The Long Term Effect of Oil Spills on a Class 1 Trout Streams Ecosystem

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Submitted to:
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June 2006

Abstract:

In December of 2003 a 4,550-gallon oil spill on the Fairfield Hills property contained the area and flowed into Deep Brook, a stream that is classified as one of the only eight Class 1 Trout Fishing Areas. A year later in December of 2004, 4,000 gallons of fuel leaked out of a mechanical failure in the Reed Intermediate School into a nearby Deep Brook stream (Rosener). This stream feeds into the Pootatuck River, and the Housatonic, which is a tributary of the Long Island Sound. Although the area was quickly decontaminated, this project was designed in order to evaluate the long-term effects of the oil spill on the stream's ecosystem. A total of 2 sites were selected for analysis, one upstream the oil spill and one downstream. Benthic macroinvertebrates were examined using DEP Bioassessment Protocol, as well as testing soil samples for residual hydrocarbons using single wavelength IR spectrophotometer, and evaluations of water chemistry through nitrates and phosphates using a UV spectrophotometer. Through this testing water quality is shown to go be in poor to very poor conditions. Also, residual hydrocarbons are still present with in the soil downstream, and water nutrients are lower due to the spill.

I. Introduction:

After a total of two home heating # 2 oil spills by Newtown owned property effected Deep Brook stream located in Newtown Connecticut there was a rapid cleanup of the area. Yet the focus of the project was on a long-term effect of these oil spills on the ecosystem of this class 1 trout stream. Therefore through DEP Search Bioassessment Protocol the quality of the water could be determined, and through the residual hydrocarbon absorbency calculations of the streams surrounding soil the effects on the soil of the stream could be determined. Although water chemistry is at times an unreliable variable nitrates and phosphate testing of the water using a UV spectrophotometer would determine the difference in nutrition due to the oil spills. In order to find the difference, upstream of the oil spill was used as a control while downstream was tested in order to determine the long term effects.

"Clean assessable water is important, because we all live within the hydrologic cycle, and any disruptions in this cycle impacts the availability of clean, cold water in the future, which supports the basic life needs of humans and the flora and fauna that share our world"- Joe Hovious (Conservation Chair of Trout Unlimited). Due to this, the state of Connecticut's Water Quality Standards set an overall policy for management of Connecticut's surface and groundwater's in accordance with the directives provided by Section 22a-426 of the Connecticut General Statutes and Section 303 of the Federal Clean Water Act. Through the Quality Assurance Project Plan "each state must monitor, access, and report on the quality of its waters relative to designated uses established by the states water quality standards"(DEP). Part of this report, is through Benthic Macroinvertebrate sampling and other water chemistry reports that are conducted within this project.

The project is extremely important to both environmental groups and local residents for many reasons. The oil spill cost the state thousands of dollars to clean up, and in the future another spill might be even more costly. The location of these specific spills is also extremely relevant, because the effected stream is considered one of the last eight Class 1

Trout fishing areas in the state. This title indicates that the stream's environment is clean enough to maintain the ability for wild trout to naturally fulfill the entire carrying capacity of water. This title places the stream under more rigorous environmental protection regulations. For example, Deep Brook is a catch-and-release only fishing area that does not permit barbed or baited hooks. The Class 1 Trout Fishing Area title is prestigious, but along with this honor, it is necessary that the overall water quality of the stream remains at a high level so that it can continue to support natural trout reproduction. Also, Deep Brook feeds into the Pootatuck River, which is a tributary of the Housatonic River.

In order to determine the long-term effects of the two oil spills, a number of tests will be conducted. Benthic Macroinvertebrate Bioassesment, soil analysis for residual hydrocarbons that could have been left from the oil, and various water chemistry measurements. Out of all the tests that will be used to determine the overall effects of the oil spills, the most complex and informative is the Benthic Macroinvertebrate Bioassesment. Within the Benthic macroinvertebrates Bioassessment, "kick" sampling was tested on one site upstream and downstream of Deep Brook. A "kick" sample is a collection of the insects that are within the river. Although the organisms vary by size and type, most are just large enough to be seen by the naked eye, are located in riffles of the stream, and do not contain a backbone (Voushell). The diversity of the insect families found and the specific types of insect present are indicative of the amount of pollution in the environment and the quality of the water. Certain families of macroinvertebrates are preferred to be found in order to determine good water quality. For example, Ephemeroptera (mayflies) family, Trichoptera (caddisflies), and Plecoptera (stoneflies), are just a few of the macroinvertebrates that have a low ability to tolerate pollution (The Volunteer Monitor). By finding these macroinvertebrates within the water, it indicates that the water is clean enough for these sensitive organisms to survive. This test is demonstrated to be reliable, because there are Department of Environmental Protection standards available for both the fall and the spring, which can be used as a quality index to compare a unique sample. Within this standard, each insect is rated on a scale of 0-10 for its ability to tolerate pollution. The average pollution rating can be used as an indicator for the amount of contaminates in a stream. Through this average pollution rating from the macroinvertebrates that were sorted, analyzed, identified, and calculated by DEP SEARCH protocol standards the long term effects of oil spills on the water was determined.

