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Ref.:	MorrisLake2014	(14 pages)
To:	Harbour East - Marine Drive Community Council (HEMDCC), HRM	
From:	S. M. Mandaville Post-Grad Dip., Professional Lake Manage. Chairman and Scientific Director	
Date:	February 23, 2014	
Subject:	MORRIS Lake, Dartmouth:- Enriched- comparison with HRM's data of 2006-2011, and suggested restoration parameters but the zoobenthos in 1998 showed surprisingly fair to good water quality	

(*cf.* http://lakes.chebucto.org/WATERSHEDS/COWBAYR/MORRIS/morris.html)

Please feel free to ask me any questions, and I will endeavour my level best to respond either via emails and/or in person at one of your meetings, if invited to do so.

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The 15 µg/l TP chosen by the HRM as the Threshold/LCC value is too high. It is not based on the Canadian Council of Ministers of the Environment (CCME (2004)'s policy, or on any published science. What HRM staff went by was the field data at that time and not on the pre-cultural hindcast data.

The CCME (2004) guideline was the result of extensive scientific consultations conducted across North America by Environment Canada's scientists over the early 2000's. But the `concept' has been known to many of us scientists ever since approximately the early 1980's via peer reviewed published literature.

In addition, there were numerous published papers in several peer reviewed journals relating to lake management dating as long back as the 1970's. Some examples of the peer reviewed journals are the Canadian Journal of Fisheries and Aquatic Sciences (CJFAS), the North American Lake Management Society (NALMS) journals, Handbooks of the NALMS, the Ontario Ministry of Environment standards, and the Province of Quebec's standards.

Our modelled pre-cultural hindcast (+0.173 kg/ha.yr precipitation) TP value is 3.4 µg/l, and the Queen's University pre-industrial (i.e., pre-1850's) diatom inference value yields a similar 3.89 µg/l.

Our modelled value is actually lower than 3.4 µg/l for Morris Lake since we had also included the 0.173 kg/ha.yr deposition because we felt that the precipitation may not be directly related to the routine developments and some of it could be long range transport of phosphorus species. Hence, nutrient enrichment has occurred in Morris Lake.

Our Federal Environment Canada developed a superb multivariate model known as the BEAST (BEnthic Assessment of SedimenT) for the Canadian portion of the Great Lakes. We generally follow those methodologies, and supplement them with the multimetrics published by the USEPA for those lakes that we study on a detailed protocol.

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The TP (total phosphorus) value which is usually the `limiting nutrient':- <u>HRM's TP data ranged 3–39 µg/l</u> during the years 2006 to 2011 analyzed at private labs. Compare that with our 1991-1992 (12 #s, vw) data of 6-22 µg/l (lab work at an Environment Canada lab in NB), and Paul Mandell's grad thesis 1991-92 (4 #s, surf) data of 11-24 µg/l (lab work at the Province's QE II labs.

Environment Canada (2004) published a table which was derived from the 18-country OECD peer consensus (http://lakes.chebucto.org/TPMODELS/OECD/oecd.html) which I reproduce below:-

Table 4.1 Trophic classifications of lakes, with their corresponding phosphorus and chlorophyll concentrations and transparency (Secchi depth) (sources: Wetzel 2001; Vollenweider and Kerekes 1982).

Trophic level	Total Phosphorus ($\mu g \cdot L^{-1}$) Wetzel (2001)	Total Phosphorus ($\mu g \cdot L^{-1}$) Vollenweider and Kerekes (1982)	Chlorophyll *a* ($\mu g \cdot L^{-1}$) Vollenweider and Kerekes (1982) Mean	Chlorophyll *a* Max	Secchi depth (m) Vollenweider and Kerekes (1982) Mean	Secchi depth ~~Max~~ Min.
Ultra-oligotrophic	< 5	< 4	< 1	< 2.5	> 12	> 6
Oligo-mesotrophic	5-10	4-10	< 2.5	< 8	> 6	> 3
Meso-eutrophic	10-30	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic	30-100	35-100	8-25	27-75	3-1.5	1.5-0.7
Hypereutrophic	> 100	> 100	> 25	> 75	< 1.5	< 0.7

