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A Layman's Guide to Interpreting Lake Water Quality Parameters

by John D. Koppen, Ph.D. and Stephen J. Souza, Ph.D.

Great insight can be gained in assessing the environmental condition and trophic status of a lake or pond through a properly designed sampling program. A well planned water quality sampling program enables one to ascertain:

1. The existing water quality of the lake or pond,
2. Temporal changes in water quality as related to storm events, season, or increased use of the lake,
3. Inter-relationship between the growth and development of aquatic weeds and algae, and changes in water quality.

It also provides one with a means of evaluating improvements in water quality following the implementation of lake restoration/management measures.

The following briefly explains many of the parameters commonly analyzed as part of a water quality sampling program. It also supplies ranges for these parameters and their implication in terms of the trophic status of typical, temperate lakes.

Nitrogen

The five major forms of nitrogen in freshwater systems are elemental nitrogen (N2), organic nitrogen, ammonia (NH3), nitrate (NO3), and nitrite (NO2). Of these various forms the last three, NH3, NO3, NO2, are readily available to aquatic primary producers for metabolic uptake. In most monitoring programs, these three nitrogen compounds, plus Total Kjeldahl Nitrogen, a measurement of organic and ammonia nitrogen, are usually analyzed.

Ammonia nitrogen is a metabolic by-product of the decomposition of organic material, such as proteins. In most healthy freshwater systems, ammonia is present in low concentrations, usually less than 1.0 mg/l. In highly eutrophic waterbodies, particularly those which becomes devoid of oxygen (anoxic) much higher ammonia concentrations may be present. Such high ammonia concentrations can prove lethal to organisms if the pH of the lake or pond is greater than 8. Under these conditions a toxic undissociated form of ammonia becomes present in high concentrations. This undissociated form is particularly toxic to fish.

Nitrate nitrogen (NO3-N) is the preferred form of nitrogen for uptake by algae and plants. The concentration of this nutrient, particularly when measured over a prolonged time scale, can shed much information on the productivity and trophic status of a lake. Although the amount of NO3 present at any given time is a function of the extent of metabolism in a waterbody, typical concentrations for relatively healthy lakes is less than 0.05mg/l. In eutrophic waterbodies the concentration of nitrate is usually low in the upper layers due to uptake and utilization by algae. In the deeper parts of the lake the concentration of nitrate will be greater as dead plant and animal cells become broken down and decomposed. However, in the anoxic deep water layers of highly eutrophic lakes, a slight depression in the concentration of NO3 is typically observed and the amount of NH3 is elevated.

Nitrite-nitrogen (NO2-N) is typically present at very low concentration, less than 0.005 mg/l. Typically, seasonal changes in the concentration of nitrite follow a pattern similar to that of nitrate. High concentrations of nitrite may be indicative of inputs from septic systems or sewage plants.

Phosphorus

By far phosphorus is the nutrient which has received the greatest amount of attention in relation to lake eutrophication. Phosphorus is an essential element for both plant and animal life. Its importance stems from the fact that it is usually available, in a form ammenable to bio-uptake, in low concentrations relative to other essential elements. As a result, it is usually limiting, that is, it is the

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Volunteers Prepare for First Sampling Season

Patient and persistent efforts of the Federation of Lake Associations on behalf of the Citizens Statewide Lake Assessment Program have finally been fruitful. Beginning this season, volunteers will collect water quality information and samples for a 15-week period between May and September.

The immediate objective of the program is to gather accurate water quality data on each lake on a yearly basis. The long-term goal is to use this information to develop lake and watershed management strategies that will protect or restore water quality and provide for the best use of each body of water as a resource.

The success of the Citizens Program depends upon the volunteers who will be collecting the samples. Both DEC and the Federation will be providing on-site training to each pair of volunteers. Associations are required to have two teams of two people available for the training sessions. One team would be designated as the primary sampling team and the other team ready to collect samples during times when one or both members of the primary team cannot participate.

