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Pilot Limnological Studies on Church Farm Pond, a Small Man-Made Pond in Ashford, CT

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Abstract

Limnological studies can give insight into the physical, chemical and ecological conditions in a body of water. The study of lakes is interesting to biologists, but also important to the general public as it helps to ensure safe and pleasant recreational use. Church Farm Pond is a 1.2 hectare, man-made pond located in Ashford, CT. Despite being formed in 1906 and acquired by the Eastern Connecticut State University Foundation in 2009, little remains known about it. The purpose of this study was to acquire baseline information on its chemistry, physical properties, and zooplankton community over a series of several months. Cladocerans and cyclopoid copepods were the most common zooplankton groups found, with cladocerans predominating regardless of the changing seasons. Low visibility depth suggests a hyper-eutrophic pond, while chlorophyll analysis suggests a eutrophic pond. However, this was determined to be due to high levels of decaying plant matter suspended in the pond. Consistently undetectable levels of soluble nitrates and phosphates, paired with minimal phytoplankton sightings point towards an oligotrophic body. The pond's water likely does not come from a groundwater source, indicated by low conductivity, hardness, and alkalinity levels when compared to property well water. Future studies are suggested to focus on year-round data collections, zooplankton quantification and identification, and total phosphate and nitrate levels.

Keywords: Limnology, Zooplankton, New England

1. Introduction

1.1. Limnology

Limnology, the study of inland waters, dates back to the mid-19th century [1, 2]. Over 150 years later, limnology has grown to encompass the biological, chemical, and physical aspects of freshwater. Limnology adds to the knowledge base of freshwater ecology, but also provides anthropogenic benefits. Inconveniences that impact human recreational use, such as toxic algal growth, can be treated or prevented with regular water monitoring [3,4]. As a result, baseline studies are often commissioned on bodies of water on behalf of public interest.

The physical and chemical dynamics of a pond provide useful insight because they can influence its ecology. Nitrogen and phosphorous act as limiting nutrients: they are essential to organism function, particularly phytoplankton, but are found in low concentrations and therefore limit growth and population size [5]. Alkalinity acts as a buffering agent against acids coming into the system, and pH can determine which species are able to survive [5, 6]. A shift in the chemical environment can cause community shifts and interfere with chemical communication in zooplankton [7,8]. Additionally, chemical information, such as conductivity and hardness levels, can provide insight into a body's water source [5]. The creation of a watershed map can also provide information as to where most of the runoff may be coming from. Additionally, the trophic state of a body of water provides important information as to what is going on ecologically due to the biological, physical, and chemical factors associated with it. A eutrophic lake is one that has high microalgae growth, low light penetration and generally high nutrient input [9]. By contrast, an oligotrophic lake is one that features high light penetration, low microalgae presence, and low nutrient input. A mesotrophic body of water is one that is found somewhere in the middle. Plankton composition can give insights into chemical conditions and whether or not pollution is present [6]. Additionally, plankton play important ecological roles as they often exist in primary and secondary trophic levels. The presence or absence of zooplankton can have cascading effects on higher trophic levels, such as planktivorous fish. Their study, therefore, pertains to the interest of biologists and recreational water users alike.

1.2. Study site

Church Farm Pond (CFP) is located in Ashford, CT at N 41º50'17.6" W 072º10'8.9" at an altitude of 112 meters. It is a man-made pond created in 1906 by the damming of a stream that flowed through one of the property's agricultural fields [20 in 10]. The pond forms a teardrop shape approximately 1.2 hectares (12,000 m^2) in area. It is 150 meters long and varies in width between 30 meters and 60 meters, with depth ranging from 1 meter to 1.5 meters. The wider-end of the pond faces eastward, and empties into the Mt. Hope River, which flows south through a floodplain marsh area owned by Joshua's Trust. The Mt. Hope River feeds into Mansfield Hollow Lake, which then empties into the Natchaug River. A stretch of road runs between the Church Farm and Joshua's Trust properties (Figure 1). A field and house border the pond on its northern side and a residential plot borders its southern facing side. Its northwestern side is bordered by a marshland that gradually gives way to wooded land. A small, temporary stream located in the marshland to the west, feeds into the pond [10].

