§316(a) DEMONSTRATION IN SUPPORT OF A REQUEST FOR INCREASED DISCHARGE TEMPERATURE LIMITS AT VERMONT YANKEE NUCLEAR POWER STATION DURING MAY THROUGH OCTOBER

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NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

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EXECUTIVE SUMMARY

Entergy Nuclear Vermont Yankee, LLC has prepared this §316(a) Demonstration Report in support of a pending request for a nominal increase in certain temperature limits during the summer period of May 16 through October 14 at the Vermont Yankee Nuclear Power Station (Vermont Yankee or Station), which is located on the western shore of the Connecticut River at Vernon, Vermont. The proposed new limits for the summer period change the existing NPDES permit limits only by adding one degree Fahrenheit to the calculated temperature rise (Delta T) that is presently allowed at certain temperatures. No change is proposed during the summer period when ambient Connecticut River water temperatures are above 78°F or below 55°F.

The request allows Vermont Yankee to improve power-generation efficiency by increasing operating flexibility, particularly during periods of reduced Connecticut River flow, and to reduce evaporative losses (i.e. water consumption). Vermont Yankee discharges heated non-contact cooling water to the Connecticut River subject to and with the benefit of a NPDES Permit VT0000264, No. 3-1199, which was issued by the Vermont Agency of Natural Resources, Department of Environmental Conservation (VANR) on 29 August 2001 and expires on 31 March 2006.

Consistent with USEPA guidance, this Demonstration Report details a Type III assessment of the potential effects of the proposed nominal increase in the thermal-discharge limitation, as it relates to nine (9) species of fish identified as Representative Important Species (RIS): American shad (*Alosa pseudoharengus*), Atlantic salmon (*Salmo salar*), spottail shiner (*Notropis hudsonius*), smallmouth bass (*Micropenus dolomieu*), yellow perch (*Perca flavescens*), walleye (*Sander vitreus*, formerly *Stizostedion vitreum*), largemouth bass (*Micropenus salmoides*), fallfish (*Semotilus corporalis*), and white sucker (*Catostomus commersoni*). The first six (6) of these RIS were included in the most recent previous 316(a) demonstration document. These six RIS represent the selected species based upon nearly 30 years of monitoring data and, therefore, allow an effective determination. The remaining three fish species (largemouth bass, fallfish, and white sucker) were added to the current Demonstration Report at the request of VANR.

This Demonstration Report is considered a Type III demonstration because a combination of retrospective and predictive evaluations is used to interpret the biological effects (if any) of the predicted river thermal regime and habitat changes under the proposed new limits compared to the existing (baseline) conditions. Predictive evaluations were used to forecast the changes in the river thermal regime and the associated fish habitats under the existing and proposed new summer Delta T limits. Predictions were made for the downstream compliance point, for lower Vernon Pool of the Connecticut River, and for the Vernon Dam fishway. Retrospective evaluations involved an examination of the recent (1991 –2002) biological monitoring data from lower Vernon Pool and from the Connecticut River in the Vernon Dam tailrace area for evidence of prior appreciable harm to the benthic macroinvertebrate and fish communities, and confirmed the absence of any such harm.

The hydrological and thermal regime in the Connecticut River during the summer periods (May 16 – October 14) of 1998 - 2002 were analyzed to establish recent river flow conditions, confirm that such conditions accord the historical period of record, and project thermal conditions under the proposed new limits. Projections were made of the predicted increase in Connecticut River water temperature at the downstream compliance monitoring location (Station 3) under existing and proposed new permit limits. Analysis of the probability of occurrence of flow and temperature conditions was used

to establish average case (50% occurrence) and extreme case (1% occurrence) reference conditions. Monthly and seasonal flows for the period 1998 – 2002 were representative of a wide range of flow conditions found in the historic (1973 through 2001) period of record. Recent summer seasons were unusually dry, particularly during 2001 and late summer 2002, with a corresponding reduction in river flow. Based upon analysis of the air temperature data from Vernon Dam as a surrogate for water temperatures during the period 1952 through 1997, it was concluded that monthly temperatures experienced during the recent five years (1998-2002) are representative of a wide array of historic monthly temperatures. The very high temperature month observed in August 2001 was nearly as extreme as can be expected for lower Vernon Pool, and analyses based at least in part on these high temperature conditions should be equally as extreme. Therefore, the use of both the recent (1998-2002) river water temperatures and Vernon Dam flow records are conservative with respect to evaluation of the proposed new permit thermal discharge limits for Vermont Yankee.

A three-dimensional time varying model was used to predict the extent of Vermont Yankee's thermal plume in lower Vernon Pool under existing and proposed new summer thermal discharge limits for the average (50% occurrence) case and extreme (1% occurrence) case conditions of flow and upstream ambient temperature. Potential fish habitat changes due to the proposed new thermal regime were quantified based on volume and river bottom area in lower Vernon Pool predicted to be at or above certain specified summer water temperatures drawn from the thermal effects literature for the RIS and supplemental fish species. The hydrothermal model was also used to predict changes that may occur in Vernon Dam fishway water temperatures due to the proposed new thermal discharge limits. This evaluation of the predicted changes found that Vermont Yankee's thermal discharge will ensure protection of the RIS and supplemental fish species for both the average and extreme case conditions of Connecticut River flow and upstream ambient temperature.

The Request, as proposed, would result in only slightly higher summer water temperatures in the Connecticut River downstream from Vernon Dam. The maximum calculated downstream temperature would only slightly exceed 81°F, which is virtually identical in terms of temperature to existing conditions. Likewise, the frequency of occurrence of temperatures greater than 81°F would be slightly higher under the proposed conditions (0.39%), compared to 0.11% of the time for existing conditions (14 hours per summer period, versus 4 hours), respectively. Under the Request, the percent of the time that the calculated Downstream Station 3 temperature would exceed any given temperature would increase, compared to current permit conditions, but that increase would be variable, depending on the temperature.

Similarly, the expected maximum temperature measured at Downstream Station 3 (Maximum Station 3 with Proposed Permit Delta T) is predicted to have exceeded 85°F for 0.15% of the time (about 6 hours per season) compared to no exceedances of 85°F under the existing permit. River water temperature measured at Downstream Station 3 would be expected to exceed 84°F for 0.57% or 21 hours per summer season compared to 0.06% or 2 hours under existing permit conditions. Exceedances under proposed permit conditions of other measured temperatures within the historic temperature range at Downstream Station 3 would be expected to increase from existing permit conditions by less than 1% at low temperature (<55°F) to a maximum of about 11.5% at 76°F.

This §316(a) Demonstration Report reflects the review of the Vermont Agency of Natural Resources (VANR), the technical advisory committee consisting of regional regulators (EAC), and Versar, Inc., a leading national consultant selected by VANR because of its expertise in addressing the hydrothermal and biological considerations in §316(a) demonstrations. As such, this §316(a)

Demonstration Report already reflects comprehensive consideration of, and response to, these reviews. Lastly, this Demonstration Report provides a retrospective evaluation of the results of the VANR- and EAC-approved benthic macroinvertebrate and fish monitoring studies performed during 1991 through 2002, a period following adoption of the incrementally higher temperature discharge limits requested in Vermont Yankee's 1990 §316(a) Demonstration. The results of these studies demonstrate that the existing discharge has not caused appreciable harm to these biological communities.

1.0 INTRODUCTION

On behalf of Entergy Nuclear Vermont Yankee, LLC (Vermont Yankee or the Applicant), this §316(a) Demonstration Report supports the Applicant's pending request (Request) for a nominal increase in certain temperature limits during the period of May 16 through October 14 at the Vermont Yankee Nuclear Power Station (Vermont Yankee or Station), which is located on the western shore of the Connecticut River (River) in Vernon, Vermont (Figure 1-1). The proposed new limits would allow Vermont Yankee to improve power-generation efficiency by increasing Station flexibility, while reducing evaporative losses attributable to cooling-tower use in an environmentally beneficial manner, particularly during periods of reduced River flow.

Under §316(a) of the Clean Water Act, a permit holder such as the Applicant, is entitled to pursue and receive a variance from otherwise applicable thermal-discharge limits, where it provides reasonable assurances, based upon information reasonably available, that the proposed alternative limit adequately "assure[s] the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made ..." 33 U.S.C. §1326(a); *see also* 40 C.F.R. §125.73.

Vermont Yankee discharges heated non-contact cooling water to the River subject to and with the benefit of a NPDES Permit VT0000264, No. 3-1199 (the Permit), which was issued by the Vermont Agency of Natural Resources, Department of Environmental Conservation (VANR) on August 29, 2001 and expires on March 31, 2006. The Permit governs discharges to the River from the Station, and specifies certain annual monitoring requirements that assure compliance with applicable limitations, including §316(a). More particularly, extensive and comprehensive environmental monitoring has been performed in the River in the vicinity of Vermont Yankee during each year since the late 1960s. The studies have covered a wide range of River temperature and flow conditions, and have included all major aquatic community components, including phytoplankton, zooplankton, benthic macroinvertebrates and resident and migratory fish. The monitoring has been performed under all thermal-discharge conditions, ranging from closed cycle to once-through cooling.

Monitoring results are scrutinized by VANR and the Environmental Advisory Committee (EAC), which meets at least once annually to review and evaluate the monitoring performed and results in accordance with the Permit requirements. The EAC is comprised of representatives of the Vermont Department of Environmental Conservation, Vermont Department of Fish and Wildlife, New Hampshire Fish and Game Department, New Hampshire Department of Environmental Services, Massachusetts Office of Watershed Management, Massachusetts Division of Fisheries and Wildlife, and Coordinator of the Connecticut River Anadromous Fish Program for the U.S. Fish and Wildlife Service. Significantly, no substantial adverse impacts to aquatic biota have been identified by the EAC in their annual reviews of the results of the Permit's monitoring program. Further, several changes that have been made to the monitoring program over the years have had the concurrence of the EAC, subject to VANR's approval.

1.1 CHRONOLOGY

A §316(a) Demonstration Report in support of Nuclear Vermont Yankee's request for a nominal increase in certain temperature limits during the period of May 16 through October 14 at the Station was first prepared by Normandeau Associates, Inc. (Normandeau) and submitted by Vermont Yankee

to VANR in February 2003. In late February 2003, Versar, Inc. (Versar) was selected to provide a third-party review of the Demonstration Report on behalf of and under the direction of VANR. Versar's final third-party review was provided to VANR on 9 May 2003 (Versar 2003). VANR then synthesized their review of the February 2003 Demonstration Report and Versar's final third-party review into a request for supplemental information dated 11 July 2003. Subsequent meetings and correspondence ensued among Vermont Yankee, their consultants, VANR, and various members of the EAC, to foster the exchange of information satisfying VANR's 11 July 2003 request. This §316(a) Demonstration Report dated April 2004, hereafter referred to as the Demonstration Report, incorporates the information supplied to VANR into the original February 2004 Demonstration Report.

1.2 ORGANIZATION OF THIS DEMONSTRATION REPORT

The U.S. Environmental Protection Agency's (USEPA's) draft 1977 316(a) Interagency Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements (the 1977 Technical Guidance), the operative guidance document (although it remains in draft), sets forth three types of demonstrations that a §316(a) variance applicant may use to establish that a discharge is appropriately protective of the balanced indigenous population. *See generally* the 1977 Technical Guidance; *see also* April 18, 1974 USEPA Draft Proposal Guidelines for Administration of the 316(a) Regulations (April 1974 Draft Guidelines); September 1974 USEPA 316(a) Technical Guidance — Thermal Discharges (September 1974 Draft Guidance) (superceded by the 1977 Technical Guidance); December 1974 USEPA/NRC/FWS (316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Power Plant Environmental Impact Statements) (1975 Draft Guidance). Indeed, USEPA suggests that state regulators, such as VANR, employ the 1977 Technical Guidance or confirm any deviations with USEPA (1977 Technical Guidance, p. 9).

As these documents provide, a Type III demonstration, such as this Demonstration Report, is a combination of predictive and empirical assessment methods and data (April 1974 Draft Guidelines, pp. 34-35). More particularly, a Type III demonstration properly entails reasonably: (1) identifying the water-body segments occupied by the relevant aquatic biological communities; (2) identifying any critical function zone in that area; (3) identifying biotic categories potentially impacted by the thermal plume; (4) selecting representative important species ("RIS") within impacted biotic categories; and (5) evaluating the potential impacts, if any, of the identified thermal plume on the selected representative important species (RIS). This Demonstration Report tracks EPA's suggested decision train above, all in a manner consistent with EPA's guidance for Type III demonstrations, particularly the 1977 Technical Guidance. In particular, Chapter 3 of the Demonstration identifies the Connecticut River ("River") segment relevant to the Demonstration, and Chapter 5 presents the aquatic communities relevant in that segment of the River. Chapter 4 identifies the critical function zone, equating the area with the locations subject to thermal influence. Chapter 2 details the identified RIS and supports the selection criteria, based upon the extensive biological data set developed over the last several decades (Chapter 6). Chapters 3 through 5, as well as the accompanying hydrothermal assessment (Appendix 3), detail the absence of potential impacts on the relevant aquatic communities, as determined by the identified RIS, attributable to the proposed thermal increase. At the request of VANR, the organization of the April 2004 Demonstration Report

was not changed with respect to the structure of the February 2003 Demonstration Report other than as needed to accommodate the information supplied.

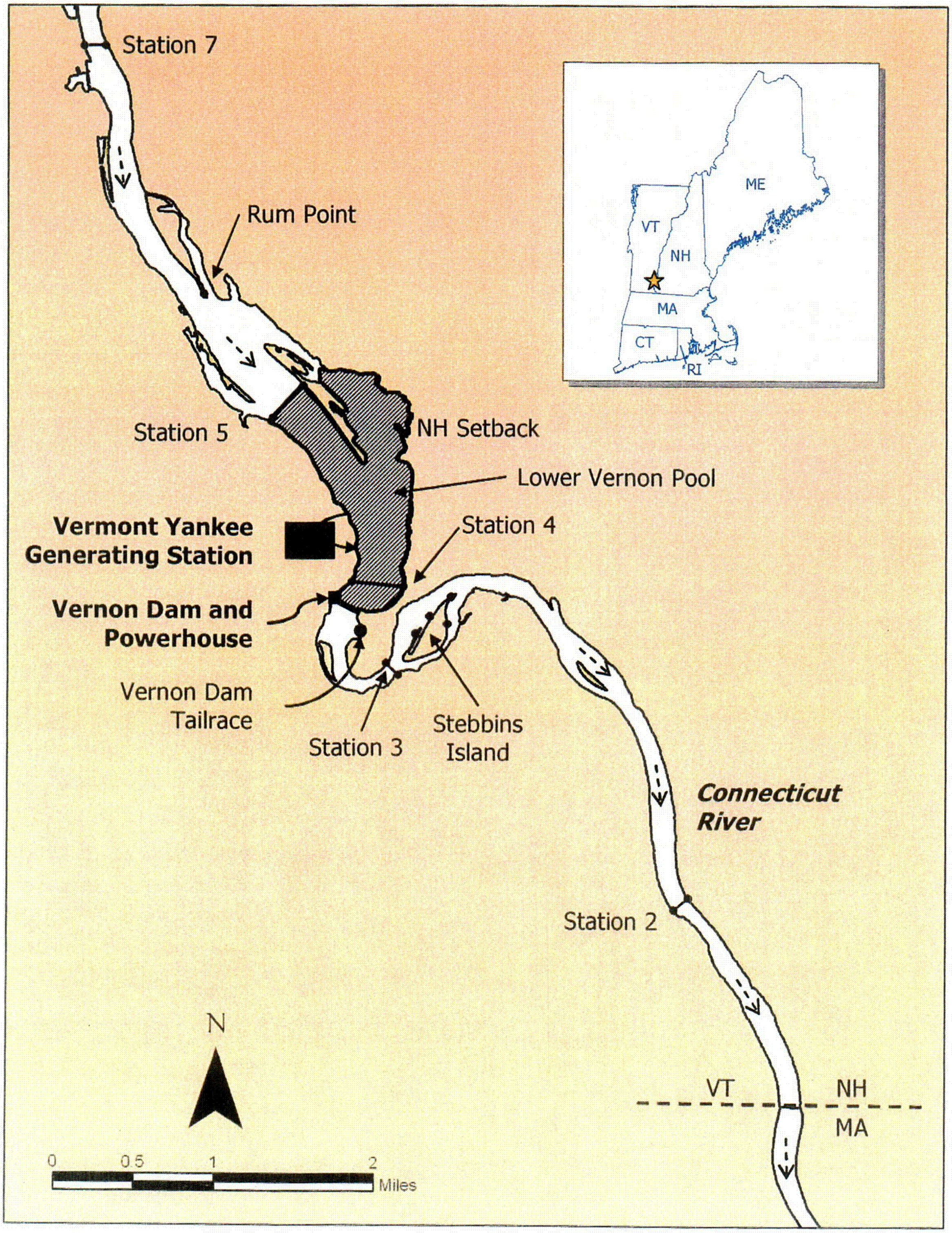


Figure 1-1. Connecticut River in the Vicinity of Vernon Pool.

2.0 SELECTION OF REPRESENTATIVE IMPORTANT SPECIES

This Demonstration Report details an assessment of the potential effects of the proposed nominal increase in the thermal-discharge limitation, as it relates to nine (9) species of fish identified as Representative Important Species (RIS) for this Demonstration: American shad (*Alosa pseudoharengus*), Atlantic salmon (*Salmo salar*), spottail shiner (*Notropis hudsonius*), smallmouth bass (*Microperus dolomieu*), yellow perch (*Perca flavescens*), walleye (*Sander vitrus,* formerly *Stizostedion vitreum*), largemouth bass (*Microperus salmoides*), fallfish (*Semotilus corporalis*), and white sucker (*Catostomus commersoni*). The first six (6) of these RIS were included in the most recent previous 316(a) demonstration document (Downey et al. 1990). These six RIS represent the selected species based upon nearly 30 years of monitoring data and, therefore, allow an effective determination. These fish species continue to be appropriate and representative species for assessment of potential thermal impact consistent with the concept of RIS, as established by the USEPA (1977), e.g., commercial or recreational value, representative members of the balanced indigenous community, an important food item for other RIS, or capable of becoming localized nuisance species. White perch (*Morone americana*) was a seventh RIS in the previous 316(a) demonstration (Downey et al. 1990) that, at the request of VANR, was not included in this Demonstration Report. Three additional fish species (gizzard shad, *Dorosoma cepedianum*; American eel, *Anguilla rostrata*; and sea lamprey, *Petromyzon marinus*) were considered in addition to the RIS in the February 2003 Demonstration Report but were also not included as RIS in this Demonstration Report at the request of VANR. Because no threatened or endangered aquatic species are known to exist in the Connecticut River in the vicinity of Vermont Yankee, none are included as RIS.

It was considered important to VANR to have both lentic and lotic habitat guilds of fish as RIS in addition to anadromous species. The remaining three (3) fish species (largemouth bass, fallfish, and white sucker) were added as RIS for the current Demonstration Report to balance the RIS between lentic and lotic guilds at the request of VANR. The lentic guild of fish represents the community inhabiting slow-flowing or ponded areas of the River like lower Vernon Pool. The lotic guild of fish represents the community inhabiting the rapid-flowing or turbulent areas of the River like the Vernon Dam tailrace. Therefore, the lentic guild of RIS for this Demonstration Report is represented by largemouth bass and yellow perch, while smallmouth bass and fallfish represent the lotic guild (Table 2-1). Walleye, white sucker, and spottail shiner are considered generalists that occupy both lentic and lotic guilds (Table 2-1). American shad and Atlantic salmon are both anadromous species, with the adults passing through both lentic and lotic habitats in the vicinity of Vermont Yankee during the spawning migration, while their egg, larval and juvenile life stages inhabit the lentic and lotic (shad) or lotic (shad and salmon) habitats at certain times of the year until they migrate to the sea (Table 2-1). Largemouth bass replaced white perch among the RIS as a lentic piscivore that is intermediate in its tolerance to non-specific environmental stressors (Table 2-1). Because of the taxonomic, trophic, and tolerance similarities between largemouth bass and smallmouth bass (same genus), the replacement of white perch with largemouth bass provides a similar pair of RIS that differ primarily in their habitat preference.

The nine RIS and other fish species present in the River near Vermont Yankee were also classified into trophic and tolerance guilds based on their feeding habits and tolerance to non-specific environmental stressors (Barbour et al. 1999). Although most fish species pass through several trophic guilds as they develop from larvae to adults, the majority of time during their life in

freshwater is typically spent as adults. Therefore, the trophic guild assignments and tolerance by Barbour et al. (1999) and used in this Demonstration Report (Table 2-1) are based primarily on the reported feeding habits and tolerance of the adult life stage, unless noted otherwise. Exceptions to the primary trophic guild or tolerance classifications occurred when there was disagreement among one or more of the seven references used to select the primary designation, and are noted in Table 2-1.

American shad, valued by anglers in some areas of the Connecticut River, is being restored to the upper River through fish passage improvements and a limited trap and transport program (CRASC 1998), and is commercially harvested in the lower Connecticut River and elsewhere on the East Coast. American shad represent the insectivore trophic guild that is intermediate in pollution tolerance (Table 2-1). They are typically found both in the lentic habitat of lower Vernon Pool and in backwater areas like the New Hampshire setback and Cersosimo Lake, and in the lotic waters of the Vernon Dam tailrace. Atlantic salmon (parr and smolts) would typically be found in the lotic habitat (Vernon Dam tailrace) when present in the vicinity of Vermont Yankee during the early part of the summer period, and also represent the insectivore trophic guild of fish that is intermediate in pollution tolerance (Table 2-1). Atlantic salmon is also the object of an on-going restoration effort in the Connecticut River and in other New England rivers to develop a self-sustaining population that may eventually support sport fisheries. Spottail shiner is a numerically important member of the balanced indigenous community and is a significant prey item for several top carnivore species such as walleye, yellow perch, largemouth bass, and smallmouth bass. Spottail shiner is found in both lentic and lotic habitats in the River near Vermont Yankee, and also represents the insectivore trophic guild that is intermediate in pollution tolerance (Table 2-1). Fallfish is a large minnow species found predominantly in lotic habitat such as that located in the Vernon Dam tailwaters. Fallfish is considered a generalist in its trophic classification, feeding on a wide variety of organisms including insects, fish, crayfish and algae. Fallfish is considered intermediate in its pollution tolerance (Table 2-1). White sucker is an adaptable member of the sucker family that is found in both lentic and lotic habitats in the River near Vermont Yankee. White sucker is considered an omnivore that is tolerant of pollution (Table 2-1). Both smallmouth and largemouth bass are numerically important members of the resident fish community in the vicinity of Vermont Yankee that are valued by anglers as gamefish. Smallmouth bass typically inhabits lotic habitats in the River near Vermont Yankee like the Vernon Dam tailrace, while largemouth bass live in lentic habitats like that found in lower Vernon Pool (Table 2-1). Both smallmouth and largemouth bass are considered to be piscivorous predators that are intermediate in their pollution tolerance (Table 2-1). Yellow perch is a lentic insectivore that is numerous in the River in lower Vernon Pool (Table 2-1). Yellow perch is a recreationally important panfish, as well as a non-migratory species that is reported to be intermediate in its pollution tolerance (Table 2-1). Although the fish monitoring data indicate that walleye is not numerous in the vicinity of Vermont Yankee, this piscivore is reported to be intermediate in its pollution tolerance, and is a non-migratory species found in both lentic and lotic habitats that is valued by anglers (Table 2-1). As RIS, these nine fish species also represent other non-RIS fishes in the same habitat and trophic guilds, with the same pollution tolerance classifications, found in the River near Vermont Yankee. Therefore, conclusions in this Demonstration Report about the interaction of each RIS with the existing and proposed new Vermont Yankee thermal limits both embodies USEPA's requirements for the RIS selected by VANR, and are also sufficiently representative of the other members of the fish community within the same habitat guild, trophic guild, and tolerance classification.

Table 2-1. Habitat[1] and Trophic[2] Guilds, and Tolerance Classifications for Connecticut River Fish Species Present in the 1991-2002 Fish Samples from Lower Vernon Pool and the Vernon Dam Tailrace.

Representative Important Species	Habitat Guild	Trophic Guild	Trophic Exceptions	Tolerance	Tolerance Exceptions
American shad	Lentic and Lotic	Insectivore	Filter feeder	Intermediate	
Atlantic salmon (parr and smolts)	Lotic	Insectivore		Intermediate	Intolerant
Spottail shiner	Lentic and Lotic	Insectivore	Generalist	Intermediate	Intolerant
Fallfish	Lotic	Generalist		Intermediate	
White sucker	Lentic and Lotic	Omnivore	Insectivore, Generalist	Tolerant	
Smallmouth bass	Lotic	Piscivore	Insectivore	Intermediate	Intolerant
Largemouth bass	Lentic	Piscivore	Insectivore	Intermediate	Tolerant
Yellow perch	Lentic	Insectivore	Piscivore, Generalist	Intermediate	
Walleye	Lentic and Lotic	Piscivore		Intermediate	

Other Fish Species Present at VY	Habitat Guild	Trophic Guild	Trophic Exceptions	Tolerance	Tolerance Exceptions
Sea lamprey (ammocetes)	Lentic	Filter feeder		Intermediate	
American eel	Lentic	Piscivore	Generalist	Intermediate	Tolerant
Blueback herring	Lentic	Filterfeeder		Intermediate	
Gizzard shad	Lentic	Omnivore	Filter feeder; Herbivore	Intermediate	Tolerant
Goldfish	Lentic	Omnivore	Generalist	Tolerant	
Common carp	Lentic	Omnivore	Generalist	Tolerant	
Eastern silvery minnow	Lentic	Herbivore	Omnivore	Intermediate	Intolerant
Common shiner	Lentic and Lotic	Insectivore	Generalist	Intermediate	
Golden shiner	Lentic	Omnivore	Insectivore,Generalist	Tolerant	
Spotfin shiner	Lentic	Insectivore		Intermediate	Tolerant
Mimic shiner	Lentic	Insectivore	Generalist	Intolerant	Intermediate
Yellow bullhead	Lentic and Lotic	Insectivore	Omnivore,Generalist	Tolerant	Intermediate
Brown bullhead	Lentic	Insectivore	Generalist	Tolerant	Intermediate
Northern pike	Lentic	Piscivore		Intermediate	Intolerant
Chain pickerel	Lentic	Piscivore		Intermediate	
Brook trout	Lentic and Lotic	Piscivore	Insectivore	Intermediate	Intolerant
Banded killifish	Lentic	Insectivore		Tolerant	Intermediate
White perch	Lentic	Piscivore	Insectivore	Intermediate	
Rock bass	Lotic	Piscivore	Insectivore	Intermediate	Intolerant
Redbreast sunfish	Lotic	Insectivore	Generalist	Intermediate	
Pumpkinseed	Lentic	Insectivore	Piscivore,Generalist	Intermediate	
Bluegill	Lentic	Insectivore	Generalist	Intermediate	Tolerant
Black crappie	Lentic	Piscivore	Insectivore,Invertivore	Intermediate	
Tessellated darter	Lentic	Insectivore		Intermediate	

[1]Source: Scarola, J.F. 1987. Freshwater Fishes of New Hampshire. NH Fish and Game Department. 132 p.

[2]Source: Appendix C in: Barbour et al. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers. Second Edition.* EPA 841-B-99-002.

Note: Exceptions were taken when there was disagreement in one or more of the seven references regarding the trophic guild or tolerance classification of a species; the alternatives are shown

3.0 HYDROLOGICAL AND THERMAL EXPERIENCE OF THE CONNECTICUT RIVER NEAR VERNON, VT: 1998 – 2002

3.1 BACKGROUND

3.1.1 The Vermont Yankee Cooling System

Vermont Yankee is located 0.75 miles upriver of Vernon Dam on a reach of the Connecticut River known as Vernon Pool. Vernon Pool extends upstream about 25 miles to the foot of the Bellows Falls Dam in Bellows Falls, VT and comprises 2,481 surface acres and 0.19366 billion cubic feet of water retained at a full-pond elevation of 220.13 ft behind the Vernon Dam and Hydroelectric Station.

Cooling water is withdrawn by Vermont Yankee (Figure 1-1) from the lowermost reach of Vernon Pool. All, a portion, or none of the cooling water may be returned to Vernon Pool as heated effluent, depending on the mode of operation of Vermont Yankee. Under open cycle, the plant is operated in a "once through" cooling mode, with all cooling water passing through the condenser cooling system and then discharged to lower Vernon Pool. Under closed cycle, all cooling water is pumped through an array of mechanical draft cooling towers, then returned to the intake area for reuse as cooling water, until a portion is discharged to the River as cooling tower blowdown. Under hybrid cycle, Vermont Yankee may modify the amount of cooling water that passes through the cooling towers and the amount that is recirculated, such that the discharge to the River may vary in both temperature and volume.

The typical range in temperature of the heated effluent during the warmer summer months is approximately 80 to 90°F, with a very infrequent worst-case maximum of about 100°F. Discharge volume may vary anywhere between a closed cycle volume of 0 cfs to the maximum once-through cooling water pumping capacity of slightly over 800 cfs.

3.1.2 Connecticut River Discharge

Connecticut River flows are highly controlled by hydroelectric generation activities both upstream and downstream of Vermont Yankee. There are nine hydroelectric dams and three storage dams on the mainstem Connecticut River upstream of Vernon Dam, and there are three hydroelectric dams and one pumped-storage facility downstream. Although storage in the Vernon headpond provides some flexibility of flow release from Vernon Dam, independent of inflow, the upriver hydro stations and Vernon Station are generally operated more or less in unison to maximize power output during times of peak power demand. The hourly flow record for Vernon Dam provides direct evidence of the highly regulated nature of the whole River (for example, see Johnston 1984).

Vernon Station, a 26.4 MW hydroelectric generating facility owned and operated by a U.S. Gen New England entity (PGE), is located on the west (VT) side of the 1,200-ft long Vernon Dam. When River discharge approaches or exceeds station capacity (about 13,280 cfs), the station generates continuously, with any surplus flow spilled from crest gates or deep gates. When River discharge is less than Vernon Station's capacity, all of the River discharge past Vernon Dam is controlled by the facility. The stipulated minimum flow at Vernon Station is 1,250 cfs or inflow if less than 1,250 cfs. This situation leads to two characteristic patterns of regulated discharge: one of high and gradually varying flow, and one of frequent (two or more flow changes during each 24-hour period) cycling

between lower and higher flows characterized by rapid transitions. The duration and magnitude of both the lower and higher flow during periods of cycling is determined largely by the availability of water from upstream sources. Vernon Station has nine hydroelectric units that range in maximum capacity from 1,280 to 1,970 cfs. "Lower" flows are maintained by operating one unit and may likewise vary from 1,250 (the permitted minimum flow) to 1,970 cfs. "Higher" flows are generated by operating multiple units and may vary from 2,560 to 13,280 cfs. Typically, "lower" flows would be maintained for a period of several hours during each day, while "higher" peaking power flows would be maintained the rest of the time. However, under very low flow conditions, PGE may operate Vernon Station continuously at or near 1,250 cfs for several consecutive days.

Because the amount of heat Vermont Yankee can discharge to the Connecticut River is highly dependent on River flow, PGE's operation of Vernon Station and the upstream hydroelectric stations, in conjunction with "ambient" River water temperature, determine to a large extent how much heat Vermont Yankee can discharge while maintaining compliance with its NPDES permit.

3.1.3 Vernon Dam Fish Passage Facilities

At Vernon Station, PGE also owns and operates for certain periods during each year a fish ladder ("fishway") and a downstream fish passage conduit to facilitate both the upstream and downstream passage of anadromous fishes, including Atlantic salmon and American shad. The fishway was installed and became operational in 1981, and the downstream fish conduit (tube) was first operated in 1991. The fishway, located near the western bank of the Connecticut River, is typically run from mid-May through the end of June of each year. The fishway is a concrete structure consisting of a vertical slot ladder from the tailrace leading up to a fish trap and viewing gallery, and an Ice Harbor style ladder that provides passage from the trap up to Vernon Pool. The fishway is supplied with a continuous flow of 65 cfs during the period of operation, and an attraction flow of 40 cfs is also discharged near the foot of the ladder. The "pipe" supplying the additional 40 cfs of attraction flow for the fishway was converted in 1994 into a "fish pipe" and is presently used as an alternate or supplemental downstream fish passage device. The primary downstream fish passage conduit (fish tube) is located in the center of the powerhouse, and 350 cfs of bypass flow is supplied through a 9-ft by 6-ft gate and tube that constricts to a 4-ft by 5-ft opening at the discharge end. The downstream fish passage conduit and the fish tube are operated continuously from April through July and from September through October of each year.

3.1.4 Thermal Discharge Limits

Temperature limits established by VANR in the existing NPDES permit coincide with two compliance periods: May 16 – October 14 ("summer") and October 15 – May 15 ("winter"). Compliance with the thermal limits established for both summer and winter periods is determined by calculating the plant-induced increase in Connecticut River water temperature above ambient conditions using Equation 1-1, which was initially proposed in the Station's 1978 §316(a) demonstration (Binkerd et al. 1978), as accepted by VANR, and has been the operative formula in every subsequent renewed NPDES permit, including the current NPDES permit.

This compliance equation is given below:

$$\Delta Tr = H/(\rho\ Cp\ Qr) \qquad \text{(Equation 1-1)}$$

Where: ΔTr = the discharge-induced temperature increase in the Connecticut River

H = the heat rejection rate to the Connecticut River

ρ = the density of water

Cp = the specific heat of water

Qr = the Connecticut River flow rate at Vernon Dam

Ambient River temperature is monitored at Upstream Station 7, a location 3.5 miles upriver of Vermont Yankee on the Vermont shore and well beyond any potential thermal effect of the Vermont Yankee cooling water discharge (Figure 1-1). The actual change in River temperature due to Vermont Yankee discharges, as well as atmospheric influences, is monitored at Downstream Station 3, located 0.65 miles downstream from Vernon Dam and 1.4 miles downstream from Vermont Yankee.

The River in the vicinity of Upstream Station 7 is approximately 700 feet wide and about 34 feet deep. The intake for this monitoring station is located at a depth of approximately 17 feet and is sufficiently upriver of Vermont Yankee as to be unaffected by operation of the Station. During periods of low River flow, the Connecticut River at Upstream Station 7 is reasonably quiescent and may stratify thermally, particularly during the summer daytime periods. The temperature difference between surface and bottom can be as much as 5°F, and lateral temperature differences of 1°F have been observed. Nevertheless, it is expected that the placement of the intake at mid-depth was intended to monitor waters that are representative of the average River temperature in this portion of the River. Thermal modeling of the Vernon headpond established that temperatures measured at Upstream Station 7 are typically representative of column-weighted average temperatures (Appendix 3).

Downstream Station 3 is located 1.4 miles downstream from Vermont Yankee and about 3,400 feet (0.65 miles) downstream of Vernon Dam. Here the Connecticut River is about 400 feet wide and up to 30 feet deep. Water temperatures measured at Downstream Station 3 are more spatially homogenous than those observed at Upstream Station 7 because of the turbulence in the Vernon tailrace, and because the flow becomes thoroughly mixed as it passes through the Vernon Hydroelectric Station or over Vernon Dam. The intake depth for this monitoring station is at about 8 feet, but depth is of little consequence here, given the well-mixed nature of the River in this location. The cyclical pattern of operation of the hydroelectric facility and the daily cycles of atmospheric heating and cooling induce corresponding cyclical patterns in temperature at Downstream Station 3.

The Connecticut River experiences significant natural changes in temperature from Upstream Station 7 to the Station and to Downstream Station 3, as discussed below. The travel time for water flowing from Upstream Station 7 to Downstream Station 3, a distance of approximately five miles, although it depends on River discharge, is typically between 10 and 30 hours.

The following chart shows the current temperature increase limitation at Station 3 as defined in the NPDES permit, and the proposed new limits, during the summer period of May 16 through October 14.

Upstream Station 7 Ambient Temperature	Calculated Temperature Increase Above Ambient at Downstream Station 3	
	Present Limits	Proposed New Limits
>78 °F	2 °F	2 °F
>63 °F, ≤78 °F	2 °F	3 °F
>59 °F, ≤63 °F	3 °F	4 °F
≥55 °F, ≤59 °F	4 °F	5 °F
<55 °F	5 °F	5 °F

Therefore, the proposed new limits for the summer period would change the existing NPDES permit limits only by adding one degree Fahrenheit to the calculated temperature rise that is presently allowed. No change is proposed during the summer period when ambient Connecticut River water temperatures are above 78°F or below 55°F.

3.2 RECENT HYDROLOGICAL AND THERMAL EXPERIENCE OF THE CONNECTICUT RIVER IN THE VICINITY OF VERMONT YANKEE

Hydrological and thermal conditions in the River have been monitored since the late 1960s, providing a significant data set. Detailed discussions of historic River flows and temperatures are provided in numerous technical reports prepared in support of the previous §316 demonstrations (e.g., Binkerd et al. 1978, Johnston 1984, Luxemberg 1990a, 1990b). The present hydrological and thermal analysis examines the hydrological and thermal conditions in the River during the summer periods (May 16 – Oct. 14) of 1998 - 2002 to establish recent River flow conditions, confirm that such conditions accord the long-term data set, and allow a sound basis for determining how in-River thermal conditions might change under the proposed Request. It also provides technical support for other related modeling and biological investigations that were undertaken in support of the proposed change in summer period thermal discharge limits at Vermont Yankee, and reported in this document.

3.2.1 Historic and Recent Hydrologic Record for the Summer Period (May 16 – Oct. 14)

3.2.1.1 Historic and Recent Monthly and Seasonal Flow Record

Near- and far-field temperature predictions of the anticipated consequences of the Request are based, in part, on the recent (1998 – 2002) flow and temperature record of the Connecticut River in the vicinity of Vermont Yankee. Therefore, it is important to demonstrate how the recent record compares to longer-term historical conditions. The long-term flow record for the Vermont Yankee area was generated from historical data for the North Walpole, NH gauging station[1], located less than 25 miles upstream of Vernon Station and operated by the United States Geological Survey (USGS). Flow data were transformed using log Pearson type III statistical methods, consistent with USGS protocols for developing streamflow statistics. Vernon flow data (generated by Vernon Station) were then compiled to allow comparison with the North Walpole data. Hourly flow data were averaged to

[1] A USGS gauging station immediately below Vernon dam was abandoned in 1973 due to backwater effects from downstream hydroelectric operations. Vernon Station also maintains a record of flow, but the majority of these data are not stored in a readily usable format. Consequently, a source of long-term flow data was needed and the USGS gauging station at North Walpole was selected as a surrogate. Although the flow record for the Connecticut River at North Walpole dates from the 1940s, it has been only since 1973 that minimum flows were maintained at 1200 cfs or higher. For that reason, only the flow record from 1973 to 2001 was used to generate the flow duration curves.

produce average daily flow. These data were then corrected based on differences in watershed area between North Walpole and Vernon (5,493 and 6,266 square miles, respectively, for a difference of 773 square miles) to allow direct comparison with the North Walpole data. Since the River is heavily regulated, particularly during low flow periods, and the 773 square mile tributary area is not, it was decided not to simply prorate flow based on the ratio 5,493/6,266. Instead, we took that portion of the 773 square mile of watershed that is gauged by USGS (West River at Jamaica, VT, which accounts for 179 square miles) and prorated this flow to estimate flow differences between North Walpole and Vernon Dam (772/179 = 4.32; and Vernon flow minus (4.32 times West River flow) = North Walpole flow. Thus, the corrected average daily flows for Vernon Station for each year from 1998 – 2002 were generated for comparison to the historical (1973 – 2001) flow record. From these data, the average monthly (i.e., average of the daily averages for the month) and average seasonal (i.e., average of the daily averages for the season) Vernon Station flows for the same period of record were generated and compared to the historical monthly and seasonal flow record.

Results indicate that monthly and seasonal flows for the period 1998 – 2002 were generally representative of a wide range of flow conditions found in the historic period of record (Figures 3-1, 3-2a-c and Table 3-1). However, very recent summer seasons were unusually dry, particularly during 2001 and late summer 2002. This "representiveness", in conjunction with the recent examples of extreme low flow, supports the use of actual River flow data from the recent (1998-2002) summer periods to examine the potential impact of the Request, while ensuring confidence in the analysis. The very low flow months were nearly as extreme as can be expected for Vernon Pool, and analyses based on these low-flow conditions should be equally as extreme. Therefore, the use of the recent (1998-2002) Connecticut River flow record is conservative with respect to our evaluation of the proposed new permit thermal discharge limits for Vermont Yankee.

Figures 3-1 and 3-2a-c illustrate the historic seasonal and monthly flow duration curves for mid-May through mid-October. Table 3-1 presents a tabular summary of these data. Figure 3-1 shows the seasonal flow duration curve (May 16 – Oct. 14) for the historical period of record (1973 -2001). It is readily apparent from the figure (and from Table 3-1) that seasonal flows for 1998 – 2002 were generally normal, with the probability of occurrence clustering around the 50th percentile mark. As discussed above, the exception was 2001, which was exceptionally dry for the summer season and was greater than the 95th percentile (less than 1 year out of 20) for the summer season.

Figures 3-2a-c present the monthly flow duration curves for the months of May (16th - 31st) through October (1st – 14th). These data are also summarized in Table 3-1. In May and June (Figure 3-2a), flows for 1998 – 2002 ranged widely, with historic flows being greater than recent flows in about 25% (May 2000) to about 90% of the years (May 1998) and in less than 10% (June 2002) to about 97% (June 1999) of the years. This means that recent flows for the month of June (and May as well, but to a lesser extreme) ranged from being quite wet to quite dry, when compared to the historic record.

Similar flow patterns were observed during all other months, as displayed in Figures 3-2b-c and Table 3-1, except that some flows were more extreme. In all months (except July), as many as two years either closely approached or exceeded the 90th percentile which means that these were very low flow months. In fact, average daily flow for August and October 2001 was less than what would be expected once in 100 years.

3.2.1.2 Recent (1998-2002) Hourly Flow Record

The analyses of flow data presented above are based on average daily flows, as derived from the North Walpole gaging station and Vernon Dam. Use of average daily flow is consistent with USGS methods. However, in regulated rivers, particularly rivers where flows cycle widely over a 24-hour period, as here, hourly flow may provide additional information about the frequency of occurrence of a particular flow. This is especially important for Vermont Yankee, because its thermal discharge is directly linked to flow and its NPDES permit requires hourly reporting. Figure 3-3 presents the flow duration curve for Vernon Dam based on recent hourly data for the entire summer seasons of 1998 – 2002. For comparison, the summer season five-year curve based on average daily flow data is also included. Although these curves largely follow one another, it can be seen that the average daily and the hourly flow duration curves are somewhat different at times, particularly in the 80th to 20th percentile range. The average daily curve reflects the general availability of water within the watershed (and from storage) on a daily basis. The hourly curve reflects that water is manipulated during a 24-hour period to achieve power generation objectives. These differences are reflected in Figure 3-3 and, as expected, hourly flow is actually lower than daily flow for 30% of the time (between the 80th and 50th percentiles) and higher than daily flow for another 30% of the time (between the 50th and 20th percentiles). Thus, these data provide a more accurate presentation of the typical flow constraints under which Vermont Yankee operates.

Table 3-2 presents in tabular form the information from Figure 3-3 for selected probabilities. Table 3-2 indicates that Vernon Dam flow as operated by PGE was greater than 1,275 cfs 99% of the time on both an hourly and daily basis. However, at the 90% probability level, hourly flow was greater than 1,412 cfs, whereas daily flow was greater than 1,507 cfs. Similarly, at a 75% probability level, hourly flow exceeded 1,688 cfs, while daily flow exceeded 2,206 cfs. This disparity between daily and hourly flows is typical of rivers where flow is regulated for hydroelectric power, and is often most pronounced in those rivers regulated for peaking power. At both higher and lower probabilities (>95%, < 20%), River flows for both hourly and daily events are more equal since in both ranges of flow, there is less opportunity for manipulating flow to achieve hydroelectric power generation objectives.

In conclusion, recent and historic flow patterns on the River are highly variable on hourly, daily, monthly and seasonal bases. However, recent (1998 – 2002) conditions were similar to those during at least the last 30 years.

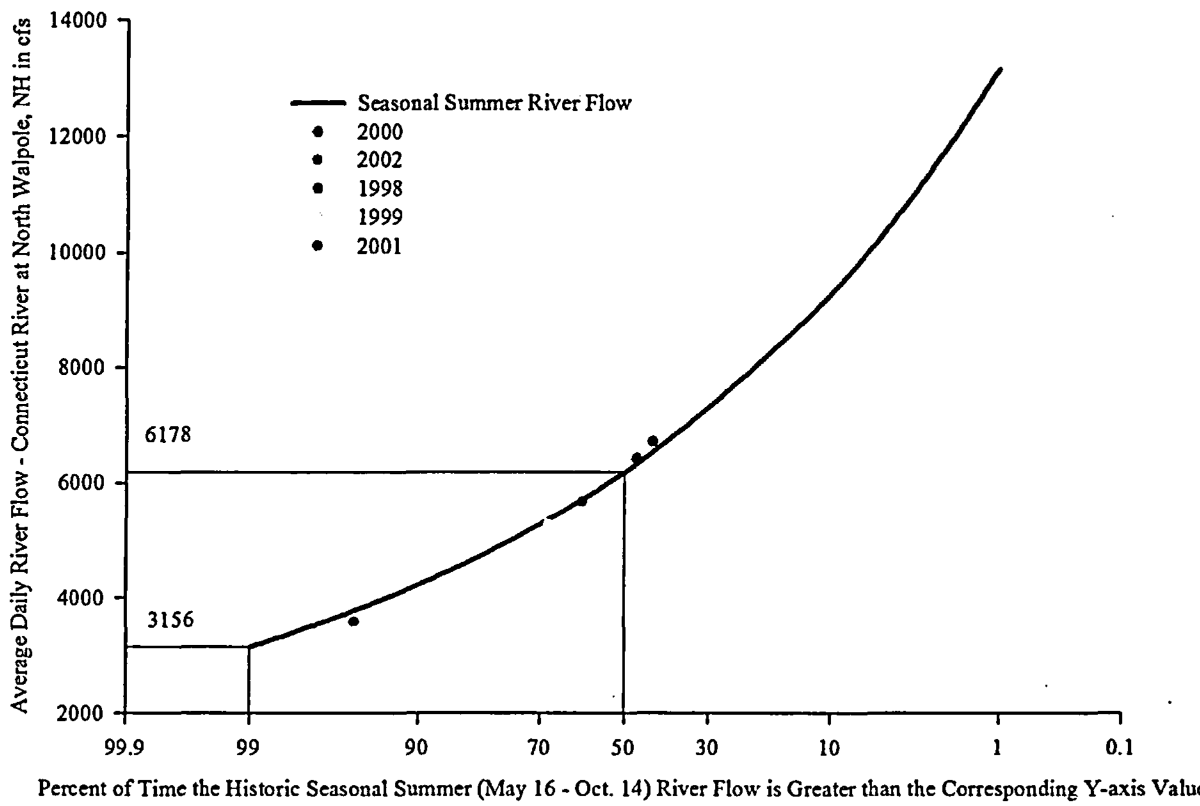
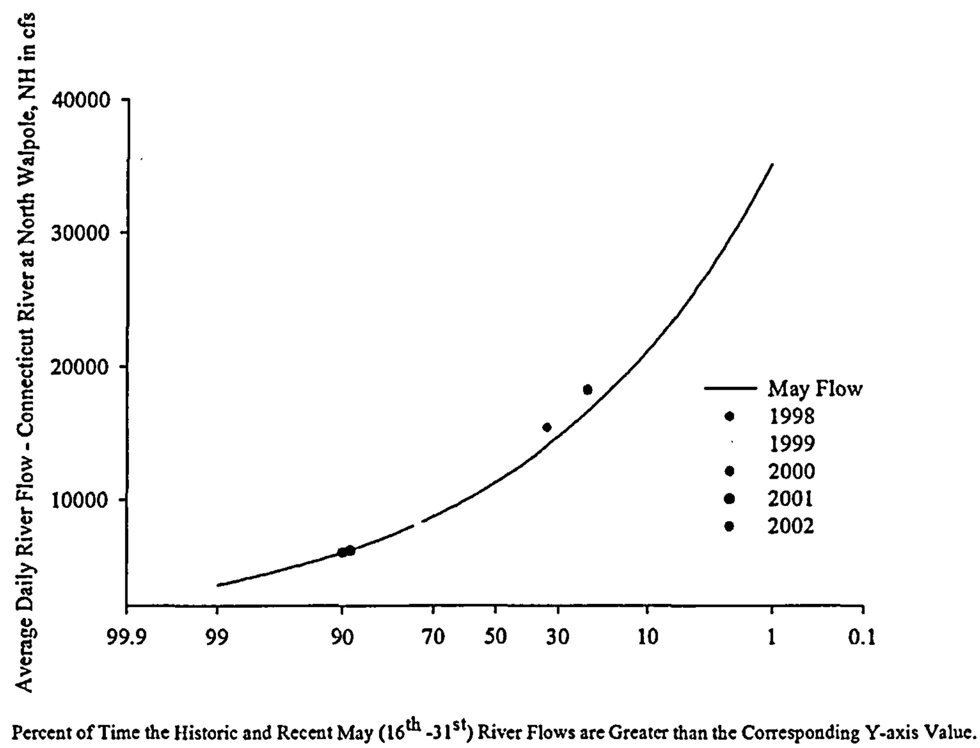


Figure 3-1. Historic Flow Duration Curve for the Connecticut River at North Walpole, NH – Summer Season (May 16 – October 14).



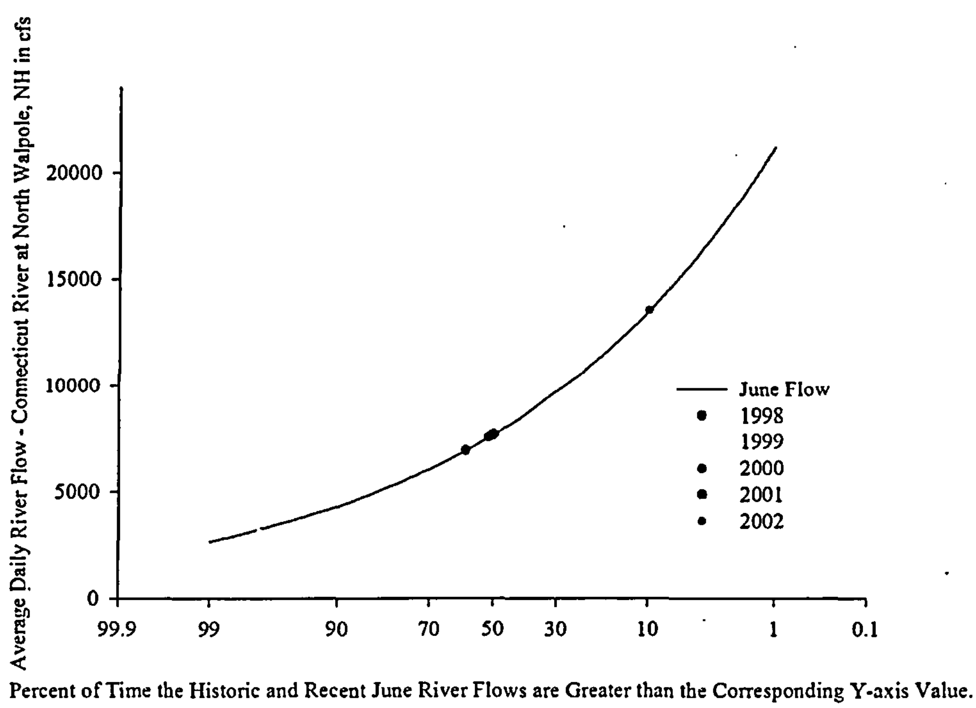
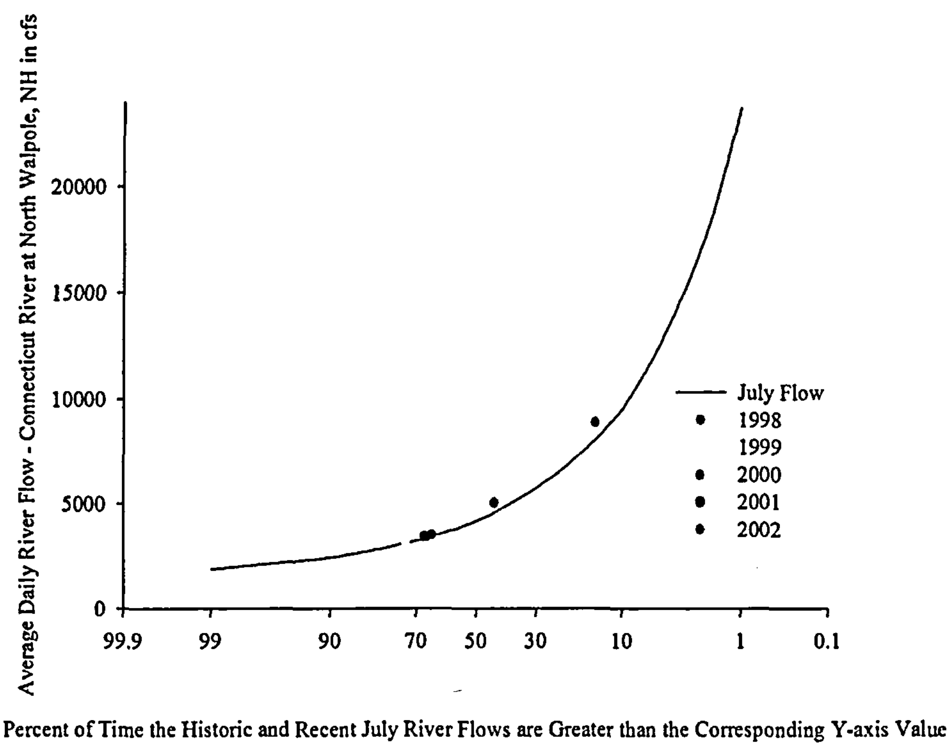


Figure 3-2a. Historic Flow Duration Curve for the Connecticut River at North Walpole, NH – May (16-31) and June.



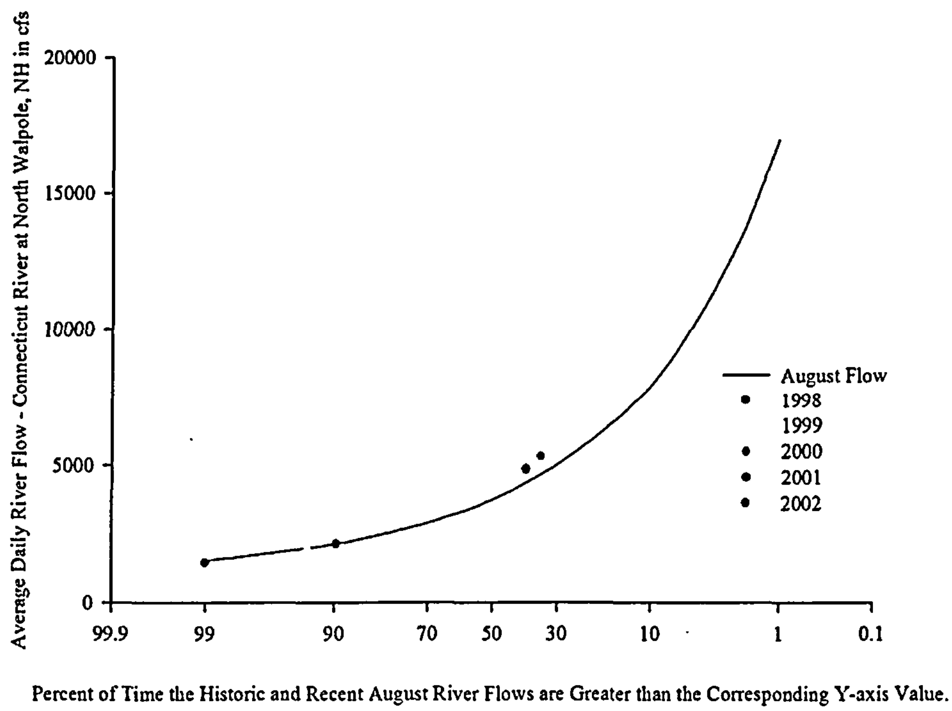
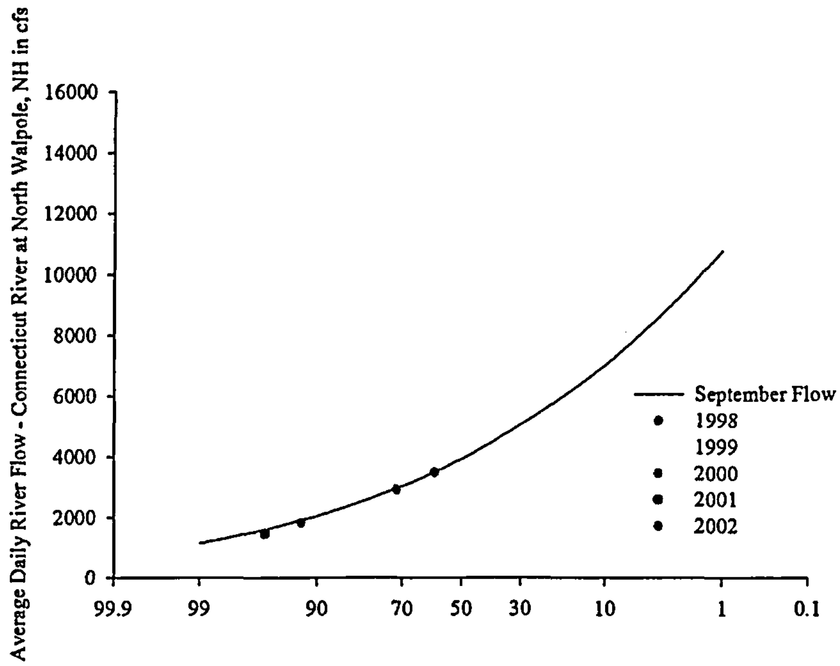
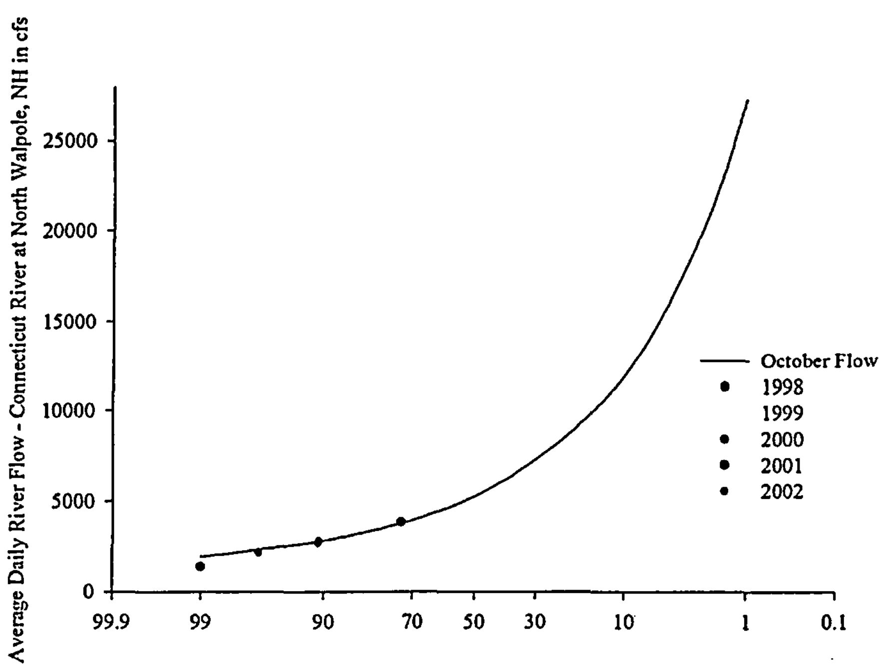


Figure 3-2b. Historic Flow Duration Curve for the Connecticut River at North Walpole, NH – July and August.

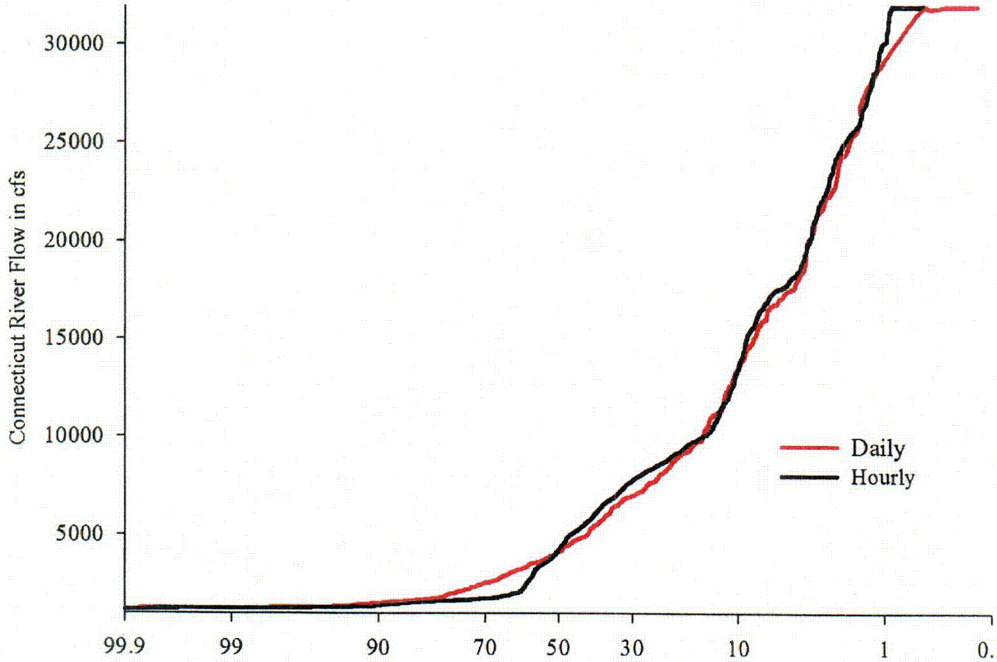


Percent of Time the Historic and Recent September River Flows are Greater than the Corresponding Y-axis Value.



Percent of Time the Historic and Recent October (1st - 14th) River Flows are Greater than the Corresponding Y-axis Value.

Figure 3-2c. Historic Flow Duration Curve for the Connecticut River at North Walpole, NH – September and October (1-14).



Percent of Time that Recent Summer Season Daily and Hourly Flows are Greater than the Corresponding Y-axis Values.

Figure 3-3. Recent (1998-2002) Summer Season (May 16 – October 14) Hourly and Daily Flow Duration for the Connecticut River at Vernon Dam.

Table 3-1. Probability (Percent of Time) that Average Monthly and Seasonal Connecticut River Flow is Greater than Listed Values During the Summer Period (May 16 – October 14).

Probability that Flow is Greater than Listed Flow (%)	May (16-31)	June	July	August	September	October (1-14)	Seasonal
				1460 ('01)		**1382 ('01)**	
99	3563	2678	1908	1529	1157	1936	3156
		3003 ('99)			**1462 ('01)**	**2164 ('02)**	**3595 ('01)**
95	4644	3404	2158	1797	1561	2329	3631
				1914 ('99)	**1837 ('02)**	**2750 ('00)**	
90	5998	4311	2470	2133	2065	2820	4225
	6000 ('98)			***2146 ('02)***			
	6150 ('01)						
75	7988	5568	3119	2734	2769	3732	4957
	8106 ('99)	**6914 ('98)**	**3197 ('99)**		**2919 ('00)**	**3832 ('98)**	**5287 ('99)**
		7529 ('00)	**3452 ('01)**				**5665 ('98)**
		7662 ('01)	**3550 ('00)**		**3550 ('98)**		
50	11305	7663	4201	3735	3943	5253	6178
	15416 ('02)		***5045 ('02)***	***4854 ('98)***			***6416 ('02)***
				5328 ('00)		**7387 ('99)**	**6718 ('00)**
25	17476	11297	7534	6340	5881	9427	8108
	18230 ('00)		**8891 ('98)**				
10	21178	13477	9534	7903	7044	11931	9266
		13551 ('02)			**8113 ('99)**		
2	30825	18847	18285	13715	9690	21711	11975
1	35164	21190	23705	16976	10784	27351	13141

Table 3-2. Probability (Percent of Time) that Average Hourly and Daily Connecticut River Flow is Greater than Listed Values During the Summer Period (May 16 – October 14).

Probability (%)	Hourly flow (cfs)	Daily Flow (cfs)
99	1275	1275
95	1317	1333
90	1412	1507
75	1688	2206
50	4234	4163
25	8425	7716
10	13725	13550
1	30137	28250

3.2.2 Historic and Recent (1998 - 2002) Thermal History for the Summer Period (May 16 – October 14)

3.2.2.1 Historic and Recent Monthly and Seasonal Atmospheric Temperature Conditions at Vernon Dam (Historic) and Vermont Yankee (Recent)

Because projections of the proposed increase in permit Delta T are based in part on recent River temperature data, we determined that, to maximize confidence in the analysis, it was appropriate to evaluate recent data within the context of a longer term temperature baseline, in a manner similar to the analysis of River flow that was presented in Section 3.2.1.1. However, Vermont Yankee has only been operating under its existing allowable Delta T values since 1991. Further, while River temperature has been recorded at Upstream Station 7 and Downstream Station 3 since the late 1960s, much of these data are not in a readily usable format for this analysis. Consequently, a preferred alternative method for evaluating temperature was selected. Because River temperature is directly related to ambient air temperature and because air temperature is widely available, historic average seasonal and monthly air temperatures were developed for a nearby station. Vernon Dam, cooperatively operated by Vernon Dam personnel and the National Climate Center, was selected, due to nearby location and to the length of the temperature record. Daily temperatures were available for 1952 – 1997. Vermont Yankee air temperature data were compiled for the summer period (May 16 – Oct. 14) for 1998 – 2002, for comparison with the historic data.

Figure 3-4 presents the historic and recent seasonal data in the form of probability versus temperature, in much the same way the River flow data were presented. The average seasonal temperature for each recent year is plotted on the temperature probability line to facilitate the determination of how seasonal air temperature in recent years compared to the historical temperature record. As is evident in Figure 3-4, average seasonal temperature for the last five years is well distributed along the historic frequency occurrence curve. Seasonal temperatures for the 1998 through 2002 periods range from about 95% (historic seasonal temperatures were greater in 95% of the years) to approximately 20% (historic seasonal temperatures were greater in only about 20% of the years). This means that recent seasonal temperatures ranged from being quite cold (2000) to quite warm (1999) with respect to historic seasonal temperatures. The other recent seasonal temperatures were well distributed between the two extremes, which demonstrates that recent seasonal air temperature were representative of the range of air temperatures documented in nearly fifty years of historic record.

Similarly, all monthly comparisons exhibit wide variability (Figures 3-5a-c). For example, the June 1999 average temperature was exceeded by only about 7% of the historic June temperatures, which means this was a very warm month. Conversely, both July 2000 and 2001 were exceeded by about 93% of the historic Julys, making these two months very cold from a historic perspective. Interestingly, August 2001 was the warmest August on record, which has a statistical probability of occurrence of about once in 200 years.

Based upon analysis of the air temperature data, we conclude that monthly temperatures experienced during 1998 through 2002 are representative of a wide array of historic monthly temperatures. Again, this combination of representiveness, in conjunction with occasional exceptionally warm months, further supports the use of actual River water temperature data from the recent (1998-2002) summer periods to examine the potential impact. The very high temperature month observed in August 2001 was nearly as extreme as can be expected for lower Vernon Pool, and analyses based at least in part on these high temperature conditions should be equally as extreme. As with River flow, the use of

the recent (1998-2002) river temperature record is conservative with respect to our evaluation of the proposed new permit thermal discharge limits for Vermont Yankee.

3.2.2.2 Measured and Calculated Temperature Response

Pursuant to its NPDES permit, Vermont Yankee's compliance with NPDES permit thermal limits is determined by calculating the temperature rise that would result after complete mixing of the discharge with the River, using Equation 1-1 (Section 3.1.4). During the summer period, the current allowable temperature increase in °F is given in Section 3.1.4.

Ambient River water temperatures are measured continuously to the nearest 0.1°F at Upstream Station 7, located 3.5 miles upriver of (Figure 1-1). Although not strictly related to compliance, River temperatures are also measured continuously to the nearest 0.1°F after complete mixing at Downstream Station 3, located approximately 0.65 downstream from Vernon Dam and 1.4 miles downstream of Vermont Yankee (Figure 1-1).

During the summer period, measured temperatures at Downstream Station 3 are almost always higher than at Upstream Station 7. More importantly, and as discussed in detail below, they are usually higher than can be explained by Vermont Yankee's discharge. Diel data trends in both Downstream Station 3 and in fishway temperature data support the conclusion that atmospheric heating of the Vernon Pool causes the difference.

Figures 3-6a-e present the measured Delta T at Downstream Station 3, representing how much warmer the measured River temperature is below Vernon Dam, compared to the water temperature measured upstream from Vermont Yankee at Upstream Station 7 (i.e., Downstream Station 3 minus Upstream Station 7). These figures also present the existing Delta T, based on the actual waste heat discharge rate from Vermont Yankee under the existing permit limits and River flow (calculated using Equation 1-1), and the difference between the two (measured Delta T minus existing Delta T) for the summer periods of 1998 – 2002.

The existing Delta T is almost always less than 2°F, and well within Vermont Yankee's NPDES permit limits (Figures 3-6a-e). However, measured Delta T (at Downstream Station 3) is almost always greater than 2°F, except occasionally during late spring/early fall when high River flows and low temperatures allow higher Delta Ts pursuant to Vermont Yankee's discharge permit. This is consistent with historic monitoring data throughout the 1970s and 1980s, when Downstream Station 3 was typically 1 – 2°F higher than Upstream Station 7, even though during the '70s Vermont Yankee was not discharging heat to the River during the summer period and during the '80s heat was discharged only experimentally (Johnston 1984; Luxenberg 1990). These data further support the observation that some other source of heat is contributing to downriver temperatures. Because there are no other thermal discharges between Vermont Yankee and Downstream Station 3, the only other source of heat is atmospheric. Similar conditions are displayed for each of the recent years of record (1998 – 2002). Measured Delta T is consistently 1 – 2°F (and occasionally 3 – 4°F) higher than what can be attributed to Vermont Yankee's discharge. Differences are generally greatest during the earlier (June and July) part of the summer season, the time when solar insolation reaches its annual maximum, which provides further evidence that atmospheric inputs heavily influence Downstream Station 3 temperatures.

Figures 3-7a-e present the hourly average temperatures for the fishway at Vernon Dam during the times the fishway was in operation for the years 1998 – 2002. For comparison purposes, Downstream

Station 3, Upstream Station 7, and calculated Station 3 with Existing Permit Delta T are also plotted on the same graphs. These plots clearly establish a periodicity in the recorded temperature associated with measured Delta T and fishway temperatures that is not reflected in either the existing Delta T or Upstream Station 7. Due to differences in scale between Figures 3-6a-e and Figures 3-7a-e, this observation is most evident in the fishway data. Careful examination indicates that this periodicity is largely diel and therefore appropriately linked to atmospheric heating or cooling of River water. Upstream Station 7 and Calculated Station 3 with Existing Permit Delta T show only minor diurnal temperature changes. In addition, fishway temperatures are frequently higher than Downstream Station 3 temperatures (typically by 1 – 2°F, but occasionally by 3 – 4°F). This difference is most apparent during the daytime and less so during the night. Because water supplying the fishway is skimmed off the surface (approximately upper 10 feet), these data strongly support the conclusion that atmospheric influences are affecting the temperature patterns in Vernon Pool.

In contrast, fishway temperatures for 2001, as presented in Figure 3-7d, were consistently lower than Downstream Station 3 temperatures for most of the period that the fishway was operated. This is inconsistent with other years, but it was confirmed by duplicate monitoring. We have no explanation for this inconsistency. Consequently, we simply present the data as collected and without discussion.

Based on the temperature differences displayed in both sets of figures (3-6a-e and 3-7a-e), the Vermont Yankee discharge generally accounts for less than 50% of the temperature increases measured in the fishway and at Downstream Station 3 during the summer season, when compared to Upstream Station 7.

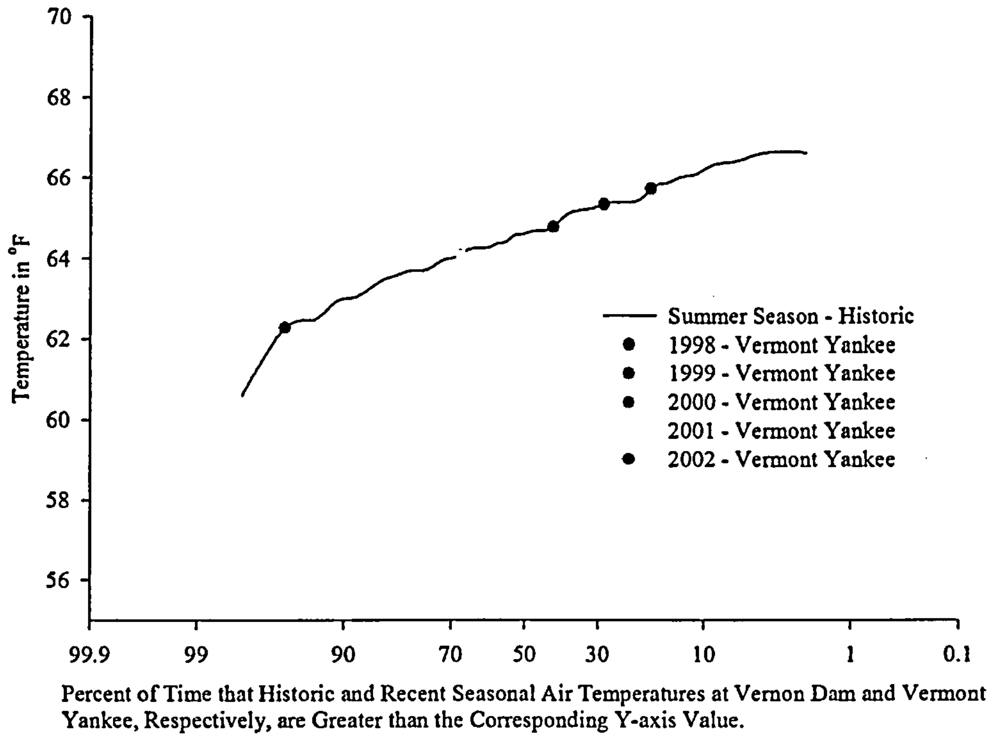
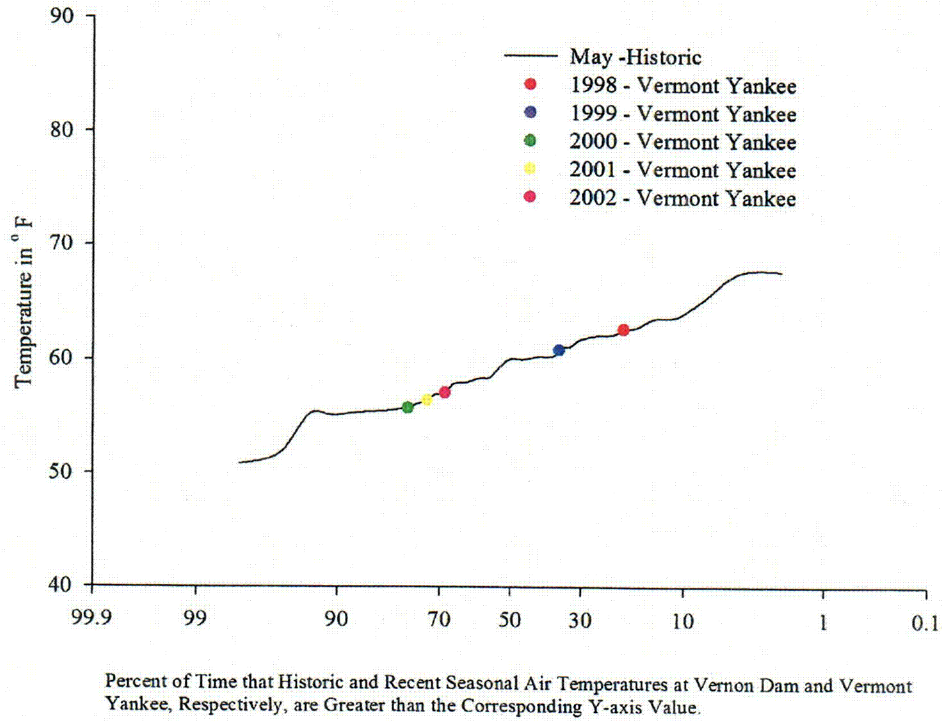


Figure 3-4. Historic Average Summer Season (May 16 – October 14) Air Temperature Duration Curve at Vernon Dam.



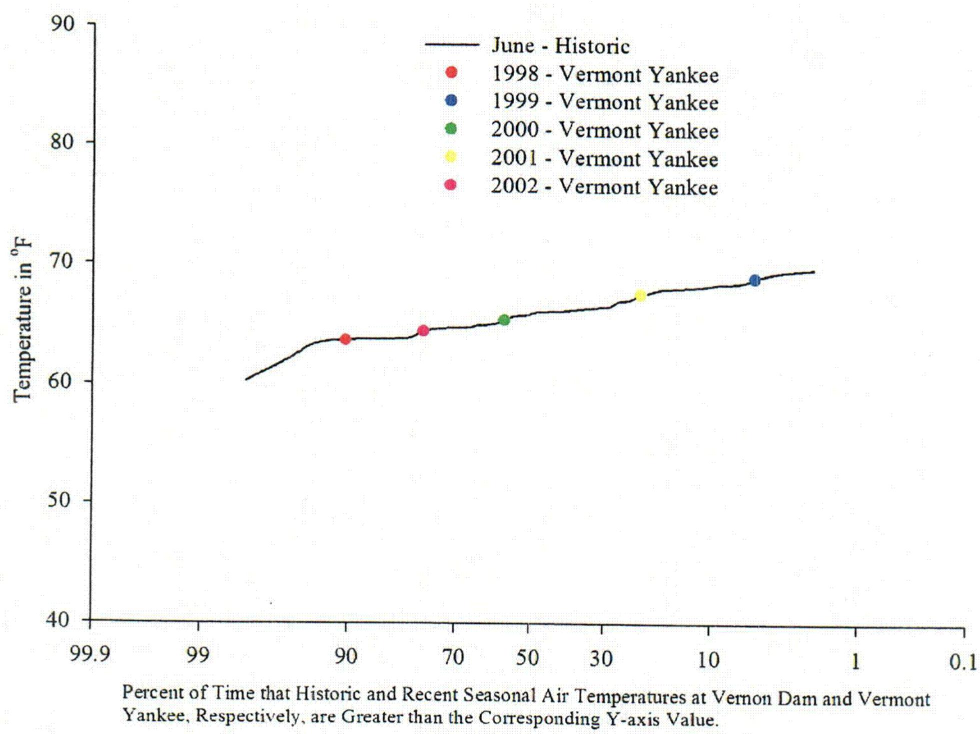
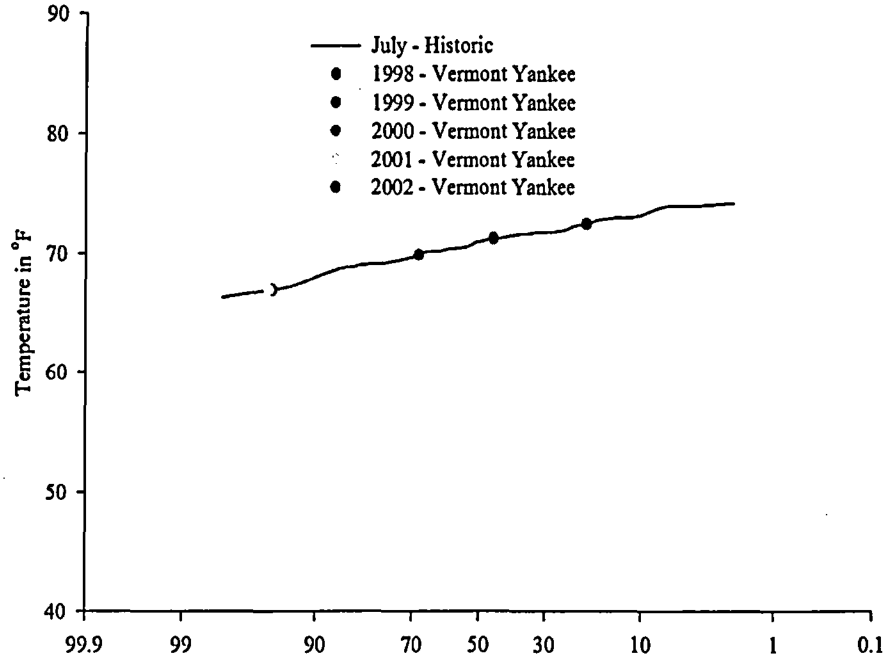
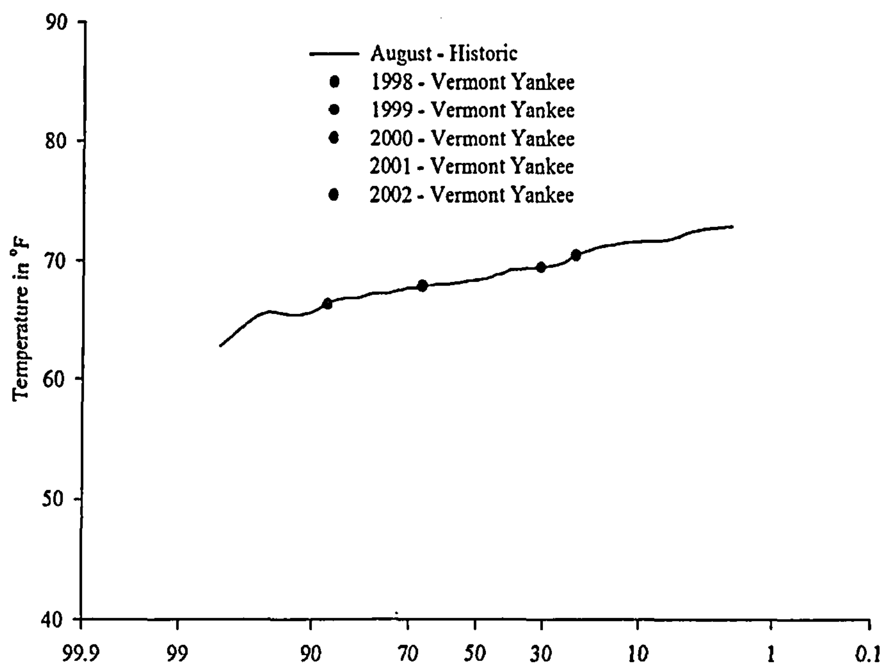


Figure 3-5a. Historic Average (May 16 – 31) and June Air Temperature Duration Curve at Vernon Dam.

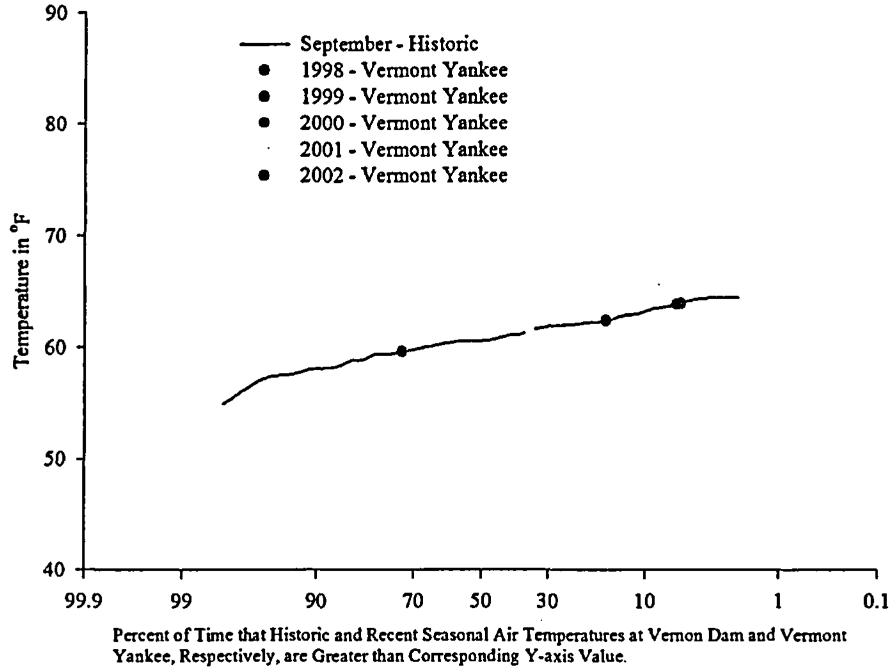


Percent of Time that Historic and Recent Seasonal Air Temperatures at Vernon Dam and Vermont Yankee, Respectively, are Greater than the Corresponding Y-axis Value.



Percent of Time that Historic and Recent Seasonal Air Temperatures at Vernon Dam and Vermont Yankee, Respectively, are Greater than the Corresponding Y-axis Value.

Figure 3-5b. Historic Average July and August Air Temperature Duration Curve at Vernon Dam.



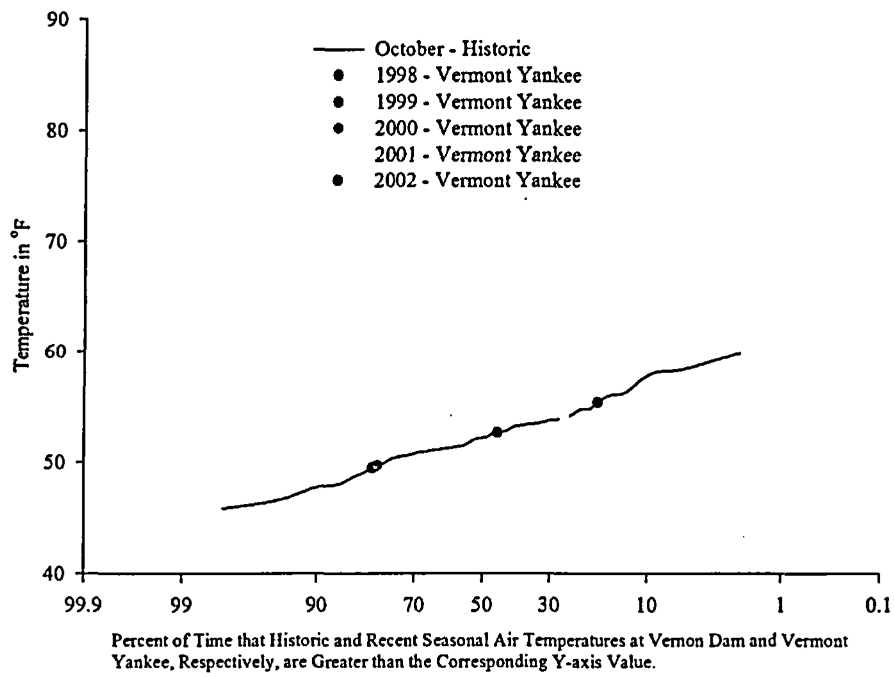


Figure 3-5c. Historic Average September and October (1-14) Air Temperature Duration Curve at Vernon Dam.

3-7

heat waste from VY using equation

(3-7) - (heat waste) shows heat not attributed by VY

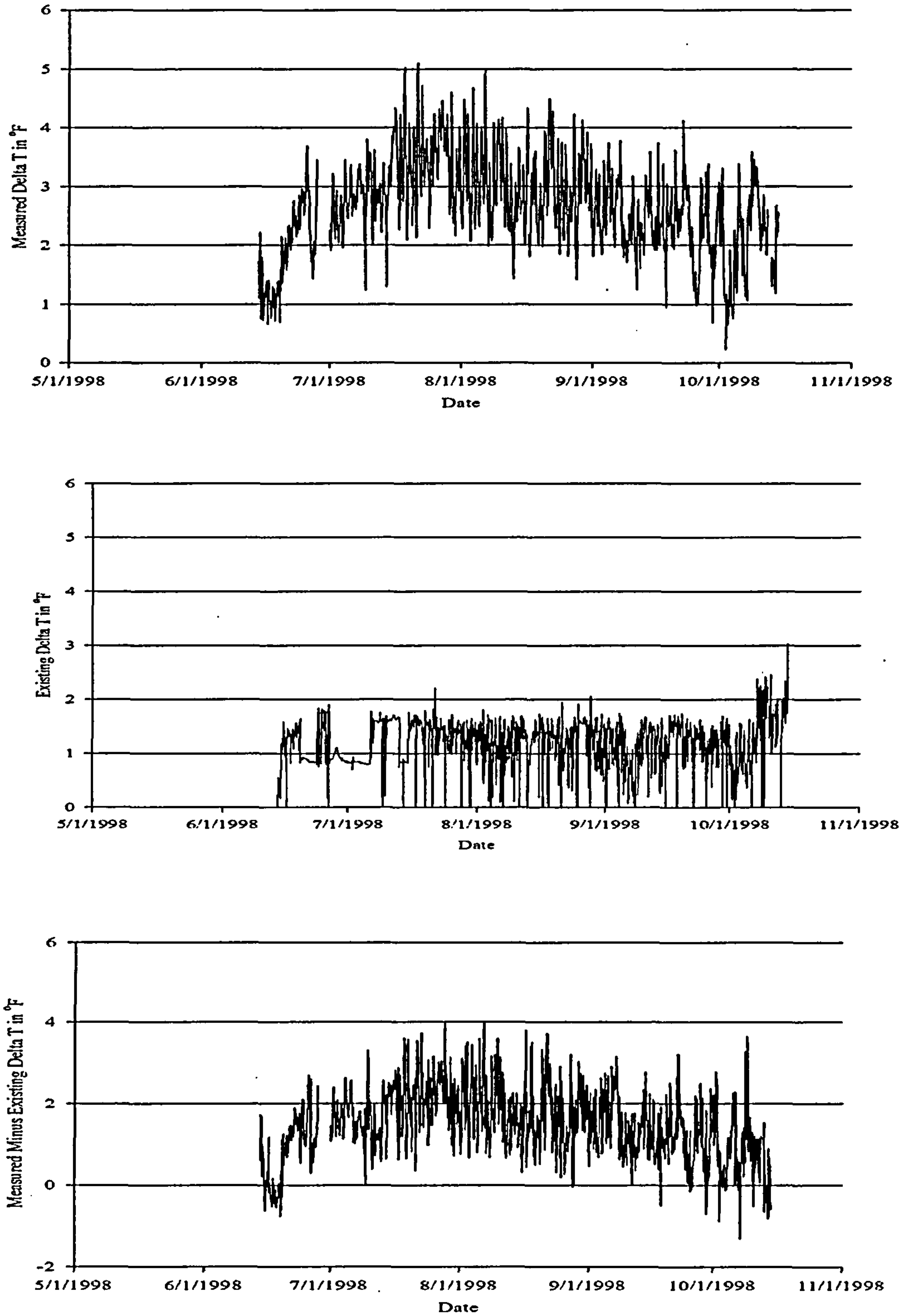


Figure 3-6a. Measured Delta T (Downstream Station 3 Minus Upstream Station 7) Compared to Existing Permit Delta T – 1998 Hourly Data.