Each sampling team will be given the necessary equipment to collect data and supplies to process the samples before sending them to the contract chemistry laboratory at the NYS Department of Health in Albany. In addition to the training sessions, teams will be guided by a DEC prepared manual describing the standardized sampling techniques. Program inquiries should be made to CSLAP Coordinator Scott Kishbaugh at (518) 457-7470

1986 Program Participants

Lake Lucille Property Owners Association	Rockland
Lake Carmel Park District	Putnam
Lake Mahopac Park District	Putnam
Three Lakes Council	Westchester
Copake Lake Conservation Society	Columbia
Nassau Lake Park Improvement Assoc.	Rensselaer
Adirondack Lake Association	Hamilton
Glen Lake Association	Warren
Goodnow Flow Association	Essex
Loon Lake Park District	Warren
Mountain View Association	Franklin
Butterfield Lake Cottage Owners Assoc.	Jefferson
Fulton Chain of Lakes Improvement Assoc.	Herkimer
Campers & Landholders Association of Joe Indian Lake	St. Lawrence
Mt. Arab Preserve Association	St. Lawrence
Twitchell Lake Fish & Game Society	Herkimer
Crooked Lake Homeowners Assoc.	Onondaga
Lake Moraine Association	Madison
North-South Pond Association	Oswego
Petonia Lake Association	Chenango
Tuscarora Lake Association	Madison
Conesus Lake Association	Livingston
Cuba Lake Cottage Owners Assoc.	Allegeny
Findley Lake Property Owners Assoc.	Chautaugua
Silver Lake Cottage Owners Assoc.	Wyoming

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Inland Lake Keyhole Development

An Analysis of Local Zoning Approaches

PART TWO

by **Mark A. Wyckoff,** AICP Editor

LITIGATION

A search for caselaw involving challenges to municipal keyhole zoning provisions revealed no cases at state appellate or supreme court levels. However, two decisions on local zoning regulations restricting access to coastal beaches have been reported. (See case summaries in Table II and 18 ALR4th 569). In each of these cases, ordinances restricting beach use to single family residences were overturned.

However, caselaw involving riparians versus a keyhole developer is growing. Most of these cases are important to drafters of keyhole zoning regulations, because in almost every instance, the Court has had to determine whether a proposed keyhole development constitutes a "reasonable use" under riparian common law doctrines. An examination of the standards courts have applied in reaching a decision on these issues, reveals that they are the same kinds of standards that planners would apply in developing a land use management plan and accompanying zoning regulations. Another benefit of study of these decisions is their value in identifying the nuances of riparian common law and the implications thereof on local keyhole regulations.

One of these cases, **Thompson V. Enz** 154 N.W.2d 473 (Mich S.Ct. 1967) appears to be the leading national case on this issue. A summary of the **Thompson** case follows. (For a full analysis of this case see also "Riparian Water Law—Lakeshore Developments", Richard C. Glesner, 1966 Wisconsin Law Review 172.) Table II presents a capsule summary of other keyhole and related cases.

Thompson V. Enz

This case concerned a proposal by a riparian developer with 1,415 feet of frontage on Gun Lake to plat the property into 144-153 lots, with all but 16 fronting on canals that connect to the lake (the 16 would front on the lake itself). The canals were proposed to have approximately 11,000 feet of frontage. Gun Lake has 2,680 acres of surface area and approximately 30 miles of shoreline. The developer planned to grant easements for rights of way permitting access to the lake through the canal. Riparian property owners sued claiming an infringement on their riparian rights.

The Court reviewed the common law of riparian rights citing authorities in Michigan and many other states and concluded that no riparian rights were created on the canal lots which were "artificial watercourses". The Court concluded that

> "While riparian rights may not be conveyed or reserved—nor do they exist by virtue of being bounded by an artifical watercourse—easements, licenses and the like for a right of way for access to a watercourse do exist and ofttimes are granted to nonriparian owners.
>
> We will, therefore, treat the proposal here as though easements for the rights of way for access are given to the back lot purchasers."

The Court went on to say that:

> "Riparian uses are divided generally into two classes. The first of these is for natural purposes. These uses encompass all those absolutely necessary for the existence of the riparian proprietor and his family, such as to quench thirst and for household purposes. Without these uses both man and beast would perish. Users for natural purposes enjoy a preferred nonproratable position with respect to all other uses rather than a correlative one.
>
> The second of these is a use for artificial purposes. Artificial uses are those which merely increase one's comfort and prosperity and do not rank as essential to his existence, such as commercial profit and recreation. Users for artificial purposes occupy a correlative status with the other riparians in exercise of their riparian rights for artificial purposes. Use for an artificial purpose must be (a) only for the benefit of the riparian land and (b) reasonable in light of the correlative rights of the other proprietors. **Evans V. Merriweather,** 4 Ill. (3 Scam.) 492, 38 Am. Dec. 106. It is clear in the case before us that the use made of the property by the defendants is for a strictly artificial purpose and must meet the test of reasonableness."