Sediments consist of silty sand spanning over 145 cm in thickness, covered by approximately 7 cm of black gyttja, a mud produced by the anaerobic bacterial digestion of peat. The sand layers, deepest to shallowest, consist of 70 cm of brown silt, 45 cm of silty sand, and 30 cm of black silty sand with partially decomposed wood and leaf detritus [10]. Older, deeper sediments show characteristics indicative of prior field status, whereas the uppermost 20 cm show evidence of high sedimentation characteristic of current pond status. Church Farm Pond's biology, as well as chemical and physical characteristics, are not very well understood due to lack of previous information. Studies on nearby bodies of freshwater provided guidelines as to what to study at Church Farm Pond.

Figure 1: An aerial view of Church Farm Pond, a man-made pond located in Ashford, CT, N 41º50'17.6" W 072º10'8.9", and its surrounding properties. The Church Farm Property is outlined in yellow, the Joshua's Trust Property is outlined in green. Makes use of imagery obtained from Google Earth, accessed Jan 2015.

1.2. Project goals

The goal of this study was to attain a preliminary picture of Church Farm Pond's ecology in order to fuel future studies. This goal was accomplished by acquiring baseline information on chemical, physical, and zooplankton community features over the course of six months. The presence or absence of relationships between seasonal change and pond properties was determined.

2. Methods

Water samples and plankton tows were taken approximately every two weeks from September 2014 to March 2015. When possible, these alternated between limnetic and littoral zone measurements. Limnetic measurements were taken at a set position on the pond marked by an anchored buoy; measurements were taken at 0.5 m depth intervals. Littoral zone measurements were taken from a set point on the eastern shore and incorporated only surface values. When the pond was frozen, an ice auger was used to reach a limnetic portion of the pond.

2.1. Chemical and physical measurements

Dissolved oxygen, conductivity, transparency, and temperature measurements were taken on site. A YSI Model 30 meter was used to quantify conductivity and temperature; a YSI Model 55 meter was used for dissolved oxygen readings. A Secchi disk and Forel-Ule color comparator were used to determine visibility depth, compensation depth, and water color. LaMotte test kits were used to measure nitrates, phosphates, hardness, and alkalinity; the accuracy of titrations was increased by using micropipettes. Water pH was measured using standard pH strips.

Chlorophyll[11] and tannin[12] analyses were conducted on samples the day of collection. If analyses could not be conducted the same day, chlorophyll filters were frozen and the filtered water was refrigerated. For chlorophyll analysis, sample water was filtered through a 0.45 μm Millipore membrane filter. Chlorophyll in the filters was extracted using a Dounce (glass-on-glass) grinder and 6 -7 ml of 90% alkalinized acetone. A blank was created by grinding up an equivalent amount of membrane filters in 6-7 ml of 90% alkalinized acetone. Due to a negative reaction between acetone and plastics, glass pipettes and materials were used in place of plastic ones; higher grade plastic centrifuge tubes were unaffected. Immediately following extraction, the samples were centrifuged to avoid fluctuation of absorbance readings. Samples were centrifuged at 3500 to 4000 rpm, ranging between 12 and 20 minutes, depending on the amount of turbidity present. Since chlorophyll cannot be pulled down within this range of intensity or duration, variation present between test dates is not problematic. The clear supernatants were drawn off and placed into respective quartz 1 cm^2 cuvettes. Absorbance was measured at 480, 630, 645, 663, 665, and 750 nm. The samples were then acidified using 4N HCl and measured at 663, 665, and 750 nm. Chlorophyll, phaeophytin, and phaeopigments were then calculated [11]. A culture of *Chlamydomonas reinhardtii* (3,885 cells/ml) was used to validate the assay.