To further understand the relevance of Ch*a* values, kindly note that the Kings County of Nova Scotia set a maximum objective <u>Ch*a* values in the low range of 2.5 µg/l</u> for 18 lakes. I herewith insert a scan from their policy in my archives:-

Kings County adopted water quality objectives for 18 lakes in the county, through amendment of MPS and LUB. The maximum objective value of chlorophyll-a for most of these lakes is 2.5 µgm/L. Seven of the lakes' objectives were set below the level of 2.5. Based on predictive modelling, the estimated maximum number of dwellings that could be added to the contributing area without exceeding the threshold value was established. This number of dwellings was set as a limit for development in the LUB. Policy in the MPS enables application for a permit with a development having "near-zero impact" through site standards or performance standards. Primarily this condition is expected to be met with septic field fill with a 20 year phosphorus input retention and a requirement to replace the fill every 20 years. A condition in adopting these limits was implementation of an annual monitoring program for a minimum of six years. The sampling required was to be completed by volunteers.

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Suggested deliberation for restoration by the Community Council:

(i) See the CCME's fact sheet (2004) for the phosphorus guidance framework (http://documents.ccme.ca/download/en/205/).

(ii) The CCME's framework recommends a maximum enrichment of 50% increase over the hindcast value of TP, and to not exceed the trigger range. The hindcast cultural (+0.173 kg/ha.yr precipitation) value is 3.4 µg/l, hence 50% increase results in a conc. of 5.1 µg/l, but the relevant trigger range is the stringent <4 µg/l. Hence, the eventual goal could be a very stringent 4 µg/l.

(iii) Compromise could be made @ 5 µg/l which would place the lake in the 4-10 µg/l range. Lake restoration results from elsewhere have been widely published in the scientific handbooks and published papers.

(iv) The 15 µg/l chosen by the HRM as the LCC is not based on any published science nor is it based on the CCME (2004) policy.

Total phosphorus (TP) trigger ranges for Canadian lakes and rivers (CCME, 2004)

Trophic status	**TP (µg/l)**
Ultra-oligotrophic	< 4
Oligotrophic	4-10
Mesotrophic	10-20
Meso-eutrophic	20-35
Eutrophic	35-100
Hyper-eutrophic	> 10

Per the CCME (2004), the framework offers a tiered approach where phosphorus concentrations should not (i) exceed predefined 'trigger ranges'; and (ii) increase more than 50% over the baseline (reference) levels. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site (i.e., hindcast values). If the upper limit of the range is exceeded, or is likely to be exceeded, further assessment is required. When assessment suggests the likelihood of undesired change in the system, a management decision must be made.

