

**Enrichment Status of  
Nine Lakes  
Bruce Peninsula Area**

1973

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**ENRICHMENT STATUS  
OF  
NINE LAKES,  
BRUCE PENINSULA AREA**

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by

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## **SUMMARY**

The moderately productive nature of most lakes in the Bruce Peninsula area as evinced from chlorophyll-Secchi disc data was indicated. In order to define clearly year to year variations in water clarity and algal conditions, a continuation of the study is recommended. Such information, if maintained on a year-to-year basis, will be extremely useful in assessing whether changes in water quality are materializing so that remedial measures can be implemented before conditions become critical.

## INTRODUCTION

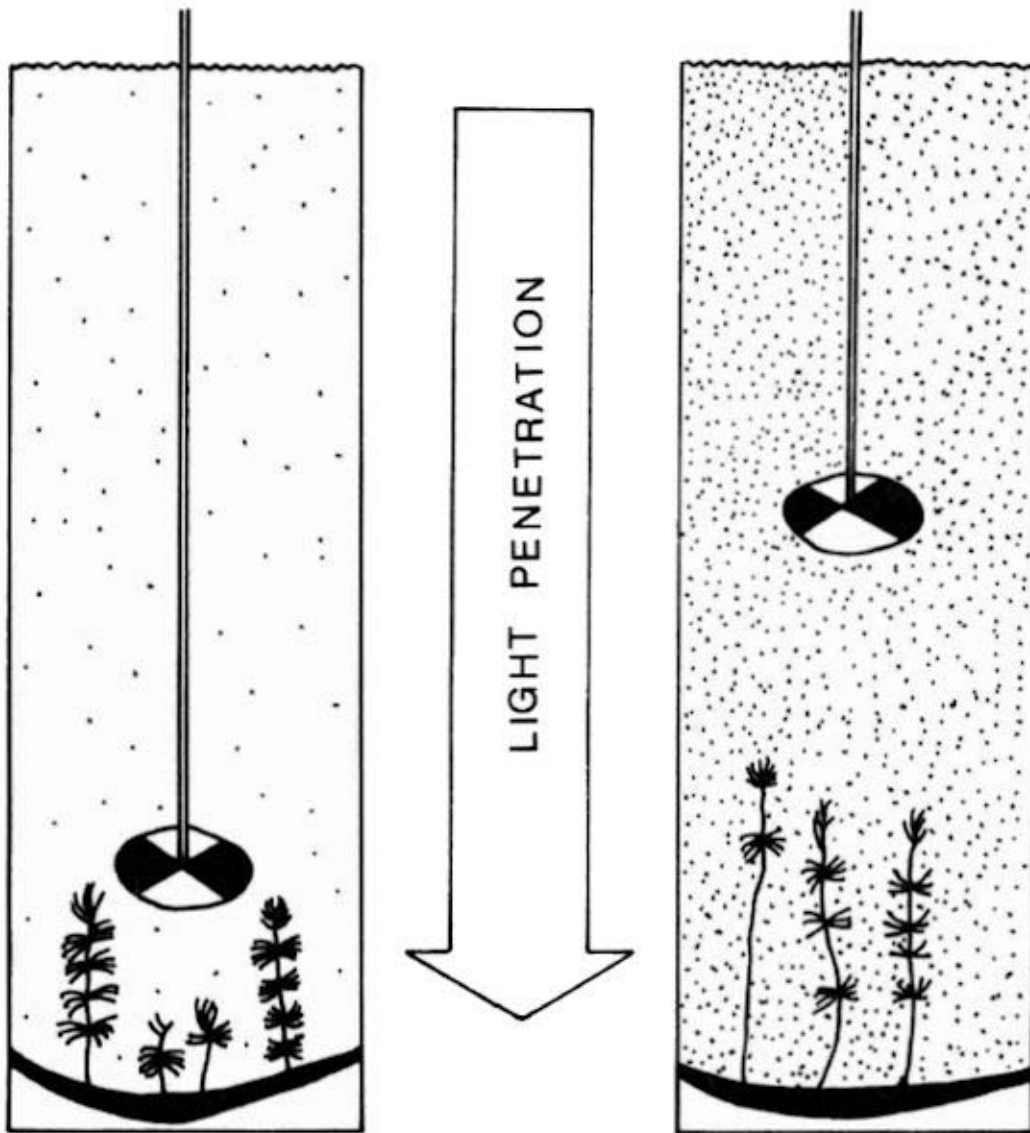
Over the past few years an increasing awareness and concern for problems of pollution in recreational lakes has materialized as a consequence of accelerated cottage development. Many individual cottagers, cottage associations and permanent shoreline residents have requested that complete water quality evaluations be carried out to assess the degree of pollution in lakes. Exhaustive physical, chemical, bacteriological and biological evaluations for a large number of lakes are beyond the financial and logistical capabilities of personnel involved in water management programmes, and in light of recent studies. are not necessary in order to categorize the quality of recreational waters. An understanding of water quality problems in recreational lakes is provided in Appendix 'A'.

