PART 9: The Chemical and Biological Quality of Streams.

[extracted from the Farmscape Ecology Program's 2006 report entitled **The Flora & Fauna of Some Columbia County Farms: Their Diversity, History and Management**]

Introduction

Farming and water interact in numerous ways. In the United States, there has been a strong emphasis in recent decades on the effects of agriculture on water quality. The reverse is more rarely explored, except in terms of simple water quantity. Farming can influence water quality in at least four general ways:

1) by affecting nutrient levels in the water
2) by altering physical conditions (e.g., amount of sediments, temperature, current)
3) by introducing toxins
4) by introducing new organisms (e.g., fecal bacteria)

Our central interest here is not so much in the details of these effects as in their consequences. In other words, What have these alterations meant for the native species living in our region's streams? Based on our own, limited work at Hawthorne Valley, we conclude that the results have probably been mixed with some species benefiting and others suffering. A central issue therefore becomes identifying which species are affected and considering the value of their conservation.[1]

Study Methods

Our data set is extremely limited geographically. The vast majority of data come from Hawthorne Valley Farm. However, on that farm we have conducted a standardized, multi-faceted sampling regime designed to describe the Farm's impact on stream water quality.

We chose sampling five points located at stream entry and exit points at Hawthorne Valley. See Figure 9.1. Each of these points was visited during May, July and September.

At each point, we ran simple water chemistry analyses (temperature, dissolved oxygen, pH, alkalinity, phosphorus, and nitrate nitrogen). The first four are basic descriptors of the aquatic environment (alkalinity is a measure the of water's ability to buffer acidic additions). Phosphorus and nitrate are two of the most common forms of nutrient pollution caused by farms. Because naturally low levels of these nutrients sometimes limit algal and plant microbial growth in water, their additions can bring about markedly enhanced growth of these organisms. This process, whereby the ecology of aquatic environments undergoes a shift towards more luxuriant growth of some organisms due to fertilization, is called *eutrophication*. While some organisms thrive, others suffer. Although the increased algae and plant life can enhance oxygen production during the daylight hours, the respiration of these organisms at night and of the decomposers at all times can result in net shortfalls of oxygen which threaten fish populations. Water chemistry was evaluated using a Hach portable colorimeter with the kind assistance of Leanna O'Grady of the Columbia County Soil and Water Conservation District.[2]

We also measured the growth of colliform bacteria using Micrology Lab's membrane-filtration colliform test kit. Colliforms are a group of bacteria commonly found in the mammalian gut. While most are innocuous, a few are pathogens, and in any case, their presence is taken as an indicator of fecal contamination. Common routes of contamination are the entry of cow manure or septic tank leakage.

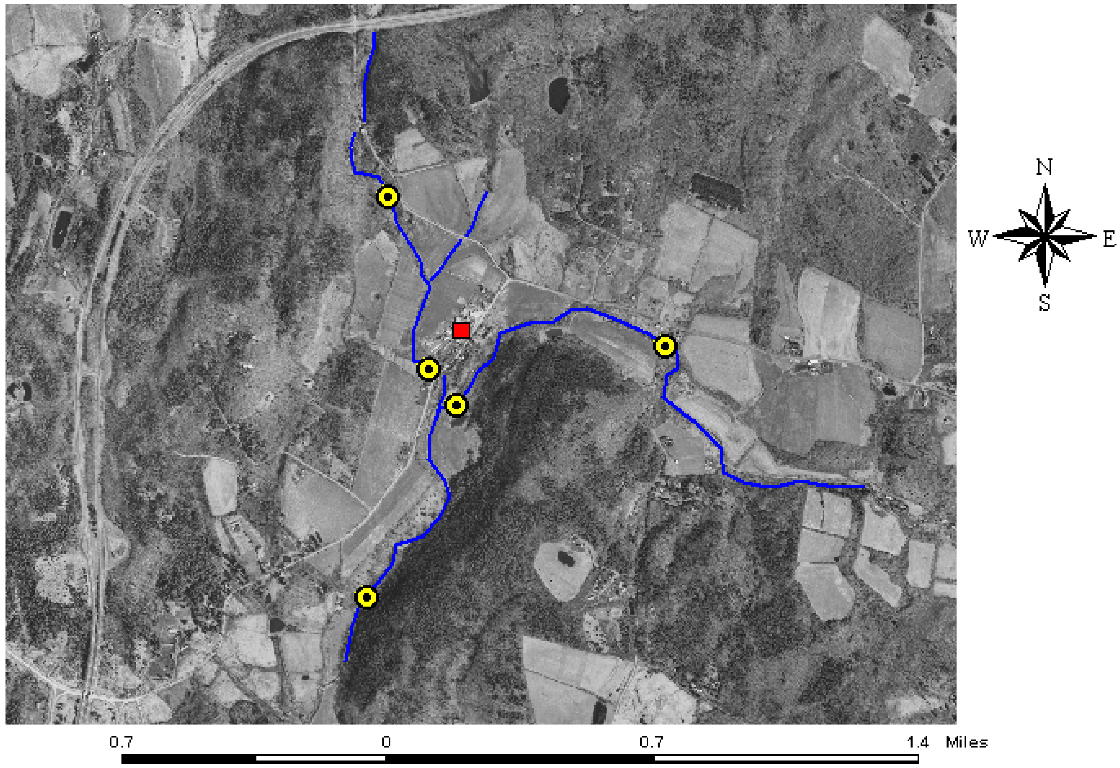


Figure 9.1. Sampling points (dot-in-yellow circles) at Hawthorne Valley. Approximate location of Hawthorne Valley Barn is shown by red rectangle. The streams all flow towards the bottom of the picture.

We also looked at the diversity and abundance of three different groups of animals as a way of assessing water quality in terms of what can live in it. Such an approach is called *biomonitoring*. While less precise than chemical measurements, this approach has several advantages: it does not rely on testing for a particular, sometimes unknown, chemical; it detects *effects* rather than causes (effects are often more enduring or obvious and, hence, easier to catch); and it generally has more public appeal (the fate of fish or frogs generally grabs the attention more readily than fluctuations in obscure chemical concentrations). The basic logic involves identifying an “ideal” biological community, which is a scientific best guess about what would live in a pristine stream. The observed community is then compared against this ideal in order to assess relative degree of alteration. Often certain species or groups of species are found to be particularly sensitive, and their abundances are a key component of the evaluation.

