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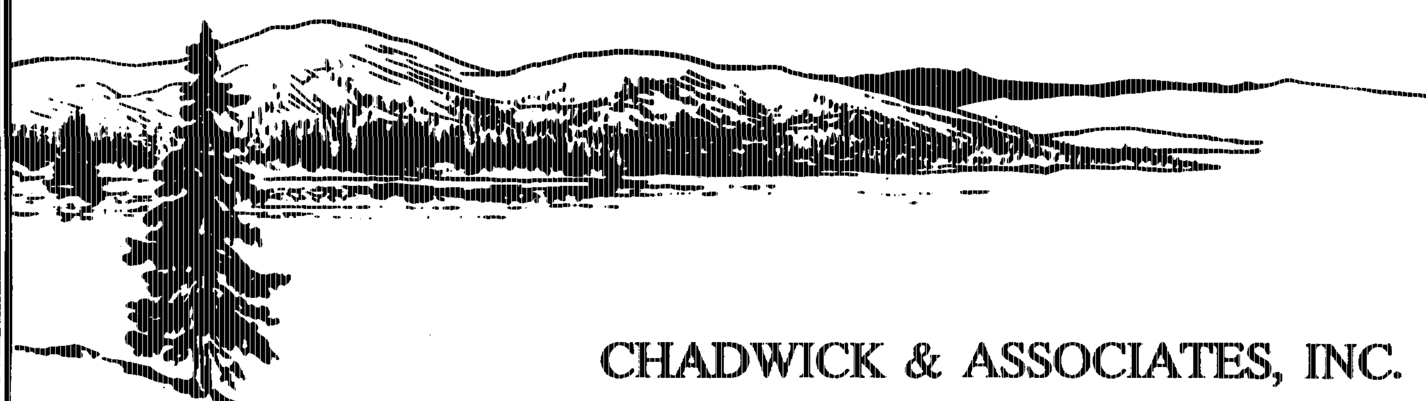
AQUATIC ECOLOGY ASSESSMENT OF THE HOUSATONIC RIVER, MASSACHUSETTS

May 1994



CHADWICK & ASSOCIATES, INC.

Aquatic Ecology Assessment of the Housatonic River, Massachusetts 1993

Prepared for

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ABSTRACT

Sampling of the fish and benthic invertebrate communities of the Housatonic River was conducted in September, 1993. The objectives of the study were to describe the habitat, fish community, and invertebrate community of the East Branch and West Branch of the river in the vicinity of Pittsfield and the mainstem of the Housatonic River from Pittsfield downstream to the Connecticut border. These biological parameters were measured in order to assess the influence of PCBs released from the GE facility in Pittsfield on the structure and general health of the fish and invertebrate communities downstream of the facility.

The fish species diversity and richness at the ten study sites compare very well to the results of previous studies on the Housatonic River and studies on other Northeastern rivers. Fish population parameters were generally similar at comparable sites upstream and downstream of the GE facility. The composition of the fish communities at the sites was determined by habitat conditions and showed no relationship to levels of PCBs.

Benthic invertebrate populations were healthy and diverse both upstream and downstream of the GE facility. Density levels of invertebrates varied widely at the study sites but apparently were determined by habitat conditions and relative levels of nutrients. Comparisons to previous studies in Northeastern streams indicate that the invertebrates of the Housatonic River in Massachusetts are similar to, or better than, expected for this region.

The fish and invertebrate populations of the Housatonic River appear to be healthy. There is no pattern of population parameters that appear to be related to sediment PCB levels. This information indicates that sediment PCBs are having no discernible ecological effect on the aquatic biota of the Housatonic River system.

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1.0 INTRODUCTION

From 1932 to March 1977, polychlorinated biphenyls (PCBs) were used at the General Electric (GE) facility in Pittsfield, Massachusetts as part of a flame-resistant, insulating liquid for transformers. These materials were inadvertently released into the East Branch of the Housatonic River prior to 1977. Studies beginning in the 1970's have identified the presence of PCBs in the bottom sediments and fish tissues from the Housatonic River (see Stewart 1982, Blasland and Bouck Engineers 1991). As a result, the Housatonic River has been the subject of numerous studies to characterize PCB distribution and transport. Most of these studies were oriented toward analysis of PCB levels and not toward the aquatic ecology of the Housatonic River.

In 1992, Chadwick & Associates, Inc. undertook a study to describe the fish community and aquatic habitat of the Housatonic River from the City of Pittsfield, Massachusetts, downstream to the Connecticut border. Qualitative sampling was conducted at nine sites in the Housatonic River and its branches in September 1992. Each site contained a diversity of fish species, and sites downstream of the GE facility compared favorably to sites upstream of the GE facility. The proportion of game fish at each site showed no longitudinal trend, but appeared to be related to habitat quality with a higher percentage of game fish at sites with better habitat. The generally good condition of fish at most sites indicated a healthy community. The data collected in 1992 compared favorably with data collected at corresponding sites in 1970 by Massachusetts Department of Fish and Wildlife (DFW). A copy of our report on the 1992 study is attached as Appendix C.

Sampling was again conducted, in September 1993, and expanded to include additional quantitative information on abundance of fish in the study reach and benthic invertebrate populations. The goals in 1993 were to: 1) Describe habitat quality in the East Branch and West Branch of the Housatonic River in the vicinity of Pittsfield, and in the mainstream Housatonic River downstream to approximately the Connecticut border (the study reach); 2) describe species composition of the fish community in the study reach, particularly relative to the distribution of PCBs in the sediments; 3) estimate the abundance of fish; 4) measure the size structure of the game fish populations; 5) evaluate the general health (condition) and overall appearance of the fish species; and 6) describe species composition, abundance, diversity, and general health of the benthic invertebrate community in the study reach, particularly relative to distribution of PCBs in the sediments.

2.0 STUDY AREA

The Housatonic River originates in central Massachusetts and is formed by the confluence of three branches (East Branch, West Branch and Southwest Branch) near the city of Pittsfield, Massachusetts (Fig. 1). From there the river flows generally south to the Connecticut border, a distance of approximately 50 miles. The river continues through Connecticut, eventually flowing into Long Island Sound. The total watershed of the Housatonic River and its tributaries in Massachusetts covers approximately 550 square miles, which represents 28% of the total Housatonic River drainage basin area. The remaining watershed is located in New York and Connecticut (Lawler, Matusky and Skelly Engineers 1975).

The study sites sampled in 1993 are shown in Figure 1 and corresponded to the 1992 study sites with the addition of Site HR5 in 1993. Two study sites were located on the East Branch of the Housatonic River, one site on the West Branch, one site on Woods Pond, and six sites on the mainstem of the Housatonic River (Fig. 1). Site HR5 was not sampled in 1992 due to problems with river access. The study sites are grouped into two general categories: shallow water sites that were sampled by wading the stream, and deep water sites that were sampled with a boat (including Woods Pond). Site descriptions are as follows:

2.1 Site Descriptions

East Branch

Site EB1 — This shallow site is located in the city of Pittsfield upstream of the GE facility. The portion of river represented by this site has a 0.84% gradient, with an average width of 39 feet. This segment of river is a shallow stream, with small pools, riffles and runs.

Site EB2 — This shallow site is located in Pittsfield downstream of the GE facility, and provided data on the urban fish community immediately downstream of the GE facility. Average river width is 39 ft, and gradient is 0.05%. The river at this location is approximately the same size as at Site EB1, but has poorer habitat due to slower water velocities, shallow depths and deposition of sand and silt.

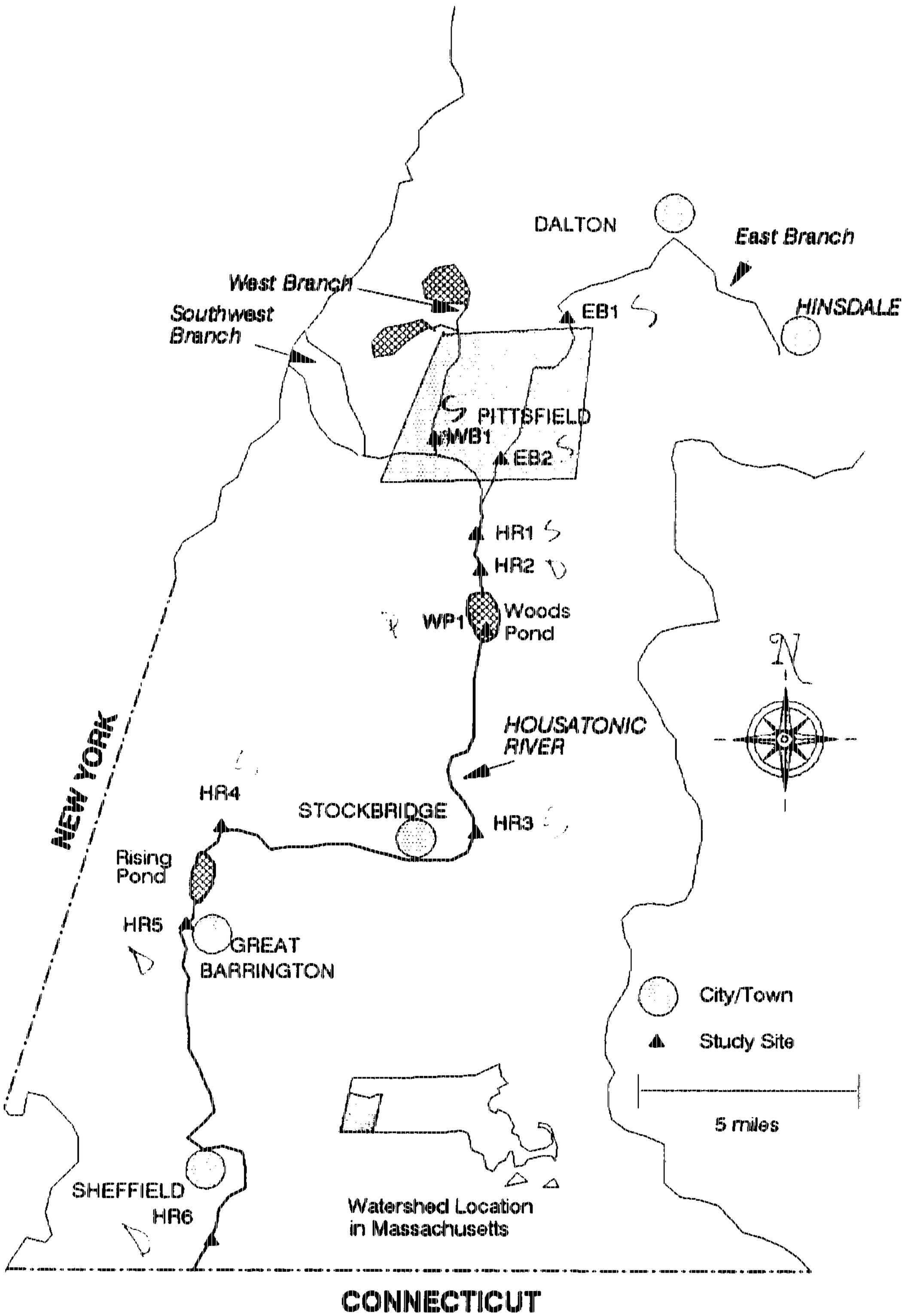

FIGURE 1: Site locations in the Housatonic River Drainage Basin from Hinsdale, Massachusetts, downstream to the Connecticut border.

West Branch

Site WB1 This shallow site is located in Pittsfield, upstream of the confluence with the East Branch. This location provided an evaluation of the status of the biological environment in this branch of the river and its influence on the Housatonic River downstream. This site is not actually upstream of the GE facility but it is on a parallel stream and is unaffected by releases from the GE facility. Thus, for purposes of this study, it is considered an "upstream" site. This segment of the river is narrower than the East Branch, with an average width of 30 ft. It has a gradient of 0.05%, and flows through a residential area.

Housatonic River

Site HR1 This shallow site is located on the Housatonic River below the confluence of the East Branch and West Branch, downstream of the inflow of Sykes Brook. This portion of the river is larger than the East Branch or West Branch, with an average width of 75 ft, and a gradient of 0.05%. The riparian zone here is less developed and less urban than the East Branch or West Branch sites.

Site HR2 This deep site is in the low gradient reach located between the New Lenox Road bridge and Woods Pond. This location provided information on the fish community in the portion of the Housatonic River where the highest PCB levels have been recorded. The influence of the flat gradient is clearly evident in this area, with a width of 84 ft, slow current and habitat composed entirely of deep pools.

Site HR3 This shallow site is in the vicinity of the Highway #20 bridge downstream of the town of Lee. The river has an average width of 101 ft and a gradient of 0.35%. Flows are swifter than at Sites HR1 and HR2, with more gravel substrate present.

Site HR4 This shallow site is located downstream of the town of Glendale, has a gradient of 0.43%, and an average width of 103 feet. The river in this area contains many large boulders which provide abundant areas of pocket water.

Site HR5 This deep site is located at the Division Street bridge, north of the town of Great Barrington and downstream of Rising Pond. The river at this location has an average width of 99 ft, and a gradient of approximately 0.17%. This portion of the river is transitional between the shallow, higher gradient upstream sections and the flatter, deep, silt-bottomed portion of the river downstream to the Connecticut border. The site is located in a deep portion of the river.

Site HR6 This deep site is downstream of the Sheffield Bridge on the Housatonic River. Average river width is 120 ft, with a flat gradient of 0.03%. Predominant land use in this area is agricultural, as evidenced by few riparian trees, and unstable streambanks.

Woods Pond

Site WP1 This deep site is located in Woods Pond, an impoundment of approximately 60 acres. Aquatic pond habitat here is unique compared to the rest of the river and, therefore, this pond site is considered separately from the stream sites.

2.2 Sediment PCB Distribution

Studies conducted during the mid 1970's identified PCBs in fish and sediments of the Housatonic River system. As a result of these studies, the Connecticut Agricultural Experiment Station, the Connecticut Department of Environmental Protection, and the U.S. Geological Survey conducted more detailed studies between 1978 and 1982 on portions of the Housatonic River in Connecticut, and to a lesser degree, Massachusetts. Results of these studies indicated the presence of PCBs in sediments in portions of the river downstream of Pittsfield (Frink *et al.* 1982).

In 1981, General Electric contracted with Stewart Laboratories to conduct an extensive study of the presence and distribution of PCBs within the Housatonic River system (Stewart Laboratories 1982). During preliminary investigations, PCBs were found in the sediments of Woods Pond and in the river upstream of Woods Pond. Sediments upstream of the GE facility and on the West Branch of the Housatonic River were found to contain PCB concentrations less than 1 ppm, with an average concentration of 0.15 ppm. PCB concentrations in river sediments between the GE facility and New Lenox Road bridge ranged from 0.52 ppm to 290 ppm, with an average concentration of 33 ppm. This section of the river contained approximately 22% of the total amount of PCBs in the Housatonic River in Massachusetts. The portion of the river from the New Lenox Road bridge downstream to Woods Pond showed PCB concentrations ranging from below detection to 270 ppm, with an average of 22 ppm. This area accounted for 50% of the total PCB mass found in the Massachusetts portion of the Housatonic River. Sediments from Woods Pond contained PCBs ranging from below detection to 220 ppm, with an average of 24 ppm, containing approximately 19% of the total amount of PCBs in the Housatonic River system in Massachusetts. Downstream of Woods Pond to the Connecticut border, PCB concentrations in sediments were considerably lower than in the river section from the GE facility through Woods Pond. From the Woods Pond dam downstream to the Rising Pond dam, PCB concentrations in river sediments ranged from below detection to 22 ppm, with an average of 3 ppm. The last section of the Housatonic River in Massachusetts, from the Rising Pond dam downstream to the Connecticut border, had PCB concentrations ranging from below detection to 2.3 ppm, with an average of less than 1 ppm.

In general, the results of the study by Stewart Laboratories (1982) indicated that PCB concentrations in sediments in the Housatonic River were highest in the portion of the river from the GE facility downstream through Woods Pond. In addition, this portion of the river accounted for approximately 91% of the total quantity of PCBs estimated to be present in the Massachusetts section of the river. Fish tissue levels of PCBs generally followed the same trend.

In late 1990 and early 1991, GE commissioned another study to sample PCBs in the Housatonic River sediments (Blasland and Bouck 1991). The objective of this study was to supplement existing data provided by the 1980 and 1982 study by Stewart Laboratories, and to attempt to confirm the distribution of PCBs in the river as defined by Stewart Laboratories. Four river reaches were selected for sampling. These reaches were: 1) GE facility to the New Lenox Road bridge, 2) New Lenox Road bridge to Woods Pond headwaters, 3) Woods Pond, and 4) Rising Pond. Sediment collected from sites between the GE facility and the New Lenox Road bridge had PCB concentrations ranging from below detection to 60 ppm, with an average concentration of 12 ppm. PCB concentrations in sediments collected between New Lenox Road bridge and Woods Pond headwaters ranged from below detection to 120 ppm, with an average of 11 ppm. Within Woods Pond, sediment concentrations of PCBs ranged from below detection to 180 ppm, with an average of 29 ppm. Within Rising Pond, PCB concentrations ranged from below detection to 22 ppm, with an average concentration of 2.4 ppm. The study determined that the highest PCB concentrations were found in Woods Pond sediments, and that the next highest concentrations were present in the river reach from New Lenox Road bridge to the headwaters of Woods Pond.

GE has also contracted with Lawler, Matusky and Skelly Engineers to monitor PCB concentrations in Housatonic River sediments in Connecticut and a small portion of Massachusetts. Based on recent sampling results, PCB concentrations in river sediments in Massachusetts from the town of Great Barrington downstream to the Connecticut state line ranged from below detection to approximately 2 ppm, with most concentrations below 1 ppm (GE 1994). Similar to previous studies, these results indicate lower concentrations of PCBs in river sediments in the lower portion of the Housatonic River in Massachusetts.

3.0 METHODS

3.1 Habitat Assessment

Quantification of habitat features at each shallow and deep study site consisted of measuring the surface area of five different types of cover along the length of each site. Cover is important to aquatic organisms, because it provides areas of rest, shelter, and protection from predators (Armour *et al.* 1983). These five cover types were snags, banks, undercuts, aquatic macrophyte beds, and rocks. Snags are areas in the stream channel where logs, stumps, branches, etc. formed pockets of isolated cover. Bank cover areas are influenced by bank structure (tree roots, overhanging bank vegetation, etc.) resulting in obstructed flow, reduced velocities, and instream cover. Undercuts are sections of the streambank that overhang part of the stream. Aquatic macrophyte beds are growths of instream vegetation of at least 4 ft^2 that would provide cover for fish and other aquatic organisms. Rock cover areas have an accumulation of large substrate particles (rubble and boulders) along the streambank or piles within the stream channel.

3.2 Water Quality

Two water quality parameters, water temperature and dissolved oxygen, were sampled weekly between May 25, 1993 and September 22, 1993 at all the study sites on the Housatonic River system by Blasland & Bouck Engineers. Maximum/minimum water thermometers were installed at each study site to provide weekly ranges of water temperature. A second thermometer was also installed at each site to serve as a backup in the event that the first thermometer failed.

In addition, more intensive monthly sampling of water quality was conducted from May 20 to October 7, 1993, at five sites on the Housatonic River (HR1, HR3, HR4, HR5, HR6). In addition to water temperature and dissolved oxygen, pH, ammonia, and nitrate were measured. This sampling was conducted by Blasland and Bouck Engineers and laboratory analyses were performed by Alpha Analytical.

3.3 Fish Populations

Fish populations were sampled at all sites in September 1993 to determine species composition, abundance, and size structure of the fish community. Sampling was conducted under the authority of a scientific collecting permit issued by the Massachusetts DFW. Sampling was conducted by making at least two sampling passes through a representative section of stream (approximately 280-700 ft) using electrofishing gear. If capture efficiency was high, then two passes were considered adequate for estimating fish populations (John Van Deventer, Boise State University, pers. comm., 17 November 1992). If capture efficiency was lower, with more than 30% of the total fish collected in the two passes collected on the second pass, then additional passes were made. Fish captured from each pass were kept separate to allow estimates of population density of each species using a maximum-likelihood estimator (Van Deventer and Platts 1983). Because larger fish are usually more easily captured than smaller ones (Reynolds 1983), separate abundance estimates were calculated for different size classes for species that exhibited a relatively wide range in sizes. Separation of the size classes helped remove size-related bias when estimating abundance. Sampling sections were blocked with 1¼ inch mesh seines to reduce the potential for large fish to enter or leave the study reach during sampling. The section of stream sampled was chosen to be representative of the habitat present in that reach of stream, in terms of pool/riffle ratio, shading, bank stability, etc.

The six shallow water sites (EB1, EB2, WB1, HR1, HR3, HR4) generally had a stable bottom substrate of sand, gravel or cobble that allowed the sites to be waded. Fish were collected with bank electrofishing gear consisting of a generator, Coffelt voltage regulator (VVP-15) and three to five electrodes. Stunned fish were held in a holding pen for recovery prior to being measured and weighed and released.

At the deep water stream sites (HR2, HR5, HR6), the unstable substrate (muck) and deep water prevented wading and efficient sampling with a bank electroshocker. At these sites, fish were sampled with an electrofishing boat. The electronic equipment was similar to that of the bank electrofishing gear, with the exception of two boom-mounted electrodes on the front of the boat. Stunned fish were held in tubs on the boat and in a holding pen near shore.

In lake environments such as Woods Pond, quantitative sampling is very difficult to accomplish because of the relatively large volume of water present and the large number of fish. It is difficult to choose a "site" in a pond and to quantitatively sample a portion of the population, as is done in streams. Therefore, qualitative fish samples were taken from Woods Pond with the electrofishing boat in all major habitat types (bank, open water, submerged vegetation, dead trees) for a total of 60 minutes of actual electrofishing. This was the same technique used at this site in 1992 (Chadwick & Associates 1993, Appendix C) except that sampling was conducted at night in 1993 and during the day in 1992.

Differences in habitat characteristics between shallow water sites and deep water sites affect species composition at these sites. Both types of habitat have representative, typical fish communities related to the specific physical characteristics present and the preferences of individual species. For example, blacknose dace and longnose dace were abundant at most of the shallow water sites, but absent from the deep water sites. The shallow water sites had the swift flowing rocky substrate habitat type normally associated with these species (Scott and Crossman 1973, Finger 1982, Cooper 1983, Scarola 1987, Page and Burr 1991), while the deep water sites did not contain this habitat.

Another important factor influencing the fish collected at the two types of sites is the reduced sampling efficiency of boat electrofishing compared to bank electrofishing. The efficiency of boat electrofishing is influenced by a number of biotic and abiotic factors. Biotic factors included fish behavior and fish size. Fish behavior, as related to habitat preferences, was discussed above. With respect to size, large fish are more easily stunned by an electrical current than small fish (Reynolds 1983), and therefore more easily collected. Given this difficulty in stunning small fish, they were more easily collected at the shallow water sites because of smaller volumes of water in which to escape the electrical current. At the deep water sites there is a greater opportunity for all fish, and especially small fish, to escape. Therefore, at the deep water sites, the sampling technique favors the collection of larger fish.

Abiotic factors that reduced efficiency of boat electrofishing included visibility, water depth, and bottom substrate (Larimore 1961, Reynolds 1983, Zalewski 1983). Larimore (1961) found that increasing depth is an important factor that decreases efficiency of electrofishing. This pattern was also observed in the Housatonic River system. The sites sampled by bank electrofishing were relatively shallow, and fish could be collected before they escaped the electric field. However, the deeper water characteristic of Sites HR2, HR5, HR6 and Woods Pond allowed the fish more opportunity to escape. They could escape by sinking into deep water after being shocked, by retreating to deep water not affected by the electrical field, and by outswimming the electrofishing boat. Efficiency of boat electrofishing is also reduced at the deeper sites by relatively poor visibility. The turbidity of the water was similar between these sites and the shallower sites sampled by bank electrofishing. However, shocked fish were more easily seen at the shallower sites because the substrate provided a dark, contrasting background. Larimore (1961) observed that fish were more easily detected against the shallow, bottom substrate. Because of the greater water depth at the deeper sites, visibility was reduced and fish at depth also could not be seen. A third abiotic factor that may have reduced boat electrofishing was the fine, organic content of the bottom substrate at Sites HR2, HR5, and HR6. Reynolds (1983) stated that mud and silt substrates reduce shocking efficiency when compared to gravel and rubble substrates because of differences in conductivity. The sites sampled by bank electrofishing were generally composed of larger substrate with less organic content, and they were more efficiently sampled.

In addition, from a practical standpoint, boat electrofishing in a river is inherently less efficient than using hand-held electrofishing equipment while wading a stream. The mobility of the electrofishing probe and the personnel collecting fish is less than when wading a stream with hand-held bank electrofishing equipment. When wading, personnel can quickly and efficiently electrofish with the hand held probes, whereas sampling from a boat is slower, allowing fish more chance to escape. In addition, personnel responsible for collecting fish in dip nets are more mobile when wading, allowing them to literally chase a stunned fish, if necessary. This mobility is lacking when sampling from a boat.

For the reasons outlined above, the fish population data collected at shallow sites are not directly comparable to data collected at deep sites. Throughout this report, fisheries data, as well as data on benthic invertebrates, will be compared between sites with similar habitat types (shallow or deep).

Collected fish were divided into three groups: game fish (sunfish, bass, trout, perch, northern pike, pickerel, bullhead, and fallfish), rough fish (suckers, carp, goldfish), and forage fish (minnows, dace, shiners, killifish, and darters). Game fish are species that are generally sought by anglers as sport fish. In many cases they are predators on other fish, at least in the adult stage of their lives. Forage fish are species that are preyed upon by game fish and other species. They characteristically tend to be relatively small in size as adults, such as minnows, and serve as prey during all of their life stages. Rough fish are species that are not usually sought by anglers, but may be too large as adults to serve as prey. They tend to be omnivorous feeders and can grow very large as adults. These general categories are commonly understood by biologists, but, nevertheless, there is some overlap between the groups. For example, young white suckers are sometimes considered forage fish due to their small size and sometimes high relative abundance. However, adult white suckers are usually too large to be preyed upon by most predators and are considered rough fish. Carp, almost always considered to be rough fish, are sometimes the target of anglers for sport.

All fish were identified and counted. All game fish and a representative sample of rough fish collected were measured for total length, weighed, and released. All forage fish and the remainder of the rough fish were counted, batch weighed, and released. This sampling provided species lists and estimates of abundance and biomass (number/acre and lbs/acre). In addition, the length-frequency data were used for analysis of the size structure of the game fish and rough fish species. The size structure of a fish population is used to evaluate the status of the population. For example, is one year (size) class present or are multiple year classes present? The presence of multiple year classes generally suggests permanent, self-supporting populations with adequate natural reproduction.

Because of equipment theft prior to sampling Site EB1, weights on forage fish could not be measured at this site. Therefore, weights for blacknose dace, bluntnose minnows, and longnose dace collected at this site were calculated from length - weight regressions developed from Site WB1 and weights for spottail shiners from Site EB1 were calculated from length-weight regressions developed from the three other stream study sites where they were collected in 1993 (HR1, HR4, HR6).

The condition or well-being of the game fish was derived using the relative weight index (W_r) as described by Wege and Anderson (1978) and Anderson and Gutreutter (1983). The relative weight index allows for comparison of condition between species and sites. To determine relative weight, fish weights are compared to length-specific standard weights constructed to represent the species as a whole. Equations used to calculate standard weights (W_s) from total length (TL) are presented in Table 1. Since no published standard weight equation exists for brown trout, unpublished equations from Dr. Willis of South Dakota State University were used. Relative weight (W_r) is then calculated by dividing the fish's actual weight by the standard weight and multiplying the result by 100. Relative weight is generally not calculated for the younger age classes.