In 1971, a practical but effective evaluation programme was carried out on seventeen recreational lakes in the Province of Ontario. The programme, which involved the collection of data on water clarity and algal populations, was highly successful owing to the enthusiastic efforts of local residents, cottagers, marina and report owners, and personnel of the Ministries of Natural Resources and Environment. The success of the programme was exemplified by the fact that in 1972 the number of lakes sampled increased from seventeen to fifty-eight. This report presents the Secchi disc - chlorophyll information collected from nine lakes in the Bruce Peninsula area of the Province during the summer of 1972, incorporates the data into a mathematical relationship for the parameters measured and comments on the findings with a view to defining the current state of enrichment or trophic status of the lakes.

## METHODS

Water clarity which governs the depth of light penetration in a lake is one of the most important parameters used in defining water quality and can be measured using a Secchi disc. The disc is divided into black and white alternating quadrants and is lowered into the water on a graduated line until the quadrants cannot be distinguished. The depth at which the disc just disappears is termed the Secchi disc depth. As depicted in Figure 1, Secchi disc depths are substantially greater in lakes having low phytoplankton (microscopic free-floating algae) numbers than in lakes characterized by high algal densities and excessive vascular aquatic plant growths. Secchi disc readings were taken on eight or nine occasions during the months of July and August, 1972, at one or two deep water sampling sites per lake. Usually two readings per visit were obtained; a mean of the two readings was recorded as the Secchi disc depth.

Chlorophyll a is the amount of photosynthetic green pigment in algae and its concentrations can be used as a rough indication of the extent of biological activity in a lake at the time of sampling since it is regulated by all of the combined physical, chemical and biological factors which affect algal production. Chlorophyll samples were taken on each visit to the lake by lowering a 32-ounce bottle provided with a restricted opening to the approximate location of the 1% incident light level or zone of effective algal production. This zone was determined as twice the Secchi disc depth. The samples were immediately preserved with 10-15 drops of a 2% magnesium carbonate solution and delivered to the Ministry of Environment's Laboratory Branch located at Highway 401 and Islington Avenue. Following filtration using 1.2 $\mu$  Millipore filters and cooling, the samples were submitted to the Chemistry I Section for analyses.



**Figure 1:** Diagram illustrating the use of a Secchi disc to measure water clarity. Greater visibility characterizes clear lakes having low algal densities (left panel) than productive lakes which contain high algal levels and have low light penetration (right panel).



## DISCUSSION OF RESULTS

The chlorophyll a concentrations and Secchi disc values collected from the nine lakes are presented in Table 1. Secchi disc readings, on the average, were lowest in Gilles Lake; the most transparent lake in the study area was Eugenia Lake - West Station. Readings for the North and South Stations of Arran Lake and Turner Lake, although equal to or lower than water clarity measurements obtained for Gilles Lake, are not comparable as the Secchi disc was visible on the sediments of the former lakes. Recent evidence from in-depth studies carried out in Lakes Joseph, Rosseau and Muskoka in the Muskoka Lakes area of the province suggests that lakes having Secchi disc readings less than 3m (meters) are eutrophic or enriched in nature while those exceeding 5m are oligotrophic or unenriched in status. Lakes having Secchi disc recordings between 3 and 5m would be mesotrophic or moderately productive; that is, they have a moderate supply of nutrients, plant growths and biological production. On the basis of these guidelines alone, two lakes (Chelsey and the West Station of Eugenia Lake) would be mesotrophic while five lakes (Gilles, Gould, Irish, Miller and Wilcox) and the East Station of Eugenia Lake would be eutrophic.

