Technical Memo

Occurrence of Nuisance Benthic Algae on the Southeastern Shores of Lake Huron, 2003

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Introduction

In 2003 water quality surveys were conducted along the southeastern shores of Lake Huron by the Environmental Monitoring and Reporting Branch to document water quality conditions in the area. A focus of the study was to examine the effects of tributaries on environmental conditions along the lakeshore by concurrently monitoring water quality in the lake and selected tributaries. Strong gradients in water quality may be observed when tributary water mixes with lake water along the shores of the Great Lakes.

A biological component of the study was a survey of the shoreline and littoral areas of the lake for incidents of heavy growth of benthic algae and shoreline fouling by algae. Benthic algae are responsive to nutrient pollution and have been used extensively as biological indicators of enrichment. This aspect of the study was initiated, in part, at the request of the Owen Sound District Office (SW Region) that has received and responded to numerous complaints of shoreline fouling by rotting organic (usually algal) material in the past 2-3 years.

There were three main objectives of the shoreline algae survey. A key objective was to examine many of the locations where shoreline fouling has been reported in order to better understand the nature of the algae problems. A more general objective was to investigate the suitability of habitat and environmental conditions for growth of *Cladophora* and other benthic algae associated with fouling problems to aid in understanding the existing conditions and to provide a basis to anticipate future problems. Finally, the survey was intended to collect baseline information and initiate monitoring to track algal problems in the coming years. There has been little monitoring of benthic algae, or algal fouling problems, on the southeastern shores of Lake Huron since the early 1980s. Shoreline sites were visited in July. A limited number of tributary sites were also visited.

The primary species of benthic algae responsible for shoreline fouling on the Great Lakes is the green algae *Cladophora glomerta* (thought to be the sole Great Lakes species of *Cladophora*). The macroscopically visible branched filaments of this alga can occur as extensive lawns of material over shallow areas of lake bottom where nutrient levels are adequate for growth. Abundance of *Cladophora* varies seasonally with maximum abundance observed in early to mid summer. A period of die back usually occurs from mid to late summer when water temperatures

reach seasonal highs. The die back period, when sloughing of filaments from the lake bottom and accumulation of algae along the shoreline occurs, is typically when fouling problems are experienced. This report focuses on the occurrence of *Cladophora*, but it is recognised that a wide variety of benthic algae occur along the shoreline of Lake Huron.

The waters of Lake Huron are considered to be of good quality, however, aesthetic problems associated with shoreline fouling by algae have become a concern in parts of the lake. Localised problems in the Goderich area appear to go back to the 1980s (Jackson 1985). While there is scientific debate as to which factors account for the apparent recent over-abundance of *Cladophora* in the lower Great Lakes, it is well established that an excessive amount of *Cladophora* is symptomatic of nutrient enrichment.

This report documents observations on the occurrence of benthic algae over a portion of the southeastern shoreline of Lake Huron, and examines the susceptibility of the shoreline to proliferation of benthic algae. The results of water quality surveys conducted in 2003 over shoreline adjacent to the mouths of the Saugeen, Maitland and Bayfield rivers will be reported separately.

Methods

Areas of publicly accessible shoreline south of Sauble Beach to south of Bayfield were visited between July 14-30, 2003 (Figure 1). A limited number of tributary sites were also visited. Observations were made at all locations of algal accumulation washed up along the shoreline. Direct observations were made via snorkeling at a subset of locations on habitat conditions and the occurrence of benthic macro algae growing to a depth of ~2m on the lake bottom. A semi-quantitative assessment of areal cover and thickness of *Cladophora* similar to Howell (1998) was planned prior to the survey. However, this was not practical due to the limited distribution and abundance of *Cladophora* observed at the survey locations. Instead, qualitative observations were made on the spatial distribution of benthic algae at each location, as well as random spot measurements of the thickness of any algae lawn/layers on the lake bottom.

Water samples for nutrient analysis were collected at sites where observations of the lake bottom were made and the sites were additionally assigned an MOE station number. Water samples were collected below the lake surface at lake depths of 1m.

Geographic positions were determined using a Garmin Etrex GPS except for a limited number of sites where position was determined by reference to topographic maps. Site positions are plotted on Ministry of Natural Resources 1:10,000 OBM maps.

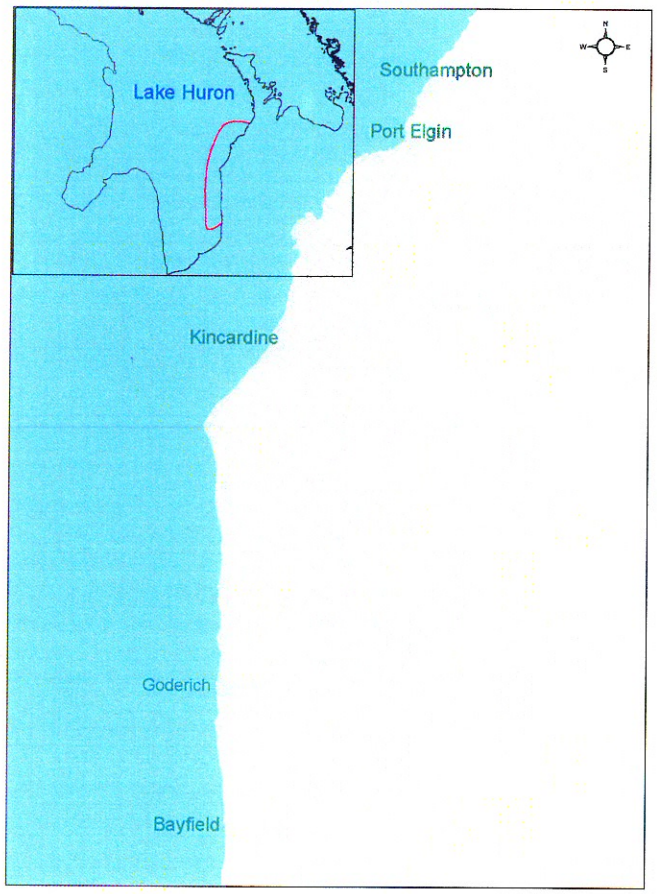

Figure 1. Survey area of shoreline along southeastern Lake Huron, July 2003.

Results and Discussion

Cladophora Occurrence and Shoreline Fouling

Limited growth of *Cladophora* was observed on areas of hard lake bottom in July 2003. Most of the lake bottom examined via snorkeling either lacked visible signs of *Cladophora* and other macro algae or had minimal amounts of algae. *Cladophora* was abundant at some locations, growing on localized areas of the lake bottom and limited to isolated segments of shoreline. The patchy distribution of algae suggests that ambient lake nutrient concentrations do not support prolific growth in most areas, but that *Cladophora* may be responding to locally elevated nutrient supply at some locations. Where abundant, *Cladophora* extended from the waterline out to some depth into the lake. The vertical thickness of *Cladophora* beds tended to become thinner with depth and disappear at depths < 1 m. Among locations where algae was observed, the extent of growth along the shoreline varied from small patches to bands along the shoreline.

Fouling of shorelines with dead *Cladophora* was minimal at the time of survey. Most locations either lacked visible accumulations or had small amounts of algae scattered on the shoreline (Figure 2). However, a small number of locations had fresh windrows of *Cladophora* accumulated near the waterline. At the time of observation, the amounts of algae on the shoreline were not extensive. At several locations, shoreline residents had collected beached algae into piles. The most obvious aesthetic problem with algae on the shoreline was observed near the discharge point of the Goderich sewage treatment plant. It must be recognized that the perception of an aesthetic problem is subjective. Lake temperatures at the time of survey ranged from 19 to 23°C and were within the range where die-off and sloughing of *Cladophora* is anticipated. The survey was conducted at a time when shore fouling is expected to occur. The severity of shore fouling by *Cladophora* can be highly variable among years reflecting varying environmental conditions from year to year.

The areas where accumulation of algae was observed on the shoreline appeared to coincide with the areas where elevated growth of algae was observed on the lake bottom. This suggests that the locations where nutrient input is stimulating growth of algae are coupled with locations where algae is washing onto the shoreline.

Cladophora and Macro Algae at Individual Shoreline Locations

Qualitative descriptions of the occurrence of *Cladophora* at selected shoreline locations are presented in order from north to south along the shoreline. Location numbers reflect the order in which sites were visited.