Expected values of the relative weight index have the same general range across species. Relative weight values are indicated by an index whose values usually fall between 70 and 130 (Murphy and Willis 1991). The range of relative weight values between 95 to 105 is considered the optimal management target for most species (Anderson 1980; Anderson and Gutreuter 1983). However, Willis *et al.* (1991) have suggested developing regional standard weights for yellow perch. The regional standard for yellow perch is 79 instead of 100. In this study the relative weight index was used to compare condition of fish between study sites and between species.

The species composition of the fish communities of the various sites were also compared using cluster analyses techniques. These techniques compare the fish communities at the sites and group them according to their similarity. The two similarity indices used for this analysis were the *Jaccard Index*, which compares sites simply in terms of the presence or absence of species and the *Percent Similarity Index*, which compares the sites in terms of the relative abundance of common species (Ludwig and Reynolds 1988). These two indices were calculated for each possible pair of study sites and then clustered using the multi-variate statistical package of Kovach (1991).

TABLE 1: Standard weight equations used to calculate relative weight.

Species	Equation	Citation
Bluegill	$\log_{10}W_s = 3.316 \log_{10}TL - 5.374$	Murphy *et al.* (1991)
Brown trout	$\log_{10}W_s = 2.962 \log_{10}TL - 4.875$	D.W. Willis, pers. comm. (1992)
Largemouth bass	$\log_{10}W_s = 3.191 \log_{10}TL - 5.316$	Murphy *et al.* (1991)
Rock bass	$\log_{10}W_s = 3.083 \log_{10}TL - 4.833$	Murphy *et al.* (1991)
Yellow perch	$\log_{10}W_s = 3.230 \log_{10}TL - 5.386$	Murphy *et al.* (1991)

In addition to relative weight, the general appearance of the fish was also examined during identification, counting and measuring. The fish were checked for unusual growths, abnormalities, external parasites, unusual colors, etc. These conditions of fish can be useful in assessing the stresses present on fish populations.

3.4 Benthic Invertebrate Populations

Given the noticeable changes in habitat availability and substrate composition at the sites along the Housatonic River, two different sampling strategies had to be used. When possible, riffle or erosional habitat was sampled. This type of cobble-gravel habitat at shallow water sites generally contains the highest abundance and diversity of aquatic invertebrates in a stream system (Hynes 1970, Minshall 1984, Ward 1975). However, as noted earlier, riffle habitat was not available at every site along the river and at these deep sites, softer substrate-depositional habitat was sampled. Based on the descriptions presented above, the sites were grouped as follows: Erosional (shallow) sites with riffle habitat included Sites EB1, EB2, WB1, HR1, HR3, and HR4. The depositional (deep) sites without riffle habitat included HR2, HR5, and HR6, and of course, Woods Pond (WP1). These group designations are the same as those used for fish sampling.

It is important that the appropriate sampling techniques be used based on the available habitat (Hynes 1970). At the shallow sites a modified Hess sampler was used, which encloses 0.1 m^2 and has a net mesh size of 500 μm (Canton and Chadwick 1984). This type of sampler is closely related to the Surber sampler and other "net" samplers and is one of the most commonly used samplers in stream riffle studies (Hynes 1970, Elliott and Tullett 1978, Crossman and Cairns 1974, Merritt and Cummins 1984, Klemm, *et al.* 1990). However, these types of samplers require relatively shallow water (roughly 1.5 ft deep or less) and some current to carry the dislodged organisms into the collection net.

These conditions were not present at the deep water sites (HR2, HR5, HR6, WP1). A more appropriate sampler, the Ekman grab, was used at these sites. This sampler encloses approximately 0.02 m^2 and literally grabs a sample of the substrate. The Ekman grab is a preferred sampler for soft sediments (Elliott and Tullett 1978, Lewis *et al.* 1982, Barton 1989, Blomqvist 1990). However, it can be difficult to operate in deeper, flowing sections of rivers (Hynes 1970), reducing its efficiency when compared to a Hess sampler used in a riffle.

Due to the considerable differences in habitat availability and the methods that needed to be used, comparisons of abundance, species diversity, or number of taxa are only made between sites with comparable habitat. Therefore, in the analysis of the benthic invertebrate data presented below, comparisons are made between the upstream sites, EB1 and WB1, and the downstream sites with riffle habitat, EB2, HR1, HR3, and HR4. Likewise, Site HR2, with soft substrate habitat, is compared to the downstream sites HR5 and HR6, which also have soft sediment. Although there was no deep water site available to be sampled upstream of the GE facility, Sites HR5 and HR6 have low PCB levels and are used as comparison data for Site HR2, with relatively high levels of PCBs.

Benthic invertebrates were sampled quantitatively at each study site by taking three replicate samples. Three samples have been shown to provide reliable estimates of benthic density (Canton and Chadwick 1988). In addition, qualitative samples from other habitat types (submerged logs, aquatic vegetation, etc.) were taken at all shallow and deep study sites with a kick-net sampler. Organisms collected were preserved in the field with 95% ethanol and returned to Chadwick & Associates' laboratory for analysis. Organisms collected were sorted from the debris, identified to the lowest taxonomic level using available keys, and counted. Chironomids were mounted and cleared prior to identification and counting. If the number of chironomids was excessive, they were subsampled prior to mounting. This analysis provided species lists and estimates of total abundance (number/m^2). Further analysis included calculation of the Shannon-Weaver Diversity Index (H') which the EPA recommends as a measure of the effects of stress on invertebrate communities (Klemm *et al.* 1990). This index generally has values ranging from 0-4, with values from 2.5-4.0 indicative of a healthy invertebrate community. Diversity values less than 1.0 indicate a stream community under severe stress (Klemm *et al.* 1990; Wilhm 1970).

Replicate sampling allowed the data to be analyzed with standard statistical tests, such as analysis of variance and standard t-tests. Where necessary, the data were $\log_{10}$ transformed to allow the use of parametric tests (Elliott 1977). As with the fish community data, the invertebrate community was analyzed using cluster analysis techniques. The two similarity indices used for this analysis were the

Jaccard Index, and the *Percent Similarity Index* (Ludwig and Reynolds 1988). These two indices were calculated for each possible pair of study sites and then clustered using the multi-variate statistical package of Kovach (1991).

4.0 RESULTS AND DISCUSSION

4.1 Habitat Assessment

Fish habitat consists of a number of components, including the depth and velocity of the water and the amount and type of cover. The physical parameters of the stream study sites on the Housatonic River are presented in Table 2. However, different fish species have different preferences in terms of these parameters (e.g., depth). Cover is a critical component of fish habitat (Armour *et al.* 1983); it provides areas for rest, shelter, and protection from predators and thus acts to attract and hold fish in an area of a stream. Areas with abundant cover generally have higher fish densities than areas without cover. The habitat assessments conducted in 1993 focused on measuring the amount and types of fish cover at the sampling sites. The data on the abundance of cover types are presented in Table 3.

Shallow Sites Upstream of GE Facility

Site EB1 on the East Branch of the Housatonic River was upstream of the GE facility. This site was located on one of the steeper portions of the river, with a gradient of 0.84%. Average channel width in this reach was 38.7 ft, with an average depth of 1.6 ft (Table 2). This portion of the river was a channelized section behind a shopping center. As a result, water depth and velocity were homogeneous, with no deep, slow moving pools and only a small amount of riffle habitat. The substrate was a combination of cobble in the riffle areas, and a mixture of sand and silt in the slower moving areas. The majority of cover in this portion of the river consisted of snags, with lesser amounts of bank, undercuts, and rocks (Table 3). No aquatic macrophytes were observed in this reach. The snag habitat consisted of small, scattered pieces of woody debris. The combined surface area of cover in this reach comprised 3.4% of the total area of the study site (Table 3). This was the lowest proportional amount of cover, compared to the other study sites.

TABLE 2: Physical parameters of stream study sites on the Housatonic River system, Massachusetts, September 1993.

Site	Site Length (ft)	Mean Site Width (ft)	Mean Site Depth (ft)	Site Area (acres)
Shallow Sites Upstream of GE Facility				
EB1	453	38.7	1.6	0.40
WB1	548	29.8	0.7	0.38
Shallow Sites Downstream of GE Facility				
EB2	485	39.0	1.3	0.44
HR1	351	74.5	1.6	0.60
HR3	423	101.0	1.3	0.98
HR4	289	103.0	2.6	0.67
Deep Sites Downstream of GE Facility				
HR2	462	84.3	6.6	0.89
HR5	466	98.7	3.6	1.06
HR6	712	119.7	6.2	1.96

TABLE 3: Abundance of cover types at stream study sites on the Housatonic River system, Massachusetts, September 1993. Values represent the percentage of total surface area of the site.

SITE	Cover Type					Total
	Snag	Bank	Undercut	Macrophytes	Rock	
Shallow Sites Upstream of GE Facility						
EB1	1.6	1.0	0.7	0	0.1	3.4%
WB1	3.7	2.9	0	0	2.3	8.9%
Shallow Sites Downstream of GE Facility						
EB2	6.1	1.2	<0.1	0	0.4	7.7%
HR1	8.3	3.3	0.3	0.4	0	12.3%
HR3	0.4	1.5	0	1.9	0.1	3.9%
HR4	0	0	0	0	25.0	25.0%
Deep Sites Downstream of GE Facility						
HR2	0.6	3.4	0	0	0	4.0%
HR5	1.7	1.5	0	0	1.7	4.9%
HR6	1.8	2.6	<0.1	0	0	4.4%

The other site upstream of the GE facility was Site WB1 on the West Branch. The average channel width in this portion of the river was 29.8 ft, and average depth was 0.7 ft (Table 2). This portion of the stream was located in a densely shaded residential area. The water depths and velocities were not as homogeneous as at Site EB1, with a relatively equal mixture of shallow riffles, deeper runs, and pools. Pools and runs composed most of the upper half of the study site, and riffles composed the bottom half. Substrate in the portion of the river was composed primarily of gravel and cobble, with smaller amounts of sand and silt. Snags were the primary cover habitat (Table 3), and were present as small collections of woody debris scattered throughout the study reach. Lesser amounts of bank and rock also provided cover habitat. The rock cover habitat was present as isolated areas along the bank where small boulders provided cover in shallow water. Overall, cover habitat comprised 8.9% of the total study reach area, which was more than at Site EB1 (Table 3).

Shallow Sites Downstream of GE Facility

Site EB2 was located on the East Branch just upstream of the confluence with the West Branch. This was also the first study site downstream of the GE facility. Channel size in this portion of the stream was similar to Site EB1, with an average width of 39.0 ft, and an average depth of 1.3 ft (Table 2). However, compared to the upstream sites, substrate was poorer in this portion of the river, with a mixture primarily of sand, silt, and small gravel. Snags were the predominant type of cover habitat, comprising 6.1% of the total area of the study reach (Table 3). The woody debris snags in this portion of the river were composed of larger diameter pieces, which would probably tend to be more stable over time than the snags at Sites EB1 and WB1. Snags at those two sites were generally composed of smaller pieces of woody debris. In addition to snags, smaller amounts of bank, rock, and undercuts also provided additional cover in this portion of the river (Table 3).

The East Branch and West Branch converge just downstream of downtown Pittsfield to form the mainstem of the Housatonic River. Site HR1 was the first site on the mainstem, just downstream of the confluence. The river channel is much wider at this point compared to the upstream areas, with an average width of 74.5 ft (Table 2). The average depth (1.6 ft) was similar to Sites EB1 and EB2. The water was slower moving in this portion of the river, with a substrate composed primarily of silt and sand. No riffles were present, only pools and low velocity runs. This is typical of low gradient streams, where the distinction between pools, runs and riffles is not as clear-cut as in higher gradient systems (Lyons and Courtney 1990). Cover habitat was represented primarily by snags (Table 3). These snags were composed of large diameter (approximately 10-12 in) logs. These debris jams were large enough to divert streamflow, thus causing scouring of the stream bed and the formation of deep pools. These pools held most of the fish in this portion of the river. Lesser amounts of cover habitat in the form of bank, undercuts, and aquatic macrophytes were also present (Table 3).

Site HR3 was the first site downstream of Woods Pond, and had an average width of 101.0 ft, and an average depth of 1.3 ft (Table 2). Water depths were generally homogeneous, consisting primarily of shallow runs (approximately 1.5 ft deep) with a small amount of riffles at the downstream end of the site. The substrate was a mixture of gravel and silt. The majority of cover habitat in this portion of the river consisted of aquatic macrophytes (Table 3). This was the only stream reach where aquatic macrophytes provided the dominant cover habitat. Bank cover (1.5%) was present in the form of dense, overhanging bank vegetation in a few, isolated locations. This portion of the river contained a pool, approximately 3-4 ft in depth, which was not associated with any snags, rocks, or other cover.

The portion of the Housatonic River represented by Site HR4 was different in character from the other study sites. The gradient was greater than most other study reaches (0.43%), leading to greater water velocities. The substrate was a mixture of cobble and boulders. Average width was 103.0 ft, with an average depth of 2.6 ft (Table 2). A unique characteristic of the habitat at this site was the highly variable nature of water velocities and depths. The large sized bottom substrate produced variable depths, and the high number of large boulders scattered throughout this portion of the river produced a latticework of short, interconnected runs between the boulders and small pocket-water pools behind the boulders. This rock cover comprised 25% of the study site area (Table 3). Other cover habitat, such as debris snags, overhanging banks, and aquatic macrophytes, were absent from this portion of the river.

Deep Sites Downstream of GE Facility

Site HR2 was located approximately two miles upstream of Woods Pond. Because of the flat gradient in this area and the impoundment effects of by Woods Pond, this portion of the river had very low water velocities and deep pool habitat along its entire length. This site, with an average depth of 6.6

ft, was the deepest of all the stream study sites (Table 2). Dense growths of overhanging bank vegetation formed most of the cover habitat in this portion of the river, but the proportion of woody debris snags was less compared most other sites (Table 3). Overall, cover habitat comprised 4.0% of the total site area. Most of the fish collected in this reach were not associated with the snags or bank cover, but were collected in the deep, open water areas near the middle of the channel.

In the vicinity of Site HR5, the Housatonic River flattens out to a gradient of 0.17%. The average channel width in this portion of the river was 98.7 ft, with an average depth of 3.6 ft (Table 2). The water velocities were noticeably slower than at Site HR4, resulting in a substrate composed primarily of sand and silt. The cover was comprised of generally equal proportions of snags, rocks, and bank habitat (Table 3). The snags were composed of relatively large diameter (10-12 in) logs. The rock cover was composed of rock piles along the bank, along with a few submerged rock piles on the river bottom.

Site HR6 was the furthest site downstream, approximately 0.5 miles upstream of the Connecticut border. The river gradient was very low (0.03%), resulting in low water velocities. This portion of the river was the widest of all the sampled sites (Table 2). As with Site HR5, this portion of the river consisted of a single, large, slow moving pool with a sand and silt substrate. Cover habitat was provided primarily by overhanging bank vegetation, and large diameter woody debris snags (Table 3). In addition, a small amount of undercut bank was present. This portion of the river was adjacent to a cow pasture and corn field, with little riparian vegetation to provide shading. Some evidence of erosion and sloughing of the banks into the river was present.

In general, the most abundant cover habitats at each of the river study sites were woody debris snags and overhanging bank vegetation. Woody debris snags play an important role in providing food and cover for warmwater game fish. For example, Benke *et al.* (1985) showed that, although snags were not very abundant in his study streams, they contained very high biomass of benthic invertebrates compared to sand and mud substrates. As a result, those snags were used as the primary food source by sunfish of the *Lepomis* genus, and as a secondary food source by largemouth bass. Angermeier and Karr (1984) also showed that invertebrates were more abundant in woody debris snags. In addition, they determined that woody debris snags were associated with higher fish abundance, higher species richness, and larger fish compared to open water areas in warmwater streams. Densities of sunfish were found to be especially higher near snags (Lobb and Orth 1991). This pattern was also observed in the Housatonic River system, where species such as bluegill, rock bass, and largemouth bass were often found associated with woody debris snags.

Woods Pond

Woods Pond is an impoundment of approximately 60 acres on the Housatonic River and its habitat is characteristic of a standing water environment. The amount of cover in Woods Pond was not quantified due to its relatively large size as compared to the other sites on the river. Cover along the bank was abundant, in the form of woody debris, submerged macrophytes, and rock piles. However, the dense beds of aquatic vegetation that were observed in the open water areas in 1992 were reduced in size in 1993. The reason for this is unknown, but possible causes may include reduced light penetration due to plankton blooms or annual climatic variation. One unique habitat feature that concentrated fish in Woods Pond was the foundation of a former bridge. This foundation formed a ledge, which provided shallow water on top, with close access to deep water beyond its edge. Large concentrations of fish were observed in the shallow water on top of the ledge when electrofishing at night.

4.2 Water Quality

Weekly maximum water temperatures were recorded from May 25 to September 22, 1993 at all of the study sites, and ranged from 9 to 30°C as shown in Table 4 and depicted graphically in Figure 2. Water temperatures were recorded within approximately 0.3 m of the surface, which was the warmest portion of the water column. Carlander (1969) reported lethal maximum temperatures of 30-35°C for rock bass, 28-39°C for bluegill, 28-37°C for largemouth bass and 25-29°C for brown trout. The maximum water temperature recorded at Site HR4 was 29°C, which is at the upper limit of temperatures lethal to brown trout. The presence of large adult brown trout at this site suggests the presence of some type of thermal refuge. These refugia could be provided by a combination of several factors, including deep water, cooler tributaries, and springs. Orciari and Leonard (1990) observed that as water temperatures neared 27°C in the Housatonic River in Connecticut, brown trout used stream mouths and spring seepages as a thermal refuge.

TABLE 4: Ranges of water chemistry parameters measured by Blasland and Bouck Engineers at study sites on the Housatonic River system, 1993. Water temperature and dissolved oxygen (D.O.) measured weekly from 5/25/93 to 9/22/93. Other parameters measured monthly from 5/25/93 to 9/22/93. NM = Not measured. ND = Not detected.

Site	Water Temp. (°C)	D.O. (mg/L)	pH	Total Ammonia (mg/L)	Unionized Ammonia (mg/L)	Nitrate (mg/L)
Shallow Sites Upstream of GE Facility						
EB1	9-28	7.8-10.2	NM	NM	NM	NM
WB1	12-30	6.9- 9.1	NM	NM	NM	NM
Shallow Sites Downstream of GE Facility						
EB2	11-27	6.6-9.4	NM	NM	NM	NM
HR1	11-32	6.7-8.8	7.9-8.3	ND-0.23	0-0.02	0.33-0.81
HR3	12-30	7.9-12.6	8.0-9.0	ND-0.08	0	0.92-2.40
HR4	13-29	6.6-19.2	7.9-8.5	ND-0.21	0	0.71-1.70
Deep Sites Downstream of GE Facility						
HR2	12-26	6.2-8.4	NM	NM	NM	NM
HR5	12-29	7.1-11.0	8.1-8.8	ND-0.14	0-0.01	0.68-1.40
HR6	14-29	6.0-15.2	8.0-8.6	ND-0.14	0	0.44-0.84
Woods Pond						
WP1	12-33	3.2-11.2	NM	NM	NM	NM

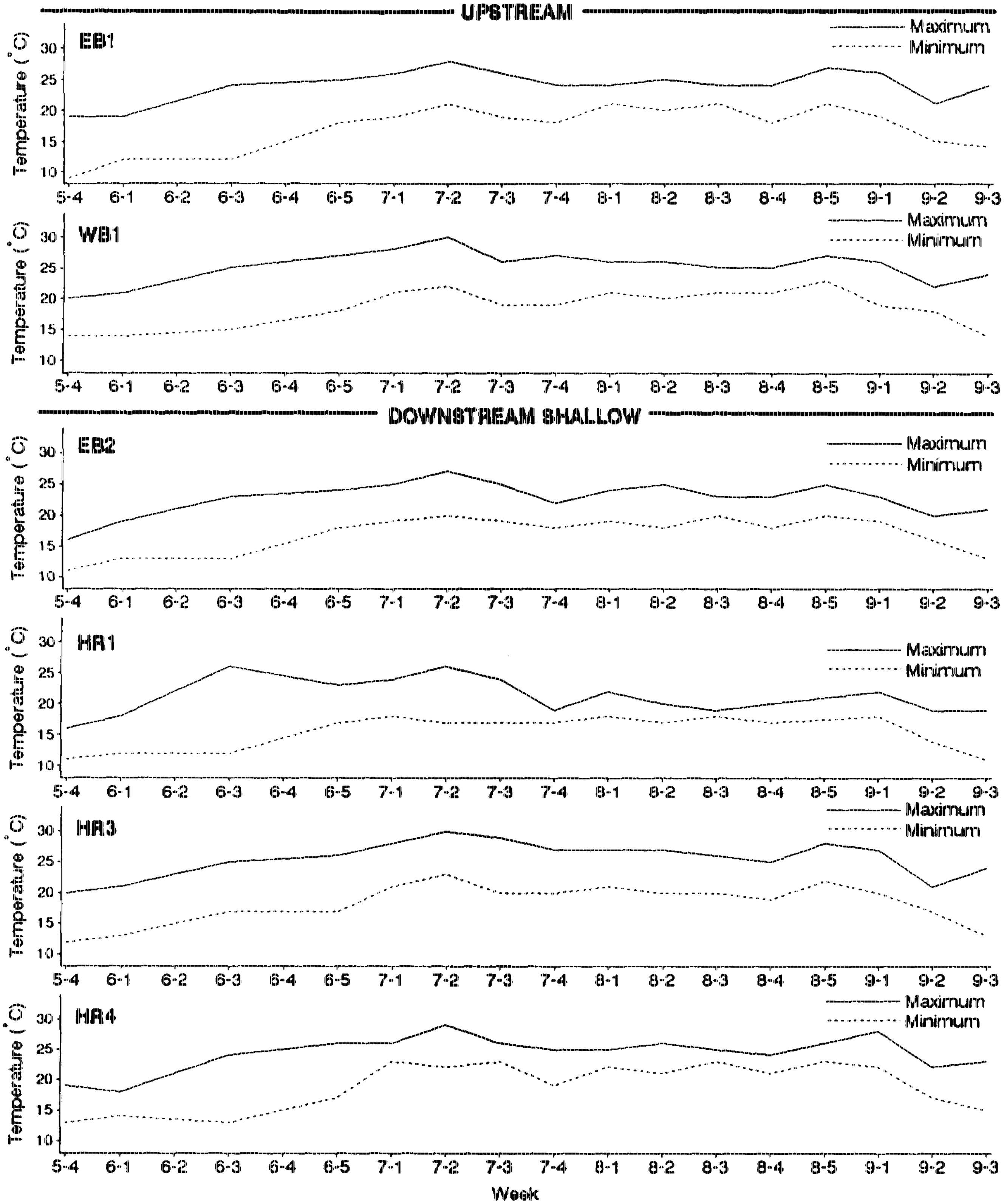

FIGURE 2: Weekly maximum and minimum water temperatures at all 1993 study sites. Data are presented by week, i.e. 1st week, 2nd week, 3rd week etc., in each month.

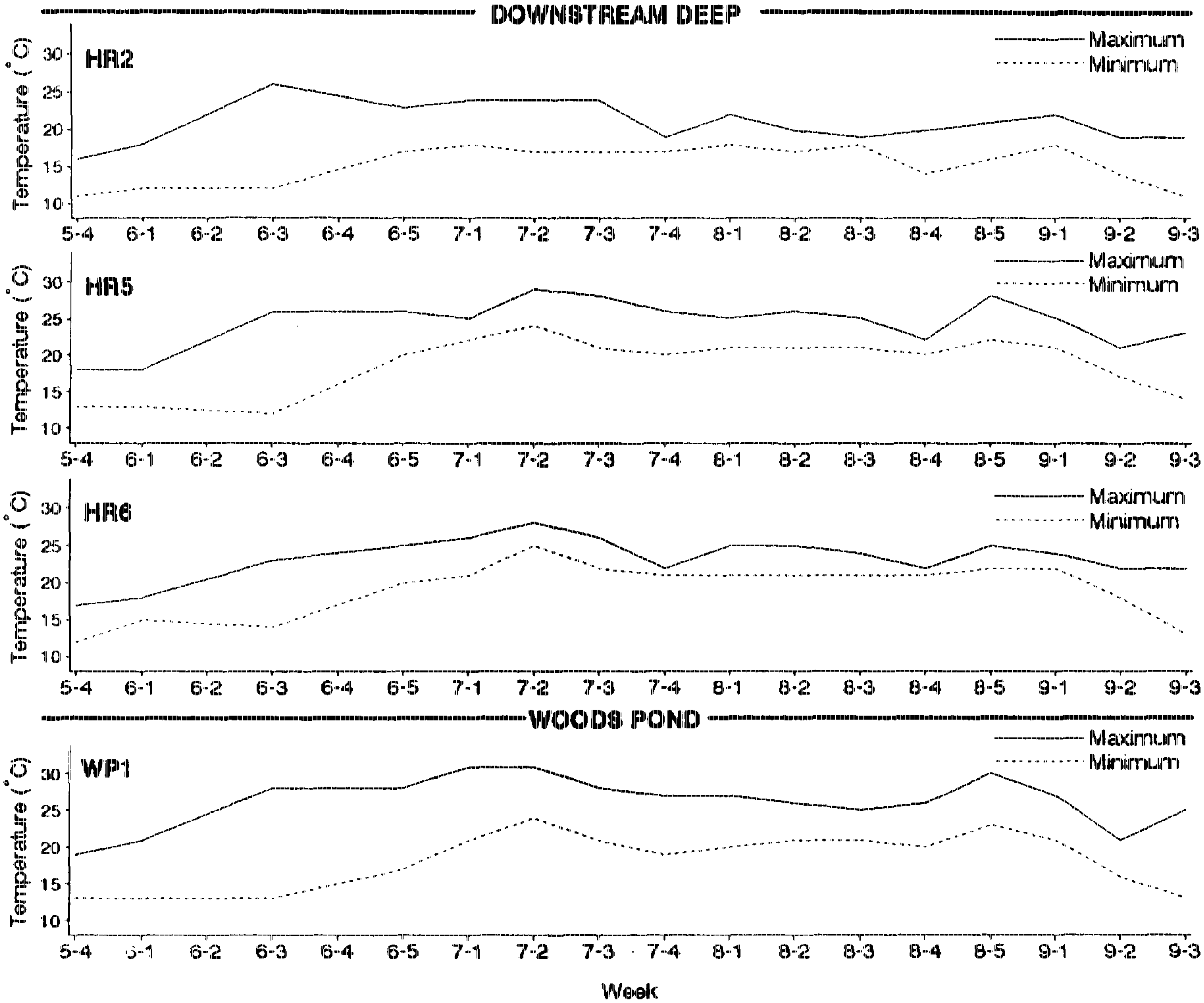

FIGURE 2: Continued.

Weekly dissolved oxygen levels ranged from 6.0 to 19.2 mg/L at all of the river sites in 1993 (Table 4). Weekly dissolved oxygen levels in Woods Pond ranged from 3.2 to 11.2 mg/L. Except for the week of September 7, when the D.O. level of 3.2 mg/L was recorded, dissolved oxygen levels in Woods Pond were generally above 6.0 mg/L, and within ranges recorded at the stream study sites. EPA water quality criteria for dissolved oxygen indicate that average levels of 5.5 mg/L and above and instantaneous readings of 3.0 mg/L and above are suitable for warmwater fish populations (USEPA 1986). Overall, the levels of dissolved oxygen measured in the Housatonic River system were within acceptable criteria.

