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TOTAL PHOSPHORUS IN THE CENTRAL BASIN OF LAKE ERIE: SURVEILLANCE IMPLICATIONS

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MANAGEMENT PERSPECTIVE PERSPECTIVE DE GESTION

Total Phosphorus in the Central Basin of Lake Erie: Surveillance Implications

Phosphore total dans le bassin central du lac Érié : implications de la surveillance

Murray N. Charlton

This is advice to participants in Lake Erie Surveillance on the best way to economize on survey work. The author finds that the summer period is the most stable for surveillance work. The historic summer data do not yet appear to have a statistically declining slope. There are, however, some indications of the expected response to reduced phosphorus loadings. The undetectable change is consistent with persisting oxygen problems. More research is needed on the magnitude of change to be expected at different times and places in the lake.

Ce qui suit est un conseil aux participants de Surveillance du lac Érié sur la meilleure façon de faire des économies pour ce qui est des relevés. L'auteur juge que la période estivale est la plus stable pour le travail de surveillance. Les données estivales historiques ne semblent pas encore présenter de pente statistiquement descendante. Il y a cependant certaines indications de la réaction prévue d'une charge réduite en phosphore. Le changement non décelable est corrélé avec des problèmes persistants d'oxygène. Il faudrait de plus amples recherches sur l'importance du changement à attendre à différents moments et endroits dans le lac.

HISTORIQUE

L'Accord Canada - États-Unis sur la qualité de l'eau des Grands Lacs a entraîné une réduction de la charge de phosphore dans la partie inférieure des Grands Lacs. Une autre des réalisations de cet accord a été la mise en route de programmes de surveillance réalisés conjointement par les deux pays. Par l'entremise de sous-comités des organismes participants, la Commission mixte internationale a récemment mis au point des projets de surveillance mis à jour pour chaque lac. L'EPA des États-Unis, traditionnellement le chef de file responsable de la surveillance du lac Érié, s'est opposée au nouveau plan et a récemment présenté une ébauche d'arguments à l'appui de ses propres plans. Ces plans semblent représenter un changement substantiel de l'effort par rapport aux travaux passés dans le lac Érié et aux plans produits par le comité. Le groupe de travail du lac Érié de la CMI a demandé les commentaires de tous ceux qui sont familiers avec l'effort de surveillance dans le lac Érié.

L'initiative de l'EPA soulève plusieurs questions dans les domaines scientifiques et politiques. Le présent rapport traitera de certaines questions scientifiques.

BACKGROUND

The Great Lakes Water Quality Agreement between Canada and the United States has resulted in reduced phosphorus loadings to the lower lakes. Another accomplishment has been the initiation of surveillance/monitoring programs shared between the two countries. The International Joint Commission has recently developed, through sub-committees of participating agencies, updated surveillance plans for each lake. The U.S. E.P.A., traditionally the lead agency responsible for Lake Erie surveillance, has balked at the new plans and has recently presented draft arguments in support of their own plans. These agency plans appear to be a substantial shift in effort relative to past work in Lake Erie and relative to the committee generated plans. The Lake Erie Task Force of the IJC has requested comments from individuals familiar with the Lake Erie surveillance effort.

The E.P.A. initiative raises several issues in both scientific and political areas. This report will deal with some of the scientific issues.

REPORT

Concern about Lake Erie and the desire to assess the effects of massive expenditures for reduced nutrient loading resulted in surveillance by both Countries. These efforts have produced a more or less continuous data set from 1970 to the present. Early in the program the pronounced seasonal cycle of nutrient chemistry was apparent and this caused most workers to extend their surveys through much of the ice free period. The natural curiosity about the seasonal cycle persists because knowledge of it helps to interpret other information. In this case the other information of interest is the 15 years of phosphorus data with regard to whether subsequent efforts can be more cost effective and whether the loading reductions reduced phosphorus concentrations in the lake.

In the historic data the earliest and latest surveys tended to occur in the early years of the data gathering effort. Figure 1 shows that these early and late surveys in the Central Basin, tended to have high phosphorus values. The high P values are variable in the Spring and Fall. It is now accepted that the high values and the variability are caused by resuspended bottom sediments. Indeed, Fig. 1 shows the effect of progressively greater depth in reducing variability from the Western to the Eastern Basin. Unless the Lake Erie surveillance community wants to correlate the concentration of P on suspended sediment with nutrient loadings there are few conceptual links between P loading and P concentrations in the water during Spring and Fall.

