SUMMARY OF ENVIRONMENTAL STUDIES NEAR THE THREE MILE ISLAND NUCLEAR STATION

October 2007

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EXECUTIVE SUMMARY

Environmental monitoring programs to address the Three Mile Island (TMI) Environmental Technical Specifications were conducted from 1974 through 1990. This report summarizes the findings for several aquatic communities and recreational fishing for those years, and includes a review of upstream passage of American shad.

The fish community was sampled by multiple gear types. Both seine and electrofishing catches reflected the effects of natural population cycles in the reach, with no consistent pattern of temporal or spatial abundance. Several representatives of the sunfish family (e.g., smallmouth bass, redbreast sunfish, rock bass) and the minnow family (spotfin shiner, spottail shiner) were consistently abundant over the study period.

The American shad restoration program implemented for the Susquehanna River has produced two major changes to the fish community. Gizzard shad now represent a major forage species, building in numbers and biomass throughout the study period. Additionally, American shad now migrate upstream as adults in spring, likely rear in the area during summer, and migrate downstream as juveniles through the survey area in the fall.

Sport fishing catches were dominated by smallmouth bass, channel catfish, rock bass, and walleye. Catch and harvest fluctuated as fish populations responded to angler preferences and variable year class success. Effort in the study area approached 40,000 angler-hours by 1990.

Annual macroinvertebrate sampling during the period identified variable numbers of taxa and species diversity, with no consistent trends in spatial or temporal abundance. Two taxa, *Limnodrilus hoffmeisteri* and *Chironomus decorus*, dominated the samples throughout the study period.

Water quality sampling at three stations occurred for water temperature, dissolved oxygen, pH, and total dissolved solids (TDS). Years and months were significantly different, reflecting hydrological influences (river flow). Similarly, no spatial differences were shown for these parameters except for TDS. Slight increases in TDS at stations below TMI may have been related to TMI operations, but were below state water quality criteria.

INTRODUCTION

Environmental monitoring programs to address the Three Mile Island (TMI) Environmental Technical Specifications were initiated in 1974 and continued annually through 1990. Over time, the programs and specifications changed as to frequency, sampling stations, parameters, and target aquatic community. The initial program objectives were to obtain a comprehensive database of established baseline conditions around TMI and thereby evaluate natural fluctuations of various ecosystem parameters identifying any significant biological changes associated with the operation of the nuclear station.

TMI is located three miles south of Middletown, Pennsylvania on an island in Susquehanna River (Figure 1). The study area encompassed a reach locally known as Lake Frederick. The lake is bounded to the north by the Middletown rapids and to the south by the York Haven and Red Hill Dams.

This report briefly summarizes the findings of the monitoring program including a review of the upstream migration of adult American shad; the American shad population was quite low through the late 1980s. Findings of each of the sampled parameters and biological communities are discussed separately below. Where appropriate, comparisons are made with findings from other areas receiving heated effluents (e.g., Conowingo Pond and the Brunner Island reach just downstream of York Haven Dam).

FISH COMMUNITY

Over the years the fish community at TMI has been sampled by many gear types, among them were seine, trap net, fyke net, and electrofishing. Additionally, efforts were initiated to characterize the ichthyoplankton community and sport fishing pressure.

The catches from the seine, electrofishing, and ichthyoplankton programs were examined for the study period to determine seasonal and annual trends in abundance and influences of Three Mile Island Nuclear Station (TMINS). For total seine catches and catch per seine haul of the common species we found that the total catch was largely influenced by the abundance of spotfin shiner, spottail shiner, and mimic shiner. Year-to-year fluctuations in the catch of these common species were generally offset by large increases in the catch of spottail shiner, white sucker, and bluntnose minnow.

The seine catches tended to reflect the effect of natural population cycles. While strong year classes were noted for several species, such as spotfin shiner, mimic shiner, pumpkinseed, and bluegill, likewise weak year classes would be evidenced by steep downturns in their abundances. EA (1986, 1987) reported that a number of factors can affect the abundance of fishes from year to year, including river flow, water temperature, food availability, and competition. For instance, substantially higher river flow in 1990 and lower water temperature, particularly July through August, favored the success of early spawning fishes such as spottail shiner and white sucker.

Previous reports (EA 1985, 1986, 1987; RMC 1988a, 1989, 1990) examined the annual catch (number per haul) of dominant fishes at stations upstream and downstream of the TMINS discharge to determine spatial differences. All values were within previously established ranges. Therefore, the variability in station catches was attributed to natural spatial and temporal distribution of these species rather than to any influence of the TMINS discharge.

Similarly, electrofishing catches showed year-to-year and month-to-month variation with no consistent pattern of temporal abundance. Fish of the sunfish family (smallmouth bass, redbreast sunfish, pumpkinseed, rock bass) were commonly collected by electrofisher. Analysis of the spatial and temporal differences in catch per minute data revealed significant differences among seasons and stations with the distribution of fish in York Haven Pond unrelated to the operation or non-operation of TMINS.

Annual, monthly, and spatial trends in fish abundance were statistically analyzed; all factors were significantly different. There was substantial year to year variation in catch rates which obscured any discernable trends. Also there was no statistical grouping of operational or non-operation years. Stations immediately below the TMINS discharge were undifferentiated statistically from those upstream. This suggests that fish abundance was affected by seasonal changes in river flow, water temperature, habitat preferences, and the natural fluctuations inherent in fish populations. There was little evidence that TMINS had any effect on the distribution and/or abundance of fishes.

Ichthyoplanton were collected throughout York Haven Pond to determine the density, distribution, and spawning success of the fish community. Ten taxa dominated the catch (gizzard shad, common carp, spottail shiner, spotfin shiner, mimic shiner, quillback, channel catfish, pumpkinseed/bluegill, tessellated darter, and banded darter). Changes in the total number and/or total density of ichthyoplankton from year to year were related to the spawning success of one or more of the common taxa.

Analysis of the ichthyoplankton abundance temporally and spatially revealed significant differences for all factors. Stations located upstream of the TMINS discharge were undifferentiated from those downstream. Therefore, fluctuations in the ichthyoplankton community appeared to be unrelated to the operation or non-operation of TMINS. Rather fluctuations noted from year to year and within years appeared more related to the dynamic physical (e.g., spawning habitat/nursery area availability) and/or environmental conditions (e.g., river flow, water temperature) in the Susquehanna River.

COMPARISONS WITH OTHER AREAS RECEIVING HEATED EFFLUENT

The fish community in this impounded reach of the Susquehanna River is similar to fish communities in other nearby river reaches. A comparison of the York Haven fisheries data with that from the Conowingo impoundment, which has also been intensively studied due to presence of the various power plants, shows the similarity in the fish community over time. The resident fishes in these impoundments are for the most part comprised of common warm-water species that are found in ponds, lakes, and reservoirs from the southeastern U.S. to Canada. The species composition of the resident fish community has changed little since the late 1960's, except for some specific fish introductions from downstream of the Conowingo Hydroelectric Station.

A list of the species collected from 1997 through 1999 in Conowingo Pond (Normandeau Associates 1998, 1999, 2000) and 1987 through 1990 in York Haven Pond (RMC Environmental Services 1988, 1989, 1990, 1991) are presented in Tables 1and 2. These impoundments were sampled with a variety of fisheries techniques (i.e., seines, trawls, trap nets, electrofishing gear, and creel surveys). Over 48 species have been collected in these impoundments. The spottail shiner, spotfin shiner, mimic shiner, bluntnose minnow, and tessellated darter are common forage species (Tables 3 and 4). Rock bass, redbreast sunfish, green sunfish, pumpkinseed, and bluegill are important pan fishes. The game fishes are channel catfish, smallmouth bass, largemouth bass, and walleye. The family compositions of fishes collected in these impoundments are shown in

Tables 5 and 6. These families should be representative of the composition and abundance of species in these impoundments today.