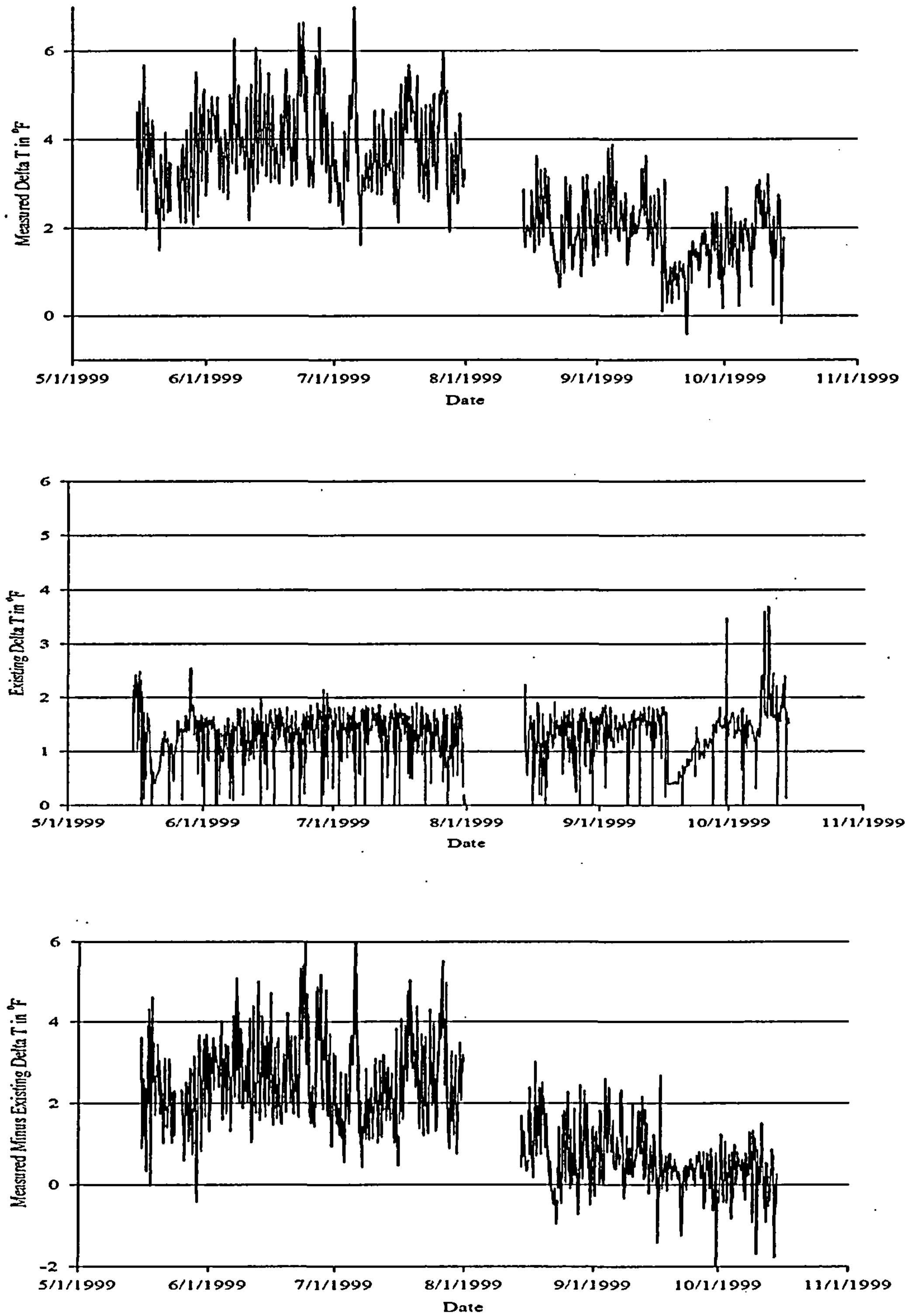


Figure 3-6b. Measured Delta T (Downstream Station 3 Minus Upstream Station 7) Compared to Existing Permit Delta T – 1999 Hourly Data.

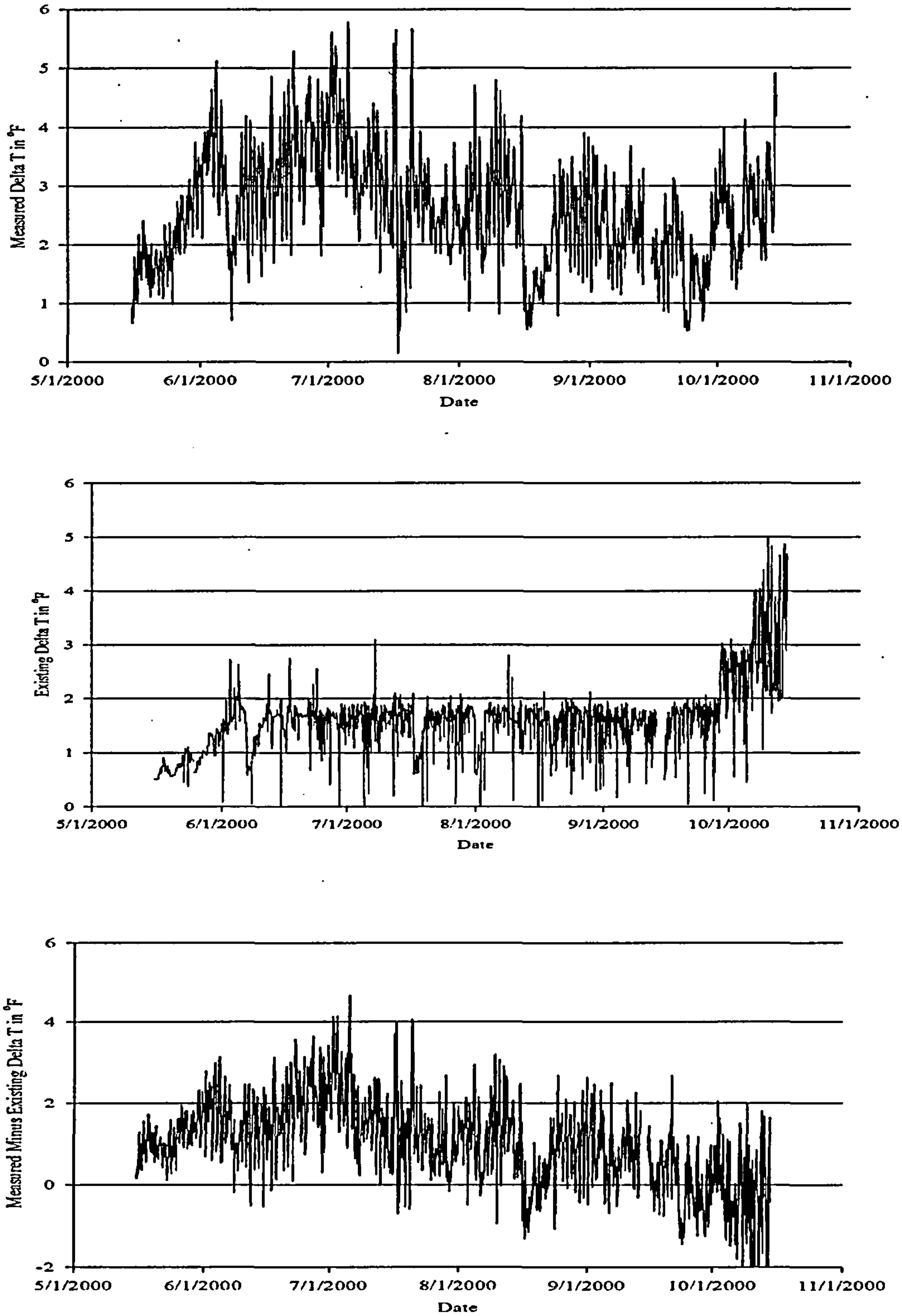


Figure 3-6c. Measured Delta T (Downstream Station 3 Minus Upstream Station 7) Compared to Existing Permit Delta T – 2000 Hourly Data.

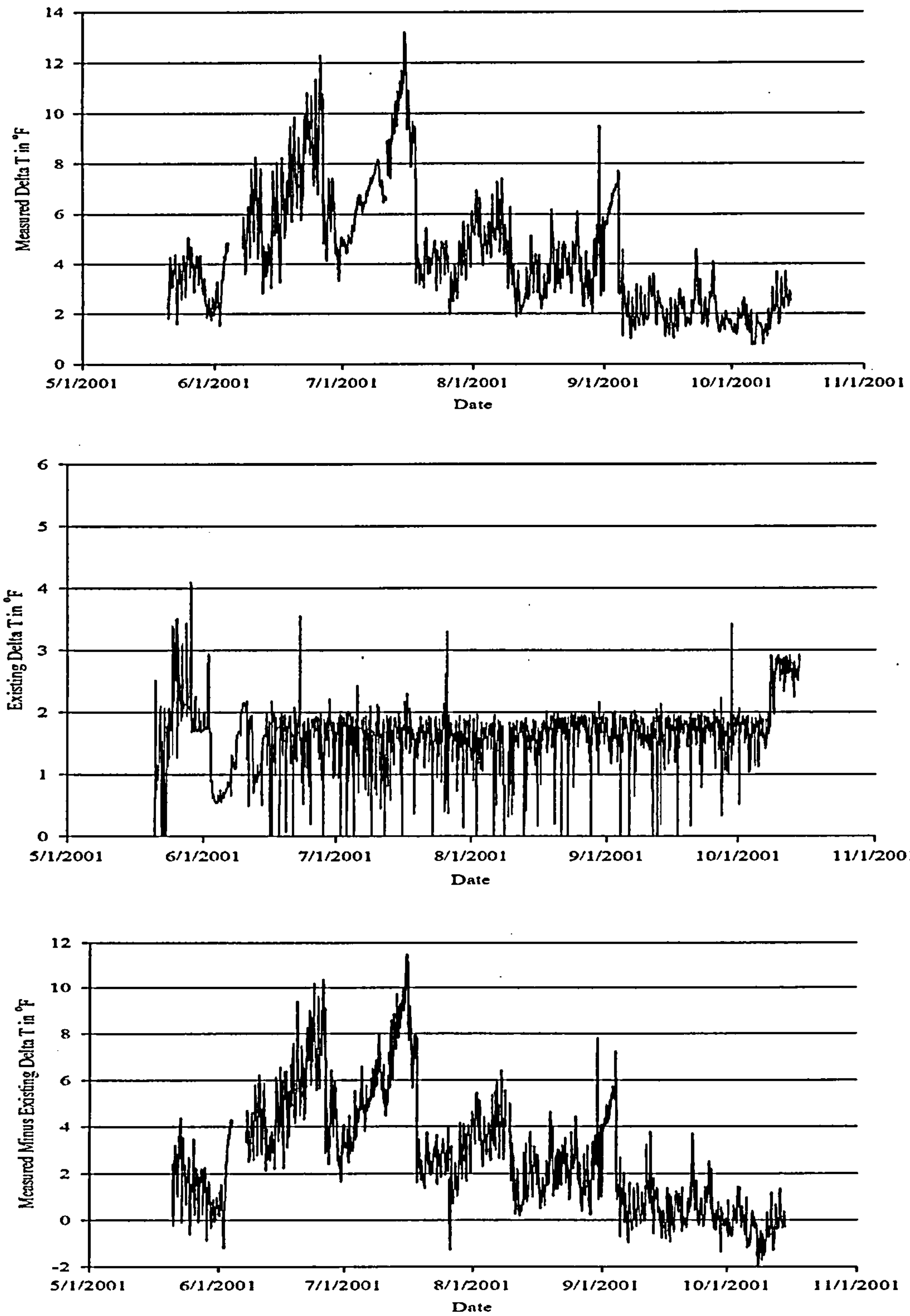


Figure 3-6d. Measured Delta T (Downstream Station 3 Minus Upstream Station 7) Compared to Existing Permit Delta T – 2001 Hourly Data.

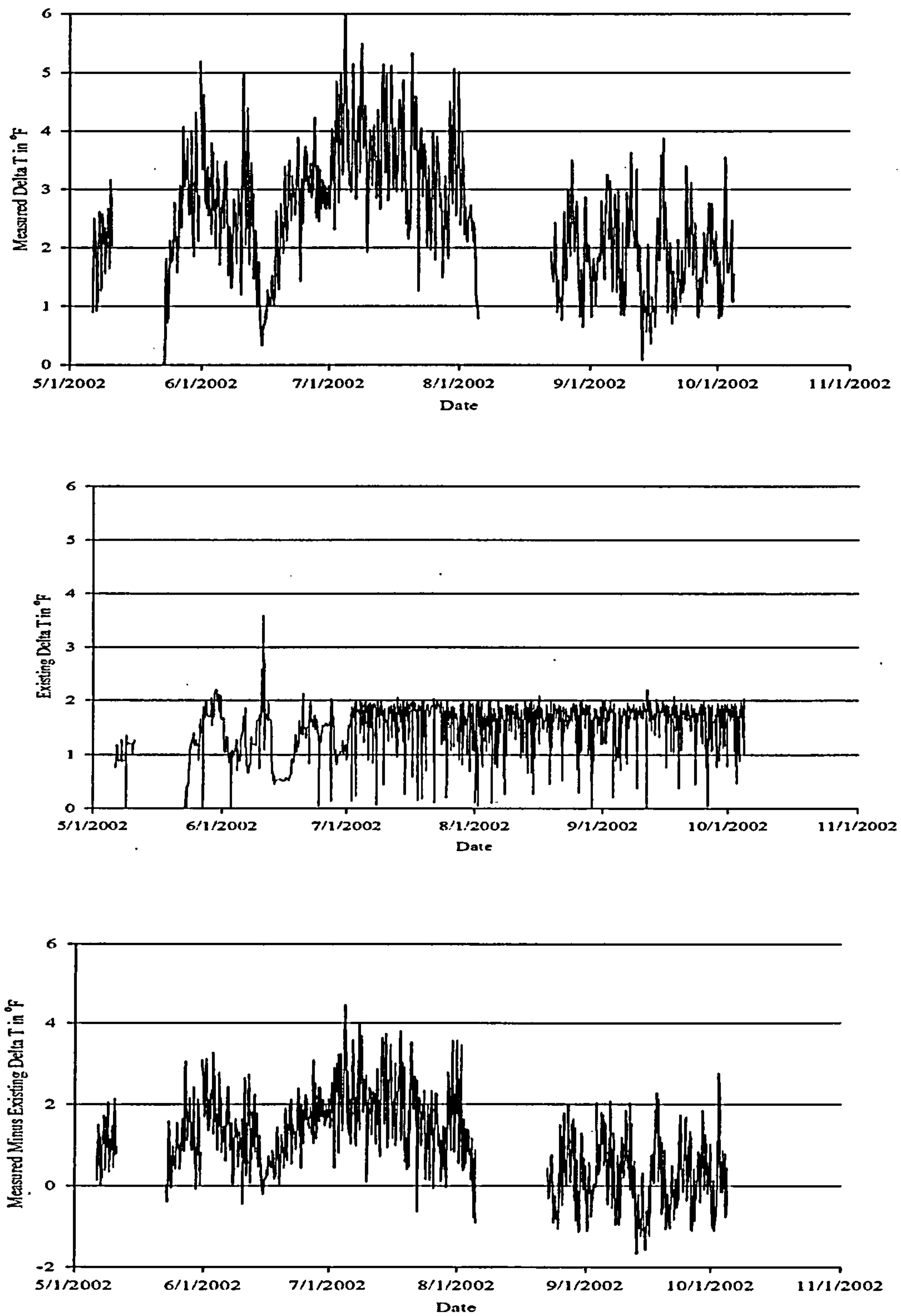


Figure 3-6e. Measured Delta T (Downstream Station 3 Minus Upstream Station 7) Compared to Existing Permit Delta T – 2002 Hourly Data.

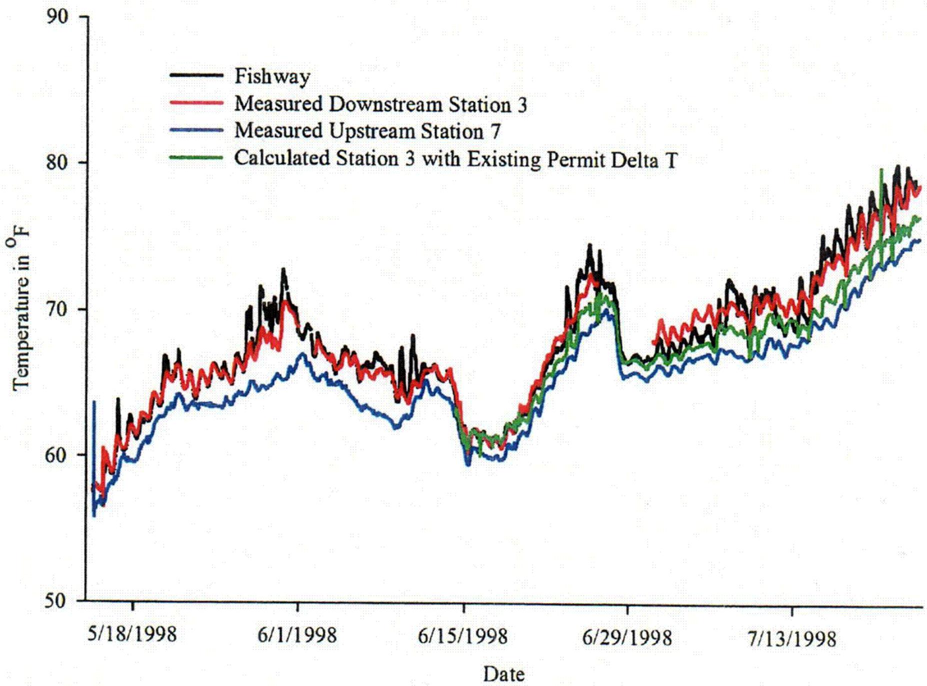


Figure 3-7a. Hourly Temperature at Selected Monitoring Stations in the Vicinity of Vernon Dam during Period of Fishway Operation – 1998.

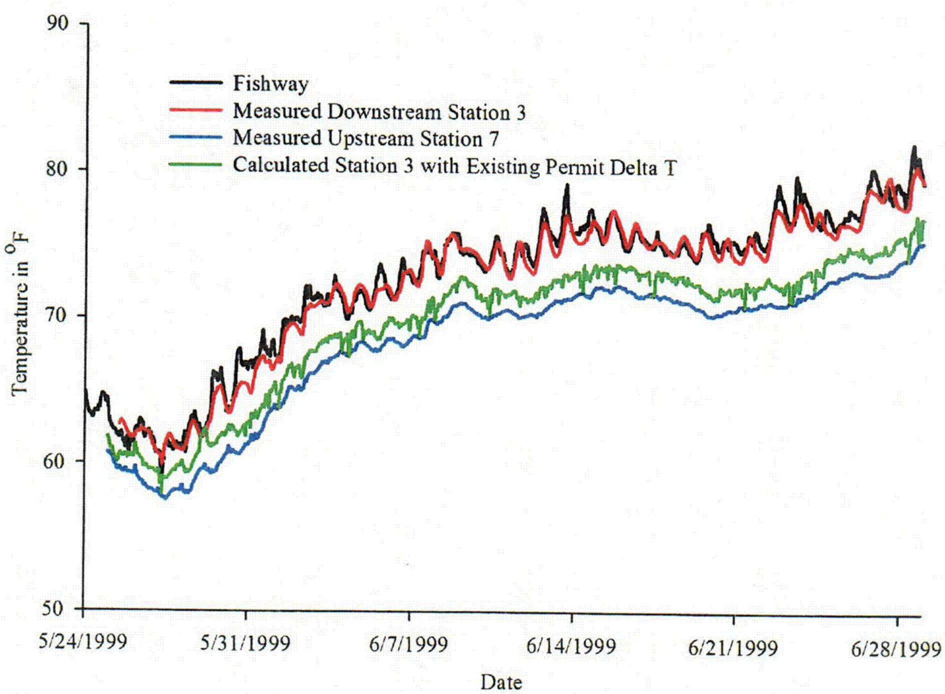


Figure 3-7b. Hourly Temperature at Selected Monitoring Stations in the Vicinity of Vernon Dam during Period of Fishway Operation – 1999.

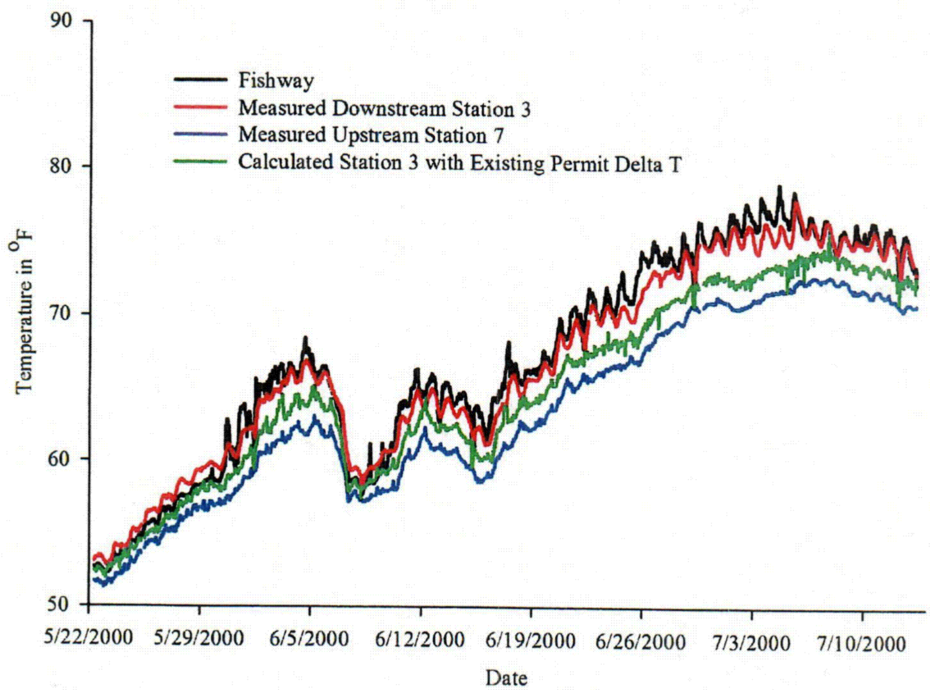


Figure 3-7c. Hourly Temperature at Selected Monitoring Stations in the Vicinity of Vernon Dam During Period of Fishway Operation – 2000.

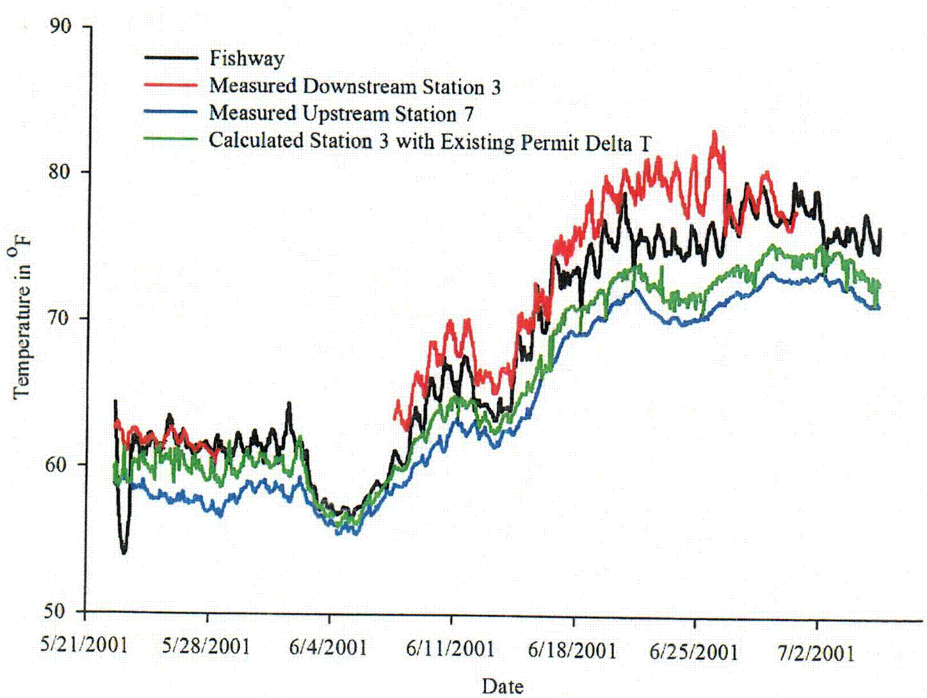


Figure 3-7d. Hourly Temperature at Selected Monitoring Stations in the Vicinity of Vernon Dam During Period of Fishway Operation – 2001.

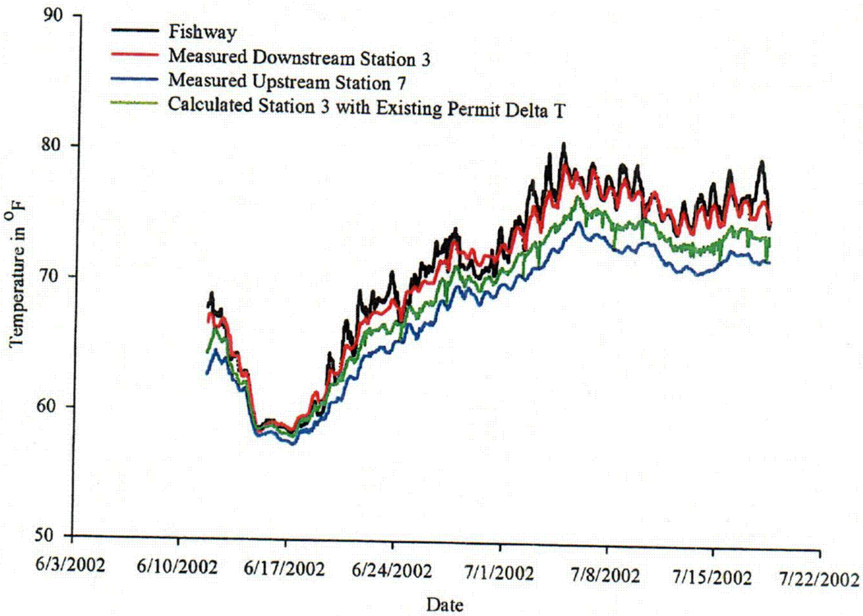


Figure 3-7e. Hourly Temperature at Selected Monitoring Stations in the Vicinity of Vernon Dam During Period of Fishway Operation – 2002.

3.2.3 Probability of Temperature Exceedance at Downstream Station 3 and Upstream Station 7 under Existing and Proposed Conditions of Thermal Discharge during the Summer Season

3.2.3.1 Analysis of 1998 -2002 Summer Seasons (May 16 – October 14) Combined in a Single Data Set

A key measure of the historic (and anticipated) thermal regime is a statistical determination of probability of occurrence of a particular temperature, often expressed as the probability of exceedance. Figures 3-8 through 3-10 present the temperature duration curves (probability of exceedance, based on hourly temperature data) for the recent past (1998 – 2002 summer seasons) for selected stations (both actual and calculated) and similar curves for the predicted temperature exceedances that would result if the allowable Permit Delta T were increased, as presented in Section 3.1.4. We also show the 50th and 1st percentile lines and associated temperatures to assist the reader in interpreting the plots. For example, Figure 3-8 shows that at Upstream Station 7, the measured River water temperatures were greater than 69.8°F for 50% of the time (for the summer seasons of 1998 – 2002), while a temperature of 78.5°F was exceeded only 1% of the time. Similarly, the 50th and 1st percentile temperature values measured at Downstream Station 3 were 72.4°F and 82.4°F, respectively, which indicates that a given temperature is exceeded a greater percent of the time at Downstream Station 3 than at Upstream Station 7. In addition to actual measured temperatures, Figure 3-8 presents the calculated temperature at Downstream Station 3 (based on Measured Upstream Station 7 and the Existing Permit Delta T from Vermont Yankee's discharge) and the Estimated Downstream Station 3 Temperature without Vermont Yankee's discharge (determined by subtracting the Existing Permit Delta T from Measured Downstream Station 3). Figure 3-9 presents similar information for predicted temperatures and probabilities and exceedance, based on Vermont Yankee's Request. Figure 3-10 presents a summary of some of the data presented in Figures 3-8 and 3-9.

Table 3-3 presents the same data contained in Figures 3-8 through 3-10 for select temperatures and associated probabilities to facilitate numerical comparisons of existing and predicted temperature occurrences. All probability determinations are based on hourly data for the entire five years of recent record, which means that there were more than 17,000 data points for each station location. In addition, the anticipated number of hours of exceedance for a summer season is also presented to assist the reader in determining the significance of percent of time exceedance.

The measured River water temperature did not exceed 80°F at Upstream Station 7 at any time during the last five years (Figures 3-8 and 3-9; Table 3-3). Upstream Station 7 (first column in Table 3-3) temperatures were higher than 75°F for 10.19% of the time and higher than 70°F for 49.18% of the time. If the effects of the Vermont Yankee discharge (second column in Table 3-3: calculated Station 3 with Existing Permit Delta T, which was determined by adding Measured Upstream Station 7 plus Existing Permit Delta T) are added to the temperature probabilities, temperature (after complete mixing of the discharge and the River flow) would have been greater than 80°F for 0.87% of the time during the last five years or about 32 hours for each summer period. Similarly, as seen in Table 3-3, the Vermont Yankee discharge would be expected to cause River temperature to be higher than 75°F for 19.04% (as compared to 10.19% of the time with no thermal discharge), and 70°F for 57.58% of the time (as compared to 49.18% of the time with no thermal discharge).

Actual temperatures, displayed as Measured Downstream Station 3 (third column in Table 3-3), were considerably higher than would have been predicted by calculated Station 3 with Existing Permit Delta T. In Table 3-3, the measured temperature at Downstream Station 3 was greater than 80°F for 7.58% of the time or about 6.71% more of the time than accounted for by Vermont Yankee's discharge (277 hours per season versus 32 hours).

The observed maximum temperature at Downstream Station 3 actually was greater than 84°F, but the temperature exceeded 84°F only 0.06 % of the time (about two hours during each summer period), and the temperature never exceeded 85°F. Similarly, Table 3-3 indicates that the probability of exceedance at Downstream Station 3 for all temperatures listed was substantially higher than could be explained by Vermont Yankee's discharge (third column compared to the second column in Table 3-3). For example, Downstream Station 3 was greater than 75°F for 36.04% of the time (versus a calculated 19.04% of the time), and was greater than 70°F for 64.73% of the time (versus an expected 57.58%).

As discussed previously, atmospheric heating of the Vernon head pond accounts for virtually all of the difference between the expected (existing) temperature response at Downstream Station 3 and the measured response. The magnitude of atmospheric heating can be conservatively estimated by subtracting Existing Permit Delta T from Downstream Station 3 measurements (this assumes no cooling of the thermal plume between the point of discharge and Downstream Station 3). Table 3-3 presents these estimates in the fourth column, which shows that, if there were no discharge from Vermont Yankee, the temperature at Downstream Station 3 would be:

- higher than 80°F for 2.63% of the time (versus the actual of 7.58% of the time),
- higher than 75°F for 25.39% of the time (versus the actual of 36.04% of the time), and
- higher than 70°F for 55.22% of the time (versus the actual of 64.73% of the time).

Thus, the thermal discharge from Vermont Yankee increased the amount of time that River temperature was greater than naturally occurring values by about 10% or less for the temperature range expected during the summer season. It should be noted that at higher temperatures (above 77°F), predicted increases are significantly less than 10%. As shown above, it is predicted that river temperature would have been greater than 80°F 2.63% of the time at Downstream Station 3 without waste heat discharged by Vermont Yankee (compared to an actual exceedance of 7.58% with the existing permit conditions and discharge). This is an increase in time of exceedance of only 4.95%. The observed maximum temperature for the 1998-2002 summer periods of record was slightly above 84°F at Downstream Station 3, and temperatures above 80°F were observed for just 10 hours during the entire five-year summer period (average of two hours per summer season).

Vermont Yankee's Request would increase the temperature of the River during the summer season after complete mixing only by as much as 1°F. This proposed temperature compliance schedule is presented in Section 3.1.4. Figure 3-9 and Table 3-3 (fifth and sixth columns) present the predicted temperature regime that would be expected if Vermont Yankee were operating under the proposed new discharge limits provided for in the Request.

With Permit Delta Ts as proposed in the Request, the calculated maximum complete mixed temperature in the River (Calculated Station 3 with Proposed Permit Delta T) would be expected to be similar to existing conditions (i.e., maximum temperature would exceed 81°F but would not exceed 82°F). However, the frequency of occurrence of temperatures greater than 81°F would be

slightly higher under proposed conditions (0.39%), compared to 0.11% of the time for existing conditions (14 hours per season versus 4 hours). The calculated temperature would exceed 80°F for 2.78% of the time. This compares to 0.87% of the time for existing conditions and represents an increase of about 70 hours per season. It is further predicted that the calculated maximum temperature would be greater than 75°F for 32.63% of the time and greater than 70°F for 64.67% of the time, compared to 19.04% and 57.58% of the time, respectively, under existing conditions.

Similarly, the expected maximum temperature at Downstream Station 3 (Table 3-3, column 6 – Maximum Station 3 with Proposed Permit Delta T) would have exceeded 85°F 0.15% of the time (about six hours per season compared to no exceedances of 85°F under the existing permit). Temperatures would be expected to exceed 84°F 0.57% of the time (21 hours compared to an existing two hours). Exceedances under proposed permit conditions of other temperatures within the expected temperature range are projected to increase from existing permit conditions by less than 1% at low temperature (<55°F) to as much as 11.5% at 76°F.

In summary, the proposed increase in Permit Delta T of as much as 1°F (depending on ambient temperature) would result in only slightly higher summer temperatures in the Connecticut River downstream from Vernon Dam. The maximum calculated Station 3 temperature (based on Upstream Station 7 plus the proposed Permit Delta T) would only slightly exceed 81°F, which is virtually identical to existing conditions. Under the proposed new summer period permit limits, the increase in the percentage of the time that the calculated Downstream Station 3 temperature would exceed any given temperature would vary, depending on the temperature. The biological effects of temperature increases of this magnitude, as discussed in detail in Section 5, are expected to be inconsequential.

3.2.3.2 *Analysis of Individual Summer Seasons (May 16 – October 14) for the Years 1998 – 2002*

The statistical analyses presented in the previous section indicate annual expectations for certain temperature exceedances. In reality, specific temperatures may not be exceeded at all in some years while in others, exceedances may be more numerous than expected. Accordingly, the frequency of occurrence of the hourly temperature records for each year, 1998 – 2002, will be presented that illustrate the percent of time that measured and predicted river temperatures exceeded (or were expected to exceed) each one-degree temperature value. Each table and figure contains both annual and five-year data (Tables 3-4a through 3-4e) and plots (Figures 3-11a through 3-11e for existing permit thermal limits and Figures 3-12a through 3-12e for proposed new permit thermal limits), respectively, to allow easy comparison between the two.

From Table 3-4a, it can be seen that maximum 1998 water temperatures, for both existing and proposed permit conditions, were considerably lower than for the five-year database taken as a whole. For example, measured River water temperature was never greater than 76°F at Upstream Station 7 during 1998, yet 76°F was exceeded 5.6% of the time there when considering the entire five-year data set. Similarly, measured River water temperature at Downstream Station 3 did not exceed 80°F during 1998, but for the five-year period of study, 80°F was exceeded 7.6% of the time. Where the thermal influence of the proposed increase in the Permit Delta T is predicted (proposed new permit values shown in the two right-hand columns of Table 3-4a), similar patterns are seen between 1998 and the five-year period.

While maximum summer temperatures during 1998 were among the lowest recorded during the entire 1998 – 2002 period, the frequency of occurrence of river temperatures greater than 65°F was actually

higher during 1998 than for the five-year study period. At Upstream Station 7, the measured River water temperature exceeded 65°F 81.6% of the time during 1998 versus 71.3% of the time during all of 1998 – 2002 (Table 3-4a). Similarly, River water temperature measured at Downstream Station 3 was greater than 65°F 84.4% of the time compared to 76.5% for the five-year period (Table 3-4a, Figure 3-11a). Therefore, lower maximum summer River water temperatures during any particular year do not necessarily mean that average summer River water temperatures will also be low in that same year. Similarly, higher than "average" maximum summer temperatures do not necessarily mean the River temperature for the entire summer will also be above average.

The rest of the individual years may be summarized as follows: maximum temperatures during 1999 (Table 3-4b) had percent of time exceedances that were highly comparable to the five-year study period for both existing and proposed permit conditions. Nevertheless, River water temperatures in the 70°F and above range (up to but not including the maximum) occurred more frequently during 1999 when compared to 1998 – 2002 period. Even so, the probability of occurrence of temperatures greater than 65°F was actually somewhat less than the average, which implies that, during 1999, River temperature rose very rapidly through the 60s into the 70s. The rapid rise in River water temperature is highly visible in Figure 3-11b, which is a plot of the data presented in Table 3-4b.

During 2000 (Table 3-4c, Figures 3-11c and 3-12c), River water temperatures were unusually cool compared to the 1998-2002 summer period of data evaluated, especially for maximum temperatures. Measured River water temperature at Upstream Station 7 in 2000 did not exceed 73°F during the entire summer. In contrast, temperature exceeded 73°F more than 24% of the time for the entire 1998 – 2002 period.

The summer season of 2001 (Table 3-4d, Figures 3-11d and 3-12d) was very warm as determined by River temperature. Measured River water temperature at Upstream Station 7 exceeded 79°F 1.8% of the time (versus 0.4% for the entire five-year data base). Maximum River water temperatures measured at Downstream Station 3 exceeded 84°F 0.3% of the time, compared to 0.1% for the whole five-year database. However, temperatures at this downstream monitoring location exceeded 80°F 25.4% in 2001 compared to 7.6% for the five-year period. Also from Table 3-4d, temperatures at Downstream Station 3 under the proposed discharge compliance criteria are predicted to exceed 85°F 0.5% of the time versus 0.2% of the time for the whole five-year period. Nevertheless, Downstream Station 3 River water temperatures would not have exceeded 86°F under either existing or proposed conditions.

Finally, maximum River water temperatures during 2002 were again somewhat lower than the average condition observed for the five-year period 1998-2002 for both existing and proposed permit conditions, although not as low as during 2000 (Table 3-4e, Figures 3-11e and 3-12e). Even though maximum temperatures were relatively low, temperatures greater than 65°F occurred with somewhat greater frequency during 2002 than for the entire five-year period. As noted above for 1998, this again implies that maximum temperatures are not necessarily closely related to seasonal temperatures trends.

Figures 3-11a – 3-11e (existing permit thermal limits) and Figures 3-12a – 3-12e (proposed new permit thermal limits) present the same data that are discussed above (from Tables 3-4a – 3-4e), but in graphical form. In addition, as shown in Figures 3-8 and 3-9, these figures also display the temperatures that correspond to 50th and 1st percentile frequency of exceedance. The 50th and 1st percentile frequency of exceedance values for the overall period 1998-2002 were used, respectively,

to represent "average case" and "extreme case" thermal modeling input conditions (Section 4 of the Demonstration) to predict the bottom area and water column volume differences between existing and proposed new permit conditions. The effects, if any, of the "average case" and "extreme case" changes were subsequently interpreted with respect to the balanced indigenous population, represented by Representative Important Species of fish on Section 5 of the Demonstration. For purposes of comparison, and consistent with the structure of Tables 3-4a through 3-4e, the plot for each individual year is shown in the bottom panel of Figures 3-11a – 3-11e and Figures 3-12a – 3-12e, with the plots for the pooled five-year data base (1998-2002) shown in the top panel.

The information presented in Figures 3-11a through 3-11e (existing permit thermal limits) and Figures 3-12a through 3-12e (proposed new permit thermal limits) can be summarized as follows:

1) 1998 (Figures 3-11a and 3-11e) was somewhat cooler than "normal" (as represented by the entire '98 –'02 data base) in both the 50th and 1st percentages of exceedance (0.7 – 1.0°F lower and 3.0 – 3.5°F lower, respectively);
2) 1999 (Figures 3-11b and 3-12b) was almost identical to the five-year data base for the 1st percentage of exceedance (0.0 – 0.3°F warmer), but was as much as 2.8°F warmer for the 50th percent exceedance values;
3) 2000 (Figures 3-11c and 3-12c) was exceptionally cool, with the 1st percentage exceedance values being about 6°F lower than the five-year data base and the 50th percentage exceedance values being more than 2°F lower;
4) 2001 (Figures 3-11d and 3-12d) was slightly warmer than "normal" at the 1st percentage level (< 1.0°F), but as much as almost 5°F warmer at the 50th percentage level.
5) 2002 (Figures 3-11e and 3-12e) was considerably cooler than "normal" at the 1st percentage exceedance level (1.3 to 3.4°F), but was slightly warmer than normal at the 50th percent level (0.2 to 1.2°F).

3.2.3.3 Analysis of Consecutive Exceedances

The previous analyses have evaluated expected temperature exceedances without regard to whether the occurrences are scattered throughout the data set or are consecutive. Exceedances are simply summed for the entire 1998-2002 summer periods being investigated (five summer seasons combined or each season individually) with the total number of hours of exceedance presented in Tables 3-3 and 3-4a through 3-4e. It is believed that this method of accounting for thermal exceedances represents an extreme-case analysis since the reader may interpret the results to be consecutive occurrences. In fact, extreme occurrences of consecutive hours with warm water temperatures are far less frequent. This section provides an analysis of consecutive exceedances to provide the reader with a better perspective of the extent to which particular River temperatures would be expected to be exceeded under the proposed new permit limits. This analysis focuses on the expected highest seasonal temperatures since maximum temperatures may be of the greatest concern.

Figures 3-13a though 3-13c present the four-week period that had the highest average hourly River water temperature for each individual year, 1998 through 2002. Data are plotted for hourly River water temperature measured at Upstream Station 7 and Downstream Station 3, and the maximum predicted Downstream Station 3 that would have occurred if Vermont Yankee had been operating under the proposed new thermal discharge criteria (maximum Station 3 with Proposed Permit Delta T). Figure 3-13a displays data for 1998 and 1999. In 1998, it can be seen that Downstream Station 3 River water temperatures were greater than 74°F and less than 80°F for the entire four-week period.

With the proposed new thermal discharge criteria, temperatures at Downstream Station 3 are predicted to have been greater than 75°F and less than 82°F for the entire four-week period of 1998. However, the highest hourly River water temperature measured at Downstream Station 3 exceeded 79°F for only seven hours during the entire four-week period. Significantly, only four of these hours were consecutive. Predicted maximum temperature under the proposed new permit limits would have exceeded 81°F for a total of three hours, none of which would have been consecutive. That maximum temperatures do not occur for extended periods of time is directly related to the influence of atmospheric conditions on River water temperature behavior. It can easily be seen in Figure 3-13a (and Figures 3-13b and 3-13c) that temperature at Downstream Station 3 cycles from relative lows to relative highs on a daily (diel) basis. This daily temperature fluctuation is typically about 2°F but is occasionally as little as 0.5°F and as much as 4°F. Consequently, maximum temperatures on both daily and seasonal bases occur for very short durations, generally only 1 – 2 consecutive hours. A more appropriate measure of biologically important temperature might be daily average or daily minimum temperature, but we conservatively provide maximum temperatures for assessing potential impact as a limiting factor.

In the bottom panel of Figure 3-13a, 1999 was somewhat warmer than 1998. The hourly River water temperature measured at Downstream Station 3 was continuously above 76°F but less than 84°F for the entire four weeks. Under proposed new permit thermal limits, Downstream Station 3 temperatures would have ranged between 77°F and 86°F. Highest measured Downstream Station 3 River water temperature exceeded 83°F for four hours, all of which were consecutive. Similarly, predicted proposed maximums exceeded 85°F for six hours, four of which would have been consecutive.

Figure 3-13b presents hourly River water temperature data for 2000 and 2001. Interestingly, 2000 had the lowest "warm" temperatures of the five-year period while 2001 had the highest. In 2000, the maximum measured River water temperature at Downstream Station 3 only briefly reached 78°F and exceeded 77°F for only nine hours, all of which were consecutive. The maximum River water temperature under proposed new permit thermal limits at Downstream Station 3 would not have reached 80°F and would have exceeded 79°F for only five hours, all of which would have been consecutive. In contrast, measured River water temperatures at Downstream Station 3 during 2001 were above 78°F for the almost the entire four-week period (except for a few hours during the end of the period). Even so, maximum measured River water temperatures at Downstream Station 3 never exceeded 85°F and only exceeded 84°F for eight hours during 2001 (only four were consecutive). Similarly, River water temperatures predicted under proposed new permit thermal limits at Downstream Station 3 would have exceeded 85°F for twelve hours and never for more than five consecutive hours.

Finally, Figure 3-13c presents 2002 data, a year that was generally representative of the average conditions for the 1998-2002 period. River water temperatures measured at Downstream Station 3 in 2002 ranged between 75°F and slightly greater than 82°F, and River water temperature predicted under proposed new permit thermal limits for Downstream Station 3 would have ranged between 76°F and slightly greater than 83°F. Measured Downstream Station 3 River water temperatures in 2002 would have exceeded 82°F for five hours, three of which were consecutive, while River water temperature predicted under proposed new permit thermal limits for Downstream Station 3 temperatures would have exceeded 83°F for 15 hours, six of which would have been consecutive.

1998-2002 Existing

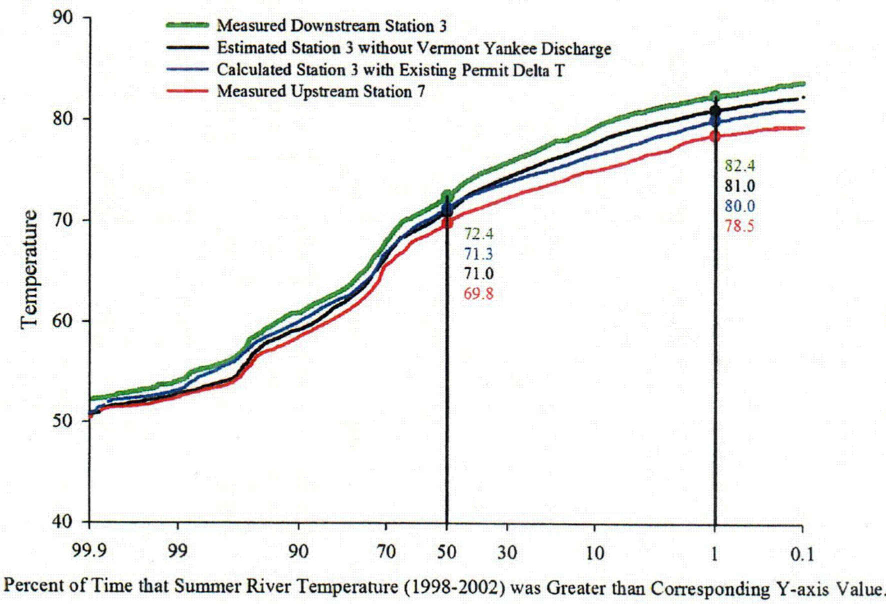


Figure 3-8. Temperature Duration Curves for the Summer Period (1998-2002) for Selected Connecticut River Monitoring Stations – Existing Vermont Yankee Discharge Conditions.

1998 - 2002 Proposed

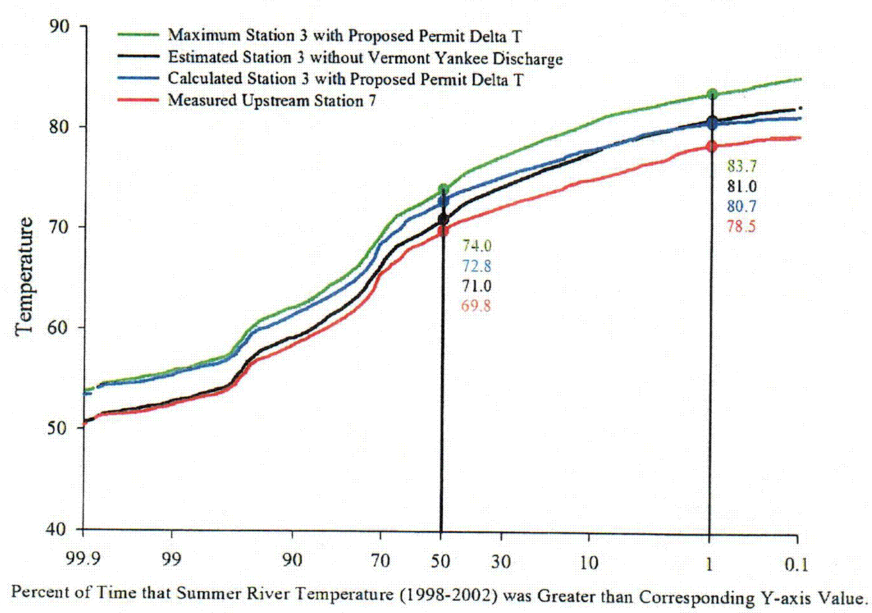


Figure 3-9. Temperature Duration Curves for the Summer Period (1998-2002) for Selected Connecticut River Monitoring Stations – Proposed Vermont Yankee Discharge Conditions.

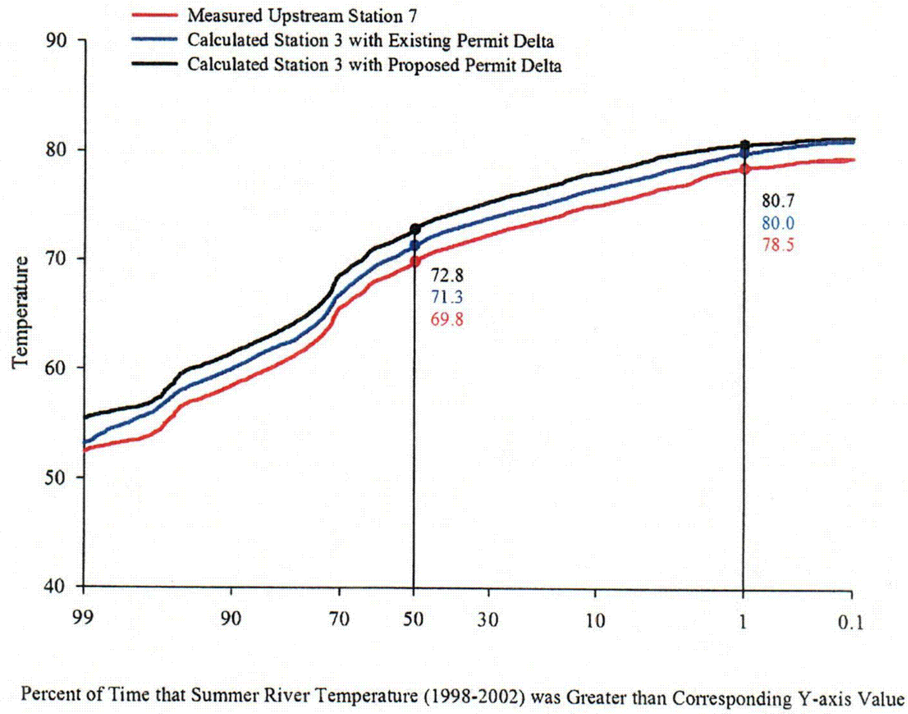
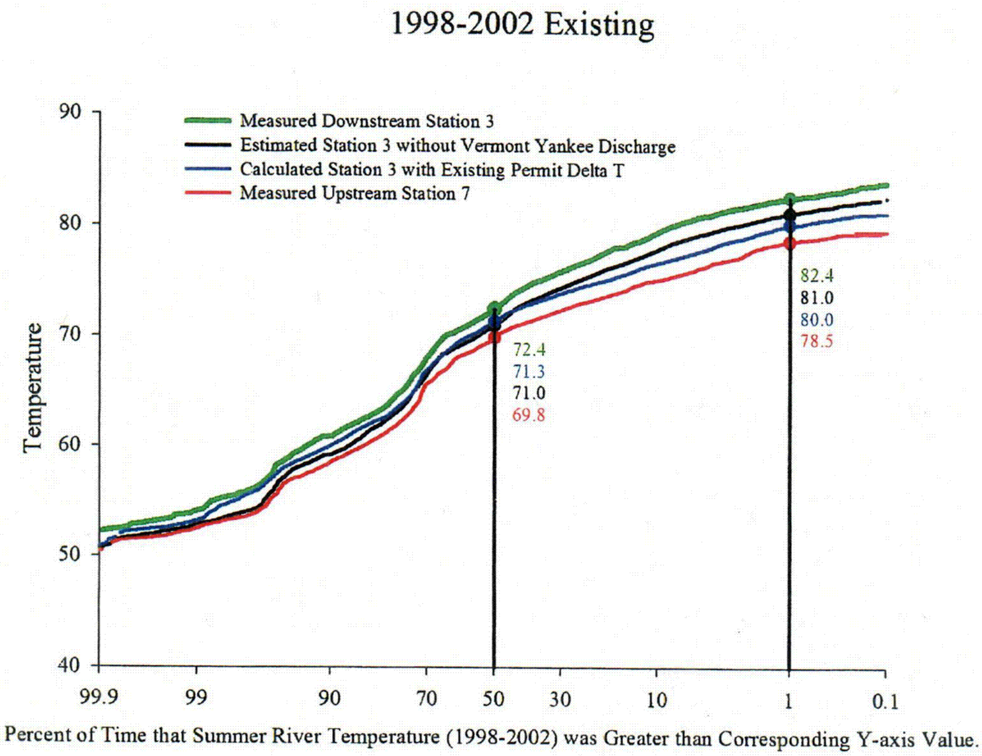


Figure 3-10. Comparison of Projected Temperature Response in the Connecticut River for Background, Existing and Proposed Vermont Yankee Discharge Conditions.



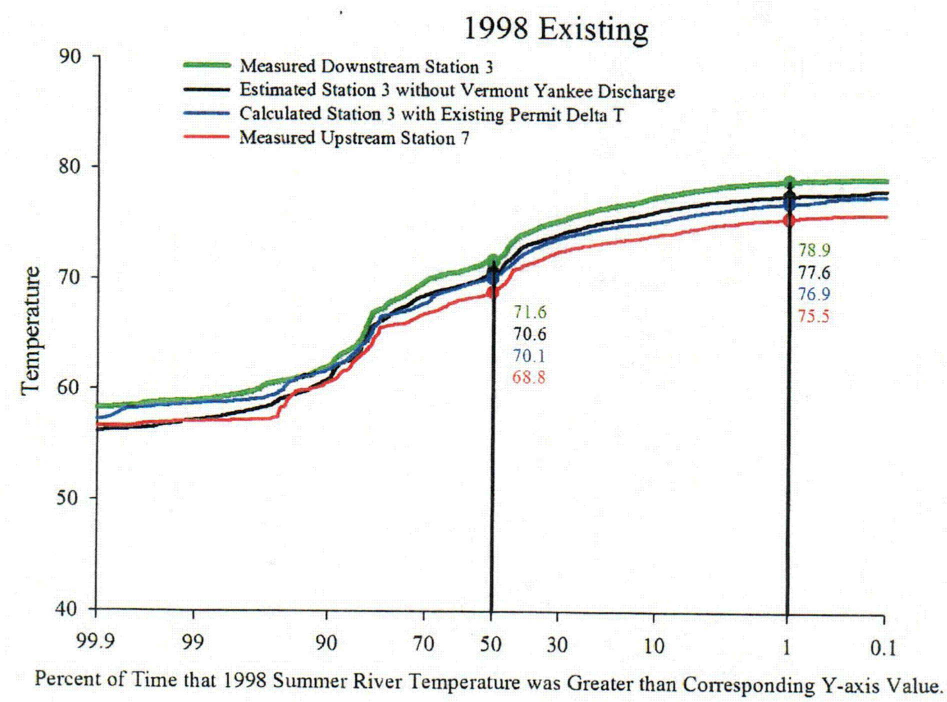
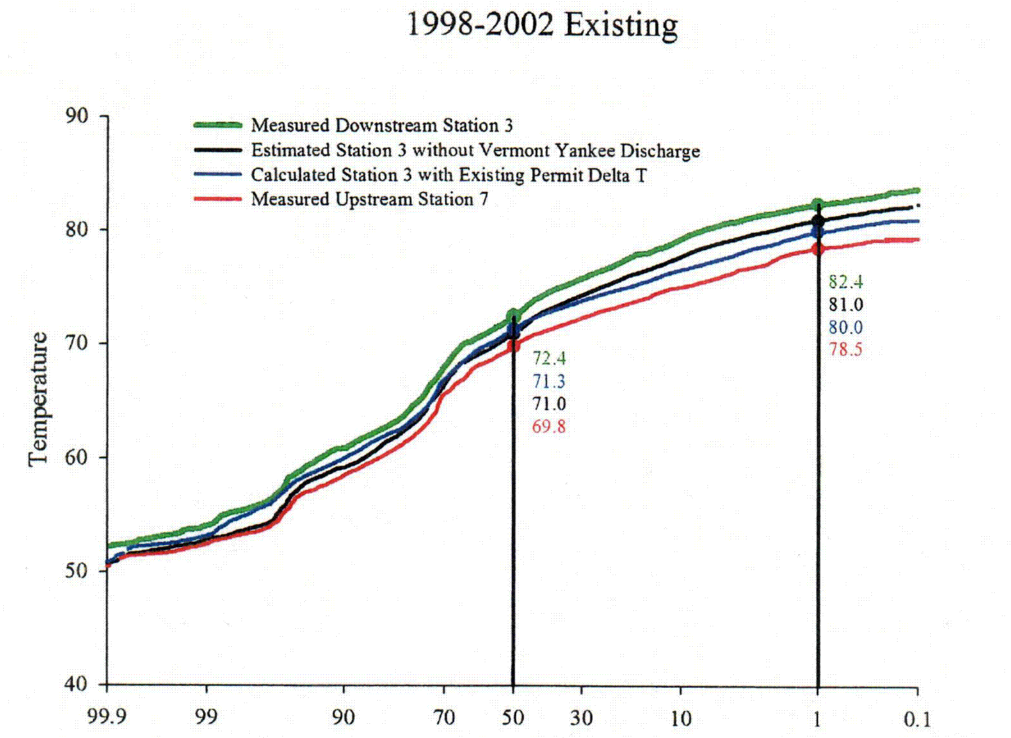


Figure 3-11a. Temperature Duration Curves for the 1998-2002 and 1998 Summer Periods for Selected Connecticut River Monitoring Stations – Existing Vermont Yankee Discharge Conditions.



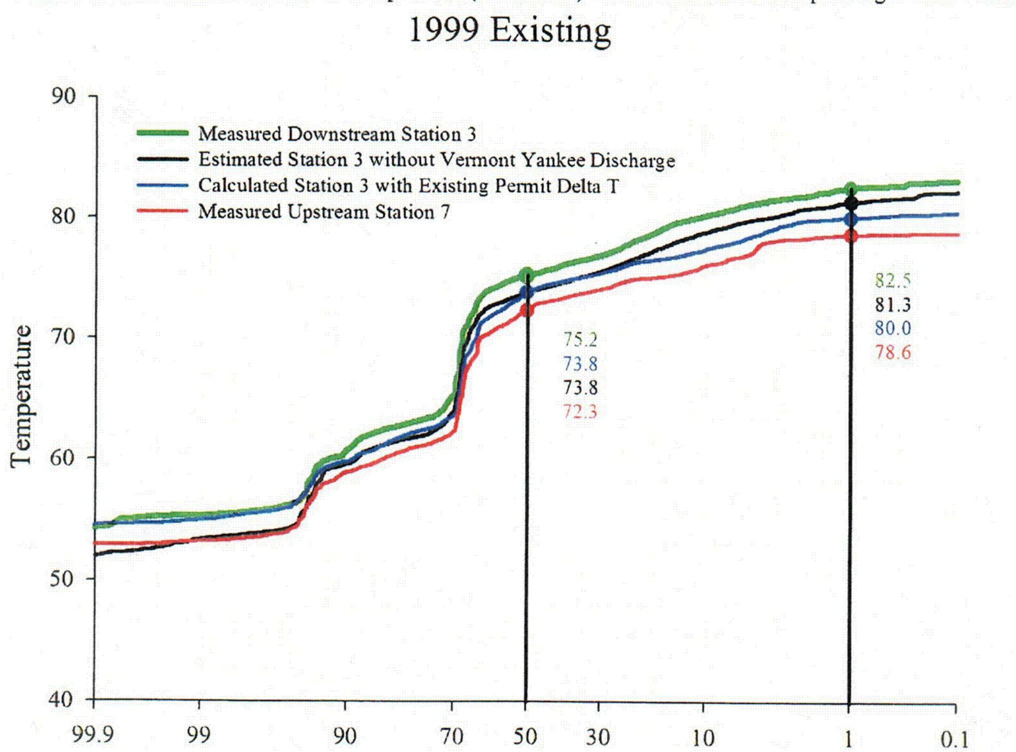
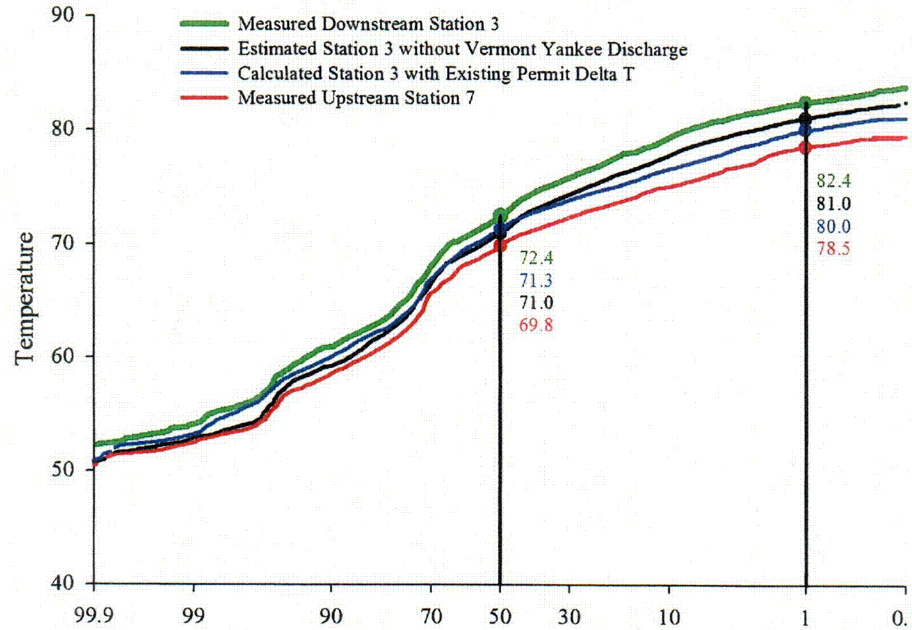


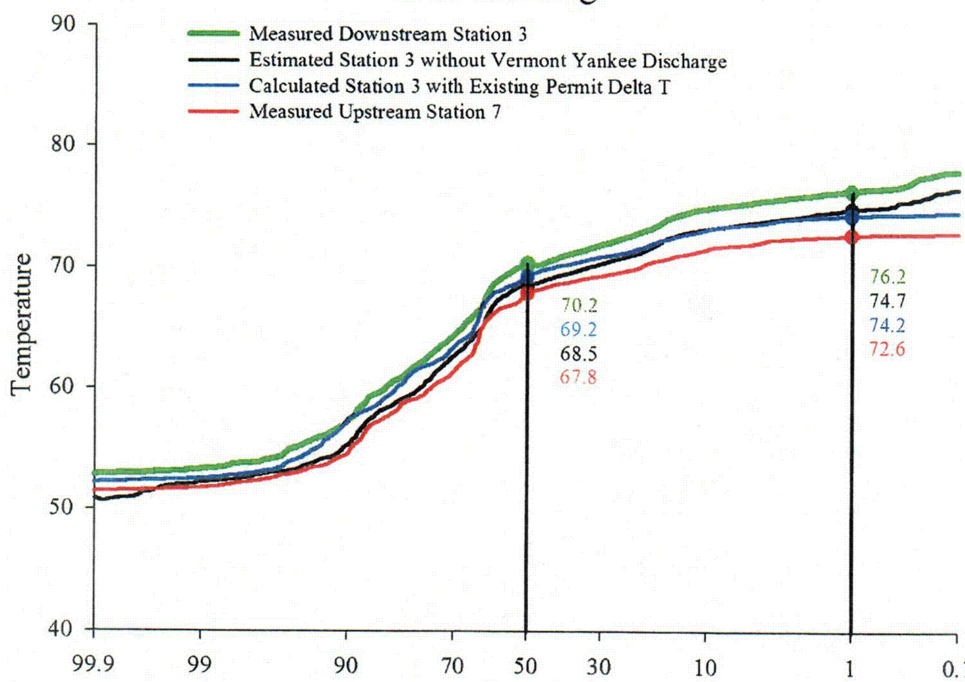
Figure 3-11b. Temperature Duration Curves for the 1998-2002 and 1999 Summer Periods for Selected Connecticut River Monitoring Stations – Existing Vermont Yankee Discharge Conditions.

1998-2002 Existing



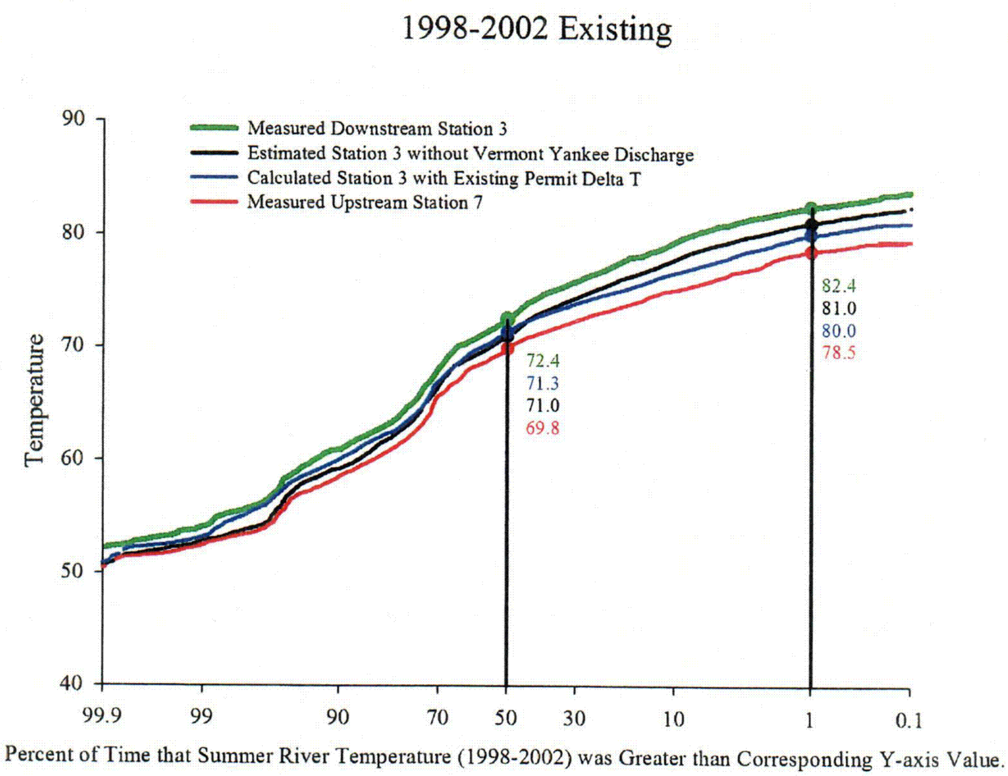
Percent of Time that Summer River Temperature (1998-2002) was Greater than Corresponding Y-axis Value.

2000 Existing



Percent of Time that 2000 Summer River Temperature was Greater than Corresponding Y-axis Value.

Figure 3-11c. Temperature Duration Curves for the 1998-2002 and 2000 Summer Periods for Selected Connecticut River Monitoring Stations – Existing Vermont Yankee Discharge Conditions.



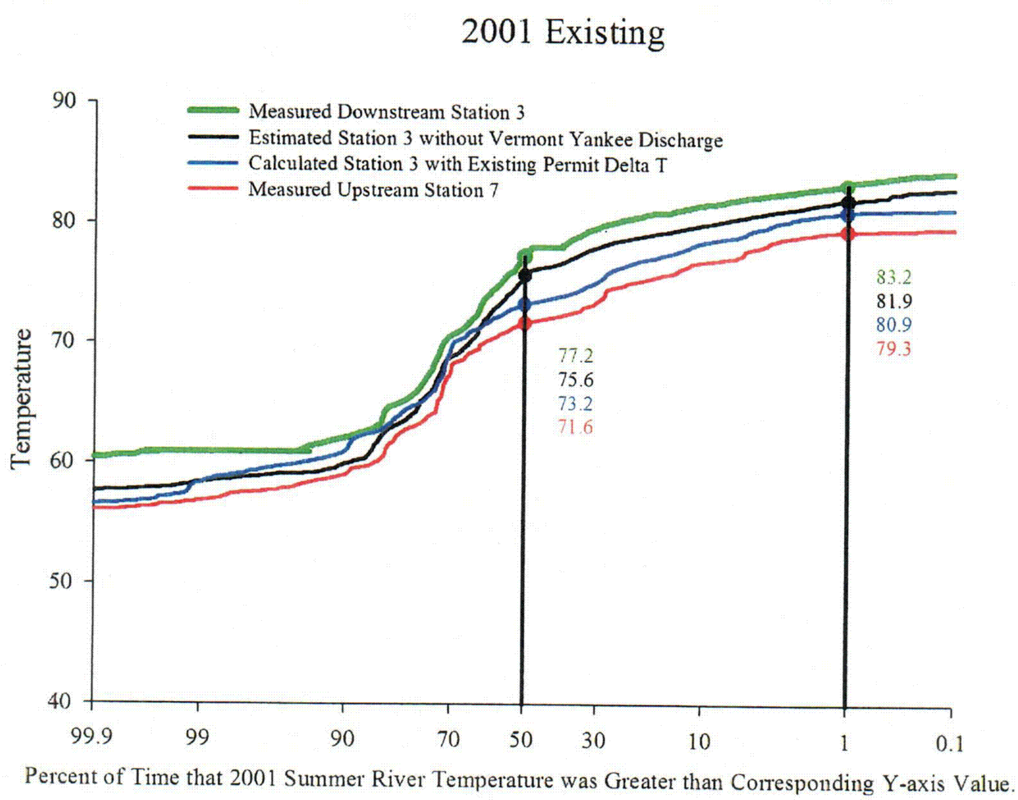
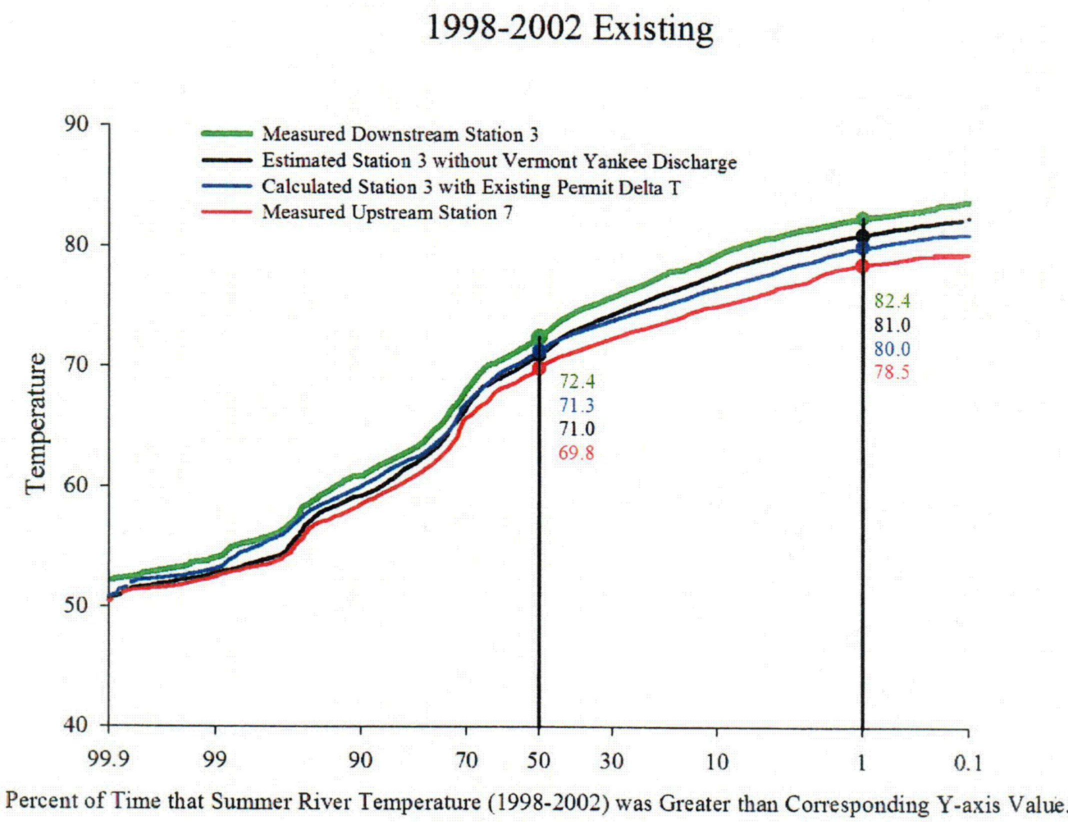


Figure 3-11d. Temperature Duration Curves for the 1998-2002 and 2001 Summer Periods for Selected Connecticut River Monitoring Stations – Existing Vermont Yankee Discharge Conditions.



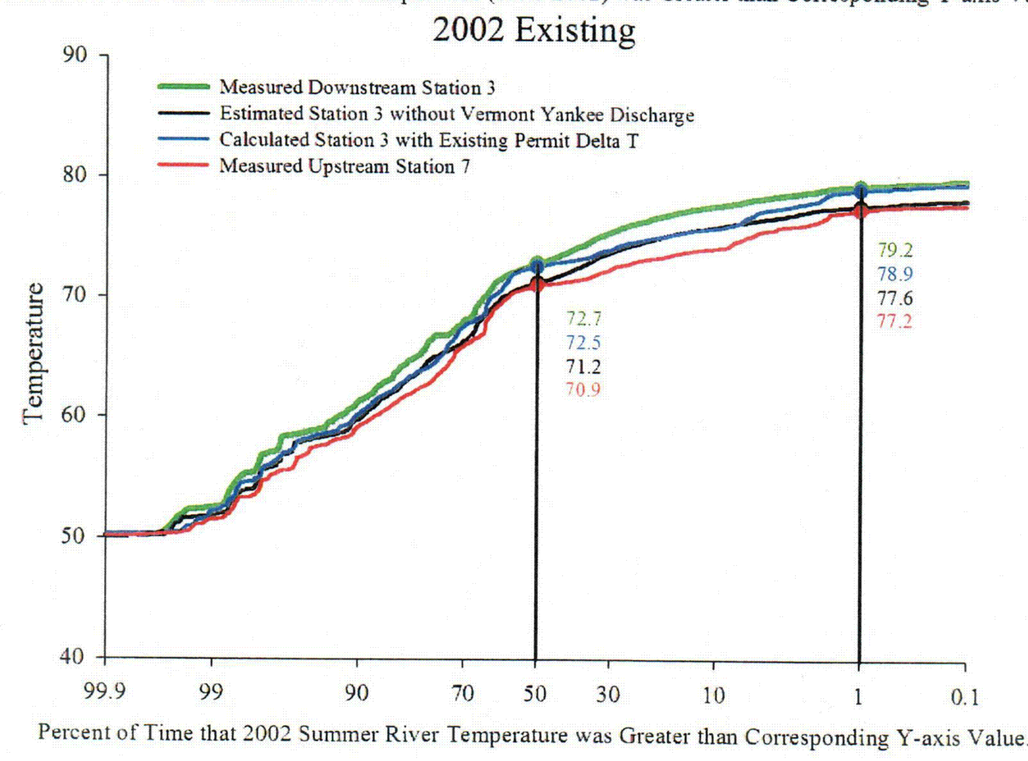


Figure 3-11e. Temperature Duration Curves for the 1998-2002 and 2002 Summer Periods for Selected Connecticut River Monitoring Stations – Existing Vermont Yankee Discharge Conditions.

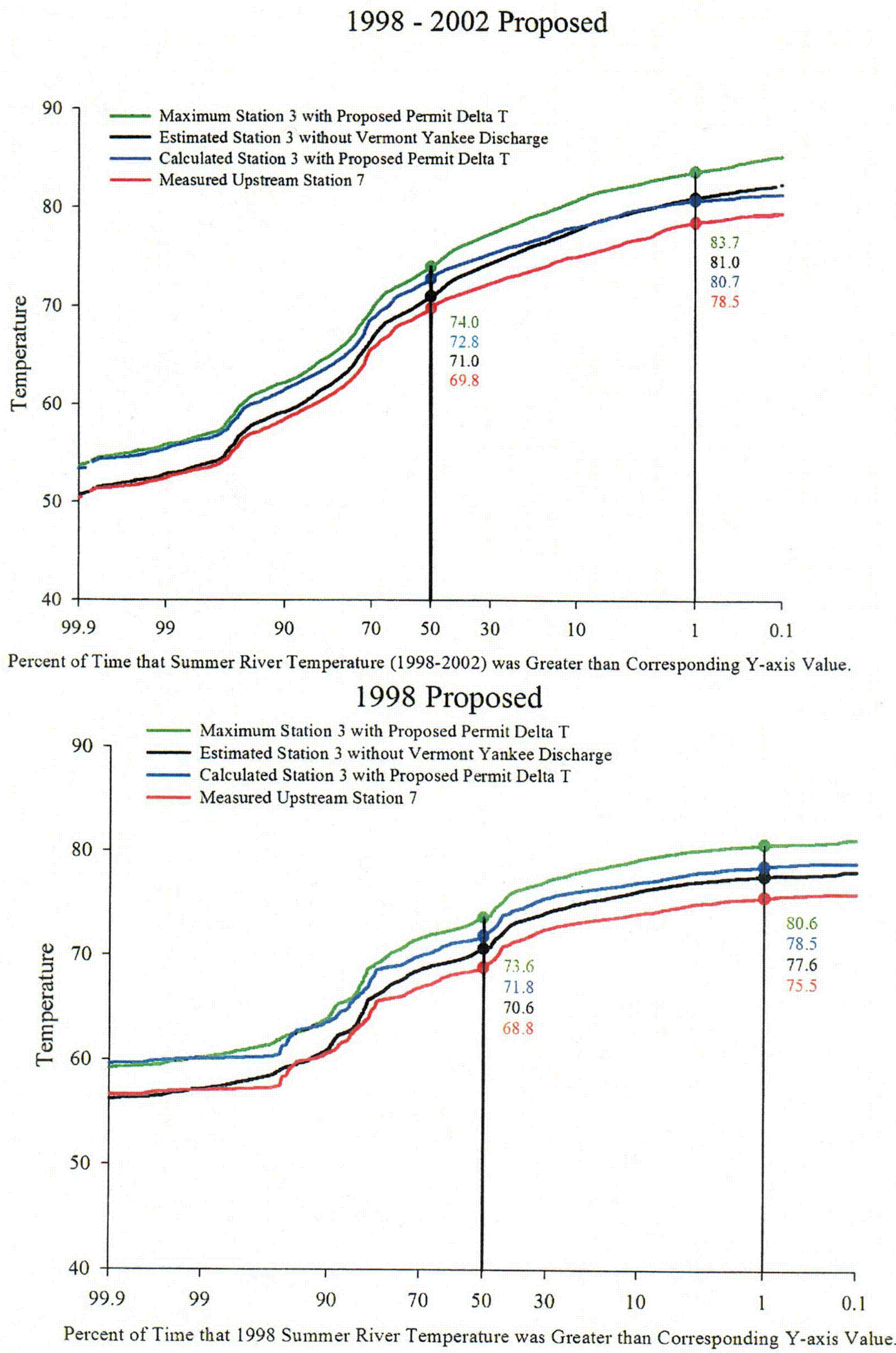
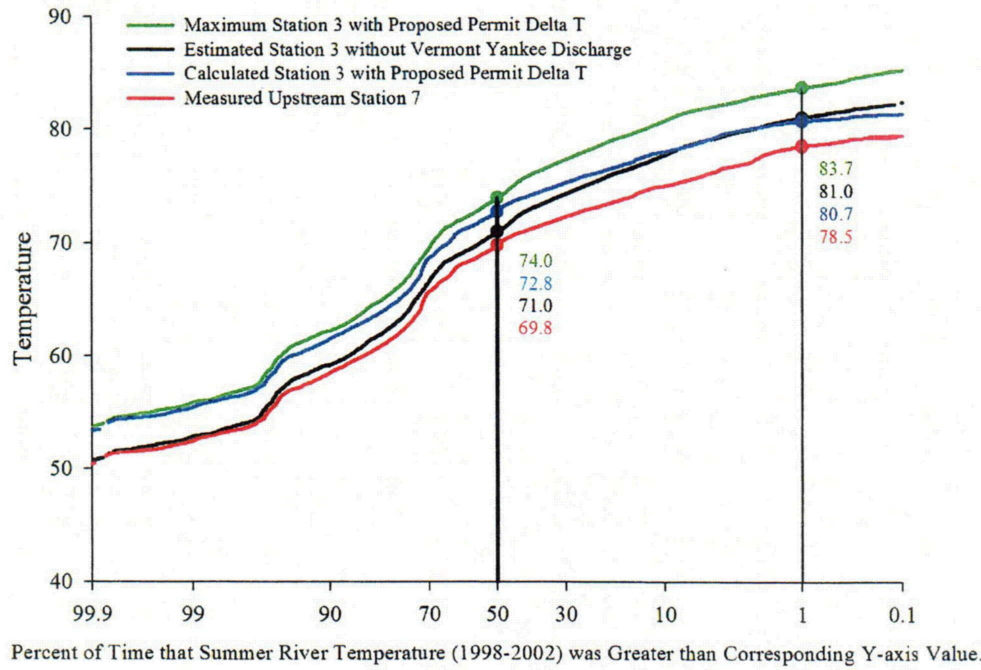


Figure 3-12a. Temperature Duration Curves for the 1998-2002 and 1998 Summer Periods for Selected Connecticut River Monitoring Stations – Proposed Vermont Yankee Discharge Conditions.

1998 - 2002 Proposed



1999 Proposed

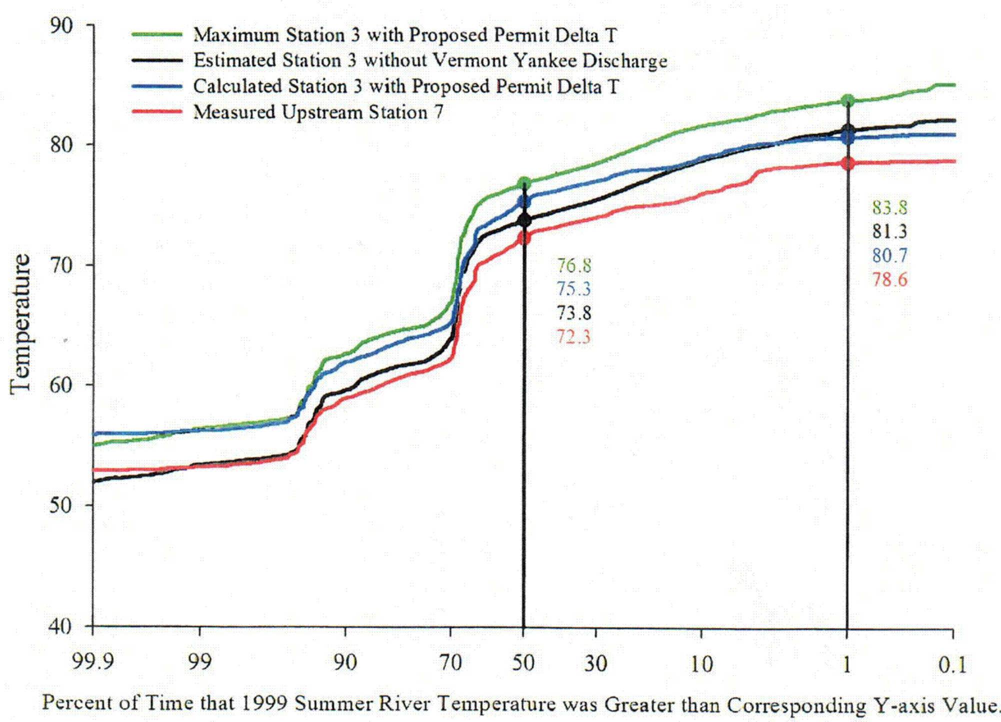
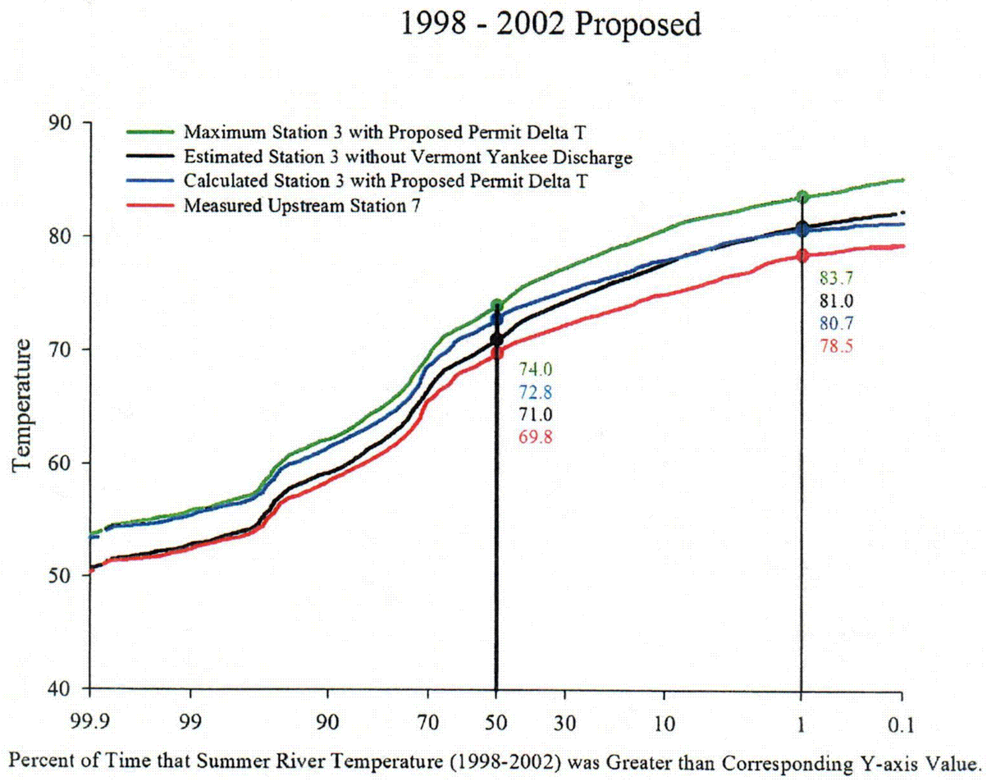


Figure 3-12b. Temperature Duration Curves for the 1998-2002 and 1999 Summer Periods for Selected Connecticut River Monitoring Stations – Proposed Vermont Yankee Discharge Conditions.