Central Lake Erie in the Spring and Fall is similar to a nearshore zone in that any P concentration can be found at any time. There is a high probability of high values caused by simple physical factors. These data are not particularly valuable for assessment of loading reduction effects.

There is a tendency now to reduce the surveys to cover the period early Summer to early Fall. This means a trend analysis encompassing all the data will almost inevitably result in larger apparent reduction in lakewater P due simply to sampling strategy. Such an effect was demonstrated by Rosa 1985.

One of Rosa's analyses (Fig. 2) was restricted to the mid-June to mid-August period in an attempt to minimize the confusing effects of the resuspension during Spring and Fall. This understandable reaction to the data results in the question: "How many data (when and where) are required for surveillance each year?

The answer depends on many assumptions; the remainder of this report depends on the assumptions that:

1) We are not attempting to calculate annual mean P concentrations since we cannot adequately sample the extreme variability and the seasonal cycle may occur at different times each year and biasing of the calculation due to resuspension is unavoidable.

2) We wish to correlate P management with other related measures such as hypolimnion oxygen and Chlorophyll.

3) We wish to minimize the amount of judgemental overhead analysis such as Limnological examination of thermal structures.

4) We wish to minimize variability caused by simple physical factors such as resuspension.

Upon observing Fig.1 and other seasonal cycles drawn by H.F.H. Dobson (Lake Erie Water Quality Atlas in prep) I am led to the conclusion that the summertime period July 1 to August 31 contains the most consistent data as there seems to be a P minimum then every year. In addition, I propose that data from the productive zone of Ø-1ØM be used since this zone is defined without Limnological examination and contains water visible to the public, will produce organic material eventually contributing to oxygen depletion, and the thermocline prevents vertical resuspension contamination at the chosen time. Finally, the data should be restricted to the offshore area.

Compared to other analyses, the main differences are that this approach actively seeks the usual P minima instead of gradually reducing the data used in the beginning and end of the season. The date "window" is arbitrary to prevent inclusion of annual minima in other months.

A data retreival from the NWRI "Star" data base was done with the following restrictions: Lake Erie Central Basin, total P betwen Ø and 1ØM, stations within an offshore polygon established by H.F.H Dobson. The polygon of Dobson is expected to give about the same results as the "homogeneous zone" used by Rosa (1985). When there were both U.S. and Canadian data I used the latter. This retreival did not yield any data for 198Ø,1,2 although U.S. data are reported by Rosa (1985). Data from an NWRI "anchor station" experiment were used for 198Ø. Over an eight day period in Aug 198Ø total P ranged from 9.Ø to 15.9 in surface water at the "anchor station (C11)". Phosphorus data in 1983 from the NWRI surveys are flagged. I examined the 1983 data individually and removed for these purposes data which seemed too high.

RESULTS

The means and standard deviations of the applicable cruise surveys are shown in Fig 3. Figure 4 shows all the qualifying means without the standard deviations. Tables 1 and 2 show data summaries and results of a linear regression of mean P against year.

These results show that the offshore data in Ø-1Øm during July and August are remarkably stable. This characteristic should make the qualifying restrictions suggested attractive for surveillance purposes.

Of course, the regression results do little to increase confidence that loading restrictions have lowered P concentrations in the Central Basin. That such a simple change of depth and time in the data used should be able to alter the presentation and impressions of a trend is startling! The main analytical differences from this and Rosa's (1985) paper would seem to be in the depth delimiter of Ø-1ØM compared to "epilimnion". Inspection of total phosphorus profiles shows that there is a chance of including high values near the thermocline if the thermal delimiter of "epilimnion is used. Also, some cruises in the first last 2 weeks of June have total P concentrations which reflect variable Spring conditions and these were excluded in this presentation. Since the correlation coefficients with time in Tables 1 and 2 do not confirm a slope I conjecture that there are still too few data to prevent conflicting analyses. On the other hand, there is an impression left by the data that the lowest values are becoming lower

I have not found reasons to reject the results of this data retrieval. The programs used are a subset of the general retreival program called "GENRET". The specific routines are called "DOBRET". In an attempt to find corroborating information I have examined data in Burns et al. (1976). Volume weighted means for the epilimnion in 197Ø were 14.9ug/L, 11.5ug/L, and 11.5ug/L in surveys beginning July 3, July 28, and Aug 25 respectively. Considering that these data are from the entire basin they are in good agreement with the results of the present retrieval. Additional data fitting the Ø-1ØM criterion were also reported for 1971 in Burns et al. (1976). There were four stations sampled on July 29 and Aug 31. Total P was measured in 14 samples resulting in a range of 9.9-16.4 ug/L with a mean of 11.6ug/L. This is in good agreement with the lower of the two cruise means in the present retrieval for 1971 and is consistent with the 197Ø data.

