Human disturbance is the primary factor that determines the distribution of macroinvertebrate and fish communities in Connecticut

IB Chemistry HL

Introduction

Through this paper, there will be an exploration and possible solutions to real-world problems/situations. More specifically, through this paper, I will explore important environmental variables that may help determine and or explain the aquatic biota ("collective term describing the organisms living in or depending on the aquatic environment"[1]) from these systems (from least disturbed small streams in Connecticut). Through this fish stream analysis conducting such an investigation and further exploring and learning about the affect water quality has on ecosystems and different species could provide an opportunity to learn about important stressors in least disturbed watersheds/water sources not just in Connecticut specifically, but also across the nation and in other countries. I chose this particular topic because I not only care about the environment but I also acknowledge the great importance water has for the world. Hopefully through this paper, readers, including myself, will gain more knowledge and a greater understanding of how the quality of water affects everyone and everything - not just in Connecticut, but in the nation and in the world, - and possible ways one can improve upon the global crisis of dwindling clean water.[2]

This study is a critical step in achieving this goal (to not allow these waters to degrade) to ensure that one is maintaining physical, chemical, and biological integrity with the "best of what's left" (*The Microscopy of Drinking Water*)[3] in Connecticut. Due to the limitation and unavailability of reliable and overall precise measuring tools to overall test the quality and purity of water, in addition to safety issues, I decided to focus and base this essay on the paper "**Characteristics of Macroinvertebrate and Fish Communities From 30 Least Disturbed Small Streams in Connecticut**." by Christopher Bellucci, Mary Becker, and Mike Beauchene[4]. Some of the safety precautions taken in this specific paper included field checks to evaluate site accessibility, standardize sampling, habitat (for example, waterstoo deep to wade were

[1] "Aquatic Biodiversity Glossary." EPA, Environmental Protection Agency, ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details&glossaryName=Aquatic%2BBiodiversity%2BGlossary.
[2] "Competing for Clean Water Has Led to a Crisis." Clean Water Crisis Facts and Information, National Geographic, 20 Aug. 2019, www.nationalgeographic.com/environment/freshwater/freshwater-crisis/.
[3] Whipple, George Chandler. "The Microscopy of Drinking Water." Google Books, Google, books.google.com/books?hl=en&lr=&id=7GLSg9RWON0C&oi=fnd&pg=PA1&dq=where%2Bis%2Bthe%2Bpurest%2Bwater%2Bfound%2Bin%2Bnature%2Bin%2Bconnecticut&ots=Ydb8_Pewf4&sig=IZgQrpM9bQaaS7JmE0P1i-Gyxtw#v=onepage&q&f=false.
[4] Bellucci, Christopher J., et al, "Characteristics of Macroinvertebrate and Fish Communities From 30 Least Disturbed Small Streams in Connecticut." Northeastern Naturalist, vol. 18, no. 4, 2011, pp. 411–444. JSTOR, www.jstor.org/stable/41429230. Accessed 14 Jan. 2020.

eliminated), and verify dam locations. In other words, sampling protocols and safety measures were needed to be used/considered when collecting data. More specifically, fish sampling was conducted from June to September in 2007 during periods of low streamflow to maximize sampling efficiency. The use of safe methods to collect data and handle fish needed to be utilized for the methodology of this investigation. Following standard methods and safe testing of water quality is required in order to ensure the safety and health of those testing the waters, the stream, and the many living organisms in the water.

Hence this paper will investigate the research question; *To what extent does human disturbance determine the distribution of macroinvertebrate* ("organisms without backbones, which are visible to the eye without the aid of a microscope. Aquatic macroinvertebrates live on, under, and around rocks and sediment on the bottoms of lakes, rivers, and streams"[5]) *and fish communities from 30 least disturbed small streams in Connecticut?*

Background:

National and state efforts to monitor and assess water quality in Connecticut from the 1980s to the 1990s focused on the restoration of "impared" streams that fell on the "high" portion of the stressor gradient.[6] However, this methodology of only focusing on bodies of water that have low quality poses its own limitations in addressing the global crisis of dwindling clean water.[7] That is one of the objectives of Cristopher J Bellucci's, Mary Becker's, and Mike Beauchene's study in which they focused on documenting the geographic location of least disturbed streams in Connecticut to describe the aquatic biota from these systems to describe important environmental variables that may help explain the distribution of such biota.

As a result of public concern over poor water quality and the promulgation of state and federal laws, such as the Connecticut Water Pollution Control Act (CWPCA) of 1967, and the Federal Water Pollution Act in 1972 and 1977 (FWPCA), monitoring the chemical and biological

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[5] "Benthic Macroinvertebrates and Biological Monitoring." EnviroScience, www.enviroscienceinc.com/services/aquatic-survey/benthic-macroinvertebrates/.

[6] Bellucci, Christopher J., et al, "Characteristics of Macroinvertebrate and Fish Communities From 30 Least Disturbed Small Streams in Connecticut." Northeastern Naturalist, vol. 18, no. 4, 2011, pp. 411–444. JSTOR, www.jstor.org/stable/41429230. Accessed 14 Jan. 2020.

[7] "Competing for Clean Water Has Led to a Crisis." Clean Water Crisis Facts and Information, National Geographic, 20 Aug. 2019, www.nationalgeographic.com/environment/freshwater/freshwater-crisis/.

quality of the state's water resources became a priority issue to track progress of clean water regulations.

