribution of light transmission at 2m in August and September.

Data Summaries

Data gathered in 1993 are summarized as basin means for each survey in fig. 9 and tables in appendix 1. Figure 9 shows that the main differences between the surveys was in the form of regenerated nutrients in the central basin and west basin and a decrease in chlorophyll in the west basin. Because the east basin remained stratified in September little change was expected there. In the shallow west and central basins, however, seasonal effects are profound. For this reason assessment of lake productivity must have a seasonal component. Obviously the lake is fundamentally different during most of the year when it is nor stratified and the water has full contact with the sediments.

General Discussion

Phosphorus loadings to Lake Erie have decreased to 50% of loads in the early 1970s. A corresponding decrease in phosphorus concentrations has occurred in the west basin with a less dramatic change in the central and east basins. The zebra mussels then are influencing the lake after a large and deliberate reduction in potential productivity. One of the main questions is how much has potential productivity been reduced?

Figure 10 shows relationships between Secchi depth and chlorophyll as well as the data on TPF and PP where the As and Ss represent August and September values respectively. The expected relation between Secchi and Chla is disrupted somewhat in September by non-chlorophyll turbidity (panel A). The relationship improved in panel B with TPUF which is a less specific indicator of particulates. Panel C shows that there was regeneration of both soluble and particulate phosphorus bearing material in September.

Historic Secchi readings west of Pelee Island are shown in Fig. 11. These results show that, prior to the late 1980s, typical high readings were 2.5m. In the late 1980s high readings of about 3m were obtained. Beginning in 1990 high readings of 4m and more were obtained. At the same time however as these highs were recorded other sites had Secchi depths in the more traditional range of 2-3m. Judging from Fig. 10, a change of Secchi depth from 3 to 4m is consistent with a loss of about 25%-35% of the particulate matter including chlorophyll at some stations. Thus, if the scattered Secchi depths of 4m and more are caused by zebra mussels their effect on productivity may be less than expected when the entire basin is considered seasonally. Clearly, the effect of the mussels must be considered in the context of changes expected from nutrient reductions. While the nutrient loads seemed to reach target around 1986 the full effects may confused by the appearance of the mussels a few years later. A long term data set on algal biomass suggests that the effects of nutrient reductions were most important in the west basin (Nicholls and Hopkins 1994). Nevertheless, the mussels have a large effect on water quality where and when conditions are suitable. An ecosystem assessment requires intensive surveys covering areas with varying mussel populations.addition, satellite images could be used both in a survey sense and a historic sense to add knowledge.