The monthly pH measurements at Sites HR1 and HR3 - HR6 ranged from 7.9 to 9.0 (Table 4). This indicated that river water was alkaline, in contrast to 1992, when measurements indicated that the pH of the river varied from acidic to alkaline (Appendix C). The pH in 1993 varied less than in 1992, although the reasons for this are not known.

Nitrate levels indicate some nutrient loading, as indicated by the range of 0.33 to 2.40 mg/L for the five Housatonic River study sites where this parameter was measured (Table 4). For comparison, Hynes (1970) reported that background nitrate levels in rainwater from Connecticut ranged from 0.05 to 0.07 mg/L. In addition, Paul and Duthie (1989) measured nitrate levels of 0.04-0.06 mg/L in an oligotrophic river in northern Quebec. However, the nitrate levels measured in the Housatonic River are within ranges typical for this region. For instance, nitrate levels in Hubbard Brook in northern New Hampshire ranged from 0.4 to 2.5 mg/L (Goldman and Horne 1983).

Maximum total ammonia levels at the Housatonic River study sites ranged from 0.08 to 0.23 mg/L (Table 4). However, the toxic form of ammonia is unionized ammonia, which comprises only a part of total ammonia. When levels of unionized ammonia were calculated from measured levels of total ammonia, the maximum values were 0.02 mg/L (Table 3). This level is considerably below the lowest acute response levels to uniodized ammonia by 29 fish species and 19 invertebrates (USEPA 1985). Toxic levels of unionized ammonia were apparently not present at study sites on the Housatonic River in the summer of 1993.

4.3 Fish Populations

Four parameters related to fish population dynamics were used to evaluate the fish populations in the Housatonic River system. These parameters are commonly used by ecologists when evaluating aquatic systems. The four parameters used in this study were: species diversity and richness (the number and kinds of species present), density (the number of fish per acre), biomass (the weight, or pounds of fish per acre), and condition or relative weight (the overall health and fitness of the fish). These parameters can be used to assess the populations at a site and to assess differences between sites.

4.3.1 Species Diversity and Richness

Species diversity and species richness are general indicators of the health of a fish community. Species diversity refers to the distribution of the different species among the families of the fish and among the general categories of game fish, rough fish and forage fish. Species richness refers to the number of species present at a site. These parameters are used in evaluating the status of a fish community and determining if an aquatic ecosystem has been degraded. For example, species richness is generally inversely related to the degree of degradation of an ecosystem (Ney 1993).

The following subsections present, first, a general discussion of the findings on fish species diversity and richness in the Housatonic River in Massachusetts, followed by a discussion of the findings for each specific group of study sites. Table 5 lists the fish species collected from the Housatonic River in Massachusetts in five studies since 1943, including the present study. Table 6 lists the species collected by Chadwick & Associates in 1992 and 1993 at each study site, while Table 7 shows the number of each species collected at each site in 1993. At the end of this section, the results of the cluster analysis of the fish community data are presented.

General Overview

A total 40 species of fish in 10 families have been collected from the Massachusetts sections of the Housatonic River in the five studies since 1943 (Table 5). Although the killifish collected by Bergin (1971) were not identified to species, these were probably banded killifish, since this is the only species of killifish whose natural distributional range includes the Housatonic River (Page and Burr 1991). Twenty of the 40 species were game fish. The muskellunge collected in 1982 by Stewart Laboratories was probably a misidentified tiger muskie, a sterile hybrid cross between a northern pike and muskellunge. Although muskellunge are not native to the region, tiger musky have been stocked in lakes in the Housatonic River Valley, from which they have escaped into the Housatonic River (Joe Bergin, Massachusetts DFW, pers. comm. Jan. 26, 1993). Overall, the species collected since 1970 in the Housatonic River are typical for this region, representing a good diversity in the fish community.

Based on the two Chadwick & Associates studies (1992 and 1993 combined), species richness at each site ranged from 11 to 17 species (Table 6). Each site displayed good species diversity, indicating a balanced fish community downstream of Pittsfield. The fish community within each study site was fairly consistent between 1992 and 1993, indicating community stability. Differences between years and between sites were generally due to the presence or absence of the less common species. The exception to this was at Site HR4, where only five species were collected in 1992, but eleven species were collected in 1993. The additional species collected in 1993 included three sunfish species and three forage fish species. This difference was probably due to the more intensive sampling effort in 1993.

A combined total of 28 species of fish were collected in 1992 and 1993 from all the study sites in the Housatonic River system (Table 6). This species richness was within ranges collected by researchers in other warmwater streams in the eastern half of North America. For example, in western Massachusetts, McCabe (1943) collected 22 species in the Deerfield River system, 27 species in the Westfield River system, 25 species in the Chicopee River system, and 18 species in the Hoosic River system. In other areas, 22 species were collected in streams in southern Ontario (Johnson 1965), 26 species in the Little Sioux River, Iowa (Hansen 1971), and 33 species in Jordan Creek, Illinois (Larimore 1961). Species composition in these streams is also similar to the Housatonic River system in that the number of species was usually dominated by minnows, followed by sunfish.

TABLE 5: List of fish species collected from Housatonic River system, Massachusetts. (Mc=McCabe 1943; M=Bergin 1971; S = Stewart Laboratories 1982; B = Blasland & Bouck Engineers 1991; C = Chadwick & Associates 1992 and 1993).

Family Common Name	Scientific Name	Housatonic River
Salmonidae		
Brook trout	*Salvelinus fontinalis*	Mc,S
Brown trout	*Salmo trutta*	Mc,B,C,M,S
Rainbow trout	*Oncorhynchus mykiss*	Mc,M,S
Centrarchidae		
Bluegill	*Lepomis macrochirus*	Mc,C,M,S
Black crappie	*Pomoxis nigromaculatus*	C,S
White crappie	*Pomoxis annularis*	C
Green sunfish	*Lepomis cyanellus*	S
Largemouth bass	*Micropterus salmoides*	Mc,B,C,M,S
Pumpkinseed	*Lepomis gibbosus*	Mc,C,M,S
Redbreasted sunfish	*Lepomis auritus*	Mc
Redear sunfish	*Lepomis microlophus*	S
Rock bass	*Ambloplites rupestris*	Mc,C,M,S
Smallmouth bass	*Micropterus dolomieu*	Mc,C
Esocidae		
Chain pickerel	*Esox niger*	Mc,C,M,S
Grass pickerel	*Esox americanus*	Mc
Northern pike	*Esox lucius*	C
Muskellunge	*Esox masquinongy*	S
Percidae		
Tessellated darter	*Etheostoma olmstedi*	C
Yellow Perch	*Perca flavescens*	Mc,B,C,M,S
Percopsidae		
Trout perch	*Percopsis omiscomaycus*	Mc
Ictaluridae		
Brown bullhead	*Ameiurus nebulosus*	Mc,C,M,S
Yellow bullhead	*Ameiurus natalis*	C
Catostomidae		
Longnose sucker	*Catostomus catostomus*	Mc,C,M
White sucker	*Catostomus commersoni*	Mc,C,M
Creek chubsucker	*Erimyzon oblongus*	Mc
Cyprinidae		
Blacknose dace	*Rhinichthys atratulus*	Mc,C,M
Bluntnose minnow	*Pimephales notatus*	C
Bridle shiner	*Notropis bifrenatus*	Mc
Common carp	*Cyprinus carpio*	C
Common shiner	*Luxilus cornutus*	Mc,C,M
Creek chub	*Semotilus atromaculatus*	Mc,C,M
Fallfish	*Semotilus corporalis*	Mc,C,M
Fathead minnow	*Pimephales promelas*	C
Golden shiner	*Notemigonus crysoleucas*	Mc,C,M
Goldfish	*Carassius auratus*	C,M
Longnose dace	*Rhinichthys cataractae*	Mc,C,M
Spottail shiner	*Notropis hudsonius*	C,M
Cyprinodontidae		
Killifish	probably *Fundulus diaphanus*	M
Banded killifish	*Fundulus diaphanus*	C
Cottidae		
Slimy sculpin	*Cottus cognatus*	Mc
Total Species Richness		40
Species Richness, Chadwick & Associates		28

TABLE 6: List of fish species collected by Chadwick & Associates, Inc. from the Housatonic River system, September 1992, 1993. X = collected in 1992 and 1993, 92 = collected only in 1992, 93 = collected only in 1993. Site HR5 not sampled in 1992.

Family	Upstream		Shallow Downstream				Deep Downstream			Pond
Common Name	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6	WP1
Salmonidae										
Brown trout	93				93	X				
Centrarchidae										
Rock bass	X	X	X	X	X	X	92	93	X	X
Black crappie						93	X	93	X	X
White crappie		93								
Bluegill	X	X		X	92	93	X	93	X	X
Largemouth bass	X	X	X	X	93	93	X	93	X	X
Pumpkinseed	X	X	X	X			X	93	X	X
Smallmouth bass								93	X	
Esocidae										
Northern pike										X
Chain pickerel	X						92	93		92
Percidae										
Tessellated darter					X			93	92	
Yellow perch	X	X	X	X			X	93	X	X
Ictaluridae										
Brown bullhead		92			X		X	93		X
Yellow bullhead		93								
Catostomidae										
Longnose sucker					X			93		
White sucker	X	X	X	X	X	X	X	93	X	X
Cyprinidae										
Goldfish							92			X
Common shiner	92	92	93		X					X
Creek chub	92	93	X	93	93					
Common carp							X	93	92	X
Fallfish	X	X	X	X	X	93			X	
Fathead minnow		93								
Golden shiner					93				93	92
Longnose dace	X	X	X	X	X	X				
Bluntnose minnow	93	X	X	X	X	X		93	93	X
Blacknose dace	X	X	X	93	X	93				
Spottail shiner	93			93		93			93	X
Cyprinodontidae										
Banded killifish					93					
Total Species Richness	15	16	11	12	16	11	11	14	14	16

A total of 7,174 fish were collected in the Housatonic River system in 1993 (Table 7). Minnows greatly dominated the number of fish collected, accounting for 71% of all fish. The most abundant minnow species was the bluntnose minnow. Suckers were the second most abundant family, accounting for 15% of all fish collected (Table 7). This numerical dominance by minnows is probably normal for many warmwater streams (Larimore 1961; Matthews 1986; Lobb and Orth 1991).

Shallow Water Sites Upstream of GE Facility

Fifteen and sixteen species of fish were collected at Sites EB1 and WB1, respectively (Table 6) upstream of the GE facility. The fish communities at each of these sites are relatively stable, as indicated by the fact that ten species at each site were collected in both 1992 and 1993. Most of the species collected in only one of the sampling years were uncommon species. For example, although white crappie, yellow bullhead, and fathead minnows were collected at Site WB1 only in 1993, they were not collected at any other site in 1992 or 1993. The brown trout collected at Site EB1 in 1993 was probably an incidental migrant from upstream areas. The state of Massachusetts actively manages the Housatonic River upstream of Pittsfield, near the town of Hinsdale, as a trout fishery (Leo Daly, Massachusetts DFW, pers. comm. Dec. 8, 1992). The species richness at these two sites combined was 19 species (Table 6).

The fish populations at these two sites were also diverse. The species present represent seven different families of fish (Table 6). All three general groups of fish (game, rough, and forage) were represented, usually by multiple species. The species diversity at these two sites indicates balanced populations.

Shallow Water Sites Downstream of GE Facility

Eleven to sixteen species were collected at Sites EB2 to HR4 in 1992 and 1993 (Table 6). The fish communities at these sites were relatively stable, similar to the shallow water sites upstream of the GE facility. For example, Sites EB2 and HR3 each had ten species that were collected in both 1992 and 1993, and Site HR1 had nine species that were collected in both years. Six new species were collected at Site HR4 in 1993, but this was probably due to increased sampling effort.

TABLE 7: Number of fish collected by Chadwick & Associates, Inc. from the Housatonic River system, September 1993.

Family	Upstream		Shallow Downstream				Deep Downstream			Pond	
Common Name	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6	WP1	TOTAL
Salmonidae											
Brown trout	1	--	--	--	1	11	--	--	--	--	13
Centrarchidae											
Rock bass	40	18	31	29	58	23	--	43	7	3	252
Black crappie	--	--	--	--	--	1	1	4	4	10	20
White crappie	--	1	--	--	--	--	--	--	--	--	1
Bluegill	6	1	--	2	--	1	3	32	44	75	164
Largemouth bass	2	2	1	18	2	32	4	22	15	26	124
Pumpkinseed	9	9	1	2	--	--	4	16	6	31	78
Smallmouth bass	--	--	--	--	--	--	--	8	11	--	19
Esocidae											
Northern pike	--	--	--	--	--	--	--	--	--	1	1
Chain pickerel	1	--	--	--	--	--	--	4	--	--	5
Percidae											
Tessellated darter	--	--	--	--	40	--	--	1	--	--	41
Yellow perch	5	21	9	94	--	--	13	18	2	50	212
Ictaluridae											
Brown bullhead	--	--	--	--	2	--	1	4	--	32	39
Yellow bullhead	--	1	--	--	--	--	--	--	--	--	1
Catostomidae											
Longnose sucker	--	--	--	--	47	--	--	1	--	--	48
White sucker	5	174	137	119	405	31	20	80	6	75	1,052
Cyprinidae											
Goldfish	--	--	--	--	--	--	--	--	--	21	21
Common shiner	--	--	153	--	3	--	--	--	--	--	156
Creek chub	--	5	3	14	27	--	--	--	--	--	49
Common carp	--	--	--	--	--	--	2	34	1	1	38
Fallfish	21	131	67	5	7	7	--	--	--	--	238
Fathead minnow	--	2	--	--	--	--	--	--	--	--	2
Golden shiner	--	--	--	--	4	--	--	--	3	11	18
Longnose dace	40	136	46	2	300	662	--	--	--	--	1,186
Bluntnose minnow	1	1,191	427	498	32	10	--	3	1	1	2,164
Blacknose dace	204	289	66	9	6	521	--	--	--	--	1,095
Spottail shiner	4	--	--	119	--	1	--	--	3	7	134
Cyprinodontidae											
Banded killifish	--	--	--	--	3	--	--	--	--	--	3
Number Collected	339	1,981	941	911	937	1,300	48	270	103	344	7,174

The single brown trout collected at Site HR3 was probably a migrant from a tributary to the Housatonic River. Although the lower Housatonic River is not actively managed as a trout fishery, the tributaries are stocked with trout (Leo Daly, Massachusetts DFW, pers. comm. December 8, 1992).

The species diversity at the shallow sites downstream of the GE facility was similar to the shallow sites upstream. Seven families of fish, representing game fish, rough fish and forage fish, were present. As at the upstream sites, the minnow and sunfish families (Cyprinidae and Centrarchidae) contained the most species. The combined species richness at the four shallow sites downstream of the GE facility grouped together was 20 species, similar to the cumulative total of 19 species found at the two sites upstream of the GE facility.

Deep Water Sites Downstream of GE Facility

Eleven to 14 species were collected at these sites in 1992 and 1993 (Table 6). Site HR2 had eight species that were collected in both years, and Site HR6 had nine species that are present in both years. These data indicate that the fish communities in these river sections were relatively stable. Site HR5 was sampled only in 1993. These three sites had somewhat similar fish communities, with eight species captured at all three of the sites over the two years of sampling.

The species diversity at these sites included multiple species of game fish, rough fish and forage fish at all three sites (Table 6). The sunfish family, Centrarchidae, was the dominant family. The sunfish as a group generally prefer the deeper, more pond-like conditions present at these sites. The combined number of species at these three sites was 18, very similar to the 19 and 20 species present in the shallow sites upstream and downstream of the GE facility, respectively.

Woods Pond

The fish community of Woods Pond has been relatively stable over the two years of sampling. Fourteen of the sixteen species collected from the pond were collected during both years. Only two of the less common species were not captured in 1993 (Table 5). As in 1992, sunfish and white suckers were the most abundant groups in 1993 (Table 7).

The results from 1993, like those for 1992, indicate the presence of a diverse, balanced fish community. Game fish, rough fish and forage fish (minnows) are all present in substantial amounts. The number of species (16) captured over the two years of sampling is higher than at all of the other individual shallow and deep Housatonic River sampling sites (Table 5) and is only slightly less than the combined number of species present in the other habitat types when grouped together. This is in spite of the relatively high levels of PCBs present in the sediment of Woods Pond, as compared to most other sites.

Cluster Analysis

As previously outlined, the fish community data from the nine stream sites were also evaluated with cluster analyses. The Jaccard Index compares sites based on the presence or absence of fish species and groups the sites by similarity. The results of this analysis indicate that the species present at the sites grouped according to similar habitat type (Fig. 3). In other words, the species present at the sites were more a function of habitat type (shallow or deep) than a function of other factors such as location relative to the GE facility. Cluster analysis using the Percent Similarity Index, which takes into account the relative abundance of the species as well as their presence or absence, resulted in a similar cluster pattern (Fig. 3). These analyses indicate that the fish communities in the Housatonic River are determined by habitat features, not the pattern of PCB sediment concentrations.

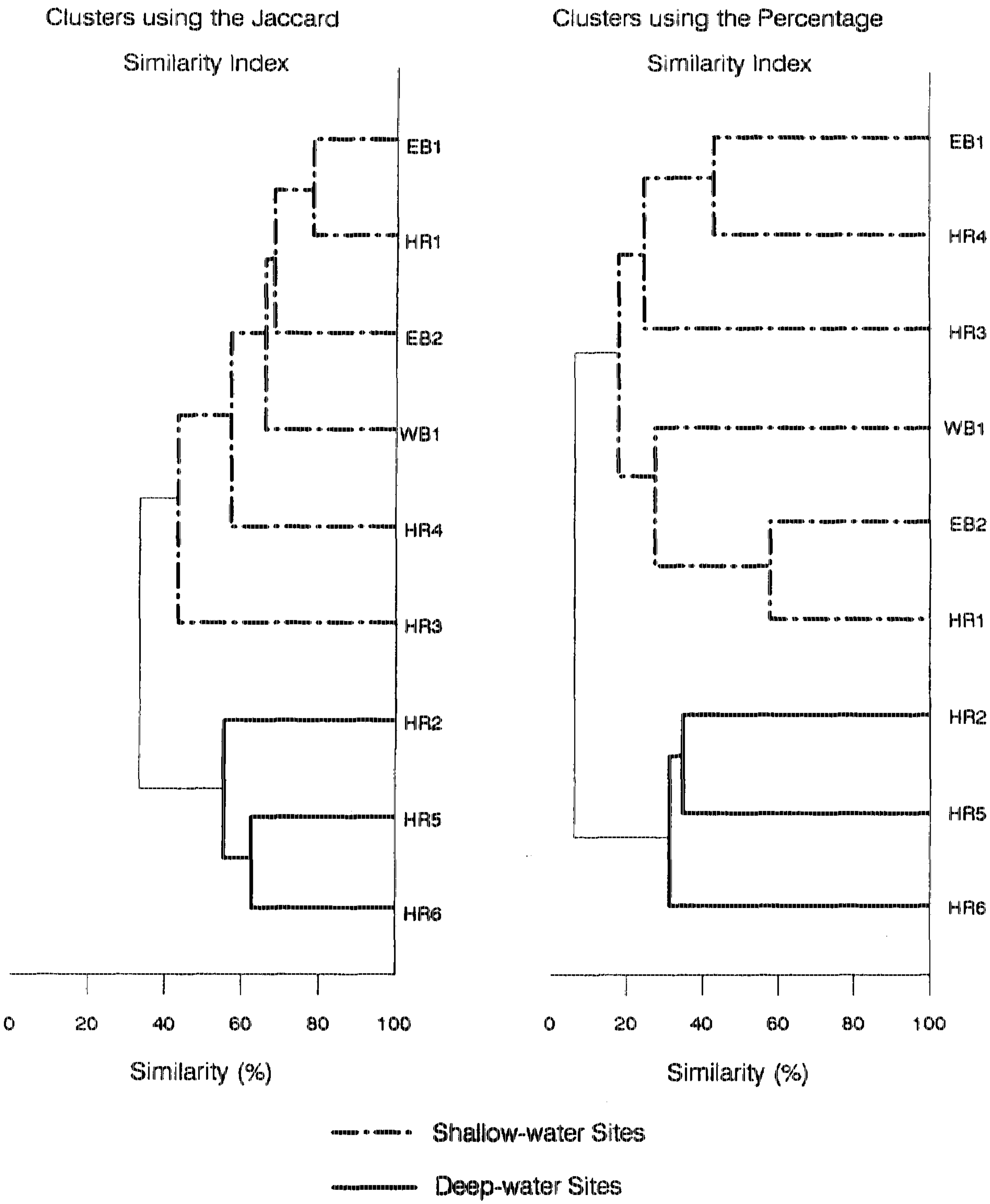

FIGURE 3: Results of cluster analyses for fish community data, nine Housatonic River stream sampling sites, 1993.

4.3.2 Density and Biomass

Traditionally, density (number of fish/acre) and biomass (pounds of fish/acre) have been among the most important biological statistics of fish population (Van Den Avyle 1993). Both of these parameters relate to the relative abundance of a fish population, based on a per unit area (in this case an acre). Because effort and cost of estimating absolute abundance in an entire river is prohibitive, relative abundance estimates based on the sampling of a representative section of stream within a watershed is an accepted method of estimating abundance.

Estimated density of fish does not account for fish size, both within a species or between species. Density can therefore overestimate the importance of smaller fish to a community. A more meaningful parameter for evaluating the structure of a fish community is biomass (lbs/acre), since it is not biased by fish size. The capacity for an aquatic ecosystem to support fish is most appropriately based on biomass rather than on density.

The data on number of fish collected during our 1993 study have been presented in Table 7 above. The estimated densities at each stream study site are shown in Appendix A, Tables A-1 through A-3. The biomass results are presented in Appendix A, Tables A-4 through A-6 (in lbs/acre for the stream study sites) and Table A-7 (total weight for Woods Pond fish), and are summarized in Figure 4. The density and biomass results for each group of sites are discussed in the following subsections.

Shallow Water Sites Upstream of GE Facility

Data on number of fish collected and estimated density indicate that minnows dominate the fish community at the shallow water sites upstream of the GE facility (Table 7; Appendix A, Tables A-1 to A-3). In general, all three major fish groups (game, rough, and forage fish) are represented at these sites, although the proportions of white suckers and bluntnose minnows at WB1 were relatively high.

Although forage fish were very abundant at Site EB1, they comprised only a small proportion of the biomass (Fig. 4). The fish community biomass at Site EB1 was dominated by game fish, and smaller proportions of forage fish and rough fish. Because of a very large population of bluntnose

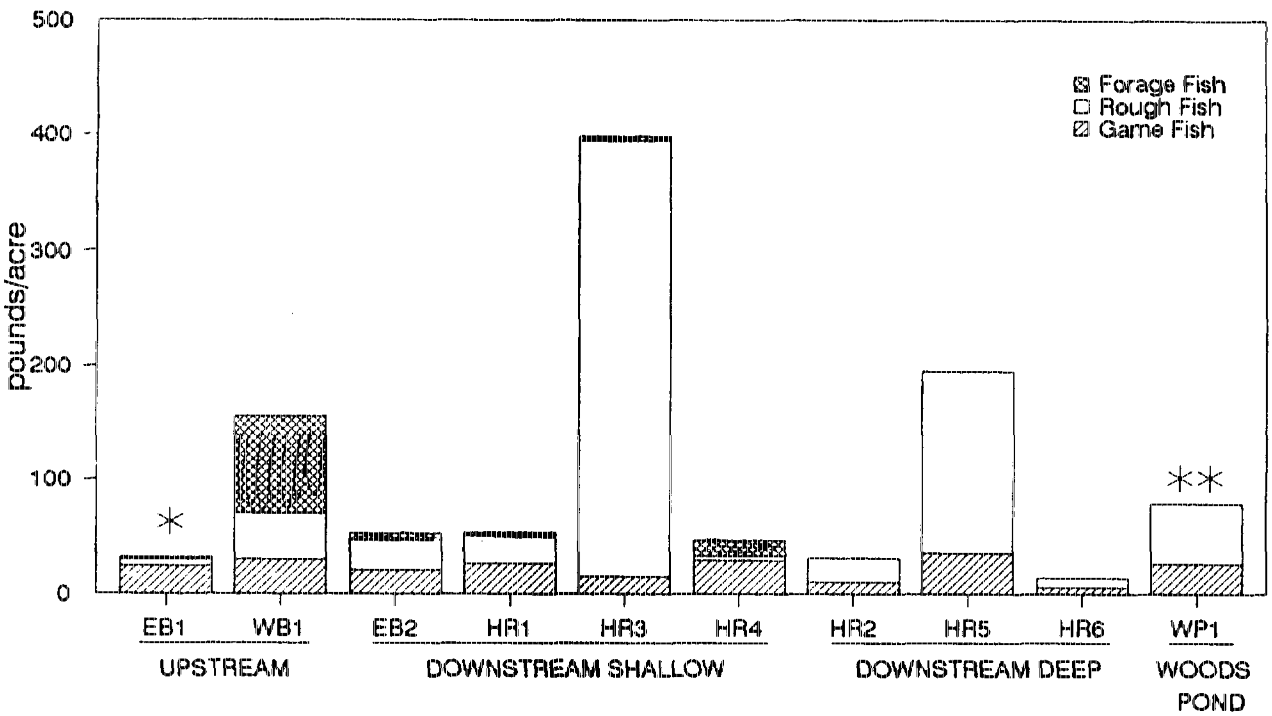

FIGURE 4: Estimated biomass of forage fish, rough fish, and game fish at study sites on the Housatonic River system, September 1993.

* Weights estimated for forage fish.

** Biomass for Woods Pond represents biomass actually collected, not estimated for entire pond.

minnows at Site WB1, forage fish dominated biomass at this site, followed by rough fish and game fish (Fig. 4).

Shallow Water Sites Downstream of GE Facility

At the shallow water sites downstream of the GE facility, as at the upstream shallow water sites, minnows dominated in terms of number collected and estimated density (Table 7; Appendix A, Tables A-1 to A-3). The exception was Site HR3, where large numbers of white suckers were collected from a 3-4 ft deep pool at this site. Densities of fish were balanced at most sites, although density of rough fish was relatively high at Site HR3.

Estimates of biomass (lbs/acre) indicate that game fish and rough fish comprised the major portion of the biomass at most shallow sites downstream of the GE facility (Fig. 4; Appendix A, Tables A-4 to A-6). Again, the exception was Site HR3, which contained over 380 lbs/acre of white suckers. Except for Site HR3, the fish communities at the shallow water sites downstream of GE had relatively balanced biomass of game, rough, and forage fish.

Deep Water Sites Downstream of GE Facility

At all of the deep water sites game fish dominated the number collected and density estimates, followed by rough fish (Table 7; Appendix A, Tables A-1 to A-3). This pattern is in contrast to the shallow water sites where minnows were dominant and is related to habitat differences between the sites and differences in the electrofishing techniques at the deep and shallow sites. The reduced maneuverability when boat electrofishing lowers the efficiency of collecting small fish.

Biomass of fish was low at Sites HR2 and HR6 (Fig. 4). As stated previously, these low biomass estimates are related to the reduced efficiency of boat electrofishing. Total biomass of fish at Site HR5 was high, approximately 200 lbs/acre. This site had submerged rock piles and dropoffs, which tended to concentrate fish, making them easier to collect. Rough fish, especially white suckers, dominated the fish biomass at the deep water sites (Fig 4; Appendix A, Tables A-4 to A-6).