For the most part, chlorophyll a concentrations were low; however, relatively high levels of 21 and 12 parts per billion (ppb) were recorded in Irish and Wilcox (East Station) Lakes on July 7 and 11, respectively. Experience has indicated that concentrations between 0 and 3 ppb (on a yearly mean) are low and reflect low to moderate algal densities. Concentrations between 3 and 5, although moderately high, may be considered acceptable for most water oriented recreational pursuits. Levels exceeding 6 ppb on a yearly average indicate high algal densities. At these higher levels deterioration of water quality for recreational activities such as swimming and water skiing may be expected, as well as a reduction in the lake's aesthetic quality. As indicated in Table 1, water quality impairment owing to troublesome chlorophyll concentrations was rarely encountered in the study lakes during the summer of 1972.

**Table 1:** Secchi disc (metres) and chlorophyll a data (parts per billion) collected from nine lakes in the Bruce Peninsula area during the summer of 1972.

Lake	Date	Secchi disc (metres)	Chlorophyll <u>a</u> (parts per billion)
Arran (South Station)	6/7	1.3*	9.8
	12/7	1.5	3.0
	19/7	1.3	1.6
	26/7	1.5	1.7
	3/8	1.3	6.5
	15/8	1.2	2.0
	17/8	1.2	2.2
	23/8	1.3	2.1
	30/8	1.2	1.9
		Mean	1.3
Arran (North Station)	6/7	1.5*	2.3
	12/7	1.5	1.0
	19/7	1.5	1.4
	26/7	1.5	1.5
	3/8	1.7	2.9
	15/8	1.5	2.0
	17/8	1.5	1.8
	23/8	1.5	1.0
	30/8	1.5	1.3
		Mean	1.5

\* Note: Light penetration to lake bottom.

**Table 1:** Continued

Lake	Date	Secchi disc (metres)	Chlorophyll <u>a</u> (parts per billion)
Chelsey (West Station)	6/7	1.3	1.4
	12/7	3.5	2.0
	19/7	4.8	1.1
	24/7	3.3	2.7
	3/8	3.1	5.1
	15/8	3.3	2.3
	17/8	3.1	3.0
	23/8	3.3	3.0
	30/8	3.1	2.4
	Mean	3.2	2.6
Chelsey (East Station)	6/7	1.3	1.5
	12/7	2.4	1.8
	19/7	3.6	1.3
	26/7	3.5	2.1
	3/8	3.1	4.1
	15/8	3.3	2.0
	17/8	3.1	3.0
	23/8	3.1	2.6
	30/8	3.1	2.1
	Mean	3.0	2.3
Eugenia (West Station)	7/7	5.5	1.7
	11/7	5.7	1.1
	17/7	5.1	0.7
	24/7	3.3	1.0
	31/7	4.5	1.1
	10/8	3.3	1.4
	16/8	4.5	1.0
	22/8	5.1	1.0
	29/8	4.8	1.0
	Mean	4.6	1.1

**Table 1:** Continued

Lake	Date	Secchi disc (metres)	Chlorophyll <u>a</u> (parts per billion)
Eugenia (East Station)	7/7	3.1	1.7
	11/7	2.7	1.0
	17/7	2.7	1.0
	24/7	2.7	1.0
	31/7	2.7	5.7
	10/8	2.4	1.5
	16/8	2.4	1.4
	22/8	2.4	1.2
	29/8	2.1	1.0
		Mean	2.5
Gilles	11/7	1.5	0.9
	31/7	1.5	3.2
	17/7	1.3	2.3
	24/7	1.3	2.2
	10/8	1.3	2.9
	16/8	1.5	3.0
	22/8	1.2	1.7
	29/8	1.5	3.3
		Mean	1,4
Gould	6/7	1.8	2.5
	12/7	1.8	2.9
	19/7	1.8	2.4
	26/7	2.1	1.1
	3/8	2.4	3.2
	15/8	2.1	2.2
	17/8	2.7	2.8
	23/8	2.4	2.4
	30/8	2.4	1.6
		Mean	2.1

