An Investigation of Diatom Communities and Freshwater Aquatic Attributes of Oden State Fish Hatchery

Oden State Fish Hatchery, Oden Creek, Emmet County, Michigan

Chuck Dollison

University of Michigan Biological Station
EEB 482: Limnology of Freshwater Ecosystems
August 13, 2014
Paul Moore

Introduction

Understanding carbon cycling is central to appreciating how food webs within aquatic ecosystems are structured and supported. To better understand specifically how food webs play an integral part in ecosystem services algal samples were collected from ceramic tiles colonized within the Oden State Fish Hatchery (OSFH), Emmet County, Michigan. Five survey locations within the hatchery were used for this investigation to include; a public feeding pond discharge site, a brood/hatchery operations discharge site, a raceway/finishing pond discharge site and two recovery locations downstream of OSFH that flow into Crooked Lake. The purpose of this investigation was to identify the base of the food web at OSFH by identifying the diatom flora and macroinvertebrates, calculate the changes within the system by measuring physical, chemical and biological attributes, and to determine what effect hatchery operation produced nutrients have on the overall system.

All of these aquatic ecosystems have riparian zones surrounding the water bodies where deadfall from vegetation enters into the system in the form of allochthonus inputs. Allochthonous contributions, organic matter, and nutrients originating outside of OSFH are transported into Crooked Lake and play an integral role in determining the productivity of the food web. Inorganic carbon in water involved in the bicarbonate equilibrium, which is connected intimately to pH control and responses to acid precipitation (Hauer and Lamberti 2006) are the result from the parent materials weathered away from the last major glaciation.

The landscape that OSFH occupies was formed during the final two glacial episodes of the Wisconsinan glaciation- the Port Huron and Greatlakean substages. This last glaciation gave way to fluctuating water levels of the Great lakes that are seen today, as well as the unique hydrology of northern Lower Michigan. The physiography of the landscape is a mosaic of glacial outwash plains, ice-contact features, moraines and lake plains. Oden State Fish Hatchery is located at 45°43′N, 84°84′W just northeast of Petoskey in Emmet County among a patchwork of lakes and streams that dominate the terrain of northern lower Michigan.

Methods

Oden State Fish Hatchery Public Feeding Pond Sampling Techniques

On July 26, 2014 a survey was conducted approximately 500 m downstream of the outflow of the public feeding pond of OSFH. Collections of physical, chemical and biological attribute data were gathered to better understand how public feeding affects the ecology of Oden Creek. The public feeding pond at OSFH receives inputs in the form of food pellets provided by visitors to hatchery. The reason the feeding pond was chosen as a survey site was because OSFH staff were concerned that the public feeding was having a negative effect downstream of this activity. ***Physical Attributes***- The following measurements were taken at each of the stream survey locations by the Hydrolab platform manufactured by OTT Hydromet; temperature (°C), dissolved oxygen (mg/L), and pH (measure of hydronium ion concentration). Temperature, dissolved oxygen, and pH were taken in one distinct cell at 60% of the total depth of the stream. The reason physical attributes were measured is to understand how the current lentic system is functioning in terms of nutrient discharge and specifically how the lentic ecosystem has changed since the last University of Michigan Biological Station (UMBS) initiated diatom investigation (Deo, *et al.* 1997) prior to the 2002 hatchery renovation. Temperature can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants, therefore measuring this attribute is important to understand the overall ecology of Oden Creek. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). A Hydrolab platform manufactured by OTT Hydromet was used for sampling temperature (°C), dissolved oxygen (mg/L), and pH (measure of hydronium ion concentration) at the surface of Oden Creek. ***Chemical Attributes***- A water chemistry sample was taken from the surface waters of the survey site were placed in polypropylene acid-washed bottles, submitted to the UMBS Analytical Chemist to derive the following; ammonia, nitrate, phosphate and silicon concentrations, as well as total nitrogen and total phosphorus at the survey site. ***Biological Attributes***- Three ceramic tiles were placed in the middle of the stream 1 m apart, perpendicular to the flow of the stream to colonize the algal community. These ceramic tiles were left at the survey site to colonize the algal community for 2 ½ weeks. Macroinvertebrates were sampled using a 0.5 m^2 Surber sampler fitted with a 500-µm mesh net at the survey locations of the stream. Once the gravel, silt and sand substrates were collected in the Surber sampler, the substrates were sieved through the 500-µm mesh and dumped into a large, white-enamel pan with enough stream water to cover the benthic aquatic macroinvertebrates for field sample processing. Each of the distinct substrate collected from the Surber samplers were placed into an individual large, white-enamel pan. All of the collected substrate was systematically sorted within the sorting pan in order to locate any benthic aquatic macroinvertebrates. Once a benthic aquatic macroinvertebrate was located within the sorting pan the individual macroinvertebrate was plucked out of the large, white-enamel pan with a pair of forceps and placed into a whirl-pak with 95% alcohol for subsequent laboratory identification. The whirl-pak was emptied into a large glass petry dish and with the aid of a dissecting microscope the collected macroinvertebrates were manually sorted into the following groups; predators, scrapers, shredders, filtering collectors, and gathering collectors. With the aid of Hauer and Lamberti 2006, Stream ecology- Methodology- Appendix 25.1, A Simplified Key to the Functional Feeding Groups of Lotic Macroinvertebrates, the sorted macroinvertebrates were tallied, placed into labelled, small glass collection jars of 95% alcohol and capped with a lid for further analyses.