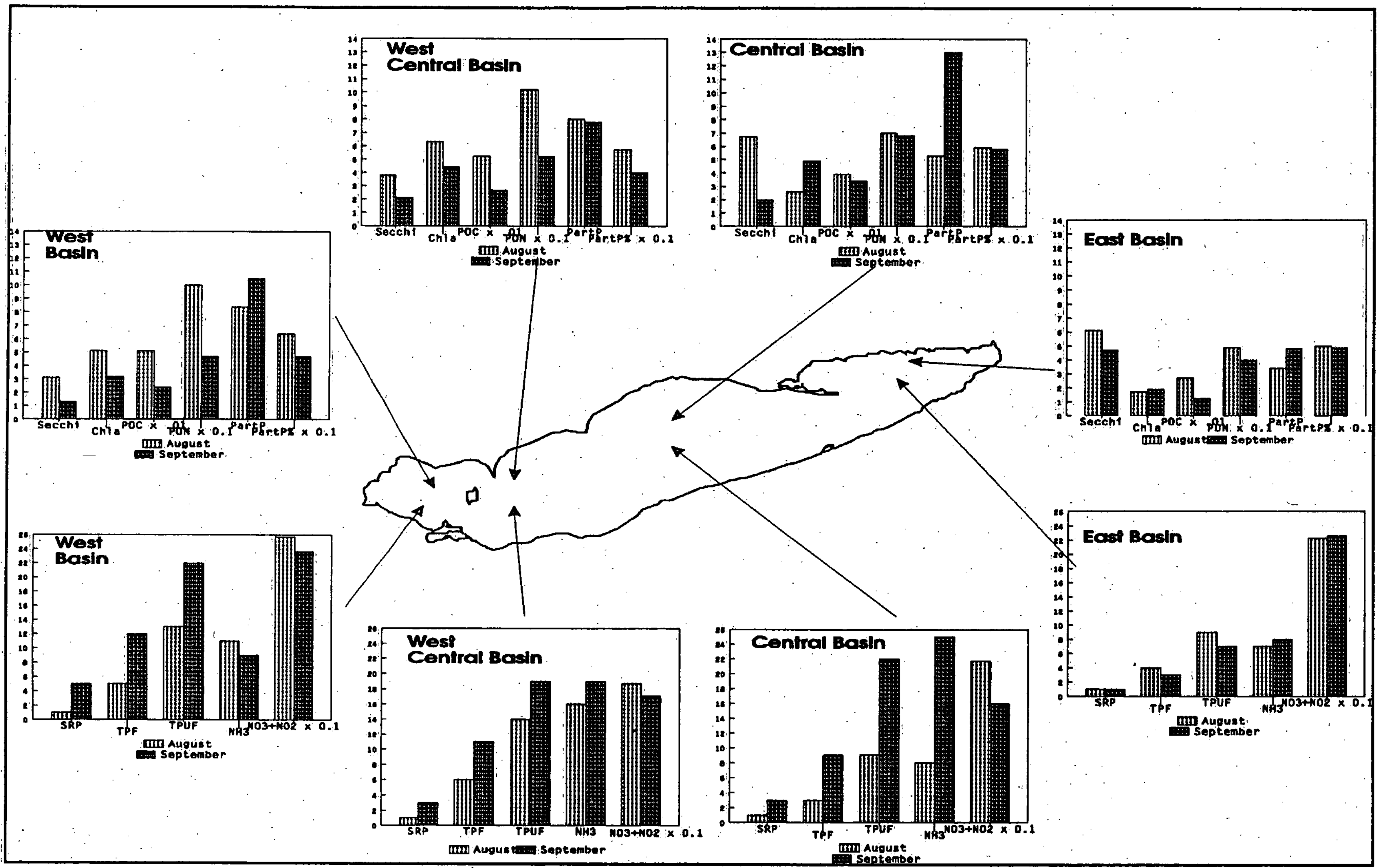

Figure 9 Cruise means for particulates (top) and solubles (bottom).