Tannin levels and color were determined by measuring the absorbance of sample water filtered in the chlorophyll process. Using reverse osmosis water as a blank, absorbance was measured at 440 and 750 nm. These were then converted into Pt units [12].

2.2. Plankton collection

Zooplankton analysis focused on identifying the most abundant groups present and calculating the relative abundance between them. The study focused on Phylum Arthropoda, Subphylum Crustacea, including Order Cladocera, Subclass Copepoda, and Class Ostracoda. A no.25 plankton net (200 meshes per inch) was used to select for net plankton [6] and was dragged horizontally along the surface, approximately 2.5 - 3 meters. The samples were then brought back to the laboratory, killed, and preserved using 90% ethanol. Total counts of each group were taken using a Sedgewick-Rafter cell and relative ratios between groups were calculated. Samples were stored in 90% ethanol and kept at room temperature for future reference.

2.3. Watershed information and trophic category

Watershed maps were created to understand the effects of runoff into CFP: one categorized land use, the other topographic information. Graphic Information System (GIS) data from the CT Department of Energy and Environmental Protection (DEEP) was utilized to determine watershed boundaries. Imagery from the United States Geological Survey (USGS) was used directly in the topographic map. Observations using Google Earth were used to create a land-use map. Trophic category determination was based off of visibility depth, phosphate, nitrate and chlorophyll levels [21, 22 in 5].

3. Results

3.1. Zooplankton analysis

Cladocerans dominated the zooplankton community on all sample dates except for two (Figure 2). December 16th showed a predominance of cyclopoid copepods at 66% with cladocerans measuring only 22.2%; March 3rd showed a 39.5% cladoceran composition. Additional zooplankton groups found included ostracods, copepod nauplii, mites, and harpacticoid copepods. Of these, ostracods were seen on three study dates; the rest were seen only once.

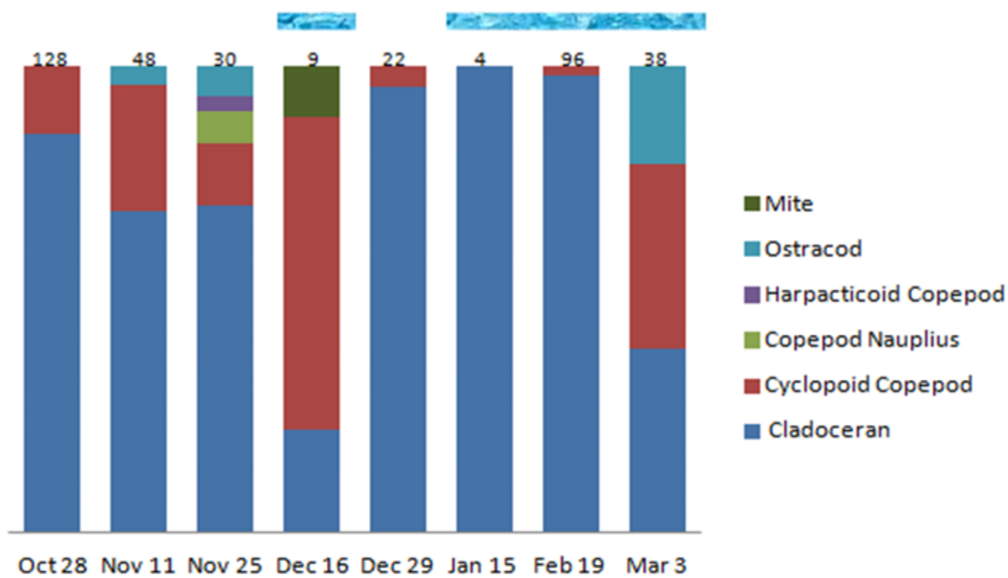

Figure 2: Relative abundance zooplankton types found in a small man-made pond, Church Farm Pond, located in Ashford, CT, between 2014 and 2015. The number of individual organisms collected on each date is marked above the bars, along with a horizontal bar indicating dates with ice cover.