Woods Pond

Estimating density and biomass of the fish in Woods Pond would be a very difficult task and was out of the scope of this study. Nevertheless, the number and mass of fish captured in Woods Pond is sufficient information to evaluate the fishery. The three most common species captured were bluegill, yellow perch, and white suckers (Table 7, Appendix A, Table A-7), which occupy different niches in the pond. This suggests a balanced fish community. As expected in pond habitat types, the sunfish (Centrarchidae) contained the most number of species (5) as well as the most individuals. The minnow family also was represented by five species, but the number of individuals was much lower than that of the sunfish. This may be due, at least in part, to the selectivity of the boat electrofishing method for larger fish.

The fish community of Woods Pond was similar to that of the three deep water sites on the Housatonic River (Table 7). Sunfish, yellow perch and white suckers were relatively abundant at all three sites.

4.3.3 Fish Condition

Fish condition, as measured by the ratio of the weight of a fish to its length, provides a measure of the fish's health or well-being (Ney 1993). Fish condition can be used to monitor the influence of environmental change or perturbations and also to identify ages or seasons when the available food is inadequate (Ney 1993). Traditionally, there have been numerous indices to describe fish condition (Carlander 1969; Murphy and Willis 1991; Murphy *et al.* 1991; Ney 1993). However, many of these indices were biased by fish size. For this reason, relative weight (W*r*) was the index of fish condition used in this study, since it is not biased by fish size. The method used to calculate relative weight was described in Section 3.3 above.

Each species has a minimum length for calculating relative weight, usually from 4 to 6 inches (Murphy and Willis 1991). Therefore, only the fish above this threshold level were used in relative weight calculations. Expected relative weight values have the same general range across most species, generally falling between 70 and 130 (Murphy and Willis 1991). Relative weight values between 95 and

105 for most species are considered to be the optimal management target, and indicate the fish are in good condition and not stressed (Anderson 1980; Anderson and Gutreuter 1983). However, Willis *et al.* (1991) observed regional differences in relative weights and suggested developing regional standards for yellow perch, instead of relying on a national standard. Therefore, instead of a relative weight standard of 100, the standard used for yellow perch in this study was 79, based on previous studies in the New England area (Willis *et al.* 1991).

The mean relative weights for the most common game fish collected at the Housatonic River study sites are presented in Table 8. These results are also discussed below for each group of study sites.

In addition to calculating relative weight, fish condition was assessed by examining the general appearance of the fish. Water quality problems may manifest themselves in increased rates of parasitism and abnormal growth patterns. However, the fish collected in 1993 appeared to be healthy, with no abnormal growths and few external parasites. The parasitic flukes observed in many yellow perch in 1992 (see Appendix C) were observed in only one fish in 1993, a perch from Woods Pond.

Shallow Water Sites Upstream of GE Facility

Relative weights of rock bass were good at Site WB1, indicating that this species was healthy and in good condition (Table 8). Only one largemouth bass was collected at Site WB1, and it was in good condition. Although only one bluegill and one brown trout were collected at Sites WB1 and EB1, respectively, their conditions were below optimal. The relative weight of yellow perch at Site WB1 was close to the standard of 79 for this species. At Site EB1 five yellow perch were collected, and their relative weight was below the standard. This may be due to the small sample size. However, the relative weight of this species at Site EB1 in 1992 was also relatively low. This suggests the yellow perch at this site may be experiencing some sort of stress. Given the generally good condition of the other species at this site, there may be some factor affecting yellow perch alone that is causing the low relative weight.

TABLE 8: Mean relative weights (W_r) of the most common game fish at sites on the Housatonic River system, September 1993.

	Species				
SITE	Bluegill	Brown Trout	Largemouth Bass	Rock Bass	Yellow Perch
Shallow Sites Upstream of GE Facility					
EB1	--	78.3	--	--	64.9
WB1	90.5		114.4	94.5	77.6
Shallow Sites Downstream of GE Facility					
EB2	--	--	115.6	91.6	--
HR1	85.2	--	102.4	88.4	80.1
HR3	--	84.6	--	92.7	--
HR4	--	81.5	--	105.2	--
Deep Sites Downstream of GE Facility					
HR2	101.9	--	110.5	--	77.6
HR5	106.1	--	106.5	87.2	80.4
HR6	105.7	--	112.1	86.2	83.2
Woods Pond					
WP1	113.3	--	100.0	--	80.0
Standard	100	100	100	100	79

Shallow Water Sites Downstream of GE Facility

Condition of game fish, as measured by relative weight, varied at the shallow water sites downstream of the GE facility (Table 8). The only bluegill collected at these sites (from HR1) had a relative weight less than optimal. Although it is difficult to draw conclusions from only one fish, the lower condition factor is probably related to habitat. Bluegills are normally associated with ponds, lakes, and pools of large rivers rather than shallow streams. This is supported by their relatively low numbers at all shallow sampling sites (Table 7). Condition of brown trout collected at Sites HR3 and HR4 was below optimal, indicating they may be stressed. High water temperatures may have been a primary cause of below optimal condition. For example, maximum water temperatures at Site HR4 reached 29°C in July (Table 4), which is at the upper end of the range of lethal temperatures (25°C-29°C) for brown trout (Carlander 1969, Raleigh *et al.* 1986, Behnke 1992). Optimal temperature requirements for growth and survival of brown trout are 12-19°C (Raleigh *et al.* 1986). Many laboratory experiments indicate that trout reduce, and finally cease, feeding as water temperatures increase from 22° to 25°C (Behnke 1992).

Largemouth bass were in good to excellent condition at Sites EB2 and HR1, although only one was collected at Site EB2. Rock bass were in good condition at Site HR4, but in less than optimal condition at the other downstream shallow water sites. The lower condition of rock bass at Sites EB2, HR1, and HR3 correlated with the absence of preferred habitat. These three sites did not have the silt-free, rock bottomed substrate normally associated with this species (Scarola 1987, Page and Burr 1991). In contrast Site HR4 had higher water velocities, which prevented the accumulation of silt on the rock substrate, and thus provided good habitat for rock bass. Condition of yellow perch at Site HR1 was good, when compared to the New England standard of 79 (Table 8). This indicates that the yellow perch were healthy at this site.

Deep Water Sites Downstream of GE Facility

The condition of game fish at the deep water sites downstream of the GE facility was generally good (Table 8). Bluegill were in good condition at all sites, indicating that they were healthy and not stressed. Similarly, largemouth bass were in good condition at all sites. Although rock bass at Sites HR5 and HR6 had less than optimal relative weights, this is probably related to the absence of their preferred habitat at these sites. Largemouth bass and bluegill prefer the slower velocities and pool habitat associated with the deep water sites (Page and Burr 1991), and this is reflected in their good condition. Compared to the New England relative weight standard of 79, condition of yellow perch was good at all of the deep water sites.

Woods Pond

The condition of the game fish in Woods Pond was good. All relative weight indices for the more numerous game species in the pond are at or above the standard weights (Table 8). This indicates healthy populations and a stable, balanced ratio of game fish to forage species. The condition of the fish indicates no unusual environmental stresses to the populations. The condition of the fish, combined with the population parameters noted above, would indicate that the presence of PCBs in the system is having no adverse effects on the fish community of Woods Pond.

4.3.4 Comparison to Previous Studies

Results from the present study have been compared to data from previous studies both in the Housatonic River drainage and in other New England drainages. Such comparisons must be made cautiously due to differences in sampling techniques and sampling effort among studies. Nevertheless, the comparisons provide a general idea of the relative health of the fish communities of the Housatonic River in Massachusetts.

A comparison of fish community composition between the Housatonic River in 1993 and previous studies in the Housatonic River drainage and other drainages in New England and other parts of the Northeast is presented in Table 9. Similar to the Housatonic River in 1933, forage fish dominated collections in four out of the other seven studies listed. However, the fish community in the Housatonic River in Massachusetts in 1970 (Bergin 1971) was not dominated by forage fish, but by rough fish, as shown in Table 9 and Figure 5, which compares the fish community composition between the present study and the 1970 study. This predominance of rough fish, mainly white suckers, in 1970 indicates that the fish community may have been unbalanced, possibly due to a shortage of habitat or food for game fish. The fish community in the Housatonic River in 1993 was in better balance, as indicated by the high proportion of forage fish compared to game fish and rough fish. The high proportion of forage fish provides a strong food base for predatory game fish. In addition, the lower proportion of rough fish in 1993 indicates a better balanced fish community, in that there were fewer rough fish to compete with more desirable species for food and habitat.

Table 10 presents a comparison of species composition of the fish communities between the Housatonic River in 1993 and previous studies in the Housatonic River drainage and other drainages in the Northeast. A total of eight families of fish were collected in 1993 as part of the present study. Previous studies in the Housatonic River drainage collected between seven and nine families. McCabe (1943) collected nine families, and Bergin (1971) collected eight families in the Housatonic River. Data from historical studies such as McCabe (1943) and Bailey and Oliver (1939) are included in this report because they provide a historical picture of the structure of fish communities prior to any effects within the last 50 years. Investigators in other drainages in the Northeast collected from four to eleven families (Table 10). The more common families, such as minnows, sunfish, and suckers, were almost always collected in the previous studies.

The number of species collected in the Housatonic River in 1993 was similar to previous years (Table 10). McCabe (1943) collected 25 species and Bergin (1971) collected 20 species in the Housatonic River. In addition, investigators in other Northeastern rivers collected from 11 to 38 species (Table 10). The number of species collected (26) in the Housatonic River in 1993 falls within this range. The number of species collected in previous studies that were common to the present study ranged from 6 to 19 species, and comprised from 50 to 95% of the total number of species collected. These data indicate a high similarity between the fish community in the Housatonic River in 1993 and other rivers in the Northeast.

TABLE 9: Comparison of fish community composition (% number collected of forage fish, game fish, and rough fish) between the present study and other studies in the Housatonic River drainage and other drainages in the Northeast. Dates in parentheses indicate appropriate year of multiple-year investigation. NA = Not available.

Stream, State	Number Collected	Community Composition (% Number Collected) Forage Fish	Game Fish	Rough Fish	Reference
Housatonic River Drainage					
Housatonic R., MA (1993)	7,174	71	13	16	Present Study
Housatonic R., MA	1,091	25	5	70	Bergin (1971)
Naugatuck R., CT	3,166	77	9	14	Mount *et al.* (1986)
Naugatuck R., CT	1,379	27	41	32	Kasul *et al.* (1990)
Other Drainages					
Ware R., MA	7,223	26	23	52	Swanson (1973)
Lewis Cr., VT (1989)	NA	90	4	5	Langdon and Fiske (1991)
Nine Mile Cr., NY	1,246	80	5	15	Finger (1982)
Town Cr., MD	1,470	73	23	4	Goodfellow and Lebo (1981)

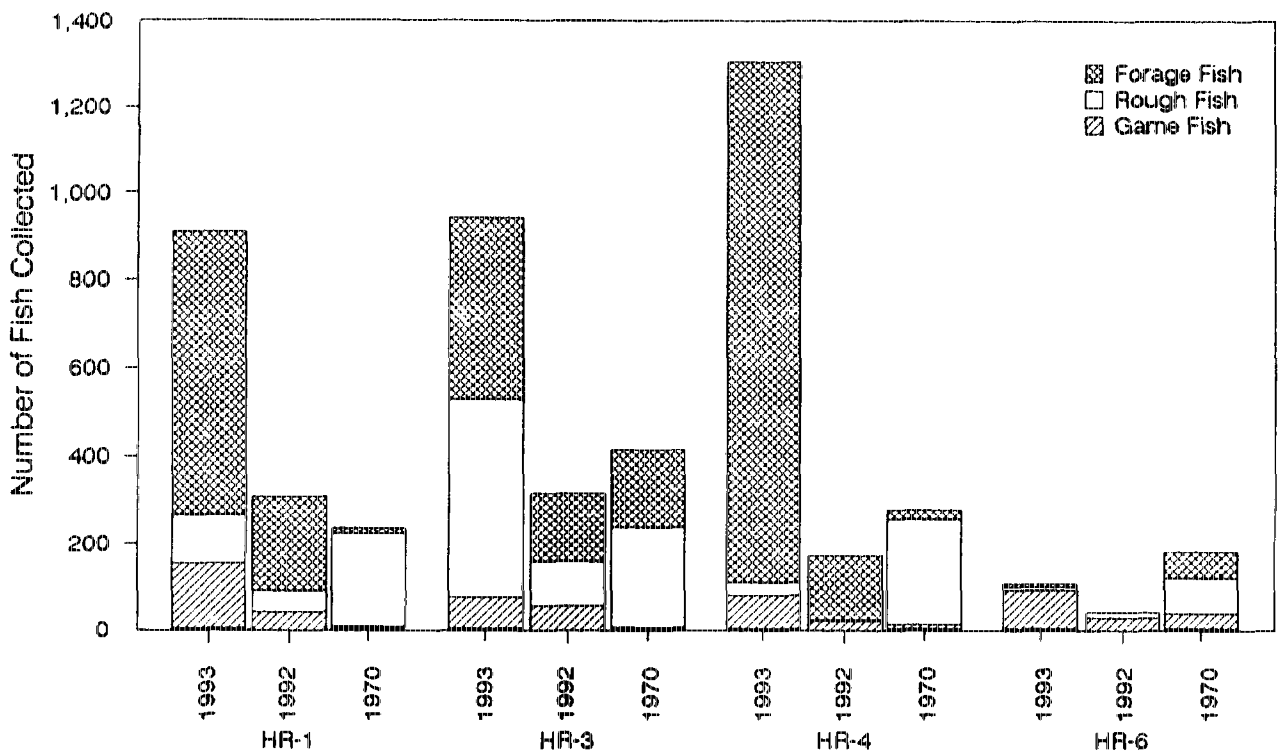

FIGURE 5: Number and proportion of forage fish, rough fish, and game fish collected from the Housatonic River by Chadwick & Associates, Inc. in 1993 and 1992, and by the Massachusetts DFW at corresponding sites in 1970.

TABLE 10: Comparison of species composition of fish communities between the Housatonic River (present study) and other studies in the Housatonic River drainage and other drainages in the Northeast. Dates in parentheses indicate appropriate year of multiple-year investigation.

Stream, State	No. of Families	No. of Species	No. of Species Common (to Present Study)	No. of Species by Family			Reference
				Minnows	Sunfish	Suckers	
Housatonic River Drainage							
Housatonic R., MA (1993)	8	26	--	10	7	2	Present Study
Housatonic R., MA	8	20	19	8	4	2	Bergin (1971)
Housatonic R., MA	9	25	17	7	6	3	McCabe (1943)
Naugatuck R., CT	7	20	16	8	5	1	Mount *et al.* (1986)
Naugatuck R., CT	8	20	17	7	6	1	Kasul *et al.* (1990)
Other Drainages							
Westfield R., MA*	11	28	17	9	6	1	McCabe (1943)
Deerfield R., MA*	9	22	16	8	3	2	"
Northern Conn. R., MA*	7	17	13	6	3	2	"
Chicopee R., MA*	10	25	19	8	5	2	"
Hoosic R., MA*	7	18	15	6	4	2	"
Ware R., MA	8	21	17	6	2	6	Swanson (1973)
Lewis Cr., VT (1989)	8	21	14	9	4	1	Langdon and Fiske (1991)
Nine Mile Cr., NY	5	16	12	7	4	2	Finger (1982)
Town Cr., MD	8	38	19	15	9	4	Goodfellow and Lebo (1981)
Miller R., NH	10	20	10	3	5	2	Bailey and Oliver (1939)
Ashuelot R., NH	11	26	13	6	4	2	"
Cold River, NH	10	20	13	5	3	2	"
Sugar R., NH	11	26	14	6	4	2	"
Mascoma R., NH	11	27	15	6	5	1	"
Amonoosuc R., NH	9	21	14	5	3	2	"
Johns R., NH	9	20	13	4	5	2	"
Israel R., NH	6	14	7	5	0	2	"
Upper Amonoosuc R., NH	10	23	12	5	3	2	"
Mohawk R., NH	4	11	6	6	0	2	"

* Includes tributaries

The minnow family dominated the number of species collected in the present study and almost all previous studies (Table 10). Ten minnow species were collected in the Housatonic River in 1993, compared to eight species in 1970 (Bergin 1971) and seven species in 1940 (McCabe 1943). Minnows also dominated in 18 of the remaining 21 stream segments previously studied. In addition, sunfish were the second most dominant family in the Housatonic River in 1993. This corresponds to most of the previous studies.

Estimates of total fish biomass (lbs/acre) for corresponding sections of the river were compared between the 1993 and the 1970 studies of the Housatonic River, as shown in Figure 6. Estimated biomass of fish in 1993 was greater than that of 1970 in three of four river sections and nearly equal in the fourth section. Although the methods differed between the two studies and the 1993 study was more intensive, the data suggest higher fish biomass in 1993 as compared to 1970. This, in conjunction with a more balanced fish community in 1993, indicates that the fish community in the Housatonic River in 1993 is healthier than in 1970.

4.4 Benthic Invertebrate Populations

Three parameters, species richness, density and diversity, are commonly used to evaluate invertebrate communities (Klemm *et al.* 1990) and are used in this study. The species richness (number of different species) and density (number of individuals per square meter) parameters are similar to those used to evaluate fish populations. Diversity for invertebrate populations is actually calculated from the raw data and expressed as the Shannon-Weaver Diversity Index (H'). This is possible due to the usually large number of invertebrates present in a sample. In contrast, the relatively few fish captured at a site would not allow meaningful calculations of this sort. For invertebrates the diversity index acts as a measure of community health or stress. A high diversity index, values between 2.5 - 4.0, indicate healthy invertebrate communities. Diversity index values less than 1.0 indicate a invertebrate community under severe stress (Klemm, *et al.* 1990, Wilhm 1970).

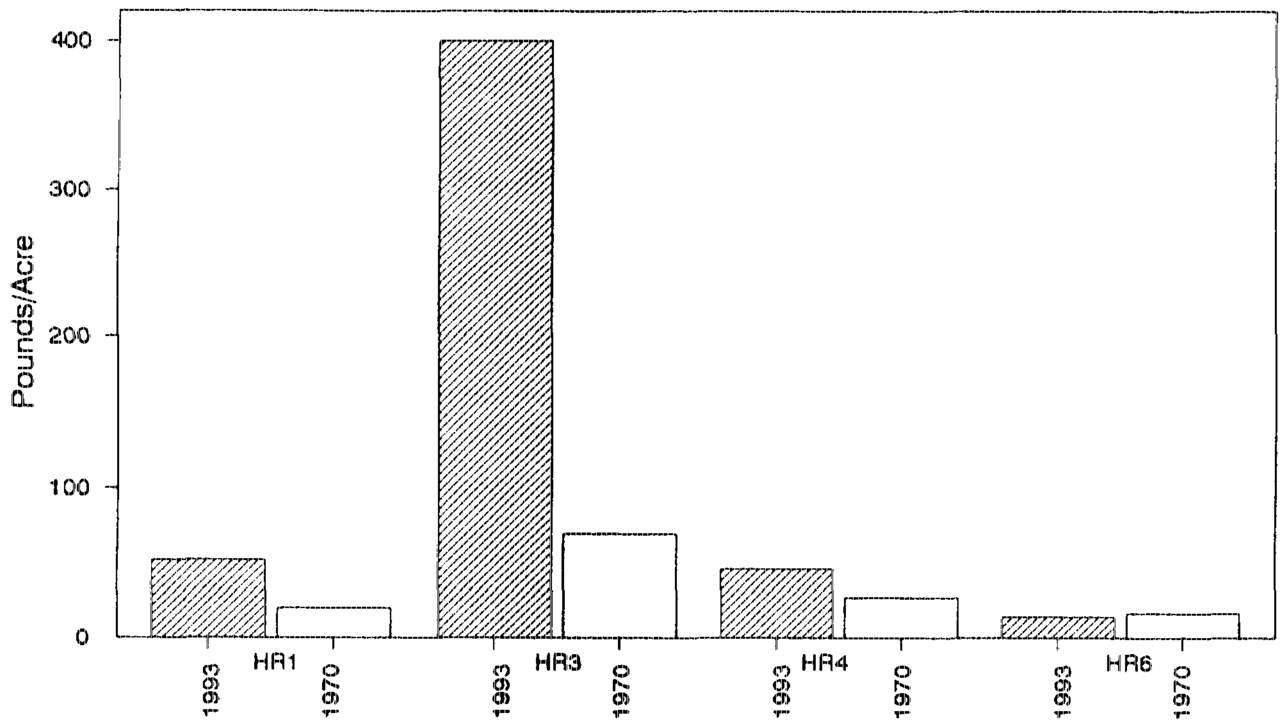

FIGURE 6: Estimated biomass (lbs/acre) of fish at sites on the Housatonic River in 1993 (present study) and 1970 (Massachusetts DFW).

4.4.1 Benthic Community Parameters

The data showing number of taxa and densities of benthic invertebrates at the study sites are provided in Figure 7 and Appendix B and are summarized in Table 11. The diversity indices are also included in Appendix B and Table 11. The results for each group of study sites are discussed in the following subsections. The cluster analysis is then presented.

Shallow Sites Upstream of GE Facility

The benthic invertebrate communities at Sites EB1 and WB1 contain a number of different orders of insects and appear to be balanced (Appendix B). The presence of pollution intolerant mayflies (Ephemeroptera) and caddisflies (Trichoptera) generally indicates that water quality at these two sites is at least fair (Bradfield 1986; Hilsenhoff 1987; Plafkin, *et al* 1989). Each of these orders of insects had multiple species at both sites. However, the caddisflies at each site were dominated by *Cheumatopsyche spp.* which are considered to be one of the more tolerant groups. This suggests that both sites may be experiencing at least some degree of enrichment with nutrients (Hilsenhoff 1987).

As stated previously, diversity indices of 2.5 to 4.0 are characteristic of healthy invertebrate communities (Klemm, *et al.* 1990; Wilhm 1970). Beckett (1978) found diversities of 2.42 at control sites and 2.24 at sites stressed by a number of factors including poor water quality and habitat degradation. The diversity index at Site EB1 was 3.56, well within the range considered healthy (Table 11). At Site WB1 the diversity index was only 2.34, somewhat below the healthy range. Also, the lower number of species collected at WB1 (35), as compared to EB1 (42), suggests that water quality conditions in the West Branch of the Housatonic River are only fair.

The densities of invertebrates at these two sites were similar and high (approximately 9,000-10,000/m^2) (Table 11). Hynes (1974) observed that under conditions of slight organic enrichment, there were increases in benthic invertebrate densities, but little decrease in diversity. This appears to be the case at Sites EB1 and WB1, with elevated densities, but only fair to good diversity values.

TABLE 11: Benthic invertebrate density (#/m^2), number of taxa, and diversity (H') at study sites in the Housatonic River system, September, 1993.

SITE	Density (#/m^2)	Number of Taxa	Diversity (H')
Shallow Sites Upstream of GE Facility			
EB1	10,429	42	3.56
WB1	9,040	35	2.34
Shallow Sites Downstream of GE Facility			
EB2	8,003	50	3.06
HR1	4,474	43	2.96
HR3	54,429	50	3.15
HR4	31,415	63	4.35
Deep Sites Downstream of GE Facility			
HR2	2,653	47	3.94
HR5	1,362	56	3.29
HR6	5,378	38	3.36
Woods Pond			
WP1	1,161	34	2.82

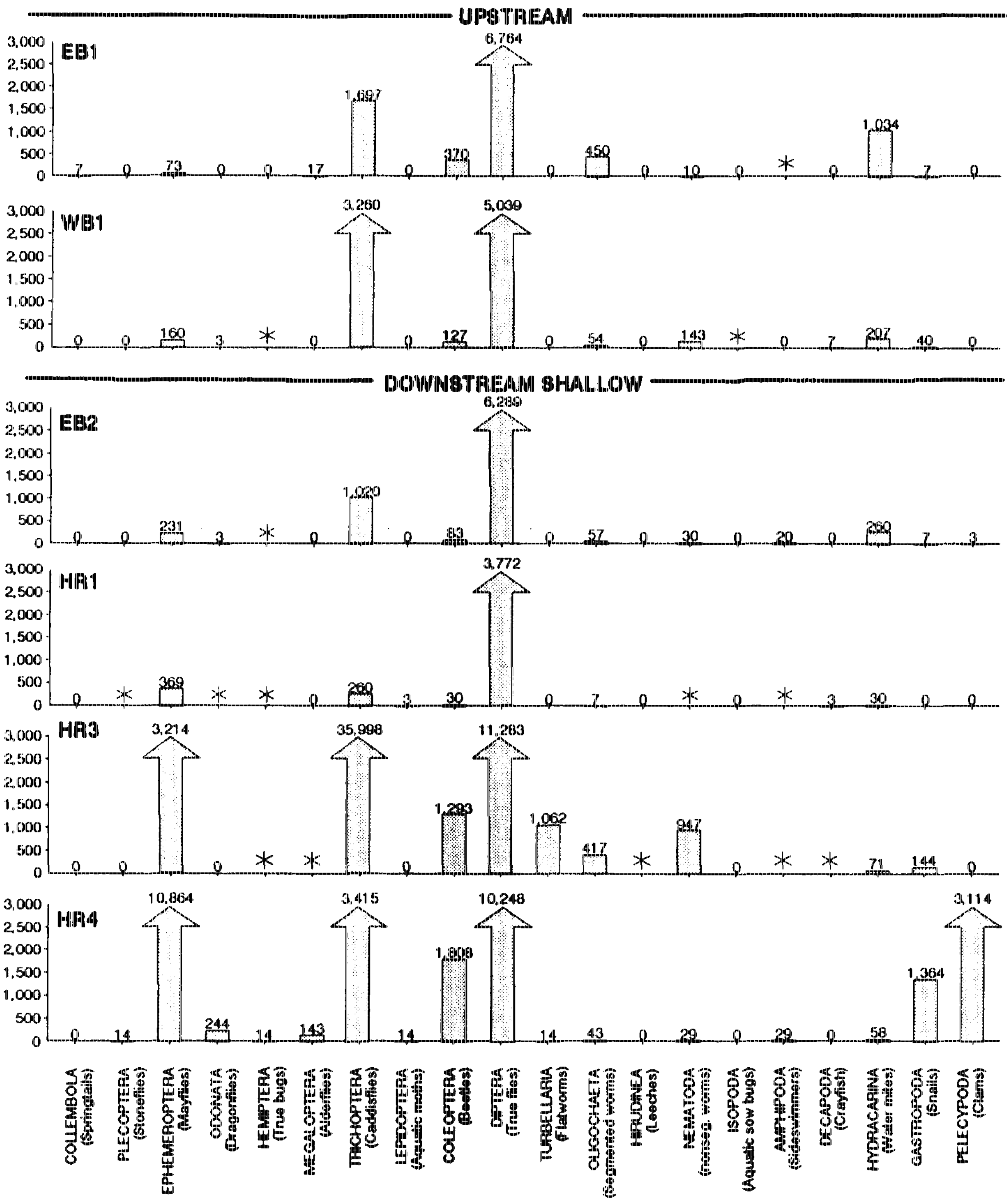

FIGURE 7: Mean densities (#/m^2) of orders of benthic invertebrates collected from study sites on the Housatonic River system, September, 1993. Asterisks denote that individuals were collected only in the qualitative kick sample.