Oden State Fish Hatchery Brood/Hatchery Operations Sampling Techniques

On July 26, 2014 a survey was conducted approximately 500 m downstream from the brood/hatchery operations main discharge location. Three ceramic tiles were placed in the middle of the stream 1 m apart, perpendicular to the flow of the stream to colonize the algal community. ***Physical Attributes-*** The following measurements were taken at each of the stream survey locations by the Hydrolab platform manufactured by OTT Hydromet; temperature (°C), dissolved oxygen (mg/L), and pH (measure of hydronium ion concentration). Temperature, dissolved oxygen, and pH were taken in one distinct cell at 60% of the total depth of the stream. The reason physical attributes were measured is to understand how the current lentic system is functioning in terms of nutrient cycling and how Oden Creek has changed over time. Temperature can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants, therefore measuring this attribute is important to understand the overall ecology of Oden Creek. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). The data collected from the Hydrolab platform and the Hach flow meter were then entered into a Microsoft® Excel 2010 spreadsheet to be manipulated for further interpretation on how nutrients cycle through Oden Creek. ***Chemical Attributes-*** A water chemistry sample was collected from the surface of the survey site and placed into a polypropylene acid-washed bottle, then submitted to the UMBS Analytical Chemist to derive the following; ammonia, nitrate, phosphate and silicon concentrations as well as total nitrogen and total phosphorus. ***Biological Attributes-*** Three ceramic tiles were placed in the middle of the stream 1 m apart, perpendicular to the flow of the stream to colonize the algal community. These ceramic tiles were left at the survey site to colonize the algal community for 2 ½ weeks. After the 2 ½ week colonization period for algal communities, the ceramic tiles were carefully retrieved from the survey site placed into separate whirl-paks with enough stream water to cover the whole ceramic tile and brought back to UMBS for processing of the diatom community. Macroinvertebrates were sampled using a 0.5 m^2 Surber sampler fitted with a 500-μm mesh net at the survey site of the stream. Once the gravel, silt and sand substrates were collected in the Surber sampler, the substrates were sieved through the 500-μm mesh and dumped into a large, white-enamel pan with enough stream water to cover the benthic aquatic macroinvertebrates for field sample processing. Each of the distinct substrate collected from the Surber samplers were placed into an individual large, white-enamel pan. All of the collected substrate was systematically sorted within the sorting pan in order to locate any benthic aquatic macroinvertebrates. Once a benthic aquatic macroinvertebrate was located within the sorting pan the individual macroinvertebrate was plucked out of the large, white-enamel pan with a pair of forceps and placed into a whirl-pak with 95% alcohol for subsequent laboratory identification. The whirl-pak was emptied into a large glass petry dish and with the aid of a dissecting microscope the collected macroinvertebrates were manually sorted into the following groups; predators, scrapers, shredders, filtering collectors, and gathering collectors. With the aid of Hauer and Lamberti 2006, Stream ecology- Methodology- Appendix 25.1, A Simplified Key to the Functional Feeding Groups of Lotic Macroinvertebrates, the sorted macroinvertebrates were tallied, placed into labelled, small glass collection jars of 95% alcohol and capped with a lid for further analyses.

Oden State Fish Hatchery Raceways/Finishing Pond Sampling Techniques

On July 26, 2014 a survey was conducted at the discharge site of the raceways/finishing pond. A state of the art effluent management system was implemented in 2002 at OSFH which manages the waste produced by the nearly ½ Million brown and rainbow trout fry produced annually at the hatchery. ***Physical Attributes***- The following measurements were taken at the survey site location by the Hydrolab platform and Hach flowmeter, both manufactured by OTT Hydromet; temperature (°C), dissolved oxygen (mg/L), pH (measure of hydronium ion concentration), and flow (L/s) at 60% depth of the stream. Temperature, dissolved oxygen, and pH were taken in one distinct cell at 60% of the total depth of the stream. The reason physical attributes were measured is to understand how the current lentic system is functioning in terms of nutrient cycling and how lentic systems change over time. Temperature can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants, therefore measuring this attribute is important to understand the overall ecology of Oden Creek. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). The data collected from the Hydrolab platform and the Hach flow meter were then entered into a Microsoft® Excel 2010 spreadsheet to be manipulated for further interpretation on how carbon flows through the system. ***Chemical Attributes***- A water chemistry sample was collected from the surface of the survey site and placed into a polypropylene acid-washed bottle, and submitted to the UMBS Analytical Chemist to derive the following; ammonia, nitrate, phosphate and silicon concentrations as well as total nitrogen and total phosphorus. ***Biological Attributes***- Three ceramic tiles were placed in the middle of the stream 1 m apart, perpendicular to the flow of the stream to colonize the algal community. These ceramic tiles were left at the survey site to colonize the algal community for 2 ½ weeks. After the 2 ½ week colonization period for algal communities, the ceramic tiles were carefully retrieved from the survey site placed into separate whirl-paks with enough stream water to cover the whole ceramic tile and brought back to UMBS for processing of the diatom community. Macroinvertebrates were sampled using a 0.5 m^2 Surber sampler fitted with a 500-μm mesh net at the survey site of the stream. Once the gravel, silt and sand substrates were collected in the Surber sampler, the substrates were sieved through the 500-μm mesh and dumped into a large, white-enamel pan with enough stream water to cover the benthic aquatic macroinvertebrates for field sample processing. Each of the distinct substrate collected from the Surber samplers were placed into an individual large, white-enamel pan. All of the collected substrate was systematically sorted within the sorting pan in order to locate any benthic aquatic macroinvertebrates. Once a benthic aquatic macroinvertebrate was located within the sorting pan the individual macroinvertebrate was plucked out of the large, white-enamel pan with a pair of forceps and placed into a whirl-pak with 95% alcohol for subsequent laboratory identification. The whirl-pak was emptied into a large glass petry dish and with the aid of a dissecting microscope the collected macroinvertebrates were manually sorted into the following groups; predators, scrapers, shredders, filtering collectors, and gathering collectors. With the aid of Hauer and Lamberti 2006, Stream ecology- Methodology- Appendix 25.1, A Simplified Key to the Functional Feeding Groups of Lotic Macroinvertebrates, the sorted macroinvertebrates were tallied, placed into labelled, small glass collection jars of 95% alcohol and capped with a lid for further analyses.