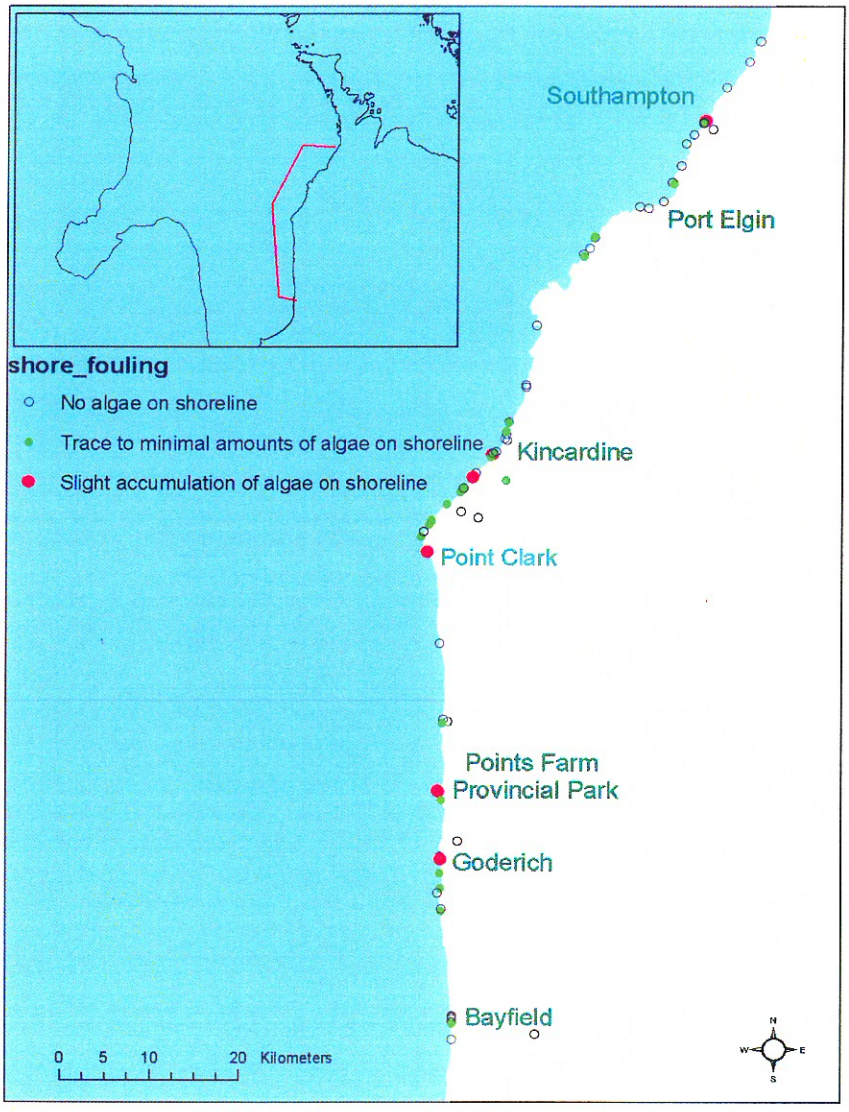

Figure 2. Shoreline fouling with *Cladophora* at locations along southeastern Lake Huron, July 2003.

Table 1. In-lake observations of *Cladophora* and other macro algae at survey locations.

Location	Map Reference	MOE Station	Bottom substrate	Benthic Macro Algae	Biological Observations
North of Southampton	1	575	Cobble/boulders; few patches of clay and gravel	Little to no *Cladophora*; isolated filaments of unidentified filamentous green algae (FGA)	Low density of zebra mussels (*D. polymorpha*) in rock crevices; layer of tan colored periphyton on rocks
North of Saugeen River Mouth	5	576	Cobble / boulders	From waterline to ca. 0.4m depth is small area (roughly 10 – 20 m wide) with heavy *Cladophora* growth; areal cover 20 – 70% and thickness ca. 10cm. *Cladophora* absent below 0.4m depth. Area of growth coincident with mouth of creek/ditch. Few patches of charaphytes.	Low density of zebra mussels; heavy layer of tan colored periphyton on rocks
Port Elgin	14	578	Cobble/boulders; mostly cobble	No *Cladophora* or filamentous green algae; isolated patches of charaphytes	Zebra mussels common at base of rocks and in crevices; gobies present; film of tan colored periphyton on rocks; periphyton growth on zebra mussels.
Macgregor Point	11	577	Stones/cobble and small boulders; occasional small patches of sand	No *Cladophora*; isolated filaments of unidentified filamentous green algae (FGA); Occasional patches of charaphytes	Zebra mussels common at base of rocks an in crevices; gobies numerous; thin layer of tan colored periphyton on rocks
South of Brucedale Conservation area	16	579	Cobble to small-medium rocks with sporadic larger boulders; thin silt layer on rocks; patches of gravel and sand amongst rocks.	No *Cladophora*; moderate amount of charaphytes on gravel and sand patches.	Zebra mussels common; periphyton growth on zebra mussels.
Inverhuron Provincial Park	58	585	Limestone plates becoming boulders/cobble below ca. 1m depth	Occasional clumps of *Cladophora* between rocks; patches of charaphytes	Zebra mussels and gobies present; clumps of Potamogeton
Stoney Island Conservation Area	57	584	Large boulders and cobble	*Cladophora* absent beyond isolated tufts	Low numbers of zebra mussels

Location	Map Reference	MOE Station	Bottom substrate	Benthic Macro Algae	Biological Observations
South of Kincardine (Boiler Beach)	56	583	Boulders/cobble	*Cladophora* absent from 0.5 to 1.8m; thickness of periphyton increases above 0.5m; clumps of *Cladophora* starting at 0.3 - 0.4 m and clumps numerous to shore; maximum thickness ca. 5cm	Low numbers of zebra mussels; gobies numerous; tan colored periphyton film on rocks
Concession 10, Huron Township (Poplar Beach)	52	581	Cobble with few boulders from shore to ca. 1m depth; sand with rocks and boulders from 1 – 2 m depth.	Rocks > 1m depth without *Cladophora*; periphyton thickness increases from 1.0 - 0.8 m; tufts of *Cladophora* start at ca. 0.8 m with beds of *Cladophora* from ca. 0.5 - 0.7 m depth to shore.	
North of Bruce Beach	54	582	Mostly sand with rock/cobble patches.	Scattered small clumps of *Cladophora* on rocks at depths < 0.8m.	
Point Farms Provincial Park	51	580	rock point into lake with lake bottom composed of cobble and boulders	no *Cladophora* at depths beyond 0.4 m. Cover with *Cladophora* variable at depths from 0 to ca. 0.4 m; on north side of point cover ca. 50 - 100% and ca. 5 cm thick; *Cladophora* absent on south side of point. Occasional patches of charaphytes.	Gobies numerous; zebra mussels in rock crevices; occasional patches of Charaphytes; rock surfaces with silt/periphyton layer
Goderich south of harbor	73	590	Cobble and small stones; consolidated and appears to be a stable surface.	No *Cladophora*; numerous patches of charaphytes from 0.5 m depth to shore.	Thin periphyton layer but heavier with brown tubular growths at ca. depths < 0.5m; Zebra mussels present.
Blacks Point	72	589	Boulders and cobble	no *Cladophora* on rock surfaces	Limited periphyton layer with tufts of tan/brown material
Union Road	69	588	sand at waterline then boulders and cobble	Little to no *Cladophora* on rock surfaces. Fragments of algae at base of rocks which may be *Cladophora*	Low numbers of zebra mussels; slight silt/periphyton film on rocks
Bayfield	64	586	cobble from shore to depth of 1m then sand and rock chunks	Limited observations due to high turbidity. No *Cladophora* layer detected on rocks.	Rocks with a pigmented periphyton layer
Crystal Springs Road	67	587	Cobble/rocks from shore to depth of 1m then sand bars. Some clay patches.	Limited observations due to high turbidity. No *Cladophora* layer detected on rocks.	Rocks with a pigmented periphyton layer plus tan colored slit/clay material

The most northerly observation point (location 77) was situated at a rocky point south of Sauble Beach (Figure 3). Based on observations from shore, *Cladophora* was not seen in shallow water at this location. Fresh algal material was not observed, although, old dried mounds of raked up beach debris may have contained some *Cladophora* and Charaphyte algae. Charaphytes are a widely distributed macrophyte-like group of green algae that grow loosely rooted by rhizoids to soft sediment in freshwater. They are not typically associated with shoreline fouling problems in the Great Lakes.