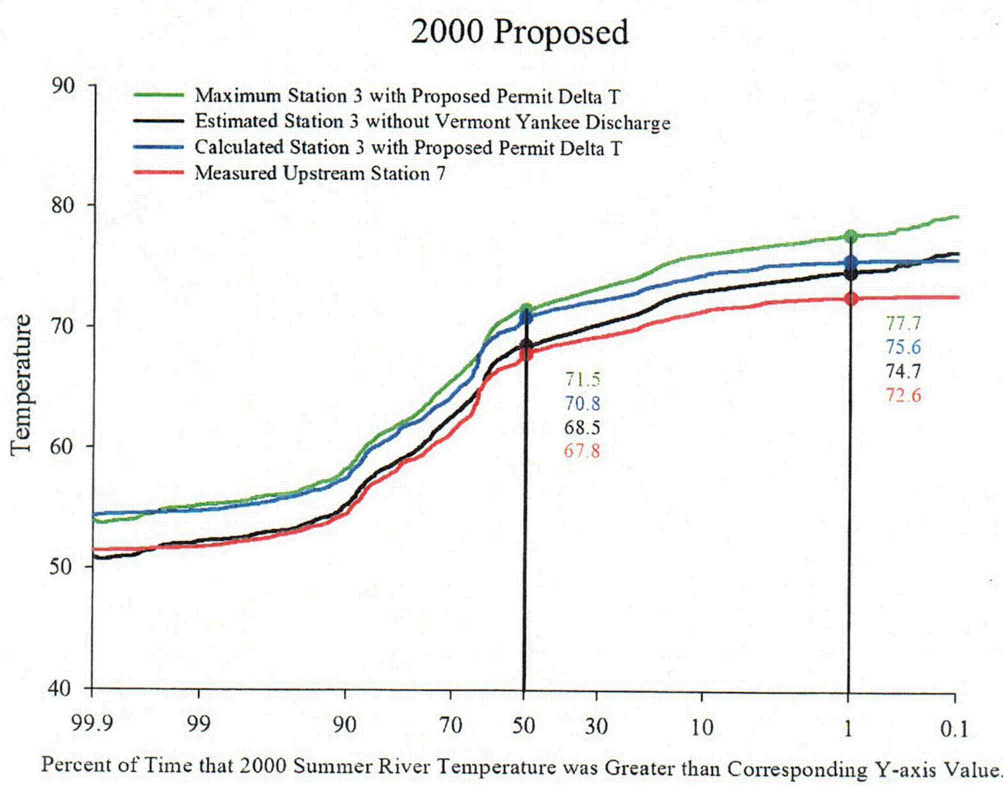
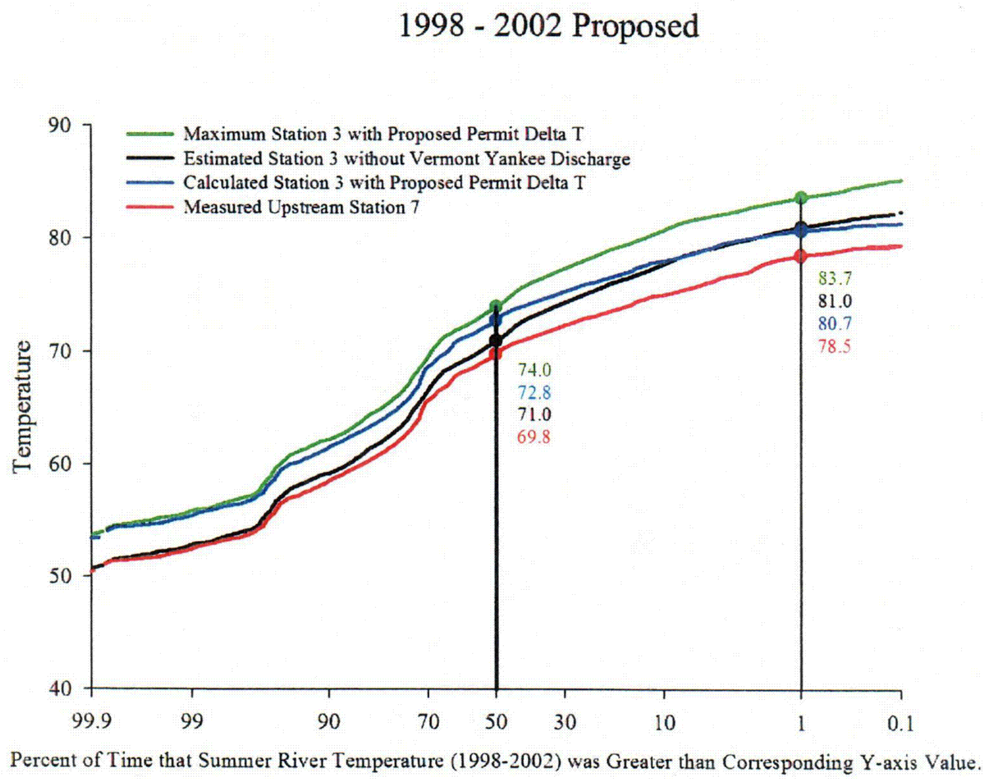


Figure 3-12c. Temperature Duration Curves for the 1998-2002 and 2000 Summer Periods for Selected Connecticut River Monitoring Stations – Proposed Vermont Yankee Discharge Conditions.



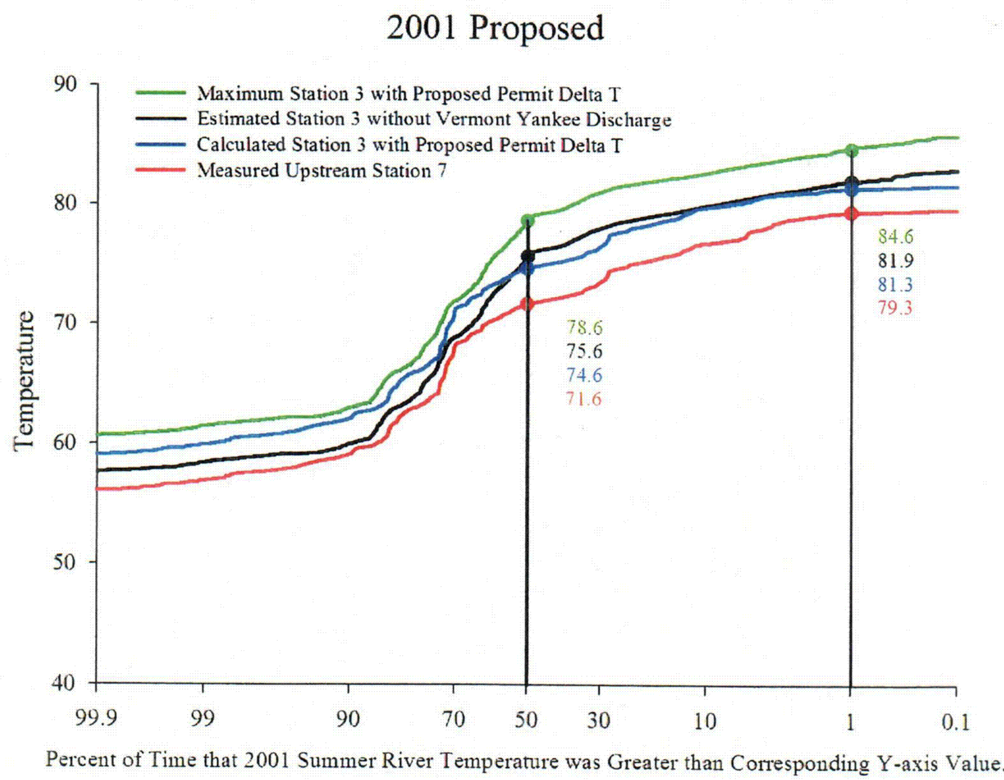
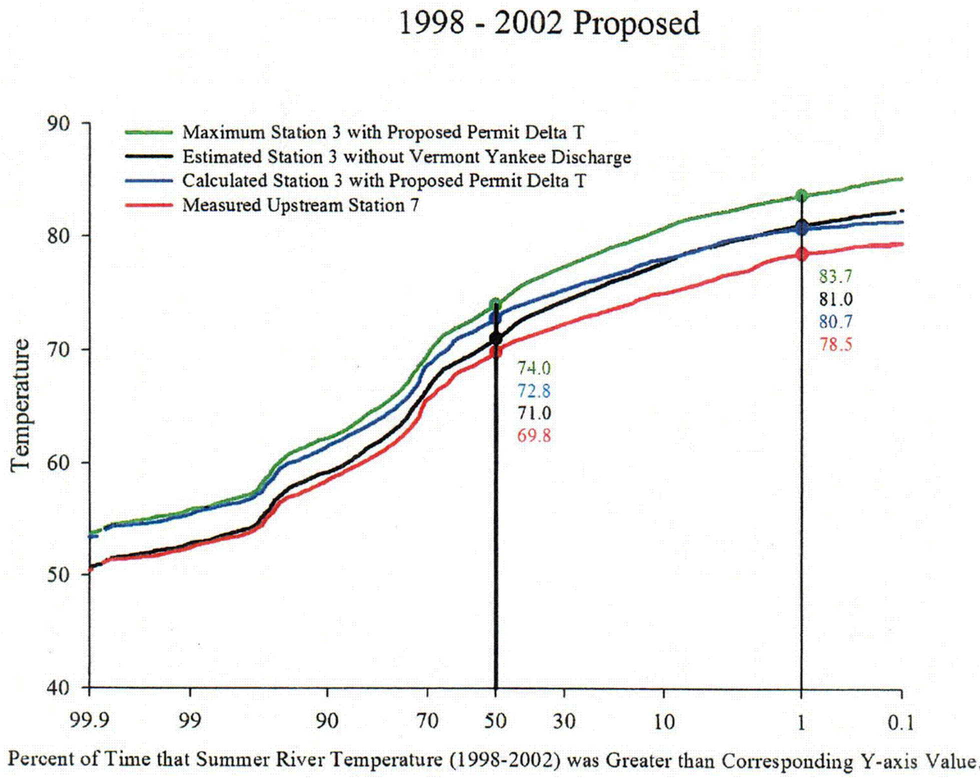


Figure 3-12d. Temperature Duration Curves for the 1998-2002 and 2001 Summer Periods for Selected Connecticut River Monitoring Stations – Proposed Vermont Yankee Discharge Conditions.



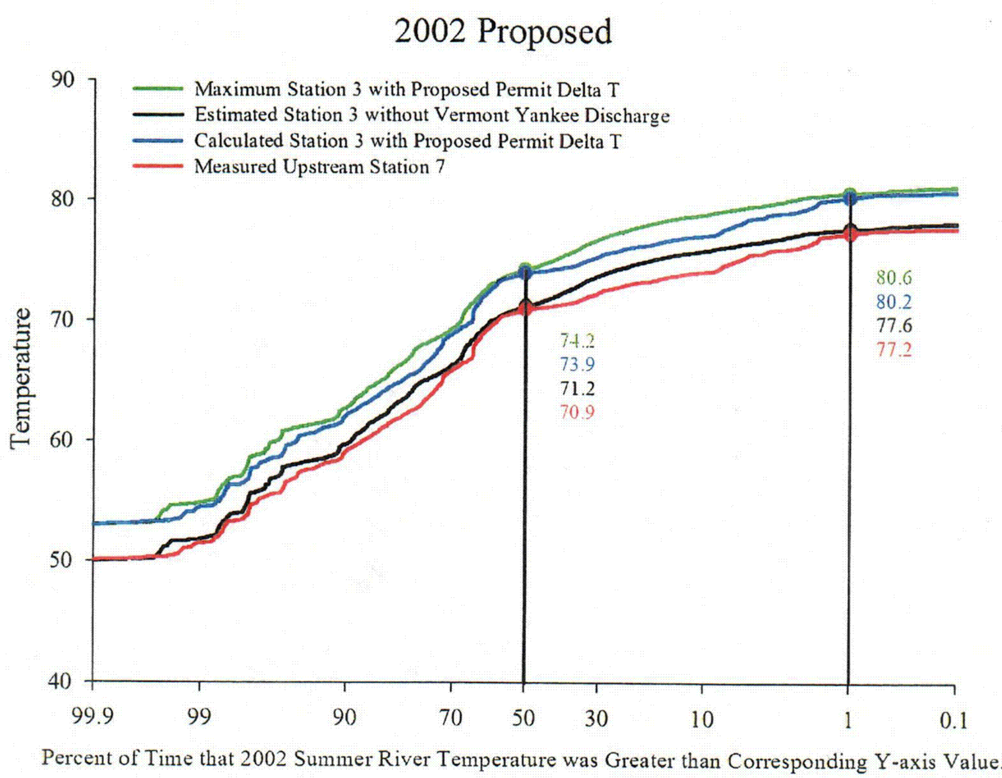
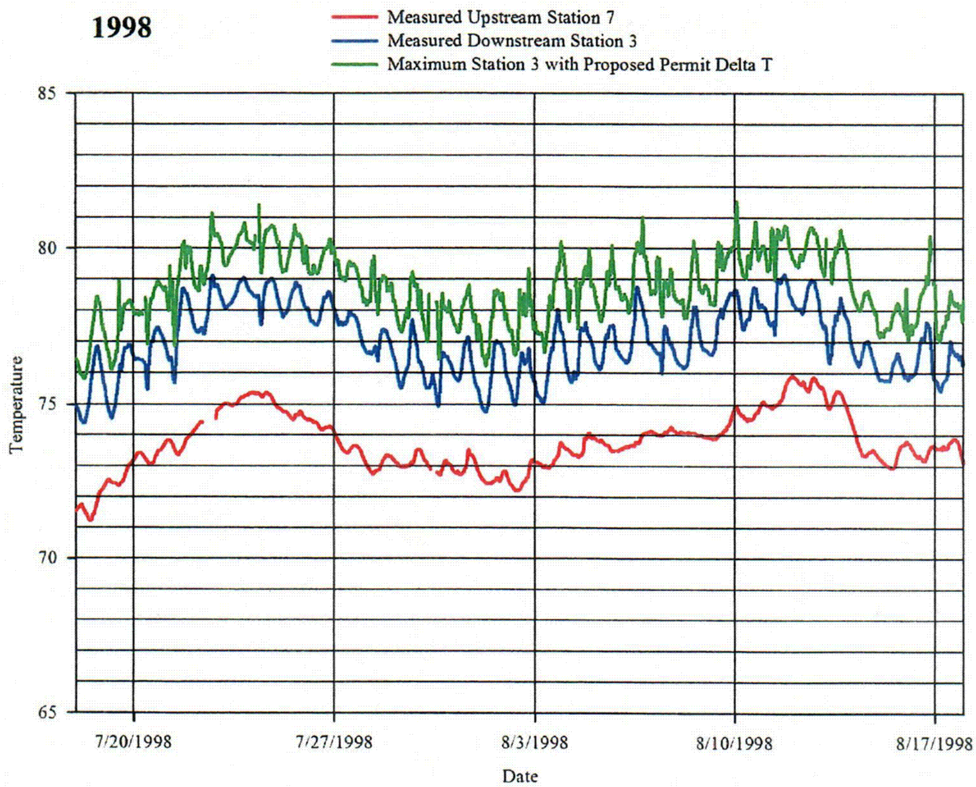


Figure 3-12e. Temperature Duration Curves for the 1998-2002 and 2002 Summer Periods for Selected Connecticut River Monitoring Stations – Proposed Vermont Yankee Discharge Conditions.



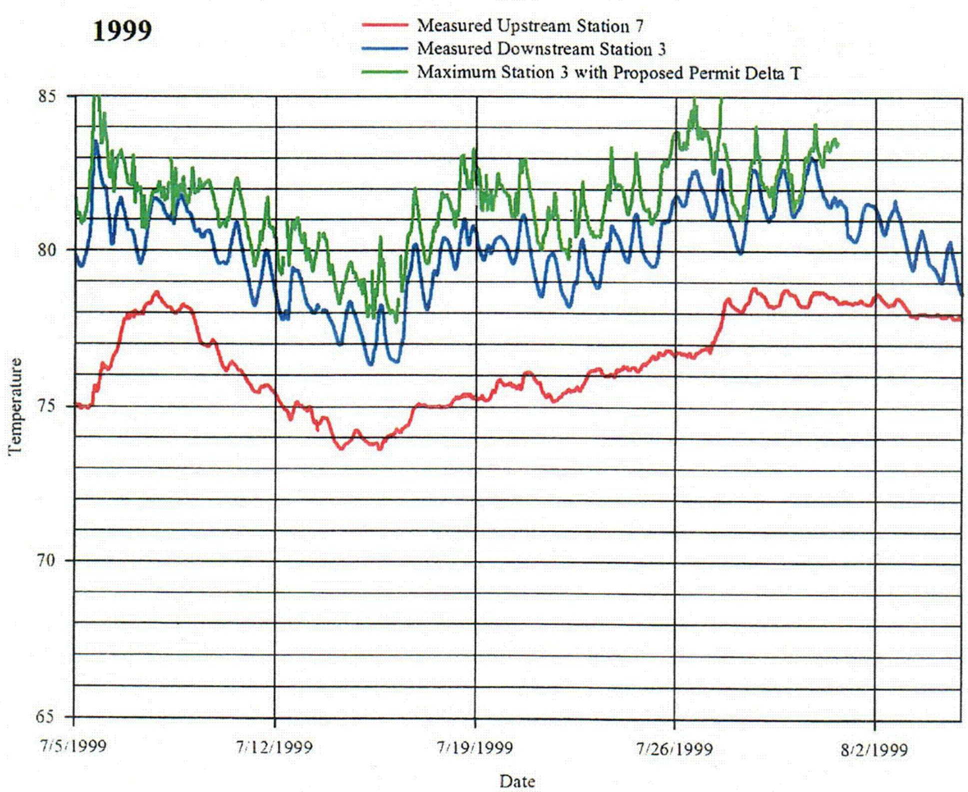
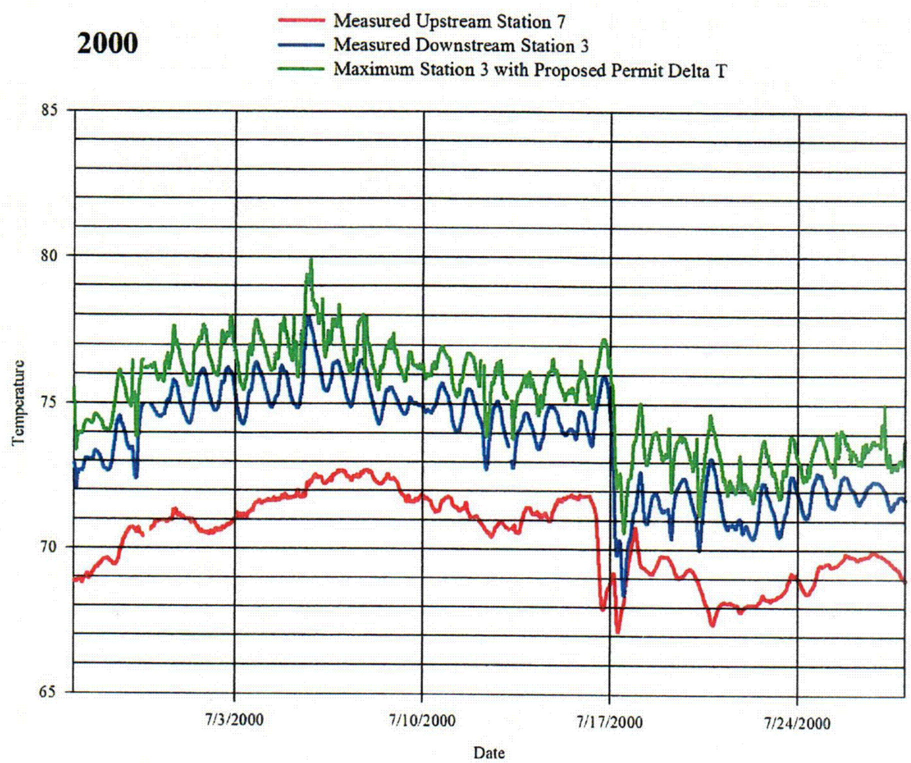


Figure 3-13a. Actual and Predicted Warmest 4-Week Period During the Summer Period (May 16 – October 14) for Selected Connecticut River Monitoring Stations – Existing and Proposed Vermont Yankee Discharge Conditions.



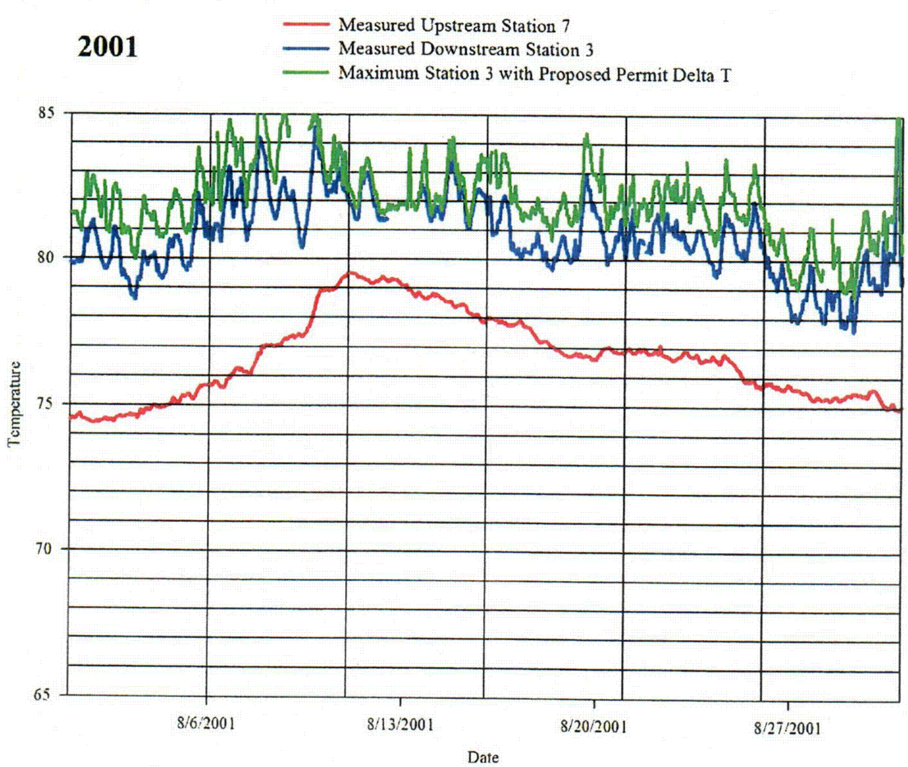


Figure 3-13b. Actual and Predicted Warmest 4-Week Period During the Summer Period (May 16 – October 14) for Selected Connecticut River Monitoring Stations – Existing and Proposed Vermont Yankee Discharge Conditions.

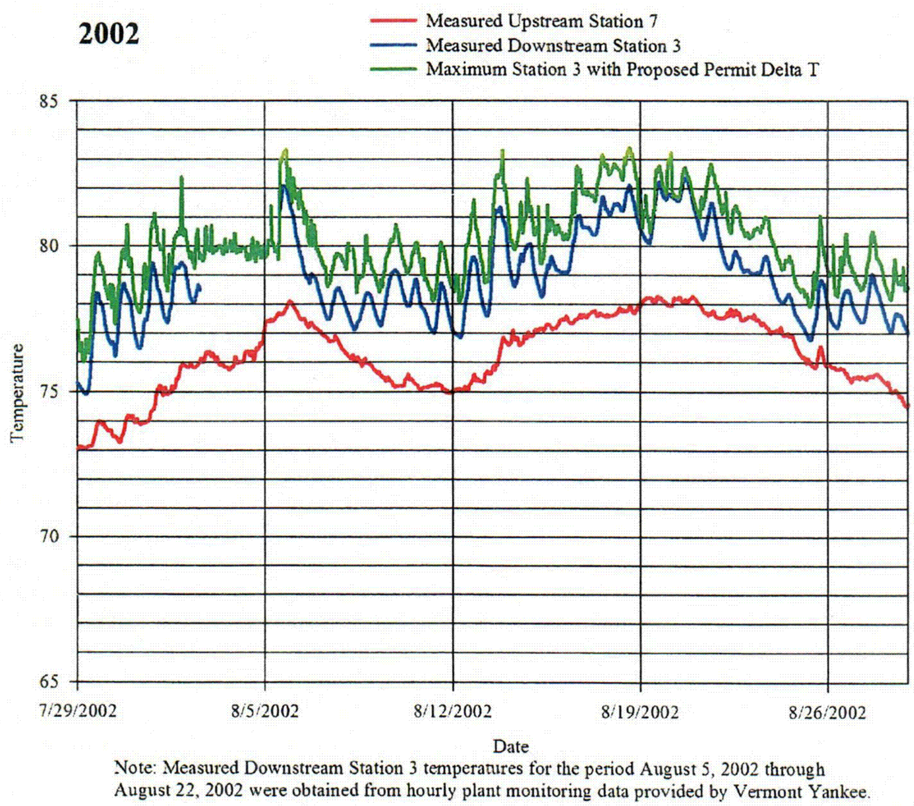


Figure 3-13c. Actual and Predicted Warmest 4-Week Period During the Summer Period (May 16 – October 14) for Selected Connecticut River Monitoring Stations – Existing and Proposed Vermont Yankee Discharge Conditions.

Table 3-3. Percent (%) of Time that Connecticut River Water Temperature Observed or Calculated for the Specified Location was greater than Each Indicated Temperature (°F) during the Combined 1998-2002 Summer Seasons (May 16 – October 14) under Existing and Proposed Permit Thermal Discharge Limits for Vermont Yankee.

Temp (F)	Existing Permit								Proposed New Permit			
	Measured Upstream Station 7		Calculated Station 3 with Existing Permit Delta T		Measured Downstream Station 3		Estimated Station 3 without Vermont Yankee Discharge		Calculated Station 3 with Proposed Permit Delta T		Maximum Station 3 with Proposed Permit Delta T	
	Percent	*Hours*	Percent	*Hours*	Percent	*Hours*	Percent	*Hours*	Percent	*Hours*	Percent	*Hours*
86	Never greater than		Never greater than		Never greater than		Never greater than		Never greater than		Never greater than	
85	Never greater than		Never greater than		Never greater than		Never greater than		Never greater than		0.15	6
84	Never greater than		Never greater than		0.06	2	Never greater than		Never greater than		0.57	21
83	Never greater than		Never greater than		0.30	11	>0.1	4	Never greater than		2.08	76
82	Never greater than		Never greater than		1.61	59	0.21	8	Never greater than		4.95	181
81	Never greater than		0.11	4	4.03	147	0.99	36	0.39	14	9.17	335
80	Never greater than		0.87	32	7.58	277	2.63	96	2.78	101	13.05	476
79	0.39	14	2.14	78	10.90	398	5.67	207	5.61	205	19.31	704
78	1.74	64	4.31	157	15.43	563	9.19	335	10.19	372	25.39	926
77	2.81	103	7.69	281	21.76	794	13.05	476	15.87	579	32.66	1,191
76	5.61	205	13.03	475	28.48	1,039	19.31	704	24.19	882	39.99	1,459
75	10.19	372	19.04	695	36.04	1,315	25.39	926	32.63	1,190	45.23	1,650
74	15.88	579	28.47	1,039	42.99	1,568	32.66	1,191	41.85	1,527	49.60	1,809
73	24.19	882	37.72	1,376	47.39	1,729	39.99	1,459	49.17	1,794	55.22	2,014
72	32.63	1,190	46.09	1,681	51.94	1,895	45.23	1,650	54.63	1,993	61.36	2,238
71	41.86	1,527	51.42	1,876	57.95	2,114	49.60	1,809	61.60	2,247	66.59	2,429
70	49.18	1,794	57.58	2,101	64.73	2,361	55.22	2,014	64.67	2,359	69.19	2,524
69	54.64	1,993	62.79	2,291	67.71	2,470	61.36	2,238	68.64	2,504	71.16	2,596
68	61.61	2,248	66.51	2,426	70.15	2,559	66.59	2,429	71.32	2,602	73.49	2,681
67	64.68	2,360	69.72	2,543	72.08	2,629	69.19	2,524	72.53	2,646	75.28	2,746
66	68.65	2,504	71.83	2,620	74.38	2,713	71.16	2,596	74.61	2,722	78.05	2,847
65	71.33	2,602	73.50	2,681	76.53	2,792	73.49	2,681	77.48	2,826	81.12	2,959
64	72.54	2,646	75.95	2,771	79.16	2,888	75.28	2,746	81.01	2,955	84.56	3,085
63	74.62	2,722	79.08	2,885	82.39	3,006	78.05	2,847	84.77	3,092	87.27	3,184
62	77.49	2,827	83.52	3,047	86.44	3,153	81.12	2,959	88.31	3,222	91.21	3,327
61	81.02	2,956	87.14	3,179	89.59	3,268	84.56	3,085	91.37	3,333	93.94	3,427
60	84.78	3,093	90.07	3,286	92.87	3,388	87.27	3,184	94.29	3,440	95.14	3,471
59	88.32	3,222	92.90	3,389	94.51	3,448	91.21	3,327	95.39	3,480	95.76	3,493
58	91.38	3,334	95.04	3,467	95.70	3,491	93.94	3,427	96.06	3,504	96.41	3,517
57	94.30	3,440	95.96	3,501	96.23	3,510	95.13	3,470	96.76	3,530	97.46	3,555
56	95.40	3,480	96.73	3,529	97.15	3,544	95.76	3,493	98.47	3,592	98.86	3,606
55	96.07	3,505	97.88	3,571	98.60	3,597	96.41	3,517	99.36	3,625	99.61	3,634
54	96.77	3,530	98.64	3,598	99.07	3,614	97.46	3,555	99.67	3,636	99.87	3,643
53	98.42	3,590	99.17	3,618	99.68	3,636	98.86	3,606	99.98	3,647	Always greater than	
52	99.37	3,625	99.83	3,642	Always greater than		99.61	3,634	Always greater than		Always greater than	
51	99.68	3,636	99.89	3,644	Always greater than		99.87	3,643	Always greater than		Always greater than	
50	99.99	3,648	Always greater than		Always greater than		Always greater than		Always greater than		Always greater than	
49	Always greater than		Always greater than		Always greater than		Always greater than		Always greater than		Always greater than	

Table 3-4a. Percent (%) of Time that Connecticut River Water Temperature Observed or Calculated for the Specified Location was Greater Than Each Indicated Temperature (°F) during the 1998 Summer Season (May 16 – October 14) (Compared to the Combined 1998-2002 Summer Seasons) under Existing and Proposed Permit Thermal Discharge Limits for Vermont Yankee.

Temp (°F)	Existing Permit				Proposed New Permit	
	Measured Upstream Station 7	Calculated Station 3 with Existing Permit Delta T	Measured Downstream Station 3	Estimated Station 3 without Vermont Yankee Discharge	Calculated Station 3 with Proposed Permit Delta T	Maximum Station 3 with Proposed Permit Delta T
86	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)
85	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (0.2)
84	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (0.6)
83	Never greater than (same)	Never greater than (same)	Never greater than (0.3)	Never greater than (<0.1)	Never greater than (same)	Never greater than (2.1)
82	Never greater than (same)	Never greater than (same)	Never greater than (1.6)	Never greater than (0.2)	Never greater than (same)	Never greater than (5.0)
81	Never greater than (same)	Never greater than (0.1)	Never greater than (4.0)	Never greater than (1.0)	Never greater than (0.4)	0.1 (9.2)
80	Never greater than (same)	Never greater than (0.9)	Never greater than (7.6)	Never greater than (2.6)	Never greater than (2.8)	4.0 (13.1)
79	Never greater than (0.4)	Never greater than (2.1)	0.2 (10.9)	Never greater than (5.7)	Never greater than (5.6)	10.5 (19.3)
78	Never greater than (1.7)	Never greater than (4.3)	5.6 (15.4)	0.1 (9.2)	2.8 (10.2)	20.2 (25.4)
77	Never greater than (2.8)	0.6 (7.7)	12.2 (21.8)	4.0 (13.1)	9.3 (15.9)	30.2 (32.7)
76	Never greater than (5.6)	4.7 (13.0)	22.6 (28.5)	10.5 (19.3)	22.4 (24.2)	39.9 (40.0)
75	2.8 (10.2)	11.6 (19.0)	32.4 (36.0)	20.2 (25.4)	33.2 (32.6)	43.9 (45.2)
74	9.3 (15.9)	25.8 (28.5)	40.6 (43.0)	30.2 (32.7)	41.2 (41.9)	47.3 49.6)
73	22.4 (24.2)	35.2 (37.7)	45.0 (47.4)	39.9 (40.0)	45.2 (49.2)	53.7 (55.2)
72	33.2 (32.6)	41.4 (46.1)	47.5 (51.9)	43.9 (45.2)	49.1 (54.6)	64.8 (61.4)
71	41.2 (41.9)	45.6 (51.4)	56.2 (58.0)	47.3 (49.6)	60.8 (61.6)	73.3 (66.6)
70	45.2 (49.2)	50.9 (57.6)	68.6 (64.7)	53.7 (55.2)	68.2 (64.7)	78.1 (69.2)
69	49.1 (54.6)	62.7 (62.8)	73.3 (67.7)	64.8 (61.4)	75.0 (68.6)	81.5 (71.2)
68	60.8 (61.6)	68.9 (66.5)	78.3 (70.2)	73.3 (66.6)	81.6 (71.3)	83.5 (73.5)
67	68.2 (64.7)	76.0 (69.7)	82.1 (72.1)	78.1 (69.2)	82.9 (72.5)	84.6 (75.3)
66	75.0 (68.7)	81.2 (71.8)	83.4 (74.4)	81.5 (71.2)	84.9 (74.6)	85.8 (78.1)
65	81.6 (71.3)	82.6 (73.5)	84.4 (76.5)	83.5 (73.5)	86.6 (77.5)	88.9 (81.1)
64	82.9 (72.4)	84.6 (76.0)	85.5 (79.2)	84.6 (75.3)	88.8 (81.0)	89.8 (84.6)
63	84.9 (74.6)	86.6 (79.1)	88.4 (82.4)	85.8 (78.1)	92.2 (84.8)	92.2 (87.3)
62	86.6 (77.5)	89.4 (83.5)	90.0 (86.4)	88.9 (81.1)	94.5 (88.3)	95.2 (91.2)
61	88.8 (81.0)	93.3 (87.1)	93.5 (89.6)	89.8 (84.6)	95.2 (91.4)	97.3 (93.9)
60	92.1 (84.8)	95.2 (90.1)	96.5 (92.9)	92.2 (87.3)	99.4 (94.3)	99.3 (95.1)
59	94.5 (88.3)	97.1 (92.9)	98.8 (94.5)	95.2 (91.2)	Always greater than (95.4)	99.97 (95.8)
58	95.2 (91.4)	Always greater than (95.0)	Always greater than (95.7)	97.3 (93.9)	Always greater than (96.1)	Always greater than (96.4)
57	99.4 (94.3)	Always greater than (96.0)	Always greater than (96.2)	99.3 (95.1)	Always greater than (96.8)	Always greater than (97.5)
56	Always greater than (95.4)	Always greater than (96.7)	Always greater than (97.2)	99.97 (95.8)	Always greater than (98.5)	Always greater than (98.9)
55	Always greater than (96.1)	Always greater than (97.9)	Always greater than (98.6)	Always greater than (96.4)	Always greater than (99.4)	Always greater than (99.6)
54	Always greater than (96.8)	Always greater than (98.6)	Always greater than (99.1)	Always greater than (97.5)	Always greater than (99.7)	Always greater than (99.9)
53	Always greater than (98.4)	Always greater than (99.2)	Always greater than (99.7)	Always greater than (98.9)	Always greater than (99.98)	Always greater than (same)
52	Always greater than (99.4)	Always greater than (99.8)	Always greater than (same)	Always greater than (99.6)	Always greater than (same)	Always greater than (same)
51	Always greater than (99.7)	Always greater than (99.89)	Always greater than (same)	Always greater than (99.9)	Always greater than (same)	Always greater than (same)
50	Always greater than (99.99)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)
49	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)

Note: Values in parentheses are percent of time exceedances for the entire 1998 – 2002 summer seasons and are included for comparison.

Table 3-4b. Percent (%) of Time that Connecticut River Water Temperature Observed or Calculated for the Specified Location was Greater Than Each Indicated Temperature (°F) during the 1999 Summer Season (May 16 – October 14) (Compared to the Combined 1998-2002 Summer Seasons) under Existing and Proposed Permit Thermal Discharge Limits for Vermont Yankee.

Temp (°F)	Existing Permit				Proposed New Permit	
	Measured Upstream Station 7	Calculated Station 3 with Existing Permit Delta T	Measured Downstream Station 3	Estimated Station 3 without Vermont Yankee Discharge	Calculated Station 3 with Proposed Permit Delta T	Maximum Station 3 with Proposed Permit Delta T
86	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)
85	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	0.2 (0.2)
84	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	0.5 (0.6)
83	Never greater than (same)	Never greater than (same)	0.1 (0.3)	Never greater than (<0.1)	Never greater than (same)	2.9 (2.1)
82	Never greater than (same)	Never greater than (same)	1.9 (1.6)	0.2 (0.2)	Never greater than (same)	7.1 (5.0)
81	Never greater than (same)	Never greater than (0.1)	5.7 (4.0)	1.4 (1.0)	Never greater than (0.4)	14.1 (9.2)
80	Never greater than (same)	0.9 (0.9)	10.5 (7.6)	4.2 (2.6)	5.3 (2.8)	19.4 (13.1)
79	Never greater than (0.4)	4.0 (2.1)	16.6 (10.9)	9.0 (5.7)	9.9 (5.6)	26.0 (19.3)
78	4.1 (1.7)	6.5 (4.3)	22.1 (15.4)	14.2 (9.2)	17.7 (10.2)	35.1 (25.4)
77	5.4 (2.8)	12.0 (7.7)	28.1 (21.8)	19.4 (13.1)	30.0 (15.9)	47.4 (32.7)
76	9.9 (5.6)	23.8 (13.0)	39.9 (28.5)	26.0 (19.3)	44.0 (24.2)	57.0 (40.0)
75	17.7 (10.2)	34.6 (19.0)	51.5 (36.0)	35.1 (25.4)	51.8 (32.6)	63.1 (45.2)
74	30.0 (15.9)	48.1 (28.5)	60.2 (43.0)	47.4 (32.7)	56.9 (41.9)	65.0 49.6)
73	44.0 (24.2)	53.5 (37.7)	63.9 (47.4)	57.0 (40.0)	63.0 (49.2)	66.4 (55.2)
72	51.8 (32.6)	59.1 (46.1)	65.2 (51.9)	63.1 (45.2)	64.3 (54.6)	67.6 (61.4)
71	56.9 (41.9)	63.3 (51.4)	66.7 (58.0)	65.0 (49.6)	65.6 (61.6)	67.9 (66.6)
70	63.0 (49.2)	64.0 (57.6)	67.5 (64.7)	66.4 (55.2)	67.0 (64.7)	68.5 (69.2)
69	64.3 (54.6)	65.6 (62.8)	68.3 (67.7)	67.6 (61.4)	67.6 (68.6)	68.7 (71.2)
68	65.6 (61.6)	67.2 (66.5)	68.5 (70.2)	67.9 (66.6)	68.2 (71.3)	69.4 (73.5)
67	67.0 (64.7)	67.8 (69.7)	68.8 (72.1)	68.5 (69.2)	68.6 (72.5)	69.9 (75.3)
66	67.6 (68.7)	68.3 (71.8)	69.7 (74.4)	68.7 (71.2)	69.3 (74.6)	72.2 (78.1)
65	68.2 (71.3)	68.8 (73.5)	70.7 (76.5)	69.4 (73.5)	70.8 (77.5)	76.2 (81.1)
64	68.6 (72.5)	69.1 (76.0)	72.6 (79.2)	69.9 (75.3)	78.3 (81.0)	85.6 (84.6)
63	69.3 (74.6)	72.8 (79.1)	79.3 (82.4)	72.2 (78.1)	84.7 (84.8)	88.7 (87.3)
62	70.8 (77.5)	80.2 (83.5)	86.8 (86.4)	76.2 (81.1)	89.3 (88.3)	92.6 (91.2)
61	78.3 (81.0)	85.4 (87.1)	89.4 (89.6)	85.6 (84.6)	92.4 (91.4)	93.3 (93.9)
60	84.7 (84.8)	89.2 (90.1)	92.0 (92.9)	88.7 (87.3)	93.4 (94.3)	93.7 (95.1)
59	89.3 (88.3)	92.9 (92.9)	92.8 (94.5)	92.6 (91.2)	94.2 (95.4)	94.2 (95.8)
58	92.4 (91.4)	93.7 (95.0)	93.6 (95.7)	93.3 (93.9)	94.7 (96.1)	94.7 (96.4)
57	93.4 (94.3)	94.3 (96.0)	94.4 (96.2)	93.7 (95.1)	95.5 (96.8)	96.7 (97.5)
56	94.2 (95.4)	95.4 (96.7)	96.0 (97.2)	94.2 (95.8)	99.6 (98.5)	98.3 (98.9)
55	94.7 (96.1)	99.0 (97.9)	99.8 (98.6)	94.7 (96.4)	Always greater than (99.4)	99.9 (99.6)
54	95.5 (96.8)	Always greater than (98.6)	99.9 (99.1)	96.7 (97.5)	Always greater than (99.7)	Always greater than (99.9)
53	99.6 (98.4)	Always greater than (99.2)	Always greater than (99.7)	98.3 (98.9)	Always greater than (99.98)	Always greater than (same)
52	Always greater than (99.4)	Always greater than (99.8)	Always greater than (same)	99.9 (99.6)	Always greater than (same)	Always greater than (same)
51	Always greater than (99.7)	Always greater than (99.9)	Always greater than (same)	Always greater than (99.9)	Always greater than (same)	Always greater than (same)
50	Always greater than (99.99)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)
49	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)

Note: Values in parentheses are percent of time exceedances for the entire 1998 – 2002 summer seasons and are included for comparison.

Table 3-4c. Percent (%) of Time that Connecticut River Water Temperature Observed or Calculated for the Specified Location was Greater Than Each Indicated Temperature (°F) during the 2000 Summer Season (May 16 – October 14) (Compared to the Combined 1998-2002 Summer Seasons) under Existing and Proposed Permit Thermal Discharge Limits for Vermont Yankee.

Temp (°F)	Existing Permit				Proposed New Permit	
	Measured Upstream Station 7	Calculated Station 3 with Existing Permit Delta T	Measured Downstream Station 3	Estimated Station 3 without Vermont Yankee Discharge	Calculated Station 3 with Proposed Permit Delta T	Maximum Station 3 with Proposed Permit Delta T
86	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)
85	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (0.2)
84	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (0.6)
83	Never greater than (same)	Never greater than (same)	Never greater than (0.3)	Never greater than (<0.1)	Never greater than (same)	Never greater than (2.1)
82	Never greater than (same)	Never greater than (same)	Never greater than (1.6)	Never greater than (0.2)	Never greater than (same)	Never greater than (5.0)
81	Never greater than (same)	Never greater than (0.1)	Never greater than (4.0)	Never greater than (1.0)	Never greater than (0.4)	Never greater than (9.2)
80	Never greater than (same)	Never greater than (0.9)	Never greater than (7.6)	Never greater than (2.6)	Never greater than (2.8)	Never greater than (13.1)
79	Never greater than (0.4)	Never greater than (2.1)	Never greater than (10.9)	Never greater than (5.7)	Never greater than (5.6)	0.2 (19.3)
78	Never greater than (1.7)	Never greater than (4.3)	<0.1 (15.4)	Never greater than (9.2)	Never greater than (10.2)	0.5 (25.4)
77	Never greater than (2.8)	Never greater than (7.7)	0.3 (21.8)	Never greater than (13.1)	Never greater than (15.9)	3.2 (32.7)
76	Never greater than (5.6)	Never greater than (13.0)	1.7 (28.5)	0.2 (19.3)	Never greater than (24.2)	10.8 (40.0)
75	Never greater than (10.2)	Never greater than (19.0)	7.1 (36.0)	0.5 (25.4)	4.8 (32.6)	17.3 (45.2)
74	Never greater than (15.9)	2.6 (28.5)	15.3 43.0)	3.2 (32.7)	12.9 (41.9)	22.4 (49.6)
73	Never greater than (24.2)	10.2 (37.7)	19.8 (47.4)	10.8 (40.0)	20.7 (49.2)	32.6 (55.2)
72	4.8 (32.6)	17.9 (46.1)	27.5 (51.9)	17.3 (45.2)	33.9 (54.6)	43.9 (61.4)
71	12.9 (41.9)	26.3 (51.4)	38.2 (58.0)	22.4 (49.6)	48.0 (61.6)	54.4 (66.6)
70	20.7 (49.2)	41.5 (57.6)	51.7 (64.7)	32.6 (55.2)	52.9 (64.7)	59.2 (69.2)
69	33.9 (54.6)	51.0 (62.8)	57.5 (67.7)	43.9 (61.4)	59.9 (68.7)	61.3 (71.2)
68	48.0 (61.6)	57.8 (66.5)	60.7 (70.2)	54.4 (66.6)	62.5 (71.3)	62.6 (73.5)
67	52.9 (64.7)	61.9 (69.7)	62.1 (72.1)	59.2 (69.2)	63.7 (72.5)	65.4 (75.3)
66	59.9 (68.7)	63.3 (71.8)	64.7 (74.4)	61.3 (71.2)	65.0 (74.6)	68.8 (78.1)
65	62.5 (71.3)	64.8 (73.5)	67.7 (76.5)	62.6 (73.5)	68.3 (77.5)	72.2 (81.1)
64	63.8 (72.5)	67.6 (76.0)	71.1 (79.2)	65.4 (75.3)	71.0 (81.0)	75.1 (84.6)
63	65.0 (74.6)	71.1 (79.1)	74.7 (82.4)	68.9 (78.1)	75.3 (84.8)	77.8 (87.3)
62	68.3 (77.5)	75.0 (83.5)	78.1 (86.4)	72.2 (81.1)	78.9 (88.3)	81.6 (91.2)
61	71.0 (81.0)	80.0 (87.1)	81.1 (89.6)	75.1 (84.6)	82.6 (91.4)	85.5 (93.9)
60	75.3 (84.8)	82.4 (90.1)	84.4 (92.9)	77.8 (87.3)	87.9 (94.3)	87.6 (95.1)
59	79.0 (88.3)	84.8 (92.9)	87.3 (94.5)	81.6 (91.2)	89.7 (95.4)	88.8 (95.8)
58	82.7 (91.4)	87.9 (95.0)	88.8 (95.7)	85.5 (93.9)	91.5 (96.1)	90.6 (96.4)
57	86.3 (94.3)	90.3 (96.0)	90.4 (96.2)	88.9 (95.1)	94.8 (96.8)	93.2 (97.5)
56	88.0 (95.4)	91.7 (96.7)	92.6 (97.2)	90.6 (95.8)	98.3 (98.5	96.5 (98.9)
55	89.8 (96.1)	93.3 (97.9)	95.2 (98.6)	93.3 (96.4)	Always greater than (99.4)	99.2 (99.6)
54	91.5 (96.8)	95.2 (98.6)	97.0 (99.1)	96.6 (97.5)	Always greater than (99.7)	99.7 (99.9)
53	94.8 (98.4)	97.3 (99.2)	99.6 (99.7)	99.3 (98.9)	Always greater than (99.98)	Always greater than (same)
52	98.3 (99.4)	99.9 (99.8)	Always greater than (same)	99.8 (99.6)	Always greater than (same)	Always greater than (same)
51	Always greater than (99.7)	Always greater than (99.9)	Always greater than (same)	Always greater than (99.9)	Always greater than (same)	Always greater than (same)
50	Always greater than (99.99)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)
49	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)

Note: Values in parentheses are percent of time exceedances for the entire 1998 – 2002 summer seasons and are included for comparison.

Table 3-4d. Percent (%) of Time that Connecticut River Water Temperature Observed or Calculated for the Specified Location was Greater Than Each Indicated Temperature (°F) during the 2001 Summer Season (May 16 – October 14) (Compared to the Combined 1998-2002 Summer Seasons) under Existing and Proposed Permit Thermal Discharge Limits for Vermont Yankee.

	Existing Permit				Proposed New Permit	
Temp (°F)	Measured Upstream *Station 7*	Calculated Station 3 with Existing Permit Delta T	Measured Downstream *Station 3*	Estimated Station 3 without Vermont Yankee Discharge	Calculated Station 3 with Proposed Permit Delta T	Maximum Station 3 with Proposed Permit Delta T
86	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)
85	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	0.5 (0.2)
84	Never greater than (same)	Never greater than (same)	0.3 (0.1)	Never greater than (same)	Never greater than (same)	2.2 (0.6)
83	Never greater than (same)	Never greater than (same)	1.3 (0.3)	0.1 (<0.1)	Never greater than (same)	6.9 (2.1)
82	Never greater than (same)	Never greater than (same)	5.7 (6.1)	0.7 (0.2)	Never greater than (same)	16.3 (5.0)
81	Never greater than (same)	0.5 (0.1)	13.4 (4.0)	3.3 (1.0)	1.8 (0.4)	29.2 (9.2)
80	Never greater than (same)	3.2 (0.9)	25.4 (7.6)	8.3 (2.6)	6.5 (2.8)	36.6 (13.1)
79	1.8 (0.4)	5.5 (2.1)	33.6 (10.9)	17.9 (5.7)	13.3 (5.6)	48.0 (19.3)
78	4.3 (1.7)	11.5 (4.3)	39.4 (15.4)	29.2 (9.2)	21.4 (10.2)	51.4 (25.4)
77	6.6 (2.8)	17.5 (7.7)	50.3 (27.8)	36.6 (13.1)	28.1 (15.9)	54.6 (32.7)
76	13.3 (5.6)	26.1 (13.0)	52.8 (28.5)	48.0 (19.3)	32.3 (24.2)	57.8 (40.0)
75	21.4 (10.2)	30.0 (19.0)	56.5 (36.0)	51.4 (25.4)	42.5 (32.6)	60.9 (45.2)
74	28.1 (15.9)	37.2 (28.5)	59.8 (43.0)	54.6 (32.7)	54.5 (41.9)	63.0 (49.6)
73	32.3 (24.2)	51.2 (37.7)	62.3 (47.4)	57.8 (40.0)	61.2 (49.2)	65.4 (55.2)
72	42.5 (32.6)	58.6 (46.1)	64.3 (51.9)	60.9 (45.2)	65.8 (54.6)	68.8 (61.4)
71	54.5 (41.9)	64.2 (51.4)	67.6 (58.0)	63.0 (49.6)	70.0 (61.6)	72.2 (66.6)
70	61.2 (49.2)	69.2 (57.6)	71.8 (64.7)	65.4 (55.2)	71.1 (64.7)	73.4 (69.2)
69	65.8 (54.6)	70.5 (62.8)	73.0 (67.7)	68.8 (61.4)	72.2 (68.7)	74.7 (71.2)
68	70.0 (61.6)	71.6 (66.5)	74.2 (70.2)	72.3 (66.6)	73.4 (71.3)	77.2 (73.5)
67	71.1 (64.7)	72.5 (69.7)	75.9 (72.1)	73.4 (69.2)	74.7 (72.5)	79.0 (75.3)
66	72.3 (68.7)	73.9 (71.8)	77.7 (74.4)	74.7 (71.2)	78.4 (74.6)	82.6 (78.1)
65	73.4 (71.3)	77.0 (73.5)	81.0 (76.5	77.2 (73.5)	82.3 (77.5)	85.1 (81.1)
64	74.7 (72.5)	79.0 (76.0)	84.3 (79.2)	79.0 (75.9)	84.1 (81.1)	86.3 (84.6)
63	78.4 (74.6)	82.8 (79.1)	85.4 (82.4)	82.6 (78.1)	85.9 (84.8)	89.6 (87.3)
62	82.3 (77.5)	85.1 (83.5)	90.3 (86.4)	85.1 (81.1)	90.2 (88.3)	96.6 (91.2)
61	84.1 (81.0)	86.3 (87.1)	94.6 (89.6)	86.3 (84.6)	95.1 (91.4)	99.4 (93.9)
60	85.9 (84.8)	89.6 (90.1)	Always greater than (92.9)	89.6 (87.3)	98.7 (94.3)	Always greater than (95.1)
59	90.2 (88.3)	96.6 (92.9)	Always greater than (94.5)	96.6 (91.2)	Always greater than (95.4)	Always greater than (95.8)
58	95.1 (91.4)	99.4 (95.0)	Always greater than (95.7)	99.4 (93.9)	Always greater than (96.1)	Always greater than (96.4)
57	98.7 (94.3)	Always greater than (96.0)	Always greater than (96.2)	Always greater than (95.1)	Always greater than (96.8)	Always greater than (97.5)
56	Always greater than (95.4)	Always greater than (96.7)	Always greater than (97.2)	Always greater than (95.8)	Always greater than (98.4)	Always greater than (98.9)
55	Always greater than (96.1)	Always greater than (97.9)	Always greater than (98.6)	Always greater than (96.4)	Always greater than (99.4)	Always greater than (99.6)
54	Always greater than (96.8)	Always greater than (98.6)	Always greater than (99.1)	Always greater than (97.5)	Always greater than (99.7)	Always greater than (99.9)
53	Always greater than (98.4)	Always greater than (99.2)	Always greater than (99.7)	Always greater than (98.9)	Always greater than (99.99)	Always greater than (same)
52	Always greater than (99.4)	Always greater than (99.8)	Always greater than (same)	Always greater than (99.6)	Always greater than (same)	Always greater than (same)
51	Always greater than (99.7)	Always greater than (99.9)	Always greater than (same)	Always greater than (99.9)	Always greater than (same)	Always greater than (same)
50	Always greater than (99.99)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)
49	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)

Note: Values in parentheses are percent of time exceedances for the entire 1998 – 2002 summer seasons and are included for comparison.

Table 3-4e. Percent (%) of Time that Connecticut River Water Temperature Observed or Calculated for the Specified Location was Greater Than Each Indicated Temperature (°F) during the 2002 Summer Season (May 16 – October 14) (Compared to the Combined 1998-2002 Summer Seasons) under Existing and Proposed Permit Thermal Discharge Limits for Vermont Yankee.

Temp (°F)	Existing Permit				Proposed New Permit	
	Measured Upstream Station 7	Calculated Station 3 with Existing Permit Delta T	Measured Downstream Station 3	Estimated Station 3 without Vermont Yankee Discharge	Calculated Station 3 with Proposed Permit Delta T	Maximum Station 3 with Proposed Permit Delta T
86	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)
85	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (0.2)
84	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (same)	Never greater than (0.6)
83	Never greater than (same)	Never greater than (same)	Never greater than (0.3)	Never greater than (<0.1)	Never greater than (same)	Never greater than (2.1)
82	Never greater than (same)	Never greater than (same)	Never greater than (1.6)	Never greater than (0.2)	Never greater than (same)	Never greater than (5.0)
81	Never greater than (same)	Never greater than (0.1)	Never greater than (4.0)	Never greater than (1.0)	Never greater than (0.4)	0.1 (9.2)
80	Never greater than (same)	Never greater than (0.9)	Never greater than (7.6)	Never greater than (2.6)	1.8 (2.8)	3.2 (13.1)
79	Never greater than (0.4)	0.8 (2.1)	1.7 (10.9)	Never greater than (5.7)	4.2 (5.6)	10.2 (19.3)
78	Never greater than (1.7)	2.9 (4.3)	8.5 (15.4)	0.1 (9.2)	8.5 (10.2)	19.9 (25.4)
77	1.8 (2.8)	7.9 (7.7)	17.0 (21.8)	3.2 (13.1)	11.7 (15.9)	29.2 (32.7)
76	4.2 (5.6)	9.8 (13.0)	26.0 (28.5)	10.2 (19.3)	24.1 (24.2)	36.1 (40.0)
75	8.5 (10.2)	19.6 (19.0)	34.0 (36.0)	19.9 (25.4)	33.3 (32.6)	42.6 (45.2)
74	11.7 (15.9)	30.8 (28.5)	40.5 (43.0)	29.2 (32.7)	46.7 (41.9)	52.5 (49.6)
73	24.1 (24.2)	40.6 (37.7)	47.9 (47.4)	36.1 (40.0)	59.0 (49.2)	60.4 (55.2)
72	33.4 (32.6)	56.6 (46.1)	57.3 (51.9)	42.6 (45.2)	62.4 (54.6)	63.7 (61.4)
71	46.8 (41.9)	60.1 (51.4)	63.0 (58.0)	52.5 (49.6)	64.9 (61.6)	66.8 (66.6)
70	59.0 (49.2)	63.4 (57.6)	65.4 (64.7)	60.4 (55.2)	65.6 (64.7)	68.5 (69.2)
69	62.5 (54.6)	65.4 (62.8)	68.0 (67.7)	63.7 (61.4)	70.1 (68.7)	71.7 (71.2)
68	64.9 (61.6)	68.2 (66.5)	70.8 (70.2)	66.8 (66.6)	73.0 (71.3)	77.3 (73.5)
67	65.6 (64.7)	72.2 (69.7)	73.7 (72.1)	68.5 (69.2)	75.1 (72.5)	80.1 (75.3)
66	70.1 (68.7)	74.5 (71.8)	77.4 (74.4)	71.7 (71.2)	77.8 (74.6)	83.1 (78.1)
65	73.1 (71.3)	76.2 (73.5)	81.1 (76.5)	77.3 (73.5)	81.6 (77.5)	85.4 (81.1)
64	75.1 (72.5)	79.1 (75.6)	84.3 (79.2)	80.1 (75.3)	85.2 (81.0)	87.9 (84.6)
63	77.8 (74.6)	83.1 (79.1)	86.0 (82.4)	83.1 (78.1)	88.0 (84.8)	89.7 (87.3)
62	81.7 (77.5)	85.9 (83.5)	88.3 (86.4)	85.4 (81.1)	90.4 (88.3)	91.3 (91.2)
61	85.2 (81.0)	88.6 (87.1)	90.5 (89.6)	87.9 (84.6)	92.8 (91.4)	95.3 (93.9)
60	88.1 (84.8)	90.6 (90.1)	92.3 (92.9)	89.7 (87.3)	95.0 (94.3)	96.3 (95.1)
59	90.5 (88.3)	92.4 (92.9)	93.9 (94.5)	91.3 (91.2)	96.0 (95.4)	97.0 (95.8)
58	92.9 (91.4)	95.7 (95.0)	95.6 (95.7)	95.3 (93.9)	97.3 (96.1)	97.7 (96.4)
57	95.1 (94.3)	96.5 (96.0)	97.3 (96.2)	96.3 (95.1)	97.9 (96.8)	98.1 (97.5)
56	96.0 (95.4)	97.3 (96.7)	97.9 (97.2)	97.0 (95.8)	98.4 (98.4)	98.6 (98.9)
55	97.3 (96.1)	97.7 (97.9)	98.4 (98.6)	97.7 (96.4)	98.6 (99.4)	98.9 (99.6)
54	97.9 (96.8)	Always greater than (98.6)	98.6 (99.1)	98.1 (97.5)	99.3 (99.7)	Always greater than (99.9)
53	98.5 (98.4)	Always greater than (99.2)	98.7 (99.7)	98.6 (98.9)	99.93 (99.99)	Always greater than (same)
52	98.6 (99.4)	Always greater than (99.8)	Always greater than (same)	98.9 (99.6)	Always greater than (same)	Always greater than (same)
51	99.3 (99.7)	Always greater than (99.9)	Always greater than (same)	Always greater than (99.9)	Always greater than (same)	Always greater than (same)
50	99.96 (99.99)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)
49	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same)	Always greater than (same	Always greater than (same)

Note: Values in parentheses are percent of time exceedances for the entire 1998 – 2002 summer seasons and are included for comparison.

3.2.4 Expected Thermal Conditions in the Tailrace Between Vernon Dam and Downstream Station 3

References in this and previous Demonstrations to completely mixed conditions below Vernon Dam reflect expected conditions at Downstream Station 3 (0.65 miles downstream from Vernon Dam) and not necessarily conditions immediately below the Dam. It was reported that measured hourly River water temperatures in the fishway were often different by a few degrees (F) than measured River water temperatures at Downstream Station 3 (see Figures 3-7a through 3-7e for the most recent five years of fishway monitoring data). Binkerd (1985) reported that observed water temperature in the fishway was often equal to or lower than the observed River water temperature at Downstream Station 3 during times of high River flow when water was spilled over the Dam crest gates, while Downey et al. (1990) reported fishway water temperature was often higher than the measured River water temperature at Downstream Station 3 during times of low River flow (no spillage). In addition to flow in the fishway, bypass flow (flow that does not pass through the turbines at Vernon Dam) is also provided for downstream fish passage and fishway attraction (and additional downstream passage). Neither of these flows has been monitored for temperature and it is therefore unknown how their temperatures compare to Downstream Station 3 temperatures. Theoretically, therefore, some level of incomplete mixing may exist in the tailrace and near the fishway entrance.

However, any incomplete mixing immediately below Vernon Dam is likely to be relatively insignificant and of brief duration. First, total bypass flow equals 455 cfs when all fish passages facilities are operational[2]. Because typical May and June River flows (median flow equals 11,305 and 7,663 cfs, respectively) greatly exceed fish passage flows, it is highly unlikely that temperature differences could exist in the tailrace below Vernon Dam, except perhaps immediately adjacent to the areas of bypass and fishway discharge.

On the other hand, in the unlikely event that Vernon Dam is only passing minimum flow (1,250 cfs), the bypass flow would be slightly more than one third of the total flow below the dam. Minimum flows of 1250 cfs occurred fewer than 36 hours during the past five summer periods (1998-2002, averaging about 7 hours per year), and are most common during the months of July and August when the fishway is not operating and passage concerns are of less importance. During periods of minimum flow, the mixing forces below the dam could be considerably reduced, with the potential for a small, horizontal (cross-river) thermal gradient for a short distance downstream of the Dam. The extent and significance of this gradient would depend on several factors: 1) the mixing characteristics below the Dam; 2) the total flow release through the Dam; 3) the temperatures of the fish passage flows (each of which could be slightly different) versus the temperature of the rest of the flow; 4) the frequency of occurrence of various flow releases but especially minimum or relatively low flow events; and 5) the duration of both low flow occurrences and times of temperature differences between fish passage flows and Downstream Station 3. However, it is extremely unlikely

[2] Primary downstream passage flow is 350 cfs, supplied by a largely surface 9-ft by 6-ft gate in the center of the powerhouse. This 350 cfs downstream passage flow is typically supplied continuously froml April through 31 July, and again from 1 September through 15 November of each year. Upstream passage is provided by a fishway located on the Vermont (western) side of the Dam and River that is supplied with 65 cfs during the period of fishway operation, typically mid-May through early-July of each year. Secondary downstream passage and fishway attraction flow is 40 cfs, supplied by a "fish pipe" which also has a near surface intake and exits near the entrance to the fishway. The fish pipe flow of 40 cfs is provided for the same period of operation as the primary downstream passage flow of 350 cfs.

that any horizontal thermal stratification that may exist under minimum flow conditions would persist 0.65 miles downstream to Station 3.

Mixing characteristics below the Dam have not been investigated since the downstream passage flow releases were first implemented. However, experience and professional judgment lead to the expectation of relatively rapid and complete mixing of fish passage discharge water with the rest of the River water, generally within a short distance of the dam and certainly at Downstream Station 3, regardless of flow conditions. We make this conclusion for the following reasons:

1) We have conducted numerous dye studies in riverine situations and have often noted the rapidity with which point source discharges mix in flowing waters. Given the turbulence and riverine conditions below the Dam, we would expect complete mixing of the various flow releases within a short distance, say a couple of hundred meters, even under minimum flow conditions. During higher flows, complete thermal mixing should occur even closer to the foot of the Dam.
2) Minimum flows are maintained by use of one of the small capacity turbines located near the fishway on the west side of the powerhouse (Goodwin, D., US GEN, 8/22/03, pers. comm.). This flow (≥795 cfs) would be expected to mix rapidly with the fishway and secondary downstream passage flow (105 cfs), which should eliminate potential thermal differences between these two flows within a very short distance of the Dam. This would create a well-mixed flow of ≥900 cfs on the west side of the channel to be combined with a downstream passage surface discharge of 350 cfs (released from the center of the powerhouse), which, as noted above, would be expected to mix completely within no more than a couple of hundred meters from the foot of the Dam.
3) Minimum flow (1,250 cfs) is seldom, if ever, released from the Dam during the time that fish passage facilities are operational. For example, during the last five years, the lowest one-hour flow reported was 1,318 cfs (2000) and the lowest average daily flow was 1,617 cfs (1999) during the period of fishway operations. The apparent near 100% occurrence of higher-than-minimum flows during the spring/early summer fish passage season further enhances below-dam mixing conditions.
4) As shown in Figures 3-7a through 3-7e, measured hourly fishway water temperatures are often 1°F higher than downstream Station 3 temperatures, occasionally 2°F higher and rarely as much as 3°F higher. Assuming that the other fish passage releases are thermally similar to the fishway, it follows that the maximum thermal gradient that could be found immediately below the Dam would typically be 1°F, occasionally as much as 2°F and rarely as much as 3°F.
5) Both River flows and temperature comparisons between fish passage flows and Downstream Station 3 change frequently. As reported in Section 3.1.2, Vernon Station is used to produce peaking power and consequently, hourly River flows generally fluctuate between lower and higher flows on a daily basis, especially during the early part of the summer season when water is more available. Similarly, temperature differences between fish passage flows and Downstream Station 3 change almost constantly in direct response to atmospheric influences. Looking again at Figures 3-7a through 3-7e reveals that maximum temperature differences typically occur for no more than an hour or two and usually fall back to zero or occasional below (i.e., fishway temperature is less than Downstream Station 3) more or less on a daily basis. Consequently, this combination of flow and natural temperature fluctuation insures that occurrence of any thermal gradients immediately below the Dam will be short-term (usually for a few hours within a few days) events, if they occur at all.

The above factors, combined with the relatively low temperatures that typically occur during the majority of the upstream fish passage time period, make it highly unlikely that the magnitude, duration and aerial extent of occurrence of below-Dam thermal gradients would have biological significance with respect to upstream fish passage or habitat utilization in the 0.65 miles of River between the foot of the Dam and Downstream Station 3. We make this conclusion for both existing and proposed permit conditions. We also conclude that the River water temperatures measured at Downstream Station 3 are representative of the mixed River temperature 0.65 miles downstream from Vernon Dam.

4.0 HYDROTHERMAL MODELING OF THE COOLING WATER DISCHARGE

A three-dimensional time-varying hydrothermal model (BFHYDRO, ASA 1996) was developed, calibrated, confirmed and used to predict the extent of Vermont Yankee's thermal plume in lower Vernon Pool of the Connecticut River under existing and proposed new summer (May 16 – October 14) thermal discharge limits (Appendix 3).

The objectives of hydrothermal modeling were to:

- forecast changes in the River thermal regime of the lower Vernon Pool under existing and proposed new summer thermal discharge limits,
- quantify the gain or loss of fish habitat with respect to the forecasted thermal regime changes, and
- predict the effects, if any, of the proposed new thermal discharge limits on water temperatures in the Vernon Dam fishway.

The hydrothermal model was developed to predict changes within the entire 25 miles of Vernon Pool between Vernon Dam and Bellows Falls Dam. However, the relevant predictions are for the River in the vicinity of Vermont Yankee in lower Vernon Pool. Lower Vernon Pool was defined as the 1.4 mile-long segment of the River bounded to the north (upstream) by water temperature monitoring stations F1, F2, F3 and F4, and bounded to the south (downstream) by Vernon Dam (Figure 1-1).

4.1 HYDROTHERMAL MODELING SCENARIOS AND CONSERVATIVE ASSUMPTIONS

The existing permit summer limits and the proposed new permit summer limits were modeled to provide a forecast of changes in the thermal regime in lower Vernon Pool under average-case and extreme-case conditions. Probability of occurrence of River flow and temperatures (Section 3 above) were used to define the average-and extreme-case conditions with respect to input for the hydrothermal model. For additional conservatism in the model predictions, the average and extreme-case flow and water temperature values were selected from the warm July-August period, not from the entire summer period as defined by the current NPDES permit (i.e., May 16 – October 14).

The average case represented the hourly Vernon Dam flow and hourly Upstream Station 7 River water temperature at the exact mid-point among all of the observed hourly flows and temperatures during the recent (1998-2002) five July – August summer periods. Half of the hourly flows and half of the hourly Upstream Station 7 water temperatures fall above, and half fall below, the specified average (50%) probability of occurrence values. The extreme case River conditions for hydrothermal modeling were defined as the lowest flow and warmest ambient water temperature with a frequency of occurrence of 1% during July-August. The selected River flow for the extreme case was so low that nearly all (99%) of the hourly flows in the recent (1998 – 2002) five summer periods were greater than this value. The selected extreme case Upstream Station 7 water temperature was similarly so high that nearly all (99%) of the hourly temperature observations in the recent (1998 – 2002) five July-August periods were less than this value. Conservatism was also incorporated into the modeling projections by assuming that the discharge flow from Vermont Yankee was always at 100°F, even though this rarely occurs. Another conservative assumption was that the amount of

waste heat discharged from Vermont Yankee is based on the Station discharging at its NPDES permit limits, which rarely occurs because Vermont Yankee typically operates the plant cooling system with a margin of about 0.2°F or more below the permit limit in an attempt to accommodate rapid changes in River flow. Table 4-1 (below) presents a summary of input conditions for average and extreme case hydrothermal modeling of the Vermont Yankee thermal discharge into lower Vernon Pool under existing and proposed new summer permit limits.

Table 4-1. Connecticut River Flow and Upstream Temperature, and Vermont Yankee Discharge Flow and Temperature Defining Average (50%) and Extreme (1%) Case Hydrothermal Modeling Scenarios for July-August.

	Average (50% Occurrence) Case		Extreme (1% Occurrence) Case	
Parameter	Existing Permit Limit (2°F Delta T)	Proposed New Permit Limit (3°F Delta T)	Existing Permit Limit (2°F Delta T)	Proposed New Permit Limit (3°F Delta T)
River Flow (cfs)	3420	3420	1275	1275
Upstream Temperature (°F)	73.5	73.5	79.0	79.0
Discharge Flow (cfs)	258.0	387.0	121.0	182.0
Discharge Temperature (°F)	100.0	100.0	100.0	100.0

4.2 HYDROTHERMAL MODELING PREDICTIONS OF CHANGES IN FISH HABITAT

Fish habitat changes due to the proposed new thermal regime were quantified based on the volume or area in lower Vernon Pool predicted to be at or above a specified summer water temperature. The thermal plume temperature contours in lower Vernon Pool, derived from predictions based on the existing permit summer limits, provide the baseline for evaluation of habitat change. The increase in River volume or River bottom area predicted by the model for the proposed new permit summer limits quantifies the change from this baseline due to the anticipated increase in thermal discharge from Vermont Yankee under average- and extreme-case scenarios (defined above in Section 4.1).

For the average case, the increase in thermal plume volume in lower Vernon Pool under the existing and proposed new permit conditions is illustrated in Figure 4-1 and Table 4-2. Plume volumes for the average case remain indistinguishable under both existing and proposed new thermal limits until the water temperature approached and exceeded 73°F. Volumes diverge between 0.1% and 5.0% over a temperature range from 73°F to 82°F. River water temperature in lower Vernon Pool never got above 82°F for the average case existing or proposed new permit discharge limits, based on the resolution of the hydrothermal model.

Plume volumes for the extreme case (Figure 4-1 and Table 4-2) exhibited a pattern similar to the average case, with volumes remaining indistinguishable under existing and proposed new thermal limits until the water temperature approaches and exceeds ambient (79°F). Volumes diverge between 0.3% and 10.8% over a temperature range from 79°F to 86°F. River water in lower Vernon Pool never got above 87°F for the extreme case existing or proposed new permit discharge limits, based on the resolution of the hydrothermal model. The implications of these predicted slight changes in

plume volume in Lower Vernon Pool between existing and proposed new summer permit limits are interpreted with respect to the reported temperature tolerances of the selected pelagic RIS in Section 5 below.

Slight changes were also observed in the River bottom area in contact with the thermal plume under the proposed new permit limits compared to existing conditions for both average and extreme cases. For the average case, the increase in bottom area contacted by the thermal plume in lower Vernon Pool under the existing and proposed new permit conditions is illustrated in Figure 4-2 and Table 4-3. Bottom areas for the average case remain indistinguishable under both existing and proposed new thermal limits until the water temperature approached and exceeded 73°F. Bottom area diverge between 0.0% and 4.8% over a temperature range from 73°F to 82°F. The Connecticut River bottom in contact with the thermal plume in lower Vernon Pool never got above 82°F for the average case existing or proposed new permit discharge limits, based on the resolution of the hydrothermal model.

Plume bottom areas for the extreme case (Figure 4-2 and Table 4-3) exhibited a similar pattern as seen for the average case, with bottom areas remaining indistinguishable under existing and proposed new thermal limits until the water temperature approaches and exceeds ambient (79°F), and then the volumes diverge between 0.1% and 7.7% over a temperature range from 79°F to 86°F. The benthic substrate in the lower Vernon Pool never got above 86°F for the extreme case existing or proposed new permit discharge limits, based on the resolution of the hydrothermal model. The implications of these predicted slight changes in plume bottom area in lower Vernon Pool between existing and proposed new summer permit limits are likewise interpreted with respect to the reported temperature tolerances of the selected bottom-oriented RIS in Section 5 below.

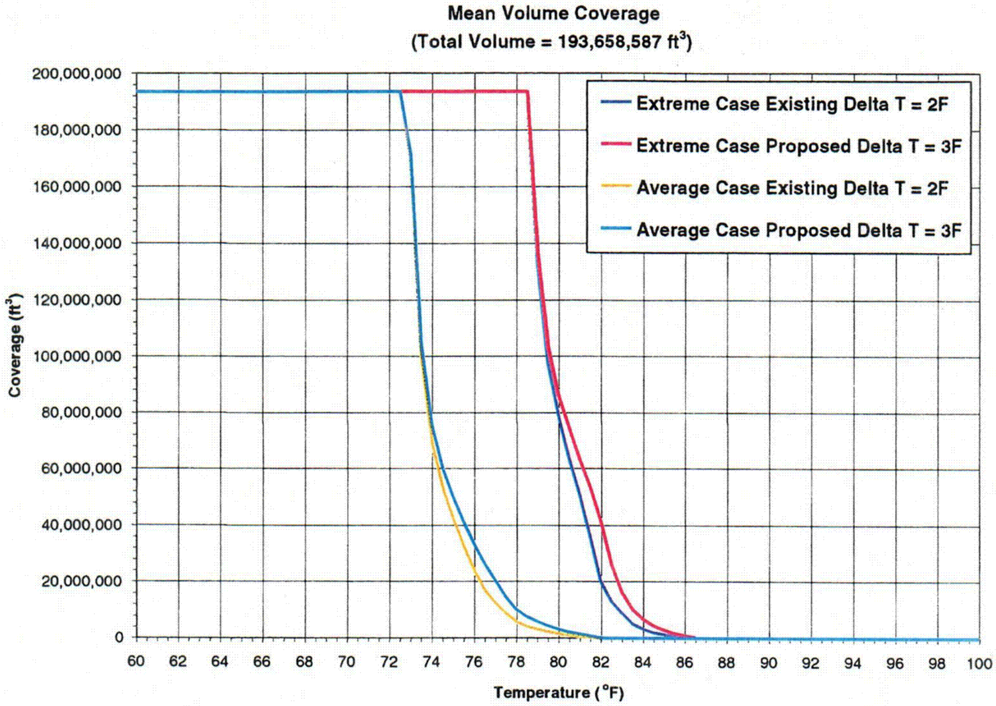


Figure 4-1. Mean volume in lower Vernon Pool of the Connecticut River predicted to be at or above a temperature contour for the average case (50% occurrence of flow and upstream Connecticut River water temperature) and extreme case (1% of occurrence of low flow and warm upstream Connecticut River water temperature) hydrothermal modeling scenarios of existing and proposed new summer permit limits for Vermont Yankee.

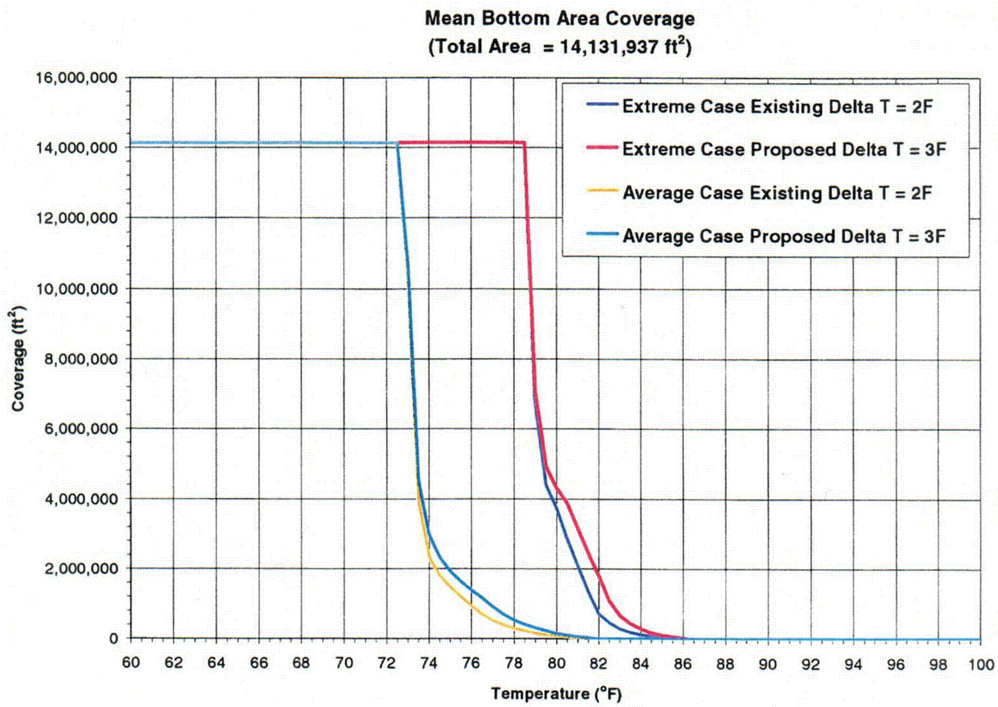


Figure 4-2. Mean bottom area in lower Vernon Pool of the Connecticut River predicted to be at or above a temperature contour for the average case (50% occurrence of flow and upstream Connecticut River water temperature) and extreme case (1% occurrence of low flow and warm upstream Connecticut water temperature) hydrothermal modeling scenarios of existing and proposed new summer permit limits for Vermont Yankee.

Table 4-2. Percent Change in the Volume of Lower Vernon Pool Predicted to be at or Above a Specified Temperature Contour (F) for Existing and Proposed New Summer Permit Limits at Vermont Yankee.

Temperature Contour (°F)	Volume (10000s of ft³) of Lower Vernon Pool at or Above Temperature							
	Average Case (50% Occurrence)				Extreme Case (1% Occurrence)			
	Delta T = 2°F Existing	Delta T = 3°F New	Difference (New-Existing)	Percent Change From Total Volume (New-Existing)	Delta T = 2°F Existing	Delta T = 3°F New	Difference (New-Existing)	Percent Change From Total Volume (New-Existing)
72	19366	19366	0	0.0%	19366	19366	0	0.0%
73	17056	17144	88	0.5%	19366	19366	0	0.0%
74	6829	7557	728	3.8%	19366	19366	0	0.0%
75	4163	4990	827	4.3%	19366	19366	0	0.0%
76	2357	3335	978	5.0%	19366	19366	0	0.0%
77	1212	2030	817	4.2%	19366	19366	0	0.0%
78	559	1021	463	2.4%	19366	19366	0	0.0%
79	309	595	286	1.5%	13432	13672	240	1.2%
80	158	334	176	0.9%	7882	8569	687	3.5%
81	65	154	89	0.5%	5061	6281	1220	6.3%
82	6	20	14	0.1%	2031	4123	2093	10.8%
83	0	0	0	0.0%	890	1621	731	3.8%
84	0	0	0	0.0%	326	675	350	1.8%
85	0	0	0	0.0%	130	286	156	0.8%
86	0	0	0	0.0%	26	90	64	0.3%
87	0	0	0	0.0%	0	3	3	0.0%
88	0	0	0	0.0%	0	0	0	0.0%

Table 4-3. **Percent Change in the Bottom Area of Lower Vernon Pool Predicted to be at or Above a Specified Temperature Contour (F) for Existing and Proposed New Summer Permit Limits at Vermont Yankee.**

Temperature Contour (°F)	Bottom Area (1000s of ft²) of Lower Vernon Pool at or Above							
	Average Case (50% Occurrence)				Extreme Case (1% Occurrence)			
	Delta T = 2F Existing	Delta T = 3F New	Difference New-Existing	Percent Change From Total Area (New-Existing)	Delta T = 2F Existing	Delta T = 3F New	Difference New-Existing	Percent Change From Total Area (New-Existing)
72	14132	14132	0	0.0%	14132	14132	0	0.0%
73	10559	10685	126	0.9%	14132	14132	0	0.0%
74	2302	2978	676	4.8%	14132	14132	0	0.0%
75	1459	1933	474	3.4%	14132	14132	0	0.0%
76	932	1394	463	3.3%	14132	14132	0	0.0%
77	517	929	412	2.9%	14132	14132	0	0.0%
78	299	538	239	1.7%	14132	14132	0	0.0%
79	154	329	175	1.2%	6771	7086	315	2.2%
80	85	160	75	0.5%	3750	4312	562	4.0%
81	39	74	35	0.2%	2093	3177	1085	7.7%
82	2	8	6	0.0%	726	1808	1082	7.7%
83	0	0	0	0.0%	294	674	380	2.7%
84	0	0	0	0.0%	132	287	155	1.1%
85	0	0	0	0.0%	52	117	65	0.5%
86	0	0	0	0.0%	21	36	14	0.1%
87	0	0	0	0.0%	0	0	0	0.0%

NOTE: 14,132,000 ft² = 324 acres.

4.3 VERNON DAM FISHWAY WATER TEMPERATURE

The hydrothermal model was also used to predict changes that may occur in the Vernon Dam fishway water temperatures due to the proposed new thermal discharge limits. As was done to examine the thermal regime in lower Vernon Pool (Sections 4.1 and 4.2 above), the existing permit summer limits and the proposed new permit summer limits were modeled to provide a forecast of changes in the fishway water temperature under average case and extreme case conditions. For each case, a fishway temperature time series was generated from model output by flow weighting the predicted temperature time series from the top three layers of the western-most grid cell at the downstream boundary (Vernon Dam), which most closely approximates the location and geometry of the fishway. Probability of occurrence of Connecticut River flow and fishway water temperatures during the period of fishway operation in the recent (mid-May – early-July of 1998 – 2002) five years were used to define the average (50%) case and extreme (1%) case summer conditions (Table 4-4). The average case for the fishway represented the hourly Vernon Dam flow and hourly Upstream Station 7 River water temperature at the exact mid-point among all of the observed hourly flows and temperatures during the recent (1998-2002) five periods of fishway operation. Half of the hourly flows and half of the hourly Upstream Station 7 water temperatures fall above, and half fall below, the specified average (50%) probability of occurrence values. The extreme case fishway conditions for hydrothermal modeling were defined as the lowest flow and warmest ambient water temperature with a frequency of occurrence of 1% during recent (1998-2002) periods of fishway operations. The same conservative assumptions about Vermont Yankee operations that were used for the plume modeling were also applied to the fishway modeling scenarios (discharge temperature was 100°F and discharge flow was based on Vermont Yankee discharging at the permit limit).

Results from the hydrothermal modeling predictions of fishway water temperature are presented for a hypothetical average (50% occurrence) day and a hypothetical extreme case (1% occurrence) day. These average and extreme case days are considered hypothetical because River flow and upstream temperature were held constant throughout the 24-hour period even though flow and upstream temperature both typically change throughout the day. The fishway water temperatures change naturally throughout the day in a typical diel pattern of atmospheric heating and cooling. For the average day (middle of the period of fishway operations), fishway water temperatures under the existing permit discharge limits change from a low of about 69.5°F in the pre-dawn hours to a high of about 71.5°F occurring in the late afternoon (Figure 4-3). A parallel cycle of diel change in fishway water temperature is predicted for the proposed new permit limits, with the curve for the average case new permit limits about 1°F higher than the curve for the existing conditions over a diel temperature range of 70.5°F to 72.5°F. For the extreme case day (near the end of the period of fishway operations), fishway water temperatures under the existing permit discharge limits change from a low of about 77.5°F in the pre-dawn hours to a high of about 80.0°F occurring in the late afternoon (Figure 4-4). The curve predicted for fishway water temperatures during the extreme case day under the proposed new permit limits is slightly less than 1°F higher than the curve for the existing conditions over the diel cycle, with a diel temperature range of about 78°F to 81°F. The implications of this predicted 1°F increase in Vernon Dam fishway water temperature under the proposed new summer permit limits are interpreted with respect to the reported temperature tolerances of the selected migratory RIS in Section 5 below.

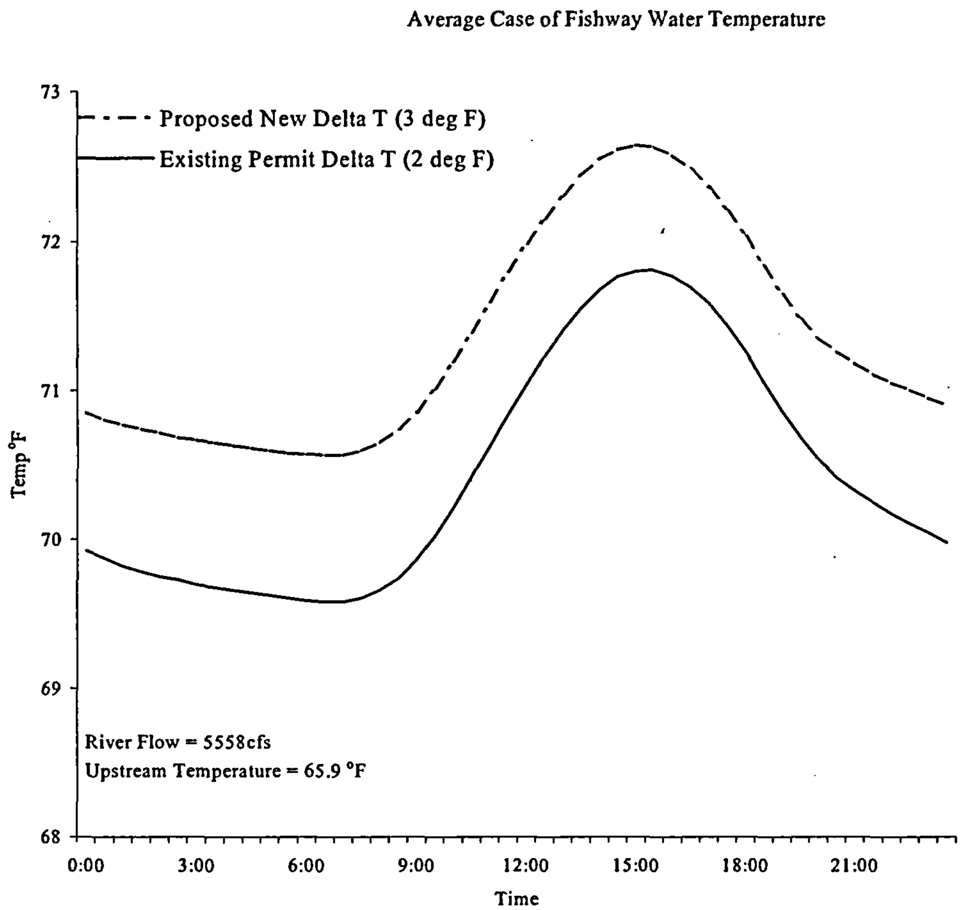


Figure 4-3. Hourly water temperature (°F) of an average (50% occurrence of flow and upstream Connecticut River water temperature) day of Vernon Dam fishway operation based on hydrothermal modeling predictions of existing and proposed new summer permit limits for Vermont Yankee

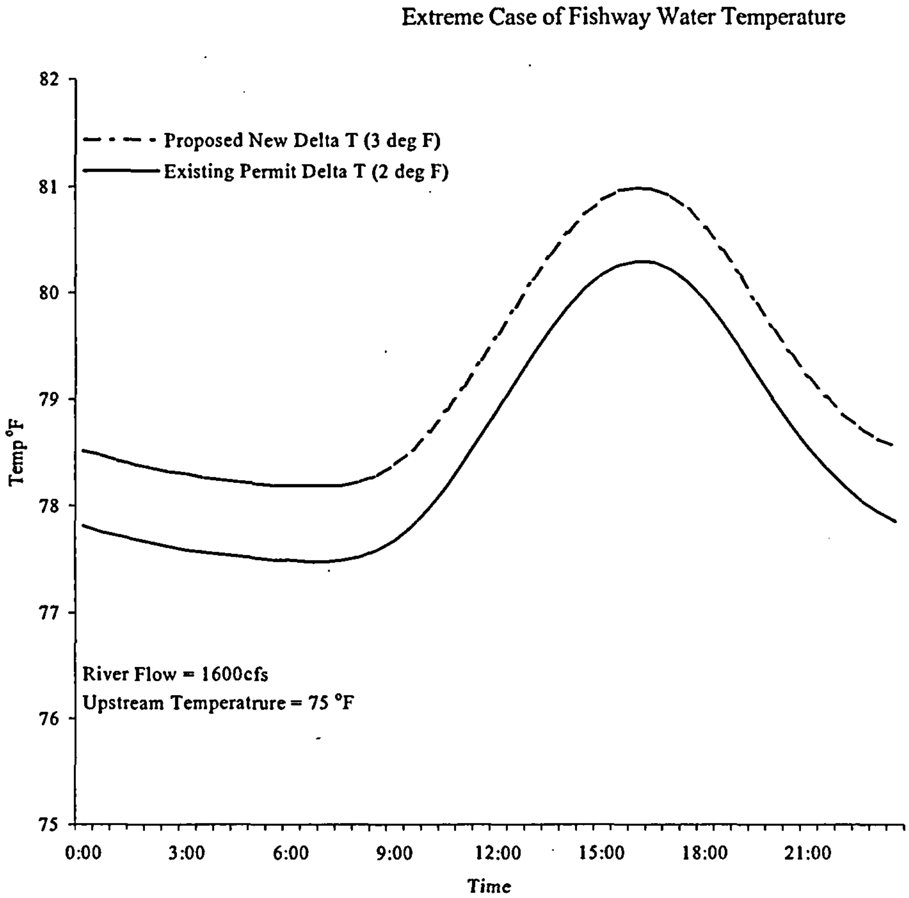


Figure 4-4. Hourly water temperature (°F) of an extreme case (1% occurrence of low flow and warm upstream Connecticut River water temperature) day of the Vernon Dam fishway operation based on hydrothermal modeling predictions of existing and proposed new summer permit limits for Vermont Yankee.

