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Environmental Quality of the Wallkill River in Orange County, New York

Report to Orange Environment

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1 Abstract

At the request of Orange Environment, Hudsonia conducted a biological and water quality survey of the Orange County (New York) portion of the Wallkill River in 1991 and 1992. We sampled fishes and macroinvertebrates and analysed summer and early fall water samples from 10 stations along the mainstem, and we reconnoitered riparian areas for vascular flora and significant habitats. The Wallkill was very turbid during the study period, with total suspended solids at or above 14 mg/l at all but three stations. Phosphate-phosphorus concentrations were extremely high (to 0.71 mg/l). Chloride levels were also high (24-51 mg/l), but were comparable to other Hudson Valley streams with developed watersheds. Nitrate and sulfate were surprisingly low for an agricultural stream. We found a diverse but sparse fish community; the dominant species was spotfin shiner, usually uncommon in Hudson River tributaries. We confirmed the presence of two state-listed rare fish species, the tadpole madtom and the eastern mudminnow; this may be the northernmost population of the eastern mudminnow in North America. We used three indices to help assess the macroinvertebrate community: the MTQ (derived from Winget (1985), a community analysis following Kurtenbach (1990), and the BCI (Winget 1985). All three indicated a macroinvertebrate community under considerable habitat and pollution stress. We found 7 species of state-listed rare plants, and at least 10 species of regionally rare plants in the Wallkill corridor. The influences of calcareous soils and the dynamics of a large stream may combine to create particular riparian habitats not found elsewhere in the Hudson Valley. We identified three areas in the river corridor that we feel deserve special protection. Further surveys should be conducted to identify other rare species and significant habitats; surveys should be extended to the New Jersey and Ulster County portions of the river.

Land use practices, storm water management, and point sources of pollutants must all be addressed and remediated if the Wallkill River stream water quality and instream habitats are to be restored to acceptable levels. We recommend preservation and restoration of riparian habitats wherever possible, to provide an ecological buffer zone for the river, and to provide important habitats for many native species of plants and animals. A continuous protected corridor along the river could also be used as a walking trail or a canoe trail. Restoration and maintenance of a wooded buffer zone between the river and land uses such as pastures, cropland, and golf courses would help protect the river from nutrient and pesticide contamination. Introduction and maintenance of instream snags along the length of the river would probably improve fish densities by improving cover and fish-food productivity. Halting the apparently massive silt loading into the Wallkill would improve both fish-spawning and invertebrate habitats.

2 Introduction

The quality of any stream and its biological communities reflect human activities in the surrounding landscapes. The watershed of the Wallkill River contains agriculture, urban areas, industry, landfills, and other land uses that generate water pollutants. Because the Wallkill is one of the largest Hudson River tributaries and it collects pollutants from a large area, it is more susceptible to degradation than smaller streams. The purpose of this study was to survey water quality and organisms in the channel of the Wallkill mainstem and associated riparian habitats, to compare the environmental quality of the river with other Hudson River tributaries, and to identify some of the major problems and opportunities for management of the Wallkill in Orange County.

Because of widespread decline and loss of populations and genetic variants of native plants, animals, and other organisms, and because of the great importance of biological diversity to humankind, we have paid much attention in our study of the Wallkill to the occurrence of rare species and their habitats. In addition to pollution and its effects on the river biota, we also looked for rare species and relatively intact habitats that are deserving of conservation action.

We studied the Wallkill in 1991 and 1992, focusing on 10 stations representing different reaches of the mainstem and potential sources of pollution. We sampled aquatic macroinvertebrates by means of Dendy plate samples and Surber samples. We conducted fish surveys using seines. We made field measurements of stream water conductivity, temperature, and dissolved oxygen, and collected a series of water samples for analysis of phosphate-phosphorus, nitrate, sulfate, chloride, and total suspended solids. We also reconnoitered riparian areas for vascular flora and significant habitats. Our report includes a discussion of the results of these surveys, as well as recommendations for conservation and management.

This project is funded in part by Orange County through a court-awarded Conservation Project. Additional support was provided by the J.M. Kaplan Fund through Orange Environment. We acknowledge the assistance of David Church, Molly Gallagher, Lianna Hoodes, Mike Edelstein, and Marty Borko. We would also like to thank Camo Laboratories for analyzing water samples at reduced rates.

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Metric units of measurement are used in this report. English equivalents are:

1 cm (centimeter)	= 0.39 inch
1 m (meter)	= 3.28 feet
1 km (kilometer)	= 0.62 mile
1 km^2 (square kilometer)	= 2.59 square miles or 100 ha
1 ha (hectare)	= 2.47 acres

3 The Wallkill River Study Area

The Wallkill River rises in northern New Jersey and flows ca 105 km north through Orange and Ulster counties in New York to its confluence with Rondout Creek, a tributary to the Hudson River. The Wallkill drains an area of ca 3300 km^2. The total change in elevation is ca 655 m, from 698 m above mean sea level at its headwaters to 43 m at its mouth (Waines 1967). The study area for this project was the river, selected tributaries, and riparian areas within Orange County only, and is mapped on the following USGS 7.5 minute quadrangles: Unionville, Pine Island, Middletown, Goshen, Pine Bush, and Walden.

Most of the Wallkill valley is underlain by shales of the Normanskill Formation. In southern Orange County, an area of perhaps 90 km^2 is underlain by Wappinger Group limestones and dolostones (Fisher et al. 1971). This area contains the most striking surficial feature of the Wallkill Valley, the thick organic deposits of the "Black Dirt" area, now substantially drained and intensively cultivated for row crops. Glacial till covers much of the remaining watershed in Orange County, with pockets of lacustrine silt and clay and scattered kame deposits (Cadwell et al. 1986).

Land uses and potential pollution sources in the Orange County portion of the Wallkill Valley include dairy farms, vegetable farms, residential and urban areas, sewage treatment plants, private and public landfills, golf courses, and roads.

4 Methods

Locations of sample stations and other observation areas mentioned in this report are shown in Figure 1. Station locations were chosen to represent various reaches and habitats of the river, and several potential pollution sources.

4.1 Water Quality

Water samples were taken at stations 1-3 on 8 October; the most recent rainfall, a trace, had been ten days earlier. Stations 4 and 5 were sampled on 14 August; the most recent precipitation, 1.57 cm, had been on 9 August. Stations 6-10 were sampled on 20 July 1992; there had been a heavy rainstorm (6.27 cm) on 16 July and a lesser storm (0.25 cm) on 18 July. Dissolved oxygen (DO), conductivity,

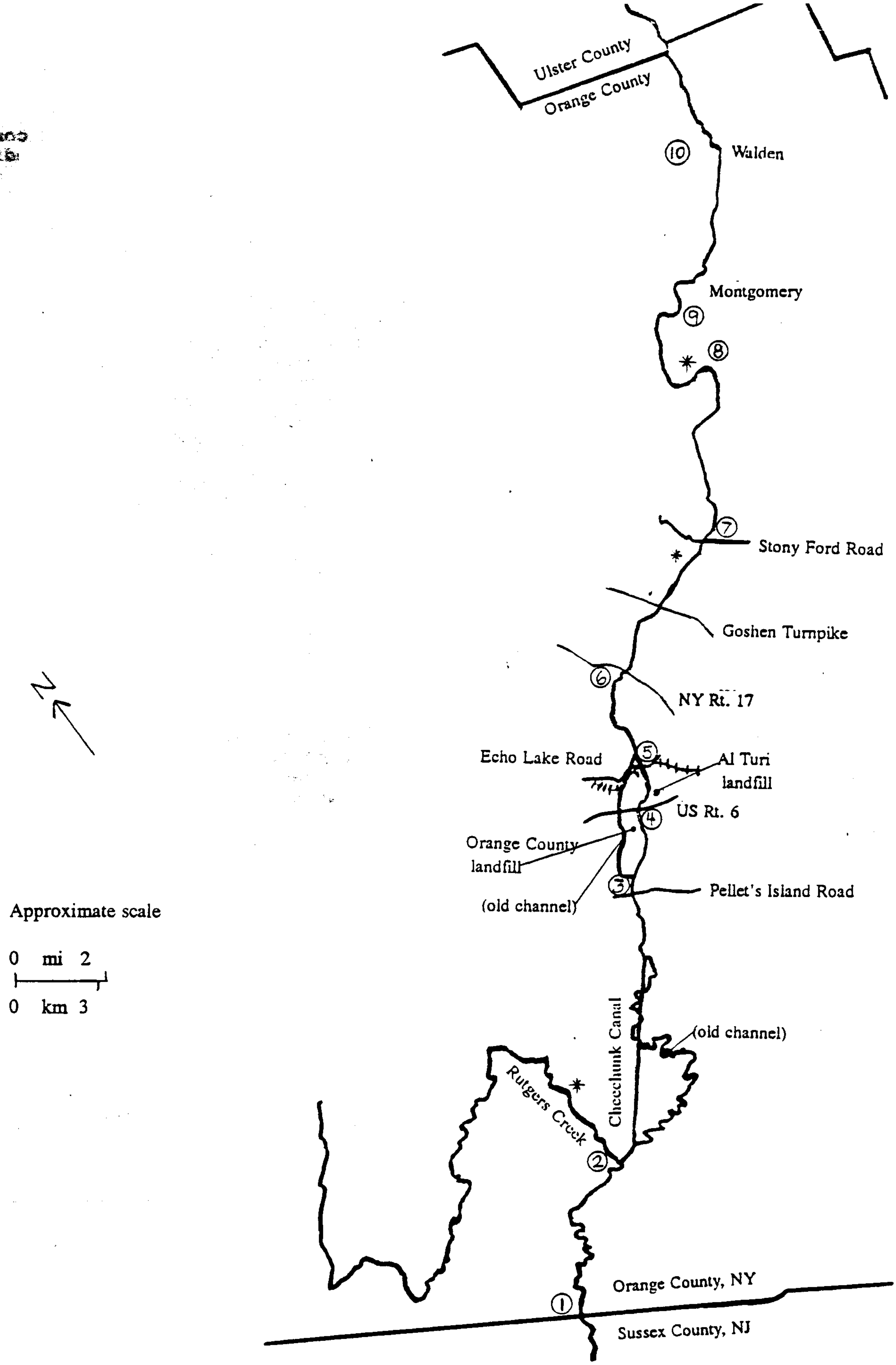

Figure 1. Location of sampling stations (1-10), other observation areas (A-F) and three special areas (*) along the Wallkill River, Orange County, New York.

and temperature were measured in the field using a YSI DO meter and a YSI conductivity probe. At each station, a water sample was collected, placed immediately in a portable cooler, and transported the same day to Camo Laboratories, Poughkeepsie, NY. Samples were analyzed by Camo using EPA standard methods (Kopp and McKee 1983) for total suspended solids (TSS), nitrate (NO_3^-), phosphate-phosphorus (PO_4^{3-}-P), sulfate ($SO_4^=$), and chloride (Cl^-).

4.2 Fishes

We intended to sample fishes quantitatively, but turbidity, water depths, and poor accessibility made quantitative sampling unrealistic for several reasons. First, although much of the study area is shallow and wadable, the Wallkill is too wide to adequately sample with our gear. Kurtenbach (1991) stated that a 5000 Watt boat shocker is the minimum gear necessary to sample fishes in rivers comparable to the Wallkill. Access with a boat shocker to some reaches of the Wallkill with a boat shocker would be very difficult. Second, the turbidity of the Wallkill rendered electrofishing gear ineffective. Shocked fish must be seen to be captured and the water clarity was typically very poor. Third, sampling fishes with a seine was very difficult in the channelized station 4 and impossible at station 3. The substrate was covered with irregular cobble and the channel was steep-sided and deep.

We sampled as thoroughly as we could with a 10-ft seine. We sampled fishes at stations 1,2,3, and 8 on 8 October, stations 4, 5, and 9 on 14 August, and stations 6,7,8, and 10 on 20 July 1992. We attempted to sample all available habitats at each station and we believe we obtained a good picture of the fish fauna in the Orange County section of the river. All fishes were identified in the field by Robert E. Schmidt.

4.3 Macroinvertebrates

Much of the Wallkill was unsuitable for Surber or travelling kick sampling techniques for macroinvertebrates due to the absence of cobble substrates, the slow current and silty bottom, and the channelization of some reaches. Instead we used Dendy plates; these are ranks of masonite plates that provide a 1-ft^2 artificial substrate for invertebrates to colonize. In addition, on 9 November 1992 we took triplicate Surber samples at station 8, the only station with a cobble bottom, to provide a comparison with our Dendy plate data.

We placed three Dendy plates at each station on 9 November 1991 and retrieved them on 21 December 1991. Each array was tied to the shore with a length of twine. Due to an early freeze, many areas were iced over at retrieval; we had to chop through ice to recover some of the samplers. Some samplers were unusable due to stranding, and one was entangled and could not be recovered. We retrieved two usable samplers at stations 2, 3, 6, and 7 and all three samplers at the other stations.

The Dendy samplers were removed from the water, the exposed surfaces were immediately scraped clean with a knife and the samplers were placed in a plastic bag and labelled. Samplers were transported to the lab and refrigerated. The following day, samplers were disassembled, all sediments were washed into a dissecting pan, and organisms were removed and preserved in 70% ethanol. Organisms were identified by Kathleen A. Schmidt to the lowest practical taxon and counted.

4.4 Flora

At the beginning of our study in the fall of 1991, Kiviat and Stevens canoed segments of the river from Station 1 (Oil City Road) up to the state line, and from Station 3 (Pellets Island) down to Station 6. For portions of the reconnaissance we were accompanied by Robert E. Schmidt, Dave Church, Molly Gallagher, and Ted Fink. In 1992, contemporaneous with other field work, Stevens and Kiviat conducted single-visit surveys, on foot, of the vascular flora at Stations 4 through 10. Barbour also reconnoitered, on foot, 6 other areas and revisited our Stations 7 and 8. During these surveys we made lists of the flora we could identify confidently in the field, and collected specimens of other species. Stevens identified most of the specimens in the laboratory, and all specimens were then submitted to consulting botanist Jerry C. Jenkins for further identification or verification. Specimens of rare species, locality records, and other selected specimens will either be retained in the herbarium of the Bard College Field Station or deposited at the New York State Museum. A list of the flora is in Sect. 12. Common and scientific names in this report mostly follow Mitchell (1986).

5 Results and Discussion

5.1 Water Quality

Stream water chemistry is affected by seasonal changes in the stream and watershed, by the timing and magnitude of runoff events, by non-point source fluctuations, and by the nature and timing of point-source pollution discharges. The effect of storm or drought conditions on pollutant concentrations will vary according to the nature of the pollutant and the timing and nature of the discharge. Low stream flows tend to concentrate existing pollutants in stream water, including those from constant point discharges. Lack of precipitation and runoff during drought periods may reduce the overall pollutant load from non-point sources such as agricultural fields, golf courses, and urban streets. Storm events tend to increase the pollutant load from non-point sources, but may also dilute the concentration in the stream such that the increased load may be obscured in water sample analysis. For these reasons, specific knowledge of the contribution of point and non-point sources to the pollutant load of the particular stream is essential to understanding of the effects of precipitation and runoff events on chemical concentrations in stream water.

Because water is continuously moving through a stream, the water chemistry in any particular water sample reflects only momentary conditions. Pulses of pollutants or other substances are easily missed by infrequent sampling, even though the immediate and long term effects on stream biota or downstream water quality may be substantial. The more frequent the sampling, the more informative the analysis for general stream conditions.

In the Wallkill study we collected water samples only once at each station over an 11-week period. Therefore we cannot analyze upstream-to-downstream or seasonal trends in water quality. We suspect that water quality changes dramatically in the course of a year, depending on runoff events, agricultural activities, and other activities in the watershed contributing to non-point source pollution. In this study we have only a glimpse of the stream conditions at each of the stations. Table 1 gives the results of our water chemistry analysis. Below we present our results in the context of data from other Hudson Valley streams, and discuss the implications for overall stream integrity in the Wallkill.

Table 1. Water chemistry data from samples taken at Wallkill River stations, Orange County, New York. TSS = total suspended solids; $SO_4^{=}$ = sulfate; Cl^- = chloride; NO_3^- = nitrate; PO_4^{3-}-P = phosphate-phosphorus; DO = dissolved oxygen; oxygen sat. = dissolved oxygen saturation.