While Connecticut is fortunate to be a 'water rich' state with over 5,800 miles of streams and rivers[8] over the years many factors and variables have unfortunately contributed to disturbing and polluting the water quality in the state; from drainage area, landscape alterations, human disturbance to dams. With fish populations in particular being sensitive to such variables and factors, it is not surprising that monitoring shifts in age and size class of Brook Trout populations in particular can warn natural resource managers of potential anthropogenic stress in healthy watersheds. Brook Trout can be viewed as a sentinel species for small, healthy, least disturbed streams in Connecticut since they are the most important indicator fish species due to their sensitivity to such alterations and disturbances in general for example to landscape alterations (Kocovshy and Carline 2006, Stranko et al. 2008).

Given Connecticut's long history of land-use disturbance (Bell 1985), it is not surprising that biological monitoring has been the foundation for assessing water quality in Connecticut's rivers and streams since the early 1980s.[9] By using organisms living in streams, such as macroinvertebrates and fish, we are able to measure the health of waters, to a certain extent.

While it is true that such results of testing and observation reflects our incomplete knowledge of how certain factors affect fish and macroinvertebrate species, the preservation of the remaining relatively clean water relies on the monitoring and assessment of waters from "imparied" streams to relatively healthy and clean streams, among other factors.

Methodology: *Summary of study*

Method of selecting the least distubed streams:

Use of GIS (geographic information system software (GIS, ESRI ArcMap Version 9.2) to select the least disturbed streams in Connecticut through the evaluation of land-use characteristics, water quantity stress, habitat fragmentation and salmonid (a fish of the salmon

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[8] "Rivers and Streams." CT.gov: Rivers and Streams, portal.ct.gov/DEEP/Water/Rivers-and-Streams.
[9] Bellucci, Christopher J., et al, "Characteristics of Macroinvertebrate and Fish Communities From 30 Least Disturbed Small Streams in Connecticut." Northeastern Naturalist, vol. 18, no. 4, 2011, pp. 411–444. JSTOR, www.jstor.org/stable/41429230. Accessed 14 Jan. 2020.

family[10]) fry stocking records. A hierarchical approach was used to select study streams by first screening at the subregional drainage basin scale using GIS, following by a catchment-level screening using GIS. This was followed by a GIS screening with field checks to determine habitat and testing suitability, for example, wade ability, pool habitat, and good mix of riffle habitat and to validate dam locations shown on the GIS used.

For those subregional basins that met the less than 80% natural land-cover criterion, additional criteria was applied for total percent impervious cover (IC) - water diversions, dams and reservoirs, and salmonid fry stocking in catchments with those sub regional basins - to obtain a list of least disturbed streams. IC was calculated using the Impervious Surface Analysis Tool, an ESRI ArcMap version 9.2 extension, using 2002 Connecticut Land Cover data following the guidelines in Prisloe et al. (2002).

Biological communities and Water quality:

Macroinvertebrate samples were collected September-October 2007 using an 800-*u*m-mesh kick net. A total of 2 m^2 of riffle habitat (12 kicks composed from multiple riffles of a stream reach) was sampled at each location. Samples were preserved in 70% ethyl alcohol and brought back to the laboratory for subsampling. A 200-organism subsample was taken using a random grid design (Plafkin et al. 1989) from each sampling location. Organisms were identified to the lowest practical taxon, using general species. A macroinvertebrate multimetric index (MMI) score for each site was calculated using a 200-organism subsample at the genus level (Gerritsen and Jessup 2007).

Fish sampling was conducted from June to September 2007 during periods of low streamflow to maximize sampling efficiency. Typically, 150 m of stream were electrofished using either a backpack unit or a single tow barge electrofishing unit (Hagstrom et al. 1995). A single pass was completed at each location, and all species were measured to the nearest centimeter (total length), counted, and immediately released into the stream. A surface-water grab sample was collected from mid-channel at least once during spring, summer, and fall 2007 at each site and analyzed for total nitrogen, ammonia, total phosphorus, pH, alkalinity, hardness, and

[10] "Salmonid." Merriam-Webster, Merriam-Webster, www.merriam-webster.com/dictionary/salmonid.

chloride. Water temperature was measured concurrent with site visits from May to September 2007 using a calibrated thermometer.

Data:

Description of 30 least disturbed streams in Connecticut: The 30 least disturbed streams had drainage areas of less than 29 km^2 and Strahler stream order that ranged from 1 to 4; all contained less than 3.5% 1C in the upstream watershed, and contained a high percentage of forested land use (Table 2). In general, the 30 least disturbed streams were located in three geographic groups: northwest Connecticut, northeast Connecticut, and the central Connecticut River valley (Fig. 2). Pendleton Hill Brook (SID 1748) was the only least disturbed stream that was located outside of these three groups. Four least disturbed streams were located in the town of East Haddam. Ashford, Canaan, and Lyme each contained 3 least disturbed streams and Barkhamsted, East Hampton, and Torrington each contained 2 least disturbed streams. Eleven towns contained one least disturbed stream. Least disturbed streams were absent from Southwestern Connecticut and along the Southern coast because the combination of urbanization, dams, diversions, and stocking practices excluded the streams.[11]

[11] Bellucci, Christopher J., et al, “Characteristics of Macroinvertebrate and Fish Communities From 30 Least Disturbed Small Streams in Connecticut.” Northeastern Naturalist, vol. 18, no. 4, 2011, pp. 411–444. JSTOR, www.jstor.org/stable/41429230. Accessed 14 Jan. 2020.