The Court then reviewed common law on reasonable use of surface waters and remanded the case back to the Circuit Court for a determination as to its reasonableness with instructions

> "to keep in mind the following factors in determining whether the use would be reasonable.
>
> **First, attention should be given to the watercourse and its attributes, including its size, character and natural state.** In determining the reasonableness of the use in the case at bar, it should be considered that Gun Lake is not a large lake, that it is used primarily for recreational purposes, and that the defendants are changing its natural state by expanding the lake frontage of their property from an actual 1,415 feet to a total inclusive of the canal, of 12,415 feet, being an increase in frontage of approximately 800 per cent.
>
> **Second, the trial court should examine the use itself as to its type, extent, necessity, effect on the quantity, quality and level of the water, and the purposes of the users.** Factors in this particular case that should be considered include: (a) that this use would permanently add approximately one family without riparian rights to each 18 acres of surface area (or 137 families); (b) the possibility that the level of the lake may be reduced by withdrawing trust waters into over 2 miles of the proposed canals, as is alleged by the Attorney General in his motion to intervene; (c) the possibility that pollution may result; (d) that there is nothing in the record showing any necessity for this use; and (e) the fact that it appears that the purpose of the defendants herein is merely commercial exploitation.

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Deep Water Aeration System Improves Water Quality

A hypolimnetic aeration system installed 12 years ago on northeastern lake has, in the words of the lake association's president "saved our lake."

Lake Waccabuc, a narrow (¼ mile wide) 124-acre body of freshwater no more than 45 feet deep, is located in South Salem, NY, just 40 miles northeast of New York City.

Peter Beardsley, president of the Three Lakes Council, an organization of 300 lake watershed residents that monitors the water quality and maintains the system, quoted from an independent study of the effect of the aeration system prepared by Martin Garrell and Alan Gibbs of Adelphi University:

> An excellent salmonid (trout) fishery was maintained throughout the summer by the aerators...Previous spotty attempts to stock Waccabuc with trout when there was no hypolimnion (deepest level) oxygen were failures...Warm-water fish apparently use the oxygenated hypolimnion as well, though not to the extent that the salmonids do, as catches of yellow perch, white perch, and bluegill sunfish from the hypolimnion indicate. Secondly, drinking water quality is improved thanks to the elimination of H2S and some heavy ions through oxidation and precipitation. Finally, the project involved an entire community through the Three Lakes Council and brought into focus certain environmental problems that could not have been otherwise squarely faced, i.e., septic system loading of watersheds, unnecessary nutrient dumping from various sources.

In contrast, a study done prior to introduction of the system predicted that Lake Waccabuc would "eutrophy at accelerated rates if no steps are taken to alleviate the situation...Although we cannot accurately predict the time required to reach the worst state of eutrophication...our best guess is from 5 to 15 years. At that point drastic action (such as dredging, in combination with some other remedial actions) could be necessary..."

In the summertime, a deepwater lake is thermally stratified into three temperature layers: the hypolimnion (at the bottom), the epilimnion (top), and the metalimnion. During the summer months the layers mix very little. Nutrient materials become trapped on the bottom and do not stimulate algae plant growth on the surface.

A polluted lake produces an excess of organic matter because of a too-rich nutrient supply. The decomposition of this matter requires more oxygen than the ecosystem may be able to provide. If the oxygen in the hypolimnion is completely consumed, the condition becomes critical, with actual fermentation transforming both organic and inorganic matter.

The aeration system used at Lake Waccabuc does not destratify the lake while in operation, instead providing deepwater oxygenation without disturbing the natural underwater environment..

The hypolimnetic aeration system introduces oxygen into the hypolimnion during the summer months to replace oxygen used in the normal decomposition of organic matter, providing oxygen that deep, coldwater fish need to survive.