**Table 1:** Continued

Lake	Date	Secchi disc (metres)	Chlorophyll <u>a</u> (parts per billion)
Irish	7/7	2.8	21.0
	11/7	2.7	3.5
	17/7	2.3	1.9
	24/7	2.4	1.8
	31/7	2.4	2.7
	10/8	2.7	2.4
	16/8	2.7	2.3
	22/8	3.1	1.8
	29/8	3.1	1.2
		Mean	2.6
Miller (North Station)	12/7	3.7	1.6
	19/7	3.3	2.3
	26/7	3.3	1.5
	3/8	3.1	3.9
	15/8	2.4	1.6
	17/8	2.3	1.4
	23/8	2.1	2.6
	30/8	2.1	1.1
		Mean	2.8
Miller (South Station)	12/7	2.4	1.7
	19/7	2.1	1.3
	26/7	2.1	1.8
	3/8	2.1	2.7
	15/8	2.1	1.7
	17/8	2.1	1.8
	23/8	2.1	1.1
	30/8	2.1	1.3
		Mean	2.1

**Table 1:** Continued

Lake	Date	Secchi disc (metres)	Chlorophyll <u>a</u> (parts per billion)
Turner	11/7	0.9*	1.0
	17/7	0.7	0.7
	24/7	0.6	1.1
	31/7	0.7	1.2
	10/8	0.7	1.3
	16/8	0.6	1.4
	22/8	0.7	1.5
	29/8	0.7	1.0
	Mean	0.7	1.2
Wilcox (East Station)	7/7	3.1	3.8
	11/7	3.2	12.0
	17/7	2.4	3.8
	24/7	3.3	1.8
	31/7	2.1	2.4
	10/8	2.7	1.6
	16/8	2.7	4.5
	22/8	2.4	2.8
	29/8	3.3	2.1
	Mean	2.8	3.9
Wilcox (West Station)	7/7	2.4	4.2
	11/7	3.2	3.5
	17/7	2.4	3.4
	24/7	3.1	2.4
	31/7	3.3	3.8
	10/8	2.4	3.3
	16/8	2.7	6.5
	22/8	3.1	5.2
	29/8	4.2	2.1
Mean	2.8	3.8	

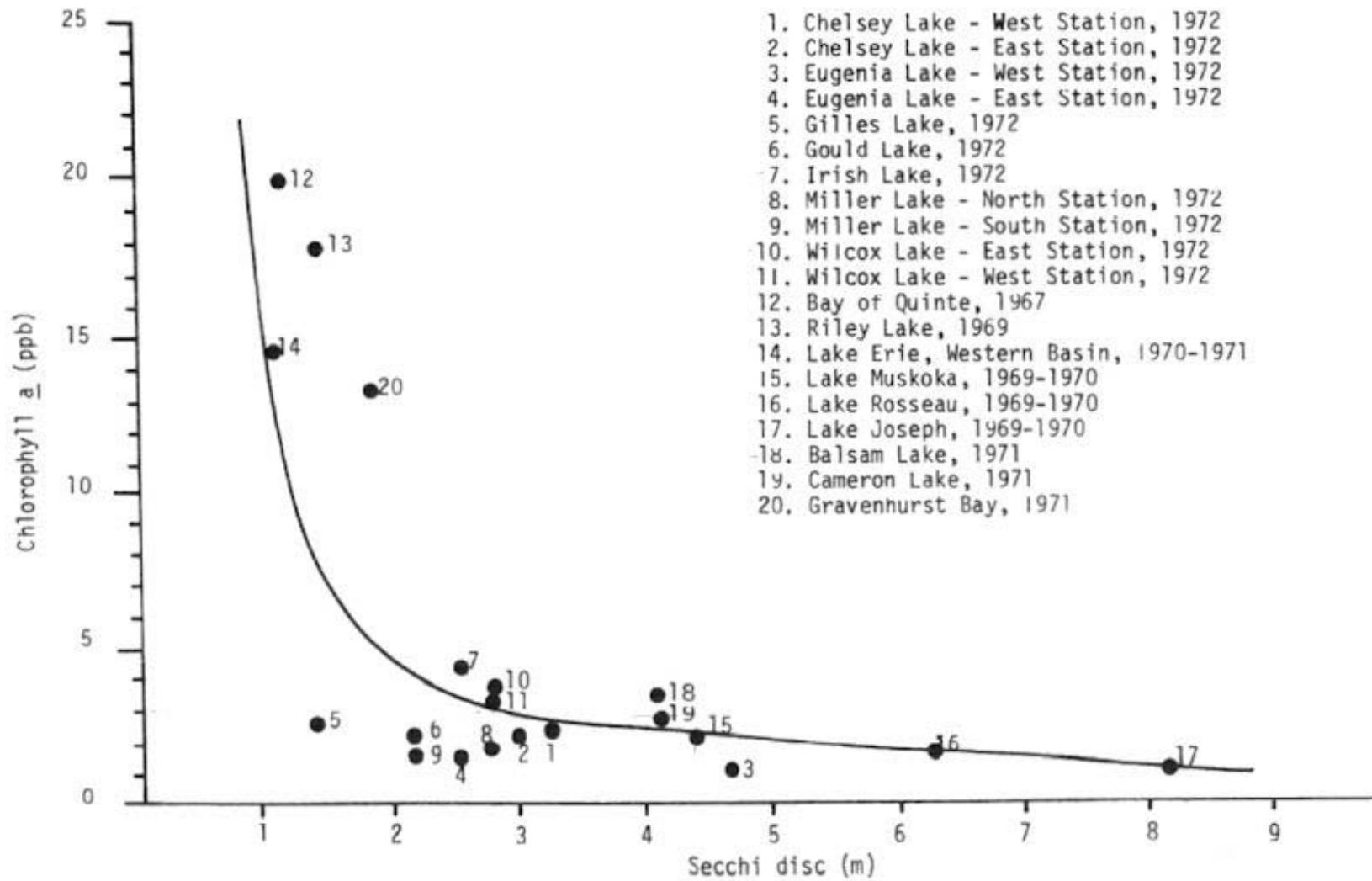
\* Note: Light penetration to lake bottom.