3.2. Physical characteristics

Specific conductivity shows a gradient with date, with the biggest increase occurring between November 25th and March 3 (Figure 3). Averages incorporating multiple depths spanned only 32.5-35 µS between September and November, but reached 44.7 µS on February 19th. Although not seen clearly in Figure 3, stratification with depth existed as well. Conductivity readings show that the highest conductivity readings on study dates was consistently found at a depth of 1.5 meters. Readings found at the surface and at 0.5 meter readings were usually very similar to one another and both different from the 1 meter and 1.5 meter depths. Conductivity, averaging all dates, measured 35.92 µS for surface readings, 35.56 µS for depths of 0.5 meters, 41.04 µS for depths of 1.0 meter, and 50.9 µS for depths of 1.5 meters. February and March possessed the lowest concentrations of dissolved oxygen. The highest concentrations were seen in late November, as shown in bright red, yellow, and green. Dissolved oxygen concentration readings were also stratified with depth; the highest concentrations are only seen above a depth of 0.5 meter. Additionally, September 30th shows low dissolved oxygen readings at a depth of 1 meter, comparable to levels observed in hypoxic February and March months. A large cooling occurs between late September and early March; average temperature gradually decreases from 15.9°C to 2.1°C.

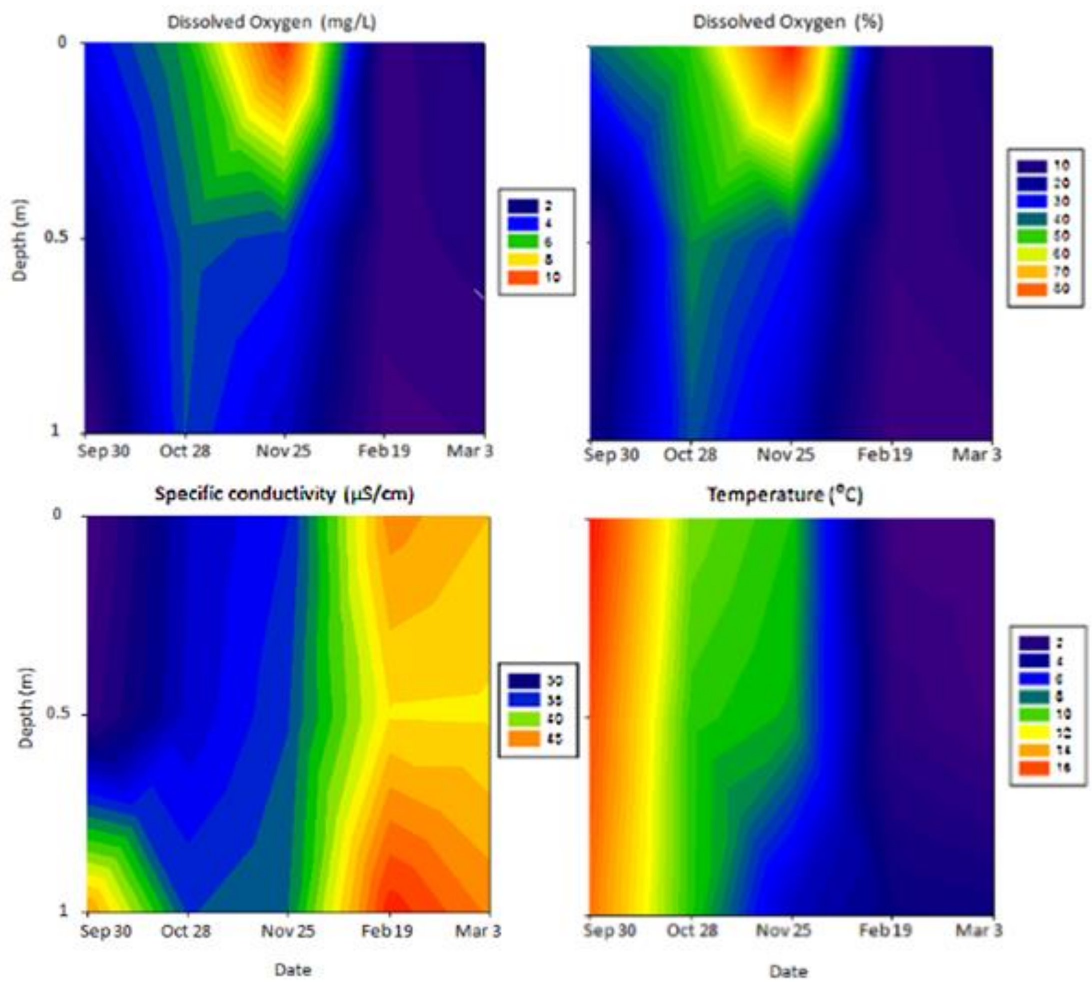

Figure 3: Various physical factors in relation to depth and date.

Specific conductivity corrected to 25o Celcius. Conducted on Church Farm Pond, a small man-made pond located in Ashford, CT. Measurements taken from late-September 2014 to mid-February 2015.

3.3. Chemical characteristics