The groups that we assessed were aquatic macroinvertebrates, salamanders, and fish. “Aquatic macroinvertebrates” are the insects, small crustaceans and other small, backbone-less animals that live in streams. “Macro” refers to the fact that we counted only those organisms visible to the naked eye. Many of these are the aquatic larvae of terrestrial insects, such as dragonflies, mayflies, and black flies. We assessed these using a protocol developed by the Hudson Basin River Watch, a non-profit organization dedicated to assessing the quality of stream and river waters in the Hudson Valley. Its approach parallels that used by the New York State biomonitoring program. Because the State has used this approach in its work, there is a relatively rich database of historical and geographic data. The field methods involved “kick-trapping” in which a hand-held, specially-designed mesh netting is held down-stream from one’s feet as one does the “stream shuffle”, scuffing the stream bottom so as to dislodge macroinvertebrates. These samples were returned to the lab where a subsample was taken and all organisms within that subsample were identified to the level of major taxonomic group (Order). Samples were not preserved, and the organisms, many of which were usually still alive, were returned to the stream. Working with live samples was more appealing to those who helped us and gave us insights into how these organisms live.[3]

Two indices (the "biotic index" and "percent model affinity") were calculated from the insect tallies – one is based upon the average pollution tolerance of the individuals in a given sample, and the other upon the similarities, in percent composition, between an actual sample and an ideal, pristine community. In both cases, certain ranges have been deemed to indicate non-impacted, slightly impacted, impacted and severely impacted waters. Of course, the precise cut-off points are somewhat arbitrary. However, taken together, the readings from our numerous samples can give us hints about our general water quality.[4]

Salamanders have not been so explicitly used in biomonitoring, but as noted in the preceding chapter, amphibians in general, perhaps because of the relative permeability of their skin and their complex metamorphosis, appear to be particularly sensitive to environmental conditions. Stream salamanders are an ecological grouping that includes those salamander species which live most of their lives in and about streams. The two species which we found in our area were Two-lined Salamander and, more rarely, Dusky Salamander. In most cases, the gilled larvae were found in the water, while the mature adults were found on-shore nearby. We used a simplified version of survey methods established by the US Geological Survey. We established 45-foot transects along the stream shoreline and flipped the rocks that were 3 feet on either side of the shoreline. We counted the number of rocks we turned over and the numbers of salamanders found in the process. For each sampling period at each site, we derived two statistics: "salamanders per rock turned in the water" and "salamanders per rock turned on land". During the census, salamanders were caught and kept in a bucket to avoid double-counting; they were returned to their habitat at the end of each census. New York State has completed a "Herp Atlas" describing the distribution of reptile and amphibian species within the State; however, we found no readily comparable data on stream-salamander *abundance* from the region.[5]

Fish do have a relatively long history of being used in biomonitoring, stemming from work done by a scientist named Karr in the 1980s. He derived an Index of Biological Integrity (IBI) from looking at fish diversity in sites of known water quality. In our area, the sensitivity of this index is limited due to the relatively low diversity of our stream fish community. However, there are published studies applying this approach to cold-water streams of Vermont, where fish diversity is similar to ours. We captured fish using a 16-foot bag seine with ¼-inch mesh. Whenever possible, fish were counted live and returned to the stream. To facilitate this we constructed a small, portable viewing aquarium and assembled a photographic guide to the live fish of our streams (see Appendix 7). Such a guide was necessary because the coloration of fishes differs radically based upon whether they are viewed in or, as is most commonly the case, out of the water. It was difficult to standardize effort due to variation amongst sites in water depth, current speed, bottom conditions, and amount of in-stream debris. So, while we did do some counting, in our final analyses we used only presence or absence of a given species. A few specimens were killed and preserved to assure proper identification. Dr. Bob Daniels, New York State ichthyologist, provided key help with identification.[6]

To provide a broader context, we mapped the county-wide distributions of each species we captured during our own work. These data, many of which go back to excellent, state-wide work done in the 1930s and 40s, were helpfully provided to us by Douglas Carlson, New York State DEC's rare-fish specialist.

Below, we will first present our results for each of these measures and then consider their overall implications. In most cases, we have only very limited data from other farms. We will mention what we do have, but will not undertake any broad descriptions.

What We Found

Water Chemistry

The graphics (Figures 9.3 and 9.4) below summarize our findings for Hawthorne Valley Farm nitrogen and phosphate measurements. Appendix 8 provides a complete tabular report of the results.

Nitrogen fertilization of our streams was detectable but relatively slight. Nitrogen levels (measured as the amount of nitrogen present in the two most common dissolved nitrogenous compounds – nitrate and nitrite) ranged from 0.17 to 1.05 parts per million (ppm). Natural levels in New York are thought to be less than 1.0

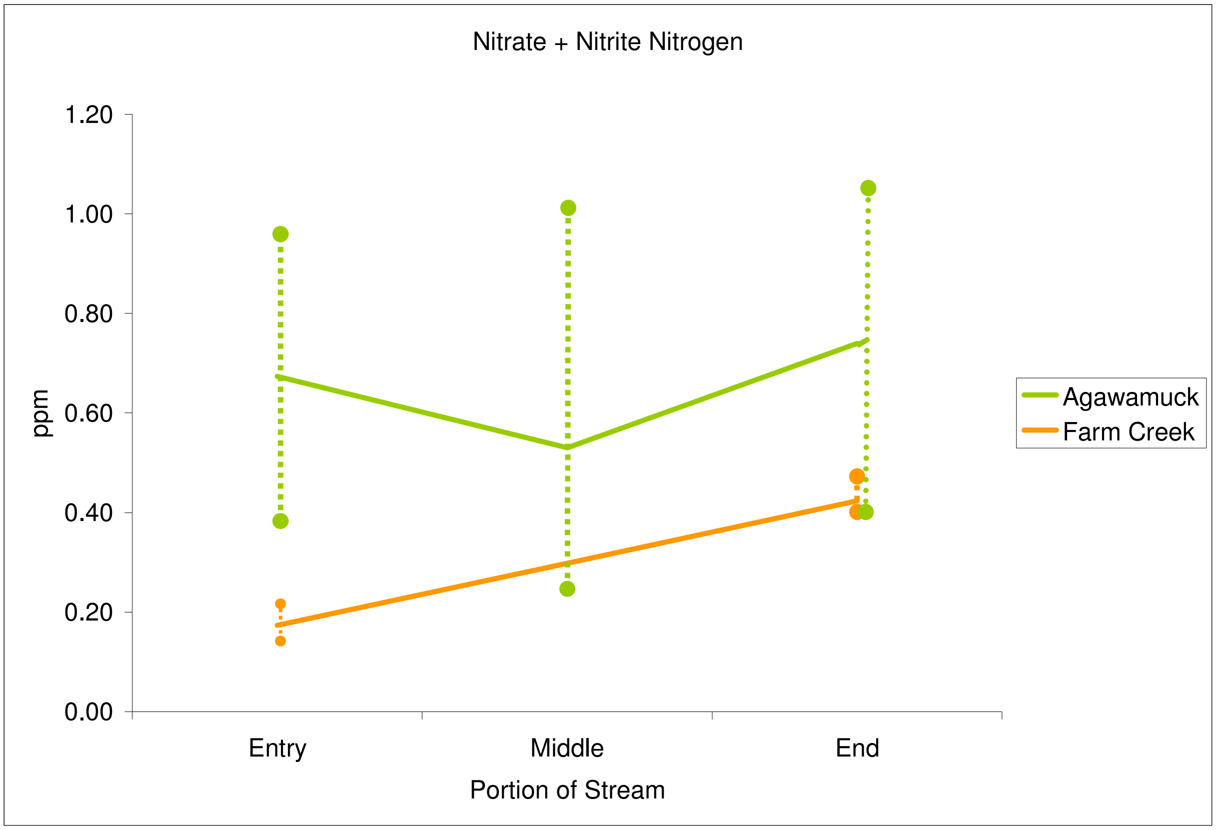
ppm. Nitrate values at or above 1.0 ppm were found only in July samples when water entering the Farm along the Agawamuck was already at .96 ppm and increased steadily to 1.05 ppm upon exiting the Farm. As the Farm Creek waters had only around .50 ppm when they entered the Agawamuck, most of this high level is probably attributable to upstream activities. While nitrogen values in the Farm Creek were low, they increased from entry to exit in all three seasonal samples, meaning that there was consistent nitrogen enrichment as the waters passed through our fields. Compared to nitrate nitrogen readings from elsewhere in the Hudson Valley, our readings were low to medium in value (Figure 9.5). A nitrate nitrogen level above 10 ppm is not permissible in drinking water; none of our readings ever approached this.[7]