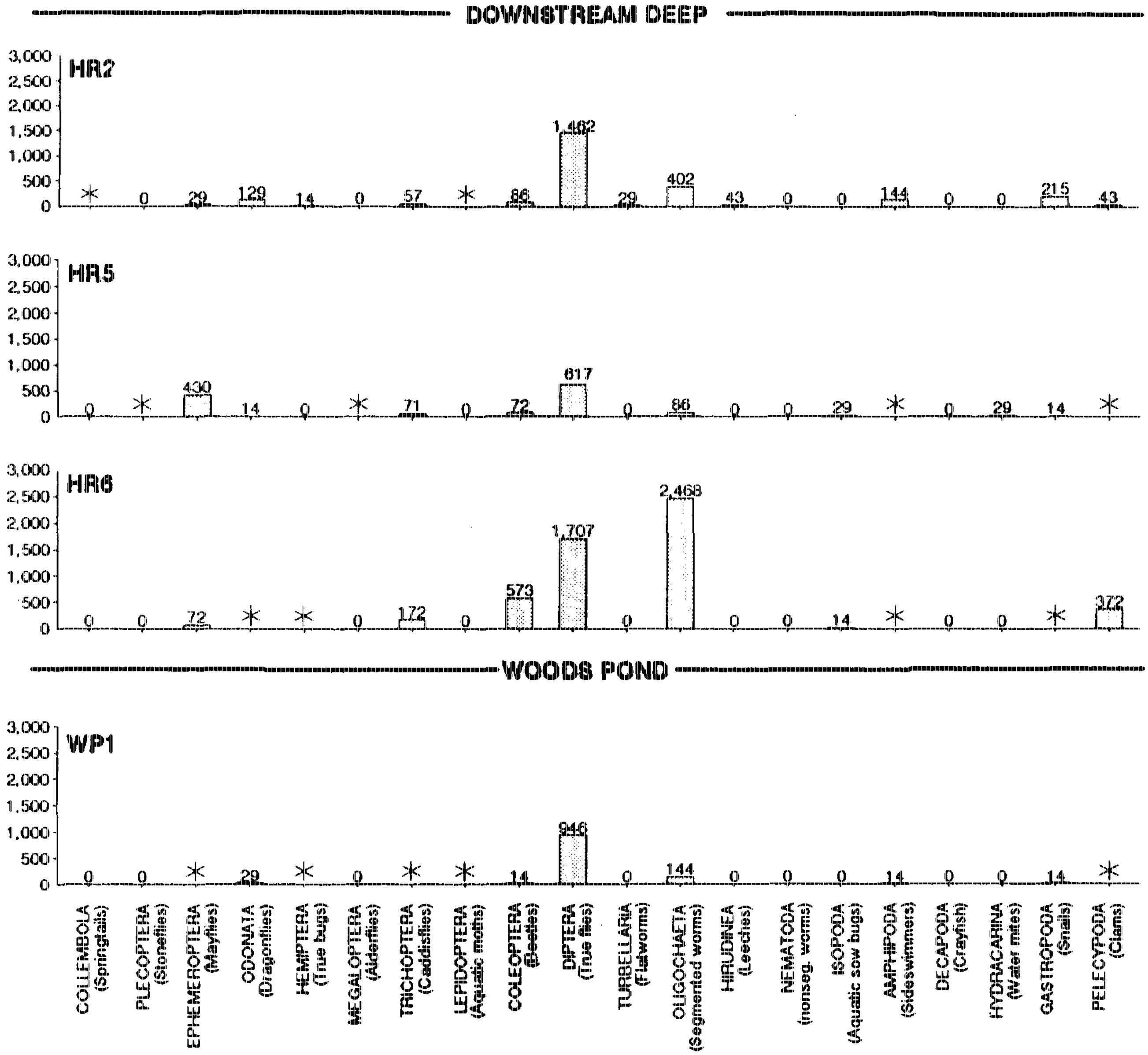

FIGURE 7: Continued.

Shallow Sites Downstream of GE Facility

In many aspects, the benthic invertebrate communities of the four shallow water sites downstream of the GE facility (Sites EB2, HR1, HR3, HR4) were similar to the two upstream sites. Species composition included balanced communities with numerous orders of insects (Appendix B). The number of species of invertebrates of the four downstream shallow water sites (43-63) was higher than at the two upstream sites (35-42) (Table 11). The presence of mayflies and caddisflies at the four downstream sites (Figure 7) again indicates that water quality is at least fair. Also, as at the two upstream sites, the caddisflies at the four downstream sites are dominated by the genus *Cheumatopsyche* and its close relative, *Hydropsyche* sp.

Diversity indices at these four sites are all above 2.5 and indicate healthy, balanced communities (Table 11). The diversities at Sites EB2, HR1 and HR3 are all very similar and are within the range of values found at the two upstream sites. The diversity value at Site HR4 was 4.35, the highest of all sites and much higher than the two upstream sites. This high value is probably at least partially a result of the suitable substrate present at this site. The cobble substrate present at HR4 generally is considered to be one of the best for supporting invertebrates (Minshall 1984).

The densities of invertebrates at the four shallow sites downstream of the GE facility vary considerably (Table 11). At all four sites the densities are relatively high. This further supports the conclusions that these four sites are exhibiting signs of elevated nutrient levels. The presence of many clean water insect forms, such as the Heptageniitd mayflies (*Stenacron* sp., *Stenonema* sp., Appendix B) indicates that these sites have generally good water quality. Much of the increased densities at Sites HR3 and HR4 are comprised of the net spinning caddisflies (*Cheumatopsyche* sp. and *Hychopsyche* sp.) (Fig. 7, Appendix B). These organisms filter and collect particles from the water column. The abundance of these organisms suggests that the river at these two sites is very productive and that the production of algae and other organic particles is high.

At Sites EB2 and HR1, similar invertebrate groups and some of the same species are present as at the two sites further downstream, HR3 and HR4 (Fig. 7, Appendix B). However, densities are considerably lower than at the sites further downstream. The difference in density between these two groups of sites appears to be the result of the level of nutrient enrichment. As shown in Table 4, the highest nitrate levels occur at Sites HR3 and HR4, the sites with highest densities of invertebrates. In contrast, the lowest densities of these four sites occurred at Site HR1, which also had the lowest nitrate levels.

The densities of invertebrates at Sites EB1 and WB1 upstream of the GE facility were not significantly different ($p \geq 0.31$, $p \geq 0.10$, respectively) from Sites HR1 or EB2 downstream of the GE facility. However, Sites HR3 and HR4 had significantly higher densities than Site EB1 ($p \leq 0.08$) and WB1 ($p \leq 0.10$). This was primarily a result of the abundance of net-spinning caddisflies, as well as high numbers of mayflies and dipterans, at these two sites. These results indicate that, on the whole, there were no discernible negative impacts to the downstream sites when compared to the upstream sites. However, as noted earlier, the invertebrate communities at HR3 and HR4 do appear to be enriched, resulting in substantially higher densities than at the two upstream sites.

Deep Sites Downstream of GE Facility

The three deep sites on the Housatonic River (HR2, HR5, HR6) are similar to ponds in their bottom substrate and depth. This type of habitat supports benthic invertebrates that are much different than those of the shallow stream sites. The invertebrate communities of ponds and the slower, deeper sections of rivers are generally dominated in their composition by invertebrates in the fly and midge group (Diptera) and by oligochaete worms (Hynes 1974, Wetzel 1975). Also, there is a tendency for these communities to be somewhat less productive and less diverse because of the unsuitability of the predominantly silt substrate and the relative uniformity of the substrate (Minshall 1984). Therefore, the invertebrate communities of deep water sites should not be compared to those of shallow stream sites.

All three deep water sites on the Housatonic River contained communities dominated by Diptera and/or oligochaetes, as is typical for these habitat types (Fig. 7). Other invertebrate groups were present, but generally in low numbers. Many species were absent or rare in the Ekman samples taken on the bottom in deep water but were present in the rare habitat types sampled by the kick sampler (Appendix B). However, their presence indicates a healthy and balanced community at these three sites.

Diversity indices at the three deep water river sites were relatively high (Table 11). The number of species at these sites is also relatively high, compared to the shallow upstream sampling sites (Table 11). This information further supports the conclusion of healthy, balanced communities of invertebrates at Sites HR2, HR5, and HR6.

The densities of invertebrates at the deep water sites, as expected, are lower than at the shallow sites (Table 11). However, there were no significant ($P \geq 0.30$) differences between the densities at HR2, the deep water site with the highest PCB levels, and the two sites further downstream, HR5 and HR6, which have much lower PCB levels in the sediments. There does not appear to be a longitudinal pattern in invertebrate populations related to PCB deposition.

Woods Pond

The benthic invertebrate fauna of Woods Pond exhibits the typical lentic species assemblage. The dipterans are dominant with oligochaetes also common (Appendix B). Almost all of the other taxa present were collected in the kick net sample in the rare habitat types around the edges of Woods Pond. As expected, because of the relatively deep water and habitat type, the diversity and number of species in Woods Pond are lower than at the Housatonic River sites (Table 11).

The presence of many insects in the kick net sample, including mayflies and caddisflies, suggest that water quality in Woods Pond is good. This information, along with a diversity index (2.82) above the threshold level of 2.5, and the presence of 34 species, clearly indicates a healthy, balanced invertebrate community in Woods Pond. Although Woods Pond appears to have levels of PCBs that are higher than most portions of the Housatonic River, there appears to be no ecological effect on the benthic invertebrate community.

Cluster Analysis

As noted above in the methods, the invertebrate data from the various stream study sites were also analyzed with cluster analysis using two similarity indices, the Jaccard Index and the Percentage Similarity Index. The results of these analyses are shown in Figure 8.

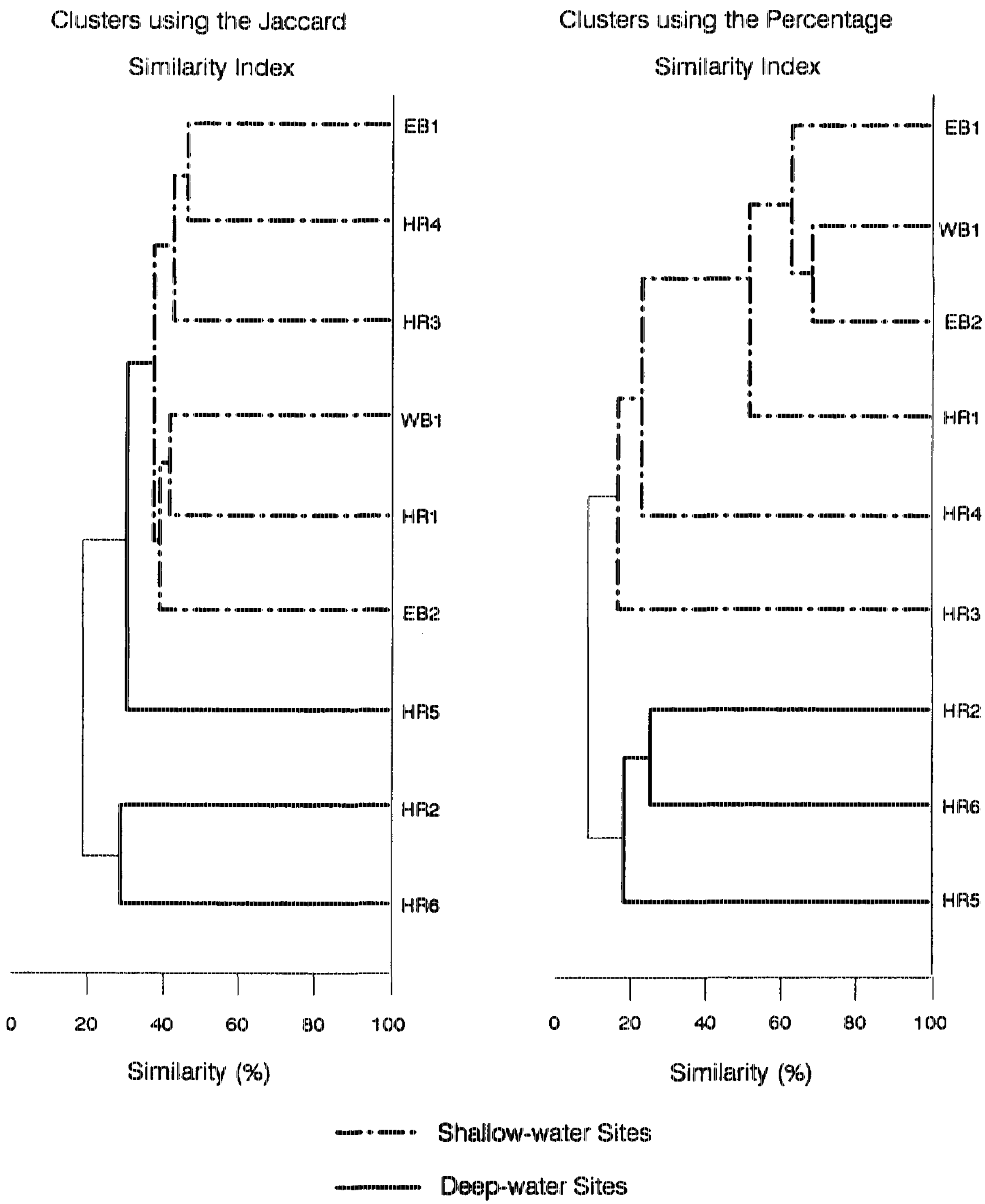

Figure 8: Results of cluster analyses for benthic invertebrate data, nine Housatonic River stream sampling sites, 1993.

As was true for the fish community data, the results of the cluster analyses indicate that the benthic invertebrate communities are determined more by habitat type than by other factors. In terms of the presence or absence of species (Jaccard Index), the shallow water sites are generally similar and separate from the deep water sites (Fig. 8). Taking into account the relative abundance of the invertebrate species present, using the Percent Similarity Index, produces a similar clustering pattern. In this case, the four most upstream sites in the drainage, Sites EB1, WB1, EB2 and HR1 were most similar (Fig. 8). All four of these sites are shallow water sites, but they occur both upstream and downstream of the GE facility. The remaining two shallow water sites, HR3 and HR4, were not as similar, probably due to the relatively high densities of caddisflies at these sites. The three deep water sites formed a separate cluster group. This pattern of clustering indicates no apparent effects of PCBs on benthic invertebrate populations.

4.4.2 Comparisons to Previous Studies

The benthic invertebrate results of the present study, in terms of number of taxa, diversity, and density, have been compared to results from previous studies both in the Housatonic River drainage system and in other river drainages in the Northeast (New England and upstate New York). These comparisons are presented in Table 12 and discussed below.

From 35 to 63 taxa of benthic invertebrates were collected from the study sites on the Housatonic River system in 1993, as part of the present study (Table 12). This abundance of invertebrate taxa indicates a healthy population in the Housatonic River system. Taxa richness in the Housatonic River system was within the range observed in previous studies in other drainages in the Northeast, which collected from 12 to 83 taxa (Table 12). Most of these studies collected a maximum of less than 40 taxa. These data suggest that species richness in the Housatonic River is relatively high compared to other streams in the Northeast.

Diversity of benthic invertebrates in the Housatonic River in 1993, as measured by the Shannon-Weaver Diversity Index (H'), ranged from 2.34 to 4.35 (Table 12). These values indicate a diverse benthic invertebrate community. Another study in the Housatonic River drainage (Naugatuck River, Connecticut) found similar benthic invertebrate diversities, ranging from 2.40 to 4.80 (Mount *et al.*

TABLE 12: Comparison of benthic invertebrate community parameters in the Housatonic River (present study) with results from other studies in the Housatonic River drainage and other drainages in the Northeast. Dates in parentheses indicate appropriate year of multiple-year study. NA = Not available.

Stream, State	No. of Taxa	Diversity (H')	Density (#/m^2)	Reference
Housatonic River Drainage				
Housatonic R., MA (1993)	35-63	2.34-4.35	1,362-54,429	Present Study
Housatonic R., CT	NA	NA	1,176- 1,295	Hagstrom *et al.* (1992)
Naugatuck R., CT	NA	2.40-4.80	1,503-81,149	Mount *et al.* (1986)
Other Drainages				
Lewis Cr., VT (1988-90)	12-83	2.33-4.73	2,150-6,450	Langdon and Fiske (1991)
Hoosic R., MA	21-39	NA	NA	Hogan (1990)
Statewide Streams, VT	28-66	3.32-5.26	NA	S. Fiske (Pers. Comm.)
Wild R., ME	27	2.20	NA	D. Courtemanch (Pers. Comm.)
Ossipee R., ME	27	3.24	NA	"
Sheepscot R., ME	30	2.92	NA	"
Susquehanna R., NY (1984)	28-32	2.65-4.13	NA	Bode *et al.* (1993)
Chenango R., NY (1979)	32-38	3.20-3.93	NA	"
Grasse R., NY (1991)	25-30	2.76-3.52	NA	"

1986). In addition, previous studies in other drainages in the Northeast also found diversities that were similar to those in the Housatonic River. These diversities ranged from 2.20 to 5.26 (Table 12). These data indicate that benthic invertebrate diversities in the Housatonic River are comparable to those in other drainages in the New England/upstate New York region.

Approximately 1,300 to 54,000 invertebrates/m^2 were collected from the Housatonic River in 1993 (Table 12). Lower densities were collected in the deep water sites, due to the sand/silt substrate. This fine substrate provided lesser amounts of interstitial spaces for invertebrate colonization compared to the substrates in the shallow water sites, which are composed of larger sized gravel and cobble. Hagstrom *et al.* (1992) collected from 1,176 to 1,295 invertebrates/m^2 in riffles in the Housatonic River in Connecticut. These densities are less than those collected in riffles in the present study (Appendix B). In another study in the Housatonic River drainage, Mount *et al.* (1986) collected from 1,503 to 81,149/m^2 in the Naugatuck River (Table 11). Eleven out of twelve sites in his study had densities less than 23,000/m^2. Langdon and Fiske (1991) collected benthic invertebrates in densities ranging from 2,150 to 6,450/m^2 in riffles in Lewis Creek, Vermont. In general, the densities of benthic invertebrates collected in the Housatonic River in 1993 are comparable to those found in other studies in the Housatonic River drainage and other drainages in the Northeast.

5.0 SUMMARY AND CONCLUSIONS

Quantitative sampling of the fish and benthic invertebrate communities of the Housatonic River was conducted in September, 1993. The objectives of the study were to describe the habitat, fish community, and invertebrate community of the East Branch and West Branch of the river in the vicinity of Pittsfield and the mainstem of the Housatonic River from Pittsfield downstream to the Connecticut border. Given the variation in habitat conditions along the river, study sites were combined into four groups: shallow sites upstream of the GE Pittsfield facility, shallow sites downstream of the GE Pittsfield facility, deep sites downstream of the GE Pittsfield facility, and Woods Pond. Shallow water sites were sampled by bank electrofishing to collect fish, and Hess sampling for invertebrates. At the deep water sites and at Woods Pond, boat electrofishing was used for fish and an Ekman grab sampler for the invertebrates. While the fish and invertebrate communities of shallow and deep river habitats are not directly comparable, the general health and condition of the populations at sites within like habitats can be appropriately compared.

Habitat and Water Quality

One of the most important habitat features influencing fish populations in rivers is the amount of cover. In the Housatonic River, cover accounted for less than 13% of the surface area at most of the study sites. The exception was Site HR4, which had 25% cover, primarily associated with the large boulder and cobble substrate. At the other river sites, cover was generally provided by bank shelter and snags. The shallow river sites tended to have a higher percentage of cover than the deep water sites.

Water quality sampling indicated that temperature, dissolved oxygen, and pH levels were generally suitable for the maintenance of warmwater fish populations. However, maximum water temperatures at all sites were near or above the reported lethal temperatures for brown trout, a coldwater species. This may be limiting the presence and condition of brown trout populations in the river. The levels of nitrates indicate that nutrient loading is present in all sampled sections of the Housatonic River.

Fish Populations

A total of 28 species of fish were collected in the Housatonic River and its headwater branches during 1992 and 1993. This compares very well with the results of earlier studies in 1943 and 1970 when 25 and 20 species were collected, respectively. The minnow family (Cyprinidae) contained the most species in the present study, with the sunfish family (Centrarchidae) also well represented. The species present are typical of the northeastern United States. A total of 7,174 fish were collected in 1993. Minnows accounted for 71% of these individuals, dominating the density of fish at nearly all of the shallow water sites both upstream and downstream of the GE facility. This dominance by minnows is typical for warmwater streams. However, in terms of biomass, rough fish and game fish comprised the major portions of the fish community at almost all of the shallow sites.

Comparisons of the fish population parameters at the shallow water sites indicate that sites both upstream and downstream of the GE facility contain healthy fish populations. Species diversity and richness were similar at shallow water sites both upstream and downstream of the GE facility. The abundance of fish, measured by density and biomass, at the downstream shallow sites were generally within the range of the upstream sites, except at downstream Site HR3 which had a very high abundance of rough fish.

The condition of the game fish at the shallow water sites also indicates that populations were healthy. Some species had relative weight indices less than the standard weight. However, these low indices are probably due to lack of adequate habitat or possibly low sample sizes for these species. There was no pattern of fish condition related to the presence of PCBs in sediments of the Housatonic River. Brown trout were in only fair condition with low relative weights throughout the study area. This may be due to the relatively high maximum temperatures throughout the system, which could induce stress to this coldwater species.

At the deep water stream sites and at Woods Pond, densities were dominated by game fish, especially sunfish species. In contrast, biomass was dominated by rough fish, especially white suckers and goldfish. These species are typical of the more lentic, pond-like habitat present at these sites. The scarcity of forage species at the deep water sites is probably a function of both lack of suitable habitat for these species and the sampling technique used at the deeper water sites. The game fish at the deep water sites and Woods Pond were in consistently good to excellent condition, with the exception of rock bass. The relatively lower condition of rock bass is probably related to the marginal rock bass habitat at these sites.

There was no deep water site available to be sampled upstream of the GE facility to serve as a true control site. However, comparisons can be made between Sites HR2 and Woods Pond in the section of river with highest PCB levels, and Sites HR5 and HR6 in the area of very low PCB levels. The species richness and diversity at these four sites are similar. Density and biomass were low at Sites HR2 and HR6, due to the habitat conditions present and the reduced efficiency of boat electrofishing, but relatively high at Site HR5. These results show no pattern corresponding to the concentrations of PCBs in the sediments, which are much higher at HR2 than at HR5 and HR6. In terms of fish condition, the relative weights of the fish species were consistently above average at all three deep water sites and at Woods Pond, with the exception of rock bass at Sites HR5 and HR6. As noted above, the lower relative weights for rock bass at these sites are probably related to habitat factors and show no relationship to PCB levels.

Comparison to a historical study conducted on the Housatonic River in 1970 tends to indicate changes in the fish community over the last two decades. The population present in 1970 contained a higher proportion of rough fish species. In contrast, game and forage fish comprised a higher percentage of the fish communities in the 1990s than in 1970. A more balanced fishery is now present in the study area. Comparisons to studies on other rivers in the Northeast, particularly New England, indicate that the present fish community of the Housatonic River is typical for the region in terms of species diversity, richness, and abundance.

Benthic Invertebrate Populations

The benthic invertebrate communities at all six shallow water sampling sites, both upstream and downstream of the GE facility, contained healthy, diverse, balanced populations with high abundance. The abundance of mayflies and caddisflies indicates that major water quality problems do not exist. However, the elevated densities of all aquatic insects, especially the net-spinning caddisflies, indicate that the entire system is experiencing an enrichment effect of nutrient inputs. A likely source of these nutrients is wastewater treatment plants discharging to the Housatonic River. Density levels at the various sites generally correspond to the nutrient levels present at these sites. In fact, the site with the highest density of benthic invertebrates (HR3) also had the highest biomass of fish and the highest nitrate levels, and of the three shallow sites on the mainstem of the Housatonic River (HR1, HR3, and HR4), the site with lowest invertebrate density (HR1) also had lowest nitrate levels.

Comparison of the benthic invertebrate parameters at the downstream shallow water sites to the upstream shallow water sites show no adverse impacts at the downstream sites. The number of taxa, diversity, and density of benthic invertebrates at the downstream shallow water sites are generally comparable to or greater than those at the upstream sites. The one exception to this is the lower invertebrate density at Site HR1, which, as noted above, appears to be related to the lower nutrient levels at that site.

At the deep water sites in the study area, including Woods Pond, the invertebrate populations are also relatively diverse, healthy and balanced, indicating that no major water quality problems exist at these sites. Also, the densities of invertebrates at all these sites are statistically similar, indicating no adverse impacts on the communities related to the pattern of PCBs in the sediments.

Comparisons of the benthic invertebrate population data from this study to data from other studies in the Northeast indicate that the population parameters of invertebrates in the Housatonic River in Massachusetts are similar to, or better than, expected for this region.

Conclusions

The fish and invertebrate populations of the Housatonic River appear to be healthy. There is no pattern of population parameters that appear to be related to sediment PCB levels. This information indicates that sediment PCBs are having no discernible ecological effect on the aquatic biota of the Housatonic River system.

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APPENDIX A

FISHERIES DATA

TABLE A-1: Estimated density (#/acre) of game fish at each stream study site on the Housatonic River system, 1993. Values in parentheses represent 95% confidence intervals. NC = confidence interval not calculated due to low capture efficiency, number/acre reflects minimum density.

Species	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6
Largemouth bass									
< 150 mm	5 (NC)	3 (NC)	0 (-)	10 (NC)	2 (NC)	65(±40)	0 (-)	11 (±2)	7 (NC)
≥ 150 mm	0 (-)	3 (±0)	2 (±0)	20 (±2)	0 (-)	0 (-)	5 (±0)	9 (±2)	1 (NC)
Total	**5**	**6**	**2**	**30**	**2**	**65**	**5**	**20**	**8**
Smallmouth bass									
< 150 mm	--	--	--	--	--	--	--	5 (NC)	5 (NC)
≥ 150 mm	--	--	--	--	--	--		3 (±0)	1 (NC)
Total	--	--	--	--	--	--	--	**8**	**6**
Rock bass									
< 100 mm	22 (NC)	8 (NC)	28 (±5)	22 (±9)	19 (NC)	9 (NC)	--	4 (NC)	2 (NC)
≥ 100 mm	92(±34)	40 (±5)	44 (±2)	28 (±1)	41 (±4)	25 (±2)	--	43(±13)	2 (±1)
Total	**114**	**48**	**72**	**50**	**60**	**34**	--	**47**	**4**
Bluegill									
< 100 mm	15 (±7)	0 (-)	--	2 (±0)	--	2 (NC)	0 (-)	11 (NC)	14 (±4)
≥ 100 mm	--	3 (±0)	--	2 (NC)	--	0 (-)	3 (±0)	19 (NC)	10 (±1)
Total	**15**	**3**	--	**4**		**2**	**3**	**30**	**24**
Pumpkinseed									
< 100 mm	22 (±7)[a]	24 (±8)[a]	2 (NC)[a]	3 (NC)[a]	--	--	0 (-)	5 (NC)	2(± < 1)
≥ 100 m	0 (-)	0 (-)	0 (-)	0 (-)	--	--	5 (NC)	11 (±6)	1 (±1)
Total	**22**	**24**	**2**	**3**	--	--	**5**	**16**	**3**
Black crappie									
< 150 mm	--	--	--	--	--	--	0 (-)	1 (NC)	2 (±1)
≥ 150 mm	--	--	--	--	--	--	1 (±0)	2 (NC)	1 (±0)
Total	--	--	--	--	--	--	**1**	**3**	**3**
White crappie									
< 150 mm	--	0 (-)	--	--	--	--	--	--	--
≥ 150 mm	--	3 (NC)	--	--	--	--	--	--	--
Total	--	**3**	--	--	--	--	--	--	--
Brown trout									
< 200 mm	0 (-)	--	--	--	0 (-)	0 (-)	--	--	--
≥ 200 mm	3 (±0)	--	--	--	1 (±0)	16 (±2)	--	--	--
Total	**3**	--	--	--	**1**	**16**	--	--	--

TABLE A-1: Continued

Species	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6
Brown bullhead									
< 200 mm	--	--	--	--	0 (-)	--	0 (-)	0 (-)	--
≥ 200 mm	--	--	--	--	2 (±0)	--	1 (±0)	4 (±2)	--
Total	--	--	--	--	**2**	--	**1**	**4**	--
Yellow bullhead									
< 100 mm	--	3 (±0)	--	--	--	--	--	--	--
≥ 100 mm	--	0 (-)	--	--	--	--	--	--	--
Total	--	**3**	--	--	--	--	--	--	--
Yellow perch									
< 100 mm	5 (NC)	53 (NC)	21 (NC)	208 (±71)	--	--	2 (±0)	0 (-)	0 --
≥ 100 mm	8 (NC)	3 (±0)	0 (-)	5 (NC)	--	--	12 (±1)	17 (±2)	1 (NC)
Total	**13**	**56**	**21**	**213**	--	--	**14**	**17**	**1**
Fallfish									
< 150 mm	45 (NC)[b]	327 (NC)	195 (±105)	0 (-)	0 (-)	10 (±2)	--	--	--
≥ 150 mm	8 (NC)[c]	21 (±6)	21 (±0)	8 (±0)	7 (±0)	0 (-)	--	--	--
Total	**53**	**348**	**216**	**8**	**7**	**10**	--	--	--
Chain pickerel									
< 200 mm	3 (NC)	--	--	--	--	--	--	0 (-)	--
≥ 200 mm	0 (-)	--	--	--	--	--	--	4 (±0)	--
Total	**3**	--	--	--	--	--	--	**4**	--

[a] < 150 mm
[b] < 140 mm
[c] ≥ 140 mm

TABLE A-2: Estimated density (#/acre) of rough fish at each stream study site on the Housatonic River system, 1993. Values in parentheses represent 95% confidence intervals. NC = confidence interval not calculated due to low capture efficiency, number/acre reflects minimum density.

