THE NEARSHORE WATER QUALITY

OF

SOUTHEASTERN LAKE HURON

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by
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I SUMMARY

The extent of eutrophication in nearshore southeastern Lake Huron during the ice—free period of 1980 substantiates the findings of Ross and Chatterjee (1977) and Hopkins (1983) that the water quality of certain localized areas in this region tends toward mesotrophy (i.e., moderate nutrient enrichment).

Although a storm event disrupted the 1980 sampling schedule and complicated data interpretation, meaningful trends were still apparent: at Grand Bend and Goderich (excluding late fall storm conditions) mesotrophy characterized the nearshore extending beyond the immediate sampling areas(i.e., beyond 3-4 km on either side of the Ausable and Maitland Rivers, respectively), while to the north at Southampton mesotrophic conditions were limited to within 1.5 km radius of the Saugeen River mouth.

Nutrient entrapment from tributary and municipal loadings, storm—induced sediment resuspension and increased shoreline erosion are believed to account for the more extensive nearshore enrichment in the southernmost areas. Finally, elevated chloride concentrations occurred in the vicinity of the Maitland River mouth, an apparent result of discharge from the Sifto salt plant located approximately 4 km upstream.

II RECOMMENDATIONS

To protect Lake Huron from environmental degradation due to the growth of nuisance algae, in particular *Cladophora*, every effort should be expended to:

i. Maintain background total phosphorus concentrations below 0.005 mg/L which Jackson and Hamdy (1982) believe approximates the lower nutritional limit for *Cladophora* growth.

ii. Improve agricultural methods to reduce nutrient (especially phosphorus) inputs associated with agricultural runoff from the Lake Huron watershed.

iii Control nutrient (especially phosphorus) inputs from municipal and industrial sources. For example, by strictly limiting effluent nutrient concentrations and by opting for methods of effluent disposal other than direct discharge to the Lake.

iv. Although unrelated to the growth of nuisance algae, appropriate measures should also be taken to minimize chloride loadings from the Maitland River.

v. Implement an annual water quality surveillance plan for Lake Huron to measure the effectiveness of abatement activities and to identify emerging problems.

III INTRODUCTION

In 1974, at the request of the International Joint Commission and under the direction of the Upper Lakes Reference Group (ULRG), the Ontario Ministry of the Environment and Environment Canada surveyed the water quality of Lake Huron (ULRG 1977a and b). The ULRG concluded that the water quality of Lake Huron was excellent except for certain localized nearshore areas, primarily embayments, river mouths and harbours. These areas showed signs of eutrophication (an enrichment process leading ultimately to fouling of water supplies, aquatic habitat degradation and fish kills).

In order to determine the extent of eutrophication and ensure the protection of open lake waters, further surveillance of affected nearshore areas was recommended. This investigation, as part of the Great Lakes International Surveillance Plan for Lake Huron, Georgian Bay and the North Channel, addresses the extent of eutrophication in three nearshore areas (Southampton, Goderich and Grand Bend) of southeastern Lake Huron during the ice—free period of 1980.

IV STUDY AREA AND WATER USES

The southeastern Lake Huron drainage basin is composed primarily of limestone bedrock overlain by clay/sand soil (Fig. 1). Almost half (45%) of the basin is pasture; 30% is cropland and 23% forest. Less than 2% of the region is affected by urban development. Local municipalities rely on Lake Huron as a water supply and as a receiving body for waste water discharge (treated municipal sewage, storm sewer runoff). None of the municipalities currently utilize tertiary treatment (i.e., phosphorus removal) at their sewage treatment facilities (Table 1).

Southeastern Lake Huron is used extensively for water oriented recreational activities (e.g., cottaging, camping, swimming and sport fishing). Sport fish include perch, rainbow trout and salmon, while the commercial fisheries (whitefish, perch and chub account for 90% of the total catch) average 355,000 lbs/yr (1972 to 1982 for the statistical district Clark Point to Grand Bend, Ontario Ministry of Natural Resources unpublished data).

Fig. 1: Nearshore southeastern Lake Huron sampling area, 1980. Diamonds and triangles represent open lake sites north and south, respectively. Open lake data courtesy of Environment Canada.

Table 1. Population, municipal works and hydrological details of the southeastern Lake Huron drainage basin (Anon 1980, MOE 1979; MOE unpublished).

SAUGEEN RIVER	Drainage Area	4,066 km^2
	Annual Mean Discharge Rate	55.4 m^3/sec
Southampton	Population	2,645 (1980)
	Water Supply	Lake Huron (chlorinated)
	Drawing Rate	2.3 x 10^3 m^3/day
	Plant Capacity	3.8 x 10^3 m^3/day
	Sewage Treatment	Oxidation ditch
	Works Capacity	3.8 x 10^3 m^3/day
	Effluent Discharge Rate	1.6 x 10^3 m^3/day to Saugeen R.
MAITLAND RIVER	Drainage Area	2,137 km^2
	Annual Mean Discharge Rate	23.3 m^3/sec
Goderich	Population	7,391(1980)
	Water Supply	Lake Huron (fluoridated and chlorinated)
	Drawing Rate	8.5 x 10^3 m^3/day
	Plant Capacity	11.8 x 10^3 m^3/day
	Sewage Treatment	Conventional secondary
	Works capacity	9.0 x 10^3 m^3/day
	Effluent Discharge Rate	7.7 x 10^3 m^3/day to L. Huron
AUSABLE RIVER	Drainage Area	865 km^2
	Annual Mean Discharge Rate	9.3 m^3/sec
Grand Bend	Population	681(1980)
	Water Supply	Lake Huron Water Supply System (chlorinated)
	Drawing Rate	0.7 x 10^3 m^3/day
	Plant Capacity	9-13 x 10^3 m^3/day
	Sewage Treatment	Lagoons
	Works Capacity	1.9 x 10^3 m^3/day
	Effluent Discharge Rate	ND to Ausable R.

ND - No data

V METHODS

In 1980 MOE allocated a total of fifty-seven sample sites to the three nearshore areas of concern: Grand Bend/Ausable River (Fig. 2), Goderich/Maitland River (Fig. 3) and Southampton/Saugeen River (Fig. 4). A single transect consisting of five stations was located off each river mouth, while the remaining thirteen or fourteen stations were distributed closer to shore extending 3 to 4 km on either side of the main transect.

Three synoptic cruises were carried out at Southampton and Goderich: early summer (late June), late summer (late August) and late fall (mid October to early November), while at Grand Bend, only the two summer cruises were conducted. In most cases, each site was sampled on three consecutive days on each cruise. At each site, Secchi depth was recorded (in duplicate) and samples for water chemistry (including chlorophyll a) were collected at 1.5m depth; analyses included: total phosphorus, ammonia, nitrate-nitrite and total Kjeldahl nitrogen, reactive silicate, chloride, conductivity and corrected chlorophyll a. All chemical analyses were performed at the Ontario Ministry of the Environment Laboratory in Rexdale, Ontario according to standard methods (MOE 1981).

VI RESULTS AND DISCUSSION

To assess localized enrichment effects sample sites in each of the nearshore areas were grouped. Two groups of three open lake sites were also included for nearshore/offshore comparison.

The data set presented here is incomplete and excessively variable because a storm event disrupted the late fall cruise (i.e., Goderich and Southampton were sampled, while Grand Bend was not). The storm event resulted in a major deterioration of water quality at Goderich which overshadowed all other time and spatial comparisons.