STATION	TSS (mg/l)	$SO_4^{=}$ (mg/l)	Cl^- (mg/l)	NO_3^- (mg/l)	PO_4^{3-}-P (mg/l)	DO (mg/l)	Oxygen Sat. (%)	Conductivity (micromhos/cm)	Temp °C	Sample Date
1	6	22	51	1.02	0.19	10.0	92.7	303	12.0	8OCT92
2	10	29	44	0.83	0.14	11.3	106.0	325	12.5	8OCT92
3	7	29	44	1.06	0.05	11.1	105.3	345	13.0	8OCT92
4	22	13	24	4.90	0.71	7.6	82.7	350	19.5	14AUG92
5	19	10	24	4.00	0.71	8.6	94.0	355	19.7	14AUG92
6	21	4	41	1.06	0.34	8.8	106.5	340	25.0	20JUL92
7	7	2	40	0.26	0.28	8.9	105.9	380	24.1	20JUL92
8	18	5	41	1.06	0.34	6.9	80.4	350	23.0	20JUL92
9	14	5	39	1.00	0.34	8.8	107.4	380	25.5	20JUL92
10	22	5	37	1.10	0.34	9.2	109.5	340	24.1	20JUL92

Phosphorus is essential for the growth of plants, but excessive amounts can lead to exorbitant plant growth and blooms of algae whose decomposition can deplete dissolved oxygen and produce substances toxic to other stream biota. Phosphorus is present naturally in some soils and bedrock. Phosphorus is present in streams almost solely as phosphates (Clesceri et al. 1989). Cultural sources of phosphorus in streams include runoff containing lawn and cropland fertilizers, septic leachate, industrial and sewage treatment plant effluent, and eroded soil from construction sites and agricultural land. Phosphate-phosphorus (PO_4^{3-}-P) concentrations in unpolluted surface waters are generally in the range of 0.01-0.10 mg/l (Wetzel 1983). Parsons and Lovett (1993) found PO_4^{3-}-P concentrations ranging up to 0.27 mg/l in Hudson Valley streams of primarily urban watersheds. Hudsonia found concentrations as high as 0.43 mg/l downstream of an aging sewage treatment plant in an Orange County stream (Stevens et al. 1994). By contrast, Parsons and Lovett (1993) and W.C. Nieder (Hudson River National River Estuarine Research Reserve, unpublished data, 1991-92) found three streams of mainly forested watersheds had PO_4^{3-}-P maxima of only 0.01-0.04 mg/l PO_4^{3-}-P.

In our Wallkill samples, phosphate-phosphorus concentrations ranged from 0.05-0.71 mg/l, but were mostly in the range of 0.14-0.34 mg/l. These are very high levels for Hudson Valley streams. In the studies cited above, even streams in highly urbanized or agricultural watersheds had PO_4^{3-}-P concentrations well below 0.20 mg/l for most of the year. It is interesting that the highest PO_4^{3-}-P levels were found at stations 4 and 5, which also had the highest TSS and NO_3^- concentrations. Because these were the only stations sampled in August, we do not know if other reaches of the Wallkill were similarly stressed at that time. Whigham et al. (1988) found that most of the phosphorus moving from agricultural fields is sorbed to soil particles, so it not surprising that high TSS in the Wallkill is associated with high PO_4^{3-}-P.

Nitrogen can occur in streams as ammonia (NH^{4+}), nitrite (NO_2^-), and nitrate (NO_3^-). Nitrate is the form most available to plants. Nitrogen is essential for plant growth, but it is often present in freshwater systems at concentrations in excess of what plants can use; unlike phosphorus, nitrogen is not limiting to plants in many freshwater aquatic environments. The major sources of nitrate in streams are drainage from fertilized croplands, livestock yards and pastures, lawns, gardens, and other fertilized lands, urban street drainage, construction sites, and sewage treatment plants. Nitrate concentrations in unpolluted fresh waters generally range from near 0 to 44 mg/l (Wetzel 1983). The maximum allowable concentration under the current federal drinking water standard is 44 mg/l NO_3^-. Parsons and Lovett (1993) found NO_3^- concentrations up to 11.8 mg/l in their study of Hudson Valley streams. The highest levels were in streams of agricultural and urban watersheds. In the most undisturbed streams, Nieder (unpublished data) and Parsons and Lovett (1993) found NO_3^- maxima of only 1.8 mg/l.

Nitrate concentrations in our Wallkill samples ranged from 0.3-4.9 mg/l, but at 6 of the 10 stations were in the range of 1.0-1.1 mg/l. These are surprisingly low levels for a stream draining a predominantly agricultural watershed. The highest concentrations were in the August samples at stations 4 and 5. We wonder if laboratory or reporting errors might be responsible for these low values.

Sulfate ($SO_4^=$) is present in certain kinds of sedimentary rock, and in rainwater, especially rain containing industrial emissions. Other major cultural sources include agricultural fertilizers, septic leachate, some industrial effluents, and sewage treatment plant effluent. Nieder (unpublished data) found $SO_4^=$ concentrations up to 85 mg/l in a Dutchess County stream receiving municipal sewage effluent, but levels in most Hudson Valley streams seem to be in the range of 10-40 mg/l. In three streams of predominantly forested watersheds, Parsons and Lovett (1993) and Nieder found $SO_4^=$ maxima of 13, 15, and 20 mg/l.

In our Wallkill River samples we found high sulfate levels (22-29 mg/l) in the October samples (stations 1, 2, and 3) and moderate to low levels (2-13 mg/l) in the July and August samples. Removal of crop cover and fall tillage could account in part for the high concentrations in the fall. The low $SO_4^=$ in July and August is surprising because $SO_4^=$ tends to be high in streams such as the Wallkill which suffer from other forms of pollution.

Chloride in unpolluted fresh waters is normally in the vicinity of 8 mg/l (Livingstone 1963). Major cultural sources of chloride include municipal and industrial effluents, sewage treatment plants, septic leachate, and road runoff. Hudsonia and others have found that chloride levels are high in Hudson Valley streams, and especially in Orange County. In our 1988-89 study of three Hudson River tributaries (Stevens et al. 1994), chloride in most of our samples was less than 80 mg/l, but we found concentrations up to 222 mg/l in one Orange County stream. By contrast, Nieder (unpublished data) and Parsons and Lovett (1993) found chloride maxima of 3-6 mg/l in undisturbed Hudson Valley streams of forested watersheds. In our 1988-89 study we found that the integrity of the macroinvertebrate community showed a substantial decline at chloride levels exceeding 25 mg/l.

In the Wallkill River, concentrations were high in all samples, never less than 24 mg/l and mostly in the range of 37-44 mg/l. Extravagant road salting practices may be responsible in part for these high levels. De-icing salts deposited on road shoulders and in ditches in winter can be mobilized by rain storms throughout the year.

Dissolved oxygen (DO) is essential to all stream fauna, but some organisms are more sensitive than others to low DO levels. Oxygen is added to stream water from the atmosphere and from aquatic plants as a by-product of photosynthesis. The concentration in water depends on temperature, ion concentrations, and biological and chemical interactions (Wetzel and Likens 1991). Oxygen is usually near saturation in small turbulent streams, and at the base of dams and natural waterfalls. Periods of high discharge in larger streams are often accompanied by increases in DO. Supersaturation occurs in many streams in spring as photosynthesis increases in aquatic plants and adds oxygen to the water. Oxygen saturation often declines in summer with increasing water temperatures, and the resulting higher metabolic rates of aquatic animals and higher rates of decomposition of organic matter. Dissolved oxygen may also be depleted by the oxygen demand created by increased turbidity which can reduce photosynthesis, and by winter ice cover which reduces atmospheric exchange. Dissolved oxygen concentrations of 8-12 mg/l are typical for freshwater streams. Concentrations below 5 mg/l are considered dangerous to fish and certain other aquatic organisms.

In the Wallkill River, dissolved oxygen was at moderate to high concentrations in most of our samples. The highest DOs (10.0-11.3 mg/l), as we would expect, were in the October samples when water temperatures were only 12-13 ^{o}C. Oxygen saturation exceeded 100% in most samples. The lowest DO (6.9 mg/l, 80% saturation) was at station 8 (July).

Conductivity is the magnitude of current which water can conduct. Any water containing ions (electrically charged atoms) will conduct an electrical current. The magnitude of the current at a given temperature is directly proportional to the total concentration of dissolved ionic substances in the water, thus conductivity measurements provide an indirect measure of dissolved ions. High conductivities may have geologic causes, or may be associated with pollutants.

Conductivities in our Wallkill samples ranged from 303 to 380 micromhos/cm. These are in the mid-range of conductivities that we have seen in other Hudson Valley streams.

Total suspended solids (TSS) is a measure of soil particles, organic matter, and other solid materials suspended in the water column. Soil erosion from agricultural fields and construction sites, and runoff from urban streets are three of the primary sources of suspended solids in streams. TSS tends to be elevated during runoff events. High turbidity in a stream can have many damaging consequences to the stream ecosystem. It reduces the light available for photosynthesis, and thus tends to reduce the phytoplankton and phytobenthic populations. It may also interfere with feeding mechanisms of zooplankton (Hynes 1970), and can discourage sight-feeding fish species. Nutrients and toxins sorbed to soil particles can be damaging to many stream organisms. High TSS is usually associated with eventual deposition of sediments on the stream bottom. Sediments can smother plants, fish eggs, aquatic insects, mollusks, and other stream organisms. The instability of a sandy or silty substrate prevents the buildup of large invertebrate populations; invertebrates are a basic food source for many freshwater fish. Sedimentation can also elevate stream beds and reduce pool sizes and depths, thus raising summer water temperatures and reducing suitable spawning and nursery areas for some fish species.

Parsons and Lovett (1993) found TSS mostly in the range of 0.1-2.5 mg/l in their study of Hudson Valley streams. Only two of their fifteen study streams exceeded 3 mg/l during non-storm sampling periods. TSS in storm flow samples from four streams ranged from 0.6 mg/l in a largely undeveloped forested stream, to 39.4 mg/l in a stream of a forested and urban watershed.

In our Wallkill samples, TSS ranged from 6-22 mg/l. All but three stations had TSS exceeding 14 mg/l. These are very high levels. Stations 6-10 were sampled on the fourth day following a significant rainstorm, which may account for the high TSS at those stations. Stations 4 and 5, however, had equally high TSS but had not received recent large rainfall. Agricultural streams in the Parsons and Lovett study never exceeded 2.5 mg/l except during a storm event when one reached 5.1 mg/l TSS. The vast amount of land in intensive agricultural uses sets the Wallkill River apart from other streams studied in the Hudson Valley.

Summary. The most unusual aspects of the Wallkill River water quality were the very high turbidity and phosphate-phosphorus concentrations. Total suspended solids were consistently at levels associated only with storm events in other Hudson Valley streams. Phosphate-phosphorus concentrations in 7 or our 10 samples were higher than those in the worst of the 15 streams studied by Parsons and Lovett (1993). Chloride was also consistently higher than in any of the non-urban streams in that study. Soil erosion and agricultural fertilizers may be responsible for the high TSS and phosphorus. Road salting, municipal sewage and septic field leachate, and possibly agricultural runoff may be the source of elevated chloride.

Because we took water quality samples only once at each station, we recommend confirmatory sampling and analysis before too much weight is placed on our data. The macroinvertebrate indices, however, also seem to indicate high pollution levels. We believe that the high phosphate and chloride concentrations are not simply artifacts of a large stream in a large drainage, but are due to excessive pollution entering the stream from numerous sources.

The Wallkill may be particularly susceptible to water quality degradation because of characteristics of the bedrock geology, especially in the southern part of the county. The dolomitic bedrock underlying and surrounding the Black Dirt region is highly soluble and is characterized in some places by sinkholes, sinking streams, and the lack of a continuous ground water table; instead the ground water resides in or flows through irregular underground solution cavities. (This region is identified as "karst" by some geologists.) Where these conditions are present, the groundwater and receiving surface waters are especially vulnerable to pollution because contaminated surface runoff may flow directly into the groundwater with no filtering by soil or bedrock (Edelstein and Makofske 1985). Also, limestone inliers in some of the shales outside the karst (Offield 1967) could act as water conduits to the solution cavities of the karst region (Waller 1981, cited in Edelstein and Makofske 1985).

5.2 Fishes

We collected a total of 22 taxa of fishes in this survey of the Orange County portion of the Wallkill River (Table 2). This is a large list of species for a Hudson River tributary. The species richness at a single station ranged from a high of 12 at station 8 to a low of 4 at station 10.

In 1977, NYSDEC sampled four Orange County stations in the Wallkill using a boat shocker, and reported a total of 18 species of fish (Pierce 1978). The NYSDEC stations were located as follows: at the NY-NJ border (our station 1), in the Cheechunk Canal (between our stations 2 & 3), a pool at Montgomery (our station 9), and the impoundment at Walden (between our stations 9 & 10). NYSDEC collected three species that we did not see in our 1992 study: eastern chubsucker (<u>Erimyzon oblongus</u>), carp (<u>Cyprinus carpio</u>), and white perch (<u>Morone americana</u>). We collected 7 taxa that NYSDEC did not report. Differences in collecting methods can easily explain the disparities in the two species lists.

Table 2. Fishes collected by seine in the Orange County segment of the Wallkill River, 1992. Effort not equal at all stations; see Methods. Station 3 was inaccessible by seine due to steep, riprapped banks.

Scientific Name	Common Name	Station									
		1	2	4	5	6	7	8	9	10	Total
Cyprinella spiloptera	spotfin shiner		5	4	7	15	60	25			116
Notemigonus crysoleucas	golden shiner							3		2	5
Notropis hudsonius	spottail shiner			1	14	3	4			2	24
Rhinichthys atratulus	blacknose dace					1					1
Rhinichthys cataractae	longnose dace					18					18
Catostomus commersoni	white sucker				1	2	5	3			11
Ictalurus natalis	yellow bullhead	1			3			4	1		9
Noturus gyrinus	tadpole madtom	2									2
Esox americanus	red fin pickerel							1	1		2
Esox niger	chain pickerel		1								1
Umbra pygmaea	eastern mudminnow								1		1
Fundulus diaphanus	banded kill fish				3		1	2	6		12
Ambloplites rupestris	rock bass					1					1
Lepomis auritus	redbreast sunfish	1	3		2						6
Lepomis auritus x gibbosus	(sunfish hybrid)	1									1
Lepomis gibbosus	pumpkin seed	17	10		1		7	19	2		56
Lepomis macrochirus	bluegill	26	3		3	4		2	12	2	52
Micropterus dolomieui	smallmouth bass				1		1	2			4
Micropterus salmoides	largemouth bass	1			1		2	6	2		12
Pomoxis nigromaculatus	black crappie	1				1		1		4	7
Etheostoma olmstedi	tessellated darter		3			4	6	4	1		18
Perca flavescens	yellow perch				1						1
Totals		50	25	5	37	49	86	72	26	10	360

Combined with the fishes found in the Wallkill tributaries, including the Shawangunk Kill, the species list for the Wallkill is the largest of any Hudson River tributary. This species richness is partially due to the large drainage size of the Wallkill; larger geographic areas are expected to contain more species (Sheldon 1988). There is also a biogeographic component to the species richness in the Wallkill. Because the Wallkill drains northeastward from northern New Jersey, an unusual drainage pattern, it may be a dispersal corridor for generally more southern species, such as the comely shiner (Notropis amoenus) which reaches its northeastern range limit on the U.S. East Coast in the Shawangunk Kill (Lee et al. 1980).

5.2.1 Fish Habitat

The distribution of fishes within stations suggests that the Wallkill in Orange County has very patchy fish habitat. Much of the substrate in the main channel of the river is sand. Uniformly sandy streams typically have a depauperate fish fauna. The fishes we collected over sandy bottoms were almost entirely a single species, spotfin shiner (Cyprinella spiloptera). We found most of the other taxa in scattered locations where the open sandy bottom was interrupted by other substrates. At station 5, for instance, most of the fishes were taken along an undercut bank and we caught nothing over the shallow sandy bottom in the middle of the creek. At other stations, fishes were concentrated around rocky riffles (e.g., stations 6 & 8). Fishes were fairly dense in the riffle area at station 6, but we caught very little in the sandy area upstream of the riffle, despite sampling several dense patches of submerged aquatic plants. The relatively high species richness at station 8 (Table 2) can be explained by the extensive rocky substrate at that location. In other areas, fish were found in silty backwaters or around fallen snags or bridge piers.

We did not note any major incidence of disease or poor condition in the fishes we collected. Because aging of fish was not within the scope of this project, we do not know if there were growth anomalies among the fishes we collected. The main stress indicator that we observed in our samples was at the community level: the dominance of spotfin shiner. This phenomenon is discussed further below.

5.2.2 Stream Modification and Pollution

There have been two major channelization projects in the Orange County section of the Wallkill. The largest is the Cheechunk Canal. We did not sample fish in the canal, but Pierce (1978) stated that "... the Cheechunk Canal is an excellent example of how a productive stream can be destroyed by stream channelization." He reported only four species of fish from the channelized area.

The reach of the Wallkill extending from upstream of our station 3, past the two landfills, to just upstream of our station 5 has also been channelized to direct the flow around the landfills. This channelization was not as severe as in the Cheechunk Canal; the Wallkill was allowed to curve somewhat through this area, but the banks have been riprapped. We were unable to sample fishes at station 3 because of this modification. At station 4 we caught only two species, in part because the riprapped bottom interfered with our ability to seine, but we think also because the channelization has severely degraded the fish habitat.