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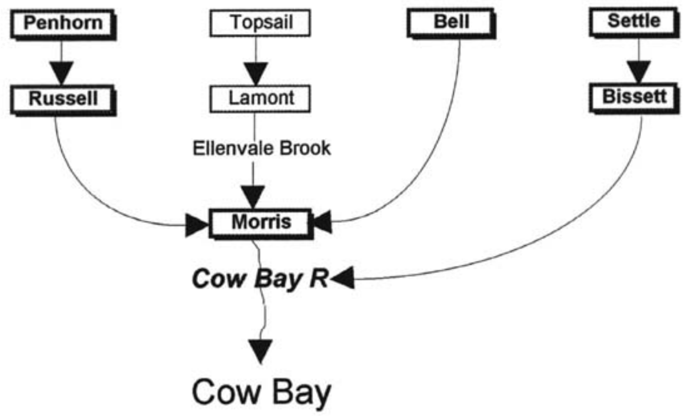
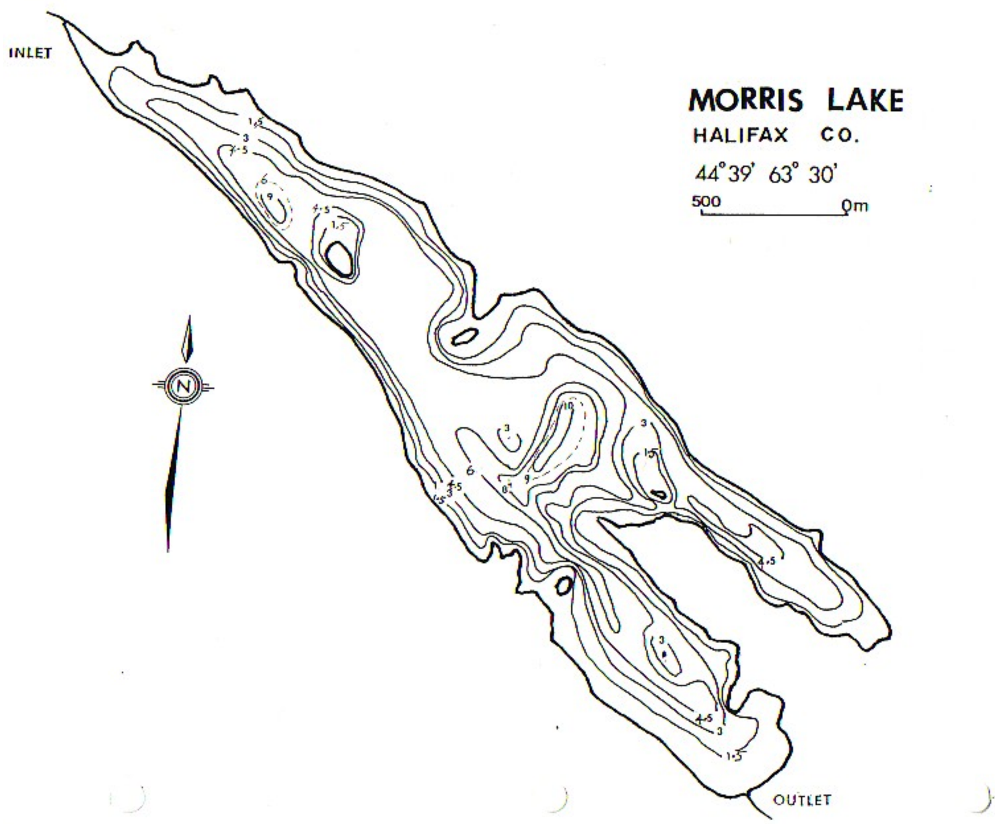
The flow chart developed by us



Lake bathymetry (as supplied by the NS. Dept. of Fisheries)



South basin deep station data archives (shallow area data can vary significantly)

Source of field data	Date(s) of sampling	#s of sampling events and type of sampling	TP (µg/l)		Cha (µg/l)	
		Deep stn.	Mean	range	mean	range
BIO	Apr. 1980	1# (surf.)	34	-	-	-
SWCSMH	May-Oct. 1990	3#s (arms depth)	13.5	11.1 – 16.7	1.74	1.04 – 2.38
BIO	Apr. 1991	1# (surf.)	7	-	6.349	-
Dartmouth Eng. Dept.	Aug. 1991	1# (surf.)	-	-	2	-
Mandell	1991-92	4#s (surf.)	17	11 – 24	3.20	1.78 – 6.45
SWCSMH	1991-92	12#s (vol. wtd.)	12	6 – 22	2.3	0.7 – 8.3
SWCSMH's Predictive Modelling (also see graph on page-8)		Pre-cultural (+0.173 kg/ha.yr precipitation)	3.4	-	-	-
		1993 Serv. Res. @ 0.52 kg/ha.yr	16.5	-	-	-
		1993 Serv. Res. @ 1.1 kg/ha.yr	29.3	-	-	-
BIO	March, 2000	3 stns, 5 #s (surf.)	15	-	3.592	-
Thiyake's Paleo Inference Model	Pre-1850's (Bottom layer of core)	Queen's University Diatom Inference Model	3.89	-	-	-
	Early 2000's (Top layer of core)		11.22	-	-	-
HRM	2006	1#s (1 m.)	<2.0	-	0.95	-
HRM	2007	3#s (1 m.)	7.7	3 – 11	2.65	0.42 – 5.44
HRM	2008	3#s (1 m.)	15.0	7 - 24	1.99	0.59 – 3.49
HRM	2009	2#s (1 m.)	22.5	6 – 39	1.43	0.37 – 2.11
HRM	2010	3#s (1 m.)	16.0	8 – 30	3.71	0.35 – 5.99
HRM	2011	3#s (1 m.)	13.7	8 – 23	5.16	2.19 – 7.30

(Acronyms & brief explanation on next page)

Acronyms & brief explanation of the aforesaid table

vol. wtd.= volume weighted discrete depth sampling
arms depth.= sampling at arms depth
surf.= surface samples
1 m.= 1 metre depth sampling