Similarly, numerous years of fish sampling associated with the Brunner Island Station thermal discharge just downstream of York Haven Dam have provided insight into fish community stability. Most recently, fish catches determined by shoreline electrofishing during 2002-2005 demonstrated comparable species composition to that above York Haven Dam, and with composition also similar to that identified during a decade of Brunner Island monitoring studies conducted from 1981-1990 (Normandeau Associates, Inc. 2005, 2006).

MIGRATORY FISH RESTORATION

One significant change in species composition in the past three decades has been the increase in the relative abundance of gizzard shad, which was inadvertently stocked into Conowingo Pond (Philadelphia Electric Company 1975) in 1972 during efforts to restore American shad to the upper Susquehanna River. Gizzard shad is now one of the dominant species throughout the lower Susquehanna River (Tables 3 and 4). Large numbers of gizzard shad are annually lifted into Conowingo Pond in the spring, along with river herrings (collectively, alewife and blueback herring), and American shad, as these species continue their upstream migration.

Aside from the increase in gizzard shad numbers, the most striking change in the fish communities of the lower Susquehanna River has been the increase in the numbers of anadromous fish moving upstream in spring (adults) and downstream in fall (juveniles). Although no anadromous fish were collected prior to 1974 (Philadelphia Electric Company 1975), adult American shad and river herrings now pass through the lower Susquehanna River impoundments in the spring, en route to upstream spawning locations. Juvenile American shad and river herring migrate downstream through these impoundments in the fall en route to the Chesapeake Bay and eventually to the Atlantic Ocean.

The appearance of these anadromous species is a result of intensive efforts to restore anadromous fish to the Susquehanna River. This restoration program, directed by a consortium of state and federal agencies, has included hatchery stockings, trap and transport of adult pre-spawned fish from below Conowingo Dam, and construction of upstream fish passage facilities at Conowingo (1972 and 1991), Holtwood (1996), Safe Harbor (1996), and York Haven (2000) dams. The riverine habitat above Lake Frederick has been identified as suitable for spawning American shad. The Pennsylvania Fish and Boat Commission annually conducts a monitoring program below York Haven at Columbia, Pennsylvania, which collects juvenile American shad.

UPSTREAM MIGRATION OF AMERICAN SHAD

As part of the intensive restoration effort for American shad, *Alosa sapidissima*, to the upper Susquehanna River a fish ladder was installed at Red Hill Dam in 2000 (Figure 1). The fish ladder is located on the east side of Three Mile Island about three miles from Middletown, Pennsylvania. The location of the ladder is on the opposite side of the island away from the influences of the TMINS intake and discharge. Consequently, the likelihood of upstream migrating adult American shad being exposed to the TMI discharge is remote. Prior to 2000, adult American shad were trucked upstream of York Haven from Conowingo Dam (RM10).

The upstream migration of American shad in the Susquehanna River, as indexed by American shad passage at Conowingo East Fish Lift, typically begins in early to mid-April and extends into early June depending upon the prevailing river flows and water temperature. Over 90% of the run is completed by the last week of May. However, low water temperature (<50°F) and high natural

river flow (>150,000 cfs) may delay the onset of passage and, alternatively, higher water temperatures and low river flows may initiate an early migration. Passage of American shad at the York Haven fish ladder generally occurs between mid-May through early June (water temperature 60-76°F). American shad peak spawning temperature is 65-68°F.

Since 2000, upstream migrating shad have had free access past the Three Mile Island area. However, prior to arriving at the York Haven ladder American shad encounter thermal plumes emanating from two large downstream stations (Peach Bottom Atomic Power Station and Brunner Island Steam Electric Station). To provide a perspective on the size of the thermal plumes from these once-through cooling stations, PBAPS uses about 3,450 cfs and Brunner Island about 1,155 cfs for cooling water. In contrast TMI uses approximately 44 cfs for cooling, thus creating a "tiny" plume relative to the other stations. It is unlikely that this thermal plume poses a barrier to American shad. Moreover, the thermal plume is located on the opposite shore of Three Mile Island from the fishway.

Peach Bottom Atomic Power Station (PBAPS) is located about 48 miles downstream of TMI, and Brunner Island is about 4 miles downstream. Studies have demonstrated that the thermal plume of neither station appears to pose a barrier to migrating American shad. Several radio telemetry studies of American shad in Conowingo Pond, a source of cooling water for PBAPS, indicated that fish were able to migrate past the thermal plume without undue difficulty. The design Δ T of PBAPS condenser cooling discharge water is about 21 °F. The most recent study was conducted in 2001 (Normandeau Associates 2001), a year of low river flow, to specifically assess the effects of PBAPS thermal effluent on upstream migration. Results of this study showed that the tagged shad bypassed the thermal plume and were not delayed by the plume. This finding is similar to that reported by Leggett (1976) in the Connecticut River relative to the thermal effluent for the Connecticut Yankee Nuclear Power Plant, where the condenser cooling water discharge volume is about 700 cfs at a Δ T of 22.5°F.

RECREATIONAL FISHERY

The Susquehanna River below Harrisburg, Pennsylvania is well known for its smallmouth bass and largemouth bass fishery, and also provides opportunities for striped bass and walleye fishing. The catch of these species comprises about 10% of the total catch in each impoundment (Tables 3 and 4). The riverine habitat in Lake Frederick would favor the production of these species.

A creel survey of the recreational fishery near TMI was conducted from April through November over 16 years (1975 through 1990). The study area encompassed Lake Frederick and the tailwater fisheries below York Haven Dam (west) and Red Hill Dam (east). Within this area, anglers were contacted in four areas; the general reservoir, west dam, east dam, and York Haven tailrace. Survey clerks contacted anglers by boat or on foot on weekends and weekdays. Anglers were asked their residence, time spent fishing, catch composition and disposition, and whether the 1979 accident at TMI Unit 2 affected catch disposition. Catch, harvest, and effort were reported as observed data and also expanded to estimate total catch, harvest, and fishing pressure.

The observed data for the entire period are summarized in Table 7. The number of anglers contacted ranged up to nearly 3,000 per season. Effort expended by the total sample of anglers ranged from 2,186 to 6,731 angler-hours per season. The largest number of fish caught and harvested occurred in 1988, whereas the fewest were in 1977. The number of hours fished by this sample followed a similar trend. Catch and harvest rates fluctuated between 0.81 and 2.02 fish per hour and 0.14 and 0.42 fish per hour, respectively. Weather conditions and river flow (discharge) and condition (turbidity) were identified as factors that affected annual fishing effort.

Lake Frederick (general reservoir) typically supported the most fishing effort and catch in each year, whereas the least effort and catch occurred near York Haven Dam (west dam). Lake Frederick effort was primarily by boat angling, whereas York Haven Dam tailrace anglers fished mostly on foot from the angling catwalk. Fish harvest was usually highest in the York Haven Dam tailrace, followed by Lake Frederick. Temporally, June supported the most angler effort during the period, and the least effort occurred in October and November.

The sport fishery near TMI is comprised mostly of local anglers. In 1990, the most recent survey year, 67% of the anglers resided in either York or Dauphin counties, which encompass the survey area. Most of the remainder originated from 24 other Pennsylvania counties and seven other states.

Four species, including channel catfish, rock bass, smallmouth bass, and walleye, historically dominated catch and harvest (Figures 2 and 3). Channel catfish formed at least 21% of the catch in the 1970s but declined thereafter. Smallmouth bass dominated the catch every year but comparatively few were harvested, particularly in years immediately following good year class production when sub-legal fish were more abundant. For example, proportional harvest was low following good year classes of smallmouth bass in 1987 and 1988 (Figure 2). In contrast, nearly half of the catch of channel catfish and rock bass was harvested fairly consistently each year. Walleye annual abundance in the catch has fluctuated broadly, also likely in response to year class abundance, and proportional harvest was consistently low.