As pointed out earlier, chlorophyll a measures the amount of photosynthetic green pigment in algae while water clarity, which is one of the most important parameters used in defining water quality, is determined by means of a Secchi disc. Personnel of the Biology Section have noted that a near-hyperbolic relationship existed between chlorophyll a concentrations and Secchi disc readings for lakes of Precambrian origin. Figure 2 describes this relationship for 945 sets of data collected from approximately sixty lakes in the province. Points for eutrophic or highly enriched lakes are characterized by high chlorophyll a concentrations and poor water clarity and are situated along the vertical axis of the hyperbola while oligotrophic waters which have low chlorophyll a levels and allow significant light penetration lie along the horizontal limb.

Data for mesotrophic lakes would be dispersed about the middle section of the curve. Chlorophyll a and Secchi disc data for Eugenia Lake (West Station) are positioned in close proximity to Lakes Muskoka, Cameron and Balsam three mesotrophic bodies of water. Gilles, Gould, Chelsey, Irish, Miller and Wilcox Lakes, as well as the East Station of Eugenia Lake appear to be slightly more productive than the aforementioned mesotrophic lakes. Significantly, all lakes were well-removed from the highly eutrophic waters of Riley Lake, Gravenhurst Bay, the Bay of Quinte and the Western Basin of Lake Erie.

As indicated in Figure 2, most lakes in the study area were somewhat below the established relationship suggesting that factors other than chlorophyll (i.e. colour, suspended material, etc.) governed light penetration. The incorporation of Arran and Turner Lakes into Figure 2 was not effected as light penetration to the sediments of these lakes would invalidate realistic interpretations.

The aforementioned data are most significant if collected on a long-term basis so that year to year variations in water clarity and algal conditions can be defined. Such information would be extremely useful in assessing whether changes in water quality are materializing so that remedial measures can be implemented before conditions become critical. It is suggested that a continuation of the chlorophyll-Secchi disc sampling programme be considered.



**Figure 2:** The relationship between chlorophyll a and Secchi disc for nine lakes in the Bruce Peninsula area of Ontario. Values for each lake are based on mean values collected during the summer of 1972. Also information from a number of other lakes are included as an indication of the relative status of lakes in the study area.



## APPENDIX A

### WATER QUALITY IN RECREATIONAL LAKES

#### Bacteriological Water Quality

For many years, cottagers have generally equated water quality with the presence or absence of conform or fecal coliform bacteria in the water. Certainly, localized bacteriological problems in recreational lakes associated with inadequate or malfunctioning cottage waste treatment systems are still all too frequent.

In June 1970, the Ontario Water Resources Commission (now within the Ministry of the Environment) implemented changes in the criteria for bacteriological quality of water. Under these criteria, water used for total body contact recreational activities is impaired when the coliform, fecal coliform and/or enterococcus geometric mean densities exceed 1,000, 100 and/or 20 per 100 ml, respectively, in a series of at least ten samples per month, including samples collected during weekend periods (OWRC 1970).

