Limnological investigations of Arnold Lake, Otsego County, NY

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INTRODUCTION

Arnold Lake (N42°36.65', W75°00.26') is a dimictic lake of glacial origin in the Town of Hartwick, Otsego County, NY (Figure 1). It has a surface area of 52.8 acres (21.4 ha) and a maximum depth of 61 ft (18.6 m) (Hill et al., 1981). The surrounding watershed is only 122.8 ac (watershed:surface area = 1:2.33) (Figure 2). There are no discrete inflows and the lake is presumably fed practically wholly by groundwater. Some attributes of the lake suggest oligotophy (such as its maintenance of high transparencies), while its high rate of hypolimnetic oxygen consumption and internal release of phosphorus indicate a more eutrophic nature.

At the request of a member of the Arnold Lake Association, a team from the Biological Field Station (BFS) visited the lake on 11 July 01 to collect baseline data on its chemistry and biology to characterize the waterbody as related to management concerns. The following were done on-site:

1) Temperature, dissolved oxygen, pH, conductivity, total phosphorus, nitrate nitrogen, chlorides, alkalinity and calcium were profiled at the deepest point of the lake.
2) Samples were collected at two sites for fecal coliform determinations.
3) Zooplankton samples were collected for the evaluation of that community, including checks for exotic introduced species (such as zebra mussel (*Dreissena polymorpha*) larva, spiny water flea (*Bythotrephes* sp.) and fish-hook water flea (*Cercopagis* sp.)).
4) Exploratory evaluations of the near-shore macro-benthic (large bottom associated animals) and meiofauna (microscopic benthic animals) communities were conducted.
5) Qualitative observations of the rooted plant communities were made, noting any presence or dominance of non-native species.

METHODS

Arnold Lake was visited on 11 July 01. Transparency was measured with a standard Secchi disk. At the deepest site encountered (17.3 m), temperature, dissolved oxygen, pH and conductivity were measured at 1 m intervals using a Hydrolab Scout 2® multiprobe digital microprocessor which had been calibrated according to manufacturer's instruction (Hydrolab Corp., 1994) immediately prior to use. Water samples were retrieved from the surface, 3, 9 and 17 m for the analyses of total phosphorus, nitrate nitrogen, chlorides, alkalinity and calcium. Additionally, two near-shore samples were collected for fecal coliform determinations (see Figure 1). A summary of methodologies for chemical analyses employed is given in Table 1.