Catch rates appeared related to the number of anglers. Generally, as the number of anglers increased the catch rate also increased. Harvest rates, however, did not exhibit a similar trend. Except in 1986 and 1990, when the lowest harvest rates occurred, values in all other years were quite similar. These trends may result from several factors: 1) in some years a relatively large number of sub-legal fish were caught; 2) anglers were fishing primarily for recreation rather than as a source of food; and/or 3) some anglers were species-specific or selective as to the size if fish chosen for harvest.

Total estimated catch, harvest, and effort in the TMI survey area is shown in Table 8. The numbers of angler-hours fished was relatively uniform during the last three survey years (35,862 to 39,953 hours). Estimated catch exceeded 59,200 fish during 1988 and 1989, years following good smallmouth bass reproduction. Estimated fish harvest exceeded 12,000 fish in 1982, 1987, and 1989.

A large number of anglers throughout the 16 survey years indicated that they released or gave away all, or at least a portion of their catch, reflecting an interest in fishing primarily for recreation. A similar trend in angler preference was noted by Denoncourt (1984) in the sport fishery associated with Brunner Island Station below York Haven Dam.

The impact of the 1979 TMINS accident on recreational fishing was assessed in subsequent years by asking whether anglers used their catch differently than they did prior to the 1979 accident. During the year immediately following the TMINS accident (1980), 7.6% of the anglers interviewed indicated that they had changed their use of catch due to the accident. The proportion of anglers expressing a change in catch usage steadily declined during the 1980s, and no anglers reported changing their catch usage in either 1989 or 1990. It now is likely a non-issue. As of 1990, most anglers reported that they eat at least a portion of their catch.

RECENT EVENTS THAT MAY INFLUENCE THE SPORT FISHERY

There are no updated creel survey data for this portion of the Susquehanna River. However, this river reach is within an ongoing 2007 creel survey effort overseen by the PFBC. The smallmouth bass remains the most important sport species in this reach of the Susquehanna River, as discussed above. Recent (2005) concerns about poor fishing for smallmouth bass expressed by fishing guides and the angling public generated a public seminar hosted by the Pennsylvania Fish and Boat Commission (PFBC) in January 2006. A further impetus for the seminar was concern over dead smallmouth bass reported by anglers in the river south of Harrisburg during the unusually severe high temperature-low flow period in 2005. The PFBC attributed fishing quality variability to normal fluctuations in year class success. In particular, recent poor fishing for smallmouth bass was largely caused by several recent cold, wet springs that dampened smallmouth bass spawning and recruitment success. Moreover, the dead smallmouth bass in summer 2005 were attributed to high natural river temperatures that facilitated infection of smallmouth bass by common water bacteria, *Flavobacterium columnare*. Substantial data presented at the seminar showed that other factors that can affect smallmouth bass populations such as water quality and food supply were unaltered.

Studies reviewed above from the Brunner Island reach below York Haven Dam and the TMI area have demonstrated the long-term stability of fish populations in both areas. The Brunner Island studies have also identified a recent introduction to the fish fauna, the flathead catfish. Initial reports of flathead catfish by anglers suggest it originated from downstream areas, and has propagated upstream via available fish passages. Electrofishing catches near Brunner Island during 2002-2005 noted several size classes, indicating they were reproducing. The fishway at Red Hill Dam provides passage further upriver to these highly predatory catfish, making it likely that they now also inhabit Lake Frederick and may be caught by anglers.

RARE, THREATENED, AND ENDANGERED SPECIES

In more than 20 years of monitoring the fish populations in these impoundments no federally listed endangered species have been collected. No species listed as threatened or endangered by Maryland or Pennsylvania are known to inhabit these impoundments. A Pennsylvania candidate species, the bowfin, has been collected from Conowingo Pond.

INVERTEBRATES

The benthic macroinvertebrate community above and below the TMI discharge was continuously studied from 1974 through 1990. During that period the sampling methodology remained the same and three of the original five sampling stations were unchanged. The overall study can be divided into three periods: early operation (1974 through 1978: TMI Units 1 and/or 2 operational), non-operation (1979 through 1985: TMI Units 1 and 2 shutdown following the March 1979 accident), and late operation (1986 through 1990: TMI Unit 1 operational). Data were analyzed to determine if differences existed between years, months, or stations (Figure 1; this is a figure of the site; does not seem to fit here. Is there a figure missing?). Comparisons were made of number of taxa, diversity and percent similarity indices, total macroinvertebrate density, and density of key taxa. Comparisons of the macroinvertebrate data during these periods revealed wide fluctuations in taxa, density, biomass, and biotic indices.

Total number of taxa collected at each station over the period was highly variable, especially at Station 1A2 (located above the TMINS discharge), which ranged from 40 to 140 taxa. Taxa richness at the TMINS discharge station (11A1) and Station 9B1 (located 1,975m below the TMINS discharge) varied less, and ranged from 50 to 80 and 45 to 91, respectively. During the

three study periods the number of taxa appeared unaffected by TMI operation or non-operation as the number of taxa generally increased through 1983 at all stations with some variation, declined thereafter, and remained relatively stable through 1990.

Diversity values for marcroinvertebrates varied widely over the period regardless of whether TMI was operating or not. Some trends of increasing or decreasing diversity were noted but were likely related to the number of taxa and individuals collected rather than the operation or non-operation of TMI.

The percent similarity indices were used to compare the overall benthic communities between station pairs. Results of the comparisons ranged from 57 to 95%. Percent similarity for the three station pairs was usually greater than 75%, indicating a high degree of similarity among station communities. The data for each station pair indicated that similarity between each of the station pairs was comparable. The two downstream stations, 11A1 and 9B1, exhibited the greatest similarity (82 percent), while the least similarity (77 percent) occurred between the upstream control station (1A2) and the station located 1,975 m downstream of TMINS (9B1). The differences that existed were attributed to minor shifts in current velocity and substrate composition. Generally, the same type of benthic community existed at all three stations.

Total macroinveretebrate density (number/m^2) at all stations was highly variable over the years, suggesting the effect of variable environmental conditions (Figure 4). Past reports have cited fluctuating river flow (resulting from flood or drought), water temperature trends, substrate differences, and insect life cycles as some of the sources for the long-term fluctuations observed at the TMINS stations (EA 1985, 1986, 1987; RMC 1988, 1989, 1990). Generally, overall densities at all stations decreased from the period of plant operation (1974 to 1978) to the period following TMINS shutdown. Total macroinvertebrate density between years was primarily due to differences in *Limnodrilus hoffmeisteri* abundance (Figure 5). Spatial density trends showed a pattern where densities were greatest at Station 11A1; after shutdown, Stations 1A2 and 9B1 had the greatest benthic abundance.

Limnodrilus hoffmeisteri has consistently been among the dominant benthic macroinvertebrate in the TMINS collections, comprising 31 to 84% of the total abundance. Generally, *L. hoffmeisteri* densities were high during the period 1976 through 1980, and much reduced from 1981 through 1984, a time of TMINS shutdown. Since 1985, *L. hoffmeisteri* densities have been variable.

The increase in *L. hoffmeisteri* density suggested a natural response to favorable environmental conditions. High densities of *L. hoffmeisteri* may be due to reduced scouring of the bottom sediment, favorable river flow, and/or warmer water temperatures in the spring and summer which may produce better reproduction conditions resulting in a population increase.

The midge, *Chironomus decorus* group, was the second most abundant annually (Figure 6). Annual station densities of *C. decorus* group have varied by an order of magnitude over the study period. No consistent abundance pattern among stations was evident.

None of the station abundance data for benthic macroinvertebrate communities suggest the influence of TMINS. Fluctuations in environmental variables, especially river flow and water temperature, seem to exert the predominant influence on the benthic communities in York Haven Pond.

