

### **Chemical Limnology:**

Depth : NEAR BOTTOM indicates the sample was collected 2 meters above the bottom of the lake

Color440: Absorbance of filtered sample taken in a 10cm cell at 440 nm wavelength. Not corrected for path length or transformation. To convert it to the units used by Cuthbert and DelGiorgio (1992) and by most papers reporting color data, multiply by 23.03.

Color280: Absorbance of sample at 280 wavelength.

Color253: Absorbance of sample at 253 wavelength.

Cond: Conductivity was measured directly in the field using the YSI Sonde 500 DO/Temp/Conductivity meter. It was not temperature corrected.

TOTNUF: Total unfiltered nitrogen. Note that the sample quality on the total nitrogen is questionable as there was a relatively high (100-400 ppm) baseline contamination due to insufficient clearing of the HCl dispenser prior to dispensing.

TOTPUF: Total unfiltered phosphorus

DRSI: Total unfiltered Dissolved Reactive Silica

### **Anions:**

This is the anions data (SO<sub>4</sub> and CL). Anions samples were all collected at 1m and were filtered with a 0.44 micron filter. Samples were generally collected on a single date

### **Cations:**

Date: Note that samples were monthly for lakes in 1998 and once in July or early August for lakes in 1999. 16 lakes were sampled in 1999 only. Collection frequency was reduced because of the very low temporal variability of the cations and to reduce the processing load on the analyzing lab.

Fe: Iron samples were ONLY analyzed in 1998. For approximately 16 of the lakes, no iron data was collected.

### **Chlorophyll:**

This is all of the raw chlorophyll and phaeopigment data.

Notes on columns:

Top: Highest depth sample collected from

Bottom: Lowest depth sample collected from

Volfiltered: Volume (ml) of sample filtered

Chl: Total undegraded chlorophyll measured using protocol of (Lorenzen, 1967). Blank values indicate that sample was collected but not successfully analyzed.

Phaeo: Total degraded phaeopigment measured using protocol of Lorenzen, 1967. Blank values indicate that sample was collected but not successfully analyzed.

Replicate #: To get a sense of variability between samples, 22 replicate samples were collected throughout the project. Replicate samples were collected in the field side by side but were not necessarily analysed in the same lab batch. Also 2 samples were collected in triplicate. 1 = first

of replicate pair or single sample collected. 2 = second of pair of replicate samples. 3 = third of triplicate samples.

Chl + Phaeo: sum of Chl and Phaeo

### **VerticalProfile:**

Unless otherwise indicated in notes, all parameters were collected using a YSI Sonde 500 Temperature/DO/Conductivity meter.

Temperature: degrees Celsius, as measured by YSI

DO: Dissolved oxygen (ppm) in water column as measured by YSI

Conductivity: Measured directly in water column using YSI

### **References:**

Cuthbert, I. D. and P. d. Giorgio (1992). "Toward a standard method of measuring color in freshwater." *Limnology and Oceanography* 37(6): 1319-1326.

Lorenzen, C. J. (1967). "Determination of chlorophyll and phaeo-pigments: spectrophotometric equations." *Limnology and Oceanography* 12: 343-346.

### **Lake Characteristics:**

Project: Identifies what part of the project a lake was sampled for.

A core landscape position project lake = LPP

A core LTER lakes sampled for biology as part of the landscape position project = LTER

One of the lakes sampled as part of Ben Greenfield MS thesis (2000) = Ben

A landscape position project lake sampled only for fish = Fish.

Lake\_order: Lake order is a numerical surrogate for groundwater influx and hydrological position along a drainage network, with the highest number indicating the lake lowest in a watershed. We define lake order as follows: -3 indicates isolated seepage lakes, -2 indicates seepage lakes connected by intermittent streams, -1 indicates seepage lakes connected by a wetland, 0 indicates headwater drainage lakes, and 1 through 4 indicate drainage lakes, with the number indicating the order of the stream that exits the lake (Riera et al. 2000).