All lakes do fill in with sediment as a result of decaying matter from within their own boundaries. Deep, clear lakes become shallow, murky lakes. But this is a gradual slow process that can take centuries to accomplish. The

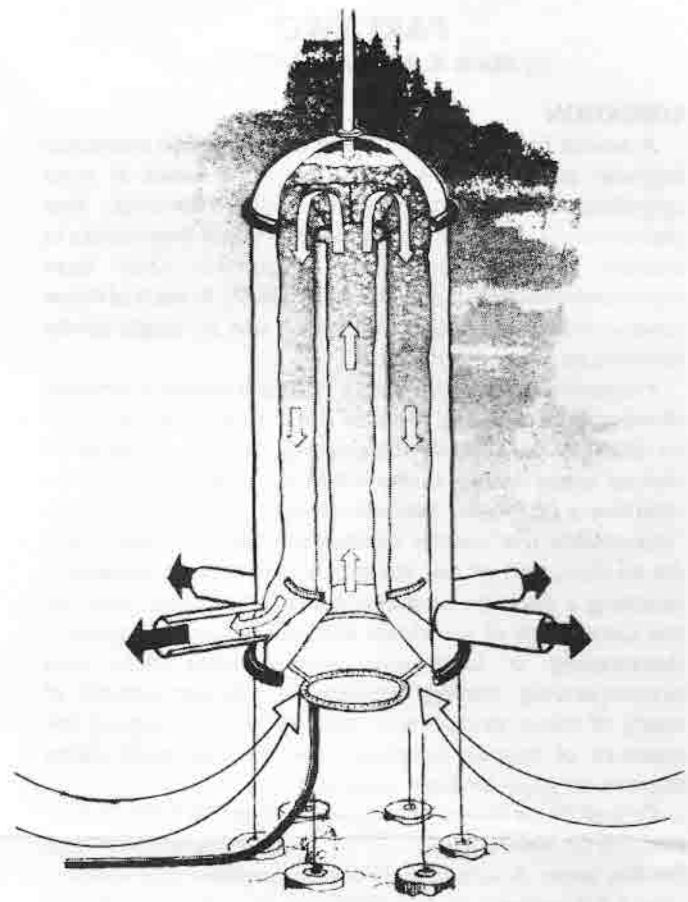

Figure 1.–Limno aerator: principle flow diagram.

presence of externally loaded nutrients in the form of human waste, septic seepage and lawn fertilizer runoff can accelerate the process so that cultural eutrophication will occur within a few decades.

At Lake Waccabuc, two aerator units are located in the deepest section of the lake at a distance apart of about 200 yards.

The basic design consists of two concentric tubes covered by a dome and interconnected by radial walls (Fig. 1). The outer tube has a number of outlets close to the lower end. From the dome a venting pipe connects the unit with the atmosphere. (This venting at the surface can either be concealed, or, as preferred by residents of Lake Waccabuc, permitted to send a light spray into the atmosphere.)

The unit is permanently anchored to the bottom by means of concrete weights and nylon bands attached to the outer tube and the lowering frame. The units in Lake Waccabuc are 15 feet high with an outer diameter of 8 feet. Designs can range from 8 feet high and 5 feet in diameter to 50 feet high and 20 feet in diameter.

At Waccabuc, a shore-based air compressor supplies the aerators with compressed air via hoses anchored to the lake bottom. The air compressor is housed in a sound-insulated shed, and the land piping is underground.

Through the diffusor, placed under the intake cone, the airflow is broken up into fine air bubbles. The bubbles rising

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Third, it is necessary to examine the proposed artificial use in relation to the consequential effects, including the benefits obtained and the detriment suffered, on the correlative rights and interests of other riparian proprietors and also on the interests of the State, including fishing, navigation, and conservation. An additional fact to be considered by the trial court in this litigation is whether the benefit to the defendant subdividers would amount merely to a rich financial harvest, while the remaining proprietors—who now possess a tranquil retreat from everyday living—would be forced to endure the annoyances which come from an enormous increase in lake users." (emphasis added)

In **Thompson II,** 188 N.W. 2d 579 (Mich S.Ct.1971) issues of laches, acquiescence and estoppel were raised.