WATER QUALITY

Historically, river flow has influenced both biological and water quality parameters. Mean river flow was calculated for the April through November portion of each of the period 1980 through 1990. Mean river flow over this period varied widely, influenced by snow melt, spring runoff,

rain events, and drought throughout the period. River flow entering York Haven Pond is divided by islands into three channels (west, center, and east) with the bulk of the flow going down the west and center channels. During period of high river flow nearly half of the river flow goes down the west channel. The intake and discharge structures for the TMINS are located along the west shore of Three Mile Island in the center channel.

To evaluate annual (1974 through 1990) trends in water quality for York Haven Pond, water temperature, dissolved oxygen (DO), pH, and total dissolved solids (TDS) data for the macroinvertebrate stations (1A2, 11A1, and 9B1) were examined. Mean, minimum, and maximum values for these parameters were summarized to look at year-to-year differences (Table 9 this table is missing from the report).

Individual measurements of water temperature, DO, pH, and TDS from 1974 through 1990 were analyzed. The results were similar for all four parameters; years and months were significantly different, but there was no difference among stations, except for TDS. Significant differences among months were expected, given the natural seasonal cycles exhibited by these variables. Significant differences among years for water temperature, DO, pH, and TDS were not unusual, because of the annual variation in precipitation, river flow, and air temperature cycles. The significant interaction of year and month was also attributed to these weather cycles.

If the TMINS discharge affected water quality, substantial sampling station differences would be expected. However, only TDS produced significant differences ($P \leq 0.05$) among stations. That is Station 11A1 (TMINS Discharge) was differentiated from Stations 1A2 and 9B1. The mean TDS at Station 11A1 was 207 mg/l, whereas the means at Station 1A2 and 9B1 were 194 and 201 mg/l, respectively. Further analysis showed that Station 1A2 was significantly different from Stations 11A1 and 9B1. The increase in TDS at the downstream stations (11A1 and 9B1) may be related to the concentration of dissolved solids during TMINS operation and subsequent discharge. However, these differences were slight, and the downstream values were well below the state water quality criteria.

The annual means, which were significantly different for all parameters, were examined for statistical groupings that could be related to years of TMINS operation (1974 to 1978 and 1986 to 1990) versus non-operation (1979 to 1985). For water temperature, only 1985 was distinguishable from all other years. There was a tendency for DO means in operational years (1974 to 1978) to align with lower values, but 1990, an operational year, was undifferentiated from 1979 to 1982, a non-operational period. Values of pH exhibited no grouping that could be related to TMINS operational status. The last three non-operational years (1983 to 1985), for example, were not differentiated from operational years 1974, 1975, 1988, 1989, and 1990. Generally, pH values increased from 1974 through 1982, decreased through 1987, rose in 1988, and have remained similar through 1990. TDS, available for six operational years, could not be differentiated from non-operational years.

Based on analysis of 17 years of data for water temperature, pH, and DO, and 13 years for TDS, there is no evidence of significant influence of the TMINS discharge on these parameters. Annual and spatial trends appear natural and related to meteorological cycles and river flow. Most water quality parameters reflected the influence of the varied geology, land, and water use practices throughout the Susquehanna River basin rather than TMINS.

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Table 1

Scientific and common names of fishes collected in Conowingo Pond, June through October 1997 through 1999.

Clupeidae	**Herrings**	**Ictaluridae**	**Bullhead catfishes**
Alosa sapidissima	American shad	Ameiurus catus	White catfish
Dorosoma cepedianum	Gizzard shad	Ameiurus natalis	Yellow bullhead
		Ameiurus nebulosus	Brown bullhead
Salmonidae	**Trouts**	Ictalurus punctatus	Channel catfish
Salmo trutta	Brown trout		
		Cyprinodontidae	**Killifishes**
Cyprinidae	**Carps and minnows**	Fundulus diaphanus	Banded killifish
Campostoma anomalum	Central stoneroller		
Clinostomus funduloides	Rosyside dace	**Percichthyidae**	**Temperate basses**
Cyprinus carpio	Common carp	Morone americana	White perch
Notropis buccatus	Silverjaw minnow	Morone saxatilis	Striped bass
Exoglossum maxillingua	Cutlips minnow	M saxatilis x M chrysops	Striped bass x white bass
Notemigonus crysoleucas	Golden shiner		
Notropis amoenus	Comely shiner	**Centrarchidae**	**Sunfishes**
Luxilus cornutus	Common shiner	Ambloplites rupestris	Rock bass
Notropis hudsonius	Spottail shiner	Lepomis sp	Lepomis sp
Notropis procne	Swallowtail shiner	Lepomis auritus	Redbreast sunfish
Notropis rubellus	Rosyface shiner	Lepomis cyanellus	Green sunfish
Cyprinella spiloptera	Spotfin shiner	Lepomis gibbosus	Pumpkinseed
Notropis volucellus	Mimic shiner	Lepomis macrochirus	Bluegill
Pimephales notatus	Bluntnose minnow	Micropterus dolomieu	Smallmouth bass
Rhinichthys atratulus	Blacknose dace	Micropterus salmoides	Largemouth bass
Rhinichthys cataractae	Longnose dace	Pomoxis annularis	White crappie
Semotilus atromaculatus	Creek chub	Pomoxis nigromaculatus	Black crappie
Semotilus corporalis	Fallfish		
		Percidae	**Perches**
Catostomidae	**Suckers**	Etheostoma blennioides	Greenside darter
Carpiodes cyprinus	Quillback	Etheostoma olmstedi	Tessellated darter
Catostomus commersoni	White sucker	Etheostoma zonale	Banded darter
Hypentelium nigricans	Northern hogsucker	Perca flavescens	Yellow perch
Moxostoma macrolepidotum	Shorthead redhorse	Percina caprodes	Logperch
		Percina peltata	Shield darter
		Stizostedion vitreum	Walleye

Data compiled from Normandeau Associates (1998, 1999, 2000).

Table 2

Scientific and common names of fishes collected in York Haven Pond, April through November 1987 through 1990.

Anguillidea	**Freshwater eels**	**Catostomidae**	**Suckers**
Anguilla rostrata	American eel	Carpiodes cyprinus	Quillback
		Catostomus commersoni	White sucker
Clupeidae	**Herrings**	Hypentelium nigricans	Northern hogsucker
Alosa pseudoharengus	Alewife	Moxostoma macrolepidotum	Shorthead redhorse
Alosa sapidissima	American shad		
Dorosoma cepedianum	Gizzard shad	**Ictaluridae**	**Bullhead catfishes**
		Ameiurus catus	White catfish
Osmeridae	**Smelts**	Ameiurus natalis	Yellow bullhead
Osmerus mordax	Rainbow smelt	Ameiurus nebulosus	Brown bullhead
		Ictalurus punctatus	Channel catfish
Salmonidae	**Trouts**	Noturus insignis	Margined madtom
Salmo gairdneri	Rainbow trout		
Salmo trutta	Brown trout	**Cyprinodontidae**	**Killifishes**
Salvelinus fontalis	Broook trout	Fundulus diaphanus	Banded killifish
Esocidae	**Pikes**	**Percichthyidae**	**Temperate basses**
Esox lucius	Northern pike	Morone saxatilis	Striped bass
Esox masquiningy	Muskellunge	M saxatilis x M chrysops	Striped bass x white bass
Esox niger	Chain pickerel		
Esox lucius x E. masquinongy	Tiger muskie	**Centrarchidae**	**Sunfishes**
		Ambloplites rupestris	Rock bass
Cyprinidae	**Carps and minnows**	Lepomis auritus	Redbreast sunfish
Campostoma anomalum	Central stoneroller	Lepomis cyanellus	Green sunfish
Cyprinus carpio	Common carp	Lepomis gibbosus	Pumpkinseed
Exoglossum maxillingua	Cutlips minnow	Lepomis macrochirus	Bluegill
Nocomis micropogon	River chub	Micropterus dolomieu	Smallmouth bass
Notemigonus crysoleucas	Golden shiner	Micropterus salmoides	Largemouth bass
Notropis amoenus	Comely shiner	Pomoxis annularis	White crappie
Luxilus cornutus	Common shiner	Pomoxis nigromaculatus	Black crappie
Notropis hudsonius	Spottail shiner		
Notropis procne	Swallowtail shiner	**Percidae**	**Perches**
Notropis rubellus	Rosyface shiner	Etheostoma olmstedi	Tessellated darter
Cyprinella spiloptera	Spotfin shiner	Etheostoma zonale	Banded darter
Notropis volucellus	Mimic shiner	Perca flavescens	Yellow perch
Pimephales notatus	Bluntnose minnow	Percina peltata	Shield darter
Rhinichthys atratulus	Blacknose dace	Stizostedion vitreum	Walleye
Rhinichthys cataractae	Longnose dace		
Semotilus atromaculatus	Creek chub		
Semotilus corporalis	Fallfish		

Data compiled from RMC Environmental Services (1988, 1989, 1990, 1991).