Separate criteria are in force for private water supplies for individual dwellings and cottages. The raw water must be of such quality that it can be used with a minimum of treatment, limited to disinfection, filtration and/or softening. Microbiological criteria for private water supplies is provided in Table 1, of the Appendix.

Although bacteriological contamination is undoubtedly of most direct significance to cottagers, this type of pollution can be readily identified and through the implementation of effective controls, a rapid return to satisfactory water quality can be achieved.

#### Eutrophication

It is only within recent years that the more lasting effects of a type of pollution best described as nutrient enrichment have become clearly recognized. This process, scientifically known as EUTROPHICATION, is associated with sedimentation and increases in the dissolved mineral content of a lake - specifically substances such as phosphate, nitrates, carbonates and numerous trace elements - increases which occur as a result of

**Table 1:** Microbiological criteria for private water supplies.

Micro-organisms		Permissible Criteria		Desirable Criteria
		Chlorination only	Chlorination and Filtration	No Treatment
Coliforms	(35°C)	100/100 ml	400/100 ml	0/100 ml
Fecal Coliforms	(44.5°C)	10/100 ml	40/100 ml	0/100 ml
Enterococci	(35°C)	1/100 ml	4/100 ml	0/100 ml
Total Bacteria	(20°C)	1,000/100 ml	4,000/100 ml	10/100 ml
Clostridia(in water)	(35°C)	0/100 ml	4/100 ml	0/100 ml

Raw water samples should be collected at least monthly. The Geometric Mean of sample results should not exceed the values given in the table above.

rainfall, land runoff and percolation of soil-water to the lake. Higher concentrations of these dissolved materials cause the water to become progressively more fertile and productive, stimulating the development of free-floating microscopic plants called phytoplankton - generally referred to as algae.

Algae are normal inhabitants of virtually all surface waters and fulfill an essential role in maintaining a balanced condition in the aquatic environment. They not only provide the entire nutritional base for a complex aquatic food web which includes the production of game and commercial fish species, but produce and release oxygen to the water which is vital to the metabolism of fish and all other forms of aquatic life.

The natural development of algae is regulated not only by nutritional factors, as previously mentioned, but by environmental factors such as temperature, the intensity and duration of illumination (sunlight) and by physical factors such as size, depth and shape of the lake bottom. Thus, the corresponding rates of eutrophication in different lakes are determined by varying combinations of extrinsic and intrinsic features.

All lakes, even the largest and deepest, are transitory bodies of water and are continually undergoing a gradual process of change from youth to maturity to old age, or in limnological terms, from oligotrophy to mesotrophy to eutrophy. Progressing even further, death of a lake can be equated to the onset of a "swamp" or "marsh" condition. In small, shallow lakes, this entire process may have occurred in some cases within a single century following the glacial retreat; in other instances, the process is well advanced, and still going on, and in many larger, deeper lakes remote from human influences, significant changes can only be measured on a geologic time scale (i.e. thousands of millions of years).

#### Major differences in Ontario Lakes

Lakes surrounded by granitic bedrock and the sparse infertile soils of the Precambrian Shield which covers Muskoka, Haliburton and areas further north are characterized by low rates of algal production and consequently age less than lakes surrounded by the deeper, richer soils of Southern Ontario.

Correspondingly, "nutrient-poor" lakes on the "Shield" having moderate to extreme depths, generally support a relatively low production of cold-water species such as lake trout, whitefish and herring. Such lakes are characteristically clear and well-suited to swimming and other water-oriented recreational pursuits. Also, the deeper waters are well-supplied with oxygen throughout the year. This latter condition relates to the low algal production and concomitant lack of any significant oxygen depletion associated with the decomposition of algae at the lake bottom.

Alternatively, fertile lakes, such as the Kawarthas, are more turbid owing to the increased photoplankton production and presence of suspended particulate matter. They contain substantial growth beds of submergent leafy vegetation such as water milfoil, elodea, coontail and pondweeds and produce higher yields of warm-water species such as walleye and bass.

Adequate levels of dissolved oxygen are generally present from surface to bottom since these lakes are shallow and benefit from the high level of photosynthetic activity, as well as surface aeration and complete vertical mixing during periods of windy weather. The Kawartha Lakes have been extremely productive for many years and can be considered as naturally eutrophic waters.