BIO- Bedford Institute of Oceanography
SWCSMH- Soil & Water Conservation Society of Metro Halifax's research
SWCSMH's predictive modelling- Computer modelling carried out by the Soil & Water Conservation Society of Metro Halifax
Mandell- Paul Mandell's MSc thesis (1994) at Dalhousie University; he was a contractor with the DFO at the time
HRM- Halifax Regional Municipality (2006 to 2011; the Ch*a* values are means of the 2 methodologies reported)
Thiyake- Thiyake Rajaratnam's MSc thesis (2009) at the Queen's University in Kingston, Ontario under a major NSERC grant. The grant was for the first ever paleolimnology conducted on lakes across Nova Scotia (I calculated the antilog values from her reported log values based on the diatom inference model)

Basic Morphometric and Hydrologic data

(computed by us from bathymetric maps supplied by the Provincial Fisheries Dept.)

- Shoreline length= 12.524 km
- Surface area= 160.8 ha
- maximum depth= 13 m; mean depth= 3.7 m
- volume= 5.92×10^6 cu.m.
- watershed (local)= 1050.6 ha; watershed (total)= 1737.3 ha
- Flushing rate= 3.1 times/yr (approx.)
- In-lake TP retention= 0.52

- Zr , Relative depth= 0.9 % ………. (for most lakes, Zr < 2%. Deep lakes with small surface areas exhibit greater resistance to mixing and usually have Zr > 4%).
- DL, Shoreline dev.= 2.8 …………. (DL is important because it reflects the potential for development of littoral communities which are usually of high biological productivity).
- Dv, Deve. of volume= 0.9 ………….. (For the majority of lakes, Dv will be greater than 1 (i.e. a conical depression).
- Index of Basin Permanence (IBP)=0.47 $\times 10^6$ cu.m/km ………… (The IBP is a morphometric index that reflects the littoral effect on basin volume. Lakes within the Atlantic National Parks (IBP < 0.1) are dominated by rooted aquatic plants and indicate senescence (excessive shallowness, high water color and high TP).

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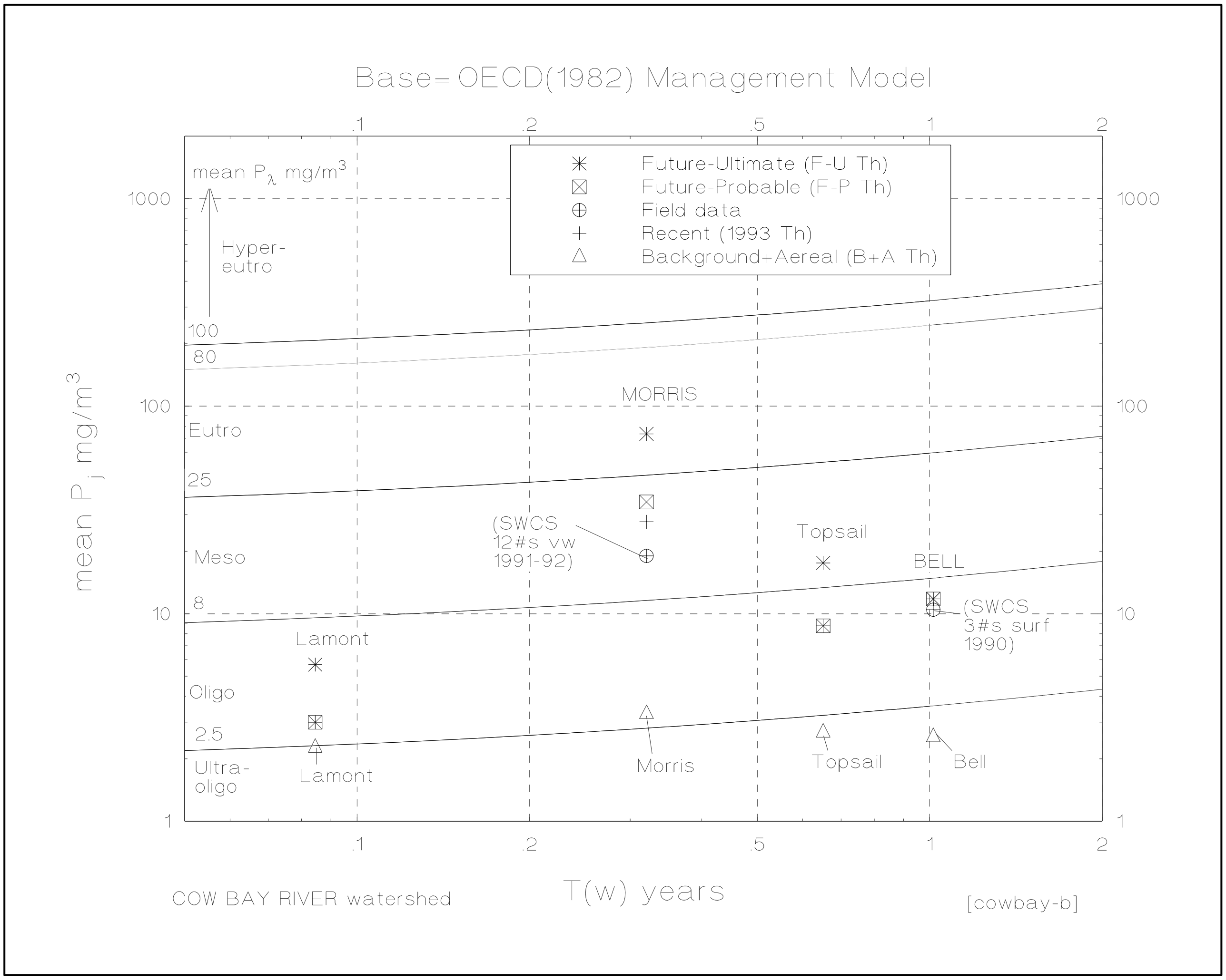
Our predictive model utilizing the 18-country OECD (Organization for Economic Co-Operation and Development) peer consensus base models



