MERRIMACK RIVER MONITORING PROGRAM

SUMMARY REPORT

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1.0 OBJECTIVE

The objective of this report is to provide an overview of the physical, chemical and biological data collected throughout a twelve-year (1967 to 1978) monitoring period at Public Service Company of New Hampshire's Merrimack Generating Station in Bow, New Hampshire. This document is a summarization and interpretation of data relevant both to the operation of Merrimack Station and to existing Merrimack River environmental conditions.

whereas seasonal low concentrations corresponded to spring and fall diatom abundance (Appendix Table C-2).

Throughout the study period, chlorophyll *a* concentrations were significantly reduced at the discharge canal compared to ambient and far-field concentrations. Similar chlorophyll *a* concentrations at both ambient and far-field stations suggest that the phytoplankton standing crop recovered downstream of the discharge canal mouth. Decreased phytoplankton standing crop at the discharge canal, as estimated by chlorophyll *a* concentrations, confirms the observation that periphyton and phytoplankton densities are often lower within the mixing zone than in ambient regions. However, recovery of these primary producers downstream of the mixing zone has been indicated by periphyton, net phytoplankton, and chlorophyll *a* studies. Therefore, any effects of Merrimack Station on the primary producers of Hooksett Pond appear to be temporary and limited to near-field regions.

5.1.3 Phytoplankton Entrainment

Entrainment studies were developed to assess the potential impacts of entrainment through the cooling system of the Merrimack Generating Station on the plankton communities. Potential impacts considered were cellular damage and destruction from mechanical forces, pressure changes, and elevated condenser temperatures as well as long-term effects including adverse changes in composition of the river's phytoplankton community.

Qualitative net studies were instituted during 1975 and 1976 to assess the mortality of entrained phytoplankton communities between the river and the discharge canal. Diatoms and green algae exhibited significantly higher mortalities within the discharge canal than at the intake structures during both years. In addition, these mortalities were higher at the discharge weir than at the discharge canal mouth, indicating recovery within the canal. In 1975, diatom mortality was

correlated with the combined effects of ambient water temperature and plant-induced temperature changes. A similar mortality/temperature interdependence was not observed in 1976, suggesting that either mechanical or chemical stresses were significant mortality factors.

Green algae mortality was not significantly related to water temperatures in 1975. However, in 1976, green algae mortality correlated with plant-induced ΔT's, with indications of a possible synergistic relationship between ambient temperature and ΔT.

Quantitative whole water/net studies were instituted in 1977 to more accurately assess mortality at the Merrimack Station circulators and condensers. These changes in the sampling design were initiated (1) to assess specific station-induced mortality as it relates to each phytoplankton division and dominant genera and (2) to sample only entrained waters.

Diatom mortality was significantly higher at the condensers than at the circulators or the intake structures in 1977. The magnitude of condenser mortality varied seasonally, with highest mortalities occurring during the late spring and mid-summer. Diatom mortalities at the condensers were associated with high condenser temperatures, although this was not proven statistically. There was no evidence of any circulator-induced diatom mortality. However, studies of individual genera during 1978 suggested a possible correlation between physical form and circulator-induced mortality. These data implied that genera with minimal surface areas, such as *Asterionella* and *Melosira* are less susceptible to mechanical damage than a genus with greater surface area, such as *Tabellaria*.

Green algae mortality was minimal during 1977. Low condenser mortalities occurred during periods of peak ambient and condenser temperatures, suggesting minimal thermal damage to this division. Similarly, there was no evidence of any circulator-induced mortality. Green algae mortality, when present in 1978, was not correlated with either thermal or mechanical effects. Genera enclosed in gelatinous

sheaths, such as *Sphaeocystis*, appeared to be less susceptible to either mechanical or thermal damage than those such as *Eudorina* which have protruding flagella.