Another aspect of the experiment is used to determine the presence of residual hydrocarbons within the soil. This is important, because if proven that there is a higher absorbance of hydrocarbons downstream, then the rapid clean up wasn't enough to get rid of the oil with in the soil. This oil could be then affecting the streams surrounding ecosystem and the stream itself. Within this test, Freon was used to extract hydrocarbons from a soil sample, because Freon does not have hydrocarbons in it and will cause accuracy. When Freon was added to the samples, the hydrocarbons within the soil were dissolved and the Freon solution was run through a Single Wavelength IR Spectrophotometer, which detects any hydrocarbons in the sample using a beam of infrared light. Comparing the samples taken from the upstream of Deep Brook (control) and the downstream of Deep Brook then determined the possible difference between the hydrocarbon amounts in the soil.

Maggie Boushell did a residual hydrocarbon analysis 11 months after the first oil spill. The results retrieved for this projects residual hydrocarbon analysis were taken 11 months after the second oil spill. By doing an ANOVA (analysis of variance) between the data retrieved from the first oil spill and the two oil spills combined a better understanding of the residual hydrocarbons of the area will be known. By comparing the variance of upstream to downstream, the combined upstream and downstream, comparison of upstream to upstream, and downstream to downstream from the two sets of data this is conducted.

To investigate the long-term affects following the oil spill of the stream water quality, chemistry testing of phosphates and nitrates was conducted using HACH protocol. This test was to help determine the water chemistry through samples of water at various sites were the Benthic Macroinvertebrate Bioassesment took place. It is important to know the amount of nitrates that are within the water, because those nitrates could affect the Housatonic. Since the Deep Brook leads into the Pootatuck, which then goes into the Housatonic River, a tributary of the Long Island Sound, determining the amount of nitrates in Deep Brook would therefore be important information. Also, determining how the algae are within the stream can be conducted through phosphates. Due to the fact that phosphates are the limiting reagent for the growth of algae this is important. Therefore a difference in phosphates would determine a lack on nutrients that should be present for healthy algae growth within the stream.

II.

Materials

Consumables	Supplies	Equipment
Zip-lock bags	Forceps	Single Wavelength IR
Ethanol	Large jars	Spectrophotometer
Freon	Permanent marker	UV Wavelength
.1 Hydrocholoric Acid	Small shovel	Spectrophotometer
Macroinvertebrate	Medium-sized glass jar with	Stereo Microscope
Dichotomous Key	a screw on top	Freezer
Sodium Bicarbonate	1 mL disposable pipettes	Computer
Buck Scientific Sealed	Mesh or screen filter	Microsoft Excel Software
Standard Cuvettes in Freon	Long-handled canvas	YSI-81 Water Quality
Quartz Cuvette	“Kicking” net	Meter
HACH nitrate standard	Waterproof gloves	
HACH phosphate standard	Waders	
	Large test tubes with tops	
	Large plastic tray	
	Petri dishes	

III. Procedure:

Part I. Residual Hydrocarbon Detection

I. Collection of Soil: Using a small shovel take about 50 grams of soil from water level at both the left and right bank of each site used for macroinvertebrate sampling. Freeze to preserve samples until you are ready to test them.

II. Preparation of the Soil Samples: Measure 10 grams of soil from a sample and place it in a glass jar. Next, add 50mL of Freon and swirl for 2 minutes. Allow the solution to settle. There should be three distinct layers of soil, Freon, and HCl. In order to extract any water out of the sample, now add Sodium Bicarbonate and allow it to react. After a white solid forms, tilt the jar slightly to the side to concentrate the layers and using a disposable pipette draw out the Freon layer and pipette about 2 mL into a quartz cuvette. Repeat with each sample.

III. Using the Single Wavelength IR Spectrophotometer: Allow the machine to warm up for at least 30 minutes. Set the mode to ABS (absorption) and when the light path is clear, calibrate the machine to read .000 with the "100% T" knob. Using the three standards, place one standard in at a time and record the absorbance reading. These three readings will form the standard Curve. Insert the cuvette with the sample in it and record the absorbance from the machine. Repeat with each sample.

IV. Analysis of Spectrophotometer Readings: Using Microsoft Excel, create a plot with the standard curve data on it and allow the program to create a formula for the part per million (ppm) values. Use this formula with your sample values for absorbance to create two columns of data (absorbance and ppm). After that, run a t-test to determine if the data is significantly different and to obtain mean values, as well as a confidence rate.