Oden State Fish Hatchery Recovery Site 1 Sampling Techniques

On July 26, 2014 a surveys was conducted at the first recovery site on Oden Creek approximately 500m downstream of the last point-source contribution (raceways/finishing pond) from OSFH operations. ***Physical Attributes***- The following measurements were taken at the survey site location by the Hydrolab platform and Hach flowmeter, both manufactured by OTT Hydromet; temperature (°C), dissolved oxygen (mg/L), pH (measure of hydronium ion concentration), and flow (L/s) at 60% depth of the stream. The following measurements were taken at the survey site location by the Hydrolab platform and Hach flowmeter, both manufactured by OTT Hydromet; temperature (°C), dissolved oxygen (mg/L), pH (measure of hydronium ion concentration), and flow (L/s) at 60% depth of the stream. Three distinct cells that were equally divided across the horizontal cross-section of the respective survey site and the flow measurements were taken at 60% of the total depth of the stream. The reason physical attributes were measured is to understand how the current lentic system is functioning in terms of nutrient cycling and how lentic systems change over time. Temperature can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants, therefore measuring this attribute is important to understand the overall ecology of Oden Creek. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). The data collected from the Hydrolab platform and the Hach flow meter were then entered into a Microsoft® Excel 2010 spreadsheet to be manipulated for further interpretation on how nutrients flow through the system. ***Chemical Attributes***- A water chemistry sample was collected from the surface of each of the survey site and placed into a polypropylene acid-washed bottle, submitted to the UMBS Analytical Chemist to derive the following; ammonia, nitrate, phosphate and silicon concentrations as well as total nitrogen and total phosphorus. ***Biological Attributes***- Three ceramic tiles were placed in the middle of the stream 1 m apart, perpendicular to the flow of the stream to colonize the algal community. These ceramic tiles were left at the survey site to colonize the algal community for 2 ½ weeks. After the 2 ½ week colonization period for algal communities, the ceramic tiles were carefully retrieved from the survey site placed into separate whirl-paks with enough stream water to cover the whole ceramic tile and brought back to UMBS for processing of the diatom community. Macroinvertebrates were sampled using a 0.5 m^2 Surber sampler fitted with a 500-µm mesh net at the survey site of the stream. Once the gravel, silt and sand substrates were collected in the Surber sampler, the substrates were sieved through the 500-µm mesh and dumped into a large, white-enamel pan with enough stream water to cover the benthic aquatic macroinvertebrates for field sample processing. Each of the distinct substrate collected from the Surber samplers were placed into an individual large, white-enamel pan. All of the collected substrate was systematically sorted within the sorting pan in order to locate any benthic aquatic macroinvertebrates. Once a benthic aquatic macroinvertebrate was located within the sorting pan the individual macroinvertebrate was plucked out of the large, white-enamel pan with a pair of forceps and placed into a whirl-pak with 95% alcohol for subsequent laboratory identification. The whirl-pak was emptied into a large glass petry dish and with the aid of a dissecting microscope the collected macroinvertebrates were manually sorted into the following groups; predators, scrapers, shredders, filtering collectors, and gathering collectors. With the aid of Hauer and Lamberti 2006, Stream ecology- Methodology- Appendix 25.1, A Simplified Key to the Functional Feeding Groups of Lotic Macroinvertebrates, the sorted macroinvertebrates were tallied, placed into labelled, small glass collection jars of 95% alcohol and capped with a lid for further analyses.