Studies comparing phytoplankton survival with ambient temperatures and entrainment ΔT's (Gurtz & Weiss, 1974; Morgan & Stross, 1969) have reported various temperatures at which phytoplankton stimulation and inhibition occur, indicating the site-specific nature of most entrainment studies. In general, thermal discharges can alter the successional patterns within the receiving water body, especially if the thermal limits of the resident species are exceeded. A general literature summary of entrainment studies (Patrick, 1969) concluded that phytoplankton mortality is most severe if (1) the experienced ΔT is large, (2) the exposure to these high temperatures is continued for several hours, and (3) the increased water temperature approaches the upper thermal tolerance limits for either major phytoplankton species or divisions. Storr (1974) concluded that mechanical stress can also contribute to entrainment mortality.

A more-complete assessment of entrainment impacts on the phytoplankton community can be obtained by comparing seasonal mortality with the percent of river water entrained during that season. Seasonal river discharge and a summary of generating units operation were computed for 1975 through 1978 (Table 5-3). Peak flow conditions were found in the spring, with an average seasonal discharge of 294 cms. Diatoms, the dominant phytoplankton division in vernal waters, experienced varying degrees of mortality due to both mechanical and thermal effects. However, even under peak generating conditions, minimal impact to the river community is expected during the spring because only 4 to 13% of the river water is actually entrained through the Merrimack Station (Figure 3-2). This premise is further supported by the absence of long-term diatom reductions observed within the mixing zone and far-field communities.

River discharge was minimal during the summer, averaging 21.5 to 168.1 cms. Green algae exhibited low entrainment mortalities through-

out the summer, even when ambient and condenser temperatures were highest. These results suggest minimal entrainment impact to the summer green algae community, even though 31% of the available river volume may be utilized for cooling purposes. The minimal entrainment impacts suggested are confirmed by the rarity of long-term community reductions at the downstream monitoring stations.

Autumnal flow values were erratic ranging from 20.8 to 146.8 cms, depending primarily on the amount of rainfall. Diatoms were the primary phytoplanktonic organisms found during autumn. When river discharge remains low and both units are operating, moderate to heavy impact could be expected since up to 63% of the available river volume may be entrained. Thus, some short-term diatom mortality is expected under these conditions. However, monitoring of the river diatom communities has indicated few far-field reductions in diatom abundance.

Morgan and Stross (1969) found that phytoplankton populations become re-established and continue normal rates of primary production within several hours after passage through the generating station cooling system. Other studies have determined that most freshwater phytoplankton species can, under favorable flow and nutrient conditions, undergo one to three cell divisions per day, thereby quickly negating any reduction in cell numbers (Talling, 1962). This high reproductive rate imparts a certain resilience to phytoplankton populations, enabling them to recover quickly from short-term impacts. This resilience may be largely responsible for the recovery of phytoplankton densities downstream of the Hooksett Pond mixing zone.

5.1.4 Conclusions

Studies of periphyton, net phytoplankton, and standing crop of primary producers as estimated by chlorophyll *a* concentrations have indicated short-term reductions in abundance of primary producers in

the near-field regions. However, reductions in the far-field regions are rare in occurrence, and temporary. Maximum impact appears to coincide with low flows and maximum thermal output during the autumn when diatoms dominate the plankton communities. Overall, there have been no long-term reductions in autotrophic production within Hooksett Pond that can be attributed to the operation of Merrimack Generating Station.

5.2 Zooplankton

5.2.1 Net Zooplankton Communities

Zooplankton communities are usually considered to be transient members of a river system, although these primary consumers can comprise an integral part of the total river biota (Whitton, 1975). The most frequently encountered zooplanktonic organisms are rotifers; micro-crustacean cladocerans and copepods are also common, but are usually of lower abundance. Development of these organisms is most pronounced within the slower portions of the river; conversely, both zooplankton diversity and abundance are characteristically reduced within the swiftly-flowing river sections.