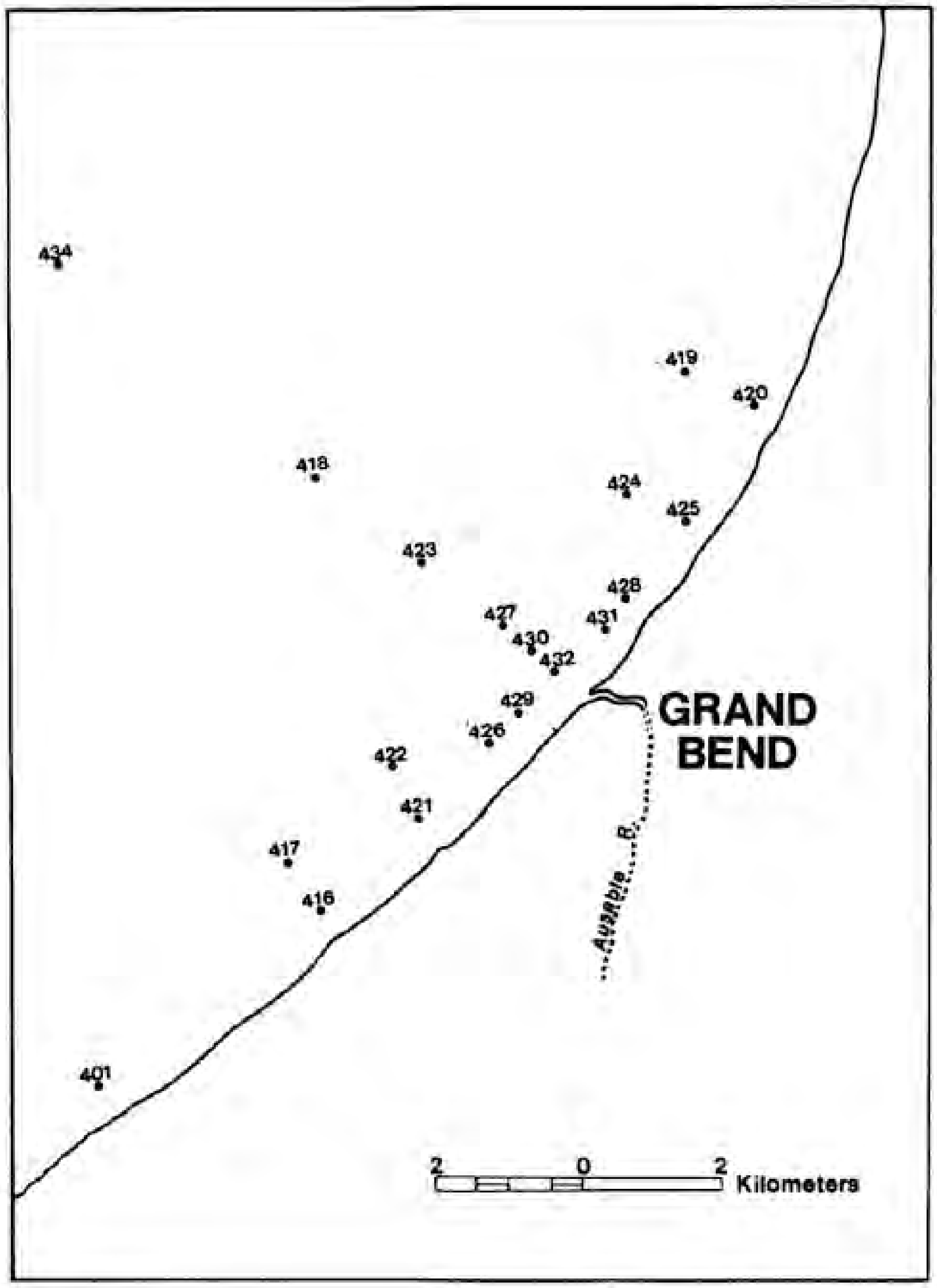

Fig. 2: Grand Bend area sample sites, 1980

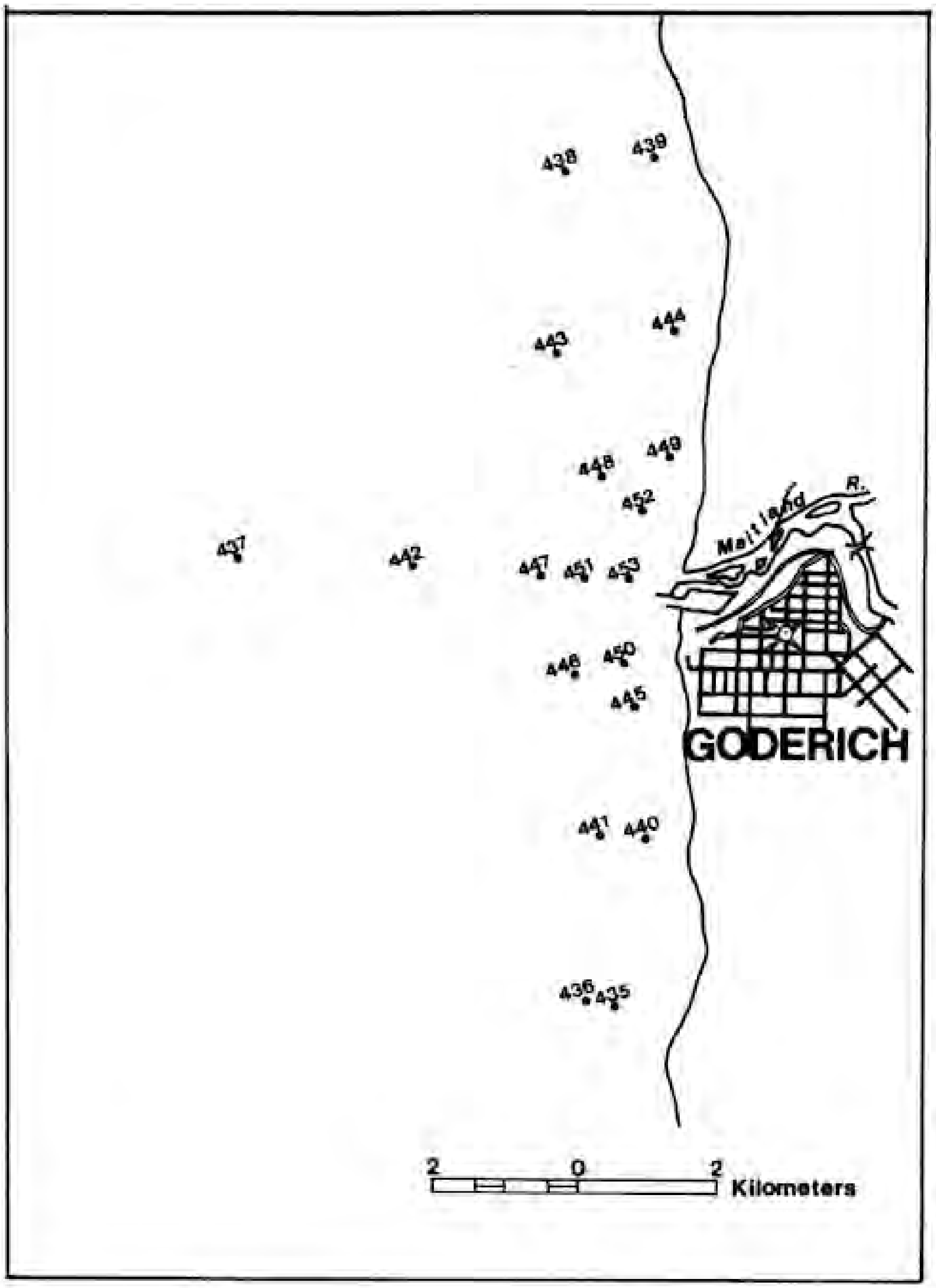

Fig. 3: Goderich area sample sites, 1980

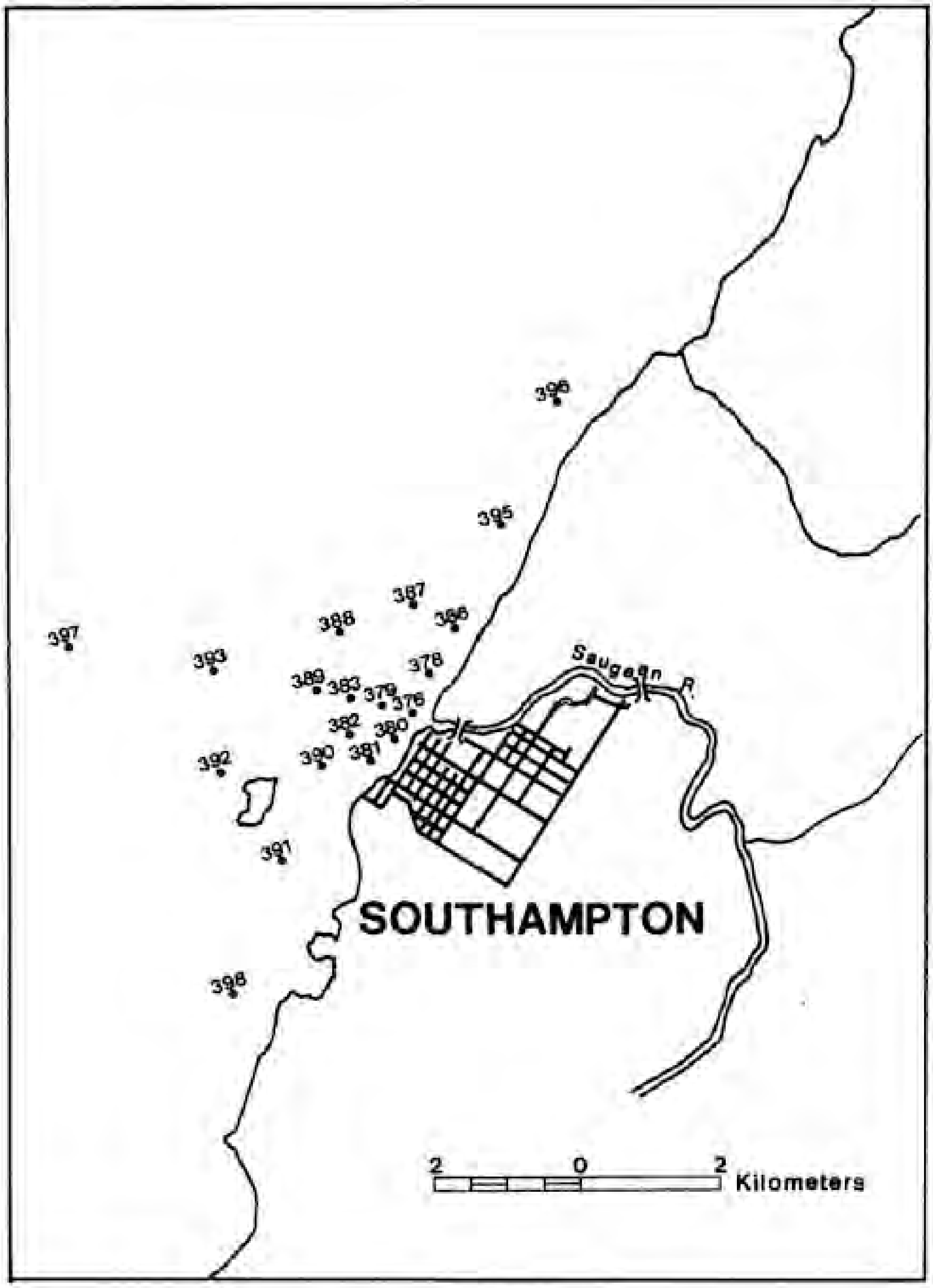

Fig. 4: Southampton area sample sites, 1980

6.1 Nutrients

Phosphorus

Background phosphorus (P) concentrations in Lake Huron are apparently too low to support the growth of the nuisance alga *Cladophora*. Instead *Cladophora* occurs locally in association with natural and anthropogenic nutrient sources. In extreme southern Lake Huron, sandy substrates limit the potential for *Cladophora* growth; however to the north, the exposed rocky shorelines of much of the main Lake, and especially Georgian Bay, provide a vast potential habitat for the alga (Neil and Owen 1964, Auer and Canale 1980, Jackson and Hamdy 1982; Jackson 1985).

During 1980, yearly (ice-free) mean concentrations of total P at Southampton, Grand Bend and Goderich were 0.006, 0.008 and 0.010 mg/L, respectively, while open lake mean values were lower at 0.004 mg/L (Table 2). In early summer mean total P levels were higher at Grand Bend (0.010 mg/L) and lower at Southampton (0.005 mg/L) and Goderich (0.006 mg/L)(Fig. 5), suggestive of nutrient entrapment in the southern portion of the basin (ULRG 1977a). By late summer, however, all three areas had similar mean total P values of between 0.005 and 0.007 mg/L. The highest mean total P levels (0.018 mg/L) occurred at Goderich in the late fall, a result of storm-induced loadings and sediment resuspension.

Mean total P concentrations showed a decreasing lakeward gradient to about 1.5 km off each of the river mouths, except in late fall when all transect values at Goderich and Southampton were elevated because of storm conditions (Fig. 6). Also, an increase in total P occurred at about 9 km off Grand Bend in early summer, further indicative of nutrient entrapment in this region.

The areal extent of enrichment at each of the nearshore areas is apparent in Fig. 7, 8 and 9 which depict the "maximum" mean total P concentration at each site over the two to three sampling cruises.

Table 2: Summary of water quality indicators in southeastern Lake Huron for the ice-free period (early summer, late summer; late fall), 1980. Yearly mean precedes minimum-maximum values.

	Southampton (Saugeen R.)	Goderich (Maitland R.)	Grand Bend* (Ausable R.)	Open Lake South	Open Lake North
Total P (mg/L)	0.006 (0.001-0.025)	0.010 (0.002-0.048)	0.008 (0.001-0.022)	0.004 (0.003-0.006)	0.004 (0.003-0.007)
NO_3+NO_2 (mg/L)	0.241 (0.160-0.430)	0.355 (0.220-1.720)	0.313 (0.220-0.880)	0.260 (0.225-0.293)	0.265 (0.240-0.281)
NH_3 (mg/L)	0.008 (0.005-0.025)	0.007 (0.005-0.030)	0.006 (0.005-0.020)	0.004 (0.002-0.006)	<0.002 (L0.001-0.005)
TKN (mg/L)	0.192 (0.110-0.460)	0.213 (0.140-0.800)	0.197 (0.140-0.290)	0.175 (0.140-0.238)	0.179 (0.148-0.249)
R. Silicate (mg/L)	0.52 (0.38-1.26)	0.52 (0.32-1.22)	0.35 (0.18-0.48)	1.00 (0.84-1.25)	1.16 (0.90-1.35)
Cond (µS/cm)	229 (202-424)	226 (200-403)	214 (205-235)	202 (189-210)	201 (191-212)
Cl (mg/L)	5.8 (5.4-7.5)	7.3 (5.6-20.5)	6.1 (5.8-6.6)	5.8 (5.5-6.1)	5.5 (5.3-5.7)
Secchi Depth (m)	4.0 (1.0-10.1)	2.1 (0.1-10.2)	3.0 (0.3-13.3)	5.5*** (5.5-5.5)	4.8** (4.0-5.5)

* Early summer and late summer only
** Late summer and late fall only
*** Late fall only
ND No data

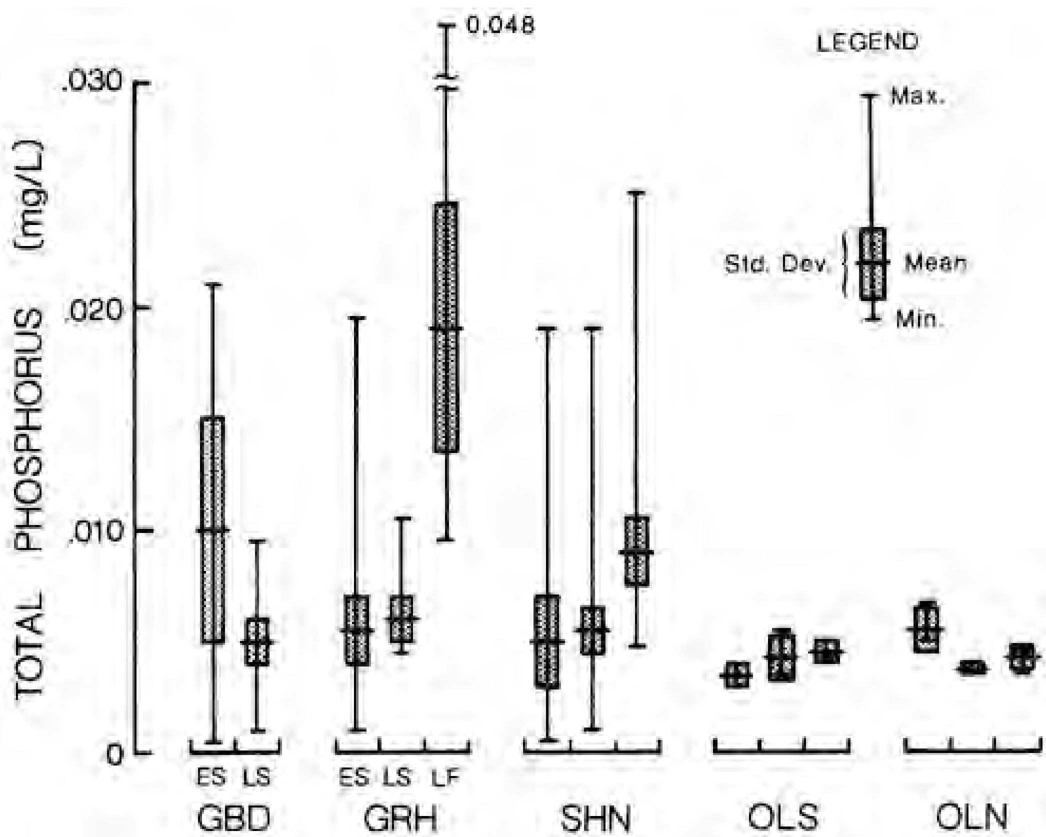

Fig. 5: Total phosphorus summary statistics for sampling areas in southeastern Lake Huron during early summer (ES), late summer (LS) and late fall (LF), 1980. Sampling areas: Grand Bend (GBD), Goderich (GRH), Southampton (SHN), Open lake south (OLS); Open lake north (OLN).