No clear trend is apparent for hardness and alkalinity with the seasonal change between autumn and winter. There Spikes and drops for both exist throughout the testing period (Figure 4). However, late December and early March exhibit less variability. These levels of hardness indicate soft water [23 in 6], which signals low levels of calcium and magnesium. This indicates little sourcing of water that passes across limestone, igneous, or carbonate rocks [6], which makes sense as these types of rock are not usually present in this part of the state. Nitrate and phosphate levels, however, remained constant. Phosphate was consistently measured as less than 0.05 ppm. Orthophosphate concentrations rarely exceed 0.01 ppm in non-polluted waters [6] . Our equipment could only accurately measure down to 0.05 ppm. However, levels were observed at much lower than the 0.05 cut-off. Therefore, although our test kits could not measure down to 0.01 ppm, there is a high probability that CFP is non-polluted. Nitrate, with the exception of one sample early on, was measured as 0 ppm. The mid-September sample was measured at 1 ppm; however this is probably due to experimental error and can be ignored. These levels are very minute, since levels rarely exceed 10 ppm in natural waters [6]. pH, not shown here, remained in the range of 6 - 7 throughout the testing period. Groundwater sources had much higher values comparatively for hardness, conductivity, and alkalinity (Figure 5). This suggests that CFP doesn't get its water from a groundwater source. If this were the case, values would much more closely resemble each other.

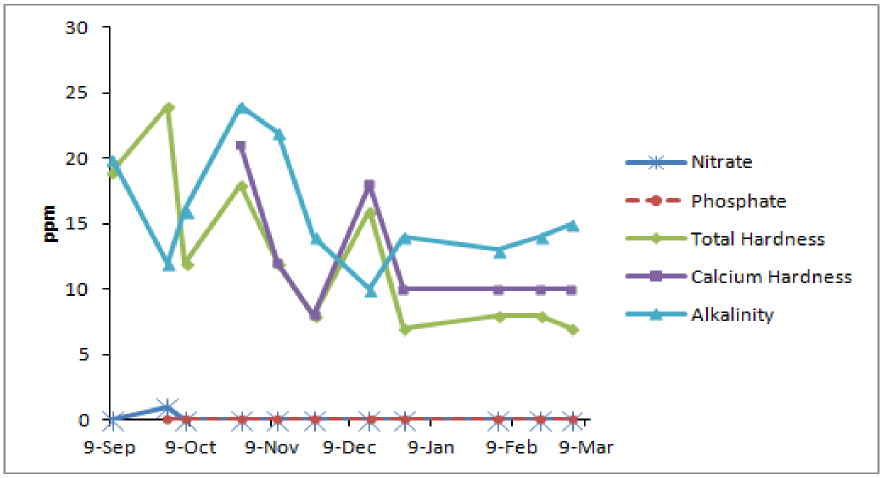

Figure 4: Chemical characteristics of a small man-made pond, Church Farm Pond, located in Ashford, CT, between September 2014 and March 2015.