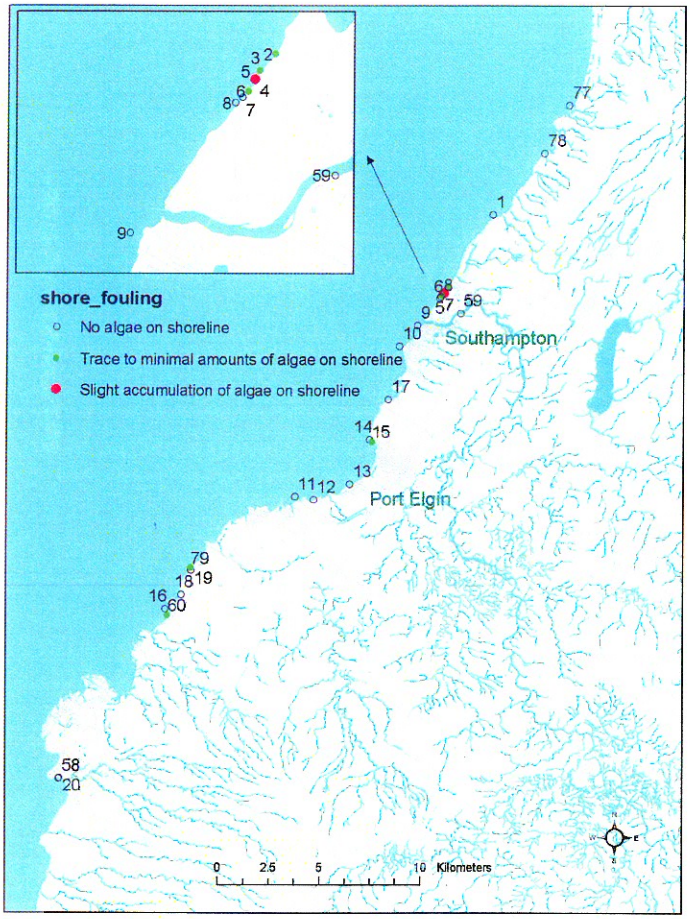

Figure 3. Shoreline observation sites from south of Sauble Beach to south of Douglas Point, southeastern Lake Huron, July 2003.

A small amount of algae was observed on shoreline north of the mouth of the Saugeen River (location 5, station 576). The location coincided with a localized area where *Cladophora* was growing on the lake bottom (Table 1; Figure 4) and suggests an area of nutrient input. The

enhanced growth of *Cladophora* is unlikely a result of the Saugeen River plume alone since the river plume affects water quality over a wide reach of shoreline. A small drain/creek draining to the shoreline near to where the algae was observed may have contributed nutrients to the area, however, water quality of drain/creek was not evaluated. Areas (locations 9 & 10) visited to the south of the Saugeen River mouth along the Southampton shoreline lacked any accumulation of algae on the shoreline.

Figure 4. Location 5 (Station 576) just north of the mouth of the Saugeen River with algae accumulated on shore. The area of algal fouling coincided with a localized area of *Cladophora* growth in the shallows along the shoreline.

Areas of shoreline examined at Port Elgin were largely free of algae. A small area with *Cladophora* was observed on rocks just north of the harbor (location 15), but was limited to shallow water adjacent to shore and a ditch that was possibly a storm sewer (Figure 5). A slight amount of dead algae was present on the shoreline. Slightly north of this location at station 578 (location 14), the lake bottom was free of any visible algal growth (Table 1), as was the case for most of the shoreline. Similarly, the lake bottom was also relatively free of *Cladophora* at Macgregor Point (location 11, station 577) south of Port Elgin (Figure 6; Table 1).

Figure 5. Location 15, north of the Port Elgin harbor, where *Cladophora* was limited to very shallow water immediately adjacent to shore and near a drain, which was possibly a storm sewer.

Figure 6. Location 11 (station 577) Macgregor Point.

Several shoreline locations were visited on Sunset Drive in the vicinity of the Brucedale Conservation Area. At location 79, where Concession Road 12 meets the lake, there was no indication of *Cladophora* growing on rocks in shallow water or washing up on the shoreline. Roughly 500m north along the shore, patches of *Cladophora* 2 – 10 cm thick were seen growing on rocks near the waterline. At this location, algae was also observed on the dry bed of a creek/ditch. South of the conservation area at station 579 (location 16), rocks were largely free of *Cladophora* (Table 1). However, a small area of lake bottom, slightly south along the shore (location 60) and adjacent to a small creek/ditch, was found to have a lawn of *Cladophora*

(Figure 7). The area with *Cladophora* extended < 50 m along shore from the mouth of the creek. A small amount of algae was accumulated on the shoreline adjacent to the mouth of this small creek/ditch.

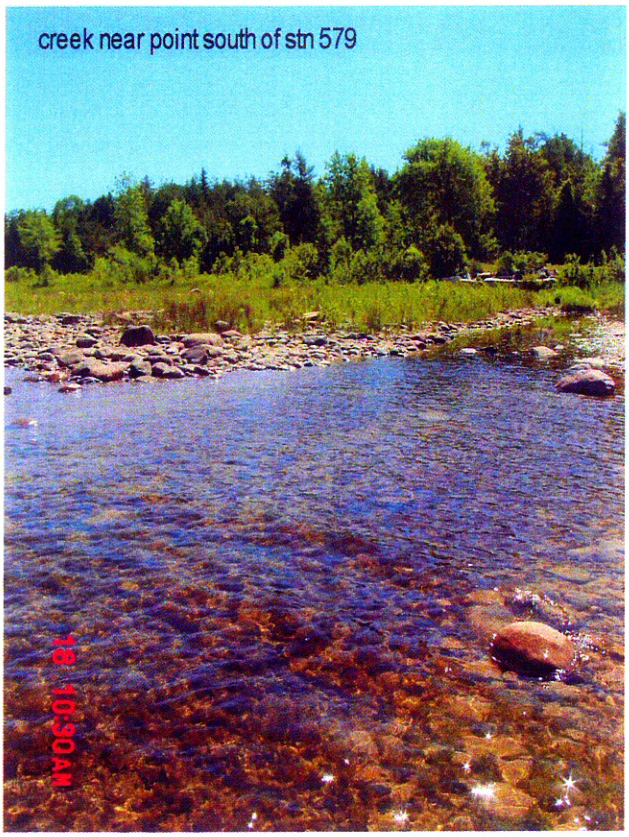

Figure 7. Location 60 having algal growth adjacent to a small creek.

Further south at Inverhuron Provincial Park (location 56, station 583) and Stoney Island Conservation area (location 57, station 584) there was little *Cladophora* or other macro algae on the lake bottom and no indication of dead algae on the beach (Table 1).

Several locations north of Kincardine had small quantities of *Cladophora* on the shore (Figure 8). Numerous small patches of algae were observed on the shoreline at location 22 but the quantity was insufficient for the formation windrows of material usually seen in fouled areas. A nearby ditch had *Cladophora* growing in it. Small, scattered clumps and slight windrows of *Cladophora* were observed at locations 27 & 28 but, at the time of observation, the amounts of

algae were minimal and were not considered to pose an aesthetic problem. High winds and turbid lake conditions prevented any in-lake observations.

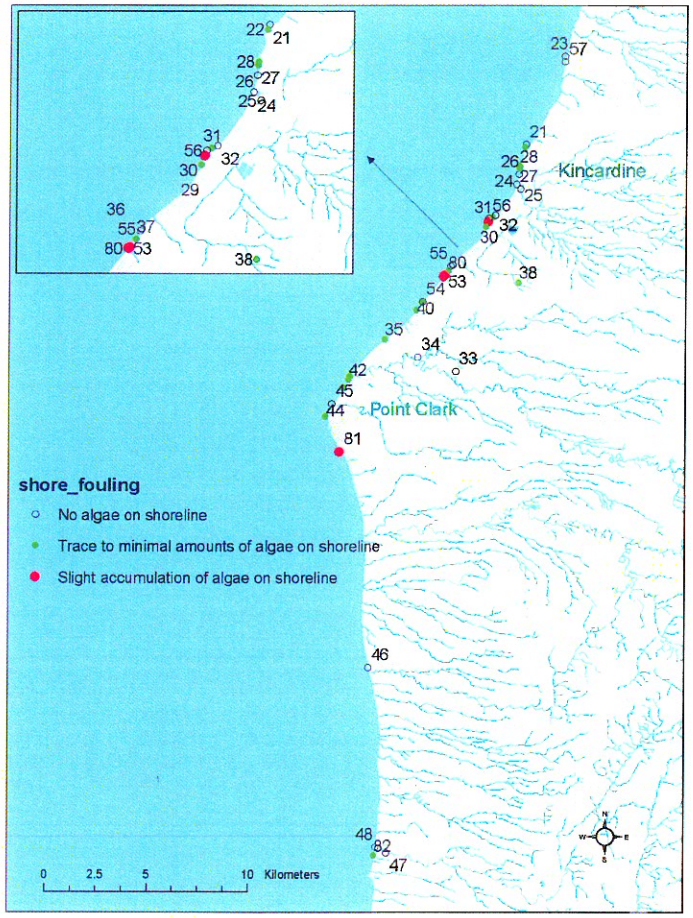

Figure 8. Shoreline observation sites from north of Kincardine to Port Albert.