Table 4-4. Connecticut River Flow and Upstream Temperature, and Vermont Yankee Discharge Flow and Temperature Defining Average (50%) and Extreme (1%) Case Hydrothermal Modeling Scenarios for the Vernon Dam Fishway Period of Operation (mid-May – early-July).

	Average (50% Occurrence) Case		Extreme (1% Occurrence) Case	
Parameter	Existing Permit Limit (2°F Delta T)	Proposed New Permit Limit (3°F Delta T)	Existing Permit Limit (2°F Delta T)	Proposed New Permit Limit (3°F Delta T)
River Flow (cfs)	5558	5558	1600	1600
Upstream Temperature (°F)	65.9	65.9	75.1	75.1
Discharge Flow (cfs)	325.0	488.0	128.0	192.0
Discharge Temperature (°F)	100.0	100.0	100.0	100.0

5.0 APPLICATION OF MODELING RESULTS TO THE BALANCED INDIGENOUS POPULATION

This section of the §316(a) Demonstration Report confirms that the cooling water discharged under the present summer period thermal limits first adopted in 1991 through issuance of a NPDES permit by VANR has not had an adverse effect on the integrity of the biological community in the Connecticut River near Vermont Yankee. Section 5.1 (below) presents a description of the baseline benthic macroinvertebrate and fish communities based on the results of the EAC-approved and permit-required benthic macroinvertebrate and fish monitoring studies performed annually during 1991 through 2002. Section 5.1 also presents an analysis of fish passage upstream and downstream past Vernon Dam in relation to Vermont Yankee's thermal discharge. Section 5.2 presents a retrospective population trend analysis of the RIS of fish, and a predictive analysis of habitat changes (if any) in lower Vernon Pool and in the Vernon Dam tailrace under the proposed new permit limits. The combination of these retrospective and predictive analyses forms the foundation for evaluation of the potential for adverse effects due to the proposed implementation of a small (1°F) incremental increase in Vermont Yankee's thermal loading to the Connecticut River during the summer permit period. The monitoring studies reported in the two previous §316(a) Demonstrations (Binkerd et al. 1978; Downey et al. 1990; summarized in Section 6.0 below), as reviewed and approved by VANR and the EAC, established that Vermont Yankee's existing thermal discharge permit limits will assure the protection and propagation of a balanced indigenous biological community in lower Vernon Pool and in the Vernon Dam tailrace area of upper Turners Falls Pool.

5.1 SUMMARY OF BIOLOGICAL MONITORING STUDIES DESCRIBING BASELINE CONDITIONS DURING 1991 THROUGII 2002

The 1991 through 2002 period is considered the baseline period for the present Demonstration Report because the existing summer period (16 May through 14 October) thermal permit limits allowing a calculated temperature increase of 2, 3, 4, or 5°F first became effective with the issuance of an NPDES permit with these limits in 1991, and the limits have remained unchanged in two subsequent permit renewals by VANR since then (1996 and 2001). Vermont Yankee was first allowed to discharge heated effluent into the River during the summer period of 1982, and these summer discharges continued annually through 1990 at the discretion of VANR; however the timing and duration of discharge varied from year to year during the 1982-1990 period, and different thermal limits were applied during these periods to experimentally evaluate potential discharge conditions (Downey et al. 1990).

The EAC direction to Vermont Yankee at the time of the 1990 §316(a) Demonstration (Downey et al. 1990) was that the phytoplankton, zooplankton, and benthic macroinvertebrate communities were classified as "low potential impact" biotic categories, per USEPA guidance (1977). Pursuant to the EAC recommendation, VANR removed phytoplankton and zooplankton sampling from the annual monitoring program requirements of the renewed NPDES permit issued by VANR on 21 March 1996, but retained annual monitoring requirements for benthic macro-invertebrate and fish communities. This Demonstration Report continues to accept the recommendation of the EAC that the phytoplankton, zooplankton, and benthic macroinvertebrate communities in the River near Vermont Yankee are low potential impact biotic categories. This

section describes the benthic macroinvertebrate and fish communities because these are the two communities that were continuously monitored during the entire 1991-2002 period that Vermont Yankee operated with the existing summer permit limits.

The Connecticut River study area where the biological monitoring programs were performed during the 1991-2002 period includes areas both upstream and downstream of Vermont Yankee within the lower Vernon Pool, and in the tailrace waters immediately below Vernon Dam. This is an appropriate study area because the vast majority of water temperature increases reasonably attributable to Vermont Yankee's thermal discharge occurs within this study area. Vernon Dam divides the study area into two primary habitat types, lentic and lotic. The slow-flowing or ponded areas of the River found in lower Vernon Pool represent the lentic habitat. The rapid-flowing or turbulent areas of the River found in the Vernon Dam tailrace represent the lotic habitat. This distinction between lentic and lotic habitats, and the aquatic communities associated with each habitat type, will be maintained throughout the ensuing retrospective and predictive analyses.

This Demonstration Report demonstrates that a balanced indigenous community of aquatic biota has been maintained in the vicinity of Vermont Yankee during the many years of plant operation and will be maintained under the proposed limits presented in the Request. Briefly, the fish and benthic macroinvertebrate communities are characterized by diversity, presence of food chain as well as predatory species, and non-domination by pollution-tolerant species. Although certain fish species have been introduced to the Vernon Pool reach of the River by human activities over the years (i.e., via fish ladder installation), none of these species can be characterized as heat-tolerant, such that they will benefit by the thermal discharge and therefore either could cause the displacement of endemic species or become so numerous as to constitute a nuisance. The biological community has changed somewhat over the years in terms of relative abundance of various species, but this variability has been relatively minor and is consistent with natural variation. Both the fish and benthic macroinvertebrate community structures are diverse and resilient and do not resemble a simpler successional stage than is natural for the locality. Continued thermal discharge has not reduced successful completion of life cycles of the indigenous species or those re-introduced migratory species. Furthermore, the thermal discharge has not eliminated any established or potential economic or recreational use of the River. Thus, the available biological monitoring data demonstrates the requisite assurance of the protection and propagation of the balanced indigenous aquatic community of the River in the vicinity of Vermont Yankee.

5.1.1 Benthic Macroinvertebrates

5.1.1.1 Methods

Macroinvertebrate samples were collected at four locations in the River from 1991 through 2001 and at two stations in 2002. Two locations (Stations 2 and 3) are downstream of Vernon Dam and two (Stations 4 and 5) are upstream of the Dam (Figure 5-1). Two sampling methods were employed: grab sampling and "rock basket" colonization samplers.

Sampling effort has varied during the 1991-2002 period due to equipment loss, changes in gear, and changes in permit monitoring requirements (Appendix 4, Tables 4-1 and 4-2). In an attempt to adjust or standardize these data for the sampling gear and deployment variability, count data from grabs were standardized into organisms collected per grab, and count data for rock baskets

was standardized as the number of invertebrates collected per rock basket per 30 days of deployment. However, these adjustments do not fully standardize for the gear differences, so statistical trend analysis was only performed on the 1996 through 2002 data collected by Normandeau using fully documented procedures (Appendix 4).

Ponar or Ekman grab samples were collected in June, August, and October in each year from 1991 until 2001 when grab sampling was discontinued pursuant to the EAC's direction. Three replicate Ponar grab samples were collected in each year, 1991-2000, at each of three sub-locations, one each near the New Hampshire and Vermont banks of the River, and one at mid-river, on a transect at each station per sample date.

Rock basket samples were collected after 30 to 60 days (average 48 ± 11, N=77) River exposure on two occasions during the interval June through October in each year, except in 2001 when VANR directed in the current NPDES permit that an additional sampling effort be undertaken at Stations 2 and 3, and that sampling at Stations 4 and 5 be eliminated.

After collection, all Ponar grab samples were rinsed over U.S. Standard No. 30 sieves (mesh opening 0.595 mm) in the field. Sample residue retained on the sieves was preserved with 70% ethanol prior to laboratory processing. In the laboratory, the contents of each replicate grab sample from each station were combined and then subsampled to an aliquot of at least 100 organisms (if present) before the macroinvertebrates were sorted under 2X magnification. The macroinvertebrates sorted from each subsample were examined with a stereomicroscope, identified to the lowest practical level, and enumerated. Where subsampling occurred counts by taxonomic category (taxon) were extrapolated to total numbers for entire sample, based on the fraction of each composite sample analyzed.

Each rock basket sample was transported in an individual bucket to the laboratory where the samplers were disassembled and the rocks were rinsed over U.S. Standard No. 30 sieves. From 2001 on, samples were rinsed and preserved in the field with 70% ethanol for later identification. All organisms found attached to the rocks in each sample were removed and preserved along with the sample residue retained on the sieves. From 1991 to 1995, rock basket samples from each station and date were combined and sorted in their entirety. The residue from one of each pair of rock basket samples collected at each station per sample date was randomly selected for macroinvertebrate sorting under 2X magnification from 1996 to 2000 and extrapolated to 2 baskets. From 2001 on, each rock basket was sorted and identified in its entirety. At least 100 macroinvertebrates were sorted from each sample (if present), and the sorted organisms were examined with a stereomicroscope, identified, and enumerated. Counts by taxon were extrapolated to total numbers for entire samples based on the fraction of each sample analyzed.

The macroinvertebrates in each sorted fraction were identified to the lowest practical taxonomic level, given their life stage and condition, using dissecting (45X magnification) and compound (1,000X magnification) microscopes. Chironomids and oligochaetes were separated by subfamily, tribe, or recognizable type prior to identification to the genus/species level. All or representative subsamples from each grouping were prepared by clearing and mounting, and identified with a compound microscope. Where subsampled, the number of specimens identified to genus/species was used to proportion the remaining individuals from each group into specific taxa. In instances where chironomids or Oligochaetes could be identified to genus or species without the aid of a compound microscope, no preparation was necessary. Taxonomic keys used

to identify all macroinvertebrates were Brinkhurst (1986), Brown (1976), Burch (1975), Burks (1953), Hitchcock (1974), Jokinen (1992), Klemm (1985), McCafferty (1975), Merritt and Cummins (1996), Peckarsky (1990), Roback (1985), Simpson and Bode (1980), Wiederholm (1983), and Wiggins (1996). In short, the protocol, sampling methodology and analysis ensure comprehensive review and well-supported conclusions.

5.1.1.2 Results and Discussion

The benthic macroinvertebrate community present in the River upstream and downstream of Vernon Dam is representative of a balanced indigenous population not adversely affected by operation of Vermont Yankee. Twelve years of monitoring produced samples that contained a diverse mixture of taxa, including invertebrate species considered sensitive to poor water quality or habitat disturbance, therefore demonstrating that such conditions exist below detectable levels affecting populations. Although the numbers of individuals, numbers of taxa, and taxonomic composition varied year to year, the observed shifts were well within the range of natural stochastic and response processes affecting invertebrate populations.

Total numbers of macroinvertebrates collected by Ponar grab and their higher level (order and above) taxonomic composition are presented in Table 5-1. Total number of invertebrates per station and year are presented graphically in Figure 5-2.

Total numbers of macroinvertebrates collected by Ekman or Ponar grab ranged from 157 individuals at Station 3 in 1999 to 4,686 individuals at Station 5 in 1998. In general, greater numbers were collected upstream of Vernon Dam in lower Vernon Pool (Stations 4 and 5) than were collected at Stations 2 and 3 located downstream of the Dam. This relationship among the stations was consistent from 1995 through 2000, likely reflective of differences in habitat productivity due to the predominance of sediments and rocky substrate upstream and downstream of Vernon Dam, respectively. Taxa of several major groups are specialized towards either soft or hard substrates and exhibit competitive advantage in these habitats (Thorp and Covich 2001).

Diptera (true flies) were collected in greatest numbers in the grabs in most years at all stations, likely due to the greater efficiency of grabs for sampling the unconsolidated soft substrate that Dipteran larvae often dominate. Oligochaeta (worms), Gastropoda (snails), and Pelecypoda (bivalves) were also numerically important in nearly all Ponar samples. Occasionally, these groups and/or Trichoptera (caddisflies), Turbellaria (flatworms), and Crustacea (scuds, sowbugs, and crayfish) were collected in greatest numbers at one or several stations. This is likely due to the spatial heterogeneity of substrates such as gravel, sand, silt and clay and the specificity of many taxa for these and other substrate types.

Total numbers of macroinvertebrates collected in rock baskets and sample composition based on higher taxonomic groups are presented in Table 5-2. Total numbers data for the rock baskets are presented graphically in Figure 5-3. Total number of macroinvertebrates collected in rock baskets ranged from 50 individuals at Station 2 in 1997 to 9,181 individuals at Station 3 in 2001. Total numbers exceeded 1,000 individuals in only six instances. There is no discernable relationship between station location and total numbers of macroinvertebrates collected.

Unlike in the case of the grab samples, Diptera were not collected in greatest numbers in the rock baskets in most years. In fact, the identity of the higher taxonomic groups collected in greatest numbers varied greatly from year to year at most stations. The exception was Station 5, where

Diptera and Crustacea were collected in greatest numbers in 10 of 12 years of sampling. This variability is likely due to the microhabitat that the rock baskets were deployed in, for instance whether they were deployed in sand or gravel substrates at a station with diverse microhabitats. Other factors that may influence the colonizing taxa are the amount of organic material captured by the rock basket, the degree of primary production during incubation, and the availability of colonizing taxa from surrounding substrate. These factors are all influenced by the particular timing and microhabitat of deployment with respect to river flow conditions. Given these and other sources of variation, the rock basket samples do reflect the availability of colonizing taxa, the overall condition of the dominant invertebrate prey taxa, and a gross measurement of abundance. These data can be used to judge not only the presence and maintenance of a balanced indigenous population but also the degree of plasticity in the invertebrate community to adjust to changes in habitat. Total numbers of macroinvertebrate taxa collected by grabs and in rock baskets and the number of taxa identified within higher taxonomic groups are shown for the years 1996 through 2002 in Table 5-3. Total numbers of taxa data are shown in Figure 5-4. Data on taxa abundance for each station prior to 1996 is unavailable as data was combined into a single taxa list (Table 5-4).

Total numbers of taxa collected by both grabs and rock basket sampling ranged from 28 at Station 2 in 2001 to 86 at Station 5 in 2000. In five of six years, greater numbers of taxa were collected upstream of Vernon Dam at Stations 4 and 5 than were collected at Stations 2 and 3 located downstream. Although total taxa numbers varied between stations and years, percent contribution to total taxonomic abundance by each major grouping varied little from 1996 to 2002 for each station (Figure 5-5 through Figure 5-8). This was especially true of Stations 4 and 5 where stable trends in species abundance in each major grouping are readily apparent, likely due to the relatively constant water flows and benthic habitat stability. Variation in major group dominance existed to a greater extent at Stations 2 and 3 but was well within natural variability, particularly given the benthic habitat disturbance resulting from spring freshet discharges from Vernon Dam and periodic high flows. For the period 1991 to 2002 for which only combined data were available, trends show a similar pattern of stable relative community taxonomic composition (Figure 5-4). This analysis shows that a stable mix of major groupings has existed in the ten-year monitoring period with no substantial shifts in dominance by particular groups. It should be noted that two events took place that resulted in changes to the character of the data. First, laboratories and contractors were changed from 1995 to 1996. Following this change, reported Oligochaeta relative species abundance increased substantially. This is likely due to increased scrutiny by Normandeau of the order Oligochaeta, which was lacking from 1991 to 1995. Many laboratories lack the technical expertise to identify to a lower taxonomic level than Oligochaeta. The presence of higher numbers of Oligochaeta taxa reflects Normandeau's higher level of expertise in that taxon. Secondly, Diptera and Oligochaeta species richness appeared to decline substantially in 2002. This is likely due to the removal of the grab sampling from the Vermont Yankee monitoring program. Grab samples tend to be highly effective in soft mud or silt substrates, benthic habitat preferred by many species of Diptera and Oligochaeta (Thorp and Covich 2001).

More taxa of Diptera (true flies) than any other higher taxonomic group were collected at all stations in all years. This likely reflects the higher generic diversity of the group regionally and as a whole (Peckarsky 1990), rather than being an environmentally driven dominance of this taxonomic group. Diptera collected at all stations belong predominantly to the family Chironomidae, a wide ranging group ubiquitous in nearly all water bodies. This group includes

highly tolerant species as well as some highly intolerant species. The high number of chironomid species and individuals should be viewed as an indicator of a wide niche availability in the study area. Other higher groups represented by more than a few taxa include Oligochaeta (worms) and Trichoptera (caddisflies). "Other" taxa include a mixture of insect groups such as Coleoptera (beetles), Plecoptera (stoneflies), and Odonata (dragonflies) and non-insect groups such as Nematoda (roundworms) and Hirudinea (leeches). These taxonomic groups all contain species that exhibit a high degree of variability in their ability to adjust to changing environmental conditions.

A nonparametric Mann-Kendall test was used to examine the 1996-2002 annual time series of each major grouping of macroinvertebrate CPUE for significant increasing or decreasing trends (Helsel and Hirsch 1991, Chapter 12). The field sampling design has consistently sampled the same stations with the same gear during the same months in each of the five consecutive years in the Ponar grab time series (1996-2000), and for each of the seven consecutive years in the rock basket time series (1996-2002), making annual mean CPUE the appropriate response variable in the time series analysis. All invertebrates for a given year were grouped into nine major taxonomic groupings (Crustacea, Diptera, Ephemeroptera, Gastropoda, Oligochaeta, Other, Pelecypoda, Trichoptera, and Turbellaria) at the request of VANR. In addition, weighted total abundance of all invertebrates was also analyzed between stations, gear, and year of collection. Rock basket effort was standardized across samples by converting total abundance of a major taxonomic grouping in a year to numbers of that taxon per basket per 30 days of deployment. Ponar grabs were converted to numbers of each major taxonomic grouping per 27 Ponar grabs. The Mann-Kendall test is robust with respect to parametric assumptions of data normality and variance heterogeneity (Helsel and Hirsch 1991; Siegel 1956), and was performed on untransformed data. The null hypothesis was that there is no statistically significant ($p<0.05$) trend in a taxon's abundance during the period analyzed as measured by the Kendall Tau b correlation coefficient. If a statistically significant negative (decreasing) trend is observed, it will be interpreted with respect to whether Vermont Yankee's thermal discharge may be a contributing factor. Finding no significant trend over time or finding a significant increasing trend will be considered to statistically support a finding of "no prior appreciable harm."

Information was lacking regarding sampling design, field efforts and laboratory protocols from 1991 to 1995. Specifically, information was lacking regarding subsampling and extrapolation of count data for samples analyzed by the former contractor (Aquatec), making abundance and macroinvertebrate CPUE data non-comparable between the two time periods. Given this unacceptable level of uncertainty associated with the comparability of the two periods (1991-1995 and 1996 – 2002), only data from the latter time period each was analyzed with the Mann-Kendall correlation tests (Appendix 5). Overall community composition and species richness appears to have remained relatively constant throughout the 1991-2002 time period. However, 80 separate analyses were completed on each taxon for each gear type and station for the 1996-2002 time period. From among these 80 tests, five tests (6.3%) resulted in significant p-values less than 0.05 (Table 5-5). Of the five significant tests, four (5.0% of 80) indicated a positive trend while the remaining one (1.3% of 80) yielded a negative trend. The negative trend occurred with Oligochaeta collected by Ponar grab at station 5 during the 1996-2002 sampling period (Kendall-Tau coefficient = -0.800, p=0.050, n=5). It should be noted that, at the significance level of $p \leq 0.05$ used for hypothesis testing with the Mann-Kendall statistic, approximately one in twenty tests will indicate a significant result by chance alone ("type I error"). Therefore, out of 80 tests,

four of the five significant results could have been found significant by chance alone, and we cannot determine which (if any) of the five is truly significant.

Macroinvertebrate relative species abundance and period-specific catch have remained nearly constant during the annual 1991 to 2002 monitoring programs. Contributions of each taxonomic group to overall species abundance has varied little over the monitoring period, allowing for changes in taxonomic scrutiny and gear changes in 1996 and 2000, respectively. Mann-Kendall correlation analyses showed a single decreasing trend from 80 analyses conducted, while four tests showed positive trends in catch for certain taxa. The remaining tests show varied non-significant trends with no readily discernable overall trend. Therefore, these retrospective analyses collectively demonstrate that the macroinvertebrate community in the vicinity of Vermont Yankee has maintained a stable community composition and is considered to statistically support a finding of "no prior appreciable harm."

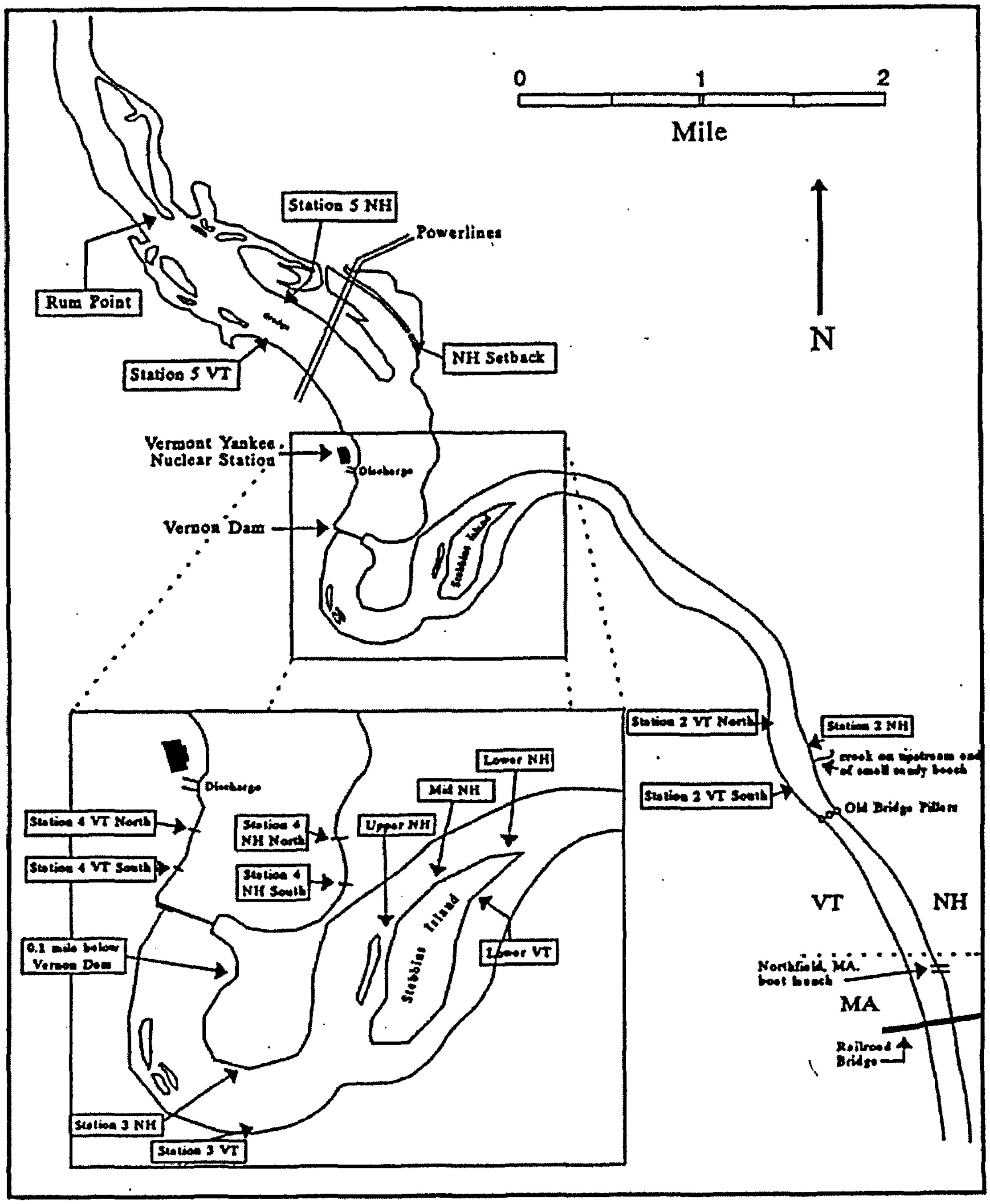


Figure 5-1. Location of sampling stations on the Connecticut River in the vicinity of the Vermont Yankee Nuclear Power Station.

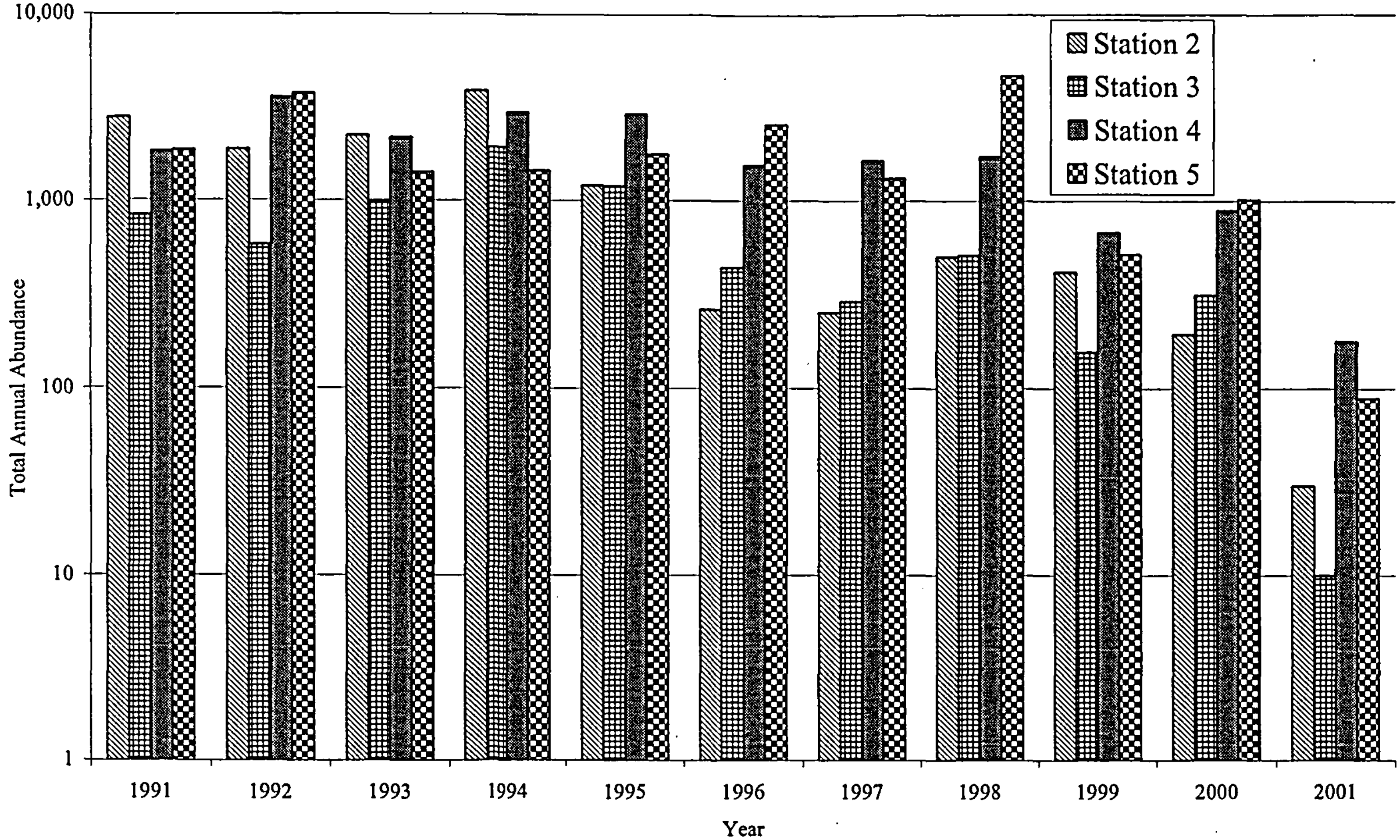


Figure 5-2. Total number of macroinvertebrates collected by Ekman and Ponar grabs in the Connecticut River upstream and downstream of Vernon Dam, 1991 through 2002. Samples were collected in June, August, and October, except in 2001 when they were collected only in June. All grab sampling was discontinued in 2002. Note the use of a log scale on the Y axis.

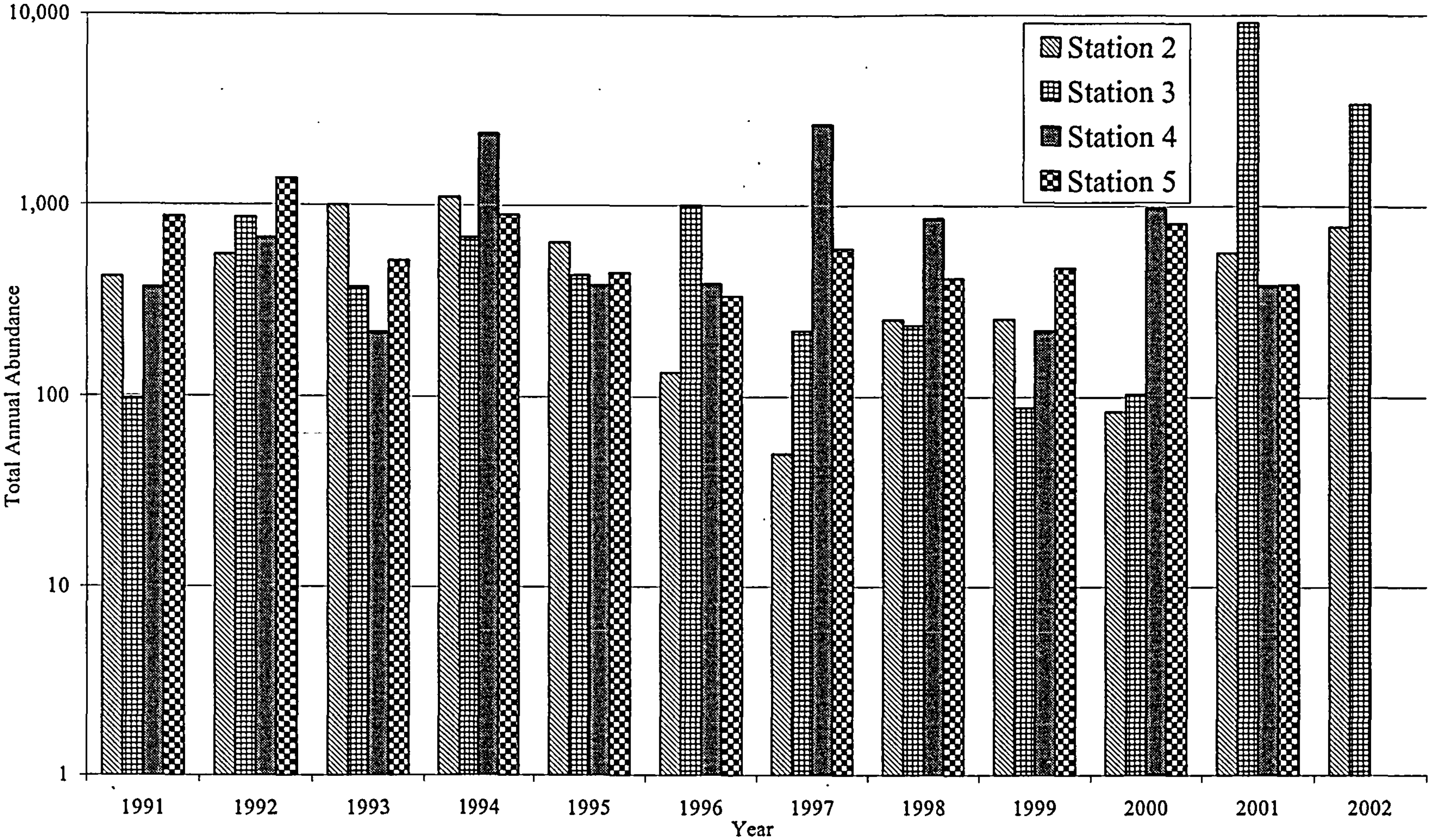


Figure 5-3. Total number of macroinvertebrates collected in rock baskets placed in the Connecticut River upstream and downstream of Vernon Dam, 1991 through 2002. Rock Basket sampling at Stations 4 and 5 was discontinued in 2002. Note the use of a log scale on the Y axis.

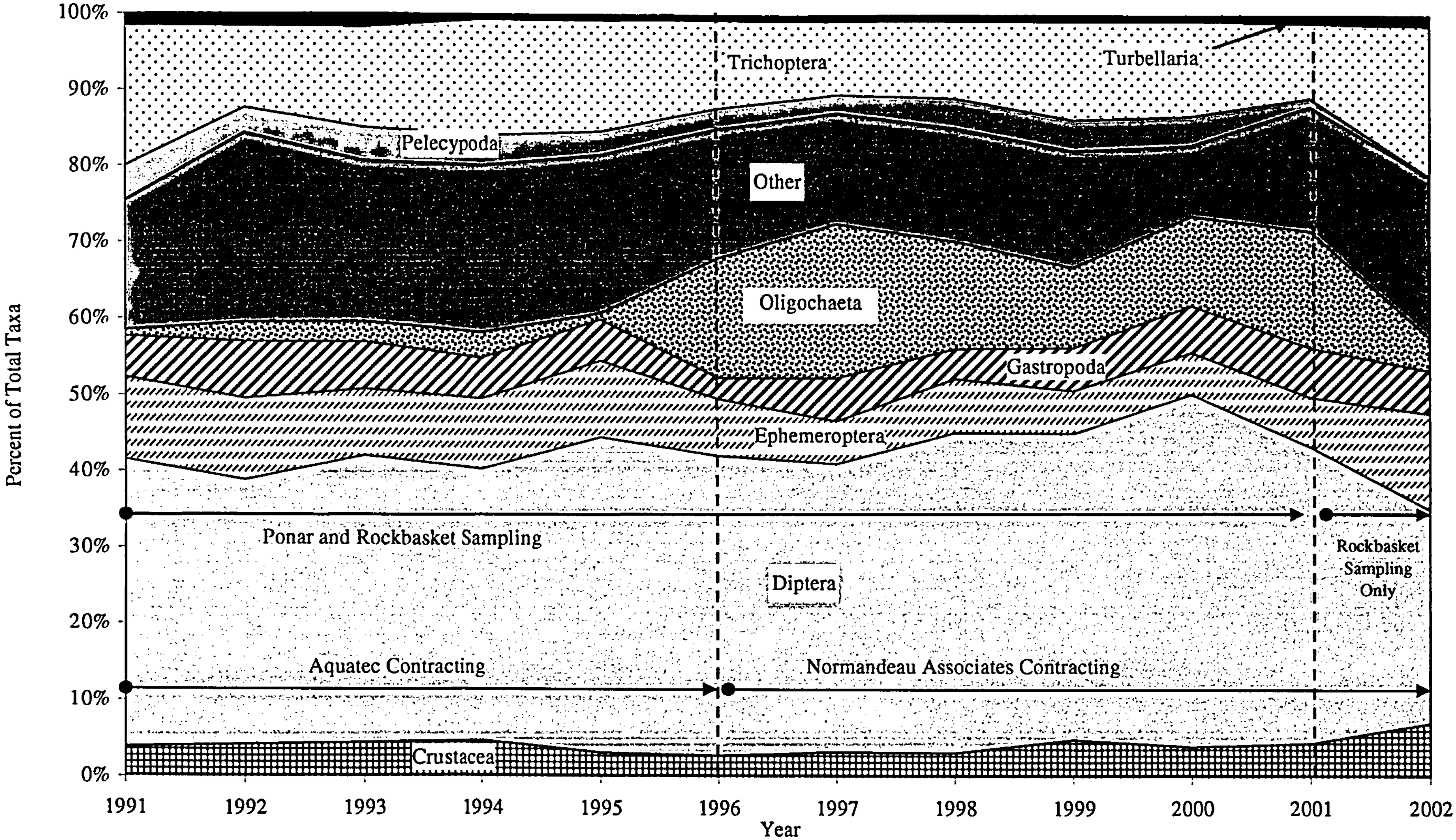


Figure 5-4. Percent of total taxa per year made up by each major taxonomic group identified from rock baskets and grab samples from 1996 to 2002. Grab sampling was discontinued in 2001. Data from 1991 to 1996 were collected by Aquatec and data from 1996 to 2002 were supplied by Normandeau Associates, Inc. The increase in Oligochaeta taxa relative abundance in 1996 is likely due to additional taxonomic scrutiny from 1996 to 2002.

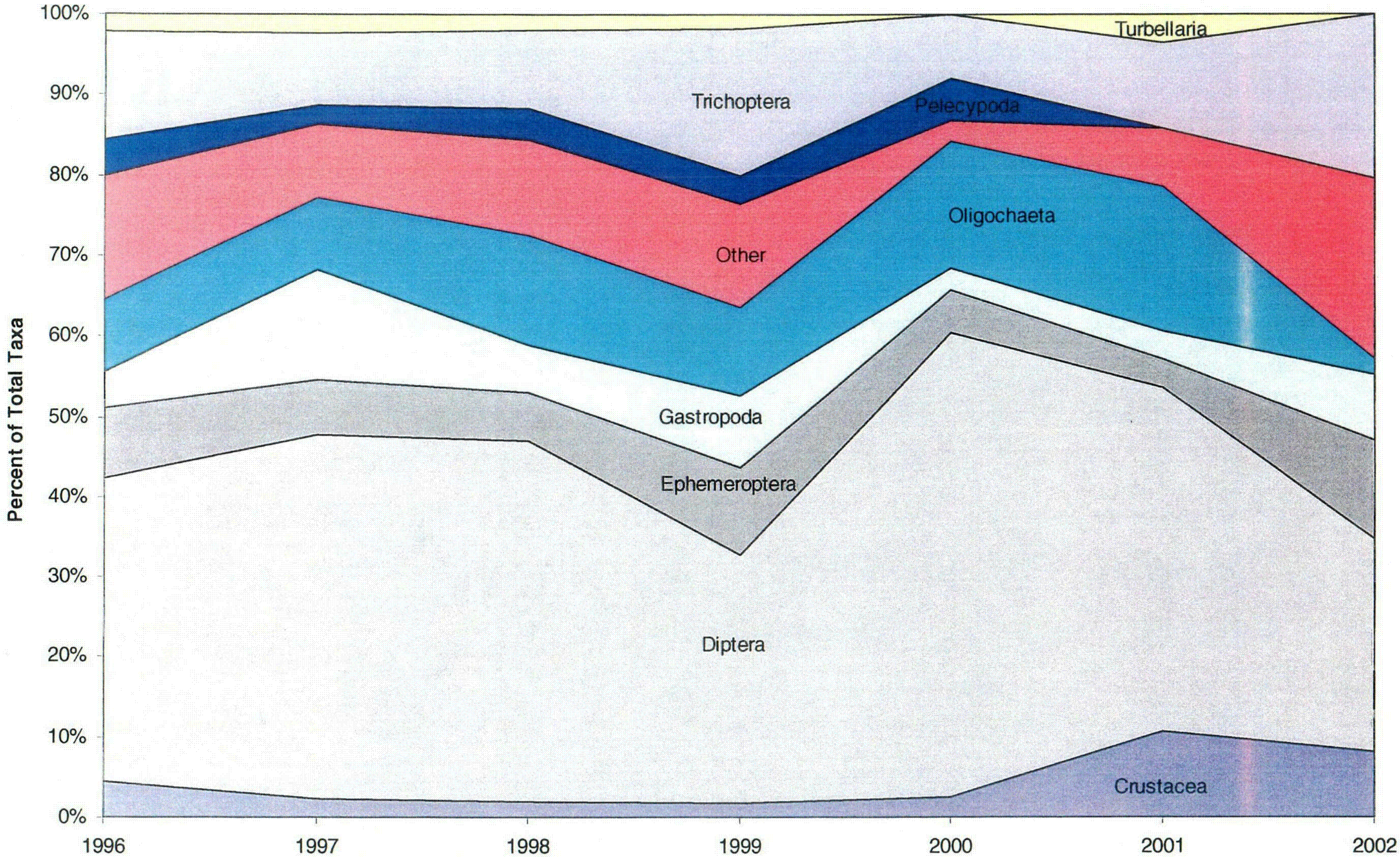


Figure 5-5. Percent of total taxa per station per year made up by each major taxonomic group identified from rock baskets and grab samples from Station 2 from 1996 to 2002.

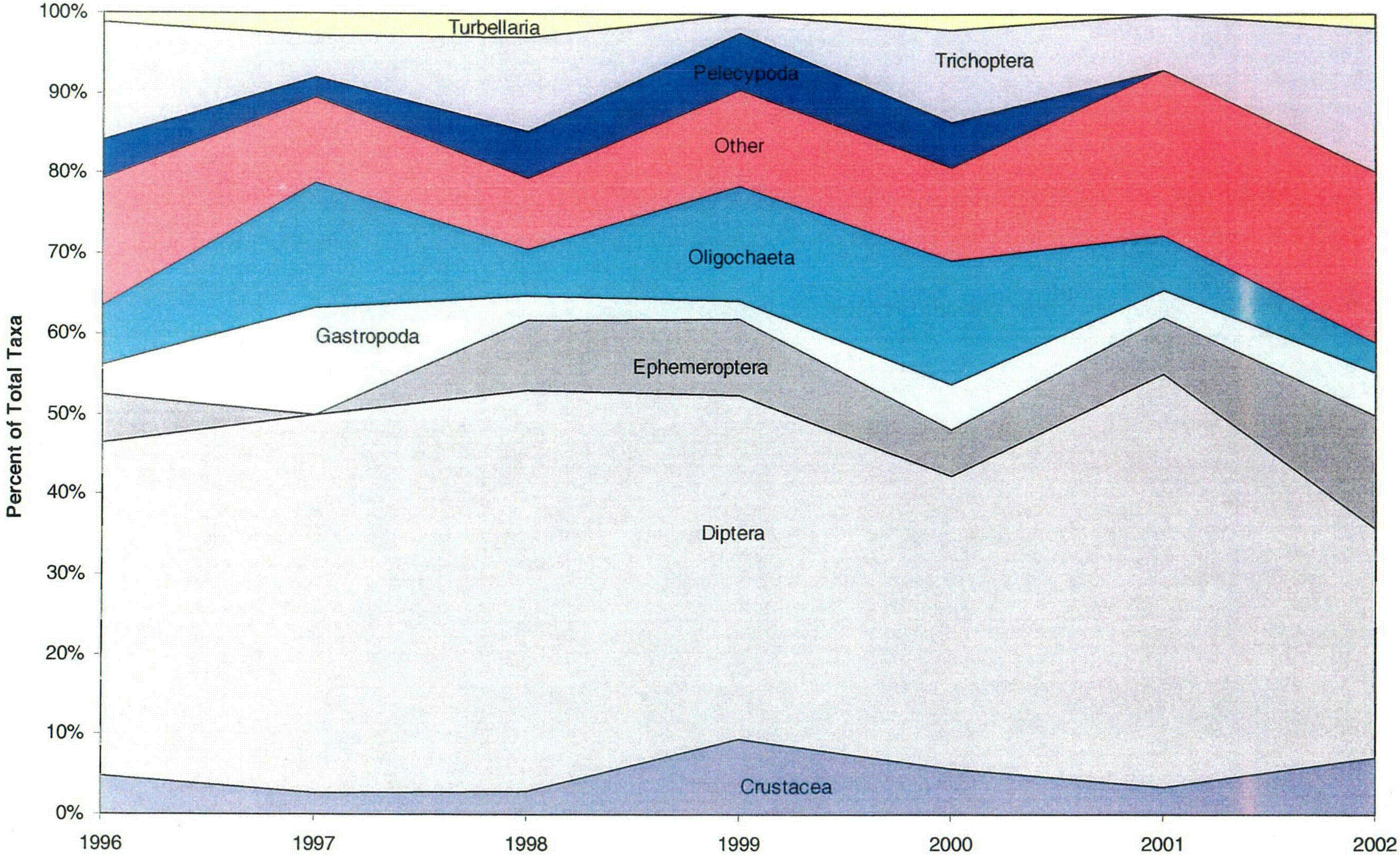


Figure 5-6. Percent of total taxa per station per year made up by each major taxonomic group identified from rock baskets and grab samples from Station 3 from 1996 to 2002.

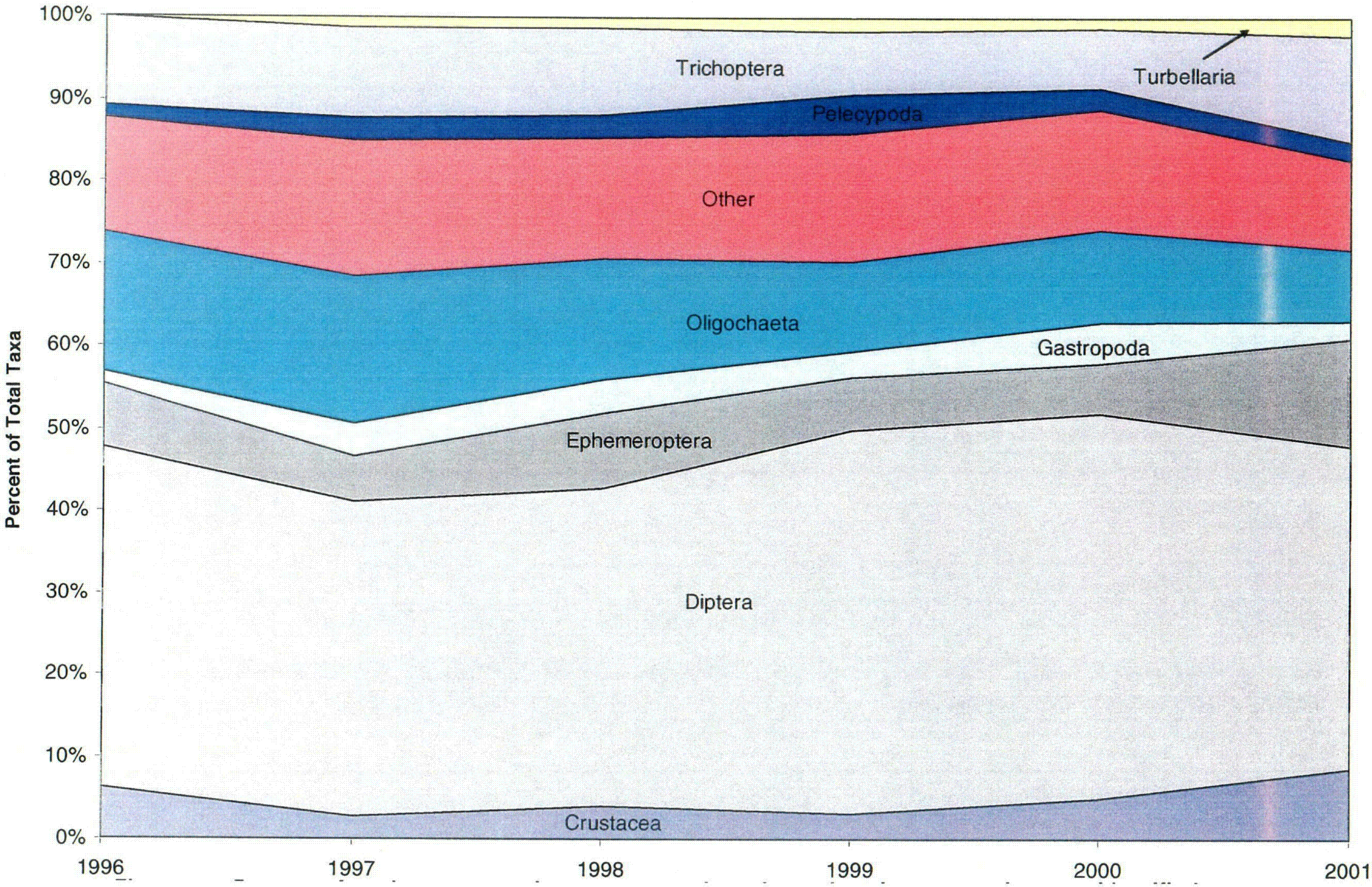


Figure 5-7. Percent of total taxa per station per year made up by each major taxonomic group identified from rock baskets and grab samples from Station 4 from 1996 to 2001.

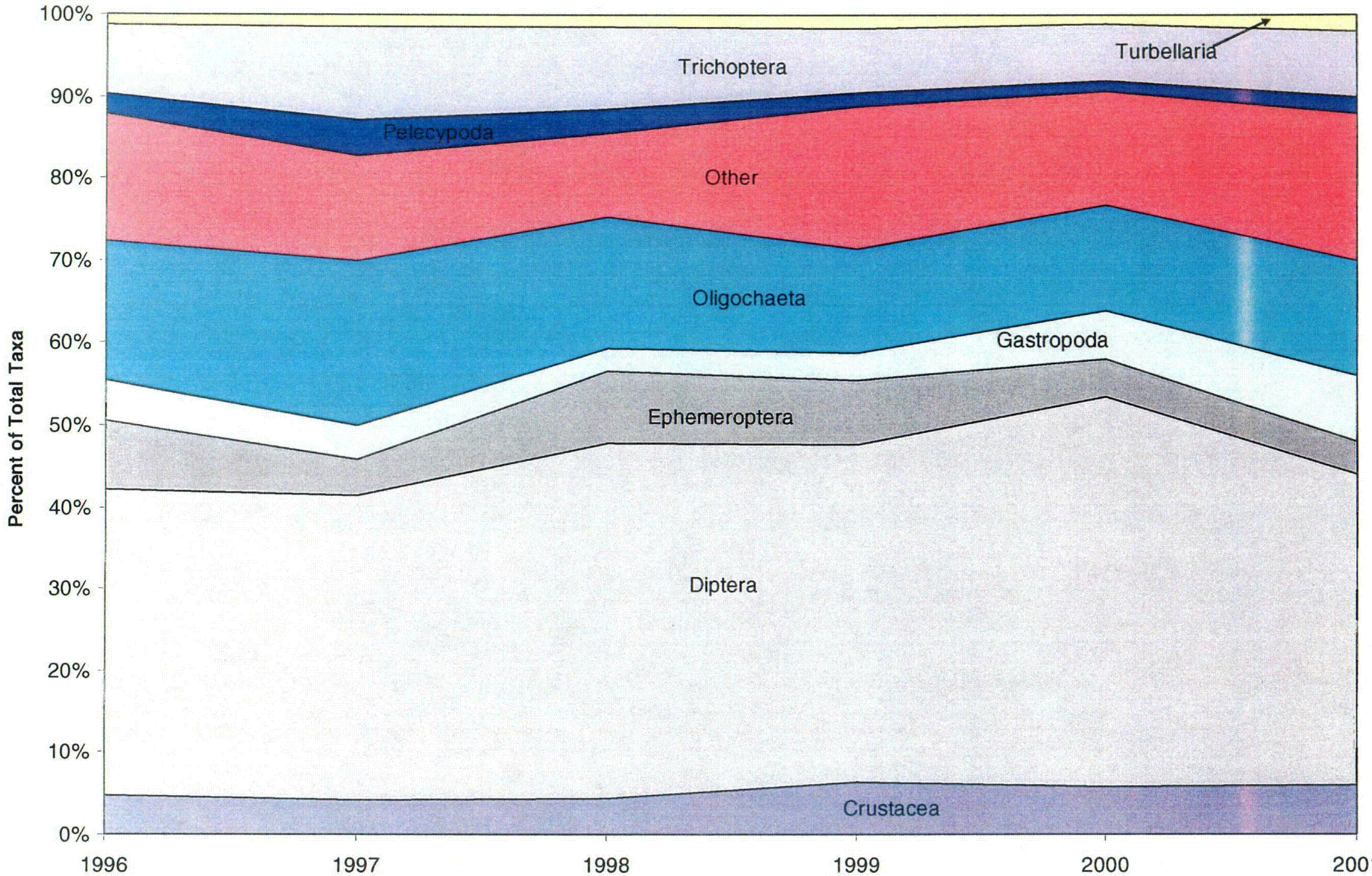


Figure 5-8. Percent of total taxa per station per year made up by each major taxonomic group identified from rock baskets and grab samples from Station 5 from 1996 to 2001.

Table 5-1. Composition of macroinvertebrates collected by Ekman or Ponar grabs in the Connecticut River upstream and downstream of Vernon Dam, 1991 through 2002.

	1991		1992		1993		1994		1995		1996		1997		1998		1999		2000		2001	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Downstream Station 2																						
Crustacea	4	0.1	185	9.9	158	7.1	29	0.7	58	4.8	0	0.0	0	0.0	0	0.0	5	1.2	0	0.0	0	0.0
Diptera	1,570	56.2	234	12.5	1,185	52.9	2,237	57.5	541	44.8	120	45.5	180	70.6	300	59.5	237	56.8	138	70.8	18	60.0
Ephemeroptera	26	0.9	35	1.9	16	0.7	156	4.0	22	1.8	9	3.4	6	2.4	6	1.2	3	0.7	3	1.5	0	0.0
Gastropoda	456	16.3	522	27.8	234	10.5	168	4.3	245	20.3	24	9.1	18	7.1	63	12.5	50	12.0	1	0.5	0	0.0
Oligochaeta	37	1.3	315	16.8	252	11.3	516	13.3	104	8.6	33	12.5	24	9.4	48	9.5	58	13.9	48	24.6	10	33.3
Other	18	0.6	25	1.3	31	1.4	33	0.8	39	3.2	9	3.4	15	5.9	15	3.0	30	7.2	1	0.5	1	3.3
Pelecypoda	67	2.4	68	3.6	80	3.6	552	14.2	29	2.4	33	12.5	3	1.2	54	10.7	9	2.2	2	1.0	0	0.0
Trichoptera	227	8.1	134	7.1	105	4.7	202	5.2	147	12.2	36	13.6	9	3.5	18	3.6	25	6.0	2	1.0	1	3.3
Turbellaria	391	14.0	359	19.1	178	7.9	0	0.0	22	1.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	2,796	100.0	1,877	100.0	2,239	100.0	3,893	100.0	1,207	100.0	264	100.0	255	100.0	504	100.0	417	100.0	195	100.0	30	100.0
Downstream Station 3																						
Crustacea	4	0.5	4	0.7	135	13.6	35	1.8	224	18.7	15	3.4	3	1.0	3	0.6	30	19.1	5	1.6	0	0.0
Diptera	168	20.2	57	9.8	378	38.0	1,169	60.4	306	25.6	144	32.7	213	73.2	477	93.0	54	34.4	116	36.7	7	70.0
Ephemeroptera	23	2.8	12	2.1	21	2.1	104	5.4	7	0.6	9	2.0	0	0.0	6	1.2	3	1.9	2	0.6	0	0.0
Gastropoda	23	2.8	8	1.4	28	2.8	19	1.0	9	0.8	6	1.4	6	2.1	0	0.0	0	0.0	60	19.0	0	0.0
Oligochaeta	34	4.1	81	13.9	222	22.3	249	12.9	310	25.9	90	20.4	24	8.2	21	4.1	52	33.1	60	19.0	1	10.0
Other	11	1.3	15	2.6	24	2.4	63	3.3	44	3.7	84	19.0	30	10.3	3	0.6	9	5.7	10	3.2	1	10.0
Pelecypoda	307	36.9	79	13.6	51	5.1	85	4.4	84	7.0	81	18.4	3	1.0	3	0.6	9	5.7	13	4.1	0	0.0
Trichoptera	158	19.0	49	8.4	97	9.8	213	11.0	55	4.6	12	2.7	12	4.1	0	0.0	0	0.0	50	15.8	1	10.0
Turbellaria	105	12.6	276	47.5	38	3.8	0	0.0	157	13.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	833	100.0	581	100.0	994	100.0	1,937	100.0	1,196	100.0	441	100.0	291	100.0	513	100.0	157	100.0	316	100.0	10	100.0
Upstream Station 4																						
Crustacea	20	1.1	85	2.4	51	2.3	41	1.4	24	0.8	3	0.2	111	6.8	9	0.5	18	2.7	223	24.9	12	6.7
Diptera	544	29.7	794	22.1	839	38.5	1,589	53.4	953	32.7	1,056	68.2	900	54.7	1,020	58.9	384	56.6	365	40.8	81	45.3
Ephemeroptera	117	6.4	46	1.3	84	3.9	114	3.8	127	4.4	9	0.6	6	0.4	48	2.8	13	1.9	23	2.6	1	0.6
Gastropoda	23	1.3	10	0.3	21	1.0	32	1.1	15	0.5	0	0.0	117	7.1	18	1.0	0	0.0	108	12.1	3	1.7
Oligochaeta	365	19.9	1,267	35.3	819	37.6	925	31.1	1,215	41.7	408	26.4	288	17.5	525	30.3	154	22.7	109	12.2	66	36.9
Other	27	1.5	29	0.8	16	0.7	39	1.3	27	0.9	15	1.0	81	4.9	30	1.7	57	8.4	23	2.6	3	1.7
Pelecypoda	704	38.4	1,283	35.8	331	15.2	169	5.7	491	16.9	33	2.1	93	5.7	36	2.1	26	3.8	16	1.8	3	1.7
Trichoptera	23	1.3	26	0.7	13	0.6	69	2.3	40	1.4	24	1.6	48	2.9	45	2.6	26	3.8	27	3.0	10	5.6
Turbellaria	9	0.5	46	1.3	3	0.1	0	0.0	21	0.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	1,832	100.0	3,586	100.0	2,177	100.0	2,978	100.0	2,913	100.0	1,548	100.0	1,644	100.0	1,731	100.0	678	100.0	894	100.0	179	100.0
Upstream Station 5																						
Crustacea	17	0.9	36	1.0	6	0.4	7	0.5	6	0.3	6	0.2	96	7.2	3,546	75.7	137	26.4	385	37.6	19	21.3
Diptera	693	37.1	1,145	30.4	295	20.8	734	50.6	520	29.2	399	15.5	546	41.2	639	13.6	168	32.4	266	26.0	17	19.1
Ephemeroptera	176	9.4	209	5.5	108	7.6	122	8.4	72	4.0	15	0.6	6	0.5	18	0.4	5	1.0	8	0.8	0	0.0
Gastropoda	33	1.8	111	2.9	19	1.3	11	0.8	0	0.0	51	2.0	120	9.0	24	0.5	24	4.6	111	10.8	8	9.0
Oligochaeta	504	27.0	1,410	37.4	747	52.8	298	20.6	695	39.1	1,689	65.8	399	30.1	204	4.4	116	22.4	135	13.2	22	24.7
Other	20	1.1	64	1.7	26	1.8	66	4.6	37	2.1	180	7.0	45	3.4	123	2.6	35	6.8	36	3.5	4	4.5
Pelecypoda	392	21.0	698	18.5	201	14.2	183	12.6	435	24.5	177	6.9	90	6.8	87	1.9	9	1.7	67	6.5	0	0.0
Trichoptera	30	1.6	93	2.5	14	1.0	29	2.0	11	0.6	51	2.0	24	1.8	45	1.0	24	4.6	16	1.6	19	21.3
Turbellaria	1	0.1	0	0.0	0	0.0	0	0.0	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	1,866	100.0	3,766	100.0	1,416	100.0	1,450	100.0	1,778	100.0	2,568	100.0	1,326	100.0	4,686	100.0	518	100.0	1,024	100.0	89	100.0

Table 5-2. Composition of macroinvertebrates collected in rock baskets placed in the Connecticut River upstream and downstream of Vernon Dam, 1991 through 2002. Upstream rock basket sampling was discontinued in 2002.

	1991		1992		1993		1994		1995		1996		1997		1998		1999		2000		2001		2002	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Downstream Station 2																								
Crustacea	20	4.8	28	5.1	107	10.7	38	3.4	58	9.0	20	14.9	2	4.0	12	4.7	114	44.5	2	2.4	101	17.7	47	6.0
Diptera	111	26.5	132	23.9	296	29.6	307	27.7	191	29.7	10	7.5	6	12.0	80	31.5	10	3.9	56	66.7	137	24.0	144	18.4
Ephemeroptera	24	5.7	67	12.1	69	6.9	207	18.7	67	10.4	50	37.3	2	4.0	28	11.0	44	17.2	0	0.0	144	25.2	232	29.7
Gastropoda	18	4.3	26	4.7	30	3.0	18	1.6	6	0.9	2	1.5	26	52.0	22	8.7	40	15.6	0	0.0	57	10.0	112	14.3
Oligochaeta	5	1.2	51	9.2	13	1.3	25	2.3	10	1.6	4	3.0	0	0.0	14	5.5	4	1.6	10	11.9	11	1.9	7	0.9
Other	43	10.3	29	5.3	20	2.0	74	6.7	52	8.1	14	10.4	2	4.0	16	6.3	22	8.6	0	0.0	22	3.9	36	4.6
Pelecypoda	7	1.7	142	25.7	5	0.5	1	0.1	1	0.2	2	1.5	0	0.0	0	0.0	4	1.6	4	4.8	0	0.0	0	0.0
Trichoptera	130	31.0	58	10.5	185	18.5	437	39.5	221	34.4	32	23.9	12	24.0	82	32.3	18	7.0	12	14.3	93	16.3	197	25.2
Turbellaria	61	14.6	19	3.4	274	27.4	0	0.0	37	5.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	1.1	6	0.8
Total	419	100.0	552	100.0	999	100.0	1,107	100.0	643	100.0	134	100.0	50	100.0	254	100.0	256	100.0	84	100.0	571	100.0	781	100.0
Downstream Station 3																								
Crustacea	1	1.0	94	10.9	41	11.0	30	4.4	19	4.4	136	13.6	0	0.0	6	2.5	24	27.3	84	80.8	47	0.5	11	0.3
Diptera	25	25.8	91	10.6	65	17.4	271	39.9	161	37.2	160	16.0	10	4.5	68	28.8	16	18.2	4	3.8	484	5.3	1050	30.7
Ephemeroptera	9	9.3	59	6.8	69	18.5	25	3.7	59	13.6	18	1.8	0	0.0	20	8.5	24	27.3	10	9.6	401	4.4	452	13.2
Gastropoda	7	7.2	18	2.1	45	12.1	74	10.9	3	0.7	6	0.6	10	4.5	4	1.7	4	4.5	6	5.8	72	0.8	13	0.4
Oligochaeta	0	0.0	16	1.9	0	0.0	0	0.0	3	0.7	356	35.5	2	0.9	4	1.7	0	0.0	0	0.0	19	0.2	2	0.1
Other	11	11.3	412	47.8	90	24.1	170	25.0	147	33.9	54	5.4	194	88.2	14	5.9	18	20.5	0	0.0	54	0.6	81	2.4
Pelecypoda	0	0.0	0	0.0	0	0.0	4	0.6	0	0.0	0	0.0	0	0.0	2	0.8	0	0.0	0	0.0	6	0.1	0	0.0
Trichoptera	8	8.2	76	8.8	63	16.9	98	14.4	39	9.0	272	27.1	4	1.8	118	50.0	2	2.3	0	0.0	7114	77.5	1722	50.4
Turbellaria	36	37.1	96	11.1	0	0.0	8	1.2	2	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	984	10.7	86	2.5
Total	97	100.0	862	100.0	373	100.0	680	100.0	433	100.0	1,002	100.0	220	100.0	236	100.0	88	100.0	104	100.0	9,181	100.0	3,417	100.0
Upstream Station 4																								
Crustacea	15	4.1	129	19.2	15	6.9	142	6.0	55	14.4	186	47.7	2,002	75.0	334	38.9	84	37.8	204	20.9	42	10.9		
Diptera	145	39.5	166	24.7	38	17.6	641	26.9	77	20.1	72	18.5	208	7.8	180	21.0	18	8.1	102	10.4	44	11.5		
Ephemeroptera	48	13.1	110	16.4	107	49.5	131	5.5	97	25.3	60	15.4	24	0.9	84	9.8	18	8.1	48	4.9	40	10.4		
Gastropoda	7	1.9	8	1.2	14	6.5	476	20.0	9	2.3	8	2.1	8	0.3	38	4.4	20	9.0	50	5.1	61	15.9		
Oligochaeta	0	0.0	112	16.7	3	1.4	132	5.5	7	1.8	26	6.7	140	5.2	96	11.2	28	12.6	64	6.5	96	25.0		
Other	96	26.2	101	15.1	20	9.3	86	3.6	42	11.0	12	3.1	92	3.4	68	7.9	40	18.0	484	49.5	50	13.0		
Pelecypoda	0	0.0	0	0.0	0	0.0	12	0.5	0	0.0	0	0.0	8	0.3	4	0.5	0	0.0	0	0.0	0	0.0		
Trichoptera	52	14.2	45	6.7	17	7.9	717	30.1	93	24.3	26	6.7	186	7.0	54	6.3	14	6.3	26	2.7	51	13.3		
Turbellaria	4	1.1	0	0.0	2	0.9	42	1.8	3	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
Total	367	100.0	671	100.0	216	100.0	2,379	100.0	383	100.0	390	100.0	2,668	100.0	858	100.0	222	100.0	978	100.0	384	100.0		
Upstream Station 5																								
Crustacea	29	3.3	14	1.0	94	18.2	15	1.7	27	6.1	84	25.0	320	53.7	168	40.4	300	63.0	424	52.0	28	7.2		
Diptera	271	31.3	815	58.9	198	38.4	378	42.1	183	41.1	106	31.5	72	12.1	56	13.5	20	4.2	44	5.4	53	13.6		
Ephemeroptera	15	1.7	42	3.0	53	10.3	126	14.0	107	24.0	64	19.0	46	7.7	82	19.7	26	5.5	30	3.7	15	3.9		
Gastropoda	18	2.1	46	3.3	8	1.6	22	2.5	17	3.8	8	2.4	26	4.4	4	1.0	72	15.1	162	19.9	39	10.0		
Oligochaeta	7	0.8	48	3.5	0	0.0	30	3.3	10	2.2	26	7.7	2	0.3	12	2.9	0	0.0	36	4.4	28	7.2		
Other	45	5.2	290	21.0	32	6.2	32	3.6	18	4.0	16	4.8	92	15.4	70	16.8	36	7.6	70	8.6	182	46.8		
Pelecypoda	8	0.9	1	0.1	0	0.0	28	3.1	0	0.0	0	0.0	4	0.7	0	0.0	0	0.0	4	0.5	1	0.3		
Trichoptera	325	37.5	122	8.8	81	15.7	246	27.4	81	18.2	32	9.5	34	5.7	24	5.8	22	4.6	46	5.6	43	11.1		
Turbellaria	148	17.1	5	0.4	50	9.7	20	2.2	2	0.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
Total	866	100.0	1,383	100.0	516	100.0	897	100.0	445	100.0	336	100.0	596	100.0	416	100.0	476	100.0	816	100.0	389	100.0		

Table 5-3. **Number of macroinvertebrate taxa collected by Ponar grabs and in rock baskets in the Connecticut River upstream and downstream of Vernon Dam, 1996 through 2001. Data previous to 1996 identifying taxa abundance at particular stations is unavailable.**

	1996	% of total 1996 taxa	1997	% of total 1997 taxa	1998	% of total 1998 taxa	1999	% of total 1999 taxa	2000	% of total 2000 taxa	2001	% of total 2001 taxa	2002	% of total 2002 taxa
Station 2														
Crustacea	2	4%	1	2%	1	2%	1	2%	1	3%	3	11%	4	8%
Diptera	17	38%	20	45%	23	45%	17	31%	22	58%	12	43%	13	27%
Ephemeroptera	4	9%	3	7%	3	6%	6	11%	2	5%	1	4%	6	12%
Gastropoda	2	4%	6	14%	3	6%	5	9%	1	3%	1	4%	4	8%
Oligochaeta	4	9%	4	9%	7	14%	6	11%	6	16%	5	18%	1	2%
Other	7	16%	4	9%	6	12%	7	13%	1	3%	2	7%	11	22%
Pelecypoda	2	4%	1	2%	2	4%	2	4%	2	5%	0	0%	0	0%
Trichoptera	6	13%	4	9%	5	10%	10	18%	3	8%	3	11%	10	20%
Turbellaria	1	2%	1	2%	1	2%	1	2%	0	0%	1	4%	0	0%
Total	45	100%	44	100%	51	100%	55	100%	38	100%	28	100%	49	100%
Station 3														
Crustacea	4	5%	1	3%	1	3%	4	10%	3	6%	1	3%	4	7%
Diptera	34	41%	18	47%	17	50%	18	43%	19	37%	15	52%	16	29%
Ephemeroptera	5	6%	0	0%	3	9%	4	10%	3	6%	2	7%	8	14%
Gastropoda	3	4%	5	13%	1	3%	1	2%	3	6%	1	3%	3	5%
Oligochaeta	6	7%	6	16%	2	6%	6	14%	8	15%	2	7%	2	4%
Other	13	16%	4	11%	3	9%	5	12%	6	12%	6	21%	12	21%
Pelecypoda	4	5%	1	3%	2	6%	3	7%	3	6%	0	0%	0	0%
Trichoptera	12	15%	2	5%	4	12%	1	2%	6	12%	2	7%	10	18%
Turbellaria	1	1%	1	3%	1	3%	0	0%	1	2%	0	0%	1	2%
Total	82	100%	38	100%	34	100%	42	100%	52	100%	29	100%	56	100%

(Continued)

Table 5-3. (Continued)

	1996	% of total 1996 taxa	1997	% of total 1997 taxa	1998	% of total 1998 taxa	1999	% of total 1999 taxa	2000	% of total 2000 taxa	2001	% of total 2001 taxa
Station 4												
Crustacea	4	6%	2	3%	3	4%	2	3%	4	5%	4	9%
Diptera	27	42%	28	38%	29	39%	30	47%	38	47%	18	39%
Ephemeroptera	5	8%	4	5%	7	9%	4	6%	5	6%	6	13%
Gastropoda	1	2%	3	4%	3	4%	2	3%	4	5%	1	2%
Oligochaeta	11	17%	13	18%	11	15%	7	11%	9	11%	4	9%
Other	9	14%	12	16%	11	15%	10	16%	12	15%	5	11%
Pelecypoda	1	2%	2	3%	2	3%	3	5%	2	2%	1	2%
Trichoptera	7	11%	8	11%	8	11%	5	8%	6	7%	6	13%
Turbellaria	0	0%	1	1%	1	1%	1	2%	1	1%	1	2%
Total	65	100%	73	100%	75	100%	64	100%	81	100%	46	100%
Station 5												
Crustacea	4	5%	3	4%	3	4%	4	6%	5	6%	3	6%
Diptera	31	37%	26	37%	30	43%	26	41%	41	48%	19	38%
Ephemeroptera	7	8%	3	4%	6	9%	5	8%	4	5%	2	4%
Gastropoda	4	5%	3	4%	2	3%	2	3%	5	6%	4	8%
Oligochaeta	14	17%	14	20%	11	16%	8	13%	11	13%	7	14%
Other	13	16%	9	13%	7	10%	11	17%	12	14%	9	18%
Pelecypoda	2	2%	3	4%	2	3%	1	2%	1	1%	1	2%
Trichoptera	7	8%	8	11%	7	10%	5	8%	6	7%	4	8%
Turbellaria	1	1%	1	1%	1	1%	1	2%	1	1%	1	2%
Total	83	100%	70	100%	69	100%	63	100%	86	100%	50	100%

Table 5-4. Number and relative abundance of macroinvertebrate taxa collected by Ekman or Ponar grabs and in rock baskets in the Connecticut River upstream and downstream of Vernon Dam, 1996 through 2002.

	Taxa Abundance											
	1991	1992	1993	1994	1995	1996[2]	1997	1998	1999	2000	2001[1]	2002
Crustacea	5	5	5	7	4	4	4	4	6	5	4	5
Diptera	49	42	43	54	54	58	47	54	50	60	36	20
Ephemeroptera	14	13	10	14	13	11	7	9	7	7	6	9
Gastropoda	7	9	7	8	7	4	7	5	7	8	6	4
Oligochaeta	1	3	3	5	1	23	25	18	13	15	14	3
Other	22	30	24	33	27	25	18	19	19	12	15	15
Pelecypoda	6	4	5	6	4	4	3	5	5	5	1	0
Trichoptera	24	13	15	23	19	17	12	13	16	16	9	14
Turbellaria	2	2	2	1	1	1	1	1	1	1	1	1
Total	130	121	114	151	130	147	124	128	124	129	92	71
	Percent of Total Taxa Collected in Year											
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Crustacea	4	4	4	5	3	3	3	3	5	4	4	7
Diptera	38	35	38	36	42	39	38	42	40	47	39	28
Ephemeroptera	11	11	9	9	10	7	6	7	6	5	7	13
Gastropoda	5	7	6	5	5	3	6	4	6	6	7	6
Oligochaeta	1	2	3	3	1	16	20	14	10	12	15	4
Other	17	25	21	22	21	17	15	15	15	9	16	21
Pelecypoda	5	3	4	4	3	3	2	4	4	4	1	0
Trichoptera	18	11	13	15	15	12	10	10	13	12	10	20
Turbellaria	2	2	2	1	1	1	1	1	1	1	1	1
Total	100	100	100	100	100	100	100	100	100	100	100	100

[1]Ponar sampling discontinued in 2001.
[2]From 1991 to 1995 Ekman grabs and rock basket samples were collected by Aquatec™. Ponar grab and rock basket data from 1996 to 2002 were supplied by Normandeau Associates, Inc. The increase in Oligochaeta taxa relative abundance is likely due to additional taxonomic scrutiny from 1996 to 2002.

Table 5-5. Statistically signifcant (95% confidence) results from a Kendall-Tau correlation analysis of each taxonomic grouping for each gear type, station and time period.

Taxa	Gear	Station	Location Relative to Vernon Dam	Time Period	Trend Direction	Kendall-Tau coefficient	p-value	n
Ephemeroptera	Rock basket	3	Downstream	1996-2002	Increasing	0.619	0.051	7
Gastropoda	Rock basket	4	Upstream	1996-2002	Increasing	0.800	0.050	5
Oligochaeta	Ponar	5	Upstream	1996-2000	Decreasing	-0.800	0.050	5
Crustacea	Rock basket	5	Upstream	1996-2002	Increasing	0.800	0.050	5
Gastropoda	Rock basket	5	Upstream	1996-2002	Increasing	0.800	0.050	5

5.1.2 Adult and Larval Fish

This section summarizes general trends in the fish community found in lower Vernon Pool and in the Vernon Dam tailwaters of the River by using the data from the routine sampling performed during 1991 – 2002, as specified in "Part III Environmental Monitoring Studies, Connecticut River – Fish and - Larval Fish" sections of Vermont Yankee's NPDES permit No. 3-1199. This fish sampling continued the majority of the monitoring tasks performed since the late 1960s and reviewed in the 1990 §316(a) demonstration (Downey et al. 1990). The total data set exceeds 30 years and illustrates relative consistency in sampling methods, locations, and effort, providing a sound basis for analysis.

5.1.2.1 Methods

Electrofishing and trap net sampling occurred during May, June, September and October of each year, unless excessively high or low water levels or extremely dense vegetation rendered sampling dangerous or ineffective. Electrofishing was performed throughout the 12-year period, while trap net sampling was discontinued at the direction of VANR and the EAC after 1999. Fish collected by both methods were identified to species, enumerated, weighed to the nearest gram (wet weight), and measured for total length to the nearest millimeter.

Electrofishing was performed with a boat electroshocker employing a bow-mounted cathode array and a Coffelt Electronics Model VVP-15 variable voltage pulsator. Sampling was carried out in the evening beginning approximately 0.5 hour after sunset. Eight stations with a total of 10 sub-locations (six located upstream and four downstream of Vernon Dam) were sampled (Appendix Tables 4-3 and 4-5; Figure 5-1; Appendix 4). Electrofishing is an active sampling method wherein the boat moves through a sampling site. Fish encountering the electrical field in front of the boat are stunned, netted from the water, temporarily held in a livewell for processing and then released. Electrofishing samples represented about 15 or 20 minutes of current applied to the water, and the catch per unit of effort (CPUE) was expressed as the number of fish caught per hour.

Trap nets consisted of a steel frame covered with 1.3-cm square-mesh knotless nylon. Each net had a 1 x 2-meter mouth opening, two 8-m long wings and a 30-m center lead. Trap nets were deployed for approximately 48 hours for each monthly sampling event and all fish collected were removed and processed after about 24 hours and at the conclusion of sampling. Eight nets were deployed at six locations upstream of Vernon Dam and six were set downstream at five locations (Figure 5-1; Appendix Tables 4-4 and 4-6). The trap net is a passive gear that depends on moving fish to encounter the wings and center lead, which guide them into the trap section of the net. Trap net CPUE was expressed as catch per 24 hours.

Ichthyoplankton samples were collected weekly from May 1 through mid-July with a 50-cm diameter, 363-micrometer mesh plankton net towed in the river near the cooling water intake structure. Sampling was only required when Vermont Yankee was operating its circulating water intake system. The net was deployed alongside or behind the sampling vessel at the surface (approximately 1 foot deep), at mid-depth (approx. 6 feet) and near bottom (approx. 12 feet). Volume of water sampled was measured with a calibrated flow meter mounted in the mouth of the net. The samples were preserved in the field and returned to the laboratory for sorting and identification. Larval fish were identified to the lowest feasible taxonomic level with the aid of standard references.

5.1.2.2 Results and Discussion

Electrofishing and Trap Netting

Over 27,700 specimens were obtained in the combined electrofishing and trap net collections during the period 1991 - 2002 (Table 5-6). The fish community depicted by the monitoring program consists of over 30 species, most characteristic of warm-water environments. The most common fishes, making up at least 5% of the combined total catch over the 12-year period, were yellow perch (29%), bluegill (12%), rock bass (10%), pumpkinseed (9%), spottail shiner (7%), smallmouth bass (7%), and white sucker (5%). Only three Atlantic salmon (all smolts) were taken in the 1,447 collections that have been made since 1991. American shad was the most numerous anadromous fish. Blueback herring was rarely seen. Sea lamprey and American eel were collected fairly regularly, but in very low numbers. Typical cold-water species, other than one brook trout collected in 2002, were not collected during this review period (1991 – 2002) and were rarely collected in prior years (Downey et al. 1990).

Appropriately, spatial differences were apparent in the relative abundance of several species with regard to catches obtained upstream versus downstream of Vernon Dam (Table 5-7). The River upstream is characterized by relatively slow-moving pool habitat that is more favorable to species typical of lentic (slow-moving) habitats, whereas the habitat downstream in the Vernon Dam tailrace is more riverine and faster flowing (lotic) in character. The most common fishes in electrofishing collections upstream were yellow perch (36%), bluegill (19%), spottail shiner (9%), pumpkinseed (9%), and largemouth bass (7%). In electrofishing collections downstream of Vernon Dam, the top ranked species were smallmouth bass (27%), spottail shiner (18%), American shad (11%), white sucker (8%), and rock bass (8%).

This distribution was confirmed in the trap net collections (Table 5-8). Yellow perch (45%), pumpkinseed (17%), rock bass (8%), bluegill (7%), and white sucker (5%) were most numerous upstream, while rock bass (34%), yellow perch (14%), brown bullhead (11%), bluegill (10%), and smallmouth bass (9%) dominated in downstream collections.

Overall, electrofishing CPUE both upstream and downstream of Vernon Dam displayed an increasing trend over the 12-year period. The upstream trap net CPUE also trended upward. Expected inter-annual variation, however, was evident in the annual average electrofishing and trap net CPUE data, which reflected the variable year-class success of the most abundant fishes (Figures 5-9 and 5-10, respectively). In general, the numbers of the top ranked species overall tended to, but did not always, fluctuate similarly from one year to the next (Tables 5-9 through 5-12). For example, the particularly high CPUE in the electrofishing sampling upstream in 1996 was largely due to a 10-fold increase in spottail shiner numbers from the prior year, along with substantial increases for bluegill and pumpkinseed. A decrease in numbers of these same species the following year then resulted in the large drop in CPUE to a more normal level.

Ichthyoplankton

Ichthyoplankton sampling over the 12-year review period yielded approximately 8,400 specimens (Table 5-13). As with the results for the other sampling methods, the numerical dominance of the different fish species collected in this sampling program varied from year to year. However, members of the family Cyprinidae (minnows and carps), together with white sucker and white perch, were usually most numerous.

It is likely that the spottail shiner was the dominant species of the Cyprinidae component in ichthyoplankton collections obtained throughout the review period, since it can be noted in Table 5-13 that no specimens were attributed to the *Notropis* sp. or Cyprinidae category after 1997, while numbers identified as spottail shiner increased coincidentally. This transition occurred due to more detailed identification to the species level of taxonomy. Specimens categorized as Centrarchidae (sunfishes) and *Lepomis* sp. were numerically important in some years. Walleye were collected in most years, but in very low numbers. American shad and largemouth bass rarely entered the ichthyoplankton catch. No smallmouth bass were identified.

Long-term Community Composition

To provide an indication of the composition and relative abundance of selected species over the 33-year study period during which fish have been sampled in connection with Vermont Yankee, the electrofishing and trap net combined collection results for sampling performed upstream and downstream of Vernon Dam for this review period are shown in comparison to collection results summarized in Downey et al. (1990) for the two prior review periods, 1968 – 1980 and 1981 – 1989, in Table 5-14. This table includes sampling results for 18 species, which represent about half of the total number collected over 33 years, and includes all RIS. These were included because they were numerically dominant in the collections or were considered to have special significance because of restoration efforts, status as a RIS in this 316(a) demonstration, or importance as game or sport fish.

The data confirm a general similarity in community composition over the three review periods, although several relatively minor differences are evident, likely as a result of natural cycles of variability in the life history of the various species, the introduction of fishways and changes in sampling methods (see Table 5-14).

American shad and blueback herring, which first appeared in the 1981 – 1989 period as a result of installation of fishways at Turners Falls Dam and Vernon Dam, continued to be collected in the most recent period and in greater numbers downstream of Vernon Dam than upstream. However, they did not represent as high a percentage of the total catch as in the prior period. Mimic shiner also was first collected in the middle review period and was an important minnow then, but in 1990 – 2001 it was a less dominant component of the combined catch, because seining was not performed after 1985. Spottail shiner and white sucker, both upstream and downstream, were important components of the fish community throughout the entire study period, but numbers collected varied without apparent trend. White perch appeared to be less numerous from period to period both upstream and downstream of Vernon Dam. In contrast, the percentage of the total catch represented by bluegill and yellow perch increased in both locations. Largemouth bass made up a greater percentage of the catch upstream than downstream and increased as a percentage of the catch over time, while smallmouth bass and rock bass became increasingly dominant in the catch downstream of Vernon Dam. As discussed above, these differences are likely related to the overall habitat difference between these areas above and below Vernon Dam. Walleye, northern pike and chain pickerel were relatively minor components of the catch in all survey periods.

None of the observed changes in fish community composition or distribution over the 33-year study period have ever been or reasonably could be attributed to operation of Vermont Yankee, based upon the data set.

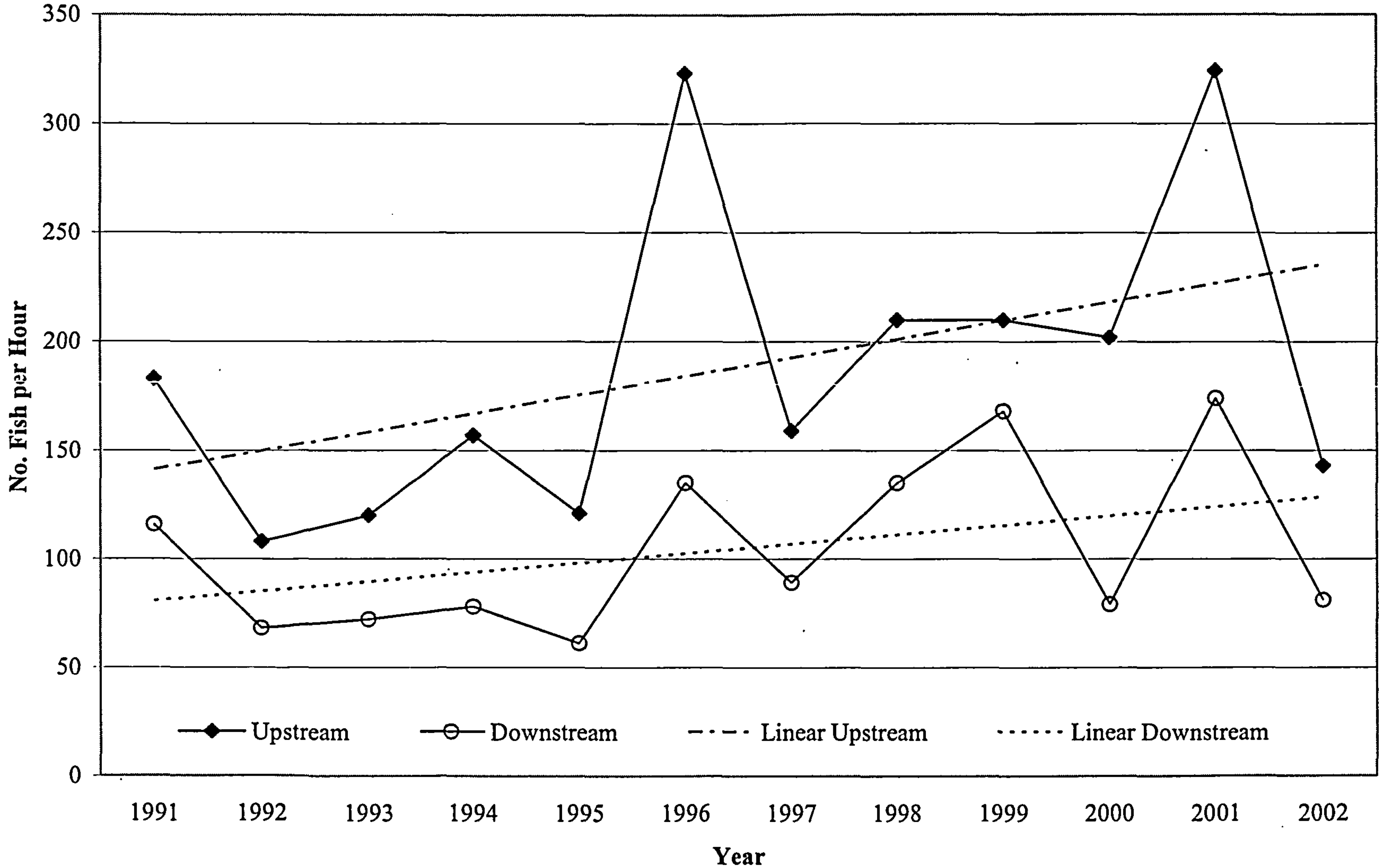


Figure 5-9. Electrofishing catch per unit effort for sample stations upstream and downstream of Vernon Dam, 1991-2002.

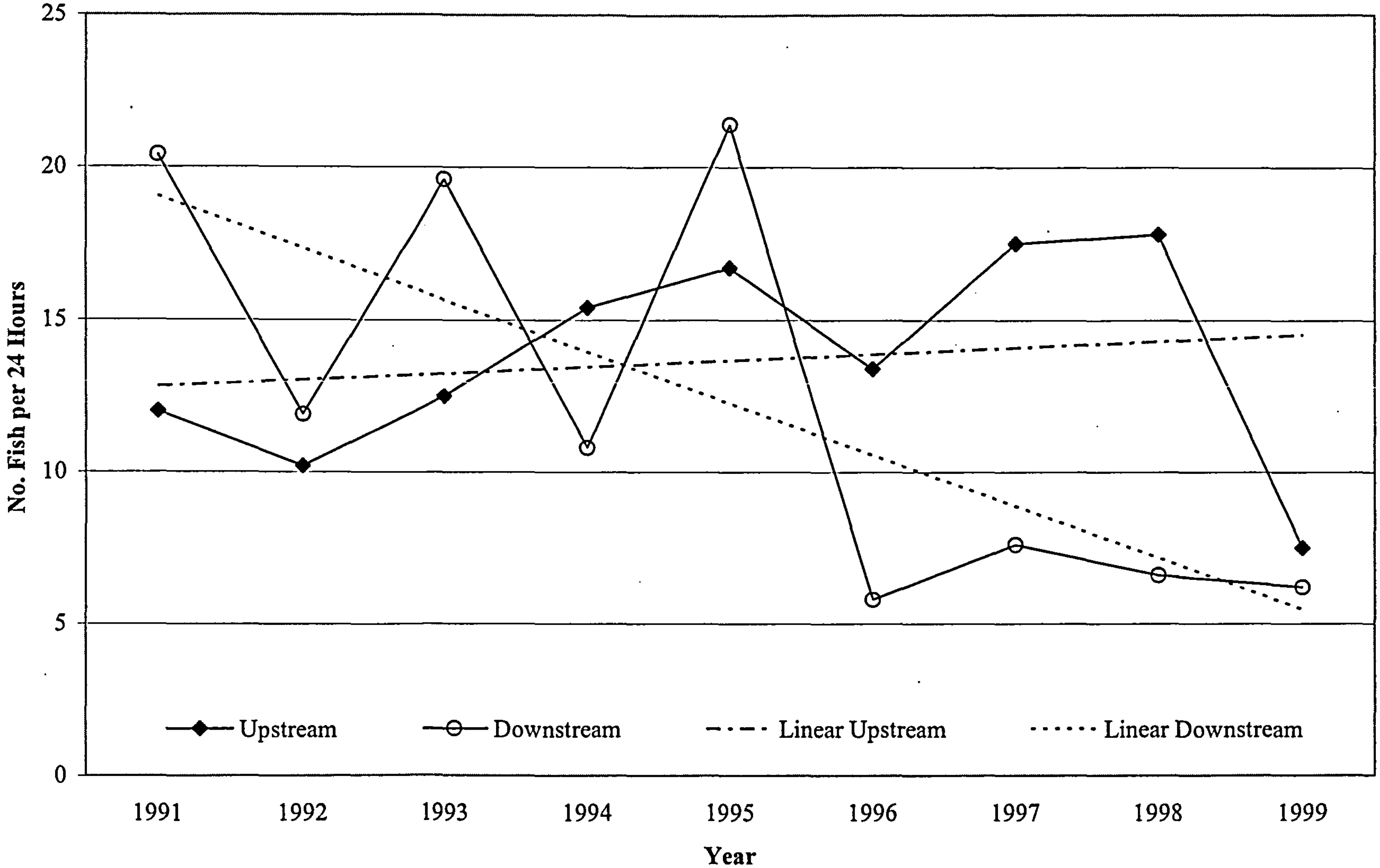


Figure 5-10. Trap net catch per unit effort for sample stations upstream and downstream of Vernon Dam, 1991 – 1999.