Species	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6
White sucker									
< 150 mm	0 (-)	330 (NC)	193 (NC)	211(±45)	6 (NC)	49(±18)	0 (-)	0 (-)	0 (-)
≥ 150 mm	12 (NC)	133 (NC)	129(±15)	34(±23)	407 (±3)	4 (NC)	24 (±5)	76 (±3)	3 (NC)
Total	**12**	**463**	**322**	**245**	**413**	**53**	**24**	**76**	**3**
Longnose sucker									
< 150 mm	--	--	--	--	3 (NC)	--	--	0 (-)	--
≥ 150 mm	--	--	--	--	46 (±3)	--	--	1 (±0)	--
Total	**--**	**--**	**--**	**--**	**49**	**--**	**--**	**1**	**--**
Common carp									
< 150 mm	--	--	--	--	--	--	0 (-)	0 (-)	0 (-)
≥ 150 mm	--	--	--	--	--	--	2 (NC)	32 (±2)	< 1 (±0)
Total	**--**	**--**	**--**	**--**	**--**	**--**	**2**	**32**	**< 1**

TABLE A-3: Estimated density (#/acre) of forage fish at each stream study site on the Housatonic River system, 1993. Values in parentheses represent ±95% confidence intervals. NC = Not calculated due to low capture efficiencies, number/acre reflects minimum density.

Species	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6
Blacknose dace	517 (14)	1,332 (476)	151 (NC)	15 (0)	6 (NC)	913 (75)	—	—	—
Bluntnose minnow	2 (0)	8,190 (3,002)	980 (NC)	1,404 (356)	34 (4)	15 (NC)	—	3 (0)	<1 (NC)
Creek chub	—	13 (9)	7 (NC)	24 (1)	28 (4)	—	—	—	—
Common shiner	—	—	512 (163)	—	3 (NC)	—	—	—	—
Fathead minnow	—	5 (NC)	—	—	—	—	—	—	—
Golden shiner	—	—	—	—	4 (2)	—	—	—	2 (NC)
Longnose dace	100 (2)	489 (132)	106 (4)	3 (0)	340 (24)	1,188 (96)	—	—	—
Spottail shiner	7 (NC)	—	—	218 (22)	—	2 (NC)	—	—	2 (1)
Tesselated darter	—	—	—	—	42 (4)	—	—	1 (0)	—
Banded killifish	—	—	—	—	3 (NC)	—	—	—	—

TABLE A-4: Estimated biomass (lbs/acre) of game fish at each stream study site on the Housatonic River system, 1993.

SITE	Largemouth Bass	Smallmouth Bass	Rock Bass	Misc Sunfish	Brown Trout	Bullheads	Yellow Perch	Fallfish	Chain Pickerel	Total
Shallow Sites Upstream of Pittsfield										
EB1	0.1	--	19.5	1.5	1.3	--	0.4	*	0.2	23.0(*)
WB1	2.1	--	7.0	1.9	--	<0.1	0.8	12.0	--	23.9
Shallow Sites Downstream of Pittsfield										
EB2	1.9	--	7.9	0.3	--	--	0.2	8.2	--	18.5
HR1	13.8	--	5.9	0.2	--	--	2.3	4.2	--	26.4
HR3	<0.1	--	10.7	--	0.4	0.8	--	3.0	--	15.0
HR4	1.6	--	11.3	0.1	15.6	--	--	0.3	--	28.9
Deep Sites Downstream of Pittsfield										
HR2	4.3	--	--	2.0	--	0.8	3.3	--	--	10.4
HR5	8.6	1.0	11.2	8.5	--	1.3	6.9	--	1.1	38.5
HR6	1.2	0.3	0.5	3.5	--	--	0.4	--	--	5.9

* Weights not available for all fish

TABLE A-5: Estimated biomass (lbs/acre) of rough fish at each stream site on the Housatonic River system, 1993.

SITE	White Sucker	Longnose Sucker	Common Carp	Total
Shallow Sites Upstream of Pittsfield				
EB1	5.8	--	--	5.8
WB1	41.7	--	--	41.7
Shallow Sites Downstream of Pittsfield				
EB2	25.5	--	--	25.5
HR1	24.3	--	--	24.3
HR3	354.9	26.9	--	381.8
HR4	4.6	--	--	4.6
Deep Sites Downstream of Pittsfield				
HR2	20.8	--	3.9	24.7
HR5	84.5	0.9	73.1	158.5
HR6	4.6	--	4.4	9.0

TABLE A-6: Estimated biomass (lbs/acre) of forage fish at each stream study site in the Housatonic River system, 1993.

SITE	Blacknose Dace	Bluntnose Minnow	Creek Chub	Common Shiner	Fathead Minnow	Golden Shiner	Longnose Dace	Spottail Shiner	Tesselated Darter	Banded Killifish	Total
Shallow Sites Upstream of Pittsfield											
EB1	1.2*	<0.1*	--	--	--	--	0.5*	<0.1**	--	--	1.7
WB1	3.3	79.0	0.2	--	<0.1	--	2.2	--	--	--	84.7
Shallow Sites Downstream of Pittsfield											
EB2	0.3	3.0	0.1	2.8	--	--	0.3	--	--	--	6.5
HR1	<0.1	1.7	0.1	--	--	--	<0.1	0.6	--	--	2.4
HR3	<0.1	0.3	0.4	<0.1	--	0.2	2.2	--	0.3	<0.1	3.4
HR4	2.6	0.2	--	--	--	--	11.1	<0.1	--	--	13.9
Deep Sites Downstream of Pittsfield											
HR2	--	--	--	--	--	--	--	--	--	--	--
HR5	--	<0.1	--	--	--	--	--	--	<0.1	--	<0.1
HR6	--	<0.1	--	--	--	<0.1	--	<0.1	--	--	<0.1

* Weights not available, biomass calculated by using mean weights from Site WB1.
** Weights not available, biomass calculated by using mean weights from Sites HR1, HR4, HR6.

TABLE A-7: Species list, number collected, and total weight (lbs) of fish collected in Woods Pond, September 1993. Fish collected by electrofishing four sites, 15 minutes each.

SPECIES	Number Collected	Weight (kg)
Game fish		
Largemouth bass	26	15.9
Rock bass	3	0.7
Misc. sunfish	116	14.1
Bullheads	32	14.6
Yellow perch	50	10.4
Northern pike	1	10.1
Total	**228**	**65.8**
Rough Fish		
White sucker	75	103.8
Common carp	1	0.2
Goldfish	21	24.5
Total	**97**	**128.5**
Forage Fish		
Bluntnose minnow	1	<0.1
Golden shiner	11	0.7
Spottail shiner	7	<0.1
Total	**19**	**0.8**
Grand Total	**344**	**195.1**

APPENDIX B

BENTHIC INVERTEBRATE DATA

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: EB 1
SAMPLED: SEPTEMBER 12, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
NSECTA					
COLLEMBOLA					
Agrenia bidenticulata	20			7	
EPHEMEROPTERA					
Baetis flavistriga					X
Caenis anceps	10	10	40	20	X
Ephemerella sp.		10	60	23	
Isonychia sp.	10			3	X
Stenacron sp.					X
Stenonema modestum			20	7	X
Stenonema terminatum	20	20	20	20	X
Stenonema vicarium					X
MEGALOPTERA					
Nigronia sp.		10	40	17	X
TRICHOPTERA					
Cheumatopsyche sp.	910	470	2500	1293	X
Hydropsyche sp.	230	140	460	277	X
Hydroptila sp.	50	40	60	50	
Hydroptilidae pupae	10			3	
Leucotrichia pictipes	50	20	100	57	X
Oecetis sp.					X
Psychomyia flavida	10		40	17	
Rhyacophila sp.					X
COLEOPTERA					
Optioservus ampliatus	20			7	
Optioservus trivittatus	140	530	420	363	X
Promoresia elegans					X
Stenelmis sp.					X
DIPTERA					
Antocha sp.	100	170	440	237	X
Atherix lantha			60	20	
Brundiniella sp.		200		67	X
Chironomidae pupae	120	390	840	450	X
Cricotopus trifasciata	560	1000	1600	1053	X
Glyptotendipes sp.	40	200		80	
Hemerodromia sp.	30	100	220	117	X
Limonia sp.					X
Microtendipes sp.	40	2700	600	1113	X
Polypedilum sp.	200	200	600	333	X
Subletta sp.	40	100		47	X
Tanytarsus sp.	240	1100	7800	3047	X
Tvetenia sp.			600	200	X
NELIDA					
OLIGOCHAETA					
Monopylephorus helobius		630	40	223	X
Unid. Oligochaeta w/o Heads		440	240	227	X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: EB 1
SAMPLED: SEPTEMBER 12, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
EMATODA					
Unid. Nematoda		30		10	
RUSTACEA					
AMPHIPODA					
Hyalella azteca					X
YDRACARINA					
Hygrobates sp.	170	440	1900	837	X
Lebertia sp.	40	130	240	137	X
Sperchon/Sperchonopsis	40		120	53	
Torrenticola sp.			20	7	
ASTROPODA					
Ferrissia sp.	10	10		7	
OTAL (#/sq. meter)	3110	9090	19080	10429	
UMBER OF TAXA *	23	23	24	32	30
SHANNON-WEAVER (H') *	3.49	3.52	3.09	3.56	

OTAL TAXA PER SITE 42

Does not include Hydroptilidae pupae, Chironomidae pupae and Unid. Oligochaeta

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: WB 1
SAMPLED: SEPTEMBER 12, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
INSECTA					
EPHEMEROPTERA					
Isonychia sp.			20	7	X
Stenacron sp.			80	27	X
Stenonema modestum		40	120	53	X
Stenonema terminatum			220	73	X
ODONATA					
Boyeria sp.					X
Gomphidae	10			3	
HEMIPTERA					
Rhagovelia sp.					X
TRICHOPTERA					
Cheumatopsyche sp.	1040	2930	5500	3157	X
Chimarra sp.					X
Hydropsyche sp.	20	90	180	97	X
Neureclipsis sp.		10		3	
Psychomyia flavida	10			3	
Coleoptera					
Optioservus trivittatus		50	100	50	X
Psephenus sp.		40	100	47	X
Stenelmis sp.	20	10	60	30	X
DIPTERA					
Ablabesmyia sp.					X
Antocha sp.	20	40	80	47	X
Atherix lantha	10			3	
Brundiniella sp.					X
Chironomidae pupae	110	110	160	127	X
Cricotopus trifasciata	500	2050	1540	1363	X
Hemerodromia sp.	30	70	80	60	X
Limonia sp.					X
Mallochohelea sp.		10		3	X
Polypedilum sp.		130		43	
Tanytarsus sp.	4670	2930	2580	3393	X
Tipula sp.					X
ANNELIDA					
OLIGOCHAETA					
Ilyodrilus mastix		50		17	
Unid. Oligochaeta w/o Heads		90	20	37	
NEMATODA					
Unid. Nematoda	70	240	120	143	X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: WB 1
SAMPLED: SEPTEMBER 12, 1993

KA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
USTACEA					
ISOPODA					
Caecidotea sp.					X
DECAPODA					
Orconectes sp.			20	7	X
DRACARINA					
Hygrobates sp.	10	40		17	X
Lebertia sp.	20	440	80	180	X
Sperchon/Sperchonopsis		30		10	
GASTROPODA					
Ferrissia sp.	40	80		40	
Physella sp.					X
TAL (#/sq. meter)	6580	9480	11060	9040	
MBER OF TAXA *	14	19	16	26	26
SHANNON-WEAVER (H') *	1.46	2.53	2.24	2.34	

TAL TAXA PER SITE 35

—Does not include Chironomidae pupae and Unid. Oligochaeta

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: EB 2
SAMPLED: SEPTEMBER 11, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
NSECTA					
EPHEMEROPTERA					
Baetis amplus		40	60	33	
Baetis flavistriga		20		7	X
Ephemera sp.	10			3	
Paraleptophlebia sp.	20	10	20	17	
Stenacron sp.			80	27	
Stenonema modestum	30		140	57	X
Stenonema terminatum			200	67	
Stenonema vicarium			40	13	
Tricorythodes sp.			20	7	X
ODONATA					
Argia sp.					X
Boyeria sp.					X
Calopteryx sp.					X
Gomphidae		10		3	
Ophiogomphus sp.					X
HEMIPTERA					
Trepobates sp.					X
TRICHOPTERA					
Cheumatopsyche sp.	40	240	2420	900	X
Hydropsyche sp.		70	120	63	X
Hydroptila sp.	10		40	17	
Mystacides sp.					X
Oecetis sp.	70	50		40	
COLEOPTERA					
Dubiraphia sp.	20	10	40	23	X
Optioservus trivittatus		20	140	53	
Promoresia elegans					X
Stenelmis sp.	20			7	
DIPTERA					
Ablabesmyia sp.					X
Antocha sp.		50	140	63	X
Atherix lantha		10		3	
Atylotus/Tabanus	20	10		10	
Brundiniella sp.	200	900	1600	900	X
Chironomidae pupae	170	370	240	260	X
Cricotopus trifasciata	100	1200	1200	833	X
Cryptochironomus sp.	200	100		100	
Dicrotendipes sp.		100		33	
Dolichopodidae					X
Heleniella sp.					X
Hemerodromia sp.	20	120	900	347	X
Mallochohelea sp.			20	7	
Polypedilum sp.	100	300		133	X
Procladius sp.		100		33	
Tanytarsus sp.	2250	4770	3480	3500	X
Tvetenia sp.			200	67	X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: EB 2
SAMPLED: SEPTEMBER 11, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
ANNELIDA					
OLIGOCHAETA					
Unid. Oligochaeta w/o Heads	30	80	60	57	X
NEMATODA					
Unid. Nematoda		10	80	30	
CRUSTACEA					
AMPHIPODA					
Hyalella azteca	30	10	20	20	
HYDRACARINA					
Hygrobates sp.		50	300	117	X
Lebertia sp.	10	70	140	73	
Sperchon/Sperchonopsis		30	160	63	
Torrenticola sp.			20	7	
GASTROPODA					
Ferrissia sp.					X
Physella sp.			20	7	
PELECYPODA					
Sphaerium sp.		10		3	
TOTAL (#/sq. meter)	3350	8760	11900	8003	
NUMBER OF TAXA *	18	27	27	39	26
SHANNON-WEAVER (H') *	2.06	2.51	3.24	3.06	

TOTAL TAXA PER SITE 50

* Does not include Chironomidae pupae. Unidentified Oligochaeta w/o heads were counted as a taxon if no other oligochaetes were identified.

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 1
SAMPLED: SEPTEMBER 11, 1993

XA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
SECTA					
PLECOPTERA					
Paragnetina sp.					X
EPHEMEROPTERA					
Baetis amplus		600		200	X
Baetis flavistriga	20	120	10	50	X
Caenis anceps	10			3	
Callibaetis sp.	10			3	
Stenacron sp.					X
Stenonema modestum	40	220	20	93	X
Stenonema terminatum		60		20	X
ODONATA					
Anomalagrion/Ishnura					X
Boyeria sp.					X
HEMIPTERA					
Corixidae					X
Merragata sp.					X
Microvelia sp.					X
TRICHOPTERA					
Cheumatopsyche sp.	60	460	100	207	X
Hydropsyche sp.	20	100	40	53	X
Nectopsyche sp.					X
Psychomyia flavida					X
LEPIDOPTERA					
Acentria sp.	10			3	
COLEOPTERA					
Laccobius sp.					X
Macronychus glabratus					X
Optioservus trivittatus		20	10	10	X
Stenelmis sp.		60		20	X
Stenus sp.					X
DIPTERA					
Antocha sp.	90	80	10	60	X
Brundiniella sp.	100	200	320	207	X
Chironomidae pupae	90	220	120	143	X
Cricotopus trifasciata	600	2680	320	1200	X
Cryptochironomus sp.			160	53	
Dicrotendipes sp.	300			100	X
Hemerodromia sp.	90	120	10	73	X
Limonia sp.					X
Mallochohelea sp.					X
Microtendipes sp.		200		67	
Polypedilum sp.	500	200		233	X
Simulium sp.					X
Tanytarsus sp.	1730	2000	1170	1633	X
Tipula sp.			10	3	
Tvetenia sp.					X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 1
SAMPLED: SEPTEMBER 11, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
ANNELIDA					
OLIGOCHAETA					
Unid. Oligochaeta w/o Heads	20			7	
NEMATODA					
Unid. Nematoda					X
CRUSTACEA					
AMPHIPODA					
Hyalella azteca					X
DECAPODA					
Orconectes sp.			10	3	
HYDRACARINA					
Hygrobates sp.	10			3	
Lebertia sp.	10	40	30	27	
TOTAL (#/sq. meter)	3710	7380	2340	4474	
NUMBER OF TAXA *	17	16	14	25	33
SHANNON-WEAVER (H') *	2.56	2.84	2.41	2.96	

TOTAL TAXA PER SITE 43

* Does not include Chironomidae pupae. Unidentified Oligochaeta w/o heads were counted as a taxon if no other oligochaetes were identified.

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 3
SAMPLED: SEPTEMBER 14, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
.NSECTA					
EPHEMEROPTERA					
Baetis amplus	86	43	86	72	X
Baetis flavistiga	301	258	1033	531	X
Baetis insignificans	215	258	86	186	
Baetis intercalaris			1378	459	X
Caenis anceps			86	29	
Callibaetis sp.					X
Ephemerella sp.		86	431	172	
Paraleptophleia sp.		43		14	
Stenacron sp.			517	172	X
Stenonema terminatum	43	215	4478	1579	X
HEMIPTERA					
Corixidae					X
MEGALOPTERA					
Corydalus sp.					X
TRICHOPTERA					
Cheumatopsyche sp.	6416	15286	43232	21645	X
Hydropsyche sp.	8569	8784	20066	12473	X
Hydropsychidae pupae		43	86	43	
Hydroptila sp.	129	344	258	244	
Leucotrichia pictipes	129	172		100	
Psychomyia flavida	1120	689	2670	1493	X
COLEOPTERA					
Optioservus ampliatus			431	144	
Optioservus trivittatus	388	646	1120	718	
Psephenus sp.		129	86	72	
Stenelmis sp.	388		689	359	
DIPTERA					
Antocha sp.	431	1120	86	546	X
Brundiniella sp.	431		689	373	X
Ceratopogon sp.					X
Chironomidae pupae	904	43	861	603	X
Cricotopus tremulus			344	115	
Cricotopus trifasciata	1292	2584	3445	2440	X
Dicrotendipes sp.					X
Glyptotendipes sp.					X
Hemerodromia sp.	560	129	86	258	
Microtendipes sp.	861			287	
Parorthocladius sp.			689	230	
Pericoma sp.					X
Polypedilum sp.	3014	215	1033	1421	X
Simulium sp.					X
Tanytarsus sp.	2153	215	1033	1134	X
Thienemanniella sp.	861		344	402	
Tvetenia sp.	6459	2584	1378	3474	X
TURBELLARIA					
Dugesia tigrina	2282	904		1062	

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 3
SAMPLED: SEPTEMBER 14, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
ANNELIDA					
OLIGOCHAETA					
Eiseniella tetraedra			431	144	
Ilyodrilus mastix	215			72	
Unid. Oligochaeta w/o Heads	603			201	
HIRUDINEA					
Erpobdella punctata punctata					X
Moorebdella fervida					X
NEMATODA					
Unid. Nematoda	818	560	1464	947	X
CRUSTACEA					
AMPHIPODA					
Gammarus lacustris					X
Hyalella azteca					X
DECAPODA					
Orconectes sp.					X
HYDRACARINA					
Hygrobates sp.		43		14	
Lebertia sp.			172	57	X
GASTROPODA					
Ferrissia sp.			431	144	
Physella sp.					X
TOTAL (#/sq. meter)	38668	35393	89219	54429	
NUMBER OF TAXA *	23	22	30	36	30
SHANNON-WEAVER (H') *	3.59	2.66	2.72	3.15	
TOTAL TAXA PER SITE 50					

* Does not include Hydropsychidae pupae, Chironomidae pupae and Unid. Oligochaeta

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 4
SAMPLED: SEPTEMBER 13, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
INSECTA					
PLECOPTERA					
Acroneuria sp.					X
Paragnetina sp.			43	14	
EPHEMEROPTERA					
Baetis amplus	129	43		57	X
Baetis flavistriga	129	129	301	186	X
Baetis intercalaris		43		14	X
Caenis anceps	2627	603	1550	1593	X
Ephemera sp.			86	29	
Ephemerella sp.	560	129	301	330	X
Isonychia sp.	2541	2368	1550	2153	X
Leptophlebidae	43		43	29	
Stenacron sp.	4564	2282	9732	5526	X
Stenonema mediopunctatum			86	29	
Stenonema terminatum	172	775	1292	746	X
Stenonema vicarium	301	129	86	172	X
ODONATA					
Argia sp.	86	129	431	215	X
Coenagrionidae	86			29	
HEMIPTERA					
Rhagovelia sp.			43	14	X
MEGALOPTERA					
Corydalus sp.	86	129	43	86	X
Nigronia sp.			43	14	
Sialis sp.		129		43	
TRICHOPTERA					
Cheumatopsyche sp.	1421	1636	732	1263	X
Chimarra sp.	474	689	129	431	X
Hydropsyche sp.	904	904	818	875	X
Hydroptila sp.	43			14	X
Leucotrichia pictipes		43	258	100	X
Nemotaulis hostilis					X
Oecetis sp.	43	43		29	X
Polycentropus sp.	904	172	172	416	X
Psychomyia flavida	301	172	388	287	X
LEPIDOPTERA					
Acentria sp.			43	14	X
COLEOPTERA					
Ancyronyx variegata					X
Dubiraphia sp.	43	43	43	43	X
Ectopria nervosa		43	43	29	
Optioservus sp.	43			14	
Promoresia elegans		43		14	X
Psephenus sp.	172		43	72	X
Stenelmis sp.	3143	904	861	1636	X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 4
SAMPLED: SEPTEMBER 13, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
INSECTA					
DIPTERA					
Ablabesmyia sp.		258		86	X
Antocha sp.	2239	861	1593	1564	X
Atherix lantha		43		14	X
Brundiniella sp.	3445	1033	3057	2512	X
Chironomidae pupae	474	301	388	388	X
Cricotopus trifasciata	4048		1507	1852	X
Dicrotendipes sp.	861	258	301	473	X
Glyptotendipes sp.					X
Hemerodromia sp.	215	258	172	215	X
Microtendipes sp.		258		86	X
Parorthocladius sp.					X
Polypedilum sp.	861	1852	301	1005	X
Simulium sp.					X
Tanytarsus sp.	1292	1809	904	1335	X
Thienemanniella sp.	861			287	X
Tvetenia sp.	431	258	603	431	X
TURBELLARIA					
Dugesia tigrina			43	14	
ANNELIDA					
OLIGOCHAETA					
Unid. Oligochaeta w/o Heads	86	43		43	X
NEMATODA					
Unid. Nematoda	43		43	29	X
CRUSTACEA					
AMPHIPODA					
Hyalella azteca	43	43		29	X
HYDRACARINA					
Hygrobates sp.					X
Lebertia sp.			86	29	
Sperchon/Sperchonopsis	43		43	29	
GASTROPODA					
Ferrissia sp.	2282	388	1421	1364	X
Planorbella campanulata					X
PELECYPODA					
Musculium sp.	43			14	
Sphaerium sp.	2885	775	5641	3100	X
TOTAL (#/sq. meter)	38967	20018	35263	31415	
NUMBER OF TAXA *	39	37	40	55	50
SHANNON-WEAVER (H') *	4.29	4.35	3.84	4.35	

TOTAL TAXA PER SITE 63

* Does not include Chironomidae pupae. Unidentified Oligochaetes w/o heads were counted as a taxon if no other oligochaetes were identified.