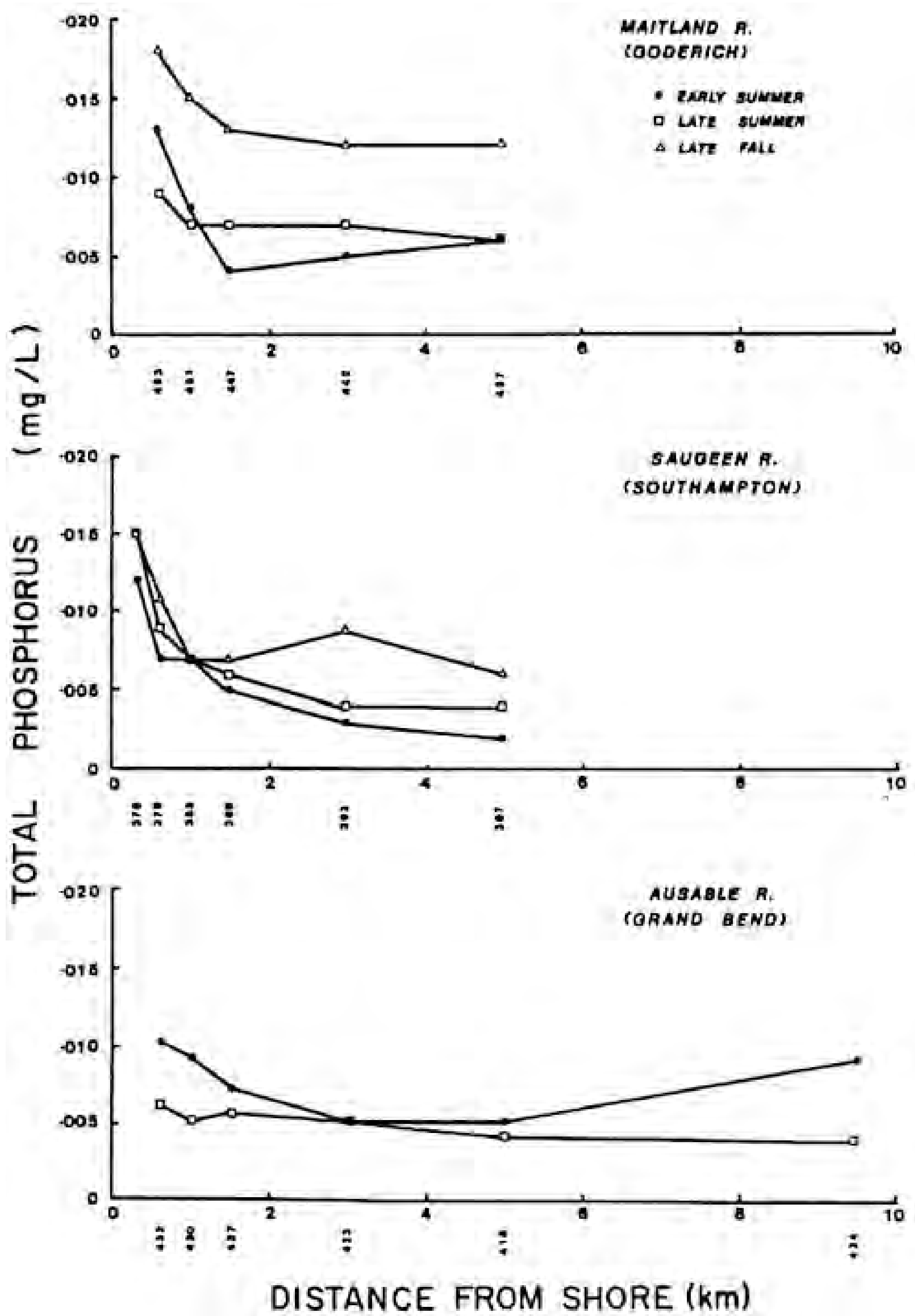

Fig. 6: Total phosphorus cruise means off river mouths in southeastern Lake Huron, 1980.

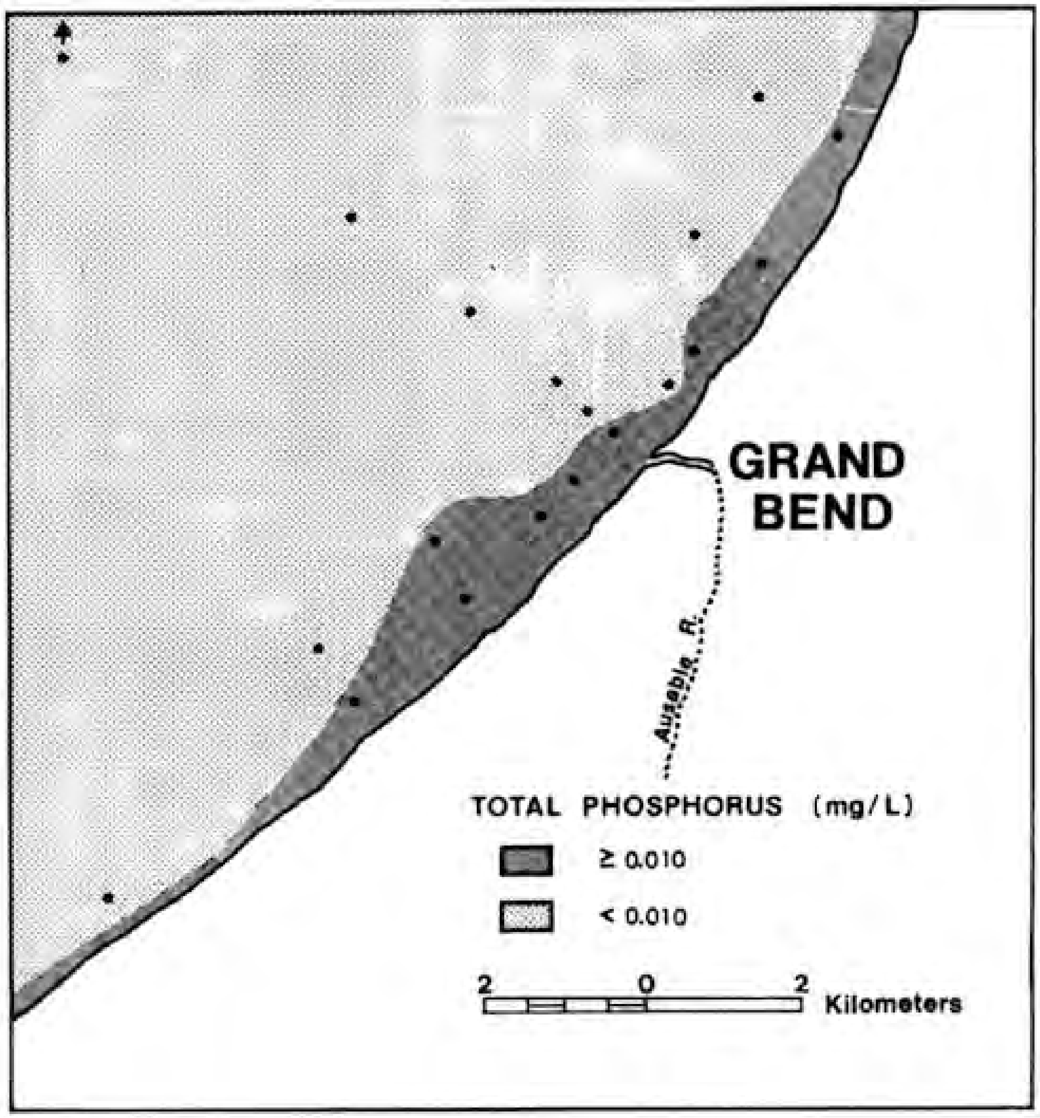

Fig. 7: Zones of total phosphorus concentration at Grand Bend, 1980. Zonation is based on the "maximum" mean value at each site over the two sampling cruises.

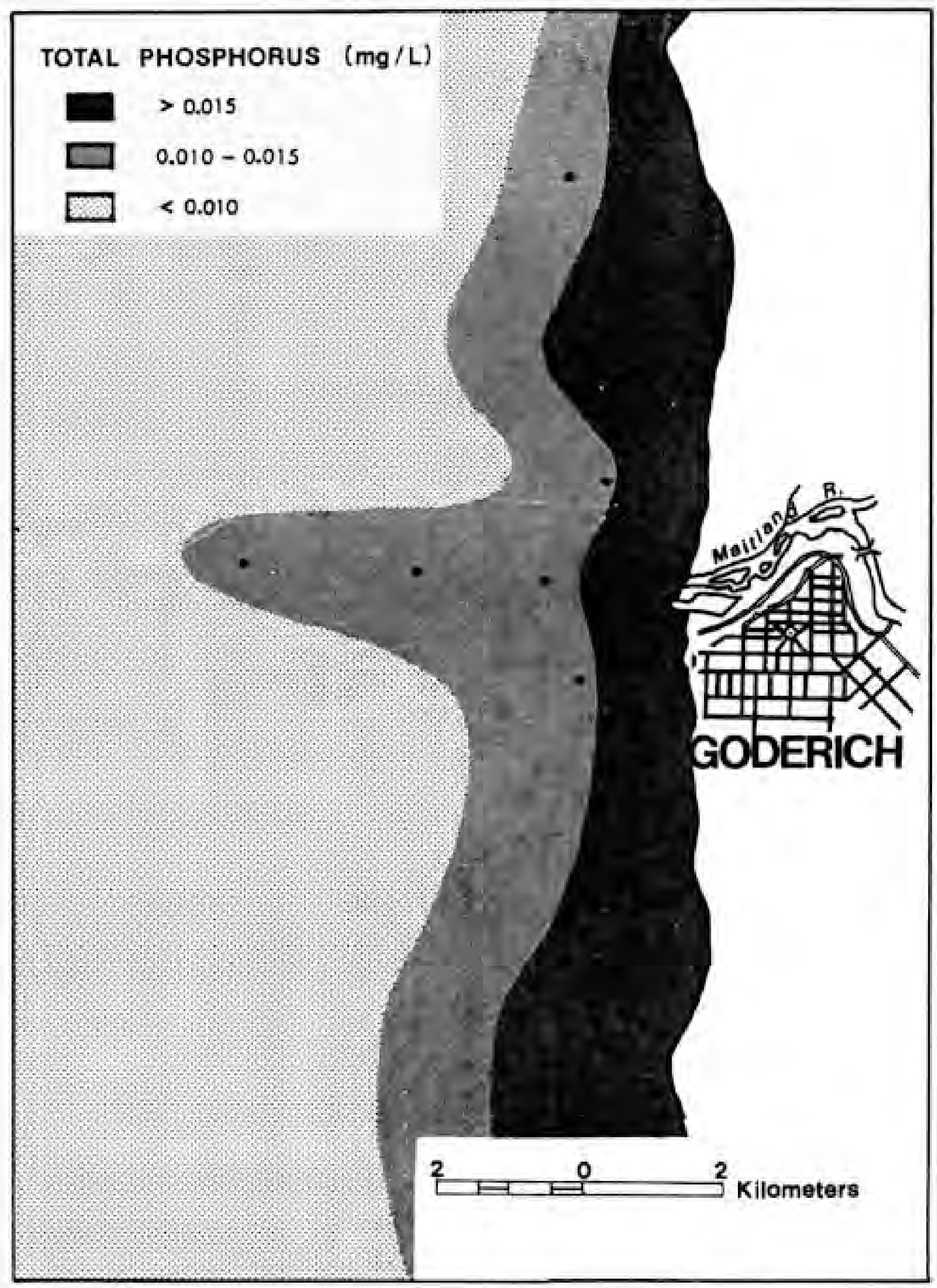

Fig. 8: Zones of total phosphorus concentration at Goderich 1980. Zonation is based on the "maximum" mean value at each site over the three sampling cruises.