Table 2. Location, drainage area, stream order, percent impervious cover, percent coniferous forest, and percent deciduous forest of thirty least disturbed streams in Connecticut, listed by station identification number (SID). SID's correspond with Figure 2.

SID	Stream	Town	Latitude	Longitude	Drainage area (km^2)	Stream order	% impervious cover	% coniferous forest	% deciduous forest
766	Stickney Hill Brook	Union	41.9833	-72.2179	6	3	2.06	58.95	27.65
1236	Beaver Brook	Lyme	41.4100	-72.3289	21	4	2.43	1.46	78.85
1239	Burhams Brook	East Haddam	41.4603	-72.3343	3	1	2.19	7.90	81.09
1435	Cedar Pond Brook	Lyme	41.4119	-72.3128	21	3	2.66	1.50	78.17
1748	Pendleton Hill Brook	Stonington	41.4748	-71.8342	10	2	2.51	2.70	76.72
1941	Bebbinton Brook	Ashford	41.8447	-72.1593	6	3	3.24	2.17	55.46
1981	Carse Brook	Sharon	41.8552	-73.3755	14	3	2.43	0.66	84.99
2291	Branch Brook	Eastford	41.9108	-72.1245	13	3	1.97	65.78	18.88
2293	Knowlton Brook	Ashford	41.8492	-72.1783	18	4	2.89	1.24	73.13
2294	Gardner Brook	Ashford	41.8643	-72.1598	4	2	3.37	1.42	67.21
2295	Mott Hill Brook	Glastonbury	41.6615	-72.5365	7	2	2.17	1.97	83.75
2296	Beaver Meadow Brook	Haddam	41.4553	-72.5288	4	2	2.97	27.42	60.03
2297	Hemlock Valley Brook	East Haddam	41.4283	-72.4226	7	3	3.00	5.53	65.14
2298	Hungerford Brook	Lyme	41.4255	-72.4094	7	3	3.41	1.35	69.16
2299	Rugg Brook	Winchester	41.9328	-73.1214	5	2	1.93	59.95	23.08
2301	Kettle Brook	Barkhamsted	41.9324	-72.9442	4	3	1.77	63.53	31.37
2302	Roaring Brook	Barkhamsted	41.9454	-72.9475	4	2	1.53	77.61	15.20
2303	Powder Brook	Harwinton	41.7541	-73.0170	3	2	2.23	1.00	62.97
2304	Day Pond Brook	Colchester	41.5623	-72.4338	3	2	3.17	6.57	72.88
2305	Elbow Brook	East Hampton	41.5211	-72.4869	2	2	2.67	0.00	87.66
2306	Flat Brook Central	East Hampton	41.5544	-72.4523	6	2	3.09	1.10	81.88
2307	Early Brook	East Haddam	41.4978	-72.3435	6	2	3.17	0.69	81.49
2308	Muddy Brook	East Haddam	41.4756	-72.3420	3	2	2.91	7.26	79.04
2309	Flat Brook North	Canaan	41.9459	-73.3200	7	2	2.45	15.24	68.84
2310	Whiting Brook	Canaan	41.9730	-73.3178	2	2	1.21	48.89	47.37
2311	Hall Meadow Brook	Torrington	41.8861	-73.1689	27	3	2.13	35.67	50.13
2312	Jakes Brook	Torrington	41.8646	-73.1679	4	3	2.08	23.09	63.94
2331	Stonehouse Brook	Chaplin	41.7812	-72.1509	14	4	2.66	0.29	77.98
2334	Chatfield Hollow Brook	Madison	41.3314	-72.5950	29	4	3.20	0.52	75.86
2342	Brown Brook	Canaan	41.9267	-73.2799	14	3	1.22	50.63	39.66

Table 6. Median site characteristics for least disturbed macroinvertebrate site classes. The Kruskal-Wallis test was used to compare site characteristics between classes and those that showed significantly differences ($P < 0.05$) are noted with an asterisk.

Site characteristic	Class 1	Class 2	Class 3	P value
Drainage area (km^2)	16.07	3.84	6.31	0.004*
Stratified drift (%)	4.47	2.01	5.79	0.195
Road density (number per km^2)	8.40	7.43	8.62	0.500
Dam density (number per km^2)	1.64	0.93	0.95	0.147
Water temperature (°C)	18.13	16.08	16.96	0.001*
Total suspended solids (mg/l)	3.0	2.0	2.0	0.339
Alkalinity (mg/l)	18.5	9.0	9.0	<0.001*
Hardness (mg/l)	25.0	11.0	14.0	<0.001*
Chloride (mg/l)	6.28	5.48	10.70	0.001*
Ammonia (mg/l)	0.011	0.008	0.015	<0.001*
Total nitrogen (mg/l)	0.328	0.264	0.357	0.044*
Total phosphorus (mg/l)	0.016	0.008	0.011	<0.001*
Macroinvertebrate MMI	65.50	80.00	69.00	0.011*

Table 7. Median site characteristics for least disturbed fish site classes. The Kruskal-Wallis test was used to compare site characteristics between classes and those that showed significantly differences ($P < 0.05$) are noted with an asterisk.