Table 5-6. Combined electrofishing and trap net catches in the vicinity of Vermont Yankee, 1991 - 2002.

	Electrofishing		Trap net		Combined	
Species	Total No.	%	Total No.	%	Total No.	%
Sea lamprey	52	0.3	25	0.2	77	0.3
American eel	67	0.4	39	0.3	106	0.4
Blueback herring	2	<0.1	4	<0.1	6	<0.1
American shad	599	3.7	119	1.0	718	2.6
Gizzard shad	6	<0.1	0	0.0	6	<0.1
Goldfish	1	<0.1	0	0.0	1	<0.1
Common carp	76	0.5	52	0.4	128	0.5
E. silvery minnow	29	0.2	0	0.0	29	0.1
Common shiner	24	0.1	0	0.0	24	0.1
Golden shiner	601	3.7	170	1.5	771	2.8
Notropis sp.	22	0.1	0	0.0	22	0.1
Spottail shiner	1,872	11.7	141	1.2	2,013	7.3
Spotfin shiner	1	<0.1	0	0.0	1	<0.1
Mimic shiner	54	0.3	0	0.0	54	0.2
Fallfish	300	1.9	10	0.1	310	1.1
White sucker	928	5.8	570	4.9	1,498	5.4
Yellow bullhead	46	0.3	46	0.4	92	0.3
Brown bullhead	116	0.7	759	6.5	875	3.2
Northern pike	72	0.4	20	0.2	92	0.3
Chain pickerel	166	1.0	207	1.8	373	1.3
Atlantic salmon	1	<0.1	2	<0.1	3	<0.1
Brook trout	1	<0.1	0	0.0	1	<0.1
Banded killifish	7	<0.1	0	0.0	7	<0.1
White perch	108	0.7	278	2.4	386	1.4
Rock bass	602	3.7	2,148	18.4	2,750	9.9
Lepomis sp.	70	0.4	12	0.1	82	0.3
Redbreast sunfish	2	<0.1	14	0.1	16	0.1
Pumpkinseed	1,102	6.9	1,403	12.0	2,505	9.0
Bluegill	2,368	14.7	964	8.3	3,332	12.0
Smallmouth bass	1,395	8.7	578	5.0	1,973	7.1
Largemouth bass	841	5.2	115	1.0	956	3.4
Black crappie	57	0.4	54	0.5	111	0.4
Tessellated darter	10	0.1	6	0.1	16	0.1
Yellow perch	4,273	26.6	3,735	32.0	8,008	28.9
Walleye	188	1.2	203	1.7	391	1.4
Total Number	**16,059**	**100.0**	**11,675**	**100.0**	**27,734**	**100.0**
No. collections	496		951		1,447	

Table 5-7. Comparison of electrofishing catches upstream and downstream of Vernon Dam, 1991 - 2002.

	Upstream			Downstream			Combined	
Species	Total No.	%	No. Fish/Hr.	Total No.	%	No. Fish/Hr.	Total No.	%
Sea lamprey	27	0.2	0.4	25	0.5	0.5	52	0.3
American eel	26	0.2	0.4	41	0.9	0.9	67	0.4
Blueback herring	0	0.0	0.0	2	<0.1	<0.1	2	<0.1
American shad	83	0.7	1.3	516	11.1	10.7	599	3.7
Gizzard shad	1	<0.1	<0.1	5	0.1	0.1	6	<0.1
Goldfish	0	0.0	0.0	1	<0.1	<0.1	1	<0.1
Common carp	54	0.5	0.8	22	0.5	0.5	76	0.5
E. silvery minnow	16	0.1	0.2	13	0.3	0.3	29	0.2
Common shiner	1	<0.1	<0.1	23	0.5	0.5	24	0.1
Golden shiner	549	4.8	8.3	52	1.1	1.1	601	3.7
Notropis sp.	1	<0.1	<0.1	21	0.5	0.4	22	0.1
Spottail shiner	1,09	9.2	15.9	823	17.7	17.1	1,872	11.7
Spotfin shiner	0	0.0	0.0	1	<0.1	<0.1	1	<0.1
Mimic shiner	28	0.2	0.4	26	0.6	0.5	54	0.3
Fallfish	2	<0.1	<0.1	298	6.4	6.2	300	1.9
White sucker	567	5.0	8.6	361	7.8	7.5	928	5.8
Yellow bullhead	45	0.4	0.7	1	<0.1	<0.1	46	0.3
Brown bullhead	105	0.9	1.6	11	0.2	0.2	116	0.7
Northern pike	42	0.4	0.6	30	0.6	0.6	72	0.4
Chain pickerel	143	1.3	2.2	23	0.5	0.5	166	1.0
Atlantic salmon	0	0.0	0.0	1	<0.1	<0.1	1	<0.1
Brook trout	0	0.0	0.0	1	<0.1	<0.1	1	<0.1
Banded killifish	5	<0.1	0.1	2	<0.1	<0.1	7	<0.1
White perch	94	0.8	1.4	14	0.3	0.3	108	0.7
Rock bass	231	2.0	3.5	371	8.0	7.7	602	3.7
Lepomis sp.	63	0.6	1.0	7	0.2	0.1	70	0.4
Redbreast sunfish	1	<0.1	<0.1	1	<0.1	<0.1	2	<0.1
Pumpkinseed	1,029	9.0	15.6	73	1.6	1.5	1,102	6.9
Bluegill	2,112	18.5	31.9	256	5.5	5.3	2,368	14.7
Smallmouth bass	160	1.4	2.4	1,235	26.6	25.6	1,395	8.7
Largemouth bass	777	6.8	11.7	64	1.4	1.3	841	5.2
Black crappie	50	0.4	0.8	7	0.2	0.1	57	0.4
Tessellated darter	9	0.1	0.1	1	<0.1	<0.1	10	0.1
Yellow perch	4,057	35.5	61.3	216	4.6	4.5	4,273	26.6
Walleye	86	0.8	1.3	102	2.2	2.1	188	1.2
Total Number	11,413	100.0	172.5	4,646	100.0	96.4	16,059	100.0
No. Collections	284			212			496	
Effort (hours)	66.2			48.2			114.4	
No. Fish/Hr.	172			96			140	

Table 5-8. Comparison of trap net catches upstream and downstream of Vernon Dam, 1991 - 1999.

	Upstream			Downstream			Combined	
Species	Total No.	%	No./24 Hrs.	Total No.	%	No./24 Hrs.	Total No.	%
Sea lamprey	0	0.0	0.00	25	0.5	0.07	25	0.2
American eel	7	0.1	0.01	32	0.7	0.09	39	0.3
Blueback herring	0	0.0	0.00	4	0.1	0.01	4	<0.1
American shad	4	0.1	0.01	115	2.4	0.31	119	1.0
Common carp	40	0.6	0.08	12	0.3	0.03	52	0.4
Golden shiner	140	2.0	0.28	30	0.6	0.08	170	1.5
Spottail shiner	32	0.5	0.06	109	2.3	0.29	141	1.2
Fallfish	0	0.0	0.00	10	0.2	0.03	10	0.1
White sucker	349	5.0	0.69	221	4.6	0.60	570	4.9
Yellow bullhead	40	0.6	0.08	6	0.1	0.02	46	0.4
Brown bullhead	220	3.2	0.44	539	11.3	1.46	759	6.5
Northern pike	12	0.2	0.02	8	0.2	0.02	20	0.2
Chain pickerel	172	2.5	0.34	35	0.7	0.09	207	1.8
Atlantic salmon	0	0.0	0.00	2	<0.1	0.01	2	<0.1
White perch	244	3.5	0.48	34	0.7	0.09	278	2.4
Rock bass	548	7.9	1.09	1,600	33.6	4.33	2,148	18.4
Lepomis sp.	1	<0.1	<0.01	11	0.2	0.03	12	0.1
Redbreast sunfish	3	<0.1	0.01	11	0.2	0.03	14	0.1
Pumpkinseed	1,144	16.5	2.27	259	5.4	0.70	1,403	12.0
Bluegill	508	7.3	1.01	456	9.6	1.23	964	8.3
Smallmouth bass	156	2.3	0.31	422	8.9	1.14	578	5.0
Largemouth bass	91	1.3	0.18	24	0.5	0.06	115	1.0
Black crappie	33	0.5	0.07	21	0.4	0.06	54	0.5
Tessellated darter	1	<0.1	<0.01	5	0.1	0.01	6	0.1
Yellow perch	3,091	44.7	6.14	644	13.5	1.74	3,735	32.0
Walleye	83	1.2	0.16	120	2.5	0.32	203	1.7
Total Number	6,920	100.0	13.75	4,755	100.0	12.86	11,675	100.0
No. Collections	552			399			951	
Effort (hours)	12,076			8,872			20,948	
No. Fish/24 Hrs.	13.8			12.9			13.4	

Table 5-9. Numbers and percent of fish collected by electrofishing upstream of Vernon Dam, 1991 - 2002.

Species	1991		1992		1993		1994		1995		1996		1997		1998		1999		2000		2001		2002		Total No.	%	No. Fish/Hr.
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%			
Sea lamprey	2	0.1	0	0.0	1	0.1	0	0.0	0	0.0	1	0.1	9	1.4	5	0.6	4	0.5	1	0.1	4	0.3	0	0.0	27	0.2	0.4
American eel	7	0.5	2	0.2	8	0.8	4	0.4	2	0.2	0	0.0	0	0.0	2	0.2	1	0.1	0	0.0	0	0.0	0	0.0	26	0.2	0.4
Blueback herring	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0
American shad	19	1.3	29	3.3	5	0.5	2	0.2	24	2.4	3	0.3	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	83	0.7	1.3
Gizzard shad	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Goldfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Common carp	11	0.8	6	0.7	8	0.8	7	0.7	11	1.1	2	0.2	1	0.2	2	0.2	3	0.4	2	0.3	0	0.0	1	0.2	54	0.5	0.8
E. silvery minnow	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	1.1	5	0.6	0	0.0	2	0.3	16	0.1	0.2
Common shiner	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Golden shiner	74	5.2	70	8.0	16	1.7	41	4.0	46	4.7	39	3.5	15	2.4	74	8.1	66	7.8	24	3.1	55	4.2	29	5.0	549	4.8	8.3
Notropis sp.	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Spottail shiner	104	7.3	73	8.4	46	4.9	85	8.3	23	2.3	249	22.2	146	22.9	39	4.3	76	9.0	50	6.4	141	10.9	17	2.9	1,049	9.2	15.9
Spotfin shiner	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Mimic shiner	6	0.4	0	0.0	0	0.0	17	1.7	5	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	28	0.2	0.4
Fallfish	1	0.1	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	<0.1	<0.1
White sucker	121	8.5	86	9.9	75	7.9	108	10.6	73	7.4	22	2.0	11	1.7	8	0.9	13	1.5	11	1.4	21	1.6	18	3.1	567	5.0	8.6
Yellow bullhead	5	0.4	4	0.5	5	0.5	4	0.4	7	0.7	2	0.2	0	0.0	2	0.2	4	0.5	7	0.9	5	0.4	0	0.0	45	0.4	0.7
Brown bullhead	19	1.3	19	2.2	29	3.1	8	0.8	20	2.0	1	0.1	2	0.3	2	0.2	0	0.0	3	0.4	2	0.2	0	0.0	105	0.9	1.6
Northern pike	7	0.5	11	1.3	6	0.6	2	0.2	6	0.6	4	0.4	0	0.0	0	0.0	0	0.0	4	0.5	1	0.1	1	0.2	42	0.4	0.6
Chain pickerel	17	1.2	29	3.3	5	0.5	4	0.4	5	0.5	12	1.1	14	2.2	20	2.2	9	1.1	12	1.5	11	0.8	5	0.9	143	1.3	2.2
Atlantic salmon	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Brook trout	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Banded killifish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	4	0.3	0	0.0	5	<0.1	0.1
White perch	19	1.3	11	1.3	7	0.7	34	3.3	18	1.8	0	0.0	1	0.2	0	0.0	1	0.1	0	0.0	0	0.0	3	0.5	94	0.8	1.4
Rock bass	37	2.6	26	3.0	10	1.1	5	0.5	18	1.8	41	3.7	9	1.4	17	1.9	18	2.1	24	3.1	21	1.6	5	0.9	231	2.0	3.5
Lepomis sp.	0	0.0	1	0.1	1	0.1	12	1.2	49	5.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	63	0.6	1.0
Redbreast sunfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Pumpkinseed	157	11.0	94	10.8	144	15.2	97	9.5	68	6.9	109	9.7	11	1.7	71	7.8	23	2.7	70	9.0	104	8.0	81	14.0	1,029	9.0	15.6
Bluegill	128	9.0	56	6.4	99	10.5	118	11.5	135	13.7	222	19.8	46	7.2	234	25.8	296	35.2	221	28.4	360	27.8	197	34.1	2,112	18.5	31.9
Smallmouth bass	15	1.1	10	1.1	18	1.9	11	1.1	22	2.2	12	1.1	7	1.1	26	2.9	21	2.5	10	1.3	2	0.2	6	1.0	160	1.4	2.4
Largemouth bass	151	10.6	83	9.5	99	10.5	58	5.7	69	7.0	44	3.9	30	4.7	31	3.4	43	5.1	47	6.0	91	7.0	31	5.4	777	6.8	11.7
Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	0.4	3	0.5	7	0.8	10	1.2	12	1.5	9	0.7	4	0.7	50	0.4	0.8
Tessellated darter	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	0	0.0	0	0.0	4	0.3	1	0.2	9	0.1	0.1
Yellow perch	507	35.6	260	29.8	352	37.2	394	38.5	373	37.7	346	30.9	324	50.9	360	39.6	240	28.5	272	34.9	454	35.0	175	30.3	4,057	35.5	61.3
Walleye	15	1.1	1	0.1	12	1.3	12	1.2	13	1.3	6	0.5	7	1.1	6	0.7	3	0.4	2	0.3	7	0.5	2	0.3	86	0.8	1.3
Total Number	1,424	100.0	872	100.0	946	100.0	1,023	100.0	989	100.0	1,120	100.0	637	100.0	908	100.0	841	100.0	779	100.0	1,296	100.0	578	100.0	11,413	100.0	172.5
No. Collections	24		24		24		24		24		20		24		24		24		24		24		24		284		
Effort (hours)	7.8		8.1		7.9		6.5		8.2		3.5		4.0		4.3		4.0		3.9		4.0		4.0		66.2		
No. Fish/Hr.	183		108		120		157		121		323		159		210		210		202		324		143		172		

Table 5-10. Numbers and percent of fish collected by electrofishing downstream of Vernon Dam, 1991 - 2002.

Species	1991		1992		1993		1994		1995		1996		1997		1998		1999		2000		2001		2002		Total No.	%	No. Fish/Hr.
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%			
Sea lamprey	0	0.0	1	0.2	3	0.7	0	0.0	0	0.0	7	1.7	0	0.0	6	1.6	3	0.7	0	0.0	3	0.6	2	0.9	25	0.5	0.5
American eel	13	2.0	1	0.2	10	2.4	7	1.6	1	0.3	1	0.2	1	0.4	3	0.8	0	0.0	2	1.0	0	0.0	2	0.9	41	0.9	0.9
Blueback herring	0	0.0	2	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	<0.1	<0.1
American shad	166	25.6	37	9.2	82	19.9	43	9.6	59	15.6	10	2.4	39	16.2	12	3.3	1	0.2	12	6.0	34	7.3	21	9.8	516	11.1	10.7
Gizzard shad	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	2	0.5	0	0.0	0	0.0	1	0.2	1	0.5	0	0.0	0	0.0	5	0.1	0.1
Goldfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Common carp	3	0.5	1	0.2	3	0.7	4	0.9	7	1.8	4	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	22	0.5	0.5
E. silvery minnow	0	0.0	0	0.0	0	0.0	0	0.0	6	1.6	0	0.0	0	0.0	5	1.4	0	0.0	0	0.0	0	0.0	2	0.9	13	0.3	0.3
Common shiner	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	21	4.6	1	0.5	1	0.2	0	0.0	23	0.5	0.5
Golden shiner	5	0.8	2	0.5	4	1.0	4	0.9	0	0.0	14	3.3	4	1.7	4	1.1	10	2.2	3	1.5	1	0.2	1	0.5	52	1.1	1.1
Notropis sp.	0	0.0	0	0.0	0	0.0	8	1.8	2	0.5	0	0.0	0	0.0	0	0.0	0	0.0	2	1.0	9	1.9	0	0.0	21	0.5	0.4
Spottail shiner	107	16.5	104	25.9	49	11.9	60	13.5	27	7.1	171	40.6	64	26.6	37	10.1	65	14.3	51	25.4	48	10.3	40	18.6	823	17.7	17.1
Spotfin shiner	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Mimic shiner	15	2.3	0	0.0	4	1.0	6	1.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	26	0.6	0.5
Fallfish	49	7.6	22	5.5	11	2.7	27	6.1	9	2.4	6	1.4	0	0.0	25	6.8	86	19.0	26	12.9	24	5.2	13	6.0	298	6.4	6.2
White sucker	73	11.3	62	15.5	40	9.7	71	15.9	30	7.9	18	4.3	7	2.9	17	4.7	20	4.4	6	3.0	11	2.4	6	2.8	361	7.8	7.5
Yellow bullhead	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Brown bullhead	1	0.2	1	0.2	2	0.5	0	0.0	5	1.3	0	0.0	0	0.0	0	0.0	2	0.4	0	0.0	0	0.0	0	0.0	11	0.2	0.2
Northern pike	2	0.3	7	1.7	0	0.0	6	1.3	10	2.6	3	0.7	1	0.4	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	30	0.6	0.6
Chain pickerel	3	0.5	6	1.5	4	1.0	2	0.4	0	0.0	3	0.7	3	1.2	0	0.0	0	0.0	1	0.5	1	0.2	0	0.0	23	0.5	0.5
Atlantic salmon	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Brook trout	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.5	1	<0.1	<0.1
Banded killifish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.9	2	<0.1	<0.1
White perch	1	0.2	1	0.2	8	1.9	0	0.0	2	0.5	0	0.0	1	0.4	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	14	0.3	0.3
Rock bass	30	4.6	25	6.2	22	5.3	37	8.3	47	12.4	37	8.8	6	2.5	43	11.8	38	8.4	13	6.5	60	12.9	13	6.0	371	8.0	7.7
Lepomis sp.	6	0.9	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	0.2	0.1
Redbreast sunfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Pumpkinseed	11	1.7	3	0.7	3	0.7	4	0.9	4	1.1	5	1.2	3	1.2	10	2.7	5	1.1	10	5.0	5	1.1	10	4.7	73	1.6	1.5
Bluegill	8	1.2	12	3.0	15	3.6	28	6.3	25	6.6	37	8.8	5	2.1	28	7.7	12	2.6	23	11.4	41	8.8	22	10.2	256	5.5	5.3
Smallmouth bass	101	15.6	85	21.2	99	24.0	109	24.4	118	31.1	73	17.3	72	29.9	141	38.6	127	28.0	42	20.9	197	42.5	71	33.0	1,235	26.6	25.6
Largemouth bass	8	1.2	5	1.2	15	3.6	3	0.7	8	2.1	3	0.7	5	2.1	3	0.8	5	1.1	0	0.0	8	1.7	1	0.5	64	1.4	1.3
Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.8	0	0.0	0	0.0	1	0.2	3	1.4	7	0.2	0.1
Tessellated darter	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.1
Yellow perch	28	4.3	11	2.7	21	5.1	18	4.0	6	1.6	21	5.0	28	11.6	20	5.5	45	9.9	2	1.0	15	3.2	1	0.5	216	4.6	4.5
Walleye	18	2.8	13	3.2	16	3.9	9	2.0	9	2.4	5	1.2	2	0.8	5	1.4	12	2.6	6	3.0	3	0.6	4	1.9	102	2.2	2.1
Total Number	648	100.0	401	100.0	412	100.0	446	100.0	379	100.0	421	100.0	241	100.0	365	100.0	453	100.0	201	100.0	464	100.0	215	100.0	4,646	100.0	96.4
No. Collections	20		20		20		20		20		16		16		16		16		16		16		16		212		
Effort (hours)	5.6		5.9		5.7		5.7		6.2		3.1		2.7		2.7		2.7		2.6		2.7		2.7		48.2		
No. Fish/Hr.	116		68		72		78		61		135		89		135		168		79		174		81		96		

Table 5-11. Numbers and percent of fish collected by trap net upstream of Vernon Dam, 1991 - 1999.

Species	1991		1992		1993		1994		1995		1996		1997		1998		1999				
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Total No.	%	No. Fish/24 Hrs.
Sea lamprey	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.00
American eel	2	0.3	1	0.2	0	0.0	1	0.1	1	0.1	1	0.2	1	0.1	0	0.0	0	0.0	7	0.1	0.01
Blueback herring	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.00
American shad	0	0.0	0	0.0	0	0.0	0	0.0	3	0.3	0	0.0	0	0.0	1	0.1	0	0.0	4	0.1	0.01
Common carp	10	1.6	8	1.4	9	1.3	5	0.6	2	0.2	1	0.2	1	0.1	3	0.3	1	0.2	40	0.6	0.08
Golden shiner	11	1.7	14	2.5	7	1.0	36	4.1	17	1.8	18	3.1	18	1.6	9	0.8	10	2.3	140	2.0	0.28
Spottail shiner	2	0.3	11	2.0	10	1.4	2	0.2	3	0.3	0	0.0	4	0.4	0	0.0	0	0.0	32	0.5	0.06
Fallfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.00
White sucker	16	2.5	24	4.3	56	8.1	41	4.6	55	5.8	47	8.0	57	5.2	37	3.5	16	3.6	349	5.0	0.69
Yellow bullhead	0	0.0	0	0.0	2	0.3	7	0.8	18	1.9	2	0.3	4	0.4	3	0.3	4	0.9	40	0.6	0.08
Brown bullhead	1	0.2	7	1.2	41	5.9	27	3.0	24	2.6	35	6.0	37	3.4	28	2.6	20	4.5	220	3.2	0.44
Northern pike	1	0.2	0	0.0	0	0.0	2	0.2	4	0.4	1	0.2	4	0.4	0	0.0	0	0.0	12	0.2	0.02
Chain pickerel	9	1.4	15	2.7	23	3.3	28	3.2	19	2.0	26	4.4	13	1.2	27	2.5	12	2.7	172	2.5	0.34
Atlantic salmon	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.00
White perch	25	4.0	43	7.6	19	2.7	16	1.8	61	6.5	15	2.6	36	3.3	18	1.7	11	2.5	244	3.5	0.48
Rock bass	57	9.1	49	8.7	65	9.4	79	8.9	110	11.7	50	8.5	81	7.4	51	4.8	6	1.4	548	7.9	1.09
Lepomis sp.	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1	<0.01
Redbreast sunfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	1	0.1	1	0.1	0	0.0	3	<0.1	0.01
Pumpkinseed	143	22.7	126	22.3	164	23.7	128	14.4	142	15.1	152	25.9	78	7.1	138	12.9	73	16.4	1,144	16.5	2.27
Bluegill	75	11.9	49	8.7	49	7.1	75	8.5	43	4.6	58	9.9	26	2.4	78	7.3	55	12.4	508	7.3	1.01
Smallmouth bass	19	3.0	15	2.7	22	3.2	16	1.8	20	2.1	11	1.9	26	2.4	22	2.1	5	1.1	156	2.3	0.31
Largemouth bass	7	1.1	2	0.4	16	2.3	4	0.5	14	1.5	2	0.3	19	1.7	21	2.0	6	1.4	91	1.3	0.18
Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	18	1.6	10	0.9	3	0.7	33	0.5	0.07
Tessellated darter	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	1	<0.1	<0.01
Yellow perch	249	39.6	197	34.9	201	29.0	410	46.2	393	41.8	156	26.5	660	59.9	608	56.7	217	48.9	3,091	44.7	6.14
Walleye	1	0.2	3	0.5	9	1.3	10	1.1	12	1.3	10	1.7	17	1.5	17	1.6	4	0.9	83	1.2	0.16
Total Number	629	100.0	564	100.0	693	100.0	887	100.0	941	100.0	588	100.0	1102	100.0	1072	100.0	444	100.0	6,920	100.0	13.75
No. Collections	64		64		64		64		64		45		64		63		60		552		
Effort (hours)	1,256		1,333		1,334		1,378		1,353		1,056		1,511		1,442		1,414		12,076		
No. Fish/24 Hrs.	12.0		10.2		12.5		15.4		16.7		13.4		17.5		17.8		7.5		13.8		

Table 5-12. Numbers of fish collected by trap net downstream of Vernon Dam, 1991 - 1999.

Species	1991		1992		1993		1994		1995		1996		1997		1998		1999				
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Total No.	%	No. Fish/24 Hrs.
Sea lamprey	0	0.0	10	1.9	0	0.0	1	0.2	1	0.1	0	0.0	5	1.4	8	2.6	0	0.0	25	0.5	0.07
American eel	2	0.2	1	0.2	1	0.1	2	0.4	9	0.9	0	0.0	16	4.5	0	0.0	1	0.4	32	0.7	0.08
Blueback herring	0	0.0	3	0.6	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	4	0.1	0.01
American shad	4	0.4	12	2.3	32	3.9	4	0.9	1	0.1	0	0.0	15	4.2	46	14.9	1	0.4	115	2.4	0.30
Common carp	2	0.2	1	0.2	3	0.4	2	0.4	3	0.3	0	0.0	1	0.3	0	0.0	0	0.0	12	0.3	0.03
Golden shiner	1	0.1	16	3.1	4	0.5	3	0.6	0	0.0	1	0.7	2	0.6	3	1.0	0	0.0	30	0.6	0.08
Spottail shiner	8	0.9	16	3.1	19	2.3	47	10.1	6	0.6	3	2.1	3	0.8	7	2.3	0	0.0	109	2.3	0.29
Fallfish	0	0.0	1	0.2	2	0.2	1	0.2	1	0.1	0	0.0	3	0.8	0	0.0	2	0.8	10	0.2	0.03
White sucker	41	4.5	15	2.9	23	2.8	13	2.8	54	5.6	7	4.9	33	9.2	31	10.1	4	1.5	221	4.6	0.58
Yellow bullhead	0	0.0	1	0.2	0	0.0	0	0.0	5	0.5	0	0.0	0	0.0	0	0.0	0	0.0	6	0.1	0.02
Brown bullhead	484	53.5	14	2.7	7	0.8	0	0.0	24	2.5	3	2.1	4	1.1	3	1.0	0	0.0	539	11.3	1.42
Northern pike	1	0.1	1	0.2	1	0.1	1	0.2	4	0.4	0	0.0	0	0.0	0	0.0	0	0.0	8	0.2	0.02
Chain pickerel	5	0.6	15	2.9	1	0.1	6	1.3	2	0.2	2	1.4	2	0.6	1	0.3	1	0.4	35	0.7	0.09
Atlantic salmon	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	<0.1	0.01
White perch	5	0.6	14	2.7	2	0.2	4	0.9	4	0.4	3	2.1	0	0.0	2	0.6	0	0.0	34	0.7	0.09
Rock bass	111	12.3	235	45.8	317	38.1	237	51.1	442	45.5	46	32.4	70	19.6	68	22.1	74	28.1	1,600	33.6	4.22
Lepomis sp.	0	0.0	0	0.0	11	1.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	0.2	0.03
Redbreast sunfish	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	2.8	1	0.3	0	0.0	11	0.2	0.03
Pumpkinseed	27	3.0	37	7.2	56	6.7	29	6.3	78	8.0	14	9.9	7	2.0	5	1.6	6	2.3	259	5.4	0.68
Bluegill	30	3.3	25	4.9	211	25.4	17	3.7	108	11.1	28	19.7	13	3.6	11	3.6	13	4.9	456	9.6	1.20
Smallmouth bass	79	8.7	27	5.3	51	6.1	48	10.3	79	8.1	13	9.2	58	16.2	43	14.0	24	9.1	422	8.9	1.11
Largemouth bass	2	0.2	2	0.4	2	0.2	3	0.6	11	1.1	0	0.0	3	0.8	0	0.0	1	0.4	24	0.5	0.06
Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	2	1.4	3	0.8	14	4.5	1	0.4	21	0.4	0.06
Tessellated darter	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	1.9	5	0.1	0.01
Yellow perch	96	10.6	44	8.6	64	7.7	35	7.5	122	12.6	16	11.3	97	27.1	43	14.0	127	48.3	644	13.5	1.70
Walleye	5	0.6	23	4.5	24	2.9	11	2.4	15	1.5	4	2.8	13	3.6	22	7.1	3	1.1	120	2.5	0.32
Total Number	905	100.0	513	100.0	831	100.0	464	100.0	971	100.0	142	100.0	358	100.0	308	100.0	263	100.0	4,755	100.0	12.55
No. Collections	48		48		48		48		48		25		48		47		41		401		
Effort (hours)	1,066		1,037		1,016		1,031		1,087		584		1,136		1,116		1,023		9,096		
No. Fish/24 Hrs.	20.4		11.9		19.6		10.8		21.4		5.8		7.6		6.6		6.2		12.5		

Table 5-13. Summary of total number and percent catch of larval fish collected in the Vermont Yankee ichthyoplankton program, 1991 - 2002.

Species	Year	Number Collected	Percent of Catch for Each Year
Common carp	1991	1	0.1
	1992	3	0.3
	1993	6	1.2
	1994	1	0.1
	1996	3	1.0
	1997	1	0.5
	1998	9	2.0
	1999	43	9.6
	2000	2	0.4
	2001	3	0.2
	2002	2	0.1
		74	
Notropis sp. or Cyprinidae	1991	516	55.8
	1992	515	59.4
	1993	174	35.4
	1994	1,658	90.5
	1995	272	61.5
	1996	129	43.1
	1997	163	83.6
		3,427	
White perch	1991	174	18.8
	1992	212	24.5
	1993	248	50.5
	1994	109	5.9
	1995	90	20.4
	1996	149	49.8
	1997	15	7.7
	1998	31	6.9
	1999	7	1.6
	2000	141	28.8
	2001	31	1.8
	2002	75	5.4
		1,282	
Lepomis sp. or Centrarchidae	1991	219	23.7
	1992	121	14.0
	1993	56	11.4
	1994	28	1.5
	1995	52	11.8
	1996	7	2.3
	1997	3	1.5
	1998	29	6.5
	1999	201	45.0
	2000	6	1.2
	2001	31	1.8
	2002	7	2.0
		780	

(continued)

Table 5-13. (Continued)

Species	Year	Number Collected	Percent of Catch for Each Year
Yellow perch	1991	110	11.9
	1992	11	1.3
	1993	4	0.8
	1994	27	1.5
	1995	25	5.7
	1996	8	2.7
	1997	12	6.2
	1998	84	16.8
	1999	20	4.5
	2000	72	14.7
	2001	2	0.1
	2002	29	2.1
		404	
Walleye	1991	4	0.4
	1992	1	0.1
	1994	2	0.1
	1995	1	0.2
	1998	14	3.0
	1999	5	1.1
	2000	2	0.4
	2001	2	0.1
		31	
American shad	1992	1	0.1
	1999	1	0.2
		2	
Spottail shiner	1993	1	0.2
	1994	1	0.1
	1998	183	40.6
	1999	113	25.4
	2000	195	39.8
	2001	978	57.9
	2002	1,236	89.7
		2,707	
Bluegill	1996	2	0.7
		2	
Fallfish	1996	1	0.3
	1998	2	0.4
	2002	3	0.2
		6	
White sucker	1997	1	0.5
	1998	90	20.0
	1999	55	12.3
	2000	71	14.5
	2001	640	37.9
	2002	2	0.1
		859	
Largemouth bass	1997	1	0.5
	1998	1	0.2
		2	
Tessellated darter	2002	4	0.3
		4	
Total (all 12 years)		**9,580**	

Table 5-14. Number of specimens of numerically important and other selected species collected upstream and downstream of Vernon Dam, 1968 - 2002. Impingement and ichthyoplankton samples are not included.

UPSTREAM	1968 - 1980[a]		1981 - 1990[a]		1991 - 2002	
Species	Total No.	%	Total No.	%	Total No.	%
American eel	20	0.1	126	0.3	33	0.2
Blueback herring	0	0.0	253	0.6	0	0.0
American shad	0	0.0	270	0.7	87	0.5
Spottail shiner	1,216	7.4	4,599	11.2	1,081	5.9
Mimic shiner	0	0.0	1,161	2.8	28	0.2
White sucker	1,386	8.4	3,874	9.4	916	5.0
Brown bullhead	52	0.3	123	0.3	325	1.8
Northern pike	0	0.0	14	<0.1	54	0.3
Chain pickerel	11	0.1	31	0.1	315	1.7
Atlantic salmon	1	<0.1	1	<0.1	0	0.0
White perch	2,828	17.1	5,157	12.6	338	1.8
Rock bass	466	2.8	1,684	4.1	779	4.2
Pumpkinseed	1,765	10.7	3,731	9.1	2,173	11.9
Bluegill	375	2.3	1,512	3.7	2,620	14.3
Smallmouth bass	583	3.5	2,259	5.5	316	1.7
Largemouth bass	271	1.6	938	2.3	868	4.7
Yellow perch	2,665	16.1	9,705	23.7	7,148	39.0
Walleye	280	1.7	396	1.0	169	0.9
Others	4,595	27.8	5,192	12.7	1,083	5.9
Total Number	**16,514**	**100.0**	**41,026**	**100.0**	**18,333**	**100.0**

DOWNSTREAM	1968 - 1980[a]		1981 - 1990[a]		1991 - 2002	
Species	Total No.	%	Total No.	%	Total No.	%
American eel	34	0.3	150	1.0	73	0.8
Blueback herring	0	0.0	84	0.5	6	0.1
American shad	0	0.0	1,501	9.6	631	6.7
Spottail shiner	2,112	16.1	882	5.6	932	9.9
Mimic shiner	0	0.0	785	5.0	26	0.3
White sucker	1,769	13.4	3,336	21.3	582	6.2
Brown bullhead	133	1.0	96	0.6	550	5.9
Northern pike	1	<0.1	19	0.1	38	0.4
Chain pickerel	29	0.2	19	0.1	58	0.6
Atlantic salmon	0	0.0	1	<0.1	3	<0.1
White perch	832	6.3	260	1.7	48	0.5
Rock bass	922	7.0	2,257	14.4	1,971	21.0
Pumpkinseed	375	2.9	502	3.2	332	3.5
Bluegill	467	3.6	722	4.6	712	7.6
Smallmouth bass	782	5.9	1,849	11.8	1,657	17.6
Largemouth bass	68	0.5	147	0.9	88	0.9
Yellow perch	1,082	8.2	1,298	8.3	860	9.1
Walleye	114	0.9	127	0.8	222	2.4
Others	4,433	33.7	1,592	10.2	612	6.5
Total Number	**13,153**	**100.0**	**15,627**	**100.0**	**9,401**	**100.0**

[a] data from 1968 - 1989 reported in Downey et al. (1990)

Note: 1968 - 1980: trap net, gillnet and seine collection methods used regularly.
1981 - 1989: trap net used regularly, gillnet not used after 1983, seine not used after 1985, electrofishing began in 1982.

5.1.3 Fish Passage at Vernon Dam

This section of the Demonstration Report presents a review of the operation of upstream and downstream fish passage facilities at Vernon Dam in relation to Vermont Yankee's existing summer period thermal discharge conditions. First, a description of Vernon Dam fish passage facilities is presented. Second, a general description of the past (Downey et al. 1990) and recent (1997-2002) thermal history in the Vernon Dam fishway is presented. Third, we present a detailed examination of the relationship between Vermont Yankee's existing thermal discharge conditions and the upstream passage of American shad. Finally, the downstream passage of Atlantic salmon smolts is considered with respect to Vermont Yankee's thermal discharge.

The fishway at Vernon Dam is owned and operated by PGE. The fishway provides a migratory pathway for upriver-migrating anadromous fish, and is located near the western bank of the Connecticut River. The fishway is typically operated from mid-May through the end of June of each year. The fishway is a concrete structure consisting of a vertical slot ladder from the tailrace leading up to a fish trap and viewing gallery, and an Ice Harbor style ladder that provides passage from the trap up to Vernon Pool. The fishway was installed and became operational in 1981, and is supplied with a continuous flow of 65 cfs during the period of operation. An attraction flow of 40 cfs is also discharged near the foot of the ladder. VANR determines the operating schedule of the fishway based largely on numbers of fish passed at the Turners Falls fishway and monitors the passage of American shad, Atlantic salmon and other selected species. Although PGE owns and operates the Vernon Dam fishway as directed by VANR, Vermont Yankee has the permit-required responsibility for continuously monitoring water temperature within the fishway during the period of operation in each year. Vermont Yankee also supports the collection of life history information from samples of spawning adult American shad that are trapped in the Vernon Dam fishway by VANR during the annual upstream migration. The life history information obtained from the samples of adult American shad includes size distribution, sex and sexual condition, and age composition. Each Annual Report summarizes the temperature data and number of fish passed, while the more detailed biocharacteristics data and other "objective-specific" studies are reported in Analytical Bulletins (Appendix 1).

Vernon Station also operates downstream fish passage facilities during certain times of the year to facilitate the downstream passage of anadromous fishes, including Atlantic salmon and American shad. The downstream fish conduit (fish tube) was first operated in 1991. This primary downstream fish passage conduit is located in the center of the powerhouse, and is supplied with 350 cfs of bypass flow through a 9-ft by 6-ft gate and tube that constricts to a 4-ft by 5-ft opening at the discharge end. A second "pipe" supplying the additional 40 cfs of attraction flow at the foot of the fishway was converted in 1994 into a "fish pipe" and is presently used as an alternate or supplemental downstream fish passage device. The downstream fish passage conduit and the fish pipe are operated continuously from April through July and from September through October of each year.

Water temperatures in the Vernon Dam fishway in relation to temperatures at Station 3 were reported in the 1990 §316(a) Demonstration (Downey et al. 1990) in connection with the modifications that were made to the flashboards at Vernon Dam in 1984 (height increased by 2 feet) and 1987 (converted to hydraulic operation). They found that water temperatures in the fishway were equal to or less than at Station 3 during high river flows and often 1 to 2°F higher, and on occasion 3 to 4°F higher, during low flows. Furthermore, Binkerd (1985) described the thermal

environment in and near the fishway during test periods of open cycle operation (nearly 100% circulating flow being discharged) and at high river flow rates in June 1984 and May 1985. During these conditions, he found that temperatures near the entrance to the fishway and in the vicinity of the fishway exit were very often less than the downstream mixed temperature. Highest plume temperatures just upriver of Vernon Dam were recorded toward the middle of the River, not at the fishway exit.

The observed water temperature data reported in the Vermont Yankee Annual Reports have consistently shown that within-day temperature variation downstream of Vernon Dam (Station 3) is relatively small, and that there is little difference between temperatures recorded in the fishway and at Station 3. Comparison of the observed daily average water temperatures recorded in the fishway and those recorded at Station 3 during the fish passage periods in 1997 – 2002 showed a similar result (Table 5-17). Water temperatures in the fishway were up to 2.6°F higher, and as much as 4.7°F lower, than temperatures at Station 3 during this six-year period, which included conditions of high as well as relatively low river flows. More importantly, as discussed in the hydrothermal section (Section 3) of this Demonstration Report, water temperatures in the fishway appear to be influenced even more significantly by atmospheric conditions than the water temperatures at Station 3.

Fish passage data provided by VANR and mean daily water temperatures recorded in the fishway are included in Tables 5-16 through 5-20 for 1998 through 2002. American shad and sea lamprey were the two species passed in greatest numbers. A maximum of seven Atlantic salmon were passed in any year, consistent with the limited success of restoration efforts in the Connecticut River to date. The data show that all of the species migrated through the Vernon Dam fishway over a wide range of water temperatures during rising as well as falling temperature periods.

The hydrothermal modeling (Section 4) shows that the proposed temperature limits will result in no greater than a 1°F increase from present conditions, a nominal increase not reasonably likely to interfere with the passage of anadromous species through the fishway.

5.1.3.1 Upstream Passage of Adult American Shad

The Vernon Dam fishway has been demonstrated to be the most efficient upstream passage facility for spawning adult American shad located on the Connecticut River. An average annual migration rate of 71.4% was observed at the Vernon fishway for the period 1995 through 2002, meaning that 71.4% of the adult shad present in Turners Pool and therefore available for upstream passage were observed to pass upstream through the Vernon Dam fishway into Vernon Pool (Table 5-21). Other fish ladders and fish lifts on the Connecticut River and on the nearby Merrimack River typically pass less than 40% of the available adult shad, and the Turners Falls fish passage facility, located at the next Connecticut River dam downstream from Vernon Dam, passed an average of only 3.6% of the adult shad upstream during the same period (1995-2002).

Although the American shad migration behavior alone should eliminate any concern about the influence of Vermont Yankee's present or proposed new temperature limits with respect to their passage upstream through the Vernon Dam fish ladder, we also examined the maximum temperature differentials that have occurred or are predicted to develop under the new permit limits between the Vernon fish ladder and the tailrace water. The observed hourly water temperatures from continuous monitoring in the Vernon fishway and downstream at tailrace

monitoring station 3 were examined for the period from the start of fishway operations (mid-May) through 10 July of each year, 1998 through 2002 (Table 5-22). In some years (*i.e.*, 1998, 2000, 2002) the Vernon fishway operated later than July 10, so we truncated the data set in those years at midnight on 10 July and recorded the highest temperature observed during the selected period. The data in Table 5-22 reveal that the mean temperature differential between the fishway and tailrace waters was slight among the five years, ranging from +0.1°F in 1998 to -2.0°F in 2001. There was little correspondence between the annual migration rates of spawning American shad upstream through the Vernon fishway and the mean or maximum temperature differentials between the fishway and tailrace waters. For example, the lowest average temperature difference of +0.1°F was seen between fishway and Vernon tailwaters in 1998, when the Vermont Yankee plant did not discharge heated effluent during the first 21 days of fishway operations, and the average migration rate was 77.4%. In 1999, when the plant discharged heated effluent during the entire period of fishway operations, the average temperature difference was +0.3°F and the average migration rate was a comparable 75.2%. The fishway averaged 2.0°F colder than the Vernon tailrace waters in 2001 with Vermont Yankee discharging heated effluent under their NPDES permit conditions for the entire fishway period of operations, and the upstream migration rate was 100% (109%). Year to year variation in freshwater flows is the most likely reason for interannual variation in adult American shad migration rates and not the relatively minor temperature differences observed between the Vernon fishway and surrounding tailwaters. The number of hours and percentage of time that the Vernon Dam tailrace and the fishway water temperatures are predicted to exceed 80°F were examined for the proposed new temperature limits for Vermont Yankee. These predictions were done conservatively by adding 1°F to the temperatures observed during the representative period 1998 through 2002. A 1°F temperature rise was the maximum temperature increase predicted under the extreme-case (1% occurrence) scenario by thermal plume modeling (Section 4). The right half of Table 5-22 shows that between 0 hours and 141 hours of tailrace water temperatures are predicted to equal or exceed 80°F depending on the year. In three years (1998, 2000, 2002), 80°F is predicted to be rarely or never exceeded in the Vernon Dam tailwater. In 1999 and 2001, 80°F is predicted to be exceeded 2.9% or 10.3% of the time prior to 11 July in the Vernon Dam tailwater. The relatively low predicted percentage exceedence of 80°F is likely to occur late in the spawning run in warm years, and these late-run fish will most likely spawn downstream in Turners Falls Pool.

The time series of hourly American shad counts for the Vernon Dam Fishway for each day of fishway operations during the period 1991 through 2001 were statistically compared with the corresponding hourly average water temperatures measured in the Vernon Dam fishway to evaluate if the Vermont Yankee thermal discharge might have a negative correlation with shad passage rates. The tabular summaries for each year 1991 through 2001(and for all years combined) showing the maximum, minimum, mean and frequency information for the time period of fishway operation, temperature data, and American shad hourly count data are located in Appendix 6. Also located in Appendix 6 are color graphs that presents the real time sequence of hourly counts and the corresponding hourly mean fishway water temperature values for each year 1991 through 2001 based on all of the valid data available for that year. Scatter plots (Figures 5-11 through 5-23) for each year show the statistical relationship (correlation) between the hourly average fishway water temperature and the corresponding number of American shad passing upstream through the Vernon Dam fishway during that hour. Each year's hourly shad passage data were partitioned into two data sets. The first set is referred to as the "Full Data Set"

and represents all hourly count observations available for that year. The second data set is referred to as the "Truncated Data Set," and provides a subset of each annual full data set that was truncated to exclude consecutive hours with zero shad counts at the beginning or end of each annual time series. Each truncated data set represents the annual time series of hourly counts beginning with the first hour in which American shad were observed at the Vernon fishway, and continuing until the last shad was counted. The top panel of each scatter plot shows the scatter of all hourly observations in the full data set, and the bottom panel shows the scatter of the hourly observations represented by the truncated data set. Also shown on each of the two scatter plots are the linear regression line, the Pearson product-moment correlation coefficient (r), and the associated significance probability (p) for the Pearson statistic. The Pearson statistic describes the direction and degree of statistical correlation between the hourly American shad counts and the associated hourly average Fishway water temperatures. A negative Pearson statistic means that shad counts decreased with increasing water temperature, and a positive Pearson statistic means that counts increased with increasing water temperature. The magnitude of the Pearson statistic ranges from –1 to +1 for a perfect negative or positive correlation, respectively. If a perfect negative or positive correlation was observed, all of the points in the scatter plot would fall exactly on the regression line. A horizontal line produces a Pearson statistic of zero (0), indicating no positive or negative relationship. The significance probability is a test showing if the Pearson statistic describes a relationship among the scatter of points that is significantly different from zero. A Pearson statistic with a probability (p) less than 0.05 is considered significantly different from zero.

Examining the tabular (Appendix 6) and graphical (Figures 5-11 through 5-23) summaries provided for each year 1991 through 2001 reveals that there is no consistent significant negative correlation between Vernon Dam fishway water temperature and the corresponding hourly shad count for either the full or truncated data sets. The time series of hourly American shad counts and the corresponding fishway water temperatures reveals a relatively consistent natural seasonal cycle to the shad spawning migration in each year, with the peak of the run occurring in early to mid-June. Superimposed on this migration cycle is a natural warming trend of the Connecticut River water throughout the fishway period of each year. Significant negative Pearson product-moment correlation coefficients were observed in five years (1991, 1992, 1993, 1995, and 1999) for both the full and truncated data sets, however the values of the Pearson statistic were only slightly different from zero. In 2000, a significant but slight positive correlation was observed between shad counts and Fishway water temperature. These weak but significant negative or positive correlations observed between hourly shad counts and fishway water temperature reflect the juxtaposition of the shad spawning run upstream through the Vernon fishway and the natural seasonal cycle of River warming, and not any causative effect related to Vermont Yankee's thermal discharge. In the remaining five years analyzed (1994, 1996, 1997, 1998, and 2001), no significant correlation was found between hourly shad counts and the corresponding fishway water temperatures.

The operating records for Vermont Yankee revealed that plant outages occurred during 1991 and 1998 while the Vernon Dam fishway was operating. There is no thermal discharge to the Connecticut River during a Vermont Yankee plant outage. Therefore, the existence of these outages provides an opportunity to directly evaluate the relationship between American shad upstream passage at the Fishway corresponding to the short-term periods immediately before,

during, and after the outage to determine if removal of the Vermont Yankee thermal discharge was related to an increase in fish passage.

In 1991, the Vernon Dam fishway operated from 0700 on 15 May through 1800 on 7 July, and American shad were first counted at 1800 on 15 May and last counted at 1500 on 7 July. The Vermont Yankee outage occurred from 2224 on 15 June through 0104 on 21 June 1991. There were 61 hours with both shad counts and fishway water temperatures available for analysis during this outage among five consecutive days of counting. Shad count data were selected from a comparable number of hours of fishway operation during the five-day periods immediately preceding (60 hours) and immediately following (60 hours) the outage for comparison with the outage period. The results are presented as scatter plots (Figure 5-12) and summary tables in Appendix 6 for 1991. It is clear from examining these scatter plots and associated statistical correlation analysis that there was no change in American shad passage rates at the Vernon Dam fishway when Vermont Yankee ceased discharging heated effluent into the Connecticut River. In fact, there was no significant correlation between hourly shad counts and the corresponding water temperatures before, during, or after the outage period in 1991. The absence of a significant correlation between shad counts and temperature during these three five-day periods provides further support for the conclusion stated above that the slight but significant negative correlations observed for the entire 1991 period were generated by the juxtaposition of the shad spawning run and the natural seasonal cycle of warming, and not any causative effect related to Vermont Yankee's thermal discharge. The absence of significant correlations between hourly shad counts and fishway water temperature also allows for the application of one-way analysis of variance (ANOVA) to test for significant differences in the mean hourly shad counts among the before, during, and after outage periods of 1991. The ANOVA model for the untransformed hourly count data was significant ($F = 3.57$, $p = 0.0301$), and the mean hourly shad count was not significantly different (Scheffe's test, $\alpha = 0.05$) during the outage compared to the period before the outage. The mean hourly shad counts were significantly lower for the period immediately after the outage in 1991 compared to before the outage but were not different from the mean count during the outage, reflecting the natural seasonal decrease of shad migration as it approaches the end of the spawning run. The ANOVA model conclusions were the same if run on log-transformed ($\log10$ x + 1) hourly shad counts, with the model slightly more significant ($F = 4.17$, $p=0.0169$). Therefore, statistical evaluation of the Vernon Dam fishway hourly shad counts from periods before, during, and after a Vermont Yankee outage in 1991 demonstrate conclusively that there was no measurable effect of Vermont Yankee's thermal discharge on the upstream migration of spawning American shad.

In 1998, the Vernon Dam fishway operated from 0800 on 18 May through 1600 on 27 June, and American shad were first counted at 0800 on 18 May and last counted at 1500 on 27 June. Two Vermont Yankee outages occurred during 1998: one from 0651 on 20 March through 1539 on 3 June encompassing the first 16 days of fishway operations, and the second from 0135 on 9 June through 0503 on 14 June 1998. There were 191 hours with both shad counts and fishway water temperatures available for analysis during the first outage period in 1998, and a significant positive relationship was observed between hourly shad counts and the corresponding fishway water temperatures (Figure 5-20). This means that as the water warmed naturally without any influence of Vermont Yankee's thermal discharge, shad counts increased as part of the natural spawning migration. The operational period when Vermont Yankee discharged heated effluent between the first and second outage in 1998 had 60 hours with both shad counts and fishway

water temperatures, and there was no significant relationship observed between hourly shad counts and fishway water temperatures (Figure 5-20). The second outage in 1998 also had 60 hours of shad counts and water temperatures, and again no significant relationship was observed between count and temperature. The five-day operational period immediately following the second outage in 1998 only had 18 hours with both shad counts and fishway water temperature data available, and no significant relationship was observed between count and temperature. A one-way ANOVA model was also applied to test for significant differences in the mean hourly shad counts between the middle outage period and the two flanking operational periods of 1998. The ANOVA model did not include data from the first outage period because the significant positive correlation found between hourly shad counts and fishway water temperatures during that period would cause these data to violate a fundamental assumption of ANOVA requiring independence of the response variable (count) from co-varying conditions (temperature) within the blocking variable (period). The ANOVA model for the untransformed hourly count data was significant ($F = 3.61$, $p < 0.0298$), and no significant differences were found among the mean hourly shad counts for the operational or outage periods tested (Scheffe's test, $\alpha = 0.05$) in 1998. The ANOVA model conclusions were the same if run on log-transformed ($\log10\ x + 1$) hourly shad counts, although the middle operational period had a significantly higher mean hourly shad count than the second operational period (Scheffe's test, $\alpha = 0.05$). Therefore, statistical evaluation of the Vernon Dam fishway hourly shad counts from two outage periods in 1998 and the corresponding operational periods again support the conclusion that there was no measurable effect of Vermont Yankee's thermal discharge on the upstream migration of spawning American shad. It was clear from examining the 1998 shad counts and corresponding Vernon Dam fishway water temperatures occurring during two Vermont Yankee outage periods and during the corresponding operational periods that the seasonal cycle of American shad upstream migration was not influenced by the discharge of thermal effluent from Vermont Yankee.

5.1.3.2 Downstream Passage of Atlantic Salmon Smolts

Nearly all of the Atlantic salmon smolt emigration downstream past Vernon Dam is completed by approximately 7 June of each year (McCormick and Haro, Attachment A4 to Versar 2003), which occurs before river-water temperatures remain above the reported limiting temperature for migration of 72.5°F for extended periods of time. In this section we evaluate the hypothesis that delays in the downstream passage of Atlantic salmon smolts through Vernon Dam due to their passage through Vermont Yankee's thermal plume may indirectly cause late arrival at warmer temperatures at the next downstream dams (Turner's Falls, and Holyoke, Hadley, Cabot Stations), so even if the smolts all pass downstream through Vernon Dam, they may be delayed and not pass the next set of downstream dams.

Researchers have reported that increases in water temperature during the downstream salmon smolt migration accelerate the loss of smolt characteristics (McCormick et al. 1999, Duston et al. 1991). On the Connecticut River, loss of smolt characteristics in wild fish occurred after the peak of migration in 1993 through 1997 (McCormick et al 1999). However, in warm years, such as 1993, significant decreases in smolt characteristics were reported on 20 May and approximately 20% of the downstream smolt run occurred after this date. Salmon smolts migrating past Vernon Pool may experience delays at Vernon Dam, either due to the warmer water from the thermal plume acting as a block to their migration, or due to delays passing Vernon Dam. Delays increasing the time spent by smolts in the warmer water of lower Vernon Pool could cause the

rapid loss of their smolt characteristics and cessation of the downstream migration. Duston et al. 1991 reported a significant loss of smolt characteristics in tests with hatchery smolts held for several weeks in water temperatures of 10, 13 and 16°C (ambient water temperature was 5° C at the start of the test). In this study, decreases in mean gill Na+, K+ - ATPase activity was greater in groups held at the higher water temperatures. In both these studies, it took several weeks of holding the salmon in warmer temperatures before the salmon smolts lost a significant amount of their smolt characteristics. However, radio-telemetry studies conducted in the vicinity of Vermont Yankee over years have consistently documented that salmon smolts are not delayed in their downstream migration by the thermal plume. Salmon smolts migrating past Vermont Yankee's thermal plume would not be subject to the warmer water for longer than 12 hours on average based on the telemetry studies discussed below, and they can avoid the warmest water from the thermal plume by either swimming around or under it because the plume does not block the entire River cross section in lower Vernon Pool.

Four studies conducted in Vernon Pool of the Connecticut River over the years have documented that salmon smolts moved downstream through Vermont Yankee's thermal plume without exhibiting significant delays. Downey et al. (1990) reported that the behavior of out-migrating smolts in the vicinity of Vermont Yankee's thermal plume was investigated using radio telemetry in 1980 and 1981 and again in 1988 and 1989. From these investigations, Downey et al. (1990) concluded that fully smoltified Atlantic salmon moved through Vermont Yankee's thermal plume and downstream past Vernon Dam without any discernable avoidance behavior. Downey et al. (1990) also concluded that thermal blockage of salmon smolts did not occur, a conclusion evaluated and accepted by VANR. This same study also reported that behavioral delays were not observed for adult salmon migrating upstream through the Vernon Dam fishway and past Vermont Yankee's thermal plume, even though Vermont Yankee was operating in a hybrid or open-cycle mode during the period of documented upstream passages at the fishway (Downey et al. 1990). Accordingly, they concluded that thermal blockage of migrating Atlantic salmon adults and smolts did not occur, a conclusion also evaluated and approved by VANR.

The radio-telemetry studies by Downey et al. (1990) of Atlantic salmon smolt outmigrations were performed under provisional thermal discharge conditions prior to the 1991 implementation of Vermont Yankee's existing summer period thermal permit discharge limits. Three additional studies were performed with Vermont Yankee's thermal discharge under the existing summer period permit limits, and these studies provide definitive support for the conclusions by Downey et al. (1990) that Vermont Yankee's thermal discharge has no measurable effect on downstream migrating Atlantic salmon smolts. No increase in forebay residency time was observed in the downstream migration of radio-tagged fish at Wilder, Bellows Falls, or Vernon Hydroelectric Stations. The results of three Atlantic salmon smolt radio telemetry studies performed for New England Power Company (now PGE) at Vernon Dam between 14-27 May 1994, 4-15 May 1995, and 30 May to 8 June 1996 all indicated that radio-tagged emigrating Atlantic salmon smolts released into Vernon Pool (either 0.6 miles or 4.1 miles upstream of Vernon Dam) moved through the existing Vermont Yankee thermal plume and downstream through Vernon Dam with a residency time in the Vernon Dam forebay averaging 8 hours, 53 minutes during the 1994 study (n = 148; Table 5-23), 11 hours, 15 minutes during the 1995 study (n = 142; Table 5-23), and 6 hours, 26 minutes in 1996 (n=89; Table 5-23).

The average smolt travel time from a release point 0.6 miles upstream of Vernon Dam and past the Vermont Yankee discharge (n = 116) was 4 hours 49 minutes (Table 5-23). Travel time was defined as the period between release and arrival in the zone of detection by the telemetry receivers. The travel time duration includes recuperation of fish from the effects of handling and tagging. Smolt travel time from a release point 4.1 miles upstream and past the Vermont Yankee discharge was 8 hours 13 minutes (n = 32) in 1994 and 9 hours 57 minutes (n = 142) during the 1995 study (Table 5-23). Smolt transit time as measured from the Bellows Falls Dam forebay, 32 miles upstream of Vernon Dam, and past the Vermont Yankee discharge averaged 1 day, 2 hours, and 58 minutes in 1994; these fish (n = 48) had been released above Wilder Dam, 70 miles upstream (Table 5-23). The travel times observed during these two studies do not indicate delays in downstream migration or an increase in residency by Atlantic salmon smolts caused by the presence of the existing Vermont Yankee thermal discharge plume.

Connecticut River water temperature was measured in the Vernon Dam forebay during these three most recent studies, and the range of temperatures was 50.9°F to 69.0°F between 10 May and 13 June in 1994, 51.8°F to 57.2°F between 3 and 22 May 1995, and 60.0°F to 72.5°F between 30 May and 8 June 1996 (Table 5-23). Vermont Yankee was operating and discharging heated cooling water during these three study periods, and in 1995 was still operating under the winter permit discharge temperature limit allowing a temperature rise of up to 13.4°F during the telemetry study period of 4-15 May 1995.

Based on the results of these three studies, Atlantic salmon smolts did not exhibit any delays in downstream migration nor did they encounter temperatures that are considered limiting to smolts during the migration period of April 20 to June 7, based on written comments provided in April 2003 by S. McCormick and A. Haro, Research Scientists at the USGS Conte Lab in Turners Falls, MA, and J. Rowan, USFWS, Connecticut River Coordinator (Versar 2003), which are quoted here:

> *"Migration of juvenile Atlantic salmon smolts in the mainstem of the Connecticut River occurs from April 20 to June 7. The upper limit for survival of Atlantic salmon juveniles is 82.0°F (with 7 days exposure) and the upper limit for feeding is 72.5°F."*

Temperature predictions between 16 May and 7 June (representing the portion of the smolt migration period of April 20 to June 7 that occurs during Vermont Yankee's summer permit period) for the 1998 – 2002 period of record used for the hydrothermal evaluation (Section 3 of this Demonstration Report), and conservatively adding the maximum case addition of 1°F to the observed highest recorded hourly water temperatures between 16 May and 7 June at Upstream Station 7, Downstream Station 3, and the Vernon Dam Fishway, allow computation of the number of hours and percentage of time that temperatures at each location are predicted to exceed 72.5°F under the proposed new temperature limits for Vermont Yankee:

Maximum Measured and Predicted Connecticut River Water Temperatures During that Period of Downstream Emigration of Atlantic Salmon Smolts that Coincided with the Vermont Yankee Summer Permit Period, 16 May through 7 June, 1998 – 2002						
Year	Highest Upstream Station 7 Temperature		Highest Fishway Temperature		Highest Downstream Station 3 Temperature	
	Measured (°F)/ Hours that Exceeded 72.5°F	Predicted (°F)/ Hours that Exceeded 72.5°F	Measured (°F)/ Hours that Exceeded 72.5°F	Predicted (°F)/ Hours that Exceeded 72.5°F	Measured (°F)/ Hours that Exceeded 72.5°F	Predicted (°F)/ Hours that Exceeded 72.5°F
1998	67.1/0	68.1/0	72.8/3	73.8/10[1]	70.6/0	71.6/0
1999	69.9/0	69.9/0	75.0/45	76.0/82[2]	75.3/28	76.3/82[3]
2000	63.1/0	64.1/0	68.4/0	69.4/0	66.9/0	67.9/0
2001	59.4/0	60.4/0	64.4/0	65.4/0	64.6/0	65.6/0
2002	In 2002, the fishway was not operated until 11 June, due to high water. Consequently, no data prior to 7 June are reported here.[4]					

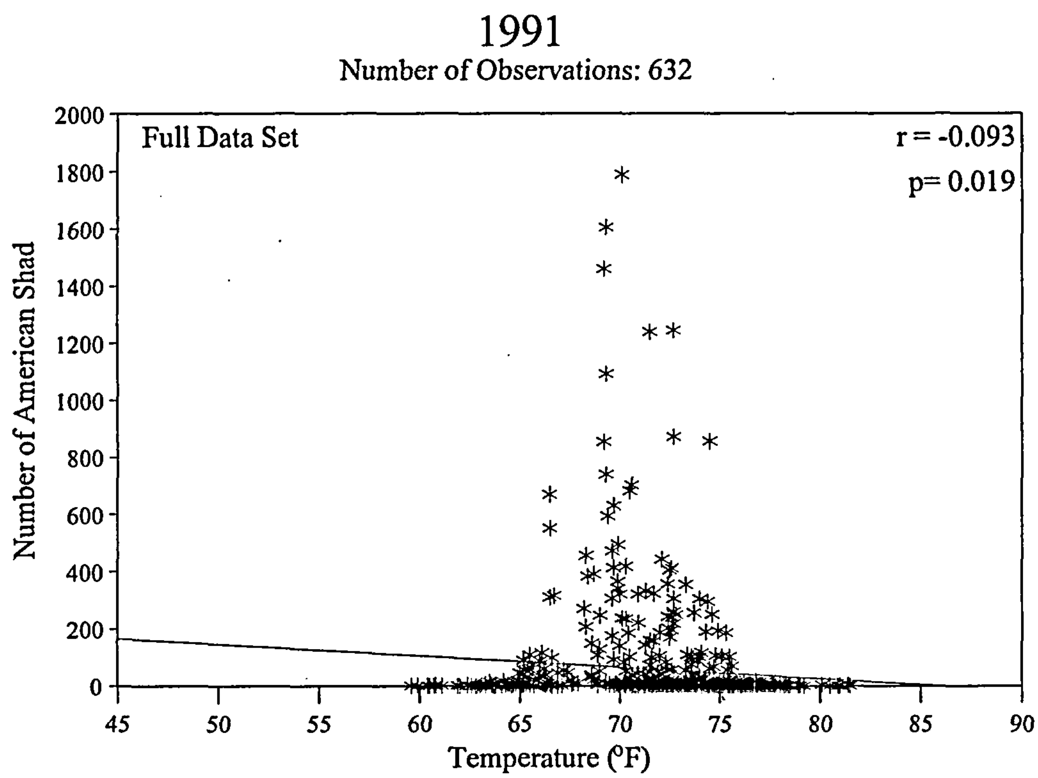
[1] Under new permit conditions, fishway water temperatures would have exceeded 72.5°F for 10 hours between 28 and 31 May 1998, or for 1.7% of the 1998 fishway monitoring period (584 hours total).

[2] Under new permit conditions, fishway water temperatures would have exceeded 72.5°F for 82 hours between 2 and 7 June 1999, or for 16.8% of the 1999 fishway monitoring period (488 hours total). This is an increase of 37 hours from existing permit conditions.

[3] Under new permit conditions, Downstream Station 3 water temperatures would have exceeded 72.5°F for 82 hours between 3 and 7 June 1999, or 16.8% of the 1999 fishway monitoring period (488 hours total). This is an increase of 54 hours from existing permit conditions.

[4] The 2002 period of fishway temperature monitoring started on 11 June, after the end of the smolt migration. However, the maximum fishway temperature on 11 June was 67.8°F, which implies that exceedances of 72.5°F prior to 7 June were unlikely.

Based on actual monitoring results at Stations 7, 3 and the fishway, it is predicted that temperatures would have exceeded 72.5°F at no more than two of the monitored locations in only two of the five years evaluated in this Demonstration. No exceedances were expected during, 2000, 2001 and 2002. During 1998 and 1999, 72.5°F was predicted to be exceeded 1.7 and 16.8% of the time, respectively, prior 8 June in the fishway, and 0 and 16.8% of the time, respectively, prior to 8 June at Downstream Station 3. Only in 1999 would the new permit criteria have resulted in significantly greater numbers of hours where temperatures exceeded 72.5°F during the salmon smolt emigration period and then by only 37 and 54 hours at the fishway and Downstream Station 3, respectively.



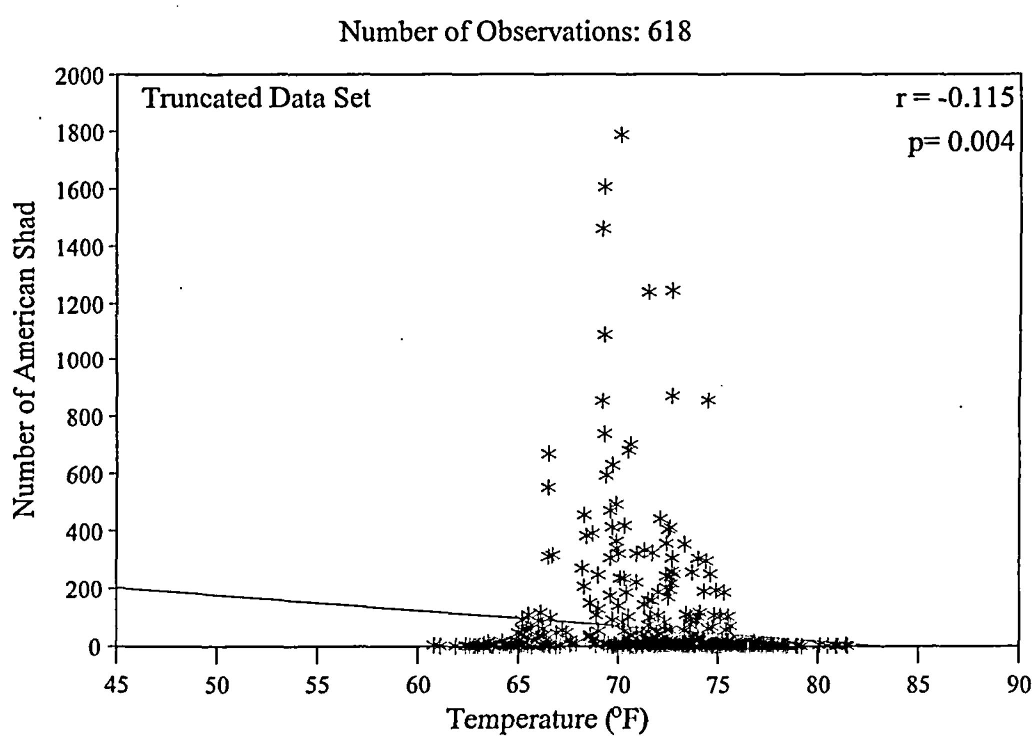


Figure 5-11. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1991.

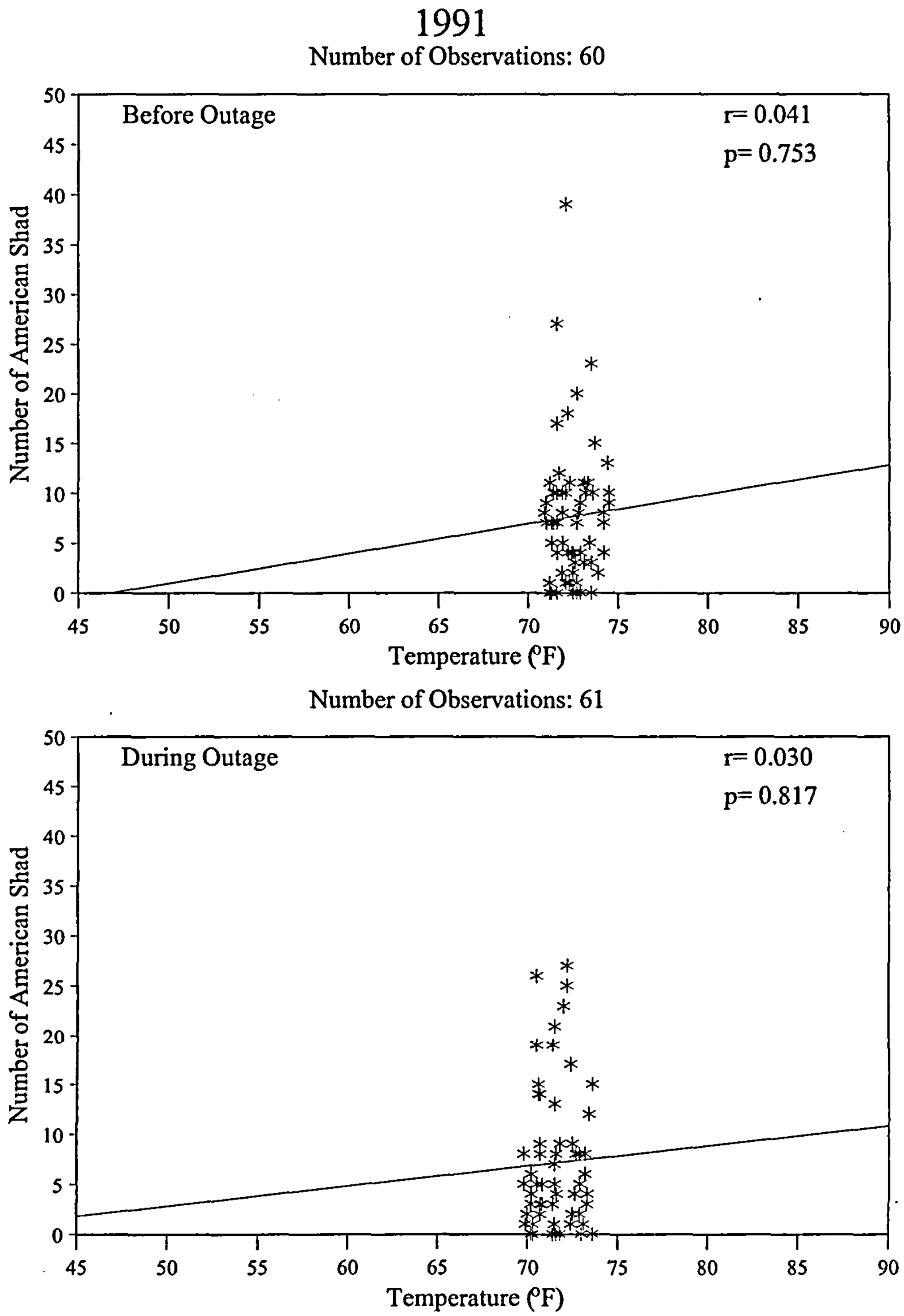
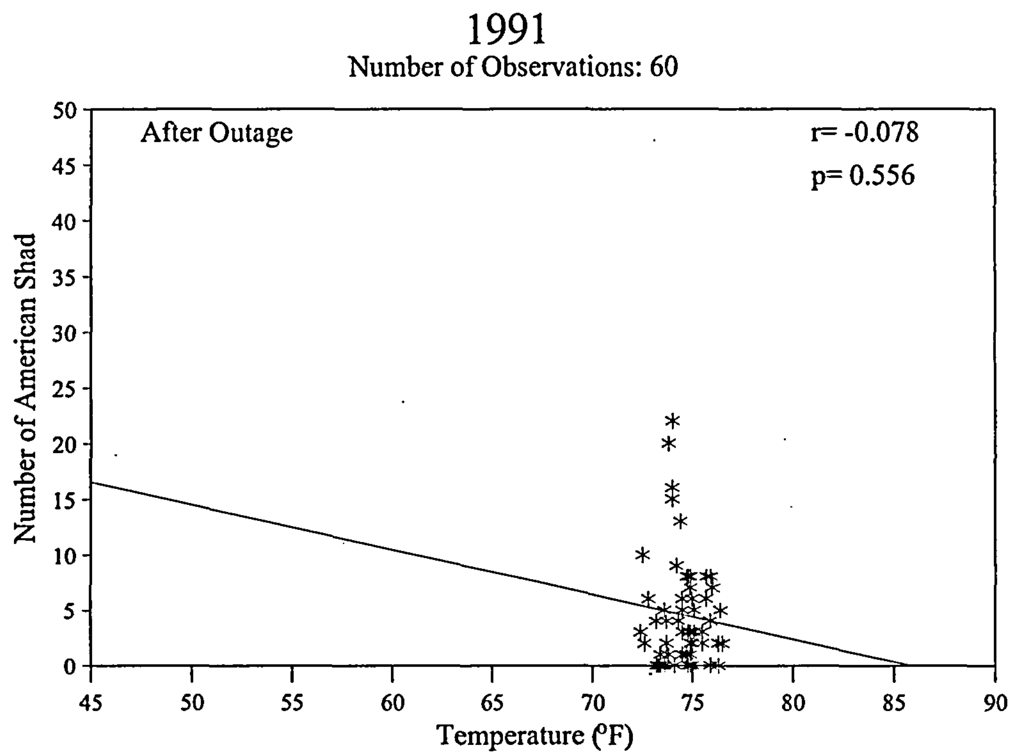


Figure 5-12. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, before, during and after a Vermont Yankee outage occurring during May-July 1991.



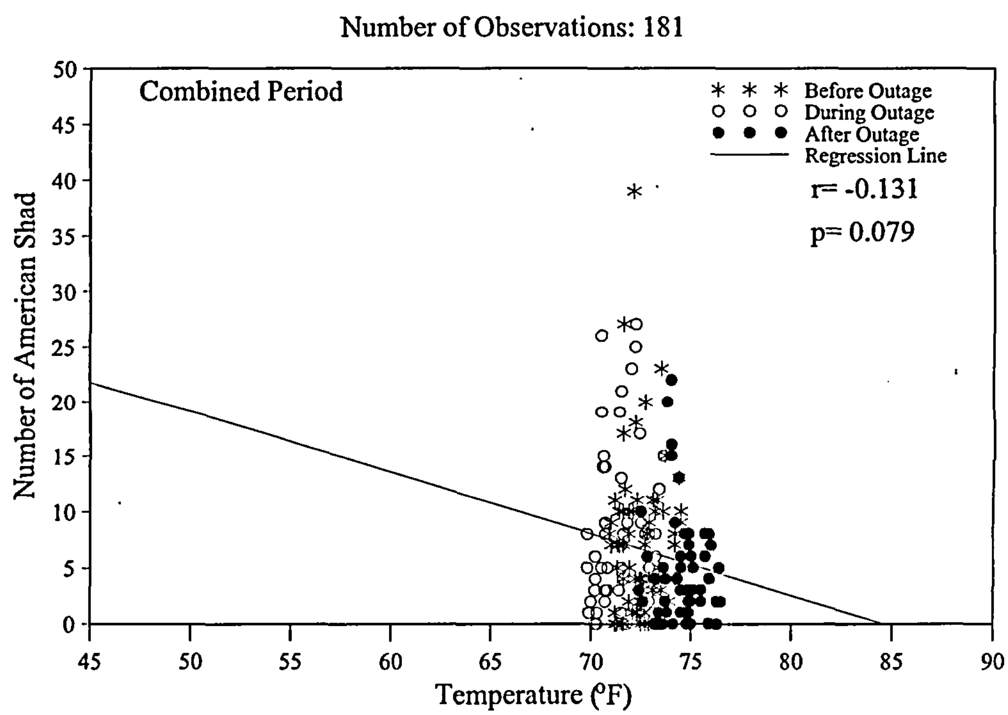


Figure 5-12. (Continued)

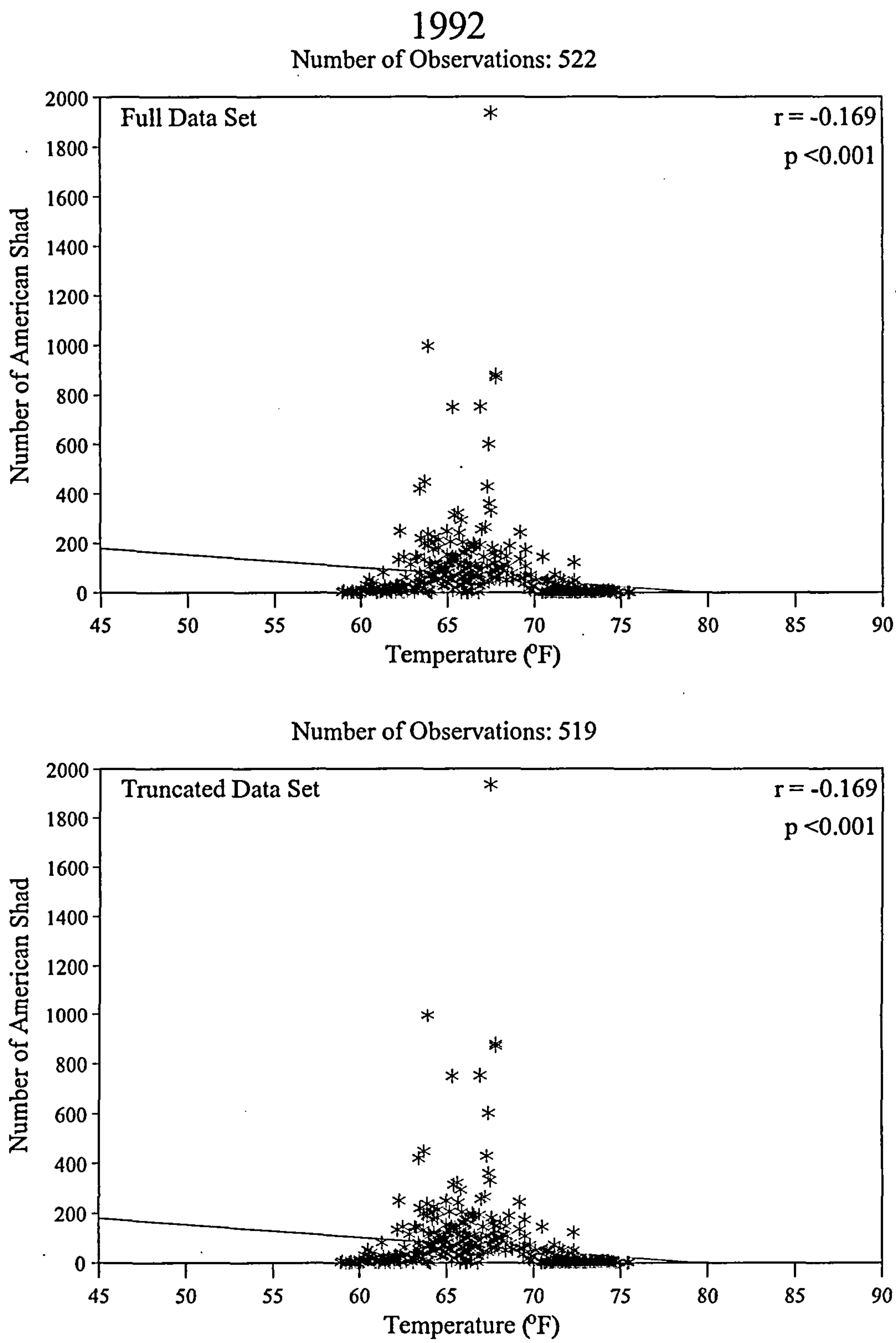
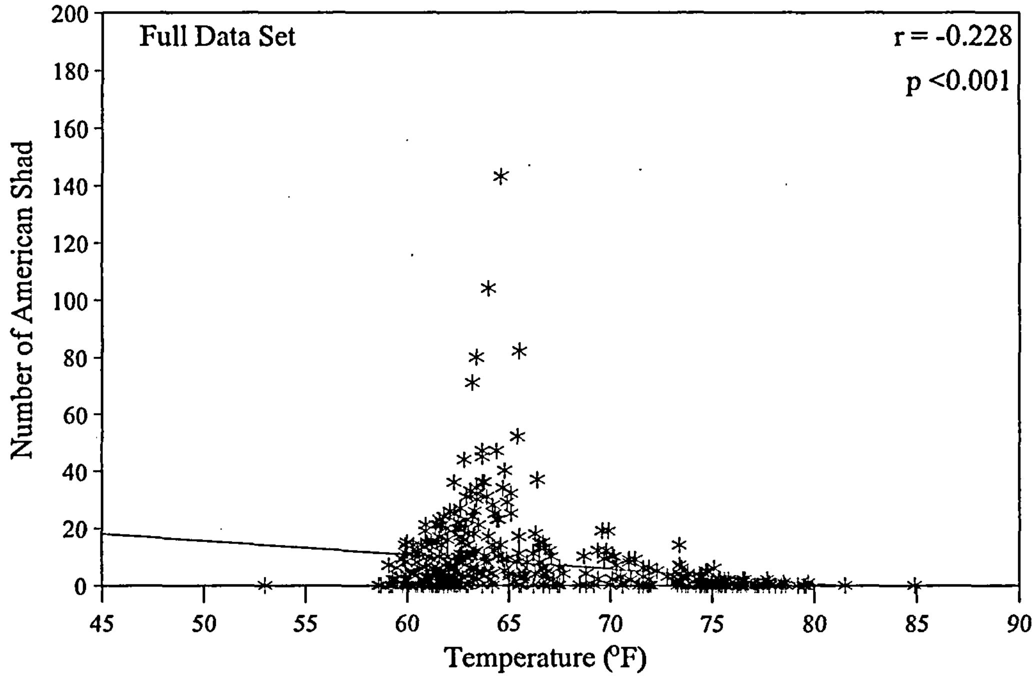


Figure 5-13. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1992.

1993

Number of Observations: 468



Number of Observations: 455

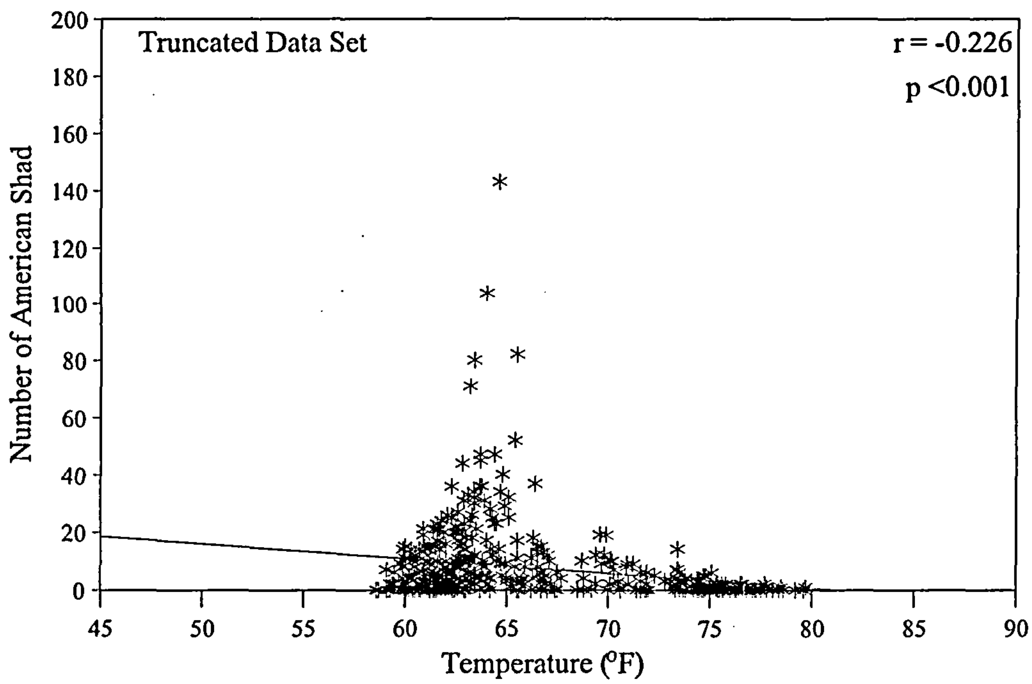
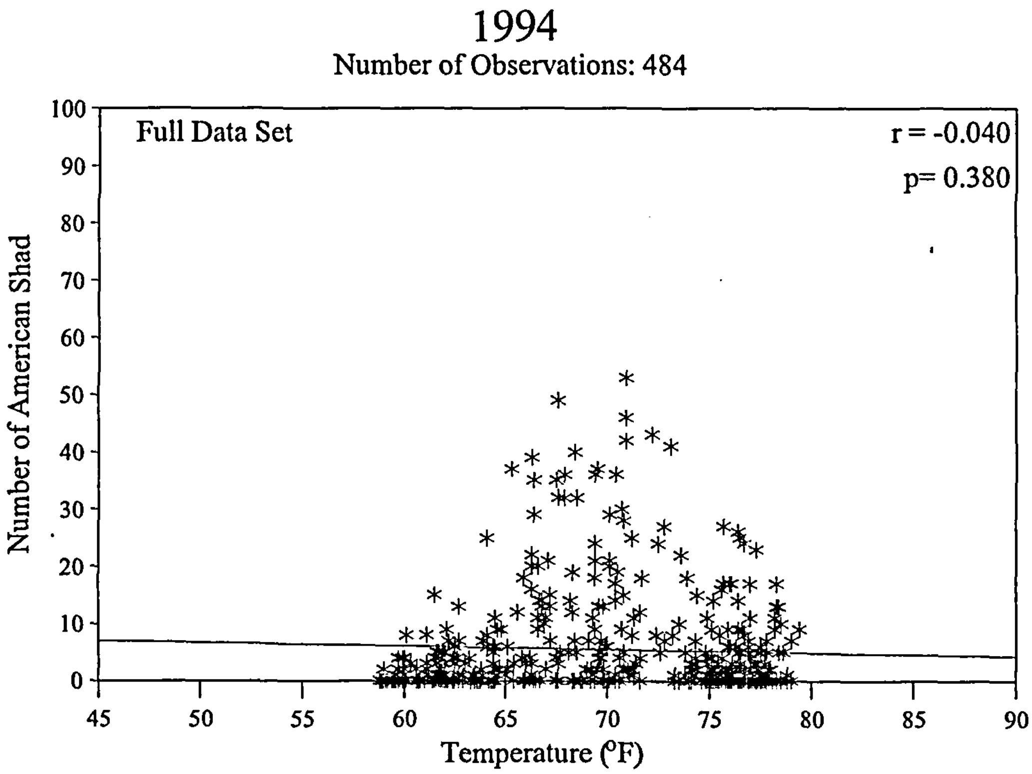


Figure 5-14. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1993.