Developing a Management Plan

High demand for inland water based recreational opportunities continues to create heavy pressures on inland lakes. Ironically, many of these pressures are compounded by state and local programs designed to improve lake quality or to create jobs in tourist areas. For example:

- successful state or regional advertising campaigns to get tourists to visit and vacation in inland lake resort areas increases lake use.
- successful efforts to improve water quality with municipal waste treatment systems combined with the improved sensitivity of lakefront property owners to runoff carrying soil, fertilizer and pesticides into the lake, has markedly improved the quality of many inland lakes, and hence their attractiveness to users, tourists and prospective purchasers.

When these factors are combined with the following circumstances, a broader picture of some of the pressures on inland lakes emerges. For example:

- available and developable lakefront lots close to metropolitan areas are rare; and the subsequent incentive is high (market demand) to try to put margianl land into use (wetlands, high banks, etc.) and to develop on lakes farther away.
- over the past decade the efforts of developers to sell condominiums and time share units in resort areas has been successful (with the exception of the recession years).
- the supply of natural inland lake property is fixed. And
- aggressive state and private conservation group efforts to increase and/or improve public access on waterways continues.

Thus the interests are varied, the actors are many, and some of the objectives are at cross purposes. Local governments are frequently caught in the middle. As a result, local governments are beginning to realize, that promoting both water quality and tourism may merely further degrade their lakes unless these actions are undertaken in the context of a **coordinated lake management plan.** The task is a complicated one because **at the root of it is allocation of the lake resource among competing users with varied rights and broader desires.** Usually however, competing uses are addressed by focusing on solving specific problems including: 1) controlling surface lake use; 2) controlling new development around a lake; 3) improving/maintaining water quality; 4) flood control; and 5) improving the fisheries/wildlife habitat (often by measures focused on adjacent wetlands protection). **Clearly the problems of keyhole development fall squarely within this scope of issues and should not be addressed in isolation.**

In some states, strong efforts have been undertaken to meet the challenge, such as Wisconsin and Minnesota. In other states the need has been recognized, and the call uttered, but no legislative action has been forthcoming. (see for example "South Dakota's Lakes: A Valuable Resource in Need of Land Use Protection", Steven M. Johnson, 20 South Dakota Law Review 618). **In most states, no comprehensive state-local management approach is in place, instead, a variety of statutes and administrative programs carry the load. These include for example, laws regulating dredging and filling of inland lakes and streams, wetland and floodplain regulations, and local watercraft controls.**

While the need for comprehensive inland lake management plans may be clear, the practical considerations arguing against them are often very strong. These arguments start with a severe lack of equivalent detailed information on each lake, and the money for such studies. Statutory and case law present effective limitations in some instances. As a result, a comprehensive solution boils down to a need for states and municipalities to effectively cooperate in melding a workable solution to identified problems.

An inland lake management plan should be based on both the natural and social "carrying capacity" of the lake basin for development. Such a plan would be heavily rooted in solving existing water quality problems, and preventing the occurrence of similar ones, but should also focus on long term development and use of the lake. The potential for keyhole development in not just one or two, but many locations around the lake, also needs to be considered.

One of the problems with current case by case keyhole litigation is that reasonable use determinations are made in the context of the existing situation, thus to a great extent it is "first come first served". Future property owners otherwise similarly situated, may find that the use of their riparian property for a keyhole development may be found unreasonable, because of crowded lake use by current riparians and their licensees. What recourse if any do they have? Besides, a case by case determination is not very predictable. A local regulatory approach based on sound planning unique to each lake, could address that issue in a fairer way. Note that several of the Michigan cases listed in Table II went through the appellate courts several times before a final solution was fashioned. In large measure, this is due to the courts inability to deal with resource allocation issues.

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essential nutrient in shortest supply. In eutrophic waterbodies phosphorus, due to external and internal sources, becomes available in concentrations sufficient to support and sustain algae blooms. Since the rate and extent of primary production in most freshwater systems is limited by phosphorus, the more that becomes available, the more algae and plant production that can be supported. Thus, most management programs attempt to limit phosphorus pollution to lakes and thereby limit plant and algae production.