Our ability to detect pollution effects using fish communities was hampered by our inability to sample quantitatively and by the confounding effects of channelization. One station, however, was clearly degraded by water pollution and this degradation was reflected in the fish community. In Walden (station 10) the river had an extensive rocky riffle with a moderate gradient which should have had a rich fish community, yet we collected only four species and very few individuals. The rocks in the middle of the river were coated with a dense mat of midge (Chironomidae) tubes. Chironomids are found in all kinds of stream habitats, but are most abundant in organically polluted and nutrient-enriched waters. We think the sewage treatment plant upstream of this station has severely affected the fish community.

5.2.3 Rare or Interesting Fishes

Two species of fish collected in this study deserve further comment. The eastern mudminnow (Umbra pygmaea) (S3), collected at station 9, probably represents the northernmost population in North America. Smith (1985) documented this population very close to our collecting site. It is encouraging that the population still persists. Animals at the extremes of their ranges are often instructive objects of study because that is where the greatest genetic variability may occur, and the species is most likely to be vulnerable to natural or human-caused stress.

At station 1, we collected 2 specimens of the tadpole madtom (Noturus gyrinus) (S3), a small, secretive catfish. Smith (1985) recorded this species from the upper Wallkill but had no recent records from that area. Tadpole madtoms prefer dense submerged vegetation which is precisely the habitat we sampled. We have noted that this species has disappeared from Quassaic Creek (Orange County), so it is gratifying to document its presence in the Wallkill.

5.2.4 Historical Data on Fish Communities

The Wallkill in Orange County was surveyed by NYSDEC in the 1930s, along with every other major stream in the state. Lists of species collected were transcribed from NYSDEC files by M. Gallagher. The 1930s survey reported 24 species; we and Pierce (1978) together documented 25. Species reported in the 1930s survey that we did not collect were: fallfish (Semotilus corporalis), cutlips minnow (Exoglossum maxillingua), common shiner (Luxilus cornutus), creek chub (Semotilus atromaculatus), brown bullhead (Ictalurus nebulosus), American eel (Anguilla rostrata), and silvery minnow (Hybognathus regius). The first four of these species are common small stream fishes in the Hudson Valley. Neither we nor Pierce sampled tributary streams where these species are likely to be found. We do not know whether the 1930s survey teams sampled tributaries or caught these species in the mainstem. The brown bullhead and American eel are surely present in the Wallkill but were not accessible to our gear. The record of the silvery minnow is interesting. Currently this species seems to be limited to the Hudson estuary where it is rarely seen.

Species that we and Pierce (1978) reported that were not seen in the 1930s survey were tadpole madtom, eastern mudminnow, white perch, black crappie, chain pickerel, yellow perch, and banded killifish. The first two species were discussed earlier in this report. The next four species are all considered sport fish and may have been stocked since the 1930s or simply missed in these early surveys. The banded killifish was a popular baitfish in the Hudson Valley and upland populations may have been introduced by fishermen.

We see no major overall change in the fish community since the 1930s survey. The biggest change may be an increase in species due to stocking activities for sport fishing.

5.2.5 Biology of the Spotfin Shiner

Spotfin shiners were a dominant species wherever we collected them, ranking either first or second in abundance. They comprised an average of 42% (range 17-80%) of the individuals collected at those stations where they were present. It is unusual for this species to be so common in a Hudson River tributary. We have recorded them elsewhere in the Hudson Valley (Schmidt and Kiviat 1988) but always as a rarity.

Much of the literature written on this species preceeded a recent major taxonomic re-evaluation of North American minnows. Thus the literature refers to the spotfin shiner by its older junior synonym, _Notropis spilopterus_, rather than the current _Cyprinella spiloptera_.

The spotfin shiner is a small to moderate size minnow, often reaching 6.5 cm standard length (Gibbs, 1957) and recorded as large as 9 cm (Thiesing 1989). This species can reach an age of three years but most individuals do not live beyond two (Thiesing 1989).

Spotfins are characterized as fractional crevice spawners (Gale and Gale 1977), a characteristic common to the genus _Cyprinella_. Spotfins have been observed depositing eggs in a variety of crevices: under bark of submerged logs (Hankinson, 1930), under tree roots and flat rocks (Stone, 1940; Pflieger, 1965), and in disintegrating bridge abutments (Gale and Gale, 1977). The term fractional describes the females' release of only part of their eggs in each spawning act. Total numbers of eggs per female can be as high as 7500 (Gale and Gale, 1977).

Of more significance to the Wallkill is this animal's habitat selection and feeding behavior. Vadas (1992) considered the spotfin shiner a habitat generalist (i.e., found in many habitat types), an observation supported by Thiesing (1989). Vadas suggested that habitat generalists should be more common than habitat specialists in fluctuating environments such as the flooding and drought intermittancy of his Goose Creek, Virginia, study area.

Spotfins have been reported to consume a large amount of terrestrial insects (White and Wallace, 1973; Thiesing, 1989). More careful studies (Vadas, 1990; and particularly Mendelson, 1975) indicated that, in addition to terrestrial insects, spotfins feed almost exclusively on insect drift in the water column. Thiesing (1989) suggested this possibility but did not sample drift in her study in the Shawangunk Kill.

5.3 Macroinvertebrates

Stream macroinvertebrates are thought to be good indicators of environmental conditions in part because they cannot move away from pollution or leave the stream altogether (except as adults of some taxa). The sensitivity of macroinvertebrate taxa to various pollutants is determined to a large extent by their feeding and reproductive habits, and their strategies for obtaining oxygen. Organic pollutants tend to reduce the abundance of some species and permit others to survive or even thrive, thus reducing diversity and altering community structure, but not necessarily reducing overall abundance. Because we understand the general tolerances of some mocroinvertebrate taxa to organic pollution, analysis of community structure can be useful for obtaining information on the status of organic pollution in a stream. Siltation and toxic pollutants, on the other hand, tend to have a non-selective impact on the macroinvertebrate community; that is, they tend to deplete the abundance of all species without necessarily altering species composition of the community. The abundance and structure of the macroinvertebrate community present at any time is dependent on hatching cycles and on immediate and longer term water quality and substrate conditions.

Numbers of individuals and densities of macroinvertebrate taxa in our samples are given in Table 3. We collected low numbers of macroinvertebrate individuals and taxa on the Dendy samplers. Dendy samplers tend to be colonized more sparsely than instream rocks, but ours and other studies seem to show that the taxon groups that colonize Dendys, although reduced, are fairly representative of the stream as a whole.

We used three indices to derive stream habitat quality information from our macroinvertebrate data and to compare that information to other studies: the Mean Tolerance Quotient (derived from Winget 1985), a community analysis following Kurtenbach (1990), and the Biotic Condition Index (BCI, Winget 1985). Figure 2 compares the BCI and community index results.

5.3.1 Mean Tolerance Quotients (MTQ)

Winget (1985) studied the physical habitats and macroinvertebrates in 28 streams in western states, and conducted correlation analyses of the physical and chemical parameters with macroinvertebrate density, biomass, and diversity. He established what he calls "Tolerance Quotients" (TQs) for many macroinvertebrate taxa, denoting their sensitivity to and tolerance thresholds for gradient, substate roughness, alkalinity, and sulfate concentrations. TQs range from a low of 4, denoting the greatest habitat sensitivity, to a high of 108, denoting high tolerance for pollution and habitat stress. Hudsonia uses an index we call the "Mean Tolerance Quotient" (MTQ) to represent the overall pollution tolerance or intolerance of the macroinvertebrate community sampled. The MTQ ranges from 4 (least tolerant) to 108 (most tolerant), and is simply a weighted average of the Tolerance Quotients for all taxa in a sample.

The MTQs calculated from our Wallkill samples were uniformly poor; all but one station had MTQs of 100 or greater. The highest score, 90, was at station 1, the upper-most station in Orange County.

5.3.2 Kurtenbach's Community Analysis

The second index we used was a community-based index that had been used in the New Jersey section of the Wallkill by Kurtenbach (1990). This index consists of five metrics; each is described below. A number is calculated for each metric and then the metric is assigned a score of 0, 3, or 6, a zero implying poor water quality and a six implying good water quality (Table 4). For each station, the sum of the scores of the 5 metrics are designated as "non-impacted" (total score = 24-30), "moderately impacted" (9-21), or "severely impacted" (0-6).

The first metric is taxon richness measured by the total number of families of macroinvertebrates in the sample. This is one component of the standard measure of diversity which is known to be affected by water quality. A decrease in water quality tends to reduce taxon richness by eliminating the more pollution intolerant taxa.

The second metric measures the number of families of generally pollution intolerant aquatic insects. "EPT richness" is calculated by counting up the number of families of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) excluding the trichopteran family Hydropsychidae, a very pollution tolerant group.

The third metric, percent dominance, is a measure of evenness. In unpolluted streams, abundances of taxa are usually relatively equal (or even). If a single taxon comprises a high percentage of the sample, there may be a water quality problem. Percent dominance is calculated by dividing the number of individuals of the most abundant taxon by the total number of individuals in the sample.

Table 3. Numbers of individuals, densities, and Tolerance Quotients (Winget 1985) of macroinvertebrate taxa in a Surber sample (station 8A only), and in Dendy samples (all other stations) in the Wallkill River, fall of 1991. Three Dendy plates were recovered from stations 1,4,5,8,9, and 10, and two plates were recovered from stations 2,3,6 and 7. "#" = total number of individuals collected in three replicates. "msf" = mean density per square foot.

		TQ	STATION																					
			1		2		3		4		5		6		7		8		8A		9		10	
			#	msf	#	msf	#	msf	#	msf	#	msf	#	msf	#	msf	#	msf	#	msf	#	msf	#	msf
DIPTERA																								
Chironomidae	Undetermined	108	2	0.7	12	6.0	13	6.5	1	0.3	14	4.7			1	0.5			158	52.7			7	2.3
Chironominae	Chironomus riparius group	108							3	1.0									1	0.3				
	Cryptochironomus fulvus group	108																	5	1.7				
	Dicrotendipes neomodestus	108							1	0.3									1	0.3				
	D. nervosus	108	1	0.3															4	1.3				
	Glyptotendipes lobiferus (?)	108																	39	13.0	2	0.7		
	Polypedilum sp.	108							1	0.3														
	Pseudochironomus sp.	108	1	0.3																				
	Rheotanytarsus exiguus group	108													4	2								
	Tanytarsini, undetermined	108									1	0.3	1	0.5					11	3.7	11	3.7	12	4.0
Tanypodinae	Thienemannimyia group	108	2	0.7			3	1.5			2	0.7					1	0.3	13	4.3				
Orthocladiinae	Cricotopus bicinctus group	108																	1	0.3				
	Corynoneura sp.	108			1	0.5							1	0.5										
	Parametriocnemus sp.	108											1	0.5										
Empididae	Hemerodromia sp.	95																	2	0.7			1	0.3
Ceratopogonidae	Culicoides sp.	108							1	0.3														
Tipulidae	Undetermined						1	0.5																
TRICHOPTERA																								
Hydropsychidae	Cheumatopsyche sp.	108					1	0.5			4	1.3	4	2.0			29	9.7	66	22.0				
	Hydropsyche betteni	108									1	0.3	1	0.5										
Polycentropidae	Polycentropus nr. cinereus	72	1	0.3	2	1.0																		
	Phylocentropus sp.		1	0.3																				
Leptoceridae	Mystacides sp.	54																	1	0.3				
	Oecetis nr. cinerascens				1	0.5																		
Hydroptilidae	Hydroptila sp.	108																	2	0.7				
NEUROPTERA																								
Sialidae	Sialis sp.	72	1	0.3																				
PLECOPTERA																								
Taeniopterygidae	Taeniopteryx sp.						1	0.5			2	0.7					1	0.3						
Capniidae	Allocapnia sp.						6	3.0	1	0.3														
COLEOPTERA																								
Elmidae	Ancyronyx variegata	104																	1	0.3				
	Dubiraphia sp.	104							3	1.0									58	19.3				
	Macronychus glabratus	104					1	0.5																
	Stenelmis sp.	104							1	0.3									2	0.7				
Haliplidae	Undetermined	54																	1	0.3				

(continued)

(Table 3, continued)

		TQ	STATION 1 #	1 msf	2 #	2 msf	3 #	3 msf	4 #	4 msf	5 #	5 msf	6 #	6 msf	7 #	7 msf	8 #	8 msf	8A #	8A msf	9 #	9 msf	10 #	10 msf
ODONATA																								
Coenagrionidae	Argia spp.	108	1	0.3			2	1.0			1	0.3			1	0.5	1	0.3			2	0.7		
	Coenagrion/Enallagma complex																				2	0.7		
	Enallagma sp.	72	7	2.3																				
Macromiidae	Macromia illinoiensis																		1	0.3				
EPHEMEROPTERA																								
Heptageniidae	Stenacron sp.						1	0.5			5	1.7											1	0.3
	Stenonema sp.	48									3	1.0					2	0.7	1	0.3				
Undetermined											1	0.3			1									
NON-INSECTS																								
Gastropoda	Amnicola limosa	108							1	0.3									5	1.7	1	0.3		
	Ferrissia rivularis	108							2	0.7									1	0.3				
	Ferrissia sp.	108																	1	0.3				
	Fossaria sp.	108							2	0.7														
	Menetus dilitatus	108							1	0.3									3	1.0	2	0.7		
	Physa heterostropha	108							7	2.3	4	1.3	1	0.5	1						3	1.0	4	1.3
	Undetermined	108																						
Bivalva	Sphaeriidae, undetermined																		31	10.3				
	Undetermined								1	0.3														
Isopoda	Caecidotea r. racovitzai		2	0.7																				
Amphipoda	Gammarus fasciatus	98			26	13.0	11	5.5	3	1.0	1	0.3	2	1.0	6	3	4	1.3	69	23.0	4	1.3	59	19.7
Turbellaria	Dugesia tigrina	108																	5	1.7	13	4.3		
	Undetermined	108																	5	1.7				
Ostracoda	Hydracarina, undetermined		1	0.3																				
	Lebertia sp.																		1	0.3				
Cyclopidae	Undetermined		1	0.3																				
OLIGOCHAETA																								
Tubificidae	Bothrioneurum vejdovskyanum(?)	108					1	0.5	82	27.3									55	18.3				
	Undetermined	108	1	0.3			1	0.5											141	47.0				
Nematoda	Undetermined	108																	2	0.7				
Undetermined		108	1	0.3			6	3.0	20	6.7							1	0.3	24	8.0	6	2.0	5	1.7
TOTAL			23	7	42	21	48	24	131	43.7	39	13	11	5.5	14		39	13	711	237	46	15.3	89	29.7
MTQ				90		100		105		108		102		106		103		104		106		107		101

The fourth metric also addresses evenness, but only of the pollution-intolerant forms. Low percent composition of these taxa may indicate a decline in water quality. This metric is calculated by summing the number of individuals of Ephemeroptera, Plecoptera, and Trichoptera (excluding the tolerant Hydropsychidae) and dividing the total by the total number of individuals in the sample.

The fifth metric is called the Hilsenhoff Biotic Index. This, like the MTQ, is essentially a weighted average of the tolerance values for taxa in each sample. Each taxon is assigned a tolerance value ranging from 0-10 reflecting the organism's ability to tolerate pollution. A zero implies no pollution tolerance and a ten implies high tolerance. Tolerance values were taken from Bode et al. (1991) and Kurtenbach (1990). The number of individuals of each species is multiplied by the species' tolerance value, products are summed for a given sample, and the sum is divided by the total number of individuals of all species in the sample.

Table 4. Scoring criteria for the macroinvertebrate community-based index, from Kurtenbach (1990).

Metric	Score 6	Score 3	Score 0
1. Number of families	>10	5-10	0- 4
2. Number of EPT* families	> 5	3- 5	0- 2
3. Percent dominance	<40	40-60	> 60
4. Percent EPT*	>35	10-35	< 10
5. Hilsenhoff Biotic Index	0-4	>4- 6	>6-10

*EPT = Ephemeroptera, Plecoptera, and Trichoptera

We calculated the community index for each of our stations and for each sample reported by Cooper and Neuderfer (1973), who sampled the entire New York portion of the Wallkill. Kurtenbach (1990) used the travelling kick method and based his calculations on the first 100 macroinvertebrates identified (as specified in the Rapid Biological Assessment [RBA] protocol).

Kurtenbach (1990) reported that the Wallkill was not polluted in the vicinity of Hamburg, NJ, but was moderatedly polluted (community index of 15) at the two stations closer to the New York border. By the same community index, all of our stations were classified as moderately or severely impacted. Two of our stations (3 and 5) had community index values of 15 or higher (maximum or best is 30). Four of our stations (4, 6, 9, and 10) fell into the "severely impacted" category. Stations 4 and 6 also had the lowest BCI values. The community index also showed the same general decline upstream to downstream (within Orange County) as we saw with the BCI (Fig. 2), although the community index decline was less pronounced. At station 10, where the fish population was very poor, the community index was also poor (one of the two lowest values).