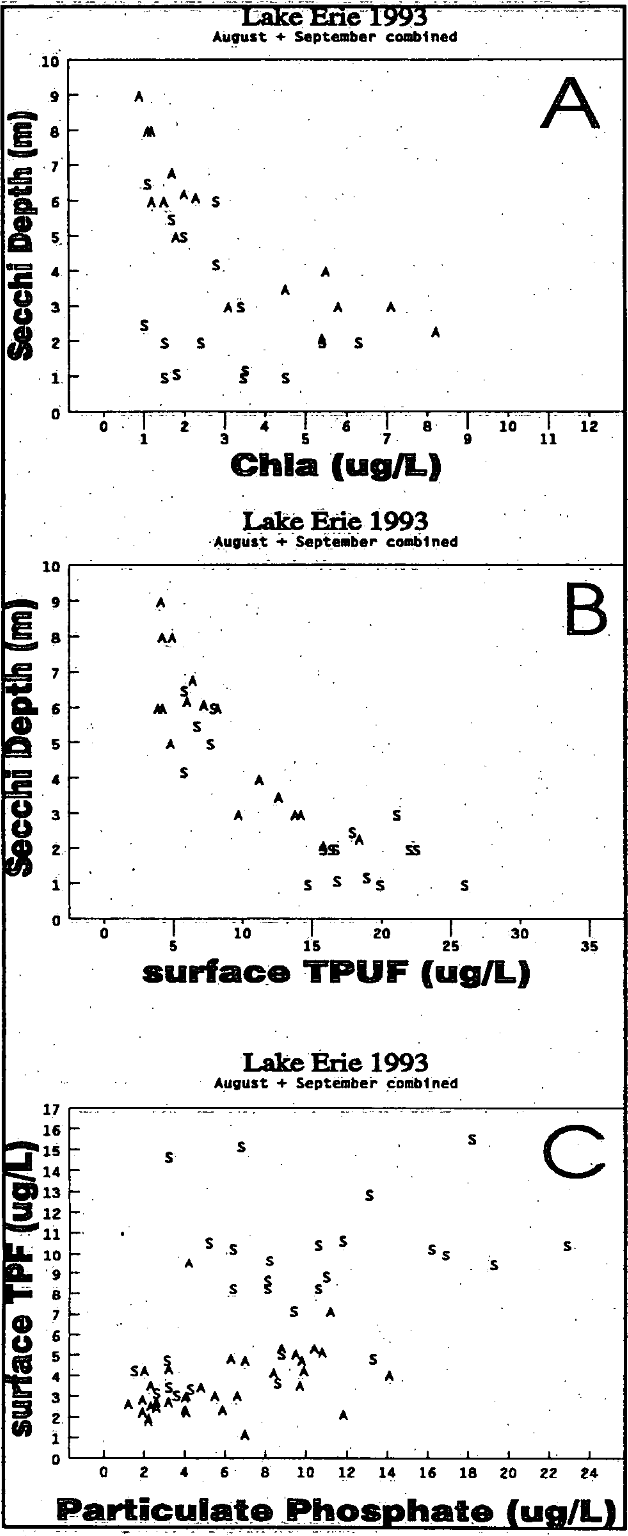

Figure 10 Relationship between Secchi, Chla, TPUF, TPF, and PartP.

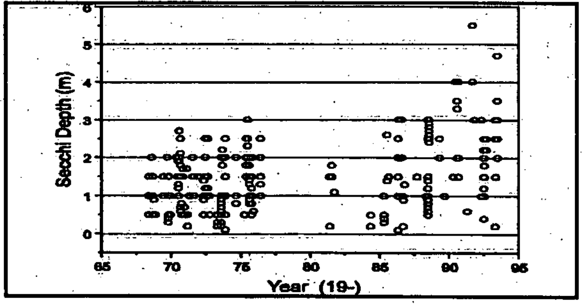

Figure 11 Historic Secchi Depths west of Pelee Island.

The patterns of conductivity shown in the vertical profile transects may indicate a way to delineate water masses in the west basin. This may be important since it is known that relatively clean Lake Huron water occasionally is found in the west basin. Again, the need is for more information to be able to assess the ecosystem effects of the mussels.

A potentially important effect of zebra mussels may be their effect on the processing of contaminants. By filtering material from the water and producing faeces and pseudo faeces, zebra mussels can alter the particle dynamics. To test this I have compared the fraction of total P which is particulate in 1970 and 1993. Table 1 shows that the fraction of total P which was particulate was somewhat lower in the central and east basins in August. The particulate P fraction was significantly lower in the west and east basins in September. This is an example of data which are available and the meaning of the comparison will not be clear until all the data are used. If there has been some shift due to zebra mussels the sedimentation of contaminants may be affected and this may translate into a threat to the edibility of the fish.

Table 1: Percent Particulate P of Total P

	August		September	
	1970	1993	1970	1993
West Basin	65	64	62	47
Central Basin	67	59	64	58
Eastern Basin	68	50	56	49

Conclusions

1) More work is required to determine the effects of zebra mussels on water quality in Lake Erie.

2) Although effects on chlorophyll may be on the order of 25% in one end of the lake this, combined with other effects such as changing species composition of producers and consumers, may constitute a threat to fish production.

3) Preliminary results indicate that there may have been some shifts in particle dynamics coincident with the achievement of nutrient load goals and arrival of zebra mussels.