The overriding factor of artificial fertilization has created different types of problems in these two major types of lakes. Enrichment studies have been carried out by personnel of the Ministry of Environment at the request of concerned cottagers on lakes in northern and central Ontario such as Little Panache (near Sudbury), Riley Lake (near Gravenhurst), Silver Lake (near Port Carling), Big Straggle Lake (near Bancroft) and several others which can be considered representative of most lakes on the Shield. To varying degrees, these investigations revealed the classical evidence and undesirable features of induced fertilization in these thermally stratified lakes. Affected lakes are characterized by increased phytoplankton levels, the development of high numbers of blue-green algae in late summer and reduced pH and dissolved oxygen concentrations in the deeper waters associated with the decomposition of settled algae and higher carbon dioxide, nutrient and iron levels, again particularly evident in the deeper water where reducing conditions prevail.

Associated undesirable effects of induced eutrophication in one or more of these situations were a reduction in water clarity and related impairment of the recreational and aesthetic qualities of the water, objectionable accumulations of blue-green algae along shorelines and associated malodorous conditions on decomposition, a decrease in the quality of the water for drinking and domestic purposes including clogging of water intake filters, a reduction of the area suitable for game fish owing to oxygen reduction in the deeper waters and a further reduction in fish production through elimination of desirable fish-food organisms.

In lakes like the Kawarthas, on the other hand, increased enrichment resulting from agricultural runoff, urbanization along the system and inadequate containment of cottage wastes has placed increasing stress on an already productive aquatic environment. Here, artificial nutrient inputs have intensified the production and frequency of blooms of blue-green algae and have enhanced the production of aquatic plants to the point where many activities such as swimming, water skiing and unimpeded boating are practically impossible. Prolonged periods of hot, calm weather have periodically caused decomposition of algae and aquatic plants in isolated bays where limited water exchange has resulted in dissolved oxygen depletion and accompanying fish mortalities. Also, periodic winter kills of fish resulting from organic decomposition have been a recurring problem. It is certain that heavy densities of weeds in many areas interfere with the harvest of game fish and it is a moot point whether or not existing conditions actually favour or interfere with optimum game fish production.

#### How the cottagers can help

In a direct way, each cottager can do his part by ensuring that his waste treatment system conforms to present standards and is operating efficiently. Neighbouring cottagers should be encouraged to do likewise and situations such as effluent ponding or surfacing, which will obviously contribute to water pollution, should be brought to the immediate attention of local public health authorities. The use of phosphate-free washing compounds is highly recommended. In past years approximately 50% of the phosphorus contributed by human sewage was added by detergents. On August 1, 1970, federal regulations reduced the phosphate content as  $P_2O_5$  in laundry detergents from approximately 50% to 20%. Additional regulations which were effected on January 1, 1973, further decreased

the phosphate content to 5%. Cottagers having any doubt about the possibility of nutrients reaching the lake from their treatment systems should refrain from installing automatic dishwashers which require high phosphate cleaning products (a 1970 questionnaire indicated that about 30% of the cottages in the Muskoka Lakes have automatic dishwashers). Such conveniences may contribute significant amounts of phosphorus to recreational lakes. Indeed, in most of Ontario's vacation land, lake water used by cottagers is sufficiently soft to allow for the exclusive use of soaps and soap flakes.

A significant number of cottage owners apply lawn and garden fertilizers each year to promote vigorous growth. Use of fertilizers should be restricted as much as possible and should be discontinued if translocation to the lake is deemed likely.

Unless cottagers endeavour to understand the causes and consequences of artificial nutrient enrichment and eliminate offending practices and inadequate treatment systems, water quality is certain to be undermined for future generations.

## GLOSSARY OF TERMS

- ALGAE - An assemblage of simple, mostly microscopic non-vascular plants containing photosynthetic pigments such as chlorophyll. Algae occur suspended in water (phytoplankton) and attached to rock and other suitable substrates. Some algae may produce nuisance conditions when environmental parameters are suitable for prolific growth.
- CHLOROPHYLL - The photosynthetic green pigment which occurs in all algal divisions.
- EUPHOTIC ZONE - The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.
- EUTROPHIC - Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.
- EUTROPHICATION- The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the production of dense nuisance growths of algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.
- MESOTROPHIC- Water characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).
- OLIGOTROPHIC - Water containing a small nutrient supply and consequently characterized by low rates of organic production.
- SECCHI DISC - A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants and so painted that two quadrants directly opposite each other are painted black and the intervening ones white. The Secchi disc is used to estimate the depth of the euphotic zone.