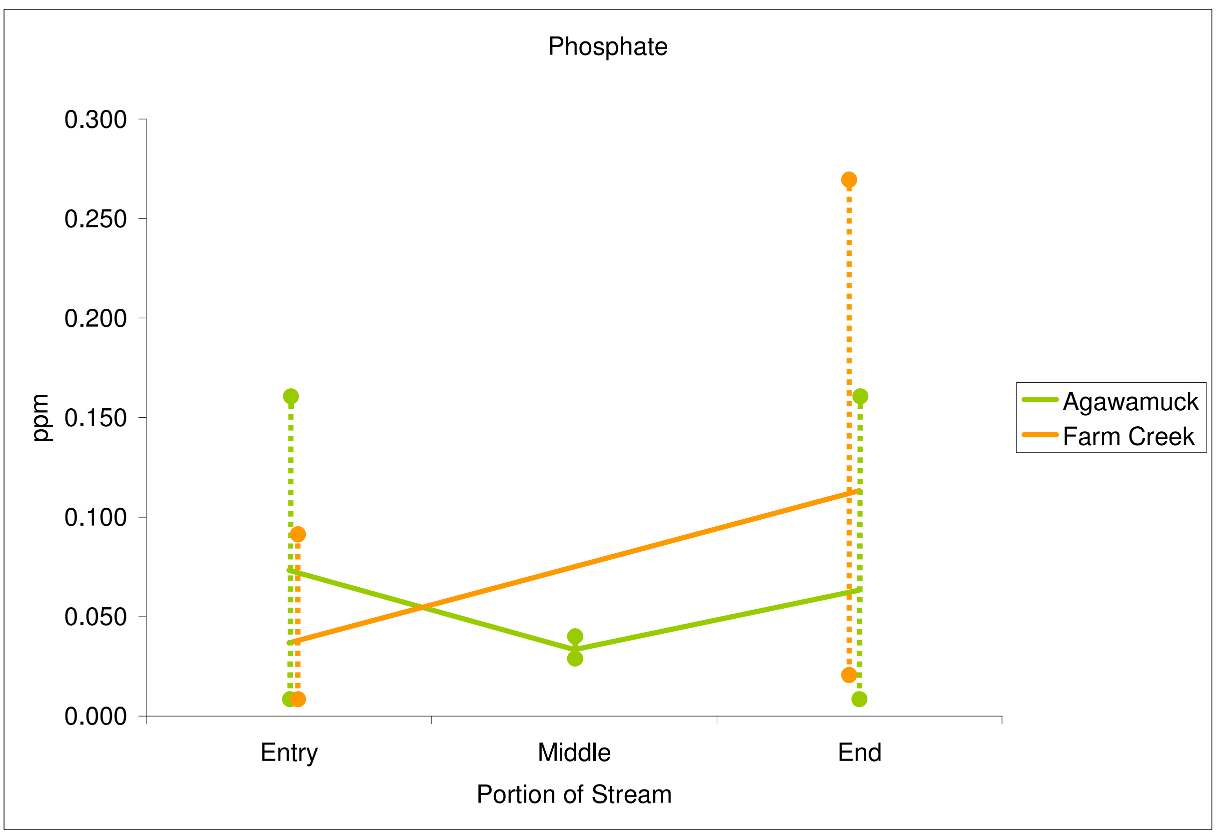
Phosphate levels did not show consistent patterns along the Agawamuck. They did, however, consistently increase from the beginning to the end of the Farm Creek. Values at the entry ranged from 0 to .09 ppm; values near the end of the Farm Creek (i.e., shortly before it joined the Agawamuck) were from .02 to .27 ppm. Background levels of phosphate are estimated at around .05 ppm. Readings in our streams regularly exceeded this with the maximum value being the .27ppm recorded in July at the end of the Farm Creek. In other words, while the highest nitrate pollution seemed to be associated with upstream inputs on the Agawamuck, the highest phosphorus contamination seemed to occur on-farm. Further, it would appear that, relative to accepted backgrounds, Hawthorne Valley's phosphorus run-off is a greater problem than that of its nitrogen. (Only two nitrate-nitrogen measurements reached or exceeded the background of 1.0 ppm; six of our phosphate measurements reached or exceeded the .05 ppm background). Relative to readings from elsewhere in the Hudson Valley (Figure 9.5), our phosphorus readings were mostly low, with one reaching medium levels.