Many environmental factors can affect zooplankton productivity in a river. Season, light intensity, water temperature, and nutrient concentrations influence zooplankton by regulating the growth of the phytoplankton community which is their primary food source. Fluctuations in zooplankton abundance can be directly related to variations in phytoplankton density, with peak zooplankton concentrations usually lagging maximum phytoplankton abundance (Whitton, 1975; Reid, 1961). Similarly, changes in aquatic macrophyte composition and abundance within a river may also alter zooplantkon abundance. Chandler (1937; cited in Whitton, 1975) and Hynes (1970) have reported that most of a riverine zooplankton community, especially organisms possessing long spines, can be filtered from the water column by only 20 linear meters

of aquatic vegetation. Rotifer densities seem to be inversely related to rainfall; during periods of heavy precipitation, most of these organisms are swept from the river system. The populations become re-established rapidly after the water level subsides and a stable primary producing community again becomes established (Whitton, 1975).

Total zooplankton abundance decreased from 1972 through 1978 (Table 5-4), but this change was not related to the operation of Merrimack Generating Station since the densities declined upstream and downstream of the station.

Observed changes within the Hooksett Pond zooplankton community were minimal from 1972 through 1974. Rotifers, ciliophorans, and copepods dominated the zooplankton community, with greatest densities occurring during the late summer and early autumn (Table 5-4). The lack of consistent changes in either density or community structure, from the ambient to far-field stations, indicates no permanent changes in the zooplankton community downstream of the Merrimack Station. Among-station differences in the zooplankton community structure were more evident in 1975 and 1976. In 1975, densities were greater at the discharge canal than in ambient regions. Conversely, zooplankton densities were greater at the ambient station than at the far-field station in 1976. No among-station differences were noted in 1977 or 1978. Copepod nauplii and rotifers, primarily *Lecane*, *Trichocera*, *Polyartha*, and *Kellicottia* were the dominant zooplankton observed throughout these latter study years. Again, the lack of consistent among-station changes in either zooplankton density or community structure throughout Hooksett Pond, suggests no long-term zooplankton changes attributable to operation of Merrimack Station.

5.2.2 Zooplankton Entrainment

Zooplankton entrainment studies were instituted in 1975 to assess the potential impacts of entrainment through the cooling system

of the Merrimack Generating Station. No significant among-station changes were evident in 1975; however, in 1976, mortalities were significantly higher at the discharge weir and canal than in the river. These effects did not correlate with either high ambient or condenser temperatures. Entrainment studies during 1977 and 1978 were redesigned (1) to assess specific station-induced mortality as it relates to both major zooplankton groups and dominant genera, and (2) to sample only entrained water. *Lecane, Trichocera, Polyartha, Kellicottia* and copepod nauplii were the predominant zooplankton observed. However, overall low zooplankton densities within the entrained water (1 organism/liter) precluded any statistical analyses or mortality estimates.

Studies comparing zooplankton survival with both ambient temperatures and condenser temperatures have established varying lethal temperatures (30-35°C) for 100% zooplankton entrainment mortality, indicating the site-specific nature of most entrainment studies (Massengill, 1976b; Davis and Jensen, 1975; and Storr, 1975). Zooplankton entrained in the Merrimack Station cooling system would typically be exposed to temperatures above 35°C during the summer. However, the absence of long-term reductions of zooplankton abundance within the mixing zone and downstream reaches suggests no permanent changes in the Hooksett Pond zooplankton community due to Merrimack Station operation.

5.2.3 Conclusions

The lack of among-station differences in the net zooplankton communities, coupled with apparent minimal entrainment mortality, in terms of the numbers of organisms entrained, suggests no reduction or adverse change in the Hooksett Pond zooplankton community due to the operation of the Merrimack Generating Station.

or reduction of physiological resistance to disease. Indirect influences may include alteration of water quality parameters, particularly dissolved oxygen, or the life cycles of the organisms that fish utilize as food. The impacts of entrainment, entrapment, and thermal additions on the Hooksett Pond fish community are discussed in the following sections.