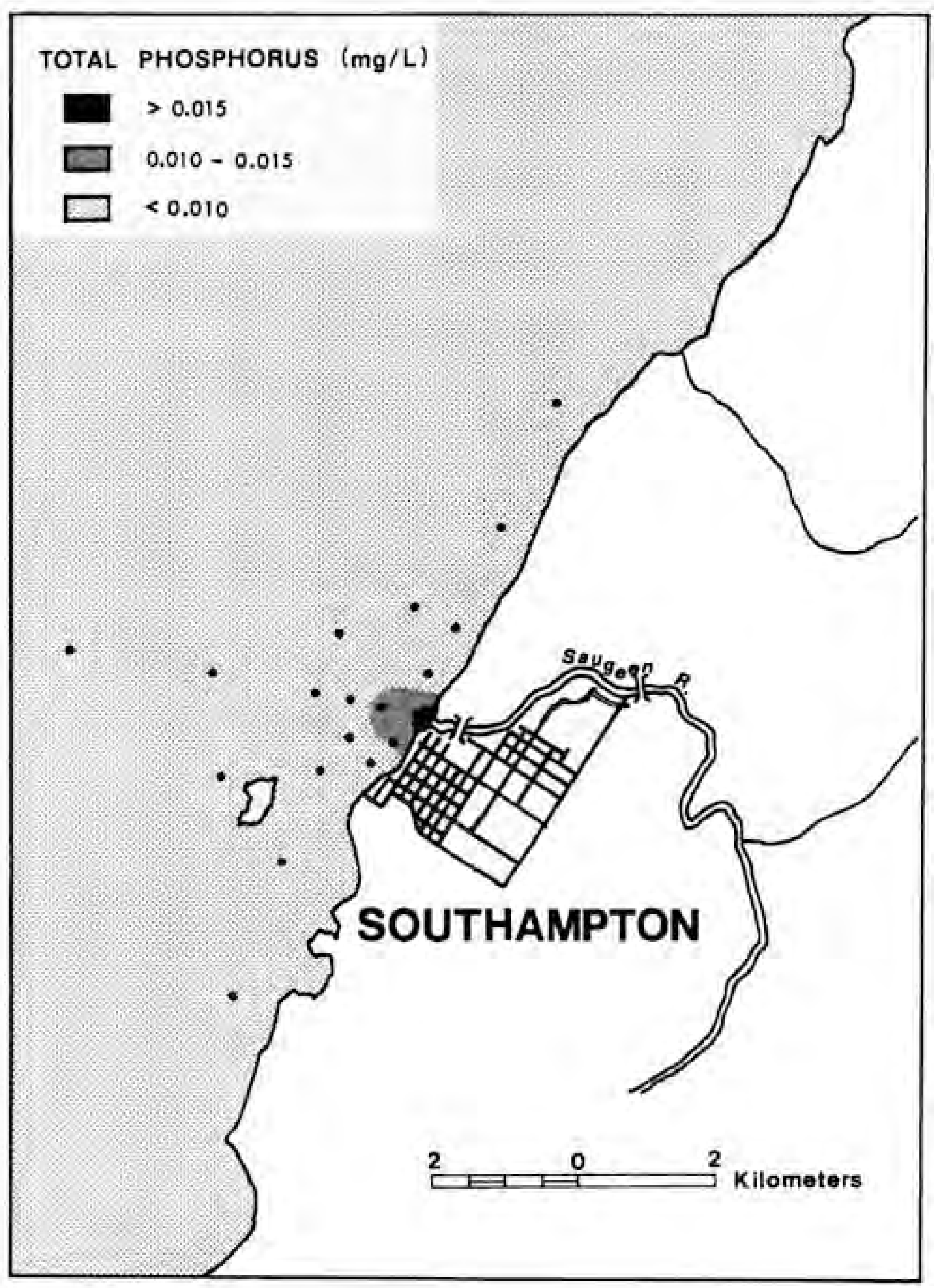

Fig. 9: Zones of total phosphorus concentration at Southampton, 1980. Zonation is based on the "maximum" mean value at each site over the <u>three</u> sampling cruises.

Not surprisingly, the extent of enrichment at Grand Bend was considerably less than at Goderich since late fall (storm event) data was not collected at the former location; at Southampton, elevated total P levels were contained within a 1 km radius of the Saugeen River mouth.

Nitrogen

Nitrogen, an essential element for algal growth, may become limiting when P is in excess. Yearly mean concentrations of nitrate—nitrite nitrogen (NO_3 + NO_2), a readily available form of inorganic nitrogen, showed minimal variability between site groups suggestive of P limited conditions. Values were highest at Goderich (0.355 mg/L) and Grand Bend (0.313 mg/L) and lower at Southampton (0.241 mg/L), while open lake mean values ranged from 0.260 mg/L in the south to 0.265 mg/L in the north (Table 2).

In late summer, all site groups (including the open lake locations) experienced minimum mean NO_3 + NO_2 values of between 0.218 and 0.251 mg/L (Fig. 10). The highest mean values occurred at Goderich in late fall (0.564 mg/L) and at Grand Bend (0.393 mg/L) in early summer, consistent with trends in total P. Decreasing lakeward gradients in mean NO_3 + NO_2 were evident to 1.5-2 km off each of the river mouths, at least once during the year (Fig. 11).

Yearly mean concentrations of total Kjeldahl nitrogen (TKN), primarily a measure of organic nitrogen, also showed little variability between the site groups; TKN values ranged from 0.175 mg/L (open lake south) to 0.197 mg/L (Grand Bend) (Table 2). In addition, yearly mean concentrations of ammonia (NH_3), an unstable inorganic form of nitrogen commonly found in domestic and industrial waste water, were relatively low at all site groups; NH_3 values ranged from less than 0.002 mg/L (open lake north) to 0.008 mg/L (Southampton) (Table 2).

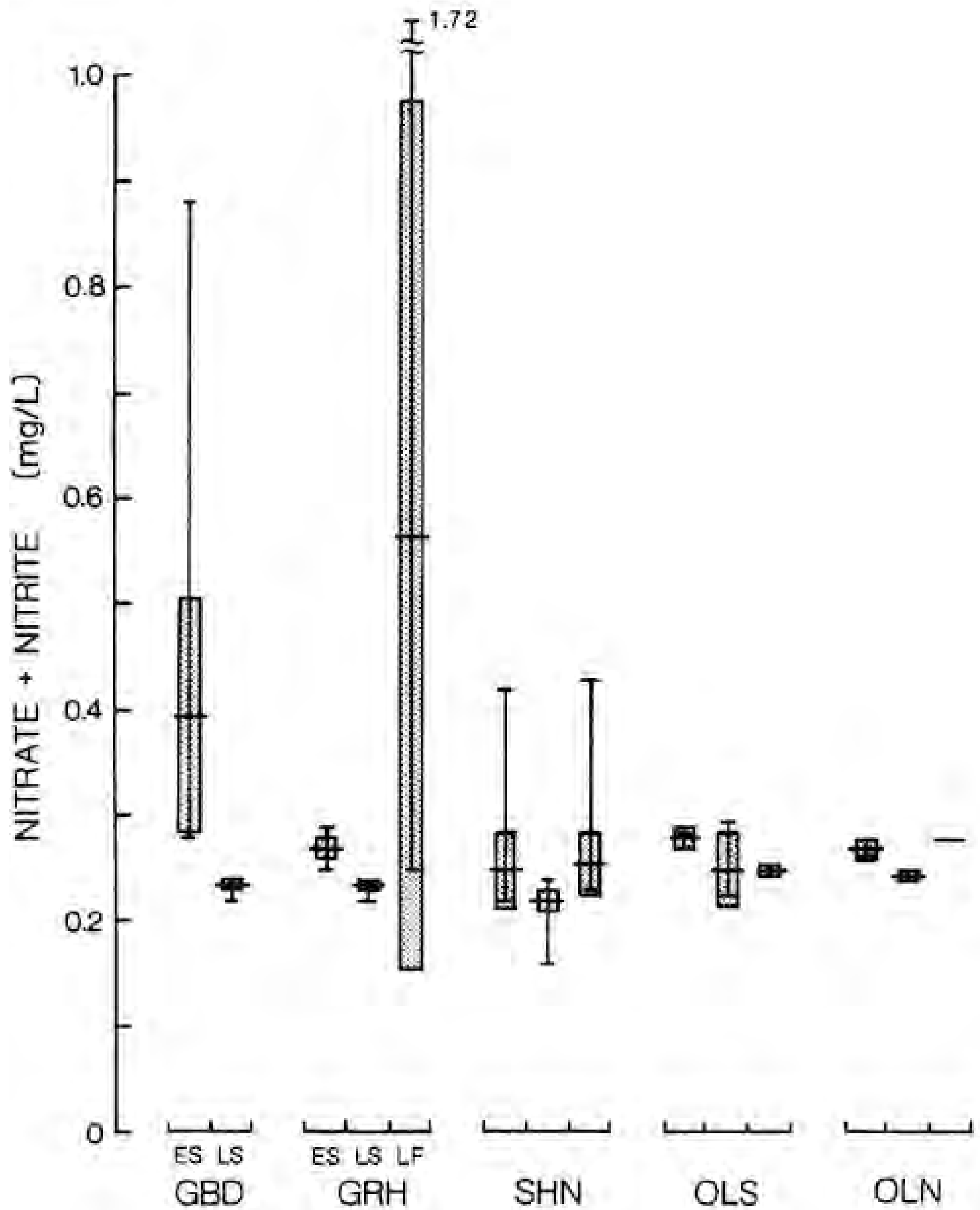

Fig. 10: Nitrate + nitrite nitrogen summary statistics for sampling areas in southeastern Lake Huron during early summer (ES), late summer (LS) and late fall (LF), 1980. Sampling areas: Grand Bend (GBD), Goderich (GRH), Southampton (SHN), Open lake south (OLS); Open lake north (OLN). See Fig. 5 for legend.