Notes for the log-log graph above:-

The X-axis is the water retention time. The Y-axis is the inflow TP concentration. The pelagic (i.e., open water) phosphorus concentrations are shown as curved lines with values of 2.5, 8, 25, 80, and 100 µg/l expressed as total phosphorus (TP)) delineating the OECD management model categories of nutrient enrichment. Chlorophyll*a* values have not been plotted though they can be with some more work. We have also not updated the model with the latter field data of various sources inclusive of HRM's from the Table on page-6 since it would get cluttered. The multiple biological inference values were not plotted in it either.

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Email from Renee Roberge P.Eng. of the HRM's EMS Dept.

Date: Fri, 02 Jul 1999 18:08:44 -0300
From: "Renee Roberge" <robergr@region.halifax.ns.ca>
Subject: Morris and Russell Lakes

Shalom,

How are things going? I have not talked to you for so long... and I apologize, too many things to do.

I have two questions for you. First, I should mention for your information that HRM has initiated a Master Planning Exercise with respect to development of the Morris and Russell Lakes areas. One goal is to protect the quality of the water and several policies were approved by Council to achieve that. The policies were mainly based on the report conducted by Griffiths Muecke Associates and Gordon Ratcliffe Landscape Architects in May of 1998.

I am unsure about certain issues and would like to have your opinion on these two points:

My questions:

1) sampling is recommended into the lakes (mainly Morris Lake at this time) to establish background data before development proceeds. The developers would have to follow severe erosion and sediment control methods but still periodic monitoring is recommended in order to set a critical threshold level.

Are you planning any monitoring of the lakes as part of your regular program?

2) The consultant also recommends methods that would maximize phosphorus removal. One idea that was talked about was to use wetlands. It seems now they will use the existing wetlands, i.e., direct stormwater to these wetlands.

I have some concerns with this and would like to have your views on this idea.

Nothing has been decided yet and I am looking for your opinion on these issues because I know you have a lot of experience in that field and you are quite knowledgeable of the study area.

Thank you.

Renée
490-6941

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Summary only of select phytoplankton analyses (does not include all yet)

(*cf.* SWCSMH, 1992. 56 leaves. Refer to that report for the detailed listing of species.)

Like most of the lakes studied in this report, in early summer there were unicellular green algae and a few other species, but no species greatly outnumbered the others. This low density persisted through July with just a shift in the species make-up, *Microcystis aeruginosa* and other species becoming more common. In August there were different species dominant and present again, but the overall density remained fairly low.