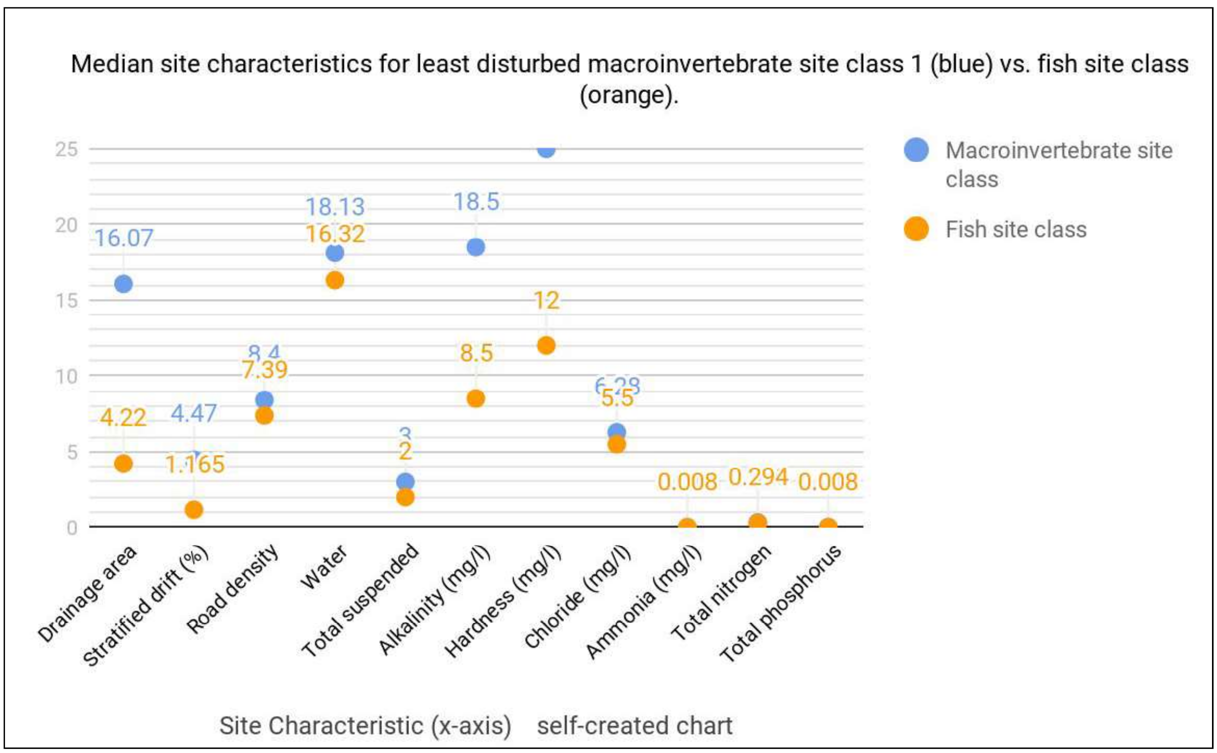
Site characteristic	Class 1	Class 2	Class 3	P value
Drainage area (km^2)	4.22	20.69	6.31	<0.001*
Stratified drift (%)	1.165	9.64	3.72	0.014*
Road density (number per km^2)	7.39	7.84	9.16	0.140
Dam density (number per km^2)	0.00	1.94	1.06	0.003*
Water temperature (°C)	16.32	18.08	16.47	0.003*
Total suspended solids (mg/l)	2.0	2.0	3.0	0.595
Alkalinity (mg/l)	8.50	13.00	14.81	<0.001*
Hardness (mg/l)	12.00	16.00	21.00	<0.001*
Chloride (mg/l)	5.50	8.60	8.03	0.05
Ammonia (mg/l)	0.008	0.017	0.010	<0.001*
Total nitrogen (mg/l)	0.294	0.417	0.304	<0.001*
Total phosphorus (mg/l)	0.008	0.020	0.010	<0.001*

Data Processing:

A profound difference between site classes in both macroinvertebrate and in fish site classes is in the site characteristic of drainage are (km^2). For example, the median site characteristics for least disturbed macroinvertebrate site classes (see table 6) was 16.07 for class one and 3.84 for class two. So between two classes, there was approximately 12.23 difference, which is significant in showing the extent to which dramatic changes to the stream, for example decreased drainage area, negatively impacts the living organisms in the stream. The significant impact of dwindling drainage area is also seen in the fish class sites, as for class one it was 4.22, while this value significantly increased by 16.47 as class two had a value of 20.69. This value dramatically decreased by a value of 14.38 as class three had a value of 6.31 as shown in table 7. Similarly, another significant factor that determined distribution of these populations, like drainage area, was stratified drift (%). Both of these variables connect to a greater factor that negatively impacts such populations, which is dramatic changes to the environment/stream, such as human disturbance. Because many species of fish are vulnerable and sensitive to such changes to where they live, for example the stream's water level decreasing as seen in the drainage are in the tables above, it is not surprising that water levels and human disturbance are one of the many major factors and variables that determine the distribution of these communities.