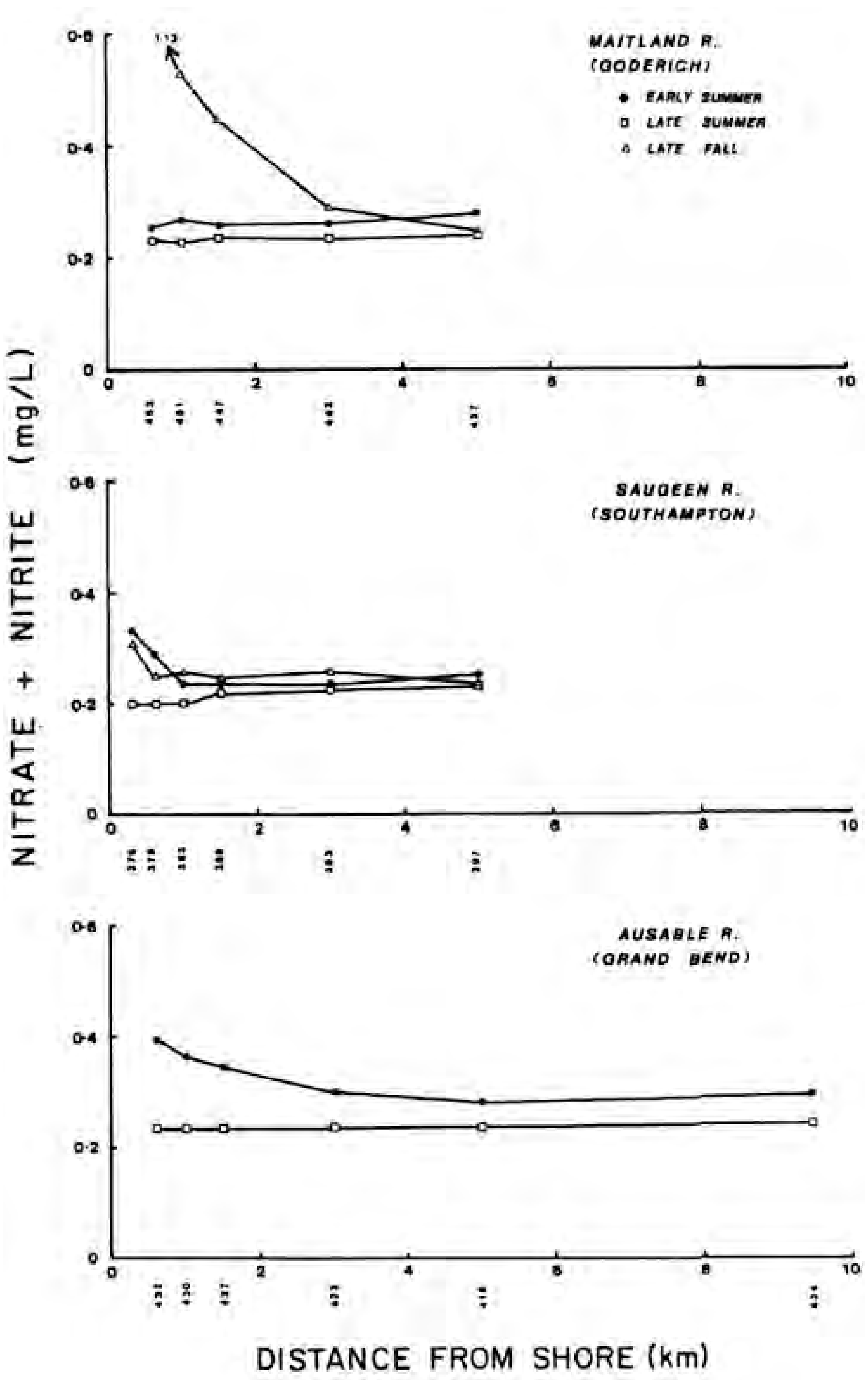

Fig. 11: Nitrate + nitrite nitrogen cruise means off river mouths in southeastern Lake Huron, 1980.

Silicate

Silicate is an essential component in the synthesis of diatom cell walls. Yearly mean reactive silicate concentrations (as Si) at the three nearshore site groups ranged from 0.35 to 0.52 mg/L, about half that of the open lake values (Table 2). This difference was probably due to increased silicate utilization by nearshore diatom populations. Mean silicate levels were also higher in the north in proximity to the Shield.

There were no consistent temporal trends in silicate among any of the site groups, although levels were noticeably higher at Goderich in late fall (again reflective of storm conditions) (Fig. 12). Evidence of silicate loading was apparent to about 1.5 km offshore at Southampton and Goderich (during late fall only). There were no apparent loadings, however, at Grand Bend (Fig. 13).

6.2 MAJOR IONS

Chloride, a conservative ion useful in tracing water masses, is a major anion in domestic wastes and many natural water supplies. Yearly mean chloride concentrations at Goderich (7.3 mg/L) were elevated compared to the remaining site groups (5.5 - 6.1 mg/L) due to chloride loadings from the Sifto salt plant near the mouth of the Maitland River (Ross and Chatterjee 1977). In addition, all nearshore site groups had marginally higher values than the open lake. There was also a slight increasing trend in chloride levels toward the south.

Mean chloride concentrations were relatively stable over time at each of the site groups, except at Goderich because of high levels in late fall and early summer (Fig. 14). Decreasing lakeward gradients in mean chloride concentration were apparent to 1.5 km off Goderich and 1 km off Southampton. At Grand Bend, lakeward gradients were almost imperceptible (Fig. 15).

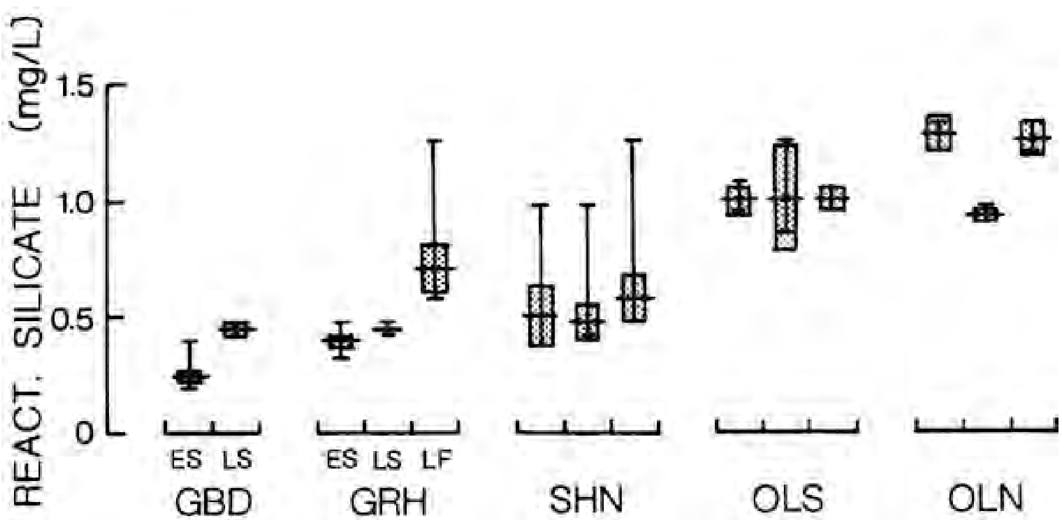

Fig. 12: Reactive silicate summary statistics for sampling areas in southeastern Lake Huron during early summer (ES), late summer (LS) and late fall (LF), 1980. Sampling areas: Grand Bend (GBD), Goderich (GRH), Southampton (SHN), Open lake south (OLS); Open lake north (OLN). See Fig. 5 for legend.

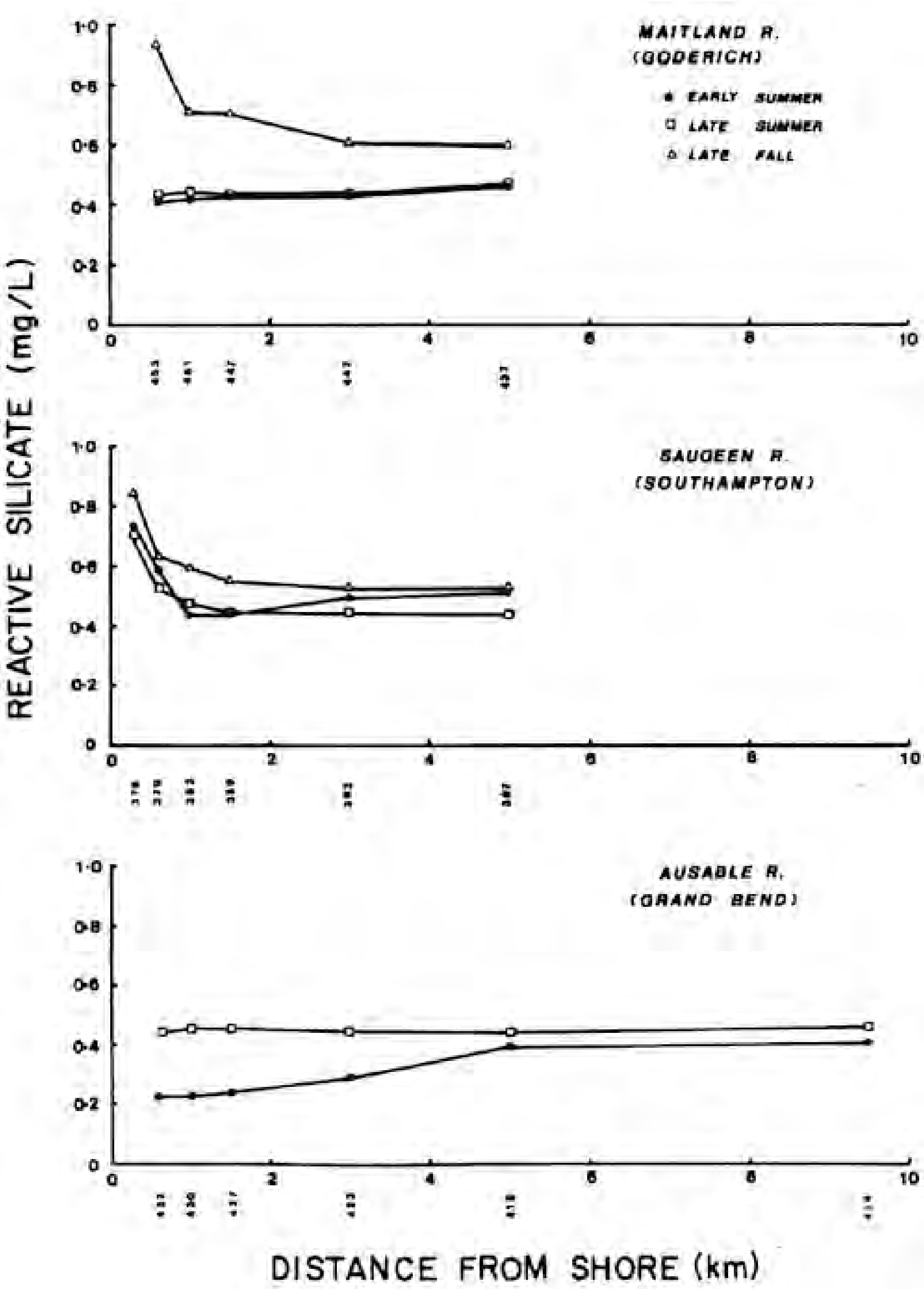

Fig. 13: Reactive silicate cruise means off river mouths in southeastern Lake Huron, 1980.

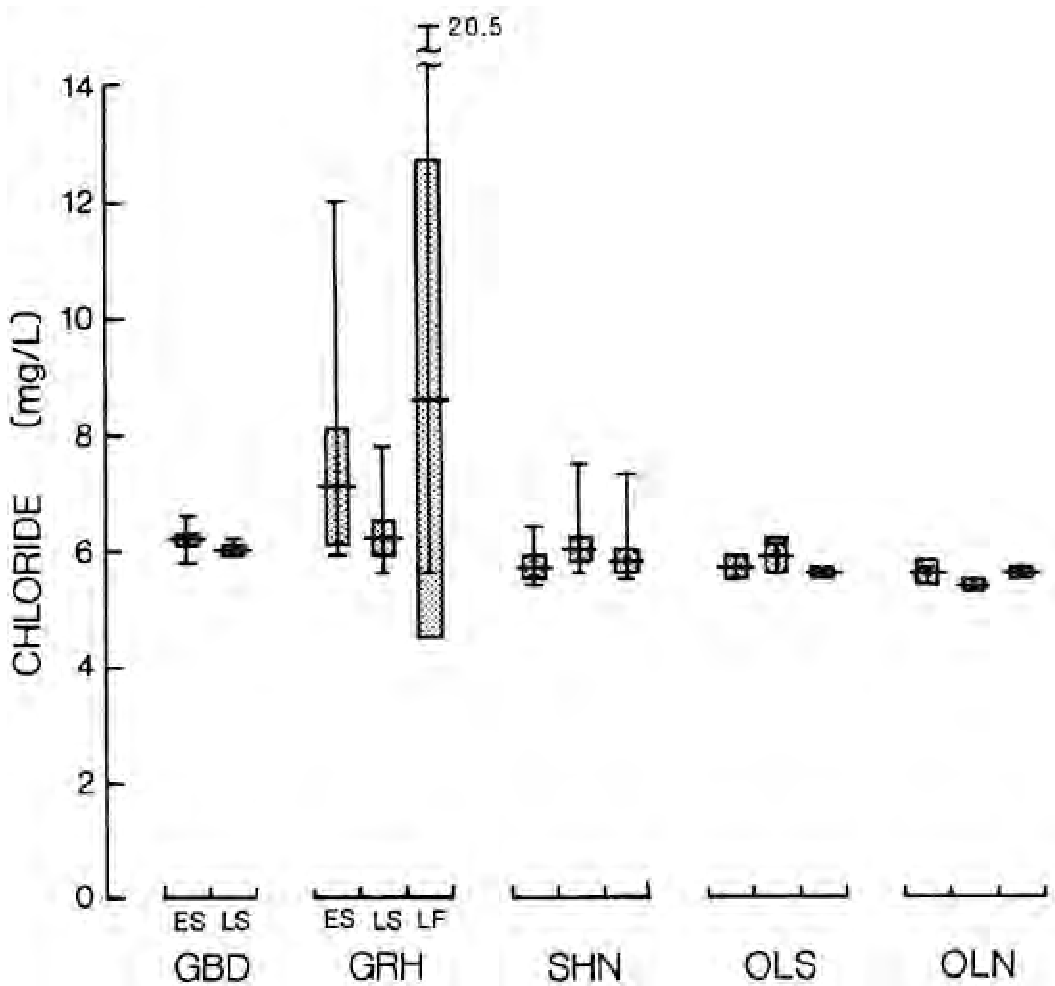

Fig. 14: Chloride summary statistics for sampling areas in southeastern Lake Huron during early summer (ES), late summer (LS) and late fall (LF), 1980. Sampling areas: Grand Bend (GBD), Goderich (GRH), Southampton (SHN), Open lake south (OLS); Open lake north (OLN). See Fig. 5 for legend.