V. Analysis of Variance: Using Microsoft Excel

Part II: Riffle Dwelling Benthic Macroinvertebrate Bioassessment

I. Collection of Macroinvertebrates ("kicking"): The sample site for Macroinvertebrates of the area must be an appropriate site both upstream and downstream to the oil spill. In order for it to be appropriate it should have a "riffle" and area where the water is constantly moving, and have a bottom, which is accessible. Place the canvas net in the water facing the current, starting at the right bank of the stream. Pick up various large rocks in from of the net and scrub off sediment and particles into net. Then kick at the stream bottom in front of the net to free loose sediment and particles. Empty the sediment into a large plastic bin or tray. Run the sample through a screen or mesh filter to concentrate the contents. Repeat this procedure eleven times, moving diagonally up stream to the opposite bank. Finally, put all the sediment collected in a closed jar and fill the jar with ethanol to preserve the sample. Repeat this procedure at the other sites.

II. Sorting Macroinvertebrates: Pour the sample taken from one site into a clean plastic tray for easy access. Place a small sample of the debris into a Petri dish and dilute with ethanol. Using a stereomicroscope, carefully and systematically scan the contents of the Petri dish for macroinvertebrates. Make sure to look for evidence of a head, leg, eyes or any other body parts, as well as a small case made out of sand grains or tiny pebbles that marcoinvertebrate parts could be found in. When an organism is found, remove it from the sample using forceps and place it in a clean, marked test tube with ethanol. When the sample has been fully scanned, scan a second and third time to ensure that no macroinvertebrates are left in the sample. Record the number of insects you found.

III. Identification of Macroinvertebrates: Choose one sample to work with and pour the contents of the insect test tube into a Petri dish. Choose an organism to identify and using forceps, place it in a second Petri dish with ethanol. Using a stereomicroscope examine the insect and follow the Macroinvertebrate Dichotomous Key to identify the insect's family. Record its family and discard the organism. Repeat this procedure with each organism in the sample and then repeat procedure with other sample sites.

IV. Analysis of Macroinvertebrates: Using the Macroinvertebrate Metrics Key fill in the charts that indicate the families found in each sample. Next, proceed through the metrics key answering and calculating the formulas indicated. Since the samples were collected in the fall, use the Shepaug River as the reference stream and compare values obtained from your sample stream to those published for the Shepaug River to determine the classification for the quality of the environment.

III. Water Chemistry

I. Phosphate and Nitrate testing was done through HACH standard.

II. Be sure that all Phosphate and Nitrate testing is done at the time of Macroinvertebrate sampling, because water chemistry changes easily.

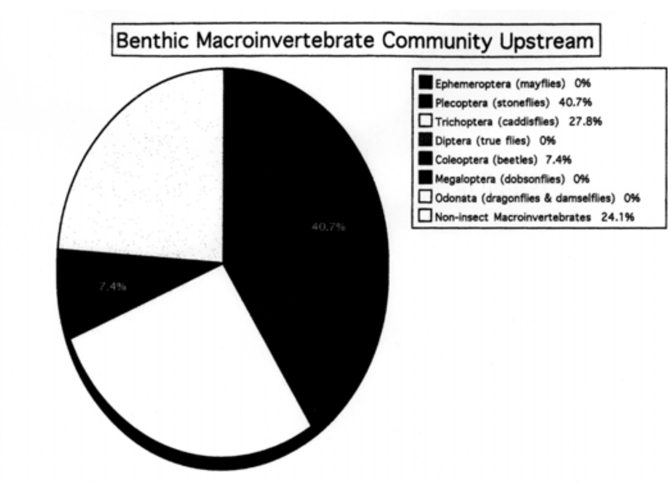
IV. Data

Benthic Macroinvertebrate Bioassesment

Benthic Macroinvertebrate Bioassesment is a procedure that uses insects to indicate quality of an aquatic environment. In this assessment, all the known characteristics of the sample of insects observed are taken into account. These include factors such as total insect population, the diversity of insect families and orders, feeding types of the individual organisms, pollution tolerance and the presence or lack of a dominant family (Boushell).

Figure 1

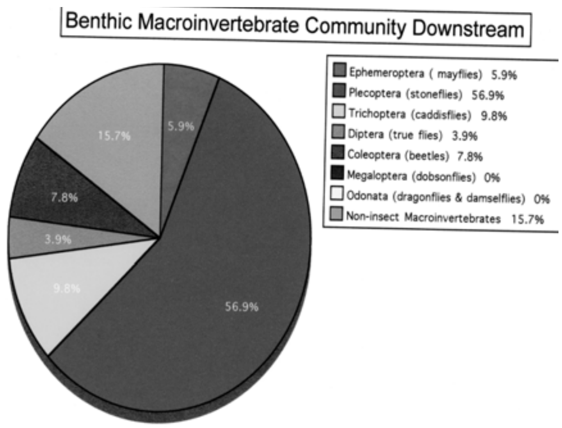
Upstream Macroinvertebrate Bioassesment results



Benthic Macroinvertebrate Bioassesment upstream has a good amount of low tolerant marcoinvertebrates present. This represent the calculated good to very good quality of the water upstream of the oil spills.