5.3.3 Biotic Condition Index (BCI)

The BCI compares the actual invertebrate community composition with one predicted from knowledge of the station's substrate, gradient, alkalinity, and sulfate concentrations. Winget (1985) assigned Tolerance Quotients (described above) to a substantial list of aquatic invertebrates, according to their apparent response to those four stream parameters. He predicted that, under extreme conditions (fine substrates, low gradient, high alkalinity, and high sulfate concentrations), the invertebrate community would comprise only the most pollution tolerant taxa. Under less extreme conditions, more taxa that are intolerant of those conditions would be found. The further the *observed* community tolerance deviates from the *predicted* community tolerance, the more likely it is that some other pollution or stress (i.e., not related to gradient, alkalinity, sulfate or substrate) is affecting the community. This deviation is expressed as a percentage (predicted ÷ observed). A BCI score of 100 means that the observed community matches Winget's (1985) predictions for the observed stream conditions and there is no additional pollution stress. A BCI score of less than 100 indicates some additional pollution stress; the lower the value, the greater the stress. The BCI can thus be useful for detecting the presence of organic compounds, heavy metals, or other common pollutants not necessarily associated with the four parameters listed above.

We calculated a BCI for the triplicate Surber samples taken at station 8 and for the Dendy plate data at each station (including station 8). We also calculated BCI values for each of the Orange County mainstem Wallkill stations sampled by Cooper and Neuderfer (1973). They used a Surber sampler at these stations without replication. We did not calculate BCIs for Kurtenbach's (1990) data for the Wallkill in New Jersey because he did not report identifications of invertebrate taxa to an adequate level for the BCI.

BCI values for the Dendy plate samples from the Wallkill in Orange County ranged between 49 and 67. We expect BCI values greater than 80 in relatively unpolluted water. The minimum values attainable (fauna composed entirely of the most tolerant organisms) were 54 (for stations 1, 2, 7, and 9) or 49 (for the rest of the stations). Station 6, with a BCI score of 49.9, had nearly at the lowest possible value.

The BCI results suggested a decline in water quality from upstream to downstream stations (Fig. 2). The two stations with the lowest BCI scores were station 4 (downstream of the Orange County landfill) and station 6 (at Cemetery Road). Surprisingly, the station just below the Al-Turi landfill (station 5) was one of the better macroinvertebrate stations in this study.

The BCI value calculated for the Surber sample at station 8 (52.7) was similar to the BCI for the Dendy samples (59.3) at that station. The Dendy plates thus appeared to provide reasonable BCI results, although the BCI score may be somewhat inflated.

BCIs calculated for the 1973 Surber data (Cooper and Neuderfer, 1973) were very similar to those from this study (53.7-61.5). The similarities are apparent in Fig. 2 where the BCI values from the two studies are juxtaposed. These results suggest that Wallkill water quality has changed little in the last 20 years.

Our sampling design did not permit reliable spatial or temporal comparisons of the data. The most important result is that scores for all macroinvertebrate indices were very poor, including those calculated for the Surber sample at station 8. The very high MTQs indicate a macroinvertebrate community that is very tolerant of pollution. Indeed, only 6 of the 44 taxa collected had Tolerance Quotients less than 90 (maximum = 108). The moderate to low Community Index values reflect both low diversity and high pollution tolerance. The uniformly low BCI scores suggest significant levels of unidentified pollutants.

In our study of three other Hudson Valley streams (Stevens et al. 1994), we found strong negative correlations between macroinvertebrate indices and chloride, sulfate, phosphate-phosphorus, and conductivity; high concentrations of any of those compounds or high conductivity were associated with very tolerant macroinvertebrate communities (high MTQs). Correlations of fish and diatom indices with water chemistry parameters were poor or inconsistent. We concluded that analysis of macroinvertebrate communities may be the best means of ascertaining the overall stream "health". Water chemistry samples reflect only momentary conditions, and most research and monitoring studies only analyze a small set of potential pollutants. The macroinvertebrate community, on the other hand, presumably integrates changing levels of water quality, and also responds to the full range of pollutants, not just the pollutants analyzed.

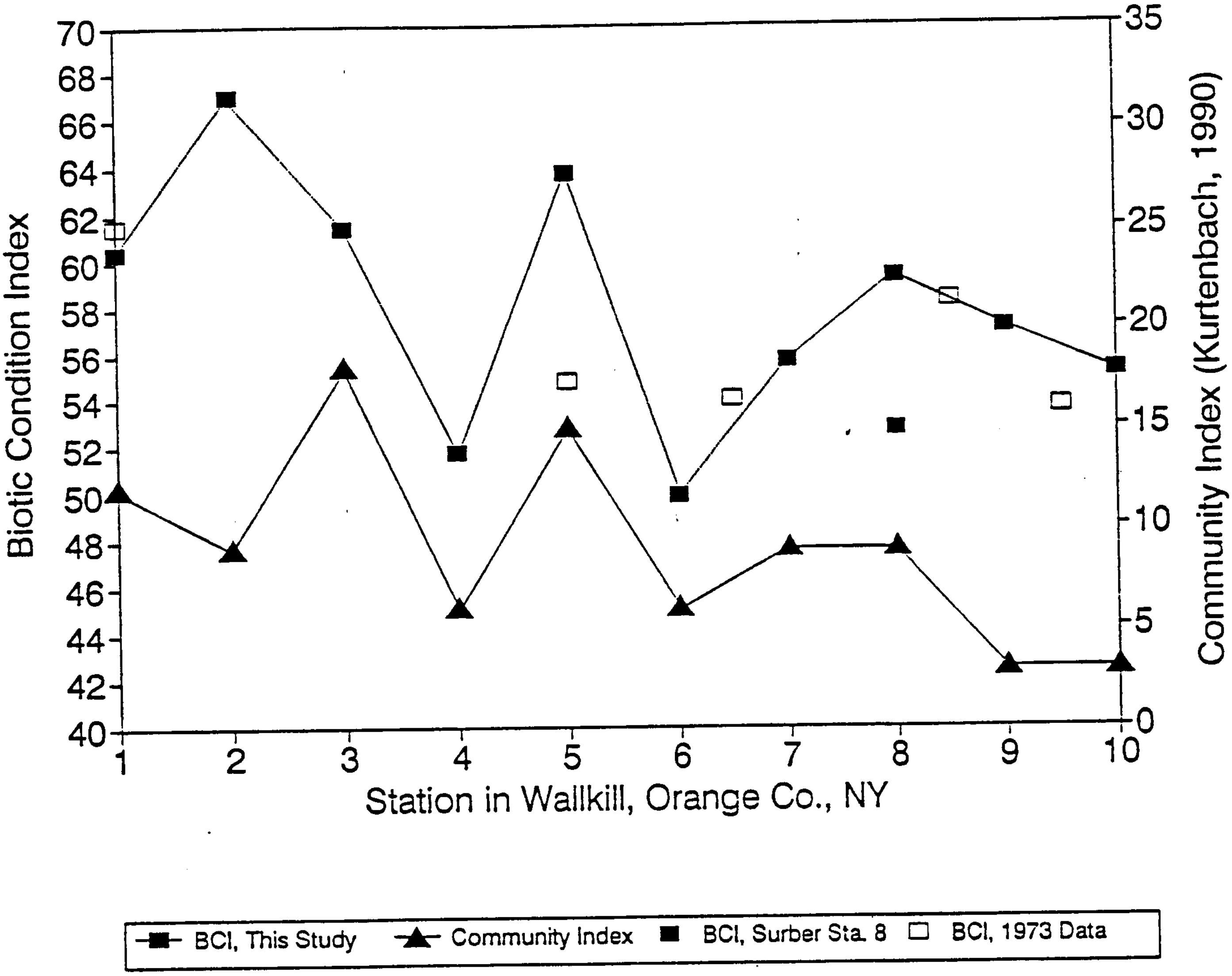

Figure 2. BCI and Community Index values from Wallkill River macroinvertebrate samples, 1973 and 1991.

6 Flora

We focused our botanical surveys both on representative reaches of the river and on localities we thought likely to support rarities. We did not survey the entire riparian zone; there may be additional occurrences of the rare plants we discuss, or occurrences of other rare species elsewhere along the river. For example, the Black Dirt area, because of its considerable extent, may yet contain rare species and significant habitats in undrained wetlands, abandoned farm fields, islands, and the old channel of the river (Black Walnut Channel).

We found several native plant species listed as rare statewide (ranked S1, S2, or S3 by the New York Natural Heritage Program [NHP], or on the NHP Watch List) (Young 1992, and addenda), and several native species we believe to be regionally-rare in Orange County and in other the Hudson Valley counties. Our criteria of rarity are discussed in Sect. 13. The following discussion does not give exact locality data for the rarer species in order to protect them from potential collectors or vandals. Further information is available from NHP or Hudsonia.

The rare plants we found were in floodplain and riparian habitats but not in the main river channel. These plants may be protected somewhat from the pollution and hydrological alteration of the river because they are perched above the main channel where the greatest concentrations of pollutants and the most intense flood scouring occur. The presence of these rarities does not indicate that all is well with the Wallkill, or that the degradation of the river is not a threat to native biological diversity. We think that a return to lower levels of pollution in the Wallkill would be favorable to these and perhaps many other rare plants and animals, and would foster the development of native plant communities in the riparian zone.

It is interesting that we found a number of rare plants but few rare fishes in the Wallkill, that the river channel and riparian areas are generally degraded and in many places have introduced flora forming a prominent component of the vegetation, and that many of the rare plants are indicative of calcareous habitats. Large rivers often have plants that small rivers and streams do not have (Nillson 1989). We think the Wallkill offers important habitats for rare flora because it is one of the largest nontidal rivers in the Hudson Valley and because of the evidently calcareous nature of its soils.

6.1 Statewide Rare Plants

Cattail Sedge (*Carex typhina*) is ranked S1S2 by NHP. There are old records from Sullivan, Dutchess, Columbia, and Westchester counties, from Long Island, the New York City area, and from the Southern Tier of New York (New York Flora Association 1990), but there are only four extant sites known in the state (Steve Young, NY Natural Heritage Program, pers. comm.). This species has not been documented previously in Orange County, and none of us had previously seen cattail sedge in the Hudson Valley. Its habitats in NY range from marshes, river flats and rich hardwood swamps to forested rocky ledges with calcicolous flora. We found cattail sedge in a sedge meadow near Rutgers Creek.

Red-root flatsedge (*Cyperus erythrorhizos*) is ranked S2 by NHP. There are recent records from Putnam, Nassau, and Suffolk counties (New York Flora Association 1990), but no previous record from Orange. Its habitats in New York range from brackish coastal ponds, freshwater wet meadows, and pond and stream edges to steep oak-pine forest and cliff communities on limestone outcrop. We found it on a young floodplain forest along the Wallkill.

River birch (*Betula nigra*) is ranked S3 on the NHP Watch List. Although very rare east of the Hudson River, this species is widespread but uncommon to rare along the Wallkill River and occasional elsewhere in Orange and Ulster counties. It is essentially restricted to river and stream floodplains, lake shores, and freshwater tidal swamps, where it apparently depends on a degree of natural disturbance from flooding and bank erosion.

Small-flowered agrimony *(Agrimonia parviflora)* Small-flowered agrimony is ranked S2S3 by NHP. In the last several years, this species has been found at a number of localities in Orange and other Hudson Valley counties. Nonetheless, we still consider it rare statewide and in the region. Small-flowered agrimony grows in sunny or semi-sunny, moist-to-wet, mildly to moderately disturbed, calcareous habitats.

Small white aster (*Aster vimineus*) is ranked S2 by NHP. In the last several years, it has been found at several localities in Orange County and a few others in Ulster, Dutchess, and Putnam. The habitat affinities are similar to those of small-flowered agrimony, but small white aster seems more rare.

Watermeal (*Wolffia braziliensis*). This species of watermeal is ranked S2 by NHP, and there is only one published record (Suffolk County) (New York Flora Association 1990). We have, however, collected *W. braziliensis* at several other Hudson Valley sites, principally east of the Hudson, in the last few years. This species may be expanding northward into New England and New York (Steve Young, pers. comm.). It may be less rare than overlooked due to its small size and similarity to *W. columbiana* and *W. borealis*. We think it should be considered rare until more field work is done in the region. *W. braziliensis* seems to occur in waters that are at least somewhat calcareous.

Winged monkeyflower (*Mimulus alatus*) is ranked S2 by NHP. There are perhaps a dozen localities known from late 1980s - early 1990s field work in the Hudson Valley. This species is associated with light to moderate shade and wet, calcareous soils along streams and the Hudson River (Sharma 1993). Winged monkeyflower is rare on the Wallkill although larger populations have been reported elsewhere in the region. There is some evidence that numbers may fluctuate from year to year.

6.2 Regionally-rare Plants

We found each of the species discussed below at one or more locations along the Wallkill. We consider these species regionally-rare on the basis of our experience and the New York Flora Association (1990) draft atlas. Some may prove to be under-collected and more common than we think, but we prefer to regard them as rare until proven otherwise.

Asa Gray's sedge (*C. grayi*) and **squarrose sedge** (*C. squarrosa*). There is no published Orange County record for Asa Gray's sedge (New York Flora Association 1990), although we have seen it at several locations east of the Hudson (at streams, wetlands, and the estuary itself). Squarrose sedge is known from the Hudson Valley, the New York City area, and the Finger Lakes region (New York Flora Association 1990). We have found squarrose sedge especially on clayey soils at several sites east and west of the Hudson River. Both species are associated with wet, calcareous soils.

Torrey's Rush (*Juncus torreyi*) There are no published records for Torrey's rush in Orange County (New York Flora Association 1990), although it is widespread elsewhere in the state. This is a rush primarily of of shallow water habitats and sandy shores (Clemants 1990). We have also found it in wet clay meadows. In this study we found it in an open floodplain forest.

Clammy cuphea (*Cuphea viscosissima*). There are old records for clammy cuphea from most Hudson Valley counties, the New York City area, and the Southern Tier (New York Flora Association 1990), but we know of no recent documentation except at the U.S. Military Academy property at West Point in 1992. We found clammy cuphea at one wet meadow location on the Wallkill.

We found **green dragon** (*Arisaema dracontium*) at two locations on the Orange County portion of the Wallkill. This species is rare in the Hudson Valley, where it is associated with wet, calcareous soils along streams and at least one station on the Hudson River.

Ground-cherries (*Physalis heterophylla, P. subglabrata*). *P. heterophylla* is a new record for Orange County although there are widespread old records elsewhere in New York (the only recent record is in western New York) (New York Flora Association 1990). *P. subglabrata* has no recent records in New York but there are old records in Putnam and Ulster counties (none in Orange) (New York Flora Association 1990). The latter species, particularly, may be regionally-rare but we know little of these species.

Ninebark (*Physocarpus opulifolius*). This shrub is common along the shoreline of the fresh-tidal Hudson River (e.g. in northern Dutchess County) but we have not previously seen it away from the Hudson in eastern New York.

Swamp loosestrife (*Decodon verticillatus*). This species is at least scarce, possibly regionally-rare, in the Hudson Valley. It is associated with perennially wet, often organic soils. We found swamp loosestrife at four Wallkill locations.

Tumbleweed (*Amaranthus blitoides*) and **Water-hemp** (*A. tuberculatus*). We have seen neither amaranth previously in the Hudson Valley. Tumbleweed is known from old Ulster and Putnam county records, and water-hemp from old Greene County and Staten Island records (New York Flora Association 1990).

Some of the other plants we collected along the Wallkill appear to be Orange County records according to the New York Flora Association (1990) atlas, although these are not necessarily regionally-rare species. Among these were the lovegrasses *Eragrostis hypnoides* and *E. pectinacea*, and toad-rush (*Juncus bufonius*). At several locations along the Shawangunk Kill in Ulster County Hudsonia found in 1993 the first New York record of the grass *Diarrhena americana*. Because the Wallkill River also flows south to north, is near the Shawangunk Kill, and supports many of the same rare plant species, there is some chance that diarrhena also occurs here.

6.3 Introduced Flora and Floodplain Habitats

We found it striking that the floodplain meadows of the Wallkill had vegetation in which many introduced plant species were prominent. Among these species are purple loosestrife, Japanese hops, purslane, moneywort, garlic-mustard, and in somewhat drier floodplain areas multiflora rose, Bell's honeysuckle, and common buckthorn. Some of these plants (e.g. purslane, Japanese hops) are absent from, or scarce in, floodplain meadows of other Hudson River tributaries.

Well-established introduced species are often more tolerant of water pollution, soil disturbance, or other habitat modification than are many native species. Some of the introduced plants (e.g. purple loosestrife) associated with waterways and wetlands tend to be particularly aggressive invaders of native vegetation. Where certain introduced plant species are common or abundant, they may be indicators of environmental degradation; the abundance is a result of these more degradation-tolerant species outcompeting the more sensitive natives. Likewise, where a plant community contains a large number of introduced species, environmental degradation is often a factor.