Table 3

Number and percent composition of fishes collected by all gear types in Conowingo Pond, June - October 1997 - 1999

	1997		1998		1999		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
American shad	0	0.00	1	0.00	1	0.01	2	0.00
Gizzard shad	701	3.00	1,152	5.27	3,019	19.70	4,872	8.04
Brown trout	1	0.00	2	0.01	0	0.00	3	0.00
Central stoneroller	2	0.01	0	0.00	2	0.01	4	0.01
Rosyside dace	67	0.29	24	0.11	67	0.44	158	0.26
Common carp	102	0.44	159	0.73	147	0.96	408	0.67
Cutlips minnow	4	0.02	0	0.00	7	0.05	11	0.02
Golden shiner	61	0.26	39	0.18	15	0.10	115	0.19
Comely shiner	147	0.63	109	0.50	148	0.97	404	0.67
Common shiner	21	0.09	142	0.65	55	0.36	218	0.36
Spottail shiner	431	1.84	1,704	7.79	79	0.52	2,214	3.65
Swallowtail shiner	11	0.05	7	0.03	7	0.05	25	0.04
Rosyface shiner	29	0.12	20	0.09	6	0.04	55	0.09
Spotfin shiner	2,869	12.27	5,165	23.61	4,308	28.11	12,342	20.37
Bluntnose minnow	1,373	5.87	1,191	5.44	885	5.77	3,449	5.69
Blacknose dace	14	0.06	5	0.02	23	0.15	42	0.07
Longnose dace	25	0.11	1	0.00	9	0.06	35	0.06
Creek chub	38	0.16	12	0.05	47	0.31	97	0.16
Fallfish	5	0.02	4	0.02	3	0.02	12	0.02
Silverjaw minnow	0	0.00	0	0.00	2	0.01	2	0.00
Mimic shiner	872	3.73	665	3.04	86	0.56	1,623	2.68
Quillback	508	2.17	453	2.07	84	0.55	1,045	1.73
White sucker	370	1.58	7	0.03	142	0.93	519	0.86
Northern hog sucker	23	0.10	2	0.01	4	0.03	29	0.05
Shorthead redhorse	77	0.33	77	0.35	41	0.27	195	0.32
White catfish	6	0.03	12	0.05	7	0.05	25	0.04
Yellow bullhead	15	0.06	13	0.06	14	0.09	42	0.07
Brown bullhead	44	0.19	43	0.20	29	0.19	116	0.19
Channel catfish	7,829	33.50	5,745	26.26	1,519	9.91	15,093	24.92
Banded killifish	0	0.00	0	0.00	3	0.02	3	0.00
White perch	9	0.04	0	0.00	9	0.06	18	0.03
Striped bass	10	0.04	0	0.00	0	0.00	10	0.02
Rock bass	67	0.29	84	0.38	78	0.51	229	0.38
Redbreast sunfish	5	0.02	13	0.06	16	0.10	34	0.06
Green sunfish	263	1.13	478	2.19	398	2.60	1,139	1.88
Pumpkinseed	198	0.85	324	1.48	184	1.20	706	1.17
Bluegill	1,834	7.85	1,920	8.78	1,368	8.92	5,122	8.46
Smallmouth bass	520	2.22	638	2.92	719	4.69	1,877	3.10
Largemouth bass	378	1.62	132	0.60	484	3.16	994	1.64
White crappie	149	0.64	114	0.52	154	1.00	417	0.69
Black crappie	9	0.04	10	0.05	2	0.01	21	0.03
Lepomis sp.	12	0.05	215	0.98	11	0.07	238	0.39
Greenside darter	0	0.00	4	0.02	4	0.03	8	0.01
Tessellated darter	4,149	17.75	1,078	4.93	1,058	6.90	6,285	10.38
Banded darter	3	0.01	5	0.02	0	0.00	8	0.01
Yellow perch	20	0.09	23	0.11	8	0.05	51	0.08
Logperch	91	0.39	71	0.32	55	0.36	217	0.36
Shield darter	4	0.02	3	0.01	1	0.01	8	0.01
Walleye	5	0.02	8	0.04	19	0.12	32	0.05
Striped bass hybrid	0	0.00	0	0.00	1	0.01	1	0.00
Hybrids	2	0.01	1	0.00	0	0.00	3	0.00
Overall	23,373	100.00	21,875	100.00	15,328	100.00	60,576	100.00
Number of species	44		42		45		48	

Data compiled from Normandeau Associates (1998, 1999, 2000).

Table 4

Number and percent composition of fishes collected by all gear types in York Haven Pond, April - November 1987 - 1990.