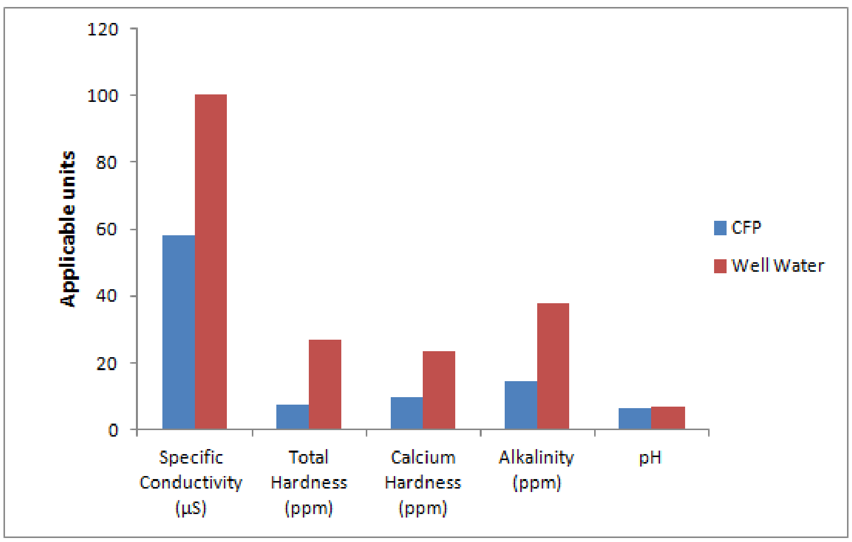

Figure 5: Chemical test comparisons between a benthic portion of Church Farm Pond water and nearby groundwater. Samples collected in Ashford, CT between mid-February and early-March.

3.4. Trophic category

Forel-Ule colors observed indicate varying concentrations of green-brown water. XVII indicates water that is 73% green and 27% brown, XVI: 80% green and 20% brown, XV: 86% green and 14% brown [11]. Visibility depth varied a bit with date, but there were no visible trends; levels stayed close to approximately 50 cm (Table 1). The conversion factor in determining compensation depth was determined to be 2.19, which falls within the normal range for natural waters [6]. Chlorophyll and plant components, with the exception of Chlorophyll-a, were all lower with subsequent measurements (Table 2).

Table 1: The color and visibility characteristics of a small man-made pond, Church Farm Pond, in Ashford, CT.

Date	Visibility depth (cm)	Compensation depth (cm)	Water depth approx (cm)	Forel-Ule Color
9/30/2014	45.5	99.6	100	XVII
10/28/2014	56	122.64	100	XV
11/25/2014	51	111.7	150	XVI
2/19/2015	100	219	150	-
3/3/2015	68	148.92	150	XVII

Table 2: Chlorophyll, color, and plant components of Church Farm Pond, a small man-made pond located in Ashford, CT. Samples collected in February and March 2015. Negative calculated values were expressed as zero. Values for a *Chlamydomonas reinhardtii* culture (3,885 cells/ml) are shown as a comparison.

Date	Chl-a (µg/l)	Chl-b (µg/l)	Chl-c (µg/l)	Color440 (Pt, mg/l)	Tannic acid (mg/l)	Phaeophytin (µg/l)	Plant carotenoids (µSPU/l)	Phaeopigments (µg/l)
Feb 3	5.08	8.67	38.48	87.88	1.74	28.46	12.3	29.76
Feb 19	0.94	2.37	9.186	62.64	1.3	18.78	15	24.9
Mar 3	4.82	0	0	113.06	2.18	0	8.51	0
Culture	9,406.80	2,858.40	369.36	-	-	2,620.32	3,108.96	3,347.86

3.5 Watershed Information

Church Farm Pond's watershed has a perimeter of 7.48 km, and an area of approximately 2.49 km^2; it stretches across two municipalities: Mansfield, CT and Ashford, CT. Church Farm Pond's watershed consists of a variety of land-types (Figure 11), but consists primarily of secondary forest with a few scattered residential areas. The Church Farm property contains a large area of protected forest, which extends westward off of the watershed map. The same holds true for Joshua's Trust, found on the property's southern border. The Church Farm property contains a pasture, but it has not been used for agricultural practices in the past century. There is only one example each of pasture, animal husbandry, or agricultural land in the surrounding watershed. All three of these are not much higher in elevation (Figure 12); the agricultural site is found at the same elevation. Regardless of elevation, all are physically isolated from CFP by the Mt. Hope River.