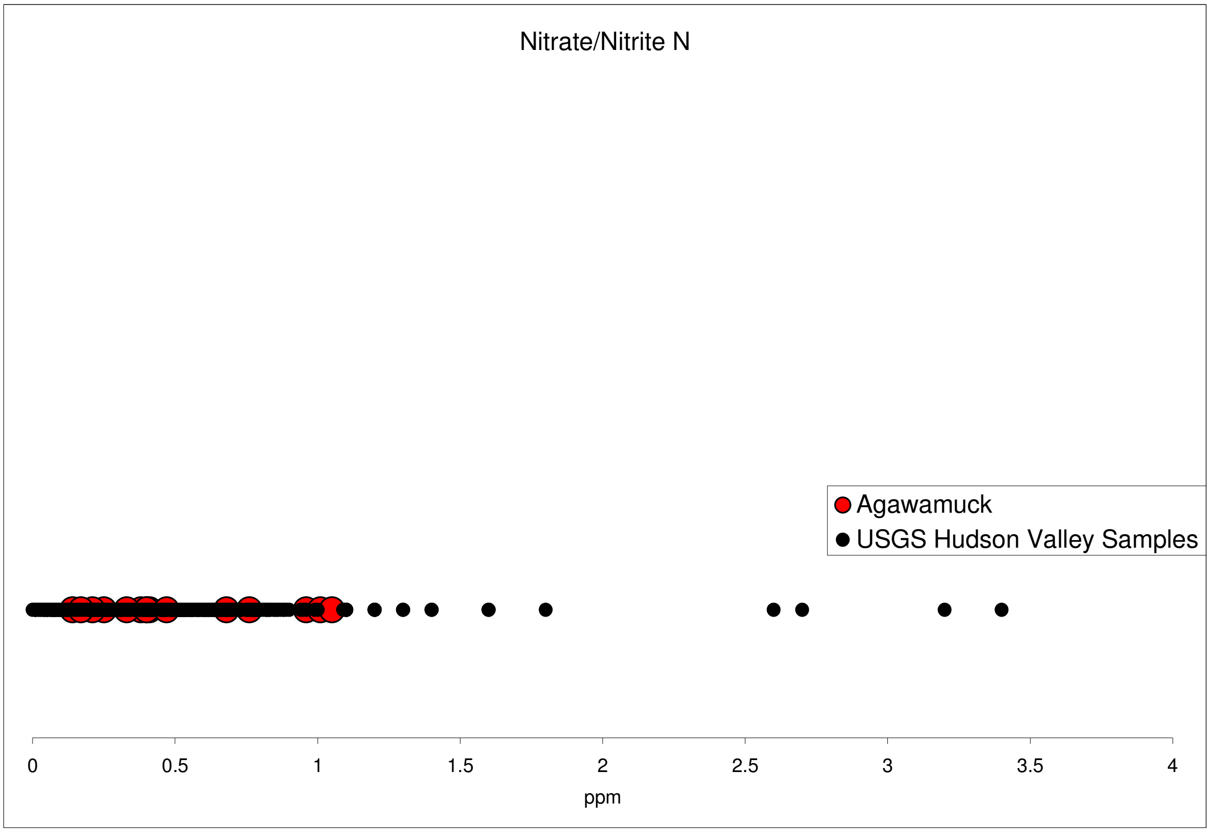
For some downstream perspective, measurements taken in July where the Agawamuck flows through The Farm at Miller's Crossing showed nitrate-nitrogen levels of 1.44 ppm (higher than any measured at Hawthorne Valley) and phosphate levels of .21 ppm (near our maximum observed values at Hawthorne Valley). We have no idea what if any of this enrichment occurred on the Farm at Miller's Crossing itself; most may well have come from up-stream.

Phosphorus, rather than nitrate, seems the more potent fertilizer of aquatic systems. The growth of algae, for example, is often reported to be limited by available phosphorus. Thus, the ecological impact of phosphorus enrichment is often more marked than that of nitrogen, and indeed, algal growth was often apparent along the stream bottoms at Hawthorne Valley. From an agricultural standpoint, low soil phosphorus in Hawthorne Valley has prompted farmer efforts to import phosphorus. At the same time, we appear to be losing measurable amounts to run-off. Phosphorus conservation efforts might thus be appropriate for both ecological and agricultural reasons.

The only consistent pattern in microbial counts was for total, although not necessarily coliform, bacteria to increase across the Farm Creek. Surprisingly, relatively high counts were found in the middle Agawamuck in Spring; these probably do not come from Hawthorne Valley Farm activity, but rather from upstream contamination and, possibly, septic system leakage. Safety limits have been derived for total coliform bacteria, although there is disagreement given the benign nature of many coliforms. For drinking and swimming, values between 2500 to 5000 counts per 100ml for total coliforms are set by the State as upper limits. Four of our readings exceeded 2500 counts/100ml. More meaningful measurements come from counting *E. coli* colonies, because these are the coliform bacteria that most often cause illness. However, we did not gather good data on this group.


Nitrate + Nitrite Nitrogen
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ppm
Entry
Middle
End
Portion of Stream
Agawamuck
Farm Creek


Phosphate
0.300
0.250
0.200
0.150
0.100
0.050
0.000
ppm
Entry
Middle
End
Portion of Stream
Agawamuck
Farm Creek