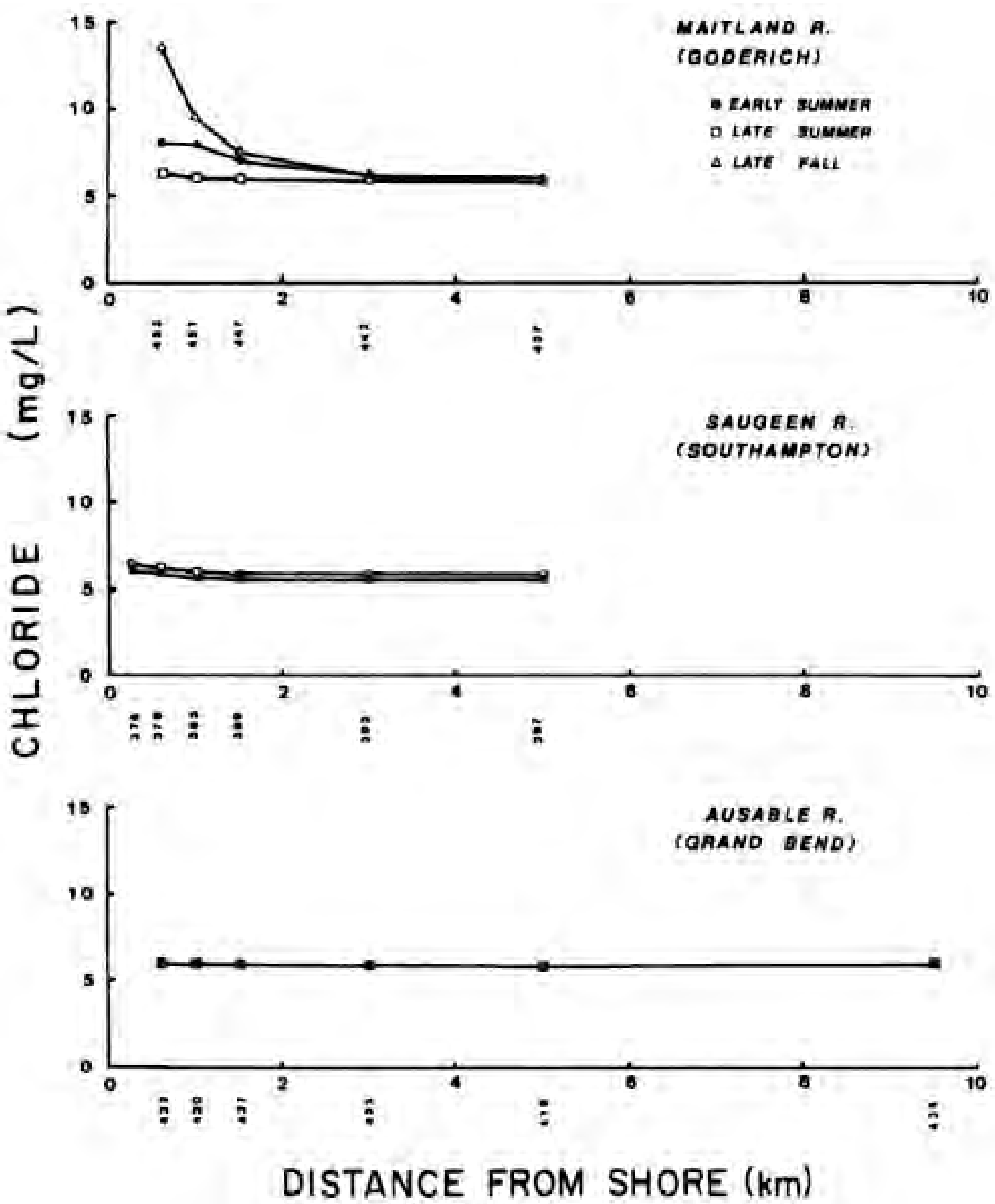

Fig. 15: Chloride cruise means off river mouths in southeastern Lake Huron, 1980.

Conductivity, an indirect measure of the various ions in solution, is routinely used to monitor changes in water quality. Yearly mean conductivity values at the three nearshore site groups ranged from 214 to 229 µS/cm, while levels in the open lake were noticeably lower at 201 to 202 µS/cm (Table 2).

6.3 Transparency

Secchi depth (SD), the depth at which a circular black and white disc lowered from the water surface disappears, is a measure of water transparency. Under normal conditions, SD correlates well with parameters such as chlorophyll a, turbidity and underwater light intensities. Consistent with trends in total P and chlorophyll a, yearly mean SD values were higher in the open lake (4.8 — 5.5 m) and lower at Southampton (4.0m), Grand Bend (3.0m) and Goderich (2.1m) (Table 2). The relatively turbid waters at the two southernmost locations reflected enhanced shoreline erosion, sediment resuspension and tributary particulate loadings characteristic of this region (Ross and Chatterjee 1977).

Mean SD values were highest in late summer, coincident with lower levels in total P, NO_3 +NO_2 and chlorophyll a (insufficient data were available for open lake temporal comparisons) (Fig. 16). The lowest mean SD value occurred at Goderich in late fall (i.e., storm conditions) when uniformly turbid waters persisted to at least 5 km offshore. Except on this occasion, all nearshore site groups showed an increasing lakeward gradient in mean SD values (Fig. 17).

6.4 Chlorophyll a

Chlorophyll a concentration is used as an inexpensive (although approximate) measure of algal standing crop and subsequently as an indicator of trophic status because of its expected response to changes in nutrient supply. Yearly mean concentrations of chlorophyll a (corrected) were highest at Goderich (0.97 µg/L), followed by Grand Bend (0.84 µg/L), and Southampton (0.67 µg/L) (no comparable data were available for the open lake) (Table 2).

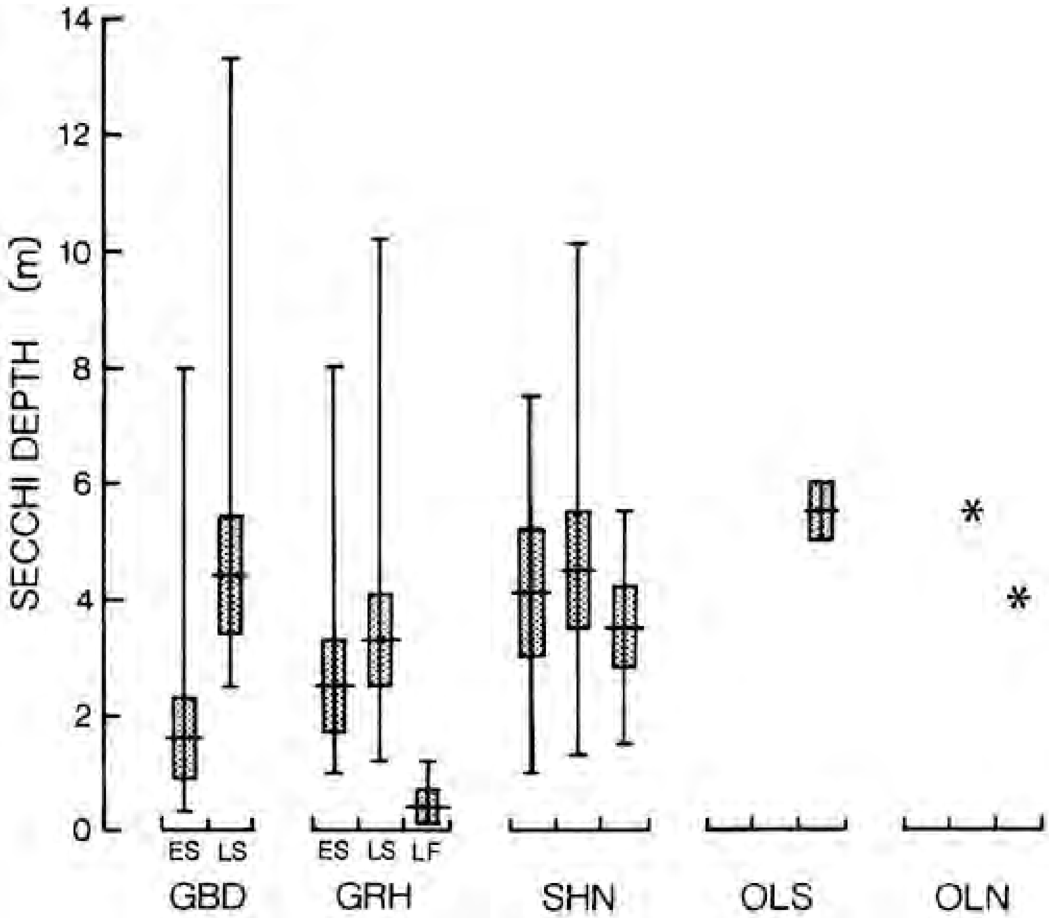

Fig. 16: Secchi depth summary statistics for sampling areas in southeastern Lake Huron during early summer (ES), late summer (LS) and late fall (LF), 1980. Sampling areas: Grand Bend (GBD), Goderich (GRH), Southampton (SHN), Open lake south (OLS); Open lake north (OLN). See Fig. 5 for legend. An asterisk (*) denotes a single value.