A limited degree of shore fouling by washed-up *Cladophora* was noted immediately south of Kincardine in the area of station 583 (location 56). At nearby location 29, a moderate amount of algae was seen on the shore and formed a small windrow of material, although, at other adjacent observation points (locations 30, 31& 32) the amount of material observed on the shore was slight. Enhanced growth of *Cladophora* as a band of material in shallow water immediately adjacent to the shoreline was observed at station 583 (location 56) (Table 1). Growth of *Cladophora* was strongly related to depth with clumps of algae absent at depths

greater than 0.4-0.5m. The shoreline band of algae did not appear to coincide with any shoreline features.

There was an extensive area with algae on shore at Poplar Beach, where Concession Road 10 intersects the lake (Figure 9). Intermittent windrows and clumps of algae were widely distributed along the beach, but not in great quantity. Residents had raked the algae into piles on the beach in some locations. Observation of the lake bottom (location 52, station 581) revealed that growth of benthic algae was strongly related to depth. *Cladophora* was abundant on the rocks from the shoreline to depths of 0.5-0.7m but absent on rocks at depths greater than 1m. A band of algae appeared to extend along the shoreline. Additional in-lake observations (to a depth of ~1.5m) were made at a site (location 55) north of location 52 where a small creek/drain meets the lake. Two spatial patterns in algae were observed. A length of shoreline roughly 5 - 20 m coincident with the drain/creek was covered with dark green/black filaments of *Cladophora* to a depths of ~1.5 m. Beyond this area growth of *Cladohora* was distributed along the shoreline as small clumps on rocks and was limited to depths of ~ <0.5 m.

Further south along the shore at Concession Road 8 (locations 39, 40, and 54), the beach had small clumps of algae (~ 2 - 5 cm in diameter). There were no windrows of algae as observed at the sites to the north. At station 582 (location 54) small scattered tufts of algae were growing on rocks at depths < 0.8 m in an area dominated by sand substrate (Table 1).

Figure 9. Location 36 Concession Road 10 with intermittent windrows, clumps, and patches of algal material distributed along shoreline.

At Concession Road 6 on Bruce Beach (location 35) areas with scattered clumps of *Cladophora* were observed along the approximately 100m of shoreline examined.

Traces of *Cladophora* were seen on the shore near the mouth of the Pine River (locations 41, 42, & 43). Traces of dried algae buried by sand and small piles of algae raked up by residents suggest that algae may have been more abundant on the beach in the past. Also observed were patches of *Cladophora* growing from sand where moving sand had likely covered rocks colonized by algae (Figure 10). At the time of observation there was a strong west wind and 1-2m waves, yet little algae was seen at the waterline suggesting that there was little algae growing on the lake bottom. There was a small amount of brown-gray organic debris pooled at the creek mouth composed of a mix of detritus, decayed algae and silt (Figure 10).

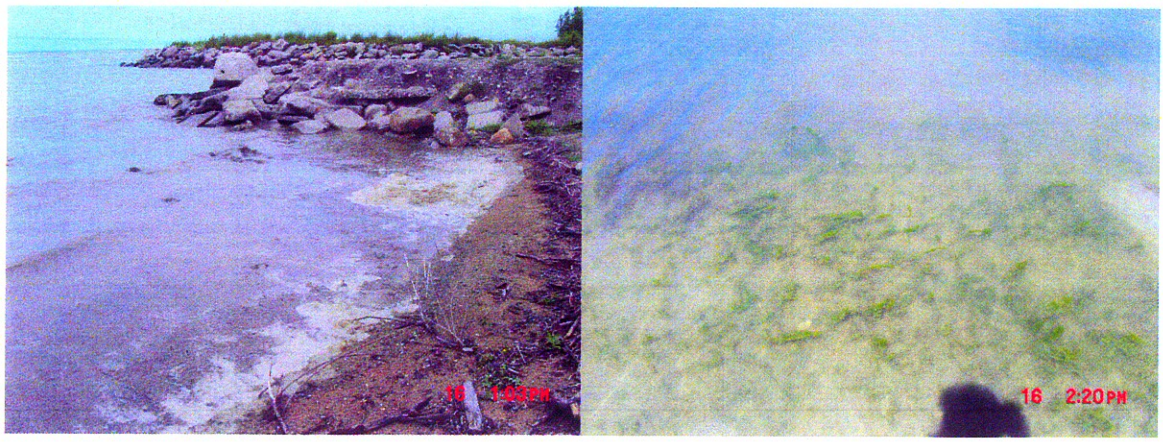

Figure 10. Location 41 at mouth of the Pine River with traces of *Cladophora* on shore. Moving sand had covered rocks that *Cladophora* was growing on.

At Point Clark (location 44), little algae was seen along the shoreline beyond isolated clumps of freshly beached *Cladophora*. Unidentified filamentous green algae was abundant in a creek mouth at location 45; however, the beach was free of algae.

At location 81, south of Point Clark on Amberly Beach, a noticeable amount of plant material was washed up onto the beach. This material, although not well described, was composed of a mixture of charaphytes and an unidentified grass-like macrophyte. The lake bottom was observed by wading along the shore and revealed the growth of charaphytes and the grass-like macrophyte.

At Kintail Beach (location 46) no algae was observed on the shoreline beyond a few partially buried pieces of *Cladophora*.

Observations along the shoreline in the Port Albert area (locations 48 and 82) suggested that there was little algae washing onto the beach. On July 16 algae was observed washing in the surf, but only a few fragments were observed on the beach. During a second visit on July 30, occasional small clumps of *Cladophora* were seen on shore.

At Point Farm Provincial Park algal material was accumulating along a beach on the north side of a rocky point into the lake (Figure 12). On the north side of the point, an abundance of *Cladophora* was observed to depths of ~0.4 m (location 50, station 580). Areal cover was 50 - 100% and the *Cladophora* layer was ~ 5 cm thick (Figure 12; Table 1). In contrast, *Cladophora* appeared to be mostly absent on the south side of the point. A large number of gulls were observed roosting on the point.

At Sunset Beach (Location 83), some *Cladophora* was washed-up on shore. Patches of *Cladophora* were growing on the lake bottom in shallow water.

Algal fouling of shoreline was observed near the discharge of the Goderich sewage treatment plant otherwise there was little algae on the shoreline at Goderich. Rotting algae was pooled at the waterline (Figure 14) near the discharge. A large man-made spit separates a beach area from the point where the sewage treatment plant discharges into the lake. *Cladophora* was abundant on rock surfaces of the spit near the sewage treatment plant but appeared to be absent on rocks on the beach side of the spit. Fouling of the Goderich shoreline by algae has been reported previously (Jackson 1985). At station 590 (location 73) south of the harbour, the lake bottom was visibly free of *Cladophora* growth and no algae was seen on the shore (Figure 13). The shoreline to the north of the mouth of the Maitland River is not publicly accessible and was not surveyed.

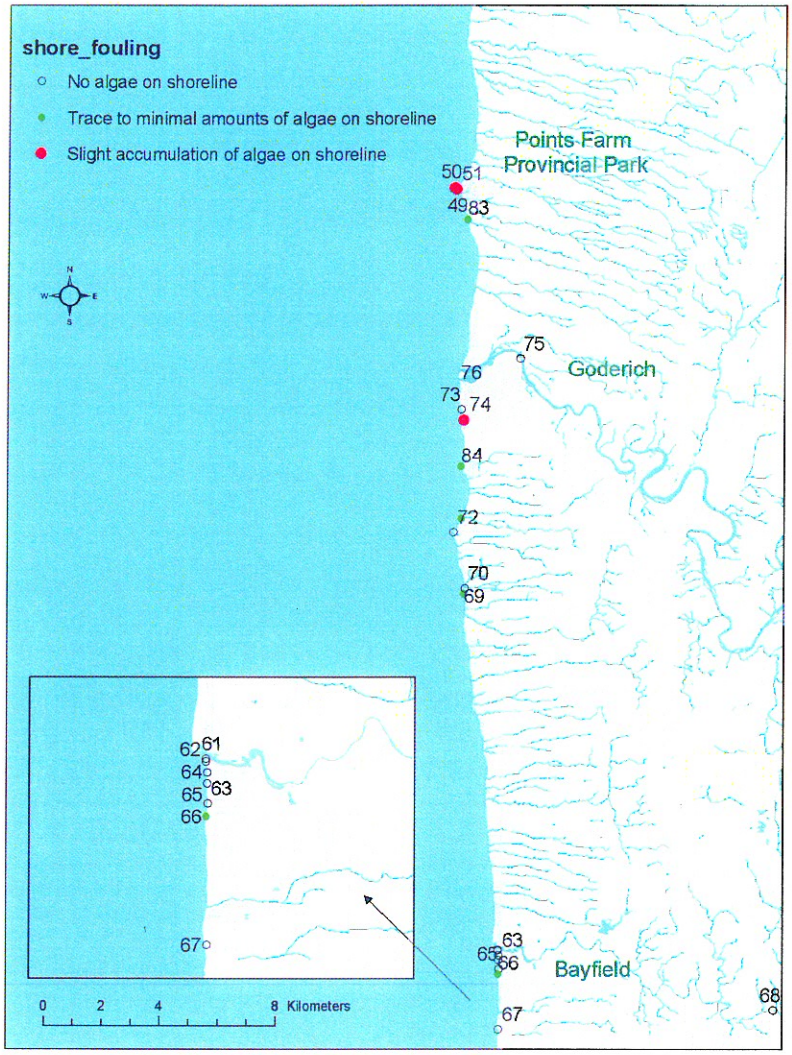

Figure 11. Shoreline observation sites from Points Farm Provincial Park to Bayfield, southeastern Lake Huron, July 2003.