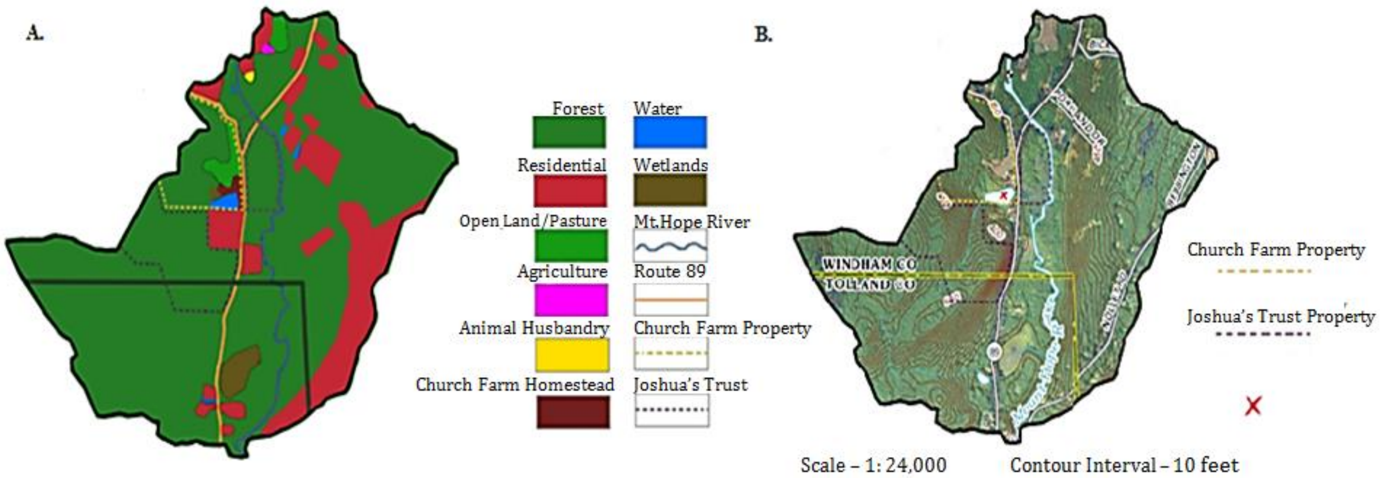

Figure 6.Watershed maps for Church Farm Pond, located in Ashford, CT.

The watershed spans across two cities; its boundary is marked by a dark green line. Mansfield, CT is found to the south, Ashford, CT to the north. **A.** Land-use map based off of information derived from CT Department of Energy and Environmental Protection GIS information [12] and observations made via Google Earth. **B.** Topography map; makes use of topographic imagery obtained from a USGS Topographic Map, downloaded from store.usgs.gov [13].