Area: lake area in acres. Using Arcview coverages, identified in Ben Greenfield MS thesis (2000) as described below

Direct\_catchment: area of surrounding catchment feeding directly into lake (square meters). For drainage lakes, delineated starting from the outlet of the immediate upstream lake.

Total\_catchment: area of surrounding catchment feeding into lake and all lakes upstream of given lake.

Max\_depth (ft): Using agency published records, listed in Ben Greenfield MS thesis (2000) as described below

Perimeter (m): Lake perimeter. Using Arcview coverages, identified in Ben Greenfield MS thesis (2000)

Shoreline\_devel: Shoreline development factor, defined in Cole's Limnology text

Wetlands\_250m: Percent wetlands within catchment within buffer strip 250 meters distance from lake. Methods in Ben Greenfield MS thesis (2000)

Wetlands\_500m: Percent wetlands within catchment within buffer strip 500 meters distance from lake. Methods in Ben Greenfield MS thesis (2000)

Mean\_depth (ft): Mean depth, using WDNR data, when available.

**Methods excerpted from Ben Greenfield's draft manuscript:**

Chosen lakes included all regional hydrologic types (drainage lakes, headwater lakes, and seepage lakes). The study lakes also ranged widely in alkalinity and surrounding wetland abundance. Five of the lakes have been routinely sampled as part of the North Temperate Lakes Long Term Ecological Research site (NTL-LTER), and one lake has been sampled as part of the Cascading Trophic Interactions Project (Bade et al. 1998).

***Chemical Data:***

Lakes were monitored for pH, alkalinity, total phosphorus, chlorophyll a, and color during June, July, and August of 1997-1999 (all other parameters were also collected during these dates). Except as specified, all chemical data were collected and analyzed according to NTL-LTER protocols, which are available to the public for inspection at the NTL-LTER web site. Crampton Lake was sampled according to protocols outlined in Bade et al. (1998). Samples were collected monthly in each lake during the same season fish were collected with the exception that color data were collected in the year prior to fish collection for the NTL-LTER lakes and Crampton lake. Total phosphorus, chlorophyll a, and pH were averaged over June, July and August. Alkalinity and color were determined once, during midsummer. All parameters other than chlorophyll were collected 1 m below the lake surface, except in the five NTL-LTER lakes, where they were collected at the water surface. Color samples were filtered through 0.4  $\mu\text{m}$  nucleopore filters and analyzed at 440 nm, which indicates overall humic content of surface waters (Cuthbert and del Giorgio 1992). Epilimnetic chlorophyll concentration was measured monthly to estimate primary productivity. Chlorophyll samples were collected on Fisher Type A/E glass fiber filters by raising and lowering sampling tubing at a constant rate while drawing water with a peristaltic pump. Samples were homogenized and stored in methanol for 24 hours prior to spectrophotometric determination of chlorophyll concentration (Lorenzen 1967). For the NTL-LTER lakes, chlorophyll data were taken from Sanderson (1998).

***Lake Characteristics Data:***

Spatial data included lake morphometry, watershed area, lake order, and surrounding wetland abundance. Maximum depth data were obtained from EPA Experimental Lake Survey records (Overton et al. 1986) and Wisconsin Department of Natural Resources surface water resources records (Black et al. 1963; Andrews and Threinen 1966; Steuck and Andrews 1977). Data on lake area, perimeter, and watershed area were obtained with ArcView using the methods of Gergel et al. (1999). We define watershed area as the direct drainage watershed. In drainage lakes, the watershed boundary extended up to the outlet of the immediate upstream lake. Total watershed area, terrestrial watershed area, and total watershed to lake area ratio were all examined. Lake order is a numerical surrogate for groundwater influx and hydrological position along a drainage network, with the highest number indicating the lake lowest in a watershed. We define lake order as follows: -3 indicates isolated seepage lakes, -2 indicates seepage lakes

connected by intermittent streams, -1 indicates seepage lakes connected by a wetland, 0 indicates headwater drainage lakes, and 1 through 4 indicate drainage lakes, with the number indicating the order of the stream that exits the lake (Riera et al. 2000). Wetland proportion was determined for a zone 500 m distant from the lake shore that fell within the drainage area. Wetlands were defined using Wisconsin Wetlands Inventory Data (WDNR 1991) and included terrestrial wetlands, emergent macrophytes, and floating macrophytes. Wetland proportion data were arcsin(square root) transformed.