Oden State Fish Hatchery Recovery Site 2 Sampling Techniques

On July 26, 2014 a survey was conducted at the second recovery site approximately 500m downstream from recovery site 1 before the confluence of Crooked Lake. ***Physical Attributes-*** The following measurements were taken at the survey site location by the Hydrolab platform and Hach flowmeter, both manufactured by OTT Hydromet; temperature (°C), dissolved oxygen (mg/L), pH (measure of hydronium ion concentration), and flow (L/s) at 60% depth of the stream. The reason physical attributes were measured is to understand how the current lentic system is functioning in terms of nutrient cycling and how Oden Creek has changed over time. Temperature can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants, therefore measuring this attribute is important to understand the overall ecology of Oden Creek. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). The data collected from the Hydrolab platform and the Hach flow meter were then entered into a Microsoft® Excel 2010 spreadsheet to be manipulated for further interpretation on how nutrients flow through the system. ***Chemical Attributes-*** A water chemistry sample was collected from the surface of the survey site, placed into a polypropylene acid-washed bottle, and submitted to the UMBS Analytical Chemist to derive the following; ammonia, nitrate, phosphate and silicon concentrations as well as total nitrogen and total phosphorus. ***Biological Attributes-*** Three ceramic tiles were placed in the middle of the stream 1 m apart, perpendicular to the flow of the stream to colonize the algal community. These ceramic tiles were left at the survey site to colonize the algal community for 2 ½ weeks. After the 2 ½ week colonization period for algal communities, the ceramic tiles were carefully retrieved from the survey site placed into separate whirl-paks with enough stream water to cover the whole ceramic tile and brought back to UMBS for processing of the diatom community. Macroinvertebrates were sampled using a 0.5 m^2 Surber sampler fitted with a 500-μm mesh net at the survey site of the stream. Once the gravel, silt and sand substrates were collected in the Surber samplers, the substrates were sieved through the 500-μm mesh and dumped into three large, white-enamel pans with enough stream water to cover the benthic aquatic macroinvertebrates for field sample processing. Each of the distinct substrate collected from the Surber samplers were placed into individual large, white-enamel pans or sorting pans. All of the collected substrate was systematically sorted within the sorting pan in order to locate any benthic aquatic macroinvertebrates. Once a benthic aquatic macroinvertebrate was located within the sorting pan the individual macroinvertebrate was plucked out of the large, white-enamel pan with a pair of forceps and placed into a collection bottle with 95% alcohol for subsequent laboratory identification. The collection bottle was emptied into a large glass petry dish and with the aid of a dissecting microscope the collected macroinvertebrates were manually sorted into the following groups; predators, scrapers, shredders, filtering collectors, and gathering collectors. With the aid of Hauer and Lamberti 2006, Stream ecology- Methodology- Appendix 25.1, A Simplified Key to the Functional Feeding Groups of Lotic Macroinvertebrates, the sorted macroinvertebrates were tallied, placed into labelled, small glass collection jars of 95% alcohol and capped with a lid for analyses of local energy flow interactions.

Results- Oden State Fish Hatchery Public Feeding Pond

Physical- The following pH readings were recorded; 8.23. The following discharge rates were recorded as 63.36 (L/s), and the following light availability were recorded; 255(μmol). ***Chemical-*** The nitrate/phosphate concentrations for the survey site were the following; 221.25, phosphate limited. ***Biological-*** Diatom relative abundance in species for the survey site were negligible, less than 65 individuals were counted, not qualifying for relative abundance (>500 individuals). The following macroinvertebrate ratios were recorded; Scrapers/shredders + Total collectors, 9.48, Filtering/gathering, 2.00, Scrapers + Filtering/Shredders + Gathering, 19.18, Predators/Total of all other groups, 0.02.

Results- Oden State Fish Hatchery Brood/Hatchery Operations

Physical- The following pH readings were recorded; 8.25. The following discharge rates were recorded as 130 (L/s), and the following light availability were recorded at 202 (μmol). ***Chemical-*** The Redfield ratio for the survey site were the following; 1:112.97, phosphate limited. ***Biological-*** Diatom relative abundance in species for the survey site were the following; *Cocconeis pediculus (133), Diatoma vulgaris (98), Cymbella proxima (86), Staurosirella leptostauron (93), Melosira varians (63), Fragilaria vaucheriae (37), Planothidium lanceolatum (65), Cocconeis placentula (57), Diatoma mesodon (46).* The following macroinvertebrate ratios were recorded; Scrapers/shredders + Total collectors, 38.5, Filtering/gathering, 0.09, Scrapers +Filtering/Shredders + Gathering, 43.75, Predators/Total of all other groups, 0.26.

Results- Oden State Fish Hatchery Raceways/Finishing Pond

Physical- The following pH readings were recorded; 7.92. The following discharge rates were recorded as 115.2 (L/s), and the light availability were recorded at 51.5 (μmol). ***Chemical-*** the Redfield ratio for the survey site were the following; 1:56.62, phosphate limited. ***Biological-*** Diatom relative abundance in species for the survey site were the following; *Fragilaria vaucheriae (209), Encyonema prostrate (148), Cocconeis placentula (129), Staurosirella leptostauron (50), Cocconeis pediculus (40), Encyonema minutum (36).* The following macroinvertebrate ratios were recorded; Scrapers/shredders + Total collectors, 16.22, Filtering/gathering, 2.20, Scrapers + Filtering/Shredders + Gathering, 11.41, Predators/Total of all other groups, 0.00.

Results- Oden State Fish Hatchery Recovery Site 1

Physical- The following pH readings were recorded; 8.15. The discharge rates were recorded as 440.76 (L/s) and the light availability were recorded at 119.75 (μmol). ***Chemical-***the Redfield ratio for the survey site were the following; 1:86.54, phosphate limited. ***Biological-*** Diatom relative abundance in species for the survey site were the following; *Fragilaria vaucheriae (159), Diatoma erinbergyi (140), Nitzchia fonticola (119), Martyana martyi (70), Encyonema prostrate (63).* The following macroinvertebrate ratios were recorded; Scrapers/shredders + Total collectors, 47.50, Filtering/gathering, 1.94, Scrapers + Filtering/Shredders + Gathering, 24.17, Predators/Total of all other groups, 0.25.