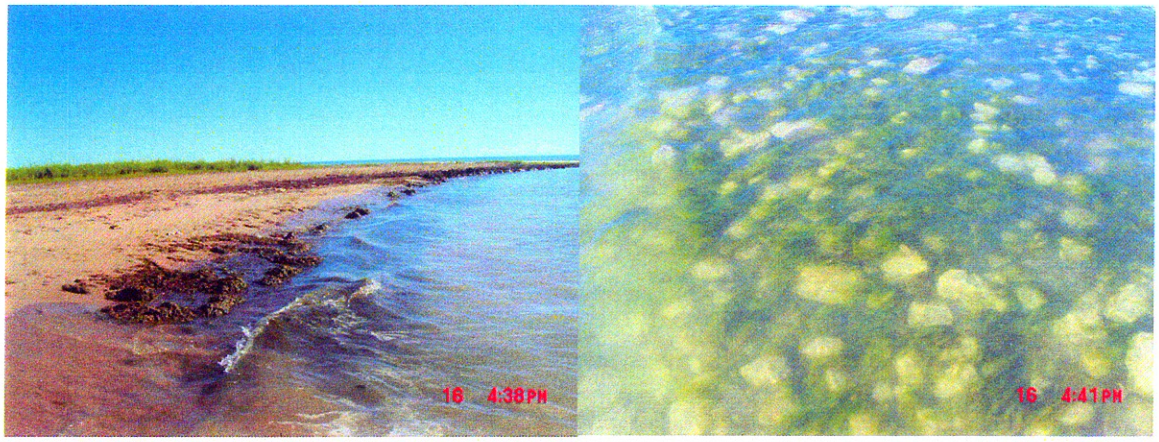

Figure 12. Location 50 (Station 580) Point Farms Provincial Park where *Cladophora* was abundant in the shallows on the north side of the point, but absent on the south side. A large number of gulls were observed roosting on the point.

Figure 13. Location 73 near Goderich (Station 590) where a spit of land (background) separates the sewage treatment plant discharge from the beach area (foreground).

Figure 14. Location 74 near the Goderich sewage treatment plant discharge into Lake Huron, showing an area of lake bottom with algae.

On the north side of Black's Point (Location 71), there was a small amount of algae on the shore and washing around the waterline, near a small area of *Cladophora* growth on the lake bottom. Algae growth on the lake bottom was highly variable. Patches of *Cladophora* were < 5 cm thick and appeared to limited to depths of ~ ≤0.5 m. South of this location, on the south side of Black's Point (location 72, station 589), there was no *Cladophora* on the rocky lake bottom.

South of Black's Point at the end of Union Road the shoreline was free of algal material except for occasional small clumps of *Cladophora*. Only one lake station (location 69, station 588) (Table 1) could be observed because of high turbidity and poor visibility when the site was visited. Rock surfaces to 1 m depth appeared to be mostly free of algae, however, tufts of filamentous algae (possibly *Cladophora*) were growing at the base of rocks. A small creek/ditch located ~100 - 200 m south of Station 588 had a moderate amount of filamentous green algae on the creek bed (Figure 15). There was only a slight flow in the creek/ditch and algal material did not appear to be moving onto the shoreline.

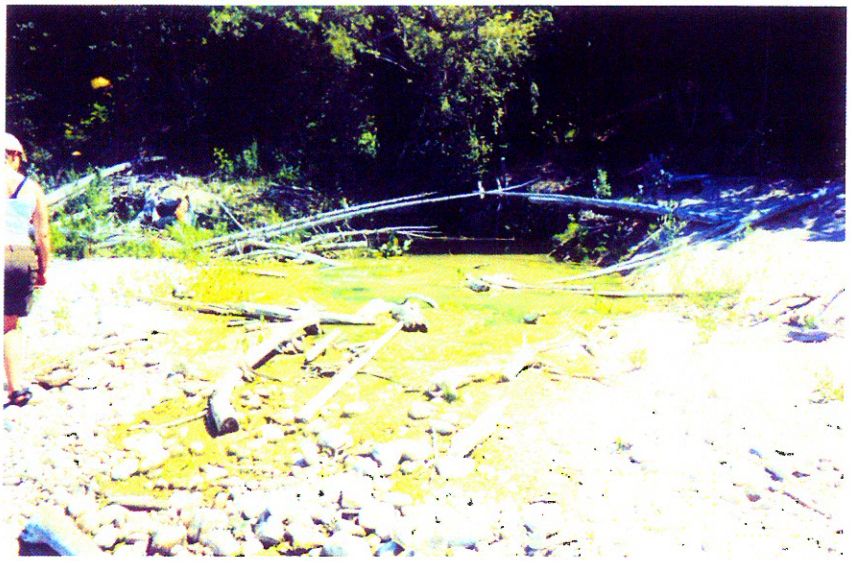

Figure 15. Location 70 with a drain covered with algae near the shoreline.

A small amount of *Cladophora* and detritus was observed at the waterline and washed on shore at a site on the southern end of Bayfield Beach (Location 66) (Figure 16). *Cladophora* was not visible on the rocks in the immediate area. Slightly north, at station 586 (location 64) and location 65, the shoreline was also free of algae. However, at Location 65, *Cladophora* that was observed in the lake on rocks at water depths of 20 - 30 cm. High turbidity precluded visual observation of the lake bottom.

At station 587 (location 67) south of Bayfield, there was no *Cladophora* on rock surfaces in the lake or washed up on the beach. Again, high turbidity limited visual observation of the lake bottom. Along the shoreline south of the observation point there was a small band of dried and decomposed *Cladophora* mixed into the sand, which suggested there had been some accumulation of algae on the beach in the past.

Figure 16. Location 66 south of Bayfield where a small amount of *Cladophora* and detritus was observed at the waterline and washed on shore.

Shoreline Water Quality During the Survey

The limited nutrient and water quality data collected at the time of algae survey suggests several locations where impacts on water quality at the shoreline had occurred. However, variability in shoreline water quality is typically high and limits the extent to which results for isolated point-in-time samples can be interpreted.