	1987		1988		1989		1990		Overall	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
American eel	0	0.00	2	0.00	0	0.00	0	0.00	2	0.00
Alewife	0	0.00	0	0.00	0	0.00	1	0.00	1	0.00
American shad	5	0.01	1	0.00	14	0.02	23	0.05	43	0.02
Gizzard shad	901	1.59	1,107	1.10	845	1.18	258	0.53	3,111	1.12
Rainbow smelt	4	0.01	0	0.00	1	0.00	0	0.00	5	0.00
Rainbow trout	0	0.00	0	0.00	3	0.00	3	0.01	6	0.00
Brown trout	2	0.00	0	0.00	1	0.00	1	0.00	4	0.00
Brook trout	1	0.00	1	0.00	1	0.00	3	0.01	6	0.00
Northern pike	0	0.00	0	0.00	0	0.00	4	0.01	4	0.00
Muskellunge	6	0.01	5	0.00	2	0.00	10	0.02	23	0.01
Chain pickerel	0	0.00	1	0.00	0	0.00	1	0.00	2	0.00
Esocidae sp.	0	0.00	1	0.00	2	0.00	0	0.00	3	0.00
Central stoneroller	1	0.00	3	0.00	0	0.00	2	0.00	6	0.00
Common carp	1,159	2.05	1,166	1.16	4,564	6.39	1,544	3.18	8,433	3.05
Cutlips minnow	1	0.00	0	0.00	0	0.00	0	0.00	1	0.00
River chub	2	0.00	0	0.00	0	0.00	2	0.00	4	0.00
Golden shiner	57	0.10	115	0.11	61	0.09	87	0.18	320	0.12
Comely shiner	111	0.20	347	0.35	115	0.16	162	0.33	735	0.27
Common shiner	73	0.13	19	0.02	5	0.01	2	0.00	99	0.04
Spottail shiner	5,978	10.56	8,415	8.38	1,153	1.62	2,358	4.86	17,904	6.47
Swallowtail shiner	18	0.03	154	0.15	254	0.36	328	0.68	754	0.27
Rosyface shiner	0	0.00	0	0.00	1	0.00	0	0.00	1	0.00
Spotfin shiner	18,222	32.20	11,119	11.07	13,465	18.87	8,474	17.47	51,280	18.52
Mimic shiner	7,245	12.80	11,817	11.76	28,129	39.41	10,465	21.58	57,656	20.82
Bluntnose minnow	592	1.05	1,276	1.27	897	1.26	1,552	3.20	4,317	1.56
Blacknose dace	2	0.00	6	0.01	1	0.00	1	0.00	10	0.00
Longnose dace	0	0.00	0	0.00	0	0.00	1	0.00	1	0.00
Creek chub	0	0.00	3	0.00	1	0.00	1	0.00	5	0.00
Fallfish	15	0.03	967	0.96	66	0.09	181	0.37	1,229	0.44
Quillback	1,325	2.34	2,222	2.21	1,688	2.37	1,031	2.13	6,266	2.26
White sucker	402	0.71	4,341	4.32	198	0.28	1,694	3.49	6,635	2.40
Northern hog sucker	48	0.08	24	0.02	5	0.01	74	0.15	151	0.05
Shorthead redhorse	97	0.17	117	0.12	51	0.07	96	0.20	361	0.13
Catostomidea sp.	5	0.01	10	0.01	5	0.01	0	0.00	20	0.01
White catfish	0	0.00	2	0.00	0	0.00	0	0.00	2	0.00
Yellow bullhead	14	0.02	18	0.02	7	0.01	11	0.02	50	0.02
Brown bullhead	3	0.01	33	0.03	4	0.01	23	0.05	63	0.02
Channel catfish	1,515	2.68	1,315	1.31	1,318	1.85	4,442	9.16	8,590	3.10
Margined madtom	2	0.00	0	0.00	0	0.00	0	0.00	2	0.00
Banded killifish	4	0.01	4	0.00	11	0.02	6	0.01	25	0.01
Striped bass	1	0.00	3	0.00	1	0.00	0	0.00	5	0.00
Rock bass	999	1.77	1,284	1.28	1,212	1.70	930	1.92	4,425	1.60
Redbreast sunfish	928	1.64	826	0.82	781	1.09	1,167	2.41	3,702	1.34
Green sunfish	114	0.20	280	0.28	588	0.82	388	0.80	1,370	0.49
Pumpkinseed	1,536	2.71	3,681	3.66	3,042	4.26	1,834	3.78	10,093	3.64
Bluegill	986	1.74	3,860	3.84	2,170	3.04	677	1.40	7,693	2.78
Lepomis sp.	7,091	12.53	35,285	35.12	1,566	2.19	1,654	3.41	45,596	16.47
Smallmouth bass	4,375	7.73	6,761	6.73	7,118	9.97	4,409	9.09	22,663	8.18
Largemouth bass	251	0.44	335	0.33	154	0.22	116	0.24	856	0.31
White crappie	123	0.22	182	0.18	146	0.20	48	0.10	499	0.18
Black crappie	143	0.25	100	0.10	64	0.09	40	0.08	347	0.13
Pomoxis sp.	74	0.13	171	0.17	174	0.24	41	0.08	460	0.17
Tessellated darter	582	1.03	1,503	1.50	800	1.12	3,136	6.47	6,021	2.17
Banded darter	279	0.49	458	0.46	304	0.43	358	0.74	1,399	0.51
Yellow perch	19	0.03	11	0.01	17	0.02	9	0.02	56	0.02
Shield darter	166	0.29	56	0.06	26	0.04	36	0.07	284	0.10
Walleye	1,094	1.93	1,001	1.00	284	0.40	770	1.59	3,149	1.14
Tiger muskie	2	0.00	1	0.00	0	0.00	1	0.00	4	0.00
Striped bass hybrid	0	0.00	1	0.00	0	0.00	0	0.00	1	0.00
Lepomis hybrid	20	0.04	50	0.05	56	0.08	42	0.09	168	0.06
Overall	56,593	100.00	100,460	100.00	71,371	100.00	48,497	100.00	276,921	100.00
Number of species	44		43		43		46		53	

Data compiled from RMC Environmental Services (1988, 1989, 1990, 1991).

Table 5

Percent family composition of fishes collected all gear types in Conowingo Pond, June through October 1997 through 1999.

Species	1997	1998	1999	Overall
Herrings	3.00	5.27	19.70	8.05
Trouts	0.00	0.01	0.00	0.00
Carps and minnows	25.97	42.27	38.47	35.02
Suckers	4.18	2.46	1.77	2.95
Bullhead catfishes	33.77	26.57	10.24	25.22
Killifishes	0.00	0.00	0.02	0.00
Temperate basses	0.08	0.00	0.07	0.05
Sunfishes	14.71	17.96	22.27	17.80
Perches	18.28	5.45	7.47	10.91

Table 6

Percent family composition of fishes collected all gear types in York Haven Pond, April through November 1987 through 1990.

Species	1987	1988	1989	1990	Overall
Freshwater eels	0.00	0.00	0.00	0.00	0.00
Herrings	1.60	1.10	1.20	0.58	1.14
Smelts	0.01	0.00	0.00	0.00	0.00
Trouts	0.01	0.00	0.01	0.01	0.01
Pikes	0.01	0.01	0.01	0.03	0.01
Carps and minnows	59.15	35.24	68.25	51.88	51.55
Suckers	3.32	6.68	2.73	5.97	4.85
Bullhead catfishes	2.71	1.36	1.86	9.23	3.14
Killifishes	0.01	0.00	0.02	0.01	0.01
Temperate basses	0.00	0.00	0.00	0.00	0.00
Sunfishes	29.40	52.57	23.92	23.40	35.34
Perches	3.78	3.02	2.01	8.89	3.94

Table 7

Summary of annual creel survey totals (observed data) for anglers, fish caught, fish kept, hours fished, catch/effort, and harvest/effort near TMINS, 1975 through 1990.

Years	Anglers	Fish Caught	Fish Kept	Hours Fished	Catch/ Effort (h)	Harvest/ Effort (h)
1975	1,560	2,386	1,255	2,953.75	0.81	0.42
1976	1,750	3,170	1,026	3,114.29	1.02	0.33
1977	1,126	1,857	820	2,186.88	0.85	0.37
1978	2,221	4,483	1,517	4,455.85	1.01	0.34
1979	2,215	4,861	1,205	3,966.15	1.23	0.30
1980	2,399	5,611	1,421	4,131.65	1.36	0.34
1981	2,672	6,764	1,684	4,627.65	1.46	0.36
1982	2,751	6,499	1,808	4,776.26	1.36	0.38
1983	2,145	5,102	1,395	3,997.73	1.28	0.35
1984	1,815	4,423	1,200	3,285.40	1.35	0.37
1985	1,750	3,671	1,447	3,458.61	1.06	0.42
1986	2,093	5,191	1,732	4,374.87	1.19	0.40
1987	2,469	7,656	1,852	4,892.44	1.56	0.38
1988	2,964	10,371	2,020	6,731.43	1.54	0.30
1989	2,535	9,597	2,018	5,751.00	1.67	0.35
1990	2,639	6,019	1,129	6,341.71	0.95	0.18

Table 8

Estimated angling parameters in the TMI creel survey area.

Year	Estimates for April - November Period		
	Angler hours	Catch	Harvest
1975	21,220	16,253	8,578
1976	21,341	19,992	6,623
1977	14,773	12,089	5,341
1978	27,992	27,976	9,490
1979	24,546	29,396	7,306
1980	26,980	36,124	9,160
1981	32,373	46,384	11,546
1982	34,053	45,603	12,546
1983	25,927	31,977	8,786
1984	21,097	28,441	7,693
1985	20,408	21,645	8,555
1986	27,452	32,575	10,902
1987	31,870	49,769	12,039
1988	38,651	59,549	11,599
1989	35,862	59,250	12,474
1990	39,953	37,955	7,158

Table 9

Mean, minimum, and maximum values of water quality parameters taken at macroinvertebrate stations near TMINS, April through November 1974 through 1990. Station prefix TM-MI- deleted from table.