Zoobenthos

Overview:- The replicate sampling of zoobenthos in 1998 at 5 littoral zones is inserted in the following pages. Most taxa were analyzed to the `family' level since we were looking for an overall picture. Unless we observe severe stresses, we do not proceed to the `genus' and `species' levels. In 1998, we did not observe any severe issues in the littoral zone. Sampling methodology was Canada's Federal EMAN protocol.

(*cf.* Hynes, K.E. 1998, SWCSMH. . Refer to that report for the detailed listing of species.)

(Sampling of zoobenthos by U of T biologist, Kim Hynes, 1998)

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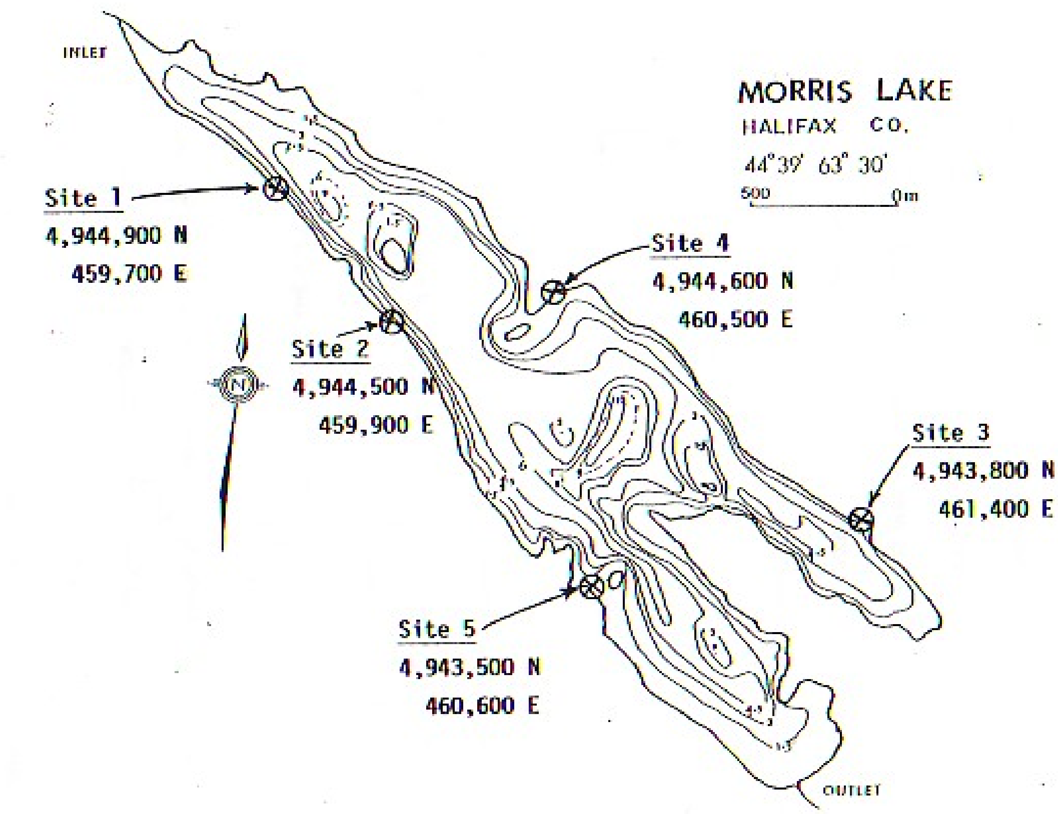
(Zodiac and survival gear provided by CFB Shearwater)

Sampling stations:-



Discussion by Kim Hynes (from her report):

"The benthic macroinvertebrate communities at sites 1, 2 and 5 were dominated by the mayflies Ephemerellidae and Heptageniidae. Oligochaeta was also numerous at site 1 and Acari at site 5. Generally, the dominance of the pollution-sensitive mayflies at all 3 sites indicates good water quality (Ohio Department of Natural Resources, unpublished). The communities at sites 3 and 4 were dominated by a mixture of pollution-sensitive mayflies and some pollution-tolerant worms and diptera families. The amphipod Hyalellidae, also present in high numbers at site 4, possesses a moderate sensitivity to pollution and is found in a wide range of water quality conditions. The communities at sites 3 and 4 generally indicate fair water quality (Ohio Department of Natural Resources, unpublished).