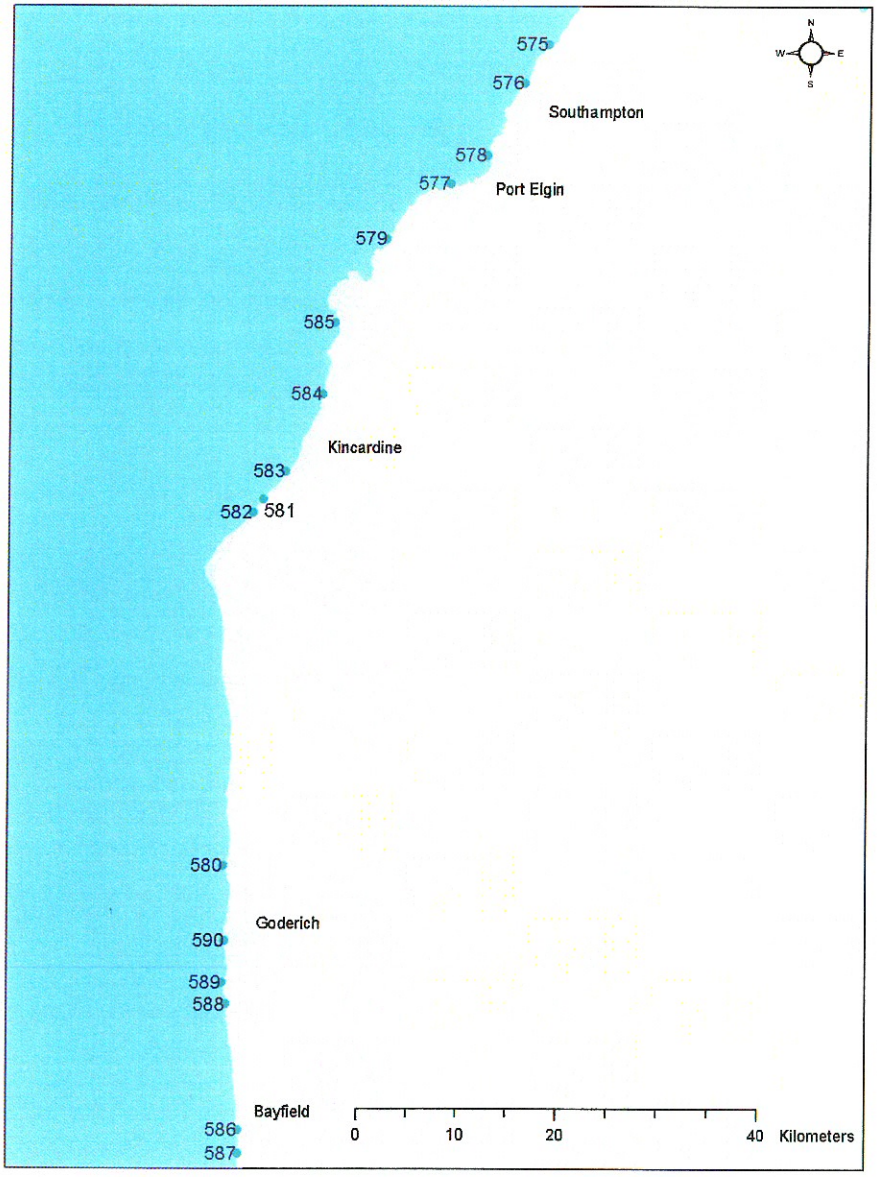

Figure 17. Location of sites where samples were collected for water quality analysis during the shoreline algae survey. Ministry of Environment station numbers are shown.

Table 2. Water quality data collected during the July 2003 shoreline algae survey. Samples were collected 0.2 m below surface at lake depths of 1 m.

Station	Day	Temp (°C)	Turbidity (FTU)	Solids (mg/L)	Conductivity (uS/cm)	Cl (mg/L)	pH	Alkalinity (mg $CaCO_3$/L)	NO_{2+3} (µg/L)	NH_{3+4} (µg/L N)	Organic N (µg/L)	TP (µg/L)	PO_4 (µg/L)	DOC (mg/L)	DIC (mg/L)	Silicate (mg/L)	Easting	Northing
575	14	20.2	1.72	2.1	230	8.6	8.16	83.7	372	111	1419	64	48.4	3	20.0	0.48	473628	4932900
576	14	23.5	7.49	14.5	239	7.1	8.47	88.3	345	13	297	44	1.2	1.7	20.1	0.46	471232	4928992
577	15	19.1	0.5	0.8	216	6.3	8.3	82.9	328	19	171	5	1.6	1.5	19.3	0.58	463915	4918910
578	15	18.9	0.75	1.4	222	6.7	8.29	84.5	399	17	223	3	1.3	1.4	19.9	0.58	467577	4921775
579	15	20.8	6.36	34.7	219	6.3	8.36	85.7	326	40	370	53	1.2	1.6	19.3	0.84	457542	4913366
580	17	19.9	8.83	14	247	8	8.34	91.9	612	23	217	13	1.9	1.8	22	0.44	441379	4850425
581	17	21.3	11.8	18.2	232	6.8	8.36	90.4	688	21	229	15	1.9	1.4	20.5	0.56	445205	4887197
582	17	22.1	13.6	20.7	235	6.7	8.34	91.4	674	20	280	18	1.8	1.4	20.6	0.54	444140	4885887
583	17	21.9	3.88	4.5	228	6.7	8.37	86.8	621	26	184	8	1.5	1.4	20.1	0.54	447438	4890019
584	17	20.9	21.4	27.2	220	6.5	8.25	82.8	414	20	380	22	1.7	1.7	19.7	0.42	451155	4897794
585	17	19.8	1.49	4.4	219	6.5	8.33	83.1	419	25	165	5	1	1.5	19.4	0.44	452328	4904963
586	24		40.9	57.1	216	6.9	8.3	83.8	385	15	435	55	2	1.2	19.3	0.36	442957	4823870
587	24		41.1	61.3	224	7.2	8.31	85.2	471	<W	638	74	2	1.1	19.3	0.38	442957	4821481
588	24		6.34	7.6	224	7.4	8.31	84.1	352	<W	188	8	1.8	1.4	18.8	0.44	441688	4836479
589	24		11.9	14.7	224	7.3	8.33	88.2	422	11	199	13	2	1.3	19.5	0.52	441324	4838611
590	24		1.5	2.6	218	7.1	8.34	82.1	333	14	196	8	1.3	1.3	18.9	0.48	441590	4842839

In Table 2, data below minimum reportable levels for the analysis method were indicated as <W. The minimum reportable value for ammonia + ammonium was 2 µg/L. Water samples from Station 576 were collected at a lake depth of 0.4 m. The interim Provincial Water Quality Objective (PWQO) for total phosphorus (TP) in Lake Huron is 10 µg/L. The PWQO for un-ionized ammonia is 20 µg/L. The fraction of ammonia + ammonium that is un-ionized ammonia is a function of the sample temperature and pH. The PWQO was not exceeded in any sample.

Turbidity and suspended solids were highly variable among locations, reflecting the variable wind conditions and extent of resuspension in the nearshore during the survey (Figure 18; Table 2). Suspended solids exceeded 10 mg/L in nine samples ranging up to 61 mg/L.

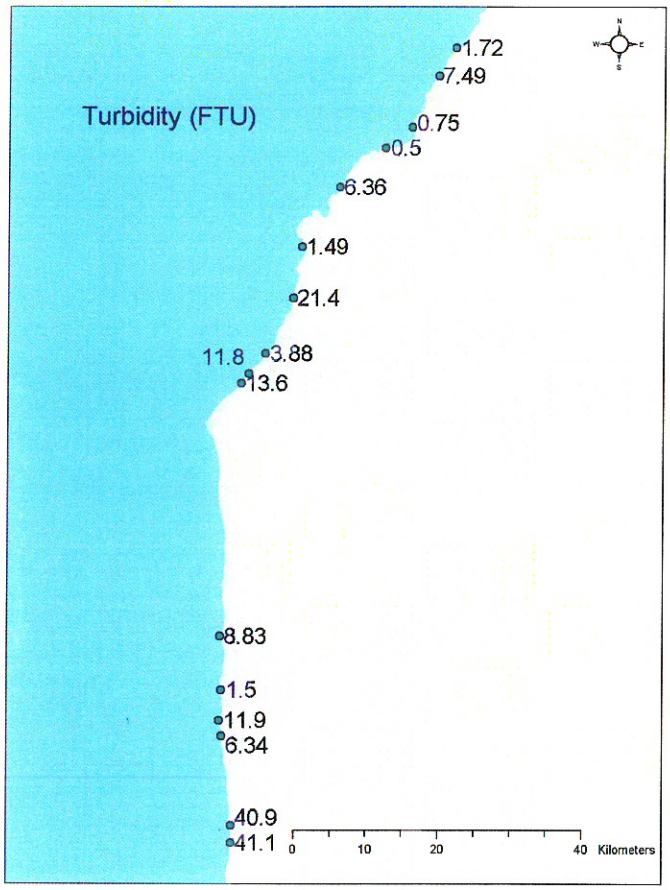

Figure 18. Turbidity levels at locations in southeastern Lake Huron, July 2003.

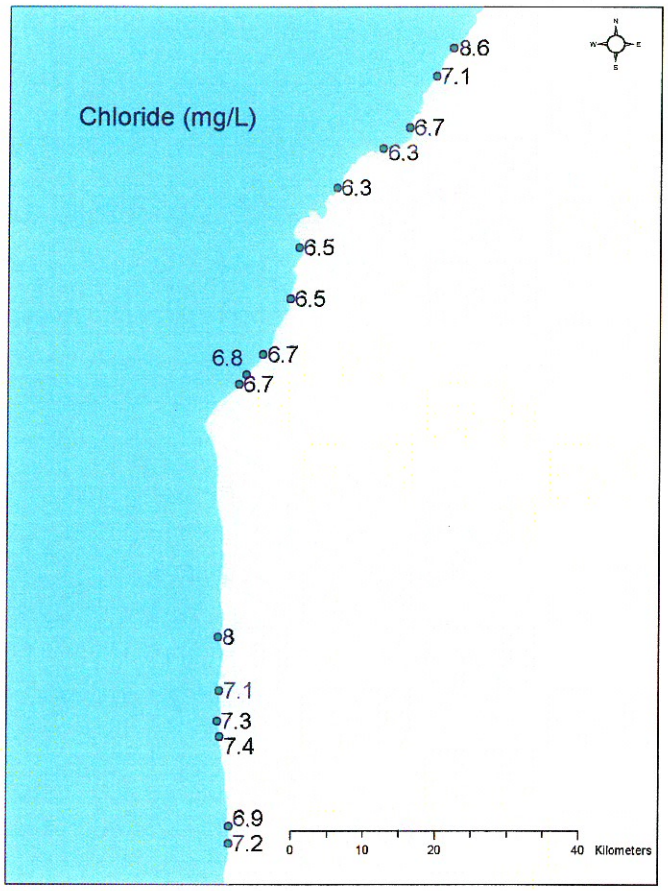

Figure 19. Chloride concentrations at locations in southeastern Lake Huron, July 2003.