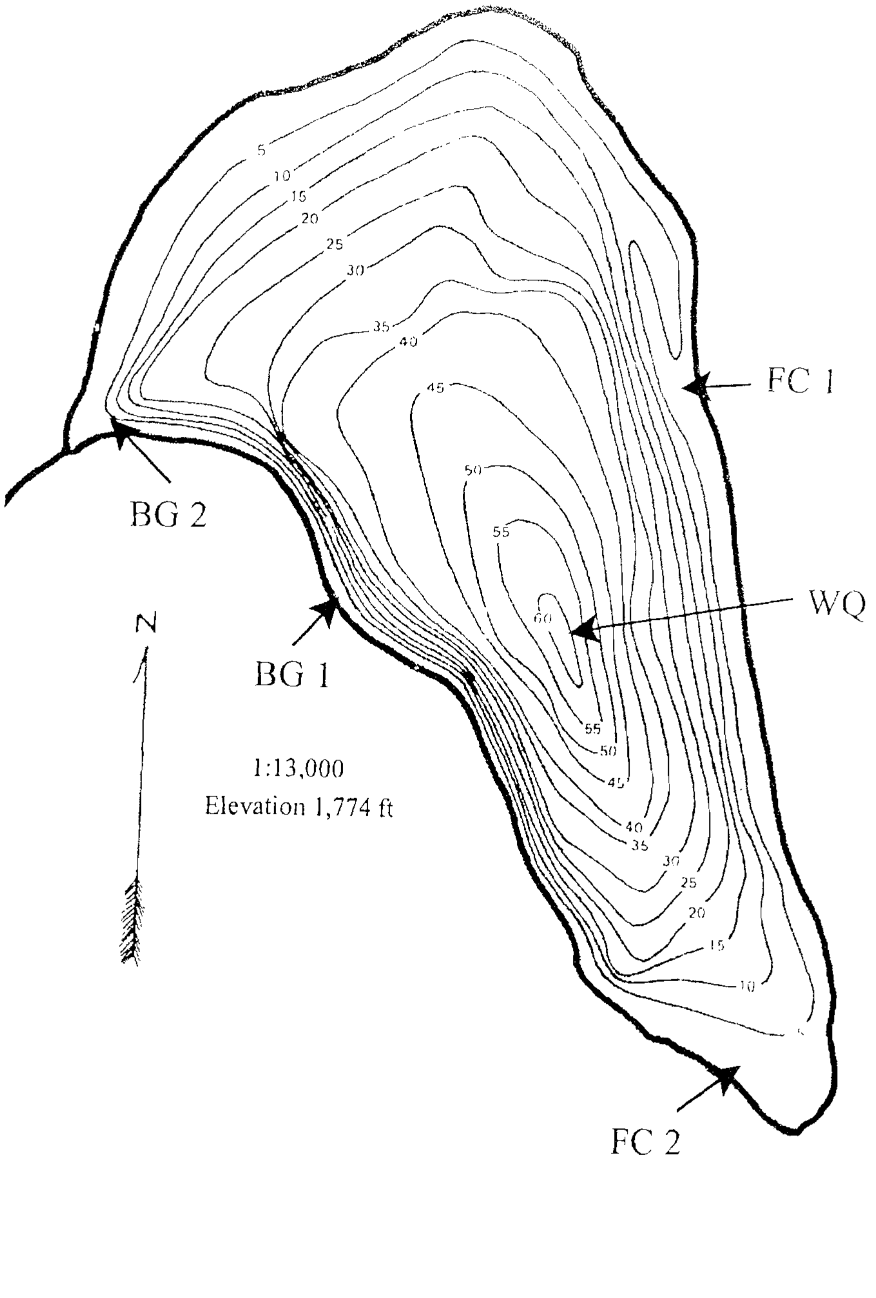

Figure 1. Arnold Lake, Otsego County, New York. Bathymetry in feet. WQ = water quality monitoring site, FC = fecal coliform sites, BG = benthic grab sites (modified from Hill et al., 1981).