	Water Temperature (°C)			pH			Dissolved Oxygem (mg/l)			Total Dissolved Solids (mg/l)		
	1A2	11A1	9B1	1A2	11A1	9B1	1A2	11A1	9B1	1A2	11A1	9B1
1990												
Mean	17.6	17.5	17.5	7.8	7.6	7.7	9.2	9.3	9.2	177	198	185
Min.	8.1	8.3	8.1	7.4	7.4	7.4	7.3	7.7	7.5	122	147	137
Max.	26.5	25.9	26.2	8.5	8.1	8.0	11.2	11.4	11.2	228	260	230
1974 - 1989												
Mean	17.4	17.7	17.9	8.0	8.0	7.9	9.2	9.4	9.3	195	208	202
Min.	3.0	3.0	3.0	6.3	6.3	6.2	3.3	3.8	3.2	85	70	87
Max.	30.0	30.0	30.5	9.4	9.1	9.0	13.2	14.4	14.0	332	382	355

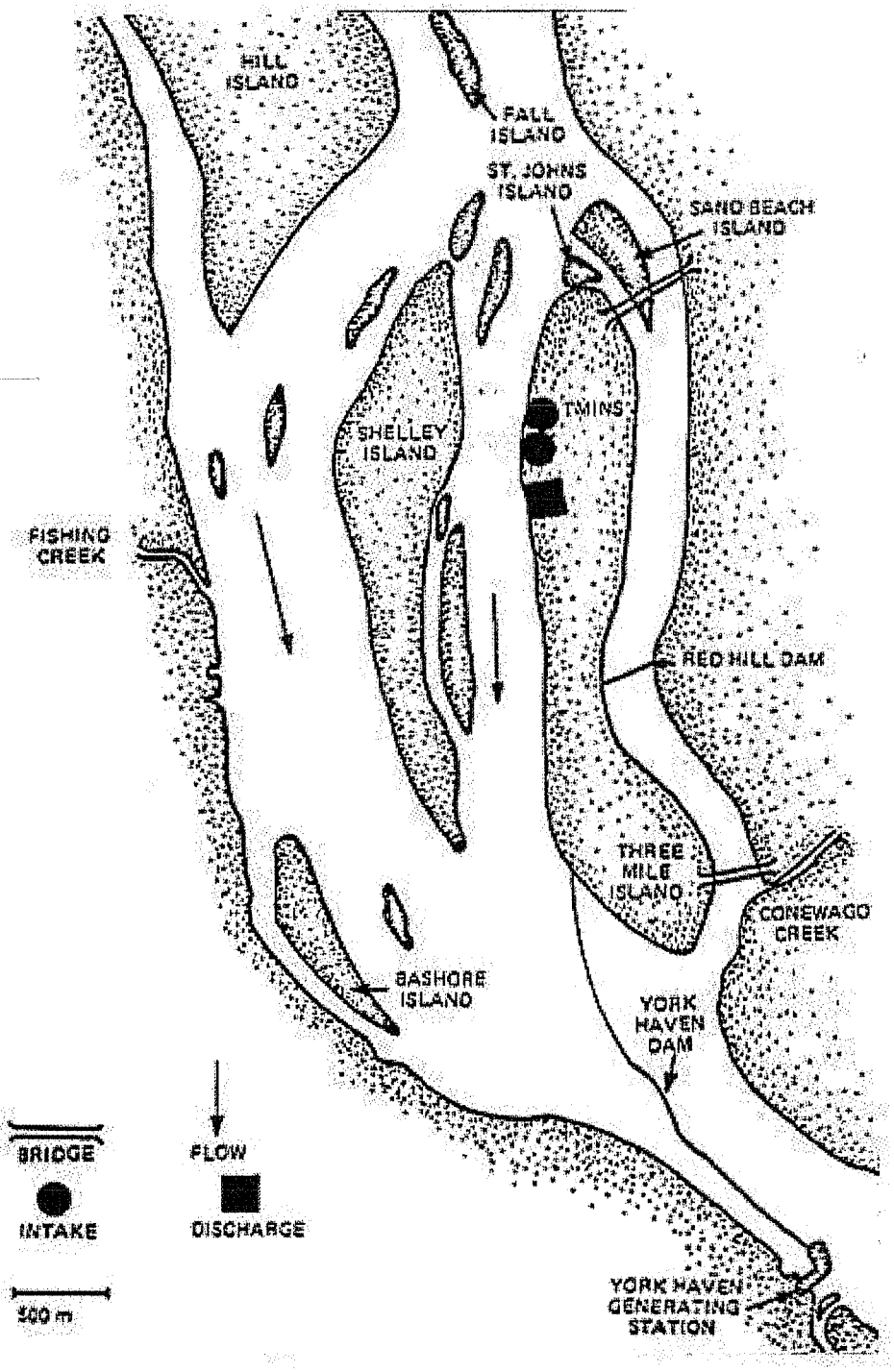

Figure 1. Map of Three Mile Island Nuclear Station aquatic study area.

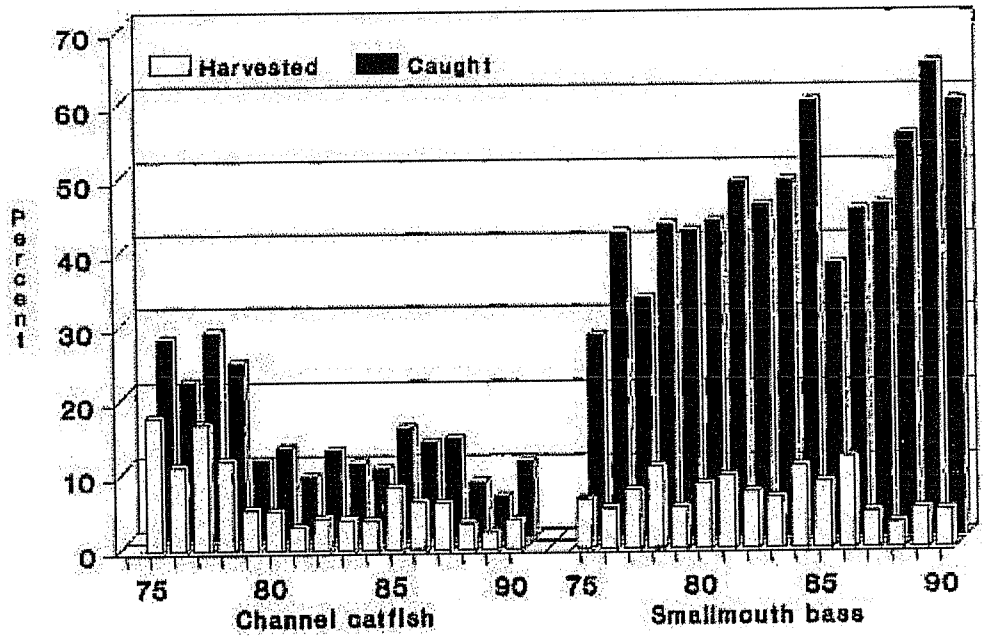

Figure 2. The percent composition of channel catfish and smallmouth bass in the recreational catch and the portion that was harvested by anglers neat TMINS, 1975 through 1990.