Results- Oden State Fish Hatchery Recovery Site 2

Physical- The following pH readings were recorded; 8.11. The discharge rates were recorded as 185.46 (L/s), and the light availability were recorded at 750 (μmol). ***Chemical-*** the Redfield ratio for the survey site were the following; 1:103.34. ***Biological-*** Diatom relative abundance in species for the survey site were the following; *Martyana martyi (717), Planothidium lanceolatum (62), Diatoma spp. (60), Amphora pediculus (27), Staurosirella leptostauron (18), Navicula trivialis (15).* The following macroinvertebrate ratios were recorded; Scrapers/shredders + Total collectors, 13.17, Filtering/gathering, 0.08, Scrapers + Filtering/Shredders + Gathering, 14.08, Predators/Total of all other groups, 0.33.

Discussion

An integral component of stream ecosystem structure and function is the relationship between flow dynamics and the movement of substratum material (Hauer and Lamberti 2006) as an abbreviation for physical geography, which defines the surface features of an area. Physiography includes the specific surface features themselves, the landforms, and the geologic parent material beneath the surface. The fluvial dynamics and subsequent habitat restructuring greatly affect benthic organisms (Stevenson 1990, Death and Winterbourn 1995, Townsend et al. 1997, Arscott et al. 2005) adding further evidence that when more plants and animals are interacting in a lentic ecosystem, more carbon is being sunk into that system. These allochthonus inputs are deposited into the aquatic system as well as the riparian buffer zone to slow or reduce flow into the river. Suspended sediments from the erosion would impair the clarity of the stream, reduce light penetration and subsequent productivity of algal colonization, as well as the zooplankton that depends on the algae. Strictly speaking, clarity or lack of suspended organic material is not a chemical property, more accurately, it is an indicator or measure of water quality related to the specific measurements of chemical and physical properties.

One of the most important of all geologic processes is the force of rainwater, snowmelt and groundwater applied to land forms by running water (Hauer and Lamberti 2006) and the flow or non-flow of nutrients into an aquatic habitat. The significant effect of running water has major ramifications for the resulting flora and fauna (Statzner et al. 1988, Gordon et al. 1992, Allan 1995, and Gore 1996) as well as the type of vegetation seen within the riparian corridors of OSFH. Carbon cycling is central to the way ecosystems operate from local to global scales.

Organic carbon is the currency of energy exchange in aquatic ecosystems (Dodds and Whiles 2010) with the major processes of carbon transformation under aerobic and anaerobic conditions dominated by photosynthesis and aerobic respiration. Primary producers in the form of the diatom community at OSFH use sunlight as energy to generate organic matter from inorganic compounds and are the most conspicuous base of food webs in the biosphere (Bott, *et al.* 1978). Even if the contribution is microscopic, primary producers are essential as a food resource for consumers (Bunn, *et al.* 1999) that create their habitat within OSFH. Tracking the flow of carbon through the OSFH by examining a bottom-up approach give ecologist a greater understanding of the complexity of carbon cycling and how minor changes in nutrients can have a major impact on the much larger ecosystem as a whole.

Food webs are the networks of pathways for the flow of energy in ecosystems from the capture of solar energy by autotrophs in the process of photosynthesis, to the departure of organisms by heterotrophic respiration. The energetic view or the concept of ecosystem ecology incorporates local constraints and interactions, but also interprets the much larger-scale processes of nutrient cycling, predominantly the flow of carbon. This view of energy pathways and the concept of carbon cycling is what drive ecosystem functions, specifically the primary producers or algal community on Oden Creek.

References

Allan, J. D. 1995. *Stream ecology.* Chapman & Hall, London, UK.

Arscott, D. B., K. Tockner and J. V. Ward. 2005. Lateral organization of aquatic invertebrates along the corridor of a braided floodplain river. *Journal of North American Benthological Society* 24: 934-954.

Bott, T. L., J. T. Brock, C. E. Cushing, S. V. Gregory, D. King and R. C. Petersen, 1978. A comparison of methods for measuring primary productivity and community respiration in streams. *Hydrobiologia* 60: 3-12.

Bunn, S. E., P. M. Davies, and T. D. Mosisch. 1999. Ecosystem measures of river health and their response to riparian and catchment degradation. *Freshwater Biology* 41: 333-345.

Death, R. G., and M. J. Winterbourne. 1995. Diversity patterns in stream benthic invertebrate communities: the influence of habitat stability. *Ecology* 76: 1446-1460.

Dodds, W. K., and M. R. Whiles. 2010. Freshwater ecology: concepts and environmental applications of limnology. Academic Press, London, UK.

Gordon, N. D., T. A. McMahon, and B. L. Findlayson. 1992. Stream Hydrology: An Introduction for Ecologist. Wiley, Chichester, UK.