Although there is some indication in Figs 3-5 that the lowest cruise means are becoming lower the stability in the data is consistent with continuing observations of low oxygen in the Central hypolimnion (anoxic again in 1985). How could this happen when the loadings to the lake have been reduced so much?

Much (77%) of the P loaded to the West Basin is retained there (Burns 1976). This is highly important because most of the controlled loadings are in the West Basin. If West Basin loads were decreased by 9000 tonnes then the reduction in the Central Basin would be 9000x0.23 = 2070 tonnes or 2070/11947 = 17% of Central Basin loading according to figures in Burns (1976). Another way to appreciate this is to assume a 50% reduction in West-Central Basin transfer figures of Burns (1976). This gives a reduction of 3107 tonnes annually which is equivalent to 3107/11947 = 26% of the load in 1970. These figures are, of course subject to several assumptions and may differ slightly depending on how much tributary loads have changed. The main point is that the effective relative loading reduction in the Central Basin may be 25% or less not ca 50% as expected from whole lake loading reductions.

A 25% reduction in July-Aug total P concentrations from those of 1970-71 would result in a decrease of about 3ug/L which is equivalent to 0.2ug/L/yr if the reduction occurred between 1970 and 1985. Thus, the maximum expected slope in the July-Aug data may be about half that of 0.5lug/L/yr in Rosa's (1985) different data set. This comparison depends on the assumed P concentration at the beginning of controls. It may be fortuitous but the slopes in Tables 1 and 2 are virtually identical with rough expectations above. More important for the Surveillance program is that a reduction of 3ug/L will be difficult to detect with certainty (see Fig. 3) and this is consistent with the failure of regression analyses in Tables 1 and 2 to confirm a trend.

CONCLUSIONS

1) The question of how best to do trend monitoring needs to be addressed with a thorough examination of all data. For example, even though total P cannot be used year round, perhaps soluble P would show a correlation with loading peaks due to Spring runoff and Fall storms. Additional research is needed.

2) Chemical trend monitoring in Central Erie can be done in July and August at 0-10M in the "homogeneous zone". There is doubt as to how many stations are needed in a homogeneous zone, perhaps very few. A cost effective operation may be to use a shore based contractor to sample from Erieau at the same few stations every week.

3) Oxygen trend monitoring has to allow the slope each year to be measured. Again this might be done at just a few stations.

4) A fully cost effective trend monitoring program will reduce potential to fully understand the lake. This should be assessed as to how far an activity can be reduced before valuable information is foregone in each unique year.

5) A slight change in criteria for the trend analysis has caused different results. Although regression analysis yielded a slope consistent with new expectations there was essentially no correlation of total P with year given the data selected. This is not inconsistent with the small relative change expected. This also seems consistent with recurring low oxygen conditions in the Central Basin hypolimnion.

6) Spring water chemistry surveys will not be useful in Lake Erie unless a system is developed to eliminate variability due to sediment effects.

7) The phosphorus budget of the Central Basin of Lake Erie should be calculated for the early 1970s and late 1980s to determine the scale of concentration reductions expected.

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Burns, N.M., F. Rosa, and C.H. Chan, 1976. Lake Erie Water Chemistry Data 1970-71. Canada Center For Inland Waters Paper #16.

El-Shaarawi, A.H. 1984. Statistical assessment of the Great Lakes Surveillance Program, 1966-1981, Lake Erie.

Rosa, F. 1985. Lake Erie Central Basin Total Phosphorus Trend Analysis from 1968 to 1982. NWRI Contribution # 85-101.

FIGURES

Figure 1 :Seasonal variation in total phosphorus in Lake Erie (from El-Shaarawi, 1984).

Figure 2: Phosphorus trends derived by Rosa (1985).

Figure 3: Cruise mean and standard deviation of total phosphorus in Lake Erie 1970-85.

Figure 4: Cruise mean total phosphorus in Lake Erie 1970-85.