### ***References cited:***

- Andrews, L. M. and C. W. Threinen (1966). Surface water resources of Oneida County. Madison, Wisconsin, Wisconsin Department of Natural Resources: 284.
- Bade, D., J. Houser, et al., Eds. (1998). Methods of the Cascading Trophic Interactions Project. Madison, Wisconsin, USA, Center For Limnology, University of Wisconsin-Madison.
- Black, J. J., L. M. Andrews, et al. (1963). Surface water resources of Vilas County. Madison, Wisconsin, Wisconsin Department of Natural Resources: 317.
- Cuthbert, I. D. and P. del Giorgio (1992). "Toward a standard method of measuring color in freshwater." *Limnology and Oceanography* 37(6): 1319-1326.
- Gergel, S. E., M. G. Turner, et al. (1999). "Dissolved organic carbon as an indicator of the scale of watershed influence on lakes and rivers." *Ecological Applications* 9(4): 1377-1390.
- Lorenzen, C. J. (1967). "Determination of chlorophyll and phaeo-pigments: spectrophotometric equations." *Limnology and Oceanography* 12: 343-346.
- Overton, W. S., P. Kanciruk, et al. (1986). Characteristics of lakes in the Eastern United States. Volume II: Lakes sampled and descriptive statistics for physical and chemical variables. Washington, D. C., U. S. Environmental Protection Agency. 2: 374 pp.
- Riera, J. L., J. J. Magnuson, et al. (2000). "A geomorphic template for the analysis of lake districts applied to the Northern Highland Lake District, Wisconsin, USA." *Freshwater Biology* 43(3): 301-318.
- Sanderson, B. L. (1998). Factors regulating water clarity in Northern Wisconsin lakes. *Zoology*. Madison, Wisconsin, University of Wisconsin: 170.
- Steuck, R. and L. M. Andrews (1977). Surface water resources of Forest County. Madison, Wisconsin, Wisconsin Department of Natural Resources: 198.
- WDNR (1991). A user's guide to the Wisconsin Wetland Inventory, Wisconsin Department of Natural Resources.

ILTER Keywords

[anions](#)

[cations](#)

[chemistry](#)

[chlorophyll](#)

[hydrology](#)

[lakes](#)

[profiles](#)

Protocol Format

Process

Protocol ID

lpp\_additional\_metadata1

Protocol Type

field

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### *Aquatic Macrophytes*

These data were collected by Karen A. Wilson as part of her PhD work in Northern Wisconsin, (Vilas and Onieda Counties) during July and August of 1998 and 1999. Details of field collections can be found in Wilson, K.A. 2002. Impacts of the invasive rusty crayfish (*Orconectes rusticus*) in northern Wisconsin lakes. Ph.D. Dissertation. University of Wisconsin, Madison. Karen was assisted by Carrie Byron, an undergraduate at UW-Madison at the time, who should be acknowledged.

#### Methods:

Submersed and floating macrophytes were surveyed along a transect running perpendicular to shore at two sites representative of muck (organic) and sand substrate macrophyte communities. We avoided sites that were obviously impacted by boat launches, swimming beaches or lakeshore cottages and chose sites where plants were clearly present. Transects extended offshore to 100 m or a depth of 4 m, whichever came first. Divers noted the presence of macrophyte species within a 0.25 m<sup>2</sup> circular quadrat at 1 m intervals along each transect. We sampled a minimum of ten quadrats within each depth range (0 - 1 m, 1 - 2 m, 2 - 3 m, 3 - 4 m). An additional ten 0.25 m<sup>2</sup> quadrats were located parallel to shore at 1, 2, 3, and 4 m depths (N = 40) adjacent to the transect (or at equivalent spacing on transects less than 4 m deep). The additional ten quadrats were located approximately 1 m apart and placed by allowing the quadrat to drift down from above.