The BMWP biotic index indicated poor water quality at all sites (Friedrich *et al*, 1996). This conflicts with the presence of pollution-sensitive mayflies in abundance at many of the sites, and is probably confounded by small sample sizes. The ASPT scores indicated good water quality at all sites (Friedrich *et al*, 1996).

The HBI index indicated excellent water quality at all sites except site 4, which was rated very good by the index (Appendix 3). The HBI is a better overall indicator of habitat quality, as it is based on pollution-tolerance, presence and relative abundance of families. The Simpson's diversity index was also good for all sites except site 2, which had a poor diversity. The community at site 2 was dominated by a pollution-sensitive mayfly. This indicated good water quality according to the biotic indices, which are based on indicator organisms' tolerances to low oxygen conditions (Friedrich *et al*, 1996). However Ephemerellidae alone made up most of the sample. Only 7 other families were present in low numbers, hence the low diversity. This suggests that, despite apparently good oxygen conditions, other factors make the habitat at this site unsuitable for a good diversity of organisms.

The substrate at all sites on Morris Lake was dominated by gravel to boulder sized particles (>2mm), which is generally considered a preferable habitat for most benthic macroinvertebrates. Such a substrate usually supports a good diversity of aquatic benthic organisms (Allan, 1995). This is the case for all sites except the low diversity community at site 2.

Chlorophyll *a* and total phosphorus concentrations indicate that Morris Lake is at the low end of the oligotrophic range, possibly ultra-oligotrophic. Such a lake generally has good oxygen and nutrient conditions to support a good diversity of organisms (Horne and Goldman, 1994; Mason, 1996), which corresponds well with the results of the benthic macroinvertebrate sampling at all sites, with the exception of the low diversity at site 2.

All other chemical and physical parameters measured at Morris Lake fell within established guidelines for drinking water, recreation or protection of aquatic life, including pH. No factors measured in the study of Morris Lake offer any explanation for the low diversity at site 2."

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Table E: Taxa identified in two replicate samples (A and B) at five sites on Morris Lake.

Taxonomic Group	**Number Collected**									
Kingdom, Phylum (Subphlylum), Class	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**
ANIMALIA, ANNELIDA										
HIRUDINEA (order) (leeches)	1	-	-	-	-	-	-	-	-	-
OLIGOCHAETA (order) (aquatic worms)	2	10	1	1	6	4	2	6	2	7
ANIMALIA, ARTHROPODA (CHELICERATA), ARACHNIDA										
ACARI (subclass) (water mites)	1	1	1	-	1	1	2	-	6	10
ANIMALIA, ARTHROPODA (CRUSTACEA), BRANCHIOPODA (water fleas)*										
ANOMOPODA (order)										
Family: Chydoridae	138	160	19	53	-	11	3	6	15	36
Daphniidae	-	-	-	-	-	-	-	-	-	-
Macrothricidae	3	4	-	-	1	-	-	-	1	2
CTENOPODA (order)										
Family: Holopediidae	-	-	-	-	-	-	-	-	-	-
Sididae	3	-	-	-	-	-	-	-	-	-
ONYCHOPODA (order)										
Family: Polyphemidae	-	-	-	-	-	-	-	-	-	-
SPINICAUDATA (order)	-	-	-	-	-	-	6	-	1	1
ANIMALIA, ARTHROPODA (CRUSTACEA), COPEPODA (copepods)*										
CALANOIDA (order)	-	-	-	-	-	-	-	-	-	-
CYCLOPOIDA (order)	60	30	40	31	3	19	51	41	61	57
HARPACTICOIDA (order)	52	22	32	23	8	16	18	6	45	98
ANIMALIA, ARTHROPODA (CRUSTACEA), MALACOSTRACA										
AMPHIPODA (order) (scuds)										
Family: Gammaridae	-	-	-	-	-	-	-	-	-	-
Hyalellidae	2	1	-	1	-	-	4	14	2	10
ANIMALIA, ARTHROPODA (UNIRAMIA), INSECTA										
COLEOPTERA (order) (water beetles)**										
Family: Dytiscidae (predaceous diving beetles)	-	-	-	-	-	-	-	-	-	-
Elmidae (riffle beetles)	1	1	-	-	-	1	-	-	4	1
Hydrophiloidea(water scavenger beetles)	-	-	-	-	1	-	-	-	-	-
Scirtidae (marsh beetles)	-	-	-	-	-	-	-	-	-	-
DIPTERA (order) (true flies)										
Family: Chironomidae (non-biting midges)	1	-	-	1	2	3	5	6	4	4
Ceratopogonidae (biting midges)	-	-	-	-	-	-	-	-	-	-
Dolichopodidae (long-legged flies)	-	-	-	-	1	-	-	-	-	-
Empididae (dance flies)	1	-	1	-	-	-	-	-	1	3
Tipulidae (crane flies)	-	-	-	-	3	-	-	-	-	-
EPHEMEROPTERA (order) (mayflies)										
Family: Baetidae	-	-	-	-	-	-	-	-	-	-
Caenidae	1	-	-	-	-	-	-	-	1	3
Ephemerellidae	9	4	10	8	2	6	3	4	17	44
Ephemeridae	-	-	-	-	-	-	-	-	-	-
Heptageniidae	5	-	-	-	-	-	1	-	7	41
Leptophlebiidae	-	-	-	-	-	2	-	-	-	3
LEPIDOPTERA (order) (aquatic caterpillars or moths)										
Family: Pyralidae	-	-	-	-	-	-	-	-	-	-
MEGALOPTERA (order)										
Family: Sialidae (alderflies)	-	-	-	-	-	-	-	-	-	-
NEUROPTERA (order) (spongillaflies)										
Family: Sisyridae	-	-	-	-	-	-	-	-	-	-
ODONATA (order)										
ANISOPTERA (suborder) (true dragonflies)										
Family: Aeshnidae	-	-	-	-	-	-	-	-	-	-
Corduliidae	-	-	-	-	-	-	-	-	-	-