Figure 2

Benthic Macroinvertebrate Downstream results



Downstream Macroinvertebrate Bioassesment results indicate that although there are low tolerant families found downstream, there are still a larger amount of high tolerant macroinvertebrates that have caused the change in numerical score compared to upstream.

Figure 3

Bioassesment Criteria

Parameter	600 Shepaug River	Deep Brook Upstream	Deep Brook Downstream
Result comparison to Reference Stream(total points from Deep Brook/total points from reference site)*100%	100%	72.22%	44.44%
Bioassessment	non-impaired	slightly impaired	moderately impaired
Water Quality	excellent	very good to good	fair to poor

Bioassesment Criteria displays the percentage ranges for the environmental qualities and shows the general traits that accompany each of the four labels. Downstream to the spill was rated as moderately impaired and the area upstream to the spill was rated as a slightly impaired environment

Figure 4

Residual Hydrocarbon Results

Upstream Hydrocarbons (ppm)	Downstream Hydrocarbons (ppm)
73.9	129.7
71.9	123.9
65.3	87.3
64.4	77.8
67.7	149.7
64.9	116.3
62.5	124.9
57.2	102
56.8	96.3
	92.7
	129.7
	124

Residual Hydrocarbon results demonstrate the absorbance levels of residual hydrocarbon found upstream and downstream of the oil spills. Upstream there is less residual hydrocarbon absorbance present, while downstream there is more.

Figure 5

Analysis of Variance Results

t-Test: Two-Sample Assuming Equal Variances

	Upstream	*Downstream*
Mean	64.96	112.86
Observations	9	12
t Stat	-6.52	
P(T<=t) two-tail	3.03963E-06	
t Critical two-tail	2.09	

Analysis of variance between the data retrieved by Maggie Boushell after the first oil spill and my data after both spills had taken place at Deep Brook shows similarities and differences. In both sets of data there is less residual hydrocarbon upstream then downstream. There is more residual hydrocarbon upstream this year then there was last year. This could be due to oil run off from the road near the upstream location, or could be an indicator that the oil traveled farther upstream then people were lead to believe.

Figure 6

Phosphate Results

	Absorbance	Concentration(mg/L)
H_2O	.002	
Phosphate Standard	.120	
Upstream Deep Brook	.018	1.35
Downstream Deep Brook	.007	.42

Although water chemistry is not as informational as Macroinvertebrate Bioassesment and Residual Hydrocarbon testing since water chemistry changes, it still demonstrates that there is downstream then upstream. It is only a small difference (ppm), but still could be affecting the algae since phosphates are the limiting reagent of algae.

Figure 7

Nitrate Results

	Absorbance	Concentration(mg/L)
H_2O	.001	
Nitrate Standard	.039	
Upstream Deep Brook	.111	28.9
Downstream Deep Brook	.096	25

Nitrate results demonstrate the lack nitrates downstream of the oil spill compared to the nitrates upstream of the oil spill.

V. Conclusion

In conclusion, the class one trout stream's ecosystem has been affected by the two oil spills. Residual Hydrocarbons have are more present downstream then upstream. This therefore leads to residual oil within the soil of Deep Brook that could be affecting the stream's ecosystem. Through Macroinvertebrate sampling, it was determined that due too less intolerant macroinvertebrates were present downstream of the spill. Macroinvertebrate sampling shows that upstream Deep Brook is slightly impaired, but moderately impaired downstream. While upstream Deep Brook compared to the 600 Shepaug River Standard for the fall has a difference of approximately 28%, while downstream there is a difference of 56%. The water from the oil spills upstream at a water quality of very good to good has been unfortunately dropped to a fair to poor water quality. Phosphate and nitrate sampling has also shown a difference upstream and that of where the oil spills were located downstream. Although there is a lack of nitrate and phosphate downstream, the difference is so insignificant and small that determining the effect of the oil spills just on the phosphate and nitrate testing would be inaccurate. This is also true, due to the fact that water chemistry easily changes. All together with macroinvertebrate sampling, residual hydrocarbon testing, and other water chemistry tests, Deep brook has been affected negatively due to two oil spills in Newtown, Connecticut. Although the spill has affected the class 1 trout stream, and the quality of water is not where it is to be preferred the water seems to be repairing itself nicely. This is true, due to the fact that although not a lot of intolerant macroinvertebrates are located downstream there are still some.

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