To calculate species frequency of occurrence for each lake, we summed the number of quadrats in which a species was found and divided by the total number of quadrats sampled in the lake. Species identifications followed Crow and Hellquist (2000). Uncommon or unknown species were collected for identification and voucher specimens. Many species in north temperate lakes reproduce infrequently via seed or are sterile and reproduce only vegetatively. Therefore not all plants were identifiable to species because reproductive structures were often absent. Thus, in addition to readily identified species, we used several genus-level categories. For example, except the readily identifiable *Myriophyllum tenellum*, all other *Myriophyllum* spp. were grouped together. These categories represent a conservative measure of the number of species in many lakes (for details see Wilson, 2002).

#### ILTER Keywords

[biology](#)

[crayfishes](#)

[plants](#)

[sampling](#)

[transects](#)

Protocol Format

Process

Protocol ID

lpp\_aquatic\_macrophytes1

Protocol Type

field

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### ***Invertebrate Collection***

We used modified Hester-Dendy colonization substrates to sample benthic invertebrate communities. Each sampling device consisted of a 3"x3" top plate, alternating layers of coarse and fine mesh, a 'choreboy' commercial scrubbing puff, alternating layers of coarse (6.35 mm) and fine (3.18 mm) black plastic mesh, and a 3"x3" bottom plate (see NTL-LTER website for further description). Two Hester-Dendy samplers were set at a depth of one meter on each of three substrate types (cobble, sand and silt) within each lake for four weeks. Within each lake, areas of different substrate types were identified using WI-DNR depth contour lake maps, and substrate type was verified by direct observation. Different substrates were sampled to account for invertebrate associations with specific substrate characteristics.

All benthic invertebrates were removed from the colonization samplers, preserved in 70% ethanol, identified and enumerated. Aquatic insects were identified to family and other invertebrate were classified to order using standard taxonomic keys, e.g., Hilsenhoff (1981), Thorp and Covich (1991), Merritt and Cummins (1998). Invertebrate information from all sites was pooled to create a single invertebrate sample from each lake. From these data, estimates of invertebrate abundance, richness and evenness were calculated for each lake. Abundance estimates reflect the average number of individuals per Hester-Dendy in each lake. Richness was the cumulative number of taxa found at each site.

Lake order was used to examine the variation of the lake attributes and invertebrate assemblage characteristics along the lake landscape position gradient. Lake order is a method of classifying lakes based on the type and strength of linkages between lakes and stream networks, and has been used as a surrogate measure for lake landscape position (Riera et al. 2000). Riera and colleagues (2000) developed a numbered system to differentiate lakes without permanent inlets or outlets (seepage lakes, negative lake order), from those having inlets and outlets (drainage lakes, positive lake order). The lakes that we selected for this study were previously assigned an order from analyses of maps by Riera and colleagues (2000).

LTER Keywords

[abundance](#)

[benthic](#)

[biology](#)

[invertebrates](#)

Protocol Format

Process

Protocol ID

lpp\_benthic\_invertebrates1

Protocol Type

field

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### ***Fish Sampling***

Fish sampling was conducted on each lake at least one month after thermal stratification had taken place, beginning on the 3rd week in June and running through the 3rd week in July. This was done to minimize the effects of winter stress and spawning on fish weight given their length. Several gears were employed to estimate fish diversity in each lake, each being effective at catching a different set of fishes.

Vertical gillnets were employed to sample pelagic fishes. A spectrum of mesh sizes (19, 32, 51, 64, 89-mm stretch mesh) were used, with each mesh size effectively catching a different size range of fish. The nets were fished in the deep basin of each lake for one diel cycle.