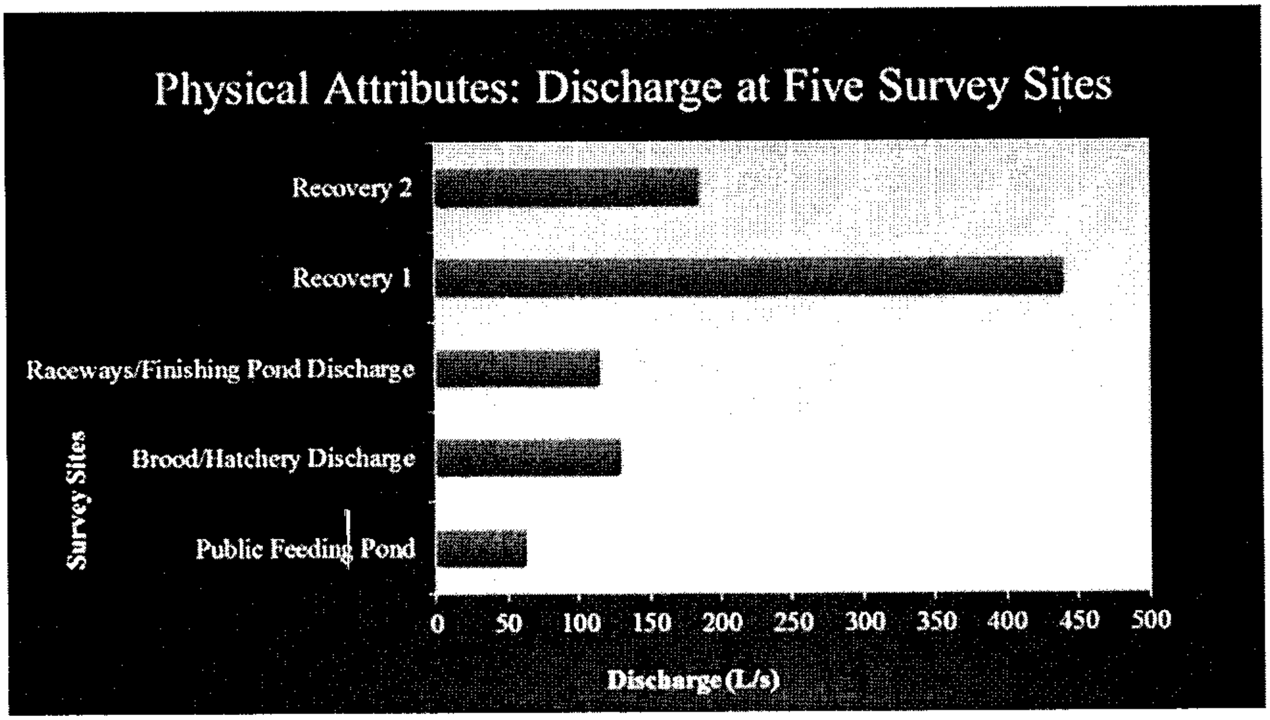
Gore, J. A. 1996. Responses of aquatic biota to hydrological change. Pages 209-230 *in* G. Petts and P. Calow (Eds.) *River Biota. Diversity and dynamics.* Blackwell, Oxford, UK.

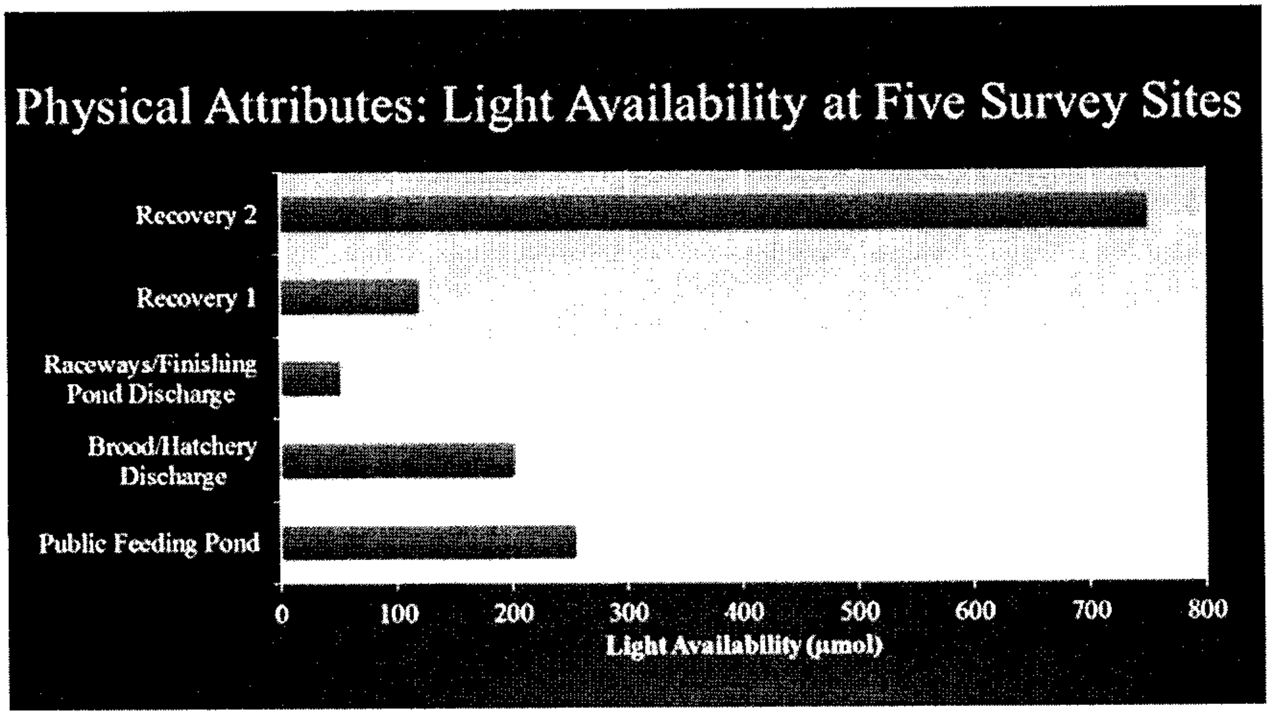
Hauer, F. R. and G. A. Lamberti. 2006. Stream ecology- Methodology. Academic Press, London, UK.