The Wallkill is a large stream and as such its habitats are naturally subject to higher nutrient levels and greater flood energies than are habitats in smaller streams (other things equal). Therefore, we must ask to what extent the prominence of introduced species in the floodplain meadows is a result of (and indicator of) human-caused environmental stress, and to what extent a result of natural processes along a large river. We believe both natural processes and human impacts are important in shaping the floodplain vegetation of the Wallkill. Human activities in the Wallkill basin have increased nutrient levels and flood forces in the river. The floodplain meadows directly adjoin the river channel where they have no protection from flood scouring or water quality. Although natural river ecology certainly influences the floodplain habitats, our observations on the intensive historic alterations of the river (channelization, wetland drainage, dams), the low-quality macroinvertebrate community, and poor water quality fit well with the picture of introduced species invasions and displacements in the floodplain flora.

Despite the prominence of introduced plants in the floodplain meadows, these habitats have ecological and environmental values worth conserving. Non-wooded (herb-dominated) habitats that are not actively managed (e.g. mowed, cultivated, grazed) are of limited extent in southeastern New York. An exception is purple loosestrife meadows, which are extensive in our region, but many of the floodplain meadows along the Wallkill are not dominated by purple loosestrife. We have not studied the functions and values of the Wallkill meadows directly, but these meadows are likely to be good foraging habitats for a variety of songbirds, and could be foraging and nesting habitat for ducks, foraging habitat for the wood turtle and various frogs, and spring-summer habitat for a variety of native butterflies and other native insects. Presumably the meadows also play a role in removing nutrients from the river water (at least seasonally), collecting sediments, and producing detritus (dead leaves, etc.) food for aquatic insects.

7 Significant Habitats

7.1 Riparian Habitats

In this discussion the term "riparian zone" includes both the areas where the water table is irregularly elevated due to proximity to an intermittent or perennial stream, and the areas adjacent to a stream but above the floodplain (i.e., where banks are steep) which drain directly into the stream. The extent of the riparian zone must be defined locally on the basis of slopes, artificial barriers, and land uses. The importance of the riparian zone to terrestrial and stream ecosystems cannot be overstated. There is continuous interaction between aquatic, riparian, and upland ecosystems through exchanges of energy, nutrients, and species (McCormick 1978), and most fish and wildlife are dependent upon riparian habitats for their survival (Hubbard 1977).

Riparian ecosystems often have high species diversity and densities, high biological productivity, a high degree of endemism, and large numbers of rare species (Hubbard 1977, McCormick 1978, Rawinski 1988). Natural and seminatural soil and vegetation in riparian meadows, shrublands, and forests provide an ecological buffer zone for the river. This buffer serves a multitude of crucial functions including: removal of nutrients, silt and other pollutants from surface runoff and shallow groundwater entering the river channel and from the river water itself during floods; stabilization of streambank and floodplain soils; maintenance of stream flows during drought periods; contribution of leaves and wood to the aquatic habitat and food web; filtering of noise, visual disturbance, and intrusion of human activities from the habitats of sensitive biota; and providing habitats for species that depend on riparian areas or that are more successful there than in other habitats. The buffer zone not only protects the river from humans but also protects human activities from river flooding.

Soil texture, flooding regime, and types of vegetation cover all determine the influence of the riparian zone on stream quality, but for the reasons mentioned above we consider all riparian areas to be significant or potentially significant habitats. Nationwide, 70-90% of pre-colonial riparian habitats have been destroyed or severely degraded (McCormick 1978). The restoration of degraded riparian habitats, and the protection of functioning riparian ecosystems are essential to rehabilitation and maintenance of the physical and biological integrity of streams.

7.2 Riparian Forests.

In studies of streams in forested landscapes in the Northeast, Likens et al. (1970) and Bormann et al. (1968, 1969) found that over 99% of the energy in aquatic food webs originated in adjacent forest ecosystems. Floodplain forests absorb more flood energy (i.e. protect downstream areas from flooding more) than do meadows. Forests are probably more effective at removing dissolved nutrients from the river water, and produce better-quality detritus for aquatic food chains (aquatic insects and fish). Numerous studies have found that riparian forests are important nitrogen sinks, and that they significantly reduce acidity of groundwater and precipitation (e.g., Peterjohn and Correll 1986, Schnabel 1986).

In a basin with extensive agricultural and residential land uses, forests that are older or that cover larger areas are especially important habitat for many kinds of birds and other animals, as well as plants. A few of the important habitat functions of riparian forests are: rest areas for northward-migrating birds in spring; breeding and roosting areas for birds, small mammals, amphibians, reptiles, and invertebrates that use cavities in large or flood-damaged trees, and the cavities in and spaces under large fallen branches and trucks; foraging and nesting habitat for wood turtle (that also use the stream channel); habitat for other animals that require forests near water or wet soils; habitat for species associated with tree species that occur mainly or only in riparian areas (e.g. the rare sycamore ball bug *Belonochilus numenius*), and sources of snags (trunks and large branches) that provide critical habitat features for many fishes, invertebrates, water birds, and reptiles in the river channel. (The last function may be especially important along the Wallkill due to the shortage of snags in the channel.) Woody roots on streambanks provide overhangs that are valuable escape and cover habitats for fish, invertebrates and mammals. Forested streambanks and floodplains also provide shade that helps maintain cool stream water temperatures essential to many aquatic organisms, and are more effective than herbaceous cover at preventing erosion of streambank and floodplain soils.

Removal of a forested canopy from stream edges results in significant increases in stream water temperatures (Burton and Likens 1973, Rishel and Lynch 1980). Subsequent erosion of stream banks creates a wider, shallower stream which is warmer still. Water temperature is a major controlling factor for stream organisms, and is an important determinant of community structure, behavior, growth, reproductive activity, and temporal succession (Hynes 1970, Ward and Stanford 1979). Even a single row of trees along a stream bank is better than none at all, but forest width determines the capacity of riparian forests to carry out a variety of water quality and biological functions. The broader the forested zone along a stream, the higher the abundance of amphibians, reptiles and some mammals (Dickson 1989 and Reay et al. 1991 cited in Keller et al. 1993), other factors equal. Keller et al. (1993) recommended riparian forests at least 100 m wide to provide nesting habitat for area-sensitive bird species; they felt that wider forests are preferable. Riparian forests of any age and size along the Wallkill River and its tributaries deserve protection for their present and potential habitat value and for their contribution to the physical and biological integrity of the stream.

According to a sketch map prepared by John P. Tramontano (Orange County Community College) in 1993 and provided to Hudsonia by Martin Borko, the best riparian forests are concentrated along the Wallkill channel from just above Pellets Island Road to just above Montgomery, with gaps at the landfills, Route 17, below the Goshen Turnpike, and near the 416/Interstate 84 intersection. The map also shows important areas for some distance below (downstream of) the New Jersey line and just above (upstream of) the Ulster County line. Tramontano considered the location and extent of riparian wooded habitat and the size of trees in his determinations of habitat quality. He regarded the best riparian forests to be also the best birding areas on the Orange County portion of the Wallkill. Hudsonia did not attempt to corroborate the map.

7.3 Riparian Forest near Stony Ford Road

The floodplain area upstream of Stony Ford Road had silver maple forest, red ash-shagbark hickory forest, tall wet meadow, shrubby oldfields and agricultural fields (mowed and unmowed at survey time). One maple grove had 12-15 trees 70-100 cm dbh. Other large trees were a double stemmed 210 cm sycamore, a 100 cm sycamore and a 120 cm silver maple. The regionally rare lizard's-tail was among the forest herbs. Unmowed meadows had small-flowered agrimony (S2S3) and the regionally rare squarrose sedge. West of those areas was a selectively-logged floodplain forest with diverse shrubs and herbs (see flora list in Section 12), including the regionally rare ninebark and Torrey's sedge, small white aster (S2), red-root sedge (S2) and three-seeded mercury (NYNHP watch list). South of the streamside forest were hayfields, oldfields and hedgerows with diverse shrubs and herbs, including small-flowered agrimony, small white aster, and clammy cuphea (regionally rare). Small white aster was also abundant and widespread in the meadow just west of Stony Ford Road. This entire area, though somewhat disturbed, is well worth protecting. It is extensive (over 40 ha) and relatively free of serious damage, with diverse wildlife habitats and a large number of rare plant species. The various habitats could support many bird species, and some rare reptiles such as wood turtle (Special Concern) and box turtle. Tramontano considered the riparian habitats above and below Stony Ford Road to be the best on the Orange County reach of the Wallkill.

7.4 Floodplain Habitats East of Route 211 Bridge

Southeast of the Rt 211 bridge (south of the Canning Road intersection) was an extensive area of stream and floodplain habitats including vegetated stream-washed sand bank, floodplain forest, tall meadow, shrub swamp, calcareous seeps and old oxbows with pools and flood channels. The wild habitat area extended well beyond the 8 ha or so that we investigated. The floodplain meadow bordering Rt 211 had mostly reed canary grass and purple loosestrife, with scattered small box elders and silky dogwoods, vines such as wild cucumber and Japanese hops, and broad-leaved herbs such as smartweeds, clearweed and garlic mustard. A 2 x 10 m section of sandy riverbank had dense short herbs, high in species diversity but including no rare plants. Two plants found here, marsh watercress and giant chickweed, are at least uncommon in this region. High floodplain meadows had a few plants of small white aster and small-flowered agrimony. A calcareous spring flowed from a gravelly clay layer at the base of a low wooded slope east of the meadows. The spring fed a shrub-herb marsh with buttonbush, silky dogwood, lizard's-tail, rice cut-grass, three-way sedge and other herbs. An area of high floodplain north of the seep was atypical in having beech, sugar maple, basswood, pignut hickory and hop-hornbeam. This mesophytic assemblage may reflect the better drainage of the coarser soils here. Oxbows among patches of high floodplain had small pools with vegetated margins; one flood channel had winged monkeyflower. The beauty, seclusion, diversity of natural features and communities, and rare plants make this an area worth protecting in its entirety. We do not know its full extent, and it may harbor other rare species or special habitats.

7.5 Rutgers Creek

Barbour examined a wooded portion of Rutgers Creek north of (upstream of) the southern Lower Road bridge. This reach of the creek was mostly cobble-bottomed, and had a remarkably large crayfish population; Barbour observed densities of 10-20 crayfish per square meter of stream bed in places. there were also extensive beds of lizard's-tail (regionally rare), some with climbing hempweed (scarce). In a floodplain channel west of the creek there were about 15 winged monkeyflower (S2) plants under beech trees, and in a nearby patch of sedge meadow he found the rare cattail sedge (S1). South of the Lower Road bridge where the creek corridor had only narrow wooded margins along plowed fields, Barbour found climbing hempweed and two individuals of winged monkeyflower. The wooded corridor north of the bridge should be protected because of the relative lack of disturbance and the unusual stream habitats and rare plants.

A permit application for placement of a natural gas pipeline across Rutgers Creek was accepted by NYSDEC in August 1994. We do not know the location of the proposed crossing. We recommend that the Lower Road area be avoided, and that any construction work in Rutgers Creek be conducted with great care to avoid siltation or other disturbance of downstream habitats.

It may be useful to mention two rare species that probably do *not* occur along the Wallkill in Orange County. Historically there were a number of sites for the endangered bog turtle in the Wallkill basin in Orange County, but only one of those has been recently verified. A 1992 Hudsonia survey for the New York State Department of Environmental Conservation failed to find this species in Orange County, and we saw much evidence of damage to wetlands in areas where bog turtles were found historically. There may yet be a local bog turtle population but if so it is likely to be away from the river rather than in the riparian habitats *per se* because of the bog turtle's affinities for low-nutrient, groundwater seepage fens with low sparse vegetation. The threatened Blanding's turtle, although present in Dutchess County, has never been confirmed in the western portion of the Hudson River basin.

8 Restoration Opportunities

Streams are dynamic ecosystems with a remarkable capacity for self-renewal if the causes of ecological stress are eliminated. The Wallkill River presents many opportunities for restoration, most of which may be conducted on a small-scale, piecemeal basis. Many of the restoration projects we describe below can be conducted by private landowners at little expense or inconvenience. Other projects will require some technical or financial assistance, and others will need the cooperation and assistance of county, state, and federal agencies in design, permitting, and execution.

8.1 Buffer Zones

Buffer zones of substantially undisturbed soils and vegetation serve many critical functions for streams including protecting the water quality of surface runoff and groundwater entering the stream, maintaining cool stream temperatures, controlling erosion and sedimentation, and contributing organic debris that is important to stream organisms. The buffer zone can itself be valuable habitat for birds, mammals, amphibians, reptiles, and invertebrates that depend on riparian habitats. The buffer zone can also mitigate flood impacts on cultural resources, and help maintain water quality during flood events.

The optimum width for buffer zones depends on the purposes to be served, the potential impacts to the buffer zone and stream, and the local environmental conditions (e.g., soil texture, soil chemistry, vegetation cover). Hilditch et al. (1992) reviewed the literature on the values of buffer zones, and recommended widths for various purposes. We recommend establishment and maintenance of buffer zones wherever possible along the entire length of the Wallkill River and its tributaries.

8.2 Fencing

Streambanks that are trodden and grazed by livestock are sources of sediments, and of nutrient and pathogen pollutants. Grazing and trampling destroys plant cover and soil stability, leading to erosion of banks, destruction of stream bank habitats (e.g., undercut banks) widening of stream channels, and siltation of stream beds. Livestock feces contain high levels of nitrogen, coliform bacteria, and sometimes other pathogens. For improving stream bank stability, a fenced buffer zone of any width between grazed areas and streams is better than none at all. For nutrient removal from pasture runoff, Magette et al. (1989) recommended buffer zones greater than 4.6 m wide. According to Draper et al. (1978) a 10 m buffer can remove 90% of the nutrients in runoff from livestock pastures. Buffer zones to serve other functions, such as riparian wildlife habitat, should be broader. All pasture areas adjacent to streams should be fenced to prevent cattle from grazing, trampling, and defecating in or near the stream. If there is no other drinking source for livestock, a narrow, hardened, fenced ramp would permit access to the stream without undermining soil stability.

8.3 Snags

Sands and fine gravels, the predominant substrate in the Wallkill in Orange County, are of little value as habitat for benthic macroinvertebrates (Keup 1988). In many sand streams, the highest densities of aquatic invertebrates are found on snags and in debris dams that snags create (e.g., Smock et al. 1992). Along with channelization, state and federal agencies have long had a tendency to "de-snag" rivers and streams at regular intervals. Snags, of course, slow down the current and may redirect flows, both undesirable effects if the point of channelization was to move water quickly. De-snagging, however, drastically reduces the fish food productivity of sandy streams. The fish community in the Wallkill in Orange County might be significantly improved by the introduction and maintenance of snags along the length of the river. With more cover and food, the fish population would probably increase, and relative abundance would probably shift more toward fishes that feed on the benthos; thus the dominance of spotfin shiners would probably be lessened. Installation of snags could be conducted on an experimental basis at first on one or several stretches of the stream. With careful documentation of fish and invertebrates before and for several years after snag placement, the effects of snags on the stream could be determined.

8.4 Planting of Woody Plants

Woody vegetation is most effective at holding stream bank soils in place. Woody root systems create overhangs which are important habitats for fishes, mammals, reptiles, and amphibians. The shade provided by woody vegetation, especially trees, helps maintain the cool stream temperatures which are essential to many stream organisms. The Wallkill would be incrementally improved by planting of trees and shrubs on non-wooded banks wherever possible; only species native to the Wallkill watershed should be used.

8.5 Restoration and Protection of Wetlands

It is safe to say that all wetlands in the entire watershed contribute to the water quality of the Wallkill and its tributaries. Wetlands are important sites for nutrient processing, sediment retention, and other means of water quality maintenance and renovation. Whigham et al. (1988) concluded that wetlands in the upper parts of a drainage system have the greatest impact on water quality, and that riparian wetlands subject to flooding are especially important. Riparian wetlands apppear to be more effective than non-wetlands at denitrification, and may be important catchment areas for phosphorus escaping cultivated fields (Whigham et al. 1988, Gilliam et al. 1986). The State of New York regulates only wetlands 5 ha or larger in most cases. Although activities in any wetland may be regulated by the U.S. Army Corps of Engineers (COE), the federal government cannot be relied upon to detect unpermitted activities or permit violations. Local public and private wetland protection initiatives may be the most effective. A program to monitor, restore, and maintain the functional values of wetlands throughout the watershed could be coordinated by citizen volunteers under the supervision of a wetland ecologist.

8.6 Sewage Treatment

The sewage treatment plant at Walden is clearly degrading the Wallkill water quality. The plant's operation should be assessed and remediated, including upgrading to tertiary treatment if appropriate.