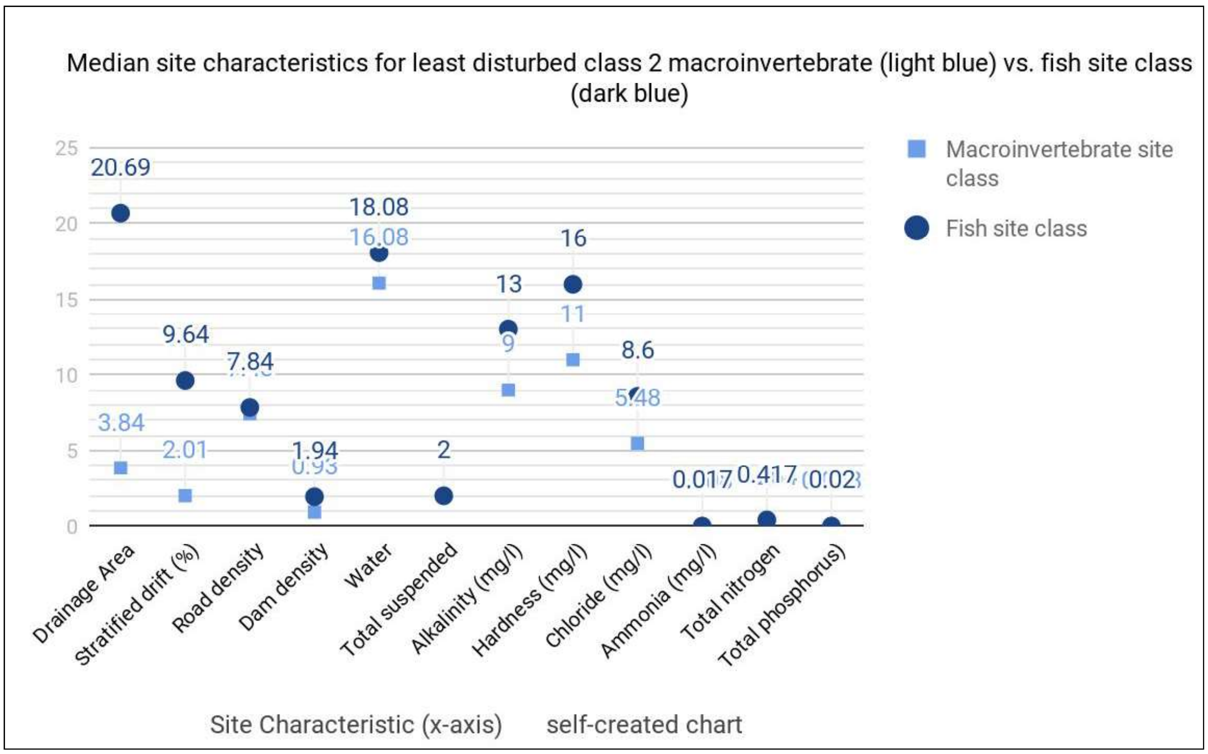
From the data above,[12] the areas identified as least distrubed have not been subject to land uses, such as urbanization, that can have long-term effects on biological communities (Foster 1992 et al. 2003, Harding et al. 1998, Maloney et al. 2008, Wenger et al. 2008). In short, the identification of least disturbed streams by eliminating known anthropogenic stressors, like pollutants and environmental pollution originating in human activity, is valuable as specifying and focusing on specific factors and variables that determine the distribution of macroinvertebrate and fish communities from 30 least disturbed small streams in Connecticut.

The chart below compared the median site characteristics for least disturbed macroinvertebrate site class 1 versus site class 1 fish site class. The biggest difference is seen in the drainage area and in the diet characteristic of alkalinity which is quite interesting, given that the rest of the site characteristics for both the macroinvertebrate and the fish are relatively similar and close together in values as seen in the chart below. Hence, it can be concluded that sudden changes to the environment in which such living organisms live, such as the water level greatly affects such populations.



[12] Bellucci, Christopher J., et al, "Characteristics of Macroinvertebrate and Fish Communities From 30 Least Disturbed Small Streams in Connecticut." Northeastern Naturalist, vol. 18, no. 4, 2011, pp. 411–444. JSTOR, www.jstor.org/stable/41429230. Accessed 14 Jan. 2020.