Statzner, B., J. A. Gore, and V. H. Resh. 1988. Hydraulic stream ecology: Observed patterns and potential applications. *Journal of the North American Benthological Society* 7: 307-360.

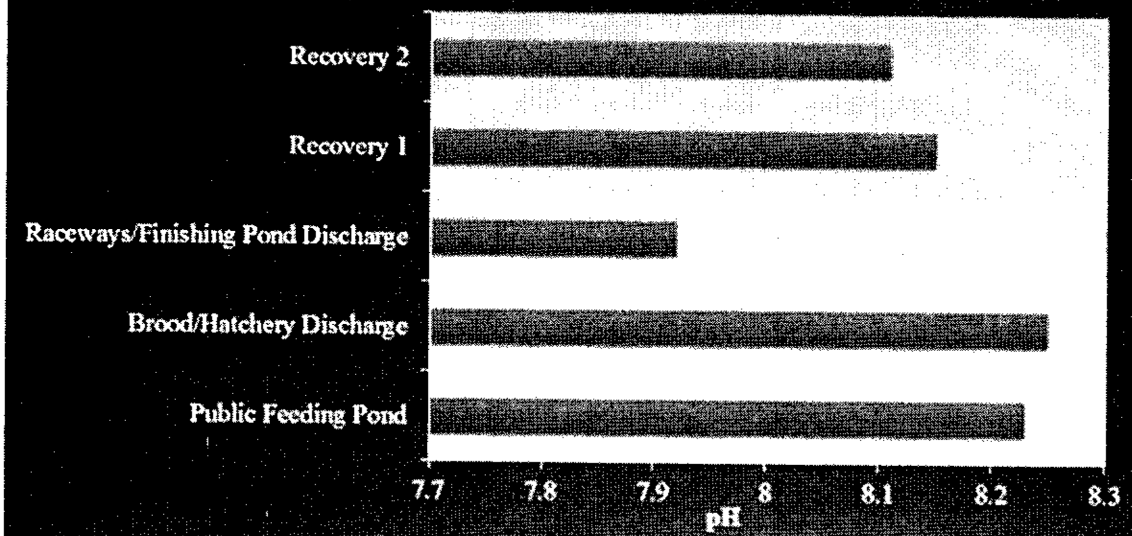
Stevenson, J. J. 1990. Benthic algal community dynamics in a stream during and after a spate. *Journal of the North American Benthological Society* 9: 277-288.

Townsend, C. R., M. R. Scarsbrook, and S. Dolédec. 1997. Quantifying disturbance in streams: alternative measures of disturbance in relation to macroinvertebrate species traits and species richness. *Journal of the North American Benthological Society* 16: 531-544.


Physical Attributes: Discharge at Five Survey Sites
Recovery 2
Recovery 1
Raceways/Finishing Pond Discharge
Brood/Hatchery Discharge
Public Feeding Pond
Survey Sites
0
50
100
150
200
250
300
350
400
450
500
Discharge (L/s)


Physical Attributes: Light Availability at Five Survey Sites
Recovery 2
Recovery 1
Raceways/Finishing Pond Discharge
Brood/Hatchery Discharge
Public Feeding Pond
0
100
200
300
400
500
600
700
800
Light Availability (μmol)

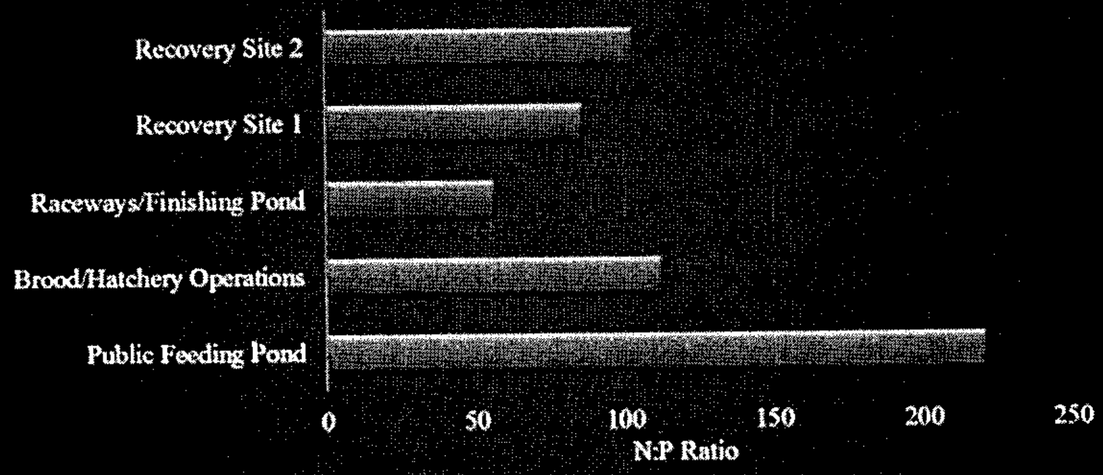
Chemical Attributes: pH at Five Survey Sites