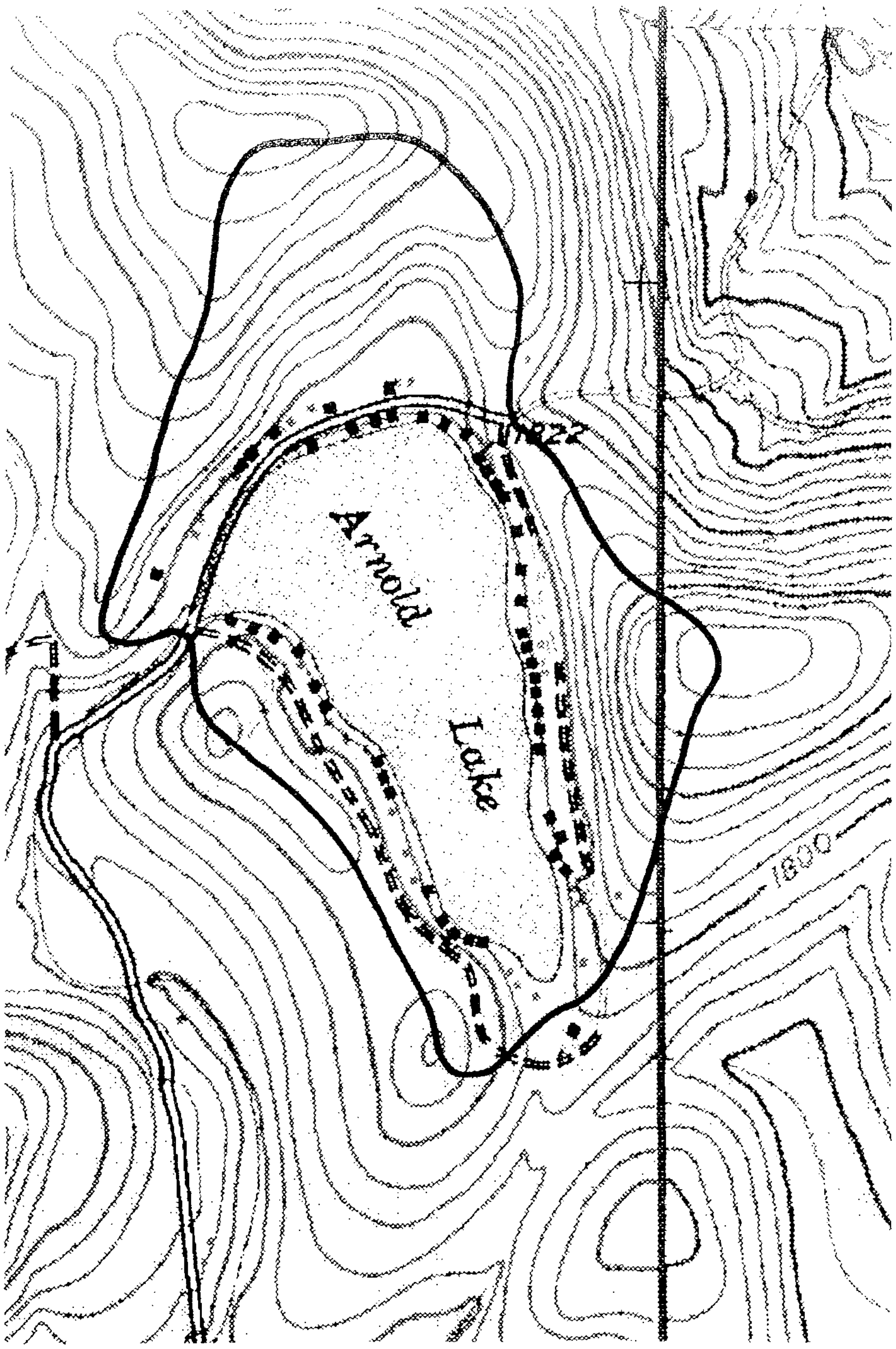

Figure 2. The watershed of Arnold Lake, Otsego County, New York.

Parameter	Sample volume	Preservation	Method	Reference
Total Phosphorus-P	40 ml	H_2SO_4 to pH<2	Persulfate digestion followed by single reagent ascorbic acid	EPA, 1983
Nitrite+Nitrate-N	25 ml	Filter and cool to <4° C	Cadmium reduction	APHA, 1989
Calcium	50 ml	None	EDTA titrimetric	EPA, 1983
Chloride	100 ml	None	Mercuric nitrate titration	APHA, 1989
Alkalinity	100 ml	Cool to <4°C, measure ASAP	Titration to pH=4.6	APHA, 1989
Fecal Coliform	500 ml (in triplicate)	Iced, process ASAP	Membrane filter technique	APHA, 1989

Table 1. Summary of laboratory methodologies employed.

Qualitative zooplankton samples were collected with a .25 m diameter 63 *u*m mesh plankton net. Both horizontal and vertical (surface to 10 m) tows were taken. Samples were preserved with 1% Lugol's iodine and were surveyed under a dissecting microscope.

The benthic macoinvertebrate and meiofaunal communities were evaluated by collecting substrate samples with a 15x15 cm (225 cm^2) Eckman dredge using an extension handle. Substrate was transferred to 2 l plastic jars and preserved with 70% ethanol. Organisms were separated from the material and identified using procedures outlined in Thorp and Covich (2001).

While on the lake, qualitative notes were made on the presence of rooted aquatic plants. Engine failure prevented an inventory as complete as had been planned. Species identification followed Fasset (1957) and Crowe and Helquist (2000).