8.2.1 Ichthyoplankton Pump Entrainment

The susceptibility of drifting fish larvae (ichthyoplankton) to entrainment through the Merrimack Station cooling water system was studied from 1975 to 1977 using an epibenthic larvae trawl in front of the intake structures, at the discharge weir, in the discharge canal, and at the canal mouth. Sunfish (*Lepomis* spp.) were the most frequently collected larvae, but even these were not found in appreciable numbers in front of the intake structures (Appendix Table E-3). Larval sunfish were collected primarily during June, July, and early August, with a typical total length of 5 to 10 mm (range = 4.8 to 17.9 mm). Reduced larval abundance after mid-August was probably the result of larval growth increasing the ability of these individuals to avoid the trawl. Collections from 1975 to 1977 indicated that sunfish larvae drift from the upstream littoral zone past the station cooling water intakes. Sunfish larvae collected in larval tows in front of the intakes during 1975 were dead, but all larvae were collected alive during 1976 and 1977. Qualitative sampling with a dipnet in the littoral zone immediately upstream of the intakes during 1977 collected minnow, white sucker, and golden shiner larvae, but none of these species were collected in the trawl samples.

The method for sampling ichthyoplankton entrainment was modified in 1978. Water entering the intake of Unit I was sampled on a diel basis using an ichthyoplankton pump system from May 23 through July 27, 1978. White sucker, golden shiner, minnow (*Notropis* spp.), and sunfish larvae were most commonly collected (Appendix Table E-4).

Most larvae were collected during the night. White sucker and minnow larvae were found only in the samples collected between 2000 and 0400 hours. Golden shiner larvae also predominated during the period from 2000 hours to 0400 hours, although some were collected in the early morning and during the afternoon. Minnow, golden shiner, and white sucker larvae were abundant in the littoral zone just upstream of the power plant intake structure during 1977, but were not captured during daytime sampling at the intakes. This suggests that these species are more susceptible to entrainment during periods of darkness. Other studies have also reported an increase in the number of larvae subject to entrainment during periods of darkness (Knutson, 1974; Marcy, 1976a; Teleki, 1976).

Sunfish larvae were collected during both light and dark periods, with the majority captured between 1200 and 1600 hours. This periodic occurrence is likely the principal reason that sunfish larvae were the dominant organisms collected during the previous years of ichthyoplankton sampling in front of the intakes during the day. It is probable that the smaller centrarchid larvae (4-8 mm) that were drifting past the intakes had left the nest prematurely. These individuals may be considered lost from the population because their probability of survival is minimal outside the nest at this life stage. Therefore, entrainment of these drifting larvae should not influence the resident population more than natural mortality factors. Overall, the number of larvae collected during the 1978 entrainment sampling was considered to be minimal.

Ichthyoplankton sampling has provided qualitative evidence that Merrimack Station does not deleteriously influence Hooksett Pond fish populations through pump entrainment, although there is no quantitative estimate of horizontal larval distribution or the percent of larvae available within the river that are actually entrained. First, most resident fish species in Hooksett Pond do not have pelagic eggs or larvae. Centrarchids and bullheads are nest-builders and guard their eggs and larvae. Those larvae leaving the nest prematurely are gen-

erally considered to be lost from the population because their chances for survival are low. Other fish species such as white suckers, common shiners, golden shiners and white perch have adhesive, demersal eggs and the larvae typically develop in or near the substrate. This reduces the potential for pelagic drift and decreases the probability of entrainment. White sucker, golden shiner, minnow and sunfish larvae were collected in small quantities during 1978 entrainment sampling (Appendix Table E-4), indicating that the pump entrainment impact upon these species is minimal.

Second, any adverse effects of Merrimack Unit II entrainment upon the indigenous fish community in Hooksett Pond probably would have occurred within the first few years of station operation. At that time, the station may have induced additional mortality upon the parent stock populations and therefore reduced reproductive potential and subsequent standing crops. Fish populations, however, may intrinsically compensate for losses by a decrease in death rate or increase in birth rate as the population density declines. Many fish populations have been exploited by man through commercial and sport fishing and power plants without becoming extinct due to this utilization. An extensive review of the literature by McFadden (1977) illustrates the resilience of fish populations even when exploitation rates approach 50% for some age classes annually. Mortality of larval fish due to entrainment at Merrimack Station may therefore have minimal adverse effects upon the Hooksett Pond fish populations because of this compensation.