4) The impact of zebra mussels on contaminants through alteration of particle dynamics needs to be determined.

Acknowledgements:

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Table A1. Surface Water Quality August; Lake Erie 1993

STN	Lat. N	Lon. W	Secchi	Chla	POC	PON	TRANS	T °C	SRP	TPF	TPUF	NH$_3$	NO$_3$+NO$_2$	Part. P	Part. P
			(m)	Integrated sample (µg/L)			(%)	Sampling depth 2m (µg/L)							(%)
West Basin															
972	41/51/57	83/11/57	3	7.1	481	86	58	26.1	1	5	14	7	293	8.8	62
343	41/50/35	83/04/59	3	3.1	414	73	69	25.7	1	3	10	6	254	6.6	68
357	41/49/33	82/58/14	4	4.5	459	96	66	25.0	1	4	13	9	254	8.5	67
337	41/41/19	82/51/24	2	5.4	702	121	54	27.1	1	5	16	11	321	10.4	66
344	41/46/57	82/50/26		5.1	463	102	64	25.1	1	5	15	17	215	9.5	65
968	41/44/29	82/44/00	4	5.5	511	120	69	24.9	1	5	11	17	204	6.3	56
West Central Basin															
30	41/34/04	82/38/07		6.5	538	91	66	25.6	1	4	14	14	143	9.9	70
338	41/41/57	82/37/58	2	8.2	683	130	58	24.4	1	7	18	34	154	11.2	61
339	41/43/40	82/30/58		8.9	586	125	53	24.4	1	5	16	11	128	10.8	68
340	41/45/22	82/24/03	3	5.8	435	96	68	24.0	1	10	14	14	226	4.2	30
341	41/47/05	82/16/54	6	2.3	377	66	73	22.5	1	3	7	7	282	4.1	57
Central Basin * not used for computation															
961	41/54/33	82/10/56		2.0	364	74	72	23.3	1	4	13	9	333	9.7	73
22	41/42/50	82/10/09		11.4	840	154	58	25.2	1	4	18	11	122	14.1	77
342	41/48/48	82/09/58		3.2	397	73	74	22.6	1	3	9	8	276	5.5	64
35	41/57/51	82/02/30		4.0	469	97	69	24.2	1	5	12	13	257	7.0	59
957	41/40/58	81/44/32		2.1	364	68	70	24.3	1	2	8	7	204	5.9	71
18*	41/31/52	81/42/32		4.8	612	107	64	24.9	1	5	15	14	263	9.8	67
84	41/56/31	81/39/07		0.9	336	56	77	24.0	1	3	5	4	213	2.6	51
14	42/06/30	81/34/30		2.5	430	74	73	24.1	0	4	8	11	213	4.8	58
955	41/48/00	81/26/36		1.8	294	63	72	24.5	1	2	6	8	215	4.0	63
953	42/12/22	81/26/22		1.1	297	45	78	24.1	0	2	14	6	206	11.9	84
40	42/21/24	81/26/21		1.9	367	59	74	24.2	0	3	7	7	211	4.0	57
949	42/15/00	81/06/30	5	1.8	399	59	73	25.0	1	3	5	2	177	1.9	40
255	42/08/33	80/59/29	7	1.7	340	60	75	24.4	1	2	6	8	195	4.1	64
43*	42/34/27	80/44/03	6	1.2	264	48	77	24.0	1	2	4	3	204	1.9	45
946	42/09/56	80/38/30	9	0.9	290	50	79	24.6	1	2	4	8	215	2.2	54
945	42/24/09	80/37/53	6	1.5	228	42	78	23.3	1	3	4	3	198	1.2	31
6*	42/27/50	80/23/59	8	1.2	314	61	79	22.3	0	3	5	11	207	2.3	47
47*	42/17/39	80/18/21	8	1.1	261	50	80	26.1	1	2	4	7	204	2.2	52
East Basin															
283	42/34/06	80/06/36													
938	42/38/04	80/03/23													
49	42/36/34	79/56/05		1.1	242	42	79	23.1	1	4	6	8	220	2.0	32
23	42/30/06	79/53/20	6	2.0	223	43	79	23.3	1	3	6	6	219	3.2	53
940	42/26/30	79/50/03	6	1.5	278	54	77	26.0	0	1	8	9	213	6.9	85
934	42/42/30	79/30/30		1.5	294	55	76	23.3	1	3	5	7	229	2.6	48
935	42/35/32	79/28/04		1.1	351	56	78	27.5	1	4	6	11	221	2.3	39
54	42/39/02	79/08/06		2.8	235	42	74	23.5	1	4	8	9	255	3.2	42