Some of the important external sources for phosphorus are fertilizers, septic leachate, sewage effluent, detergents and soaps, particulate material transported by stormwater, and even precipitation. Lake sediments, particularly those which are highly organic or mucky, can serve as an internal source of phosphorus loading especially if the overlying waters become devoid of oxygen. The decomposition of dead algal cells or aquatic weed tissue are other internal sources of phosphorus.

Chlorophyll

Chlorophyll is a photosynthetic pigment common to all green plants. It is important in relation to water quality in that it is utilized as a measure of in-lake productivity associated with phytoplankton or algae.

Mathematical models are available which can predict the summer concentration of chlorophyll based on the spring concentration of total phosphorus. This has important bearing on the management of lakes. In addition, relationships exist between other water quality parameters such as Secchi disc depth, alkalinity, dissolved oxygen and pH which have important bearing on the trophic status and ecological balance of a freshwater system.

pH

The pH of water is a common, easily measured parameter. However, the importance and relevance of this parameter is often not fully appreciated.

By definition pH is a measure of the concentration of free hydrogen ions. In pure water the pH is 7.0. Salts, acids, and bases are normal components of natural waters and will result in some deviation in pH. Those materials which increase the concentration of hydrogen ions (H^+) will decrease the pH (more acidic), where those which decrease the concentration of H^+ will increase the pH (more basic).

Changes in the pH of a lake, as well as being influenced by the addition of salts, acids and bases, is influenced by photosynthesis. During photosynthesis, plants fix carbon dioxide (CO_2). As mentioned previously (see Alkalinity) CO_2 is an important component in the bicarbonate-carbonate buffering system of a lake. In photosynthesis, as CO_2 is fixed, a shift in bicarbonate-carbonate buffering system is shifted resulting in a decrease in the concentration of H^+. This causes the pH to increase, and the lake to become more alkaline or basic. Under conditions of excessive productivity, it may be possible to elevate the pH to 8 or 9. This is particularly true in soft water lakes with poor buffering capacity.

In typical north temperate lakes the pH ranges from 6 to 9. In seepage lakes which drain calcareous or limestone deposits, the pH may be substantially in excess of 9. In contrast, lakes which drain igneous deposits and are subject to the accumulation of acids and humic substances may have pH concentrations typically below 5. Lakes which display wide daily fluctuations in pH are indicative of a poorly buffered, highly productive system. Many eutrophic lakes fall into this category.

Secchi Disc Transparency

A widely used, very simple means of determining the productivity of a lake is Secchi Disc transparency. Secchi disc depth, is that depth where a weighted white disc, when suspended from the shade side of a boat, just disappears from view. Numerous models have been developed to relate Secchi depth with productivity, chlorophyll a concentration, and even the concentration of nutrients.

In its simplest interpretation, Secchi disc depths in excess of 8 m are indicative of low productivity lakes (oligotrophic). Secchi depths of 8 m to 4 m are associated with medium productive lakes (mesotrophic). Lakes with Secchi disc depths of 2 m or less are associated with eutrophic lakes. In lakes where suspended sediments are also present, the Secchi disc transparency will be reduced due to the suspended material as well as algae present in the water.

To be continued in next issue

Commission for Oneida Lake

Assemblyman Michael Bragman has introduced a new bill (9778) this session which would create the Oneida Lake Commission. The responsibilities and powers of the proposed Commission will be to collect and study data relating to the area water, fishery and wildlife resources so as to plan for and promote the development, use and conservation of these resources. It will also advise in securing and maintaining a proper balance between industrial, commercial, agricultural, recreational, and residential uses within the Oneida Lake Region.

The bill, which is currently in the Assembly Environmental Conservation Committee, has only recently acquired the support of the Oneida Lake Association. According to one O.L.A. Director, it has taken 1½ years for the 5000 member association to accept the idea of another authority in the region, but now, with the association and numerous sportsman organizations behind the proposal, it has a good chance of passing.

The commission is to consist of nine members all of whom are appointed by the governor: four upon the recommendation of each of the county legislatures of the counties of Onondaga, Oneida, Oswego, and Madison respectively; two, both of whom are members of the Oneida Lake Association; one upon the recommendation of the governor; one upon the recommendation of the temporary president of the senate; and one upon the recommendation of the speaker of the assembly.

Proponents of the bill are hopeful that the commissions first project will be a new walleye fish hatchery for Oneida Lake.