Fyke nets were employed to sample fishes in the shallow near shore areas. Mini fyke nets with a mouth opening 0.75-m high by 1.25-m wide constructed with 4-mm delta mesh, with a 1-m by 5-m single lead were set so as the lead ran perpendicular from shore and that the mouth sat in approximately 1-m of water. There were 3 nets set at differing locations defined by substrate type (muck, sand and cobble) for one diel cycle. Three crayfish traps were set along side each of the fyke nets so as to sample the same habitat type sampled by each fyke net.

Electrofishing occurred in the near shore area between 0.3 and 1.5-m in depth. Two 30 minute transects were performed such that a variety of substrate types were sampled. The dipnets used to net fish during electrofishing consisted of 4-mm delta mesh and were capable of retaining small fishes (down to 20-mm). Our goal was to capture and identify as many game and non-game fish species as possible.

### ***Fish Processing***

Fish caught in each gear type were processed by measuring mass and total length of all fish of each species; however, a subset of each species was measured when the catch rate was high. Two fish in each 5-mm size class for each species were weighed and length measurements were taken so as to collect weight measurements for a wide size range of each species. If the catch of a given species in a given size class (small, medium or large) within a particular set or electro-shocking run exceeded 30 fish, 30 were measured for each species. Those not measured for length in each size class were counted and recorded so as to associate them with those that were measured to allow length frequency distributions to be generated while expediting our processing and avoiding redundant weight and length measuring. Each fish was identified to genus and species using the taxonomic key in Becker (1983). Any game fish killed were turned over to the appropriate Department of Natural Resource Game Warden.

LTER Keywords

[biology](#)

[fishes](#)

[sampling](#)

Protocol Format

Process

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lpp\_fish1

Protocol Type

field

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### ***Mollusk Collection***

Methodological Detail from David Lewis' Ph.D. Dissertation and Lewis and Magnuson (2000)  
We surveyed each lake once for snails and several variables that potentially influence snail distribution. Prior to sampling, lake habitat was determined by mapping around the entire shoreline of a lake at 30 m intervals or by consulting habitat maps (Petrie et al. 1993) that we confirmed for accuracy. Sample sites were chosen randomly, stratifying by habitat type. Snails were sampled from four habitat types in each lake: sand, cobble, woody debris, and macrophytes. The first three categories were sampled at three to five locations apiece in each lake. Sand and cobble sites were usually free of structure such as coarse woody debris and macrophytes. Preliminary sampling indicated that haphazardly located quadrats resulted in a gross underestimation of species richness. We sought to ensure that the search area for these patchily distributed organisms was appropriately scaled, depending on local snail density. Therefore, we used search time as the standard for effort, and each site was searched using SCUBA over a depth range of 0.5 - 4 m for 8 minutes. Timed search has been successfully applied to snail sampling in other physically complex habitats (Tattersfield 1996). For the macrophyte habitat, we sampled up to five sites in each lake, if available, by sweeping a D-net through 1.5 m<sup>2</sup> (bottom surface area) of submerged macrophytes per site. Fewer sites were sampled from lakes that had only one or two habitat types per lake, and in which only one patch of a particular habitat could be found. Snails were identified to species according to Burch (1982) with supplemental information from Baker (1928) and Clarke (1973).

We analyzed sampling efficiency for each lake by estimating a potential maximum species richness. For each lake, we randomly ordered the individual samples and constructed a cumulative species richness sampling curve. This was conducted 100 times and a mean sampling curve was calculated. The mean sampling curve was then analyzed with asymptotic (cumulative richness =  $1 - C [1 - \exp(-2 C \text{ sample sequence number})]$ ) and Walford (1946; see Ricker 1975) growth curves to estimate a potential maximum species richness.

ILTER Keywords

[biology](#)

[distribution](#)

[mollusks](#)

[sampling](#)

[snails](#)

[species richness](#)

Protocol Format

Process

Protocol ID

lpp\_mollusks1

Protocol Type

field

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