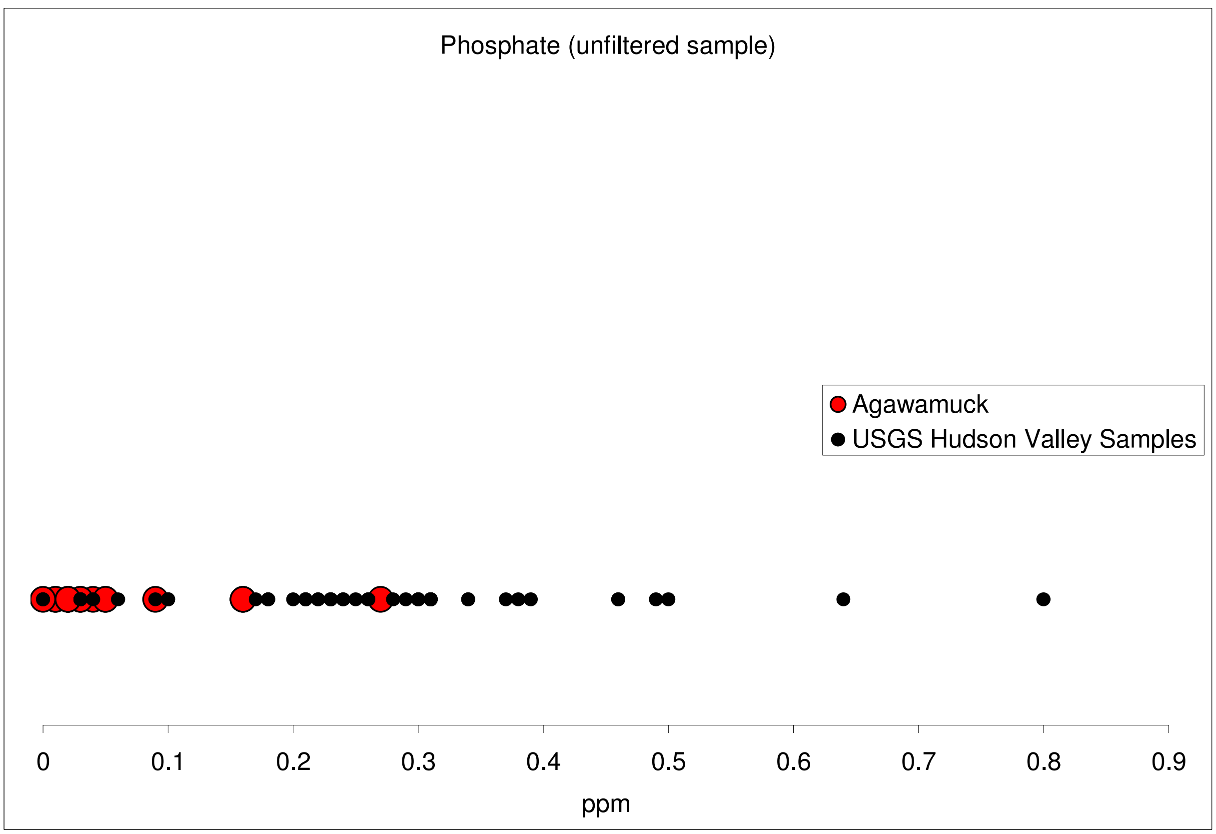


Figure 9.2-.5. Nitrate/Nitrite Nitrogen and Phosphate values recorded in the Agawamuck and also (bottom two figures) other places in the Hudson River watershed. In the figures on page 67, mean values for the three sampling periods (May, July, September) are connected by solid lines, while the dotted lines show the range of values around each mean. In the lower two figures, we have plotted our measurements together with those of other Hudson Valley waterways for context.

Measurements of pH, temperature, alkalinity, and dissolved oxygen varied seasonally, but showed few obvious geographic patterns (see Appendix 8 for individual values). The Farm Creek was roughly 2-3 ^{o}C warmer than the Agawamuck, but there was no measurable warming as the water crossed the Farm. The difference was most likely due to the warming of the waters in Acker Pond or other upstream, open wetlands. Dissolved oxygen levels were generally lowest in mid-summer, although we did have an anomalous (erroneous?) reading of 3.1 mg/L from the central Agawamuck in September. Nonetheless, values were usually above the 6.0 mg/L recommended for trout streams. In Autumn, when trout breed, most values were above the 7.0 mg/L recommended for trout spawning. Because of daily fluctuations in plant production of oxygen, dissolved oxygen levels can vary greatly during a 24-hour period; we did not attempt to follow daily variation, and so our conclusions are weak. Alkalinity ranged from 44 to 72 ppm and was consistently higher in the Agawamuck. Alkalinities above 20 ppm are thought to render streams relatively insensitive to acid rain. High alkalinity, measured as a water's ability to buffer acids, is most often attributed to the presence of carbonate or bicarbonate ions. These ions, in turn, are usually derived from limestone. Lakes located on granite, for example, tend of have low alkalinity and high susceptibility to acid rain. Columbia County geology includes a smattering of limestone, and it is likely that this contributes to our relatively high alkalinity and near neutral pHs (6.6-7.8). Our streams are probably adequately buffered against acid rain. In sum, none of these values indicate obvious problems.

The aquatic insects and their kith which live in a creek can tell you about the health of those waters. However, rather than being a clear good/bad signal, the results are more often simply suggestive descriptions, especially when the waters are only slightly impacted. According to our two different indices based on macroinvertebrates, our streams ranged from non-impacted to slightly impacted. Our general conclusion would be that the aquatic invertebrates were reflecting waters that, as we have already seen, are somewhat nutrient enriched, but that may be without other major problems. A more rigorous, but geographically and temporally limited, assessment done by Kelly Nolan of Hudson Basin River Watch reached a similar conclusion for the waters behind Hawthorne Valley School. In general, we found ample examples of the relatively sensitive mayflies, stoneflies, and caddisflies, including especially sensitive families within those groups such as the "roach-like stoneflies" and the "giant stoneflies".

The relationship between stream salamanders and water quality has not been as thoroughly studied as that between water quality and invertebrates or fish. The vast majority of the salamanders which we encountered during our stream surveys were Two-lined Salamanders. These are considered to be relatively tolerant, widespread species, yet their number is thought to be useful in separating colder, headwater streams from other streams which, for natural or human-caused reasons, are warmer, slower moving and/or temporary. This species exists as an aquatic larvae for 2 or 3 years before becoming terrestrial, whereas the Dusky Salamander (the other species which we found) lays eggs on wet ground and develops quickly so that it does not need perennial flow. Aside from needing perennial flow, the Two-lined Salamander lays its eggs on the undersides of objects in the stream, such as rocks; high siltation might thus reduce available egg-laying sites. In our region, at least, the Dusky Salamander seems the rare species. Perhaps this is because it reportedly favours slightly lower streams, ones that may have been more radically altered by past human action. Hudsonia states that the Dusky Salamander is more sensitive to stream alteration, although it may be that the relative sensitivities vary depending upon the specific impacts being considered.[8]

In any case, our results, showing markedly higher numbers of salamanders along the Agawamuck, would suggest that at least in terms of water flow and habitat structure, this is perhaps closer to a natural headwater stream. The occasional presence of Dusky Salamanders along both the Farm Creek and the Agawamuck is taken as a positive sign. However, to build perspective, the exploration of other sites around the County is needed.

Fish

The results of our fish work are perhaps best understood by highlighting what the presence of each species implies about aquatic habitat quality. Quite a lot of work has been done to design aquatic health indices based upon fish; as a result, the relative sensitivity of each species has been determined. Table 9.1 lists the species we have found and summarizes their sensitivities based upon published studies. The photographic guide in Appendix 7 illustrates most of these species, along with maps of their known distribution in the County.[9]

Table 9.1. Classification of the fish caught during our preliminary surveys. In parentheses we give the literature-derived judgments of the sensitivity of each species to habitat alternations. "Tol." = tolerant; "semi-Sens"= semi sensitive; "Sens." = sensitive.