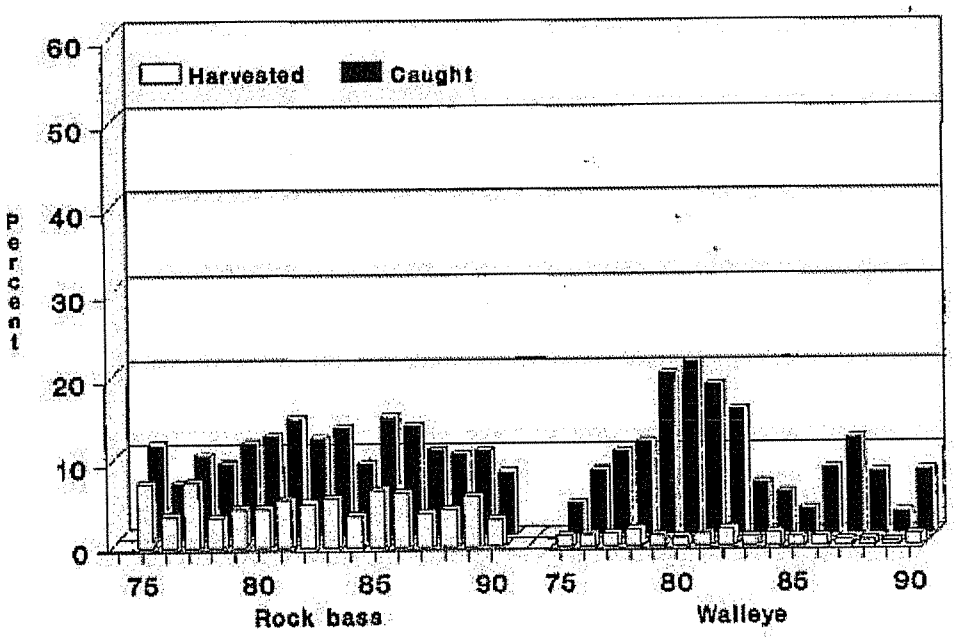

Figure 3. The percent composition of rock bass and walleye in the recreational catch and the portion that was harvested by anglers near TMINS, 1975 through 1990.

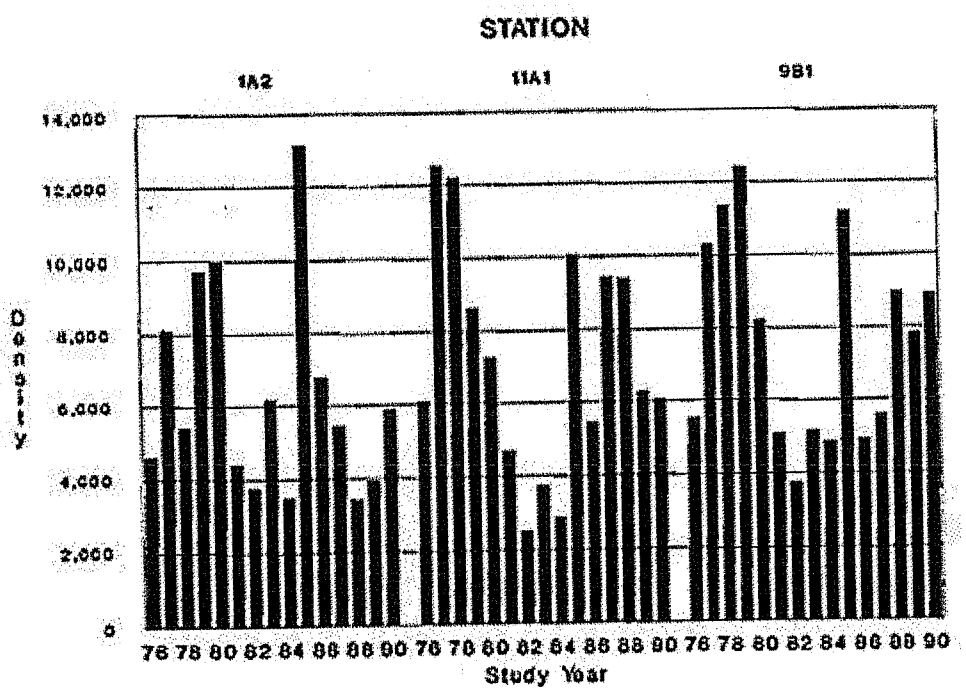

Figure 4. Annual mean total macroinvertebrate density (no./m^2) from stations near TMINS, 1976 through 1990.

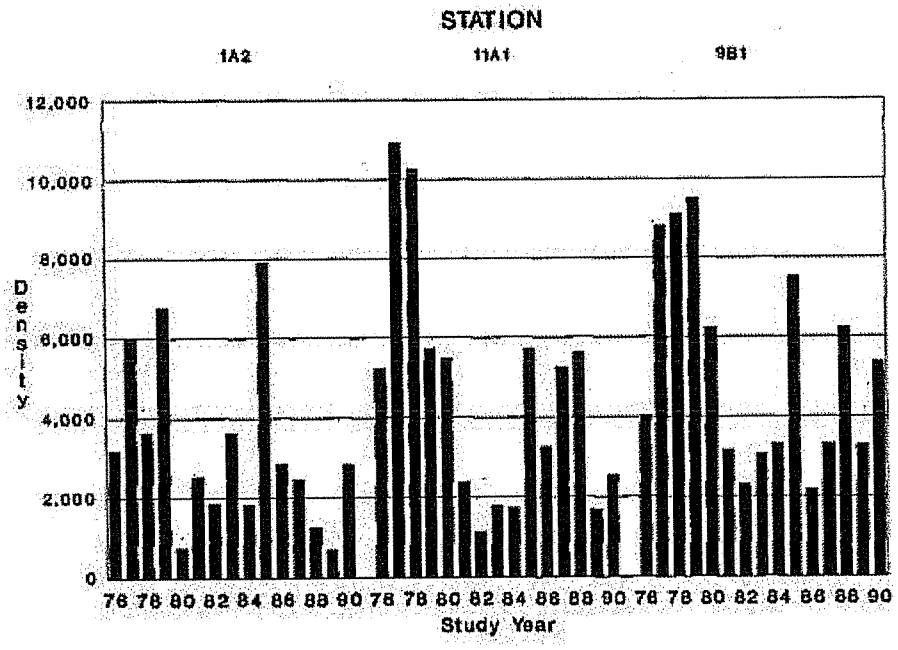

Figure 5. Annual mean densities (no./m^2) of *Limnodrilus hoffmeisteri* at the macroinvertebrate stations neat TMINS, 1976 through 1990.

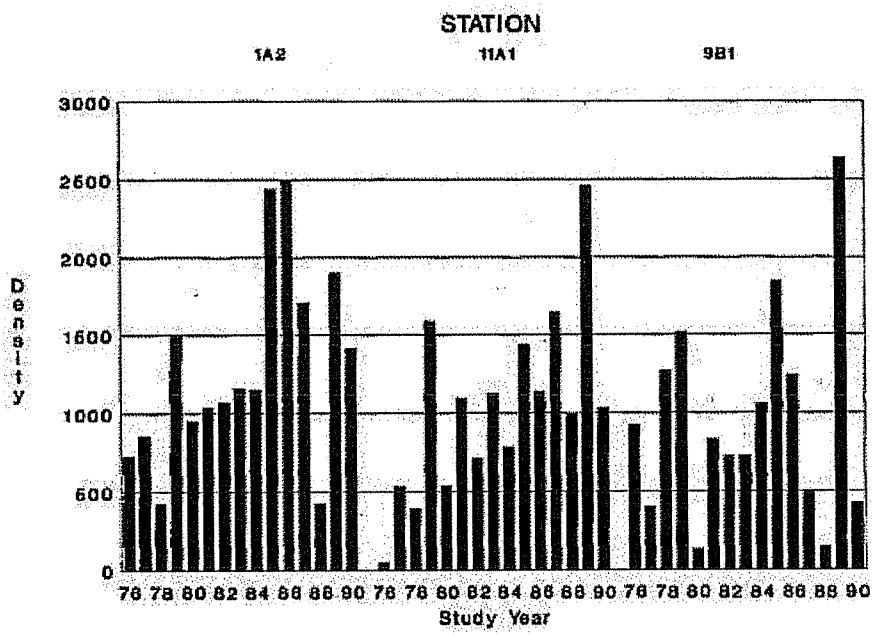

Figure 6. Annual mean densities (no./m^2) of *Chironomus decorus* at the macroinvertebrate stations near TMINS, 1976 through 1990.