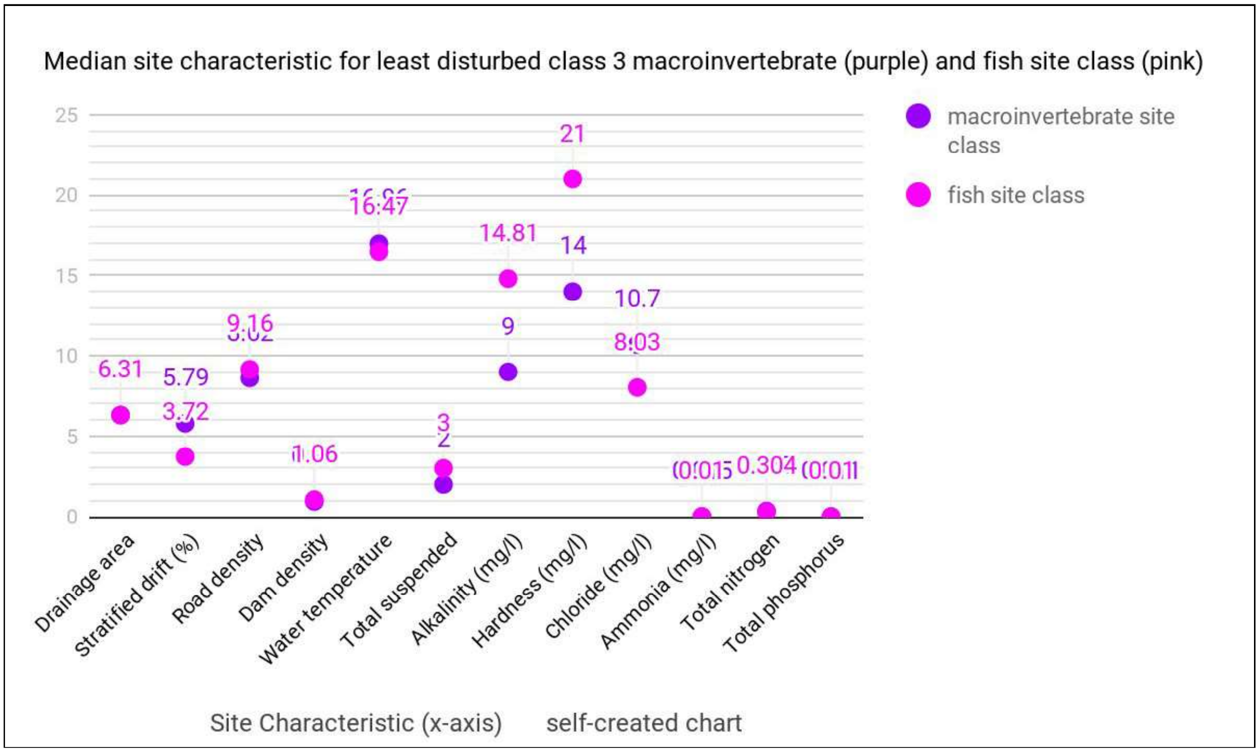
Similarly, in the (second) chart below, the most significant differences in the site class values was in drainage area and in stratified drift. While there are smaller differences in values for example in the site characteristic of alkalinity, hardness and in chloride, the majority of these site characteristics involved the composition and overall quality of the water. However, like in class one, the most significant factor determining the distribution of these populations as drainage is stratified drift. Stratified drift are well-sorted layers of sand and gravel that have been deposited by glacial meltwater.[13] In short, the water level and the amount of water in the river greatly affected the organisms living in the stream, who, with dwindling food, resources and space, were negatively impacted due to increased competition for food and other basic necessities to survive.



This is also seen in the chart below, where, although there are not that many significant values in site classes, the most significant difference in values is hardness. Water hardness is defined as the amount of dissolved calcium and magnesium in the water. Hard water is high in

[13] Salisbury, Rollin D. "Studies for Students: Stratified Drift." The Journal of Geology, vol. 4, no. 8, 1896, pp. 948–970. JSTOR, www.jstor.org/stable/30054993. Accessed 2 Apr. 2020.

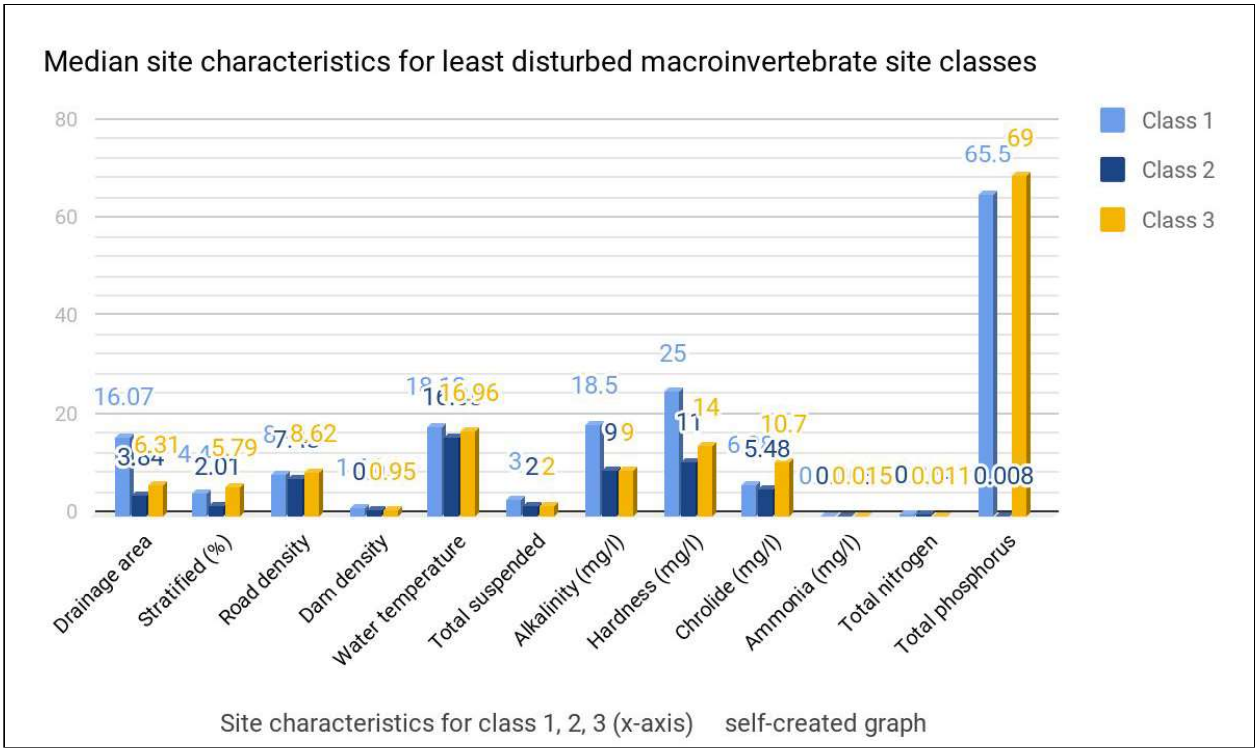
dissolved minerals, largely calcium and magnesium.[14] In this sense, long-term variables and factors, such as the quality of water, arguably, does not have an immediate impact on the organisms living in the water, such as macroinvertebrate and fish populations, unlike immediate and damaging factors like human disturbance to such sensitive and susceptible water sources.