Table A2. Surface Water Quality September; Lake Erie 1993

STN	Lat. N	Lon. W	Secchi (m)	Chla	POC	PON	TRANS. (%)	T °C	SRP	TPF	TPUF	NH_3	NO_3+NO_2	Part. P	Part. P (%)
				Integrated sample (µg/L)				Sampling depth 2m (µg/L)							
West Basin															
972	41/51/57	83/11/57	1	1.5	145	24	40	15	3	8	15	4	246	6.4	44
343	41/50/35	83/04/59	1	1.8	222	43	29	15	3	9	17	8	258	8.1	48
357	41/49/33	82/58/14	1	3.5	236	55	29	16	3	8	19	1	258	10.6	56
337	41/41/19	82/51/24		6.1	339	66	11	16	8	16	34	11	214	18.2	54
344	41/46/57	82/50/26	1	4.5	391	63	16	16	4	13	26	14	259	13.1	50
968	41/44/29	82/44/00	2	1.5	113	33	53	16	7	15	22	15	182	6.8	31
West Central Basin															
30	41/34/04	82/38/07		11.5	517	130	38	16	3	10	27	7	138	16.2	61
338	41/41/57	82/37/58	3	1.0	65	12	66	16	7	15	18	19	218	3.2	18
339	41/43/40	82/30/58	2	2.4	145	28	52	16	2	11	16	23	171	5.2	33
340	41/45/22	82/24/03	2	1.5	317	29	52	16	2	10	17	21	187	6.4	38
341	41/47/05	82/16/54	2	5.4	304	63	50	16	1	8	16	23	141	8.1	49
Central Basin * not used for computation															
961	41/54/33	82/10/56	2	6.3	302	83	54	16	4	11	23	38	148	11.8	52
22	41/42/50	82/10/09													
342	41/48/48	82/09/58													
35	41/57/51	82/02/30	3	3.4	234	52	63	17	5	11	21	26	164	10.6	50
957	41/40/58	81/44/32		7.6	356	106	25	16	1	10	29	35	119	19.3	67
18*	41/31/52	81/42/32		9.1	385	82	8	17	1	11	33	13	283	22.9	69
84	41/56/31	81/39/07													
14	42/06/30	81/34/30		2.8	190	50	54	17	3	10	18	22	160	8.2	46
955	41/48/00	81/26/36		8.4	593	67	30	17	6	10	27	27	119	16.9	63
953	42/12/22	81/26/22													
40	42/21/24	81/26/21													
949	42/15/00	81/06/30													
255	42/08/33	80/59/29	1	3.5	219	54	20	17	3	9	20	20	182	11.0	55
43*	42/34/27	80/44/03													
946	42/09/56	80/38/30													
945	42/24/09	80/37/53		2.6	504	65	7	16	0	5	18	10	232	13.3	73
6*	42/27/50	80/23/59		1.6	197	36	37	15	0	4	12	19	251	8.6	70
47*	42/17/39	80/18/21	6	1.7	96	22	79	16	0	4	7	19	235	3.2	48
East Basin															
283	42/34/06	80/06/36	2				56	15							
938	42/38/04	80/03/23	4	2.8	169	40	77	18	0	4	6	8	231	1.5	26
49	42/36/34	79/56/05		1.6	176	43	77	18	0	3	7	6	202	3.6	54
23	42/30/06	79/53/20	7	1.1	93	29	78	17	0	3	6	9	222	2.6	45
940	42/26/30	79/50/03	5	2.0	145	14	77	16	0	3	8	11	224	4.3	56
934	42/42/30	79/30/30	6	2.8	81	24	77	18	0	5	8	7	251	3.1	39
935	42/35/32	79/28/04		1.6	129	27	52	17	1	5	14	7	213	8.8	63
54	42/39/02	79/08/06		1.5	79	104	20	16	2	7	17	4	217	9.4	57