Offshore chloride is generally stable relative to the nearshore, which is expected to fluctuate with shoreline inputs. During the survey, chloride ranged from 6.3 - 8.6 mg/L (Figure 19). In comparison chloride ranged from 6.1 - 8.8 mg/L in 2002 and 2003 at index and reference stations on the eastern shores of Lake Huron that are periodically monitored by MOE (Table 3). The range in chloride at index and reference stations declines to 6.1 - 7.0 mg/L when two stations that are periodically affected by tributary plumes are excluded. The chloride concentrations measured during the shoreline algae survey do not suggest areas of elevated chloride with the possible exception of station 575 (north end of survey area).

In the nearshore, nitrate concentration can vary greatly due to biological uptake, however, variability is usually seen as a reduction in concentration from ambient lake levels except where

there are inputs from the shore. Nitrate concentrations ranged from 326 to 688 µg/L and exceeded 600 µg/L in four samples (Figure 20). Although little significance can be placed on the results of these isolated samples, concentrations greater than 600 µg/L suggest nutrient input to the lake at the time of sampling.

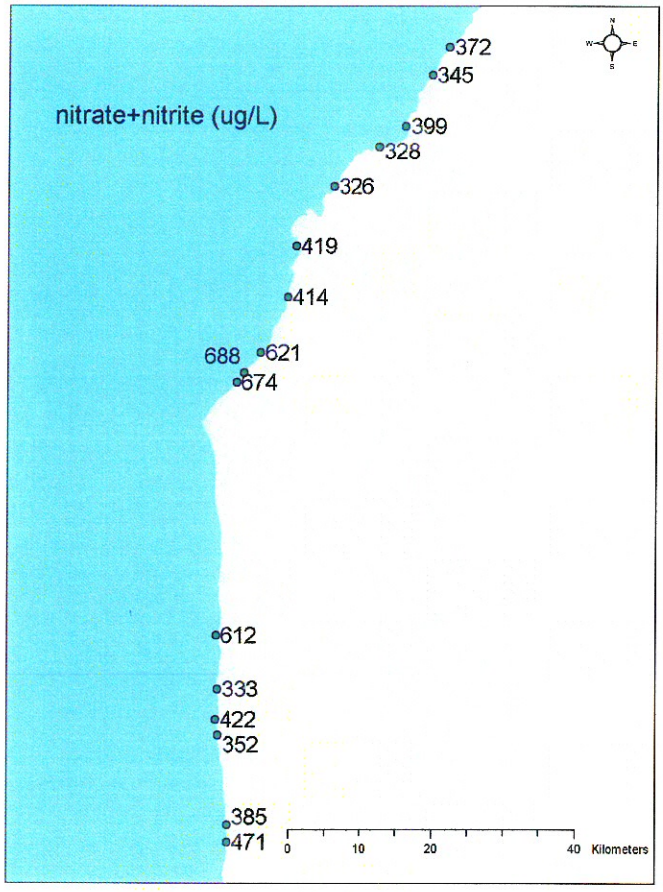

Figure 20. Nitrates concentration at locations in southeastern Lake Huron, July 2003.

Open waters of southeastern Lake Huron are oligotrophic. Ambient total phosphorus is expected to be near 5 µg/L. In contrast, TP in the shoreline samples ranged from 3 - 74 µg/L; 10 samples were > 10 µg/L (Figure 21). Water samples in this survey were not filtered. Organic debris in shoreline samples can result in elevated total P and organic N concentrations and make interpretation of nutrient data difficult. Elevated TP concentrations coincided with

moderate to high levels of suspended solids in many samples. Total phosphorus is highly correlated with suspended solids in the dataset. Conversely, nitrate and chloride concentrations were not significantly correlated to TP concentrations ($p>0.25$) as is expected with land-based sources of nutrients. In the absence of additional information, it is not possible to determine the degree to which elevated TP concentrations reflect local enrichment or are an artifact of sampling. Results for station 575, the most northerly site, are less equivocal and suggest enrichment. An elevated TP concentration is coincident with low turbidity, elevated chloride and DOC. Shoreline fouling by benthic algae was not observed at the site, and field observations did not suggest anything anomalous at the time of sampling.

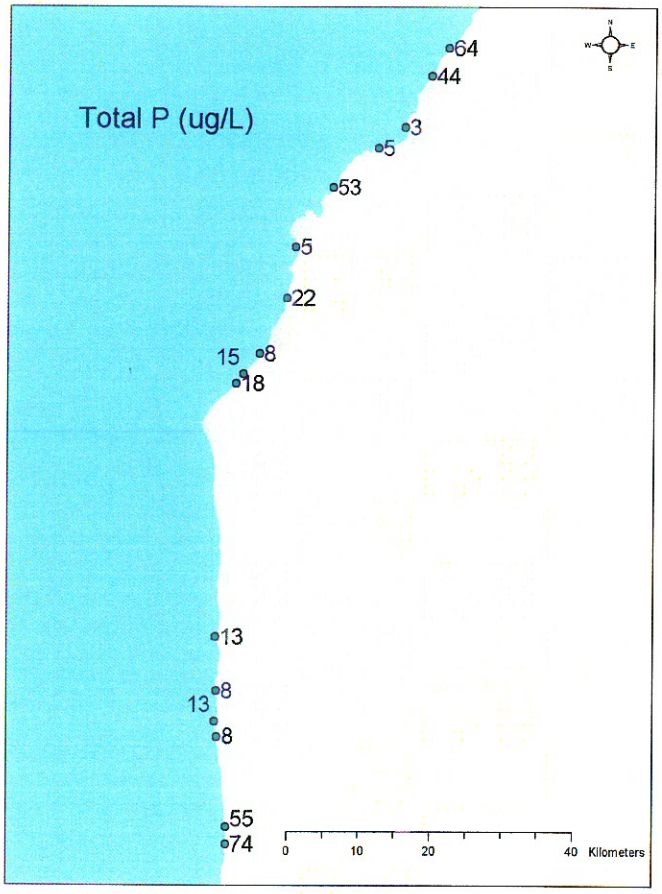

Figure 21. Total phosphorus (TP) concentrations at locations in southeastern Lake Huron, July 2003.

Factors Affecting *Cladophora* Growth

Nutrients

Phosphorus is the main nutrient thought to limit the growth of *Cladophora* in Lake Huron (Auer et al 1983). Jackson and Hamdy (1982) used an empirical relationship between water TP and *Cladophora* tissue concentrations of P to predict the increase in TP above the ambient concentration required to stimulate growth of *Cladophora* over areas of bare rocky bottom in southern Georgian Bay. They suggested that the minimum cell quota for growth (given as 0.04% P DW) occurred at an ambient TP level of approximately 5 μg/L, consistent with their observation that *Cladophora* was absent from many areas of Georgian Bay where average TP was ~5 μg/L. They concluded, based on the sporadic occurrence of *Cladophora* in Georgian Bay in association with sites of nutrient enrichment, that *Cladophora* was extremely efficient at scavenging nutrients and would colonize suitable substratum given the slightest nutritional advantage.

Selected nutrients were measured in 2002 and 2003 at reference and index stations in Lake Huron maintained by the Ministry of the Environment and provide information on ambient nutrient concentrations in the nearshore (Table 3). Average TP concentrations ranged from 3 to 8 μg/L. Ipperwash (Station 606) and Kincardine (Station 131) represent nearshore area away from the immediate effects of major rivers. For these sites, TP concentrations ranged from 3 to 5 μg/L between August 2002 and November 2003. Inorganic nitrogen concentrations in Lake Huron are high relative to phosphorus concentrations and are not thought to limit *Cladophora* growth. Nitrate concentrations exceeded 300 μg/L for all but three sampling occasions over the index/reference station surveys in 2002 and 2003 (Table 3).

The absence of *Cladophora* over wide areas of the lake bottom is likely due to phosphorous limitation due to ambient levels that are below minimum growth requirements. It is suspected that there were sources of phosphorus input to the lake at the locations where *Cladophora* growth was observed. The 2003 observations on the occurrence of benthic algae are similar to those of Jackson (1985) who, based on studies conducted in 1980, concluded that the shoreline of Lake Huron was largely devoid of attached filamentous algae, despite favorable physical conditions for growth. In Jackson's study, the absence of algae was attributed to phosphorus

levels too low to support basin-wide growth. However, the growth of algae was observed on a local basis in association with natural or anthropogenic nutrient sources (Jackson 1985).