TABLE 1

TOTAL PHOSPHORUS CRUISE MEANS LAKE ERIE 0-10M
JULY-AUG CENTRAL BASIN

YEAR	MEAN
1970.509	10.5
1970.575	10.9
1970.652	11.5
1971.512	26.8
1971.630	11
1972.589	13.5
1972.663	15
1973.547	11.7
1974.506	11.7
1974.621	11
1974.663	11.1
1975.531	10.1
1975.542	9.8
1976.646	17.9
1977.515	11.9
1977.575	11.2
1977.610	12.9
1977.668	15.5
1978.545	10.2
1978.643	12.7
1979.512	10
1979.567	10.7
1979.646	11.7
1980.528	8.4
1980.632	11.79
1983.534	8.9
1983.569	11
1983.610	9.8
1983.646	12.6
1984.550	11.76
1984.610	11.46
1984.638	11.8
1984.663	8.36
1985.512	8.9
1985.567	13.4
1985.630	12.2

Regression Output:

Constant		400.2435
Std Err of Y Est		3.087661
R Squared		0.093003
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	-0.19627	
Std Err of Coef.	0.105118	

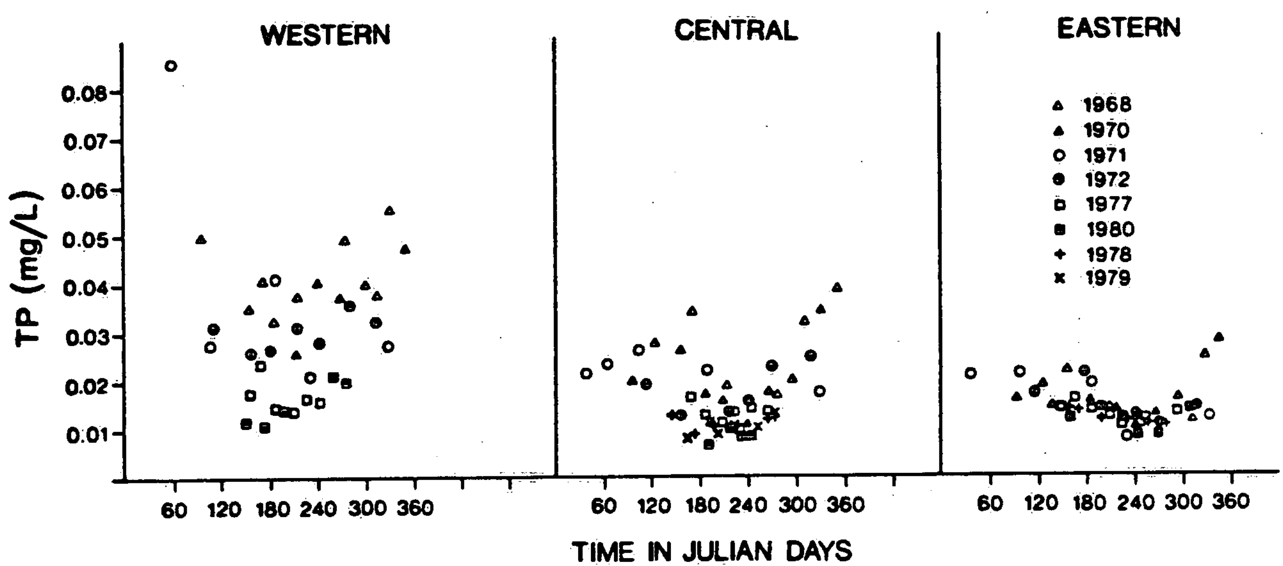
TABLE 2

MEANS OF CRUISE MEANS TOTAL P LAKE ERIE 0-10M
JULY-AUG CENTRAL BASIN

YR	MEAN
1970.069	11.0
1971.062	18.9
1972.116	14.3
1973.518	11.7
1974.133	11.1
1975.027	10.0
1976.137	17.9
1977.058	12.9
1978.085	11.5
1979.066	10.8
1980.58	10.1
1983.081	10.6
1984.615	10.9
1985.060	11.5

Regression Output:

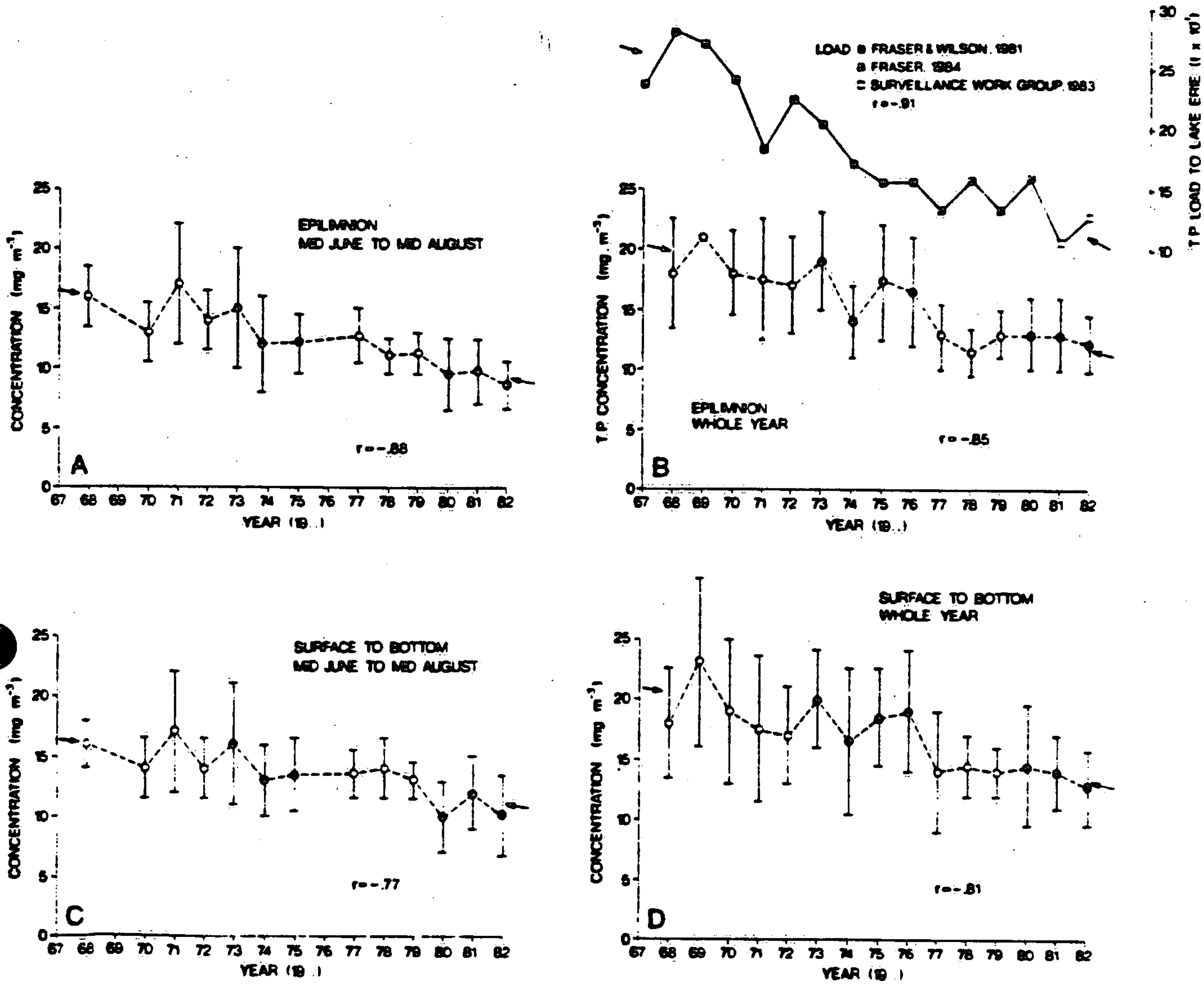
Constant	483.573
Std Err of Y Est	2.648
R Squared	0.173
No. of Observations	14.000
Degrees of Freedom	12.000
X Coefficient(s)	-0.23834
Std Err of Coef.	0.150374



Mean TP against Julian days for the Western, Central and Eastern basins.