8.7 Floodplain Meadows

An effort to eradicate the many introduced plant species that dominate the floodplain meadows of the Wallkill would probably be futile until other aspects of the Wallkill ecosystem are rehabilitated. Propagules of alien plants are legion in a large stream draining a developed landscape, and the high nutrient levels and turbidity in the Wallkill, together with flood forces augmented by channelization, may combine to produce prime conditions for the invasion of introduced plants on floodplain meadows. Experimental removal (by handpulling or other low-impact mechanical means) of small patches of, e.g., Japanese hops, could provide some baseline information for larger scale restoration projects in the future. The U.S. Fish and Wildlife Service is releasing biological control agents for purple loosestrife, and the U.S. Department of Agriculture for multiflora rose; it is possible that these two pest plants will eventually be reduced in density throughout their North American ranges. Attempts at large-scale control of these species along the Wallkill should be postponed until the results of biocontrol are known. The rare plants along the Wallkill and their habitats (Sect. 6) deserve further study and conservation action. There may be local situations where small-scale control of purple loosestrife, multiflora rose, or other aggressive, pollution-tolerant introduced or native plants would benefit rare species, but this requires further observation to determine.

Charles Keene (Museum of the Hudson Highlands, *fide* David Church and others) has suggested that low floodplain areas along portions of the Wallkill could be "restored" and adapted to more effectively remove pollutants from the river water. This is a timely consideration; a similar experiment is being conducted on the Olentangy River in Columbus, Ohio, by William Mitsch and others at the University of Ohio. Because the available floodplain habitats on the Wallkill are elevated 1-3+ m above summer water level, the floodplain now serves a treatment function mainly at flood stages. Excavating some areas to within 0.3-0.5 m of the average stream water elevation would expose the areas to more frequent flooding. Any such excavation would presumably fill in over time unless artificially maintained. We do not have a specific recommendation or a good sense of the ecological tradeoffs that might be involved in altering the floodplain to attempt to improve its capacity to absorb nutrients and silt. The results of the Olentangy experiment (or results of any similar projects on other rivers) might provide some guidance. The Olentangy River at Columbus is roughly the size of the Wallkill in Orange County.

8.8 Inactive Dams

Dams are harmful to stream ecosystems in several ways. Dams alter downstream flows, block upstream fish migration, and trap organic debris. The reduction of stream flows caused by dams can be critical during drought periods when low flows can lead to elevation of stream temperatures, reduction of dissolved oxygen, reduction of spawning habitats, reduction of fish food invertebrate habitat, and concentration of pollutants. Removal of dams that are no longer in use, if done carefully, would do much to improve the Wallkill for aquatic organisms. Sediments impounded upstream of the dam should be dredged prior to dam removal to prevent downstream siltation. The dam should then be dismantled slowly to avoid the sudden release of a large volume of water. All phases of dredging and dam removal should be carried out at appropriate times of year and under the supervision of qualified stream engineers and biologists. State and federal permits would be required for any such project.

8.9 Removal of Riprap

The presence of riprap in a stream channel creates a uniform, unvegetated stream edge and bottom which is of little value to stream biota. Many macroinvertebrate and fish species require irregular substrates and diverse microhabitats for feeding, cover, and reproduction. Riprapped channel reaches thus tend to be biologically spare, inhabited by a few generalist species which contribute little to stream biological diversity. Riprap also increases stream velocity, and thus tends to increase the stream's downstream erosive power and flood impacts. Removal of riprap in the channelized reaches of the Wallkill would permit the establishment of stream bank vegetation and the diverse microhabitats that inevitably develop on an unreinforced bank. A vegetated stream bank would also be more accessible to amphibians and mammals moving in and out of the stream. Stream bank soils have some capacity to process water pollutants, and stream bank vegetation encourages the deposition of suspended solids. Riprap removal should be done in a piecemeal fashion with as little disturbance to the stream as possible. Great care should be taken to prevent erosion of the newly exposed stream bank soils. The use of fiber technology (Stevens 1994) and biological engineering (e.g., using live and dead plant material) including immediate planting of woody vegetation may be advisable. All work should be carried out in appropriate seasons under the supervision of qualified stream engineers and biologists.

8.10 Restoration of Original Channel

The two major channelized reaches of the Wallkill River - the Cheechunk Canal and the diversion around the landfills - represent the poorest stream habitats for aquatic organisms and stream-dependent wildlife, and almost certainly augment bank erosion and flood impacts downstream. The importance of the Cheechunk Canal to the Black Dirt agricultural region is obvious, but perhaps there are alternative means of maintaining adequate drainage of that area while permitting the Wallkill to resume its original path. Restoration of the Wallkill to its original meandering channel (Black Walnut Channel) would greatly enhance the stream quality there and downstream. Establishment of a substantial buffer zone along this reach would further improve stream habitats and would enlarge the pollution processing capacity of the stream corridor. Diverting water in cropland drainage ditches into created wetland detention areas prior to discharge into the Wallkill would reduce pollution and siltation stress, which may be extreme in this area. If channel restoration is deemed infeasible in the near term, establishment of buffer zones along the existing channel and construction of detention areas for cropland drainage should nonetheless be pursued.

9 Summary

The Wallkill River appeared to be severely degraded by non-point source and point-source pollutants. Siltation and phosphorus pollution were much worse than in other Hudson Valley streams for which we have recent, reliable data. Chloride concentrations were also high. The station immediately downstream from the landfills had among the highest TSS and by far the highest nitrate and phosphate-phosphorus concentrations. Sulfate levels were moderate to high in the upstream stations, but extraordinarily low downstream of station 5. Nitrate concentrations were exceptionally low for a stream in an agricultural watershed. Laboratory or reporting errors are a possible explanation for the low nitrate and sulfate values given here.

Apart from the obvious degradation in the Village of Walden from the sewage treatment plant, the fish community provides some clues about how the Wallkill ecosystem is structured and how stream quality could be improved. We observed a diverse but apparently low-density fish community in the Orange County portion of the Wallkill; the dominant species was a surface and drift-feeding minnow, a habitat generalist well suited to an unpredictably fluctuating environment. The sandy and fine-gravelly substrates that predominate in the Wallkill provide poor habitat for benthic invertebrates and thus produce a low abundance of fish food. The removal of snags and debris dams from the stream channel has further reduced fish food productivity.

In general, the macroinvertebrate communities indicated a degraded river that worsened further downstream. This degradation began in New Jersey and persisted throughout the Orange County section of the Wallkill. Our samples consisted almost entirely of taxa highly tolerant of pollution according to tolerance values assigned by Winget (1985), Bode et al. (1991), and Kurtenbach (1990).

At two sites our data indicated localized pollution problems that should be investigated further. The station downstream of the Orange County landfill indicated worse conditions than other stations located either upstream or downstream. The sewage treatment plant in Walden is clearly degrading water quality.

Our riparian surveys were by no means comprehensive, but nonetheless we found 7 species of state-listed rare plants and at least 10 species of regionally rare plants in the areas we examined along the Wallkill corridor. Other rare species may well be present. The combined influence of calcareous soils and large stream dynamics may produce riparian conditions along the Wallkill that are unique in the Hudson Valley.

The riparian habitats (including islands and the lower reaches of some tributaries), despite degradation, have especially important functions and values. These areas provide an ecological buffer zone for the river and important habitat for many native plants and animals. For these reasons, a continuous corridor of riparian lands along the Wallkill should be protected (and in some areas restored). Such a corridor could also potentially be used for a walking or canoeing trail. Corridor conservation could be accomplished by means of conservation easements, land owner agreements, and other protective mechanisms administered by a land trust or another private or public agency. Consideration should be given to the privacy of human residents of the riparian zone as well as to sensitivities of certain rare plants and animals. A compilation of existing data on the use of the Wallkill River corridor by birds, and possibly additional bird surveys, would be useful in designing and fine-tuning a riparian conservation plan.

Likens and Bormann (1974) declared that "management 'solutions' that consider rivers or lakes as entities in isolation from their watersheds and airsheds are sheer folly." For all streams, but especially for streams with large drainage areas such as the Wallkill, evaluation of multiple and cumulative impacts of activities throughoutt the drainage is an essential component of stream management. Such evaluations should encompass not only the large projects that receive regulatory review, but also the small unregulated projects. Even though small unrelated actions may be largely nonjurisdictional, they should nonetheless be considered in the calculation of total impacts. Small habitat modifications are routinely overlooked by planners and regulators, but, depending on their nature, timing, and location, may have significant impacts on a stream. Such activities as small-scale excavation or filling in the riparian zone, tree cutting along stream banks, addition of stormwater discharge, runoff from construction sites, runoff from salted and sanded highways, minor oil spills, new buildings, and new pavement all have the potential to harm stream water quality or stream habitats. Habitat modification can alter fish behavior, growth, reproduction, organ function, and gene function (Heath 1987). Extremely low concentrations of toxins can have significant effects on fish populations; the effects are sometimes sublethal, but may alter growth, reproduction, and immune responses (Burn 1991). Siltation of streams can destroy spawning beds, smother fish eggs, and destroy macroinvertebrate habitat.

Although in keeping with political realities, isolating a section of a river for study, such as the Wallkill in Orange County, limits our understanding of the river system and our capabilities to conserve and manage river resources. River resources (wild biota, water, cultivable floodplain soils, recreation opportunities, waste assimilation capacity) are proportional to the integrity of the entire river system. There are cogent reasons to study the Wallkill in its entirety, including the Ulster County and the New Jersey reaches. The U.S. Fish and Wildlife Service created the Wallkill River National Wildlife Refuge in 1990, a 3000+ ha parcel of land along a 14.5 km stretch of the Wallkill in New Jersey. The water quality of the Wallkill entering New York from New Jersey is apparently poor, but is quickly masked by non-point sources in Orange County. There may be opportunities for integrating conservation of the Wallkill corridor in Orange County with the New Jersey refuge.

There are many opportunities for "restoration," or at least ecological improvement of habitats along the Wallkill. Maintenance of buffer zones wherever possible along the Wallkill is recommended. Areas where riparian habitats have been damaged, altered, and subjected to land uses incompatible with buffer functions could benefit from re-establishment of seminatural riparian habitats. For example, where the golf course below the Al Turi landfill closely approaches the river channel, establishment of a wider buffer zone of native forest tress and shrubs would benefit the river and its biota. Wherever pastures directly border the river, fences should be erected to prevent trampling of the riverside zone, and manure contamination of the river. Restoration of woody vegetation in such areas would prevent further erosion of floodplain pastures. It may also be possible to restore some of the channelized reaches to a more natural (non-channelized) condition.

Ultimately, much of the ecological "health" or integrity of the river will depend on reduction of the pollutants (nutrients, chloride, silt, etc.) entering from agricultural lands, sewage treatment plants, storm drains, landfills, construction sites, highways, lawns, and other sources in the corridor and elsewhere in the basin. It is not our intention to single out particular land uses or pollution sources for blame. People of the Wallkill basin, as everywhere in the Hudson Valley region, need to come to grips with the degradative effects of necessary and ordinary activities on common property resources especially including streams and wetlands. Nutrient enrichment, chloride pollution, and siltation are very widespread in the Hudson Valley. In a study of three Hudson River tributaries (Moodna, Quassaic, and Fishkill creeks), we found that modest levels of chloride, phosphate, and sulfate were associated with major losses of the integrity of the macroinvertebrates, implying that widespread extant and ordinary-seeming pollution is having a serious impact on streams. Because river pollution is cumulative, this should be of concern to everyone who uses (or might in the future use) river resources including water supply, fisheries, recreational resources, and the capacity of the river to assimilate sewage and agricultural runoff.

In previous studies of the Shawangunk Kill, a major tributary of the Wallkill, we found that it supported an unusual number of rare animals and plants (fishes, invertebrates, and plants) for a stream in the mid-Hudson basin (Barbour and Stevens 1994, Schmidt and Kiviat 1989, Kiviat 1991). The lower Shawangunk Kill is essentially free-flowing and has not experienced intensive hydrological alteration or pollution. There was a proposal to withdraw large quantities of Shawangunk Kill water for public supply, because (in our interpretation) of the high quality of the Shawangunk Kill water and the low quality of the Wallkill River water. It is not in the long-term interests of our society or of nature to degrade a river, thus forcing ourselves to degrade another river in order to obtain the environmental services that should be available from the first river. The Wallkill River is the hydrologic centerpiece of Orange County, and we believe that the Wallkill could become a much more prominent cultural and natural amenity to residents and tourists in Orange County with investments in stewardship that are financially minor compared to, for example, the maintenance of major public infrastructure components such as highways, water supply, and sewage treatment.

10 Recommendations

Further Studies

1. Monitor the leachate and surface runoff entering the Wallkill from the Orange County landfill. Install leachate barriers and collection systems if appropriate.

2. Conduct surveys along the Wallkill corridor for butterflies, dragonflies and damselflies, amphibians and reptiles, breeding birds and wintering birds of prey to help identify the most biologically valuable riparian habitats.

3. Conduct stream corridor surveys of the Ulster County and New Jersey segments of the Wallkill.

Wallkill Restoration

1. Establish and maintain buffer zones of substantially undisturbed soils and vegetation wherever possible along the entire length of the mainstem and tributaries of the Wallkill River in Orange County. Buffer zones are most important in areas of intensive development, and in areas such as cropland and golf courses where runoff is contaminated with fertilizers and pesticides.

2. Fence pastures so that livestock cannot trample and graze the banks of the Wallkill and its tributaries. Farmers could be offered a financial incentive to fence their pastures, if feasible.

3. Divert cropland, pasture, and golf course drainage to created wetland detention areas wherever possible so that sediments can be intercepted and nutrient and toxic pollutants can be processed somewhat before entering the Wallkill.

4. Plant native species of trees and shrubs on non-wooded banks wherever possible.

5. Add snags to the mainstem channel to improve habitat for invertebrates and fish.

6. Assess and remediate the Walden sewage treatment plant operations. Upgrade sewage treatment if appropriate.

7. Insist on implementation of Best Management Practices for management of stormwater runoff from roads, parking lots, and residential and urban districts.

Other Projects

1. A canoeing "trail" with a printed guide to the Wallkill would encourage recreational and educational use of the river with minimal impact on biota and land owners. We think this would be a good way to promote interest in, and stewardship of, the resources of the river. The guide would describe available landings on public property, hazards, natural and cultural landmarks, and the "canoeability" of different river segments at different seasons. If there are conflicts with, e.g. sensitive breeding birds, the guide could urge that boaters stay off certain river segments during the breeding season. The guide should also steer boaters away from habitats that are sensitive for other reasons such as the occurrence of rare plants that may be vulnerable to trampling or picking. We urge that snags *not* be removed from the river unless these are directly threatening bridges or other structures. At survey time there were few snags in the Wallkill channel. Snags are very important for fish and other biota, and canoeists can accept the occasional need to haul over a snag as part of the river experience.

2. Establish a "riverwatch" program to a) monitor land use activities in the Wallkill watershed and direct or indirect impacts to the river, 2) alert local, state, and federal regulatory agencies to unauthorized activities and permit violations, and 3) to identify restoration opportunities and areas needing further study.

3. Encourage riparian land uses that are compatible with streams, such as buffer zones, open space, and low-intensity recreation.

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12 List of Flora

Plant species found during the 1991−1992 Wallkill River study. Stations 1−10 are biological and water quality sampling stations. Areas A−E are other observation areas along the Wallkill and selected tributaries (see Fig. 1). Scientific names and most common names follow Mitchell (1986). A question mark (?) indicates an uncertain identification at that location.