4. Discussion

The zooplankton community at Church Farm Pond was dominated by cladocerans. This is mirrored by a study conducted at Mansfield Hollow Lake [1]. Cladocerans filter feed, whereas cyclopoid copepods are predators; perhaps conditions are better suited for filter-feeding, such as a higher presence of detritus than live prey [17]. However, no calanoid copepods were found in this pond, and they filter feed [18]. There were minimal sightings of other zooplankton, like ostracods, mites, and copepod nauplii. This may be due to the fact that plankton collections were conducted via horizontal surface tows. This means that only neuston and plankton living in the upper epilimnion could be collected. While this is an effective overview of the zooplankton community, it does eliminate some groups that may be living elsewhere, such as in the benthos. It is possible that these minimally sighted plankton lived outside of the normal range of net collection. Ostracods, for instance, are usually bottom-dwellers or found in shallow water [19]. However, cyclopoid copepods are also described as primarily benthic, yet appeared regularly in plankton tows [17]. Another possibility is that these organisms represent very small percentages of the zooplankton community or are less regularly distributed; therefore less readily collected. Future studies could focus on both vertical and horizontal plankton tows, as well as potential sediment samples. The data did not indicate any zooplankton blooms, which would be seen by drastic increases in collection size. Rather it showed a slightly variable collection size, which could be attributable to plankton patchiness. The extremely low plankton collection sizes on December 16th and January 15th (Figure 2), were due to a lack of an ice auger, making it difficult to access water sufficient for a normally sized plankton tow. March 3rd shows a mix of organisms, including an irregularly high amount of ostracods; a patch may have been encountered.

Seasonal change appears to be the strongest factor in temperature gradients found in CFP, which makes sense with cooling air temperatures into the winter season. The largest drop in temperature was observed between September and October with a 6.3°C decrease, whereas the four-month span between November and March only saw a decrease of 4.8°. This is slightly surprising, meaning that the majority of temperature decline occurs in early fall instead of winter. Temperature readings collected on February 19th and March 3rd show inverse stratification, where coldest temperatures are seen near the surface, which is characteristic of winter zonation in temporal boreal zones. However, little evidence of autumn turnover seems present: September, October, and November all show a decline in temperature with depth, characteristic of summer stratification.

Chlorophyll levels were shown to decrease with date. This is likely due to ice cover, approximately 38.5 cm thick, on the latter two dates that was not present on February 3rd. This greatly decreased sunlight accessible by phytoplankton, most likely resulting in lower activity level and population size. Additionally, any new terrestrial plant material would be unable to fall into the water and contribute to chlorophyll levels. Overall, chlorophyll-c was the most prevalent, whereas chlorophyll-a was the least common. This is contrary to the common notion that chlorophyll-a is the most abundant of the three pigments. It also highlights high cyanobacterial activity in the pond. CFP can be categorized as an oligotrophic body of water. Visibility depth indicates hypereutrophic water, while mean chlorophyll and maximum chlorophyll levels indicates eutrophic water [18, 19 in 5]. However, minimal sighting of phytoplankton and low soluble nitrate and phosphate levels point towards an oligotrophic system. The low visibility depth and high chlorophyll levels are thought to be due to decaying plant cells in the pond due to the large quantity of *N.odorata* and *N.advena*. The water column itself may not be productive, but the rooted plant productivity is likely high. Green apparent color can be caused by the presence of phytoplankton and algae, as well as low-levels of humic compounds [14]. Since substantial amounts of phytoplankton were not seen, this hue is more likely due to suspended plant matter and humic compounds. These humic compounds, also known as dissolved organic matter, can also give a brown appearance to water.Compensation depths that reach or exceed water depth show that vegetation is not light limited anywhere in the pond.

Church Farm Pond's surrounding watershed is comprised primarily of forested land, with minimal agricultural land and no industrial or commercial sites. The Church Farm property itself contains a pasture, but it has not been used for agricultural practices in the past century. All active farming lands are found at a comparable elevation and are physically isolated from CFP by the Mt. Hope River (Figure 6). Therefore, there is no estimated risk of herbicide or pesticide pollution in Church Farm Pond. This is strongly supported by the absence of high levels of either nitrogen or phosphorous.

This study was conducted in order to acquire baseline information on Church Farm Pond, a unique man-made pond owned by the Eastern Foundation. This study has set the groundwork for future studies that look at Church Farm Pond both as an isolated habitat and as a model for larger aquatic biology concepts. Possible follow-up studies include quantifying zooplankton abundance over a longer span of time and identifying the major zooplankton species present, particularly cladocerans. Longer-term chemical and physical collections mimicking those of this study can also be collected to get a year-round picture that includes the spring and summer seasons.

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