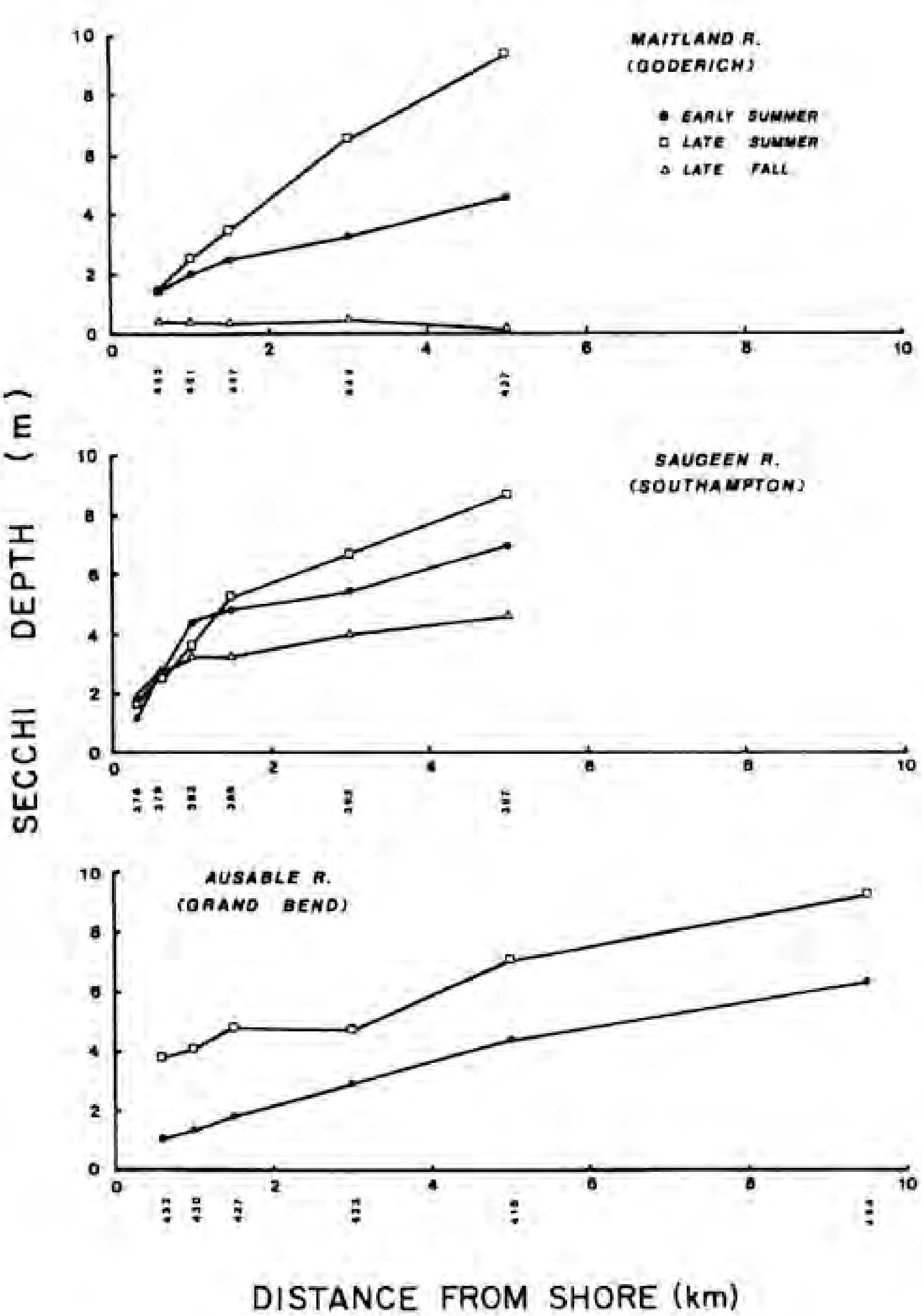

Fig. 17: Secchi depth cruise means off river mouths in southeastern Lake Huron, 1980.

At each of the site groups, mean chlorophyll a concentrations were higher in the early summer and late fall and lower in the late summer (Fig. 18). A decreasing lakeward gradient was evident to 1.5 km off Goderich and Southampton, while only a slight gradient was apparent off Grand Bend (Fig. 19). The approximate areal extent of algal biomass levels in each nearshore area is shown in Fig. 20, 21 and 22 which depict the "maximum" mean chlorophyll a concentration at each site over the two or three sampling cruises. As with total P, the zone of elevated chlorophyll a concentration was greater at Goderich (i.e., fall storm conditions) and Grand Bend than at Southampton.

6.5 Comparability of Intake Data

In a separate report, Hopkins (1983) has documented the water quality at three water supply intakes in southeastern Lake Huron covering the period 1976 to 1981. While the main intended use of intake data is for long term trend analysis, the data can also be used for short term (seasonal) evaluations of water quality. Relative to the 1980 surface data presented here, the intake findings were comparable for most water quality indicators; only total P levels were appreciably different (i.e., intake levels were about twice as high as surface values).

Since the intake data reflect deep water conditions, the higher total P levels are not unexpected. Incursions of phosphorus-rich hypolimnetic waters and resuspension of bottom sediments during storm events, as well as the fact that the intake data represent year-round conditions, could account for the apparent differences between the deep water (i.e., intake data) and surface water total P levels (Hopkins 1983).

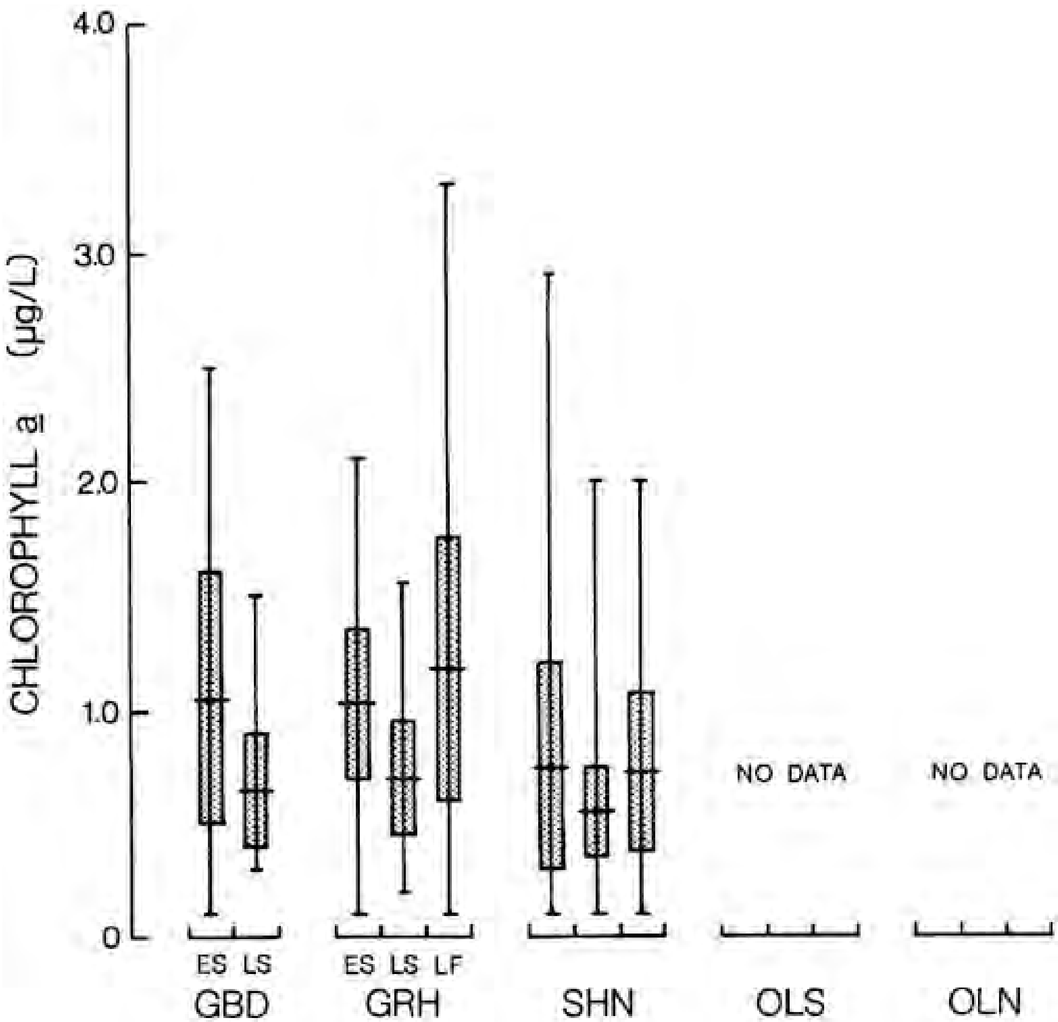

Fig. 18: Chlorophyll a (corrected) summary statistics for sampling areas in southeastern Lake Huron during early summer (ES), late summer (LS) and late fall (LF), 1980. Sampling areas: Grand Bend (GBD), Goderich (GRH), Southampton (SHN), Open lake south (OLS); Open lake north (OLN). See Fig. 5 for legend.

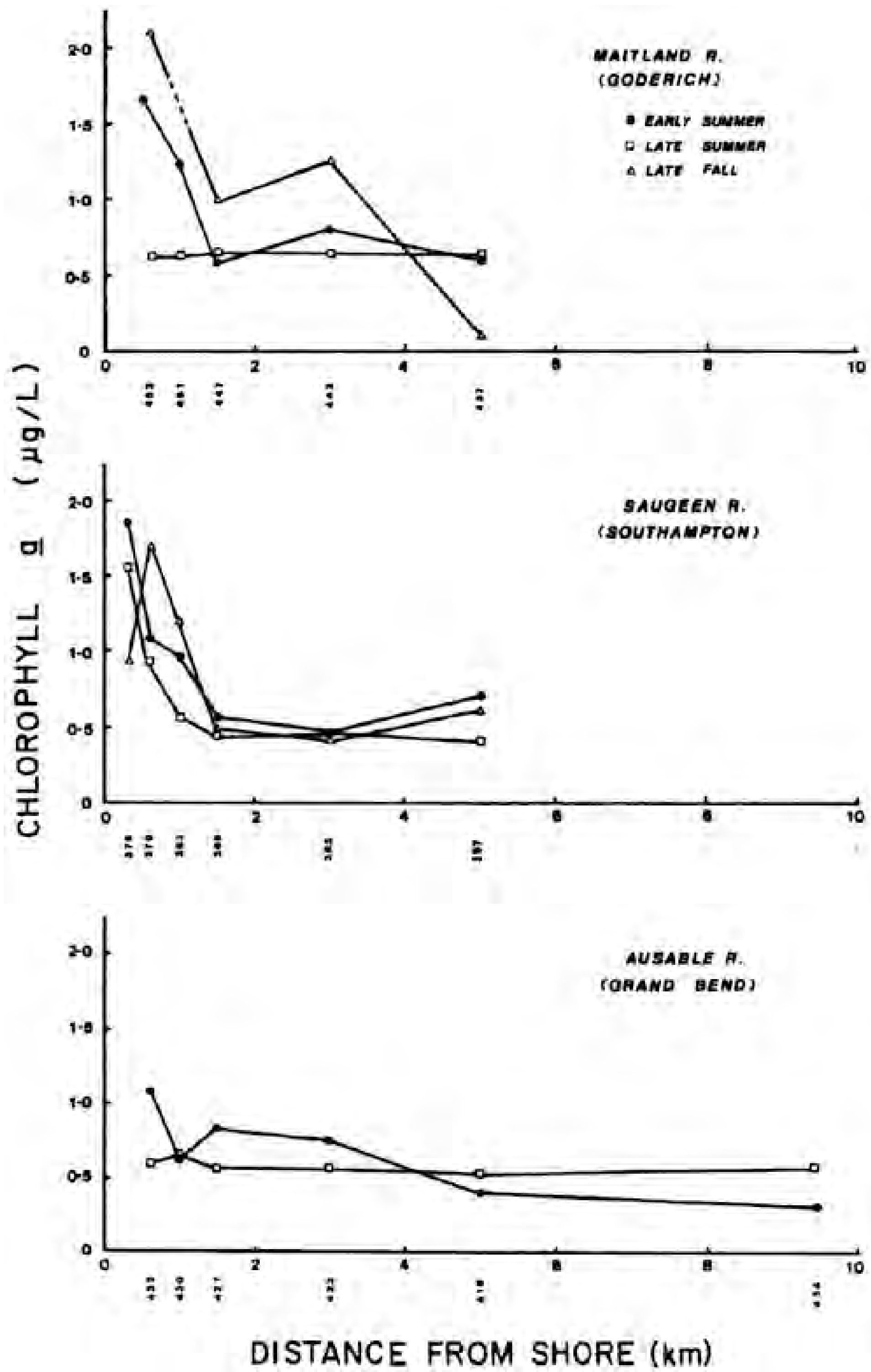

Fig. 19: Chlorophyll a (corrected) cruise means off river mouths in southeastern Lake Huron, 1980.