COMMON NAME	SCIENTIFIC NAME	STATIONS									OTHER AREAS					
		1	3	4	5	6	7	8	9	10	A	B	C	D	E	F
Agrimony	Agrimonia			x					x							
Agrimony	Agrimonia gryposepala				x										x	
Agrimony, small−flowered	Agrimonia parviflora				x		x	x			x					
Alder	Alnus														x	
Amaranth	Amaranthus						x									
Angelica, purple−stem	Angelica atropurpurea						x			x						x
Arrowhead, broadleaf	Sagittaria latifolia						x									
Arrowwood, northern	Viburnum recognitum						x		x	x						
Arum, arrow	Peltandra virginica				x	x		x	x					x	x	
Ash	Fraxinus									x			x			
Ash, red	Fraxinus pensylvanica	x		x	x	x	x	x	x	x	x				x	x
Ash, white	Fraxinus americana			x		x	x				x		x			x
Aspen, quaking	Populus tremuloides											x	x			
Aster	Aster		x	x	x	x	x		x							
Aster, calico	Aster lateriflorus									x				x		
Aster, heath	Aster pilosus						x									x
Aster, New England	Aster novae−angliae						x									
Aster, rice−button	Aster dumosus												x			
Aster, small white	Aster vimineus						x	x								x
Aster, tall white	Aster lanceolatus						x						x		?	x
Aster, white wood	Aster divaricatus													x		
Aster, white wreath	Aster ericoides												x			
Avens	Geum			x		x	x		x	x						x
Avens, white	Geum canadense			x		x	x	x	x	x	x		x	x	?	
Barberry, European	Berberis vulgaris					x										
Barberry, Japanese	Berberis thunbergii			x	x		x			x					x	
Basswood	Tilia americana							x								
Beard−tongue	Penstemon digitalis						?	x								
Bedstraw	Galium				x											
Bedstraw, marsh	Galium palustre							x								
Bedstraw, stiff marsh	Galium tinctorium						x									
Bedstraw, white	Galium mollugo				x						x					x
Beech, American	Fagus grandifolia							x						x		
Beggar−ticks	Bidens	x	x							x				x		
Beggar−ticks	Bidens tripartita						x							x	x	x
Bentgrass, autumn	Agrostis perennans									x						
Bentgrass, colonial	Agrostis capillaris									x						
Bentgrass, creeping	Agrostis stolonifera s.l.				x											
Bindweed	Convolvulus			x												
Bindweed, black	Polygonum convolvulus				?											
Bindweeed, fringed	Polygonum cilinode								?							
Birch, river	Betula nigra	x				x	x	x		x				?	x	x
Bitternut	Carya cordiformis						x			x						x
Blackberry, northern	Rubus allegheniensis						x						x			
Black−haw	Viburnum prunifolium							?								
Bladdernut	Staphylea trifolia					x	x		x					x		
Bluegrass	Poa			x		?		?								
Boneset, white	Eupatorium perfoliatum						x									
Bottlebrush	Elymus hystrix var. hystrix													x		
Bouncing−bet	Saponaria officinalis				x											
Boxelder	Acer negundo					x	x	x	x							x
Brachyeletrum	Brachyeletrum erectrum												x			x
Bramble	Rubus											x				
Brooklime	Veronica beccabunga						?									
Buckthorn, common	Rhamnus cathartica		x	x	x		x				x		x			
Bull−thistle	Cirsium vulgare				x		x									
Bulrush	Scirpus atrovirens							x		x						
Bulrush, pendulous	Scirpus pendulus						x									
Burdock	Arctium			x												
Burdock	Arctium vulgare				x											

(continued)

(List of Flora, continued)

COMMON NAME	SCIENTIFIC NAME	STATIONS									OTHER AREAS					
		1	3	4	5	6	7	8	9	10	A	B	C	D	E	F
Bur–reed	Sparganium	x												x		
Butternut	Juglans cinerea				x		x							x		
Buttonbush	Cephalanthus occidentalis							x							x	
Canary–grass, reed	Phalaris arundinacea	x		?	x	x	x	x		x						
Cardinal–flower	Lobelia cardinalis													x	x	
Catalpa	Catalpa									x						
Cat–nip	Nepeta cataria			x				x					x			
Cattail	Typha							x								
Cattail, broadleaf	Typha latifolia						x								x	
Celandine, greater	Chelidonium majus			x												
Charlock	Sinapis arvensis												x			
Cherry, black	Prunus serotina			?	x					x			x			
Chickweed, giant	Myosoton aquaticum							x	x							
Chicory	Cichorium intybus				x											x
Cinquefoil, sulfer	Potentilla recta						x									
Clearweed	Pilea pumila			x	x	x	x	x	x	x	x		x	x	?	x
Clover, alsike	Trifolium hybridum						x									
Clover, red	Trifolium pratense												x			
Clover, white	Trifolium repens												x			
Cocklebur, common	Xanthium strumarium	x	x				?								x	
Coontail	Ceratophyllum													?		
Coontail	Ceratophyllum demersum	x														
Cottonwood, eastern	Populus deltoides		x	x	x	x				x			x			
Cow–parsnip	Heracleum lanatum														x	
Creeper, Virginia	Parthenocissus			x	x			x		x		x	x			
Creeper, Virginia	Parthenocissus quinquefolia			x	x	x		x	x	x						
Cress	Rorippa						?									
Crowfoot, buttercup	Ranunculus						x									
Cucumber, bur	Sicyos angulatus								?							
Cucumber, prickly	Echinocystis lobata			x			x	x					x			
Cuphea, clammy	Cuphea viscosissima						x									
Currant	Ribes			x			x									
Currant, wild black	Ribes americanum					x										
Cutgrass	Leersia							x					x	x	x	
Cyperus	Cyperus erythrorhizos						x									
Dames–rocket	Hesperis matronalis			x			x			x						x
Dandelion, common	Taraxacum officinale													x		
Day–lily, orange	Hemerocallis fulva			x												
Dewberry, American	Rubus flagellaris						x	x								
Ditch–stonecrop	Penthorum sedoides						x							x		
Dock, bitter	Rumex obtusifolius							x								
Dodder	Cuscuta gronovii													x	x	
Dogwood, gray	Cornus foemina ssp. racemosa				x		x	x			x				x	
Dogwood, silky	Cornus amomum	x		x	x		x	x	x	x					?	x
Dragon, green	Arisaema dracontium			x				x								
Duckweed, common	Lemna minor	x		x	x	x	x	x					x		x	
Duckweed, great	Spirodela polyrhiza	x				x	x	x				x			x	
Elderberry, common	Sambucus canadensis							x		x						
Elecampane	Inula helenium							x								
Elm	Ulmus		x	x	x		x	x	x							
Elm, American	Ulmus americana				x	x				x			x			x
Elm, slippery	Ulmus rubra						x	x			x				?	x
Evening–primrose, common	Oenothera biennis				x					x						
Eyebane	Chamaesyce maculata						x									
False–buckwheat, climb'g	Polygonum scandens										x	x	x			x
False–nettle	Boehmeria cylindrica			x		x	x	x		x	x		x	x	x	
False–pimpernel	Lindernia dubia							x	x							
Felon–herb	Artemisia vulgaris			x												
Fern, crested	Dryopteris cristata						x									
Fern, marsh	Thelypteris palustris						x	x							x	
Fern, royal	Osmunda regalis							x								
Fern, sensitive	Onoclea sensibilis						x	x		x	x					
Fern, spinulose wood	Dryopteris carthusiana												x		x	

(continued)

(List of Flora, continued)

COMMON NAME	SCIENTIFIC NAME	STATIONS									OTHER AREAS					
		1	3	4	5	6	7	8	9	10	A	B	C	D	E	F
Field–thistle	Cirsium discolor						x									
Figwort	Scrophularia							x					x			
Fireweed	Erechtites hieracifolia		x				x					x				
Fleabane	Erigeron						x									
Fleabane, daisy	Erigeron annuus												x			
Fleabane, daisy	Erigeron strigosus			x												
Galingale	Cyperus strigosus	?					x	x	x							
Garlic–mustard	Alliaria petiolata			x	x	x	x	x	x	x		x				x
Geranium, wild	Geranium maculatum													x		
Germander, wild	Teucrium canadense			x				x			x					
Ginger, wild	Asarum canadense					x										
Goldenrod	Solidago			x	x			x								
Goldenrod, bush	Euthamia graminifolia						x									
Goldenrod, Canada	Solidago canadensis						x	x					x			x
Goldenrod, late	Solidago gigantea						x									x
Goldenrod, tall	Solidago canadensis var. scabra										x					x
Goldenrod, tall hairy	Solidago rugosa				x		x			x	x	x	x		x	
Grape	Vitis			x	x			x	x	x			x			
Grape, frost	Vitis riparia							x								
Grass(es)	Poaceae						x	x								
Grass, barnyard	Echinochloa crus–galli						x		x		?					
Grass, cockspur	Echinochloa muricata								?							
Grass, orchard	Dactylis glomerata				x		x									
Greenbrier	Smilax rotundifolia													x		
Ground–cherry	Physalis														x	
Ground–cherry	Physalis subglabrata									x						
Ground–cherry, clammy	Physalis heterophylla							?								
Groundnut	Apios americana							x		x						
Hare–figwort	Scrophularia lanceolata							x								
Hawthorn	Crataegus						x	x	x							
Hedge–bindweed	Calystegia sepium											x				
Hedge–mustard	Sisymbrium							x								
Hedge–mustard	Sisymbrium officinale											x				
Hedge–nettle, creeping	Stachys tenuifolia						x									
Hemlock	Tsuga canadensis														x	
Hempweed, climbing	Mikania scandens													x		
Hemp, Indian	Apocynum cannabinum						x						x			
Hickory, pignut	Carya glabra							x								
Hickory, shagbark	Carya ovata						x								x	x
Hog–peanut	Amphicarpea bracteata			x			x			x						
Honewort	Cryptotaenia canadensis					x				x						
Honey–locust	Gleditsia triacanthos				x											
Honeysuckle	Lonicera									x						
Honeysuckle, Bell's	Lonicera x bella			x	x	x									?	
Honeysuckle, Japanese	Lonicera japonica			x												
Honeysuckle, Morrow	Lonicera morrowi			?												
Honeysuckle, Tartarian	Lonicera tatarica						?									
Hop–hornbeam	Ostrya virginiana							x								
Hops, Japanese	Humulus japonicus						x	x	x		x					
Hornbeam	Carpinus caroliniana						x									
Horse–nettle	Solanum carolinense			x	x		x	x	x				x			x
Horseradish	Armoracia rusticana												x			
Horsetail, field	Equisetum arvense				x	x										
Horseweed	Conyza canadensis															x
Indian–tobacco	Lobelia inflata						x							x		
Iris, yellow	Iris pseudacorus								x							
Ironweed	Vernonia noveboracensis	x					x		x							
Jack–in–the–pulpit	Arisaema triphyllum			x									x			
Jewelweed	Impatiens									x						
Jewelweed, pale	Impatiens pallida			x												
Jewelweed, spotted	Impatiens capensis		x	x	x	x	x	x	x		x	x	x		x	x
Joe–pye–weed	Eupatorium fistulosum							x								
Joe–Pye–weed	Eupatorium													x		

(continued)

(List of Flora, continued)

COMMON NAME	SCIENTIFIC NAME	STATIONS 1	3	4	5	6	7	8	9	10	OTHER AREAS A	B	C	D	E	F
Joe–Pye–weed, spotted	Eupatorium maculatum						?			x				x	x	
Jumpseed	Polygonum virginianum						x	x	x					x		
Knapweed, bushy	Centaurea maculosa												x			
Knot–rush	Juncus nodosus						x									
Knotweed	Polygonum aviculare						x									
Lady's–sorrel	Oxalis stricta			x	x	x	x	x	x							
Ladys–thumb	Polygonum persicaria												x			
Live–forever	Sedum telephium													x		
Lizards–tail	Saururus cernuus	x					x	x		x				x		x
Lobelia, great	Lobelia siphilitica													x		
Loosestrife, fringed	Lysimachia ciliata						x	x		x						
Loosestrife, purple	Lythrum salicaria	x	x	x	x	x	x	x	x	x	x			x	x	x
Loosestrife, swamp	Decodon verticillatus							x							x	
Lovegrass	Eragrostis hypnoides	x			x			x	x							
Lovegrass	Eragrostis pectinacea								x							
Mannagrass, fowl	Glyceria striata							x								
Maple, Norway	Acer platanoides									x						
Maple, red	Acer rubrum			x	x	x	x	x							x	
Maple, silver	Acer saccharinum	x	x	x	x	x	x	x	x	x	x		x			x
Maple, sugar	Acer saccharum			x				x		x					x	
Meadow–rue, tall	Thalictrum pubescens						x			x						
Milkweed, common	Asclepias syriaca						x	x					x			x
Milkweed, swamp	Asclepias incarnata						x	x								
Mint, field	Mentha arvensis						x	?								
Mint, red	Mentha x gentilis					?										
Moneywort	Lysimachia nummularia			x	x	x	x	x	x		x			x	x	x
Monkeyflower, common	Mimulus ringens	x					x		x				x			
Monkeyflower, winged	Mimulus alatus							x						x		
Moonseed	Menispermum canadense			x									x			
Moss	Hypnum													x		
Moss	Mnium						x			x						
Motherwort	Leonurus cardiaca			x			x	x								
Mountain–mint	Pycnanthemum virginianum						x									
Mulberry, white	Morus alba					x		x		x						
Mullein	Verbascum thapsus												x			
Nettle, stinging	Urtica dioica	x				x	x	x	x	x		x	x			x
Nightshade, black'	Solanum nigrum						x					x				
Nightshade, climbing	Solanum dulcamara					x		x								
Nightshade, enchanters	Circaea lutetiana ssp. canadensis			x		x		x	x	x		x				
Ninebark	Physocarpus opulifolius						x									
Nut–grass, yellow	Cyperus esculentus				x											
Oak, northern red	Quercus rubra														x	
Oak, pin	Quercus palustris						x	x		x				x	x	
Oak, swamp white	Quercus bicolor						x	x						x		x
Oak, white	Quercus alba								x					x		
Osier, green	Cornus alternifolia			x												
Ox–eye daisy	Leucanthemum vulgare												x			
Parsnip, wild	Pastinaca sativa					?										
Pear	Pyrus communis							x								
Pea, Everlasting	Lathyrus sylvestris				x											
Pennywort	Hydrocotyle americana						x		x	x						
Pickerelweed	Pontederia cordata												x			
Pinkweed	Polygonum pensylvanicum				x		x	x								x
Plantain, buck–horn	Plantago lanceolata				x											
Plantain, common	Plantago major				x			x								
Poison–ivy	Toxicodendron radicans			x	x	x	x	x	x	x			x		x	
Poke	Phytolacca americana				x		x					x				x
Pond–lily, yellow	Nuphar luteum	x														
Pondweed	Potamogeton natans	x														
Pondweed	Potamogeton nodosus					x										
Pondweed, curly	Potamogeton crispus					x										

(continued)

COMMON NAME	SCIENTIFIC NAME	STATIONS 1	3	4	5	6	7	8	9	10	OTHER AREAS A	B	C	D	E	F
Pondweed, sago	Potamogeton pectinatus					x										
Prickly–ash, American	Zanthoxylum americanum														x	
Privet	Ligustrum														x	
Purple–leaf willow–herb	Epilobium coloratum						x			x					x	
Purslane	Portulaca oleracea				x		x									
Purslane, water	Ludwigia palustris	x					x	x	x							
Pussy–willow	Salix discolor						x									x
Queen–Annes–lace	Daucus carota				x		x									
Quickweed	Galinsoga						x									
Ragged–robin	Lychnis flos–cuculi									x						
Ragweed, common	Ambrosia artemisiifolia			x			x					x				x
Ragweed, giant	Ambrosia trifida						x		x				x			x
Raspberry, black	Rubus occidentalis			x	x			x								
Raspberry, red	Rubus idaeus						x									
Reed, common	Phragmites australis					x			x	x			x			
Rose, multiflora	Rosa multiflora			x	x	x	x	x	x	x					x	
Rose, swamp	Rosa palustris						x									
Rush, soft	Juncus effusus						x	x								
Rush, Torrey's	Juncus torreyi						x									
Sedge	Carex gynandra						x	x								
Sedge	Carex typhina													x		
Sedge(s)	Carex							x								
Sedge, Asa Gray's	Carex grayi				x		x	x	x							
Sedge, blunt broom	Carex tribuloides			?				x		?						
Sedge, crested	Carex cristatella						x									
Sedge, fox	Carex vulpinoidea						x	?		x						
Sedge, hop	Carex lupulina						x	?								
Sedge, pointed broom	Carex scoparia						x									
Sedge, shallow	Carex lurida						x	x								
Sedge, squarrose	Carex squarrosa						x	x								
Sedge, three–way	Dulichium arundinaceum						x	x								
Self–heal	Prunella vulgaris				x		x							x		x
Shepherds–purse	Capsella bursa–pastoris						x									
Skullcap, common	Scutellaria galericulata				x		x	x								
Skullcap, mad–dog	Scutellaria lateriflora				x											
Skunk–cabbage	Symplocarpus foetidus									x					x	
Smartweed	Polygonum	x	x				x									
Smartweed	Polygonum cespitosum			x	x	x				x						
Smartweed, dotted	Polygonum punctatum							x	x	?						x
Smartweed, large water	Polygonum robustius														x	
Snakeroot, black	Sanicula marilandica			x												
Sneezeweed	Helenium autumnale							x						x		
Solomons–seal, false	Smilacina racemosa								x							
Speargrass	Poa annua			x	x	x	x			x						
Speedwell, water	Veronica anagallis–aquatica				x	x										
Spicebush	Lindera benzoin					x	x	x		x				x		
Spikerush	Eleocharis	x				x	x	x								
Spikerush	Eleocharis obtusa var. obtusa							?								
Star–grass, water	Heteranthera dubia	x				x		x								
Stickseed	Hackelia virginiana			x									x			
Stick–tights	Bidens cernua						x							x		
Strawberry, wild	Fragaria virginiana						x	x								
St. Johns–wort	Hypericum perforatum						x									
St. Johns–wort, dwarf	Hypericum mutilum						x									
Sumac, poison	Toxicodendron vernix					x										
Sumac, staghorn	Rhus typhina											x	x			
Sundrops	Oenothera perennis											x				x
Sweet–clover, white	Melilotus alba				x											
Sweetflag	Acorus							x								x
Sycamore, American	Platanus occidentalis		x	x	x	x	x				x		x	x	x	x
Tearthumb, arrow–leaf	Polygonum sagittatum						x	x			x				x	x
Tearthumb, halberd–leaf	Polygonum arifolium						x	x								
Teasel, common	Dipsacus fullonum							x					x			x