Fisheries surveys in Hooksett Pond have indicated that the resident fish populations are healthy and reproduce successfully. Since Merrimack Unit II has been in operation for 10 years, these populations have sustained themselves either because of negligible entrainment impact or through compensation, apparently offsetting any losses due to pump entrainment. As a result, larval entrainment is probably not a limiting factor affecting population structures in Hooksett Pond at this time.

8.2.2 Entrapment

The fish entrapment monitoring program for Merrimack Station Units I and II was conducted originally from January 1976 through December 1977 for the purpose of documenting "the types, numbers and frequency of occurrence of fishes entrapped upon the intake screens."

Results of entrapment monitoring during 1976 indicated that the total number of fish impinged throughout the year was 1449, representing 17 species. Bullhead, yellow perch, minnows and sunfish comprised most of the individuals impinged (Appendix Table E-5). Gamefish species such as largemouth and smallmouth bass accounted for only 4% of the catch by number. Projections utilizing 1976 and 1977 data estimated a total annual impingement during 1977 of 2504 fish, of which 74% or 1853 individuals would be minnows.

Based on the 1976 and 1977 entrapment monitoring, the NHWSPCC and USEPA granted a waiver for future entrapment monitoring at Merrimack Station with two stipulations. First, impingement monitoring would resume during May and June 1978, if downstream movement of Atlantic salmon smolts was observed in Hooksett Pond. Second, entrapment monitoring would be conducted from August through October 1978 to determine the entrapment susceptibility of American shad juveniles introduced by PSCoNH during 1978. Entrapment monitoring was, subsequently conducted at Unit I during these stipulated periods, and provided further indication of low impingement rates for resident fish species. Brown bullhead, fallfish, golden shiner, and yellow perch were the species most commonly impinged; only one smallmouth bass, three largemouth bass, and one American shad were collected during the 13 sampling periods (Appendix Table E-6). Greatest entrapment rates appeared to coincide with increased river flow, suspended debris and turbidity, as has been observed during other PSCoNH entrapment studies. Because no salmon smolts and only one American shad were collected during 1978, this entrapment program gave preliminary evidence that American shad juveniles and Atlantic salmon

smolts would not be impinged in substantial numbers while migrating downstream through Hooksett Pond.

8.2.3 Potential Thermal Effects on Representative Finfish Species

Seven of the nineteen resident species in Hooksett Pond were chosen for discussion as representatives of the finfish community on the basis of abundance, sport potential, and value as forage for other species:

TABLE 8-2. REPRESENTATIVE FINFISH SPECIES AND THEIR IMPORTANCE. MERRIMACK RIVER SUMMARY REPORT, 1979.

SPECIES	IMPORTANCE
Smallmouth bass	Gamefish, abundant
Largemouth bass	Gamefish
Pumpkinseed	Community dominant
Yellow perch	Gamefish, abundant, juveniles provide forage
White sucker	Abundant
Brown bullhead	Abundant
Golden shiners	Forage

Anadromous fish species were excluded from consideration because they are not naturally present or self-sustaining in the Merrimack River at this time. The relationship between Merrimack Station and American shad viability in Hooksett Pond has been discussed in NAI (1979b).

Each representative species will be discussed in the following sections with regard to growth, condition, distribution and temperature criteria as observed in Hooksett Pond and established in the literature.

9.0 SUMMARY AND CONCLUSIONS

The addition of heat is the primary physical influence of Merrimack Station on Hooksett Pond. Modifications of the cooling water system during 1972 effectively decreased the mean temperature of the discharged cooling water by 4°C. Present levels of thermal addition to Hooksett Pond sometimes exceed the conditional guidelines established in 1975 for operation of Merrimack Station, but the chemical and biological portions of this monitoring program have consistently demonstrated that existing levels of thermal loading have not been harmful to fish or other aquatic life forms.