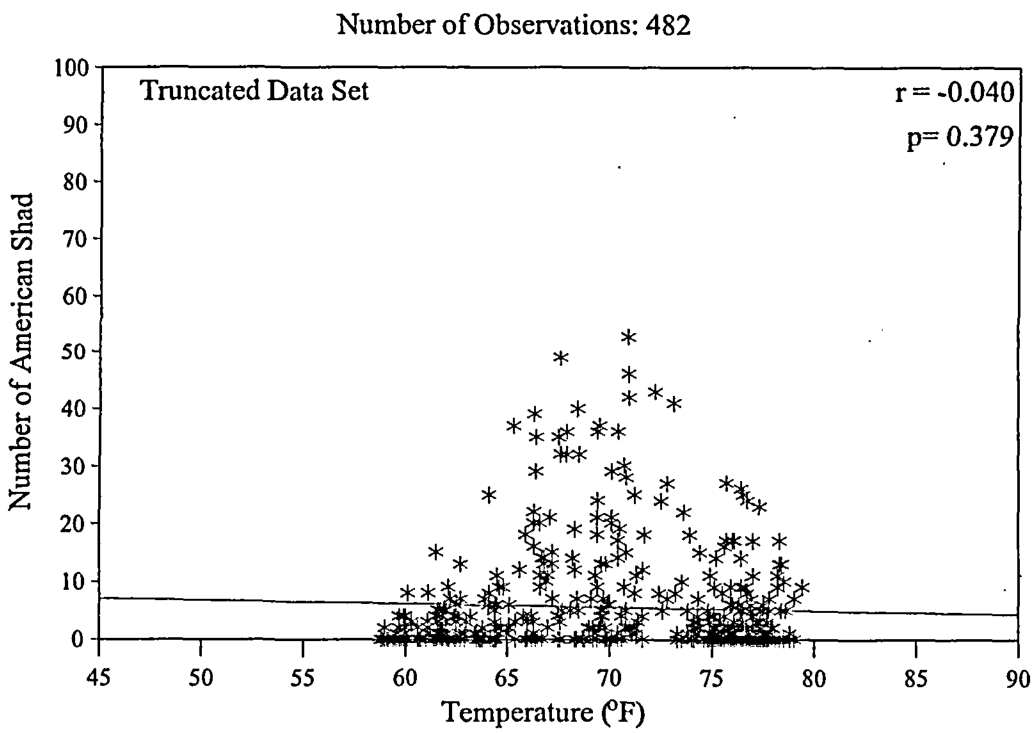
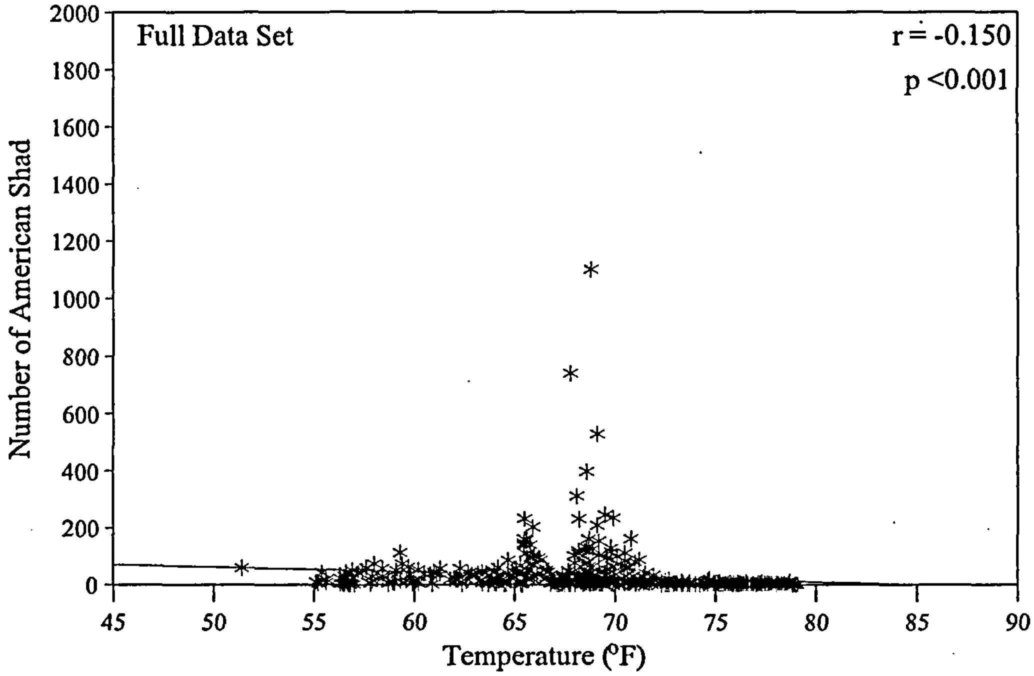


Figure 5-15. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1994.

1995

Number of Observations: 579



Number of Observations: 577

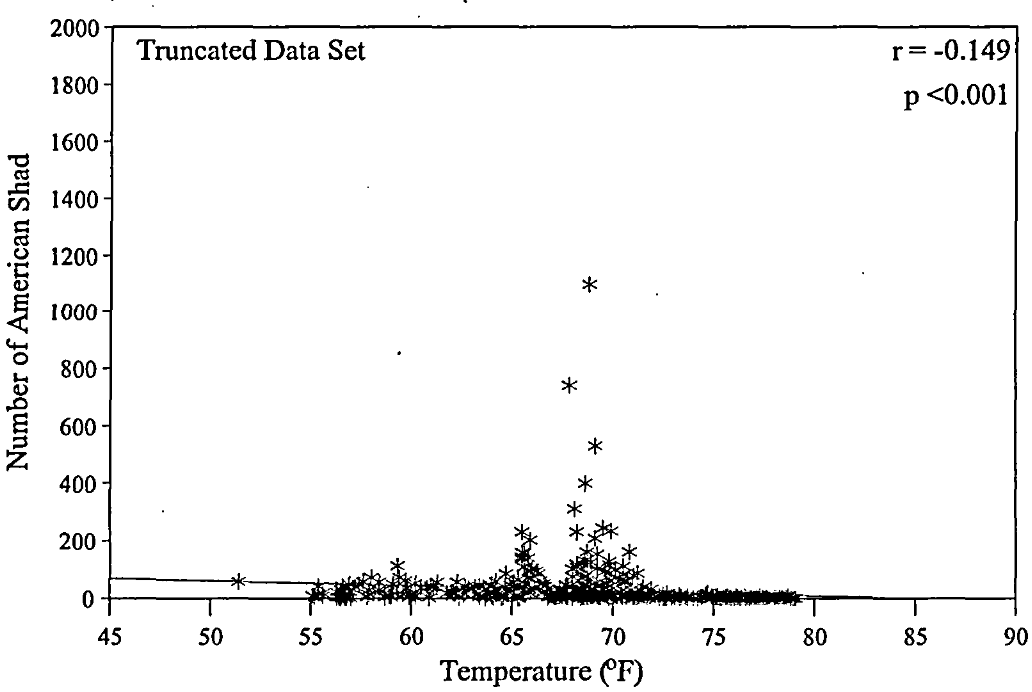


Figure 5-16. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1995.

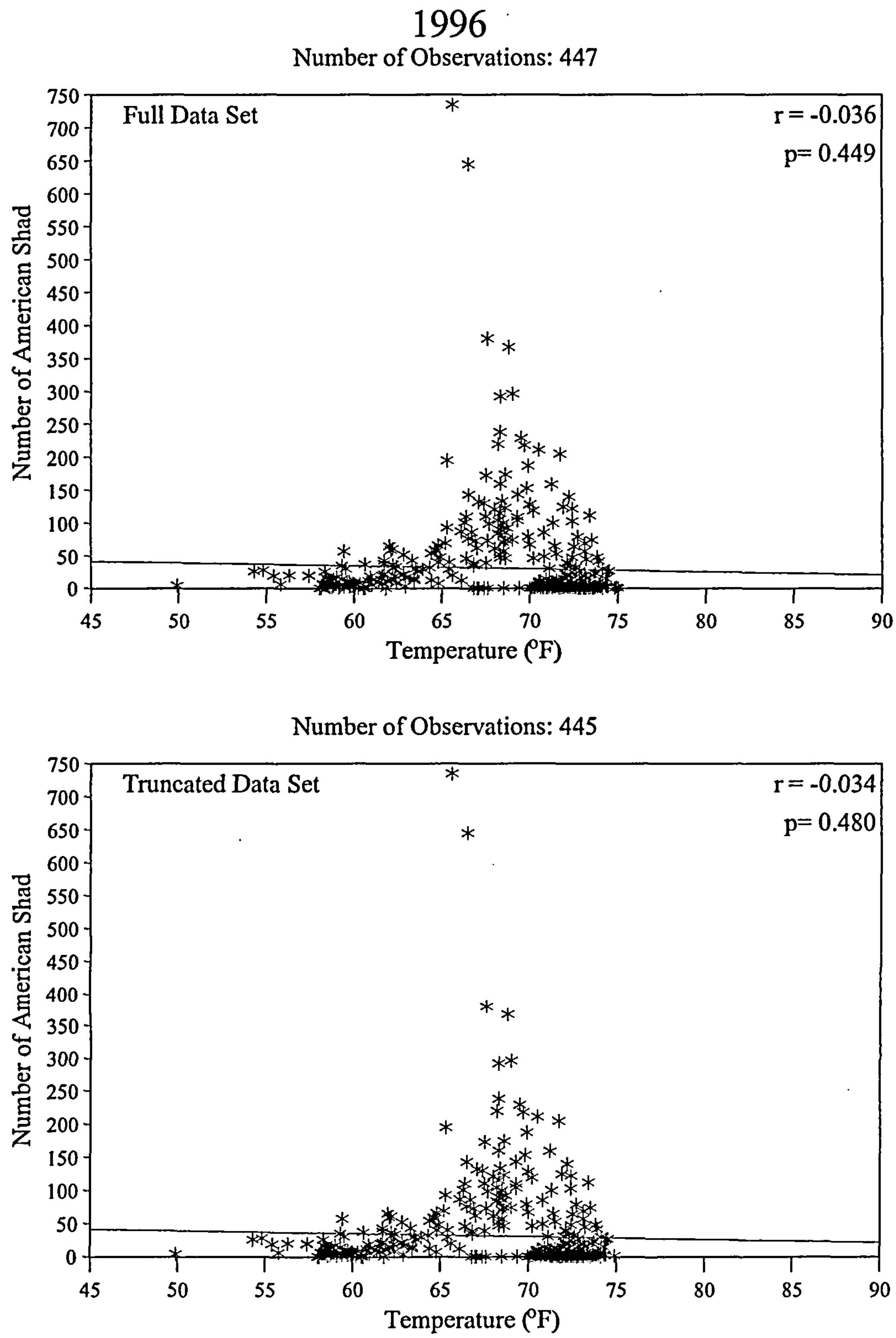


Figure 5-17. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1996.

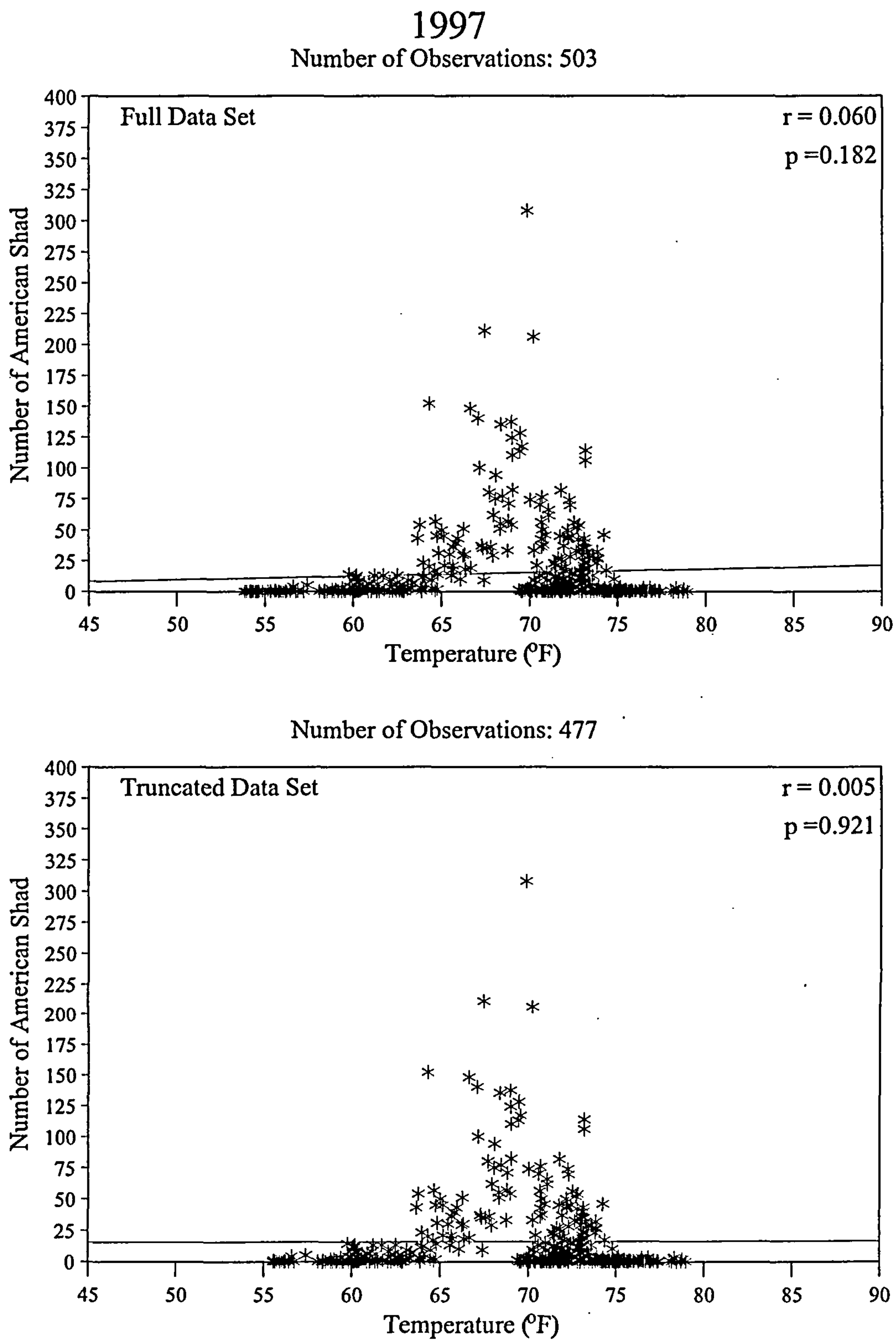
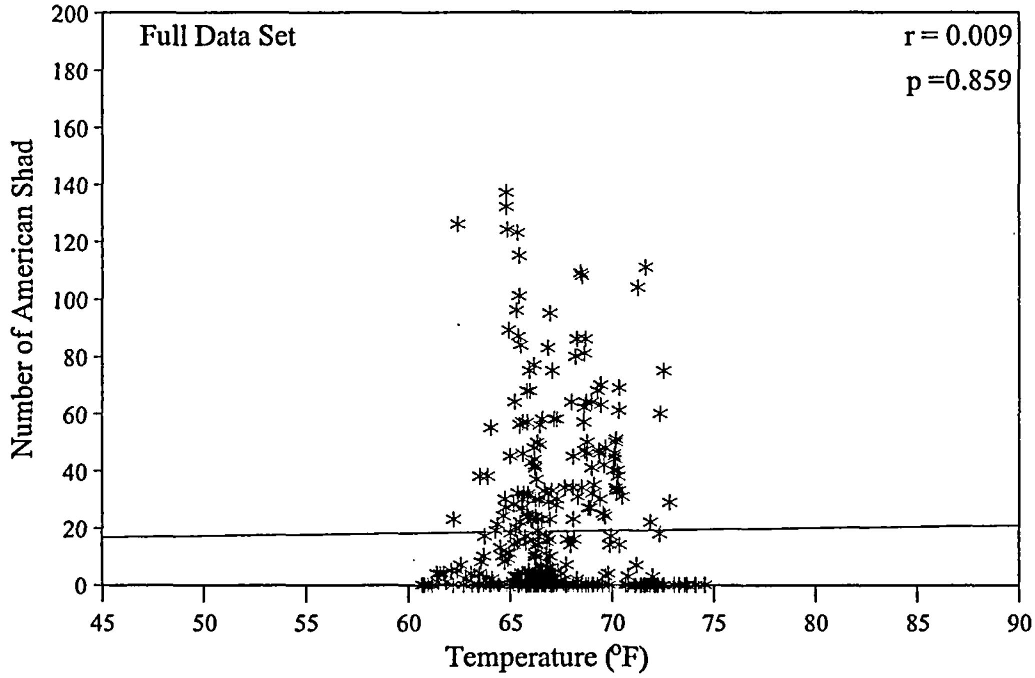


Figure 5-18. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1997.

1998

Number of Observations: 391



Number of Observations: 388

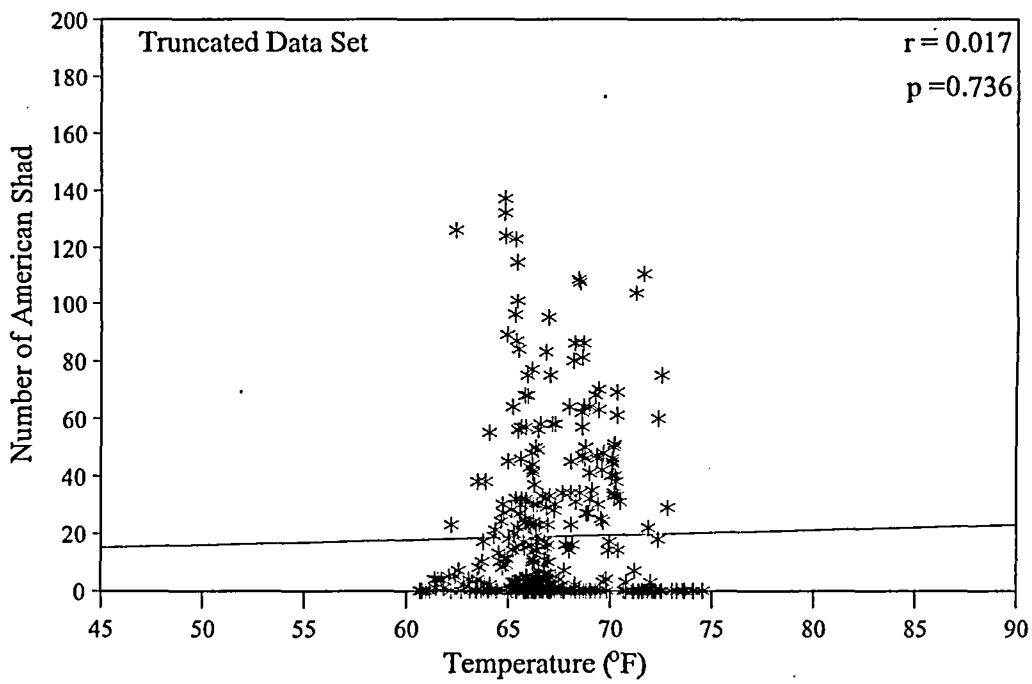


Figure 5-19. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1998.

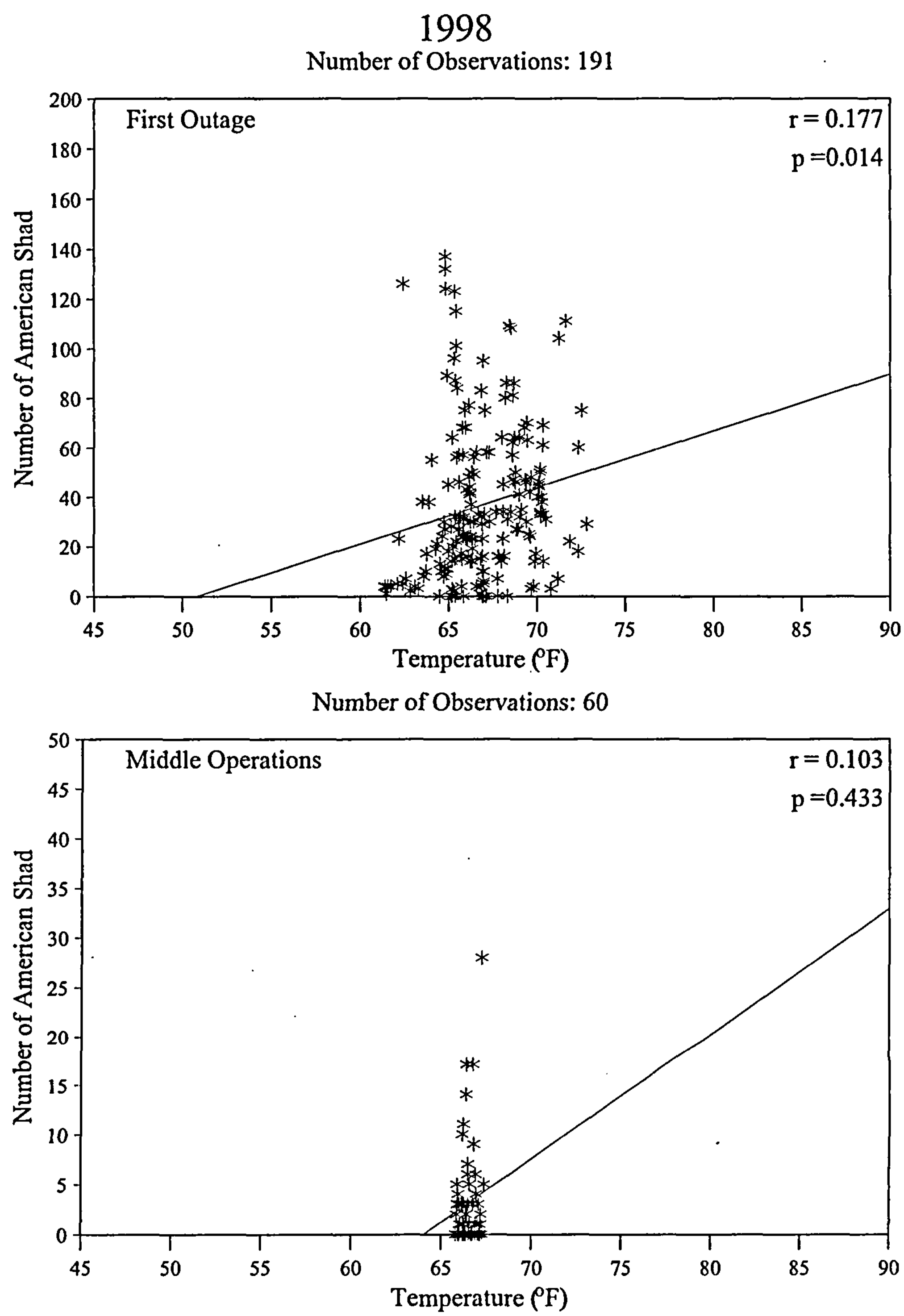
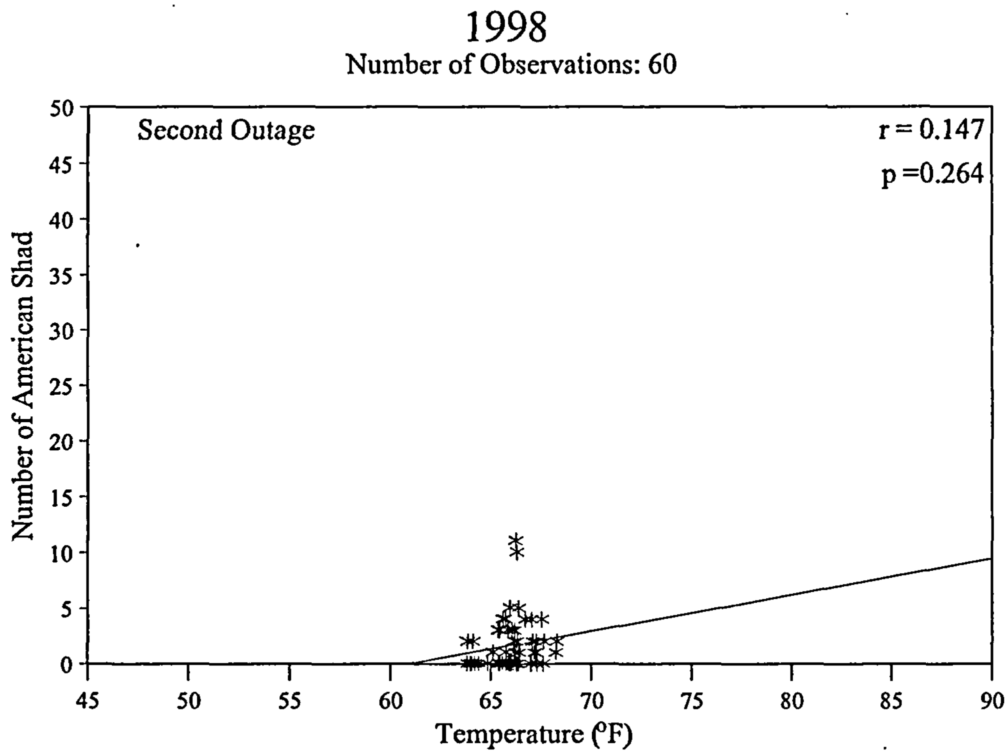


Figure 5-20. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, before, associated with two outage periods occurring during May-July 1998.



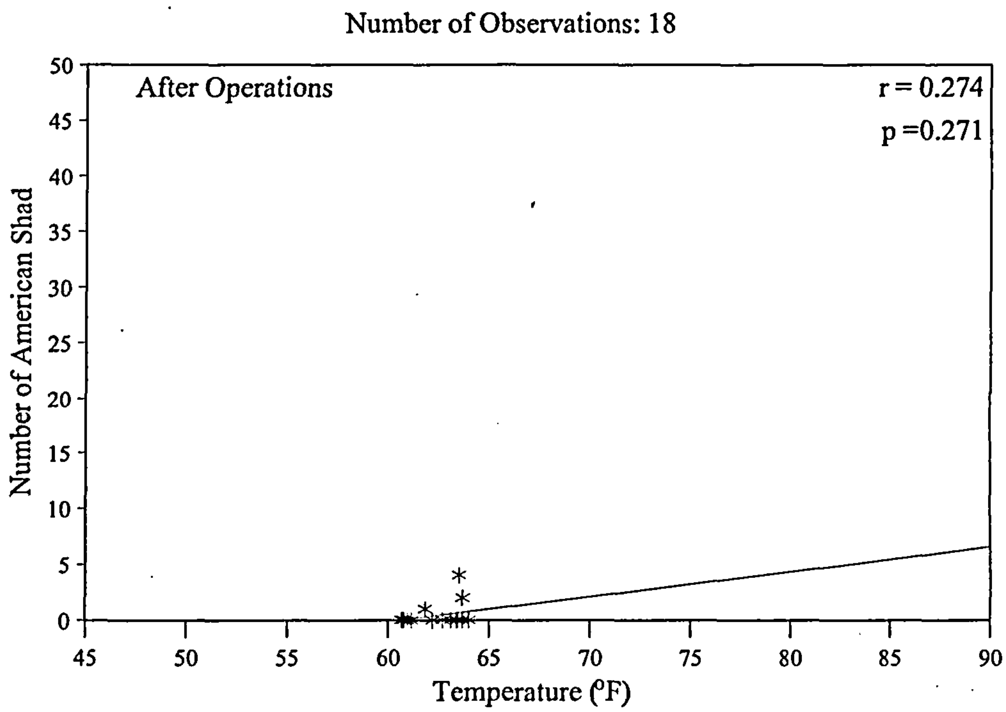


Figure 5-20. (Continued)

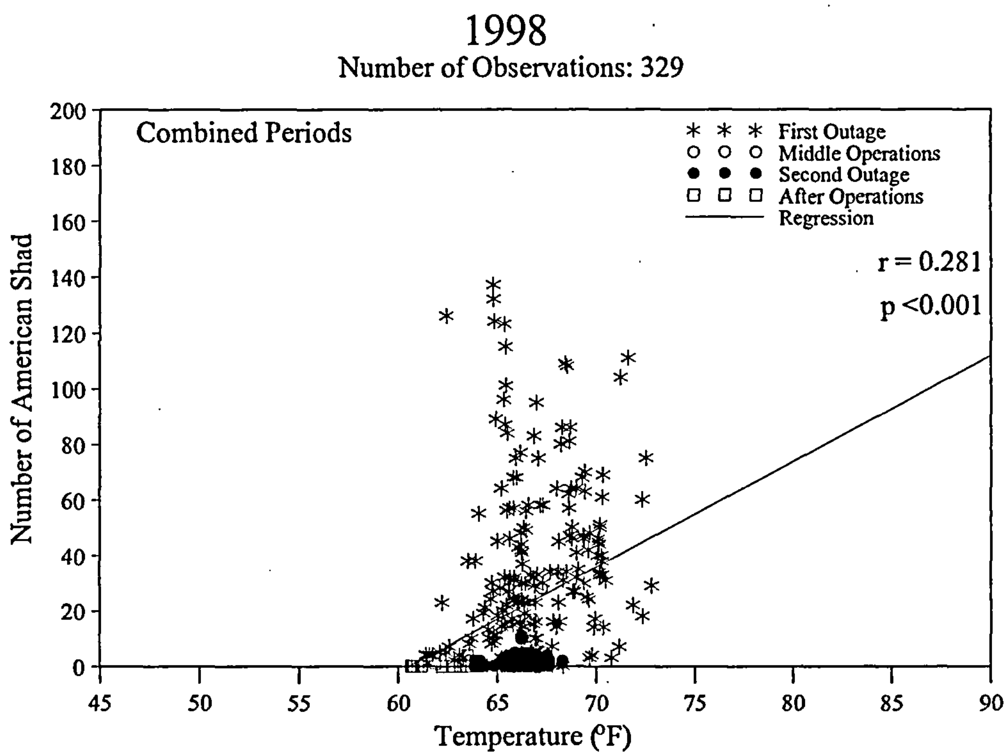


Figure 5-20. (Continued)

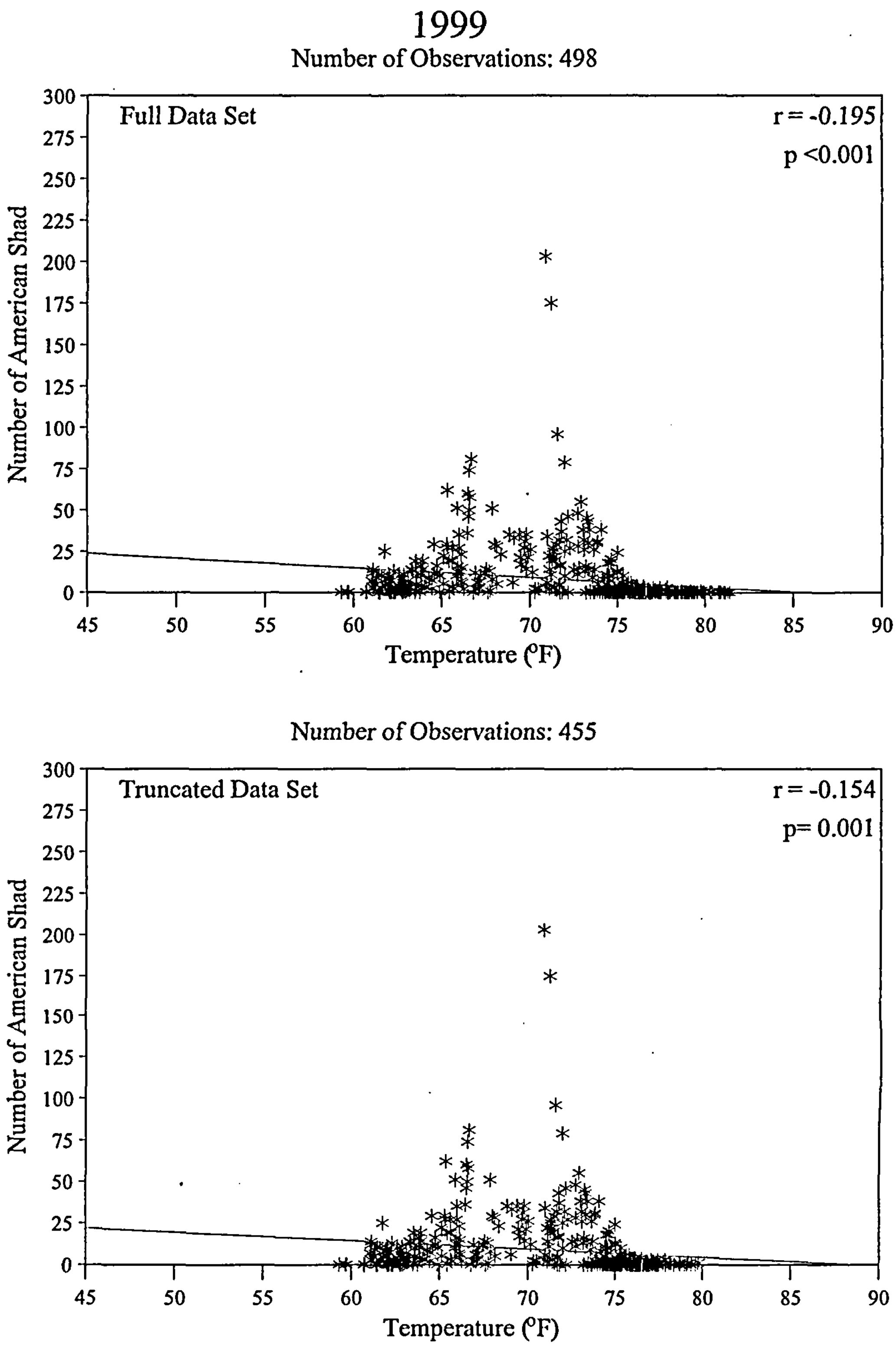


Figure 5-21. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 1999.

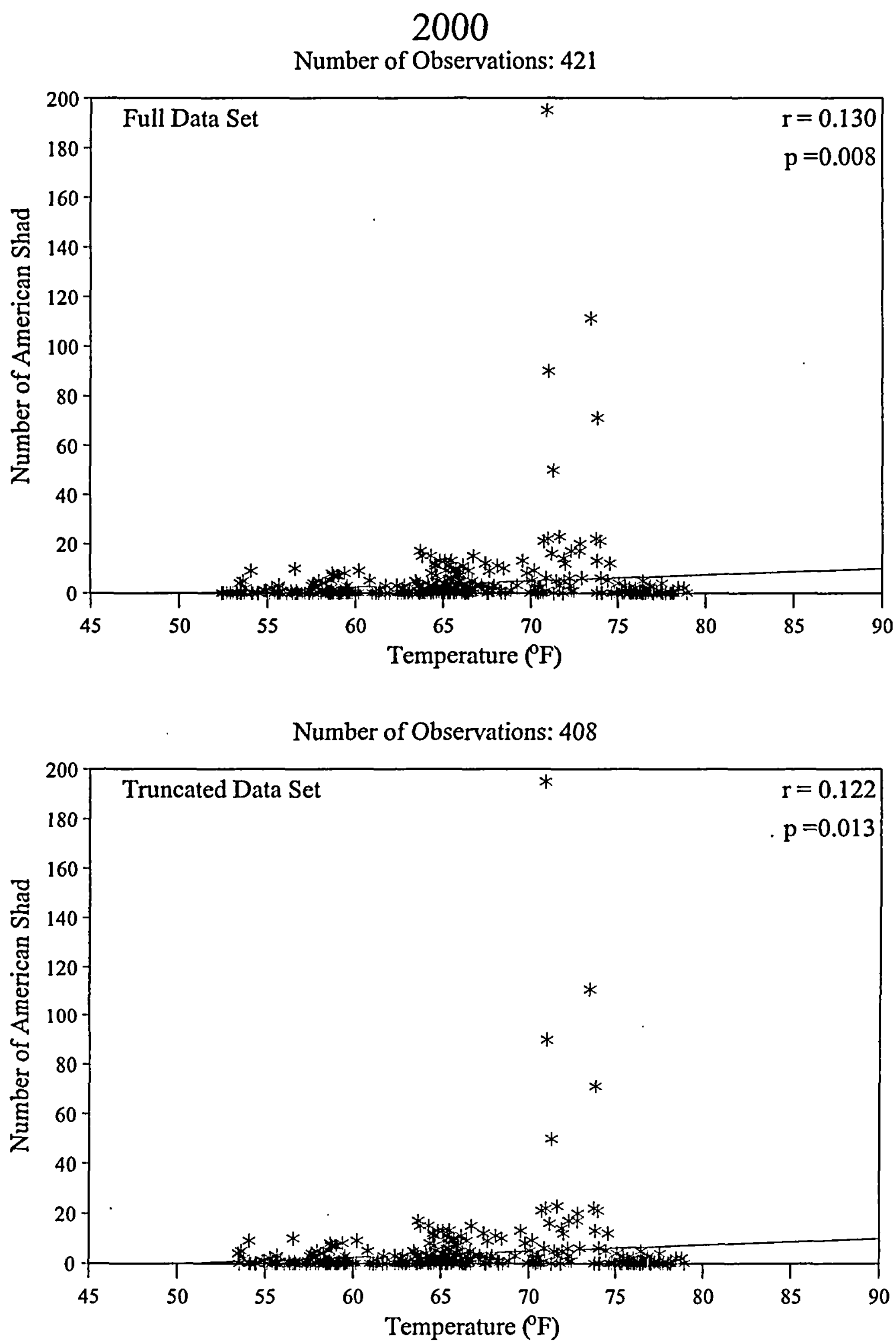
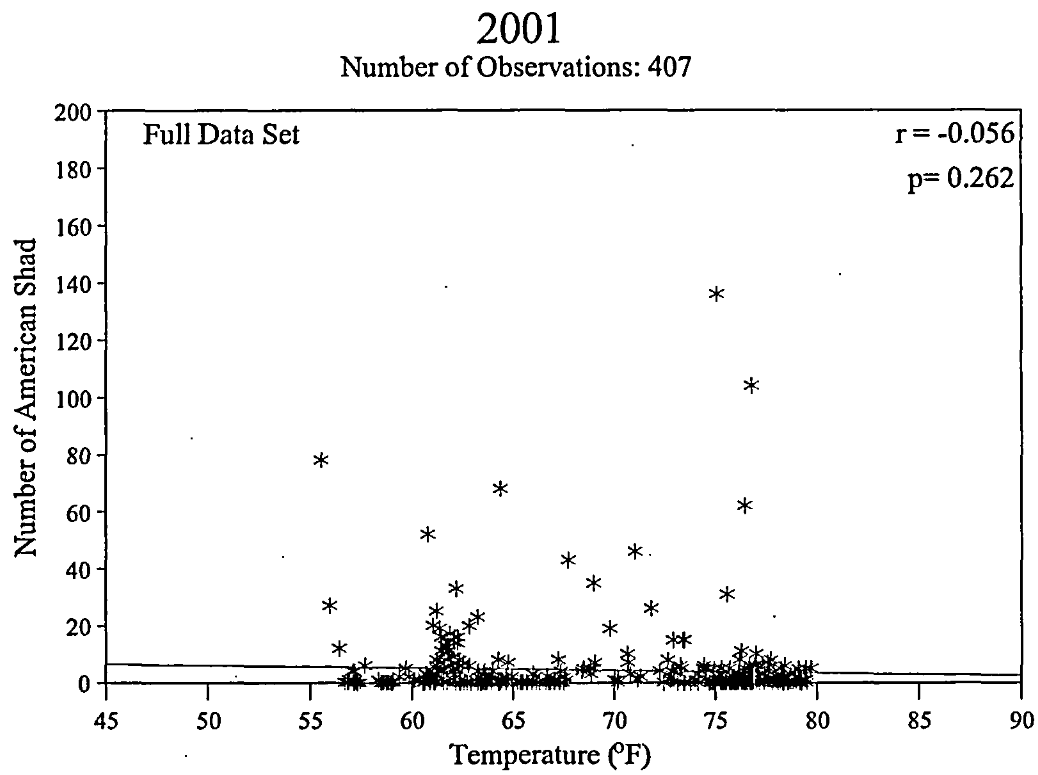


Figure 5-22. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 2000.



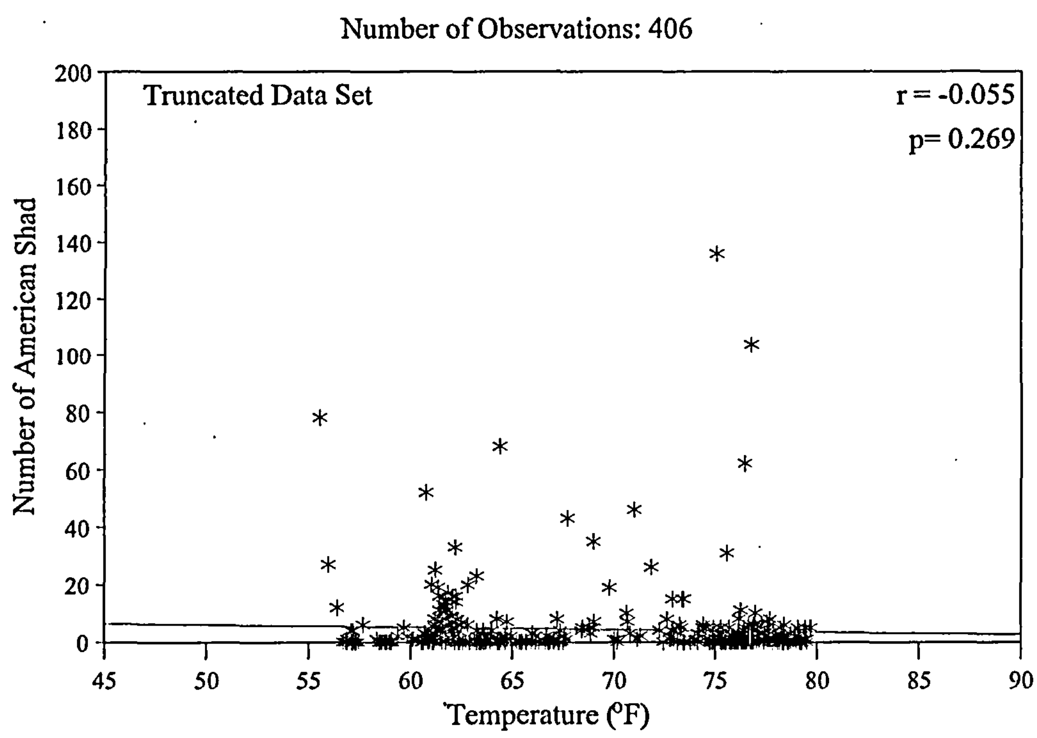


Figure 5-23. Scatter plots, Pearson product-moment correlation coefficient (r), and significance probablity value (p) for the relationship between hourly average temperature (°F) and the corresponding number of adult American shad passing upstream through the Vernon fishway on the Connecticut River, Vernon, Vermont, May-July 2001.

Table 5-15. Comparison of mean daily water temperatures recorded in the Vernon fishway and at Station 3, 1997-2002.

DATE	1997 FW	1997 S3	FW-S3	1998 FW	1998 S3	FW-S3	1999 FW	1999 S3	FW-S3	2000 FW	2000 S3	FW-S3	2001 FW	2001 S3	FW-S3	2002 FW	2002 S3	FW-S3
5/14				57.92	57.95	-0.03												
5/15				58.63	58.84	-0.22												
5/16				60.37	60.16	0.21												
5/17				61.41	61.20	0.21												
5/18				61.92	62.24	-0.32	65.39	64.71	0.68									
5/19				63.29	63.47	-0.18	65.56	65.00	0.57									
5/20				65.10	64.61	0.49	62.68	63.30	-0.63									
5/21				65.91	65.76	0.15	62.23	62.69	-0.46									
5/22				65.19	65.19	0.00	63.16	63.07	0.09	52.64	53.31	-0.67	59.50	62.74	-3.24			
5/23				64.94	65.03	-0.09	63.89	63.55	0.34	52.95	53.54	-0.59	58.08	62.08	-4.00			
5/24				65.62	65.65	-0.03				53.97	54.54	-0.57	61.46	61.87	-0.40			
5/25				65.77	65.68	0.09	62.02	62.60	-0.58	55.28	55.93	-0.65	62.12	61.84	0.28			
5/26	54.31	54.95	-0.64	65.97	65.92	0.04	62.15	62.01	0.14	56.22	56.96	-0.73	61.79	61.88	-0.09			
5/27	55.15	55.61	-0.47	67.81	66.66	1.15	60.90	61.11	-0.21	57.14	57.98	-0.84	61.38	61.29	0.09			
5/28	55.67	56.54	-0.87	68.87	67.56	1.31	62.15	61.79	0.37	57.94	58.78	-0.84	61.31	60.87	0.44			
5/29	57.66	57.39	0.28	69.76	68.11	1.65	64.37	63.63	0.74	58.64	59.62	-0.98	61.21	60.90	0.31			
5/30	59.51	58.23	1.28	70.88	69.01	1.87	65.64	64.61	1.03	60.02	60.15	-0.13	61.52	60.90	0.62			
5/31	61.00	59.60	1.40	70.08	69.68	0.39	67.46	66.41	1.05	61.91	61.14	0.77	61.59	60.90	0.69			
6/1	60.51	60.08	0.43	68.56	66.31	2.25	68.76	68.08	0.68	63.67	62.86	0.82	62.26	60.90	1.36			
6/2	60.01	59.72	0.29	67.61	67.15	0.46	70.92	70.08	0.84	65.40	64.47	0.93	60.52	60.90	-0.38			
6/3	60.36	59.38	0.98	66.93	66.91	0.02	71.53	71.51	0.03	66.19	65.59	0.60	57.64	60.90	-3.27			
6/4	61.46	60.37	1.10	66.62	66.47	0.15	71.02	71.45	-0.44	66.89	66.11	0.78	57.07	60.90	-3.83			
6/5	62.59	61.58	1.01	66.77	66.65	0.12	71.97	71.62	0.35	66.23	65.74	0.49						
6/6	64.25	62.89	1.36	66.08	65.77	0.31	72.44	72.25	0.20	64.37	64.60	-0.23						
6/7	64.37	63.31	1.05	66.66	65.75	0.91	73.70	73.64	0.05	59.37	60.26	-0.88	60.01	63.87	-3.86			
6/8	65.58	64.80	0.78	66.10	65.69	0.41	74.66	74.61	0.05	58.56	59.14	-0.58	61.87	64.33	-2.46			
6/9	66.78	65.70	1.08	65.23	64.46	0.78	74.29	74.54	-0.25	59.61	60.23	-0.62	64.43	66.91	-2.47			
6/10	68.11	66.88	1.23	65.83	64.48	1.35	74.20	74.11	0.09	62.60	61.77	0.83	66.05	68.52	-2.47			
6/11	69.74	68.49	1.25	65.75	65.48	0.27	74.21	73.82	0.39	64.86	63.78	1.07	66.41	68.76	-2.35	68.33	67.19	1.14

(continued)

Table 5-15. (Continued)

DATE	1997 FW	1997 S3	FW-S3	1998 FW	1998 S3	FW-S3	1999 FW	1999 S3	FW-S3	2000 FW	2000 S3	FW-S3	2001 FW	2001 S3	FW-S3	2002 FW	2002 S3	FW-S3
6/12	71.01	70.04	0.97	65.97	65.98	-0.02	75.37	74.76	0.61	65.14	64.32	0.82	64.57	66.65	-2.07	66.95	66.60	0.35
6/13	71.34	70.26	1.08	65.48	65.57	-0.09	76.39	75.52	0.87	64.44	63.76	0.68	63.92	66.09	-2.17	64.09	64.29	-0.20
6/14	72.10	71.21	0.90	63.43	63.62	-0.19	76.47	75.75	0.72	64.25	63.33	0.92	66.60	68.09	-1.49	61.33	61.28	0.04
6/15	72.15	71.42	0.73	61.42	61.39	0.03	76.35	76.38	-0.02	62.90	62.00	0.90	69.50	70.66	-1.16	58.88	58.70	0.18
6/16	72.41	71.89	0.52	61.38	61.44	-0.06	75.48	75.79	-0.31	63.35	62.18	1.16	72.00	72.76	-0.77	58.85	58.92	-0.07
6/17	72.06	71.28	0.78	61.15	61.02	0.13	75.07	75.11	-0.04	66.31	64.84	1.48	73.10	75.29	-2.19	58.65	59.00	-0.35
6/18	71.88	71.12	0.76	61.66	61.43	0.23	74.76	74.97	-0.21	65.90	65.15	0.75	73.88	76.87	-2.99	59.72	60.44	-0.72
6/19	71.24	71.00	0.23	62.43	62.52	-0.10	75.16	75.04	0.12	66.74	66.08	0.65	75.20	78.09	-2.89	61.80	61.85	-0.05
6/20	70.53	70.40	0.12	63.79	64.03	-0.24	75.11	74.65	0.46	68.14	67.33	0.81	76.73	79.25	-2.52	64.55	63.95	0.60
6/21	72.37	70.98	1.39	65.42	65.75	-0.33	75.18	74.66	0.52	69.62	68.73	0.90	75.66	79.32	-3.67	66.84	65.99	0.85
6/22	73.12	72.13	0.99	67.03	67.59	-0.55	76.64	75.85	0.79	70.47	69.81	0.66	75.60	80.25	-4.65	68.31	67.42	0.89
6/23	71.70	71.96	-0.26	68.89	68.69	0.20	77.84	77.05	0.79	70.65	70.14	0.52	75.25	79.72	-4.46	69.30	68.07	1.23
6/24	71.22	71.28	-0.07	70.50	70.18	0.31	77.06	76.62	0.44	71.31	70.16	1.16	75.35	79.07	-3.72	68.17	68.48	-0.31
6/25	71.79	70.85	0.94	73.12	71.80	1.32	76.75	76.20	0.55	72.18	70.36	1.82	75.80	80.19	-4.40	70.58	69.72	0.86
6/26	71.03	70.46	0.57	72.11	71.73	0.38	78.37	77.63	0.74	74.24	72.54	1.70	76.43	79.25	-2.83	71.93	70.64	1.29
6/27	69.74	69.89	-0.15	71.54	71.62	-0.08	78.79	78.64	0.15	73.99	72.96	1.03	77.89	77.72	0.17	73.04	72.22	0.82
6/28	72.13	70.36	1.77	67.40	71.62	-4.22	79.81	78.92	0.90	74.27	73.52	0.75	78.46	79.18	-0.71	71.39	72.25	-0.86
6/29	74.10	72.00	2.09	66.94	71.62	-4.68	79.92	79.05	0.87	74.84	72.64	2.20	77.15	78.23	-1.08	70.78	71.79	-1.01
6/30	75.78	73.40	2.38				79.23	78.48	0.76	75.38	75.06	0.33	78.20	77.31	0.89	72.23	72.32	-0.08
7/1	75.43	73.78	1.65	67.53	68.67	-1.14	77.00	78.35	-1.35	76.05	75.23	0.82	78.01	77.97	0.04	73.71	73.35	0.37
7/2	75.80	74.55	1.25	67.51	68.55	-1.03	75.11	77.66	-2.55	76.67	75.50	1.17	75.91	77.97	-2.05	75.88	74.52	1.36
7/3	74.91	74.42	0.50	67.79	68.76	-0.97				76.90	75.32	1.58	76.13	77.97	-1.83	77.13	75.70	1.42
7/4	74.84	74.57	0.27	68.39	69.54	-1.16				77.23	75.56	1.67	76.13	77.97	-1.83	78.38	77.24	1.14
7/5	74.94	74.71	0.23	68.60	69.92	-1.32				77.11	76.21	0.89	75.40	77.97	-2.57	78.31	78.01	0.31
7/6	75.49	74.58	0.91	68.86	69.83	-0.97				76.12	76.05	0.07				78.06	77.72	0.34
7/7	75.01	74.77	0.23	71.01	70.41	0.60				75.84	75.73	0.11				77.48	77.17	0.31
7/8				70.91	70.08	0.82				75.18	75.06	0.12				77.88	77.25	0.62
7/9				69.94	69.81	0.13				75.29	74.95	0.35				77.75	76.94	0.81
7/10				71.04	70.73	0.30				75.73	75.12	0.61				76.45	76.42	0.03
7/11				70.25	70.75	-0.50				75.21	74.80	0.40				75.55	75.68	-0.13

(continued)

Table 5-15. (Continued)

DATE	1997 FW	1997 S3	FW-S3	1998 FW	1998 S3	FW-S3	1999 FW	1999 S3	FW-S3	2000 FW	2000 S3	FW-S3	2001 FW	2001 S3	FW-S3	2002 FW	2002 S3	FW-S3
7/12				69.22	70.47	-1.25				74.57	74.29	0.28				75.07	74.90	0.17
7/13				70.12	70.80	-0.68				73.29	70.75	2.55				75.70	75.14	0.56
7/14				70.85	71.43	-0.58										76.58	75.54	1.04
7/15				73.81	72.76	1.05										77.04	76.16	0.88
7/16				74.62	73.53	1.09										76.62	76.31	0.31
7/17				75.34	74.08	1.26										77.83	75.90	1.93
7/18				75.91	75.47	0.44										76.22	75.91	0.31
7/19				76.58	75.80	0.78												
7/20				77.45	76.66	0.78												
7/21				78.15	77.32	0.82												
7/22				78.38	77.98	0.40												
7/23				78.58	78.33	0.25												
No. Days	43	43	43	70	70	70	45	45	45	53	53	53	43	43	43	38	38	38
Mean	68.40	67.65	0.75	67.89	67.82	0.07	71.94	71.72	0.22	67.24	66.72	0.52	68.58	70.35	-1.77	71.25	70.82	0.43
Max	75.80	74.77	2.38	78.58	78.33	2.25	79.92	79.05	1.05	77.23	76.21	2.55	78.46	80.25	1.36	78.38	78.01	1.93
Min	54.31	54.95	-0.87	57.92	57.95	-4.68	60.90	61.11	-2.55	52.64	53.31	-0.98	57.07	60.87	-4.65	58.65	58.70	-1.01

Table 5-16. Numbers of monitored fishes passed through the fishway at Vernon Dam and mean daily water temperatures in the fishway in 1998.

Date	Atlantic Salmon		American Shad		Sea Lamprey		Mean T.
	Daily	Cum.	Daily	Cum.	Daily	Cum.	
5/18	0	0	50	50	5	5	61.9
5/19	0	0	205	255	30	35	63.3
5/20	0	0	248	503	31	66	65.1
5/21	0	0	302	805	56	122	65.9
5/22	0	0	790	1,595	226	348	65.2
5/23	0	0	220	1,815	174	522	64.9
5/24	1	1	228	2,043	1,138	1,660	65.6
5/25	0	1	925	2,968	1,702	3,362	65.8
5/26	0	1	598	3,566	642	4,004	66.0
5/27	0	1	393	3,959	1,803	5,807	67.8
5/28	0	1	778	4,737	1,426	7,233	68.9
5/29	0	1	522	5,259	1,155	8,388	69.8
5/30	2	3	320	5,579	2,006	10,394	70.9
5/31	0	3	510	6,089	2,127	12,521	70.1
6/1	0	3	675	6,764	1,357	13,878	68.6
6/2	1	4	169	6,933	685	14,563	67.6
6/3	1	5	57	6,990	296	14,859	66.9
6/4	0	5	99	7,089	175	15,034	66.6
6/5	0	5	33	7,122	163	15,197	66.8
6/6	2	7	22	7,144	86	15,283	66.1
6/7	0	7	21	7,165	127	15,410	66.7
6/8	0	7	15	7,180	229	15,639	66.1
6/9	0	7	15	7,195	143	15,782	65.2
6/10	0	7	12	7,207	194	15,976	65.8
6/11	0	7	12	7,219	131	16,107	65.7
6/12	0	7	41	7,260	115	16,222	66.0
6/13	0	7	18	7,278	101	16,323	65.5
6/14	0	7	7	7,285	111	16,434	63.4
6/15	0	7	0	7,285	0	16,434	61.4
6/16	0	7	0	7,285	0	16,434	61.4
6/17	0	7	0	7,285	0	16,434	61.1
6/18	0	7	0	7,285	0	16,434	61.7
6/19	0	7	0	7,285	0	16,434	62.4
6/20	0	7	0	7,285	0	16,434	63.8
6/21	0	7	0	7,285	0	16,434	65.4
6/22	0	7	0	7,285	0	16,434	67.0
6/23	0	7	0	7,285	0	16,434	68.9
6/24	0	7	0	7,285	4	16,438	70.5
6/25	0	7	0	7,285	0	16,438	73.1
6/26	0	7	0	7,285	0	16,438	72.1
6/27	0	7	4	7,289	0	16,438	71.5
Total		7		7,289		16,438	

Table 5-17. Numbers of monitored fishes passed through the fishway at Vernon Dam and mean daily water temperatures in the fishway in 1999.

Date	Atlantic Salmon		American Shad		Sea Lamprey		Striped Bass		Gizzard Shad		Mean T.
	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	
5/14	0	0	198	198	1	1	0	0	0	0	
5/15	2	2	106	304	0	1	1	1	0	0	
5/16	0	2	96	400	0	1	3	4	0	0	
5/17	0	2	385	785	0	1	0	4	0	0	
5/18	0	2	578	1,363	24	25	0	4	0	0	65.4
5/19	0	2	573	1,936	32	57	0	4	0	0	65.6
5/20	0	2	11	1,947	0	57	0	4	0	0	62.7
5/21	0	2	42	1,989	5	62	0	4	0	0	62.2
5/22	0	2	111	2,100	11	73	0	4	0	0	63.2
5/23	1	3	118	2,218	6	79	0	4	4	4	63.9
5/24	0	3	91	2,309	28	107	0	4	0	4	
5/25	0	3	92	2,401	4	111	0	4	0	4	62.0
5/26	0	3	53	2,454	0	111	0	4	0	4	62.2
5/27	1	4	38	2,492	3	114	0	4	0	4	60.9
5/28	0	4	35	2,527	10	124	0	4	0	4	62.2
5/29	0	4	117	2,644	76	200	0	4	0	4	64.4
5/30	0	4	60	2,704	48	248	0	4	0	4	65.6
5/31	1	5	243	2,947	52	300	0	4	0	4	67.5
6/1	0	5	179	3,126	135	435	0	4	0	4	68.8
6/2	0	5	268	3,394	136	571	0	4	0	4	70.9
6/3	1	6	140	3,534	96	667	0	4	2	6	71.5
6/4	0	6	13	3,547	53	720	0	4	0	6	71.0
6/5	0	6	801	4,348	38	758	0	4	1	7	72.0
6/6	0	6	403	4,751	13	771	0	4	2	9	72.4
6/7	0	6	138	4,889	36	807	0	4	2	11	73.7
6/8	0	6	52	4,941	12	819	1	5	17	28	74.7
6/9	1	7	27	4,968	4	823	0	5	6	34	74.3
6/10	0	7	14	4,982	6	829	0	5	7	41	74.2
6/11	0	7	6	4,988	4	833	0	5	12	53	74.2
6/12	0	7	8	4,996	1	834	0	5	5	58	75.4
6/13	0	7	33	5,029	1	835	0	5	4	62	76.4
6/14	0	7	16	5,045	0	835	0	5	10	72	76.5
6/15	0	7	8	5,053	0	835	0	5	11	83	76.4
6/16	0	7	4	5,057	0	835	0	5	4	87	75.5
6/17	0	7	12	5,069	0	835	0	5	6	93	75.1
6/18	0	7	7	5,076	1	836	0	5	0	93	74.8
6/19	0	7	1	5,077	0	836	0	5	1	94	75.2
6/20	0	7	4	5,081	0	836	0	5	0	94	75.1
6/21	0	7	3	5,084	0	836	0	5	0	94	75.2
6/22	0	7	6	5,090	0	836	0	5	0	94	76.6
6/23	0	7	2	5,092	0	836	0	5	1	95	77.8
6/24	0	7	4	5,096	0	836	0	5	4	99	77.1
6/25	0	7	0	5,096	0	836	0	5	4	103	76.7
6/26	0	7	1	5,097	0	836	0	5	0	103	78.4
6/27	0	7	0	5,097	0	836	0	5	1	104	78.8
6/28	0	7	0	5,097	0	836	0	5	2	106	79.8
6/29	0	7	0	5,097	0	836	0	5	6	112	79.9
6/30	0	7	0	5,097	0	836	0	5	2	114	79.2
Total		**7**		**5,097**		**836**		**5**		**114**	

Table 5-18. Numbers of monitored fishes passed through the fishway at Vernon Dam and mean daily water temperatures in the fishway in 2000.

Date	Atlantic Salmon		American Shad		Blueback Herring		Sea Lamprey		Gizzard Shad		
	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Mean T.
5/22	0	0	0	0	0	0	0	0	0	0	52.64
5/23	0	0	0	0	0	0	0	0	0	0	52.95
5/24	0	0	20	20	0	0	0	0	0	0	53.97
5/25	0	0	13	33	0	0	0	0	0	0	55.28
5/26	0	0	3	36	0	0	0	0	0	0	56.22
5/27	0	0	15	51	0	0	0	0	0	0	57.14
5/28	0	0	29	80	0	0	0	0	0	0	57.94
5/29	0	0	47	127	0	0	0	0	0	0	58.64
5/30	0	0	19	146	0	0	1	1	0	0	60.02
5/31	0	0	24	170	0	0	5	6	0	0	61.91
6/1	0	0	44	214	0	0	5	11	0	0	63.67
6/2	0	0	75	289	0	0	4	15	0	0	65.40
6/3	1	1	57	346	0	0	9	24	0	0	66.19
6/4	1	2	58	404	0	0	15	39	0	0	66.89
6/5	0	2	18	422	0	0	9	48	0	0	66.23
6/6	0	2	45	467	0	0	11	59	0	0	64.37
6/7	0	2	3	470	0	0	0	59	0	0	59.37
6/8	0	2	1	471	0	0	2	61	0	0	58.56
6/9	0	2	1	472	0	0	0	61	0	0	59.61
6/10	0	2	3	475	0	0	12	73	0	0	62.60
6/11	0	2	43	518	0	0	38	111	0	0	64.86
6/12	0	2	36	554	0	0	23	134	0	0	65.14
6/13	1	3	28	582	0	0	13	147	0	0	64.44
6/14	2	5	5	587	0	0	16	163	0	0	64.25
6/15	0	5	47	634	0	0	13	176	0	0	62.90
6/16	0	5	10	644	0	0	18	194	0	0	63.35
6/17	0	5	14	658	0	0	143	337	0	0	66.31
6/18	0	5	2	660	0	0	46	383	0	0	65.90
6/19	0	5	13	673	0	0	92	475	0	0	66.74
6/20	0	5	20	693	0	0	79	554	0	0	68.14
6/21	0	5	35	728	0	0	52	606	0	0	69.62
6/22	0	5	35	763	0	0	56	662	0	0	70.47
6/23	0	5	5	768	0	0	73	735	0	0	70.65
6/24	0	5	75	843	0	0	56	791	0	0	71.31
6/25	0	5	430	1273	0	0	38	829	1	1	72.18
6/26	0	5	260	1533	0	0	23	852	0	1	74.24
6/27	0	5	0	1533	0	0	0	852	0	1	73.99
6/28	0	5	2	1535	2	2	2	854	2	3	74.27
6/29	0	5	0	1535	0	2	0	854	0	3	74.84
6/30	0	5	0	1535	0	2	0	854	0	3	75.38
7/1	0	5	0	1535	0	2	0	854	0	3	76.05
7/2	0	5	0	1535	0	2	0	854	0	3	76.67
7/3	0	5	0	1535	0	2	0	854	0	3	76.90
7/4	0	5	9	1544	0	2	1	855	0	3	77.23
7/5	0	5	0	1544	0	2	0	855	0	3	77.11
7/6	0	5	0	1544	0	2	0	855	0	3	76.12
7/7	0	5	4	1548	0	2	0	855	1	4	75.84
Total		5		1548		2		855		4	

Table 5-19. Numbers of monitored fishes passed through the fishway at Vernon Dam and mean daily water temperatures in the fishway in 2001.

Date	Atlantic Salmon		American Shad		Sea Lamprey		Striped Bass		Gizzard Shad		
	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Mean T.
5/22	0	0	68	68	0	0	0	0	0	0	59.5
5/23	0	0	123	191	9	9	0	0	0	0	58.1
5/24	0	0	100	291	2	11	0	0	0	0	61.5
5/25	0	0	107	398	28	39	0	0	1	1	62.1
5/26	0	0	95	493	13	52	0	0	0	1	61.8
5/27	0	0	45	538	16	68	0	0	0	1	61.4
5/28	0	0	38	576	24	92	0	0	0	1	61.3
5/29	0	0	33	609	12	104	0	0	0	1	61.2
5/30	0	0	46	655	6	110	0	0	2	3	61.5
5/31	0	0	42	697	9	119	0	0	1	4	61.6
6/1	0	0	41	738	64	183	0	0	0	4	62.3
6/2	0	0	17	755	12	195	0	0	0	4	60.5
6/3	0	0	5	760	6	201	0	0	0	4	57.6
6/4	0	0	0	760	0	201	0	0	0	4	57.1
6/5	0	0	5	765	24	225	0	0	0	4	
6/6	0	0	1	766	10	235	0	0	0	4	
6/7	0	0	10	776	111	346	0	0	0	4	60.0
6/8	0	0	2	778	66	412	0	0	0	4	61.9
6/9	0	0	5	783	196	608	0	0	0	4	64.4
6/10	0	0	0	783	373	981	0	0	0	4	66.1
6/11	0	0	18	801	325	1,306	0	0	0	4	66.4
6/12	0	0	3	804	210	1,516	0	0	0	4	64.6
6/13	0	0	24	828	251	1,767	0	0	0	4	63.9
6/14	0	0	65	893	303	2,070	0	0	0	4	66.6
6/15	0	0	94	987	270	2,340	0	0	0	4	69.5
6/16	0	0	107	1,094	366	2,706	0	0	0	4	72.0
6/17	1	1	64	1,158	265	2,971	0	0	0	4	73.1
6/18	0	1	15	1,173	132	3,103	0	0	0	4	73.9
6/19	0	1	10	1,183	49	3,152	1	1	0	4	75.2
6/20	0	1	17	1,200	29	3,181	0	1	0	4	76.7
6/21	0	1	5	1,205	11	3,192	0	1	0	4	75.7
6/22	0	1	6	1,211	8	3,200	0	1	0	4	75.6
6/23	0	1	0	1,211	8	3,208	0	1	0	4	75.3
6/24	0	1	179	1,390	1	3,209	0	1	0	4	75.4
6/25	0	1	208	1,598	2	3,211	0	1	0	4	75.8
6/26	0	1	19	1,617	1	3,212	0	1	0	4	76.4
6/27	0	1	13	1,630	0	3,212	0	1	0	4	77.9
6/28	0	1	14	1,644	0	3,212	0	1	0	4	78.5
6/29	0	1	22	1,666	0	3,212	0	1	0	4	77.2
6/30	0	1	29	1,695	0	3,212	0	1	0	4	78.2
7/1	0	1	40	1,735	0	3,212	0	1	0	4	78.0
7/2	0	1	5	1,740	0	3,212	0	1	0	4	75.9
7/3	0	1	4	1,744	0	3,212	0	1	0	4	76.1
Total		1		1,744		3,212		1		4	

Table 5-20. Numbers of monitored fishes passed through the fishway at Vernon Dam and mean daily water temperatures in the fishway in 2002.

Date	Atlantic Salmon		American Shad		Sea Lamprey		
	Daily	Cum.	Daily	Cum.	Daily	Cum.	Mean T.
6/5	0	0	9	9	36	36	
6/6	0	0	159	168	289	325	
6/7	0	0	26	194	24	349	
6/8	0	0	37	231	0	349	
6/9	0	0	19	250	0	349	
6/10	0	0	39	289	46	395	
6/11	0	0	23	312	852	1,247	68.3
6/12	0	0	8	320	345	1,592	67.0
6/13	0	0	1	321	12	1,604	64.1
6/14	0	0	0	321	7	1,611	61.3
6/15	0	0	0	321	9	1,620	58.9
6/16	0	0	0	321	9	1,629	58.8
6/17	0	0	0	321	9	1,638	58.7
6/18	1	1	0	321	77	1,715	59.7
6/19	0	1	0	321	3	1,718	61.8
6/20	0	1	0	321	186	1,904	64.5
6/21	0	1	0	321	38	1,942	66.8
6/22	0	1	0	321	57	1,999	68.3
6/23	0	1	8	329	48	2,047	69.3
6/24	0	1	3	332	10	2,057	68.2
6/25	0	1	0	332	27	2,084	70.6
6/26	0	1	0	332	30	2,114	71.9
6/27	0	1	2	334	68	2,182	73.0
6/28	1	2	10	344	23	2,205	71.4
6/29	0	2	1	345	2	2,207	70.8
6/30	0	2	6	351	1	2,208	72.2
7/1	0	2	4	355	2	2,210	73.7
7/2	0	2	1	356	0	2,210	75.9
7/3	0	2	0	356	0	2,210	77.1
Total		2		356		2,210	

Table 5-21. Upstream passage and migration rates for American shad at three consecutive dams on the Connecticut River, 1995-2002.

	Approximate Number of American Shad			Migration Rate (%)	
Year	Holyoke	Turners Falls	Vernon	Turners/Holyoke	Vernon/Turners
1995	190,000	18,912	15,771	10.0%	83.4%
1996	276,289	18,485	18,884	6.7%	102.2%
1997	298,000	9,216	7,384	3.1%	80.1%
1998	311,704	10,527	8,151	3.4%	77.4%
1999	193,782	6,756	5,083	3.5%	75.2%
2000	225,000	2,590	800	1.2%	30.9%
2001	273,000	1,520	1,666	0.6%	109.6%
2002	376,000	2,870	356	0.8%	12.4%
			Mean =	**3.6%**	**71.4%**

Table 5-22. Vernon Dam Fishway Periods of Operation and Observed Water Temperatures 1998-2002.

Year	Fishway Operations		Observed Water Temperatures °F at Monitoring Station From Start of Fishway through 10 July						Predicted Hours At or Above 80°F Under New Permit		Percent of Time 15 May - 10 July At or Above 80°F Under New Permit	
	Start Date	End Date	Max Temp.[1]	Max Temp.[1]	Max Temp.[1]	Mean Difference	Min Difference	Max Difference	Downstream		Downstream	
			Upstream Sta. 7	Downstream Sta. 3	Fishway	Fishway Sta. 3	Fishway Sta. 3	Fishway Sta. 3	Sta. 3	Fishway	Sta. 3	Fishway
1998	14-May-98	23-Jul-98	70.2	72.6	74.6	0.1	-2.3	3.3	0	0	0.0%	0.0%
1999	18-May-99	2-Jul-99	78.7	83.5	81.9	0.3	-3.6	2.6	40	88	2.9%	6.4%
2000	22-May-00	13-Jul-00	72.7	78.0	79.0	0.5	-6.4	3.6	0	1	0.0%	0.1%
2001	22-May-01	5-Jul-01	73.6	83.2	79.7	-2.0	-7.5	2.2	141	19	10.3%	1.4%
2002	11-Jun-02	18-Jul-02	74.8	79.2	80.8	0.4	-1.3	3.0	4	29	0.3%	2.1%

Notes: Vermont Yankee did not discharge heated effluent during the period 30 March through 3 June 1998 due to a refueling outage.

[1]Maximum temperatures observed upstream, downstream, or in the fishway were selected independently and may not occur on the same date and time

Table 5-23. Travel and residency time of Atlantic , and 1996; at Wilder Station in 1994; and at Bellows Falls in 1995.

Year	Sample Size	Vernon Dam Forebay Water temp.	(miles up	verage Residency me at Vernon Dam ll 3 Release Groups	Range of Residency Time at Vernon Dam
14-27 May 1994 A	Vernon 194	50.9-69°F 50.9-69°F 50.9-69°F	0.6 mi (n = 116 4.1 mi 75 mi (n = 4	8 hr 53 min 6 hr 35 min	2 min to 3d 8hr 28min 2 min to 2d 14hr 50 min
4-15 May 1995 B	Vernon 193	.51.8-57.2°F 51.8-57.2°F	4.1 mi 32 mi (n =	11 hr 15 min 14 hr 1 min	10 min to 2d 22 hr 30 min 26 min to 3d 7hr 5 min
30 May to 8 June 1996 C	Vernon 89	60.0-72.5°F	4.1 m	6 hr 26 min	2 min to 3d 16hr 25 min
13 May to 2 June 1994 D	Wilder 169	49 - 61°F	appro	vg residency time at Wilder 16 hr 11 min	range of residency time at Wilder 1 min (immediate passage) to 3 days 7 hours
3-6 May 1995 E	Bfalls 152	51-56°F	approx of	vg residency time at Bellows 11 minutes not reported	range of residency at Bellows 1 min to 1.5 hours 1 min to 1 day 9 hours

Fish diversion boom excluded 121 of the 144 (84%) smolts from the forebay
Station (i.e. n = 144).
23 of the 144 smolts observed swam under the fish diversion boom and the
Citations:
A Normandeau Associates, Inc., RMC Division (1994a).
B Normandeau Associates, Inc., (1995a)
C Normandeau Associates, Inc., (1996)
D Normandeau Associates, Inc., RMC Division (1994b)
E Normandeau Associates, Inc. (1995b)

5.2 TEMPERATURE EFFECTS ASSESSMENT FOR NINE REPRESENTATIVE IMPORTANT SPECIES OF FISH

This section presents both a retrospective (Type I) analysis based on the distribution and life history of each of the nine RIS, and a predictive (Type II) analysis of the effects (if any) of habitat changes resulting from Vermont Yankee's proposed new summer period thermal discharge limits. The combination of a retrospective and a predictive analysis is considered a Type III §316(a) demonstration by the U.S. EPA (EPA 1977).

The retrospective analysis was used to establish the existing baseline conditions and to determine if the interannual trends in RIS abundance in lower Vernon Pool and in the Vernon Dam tailwaters during this baseline period substantiate a finding of no prior appreciable harm. The occurrence and relative abundance of each RIS of fish found in the vicinity of Vermont Yankee was described during the most recent 12-year period of permit-required monitoring (1991-2002). The 1991 through 2002 period was considered the baseline period because the existing summer period (16 May through 14 October) thermal permit limits allowing a calculated temperature increase of 2, 3, 4, or 5°F first became effective in 1991, and have remained unchanged since then. Vermont Yankee was first allowed to discharge heated effluent into the Connecticut River during the summer period of 1982, and these summer discharges continued annually through 1990 at the discretion of VANR; however the timing and duration of discharge varied from year to year and different thermal limits were applied during these periods to experimentally evaluate discharge conditions (Downey et al. 1990).

A nonparametric Mann-Kendall test was used to examine the 1991-2002 time series for significant increasing or decreasing trends (Helsel and Hirsch 1991, Chapter 12) in annual total catch per unit of effort (CPUE) for each of the nine RIS. The field sampling design has relatively consistently sampled the same stations with the same gear during the same months in each of the twelve consecutive years in the electrofishing time series, and for each of the nine consecutive years in the trap net time series (1991-1999), making annual total CPUE the appropriate response variable in the time series analysis (Appendix 4). The Mann-Kendall test is robust with respect to parametric assumptions of data normality and variance heterogeneity (Helsel and Hirsch 1991; Siegel 1956), and was performed on untransformed annual total CPUE. The null hypothesis was that there is no statistically significant ($p<0.05$) interannual trend in abundance during the period analyzed as measured by the Kendall Tau b correlation coefficient. If a statistically significant negative (decreasing) trend was observed, it was interpreted with respect to whether the plant thermal discharge may be a contributing factor by examining the time series trend in a subset of the data representing the population directly exposed to Vermont Yankee's thermal plume compared to the population outside of the influence of the plume. Finding no significant trend over time or finding a significant increasing trend was considered to statistically support a finding of "no prior appreciable harm."

The predictive analysis was based on estimates of change in habitat suitability within lower Vernon Pool and the Vernon Dam tailwaters for selected life history or thermal response functions under proposed new thermal limits for both the average case (occurs 50% of the time) and extreme case (occurs 1% of the time) hydrothermal model scenarios discussed in Sections 3 and 4. This predictive assessment relies on the thermal effects parameters for each RIS obtained from the available published literature (see Appendix 2). Habitat suitability in lower Vernon Pool was quantified using the volume and bottom area predicted to be at or above the water temperature reported for each thermal effects parameter. The thermally influenced portion of lower Vernon Pool (located from

Vermont Yankee's discharge weir downstream to Vernon Dam) is represented by 324 acres of bottom habitat and 0.194 billion cubic feet of volume out of a total of 2,481 acres and 1.3814 billion cubic feet of volume contained in the entire Vernon Pool between Vernon Dam upstream to the foot of Bellows Falls Dam. A data table is presented for each RIS of fish that summarizes the percent and amount (volume or area) of habitat predicted to exceed the thermal effects temperatures under the existing and proposed new summer temperature limits for the average and extreme case hydrothermal model scenarios.

The predictive analysis for the Vernon Dam tailrace area was based on the difference in probability of occurrence and time exposure of the mixed River water temperatures observed or predicted to occur at Station 3 for Vermont Yankee's existing or proposed new thermal discharge limits. Station 3 is located 0.65 miles downstream from Vernon Dam (Figure 1-1). The River is about 40 ft wide and 10 to 30 feet deep at Station 3, and water temperatures are spatially more homogeneous than upstream in lower Vernon Pool due to the mixing of water as it passes through the Vernon Station hydroelectric turbines. The following example illustrates how the time increase is derived for 83°F, the avoidance temperature for yellow perch (Appendix 2). Under the existing conditions, the measured downstream Station 3 river water temperatures were equal to or exceeded 83°F for 0.30% of the hours during the combined summer periods of 1998-2002 (Table 3-3, column 4). Under the proposed new summer thermal limits, the predicted Station 3 river water temperatures would equal to or exceeded 83°F for 2.08% of the summer period hours (Table 3-3, right hand column). The increase in percent of time at or above a given temperature under the proposed new limits is calculated as the difference between the proposed new and existing percent exceedances, which for 83°F is 1.8% (2.08% - 0.30% = 1.78% ~ 1.8%). Therefore, we predict that under Vermont Yankee's proposed new summer thermal limits, the measured downstream Station 3 river water temperatures will be at or above the reported avoidance temperature of 83°F for yellow perch for 1.8% of the summer period hours. There are 3,648 hours during the entire summer period from 16 May through 14 October of each year, therefore the predicted Station 3 water temperature is expected to be at or above 83°F for about 65 hours more under the new permit limits compared to the existing permit limits.

The temperature response data and supporting literature sources for each RIS are provided in Appendix 2 and include: (1) the maximum temperature for summer survival and/or upper incipient lethal temperature, (2) the avoidance temperature, (3) the optimum temperature for growth, (4) the preferred temperature, (5) the temperature of first spawning, and (6) the temperature for egg incubation and larval development (referred to as early life history). The following paragraphs briefly define these terms, and how the thermal response data were developed for each of the six categories.

There are fundamentally two different classes of thermal effects parameters among the six categories: exclusionary and indicator temperature limits. The maximum temperature and the avoidance temperature are considered exclusionary thermal effects because the fish species will not be found in habitat where the water temperature is at or above the reported values for any sustained period of time. The fish species is, therefore, excluded from use of the portion of the habitat for the time that the portion is at or above the maximum or avoidance temperatures. The remaining four categories of thermal effects parameters, optimum, preferred, spawning and early life history, are considered indicator parameters because they are water temperature values that coincide with the physiological or life history events represented by the thermal effects parameters. For example, a given fish species is not likely to change its distribution in response to the water temperature in the habitat occupied that

is not at the optimum or preferred temperature. The fish species is likely to remain exposed to water temperatures that are different than the optimum or preferred temperatures for different periods of time under existing or predicted new thermal discharge limits rather than actively search for optimum or preferred conditions. Likewise, the spawning and incubation or larval development thermal effects parameters describe the water temperatures occurring during those life history events.

The "maximum temperature" for summer survival is generally regarded as a peak temperature during the warmest time of the year that can be tolerated by a species for brief time periods, and is therefore considered exclusionary. The maximum temperature is higher than the indicator temperatures. The maximum temperature is routinely derived from field observations. The "upper incipient lethal temperature" or UILT is a lethal threshold temperature obtained from laboratory experiments in which fish are removed from a temperature they are acclimated to and placed in a range of other temperatures that typically result in a range of survival from 100% to 0%. The ultimate upper incipient lethal temperature or UUILT is the temperature beyond which no increase in lethal temperature results from increase in acclimation temperature. It is important to understand that fish will avoid water temperatures that exceed the avoidance temperature when escape routes are available and will not succumb to lethal temperatures unless trapped. "Optimum temperatures for growth" are developed from field observation of feeding behavior, which usually yield a range of temperatures, or more precisely from physiological experiments. A commonly used temperature criterion for growth is the maximum weekly average temperature or MWAT. The MWAT is considered the highest temperature that will maintain growth of the organism at levels necessary for sustaining actively growing and reproducing populations. The MWAT is calculated as a temperature that should not exceed one-third of the range between the optimum temperature for growth and the UUILT of the species. For many species, the final preferred temperature has been found to be coincident with optimum temperatures for growth and is used as a surrogate for optimum growth temperature when the latter is unavailable.

Since fish are motile, behavior responses to a thermal variation include avoidance, preference or merely a physiological adjustment as they pass through or remain exposed to it. Determination of temperatures that are avoided and preferred is usually based on laboratory experiments, but field collection data provided useful information when reported in the literature. The mid-range of the observed and reported temperatures for spawning and for egg incubation and larval development were selected as the indicator temperatures for these life history events. While the effects of all variables that regulate fish populations are incompletely understood, direct effects of temperature are accepted and allow evaluation of the potential impacts of the predicted temperature regime from the proposed new thermal limits by Vermont Yankee during the summer period.

5.2.1 American Shad

American shad (*Alosa sapidissima*) is an anadromous species that inhabits the Atlantic Coast waters from Newfoundland south to Florida, and they are most abundant from Connecticut to North Carolina. American shad were introduced on the Pacific Coast in 1871 into the Sacramento and Columbia Rivers. They can now be found from southern California to Cooks Inlet, Alaska (Scott and Crossman 1973).

American shad juveniles represent the insectivore trophic guild of fish species that are reported to be intermediate in their tolerance to pollution (Table 2-1). While migrating upstream, adult American shad consume little to no food. Juvenile American shad have also been classified in the filter feeder trophic guild by some researchers and feed on *Daphnia* sp., immature midges (chironomids), and other freshwater planktonic crustaceans (Scott and Crossman 1973).

During the 30 years of monitoring at Vermont Yankee, juvenile and adult American shad have been collected both upstream and downstream of Vernon Dam. Installation and operation of the Vernon Dam fishway in 1981 allowed access to the spawning and nursery habitat in lower Vernon Pool for the first time since the dam was built. Accordingly, the proportion of the total electrofishing and trap net catch composed of juvenile American shad in lower Vernon Pool was 0% in 1968-1980, the proportion of the catch increased to 0.7% in 1981-1990, and was 0.4% in 1991-2002 (Table 5-14). Downstream of Vernon Dam, American shad were zero percent of the electrofishing and trap net catch in 1968-1980, 9.5% in 1981-1990, and 7.4% in 1991-2002.

The annual catch of American shad by electrofishing from 1991-2002 in lower Vernon Pool (Table 5-9) was highest in 1992 (3.6 fish per hour). No American shad were caught by electrofishing in the lower Vernon Pool in years 1997, 1998, 1999, 2001, or 2002. Catch per unit effort of American shad by electrofishing was higher downstream from Vernon Dam (Table 5-10) where the highest annual CPUE was in 1991 (30 fish per hour) and the lowest in 1999 (0.4 fish per hour). A total of four American shad were collected by trap netting in lower Vernon Pool between 1991 and 1999 (Table 5-11) with the highest CPUE in 1995 (0.05 fish per day). The annual CPUE by trap netting downstream from Vernon Dam (Table 5-12) ranged between a high in 1998 of 1.0 fish per day and a low of zero fish per day in 1996.

There was one statistically significant negative (decreasing) trend observed in American shad annual total CPUE during the 1991-2002 period. The decreasing trend was observed in the time series of annual total electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau b of –0.625 with a probability level of p=0.007 (Figure 5-24a). The electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall Tau b of –0.242 with a probability level of p=0.273 (Figure 5-24c). Kendall's Tau b correlation coefficient for the annual total trap net CPUE time series from lower Vernon Pool was 0.215 with a probability level of 0.469 (Figure 5-24b), and the correlation coefficient for the trap net data from the Vernon Dam tailrace was 0.000 with a probability level of p=1.000 (Figure 5-24d). This decrease appears to be correlated with lower annual fish passage counts in recent years at the Vernon Dam fishway beginning in about 1997 and continuing through 2003 (Table 5-21).

A closer examination of the significantly decreasing interannual trend in juvenile American shad CPUE observed in the general electrofishing program during 1991-2002 revealed that the decrease occurred both at sampling stations upstream from Vermont Yankee's discharge and at stations

exposed to the thermal plume in lower Vernon Pool (Figure 5-25, Table 5-24). Stations 5, Rum Point, and the New Hampshire Setback (Figure 5-1) were all upstream from the influence of Vermont Yankee's thermal plume, and the trend in the combined general electrofishing CPUE for juvenile American shad from these upstream locations exhibited a significant decreasing trend with a Kendall Tau b correlation coefficient of -0.642 and a significance probability of p=0.007 (Figure 5-25a). Station 4 was within lower Vernon Pool but downstream from Vermont Yankee's discharge (Figure 5-1), and the trend in the combined general electrofishing CPUE for juvenile American shad from this downstream location exhibited a decreasing trend with a Kendall Tau b correlation coefficient of -0.431, although this decrease was not significant because the probability of p=0.066 was greater than the test probability of p=0.05 (Figure 5-25b). Therefore, it is unlikely that the finding of an overall significant decrease in juvenile American shad CPUE from the general electrofishing program conducted in lower Vernon Pool during the period 1991 through 2002 can be attributed to Vermont Yankee's thermal discharge.

The decrease in American shad CPUE observed in the general electrofishing program conducted in lower Vernon Pool during the period 1991 through 2002 is most noticeable beginning in 1996 or 1997 and continuing through 2002 (Figures 5-24, 5-25). When Normandeau first began the field program in 1996, our field biologists observed what appeared to be the ineffectiveness of the electrofishing gear to stun and capture juvenile American shad in lower Vernon Pool, while the same gear and deployment practices were effective in capturing juvenile American shad in the Vernon Dam tailrace (Normandeau 1998, Appendix 1 - Bulletin # 70). The observed ineffectiveness applied to both the general electrofishing survey, and to a supplemental survey referred to as the anadromous fish electrofishing survey, which sampled biweekly in the intervening times between the monthly general electrofishing sampling events in each year. Numerous discussions were held between Normandeau, the EAC, and VANR, and several field evaluations were performed among these parties in a failed attempt to diagnose and remedy the situation. Finally, in 2000, and with the concurrence of the EAC and VANR, the anadromous electrofishing program in lower Vernon Pool was replaced with a biweekly program of seining and midwater trawling (Normandeau 2001, Appendix 1 - Bulletin # 76). The anadromous fish electrofishing survey continues annually to date in the Vernon Dam tailrace area. Therefore, the significant decrease in American shad annual total CPUE for electrofishing in lower Vernon Pool is most likely due to a change in the collection efficiency of the sampling method beginning in 1996 and not due to any effect of Vermont Yankee's thermal plume.

Based on the maximum and avoidance threshold temperatures (Table 5-25) for American shad, and the predicted plume temperature contours (Figures 5-26 and 5-27), the increase in river water temperature due to the new permit limits would exclude American shad from using between 0 and 0.3 acres of existing benthic habitat (0.0% to 0.1% of 324 acres) under the proposed new Vermont Yankee thermal limits that they presently have access to under the existing permit limits. No habitat exclusion is predicted for the maximum survival temperature with either modeling scenario because the thermal plume never reaches 90°F. The excluded 0.3 acres of bottom habitat is predicted to occur for the avoidance temperature of 86°F modeled under the extreme case (1% occurrence) low flow and upstream temperature conditions. This acreage is located near and immediately downstream from the plant discharge weir on the west side of lower Vernon Pool (Figure 5-27). The 0.3 acres of bottom habitat avoided by American shad during extreme conditions, represents 0.01% of the total aquatic habitat area available in Vernon Pool.

The exclusion of American shad from up to 0.3 acres of bottom habitat is lower Vernon Pool describes the spatial extent of the predicted impact for the extreme (1% occurrence) case with respect to the avoidance temperature for American shad (Table 5-25), but the temporal aspect during which the exclusion is predicted to occur should be considered to fully understand the extent of the predicted impacts. For example, 0.3 additional acres of benthic habitat under the extreme case scenario are predicted to be warmer than the avoidance temperature of 86°F for American shad. This means that during 1 percent of the summer period (36 hours), 0.3 more acres of habitat will exceed the reported avoidance temperature under the proposed new thermal limits than under the existing limits. For the average case summer period conditions modeled, there is no increase in the extent of the thermal plume area above 86°F because the entire plume never reaches 86°F for both the proposed new limits and for the existing conditions. It should be noted that Station 7, upstream from Vermont Yankee discharge, is never at or above 80°F during the summer period, so Vermont Yankee's mixed thermal discharge never reaches the avoidance temperature of 86°F under the existing permit delta T (+2°F) or under the proposed new summer period delta T (+3°F).

There is no change in the predicted habitat volume or bottom area for both the average case and extreme case conditions under the proposed new summer temperature limits compared to the existing discharge conditions in regards to all indicator thermal effects parameters for American shad (Table 5-25). American shad has a optimum temperature for growth at 70°F, preferred temperature is 65°F, the mid-range of the reported spawning temperature is about 65°F, and the mid-to upper incubation temperature for egg and larval development is 70°F (Table 5-25). The indicator thermal effects parameters are naturally exceeded in Vernon Pool before the summer period; therefore no change is predicted for any of these parameters.

The water temperature at Station 3 never reaches the maximum temperature for summer survival (UILT) or the avoidance temperature for American shad (Table 5-25), under the proposed new thermal discharge limits, therefore there is no predicted increase in hours that Station 3 exceeds these temperatures. The optimum temperature for both growth and larval development is predicted to be exceeded for 162.7 hours or 4.5% more of the time under the proposed new limits compared to the existing limits. The predicted increase in time at or above both the preferred temperature and spawning temperature is 167.4 hours or 4.6% (Table 5-25).