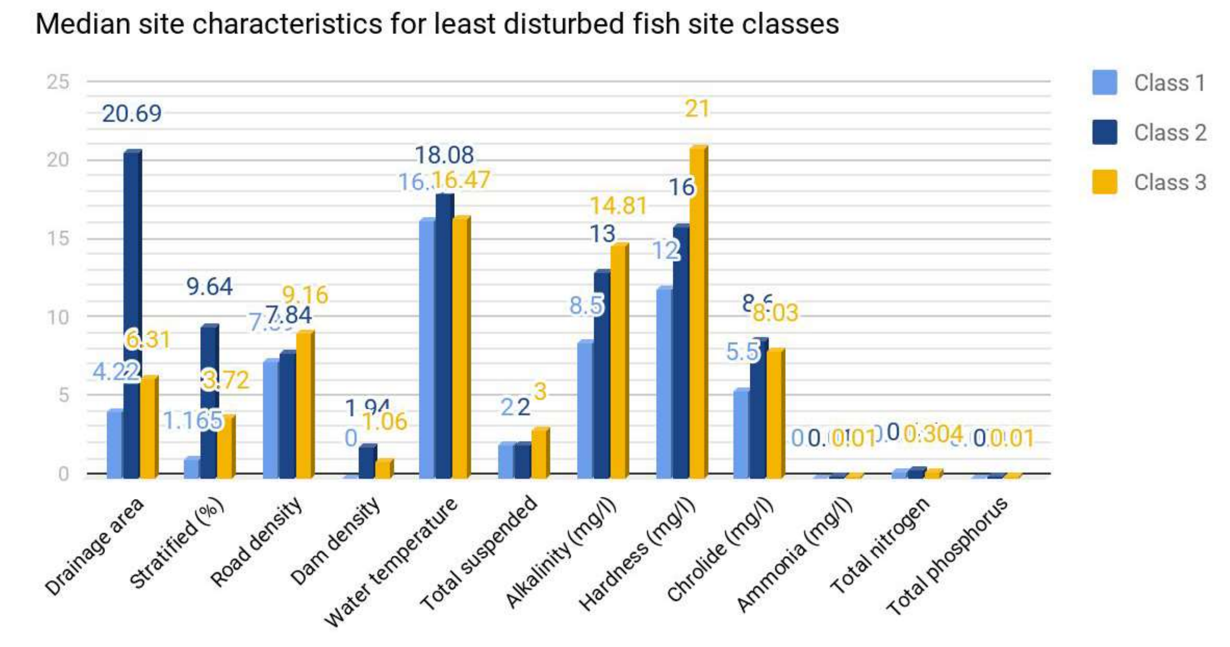
The graph below depicts class 1, 2, and 3 of median site characteristics for least disturbed macroinvertebrate site classes. By making a comparison in values between all three classes, one can see how the most significant difference in values of these three clases was in water hardness and drainage area with each class having distinct and fluctuating values. Based upon the comparison of the values of the three classes for the macroinvertebrate site clases, the site characteristics that created the most varied and fluctuating values between the three classes was water hardness and drainage area. This reveals that drainage area negatively affects the living organisms in the river by the reduction of water level which not only creates an environment where such populations have to compete to survive for food and other basic necessities, but the overall concentration of the different materials and other substances present

[14] "Hardness of Water." Hardness of Water, USGS Science for a Changing World, www.usgs.gov/special-topic/water-science-school/science/hardness-water?qt-science_center_objects=0#qt-science_center_objects.

in the water is intensified and magnified. For example, the amount and concentrations of minerals, natural waste and toxins from humans has increased due to water scarcity.



This is also seen in the median site characteristics for least disturbed fish site clases 1, 2 and 3 (see graph below), with the site characteristic of drainage area, percent of stratification and water hardness having the most difference in values between the fish clases among all of the other site characteristics. In particular, the data reveals that the drainage area was 4.22 for class 1 fish site, compared to class 2 which had a value of 20.69. This value significantly decreased for class three, as evidenced by having a value of 6.31. This significant difference in the increase and decrease of values between class one, class two, and class three reveals the tremendous impact drainage area affects and impacts such populations. With the ongoing threat of urbanization, Connecticut’s history of land use disturbance, and the continuation of human disturbance even in the 30 least disturbed streams in Connecticut reveals the vulnerability and unfortunate risk such living organisms and water bodies are at.