Hooksett Pond nutrient concentrations have not been altered by operation of Merrimack Generating Station. Nutrient concentrations declined sharply between 1970 and 1971, most likely as the result of pollution abatement activities in the upper Merrimack River basin. Present concentrations of nitrate and nitrite are within state and federal guidelines. Total phosphate phosphorus concentrations exceed New Hampshire Class B water quality standards, but are normally within levels recommended by federal guidelines for flowing waters.

Dissolved oxygen concentrations in Hooksett Pond have consistently attained federal standards (>5.0 mg/l) since 1972, and have rarely decreased below New Hampshire cold-water standards (6.0 mg/l; 75% saturation). Although the New Hampshire Water Supply and Pollution Control Commission has indicated that low oxygen concentrations have been partially responsible for nonattainment of Class B standards in this portion of the Merrimack River, this monitoring program has indicated only isolated incidents of substandard oxygen concentrations during the past seven years. Discharged cooling water from Merrimack Station has typically been 90 to 100% oxygen saturated, although absolute oxygen concentrations have been reduced as much as 1.8 mg/l compared to ambient because of decreased oxygen solubility at higher temperatures. These reduced oxygen concentrations have not been of sufficient magnitude to jeopardize the Hooksett Pond aquatic ecosystem.

Studies of periphyton, net phytoplankton, and standing crop of primary producers as estimated by chlorophyll *a* concentrations have indicated short-term reductions in abundance of primary producers in the near-field regions. However, reductions in the far-field regions are rare in occurrence, and temporary. Maximum impact appears to coincide with low flows and maximum thermal output during the autumn when diatoms dominate the plankton communities. Overall, there have been no long-term reductions in autotrophic production within Hooksett Pond that can be attributed to the operation of Merrimack Generating Station. In addition, the lack of among-station differences in the net zooplankton communities, coupled with apparent minimal entrainment mortality in terms of the numbers of organisms entrained, suggests no reduction or adverse change in the Hooksett Pond zooplankton community due to the operation of the Merrimack Generting Station.

Field surveys from 1970 to 1974 did not reveal any significant trends in aquatic macrophyte abundance and distribution; the variability evident between years is most likely attributable to long-term riverine cycles. Comparisons of similar habitats above and below the discharge canal revealed differences of lower magnitude than those occurring between years within a given station. These observations suggest that heated effluent from the Merrimack Station has generally had no adverse effect on the distribution and abundance of aquatic macrophytes in the Merrimack River.

Benthic macroinvertebrate distribution throughout Hooksett Pond was influenced primarily by water velocity and substrate composition. The communities observed at mid-channel are, therefore, distinct from the littoral communities; the littoral communities have higher densities and number of taxa because of the finer substrate and increased amount of organic matter. Benthic macroinvertebrate communities upstream and downstream of the Merrimack Generating Station were similar. This similarity may be attributed to: 1) the thermal tolerance of the benthic macroinvertebrate communities, and 2) the surface-configuration of the discharge plume which tends to ameliorate any potential effects.

Therefore, the operation of Merrimack Generating Station has not adversely affected the downstream benthic macroinvertebrate communities in comparison with those from ambient regions.

Hooksett Pond supports a diverse, warm-water finfish community. Fishery surveys from 1967 to 1978 have indicated the continued abundance of the dominant species: smallmouth bass, pumpkinseed, golden and common shiner, white sucker and brown bullhead. The resident populations appear to be healthy and to reproduce successfully. The operation of Merrimack Station appears to have had minimal impacts on these populations through entrapment, entrainment, and thermal additions. The continued success of these species throughout Hooksett Pond indicates that the populations have sustained themselves either because of negligible impact or through compensation, offsetting any losses due to the operation of Merrimack Station.