(continued)

COMMON NAME	SCIENTIFIC NAME	STATIONS									OTHER AREAS					
		1	3	4	5	6	7	8	9	10	A	B	C	D	E	F
Thistle, Canada	Cirsium arvense				x		x	x					x			
Three–seeded–mercury	Acalypha virginica						x								x	
Tickseed–sunflower	Bidens coronata							x						x		
Toad–rush	Juncus bufonius				x											
Tree–of–heaven	Ailanthus altissima			x	x								x			
Trefoil, birds–foot	Lotus corniculata												x			
Tumbleweed	Amaranthus blitoides						x									
Turtlehead	Chelone glabra									x					x	
Umbrella–wort, heartleaf	Mirabilis nyctaginea												x			
Vervain, blue	Verbena hastata	x					x	x								
Vervain, white	Verbena urticifolia			x	x	x	x	x		x			x			
Violet	Viola			x		x	x		x	x			x			x
Violet, common	Viola sororia							x								
Virgins–bower	Clematis virginiana						x					x				
Walnut, black	Juglans nigra			x			x				x					
Watercress, marsh	Rorippa palustris							x								
Water–hemlock	Cicuta maculata			x	x	x		x								
Water–hemlock, bulb–b.	Cicuta bulbifera							x								
Water–hemp	Amaranthus tuberculatus				x				x							
Water–horehound	Lycopus						x									
Water–horehound	Lycopus americanus				x		x	x								
Water–horehound	Lycopus virginicus						x	x								
Watermeal	Wolffia			x												
Watermeal	Wolffia borealis														x	
Watermeal	Wolffia braziliensis				x											
Watermilfoil, Eurasian	Myriophyllum spicatum					x		x								
Water–millet	Echinochloa walteri															x
Water–parsnip	Sium suave						x	x								
Water–pepper	Polygonum hydropiper						x	x			x					x
Water–plantain	Alisma plantago–aquatica						x		x							
Water–starwort	Callitriche						x	x								
Waterweed	Elodea							x		x						
Whitegrass	Leersia virginica			x	x			x	x							
Wild–millet	Echinochloa	x					x									
Wild–rye(s)	Elymus					x		x					x			x
Wild–rye, Virginia	Elymus virginicus			x	x			x	x	x					x	
Willow–weed	Polygonum lapathifolium						x									
Willow(s)	Salix	x	x		x	x				x			x			
Willow, crack	Salix fragilis				?		x	x								
Willow, white	Salix alba					x	x	?			x	x	x			
Wineberry	Rubus phoenicolasius				x											
Winterberry	Ilex verticillata						x					x				
Withe–rod	Viburnum cassinoides									x						
Wolf's–milk	Euphorbia esula												x			
Wood–nettle	Laportea canadensis			x			x	x	x				x			x
Wood–reed, stout	Cinna arundinacea			x						x						
Woolgrass	Scirpus cyperinus							x								
Wormseed–mustard	Erysimum cheiranthoides					x	x		x							
Woundwort	Stachys palustris								x							
Yam, wild	Dioscorea villosa						x	x	x			x		x	x	
Yard–rush	Juncus tenuis						x	x								
Yarrow, common	Achillea millefolium				x		x									
Yellow–cress, creeping	Rorippa sylvestris						x	x	x							

13 Critaria of Rarity

Rare native species are important because their disappearance or decline often warns us of environmental deterioration (e.g., water or air pollution). All native species play a role in the structure and function of ecological systems. Furthermore, any species of plant or animal is potentially useful to human society; for example, for studying human disease and other phenomena in the laboratory, as a source of pharmaceutical chemicals, as a "gene bank" for crop and domestic animal improvement, for food, fiber, etc., and as an object of study and enjoyment.

Although in any region, most rare species are those species at their geographical range margins and are more common somewhere else, biological conservation must begin at a species' range margins where much genetic variability occurs and where the species is most likely vulnerable to natural or human-caused stress. In some cases, even fairly common species can be vulnerable, and severe decline or extirpation can occur rapidly if habitats are destroyed or other conditions change.

Table 5. Summary of rare species lists. A = all groups of animals; B = birds only; P = plants; listing categories are in parentheses. * indicates non-governmental lists. See text for explanation.

List	*Taxa*	*Rankings*
Federal Endangered Species	AP	Endangered, Threatened
American Birds Blue List (AB)*	B	Blue List, Special Concern
Migratory Nongame Birds of Management Concern	B	Management Concern
Migrants in Jeopardy*	B	In Jeopardy
New York Endangered Species (DEC)	A	Endangered, Threatened, Special Concern
New York Natural Heritage Program	AP	various (see below)
New York Protected Native Plant List	P	Endangered, Threatened, Rare, Exploitably Vulnerable
Regionally-rare*	AP	Regionally-rare (see text)

The concepts of rarity and vulnerability can be more-or-less objectively and consistently defined and applied. We have used, as much as possible, lists and evaluations of rare species at the national and state geographic levels, because these lists integrate information from many sources and provide a perspective that is not available on a regional or local level (see Table 5). Generally speaking, we do not consider of conservation significance those species (particularly of birds) that are highly mobile and occasionally show up in our area as "accidentals" but do not use the Hudson Valley on a regular and manageable basis; examples are the sandhill crane and the western meadowlark.

The New York State Department of Environmental Conservation (DEC) prepared a list of Endangered, Threatened, and Special Concern animals that became part of the State Environmental Conservation Law in 1983. Endangered Species are those that are imminently in danger of disappearing from New York State. Threatened Species have declined significantly and may become endangered if conditions in their environment continue to worsen and successful management actions are not undertaken. Special Concern Species are believed to be declining or vulnerable and may become Threatened or Endangered in the future, but often not enough is known about population levels and the ecology of these species to reach conclusions about their actual status and vulnerability.

The "Rare Animal Status List" and "Rare Plant Status List" of the New York Natural Heritage Program (NHP) (New York Natural Heritage Program 1992a, Young 1992) include many animals listed as Endangered, Threatened and Special Concern by the DEC, but also include many other species considered rare or vulnerable in the state. Each Heritage-listed species has been assigned a global rarity ranking and a state rarity ranking by the Heritage program and these rankings are updated every year or so (see below). A standardized letter of inquiry to the DEC Significant Habitat Unit requesting a summary of available file data on occurrences of rare animals, rare plants, rare plant communities, and other special habitat occurrences is appropriate as part of any environmental planning for land use change. This inquiry results in a search of files originating in three DEC offices: Significant Habitat Unit, Endangered Species Unit, and Natural Heritage Program. Available data, of course, do not necessarily include all significant occurrences at a site.

Some species are rare statewide and appear to meet NHP criteria but have not been listed by NHP, because of delays in evaluating data. A few species listed by NHP are actually more common than published data indicate, and in our opinion should not be on the Heritage lists; examples are the red-breasted sunfish and mummichog. We note these species and explain the basis for our conclusions. Many groups of invertebrate animals and non-vascular plants have not been reviewed at all by NHP and thus many rare species are not on the Heritage lists. Examples of non-reviewed groups are the fingernail clams, true flies, and fungi. Hudsonia considers species in groups not reviewed by NHP only when there is salient evidence of rarity.

The New York State list of protected plants lists species as Endangered, Threatened, Rare, or Exploitably Vulnerable. These categories are defined below. Protected plants may still be picked, collected, or bulldozed with the landowner's permission.

The Blue List is published every few years by American Birds (Tate 1986) and includes those species of birds in the U.S. which are thought to be undergoing long-term declines in numbers. The Blue List is referred to as an "early warning list" for species not in serious enough trouble to have been Federally listed as Endangered. It is based on reports filed by many active birdwatchers throughout the country with reference to their observations in the previous years. The 1986 Blue List has two categories: Blue-listed, and Special Concern (the latter indicates lesser declines, often restricted to certain regions).

The U.S. Fish and Wildlife Service Office of Migratory Bird Management (1987) published a list of 30 migratory, nongame bird species evincing population decline or instability throughout a significant portion of their ranges. These birds are deemed "Migratory Nongame Birds of Management Concern". Nine of the listed species breed (or have bred) in the Hudson Valley.

Neotropical "Migrants in Jeopardy" are 57 North American breeding birds, mostly insect eaters, that winter in tropical forests of Latin America. These species are "considered by many ornithologists to be at grave risk because of rapidly accelerating deforestation in Central and South America." The list, extracted from *The Birder's Handbook*, is based on the work of John Terborgh and David Wilcove (Wille 1990). Although conserving breeding habitat for these species may not address the root problem, this action reduces an additional source of stress to populations.

"Regionally-rare" species are native plants and animals which are rare in the mid-Hudson region and in the county under consideration. These judgments are based on the extensive field experience of biologists associated with Hudsonia and other biologists. Usually, a species we call regionally-rare has been found by us at fewer than 10 localities in the county during the 1970s and 1980s. Although we are not aware of all of the extant populations of all rare species in the region, the regionally-rare ranking serves at least as a measure of relative rarity in our region. For vascular plants, we also refer to the *Preliminary Vouchered Atlas of New York State Flora* (New York Flora Association 1990) and an unpublished list compiled ca 1974 by the late Stanley J. Smith (New York State Museum) which indicates the number of occurrences of each species in each DEC Region of New York; this list was based on specimens in the State Museum and other herbaria as well as Smith's own field observations but the time depth of occurrences is not known and may go back many decades. DEC Region 3 includes

Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, and Westchester counties. Most plants with 10 or fewer occurrences for Region 3 in the Smith list can safely be considered regionally-rare, and some species with 11-20 occurrences may now be regionally-rare and must be judged in part by our recent field knowledge. The Smith list is more useful for comparing species within groups (e.g., sedges or ferns) because different groups receive different amounts of attention from collectors (Jerry C. Jenkins, pers. comm.). The definition and listing of regionally-rare species in the mid-Hudson is just beginning, and should serve as a useful but not dogmatic guide for conservation. There is no official or legal list of regionally-rare species. Most regionally-rare species depend upon habitat types which themselves are rare and vulnerable.

Plants and animals tend to be more sensitive to environmental changes at their range margins, where the species are subsisting close to the limits of their environmental tolerances. Many endangered and threatened species started out as species that were rare statewide or regionally rare and were subjected to deteriorating ecological conditions of various kinds causing eventual contraction of the geographic ranges and/or declines in population numbers. (Examples from New York and neighboring states include the peregrine falcon, the red-shouldered hawk, the timber rattlesnake, and goldenclub [an aquatic plant], and in other states many freshwater mussels and small fishes.) Furthermore, the bulk of the genetic variation in a species often occurs at its geographic range margins. Many subspecies and species have not yet been described by biologists, thus we are not even aware of all of the major variants. It is of considerable recreational, educational, scientific, and commercial interest that the diversity of species naturally present in a region, and the conservation of representative natural communities and habitats, be maintained in the long term so these resources are available to society. These are among the reasons for concern about the conservation of regionally-rare and statewide rare (Heritage) species.

Generally speaking, Federally-listed Endangered and Threatened species are most important, followed by State-listed Endangered and Threatened species. Next in importance are State Natural Heritage Program listed species, State Special Concern species and (for birds) Management Concern and Blue-listed species. Finally, regionally-rare species are of concern in our region, though not necessarily on a statewide basis.

Explanation of Heritage Ranking System

This key is reprinted from the New York Natural Heritage Program New York Rare Plant Status List, August 1992.

Each element has a global and state rank. The global rank reflects the rarity of the element throughout the world and the state rank reflects the rarity within N.Y.S. Infraspecific taxa are also assigned a taxon rank to reflect the infraspecific taxon's rank throughout the world.

Global Rank

G1 = Critically imperiled throughout its range due to extreme rarity (5 or fewer sites or very few remaining individuals) or extremely vulnerable to extinction due to biological factors.

G2 = Imperiled throughout its range due to rarity (6 - 20 sites or few remaining individuals) or highly vulnerable to extinction due to biological factors.

G3 = Either very rare and local throughout its range (21 - 100 sites), with a restricted range (but possibly locally abundant), or vulnerable to extinction due to biological factors.

G4 = Apparently secure throughout its range (but possibly rare in parts).

G5 = Demonstrably secure throughout its range (however it may be rare in certain areas).

GH = No extant sites known but it may be rediscovered.

GX = Species believed extinct.

GU & G? = Status unknown.

State Rank

S1 = Critically imperiled in New York State because of extreme rarity (5 or fewer sites or very few remaining individuals) or extremely vulnerable to extirpation from New York State due to biological factors.

S2 = Imperiled in New York State because of rarity (6 - 20 sites or few remaining individuals) or highly vulnerable to extirpation from New York State due to biological factors.

S3 = Rare in N.Y.S. (usually 21 - 100 extant sites).

S4 = Apparently secure in N.Y.S.

S5 = Demonstrably secure in N.Y.S.

SH = No extant sites known in N.Y.S. but it may be rediscovered.

SX = Apparently extirpated from N.Y.S.

SE = Exotic, not native to N.Y.S.

SR = Reported from the state, but existence has not been documented.

SU = Status uncertain because of the cryptic nature of the plant.

Taxon Rank (T-rank)

The T-ranks are defined the same way the Global ranks are but the T-rank only refers to the rarity of the subspecific taxon not the rarity of the species as a whole.

A "Q" indicates a question exists whether or not the taxon is a good taxonomic entity.

A "?" indicates that an identification question exists about known occurrences. It also indicates the rank presumably corresponds to actual occurrences even though the information has not been documented in heritage files or historical records. It serves to flag species that need more field studies or specimen identification.

DOUBLE RANKS (i.e. S1S2, S2S3)

The first rank indicates rarity based upon current documentation. The second rank indicates the probable rarity after all historical records and likely habitat have been checked. Double ranks denote species that need additional field surveys.

New York State Plant Legal Status

The following catagories are defined in regulation 6NYCRR part 193.3 and apply to New York State Environmental Conservation Law section 9-1503.

E = Endangered Species: listed species are those with
1) 5 or fewer extant sites, or
2) fewer than 1,000 individuals, or
3) restricted to fewer than 4 USGS 7.5 minute topographical maps, or
4) species listed as endangered by the U.S. Department of the Interior, as enumerated in the Code of Federal Regulations 50 CFR 17.11.

T = Threatened: listed species are those with
1) 6 to fewer than 20 extant sites, or
2) 1,000 to fewer than 3,000 individuals, or
3) restricted to not less than 4 or more than 7 USGS 7.5 minute topographical maps, or
4) listed as threatened by the U.S. Department of the Interior, as enumerated in the Code of Federal Regulations 50 CFR 17.11.

R = Rare: listed species have
1) 20 to 35 extant sites, or
2) 3,000 to 5,000 individuals statewide.

V = Expoitably vulnerable: listed species are likely to become threatened in the near future throughout all or a significant portion of their range within the state if causal factors continue unchecked.

U = Unprotected

Federal Status

The categories of federal status are defined by the United States Department of the Interior as part of the 1974 Endangered Species Act (see Code of Federal Regulations 50 CFR 17). Recent changes in federal status were published in the Federal Register on February 21, 1990 (Vol. 55(35): 6184-6229). A summary of federally listed plants is in the U.S. Fish and Wildlife Service Publication "Endangered & Threatened Wildlife and Plants" (July 15, 1991).

(blank) = No Status

LE = The taxon is formally listed as endangered.

LT = The taxon is formally listed as threatened.

PE = The taxon is formally proposed as endangered but a final ruling has not been made.

PT = The taxon is formally proposed as threatened but a final ruling has not been made.

C1 = Candidate, category 1--The taxon with sufficient information to list as endangered or threatened.

C2 = Candidate, category 2-- The taxon may be appropriate for listing but for which more data are needed.

3A = The taxon is considered extinct by the U. S. Fish and Wildlife Service.

3B = The Taxon is no longer considered taxonomically distinct by the U. S. Fish and Wildife Service and thus not appropriate for listing.

3C = The taxon has been shown to be more abundant, widespread, or better protected than previously thought and therefore not in need of official listing.

* = The taxon is possibly extinct.

<u>NHP LIST</u>

Y = Yes, a taxon on the New York Natural Heritage Program rare plant status list.

W = Watch list, a taxon that may be rare or declining in New York, more data is needed before including it on the rare plant status list.

14 Project Staff

Table 6. Project personnel. Experience is in years (minimum).

Worker	Degree	Experience	Role in Wallkill study
Barbour, Spider	B.S.	21	Flora, habitat surveys
Jenkins, Jerry C.	B.A.	25	Identified or verified plant specimens
Kiviat, Erik	Ph.D.	23	Habitat, flora, fauna; administration
Schmidt, Robert E.	Ph.D.	23	Fish, invertebrate surveys
Stevens, Gretchen	B.S.	12	Flora survey & identification; water quality