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 2
SAMPLED: SEPTEMBER 16, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
INSECTA					
COLLEMBOLA					
Bourletiella sp.					X
Isotomurus sp.					X
EPHEMEROPTERA					
Caenis anceps	43	43		29	X
Callibaetis sp.					X
ODONATA					
Anamalagrion/Ischnura	172			57	X
Enallagma sp.	215			72	X
HEMIPTERA					
Mesovelia sp.					X
Microvelia sp.					X
Neoplea sp.	43			14	X
TRICHOPTERA					
Cheumatopsyche sp.					X
Nemotaulius hostilis					X
Oecetis sp.		43		14	
Phryganea sp.		43		14	
Polycentropus sp.	86			29	X
LEPIDOPTERA					
Acentria sp.					X
COLEOPTERA					
Dubiraphia sp.		172	86	86	
Peltodytes sp.					X
Promoresia elegans					X
DIPTERA					
Ablabesmyia sp.	215			72	X
Antocha sp.					X
Atylotus/Tabanus		43		14	
Bezzia/Palpomyia		86		29	
Chironomidae pupae	86	43	43	57	X
Cricotopus tremulus					X
Cricotopus trifasciata					X
Cryptochironomus sp.	86		43	43	
Dicrotendipes sp.	560	1033	388	660	X
Helius sp.					X
Hemerodromia sp.					X
Nanocladius sp.			344	115	
Natarsia sp.	86			29	
Orthocladius sp.			43	14	
Pentaneura sp.					X
Polypedilum sp.		86	43	43	X
Procladius sp.	344	344		229	
Sphaeromias sp.		43		14	
Tanytarsus sp.		258	129	129	
Thienemanniella sp.					X
Tvetenia sp.			43	14	

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 2
SAMPLED: SEPTEMBER 16, 1993

\XA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
JRBELLARIA					
Dugesia tigrina		86		29	
INELIDA					
OLIGOCHAETA					
Unid. Immature Tubificidae w/o Capilliform Chaetae		86		29	
Unid. Oligochaeta w/o Heads		990	129	373	
HIRUDINEA					
Helobdella stagnalis		129		43	
CRUSTACEA					
AMPHIPODA					
Hyalella azteca	388		43	144	X
\STROPODA					
Amnicola limosa	301	215	86	201	X
Ferrissia fragalis		43		14	
Marstonia decepta					X
Physella sp.					X
PELECYPODA					
Sphaerium sp.	86	43		43	
TOTAL (#/sq. meter)	2711	3829	1420	2653	
NUMBER OF TAXA *	13	17	10	28	29
IANNON-WEAVER (H') *	3.41	3.26	3.04	3.94	

TOTAL TAXA PER SITE 47

* Does not include Chironomidae pupae and Unid. Oligochaeta w/o Heads

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 5
SAMPLED: SEPTEMBER 15, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
NSECTA					
PLECOPTERA					
Paragnetina sp.					X
EPHEMEROPTERA					
Baetis flavistriga					X
Baetis insignificans					X
Baetis intercalaris					X
Caenis anceps	775	474		416	X
Ephemerella sp.		43		14	X
Isonychia sp.					X
Leucrocuta sp.					X
Stenacron sp.					X
Stenonema terminatum					X
Stenonema vicarium					X
Tricorythodes sp.					X
ODONATA					
Enallagma sp.					X
Gomphidae		43		14	X
MEGALOPTERA					
Corydalus sp.					X
TRICHOPTERA					
Cheumatopsyche sp.					X
Chimarra sp.					X
Hydropsyche sp.					X
Leucotrichia pictipes					X
Macrostemum sp.					X
Micrasema sp.					X
Mystacides sp.	43			14	
Nectopsyche sp.					X
Oecetis sp.	43	129		57	
Oxyethira sp.					X
COLEOPTERA					
Dineutus sp.					X
Dubiraphia sp.	43	43		29	
Haliplus sp.	43			14	
Optioservus trivitattus					X
Promoresia elegans					X
Psephenus sp.					X
Stenelmis sp.	43	43		29	X
DIPTERA					
Antocha sp.					X
Bezzia\Palpomyia		86		29	
Chaoborus sp.		43		14	
Chironomidae pupae		86		29	X
Cryptochironomus sp.		129		43	
Dicrotendipes sp.					X
Einfeldia sp.	86		43	43	
Guttipelopia sp.	43	86		43	
Hemerodromia sp.					X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 5
SAMPLED: SEPTEMBER 15, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
NSECTA					
DIPTERA					
Mallochohelea sp.	43			14	
Microchironomus sp.		129		43	
Pentaneura sp.					X
Polypedilum sp.					X
Simulium sp.					X
Tanytarsus sp.	517	560		359	
Tvetenia sp.					X
ANNELIDA					
OLIGOCHAETA					
Unid. Oligochaeta w/o Heads	172		86	86	
RUSTACEA					
ISOPODA					
Caecidotea sp.	86			29	
AMPHIPODA					
Hyalella azteca					X
YDRACARINA					
Hygrobates sp.	43	43		29	
ASTROPODA					
Amnicola limosa					X
Gyraulus sp.	43			14	X
Physella sp.					X
ELECYPODA					
Musculium sp.					X
Sphaerium sp.					X
TOTAL (#/sq. meter)	2023	1937	129	1362	
UMBER OF TAXA *	14	13	2	20	41
HANNON-WEAVER (H') *	2.79	3.13	0.92	3.29	

TOTAL TAXA PER SITE 56

Does not include Chironomidae pupae. Unidentified Oligochaeta w/o heads were counted as a taxon if no other oligochaetes were identified.

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 6
SAMPLED: SEPTEMBER 10, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
INSECTA					
EPHEMEROPTERA					
Caenis anceps	172		43	72	
Callibaetis sp.					X
ODONATA					
Enallagma sp.					X
HEMIPTERA					
Gerris sp.					X
Microvelia sp.					X
Neoplea sp.					X
Notonecta sp.					X
Paravelia sp.					X
Sigara sp.					X
TRICHOPTERA					
Hydroptilidae	172			57	
Neotrichia sp.	86			29	
Oecetis sp.			86	29	
Oxyethira sp.	172			57	
COLEOPTERA					
Dubiraphia sp.	732	646	258	545	
Laccophilus sp.					X
Macronychus glabratus	43			14	
Peltodytes sp.					X
Stenelmis sp.	43			14	
DIPTERA					
Anopheles sp.					X
Brundiniella sp.					X
Ceratopogon sp.	43			14	
Chironomidae pupae	43			14	
Cryptochironomus sp.	388		43	144	
Dicrotendipes sp.	129			43	
Glyptotendipes sp.	129	43		57	
Mallochohelea sp.			1421	474	
Microtendipes sp.			43	14	
Orthocladius sp.	129			43	
Polypedilum sp.	129	43		57	X
Procladius sp.	517		43	187	
Sphaeromias sp.			86	29	
Tanytarsus sp.	1249	344	301	631	X
ANNELIDA					
OLIGOCHAETA					
Monopylephorus helobius			3100	1033	
Unid. Oligochaeta w/o Heads	301		4005	1435	

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: HR 6
SAMPLED: SEPTEMBER 10, 1993

XA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
USTACEA					
ISOPODA					
Caecidotea sp.	43			14	X
AMPHIPODA					
Hyalella azteca					X
STROPODA					
Physella sp.					X
LECYPODA					
Musculium sp.			43	14	
Pisidium sp.	43	301	172	172	
Sphaerium sp.	43	215	301	186	
TOTAL (#/sq. meter)	4606	1592	9945	5378	
MBER OF TAXA *	18	6	13	24	17
ANNON-WEAVER (H') *	3.50	2.13	2.29	3.36	

TOTAL TAXA PER SITE 38

Does not include Chironomidae pupae and Unid. Oligochaeta

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: WOODS POND
SAMPLED: SEPTEMBER 13, 1993

TAXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
INSECTA					
EPHEMEROPTERA					
Caenis anceps					X
Callibaetes sp.					X
ODONATA					
Anomalagrion/Ischnura					X
Coenagrion sp.					X
Coenagrionidae		86		29	X
Libellula sp.					X
HEMIPTERA					
Microvelia sp.					X
Trichocorixa sp.					X
TRICHOPTERA					
Nectopsyche sp.					X
Neotrichia sp.					X
Oxyethira sp.					X
LEPIDOPTERA					
Acentria sp.					X
COLEOPTERA					
Haliplus sp.		43		14	X
DIPTERA					
Ceratopogon sp.		86		29	
Chaoborus sp.			301	100	
Chironomidae pupae		86		29	X
Cladopelma sp.	517	732		416	X
Culicoides sp.		86		29	
Dicrotendipes sp.		43		14	X
Glyptotendipes sp.					X
Hedriodiscus/Odontomyia					X
Natarsia sp.					X
Paratanytarsus sp.					X
Paratrichocladius sp.					X
Polypedilum sp.					X
Procladius sp.	301	474		258	
Sphaeromias sp.		172		57	
Tanytarsus sp.	43			14	X
ANNELIDA					
OLIGOCHAETA					
Unid. Oligochaeta w/o Heads		431		144	
CRUSTACEA					
AMPHIPODA					
Hyalella azteca		43		14	X

MACROINVERTEBRATE DENSITY
CLIENT: GENERAL ELECTRIC
SITE: WOODS POND
SAMPLED: SEPTEMBER 13, 1993

AXA	REP 1	REP 2	REP 3	COMPOSITE DENSITY	KICK
ASTROPODA					
Amnicola limosa		43		14	X
Gyraulus parvus					X
Physella sp.					X
Valvata tricarinata					X
PELECYPODA					
Sphaerium sp.					X
TOTAL (#/sq. meter)	861	2325	301	1161	
IMBER OF TAXA *	3	11	1	13	28
IANNON-WEAVER (H') *	1.19	2.85	0.00	2.82	

TOTAL TAXA PER SITE 34

Does not include Chironomidae pupae. Unidentified Oligochaeta w/o heads were counted as a taxon if no other oligochaetes were identified.

APPENDIX C

1992 REPORT

FISHERIES INVESTIGATION OF THE HOUSATONIC RIVER, MASSACHUSETTS
(CHADWICK & ASSOCIATES, 1993)

Fisheries Investigation of the Housatonic River, Massachusetts

Prepared for

GENERAL ELECTRIC CO.
Pittsfield, Massachusetts

Prepared by

CHADWICK & ASSOCIATES, INC.
5575 S. Sycamore Street, Suite 101
Littleton, Colorado 80120

March 1993

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INTRODUCTION

From 1932 to March 1977, polychlorinated biphenyls (PCBs) were used at the General Electric (GE) facility in Pittsfield, Massachusetts as part of a flame-resistant, insulating liquid for transformers. These materials were inadvertently released into the East Branch of the Housatonic River prior to 1977. Studies beginning in the 1970's have identified the presence of PCBs in the bottom sediments and fish tissues from the Housatonic River (see Blasland & Bouck Engineers 1991). As a result, the Housatonic River has been the subject of a variety of studies to characterize PCB distribution and transport. Most of these studies were oriented toward analysis of PCB levels and not toward the aquatic ecology of the Housatonic River.

In 1992, Chadwick & Associates undertook a study to describe the fish community and aquatic habitat of the Housatonic River from the city of Pittsfield, Massachusetts, downstream to the Connecticut border. The goals of this project were to: 1) describe habitat quality in the East Branch and West Branch of the Housatonic River in the vicinity of Pittsfield, and in the mainstem Housatonic River downstream to the Connecticut border, 2) determine species composition of the fish community in the study reach, 3) determine the size structure of the game fish species in the study reach, 4) measure the general health (condition) of the game fish species in the study reach, and 5) compare this information to historical data on fish populations from the Housatonic River.

STUDY AREA

The Housatonic River originates in northwestern Massachusetts and is formed by the confluence of three branches (East Branch, West Branch and Southwest Branch) near the city of Pittsfield, Massachusetts (Fig. 1). From this confluence the river flows generally south to the Connecticut border, a distance of approximately 50 miles. The river continues through Connecticut, eventually flowing into Long Island Sound. The total watershed of the Housatonic River and its tributaries in Massachusetts covers approximately 550 square miles, which represents 28% of the total Housatonic River drainage basin area. The remaining watershed is located in New York and Connecticut (Lawler, Matusky and Skelly Engineers 1975).

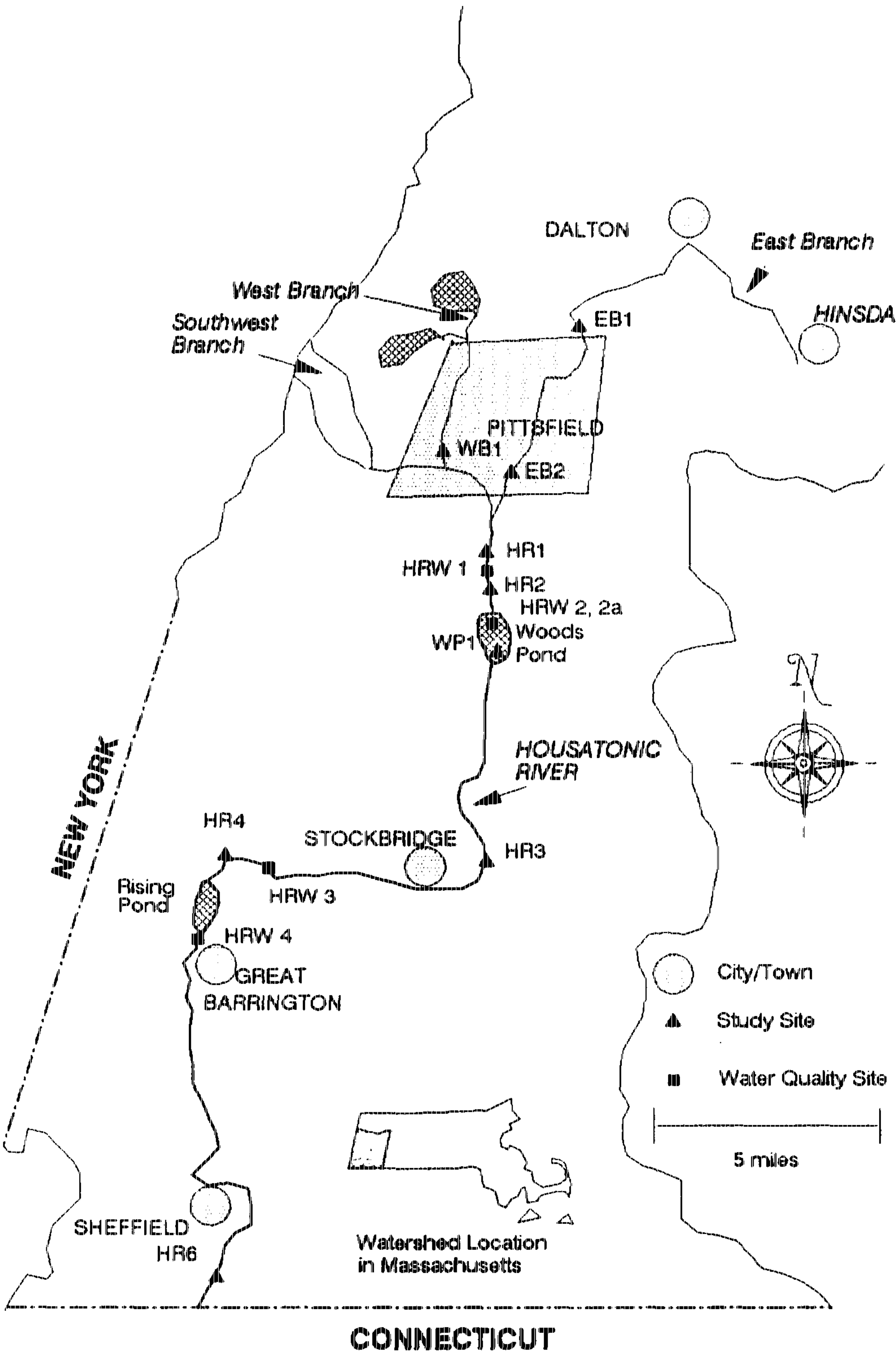

FIGURE 1: Housatonic River Drainage Basin from Hinsdale, Massachusetts, downstream to the Connecticut border.

The longitudinal profile of the Housatonic River shows that stream gradient varies substantially as it flows from Pittsfield to the Connecticut border (Fig. 2). The river channel has the steepest gradient (0.8%) between Dalton and Barton Brook, north of Pittsfield. From this point downstream to the Connecticut border the river generally flattens out, with a gradient generally less than 0.1%, although there are two steeper gradient sections from Woods Pond to Goose Pond Brook, and from Larrywaug Brook to Rising Pond (approximately 0.4%).

Two study sites were located on the East Branch of the Housatonic River, one study site on the West Branch, one study site on Woods Pond, and five study sites on the mainstem of the Housatonic River (Fig. 1). The study sites are grouped into two general categories: shallow water sites that were sampled by wading the stream and deep water sites that were sampled with a boat (including Woods Pond). Site descriptions are as follows:

East Branch

Site EB1 This shallow site was located in the city of Pittsfield upstream of the GE facility. The portion of river represented by this site had a 0.84% gradient, with an average width of 40 feet. This segment of river was a shallow stream, with small pools, riffles and runs.

Site EB2 This shallow site was located in Pittsfield downstream of the GE facility, and provided data on the urban fish community immediately downstream of the GE facility. Average river width was 46 ft, and gradient was 0.05%. The river at this location was approximately the same size as at Site EB1, but had poorer habitat due to slower water velocities, shallow depths and deposition of sand and silt.

West Branch

Site WB1 This shallow site was located in Pittsfield, upstream of the confluence with the East Branch. This location provided an evaluation of the status of the biological environment in this branch of the river and its influence on the Housatonic River downstream. This site is not actually upstream of the GE facility but it is on a parallel stream and is

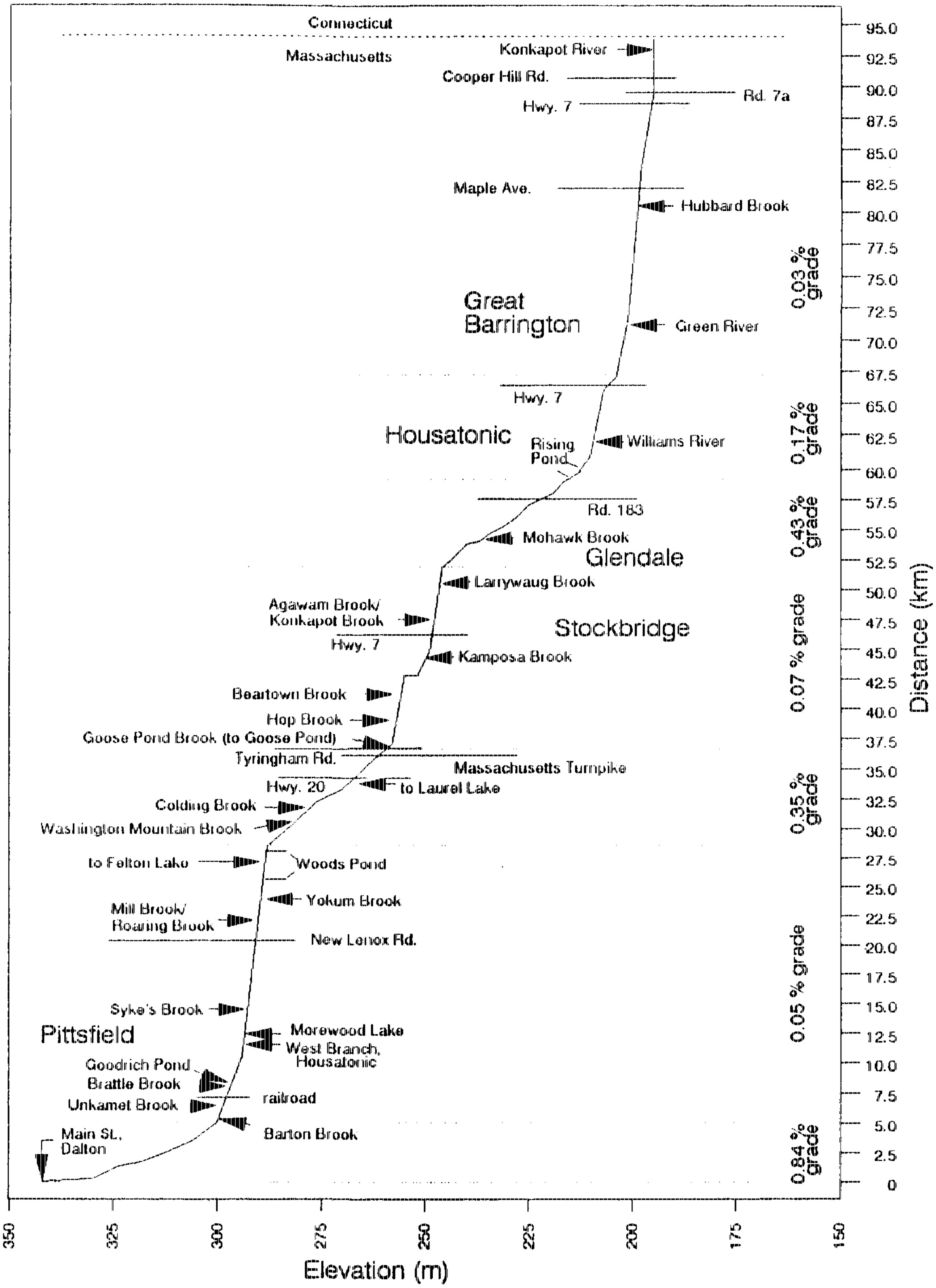

FIGURE 2: Longitudinal profile of the Housatonic River, Massachusetts.

unaffected by releases from the GE facility. Thus, for the present study, it is considered an "upstream" site. This segment of the river was narrower than the East Branch, with an average width of 29 ft. It had a gradient of 0.05%, and flowed through a residential area.

Housatonic River

Site HR1 This shallow site was located on the Housatonic River below the confluence of the East Branch and West Branch, downstream of the inflow of Sykes Brook. This portion of the river was much larger than the East Branch or West Branch, with an average width of 71 ft, and a gradient of 0.05%. The riparian zone here was less urban than the East Branch or West Branch sites.

Site HR2 This deep site was in the low gradient reach located between the New Lenox Road bridge and Woods Pond. This location provided information on the fish community in the portion of the Housatonic River where the highest sediment PCB levels have been recorded. The influence of the flat gradient was clearly evident in this area, with very slow current and habitat composed entirely of deep pools.

Site HR3 This shallow site was in the vicinity of the Highway #20 bridge downstream of the town of Lee. The river had an average width of 104 ft and a gradient of 0.35%. Flows were swifter than at Sites HR1 and HR2, with more gravel substrate present.

Site HR4 This shallow site was located downstream of the town of Glendale with a gradient of 0.43%, and an average width of 106 feet. The river in this area contained many boulders which provided abundant areas of pocket water.

Site HR6 This deep site was downstream of the Sheffield Bridge on the Housatonic River. Average river width was approximately 90 ft, with a flat gradient of 0.03%. Predominant land use in this area was agricultural, as evidenced by few riparian trees, and unstable streambanks.

Woods Pond

Site WP1 This site was located in Woods Pond, an impoundment of approximately 60 acres. Aquatic pond habitat here was unique compared to the rest of the river and, therefore, this pond site is considered separately from the stream sites. Submerged aquatic vegetation was abundant, and, along with deeper water, provided good fish habitat.

METHODS

Habitat Assessment

Quantification of habitat features at each study site consisted of measuring the proportion of pools, riffles, and runs along the length of each site. The following habitat definitions of pool, riffle, and run are from Platts *et al.* (1983). A pool is the portion of a stream that has slow water velocity and is usually deeper than a riffle or run. Pools provide cover for fish in the form of deeper water and refuge from currents. A riffle is the portion of the water column where water velocity is fast, stream depths are shallow, and stream gradient is relatively steep. In many streams, riffles produce most of the fishes' aquatic food, provide spawning areas for some species, and provide cover for young fish. A run is that portion of the water column that is too deep to be a riffle and too fast to be a pool. Runs do not form distinguishable pools or riffles, but have deep water and moderate velocities. Warmwater species such as largemouth bass, rock bass, bluegill, and yellow perch spawn and rear their young in pool habitat.

Habitat at each site was given a subjective rating of good, fair, or poor according to the professional judgement of the field crew. These ratings were based on physical characteristics of the stream and included the amount of cover present (instream snags or overhanging bank vegetation), the stability of the streambanks, water depth, and presence of channelization. This rating system is analogous to the habitat assessment procedure used in conjunction with the Rapid Bioassessment Protocols recommended by the EPA (Plafkin *et al.* 1989). These protocols are used to evaluate the biological integrity of a stream.

Water Quality

Water quality was sampled once per week between July 13, 1992 and September 8, 1992 at four sites on the Housatonic River by Blasland & Bouck Engineers (Fig. 1). The water quality sites were located near fish sampling sites but do not correspond exactly to those sites (Fig. 1). Analyses included measurement of several important parameters including temperature, dissolved oxygen, pH, total ammonia, nitrate, and orthophosphate. The limited amount of water sampling precludes an in-depth discussion of water quality. A study providing for more extensive sampling (more sites, more sampling dates) in 1993 could better define seasonal ranges in water temperature and the other water quality parameters.

Fish Populations

Fish populations were sampled at all sites in September 1992 to determine species composition and size structure of the fish community. At sites that were shallow with a stable bottom (EB1, WB1, EB2, HR1, HR3, HR4), sampling was conducted by making one pass through a measured section of stream (350-550 ft) using a bank electrofishing unit. Sampling was qualitative, but an attempt was made to collect as many fish as possible.

At the three sites that were deeper and not wadable (HR2, HR6, Woods Pond), fish were sampled from an electrofishing boat. The two river sites (HR2, HR6) were each sampled for 30 minutes by making a 15 minute electrofishing pass up one bank, then moving to the opposite bank and making another 15 minute upstream electrofishing pass. Woods Pond was sampled by making four 15 minute electrofishing passes in all the major habitat types (bank, open water, submerged vegetation, dead trees) for a total of 60 minutes.

Collected fish were divided into three groups: rough fish (suckers, carp, and goldfish), game fish (sunfish, bass, trout, perch, northern pike, pickerel, bullheads and fallfish), and forage fish (minnows, dace, shiners, killifish, and darters). All game fish and rough fish were identified to species, counted, measured for total length, weighed, and released. Forage fish were identified, counted, and released.

The condition or well-being of the game fish was derived using the relative weight index (W_r) as described by Wege and Anderson (1978), and Anderson and Gutreutter (1983). The relative weight index allows for comparison of condition between species and sites. Fish are compared to length-specific standard weights constructed to represent the species as a whole. This comparison yields the relative weight. Relative weight is generally not calculated for the younger age classes. Expected values of the relative weight index have the same general range across species and generally fall between 70 and 130 (Murphy and Willis 1991). Relative weight values between 95 to 105 are considered the optimal management target (Anderson 1980; Anderson and Gutreuter 1983). However, Willis *et al.* (1991) suggested calculating regional standards for yellow perch, instead of relying on a nationwide standard weight, due to high variability in relative weights for this species. Therefore, instead of a relative weight standard of 100, the standard used for yellow perch in this study was 79, based on previous studies in the New England region. In this study the relative weight index was used to compare condition of fish between study sites and between species.

Differences in habitat characteristics between shallow water sites and deep water sites affect species composition at these sites. Both types of sites can have representative, typical fish communities related to the specific physical characteristics present and the preferences of individual species. Therefore, the fish population data collected at shallow sites are not directly comparable to data collected at deep sites. In this report, fish population and habitat data will be compared between sites with similar habitat types (shallow or deep).

RESULTS AND DISCUSSION

Habitat Assessment

Shallow Water Sites Upstream of GE Facility

Both of the sites upstream of the GE facility (EB1, WB1) had fair habitat (Table 1). Site EB1 on the East Branch of the Housatonic River was located on one of the steeper portions of the river, with a gradient of 0.84% (Fig. 2). Average channel width was 40 ft, and the habitat was dominated by pools, and runs (Table 1). The substrate was a mixture of cobble and sand, covered with silt. This site was a channelized section behind a shopping center, with no high quality, deep pools. There were some areas of sparse instream cover in the form of woody debris, and overhead streambank cover in the form of trees was common. This site was rated as fair habitat due to it homogenous character and lack of diverse instream cover.

Site WB1 on the West Branch had an average channel width of 29 ft, and the habitat was approximately evenly divided between pools, riffles and runs (Table 1). This site had somewhat better habitat than Site EB1. The substrate was composed primarily of gravel and cobble, with a small amount of sand and silt. The lower half of the site was composed mostly of shallow riffles with one mid-channel pool. The upper half of the site had better habitat, with deeper pools and runs, and a few woody debris snags providing instream cover. The stream in general was small and shallow and, overall, the habitat at this site was rated as fair.

Shallow Water Sites Downstream of GE Facility

Site EB2 was located just upstream of the confluence with the West Branch. The average channel width was 46 ft, and the substrate at this site was finer than at Sites EB1 and WB1, with a mixture primarily of sand and silt, with some small gravel. As with Site EB1, this site had homogeneous habitat comprised primarily of slow, shallow runs. Instream cover was poor, consisting of a few clumps of aquatic plants. Habitat at this site was rated as poor due to limited cover and poor substrate.

At Site HR1 the average channel width was 71 ft, and substrate composed primarily of sand and silt, with small areas of gravel. No riffles were present, and habitat consisted of runs and pools. Two deep pools were present at this site, each containing a small amount of large, woody debris. Because of the limited cover present at this site, habitat was rated as fair.

TABLE 1: Habitat parameters for fish sampling sites, Housatonic River System, September 1992.