Figure 1

Figure 2



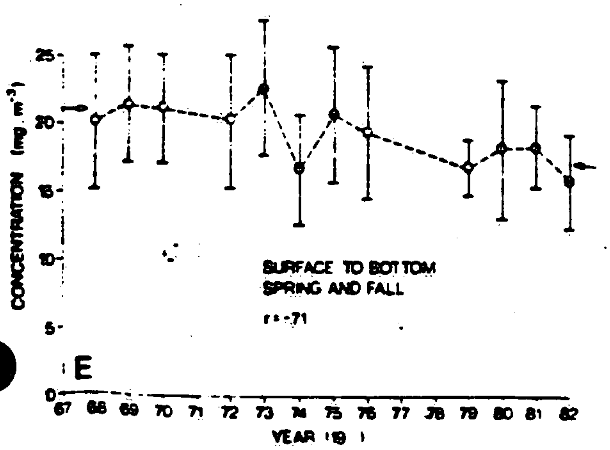


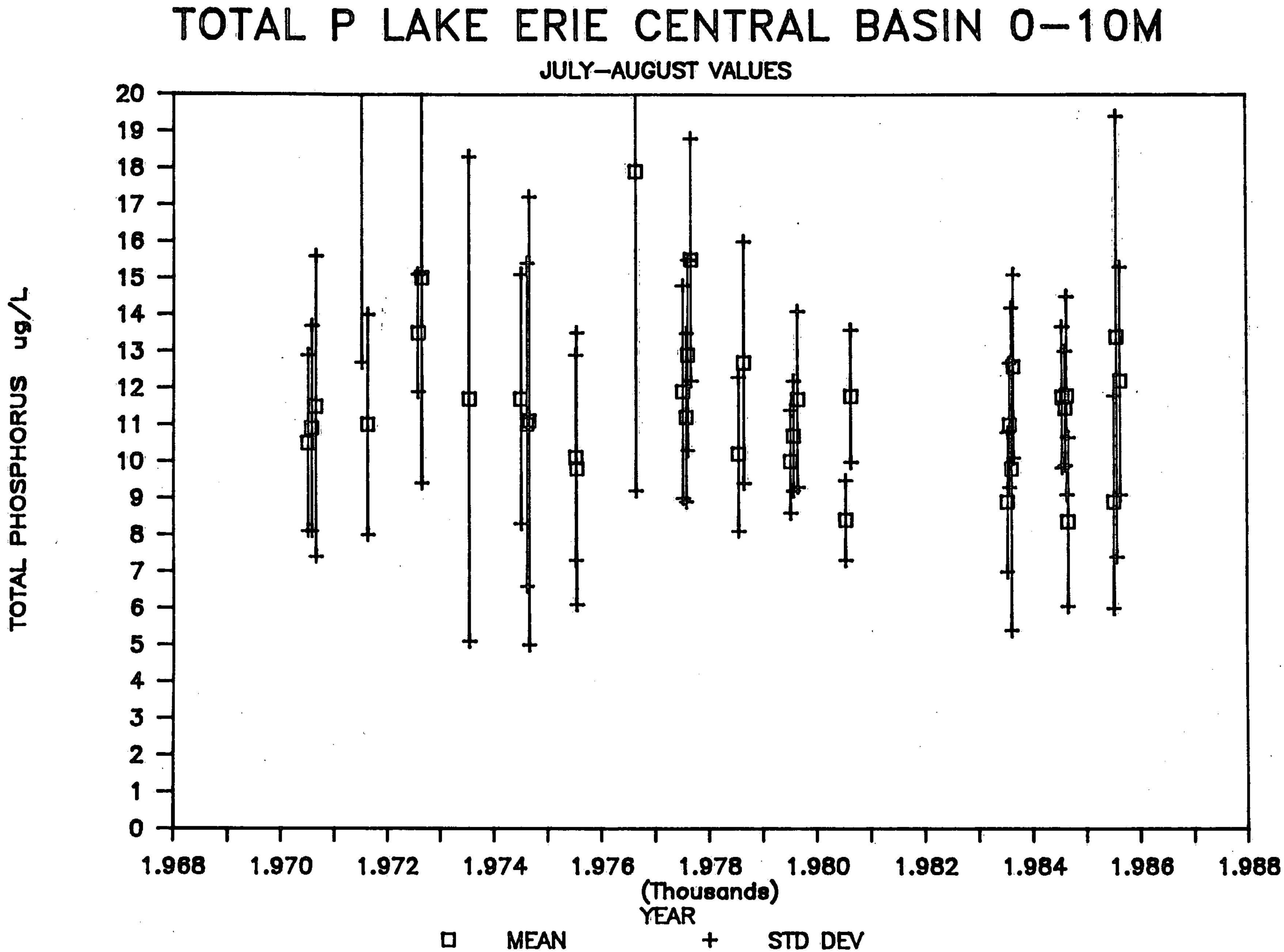
Figure 2

LAKE ERIE CENTRAL BASIN TOTAL PHOSPHORUS CONCENTRATION TRENDS, AND TOTAL LOADINGS TO LAKE ERIE.

○ CAN DATA

● US DATA

Figure 3



TOTAL P LAKE ERIE CENTRAL BASIN 0—10M
JULY—AUGUST VALUES
TOTAL PHOSPHORUS ug/L
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1.968
1.970
1.972
1.974
1.976
1.978
1.980
1.982
1.984
1.986
1.988
(Thousands)
YEAR
MEAN
STD DEV

Figure 4

TOTAL P LAKE ERIE CENTRAL BASIN 0–10M

JULY–AUGUST CRUISE MEANS OFFSHORE