Order: Cypriniformes

Family: Cyprinidae

Golden Shiner – *Notemigonus crysoleucus* **(Tol.)**

Common Shiner – *Notropis cornutus* **(semi-Sens.)**

Spottail Shiner – *N. hudsonius* **(semi-Sens.)**

Fathead Minnow – *Pimephales promelas* **(Inroduced; Tol.)**

Bluntnose Minnow – *P. notatus* **(Tol.)**

Eastern Blacknose Dace – *Rhinichthys atratulus* **(Tol.)**

Longnose Dace – *R. cataractae* **(semi-Sens.)**

Creek Chub – *Semotilus atromaculatus* **(Tol.)**

Fallfish – *Semotilus corporalis* **(Sens.)**

Family: Catostomidae

Longnose Sucker – *Catostomus catostomus* **(semi-Sens.)**

White Sucker – *C. commersoni* **(Tol.)**

Order: Salmoniformes

Family: Salmonidae

Brook Trout – *Salvelinus fontinalis* **(Sens.)**

Brown Trout – *Salmo trutta* **(Introduced; Sens.)**

Order: Perciformes

Family: Centrarchidae

Pumpkinseed – *Lepomis gibbosus* **(Tol.)**

Bluegill – *L. macrochirus* **(Inroduced; Tol.)**

Largemouth Bass – *Micropterus salmoides* **(Introduced; Tol.)**

Family: Percidae

Tessellated Darter – *Etheostoma olmstedi* **(Tol.)**

Order: Scorpaeniformes

Family: Cottidae

Slimy Sculpin – *Cottus cognatus* **(Sens.)**

It would, of course, be exciting to follow the history of these species over the past, say, 300 years. However, in most cases we do not have the historical data to permit this. The earliest European accounts are often general, and certain determination of the species referred to is often difficult. Works of the 19th century, with some exception, focus on identification and give only a rudimentary idea of distribution and abundance. In both cases, the lion's share of the information is about prominent food fish; relatively little pertains to minnows and the like. The New York State biological surveys of the 1930s and 40s were the first attempt within the State to systematically describe the distributions of the more "obscure" stream fish. Additional sampling has occurred since then, although not in the systematic fashion of those early surveys.[10]

The county-wide distribution maps of these species suggest four general groupings of our stream fish: *Ubiquitous Species* – those basically found throughout the County; *Lowland Species* – those found most commonly in the western, Hudson-Valley half of the County and in the Harlem Valley; *Upland Species* – those found most commonly in the hillier, eastern portion of the County; and *Foothill Species* – those found where the larger valleys abut the hills, but not extending up into those hills. These are subjective, short-hand categorizations of the fish distributions; they describe occurrence patterns in the County, rather than widespread, ecological generalities. Examples of the four distribution patterns are illustrated in Figure 9.6.

In terms of judging the ecological effects of agriculture in the County, we can only speculate. The common lowland and ubiquitous species would, by implication, appear to have a relatively high tolerance for the agriculture which has influenced much of larger valley bottoms for the past three centuries. Upland species may be the ubiquitous species that were not tolerant of agriculture and/or species which require the headwater environmental conditions found in the higher hills. The Foothill species could, likewise, be sensitive lowland species which now only survive on the less-heavily worked margins of those lowlands or species which require environmental conditions specific to the "foothills". To explore this in more detail, we summarized our classification in Table 9.2, and then considered published information on the individual ecologies of each species.

Table 9.2. Species captured during our surveys categorized according to their distribution patterns. Species in green, bold type have been categorized as "sensitive" in the literature; species in green, regular type have been classified as "semi-sensitive", while those in standard black type were described as "tolerant".

Ubiquitous	Lowland	Upland	Foothill
Common Shiner	Bluegill	**Brook Trout**	Bluntnose Minnow
Creek Chub	**Fallfish**	**Brown Trout**	Fathead Minnow
Eastern Blacknose Dace	Golden Shiner	**Slimy Sculpin**	Longnose Dace
White Sucker	Largemouth Bass		Longnose Sucker
	Pumpkinseed		
	Spottail Shiner		
	Tessellated Darter		

The Upland Species are all sensitive coldwater sorts. Agriculture or other developments have no doubt affected them where the canopy has been opened, flow slowed, siltation increased or water quality impaired in some other way. However, they may never have been especially common in the larger, warmer river valleys.

In contrast, at least two of the "Foothill Species" (the Longnose Dace and Longnose Sucker) may have formerly been more widespread. These species are reportedly fond of slower, warmer waters, and yet are sensitive to deteriorations in these larger streams and rivers. Their peripheral distribution may illustrate the relicts of populations that were formerly more widely distributed across the lowlands. Bluntnose and

Fathead Minnows, on the other hand, seem to be hearty species, and their apparent “Foothills” distributions may be related to effects other than exclusion from bigger streams.

As we have already discussed, “Ubiquitous” and “Lowland” species would appear to be relatively little impacted by agriculture.

There are at least five species of stream fish which we have not yet caught in our surveys, but which others have caught in the County and whose regional statuses suggests they are suffering due to declining stream quality: Eastern Silvery Minnow, Creek Chubsucker, Northern Hog Sucker, Bridle Shiner and Satinfin Shiner. These are generally species of the larger, warmer, and slower valley streams. They have been reported to be declining in New York and/or adjacent areas, often due to siltation or water pollution.[11]

Several of the species discussed above have apparently declined due to reduction in stream quality. At least some of this deterioration may have been due to past and current agricultural impacts. Increased siltation, as can be caused by soil erosion, probably has reduced the habitats available to some of these species. Pesticide contamination and nutrient run-off may have also had impacts. The opening of stream banks and the straightening and clearing of stream channels has probably also reduced habitat quality. Housing and commercial development along streams has probably had some of the same effects, with the addition of stream and river damming for private ponds or power production. The 1930s DEC fish surveys make frequent mention of the impacts of raw sewage contamination of streams and of toxic industrial effluent. Runoff from road ways and acid rain may have also reduced water quality. In most cases, it may not be possible to isolate the impacts of these various effects. However, at the same time, it is apparent that there is reason to encourage any activity which reduces contamination of streams. On farms, perhaps the single most important management action would be to allow the revegetation of stream banks, this can not only restore in-stream habitat complexity (as streams are allowed to wander somewhat and as debris accumulates) but also such buffers can help intercept the run-off of soil, nutrients and agrochemicals before they reach the streams.[12]

<u>Summary of Hawthorne Valley Conditions</u>.
Our stream waters show definite evidence of agricultural influence. At least during some times of year, the main branch of the Agawamuck enters farm property with a substantial nutrient load. It does not improve during its travel through our property. However, because of the abundant forest cover and clear waters, aquatic habitat generally seems fairly good along this stretch. The Farm Creek showed more distinct impacts, perhaps because it travels partially through open fields and because we assessed it right where it left the core of the Farm. Nutrients, especially phosphate, and bacteria consistently increased across Hawthorne Valley property; aquatic invertebrate counts, low salamander levels, and reduced fish diversity suggest there may have been faunal consequences. While none of the measured nutrient or microbial levels is extreme, the measurements are elevated. The relatively high phosphate run-off would suggest that manure is being deposited directly into streams or is leaking in from above-ground sources. (Once in the soil, phosphate leakage is normally slight, and so compost that has been incorporated into fields is unlikely to be a major source).