Gomphidae	-	-	-	-	-	-	-	-	-	-
ZYGOPTERA (suborder) (damselflies)										
Family: Coenagrionidae	-	-	-	-	-	1	-	-	-	-
PLECOPTERA (order) (stoneflies)										
Family: Leuctridae	-	-	-	-	-	-	-	-	-	-
Perlidae	-	-	-	-	-	-	-	-	-	-
Perlodidae	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA (order) (caddisflies)										
Family: Hydroptilidae	-	-	-	-	-	-	-	-	-	-
Lepidostomatidae	-	-	-	-	-	-	-	-	-	-
Leptoceridae	-	-	-	-	-	-	-	-	-	1
Limnephilidae	-	-	-	-	-	-	-	-	-	1
Molannidae	-	-	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	-	-	-	-
Polycentropodidae	1	-	-	-	-	-	-	-	-	-
Psychomyiidae	-	-	-	-	-	-	-	-	-	-
Rhyacophilidae	-	-	-	-	-	-	-	-	-	-
ANIMALIA, CNIDARIA, HYDROZOA										
HYDROIDA (order) (hydra)	-	-	-	-	-	-	-	-	-	-
ANIMALIA, MOLLUSCA, BIVALVIA (mussels and clams)										
Family: Sphaeriidae	-	-	-	-	-	-	-	-	-	-
ANIMALIA, MOLLUSCA, GASTROPODA (snails)										
Family: Valvatidae	-	-	-	-	-	-	-	-	-	-
ANIMALIA, NEMATODA (round worms)	1	-	-	1	2	-	1	1	2	1
ANIMALIA, PLATYHELMINTHES, TURBELLARIA (flatworms)	-	1	-	-	-	-	-	-	-	-
Total Organisms	**282**	**234**	**104**	**119**	**30**	**64**	**96**	**84**	**169**	**323**

*taxa identified in samples but not included in the analysis because they are not benthic, but swim in the water column

**larval beetles are included in the analysis, however adult beetles are semi-aquatic or swim in the water column and are not totally benthic, and hence are not included in the analysis. The following are adult beetles collected:

ANIMALIA, ARTHROPODA (UNIRAMIA), INSECTA										
COLEOPTERA (order)										
Family: Dytiscidae	-	4	-	-	-	-	-	-	-	-
Haliplidae	-	1	2	-	-	-	-	1	2	4