Site characteristics for class 1, 2, 3 (x-axis)   self-created graph

Data Uncertainty:

Based upon the fact that the “best available physical, chemical, and biological habitat conditions given today’s state of the landscape” were found using the geographic information system software (GIS, ESRI ArcMap Version 9.2) to select drainage basins by their natural attributes and by eliminating known or suspected anthropogenic stressor variables to best approximate a least disturbing watershed condition, this method of selecting the ‘cleanest’ streams and rivers using a geographic information system software may present its own respective limitations, inaccuracies, and uncertainty in its information and data.

Since wadeable perennial streams with watersheds 2-2,000 km^2 were considered and only used for this particular study, this approach of just using wadeable streams poses, arguably, a great limitation on the data of this study. Unfortunately, by limiting the data to a particular factor of the level of the stream, the data is less varied and only a certain amount of analysis and conclusions can be deducted. Impervious cover has been shown to act as a surrogate measure of negative impacts to aquatic life in streams (Bellucci 2007, Morse et al. 2003, Roy et al. 2005, Stranko et al. 2008, Wang et al. 2001). Also, the reduction in stream flow from water diversions can reduce the available aquatic habitat and therefore negatively impact the abundance and diversity of aquatic life in such streams (Bain et al. 1988, Freeman and Marcinek 2006, Konrad et al. 2008, Poff et al. 1997) such altering the accuracy of the data since only wadeable streams were selected to study and analyze.

Unfortunately because dams are so widespread and common, their presence could not be completely eliminated or else there would be the risk that there would be no streams left in the study population. While there was an attempt to eliminate large dams from the analysis and included an acceptable threshold distance downstream from smaller dams, there is still data uncertainty as they contribute to stream habitat fragmentation and change the natural dynamics of stream ecosystems (Braatne et al. 1999, Graf 1999, Ligon et al. 1995, Poff and Hart 2002, Stanford and Ward 1989). While a distance of 1.6 km was kept to filter immediate ecological impacts from small dams for this particular study, this factor still created data uncertainty.

Fish stocking in general can have negative impacts on natural fish populations (Faush 1988, Kreuger and May 1991) and therefore was a consideration to identifying least disturbed streams in Connecticut. However this study did not exclude streams that were stocked with adult salmonids because the selection criteria used dictated small, remote streams which are typically not stocked with adult salmonids.While this assumption was made, it was hypothesized that if captured, adult stocked salmonids would be easily identified in the field. While this is true, this may have contributed to additional data uncertainty as fish stock practices in CT, in general, are popular. Fortunately though, most occurrences of juvenile Atlantic Salmon in CT are stocked fish and were therefore such streams stocked with *Salmo trutta* L. (Brown Trout) fry, and *Salmo salar* L. (Atlantic Salmon) were eliminated because it is not possible to discriminate naturally reproduced Brown Trout fry from stocked fry.

For this particular study it would have been interesting to test and compare different streams during different seasons over an extended period of time. By testing and analyzing the water quality of these relatively clean streams and sources of water, one might find valuable information on what specific factors and variables contribute to the health and wellbeing of the organisms that live in these streams which reflect and reveal the water's quality.

To extend the findings of this particular study, it would be interesting to study and explore why there are different values in site characteristics between macroinvertebrates and fish populations, and even within different site classes which could provide valuable information in order to get a better understanding of such living organisms and where they live.

Conclusion:

Based upon the findings of this survey, it is clearly shown by the data that dramatic changes to rivers and streams in Connecticut, for example, due to human disturbance is, arguably, the most significant factor that determines the distribution of macroinvertebrate and fish communities from 30 least disturbed small streams in Connecticut. Human disturbance greatly determines the distribution of macroinvertebrate and fish communities from 30 least disturbed small streams in Connecticut.

While it is true that human disturbance and our impact to the overall water quality in the state, nationwide, and all around the world is known, through this study one can truly understand and see the unfortunate short and long term consequence human disturbance has on streams and living organisms living in the water. Human disturbance has many different forms - from land-use disturbance, urbanization to the releasing of harmful chemicals and substances to such vulnerable water bodies and the living organisms living in them.

While this particular study had a limitation of focusing on the 30 least disturbed streams specifically in Connecticut and not comparing it to other streams not just in Connecticut but in other states, this specific focus and analysis on the purest water sources is greatly valuable. For example, by analyzing the purest water sources, specific factors and variables can be found that contribute to the distribution of living organisms' populations. Based upon the methodology of this investigation, the method of using a geographic information system software (GIS) could have limited the overall data of this investigation based upon the heavily reliance on such a system instead of manually testing, or using a different method to find the streams that have the best water quality in the state.

A possible way for the improvement and extension of this investigation is to test the least disturbed streams over an extended period of time, for example during different seasons and over the course of years to compare results from different time periods. This investigation is significant; the mere fact that the most undisturbed streams in Connecticut are located is valuable as the testing and analyzing of the remaining relatively pure water sources in the state reveals the health, population number, and type of organisms living in such waters. The further analysis of such organisms and populations such as macrointerbre and fish populations indicates ways we, humans, can help improve other streams and waterbodies - to mimic and understand why such organisms flourish in such waters.

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