Chemical Attributes: Water Chemistry

Survey Site	*PO_4 (µg/L)*	*Total P (µg/L)*	*NO_3 (µg/L)*	*NH_4 (µg/L)*	*Total N (mg/L)*	*SiO_4 (mg/L)*
Public Feeding Pond	*2.6*	*6.7*	*383.5*	*37.9*	*0.489*	*8.7*
Brood/Hatchery Operations	*9.2*	*13.8*	*692.9*	*56.7*	*0.795*	*9.3*
Raceways/Finishing Pond	*16.1*	*23.9*	*607.8*	*142.5*	*0.793*	*8.6*
Recovery Site 1	*10.6*	*16.2*	*611.6*	*80.2*	*0.722*	*9.3*
Recovery Site 2	*8.8*	*13.7*	*606.3*	*65.4*	*0.701*	*8.4*

Chemical Attributes: N:P Redfield Ratio



Biological Attributes: MacroInvertebrates

Survey Site	*Shredders*	*Filtering Collectors*	*Gathering Collectors*	*Scrapers*	*Predators*	*Totals*
Public Feeding Pond	*33*	*6*	*3*	*16*	*1*	*59*
Brood/Hatchery Operations	*4*	*3*	*33*	*10*	*13*	*63*
Raceways/Finishing Pond	*27*	*11*	*5*	*6*	*0*	*49*
Recovery Site 1	*6*	*31*	*16*	*3*	*14*	*70*
Recovery Site 2	*12*	*1*	*12*	*2*	*9*	*36*
Totals	*82*	*52*	*69*	*37*	*37*	*277*

Results - Top 10 Species

Site 2A

Genus	species	Relative Abundance
Cocconeis	*pediculus*	65
Diatoma	*vulgaris*	63
Cymbella	*proxima*	53
Staurosirella	*leptostaron*	40
Melosira	*varians*	38
Fragilaria	*vaucheriae*	37
Planothidium	*lanceolatum*	28
Cocconeis	*placentula*	27
Diatoma	*mesodon*	23
Synedra	*vaucheriae*	20

79.0%

Site 2B

Genus	species	Relative Abundance
Cocconeis	*pediculus*	68
Staurosirella	*leptostaron*	53
Fragilaria	*vaucheriae*	42
Planothidium	*lanceolatum*	37
Diatoma	*vulgaris*	35
Cymbella	*proxima*	33
Cocconeis	*placentula*	30
Reimeria	*uniseriata*	27
Melosira	*varians*	25
Diatoma	*mesodon*	23

74.7%

Results - Top 10 Species

Site 3A

Genus	species	Relative Abundance
Fragilaria	*vaucheriae*	157
Cocconeis	*placentula*	55
Tabelaria	*vaucheriae*	53
Encyonema	*prostrata*	42
Synedra	*vaucheriae*	32
Encyonema	*minutum*	16
Planothidium	*lancelatum*	16
Staurosirella	*leptostaron*	15
Gomphoneis	*spp.*	15
Cocconeis	*pediculus*	14

83%

Site 3B

Genus	species	Relative Abundance
Encyonema	*prostrata*	106
Cocconeis	*placentula*	74
Fragilaria	*vaucheriae*	52
Synedra	*vaucheriae*	49
Nitzchia	*fonticola*	35
Staurosirella	*leptostaron*	35
Acnanthidium	*spp.*	33
Cocconeis	*pediculus*	26
Encyonema	*minutum*	20
Gomphonema	*spp.*	13

88.6%

Results - Top 10 Species

Site 4A

Genus	species	Relative Abundance
Fragilaria	vaucheriae	102
Diatoma	erinbergyi	59
Synedra	vaucheriae	50
Nitzchia	fonticula	40
Martyana	martyi	39
Staurosirella	leptostaron	33
Encyonema	prostrata	21
Melosira	varians	17
Gomphoneis	spp.	17
Cocconeis	placentula	16

78.8%

Site 4B

Genus	species	Relative Abundance
Diatoma	erinbergyi	81
Nitzchia	fonticula	79
Fragilaria	vaucheriae	57
Planothidium	lancelatum	47
Encyonema	prostrata	42
Martyana	martyi	31
Synedra	vaucheriae	22
Acnanthidium	spp.	18
Navicula	tripunctata	16
Nitzchia	dissipata	14

81.4%

Results - Top 10 Species

Site 5A

Genus	Species	Relative Abundance
Martyana	martyi	275
Planothidium	lancelatum	58
Diatoma	spp.	49
Amphora	pediculus	26
Navicula	trivialis	11
Diatoma	vulgaris	10
Cocconeis	placentula	9
Staurosirella	leptostaron	8
Nitzchia	fonticola	7
Achnanthidium	deflexum	4

91.4%

Site 5B

Genus	Species	Relative Abundance
Martyana	martyi	442
Diatoma	spp.	11
Staurosirella	leptostaron	10
Cocconies	placentula	8
Planothidium	lancelatum	4
Navicula	trivialis	4
Amphora	pediculus	3
Staurosirella	rhomboides	3
Sellaphora	rexii	3
Encyonema	minutum	3

98.2%

Results - Species Diversity

Site	Shannon Diversity Index
2A	2.859201317
2B	2.941612966
3A	2.560966025
3B	2.501519185
4A	2.749280764
4B	2.671275469
5A	1.809369436
5B	0.444137369

Mood's test finds significant difference in H' when considering all 4 sites ($p<0.05$).

Post-hoc tests to determine which site(s) cause difference are inconclusive.

Northern Lower Michigan:
Oden State Fish Hatchery