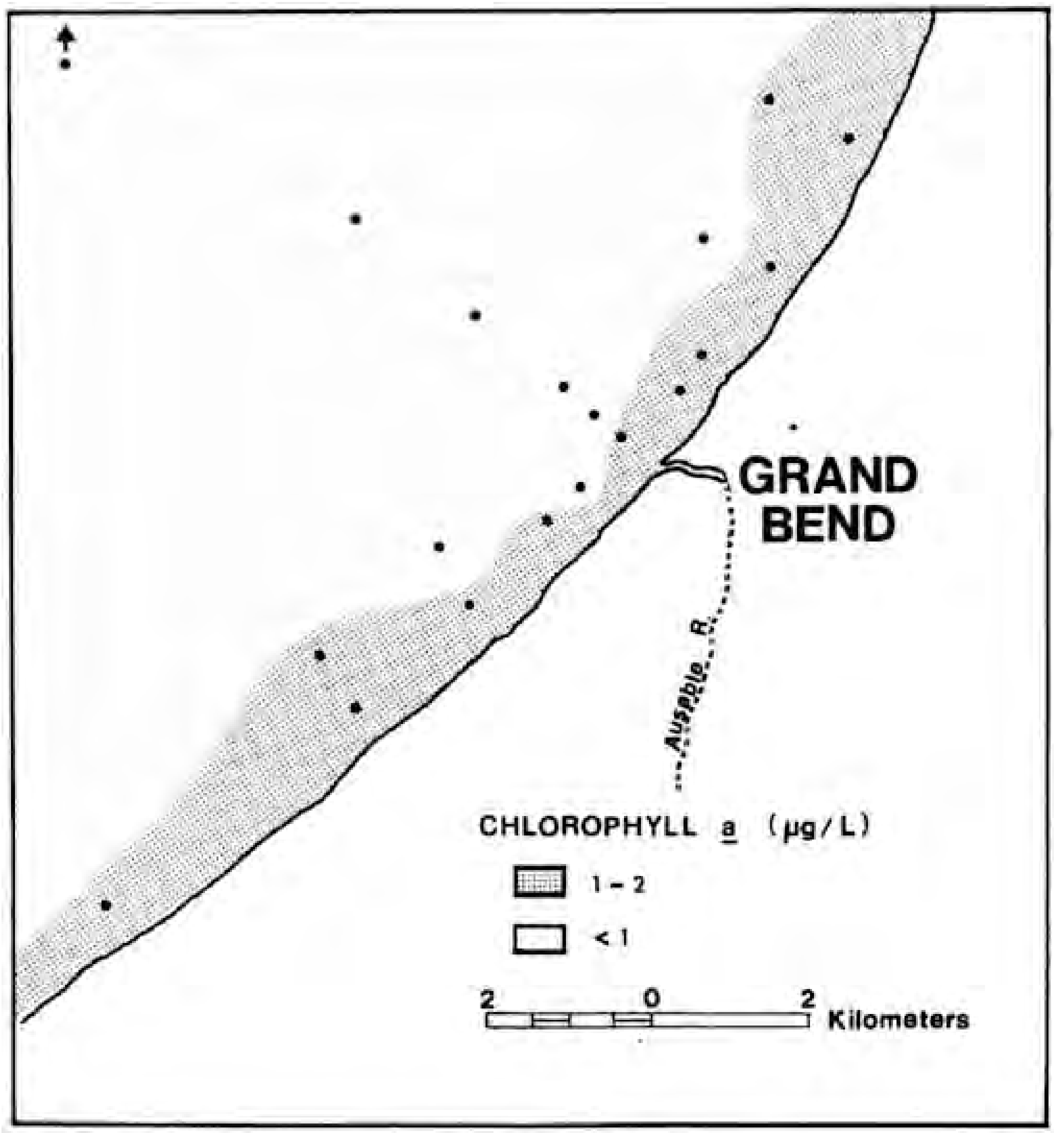

Fig. 20: Zones of chlorophyll a concentration (corrected) at Grand Bend, 1980. Zonation is based on the "maximum" mean value at each site over the three sampling cruises.

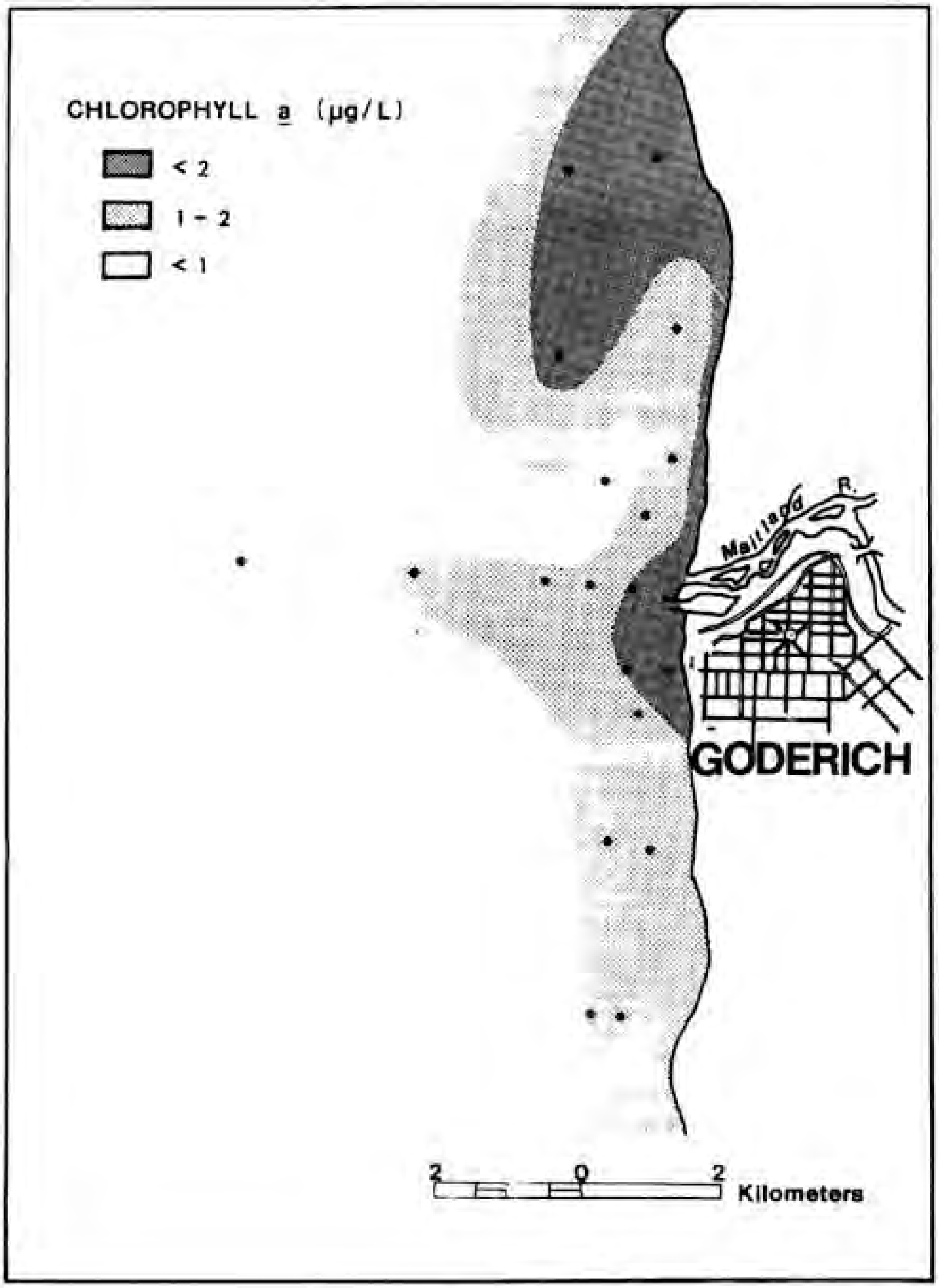

Fig. 21: Zones of chlorophyll a concentration (corrected) at Goderich, 1980. Zonation is based on the "maximum" mean value at each site over the three sampling cruises.

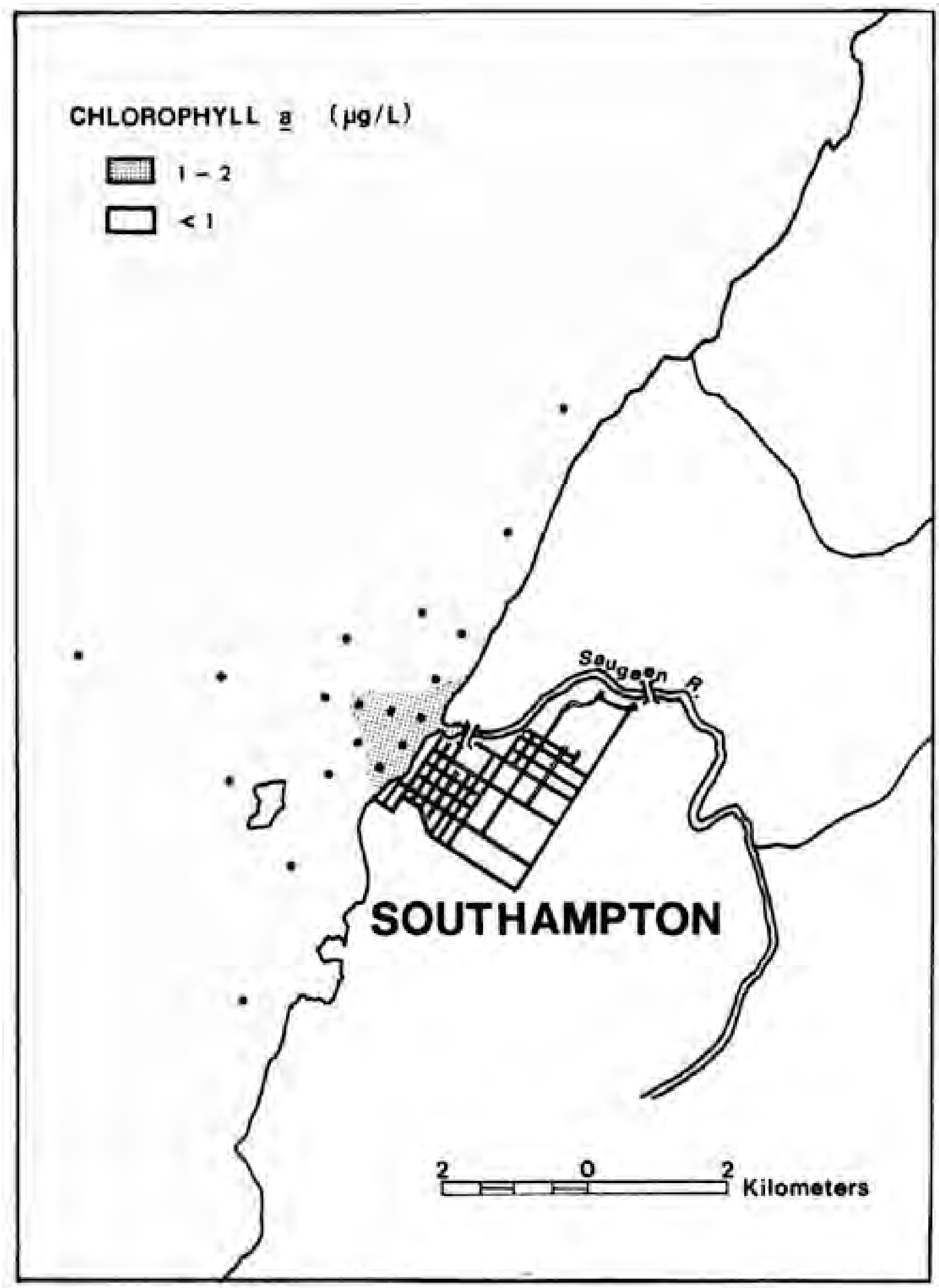

Fig. 22: Zones of chlorophyll a concentration (corrected) at Southampton, 1980. Zonation is based on the "maximum" mean value at each site over the three sampling cruises.

VII CONCLUSIONS

During the ice-free period of 1980, obvious signs of eutrophication in southeastern Lake Huron occurred at each of the three nearshore areas investigated. It can be generally concluded that the water quality of these areas tends toward mesotrophy (i.e., moderate nutrient enrichment). Reductions in water quality were most extensive at Grand Bend and Goderich, and least extensive at Southampton to the north. Nutrient entrapment from tributary and municipal loadings, storm-induced sediment resuspension, and increased shoreline erosion are believed to account for the more widespread nearshore enrichment in the southernmost areas. Elevated chloride concentrations at the mouth of the Maitland River are apparently due to upstream discharge from the Sifto salt plant.

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