RESULTS AND DISCUSION

Profiles of the physical parameters in Arnold Lake are given in Table 2. Secchi transparency was 4.9 m. Thermal stratification was evident beginning at 5m; above that (the epilimnion) the waters were well mixed. There was a pronounced metalimnetic oxygen maxima (supersaturation of oxygen through the thermocline). While indicators of algae abundance (i.e. chlorophyll *a*) were not collected, undoubtedly algal photosynthesis was responsible. Below 10 m, dissolved oxygen concentrations fell sharply as a result of algal respiration and/or decomposition. Waters below 14 m were essentially anoxic. Because the sampling took place in mid-summer, one would expect a continued decline in oxygen, likely to the point where the entire hypolimnion (cold water below 5 m) became anoxic prior to fall overturn. This is consistent with investigations over the past several years (Sohacki, unpublished data). pH was variable with depth, as to be expected given the lake's low alkalinity values (see below). Arnold Lake's limited ability to buffer against pH changes is reflected in high values in the epilimnion due to photosynthesis and lower values in the hypolimnion due to respiration and decomposition. Conductivity (an indirect measure of ions in solution) was low throughout the column, reflective primarily of low levels of calcium (see below). Increases near the bottom are related to the anoxic situation there. Many compounds, including iron and phosphorus, become reduced under such conditions and are converted from an insoluble form to a soluble one.

Depth (m)	Temperature (^oC)	Dissolved O_2	PH	Conducitivity (*u*mho/cm)
Surface	21.67	8.93	8.59	63
1	21.67	8.72	8.59	63
2	21.64	8.87	8.57	63
3	21.25	8.96	8.76	63
4	20.74	8.89	8.66	63
5	17.91	10.35	8.35	63
6	15.02	10.76	8.15	63
7	11.63	11.33	7.89	63
8	9.43	10.42	7.74	63
9	8.19	8.55	7.56	64
10	7.30	6.56	7.40	65
11	6.81	4.14	7.28	66
12	6.44	2.62	7.02	68
13	6.31	2.07	6.91	69
14	6.18	0.76	6.84	70
15	6.08	0.12	6.73	70
16	5.96	0.03	6.66	73
17	5.93	0.02	6.63	75
Max = 17.3 m,	Secchi = 4.9 m			

Table 2. Physical profiles of Arnold Lake, 11 July 01.

Chemical profiles of the lake are given in Table 3. Alkalinity and calcium (which tend to be highly correlated in our area) are quite low. A potential problem associated with these conditions relates to a potential sensitivity to acid precipitation. However, little evidence of this problem exists locally, as even regional lakes on acid shales (as is Arnold) have substantially higher alkalinity values (10-20 mg/l as $CaCO_3$) than do many Adirondack lakes, where values often approach 1.0 mg/l. A benefit of having low calcium levels is that the lower tolerance limit for the exotic zebra mussel is approximately 40 mg/l (D'Itri, 1998). Arnold Lake is well below that and will not be threatened by that pest.

Depth (m)	Alkalinity (mg/l as $CaCO_3$)	Calcium (mg/l)	Chlorides (mg/l)	Nitrates (mg/l)	Total phosphorous (*u*g/l)
Surface	9.5	7.1	10.5	0.15	10.0
3	12.0	7.1	9.3	0.12	10.0
9	13.5	7.9	8.3	0.11	19.5
17	19.0	8.6	7.8	0.11	93.0

Table 3. Chemical profiles of Arnold Lake, 11 July 01.

It has long been recognized that nutrient concentrations dictate algal production in lakes (Vollenweider, 1968). The total nitrogen:total phosphorous ratio in algal biomass is generally 7-10 (Vallentyne, 1974). Based upon the ratio of nitrates:total phosphorus in Arnold Lake (at 12 to 15) in the epilimnion, one would expect phosphorous limitation. Internal loading of that nutrient is evident, as concentrations near-bottom are roughly ten times that of surface waters. This phenomenon is associated with the deoxygenation of waters overlying sediments, resulting in a reducing environment and a subsequent release of phosphorous from iron complexes (i.e., Marsden, 1989). It seems likely that when that phosphorous is redistributed throughout the water column during fall turnover algal blooms would be stimulated. This situation makes efforts to manage phosphorous by reducing external sources difficult. However, controlling inputs during the summer would maintain water quality throughout most of the recreational season. Any reduction will slow eutrophication (the process by which algal production increases, transparency decreases and rates of oxygen depletion increase, with an eventual increase in submergent and emergent rooted vegetation).

Fecal coliform concentrations were quite low at the two sites examined, with 1.1 colonies/100 ml at the east shore and 5.3 colonies/100 ml in the south cove. This is well below levels at which agencies tend to consider closing public bathing beaches (France, pers. comm.). High concentrations are indicative of fecal contamination which may be from faulty septic systems, although any warm-blooded animal could be the source. It should be noted that recent research has revealed that phosphorus inputs from septic systems can be substantial even in the absence of coliform bacteria. Phosphorus retention of soils is limited, especially in soils low in calcium carbonate. As soils become saturated, plumes can migrate down grade at rates of 1-2 m, or more, a year (Robertson et al., 1998).