Light

Optimal growth of *Cladophora* requires moderately high levels of photosynthetically active radiation (400-700 nm PAR). Graham et al. (1982) reported that the optimal light level for *Cladophora* growth was in the range of 300-600 $\mu E/m^2s$ under optimal growing temperatures in laboratory conditions. The depth to which benthic algae grow can be strongly limited by light in areas with high turbidity and low water clarity. Observation of water clarity along the shores of Lake Huron suggests that water clarity is frequently high.

Optical measurements were made at reference and index stations in 2002 and 2003 (Table 3). PAR attenuation coefficients can be used to provide insight on the light regime of the lake bed. Assuming that full sunlight on a summer day provides a subsurface level of approximately 1800 $\mu E/m^2s$ of PAR, then maximum depths with optimal levels of PAR for growth of *Cladophora* can be approximated from attenuation coefficients. Over the 2002 and 2003 surveys PAR attenuation coefficients were $< 0.26m^{-1}$ for 83% of the measurements and frequently $<0.16m^{-1}$. With an attenuation coefficient of $0.25m^{-1}$ under full summer sun, it is expected that there would be adequate light for optimal growth (300 $\mu E/m^2s$) to a depth of approximately 7m. It is unlikely that the sharp decline in abundance and occurrence of *Cladophora* with depth observed at numerous locations in July 2003 was due to light limitation. High levels of turbidity and low water transparency were observed in the nearshore on several occasions after strong winds and waves. However, it is unlikely that the persistence of such events would be sufficient to limit growth of benthic algae.

Table 3. Selected water quality features of Ontario Ministry of the Environment index and reference stations on eastern shores of Lake Huron, 2002 and 2003.

Station – Area	Date (dd/mm/yy)	Depth (m)	K_{par} (m^{-1})	Secchi (m)	Chlorophyll-a (µg/L)	TP (µg/L)	Nitrates (µg/L)	Suspended solids (mg/L)	DOC (mg/L)	Chloride (mg/L)
Cape Ipperwash (606)	11/05/02	19.2	0.21	11.0	0.7	4	328	0.7	1.5	6.6
	05/11/02	19.1	nd	6.5	0.8	3	301	0.8	1.3	6.8
	03/06/03	19.2	0.16	3.0	1.0	5	740	1.9	1.9	7.0
	13/08/03	19.2	0.12	10.9	0.5	4	313	0.5	1.6	7.0
	12/11/03	19.2	0.21	4.4	0.8	4	336	1.0	1.6	6.6
Goderich (604)	13/08/02	9.5	0.25	4.0	0.6	5	320	1.9	1.5	7.3
	05/11/02	9.0	0.70	1.0	1.5	8	329	7.6	1.4	7.4
	03/06/03	9.0	0.25	5.0	0.4	5	765	1.4	2.1	7.8
	13/08/03	9.0	0.22	5.6	0.9	5	564	1.0	2.1	8.8
	12/11/03	9.2	0.52	1.8	2.1	7	835	3.7	1.9	8.3
Kincardine (131)	19/08/02	26.2	0.10	11.0	0.7	3	304	0.7	1.5	6.4
	05/11/02	26.6	0.13	8.0	1.3	3	318	0.5	1.2	6.6
	03/06/03	26.2	0.11	16.2	0.5	4	344	0.5	1.6	6.1
	14/08/03	25.9	0.12	16.0	0.5	3	319	0.5	1.6	6.4
	30/10/04	26.1	0.12	10.4	0.6	3	307	0.6	1.5	6.5
Southampton (607)	20/08/02	16.7	0.20	7.5	0.6	5	298	1.1	1.7	6.5
	06/11/02	14.9	0.15	5.0	0.4	4	321	0.6	1.3	6.6
	02/06/03	16.4	0.14	9.3	0.3	4	413	0.5	1.9	6.7
	14/08/03	16.6	0.13	9.3	0.6	4	381	1.4	2.7	7.9
	27/10/03	16.3	0.27	6.0	0.9	8	380	1.1	1.9	7.1

Station – Area	Date (dd/mm/yy)	Depth (m)	K_{par} (m^{-1})	Secchi (m)	Chlorophyll-a (µg/L)	TP (µg/L)	Nitrates (µg/L)	Suspended solids (mg/L)	DOC (mg/L)	Chloride (mg/L)
Stokes Bay (608)	15/08/02	10.5	0.20	6.5	0.9	5	254	1.5	1.7	6.3
	30/10/02	10.0	0.17	9.5	0.4	4	311	0.9	1.6	6.5
	06/06/03	10.2	0.17	9.8	0.3	3	256	0.6	1.7	6.3
	03/09/03	10.3	0.32	2.5	2.3	6	198	1.9	1.4	6.6
	23/10/03	10.2	0.16	7.8	0.5	3	295	0.5	1.4	6.6

In Table 3, water quality measurements were for depth-integrated samples over the mixed portion of the photic zone and are means of three replicate analyses with the exception of secchi depth and PAR attenuation (Kpar). Estimates of Kpar were for a segment of the PAR attenuation profile with depth extending from 1 m below surface to the deepest point of the profile which is typically around 1 m above the lake bed. Chlorophyll-a values were for total chlorophyll. Some the results for chlorophyll-a, total phosphorous (TP), and suspended solids were below minimum reportable values (<W) which were 0.2 µg/L, 2 µg/L and 0.5 mg/L, respectively. When values were <W, null values were used to calculate means.

Substrate

The character of substrates along shore will predetermine the potential growth and distribution of *Cladophora* because it specifically requires a hard stable surface for attachment. Observation of lake bottom at sites during the July survey suggested that there is an abundance of hard substrate at many locations. Sheets of limestone or shale typical of the *Cladophora* infested areas of Lake Ontario and Lake Erie were generally absent with a few exceptions. The dominant hard substrates were cobbles and boulders of various sizes and were interspersed with deposits of gravel and sand. The smaller rock sizes may be unstable, especially during storm events that result in strong wave action from onshore winds. Ice scouring of the shallow lake bottom in the spring may also redistribute rock surfaces and impede the development of benthic algae. The boulder-sized rocks common along the shoreline likely provide stable surfaces for *Cladophora* growth. It is unlikely that a lack of suitable growing surfaces limits the distribution of *Cladophora* over the study area.

Conclusions and Recommendations

There was only minimal shoreline fouling with algal material among the locations surveyed in July 2003. Shoreline windrows of fresh algal material had accumulated near the waterline or had washed onto the beach at several locations, but the quantity of material was never extensive. A small area of shoreline directly adjacent to the Goderich sewage treatment plant discharge was the only location where aesthetic conditions would readily be recognized as affected by rotting algae on shore.

Shoreline fouling was usually adjacent to areas with enhanced growth of *Cladophora* on the lake bottom. The lake bottom at most locations either lacked visible signs of *Cladophora* or had minimal growth. At no point did *Cladophora* extend beyond depths of 1 m, even at locations with enhanced growth.

The limited distribution of *Cladophora* on the lake bottom strongly suggests that ambient TP levels limited the potentially prolific growth of *Cladophora*. There was sporadic occurrence of *Cladophora* among locations suggesting that shoreline inputs locally elevated TP levels and stimulated the growth of *Cladophora.*

The growth of *Cladophora* tended to be negatively related to depth even over the very shallow depths where it occurred. Since light did not appear to be limiting for growth of *Cladophora* at the depths over which growth declined, the decline was likely due to dilution of shoreline nutrient inputs.

Further investigation of water quality conditions along the shoreline between Kincardine and Point Clark is suggested to better understand sources of nutrient supply along the shoreline. While the extent of the algae problem observed in July 2003 was limited, the observed pattern of algae growth at sites in this area provides evidence of nutrient enrichment. Physical conditions for growth of benthic algae are good and further nutrient enrichment may create a more significant fouling problem. The suggested focus of study should be on mechanisms of nutrient supply and dispersal along the shoreline through: i) small point source input via drains, small creeks and small tributaries to the shoreline, and, ii) sub-surface drains and groundwater flow at the land/water interface.

There were several shortcomings of the shoreline algae survey. Shallow water observations of the lake bottom were limited or lacking at several locations because of poor visibility due to onshore winds and high turbidity. The geographic extent of observations was limited in some areas. A follow-up survey over wider a geographic range in the next 1-2 years is suggested to better establish patterns of occurrence of nuisance benthic algae and to serve as a baseline for periodic surveys in the future. Monitoring of the occurrence patterns of benthic algae along the shoreline of southeastern Lake Huron should be considered as an approach for tracking changes in phosphorus pollution.

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