American shad typically begin ascending the Connecticut River in April and continue through early July. Spawning takes place in open water, and the fertilized eggs are carried by the current. Peak spawning activity generally occurs within a temperature range of 57 to 70°F. The young spend the summer in fresh water and migrate downstream in late summer and fall. Eggs and larvae of American shad have not been collected in the nearfield ichthyoplankton sampling performed annually in lower Vernon Pool as a permit-required monitoring program. Under the proposed new temperature limits for Vermont Yankee, there is little potential for the thermal plume to adversely affect the spawning of American shad. No difference was calculated in the available plume volume or bottom area under the average or extreme case thermal plume conditions for American shad spawning or early life history (Table 5-25, Figures 5-26 and 5-27). The ideal temperatures for spawning and for juvenile shad are naturally exceeded before the summer period. It has been found, however, that juvenile American shad are capable of detecting and avoiding potentially lethal temperature changes (Moss 1970).

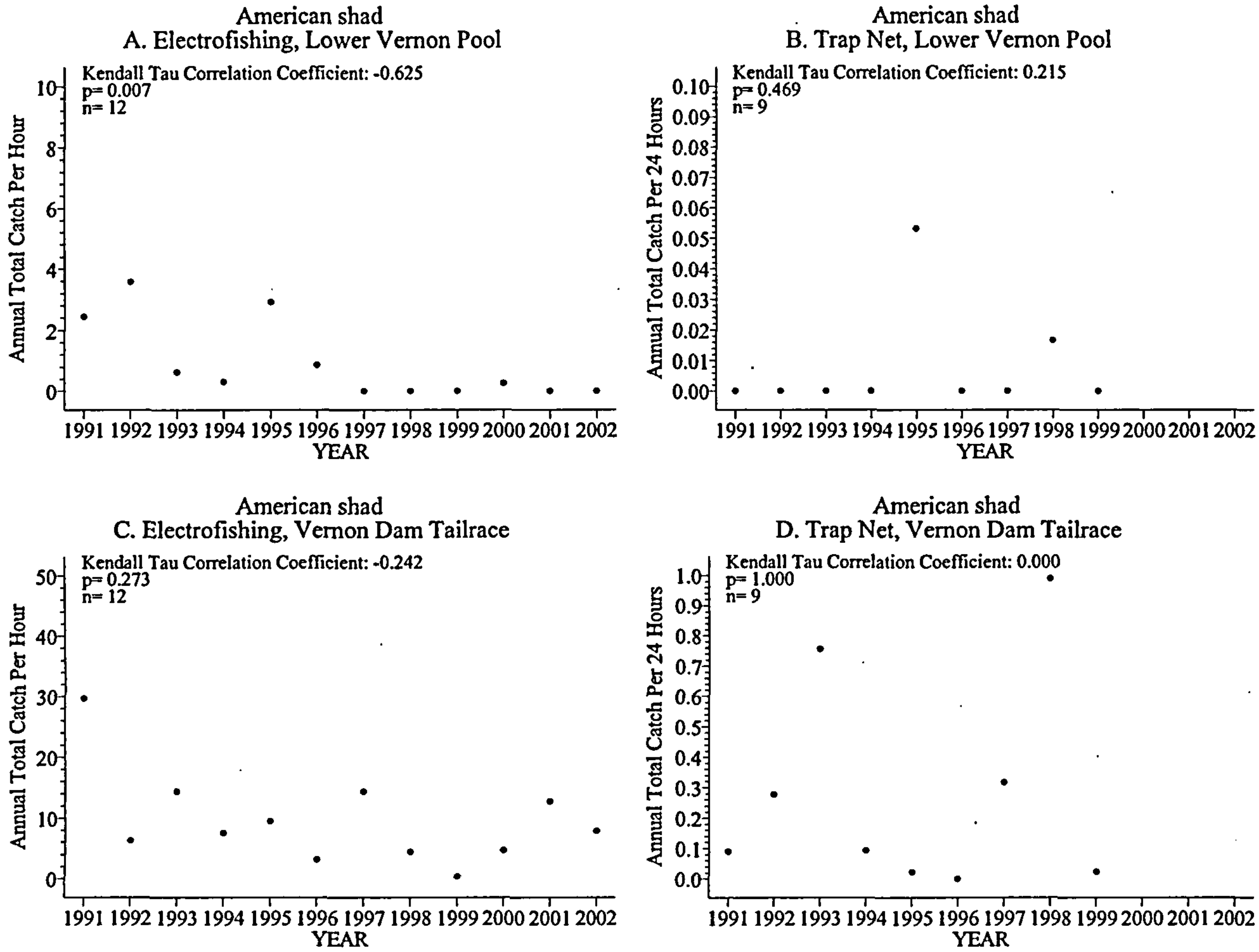
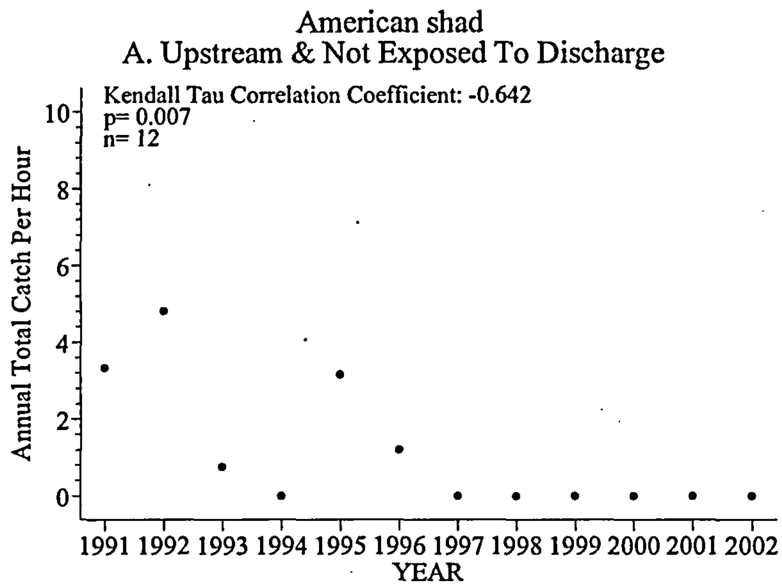


Figure 5-24. Scatter plots comparing American shad annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



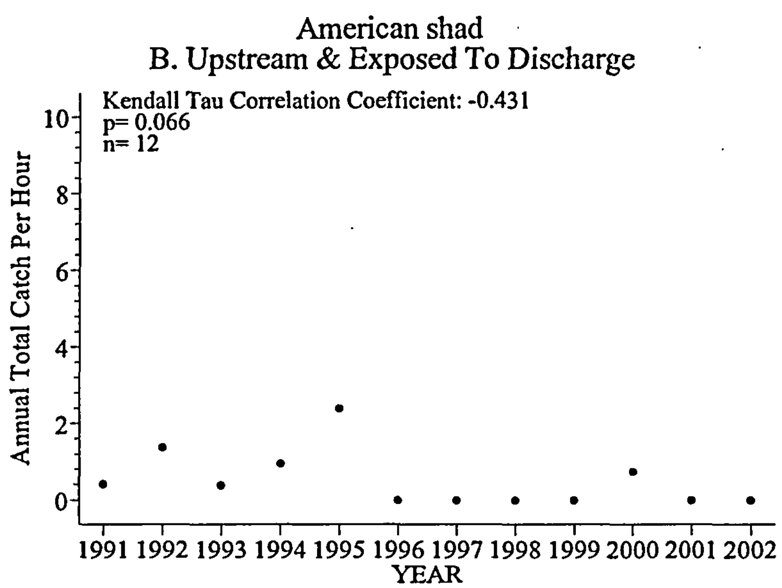
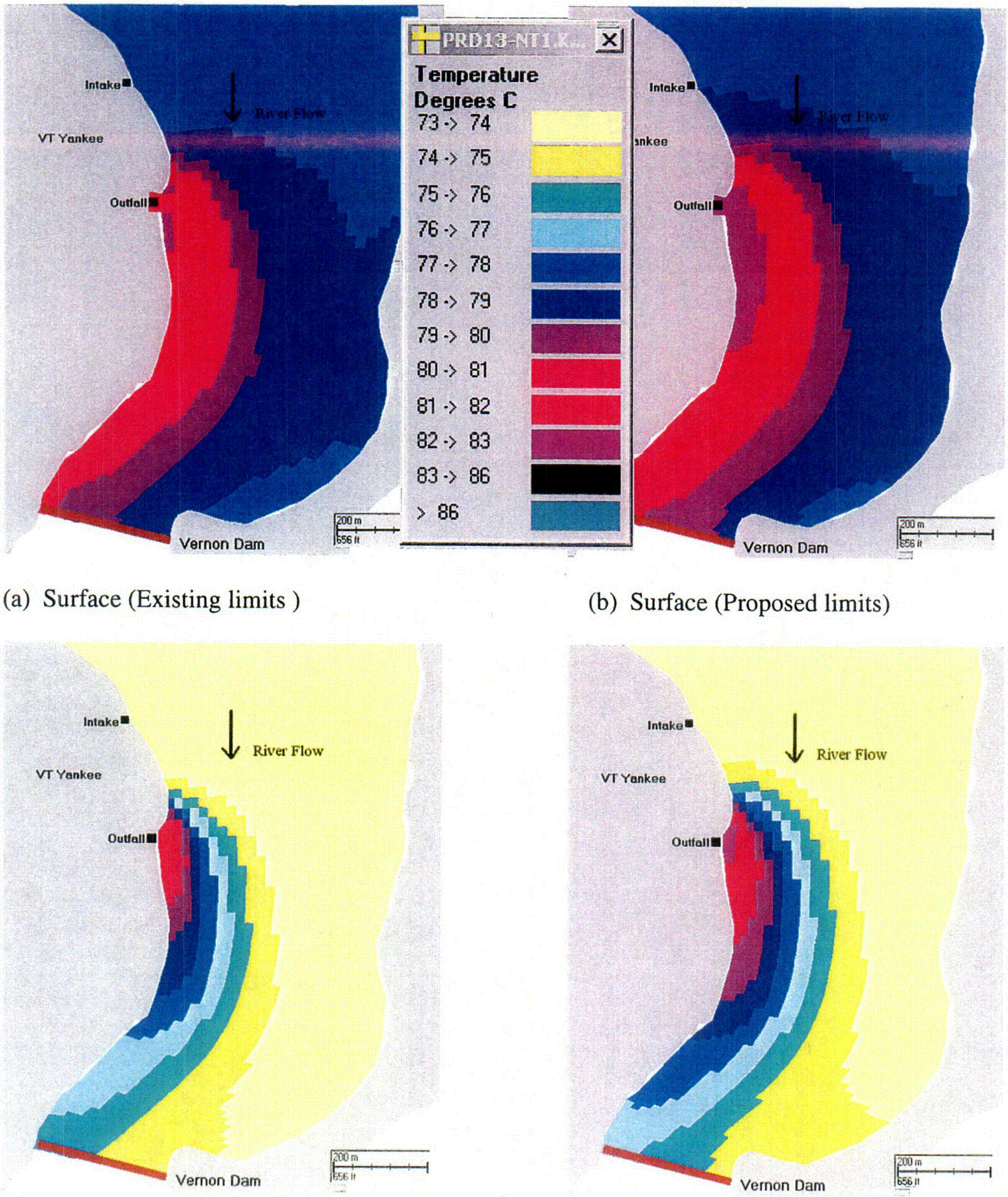


Figure 5-25. Annual total catch per unit effort of American shad collected by general electrofishing in areas exposed and not exposed to the discharge in lower Vernon Pool during 1991-2002.



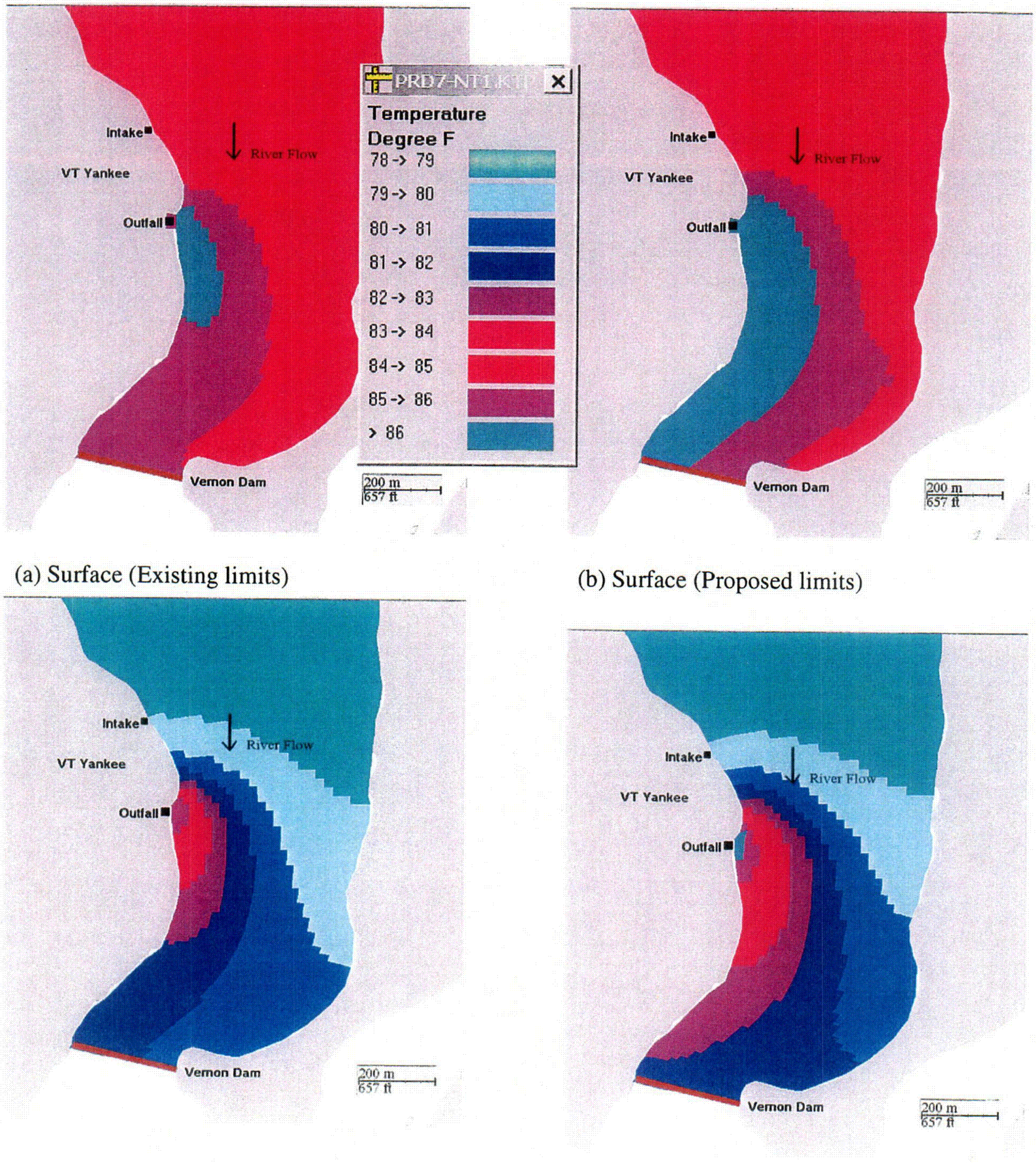
(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-26. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the American shad avoidance temperature of 86°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Existing limits)

Figure 5-27. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the American shad avoidance temperature of 86°F.

Table 5-24. Annual total catch per unit effort of American shad collected by general electrofishing in Connecticut River, in the vicinity of Vernon, VT during 1991-2002.

	Upstream of Vernon Dam & Not Exposed to Discharge				Upstream of Vernon Dam & Exposed to Discharge				Total			
	N	Count	Effort (h)	CPUE	N	Count	Effort (h)	CPUE	N	Count	Effort (h)	CPUE
1991	16	18	5.40	3.33	8	1	2.40	0.42	24	19	7.80	2.44
1992	16	25	5.20	4.81	8	4	2.90	1.38	24	29	8.10	3.58
1993	16	4	5.30	0.75	8	1	2.60	0.38	24	5	7.90	0.63
1994	16	0	4.40	0.00	8	2	2.10	0.95	24	2	6.50	0.31
1995	16	18	5.70	3.16	8	6	2.50	2.40	24	24	8.20	2.93
1996	14	3	2.50	1.20	6	0	0.97	0.00	20	3	3.47	0.87
1997	16	0	2.67	0.00	8	0	1.33	0.00	24	0	4.00	0.00
1998	16	0	2.77	0.00	8	0	1.55	0.00	24	0	4.32	0.00
1999	16	0	2.72	0.00	8	0	1.28	0.00	24	0	4.00	0.00
2000	16	0	2.50	0.00	8	1	1.35	0.74	24	1	3.85	0.26
2001	16	0	2.67	0.00	8	0	1.33	0.00	24	0	4.00	0.00
2002	16	0	2.70	0.00	8	0	1.33	0.00	24	0	4.03	0.00

Table 5-25. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for American shad between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[1] in % Time Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Max. for summer survival, or UILT	90	0.0	0.0	0.0	0.0	0.0
Avoidance	86	0.0	-0.3	0.0	-0.1	0.0
Indicator Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Optimum for growth	70	0.0	0.0	0.0	0.0	4.5
Preferred	65	0.0	0.0	0.0	0.0	4.6
Spawning	65	0.0	0.0	0.0	0.0	4.6
Early life history	70	0.0	0.0	0.0	0.0	4.5
B. Numeric Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[2] in Hours Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in Plume Volume (ft³ * 10⁴) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Max. for summer survival, or ULT	90	0.0	0.0	0.0	0.0	0.0
Avoidance	86	0.0	-64.0	0.0	-0.3	0.0
Indicator Temperatures		**Change[3] in Plume Volume (ft³ * 10⁴) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Optimum for growth	70	0.0	0.0	0.0	0.0	162.7
Preferred	65	0.0	0.0	0.0	0.0	167.4
Spawning	65	0.0	0.0	0.0	0.0	167.4
Early life history	70	0.0	0.0	0.0	0.0	162.7

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

5.2.2 Atlantic Salmon

Atlantic salmon, an anadromous fish, inhabits the North Atlantic Ocean basin from Greenland to the Connecticut River (Scott and Crossman 1973). While native to the Connecticut River, it was extirpated with construction of the downstream dams. It is presently the subject of extensive restoration efforts, with the result that the current population in the Connecticut River is essentially entirely maintained by stocking of fry and smolts.

The following life history information is summarized from Stanley and Trial (1995). In New England, Atlantic salmon spawn in gravely tributaries of major river systems in the fall. There, the eggs overwinter and hatch into young, termed parr. Parr remain in fresh water for one or two years before undergoing a physiological transformation to the smolt stage that prepares the fish for life in the sea. Once smoltification begins in April and May, the fish move into the mainstem of the River and migrate downstream to the Atlantic Ocean. The salmon will usually spend two winters at sea before returning as adults to their natal stream in May to July to spawn. Unlike Pacific salmon, Atlantic salmon do not necessarily die after spawning, but can return to the ocean and return to spawn again.

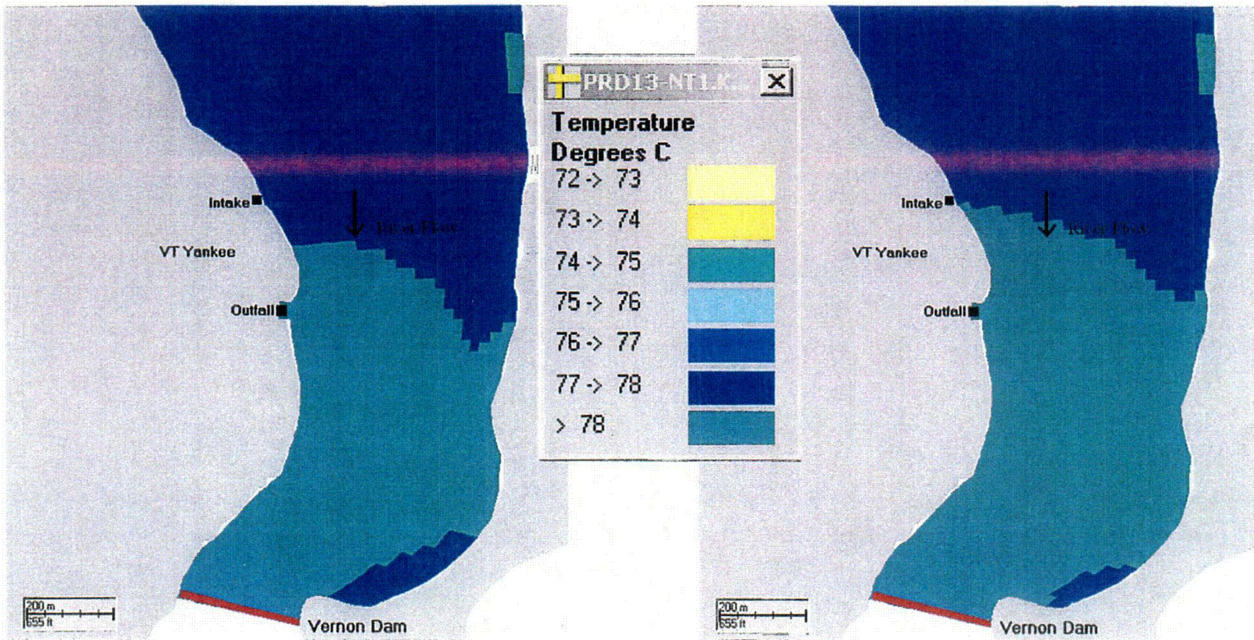
Most of the fry and parr stocking efforts in the Connecticut River basin have been in the West and White Rivers of Vermont and the Ammonoosic River of New Hampshire, all upriver of Vermont Yankee (CRASC 1998). If a wild population becomes established in the Connecticut River, spawning will most likely occur in these three primary tributaries with suitable habitat for spawning and parr survival. Reproduction in the mainstem of the Connecticut River, i.e. in the vicinity of Vermont Yankee, is highly unlikely due to lack of preferred spawning and nursery habitat. Thus, the relevant potential interaction between the thermal plume and this species will occur primarily during the transient upstream migration of adults and downstream migration of smolts. Vermont Yankee's thermal plume was found to have no influence on either the upstream migration of Atlantic salmon adults or the downstream migration of Atlantic salmon smolts past Vernon Dam (Section 5.1.3 of this Demonstration Report).

The restoration program for Atlantic salmon has met with limited success, and very low numbers of adults are re-entering the Connecticut River currently. Few adult salmon were passed at the Vernon Dam fishway over the past five years, 1998 – 2002, with a maximum of seven individuals tallied in 1998 (Tables 5-16 through 5-20). By way of further confirmation, this species is rarely collected during the regular permit-required monitoring program for Vermont Yankee; just three salmon smolts have been collected by trap net and electrofishing over the past 12 years between 1991 and 2002 (Table 5-6). No salmon were collected in lower Vernon Pool in either the electrofishing or trap netting between 1991 and 2002 (Tables 5-9 and 5-11). Downstream of Vernon Dam, one salmon smolt was captured electrofishing in 1995, and two smolts were collected in trap nets in 1991 (Tables 5-10 and 5-12). The annual salmon electrofishing CPUE downstream of Vernon Dam in 1995 was 0.2 fish per hour, which was 0.3% of the total catch (Table 5-10). The 1991 salmon trap net CPUE and percent composition downstream of Vernon Dam was 0.05 fish per 24 hours and 0.2% of total catch, respectively (Table 5-12).

The thermal effects data reviewed for this assessment confirm that, in addition to other habitat variables, the thermal environment throughout lower Vernon Pool and the Vernon Dam tailrace in upper Turners Falls Pool are not optimum for young salmon parr, therefore this lifestage is unlikely to naturally occur in this reach of the Connecticut River (Table 5-26). Available temperature effects

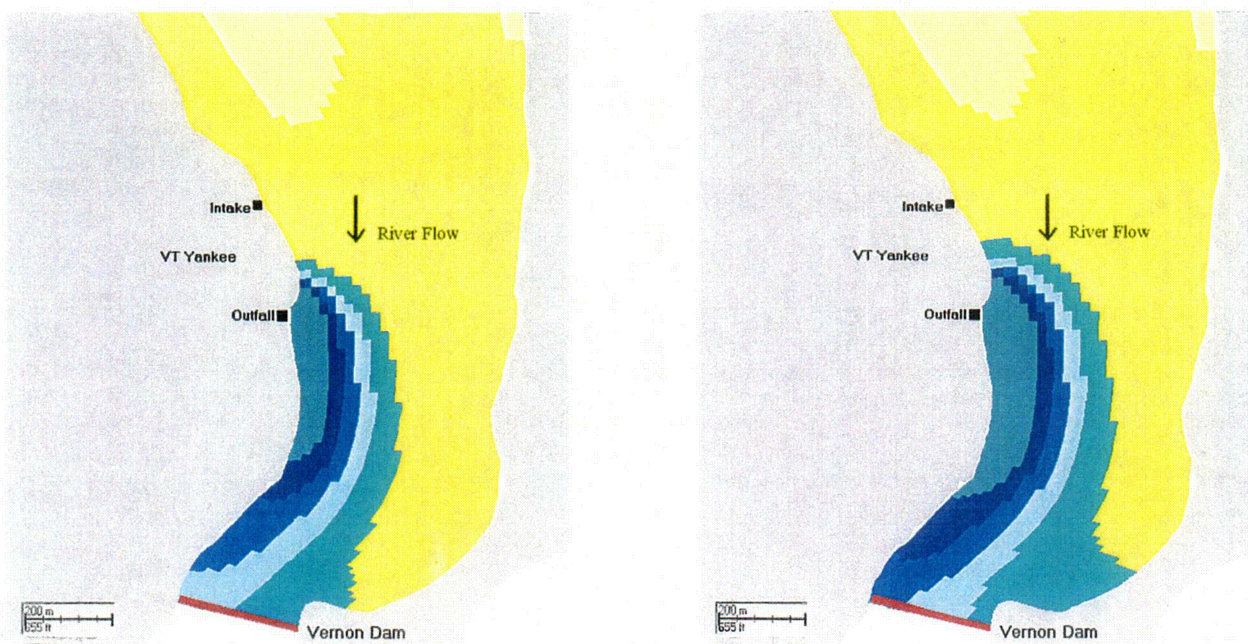
literature do not include avoidance temperatures for salmon adults or smolts. However, since parr are able to tolerate 82 °F, and adult Atlantic salmon move through the Vernon Dam fishway at temperatures as high as 74°F, it is reasonable to use 78°F as a presumed avoidance temperature for salmon smolts and adults.

Based on the exclusionary avoidance temperature of 78°F for salmon parr, as a surrogate thermal effects parameter for Atlantic salmon smolts and adults who are transient inhabitants of lower Vernon Pool during their migrations, for the average case (50% occurrence) the plume volume and bottom area above this temperature is an additional 2.4% and 1.7%, respectively (Figure 5-28, Table 5-26). The increase in river water temperature due to the new permit limits would exclude salmon parr from using between 0 and 5.5 acres of existing benthic habitat that they could have access to under the existing permit limits. For the extreme case (1% occurrence) there is no difference between the existing and proposed temperature limits (Figure 5-29, Table 5-26). The exclusion of Atlantic salmon parr from an additional 1.7% of the bottom area in the existing plume will have no effect on this fish because salmon parr reside in rivers and streams upstream of Vermont Yankee. Atlantic salmon smolts do come in contact with the thermal plume on their downstream migration each spring, which runs from May through 7 June, but studies in the vicinity of Vermont Yankee have demonstrated that the plume does not delay the downstream migration of these fish. See Section 5.1.3.2 for a discussion on the downstream passage of Atlantic salmon smolts in the vicinity of Vermont Yankee.



(a) Surface (Existing limits)

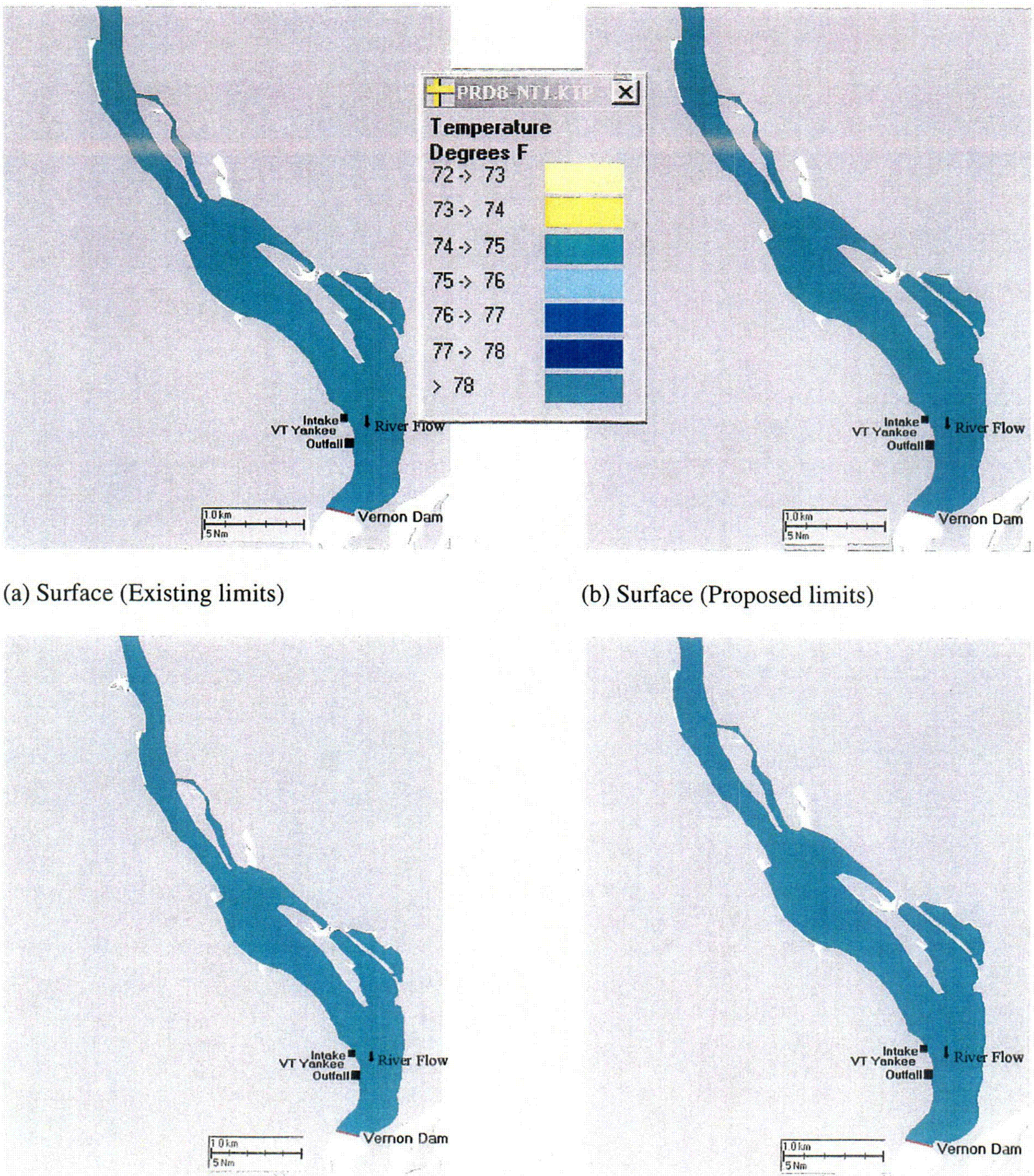
(b) Surface (Proposed limits)



(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-28. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the Atlantic salmon (parr and smolts) avoidance temperature of 78°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-29. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the Atlantic salmon avoidance temperature of 78°F.

Table 5-26. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for Atlantic salmon between the existing and the proposed new summer permit limits.

A. Percent Difference

Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[1] in % Time Station 3 is At or Above Temp °F
Exclusionary Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Max. for summer survival, or UILT	82	-0.1	-10.8	-0.04	-7.7	3.3
Avoidance	78	-2.4	0.0	-1.7	0.0	10.0
Indicator Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Optimum for growth	Not Applicable, Preferred Spawning and Nursery Habitat Absent near Vermont Yankee					
Preferred (parr)	Not Applicable					
Spawning	Not Applicable					
Early life history	Not Applicable					

B. Numeric Difference

Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[2] in Hours Station 3 is At or Above Temp °F
Exclusionary Temperatures		**Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Max. for summer survival, or ULT	82	-13.8	-2092.7	-0.1	-24.8	121.8
Avoidance	78	-462.8	0.0	-5.5	0.0	363.3
Indicator Temperatures		**Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Optimum for growth	Not Applicable, Preferred Spawning and Nursery Habitat Absent near Vermont Yankee					
Preferred	Not Applicable					
Spawning	Not Applicable					
Early life history	Not Applicable					

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

5.2.3 Spottail Shiner

Spottail shiner (*Notropis hudsonius*) is a widely distributed species ranging from southern Quebec, Canada to Georgia and west to Montana (Scott and Crossman 1973). Spottail shiners occupy a range of habitats throughout their range from sandy and silty shoals to rocky pools and runs in both small and large river systems (Page and Burr 1991), as well as inundated freshwater marshes (Rozas and Odum 1987a, 1987b). This species' temperature distribution exhibits plasticity, with southern populations exhibiting warm water species characteristics while northern populations appear more adapted to cooler waters (Coutant 1977). This species typically inhabits shallow and offshore portions of lakes, at times reaching considerable depth in the range of 35-40 meters (Wells and House 1974). Spottail shiners utilize a wide variety of prey types including limnetic microcrustaceans (i.e., Cladocera) and rheophilic prey such as black fly (Simuliidae) larvae, likely allowing this species to occupy both habitats successfully (Hess 1983). Spawning areas appear to be similarly diverse, with spawning in lacustrine habitats (in this case Lake Michigan) taking place over sandy bottoms or patches of filamentous algae (Wells and House 1974). In the Potomac River and elsewhere, eggs were found attached to sand and gravel in shallow riffles (Loos et al. 1979).

Spottail shiners' widespread habitat preferences allow them to occupy both the lentic and lotic insectivore guild (Table 2-1), consuming a variety of taxa including immature midges (Chironomidae), fingernail clams, zooplankton and fish eggs (Wells 1980). Diet appears to vary both with water depth and season, reflecting the shift in productivity dominance by the various prey taxa. In a Michigan study by Wells (1980), midges dominated the diet of fish captured in shallow water (5-13 meters), while fish captured in deeper water preyed principally on the amphipod *Pontoporia*. As generalist feeders (their alternate trophic guild), spottail shiners appear to take advantage of seasonal shifts in food abundance; for example, shifting to fish eggs during the spawning season of sympatric species. Spottail shiners are members of the generalist feeder guild throughout their life, similar to yellow perch and American shad, although differences exist depending on life stage.

During the 30-year study of Vermont Yankee's operation, spottail shiners have been a fairly abundant forage species. This species was captured by electrofishing and trap netting, although the spottail shiner CPUE from trap netting is likely to be biased low because the mesh size (3/4 inch stretch) of the trap nets exceeded the size of adult spottail shiners (<3/4 inch max body depth), thus allowing escapement from this passive gear type. In addition, predation prior to retrieval of the trap net sample may have occurred if piscivorous fish were captured in the same sample. Given these two factors, trap net data for this species and other small-bodied fish species are likely to underestimate their abundance. Spottail shiners were found in all areas of Vernon Pool, including that area in direct contact with the thermal discharge. In lower Vernon Pool, spottail shiner were 7%, 11% and 6% of the catch in the 1968-1980, 1981-1990 and 1991-2002 time periods, respectively (Table 5-14). In the Vernon Dam tailrace area of upper Turners Falls Pool, spottail shiner were 16%, 6% and 10% of the catch in the 1968-1980, 1981-1990 and 1991-2002 time periods, respectively (Table 5-14). This apparent lack of difference (t test = 0.812, p = 0.46) in relative abundance between the lower Vernon Pool and downstream of Vernon Dam is likely due to the species' wide niche breadth.

The annual catch per unit effort (CPUE) of spottail shiner by electrofishing from 1991-2002 in lower Vernon Pool (Table 5-9) was highest in 1996 (72 fish per hour) and lowest in 1995 (2.8 fish per hour). CPUE of spottail shiner by electrofishing was similar downstream from Vernon Dam (Table 5-10) where annual CPUE was highest in 1996 (55 fish per hour) and lowest in 1995 (4.4 fish per

hour). The spottail shiner annual CPUE by trap netting in lower Vernon Pool between 1991 and 1999 (Table 5-11) was highest in 1992 (0.2 fish per day) and lowest in 1996, 1998 and 1999 (0.0). The annual CPUE by trap netting downstream from Vernon Dam (Table 5-12) ranged between a high in 1994 of 1.1 fish per day and a low in 1999 of 0.0 fish per day.

No statistically significant trends were observed in spottail shiner annual total CPUE during the 1991-2002 period, supporting a finding of "no prior appreciable harm" to spottail shiner due to Vermont Yankee's existing (baseline) summer period permit limits. The time series of annual total electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau b of 0.030 with a probability level of p=0.891 (Figure 5-30a), while the electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall's Tau b of 0.091 with a probability level of p=0.681 (Figure 5-30c). Kendall's Tau correlation coefficient for the annual total trap net CPUE time series from lower Vernon Pool was -0.493 with a probability level of 0.070 (Figure 5-30b), and the correlation coefficient for the trap net data from the Vernon Dam tailrace was -0.500 with a probability level of 0.061 (Figure 5-30d).

Based on the range of limiting thermal effects threshold temperatures cited in Table 5-27 for spottail shiner, and the predicted plume temperature contours (Figures 5-31 and 5-32), the increase in river water temperature due to the new permit limits would not result in a shift in spottail shiner use in any of the existing benthic habitat (0.0% of 324 acres) under the proposed new Vermont Yankee thermal limits that they presently have access to under the existing permit limits, depending on the parameter considered. The exclusion of spottail shiner from 0 acres of benthic habitat in lower Vernon Pool describes the spatial extent of the predicted impact for the average (50%) case with respect to the optimum water temperature for growth of spottail shiner (Table 5-27).

The temporal aspect during which the habitat alteration will occur should also be considered to fully understand the extent of the predicted impacts. For the extreme case summer period conditions modeled, which are predicted to occur 1% of the time or 36 hours, there is a 0.3 acre increase (0.1%) in the extent of the benthic area above the optimal growth limit and preferred temperature of 86°F (Table 5-27). The available information indicates that an avoidance behavior and the summer survival limit temperature of 95°F will not be reached in the Vernon Pool ecosystem resulting from Vermont Yankees thermal output.

In reference to the thermal effects parameters for spottail shiner, there is no meaningful change in the predicted habitat volume or benthic area under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme-case conditions (Table 5-27). Spottail shiner is considered to be a relatively thermally insensitive RIS (Table 2-1). The upper incipient lethal temperature (UILT) representing the maximum temperature permissible for summer survival of spottail shiner is reported to be 95°F (Appendix 2). The optimum temperature for growth is reported as 86°F, the thermal avoidance temperature is 95°F, the preferred temperature is 86°F, the limiting spawning temperature is 64°F, and the limiting incubation temperature for egg and larval development is 70°F (Table 5-27). The maximum predicted losses of habitat access in the thermally effected portion of lower Vernon Pool (Table 5-27, Figures 5-31 and 5-32 of plume contours for each thermal parameter) due to the proposed new thermal limits are relatively small in both plume volume (-0.3% or about 64.0 $ft^3 * 10^4$) and plume area (0.3 acres) compared to the total available habitat (324 acres in lower Vernon Pool. This is because only a small portion of the habitat is affected by the thermal plume, and because the highest plume temperatures typically occur towards

mid-river and at the surface of the River. This mid-river surface habitat is not particularly favored by spottail shiner.

The remaining thermal parameters are not predicted to increase beyond reported life history benchmarks at Station 3. The maximum predicted increase in the time the River water at Station 3 will be at or above the preferred spawning or incubation period for growth is 5.4% or 197 hours while the predicted increase in time at or above the preferred early development temperature is 4.5% or 163 hours under the proposed new temperature limits compared to the existing limits (Table 5-27). There is no change predicted for the time exposure of spottail shiner to the maximum summer survival temperature (UILT) of 95°F, because this temperature is never reached at Station 3 under existing or proposed permit restrictions. Given the diverse array of habitats and prey items used by spottail shiners as well as the relatively small amount of habitat affected by the plume, it is likely that the effects on spottail shiner in lower Vernon Pool will be negligible.

Spottail shiners are pelagic spawners, scattering their eggs on open substrate near the shoreline, where most eggs are laid, to nine meters in depth (Wells and House 1974). Spawning appears to vary with temperature, with cooler years resulting in delayed spawning until the environment reaches optimal spawning conditions (Wells and House 1974). From this it would appear that at most, the area of the river affected by the plume may cause a slightly earlier spawning period which is unlikely to have a substantial impact on the spottail shiner populations given the relatively small proportion of the affected area. There is some potential under the proposed new temperature limits for the Vermont Yankee thermal plume to affect the spawning timing of spottail shiner in the relatively small portion of lower Vernon Pool exposed to the thermal plume. Spottail shiner spawn in Vernon Pool from early-June through mid-July, as evident by the first appearance of their larvae in the Vermont Yankee nearfield ichthyoplankton collections in lower Vernon Pool between 29 May and June 4, depending on the year (Table 5-28). The indicator thermal effects temperature of 64°F for spawning and incubation would be exceeded only 5.4% more of the time under the proposed new permit limits compared to the existing limits, so spawning is likely to occur earlier in the spring during the period when water temperatures increase. The temperature cited for early development of spottail shiner larvae and eggs has been reported at 70°F. Under the proposed thermal limits, this temperature would be reached or exceeded in 4.5% more of the time than it currently is.

The proposed new summer temperature limits for the Vermont Yankee thermal plume are expected to have no measurable effects on the lacustrine insectivore trophic guild of tolerant members of the fish community that are represented by spottail shiner in lower Vernon Pool and the Vernon Dam tailrace waters. Spottail shiner were the fifth most common species and made up about 7% of the proportional abundance in the electrofishing and trap netting catch in Vernon Pool and downstream of Vernon Dam during 1991-2002 (Table 5-6) and is expected to remain as such allowing for natural variation.

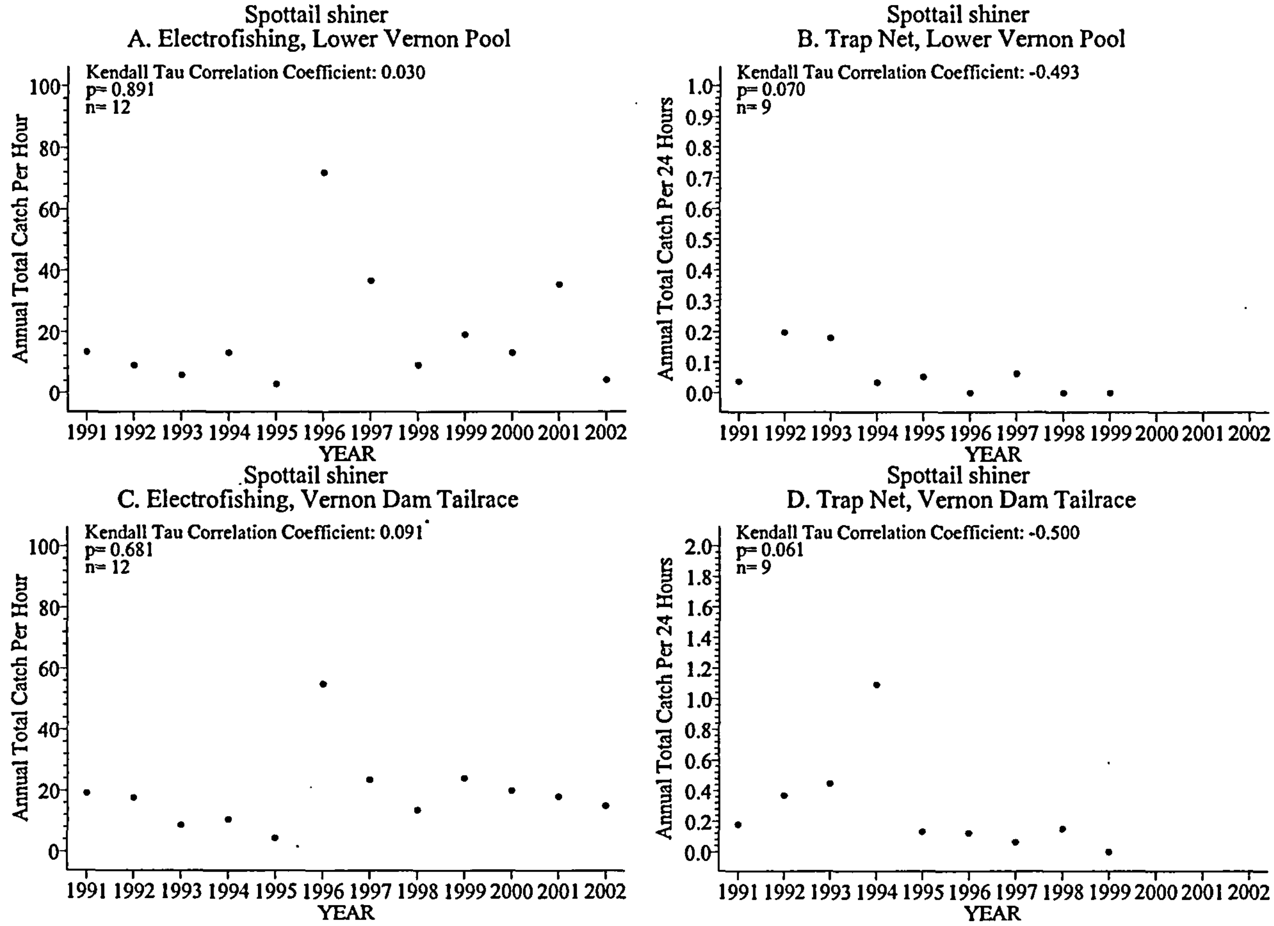
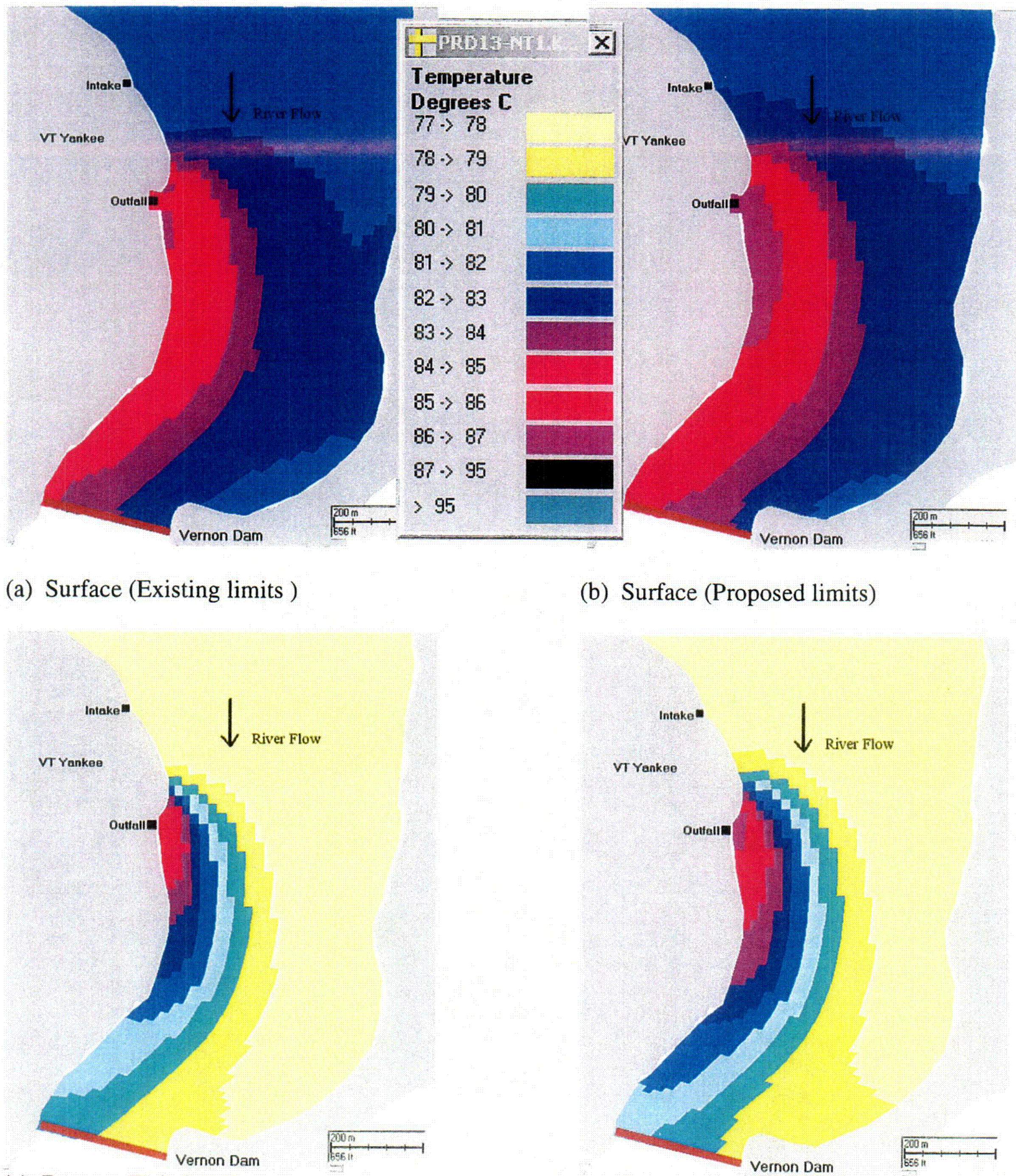


Figure 5-30. Scatter plots comparing spottail shiner annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



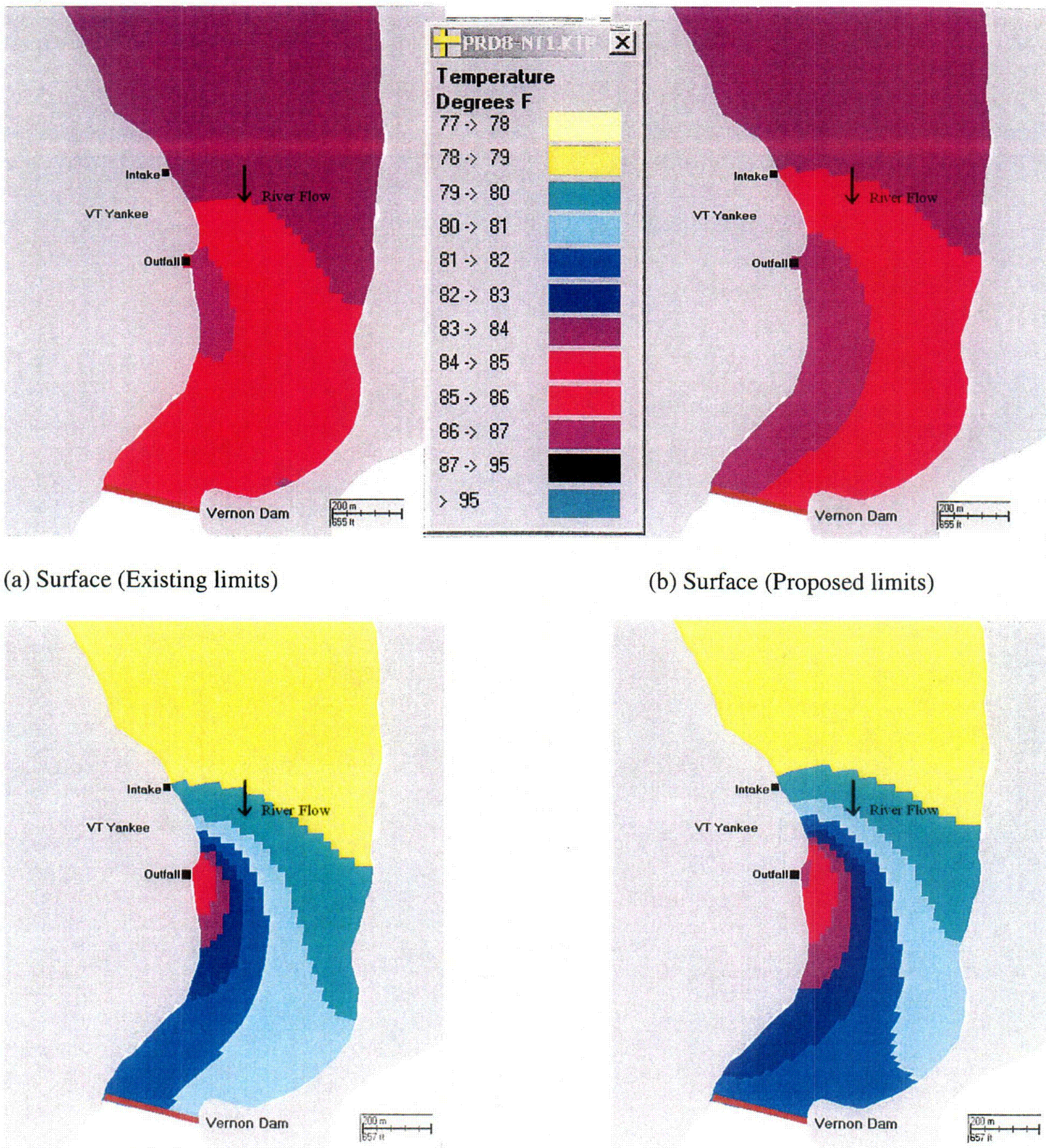
(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-31. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the spottail shiner avoidance temperature of 95°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-32. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the spottail shiner avoidance temperature of 95°F.

Table 5-27. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for spottail shiner between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[1] in % Time Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Max. for summer survival, or UILT	95	0.0	0.0	0.0	0.0	0.0
Avoidance	95	0.0	0.0	0.0	0.0	0.0
Indicator Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Optimum for growth	86	0.0	-0.3	0.0	-0.1	0.0
Preferred	86	0.0	-0.3	0.0	-0.1	0.0
Spawning	64	0.0	0.0	0.0	0.0	5.4
Early life history	70	0.0	0.0	0.0	0.0	4.5

B. Numeric Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[2] in Hours Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Max. for summer survival, or ULT	95	0.0	0.0	0.0	0.0	0.0
Avoidance	95	0.0	0.0	0.0	0.0	0.0
Indicator Temperatures		**Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Optimum for growth	86	0.0	-64.0	0.0	-0.3	0.0
Preferred	86	0.0	-64.0	0.0	-0.3	0.0
Spawning	64	0.0	0.0	0.0	0.0	197.0
Early life history	70	0.0	0.0	0.0	0.0	162.7

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

Table 5-28. Earliest and latest dates of capture of ichthyoplankton for spottail shiner, 1991-2002. Also shown are mean daily ambient Connecticut River temperatures recorded at Station 7 for the dates of capture. Note that sampling does not begin before May 1.

Year	Earliest	Temp (F)	Latest	Temp (F)
1991	-	-	-	-
1992	-	-	-	-
1993	12 Jul	78	12 Jul	78
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	02 Jun	66	13 Jul	66
1999	04 Jun	68	02 Jul	75
2000	29 May	57	11 Jul	71
2001	04 Jun	56	18 Jul	72
2002	04 Jun	54	17 Jul	69
Temp Range:		54-78		66-78
Notes:	One of the most numerous species; apparent absence prior to 1998 due to lack of identification to species			

5.2.4 Smallmouth Bass

Smallmouth bass (*Micropterus dolomieu*) are non-native to the Connecticut River, and were introduced into New Hampshire waters some time during the 1860s (Scarola 1987). The native range for this species was limited to the Great Lakes-St. Lawrence system and the systems of the Ohio, Tennessee, and upper Mississippi rivers. This species now occurs almost everywhere in the United States (Scott and Crossman 1973). Smallmouth bass inhabit cool and warm, generally clear, large creeks, streams, and rivers with gravelly and rocky substrates. Often they become a dominant species in reservoirs that impound streams with the above attributes (Jenkins and Burkhead 1993). Usually they are found around the protection afforded by the rocks of shoals and talus slopes, or submerged vegetation in moderately shallow water (Scott and Crossman 1973).

Smallmouth bass represents the lotic piscivore trophic guild of fish species that are reported to be intermediate in their tolerance to pollution (Table 2-1). Some researchers consider smallmouth bass to be insectivorous and intolerant to pollution (Table 2-1). This alternate trophic guild applies to early life stages of this species. There is a progression in feeding with increase in size from plankton, to immature aquatic insects, to crayfish and fishes (Scott and Crossman 1973). The relatively high abundance of smallmouth bass in the Vernon Dam tailwaters, and their much lower abundance in lower Vernon Pool, supports this trophic guild classification and representation within the Connecticut River fish community as a lotic piscivore.

Smallmouth bass shares the same habitat, trophic guild and pollution tolerance classification as one other Vermont Yankee RIS, walleye (Table 2-1). However, some researchers classify largemouth bass as insectivores. This classification rational is similar to that described above for smallmouth bass where young primarily feed on plankton and small insects. As an RIS, smallmouth bass also represents other non-RIS lotic piscivores with intermediate tolerance found in Vernon Pool and in the Vernon tailrace fish community, including primarily white perch (Table 2-1). Therefore, conclusions about the interaction of smallmouth bass with the existing and proposed new Vermont Yankee thermal limits embodies USEPA's concept of RIS and can also be applied to other members of the fish community within the same trophic guild and tolerance classification.

Throughout over 30 years of monitoring at Vermont Yankee, juvenile and adult smallmouth bass have been numerically important components of the River fish community sampled by electrofishing and trap nets. They are found throughout lower Vernon Pool including habitats exposed to the thermal effluent. In lower Vernon Pool, smallmouth bass were 3.5% of the catch in 1968 – 1980, 5.7% in 1981 – 1990, and 1.7% in 1991 – 2002 (Table 5-14). In upper Turners Falls Pool (the tailwaters downstream from Vernon Dam), smallmouth bass relative abundance has been higher and increasing, ranging between 5.9% and 16.8% of the catch over the three review periods. The higher relative abundance of smallmouth bass below Vernon Dam reflects its preference for lotic environments, which are found in the Vernon Dam tailrace, and avoidance of the lentic habitat upstream in lower Vernon Pool.

The annual catch rate (i.e. total catch per unit effort or CPUE) of smallmouth bass by electrofishing from 1991-2002 in lower Vernon Pool (Table 5-9) was highest in 1998 (6 fish per hour) and lowest in 2001 (<1 fish per hour). The CPUE of smallmouth bass by electrofishing was higher downstream from Vernon Dam (Table 5-10) where annual CPUE was highest in 2001 (74 fish per hour) and lowest in 1992 (14 fish per hour). The smallmouth bass annual CPUE by trap netting in lower Vernon Pool between 1991 and 1999 (Table 5-11) was highest in 1997 (0.4 fish per day) and lowest

in 1999 (0.08 fish per day). The annual CPUE by trap netting downstream from Vernon Dam (Table 5-12) ranged between a high in 1991 of 1.8 fish per day and a low in 1996 of 0.5 fish per day.

No statistically significant negative (decreasing) trends were observed in smallmouth bass annual mean CPUE during the 1991-2002 period, supporting a finding of "no prior appreciable harm" due to Vermont Yankee's existing (baseline) summer period permit limits. Additionally, there was a statistically significant increasing trend in Vernon Dam tailrace electrofishing annual total CPUE. The time series of annual total electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau of 0.061 with a probability level of p=0.784 (Figure 5-33a), while the electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall's Tau b of 0.545 with a probability level of p=0.014 (Figure 5-33c). Kendall's Tau b correlation coefficient for the annual total trap net CPUE time series from lower Vernon Pool was –0.111 with a probability level of 0.677 (Figure 5-33b), and the correlation coefficient for the trap net data from the Vernon Dam tailrace was –0.333 with a probability level of 0.211 (Figure 5-33d).

Based on the two limiting or exclusionary thermal effects threshold temperatures cited in Table 5-29 for smallmouth bass, and the predicted plume temperature contours, there is no change in the predicted habitat volume or bottom area under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme case conditions that would exclude smallmouth bass based on reported upper incipient lethal temperature (UILT) and avoidance temperature (Table 5-29). The UILT representing the maximum temperature permissible for summer survival of smallmouth bass is reported to be 98°F, the thermal avoidance temperature is 95°F.

With respect to the indicator thermal effects parameters for smallmouth bass, there is no meaningful change in the predicted habitat volume or bottom area under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme case conditions (Table 5-29). The optimum temperature for growth is reported as 90°F, the preferred temperature is 81°F, the mid-range of the reported spawning temperature is 63°F, and the mid-to upper incubation temperature for egg and larval development is 70°F (Table 5-29). The spawning indicator temperature for smallmouth bass is naturally exceeded in Vernon Pool before the summer period, and the plume is presently at or above the early life history indicator temperature during the summer period under both the existing and proposed new thermal discharge limits, therefore no change is predicted for either indicator thermal effects parameter. The predicted changes in habitat exposure with respect to the preferred indicator temperature in the thermally effected portion of lower Vernon Pool under average case (50%) conditions are small in plume volume (-0.5% or about -89 $ft^3 * 10^4$) and in plume area (-0.2% or –0.8 acres) compared to the total available habitat (19,400 $ft^3 * 10^4$ or 324 acres) in lower Vernon Pool.

There is no predicted increase in the time the mixed Connecticut River water in the Vernon Dam tailrace down to Station 3 will be at or above the maximum temperature for summer survival (UILT) or avoidance for smallmouth bass under the proposed new thermal discharge limits (Table 5-29), because those water temperatures are never reached. With respect to the indicator temperatures, there is no change predicted at or above the optimum temperature for growth. The predicted increase in time at or above the preferred temperature is 5.1% or 188 hours. The predicted increase in time the Connecticut River water at Station 3 will be at or above the spawning temperature under the proposed new discharge limits is 4.9% or 178 hours compared to the existing limits, and the predicted increase

in time the water will be at or above the incubation and larval development temperature under the proposed new discharge limits is 4.5% or 163 hours compared to the existing limits (Table 5-29). Eggs and larvae of smallmouth bass have not been collected in the nearfield ichthyoplankton sampling performed annually in lower Vernon Pool as a permit-required monitoring program, nor are they likely to be collected because spawning occurs in gravel-filled nests in shallow water (Scarola 1987).

There is little potential under the proposed new temperature limits for the Vermont Yankee thermal plume to adversely affect the spawning of smallmouth bass based on the calculated increased time the optimal spawning and early development temperatures are exceeded at Station 3. Furthermore, it should be noted that no difference was calculated in the available plume volume or bottom area under either average or extreme case thermal plume conditions for smallmouth spawning or early life history (Table 5-29, Figures 5-34 and 5-35). Additionally, the population of smallmouth bass has been significantly increasing in the Vernon Dam tailrace area.

The proposed new summer temperature limits for the Vermont Yankee thermal plume are expected to have no adverse effects on the lotic piscivore trophic guild of fish species that are intermediate tolerant members of the fish community and are represented by smallmouth bass in lower Vernon Pool and the Vernon Dam tailrace waters. Rock bass and brook trout are the non-RIS represented by smallmouth bass, and both lotic piscivores are found in very low numbers in the fish community of lower Vernon Pool and in the Vernon Dam tailwaters (Tables 5-9 through 5-12). Similar proportional representation of both RIS and non-RIS fish species are expected to persist in the tailwater fish community downstream from Vernon Dam under the proposed new thermal regime.

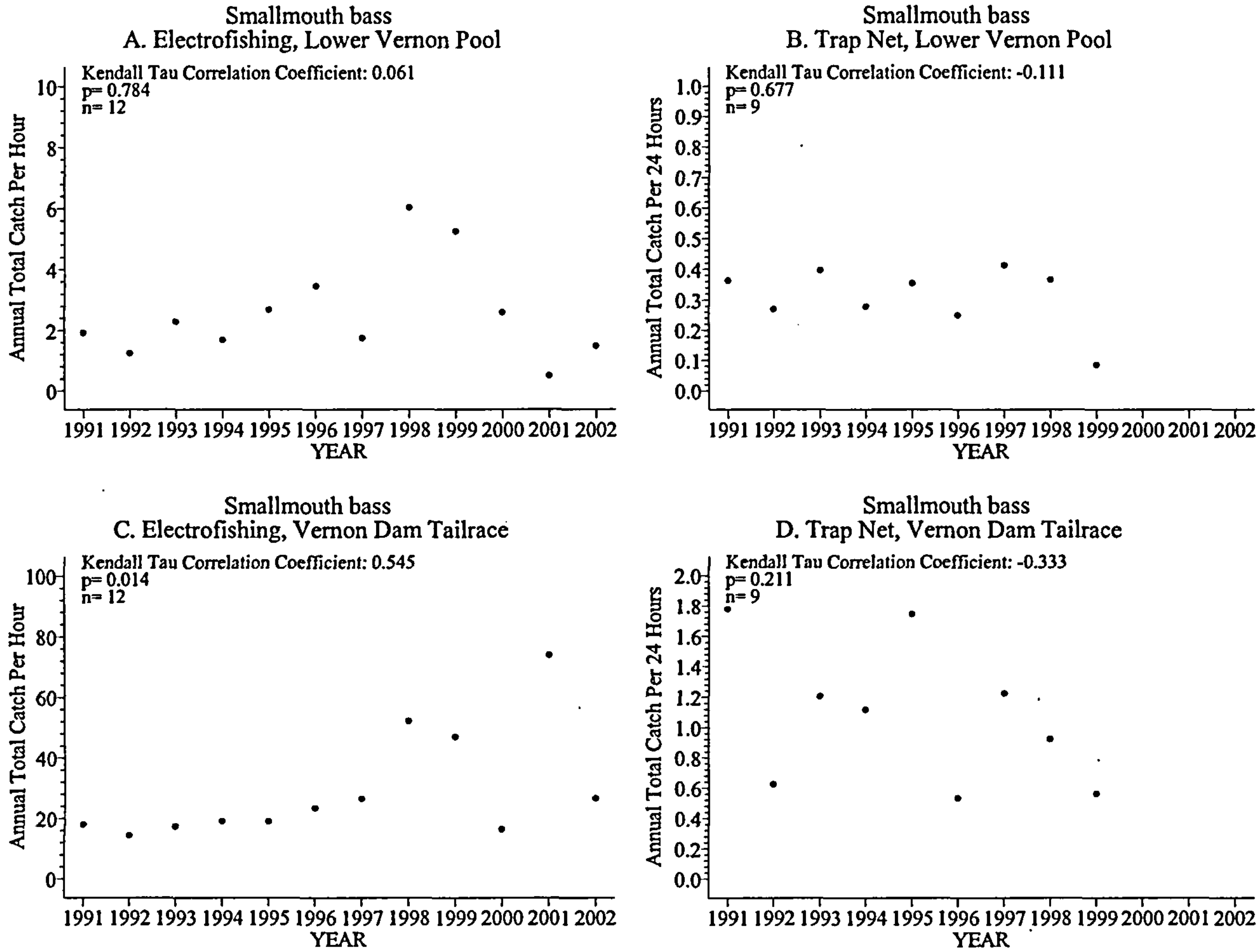
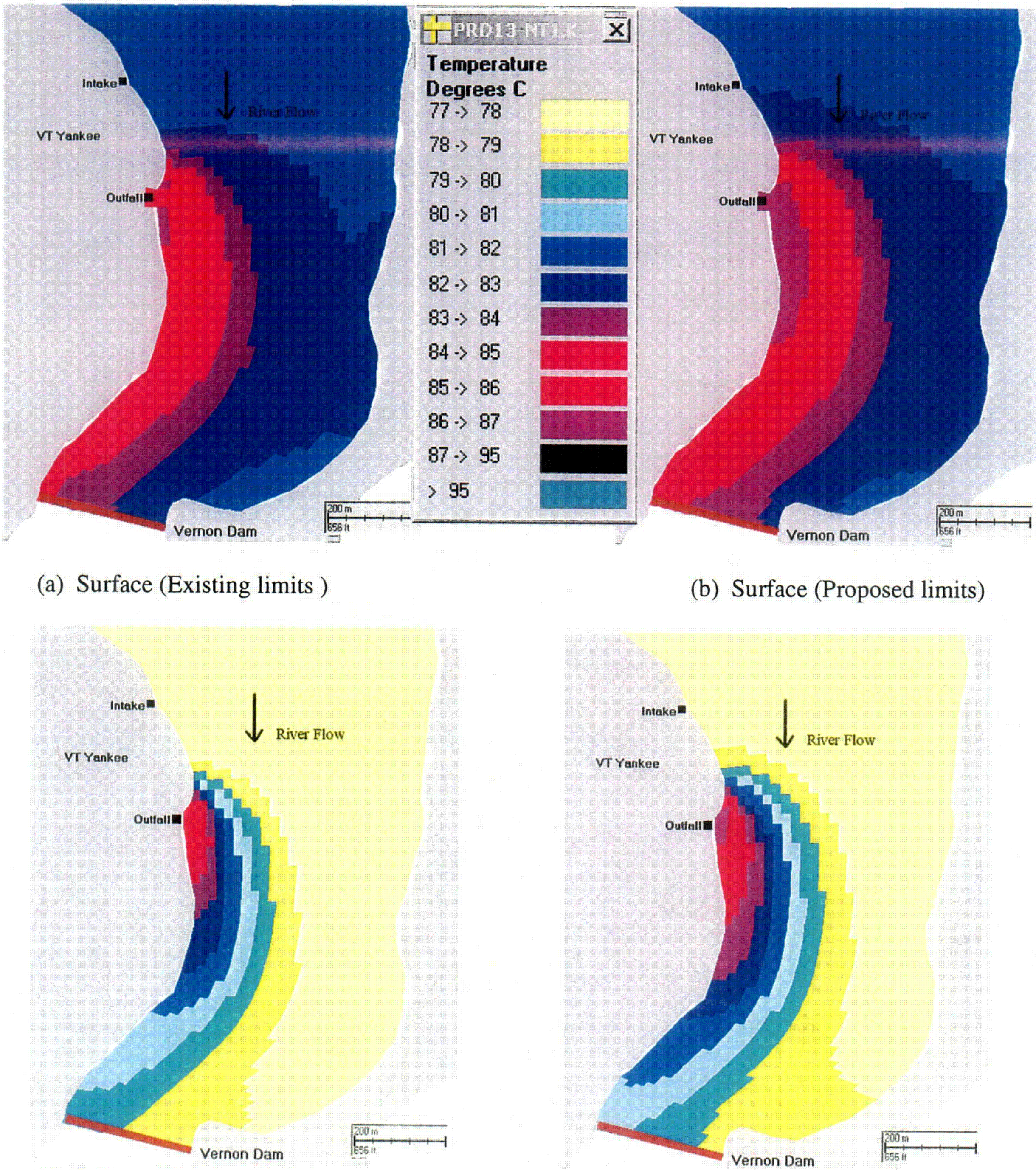


Figure 5-33. Scatter plots comparing smallmouth bass annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



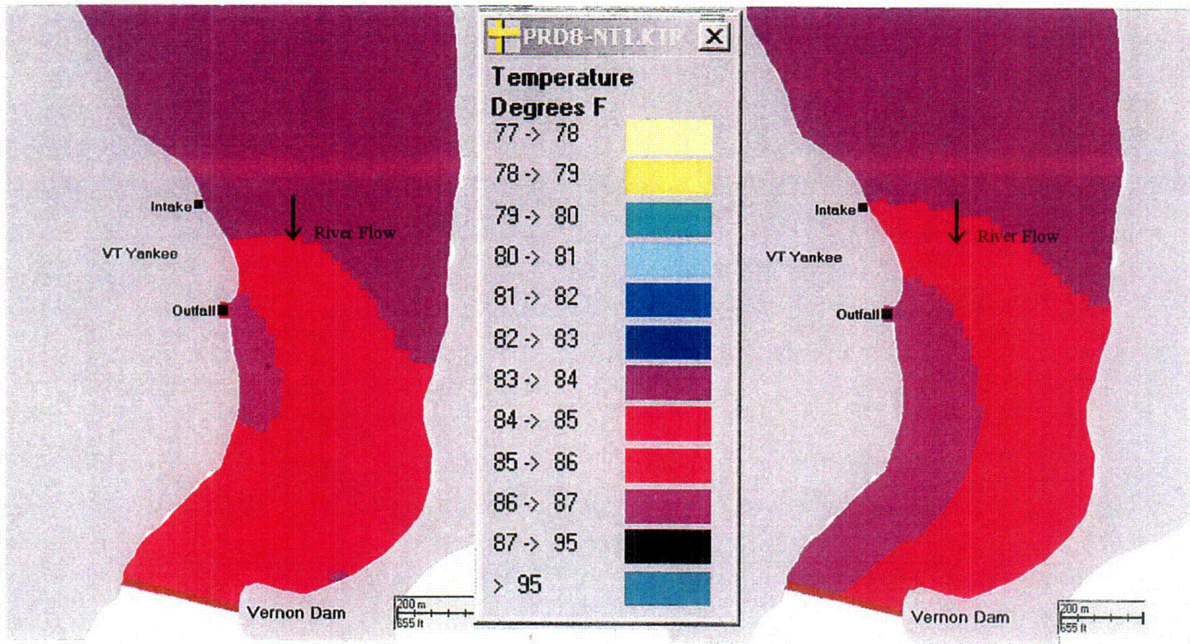
(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

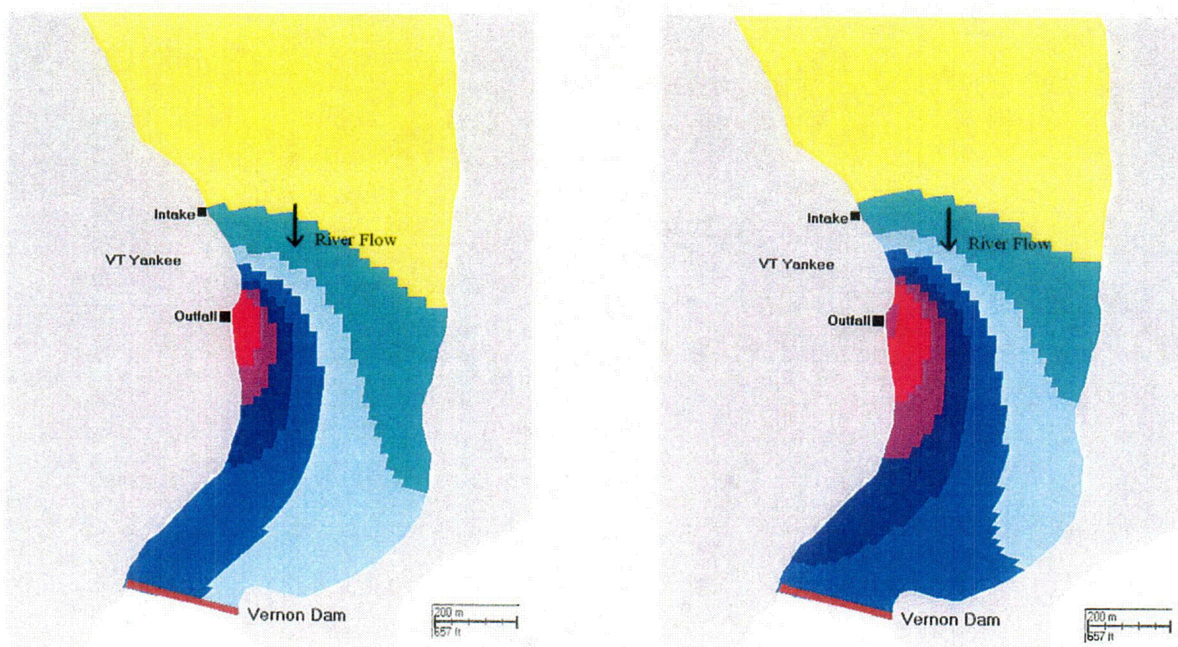
(d) Bottom (Proposed limits)

Figure 5-34. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the smallmouth bass avoidance temperature of 95°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)



(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-35. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the smallmouth bass avoidance temperature of 95°F.

Table 5-29. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for smallmouth bass between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[1] in % Time Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Max. for summer survival, or UILT	98	0.0	0.0	0.0	0.0	0.0
Avoidance	95	0.0	0.0	0.0	0.0	0.0
Indicator Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Optimum for growth	90	0.0	0.0	0.0	0.0	0.0
Preferred	81	-0.5	-6.3	-0.2	-7.7	5.1
Spawning	63	0.0	0.0	0.0	0.0	4.9
Early life history	70	0.0	0.0	0.0	0.0	4.5

B. Numeric Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[2] in Hours Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Max. for summer survival, or ULT	98	0.0	0.0	0.0	0.0	0.0
Avoidance	95	0.0	0.0	0.0	0.0	0.0
Indicator Temperatures		**Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Optimum for growth	90	0.0	0.0	0.0	0.0	0.0
Preferred	81	-89.0	-1220.1	-0.8	-24.9	187.5
Spawning	63	0.0	0.0	0.0	0.0	178.0
Early life history	70	0.0	0.0	0.0	0.0	162.7

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

5.2.5 Yellow Perch

Yellow perch (*Perca flavescens*) has a circumpolar distribution in fresh waters of the northern hemisphere (Scott and Crossman 1973). Within North America, yellow perch are widespread and very adaptable. They are found in a variety of warm- to cool-water habitats, and have historically occupied a range from Nova Scotia to South Carolina along the east coast, extending northwesterly through the Great Lakes states into Alberta, Canada. Yellow perch has been successfully introduced into nearly all states west and south of its historical range (Scott and Crossman 1973). They are often common in clear open water habitats with moderate vegetation, typically less than 30 feet deep (Lee et al. 1980).

Yellow perch represents the lentic insectivore trophic guild of fish species that are reported to be intermediate in their tolerance to pollution (Table 2-1). Some researchers consider yellow perch to be piscivorous or a generalist forager (Table 2-1), however these alternate trophic guilds undoubtedly apply to different age classes, with general foraging occurring in the earlier life stages, a predominance of piscivory in the older and larger individuals, and insectivory occurring throughout their life. The relatively high abundance of yellow perch in lower Vernon Pool, and their much lower abundance in the Vernon Dam tailwaters, supports this trophic guild classification and representation within the Connecticut River fish community as a lentic insectivore.

Yellow perch shares the same habitat, trophic guild and pollution tolerance classification as two other Vermont Yankee RIS, spottail shiner and American shad (Table 2-1). Although some researchers classify spottail shiner as a generalist forager that is intolerant of pollution, the predominant classification is the same as for yellow perch. American shad have also been classified in the filter feeder tropic guild, which undoubtedly applies to the ability of juveniles to feed on *Daphnia* sp. and other freshwater planktonic crustaceans, however both spottail shiner and juvenile American shad are also reported to feed on insect larvae (chironomids) if abundant (Scott and Crossman 1973). Both spottail shiner and juvenile American shad remain as forage fish during their presence in lower Vernon Pool, while yellow perch can only be classified as forage during their larval and juvenile life stages. As an RIS, yellow perch also represents other non-RIS lentic insectivores with intermediate tolerance found in the Vernon Pool fish community, including the closely-related tessellated darter, two minnow species (common shiner and spotfin shiner), and three centrarchids (redbreast sunfish, pumpkinseed sunfish, and bluegill, Table 2-1). Therefore, conclusions about the interaction of yellow perch with the existing and proposed new Vermont Yankee thermal limits embodies USEPA's concept of RIS and can also be applied to other members of the fish community within the same trophic guild and tolerance classification.

Throughout over 30 years of monitoring at Vermont Yankee, juvenile and adult yellow perch have been numerically important components of the Connecticut River fish community sampled by electrofishing and trap nets. They are found throughout Vernon Pool including habitats exposed to the thermal effluent. In lower Vernon Pool, yellow perch made up about 16% of the catch in 1968 – 1980, 23% in 1981 – 1990, and 39% in 1991 – 2002 (Table 5-14). In upper Turners Falls Pool (study area downstream from Vernon Dam), yellow perch relative abundance has been lower and relatively constant, ranging between 8 and 9% of the catch over the three review periods. The lower relative abundance of yellow perch below Vernon Dam probably reflects its preference for open water habitats with moderate vegetation, which are found upstream in lower Vernon Pool, and avoidance of the relatively turbulent lotic habitat in the Vernon Dam tailrace.

The annual catch of yellow perch by electrofishing from 1991-2002 in lower Vernon Pool (Table 5-9) was highest in 2001 (114 fish per hour) and lowest in 1992 (32 fish per hour). Catch per unit effort (CPUE) of yellow perch by electrofishing was lower downstream from Vernon Dam (Table 5-10) where annual CPUE was highest in 1999 (17 fish per hour) and lowest in 2002 (0.4 fish per hour). The yellow perch annual CPUE by trap netting in lower Vernon Pool between 1991 and 1999 (Table 5-11) was highest in 1997 (10.5 fish per day) and lowest in 1992 (3.6 fish per day). The annual CPUE by trap netting downstream from Vernon Dam (Table 5-12) ranged between a high in 1999 of 3.0 fish per day and a low in 1996 of 0.7 fish per day.

No statistically significant negative (decreasing) trends were observed in yellow perch annual CPUE during the 1991-2002 period, supporting a finding of "no prior appreciable harm" due to Vermont Yankee's existing (baseline) summer period permit limits. The time series of annual electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau b of 0.242 with a probability level of p=0.273 (Figure 5-36a), while the electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall's Tau b of 0.000 with a probability level of p=1.000 (Figure 5-36c). Kendall's Tau b correlation coefficient for the annual mean trap net CPUE time series from lower Vernon Pool was 0.222 with a probability level of 0.404 (Figure 5-36b), and the correlation coefficient for the trap net data from the Vernon Dam tailrace was 0.056 with a probability level of 0.835 (Figure 5-36d).

Based on the two limiting or exclusionary thermal effects threshold temperatures cited in Table 5-30 for yellow perch (maximum and avoidance), and the predicted plume temperature contours for the average case, (Figure 5-37) and extreme case (Figure 5-38) occurrence of flow and temperature, the increase in river water temperature due to the new permit limits would exclude yellow perch from using between zero and nine acres of existing benthic habitat (0.0% to 2.7% of 324 acres) under the proposed new Vermont Yankee thermal limits that they presently have access to under the existing permit limits. No habitat exclusion is predicted for the maximum survival temperature with either modeling scenario because the thermal plume never reaches 90°F. The excluded nine acres of bottom habitat is predicted to occur for the avoidance temperature of 83°F modeled under the extreme case (1% occurrence) low flow and upstream temperature conditions, and is located near and immediately downstream from the plant discharge weir on the west side of lower Vernon Pool (Figure 5-38). When put in perspective with the entire Vernon Pool, nine acres of bottom habitat represents 0.4% of the total aquatic habitat area available.

The exclusion of yellow perch from up to nine acres of benthic habitat in lower Vernon Pool describes the spatial extent of the predicted impact for the extreme (1% occurrence) case with respect to the avoidance temperature for yellow perch (Table 5-30), but the temporal aspect during which the exclusion will occur should also be considered to fully understand the extent of the predicted impacts. For example, nine additional acres (-2.7%, Table 5-30) of benthic habitat under the extreme case scenario are predicted to be warmer than the avoidance temperature of 83°F for yellow perch. This means that during one percent of the summer period (36 hours), nine additional acres of habitat will exceed the reported avoidance temperature under the proposed new thermal limits than under the existing limits. For the average case summer period conditions modeled, which are predicted to occur 50% of the time or 1,824 hours, there is no increase (0.0%) in the extent of the thermal plume area above 83°F because the entire plume never reaches 83°F for both the proposed new limits and for the existing conditions. It should be noted that Station 7, upstream from Vermont Yankee's discharge, is never at or above 80°F during the summer period (Table 3-3, Figure 3-8), so Vermont

Yankee's thermal discharge never reaches the avoidance temperature of 83°F under the existing permit delta T (+2°F) or under the proposed new summer period delta-T (+3°F).

With respect to the indicator thermal effects parameters for yellow perch, there is no meaningful change in the predicted habitat volume or bottom area under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme case conditions (Table 5-30). Yellow perch is considered to be a relatively thermally sensitive RIS with respect to its thermal effects parameters. The optimum temperature for growth is reported as 74°F, the preferred temperature is 77°F, the mid-range of the reported spawning temperature is about 50°F, and the mid-to upper incubation temperature for egg and larval development is 65°F (Table 5-30). The spawning indicator temperature for yellow perch is naturally exceeded in Vernon Pool before the summer period, and the plume is presently at or above the early life history indicator temperature during the summer period under both the existing and proposed new thermal discharge limits, therefore no change is predicted for either indicator thermal effects parameter. The predicted changes in habitat exposure with respect to the preferred indicator temperature in the thermally effected portion of lower Vernon Pool are relatively small in plume volume (-4.2% or about -817 $ft^3 * 10^4$) and in plume area (-2.9% or -9 acres) compared to the total available habitat (19,400 $ft^3 * 10^4$ or 324 acres) in lower Vernon Pool. The predicted changes in habitat exposure to the indicator temperature for optimum growth in the thermally effected portion of lower Vernon Pool (Table 5-30, Figures 5-37 and 5-38) due to the proposed new thermal limits occur for the average case modeling scenario, and are relatively small in both plume volume (-3.8% or about 728 $ft^3 * 10^4$) and plume area (-4.8% or 16 acres) compared to the total available habitat (19,400 $ft^3 * 10^4$ or 324 acres) in lower Vernon Pool. Therefore, the thermal plume affects only a small portion of the habitat because the highest plume temperatures typically occur at the surface near the Vermont Yankee discharge weir, habitat not particularly favored by yellow perch.

There is no predicted increase in the time the mixed Connecticut River water in the Vernon Dam tailrace down to Station 3 will be at or above the maximum temperature for summer survival (UILT) for yellow perch under the proposed new thermal discharge limits (Table 5-30), because this water temperature is never reached. The avoidance temperature of 83°F is predicted to be exceeded during 65 more hours or 1.8% more of the summer period time under the proposed new thermal limits compared to the existing limits. It is likely that yellow perch will shift their distribution in the Vernon Dam tailrace to avoid being there during the hours when the water temperature is predicted to exceed 83°F. With respect to the indicator temperatures, the optimum temperature for growth is predicted to be exceeded for 241 hours or 6.6% more of the time under the proposed new limits compared to the existing limits, the predicted increase in time at or above the preferred temperature is 10.9% or 398 hours, there is no change predicted for the time at or above the spawning temperature because this temperature occurs before the summer period, and the predicted increase in time the Connecticut River water at Station 3 will be at or above the incubation and larval development temperature under the proposed new discharge limits is 4.6% or 167 hours compared to the existing limits (Table 5-30).

There is little potential under the proposed new temperature limits for the Vermont Yankee thermal plume to adversely affect the spawning of yellow perch, since spawning occurs in mid-April through mid-May, a period prior to the onset of summer permit limits when water temperatures are low and Connecticut River flows are generally high. In fact, no difference was calculated in the available plume volume or bottom area under either average or extreme case thermal plume conditions for

yellow perch spawning or early life history (Table 5-30, Figures 5-37 and 5-38). In the Vernon Dam tailrace area, the indicator thermal effects temperature of 65°F for incubation and larval development would be exceeded 4.6% more of the time (167 hours) under the proposed new permit limits compared to the existing limits, however tailrace habitat it is not a preferred spawning habitat. Yellow perch typically spawn in Vernon Pool from late-April through early-May, as evident by the first appearance of their larvae in the Vermont Yankee nearfield ichthyoplankton collections in lower Vernon Pool between 1 May (the start of permit-required sampling) and 21 May, depending on the year (Table 5-31). Furthermore, the eggs are laid in a semi-buoyant mass or string that is deposited on the river bottom, and becomes attached to the substrate or vegetation (Scott and Crossman 1973). Although wind and wave action or strong currents can dislodge the egg mass, the demersal and semi-adhesive nature of the mass would serve to limit their exposure to potential thermal impact from contact with the warmest portion of the surface plume in Lower Vernon Pool.

The proposed new summer temperature limits for the Vermont Yankee thermal plume are expected to have no adverse effects on the lentic insectivore trophic guild of intermediate tolerant members of the fish community that are represented by yellow perch in lower Vernon Pool and the Vernon Dam tailrace waters. Among the non-RIS represented by yellow perch, common shiner, spotfin shiner and readbreast sunfish are found in very low numbers in the fish community of lower Vernon Pool and in the Vernon Dam tailwaters (Tables 5-9 through 5-12), and their abundance is expected to remain low under the proposed new thermal limits. Bluegill (18.5%) was second to yellow perch (35.5%) in proportional abundance in the electrofishing catch in lower Vernon Pool during 1991-2002 (Table 5-9) and is expected to remain the second most abundant lentic insectivore compared to yellow perch under the proposed new thermal limits. Pumpkinseed (9.0%) was fourth in proportional abundance just behind spottail shiner (9.2%) in the electrofishing catch in lower Vernon Pool during 1991-2002 (Table 5-9), and both are expected to remain among the most abundant members of the lentic insectivores. Similar proportional representation of both RIS and non-RIS fish species are expected to persist in the tailwater fish community downstream from Vernon Dam under the proposed new thermal regime, although in much lower proportional abundance and community dominance than in lower Vernon Pool because the habitat there is more lotic.