Table A3. Bottom Water Quality August; Lake Erie 1993

STN	Lat. N	Lon. W	TRANS. (%)	SRP	TPF	TPUF	NH_3	NO_3+NO_2
				Bottom (µg/L)				
West Basin								
972	41/51/57	83/11/57	64	1	5	16	22	304
343	41/50/35	83/04/59	24	1	6	15	4	263
357	41/49/33	82/58/14	35	1	4	13	12	240
337	41/41/19	82/51/24	23	1	5	17	29	46
344	41/46/57	82/50/26	13	1	4	14	19	215
968	41/44/29	82/44/00	71	1	6	14	24	215
West Central Basin								
30	41/34/04	82/38/07	54	1	6	23	16	7
338	41/41/57	82/37/58	56	1	5	17	42	171
339	41/43/40	82/30/58	53	6	14	15	19	12
340	41/45/22	82/24/03	59	1	5	15	101	87
341	41/47/05	82/16/54	77	1	4	13	29	232
Central Basin	* not used for computation							
961	41/54/33	82/10/56	79	1	5	10	45	293
22	41/42/50	82/10/09	62	1	5	13	102	193
342	41/48/48	82/09/58	75	1	5	15	39	287
35	41/57/51	82/02/30	77	5	5	10	60	292
957	41/40/58	81/44/32	48	1	3	9	41	226
18*	41/31/52	81/42/32	60	1	3	11	13	204
84	41/56/31	81/39/07	80	1	3	6	20	210
14	42/06/30	81/34/30	82	1	5	8	55	249
955	41/48/00	81/26/36	69	1	3	7	40	204
953	42/12/22	81/26/22	85	1	3	5	20	217
40	42/21/24	81/26/21	82	0	3	5	22	207
949	42/15/00	81/06/30	74	1	4	6	41	268
255	42/08/33	80/59/29	33	1	3	7	48	232
43*	42/34/27	80/44/03	76	1	3	6	18	236
946	42/09/56	80/38/30	80	7	3	4	42	304
945	42/24/09	80/37/53	84	1	3	4	38	317
6*	42/27/50	80/23/59	80	0	2	9	14	222
47*	42/17/39	80/18/21	81	1	3	6	11	215
East Basin								
283	42/34/06	80/06/36		0	0	0	0	0
938	42/38/04	80/03/23		0	0	0	0	0
49	42/36/34	79/56/05	91	1	5	5	36	307
23	42/30/06	79/53/20	90	1	3	4	29	294
940	42/26/30	79/50/03	90	2	5	5	45	304
934	42/42/30	79/30/30	90	1	3	3	36	363
935	42/35/32	79/28/04	88	5	4	4	37	282
54	42/39/02	79/08/06	83	1	4	5	8	260