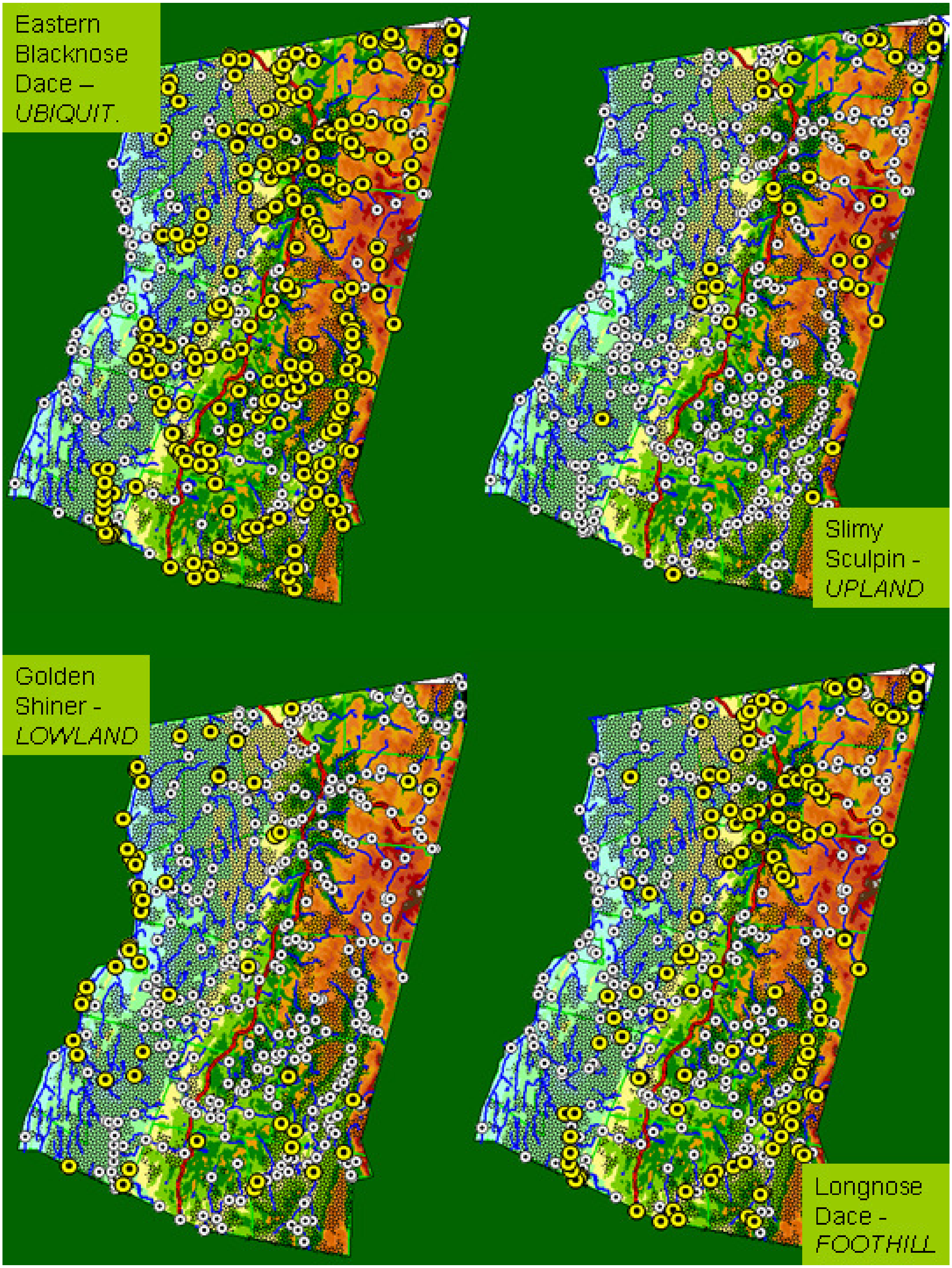


Figure 9.6. The distribution of fish in the County based upon DEC-supplied historic data and illustrating our four distribution categories. Background colors are elevation, the lowest land is to the west along the Hudson. Stippled areas are Agricultural Districts. Yellow dot-in-circles indicate sampling sites where the given species was found; smaller, white dot-in-circles show sampling sites where the fish was not caught. The Thruway and Taconic State Parkway are shown with red lines.

Management Ideas
Again, recommendations would focus on revegetating stream borders where possible and restricting the access of cattle to streams (mainly because the more available access there is, the more likely a cow will defecate in a stream). This restoration work has already begun, and a major portion of the exposed Farm Creek is already into its first year of regrowth. Any farming technique that reduces input of nutrients and agrochemicals would also be beneficial.

Both locally and at the County level, piecemeal efforts can go only so far. For example, improvement in Agawamuck water quality will depend, at least in part, on efforts made by farmers and other landowners upstream and downstream of Hawthorne Valley.

Footnotes

1- There are numerous publications considering the details of the interaction between farming and water quality. A general overview is available in the National Academy of Science's book (1993) *Soil and Water Quality: An Agenda for Agriculture* by the Committee on Long-Range Soil and Water Conservation Policy, National Research Council. This publication is available for on-line viewing at (http://www.nap.edu/books/ 0309049334/html/). The best source for more specialized regional information appears to come from USGS's National Water Quality Assessment Program. The various reports available for the Hudson River watershed can be downloaded at http://ny.water.usgs.gov/htmls/ pub/nawqaweb/report.html.

2- A good survey of the issue in relation to nitrogen and phosphorus enrichment in the United States can be had in Carpenter et al's 1998 paper entitled "Nonpoint pollution of surface waters with phosphorus and nitrogen" in *Ecological Applications* 8: 559–568.

3- There are two main sources for information on aquatic macroinvertebrate biomonitoring in New York. One is New York State DEC's Stream Biomonitoring Unit (http://www.dec.state.ny.us/website /dow/bwam/sbu.html); they have published numerous regional reports, hard copies of which are available upon request. The other is Hudson Basin River Watch, a network of volunteers who are using macroinvertebrate biomonitoring to evaluate Hudson River conditions. Their guidance document provides detailed instructions on field and analysis techniques and is available at www.hudsonbasin.org/ HBRWGD04.pdf.

4- Analyses are described in the *Hudson Basin River Watch Guidance Document* by Behar and Cheo (2004), available at the website cited above.