Site Quality	Site Length (ft)	Width (ft)	Habitat Type (%) Pool	Riffle	Run	Habitat Quality
Shallow Sites Upstream of GE Facility						
EB1	540	40	52	3	45	Fair
WB1	472	29	28	35	37	Fair
Shallow Sites Downstream of GE Facility						
EB2	547	46	11	15	74	Poor
HR1	448	71	41	0	59	Fair
HR3	489	104	0	2	98	Fair
HR4	387	106	10	4	85	Good
Deep Sites Downstream of GE Facility						
HR2	30 min	~65	100	0	0	Fair
HR6	30 min	~90	100	0	0	Fair
Woods Pond						
WP1	1 hr	--	100	0	0	Good

Habitat at Site HR3, downstream of Woods Pond, was primarily composed of shallow runs (1-2 ft deep), with a gravel and silt substrate. Average channel width was 104 feet. Instream cover consisted of submerged vegetation, but was sparse. Due to the homogeneous run habitat and small amount of cover, habitat at this site was rated as fair.

Site HR4 exhibited the best trout habitat of any of the study sites. Gradient was relatively high at this site, with a cobble and boulder substrate. Habitat consisted mostly of runs, with a few pools and riffles. Most of the pool habitat was in the form of small areas of pocket water behind large boulders. This was good habitat for trout, but lacked the submerged vegetation, woody debris, and slower water that sunfish (largemouth bass, bluegill, etc.) prefer and that was present at deep water sites.

<u>Deep Water Sites Downstream of GE Facility</u>

Site HR2 had a different type of habitat than the other river sites. This site was located approximately one mile upstream from Woods Pond. The flat gradient in this area increased water depths and slowed water velocities in this section of the river, forming deep pool habitat (>5 ft deep) along the entire length of the site. Cover was abundant, in the form of overhanging bank vegetation, woody debris, submerged vegetation along the banks, and fallen trees in the middle of the channel. Because of the large amount of cover, habitat at this site was rated as good.

Site HR6 was the furthest site downstream, approximately 0.5 miles above the Connecticut border. Habitat at this site was rated as fair, consisting entirely of pool habitat. The site was surrounded by cow pasture, with little riparian vegetation to provide shading. Vegetation on the banks was sparse, allowing the banks to cave in, and slough into the water. Instream cover was sparse, consisting of a few clumps of woody debris interspersed over a substrate of soft sand and silt. The deep water at this site would provide suitable habitat for some species.

Woods Pond

Woods Pond is an impoundment of approximately 60 acres on the Housatonic River and its habitat was characteristic of a standing water environment. Cover was abundant, in the form of woody debris, submerged macrophytes and rocks along the banks, and beds of submerged vegetation in the open water areas. Water depths exceeded 6 ft in the open water areas. This type of habitat was rated as good for species such as largemouth bass and bluegill.

Water Quality

There was no clear longitudinal trend in any of the measured water quality parameters (Table 2). Water temperatures between July and September 1992 were between 60°F and 75°F, a range suitable for all the species collected in this study, including brown trout. However, the summer of 1992 was cooler than in previous years. Water temperatures may be limiting to coldwater species, such as trout, during a summer with normal temperatures. The water temperature regime during a more normal summer should be within a suitable range for all the warmwater game fish species collected (largemouth bass, yellow perch, rock bass, and bluegill).

The pH of the water ranged widely at most sites, beyond what was expected. The cause of the fluctuations in pH can not be determined at this time. More extensive field sampling could determine seasonal changes in pH and their causes. However, the values are within the range considered suitable for aquatic biota, 6.0 - 9.0 (Thurston, *et al.* 1979). There was some indication of nutrient loading, as evidenced by the moderate levels of ammonia and nitrate, and the high levels of phosphates. This nutrient loading is probably due to nonpoint runoff from farms and towns bordering the Housatonic River. Inputs from point sources, such as wastewater treatment plants, also increase nutrient levels. Levels of dissolved oxygen (D.O.) were slightly lower than expected, which may be evidence of high biological oxygen demand (BOD) in the water. As organic matter in the water decays, oxygen is consumed, lowering levels of dissolved oxygen. The elevated nutrient levels have probably promoted the growth of aquatic primary producers (algae, plants), which upon dying and decaying raised the BOD, and thus lowered dissolved oxygen. Overall, however, the dissolved oxygen levels measured during this study in the Housatonic River were within acceptable limits.

TABLE 2: Ranges in water quality parameters, Housatonic River, 7/13/92 - 9/8/92.

Site	Temp. (°F)	D.O. (mg/L)	pH	Total Ammonia (mg/L)	Nitrate N (mg/L)	Ortho-phosphate (mg/L)
Shallow Sites Downstream of GE Facility						
HRW1	60.2-69.8	4.5-5.2	6.6-7.8	0.1-0.2	1.6-2.2	0.09-0.11
HRW3	64.8-72.8	4.8-6.6	6.7-8.0	0.1	1.1-1.2	0.08-0.10
HRW4	64.0-75.0	5.2-5.9	6.4-8.4	0.1	1.1-1.3	0.07-0.09
Woods Pond						
HRW2	63.2-73.6	4.4-6.2	6.5-7.8	0.1	1.4-1.6	0.07-0.08
HRW2a	64.6-69.0	2.4-6.2	6.7-8.1	--	--	--

Overall, there were a few minor problems in water quality such as elevated phosphates and slightly lower than normal dissolved oxygen, but these do not appear to be limiting the fish community in the Housatonic River or Woods Pond. Habitat quality appears to be limiting the fish community more than water quality. Of the nine study sites, only three had good habitat (Woods Pond, HR2, and HR4) and none were rated as excellent. Site HR2 and Woods Pond had deep pool habitat and abundant cover in the form of submerged aquatic plants and woody debris, and Site HR4 exhibited a good diversity of pools, riffles, and runs. The abundant pocket water behind the boulders provided good cover for fish at Site HR4. The remaining six sites that exhibited fair or poor habitat generally lacked sufficient instream cover (submerged plants, rocks, woody debris) to provide shelter for the game fish species.

Fish Populations - Present Study

Species richness in 1992 at the nine sites ranged from 5 to 15 species (Table 3). Except for Site HR4, which had 5 species, the remaining sites had between 9 and 15 species, displaying a good diversity. Site HR4 was the only site where trout were collected, and it had the lowest species diversity. Habitat was good at this site, but consisted of swifter water over a cobble and boulder substrate, which is a habitat type not preferred by most of the sunfish and minnow species present in other sections of the river. Therefore, while the habitat was good for trout at Site HR4, it appears that it is unique and not suitable for many of the other species collected in this study.

Although the Massachusetts Division of Fisheries and Wildlife (DFW) manages for trout in the Southwest Branch of the Housatonic River in Pittsfield, the East Branch near Dalton and Hinsdale, and many tributaries, it does not actively manage the mainstem of the Housatonic River for trout. However, the DFW has done some experimental stocking of trout in the Housatonic River in the past. For instance, approximately 400 brown trout were stocked near Glendale in the mid 1980's, to test their survival (Leo Daly, Mass. DFW, personal communication). The brown trout collected in the present study at Site HR4 may be descended from that experimental stocking. Likewise, the trout collected in this study and previous studies probably originated from the experimental stocking near Glendale or from trout stocked in tributaries to the Housatonic River, which had moved downstream.

TABLE 3: Species list and number of fish collected by Chadwick & Associates from Housatonic River System, September 1992.

Family	Upstream		Shallow Downstream				Deep Downstream		Pond
Common Name	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR6	WP1
Salmonidae									
Brown trout						6			
Centrarchidae									
Rock bass	27	34	19	13	54	16	6	5	1
Black crappie							3	2	11
Bluegill	1	2		1	1		6	3	48
Largemouth bass	8	2	2	10			18	5	34
Pumpkinseed	15	6	2	5			23	5	37
Smallmouth bass								2	
Esocide									
Northern pike									1
Chain pickerel							2		3
Percidae									
Tessellated darter					47			1	
Yellow perch	14	5	2	6			89	6	82
Ictaluridae									
Brown bullhead		3			2		2		4
Catostomidae									
Longnose sucker					2				
White sucker	14	188	77	49	99	4	29	5	36
Cyprinidae									
Goldfish							4		30
Common shiner	11	61			5				15
Creek chub	2		1						
Common carp							2	7	1
Fallfish	2	8	6	7	2			2	
Golden shiner									24
Longnose dace	26	59	13	1	87	145			
Bluntnose Minnow		434	24	218	2	3			12
Blacknose Dace	88	54	11		16				
Number Collected	208	856	157	310	317	174	184	43	339
Total Species Richness	11	12	10	9	11	5	11	11	15

Shallow Water Sites Upstream of GE Facility

The two shallow sites upstream of the GE facility contained similar species composition. Ten species were collected at both sites with three species present at only one of the two sites (Table 3). At both sites minnows were the most abundant species with rock bass the most abundant game species. The species composition includes all three general groups of fish -- game fish rough fish and forage fish. The relative abundance of game and rough fish, by weight, at the two sites indicates a balanced fish community (Table 4). The higher proportion of game fish at Site EB1 is probably a result of the deeper water, generally larger stream size and high proportion of pools and runs at this site as compared to Site WB1.

The condition of largemouth bass and rock bass at these two sites was good, with relative weight indices near the standard of 100 (Table 5). For yellow perch, the condition was fair to poor, compared to the standard weight of 79 for this species. At Site EB1 approximately half of the perch, especially the smaller individuals, were infected with an eye fluke. This parasite is a trematode worm, probably in the genus *Diplostomum* (Dr. R. Behnke, Colorado State University, personal communication). The life cycle of this parasite includes snails and fish eating birds, as well as many species of fishes (Davies *et al.* 1973). The infection of the eye may limit the ability of the fish to find food. This may account for the poor condition of yellow perch at Site EB1. The condition of bluegill at Site WB1 was also poor. However, only two small individuals of this species were collected at this site and this may account for the low relative weight.

Shallow Water Sites Downstream of GE Facility

The species composition at these four sites was similar in many respects to the two sites upstream of the GE facility. Sunfish (Centrarchidae) were the most numerous game fish, with white suckers and minnows also common. Site HR4 was unique with the presence of brown trout and approximately half as many species of fish present as at the other shallow sites in the study. This is probably related to the unique habitat at this site. As noted above, the habitat at Site HR4 consisted of a rocky substrate with high gradient and relatively fast current velocities. These are conditions that are suitable for trout, but are less suitable for the variety of sunfishes and minnows collected at the other shallow sites in the study area.

TABLE 4: Percent composition (by weight) of fish community, excluding forage fish, Housatonic River System, September 1992.

Site	Game Fish								Rough Fish			
	Largemouth Bass	Rock Bass	Misc Sunfish	Yellow Perch	Bull-heads	Brown Trout	Fall-fish	**Total Game-fish**	Suckers	Carp	Goldfish	**Total Rough Fish**
Shallow Sites Upstream of GE Facility												
EB1	<1	25	8	10	0	0	<1	43	57	0	0	57
WB1	1	14	<1	3	1	0	3	21	79	0	0	79
Shallow Sites Downstream of GE Facility												
EB2	3	7	<1	2	0	0	4	17	83	0	0	83
HR1	18	5	<1	5	0	0	9	38	62	0	0	62
HR3	0	13	<1	0	1	0	1	15	85	0	0	85
HR4	0	36	0	0	0	44	0	80	20	0	0	20
Deep Sites Downstream of GE Facility												
HR2	18	1	6	17	1	0	0	43*	32	20	5	57
HR6	6	1	1	3	0	0	<1	11	8	81	0	89
Woods Pond												
WP1	17	<1	10	11	2	0	0	43*	30	1	26	57

*Also includes chain pickerel and northern pike.

TABLE 5: Mean relative weights (W_r) of game fish species, Housatonic River, September 1992.

Site	Bluegill	Brown Trout	Largemouth Bass	Rock Bass	Yellow Perch
Shallow Sites Upstream of GE Facility					
EB1	--	--	100.4	95.2	66.4
WB1	77.7	--	102.4	101.0	74.8
Shallow Sites Downstream of GE Facility					
EB2	--	--	110.7	90.9	86.6
HR1	105.1	--	112.4	106.6	71.8
HR3	89.0	--	--	99.9	--
HR4	--	100.4	--	111.9	--
Deep Sites Downstream of GE Facility					
HR2	99.5	--	105.3	93.4	78.5
HR6	71.3	--	105.6	82.2	76.1
Woods Pond					
WP1	101.5	--	105.0	--	79.1
Standard	100	100	100	100	79

Of the species collected at the two upstream sites, all were also collected at one or more of the sites downstream of the GE facility as well. Only three species were collected at the downstream sites that were not collected at the upstream sites (Table 3). There seems to be no pattern of species composition related to longitudinal position along the Housatonic River.

The condition of the fish at the four shallow sites downstream of the GE facility was generally good (Table 5). Largemouth bass were in very good condition at the two sites where they occurred and had higher relative weight indices than at the two sites upstream of the GE facility. The brown trout collected at Site HR4 were in good condition also. The condition of bluegills was good at Site HR1 but only fair at Site HR3. However, these indices are based on only one fish captured at each site, a sample size too small for valid conclusions. Similarly, yellow perch condition was much different at the two sites where they occurred, but this may be due to the presence of very few individuals at these sites (Table 3). Eye flukes were present at one of the six yellow perch captured at Site HR1 but were not present in the two perch at Site EB2.

Rock bass occurred in relatively high numbers at all four shallow sites downstream of the GE facility. Their condition was good at three sites and was fair at Site EB2. At this site the low relative weight may be due to the habitat present. Rock bass prefer clear, gravel-bottomed streams with cover, but the habitat of Site EB2 consisted of salt/sand substrate with little cover. The lack of preferred habitat at this site and the presence of the preferred substrate habitat at the other three sites may explain the comparably low relative weight of rock bass at Site EB2.

Deep Water Sites Downstream of GE Facility

The fish communities at the two deep sites were dominated by species in the sunfish (Centrarchidae) family and yellow perch (Table 3). Carp were also present at both sites and was the most abundant species at Site HR6. A few minnow species were present in low numbers, in contrast to the abundant minnow species and individuals at the shallow sites (Table 3). This difference is due to habitat preferences of minnows and also due to the size selectivity of the boat electrofishing technique used at the deep sites.

The fish communities at the two deep sites were generally similar, with eight species common to both sites. Species that occurred at only one of the sites were consistently the less abundant species. Both sites contained communities with representatives of game fish, rough fish and forage fish species (Tables 3-4). The relative proportion of rough fish at site HR6 was particularly high due to the presence of several very large (11-16 lbs) carp (Table 4). The high proportion of rough fish at Site HR6 may be due to the somewhat degraded nature of the habitat, with unstable banks and limited cover.

The condition of fish at Site HR2 was generally good for all species, with relative weight indices near the standard (Table 5). The exception to this was rock bass with a condition slightly below the standard. This may be due to the low number of rock bass at this site (Table 3) or the absence of their preferred habitat. At Site HR6 the sample sizes of all species were low, precluding accurate calculation of relative weight. However, it appears that largemouth bass and perch were in good condition. Rock bass and bluegill were in less than optimal condition. This may be due to the habitat condition at this site. Most of the yellow perch at both sites contained the eye fluke parasites.

Woods Pond

Woods Pond contained a fish community generally similar to that of the two deep sites, HR 2 and HR6. Sunfishes (Centrarchidae) and yellow perch were abundant with few minnows (Table 3). Woods Pond contained more species than any other site in the study area although all species except golden shiners and northern pike were also collected at other sites in the Housatonic River.

There was a good balance between the weight of the rough fish and game fish in the pond (Table 4). Forage fish species were not common; however, the young sunfish, yellow perch, goldfish and white suckers serve as forage for the game fish.

The relative weight of the species in Woods Pond was consistently above the standard (Table 5). This indicates good condition of the fish. Over half of the yellow perch were infected with the eye flukes. Infection was generally restricted to the younger, smaller individuals of the population.

Fish Populations - Comparison to Past Studies

A total of 30 species of fish in 8 families have been collected from the Housatonic River in four studies since 1971 (Table 6). Sixteen of these species were game fish. The species collected are generally typical for this region, with the exception of goldfish, and represent a good diversity in the fish community. The muskellunge collected by Stewart Laboratories in 1982 was probably a misidentified tiger muskie. A tiger muskie is a hybrid cross between a northern pike and muskellunge. Muskellunge are not native to the region, but tiger muskie have been stocked in lakes in the Housatonic River valley, from which they have escaped into the Housatonic River. For example, tiger muskie were stocked in Onata Lake in the late 1970's, and soon after were being caught by anglers in the Housatonic River (Joe Bergin, Massachusetts DFW, pers. comm.).

Quantitative data from previous studies are sparse. The studies conducted by Blasland & Bouck Engineers (1991) and Stewart Laboratories (1982) were qualitative in nature, and were primarily concerned with obtaining game fish for analysis of PCB residues. The most comprehensive of the previous studies was conducted by the Massachusetts DFW in 1971, in which they conducted a survey of the fish communities of the Housatonic River. In this study they collected 20 species in 8 families (Table 6) at sites corresponding to the 1992 study section of the Housatonic River.

The proportion of forage fish, rough fish, and game fish species in different sections of the river differed between the study conducted in 1970 by the Massachusetts DFW and the present study (Fig. 3). In 1970, rough fish (mainly white suckers) comprised the largest proportion of the fish community at each of the Housatonic River study sites. However, in 1992, forage fish were the most abundant group at three out of the four study sites corresponding to the areas sampled in 1970. The abundance of forage fish in 1992 should be beneficial for game fish species, as it provides a strong forage base of small fish that serve as prey throughout their entire lifespan. In contrast, white sucker young-of-the-year may serve as prey for game fish, but adults grow too large to be preyed upon.

TABLE 6: Species list of fish species collected from Housatonic River System, Massachusetts. (M=Bergin 1971; S = Stewart Laboratories 1982; B = Blasland, Bouck & Lee Engineers 1991; C = Chadwick & Associates 1992).

Family Common Name	Scientific Name	Housatonic River
Salmonidae		
Brook trout	*Salvelinus fontinalis*	S
Brown trout	*Salmo trutta*	B,C,M,S
Rainbow trout	*Oncorhynchus mykiss*	M,S
Centrarchidae		
Bluegill	*Lepomis macrochirus*	C,M,S
Black crappie	*Pomoxis nigromaculatus*	C,S
Green sunfish	*Lepomis cyanellus*	S
Largemouth bass	*Micropterus salmoides*	B,C,M,S
Pumpkinseed	*Lepomis gibbosus*	C,M,S
Redear sunfish	*Lepomis microlophus*	S
Rock bass	*Ambloplites rupestris*	C,M,S
Smallmouth bass	*Micropterus dolomieu*	C
Esocide		
Chain pickerel	*Esox niger*	C,M,S
Northern pike	*Esox lucius*	C
Muskellunge	*Esox masquinongy*	S
Percidae		
Tessellated darter	*Etheostoma olmstedi*	C
Yellow Perch	*Perca flavescens*	B,C,M,S
Ictaluridae		
Brown bullhead	*Ameiurus nebulosus*	C,M,S
Catostomidae		
Longnose sucker	*Catostomus catostomus*	C,M
White sucker	*Catostomus commersoni*	C,M
Cyprinidae		
Blacknose dace	*Rhinichthys atratulus*	C,M
Bluntnose minnow	*Pimephales notatus*	C
Common carp	*Cyprinus carpio*	C
Common shiner	*Luxilus cornutus*	C,M
Creek chub	*Semotilus atromaculatus*	C,M
Fallfish	*Semotilus corporalis*	C,M
Golden shiner	*Notemigonus crysoleucas*	C,M
Goldfish	*Carassius auratus*	C,M
Longnose dace	*Rhinichthys cataractae*	C,M
Spottail shiner	*Notropis hudsonius*	M
Cyprinodontidae		
Killifish	*Fundulus* sp.	M
Total Species Richness, All Studies Combined		30
Species Richness, Chadwick & Associates		23

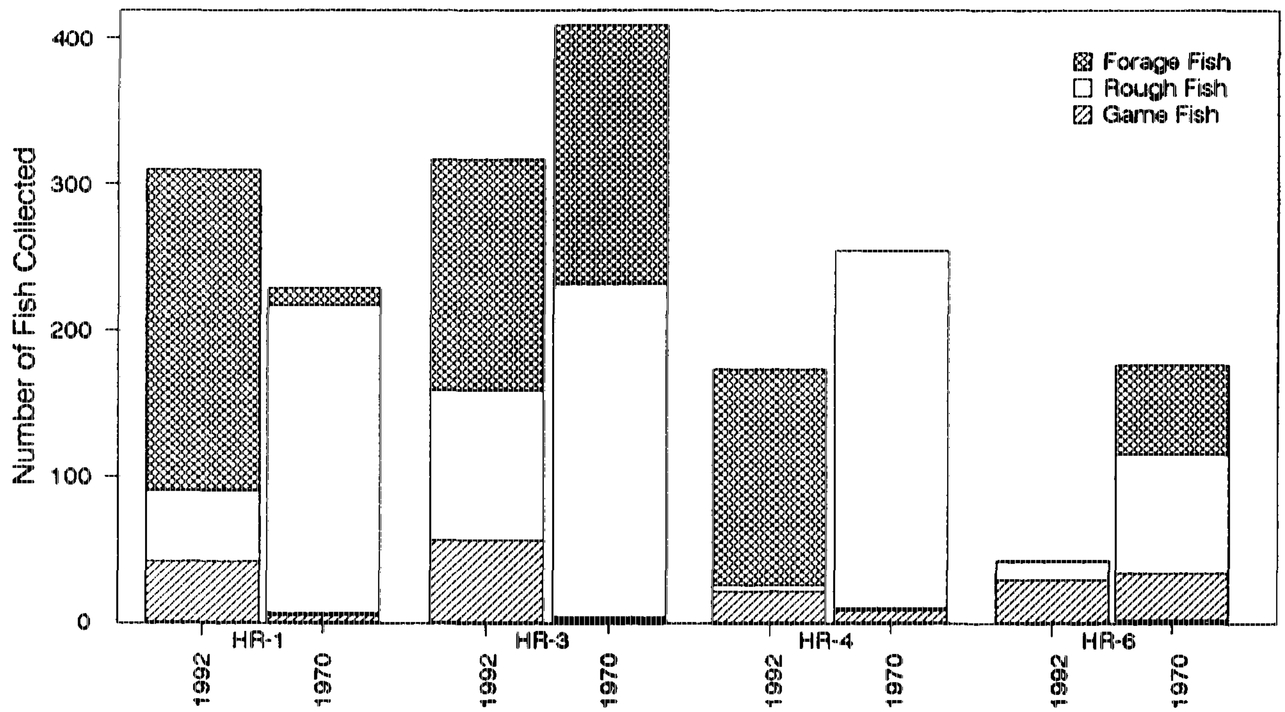

FIGURE 3: Number and proportion of forage fish, rough fish, and game fish collected from the Housatonic River in the present study and by the Massachusetts DFW in 1970.

The number of game fish collected in 1992 was greater than in 1970 in three out of four river segments (Fig. 3). Game fish also comprised a higher percentage of the total number of fish sampled in each river section in 1992 compared to 1970. The study conducted in 1970 did not calculate densities (#/hectare) of fish, so no direct comparisons can be made between densities from 1992 and 1970. However, the proportional abundances presented in Figure 3 indicate that the fish populations in 1992 at all sites except HR6, exhibited a more balanced community than that sampled in 1970.

SUMMARY AND CONCLUSIONS

The data from the 1992 sampling season are summarized in Table 7. There were no discernible effects of the GE facility on the physical habitat of the Housatonic River. Habitat quality was good at Sites HR2, HR4, and Woods Pond. The good rating at these sites was due to the abundance of cover in the form of submerged vegetation, woody debris, boulders, and deeper water. The sites with poorer habitat generally lacked cover and were homogeneous in nature and occurred both upstream and downstream of the GE facility.

Water quality was moderately affected by nutrient input, as evidenced by elevated levels of orthophosphates (Tables 2, 7). These nutrients probably had an indirect influence on oxygen levels, by promoting growth of algae and vegetation. When these plants die, they decay, thus increasing biological oxygen demand and reducing dissolved oxygen in the Housatonic River to levels slightly lower than normal for a typical river. Other water quality parameters such as water temperature and pH were within acceptable limits.

Although quantitative data on fish populations from previous studies of the Housatonic River are limited, the study conducted in 1970 by the Massachusetts DFW was the most thorough historic survey of the fish community in the Housatonic River. In that study the investigators collected 20 species of fish from 8 families. The present day fish community sampled by Chadwick and Associates contained 23 species in 7 families (Table 3), and compares well to the fish community from 1970.

At shallow sites both upstream and downstream of the GE facility, the species composition was similar. The fish communities predominantly contained minnows (Cyprinidae) and sunfish (Centrarchidae). These were balanced communities with representatives of game fish, rough fish and forge fish species present at all six shallow sites. The exception was Site HR4, which had habitat suitable for trout, but less suitable for the diversity of fish found at other sites along the Housatonic River.

TABLE 7: Summary of fisheries data for sampling sites on the Housatonic River System, September 1992.

	Habitat Quality	Water Quality	Species Richness	% Gamefish (By Wt.)	Fish Condition*				
					BG	BRN	LMB	RB	YP
Shallow Sites Upstream of GE Facility									
EB1	Fair	NA	11	43	-	--	Good	Good	Fair
WB1	Fair	NA	12	21	Fair	--	Good	Good	Good
Shallow Sites Downstream of GE Facility									
EB2	Poor	NA	10	17	--	--	Exc.	Fair	Exc.
HR1	Fair	Moderate	9	38	Exc.	--	Exc.	Exc.	Fair
HR3	Fair	NA	11	15	Fair	--	--	Good	--
HR4	Good	Moderate	5	80	--	Good	--	Exc.	--
Deep Sites Downstream of GE Facility									
HR2	Good	Moderate	11	43	Good	--	Exc.	Fair	Good
HR6	Fair	NA	11	11	Fair	--	Exc.	Fair	Good
Woods Pond									
WP1	Good	Moderate	15	42	Good	--	Exc.	--	Good

* Condition based on Relative Weight (W_r)
BG = Bluegill
BRN = Brown trout
LMB = Largemouth bass
RB = Rock bass
YP = Yellow perch

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Most of the fish species at the shallow sites were in good or excellent condition with relative weight indices near the standard. Largemouth bass and brown trout were in good or excellent condition at all shallow sites where they were present. Bluegills did not occur in sufficient numbers at shallow sites for a definite conclusion to be made, but their condition varied from fair to excellent. Rock bass were generally in good condition at shallow water sites with suitable habitat, but were in less than optimal condition at Site EB2 with less suitable habitat for this species. Yellow perch condition was only fair at two shallow sites, possibly due to the presence of parasitic eye flukes. In general, there was no pattern of fish condition related to location on the Housatonic River relative to the GE facility in Pittsfield.

At deep water sites and at Woods Pond, the fish communities contained higher proportions of sunfishes and fewer minnows. Both deep sites on the Housatonic River and Woods Pond contain healthy balanced communities with game, rough and forge fish present. However, at Site HR6, large carp accounted for the majority of the weight of the fish community. This may be due to the silty substrate and the limited cover at this site.

The condition of most species was good to excellent at the two deep sites and Woods Pond. Largemouth bass and yellow perch had relative weights near or above the standard at all three sites. For bluegill, condition was good at all sites except HR6. The poor cover conditions of HR6 may account for the low relative weights for bluegills at this site. Rock bass had low relative weights at the two deep water sites, probably because of the absence of their preferred habitat type.

In general the fish communities of the Housatonic River are diverse, balanced and healthy. There is no apparent trend in community parameters related to the GE facility or the presence of PCBs in the river.

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