The zooplankton community was comprised solely of large-bodied crustaceans. These included the cladocerans *Daphnia* sp., *Holopedium gibberum,* and *Leptodora kindtii,* as well as calanoid copepods, all at high densities. No rotifers were present. This assemblage would have an extremely high filtering capacity and undoubtedly is responsible for the lake's impressive clarity. Any shift toward fewer, or smaller-bodied, plankton would result in changes mimicking eutrophication.

The benthic community was dominated by a few taxa, but at the same time, displayed a healthy diversity of organisms. Numerically dominant taxa included chironomid larvae (non-biting midges), non-parasitic nematodes (round worms), oligochaete worms, and ostracods (seed shrimp). Also found, although in lower numbers, were isopods (aquatic pill bugs), benthic crustaceans (harpacticoid copepods and amphipods or scud), and water mites. The benthos of the littoral zone indicated a typical benthic fauna that would be expected in a normally-functioning littoral zone. A benthic community where only a few taxa are present (e.g., just oligochaetes and chironomids) indicates a problem, but that is not the case for Arnold Lake. These benthic animals help breakdown the dead plant material and in turn, many of these animals serve as food for both bait-type fish (i.e., minnows) and young game fish. They form a vital part of the lake's food web, and maintain a healthy ecosystem.

Rooted plant growth was sparse in the areas visited, reflective of the lake's steep bathymetry. An exception was near the outflow (the more gently sloping northwestern shore was not examined). Noted were white fragrant water lily (*Nymphea odorata*) and pink water lily (*Nymphea* sp., most likely *N. odorata;* ornamental variety?) and the submergents *Potamogeton natans* (floating-leaved pondweed) and *Elodea canandensis* (waterweed). Other species noted during the summer included *P. epihydrus* (leafy pondweed), *Isoetes* sp. (quillwort), *Drepanocladus* sp. (leafy liverwort moss) and *Nitella flexilis* (stonewort) (Lord, 2001). *Nitella* was probably the dominant plant (by mass), though was not obvious because of its tendency to grow in depths of 7-8.5 m (a reflection of Arnold's high transparencies). No pestiferous exotics were encountered. It is unlikely that plant management will be an issue as long as this community exists.

SUMMARY

When considering management objectives of any water body, its pristine state should be considered. By that we mean what the nature of the lake would be in the absence of all cultural disturbances. The only evidence we have indicating that Arnold Lake is not pristine is derived from state wide survey conducted in 1935 (Tressler and Bere, 1936). On 13 August of that year, near bottom dissolved oxygen concentrations were 2.8 mg/l. This year, a full month earlier, revealed anoxic conditions throughout the bottom 3 meters. This implies nutrient enrichment in recent decades. However, since internal releases of phosphorous are substantial, reversing that situation through watershed management seems unlikely. Limiting phosphorous inputs during the summer would maintain water quality during that time. Given the lake's small, forested watershed, anthropogenic inputs must be derived from near-shore development. These include the creation of impervious surfaces, shoreline destabilization, and, possibly the most important, septic system leachate. Management activities to consider include the creation of vegetated buffer strips around the lake, maintaining aquatic vegetation in shallow areas and limiting activities that agitate shallow water and the substrate beneath it. Current technologies exist that can intercept phosphorous derived from septic systems (see Baker et al., 1998).

Perhaps the most striking feature of Arnold Lake is that it seems to be devoid of exotic species. Maintaining that situation should be the primary objective of managing the lake. While the lake would not be hospitable for the notorious zebra mussel, numerous other exotic plant, plankton and fish species would thrive there. We feel that the "apparent" oligotrophic nature of the lake is due to a zooplankton community comprised of many large-bodied crustaceans. The introduction of any planktivorous fish could decimate that community which would, at the very least, compromise the aesthetic quality of Arnold Lake. Public education, through signage at the access point, ideally augmented with boat washing facilities, is recommended. Allowing the use of baitfish by fishermen should be questioned.

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