5- The most regionally relevant (from Pennsylvania) attempt to do this appears to be the SPAR program (Stream Plethodontid Assemblage Response); the final report (2004) by Rocco et al. is entitled "Stream plethodontid assemblage response (SPAR) index: development, application, and verification in the MAHA". It was published by the Penn State Cooperative Wetlands Center and can be downloaded at http://www.geog.psu.edu/ wetlands/people/grad_students/gian_exsum.html. The Ohio EPA undertook an integrated biomonitoring approach somewhat similar to our own and including salamanders. Their manual (2002) is entitled *Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams;* along with results summaries, it is available at http://www.epa.state.oh.us/dsw/wqs/headwaters/ #Project%20Reports. The USGS transect approach, which was introduced and explained to us by Robin Jung, is described in Campbell et al's (2005) "Stream salamander species richness and abundance in relation to environmental factors in Shenandoah National Park, Virginia" in *American Midland Naturalist* 153: 348–356.

6- One of Karr's seminal papers was (1981). "Assessment of biotic integrity using fish communities." *Fisheries* 6: 21–27. The paper referred to from Vermont is Robert Langdon's (2001) "A rreliminary idex of biological integrity for fish assemblages of small coldwater streams in Vermont" in *Northeastern Naturalist* 8: 819-232. Bob Daniels has done something similar for Mid-Atlantic States, Daniels et al. (2002) "An index of biological integrity for northern Mid-Atlantic slope drainages” in *Transactions of the American Fisheries Society* 131:1044–1060.

7- Reference values from elsewhere in the Hudson Valley were gathered from the USGS’s on-line water data repository (http://nwis.waterdata.usgs.gov/usa/nwis/qwdata).

8- Our basic natural history references were Hulse et al’s book (2001) *Amphibians and Reptiles of Pennsylvania and the Northeast* and Degraaf and Rudis’s (1983) *New England Wildlife: Habitat, Natural History and Distribution* (op cit.). The Hudsonia document alluded to is their *Biodiversity Assessment Manual* (op cit.).

9- Aside from the works already mentioned in endnote 6 of this section, we also consulted Frank McCormick’s (2001) “Development of an index of biotic integrity for the Mid-Atlantic highlands region” *Transactions of the American Fisheries Society* 130:857–877, 2001; and the Maryland DNR publication (2000) by Roth et al. entitled “Refinement and validation of a fish index of biotic integrity for Maryland streams” and available at www.dnr.state.md.us/streams/pubs/ea00-2_fibi.pdf.

10- The work from the 1930s and ‘40s that is referred to is that of the New York State Biological Survey. The two geographically-relevant reports are *A Biological Survey of the Mowhawk–Hudson Watershed* (1935) and *A Biological Survey of the Lower Hudson Watershed* (1937). Aside from fish, these reports also discussed water chemistry and macroinvertebrates.

11- The two works used for understanding regional fish ecology were the book (1985) *The Inland Fishes of New York State* by C. Lavett Smith and the website “An Annotated Working List of the Inland Fishes of Massachusetts”by Hartel et al. (1996) which can be viewed at http://collections.oeb.harvard.edu/Fish/ma_fish/ma_fam.htm. These authors have also published the book *Inland Fishes of Massachusetts*, but we have not had a chance to read it. We also consulted the Nature Serve website (http://www. natureserve.org/explorer/) for additional information.

12- A good review of water-affecting factors in the Hudson River watershed is “Water quality in the Hudson River Basin, New York and adjacent states,1992–95”, USGS Cirucular 1165 by Wall et al. (1998), available at http://ny.water.usgs.gov/htmls/pub/nawqaweb/report.html.

Appendix 8. Table of aquatic results from Hawthorne Valley stream

	North Entry of Agawamuck			Center of Agawamuck Prior to Farm Creek			Agawamuck at South End of Property		
	May	July	Sept	May	July	Sept	May	July	Sept
CHEM									
pH	7.1	7.2	6.7	7.3	7.5	6.7	6.8	7.8	7.3
temp (oC)	8.5	9	12	11.5	11	15	9.5	12	11
alkalinity (ppm)	52	44	54	-	60	70	45	66	72
Dissolved O2 (mg/l)	10.5	5.3	8.7	10	5	3.1	11.4	8.4	10.5
Nitrate (ppm)	0.68	0.96	0.38	0.25	1.01	0.33	0.41	1.05	0.76
Phosphate (ppm)	0.01	0.16	0.05	0.03	0.04	0.03	0.01	0.16	0.02
MICROBE									
total/100ml	25,500	3,800	10,100	47,200	8,800	2,200	109,100	6,800	5,500
colliform/100ml	2,400	200	1,200	4,100	1,600	1,000	7,900	4,900	1,900
SALAMS									
water sallys/rock	0.09	0.22	0.04	0.07	0.02	0.05	0.03	0.08	0.15
land sallys/rock	0.01	0.01	0.02	0.01	0 (83 rocks)	0.005	0.02	0 (227 rocks)	0.004424779
INSECTS									
biotic index	2.7	2.4	4.3	2.0	2.9	4.7	2.0	3.0	3.2
FISH									
Blacknose Dace	+	+	+	+	+	+	+	+	+
White Sucker						+	+	+	+
Brown Trout									
Brook Trout				+		+			
Creek Chub			+					+	+
Golden Shiner									
Common Shiner						+	+		+
Longnosed Sucker						+			
Sunny									
Large Mouth Bass								+	

	North End of Farm Creek			Farm Creek Prior to Junction with Agawamuck		
	May	July	Sept	May	July	Sept
CHEM						
pH	7.5	7.5	7.4	7.2	7	6.6
temp (oC)	11	16	14	11	16	14
alkalinity (ppm)	48	60	52	-	68	58
Dissolved O2 (mg/l)	9.5	5.7	9.9	10	6.8	8.9
Nitrate (ppm)	0.14	0.21	0.17	0.4	0.47	0.4
Phosphate (ppm)	0.02	0.09	0	0.05	0.27	0.02
MICROBE						
total/100ml	13,200	4,000	3,200	33,800	40,200	11,200
colliform/100ml	600	1,100	2,000	5,800	?	1,800
SALAMS						
water sallys/rock	0.01	0.00	0.01	0.01	0.00	0.00
land sallys/rock	0 (127 rocks)	0 (74 rocks)	0.027586207	-	0 (114 rocks)	0.015384615
INSECTS						
biotic index	2.3	2.7	2.6	2.4	4.0	3.8
FISH						
Blacknose Dace	+		+	+	+	+
White Sucker	+		+	+	+	+
Brown Trout	+	+	+			
Brook Trout						
Creek Chub	+	+	+	+	+	+
Golden Shiner		+	+			
Common Shiner	+	+	+	+	+	+
Longnosed Sucker						
Sunny			+			
Large Mouth Bass			+			