Table A4. Bottom Water Quality September; Lake Erie 1993

STN	Lat. N	Lon. W	TRANS.	SRP	TPF	TPUF	NH_3	NO_3+NO_2
			(%)	Bottom (µg/L)				
West Basin								
972	41/51/57	83/11/57	45	3	9	23	5	243
343	41/50/35	83/04/59	21	4	9	18	12	264
357	41/49/33	82/58/14	20	4	10	21	2	276
337	41/41/19	82/51/24	11	8	16	34	7	206
344	41/46/57	82/50/26	15	2	12	26	1	249
968	41/44/29	82/44/00	51	9	16	23	20	183
West Central Basin								
30	41/34/04	82/38/07	35	2	11	28	9	133
338	41/41/57	82/37/58	65	7	15	18	22	214
339	41/43/40	82/30/58	55	3	10	17	25	169
340	41/45/22	82/24/03	50	6	12	17	26	212
341	41/47/05	82/16/54	48	2	8	18	23	140
Central Basin	* not used in computation							
961	41/54/33	82/10/56	54	1	8	22	38	142
22	41/42/50	82/10/09						
342	41/48/48	82/09/58						
35	41/57/51	82/02/30	61	5	11	19	22	154
957	41/40/58	81/44/32	23	1	10	27	38	125
18*	41/31/52	81/42/32	5	1	10	33	2	310
84	41/56/31	81/39/07						
14	42/06/30	81/34/30	54	3	9	16	19	161
955	41/48/00	81/26/36	30	5	11	25	24	126
953	42/12/22	81/26/22						
40	42/21/24	81/26/21						
949	42/15/00	81/06/30						
255	42/08/33	80/59/29	20	1	9	21	14	188
43*	42/34/27	80/44/03						
946	42/09/56	80/38/30						
945	42/24/09	80/37/53	5	0	4	18	6	231
6*	42/27/50	80/23/59	34	0	4	14	13	242
47*	42/17/39	80/18/21	78	0	4	7	17	233
East Basin								
283	42/34/06	80/06/36	57					
938	42/38/04	80/03/23	90	0	4	6	17	338
49	42/36/34	79/56/05	90		4	24	1	5
23	42/30/06	79/53/20	82	0	4	5	31	312
940	42/26/30	79/50/03	84	0	5	7	35	307
934	42/42/30	79/30/30	74	0	4	5	3	231
935	42/35/32	79/28/04	61	1	4	9	20	224
54	42/39/02	79/08/06	20	1	14	8	2	218

Table A5. Surface Water Quality averages in August 1993

Basins of Lake Erie	Secchi	Chla	POC	PON	TRANS.	T °C	SRP	TPF	TPUF	NH_3	NO_3+NO_2	Part. P	Part. P
	(m)	Integrated sample (μg/L)			(%)	Sampling depth 2m (μg/L)							(%)
West Basin	3.1	5.1	505	100	63	26	1	5	13	11	257	8.4	64
West Central Basin	3.8	6.3	523	102	64	24	1	6	14	16	187	8.0	57
Central Basin	6.7	2.6	386	70	73	24	1	3	9	8	217	5.3	59
East Basin	6.1	1.7	270	49	77	25	1	3	7	8	226	3.4	50

Table A6. Surface Water Quality averages in September 1993

Basins of Lake Erie	Secchi	Chla	POC	PON	TRANS.	T °C	SRP	TPF	TPUF	NH_3	NO_3+NO_2	Part. P	Part. P
	(m)	Integrated sample (μg/L)			(%)	Sampling depth 2m (μg/L)							(%)
West Basin	1.3	3.2	241	47	30	16	5	12	22	9	236	10.5	47
West Central Basin	2.1	4.4	270	52	52	16	3	11	19	19	171	7.8	40
Central Basin	2.0	4.9	343	68	36	16	3	9	22	25	160	13.0	58
East Basin	4.7	1.9	125	40	64	17	1	4	9	7	223	4.8	49

Table A7. Bottom Water Quality averages in August 1993

Basins of Lake Erie	TRANS.	SRP	TPF	TPUF	NH_3	NO_3+NO_2
	(%)	Bottom (μg/L)				
West Basin	38	1	5	15	18	213
West Central Basin	60	2	7	17	41	102
Central Basin	72	2	4	8	44	250
East Basin	89	2	4	4	32	302

Table A8. Bottom Water Quality averages in September 1993

Basins of Lake Erie	TRANS.	SRP	TPF	TPUF	NH_3	NO_3+NO_2
	(%)	Bottom (μg/L)				
West Basin	27	5	12	24	8	237
West Central Basin	51	4	11	20	21	174
Central Basin	35	2	9	21	23	161
East Basin	70	1	6	9	16	234