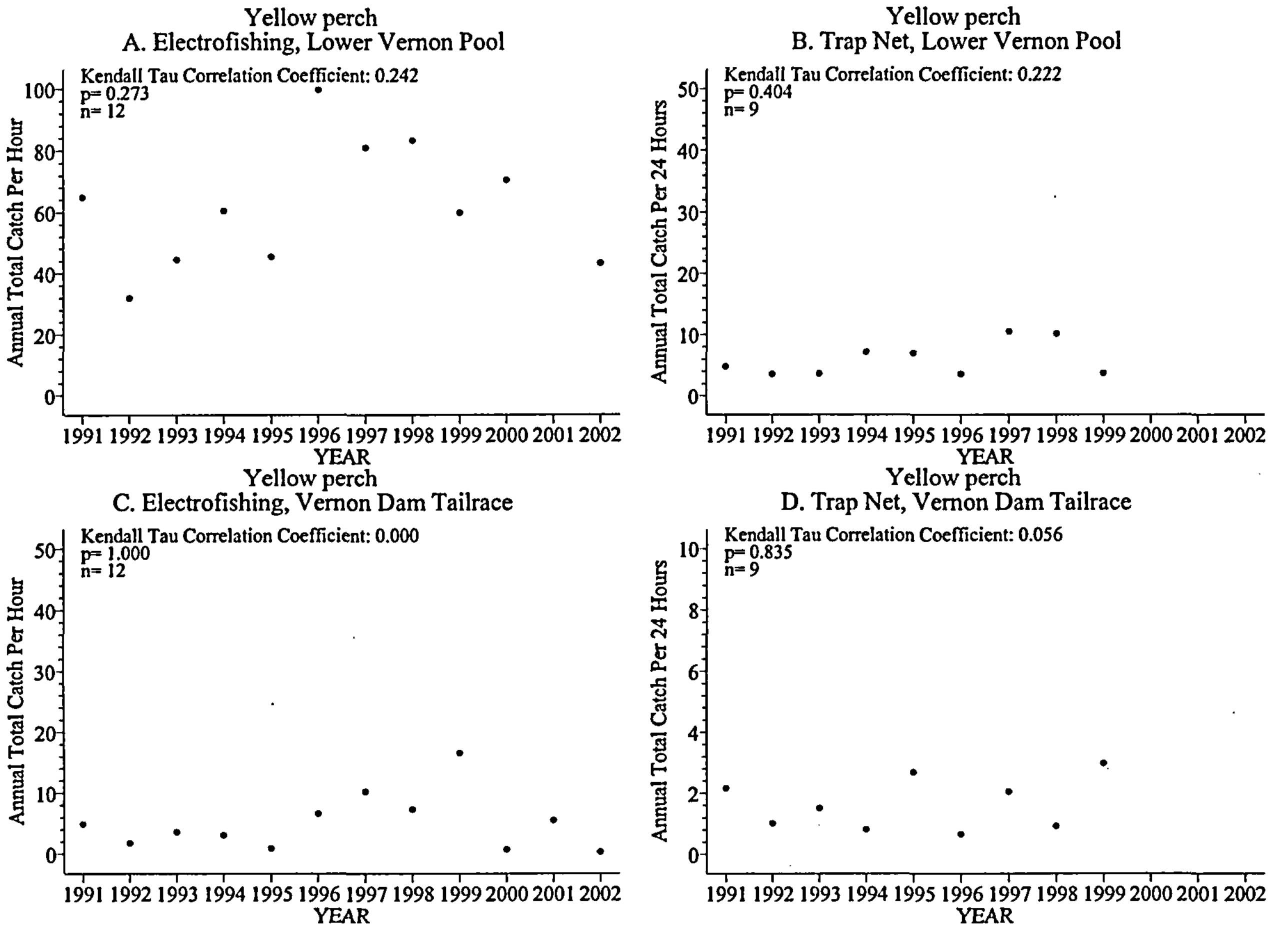
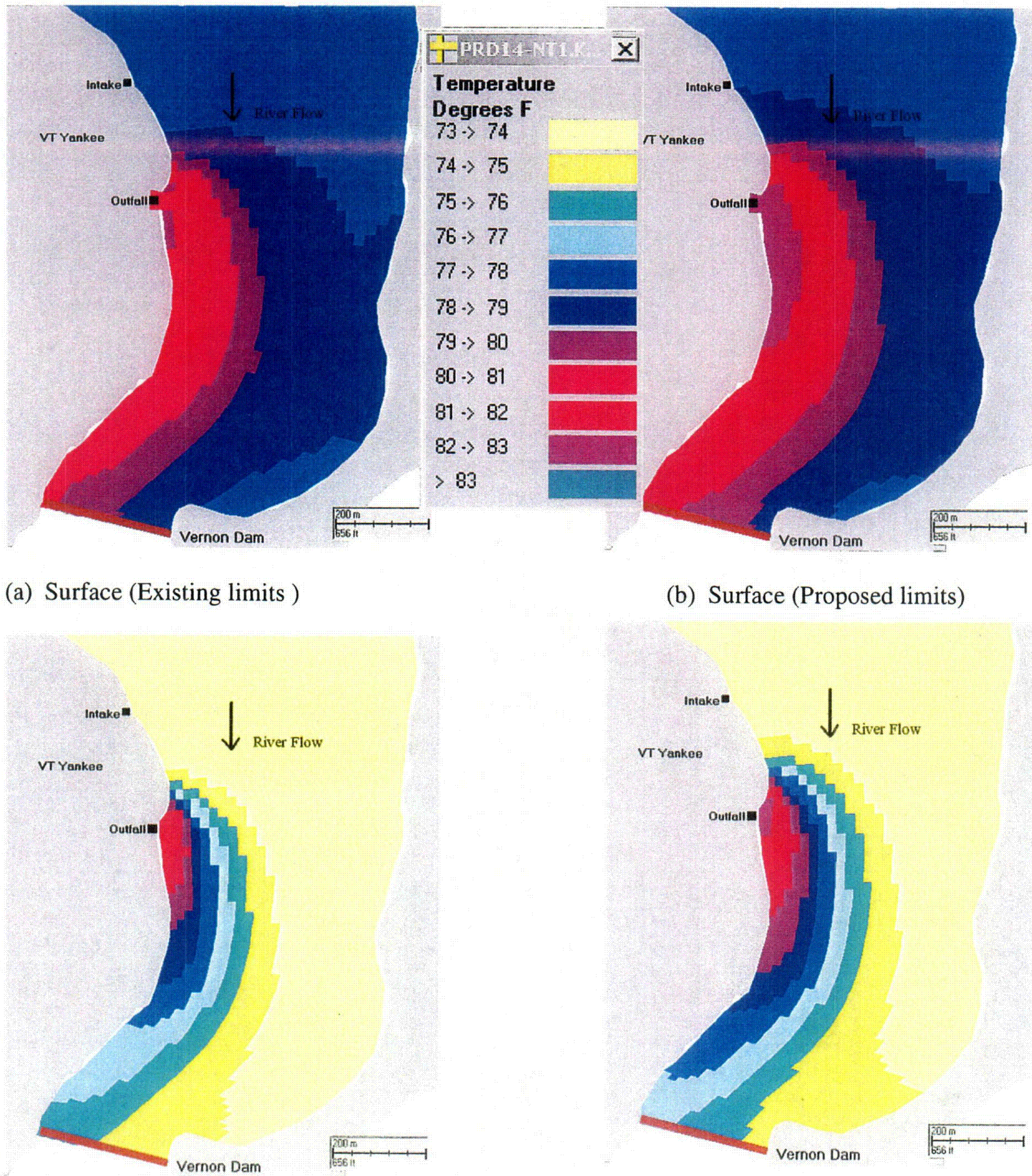


Figure 5-36. Scatter plots comparing yellow perch annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



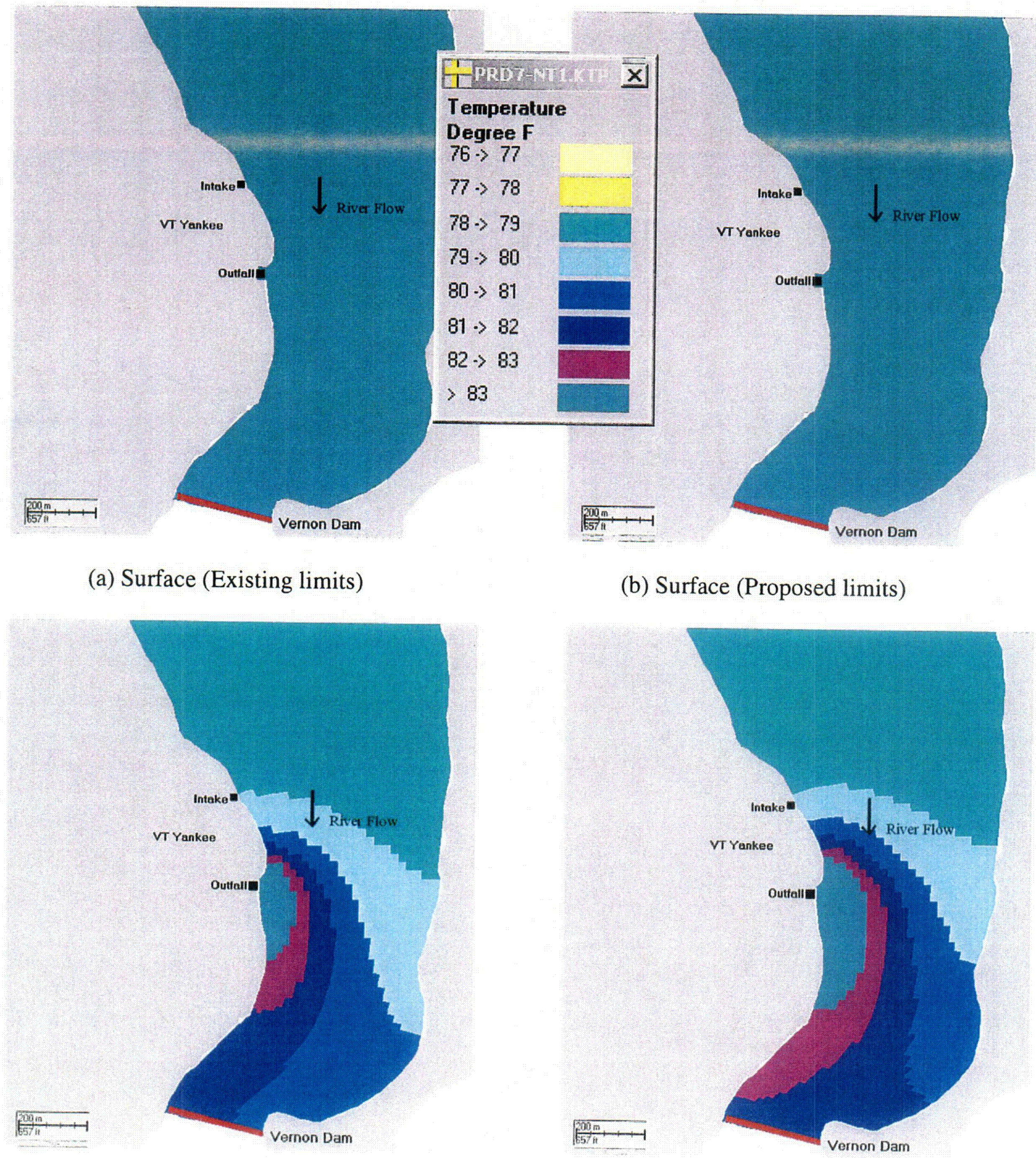
(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-37. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the yellow perch avoidance temperature of 83°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-38. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the yellow perch avoidance temperature of 83°F.

Table 5-30. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for yellow perch between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[1] in % Time Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Max. for summer survival, or UILT	90	0.0	0.0	0.0	0.0	0.0
Avoidance	83	0.0	-3.8	0.0	-2.7	1.8
Indicator Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Optimum for growth	74	-3.8	0.0	-4.8	0.0	6.6
Preferred	77	-4.2	0.0	-2.9	0.0	10.9
Spawning	50	0.0	0.0	0.0	0.0	0.0
Early life history	65	0.0	0.0	0.0	0.0	4.6

B. Numeric Difference						
Thermal Effects Parameter	**Temp (°F)**	**Average (50%) Case**	**Extreme (1%) Case**	**Average (50%) Case**	**Extreme (1%) Case**	**Increase[2] in Hours Station 3 is At or Above Temp °F**
Exclusionary Temperatures		**Change[3] in Plume Volume (ft^3 * 10^4) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Max. for summer survival, or ULT	90	0.0	0.0	0.0	0.0	0.0
Avoidance	83	0.0	-730.6	0.0	-8.7	64.9
Indicator Temperatures		**Change[3] in Plume Volume (ft^3 * 10^4) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Optimum for growth	74	-728.4	0.0	-15.5	0.0	241.1
Preferred	77	-817.5	0.0	-9.5	0.0	397.6
Spawning	50	0.0	0.0	0.0	0.0	0.0
Early life history	65	0.0	0.0	0.0	0.0	167.4

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours ≈ increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

Table 5-31. Earliest and latest dates of capture of ichthyoplankton for yellow perch, 1991-2002. Also shown are mean daily ambient Connecticut River temperatures recorded at Station 7 for the dates of capture. Note that sampling does not begin before May 1.

Year	Earliest	Temp (F)	Latest	Temp (F)
1991	02 May	53	14 May	58
1992	05 May	48	20 May	59
1993	10 May	60	19 May	59
1994	11 May	52	25 May	60
1995	12 May	53	25 May	61
1996	08 May	49	20 May	53
1997	10 May	46	18 Jun	68
1998	07 May	55	08 Jun	63
1999	05 May	54	11 Jun	70
2000	02 May	47	29 May	57
2001	21 May	52	04 Jun	62
2002	08 May	47	08 May	47
Temp Range:		46-60		47-70
Notes:		Regularly collected, usually low numbers		

5.2.6 Walleye

Walleye (*Sander vitreus,* formerly *Stizostedion vitreum*) are native to freshwater rivers and lakes of Canada and the United States, primarily east of the Rocky Mountains and west of the Appalachians. As a highly prized sport fish, walleye have been widely introduced into rivers and reservoirs, including the Connecticut River. Walleye tolerate a wide range of environmental conditions, necessary for widespread introductions, but are reported to be most abundant in medium to large (> 100 hectares) lentic and lotic systems with generally mesotrophic conditions. Such systems also share cool temperatures (or at least provide access to them, e.g., cool tributaries, deeper portions of reservoirs), shallow to moderate depths, extensive littoral areas, moderate turbidities, and access to areas of clean, rocky substrate (McMahon et al. 1984).

Walleye are highly piscivorous with an intermediate tolerance of pollution (Table 2-1). Piscivory begins early in the first year when 15 to 25 mm long (McMahon et al. 1984). Among other Connecticut River co-habitants, walleye as an RIS species share their highly piscivorous habits with northern pike and chain pickerel, both non-RIS predatory species with similar intermediate tolerances (Table 2-1). Reliance upon yellow perch (another RIS species) juveniles as food where they co-exist in northern areas has been frequently noted (e.g, Forney 1977, cited in McMahon et al. 1984). Walleye will also utilize spottail shiner (an RIS species) where available (Normandeau Associates, Inc. RMC Division, unpublished data). Clupeids can also be important food (Fitz and Holbrook 1978), and juveniles of gizzard shad and American shad also represent likely prey species in the Vernon area. As an RIS species, conclusions about the interactions of walleye with the existing and proposed new Vermont Yankee thermal limits embodies USEPA's concept of RIS and can also be applied to other members of the fish community within the same trophic guild and tolerance classification.

Throughout over 30 years of monitoring at Vermont Yankee that included sampling by numerous gear types, walleye have represented approximately 1-2% of the fish community annually (Table 5-14). Since 1991, both electrofishing and trap nets have depicted higher walleye relative abundance in the Vernon Dam tailrace than in lower Vernon Pool (Tables 5-7 and 5-8). Electrofishing CPUE in the Vernon Dam tailrace averaged 2.1 fish per hour compared to 1.3 fish per hour in lower Vernon Pool during 1991-2002 (Tables 5-9 and 5-10). The range in annual electrofishing CPUE in the Vernon Dam tailrace was 0.74 fish per hour in 1997 to 4.44 fish per hour in 1999 (Table 5-10). The range in annual electrofishing CPUE in lower Vernon Pool was 0.12 fish per hour in 1992 to 1.92 fish per hour in 1991 (Table 5-9).

Overall trap net CPUE in the tailrace was 0.3 fish per day compared to 0.2 fish per day in lower Vernon Pool (Tables 5-11 and 5-12). Annual trap net CPUE in the Vernon Dam tailrace ranged from 0.1 fish per day in 1999 to 0.6 fish per day in 1993 (Table 5-12). In comparison, annual trap net CPUE in lower Vernon Pool ranged from 0.02 fish per day in 1991 to 0.3 fish per day in 1998 (Table 5-11).

The nonparametric Mann-Kendall test used to examine the annual catch rate data for significant increasing or decreasing trends during 1991-2002 revealed a significant, increasing trend in walleye abundance for the trap net time series in lower Vernon Pool (Figure 5-39b). The Kendall Tau b coefficient was 0.667 at a probability level of $p=0.012$. All other Kendall Tau b coefficients for the various time series were negative, but no significant trends (all $p>0.05$) in abundance were detected for other locations or by electrofishing (Figure 5-39). The lack of significant decreasing trends during

the 1991-2002 period supports a finding of "no prior appreciable harm" due to Vermont Yankee's baseline summer period permit limits.

The thermally influenced portion of lower Vernon Pool (located from Vermont Yankee's discharge weir downstream to Vernon Dam) is represented by 324 acres of bottom habitat and 0.194 billion cubic feet of volume out of a total of 2,481 acres and 1.3814 billion cubic feet of volume contained in the entire Vernon Pool between Vernon Dam upstream to the foot of Bellows Falls Dam. Figures 5-40 and 5-41 depict surface and bottom thermal plume temperature contours for the existing condition and predicted condition (new summer permit limits) in lower Vernon Pool. Additionally, the contour plots were developed for the average case (50% occurrence) and extreme case (1% occurrence) of river flow. The amount of pool area and volume affected by the new permit limits was evaluated in terms of thermal effects threshold temperatures for walleye cited in Table 5-32. The temperature criteria available for walleye include upper incipient lethal temperature-UILT (89°F), upper avoidance temperature (76°F), optimum temperature for growth (74°F), preferred temperature (72°F), incubation and early development temperature (54°F), and spawning temperature (48°F). Principal literature compendiums consulted for walleye temperature criteria included McMahon et al. (1984), Wismer and Christie (1987), and Armour (1993b). Among these various temperature criteria, the upper avoidance temperature, by definition, is a temperature that elicits a behavioral response. That is, fish will move away from this temperature if available to them from among a range of choices relative to an acclimation temperature (Wismer and Christie 1987). The behavioral response to an avoidance temperature would result in exclusion of that fish species from an area of aquatic habitat. In contrast, no exclusion from habitat occurs relative to changes in the amount of time a preferred or optimum water temperature is available. Rather, the change in the amount of time at a given "indicator temperature" (e.g., optimum for growth) may result in some amount of habitat affected but not eliminated. These distinctions are noted in the accompanying thermal affects parameter tables.

In addition, the individual spawning and early development temperatures cited in Table 5-32 actually represent an approximate mid-point within a range of temperatures at which walleye will spawn (as reported in the literature, above). Whereas avoidance, UILT, and preferred temperatures may be laboratory determined, field studies or observations typically yield the ranges of temperatures for various geographic areas suitable for spawning or early development.

Relative to the avoidance temperature, the maximum predicted additional loss of habitat (i.e., exclusion) for walleye in the thermally affected portion of lower Vernon Pool as a result of the new thermal limits is relatively small (Table 5-32). An estimated additional 3.3% of 324 acres of lower Vernon Pool (equal to 10.7 acres) would exceed the upper avoidance temperature of walleye during average case conditions. Viewed temporally, these 10.6 acres of habitat would be warmer than the avoidance temperature for one-half of the summer permit period (the average condition). No additional loss of habitat area in the thermal plume is predicted for walleye during extreme-case conditions. In terms of thermal plume volume, additional losses of habitat amount to 978 $ft^3 * 10^4$ during average case conditions (50% of the summer period), but no additional losses of volume are predicted for extreme-case conditions (Table 5-32). Additionally, there is no change predicted for the time exposure of walleye to the UILT temperature of 89°F in lower Vernon Pool because this temperature did not occur previously and is not predicted to occur under the new summer permit limits (Tables 4-2 and 4-3). Finally, it should be noted that Station 7, upstream from Vermont Yankee's discharge, is typically at or above 76°F (the upper avoidance temperature for walleye) for 205 hours, or 5.61% of the summer permit period (Table 3-3, Figure 3-8).

The maximum predicted increase in the amount of time the River water at Station 3 will be above the upper avoidance temperature of 76°F is 11.5% of summer period hours, or 420 additional hours (Table 5-32). This increase is the difference between 39.99% of summer period hours predicted to be higher than 76°F at Station 3 compared to 28.48% of summer hours under the existing condition (Tables 3-3 and 3-4). There is no change predicted for the time exposure of walleye to the UILT temperature of 89°F at Station 3 because this temperature is never reached (Table 3-3 and 3-4).

Walleye are acknowledged "cool water" fishes (see Kendall 1978), and as such have well-developed mechanisms that enable them to persist in aquatic environments that routinely attain temperatures that exceed the upper avoidance temperature. For example, radio telemetry studies have shown that Susquehanna River, Maryland walleye will disperse (i.e., exhibit avoidance) to areas with cooler temperatures when summer river temperatures annually approach or exceed 80°F. Such areas typically included portions of the river directly influenced by cooler tributaries, or sections of the cooler tributaries as far as 26 miles upstream (Normandeau Associates, Inc. RMC Division, unpublished data). Based on existing permit conditions and relative to the walleye avoidance temperature, walleye likely dispersed from the Vernon Dam tailrace for approximately 28% of the summer permit period. The additional time predicted when tailrace temperatures will exceed the avoidance temperature means the dispersal may occur somewhat earlier in the summer period.

Table 5-32 also shows predicted changes in habitat affected by the new summer period thermal limits relative to several "indicator" temperatures that have been determined for walleye. Of these, the optimal growth temperature (74°F) and the preferred temperature (72°F) will occur during the summer permit period. Only a minor additional portion of thermal plume habitat area (15.5 acres) and volume in lower Vernon Pool relative to the optimal growth temperature for walleye is predicted to be affected by the new thermal limits during the summer permit period. No change in the amount of thermal plume habitat area or volume in lower Vernon Pool is predicted relative to the preferred temperature for walleye.

Downstream of Vernon Dam at Station 3, an increase of 6.6% of the summer permit period that represents 241 hours is predicted when River temperatures will exceed the optimum temperature for growth. Similarly, the increased amount of time River temperatures at Station 3 are predicted to exceed the preferred temperature for walleye (72°F) is 9.4% of the summer period, or 344 hours. Put in proper perspective, however, most walleye in temperate climates exist in natural summer temperatures that exceed lab-determined parameters such as growth optimums or preferred temperatures. Such temperatures occur as a result of routine summer warming. In practical terms, these indicator temperatures would be achieved earlier and persist longer under the new permit conditions in the summer period than during the existing permit conditions.

Table 5-32 also shows estimated water temperatures for walleye spawning and early development. Spawning occurs within a range of 43-52°F (Scott and Crossman 1973); 48°F is the approximate midpoint of this range. Similarly, the incubation and early development temperature (54°F) represents the midpoint of a range of temperatures provided in McMahon et al. (1984). Based on the data in Table 3-3, virtually all spawning and early development in the Vernon area likely occurs prior to the start of the summer permit period (May 16). For example, walleye larvae in Vernon Pool ichthyoplankton collections are infrequently collected, typically few in number (range 1-14 larvae among years), and the initial catch date annually ranged from 10 to 25 May (Tables 5-13 and 5-33). Similarly, the 29.2 hours of additional time the water temperature at Station 3 is predicted to exceed

the early development indicator temperature of 54°F (Table 5-32) is negligible and unlikely to affect walleye larval development below Vernon Dam.

In river systems with dams, tailraces typically provide the habitat (clean, coarse, rocky substrates with good water currents) necessary for successful spawning (see McMahon et al. 1984). In the Vernon area, walleye spawning likely takes place upstream of Vermont Yankee (below Bellows Falls Dam) and in the tailrace below Vernon Dam. As a result, walleye spawning in Vernon Pool likely occurs in river reaches unaffected by the thermal plume associated with Vermont Yankee. Further, spawning in either location prior to May 16 will not be affected by the proposed, new summer temperature limits.

The proposed new temperature limits for the Vermont Yankee thermal plume are expected to have no adverse effects on the other piscivores of the fish community represented by walleye in lower Vernon Pool or the Vernon Dam tailrace. Among non-RIS piscivorous species represented by walleye, black crappie, and northern pike were found in low numbers in Vernon Pool and Vernon Dam tailrace (Tables 5-9 to 5-12). Their abundance is expected to remain low under the proposed new thermal limits. Chain pickerel in Vernon Pool were more abundant than walleye within the fish community and during 1991-1999 formed 2.5% of the fish community as determined by trap nets in Vernon Pool (Table 5-11). Chain pickerel favor lentic habitats and would be expected to remain more abundant than walleye in Vernon Pool, but walleye would be expected to remain more abundant than chain pickerel in the more lotic habitats in the Vernon Dam tailrace. Overall, similar proportional representation of both RIS and non-RIS species is expected to persist in both tailwater and pool fish communities.

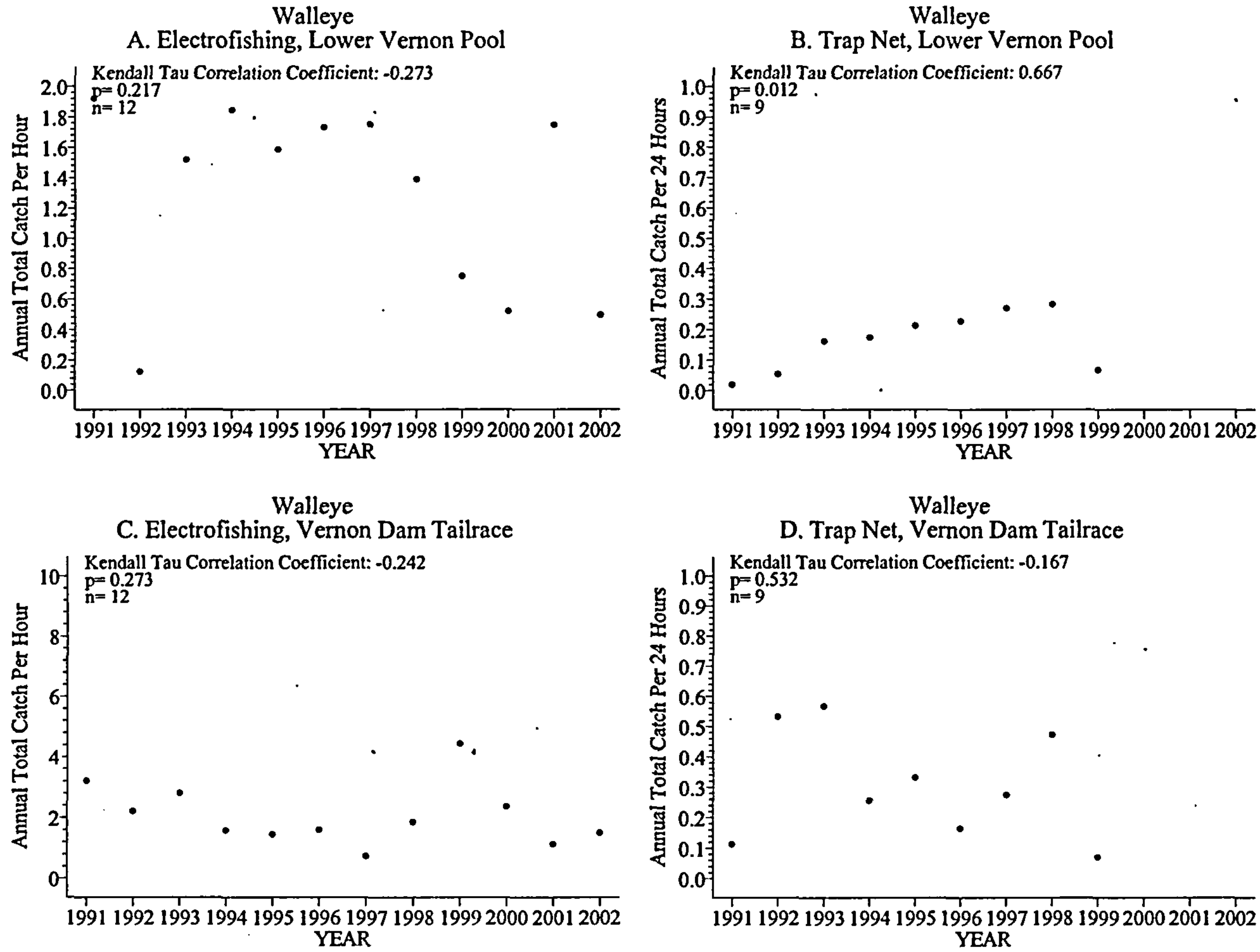
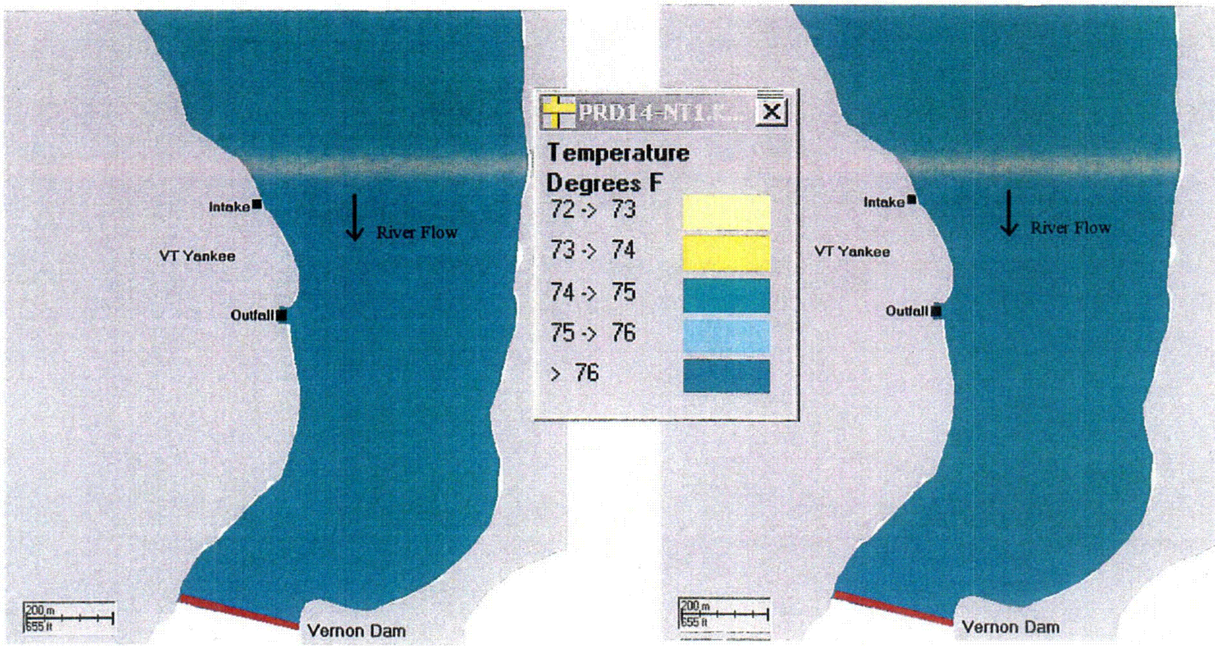
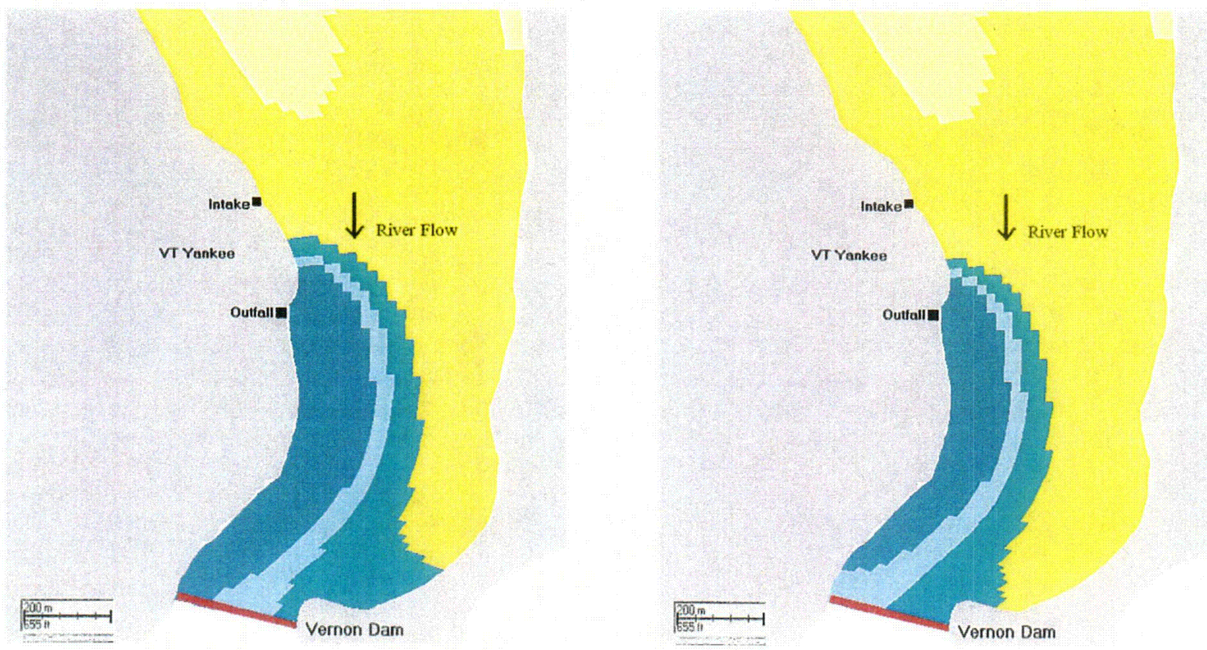


Figure 5-39. Scatter plots comparing walleye annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



(a) Surface (Existing limits)

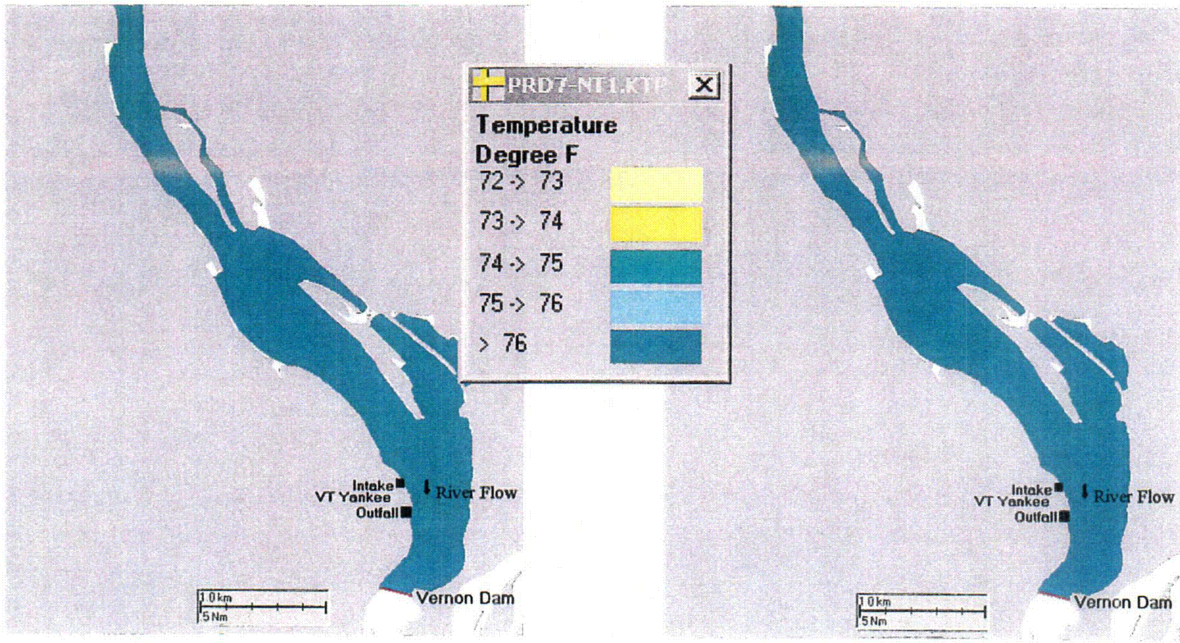
(b) Surface (Proposed limits)



(c) Bottom (Existing limits)

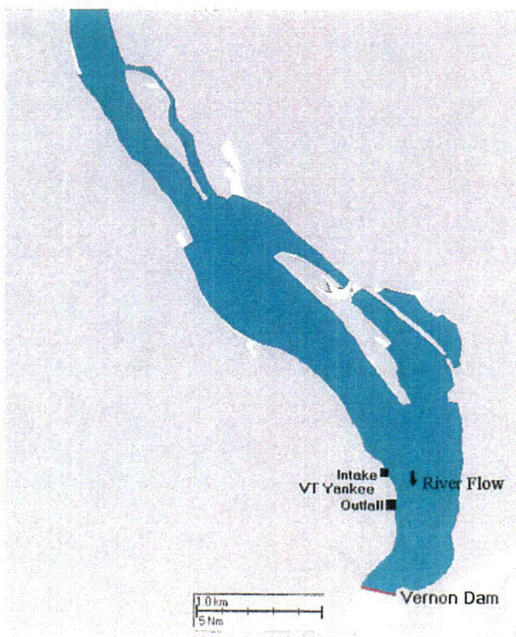
(d) Bottom (Proposed limits)

Figure 5-40. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the walleye avoidance temperature of 76°F.

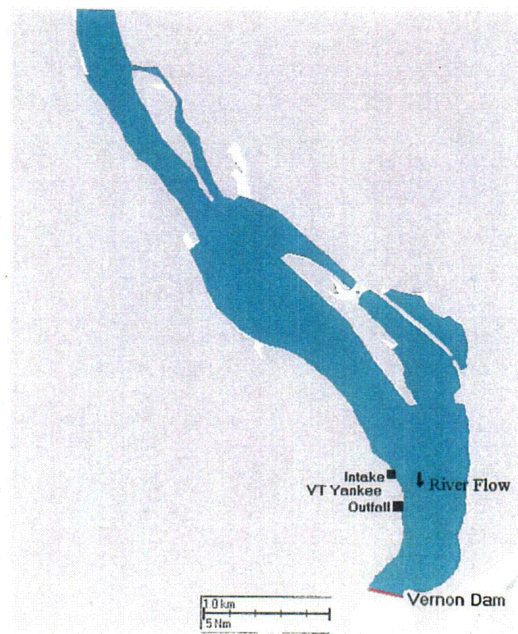


(a) Surface (Existing limits)

(b) Surface (Proposed limits)



(c) Bottom (Existing limits)



(d) Bottom (Proposed limits)

Figure 5-41. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the walleye avoidance temperature of 76°F.

Table 5-32. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for walleye between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[1] in % Time Station 3 is At or Above Temp °F
Exclusionary Temperatures		Change[3] in % Plume Volume ≥ Temperature		Change[3] in % Bottom Area ≥ Temperature		
Max. for summer survival, or UILT	89	0.0	0.0	0.0	0.0	0.0
Avoidance	76	-5.0	0.0	-3.3	0.0	11.5
Indicator Temperatures		Change[3] in % Plume Volume ≥ Temperature		Change[3] in % Bottom Area ≥ Temperature		
Optimum for growth	74	-3.8	0.0	-4.8	0.0	6.6
Preferred	72	0.0	0.0	0.0	0.0	9.4
Spawning	48	0.0	0.0	0.0	0.0	0.0
Early life history	54	0.0	0.0	0.0	0.0	0.8

B. Numeric Difference						
Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[2] in Hours Station 3 is At or Above Temp °F
Exclusionary Temperatures		Change[3] in Plume Volume (ft^3 * 10^4) ≥ Temperature		Change[3] in Bottom Area (acres) ≥ Temperature		
Max. for summer survival, or ULT	89	0.0	0.0	0.0	0.0	0.0
Avoidance	76	-977.8	0.0	-10.6	0.0	419.9
Indicator Temperatures		Change[3] in Plume Volume (ft^3 * 10^4) ≥ Temperature		Change[3] in Bottom Area (acres) ≥ Temperature		
Optimum for growth	74	-728.4	0.0	-15.5	0.0	241.1
Preferred	72	0.0	0.0	0.0	0.0	343.6
Spawning	48	0.0	0.0	0.0	0.0	0.0
Early life history	54	0.0	0.0	0.0	0.0	29.2

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

Table 5-33. Earliest and latest dates of capture of ichthyoplankton for walleye, 1991-2002. Also shown are mean daily ambient Connecticut River temperatures recorded at Station 7 for the dates of capture. Note that sampling does not begin before May 1.

Year	Earliest	Temp (F)	Latest	Temp (F)
1991	14 May	58	14 May	58
1992	20 May	59	20 May	59
1993	-	-	-	-
1994	25 May	60	01 Jun	60
1995	12 May	53	12 May	53
1996	-	-	-	-
1997	-	-	-	-
1998	15 May	57	21 May	64
1999	10 May	58	10 May	58
2000	15 May	53	22 May	52
2001	21 May	52	21 May	52
2002	-	-	-	-
Temp Range:		52-60		52-64
Notes:	Infrequently collected, very low numbers			

5.2.7 Largemouth Bass

Largemouth bass (*Micropterus salmoides*) are non-native to the Connecticut River. Like smallmouth bass, they were introduced into New Hampshire waters during the 1860s (Scarola 1987). The native range for this species included the fresh waters of the lower Great Lakes, the central part of the Mississippi River system to the Gulf Coast, Florida, and north on the Atlantic coast to Virginia. As a result of extensive introduction, it now occurs over virtually the whole Atlantic coast from Maine to Florida (Scott and Crossman 1973). Largemouth bass inhabit marshes, swamps, ponds, lakes, reservoirs, and large rivers (Jenkins and Burkhead 1993). They are often found in warm water at depths of less than 20 ft. in association with soft bottoms, stumps, and extensive growths of a variety of emergent and sub-emergent vegetation (Scott and Crossman 1973).

Largemouth bass represents the lentic piscivore trophic guild of fish species that are reported to be intermediate in their tolerance to pollution (Table 2-1). Some researchers consider largemouth bass to be insectivorous and tolerant to pollution (Table 2-1). This alternate trophic guild applies to early life stages that primarily feed on plankton and small insects (Jenkins and Burkhead 1993). The relatively high abundance of largemouth bass in lower Vernon Pool, and their much lower abundance in the Vernon Dam tailwaters, supports this trophic guild classification and representation within the Connecticut River fish community as a lentic piscivore.

Largemouth bass shares the same habitat, trophic guild and pollution tolerance classification as walleye (Table 2-1). Some researchers classify largemouth bass as insectivores. This classification rational is similar to that described above for largemouth bass where young primarily feed on plankton and small insects. As an RIS, largemouth bass also represents other non-RIS lentic piscivores with intermediate tolerance found in the Vernon Pool fish community, including white perch, American eel, brook trout, northern pike, chain pickerel, rock bass, and black crappie (Table 2-1). Therefore, conclusions about the interaction of largemouth bass with the existing and proposed new Vermont Yankee thermal limits embodies USEPA's concept of RIS and can also be applied to other members of the fish community within the same trophic guild and tolerance classification.

Throughout over 30 years of monitoring at Vermont Yankee, juvenile and adult largemouth bass have been numerically important components of the River fish community sampled by electrofishing and trap nets. They are found throughout lower Vernon Pool including habitats exposed to the thermal effluent. In lower Vernon Pool, largemouth bass comprised about 1.6% of the catch in 1968 – 1980, 2.2% in 1981 – 1990, and 4.7% in 1991 – 2002 (Table 5-14). In upper Turners Falls Pool (study area downstream from Vernon Dam), largemouth bass relative abundance has been lower, ranging between 0.5 and 0.9% of the catch over the three review periods. The lower relative abundance of largemouth bass below Vernon Dam reflects its preference for lentic environments, which are found upstream in lower Vernon Pool, and avoidance of the lotic habitat in the Vernon Dam tailrace. Scott and Crossman (1973) reported largemouth bass are rarely found in a rocky environment, which is characteristic of the Vernon Dam tailrace.

The annual catch rate (i.e. catch per unit effort or CPUE) of largemouth bass by electrofishing from 1991-2002 in lower Vernon Pool (Table 5-9) was highest in 2001 (23 fish per hour) and lowest in 1998 (7 fish per hour). The CPUE of largemouth bass by electrofishing was lower downstream from Vernon Dam (Table 5-10) where annual CPUE was highest in 2001 (3 fish per hour) and lowest in 2000 (0 fish per hour). The largemouth bass annual CPUE by trap netting in lower Vernon Pool between 1991 and 1999 (Table 5-11) was highest in 1998 (0.35 fish per day) and lowest in 1992 (0.04

fish per day). The annual CPUE by trap netting downstream from Vernon Dam (Table 5-12) ranged between a high in 1995 of 0.2 fish per day and a low in 1996 and 1998 of 0 fish per day.

No statistically significant negative (decreasing) trends were observed in largemouth bass annual mean CPUE during the 1991-2002 period, supporting a finding of "no prior appreciable harm" due to Vermont Yankee's existing (baseline) summer period permit limits. The time series of annual mean electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau b of -0.152 with a probability level of p=0.493 (Figure 5-42a), while the electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall's Tau b of -0.030 with a probability level of p=0.891 (Figure 5-42c). Kendall's Tau b correlation coefficient for the annual mean trap net CPUE time series from lower Vernon Pool was 0.278 with a probability level of 0.297 (Figure 5-42b), and the correlation coefficient for the trap net data from the Vernon Dam tailrace was –0.085 with a probability level of 0.753 (Figure 5-42d).

Based on the two limiting or exclusionary thermal effects threshold temperatures cited in Table 5-34, and the predicted plume temperature contours, there is no change in the predicted habitat volume or bottom area under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme case conditions that would exclude largemouth bass based on reported upper incipient lethal temperature (UILT) and avoidance temperature (Table 5-34). The UILT representing the maximum temperature permissible for summer survival of largemouth bass is reported to be 95°F; the thermal avoidance temperature is 90°F.

With respect to the indicator thermal effects parameters for largemouth bass, there is no meaningful change in the predicted habitat volume or bottom area for spawning or preference under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme case conditions (Table 5-34, Figures 5-43 and 5-44). The mid-range of the reported spawning temperature is 70°F and the preferred temperature is 86°F. The increase in river water temperature due to the new permit limits would impact, for the average (50%) case, up to 11 acres (3.4% of 324 acres) of existing benthic habitat for with respect to the reported temperature (75°F) for incubation and early development of largemouth bass. However, incubation and hatch success rates of 92-100% at water temperatures of 85°F have been documented in several cases (Carlander 1977). For the extreme case summer period conditions modeled, which are predicted to occur 1% of the time or 36 hours, there is no increase (0.0%) in the extent of the thermal plume or bottom area above 75°F because the entire plume is above 75°F for both the proposed new limits and for the existing conditions (Tables 4-2 and 4-3). It should be noted that Station 7, upstream from Vermont Yankee's discharge, is expected to be at or above 75°F for 372 hours (10.19%) during the summer period (Table 3-3, Figure 3-8).

There is no predicted increase in the time the mixed Connecticut River water in the Vernon Dam tailrace down to Station 3 will be at or above the maximum temperatures for summer survival (UILT) or avoidance for largemouth bass under the proposed new thermal discharge limits (Table 5-34), because those water temperatures are never reached. With respect to the indicator temperatures, there is no change predicted at or above the preferred temperature. The predicted increase in time at or above the optimum temperature for growth is 1.8% or 65 hours. The predicted increase in time the Connecticut River water at Station 3 will be at or above the spawning temperature under the proposed new discharge limits is 4.5% or 163 hours compared to the existing limits, and the predicted increase in time the water will be at or above the incubation and larval development temperature under the

proposed new discharge limits is 9.2% or 335 hours compared to the existing limits, however, tailrace habitat is not preferred spawning habitat (Table 5-34). Eggs and larvae of largemouth bass have only been collected incidentally in two years (1997 and 1998, Table 5-35) in the nearfield ichthyoplankton sampling performed annually in lower Vernon Pool as a permit-required monitoring program, nor are they likely to be regularly collected because spawning occurs in gravel-filled nest in shallow water (Scarola 1987).

The proposed new summer temperature limits for the Vermont Yankee thermal plume are expected to have no adverse effects on the lentic piscivore trophic guild of fish species that are intermediate tolerant members of the fish community and are represented by largemouth bass in lower Vernon Pool and the Vernon Dam tailrace waters. Non-RIS represented by largemouth bass (American eel, brook trout, northern pike, chain pickerel, rock bass, and black crappie) are found in very low numbers in the fish community of lower Vernon Pool and in the Vernon Dam tailwaters (Tables 5-9 through 5-12), and their abundance is expected to remain low under the proposed new thermal limits. Combined, these species were 4.3% of the total electrofishing catch in lower Vernon Pool during 1991-2002 (Table 5-9). White perch, another non-RIS represented by largemouth bass, was 1.4% of the combined trap net and electrofishing catch in lower Vernon Pool over the 1991-2002 period (Table 5-6) and is expected to remain in a similar proportion of the total catch under the proposed new thermal limits. Similar proportional representation of both RIS and non-RIS fish species are expected to persist in the tailwater fish community downstream from Vernon Dam under the proposed new thermal regime, although in much lower proportional abundance and community dominance than in lower Vernon Pool because the habitat there is more riverine.

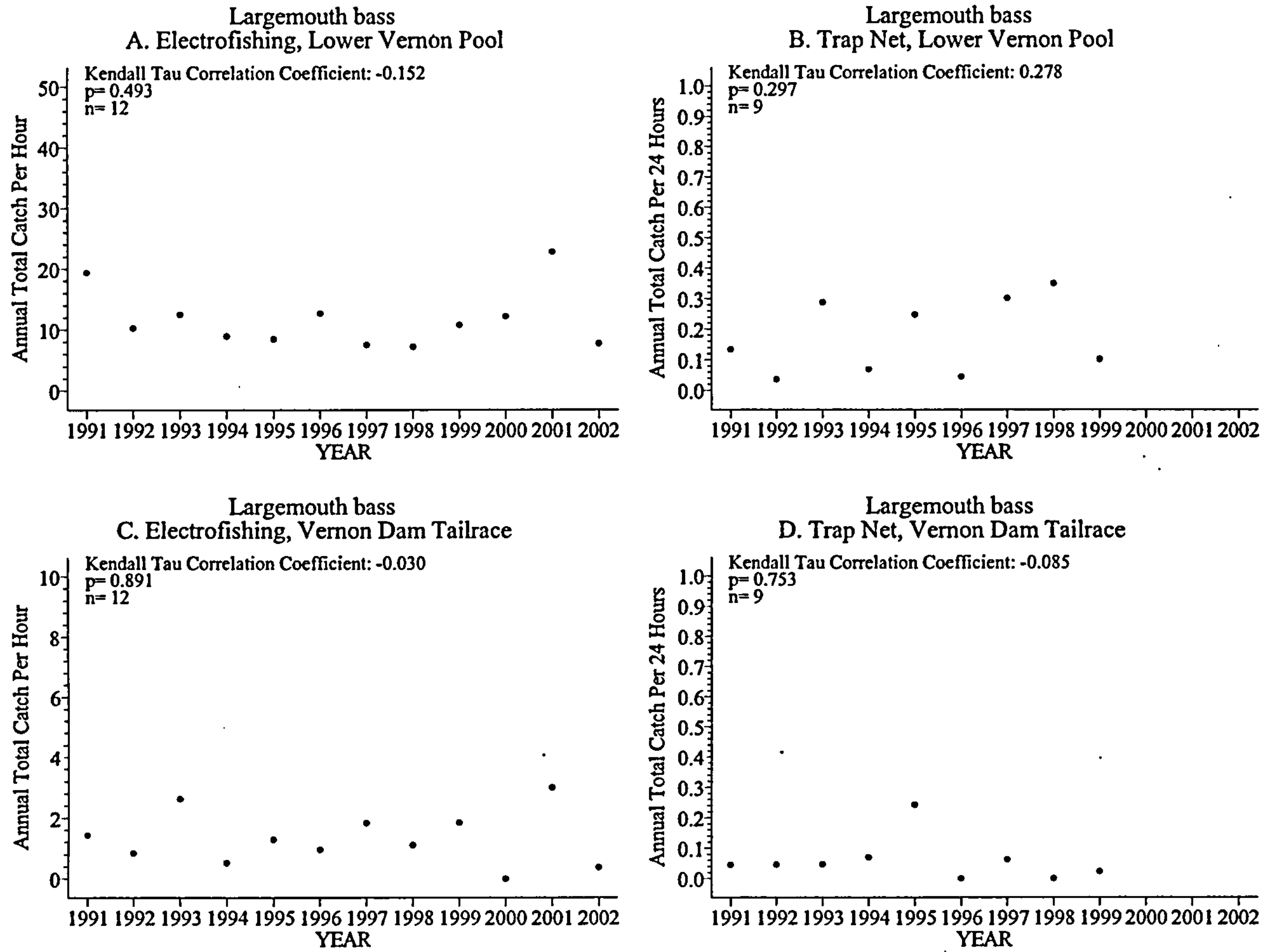
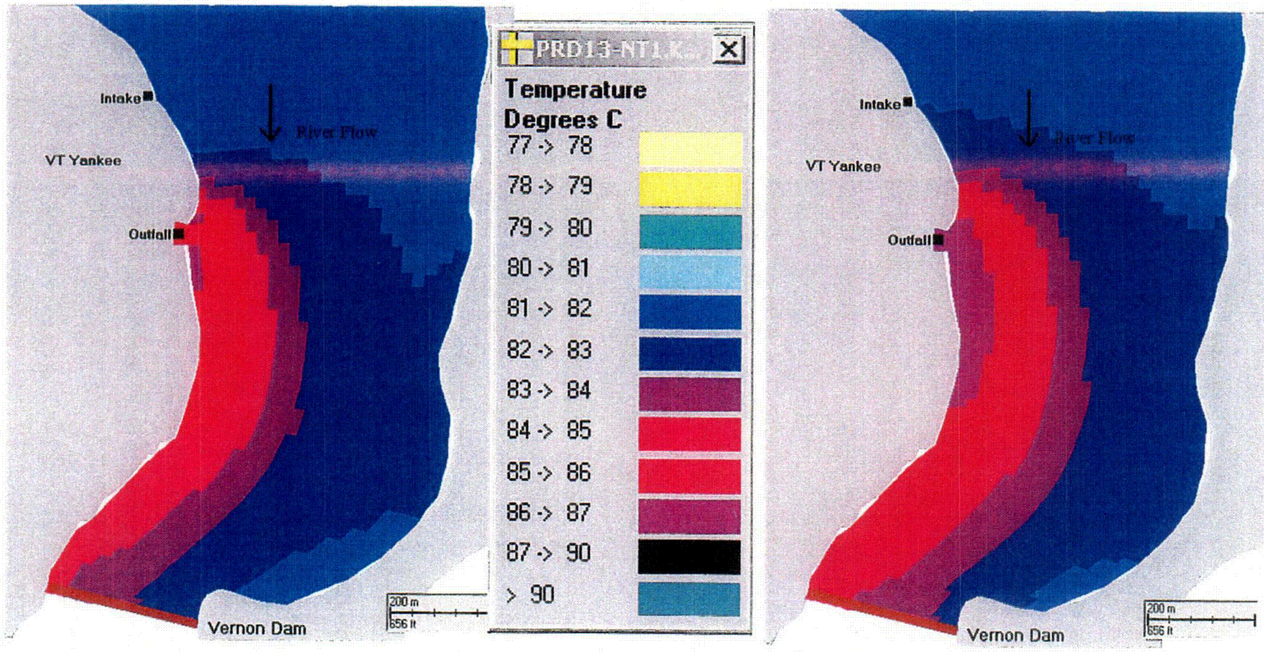
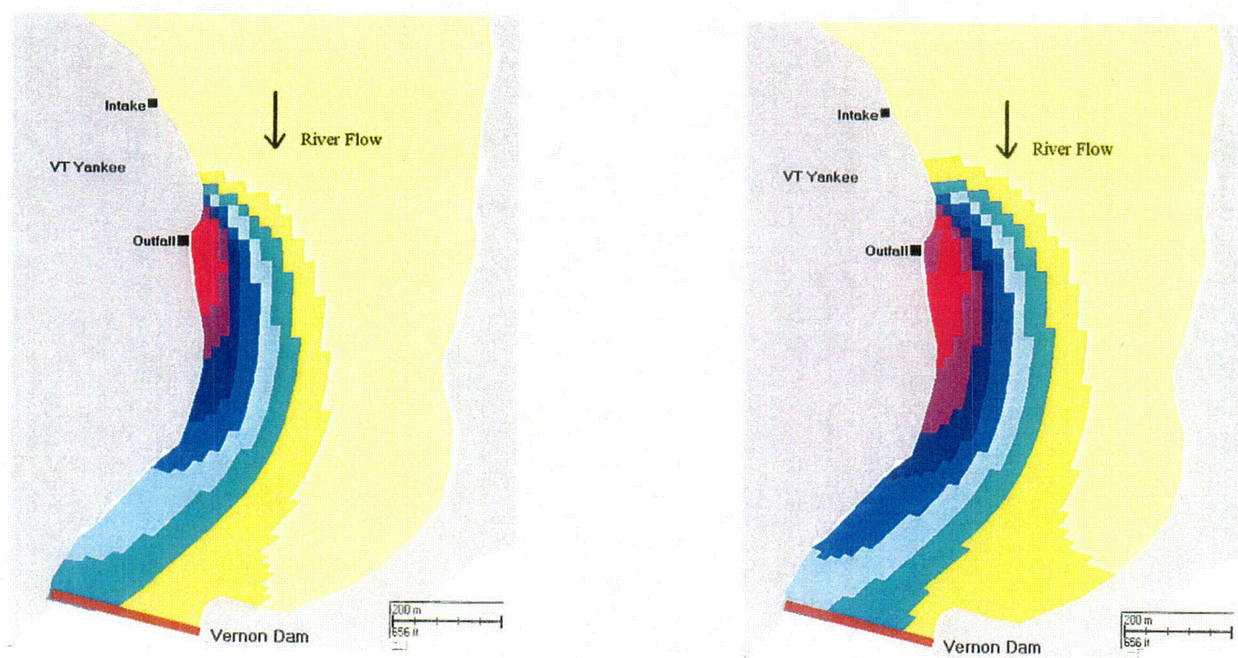


Figure 5-42. Scatter plots comparing largemouth bass annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



(a) Surface (Existing limits)

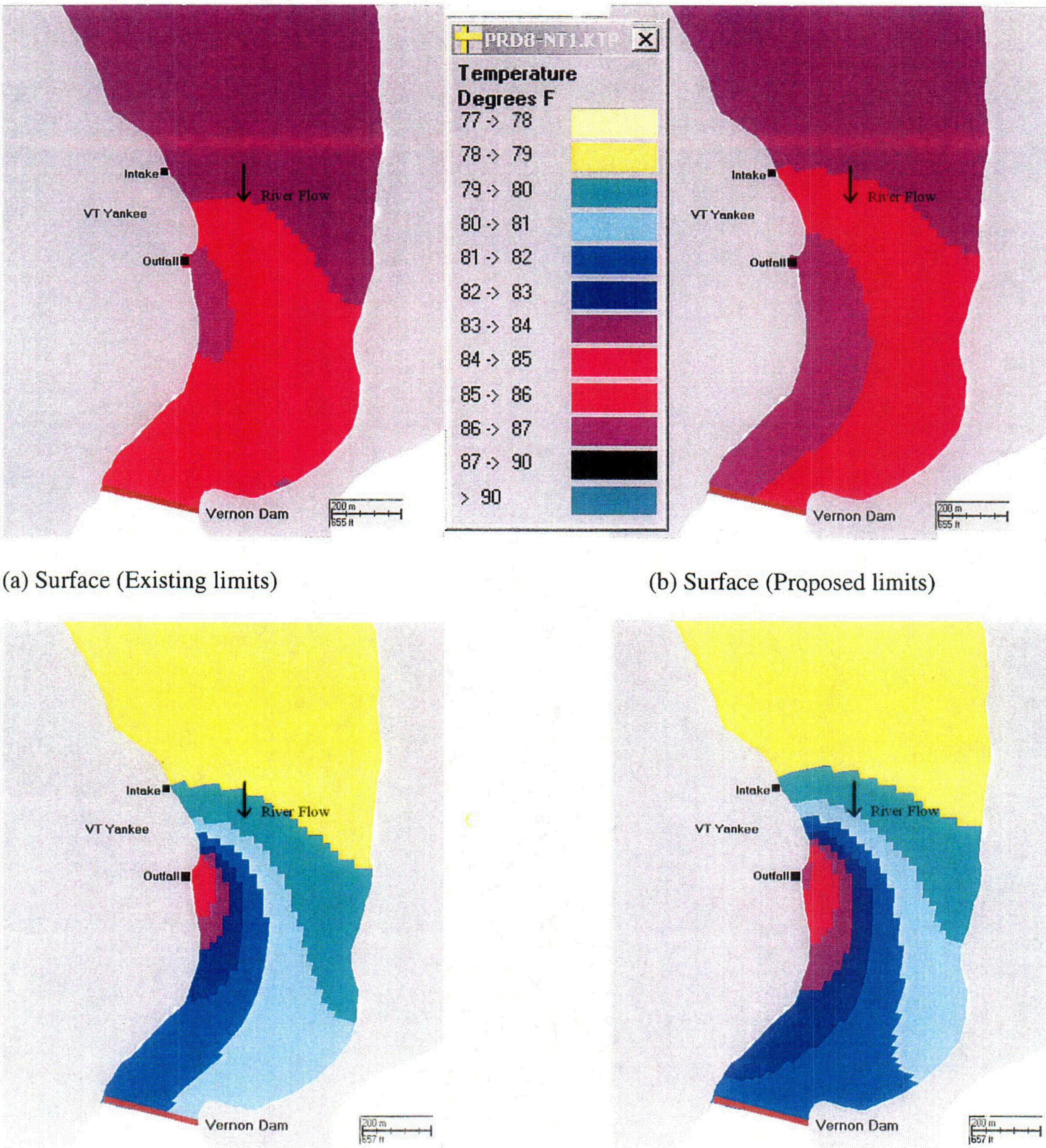
(b) Surface (Proposed limits)



(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-43. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the largemouth bass avoidance temperature of 90°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-44. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the largemouth bass avoidance temperature of 90°F.

Table 5-34. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for largemouth bass between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[1] in % Time Station 3 is At or Above Temp °F
Exclusionary Temperatures		Change[3] in % Plume Volume ≥ Temperature		Change[3] in % Bottom Area ≥ Temperature		
Max. for summer survival, or UILT	95	0.0	0.0	0.0	0.0	0.0
Avoidance	90	0.0	0.0	0.0	0.0	0.0
Indicator Temperatures		Change[3] in % Plume Volume ≥ Temperature		Change[3] in % Bottom Area ≥ Temperature		
Optimum for growth	83	0.0	-3.8	0.0	-2.7	1.8
Preferred	86	0.0	-0.3	0.0	-0.1	0.0
Spawning	70	0.0	0.0	0.0	0.0	4.5
Early life history	75	-4.3	0.0	-3.4	0.0	9.2
B. Numeric Difference						
Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[2] in Hours Station 3 is At or Above Temp °F
Exclusionary Temperatures		Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature		Change[3] in Bottom Area (acres) ≥ Temperature		
Max. for summer survival, or ULT	95	0.0	0.0	0.0	0.0	0.0
Avoidance	90	0.0	0.0	0.0	0.0	0.0
Indicator Temperatures		Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature		Change[3] in Bottom Area (acres) ≥ Temperature		
Optimum for growth	83	0.0	-730.6	0.0	-8.7	64.9
Preferred	86	0.0	-64.0	0.0	-0.3	0.0
Spawning	70	0.0	0.0	0.0	0.0	162.7
Early life history	75	-826.9	0.0	-10.9	0.0	335.3

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

Table 5-35. Earliest and latest dates of capture of ichthyoplankton for largemouth bass, 1991-2002. Also shown are mean daily ambient Connecticut River temperatures recorded at Station 7 for the dates of capture. Note that sampling does not begin before May 1.

Year	Earliest	Temp (F)	Latest	Temp (F)
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	02 Jul	72	02 Jul	72
1998	02 Jun	66	02 Jun	66
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
Temp Range:		N/M		N/M
Notes:		Rarely collected		

N/M - data not meaningful; too few data points

5.2.8 Fallfish

Fallfish (*Semotilus corporalis*) inhabits clear streams and lakes from New Brunswick, Canada, south along the East Coast of the United States to Virginia with the western limits being the Appalachian Mountains. Fallfish are common in the tributaries of the St. Lawrence River in Quebec and found along the northern shore of Lake Ontario (Scott and Crossman 1973). Adult fallfish inhabit clear, flowing, gravel-bottomed streams and lakes, while the young prefer more rapid water upstream. Larger adults have been noted to inhabit large pools and deeper runs in rivers (Scott and Crossman 1973).

Fallfish represents the lotic generalist trophic guild of fish species that are reported to be intermediate in their tolerance to pollution (Table 2-1). Fallfish are opportunistic feeders, eating aquatic insect larvae, terrestrial insects, crustaceans, and fish (Scott and Crossman 1973). Fallfish represent other generalist fish species that have an intermediate pollution tolerance and are present in lotic habitat in the Vermont Yankee study area, including redbreast sunfish, pumpkinseed, bluegill, common shiner, mimic shiner, and brown bullhead.

A total of two fallfish were captured by electrofishing upstream of Vernon Dam from 1991 – 2002 (Table 5-9). Catch per unit effort of fallfish by electrofishing was higher downstream from Vernon Dam (Table 5-10) where the highest annual CPUE was in 1999 (31.9 fish per hour) and the lowest in 1997 (0 fish per hour). No fallfish were captured in the trap nets upstream of Vernon Dam from 1991-1999 and a total of 10 fallfish were collected by trap netting downstream from Vernon Dam between 1991 and 1999 (Table 5-12). Fallfish were not captured in great numbers above Vernon Dam because they prefer flowing water found in the lotic habitat of the Vernon Dam tailrace.

No statistically significant negative trends were observed in fallfish annual total CPUE during the 1991-2002 period. The time series of annual total electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau b of –0.403 with a probability level of p=0.109 (Figure 5-45a). The electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall's Tau b of 0.182 with a probability level of p=0.411 (Figure 5-45c). No fallfish were caught in the trap nets in lower Vernon Pool (Figure 5-45b). The correlation coefficient for the trap net data from the Vernon Dam tailrace was 0.087 with a probability level of p=0.750 (Figure 5-45d).

No habitat exclusion is predicted for the maximum survival temperature with either the average (50%) or extreme (1%) model scenarios because the thermal plume never reaches 90°F (Table 5-36, Figures 5-46 and 5-47). Based on the avoidance threshold temperature for fallfish (Table 5-36), and the predicted plume temperature contours (Figures 5-46 and 5-47), the increase in river water temperature due to the new permit limits would exclude fallfish from using between 0.1 and 25 acres of existing benthic habitat (0.0% to 7.7% of 324 acres) under the proposed new Vermont Yankee thermal limits that they presently have access to under the existing permit limits. The excluded 25 acres of bottom habitat is predicted to occur for the avoidance temperature of 82°F modeled under the extreme case (1% occurrence). There will be an increase in the surface area at and downstream of the outfall, where the avoidance temperature of fallfish (82°F) will be exceeded during the average case proposed limit compared to the existing limits (Figure 5-46). During both the existing and proposed limits in the extreme case, the avoidance temperature of fallfish is exceeded naturally (Figure 5-47).

There is no change in the predicted habitat volume or bottom area for both the average case and extreme case conditions under the proposed new summer temperature limits compared to the existing

discharge conditions in regards to all indicator thermal effects parameters for fallfish (Table 5-36). Fallfish has a optimum temperature for growth at 68°F, the spawning temperature is 60°F, and the incubation temperature for egg and larval development is 65°F (Table 5-36). There in no known preferred temperature for fallfish. The indicator thermal effects parameters are naturally exceeded in Vernon Pool before the summer period; therefore no change is predicted for any of these parameters.

Under the proposed new thermal discharge limits, the water temperature at Station 3 will not reach the maximum temperature for summer survival (UILT) (Table 5-36); therefore there is no predicted increase in hours that Station 3 exceeds this temperature. The avoidance temperature of 82°F is predicted to be exceeded during 121.8 hours or 3.3% more of the summer period time. The optimum temperatures for growth and for larval development are predicted to be exceeded for 121.8 hours (3.3%) and 167.4 (4.6%), respectively. The predicted increase in time at or above spawning temperature is 82.8 hours or 2.3% (Table 5-36).

Fallfish spawn in the spring over gravel nests in flowing streams. Spawning typically occurs after water temperatures reach 59°F (Scott and Crossman 1973). Under the proposed new temperature limits for the Vermont Yankee, there is little potential for the thermal plume to adversely effect the spawning of fallfish, since spawning occurs prior to the onset of summer permit limits. Eggs and larvae of fallfish have only been collected incidentally in three years (1996, 1998, and 2002; Table 5-37) in the nearfield ichthyoplankton sampling performed annually in lower Vernon Pool as a permit-required monitoring program, and they are not likely to be regularly collected because their eggs are laid in gravel-filled nests in shallow water (Scarola 1987). No difference was calculated in the available plume volume or bottom area under the average or extreme case thermal plume conditions for fallfish spawning or for juveniles (Table 5-36).

The proposed new summer temperature limits for the Vermont Yankee thermal plume are expected to have no substantial effects on generalist trophic guild that are represented by fallfish in the lower Vernon Pool and the Vernon Dam tailrace waters.

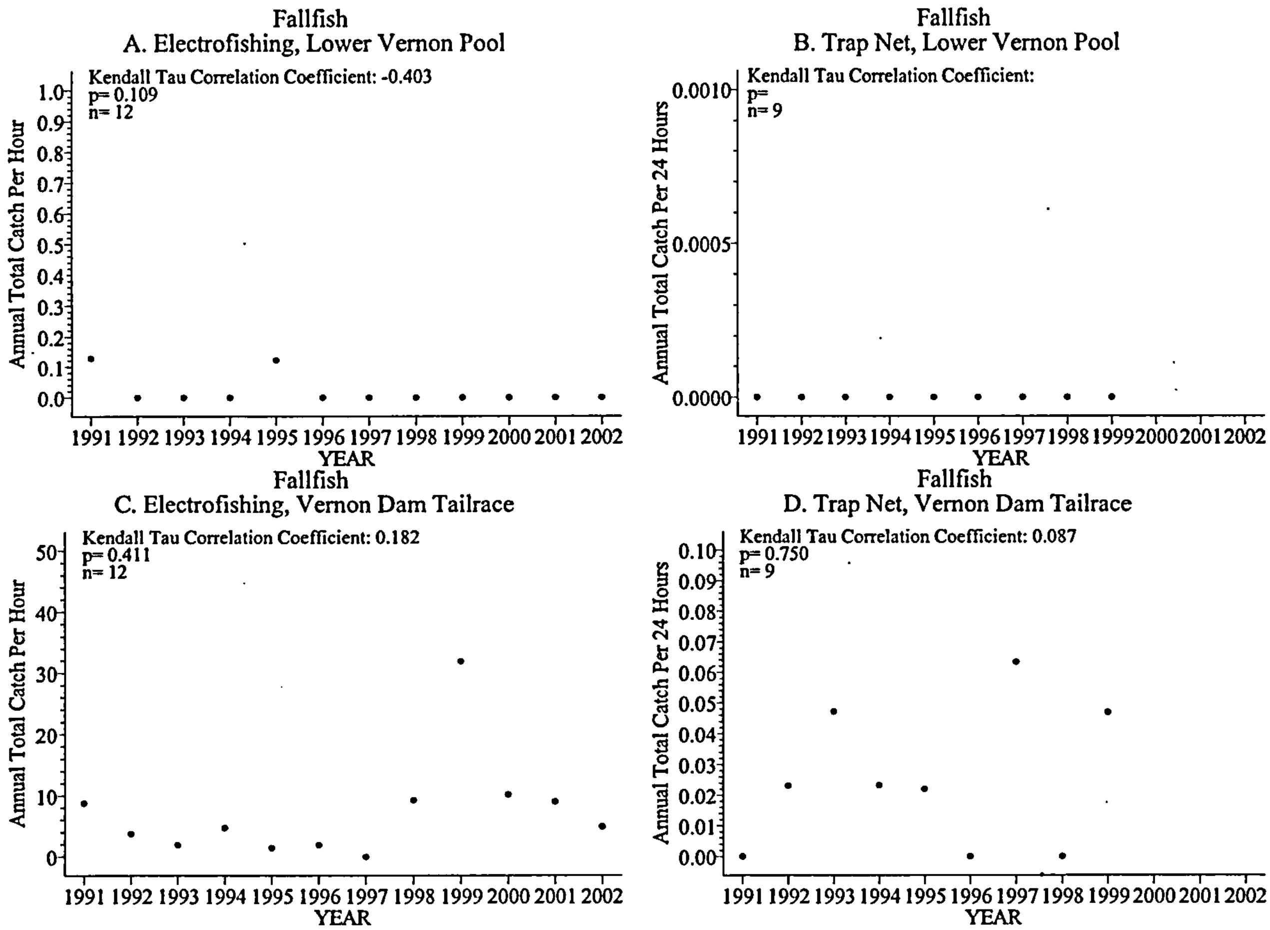
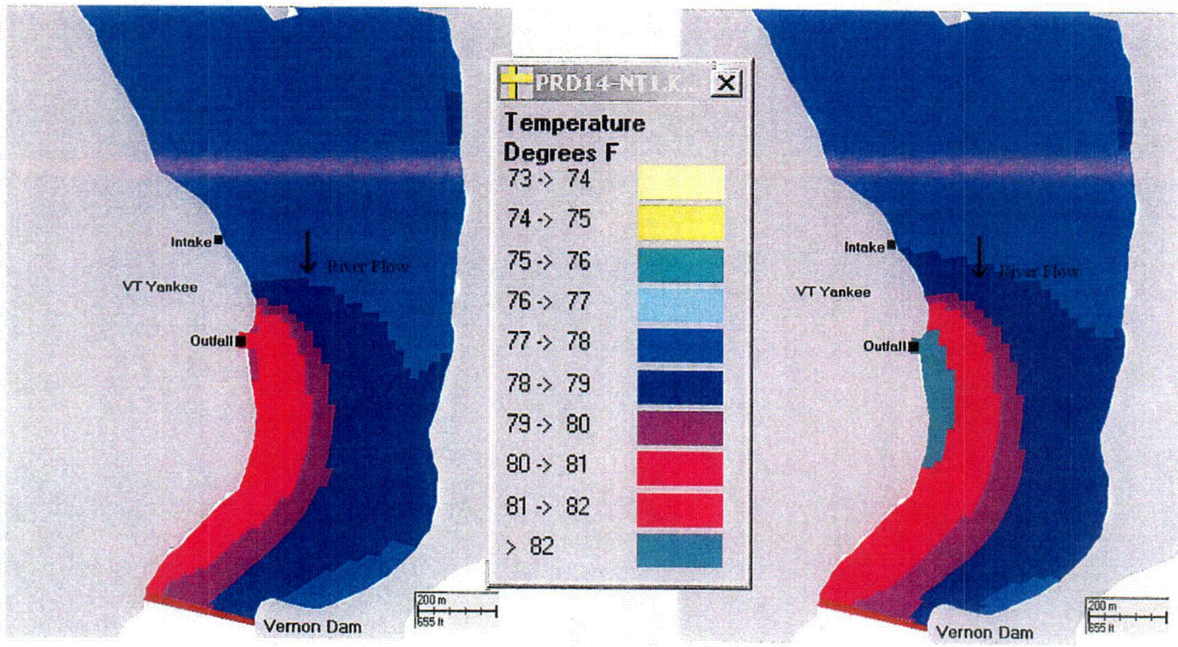
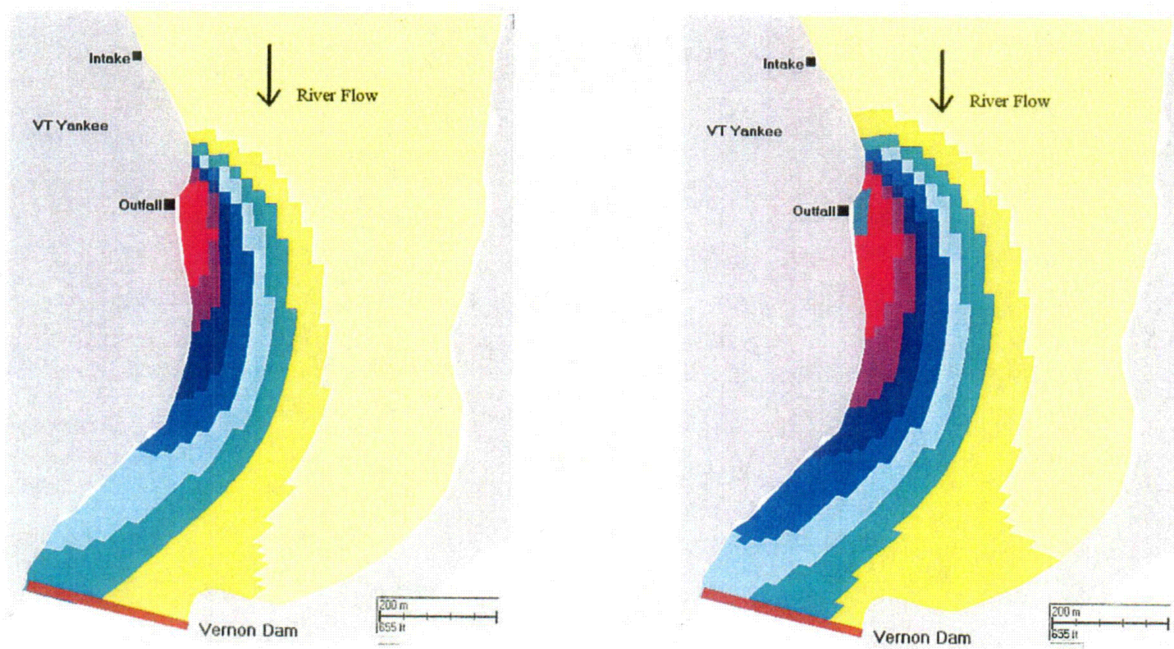


Figure 5-45. Scatter plots comparing fallfish annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.



(a) Surface (Existing limits)

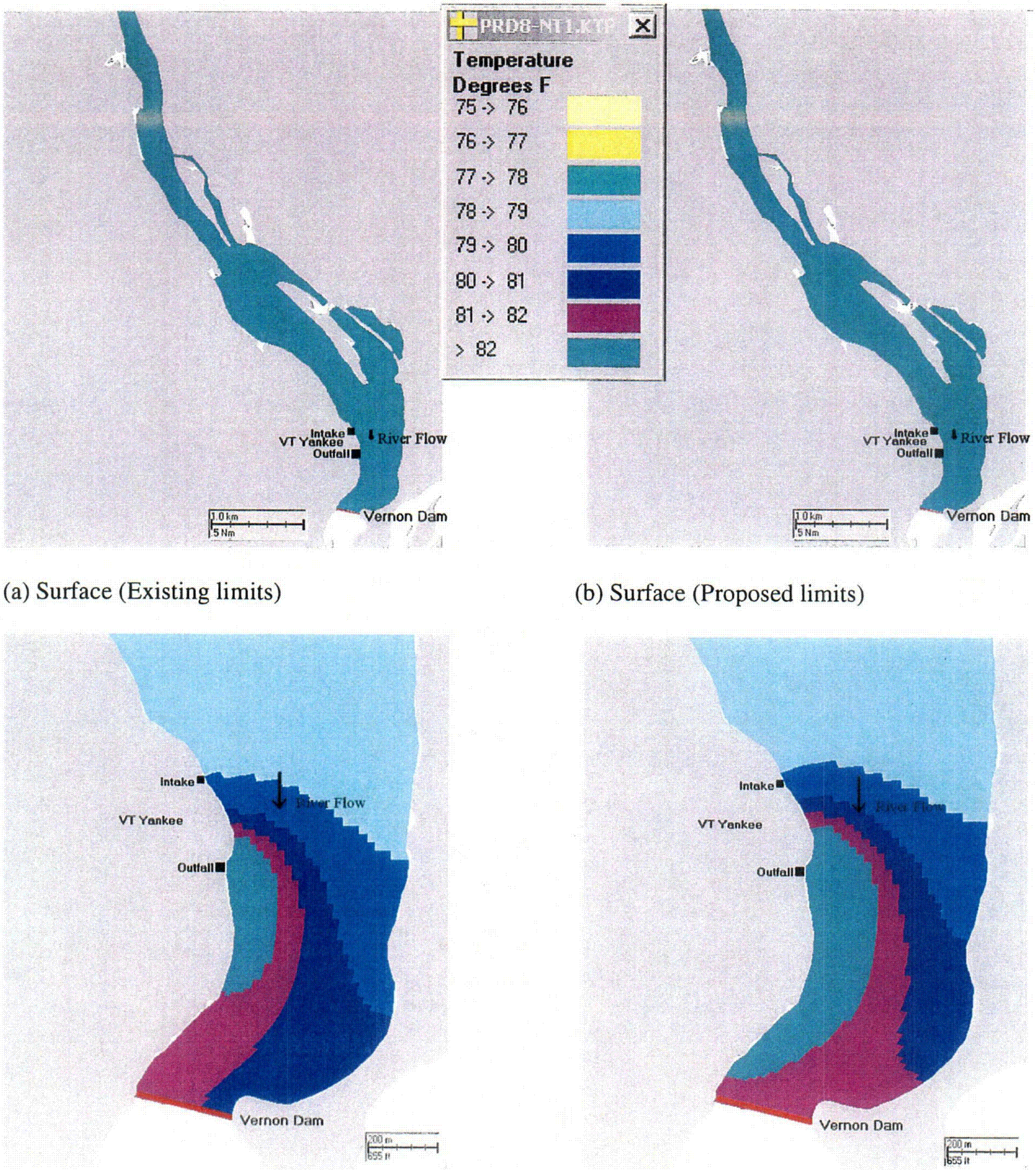
(b) Surface (Proposed limits)



(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-46. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the fallfish avoidance temperature of 82°F.



(a) Surface (Existing limits)

(b) Surface (Proposed limits)

(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

Figure 5-47. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the fallfish avoidance temperature of 82°F.

Table 5-36. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for fallfish between the existing and the proposed new summer permit limits.

Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[1] in % Time Station 3 is At or Above Temp °F
A. Percent Difference						
Exclusionary Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Max. for summer survival, or UILT	90	0.0	0.0	0.0	0.0	0.0
Avoidance	82	-0.1	-10.8	-0.04	-7.7	3.3
Indicator Temperatures		**Change[3] in % Plume Volume ≥ Temperature**		**Change[3] in % Bottom Area ≥ Temperature**		
Optimum for growth	68	0.0	0.0	0.0	0.0	3.3
Preferred	Information Not Available					
Spawning	60	0.0	0.0	0.0	0.0	2.3
Early life history	65	0.0	0.0	0.0	0.0	4.6

Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[2] in Hours Station 3 is At or Above Temp °F
B. Numeric Difference						
Exclusionary Temperatures		**Change[3] in Plume Volume (ft^3 * 10^4) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Max. for summer survival, or ULT	90	0.0	0.0	0.0	0.0	0.0
Avoidance	82	-13.8	-2092.7	-0.1	-24.8	121.8
Indicator Temperatures		**Change[3] in Plume Volume (ft^3 * 10^4) ≥ Temperature**		**Change[3] in Bottom Area (acres) ≥ Temperature**		
Optimum for growth	68	0.0	0.0	0.0	0.0	121.8
Preferred	Information Not Available					
Spawning	60	0.0	0.0	0.0	0.0	82.8
Early life history	65	0.0	0.0	0.0	0.0	167.4

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

Table 5-37. Earliest and latest dates of capture of ichthyoplankton for fallfish, 1991-2002. Also shown are mean daily ambient Connecticut River temperatures recorded at Station 7 for the dates of capture. Note that sampling does not begin before May 1.

Year	Earliest	Temp (F)	Latest	Temp (F)
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	11 Jun	63	11 Jun	67
1997	-	-	-	-
1998	02 Jul	66	02 Jul	66
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	10 Jul	66	10 Jul	66
Temp Range:		N/M		N/M
Notes:	Rarely collected			

N/M - data not meaningful; too few data points

5.2.9 White Sucker

White sucker (*Catostomus commersoni*) is restricted to North America and occurs from Arctic basins south into upper reaches of certain Gulf slope drainages (Jenkins and Burkhead 1993, Scott and Crossman 1973). White sucker, considered a nongame fish, is very generalized in habitat requirements. It populates a wide range of gradients and substrates in waters that range from clear to turbid in both lentic and lotic habitats (Jenkins and Burkhead 1993).

White sucker represents the omnivore trophic guild of fish species that are reported to be tolerant (Table 2-1). White sucker is also considered to be an insectivore or a generalist forager by some researchers (Table 2-1). This species often feeds on midge larvae, small crustaceans, clams, other invertebrates, fish eggs, algae and other plants (Jenkins and Burkhead 1993). There is a shift in the type of food consumed with increasing size. Fry begin feeding near the surface on plankton and other small invertebrates until they reach 16- 18 mm in size. At that point the mouth moves from terminal to ventral and there is a shift to bottom feeding (Scott and Crossman 1973). The proportional abundance of white sucker is similar between the lower Vernon Pool and the Vernon Dam tail waters, reflecting its classification in both lentic and lotic habitat guilds.

As an RIS, white sucker also represents other non-RIS omnivores that are classified as tolerant found in the Vernon Pool and tailrace fish communities, including common carp, goldfish, and golden shiner (Table 2-1). Therefore, conclusions about the interaction of white sucker with the existing and proposed new Vermont Yankee thermal limits embodies USEPA's concept of RIS and can also be applied to other members of the fish community within the same habitat, trophic guild, and tolerance classification.

Throughout over 30 years of monitoring at Vermont Yankee, juvenile and adult white sucker have been numerically important components of the River fish community sampled by electrofishing and trap nets. They are found throughout Vernon Pool including habitats exposed to the thermal effluent. In lower Vernon Pool, white sucker were 8.4% of the catch in 1968 – 1980, 9.4% in 1981 – 1990, and 5.7% in 1991 – 2002 (Table 5-14). In upper Turners Falls Pool (study area downstream from Vernon Dam), white sucker relative abundance, in general, has been higher, ranging between 6.8 and 21.5% of the catch over the three review periods.

The annual catch of white sucker by electrofishing from 1991-2002 in lower Vernon Pool (Table 5-9) was highest in 1994 (16.6 fish per hour) and lowest in 1998 (1.9 fish per hour). Catch per unit effort (CPUE) of white sucker by electrofishing was similar downstream from Vernon Dam (Table 5-10) where annual CPUE was highest in 1991 (13.0 fish per hour) and lowest in 2002 (2.2 fish per hour). The white sucker annual CPUE by trap netting in lower Vernon Pool between 1991 and 1999 (Table 5-11) was highest in 1996 (1.1 fish per day) and lowest in 1999 (0.3 fish per day). The annual CPUE by trap netting downstream from Vernon Dam (Table 5-12) ranged between a high in 1995 of 1.2 fish per day and a low in 1999 of 0.1 fish per day.

A statistically significant negative (decreasing) trend was observed in white sucker annual total CPUE during the 1991-2002 period for electrofishing. General electrofishing CPUE decreased significantly in both lower Vernon Pool and in the Vernon Dam tailrace (Figure 5-48). The time series of annual mean electrofishing CPUE from lower Vernon Pool exhibited a Kendall's Tau b of -0.545 with a probability level of p=0.014 (Figure 5-48a), while the electrofishing time series from the Vernon Dam tailrace area exhibited a Kendall's Tau b of -0.606 with a probability level of

p=0.006 (Figure 5-48c). No statistically significant negative (decreasing) trend was observed in white sucker annual total CPUE trap net catch during the 1991-1999 period. Kendall's Tau b correlation coefficient for the annual total trap net CPUE time series from lower Vernon Pool was 0.000 with a probability level of 1.000 (Figure 5-48b), and the correlation coefficient for the trap net data from the Vernon Dam tailrace was –0.278 with a probability level of 0.297 (Figure 5-48d).

Partitioning the white sucker CPUE data obtained by general electrofishing in lower Vernon Pool into sampling stations upstream from Vermont Yankee's discharge and stations exposed to the thermal plume revealed that significant decreasing trends existed in both areas (Figure 5-49, Table 5-38). Stations 5, Rum Point, and the New Hampshire Setback (Figure 5-1) were all upstream from the influence of Vermont Yankee's thermal plume, and the trend in the combined general electrofishing CPUE from these upstream locations exhibited a significant decreasing trend with a Kendall Tau b correlation coefficient of -0.485 and a significance probability of p=0.028 (Figure 5-49a). Station 4 was located in lower Vernon Pool but downstream from Vermont Yankee's discharge (Figure 5-1), and the trend in the combined general electrofishing CPUE from this downstream location also exhibited a significant decreasing trend with a Kendall Tau b correlation coefficient of -0.626 and a significance probability of p=0.005 (Figure 5-49b). Further partitioning of the Station 4 general electrofishing CPUE data for white sucker into the samples taken along the Vermont shore closest to Vermont Yankee's discharge, and the samples taken along the New Hampshire shore that were downstream but opposite Vermont Yankee's discharge, revealed that both subsets exhibited significant decreasing trends in white sucker CPUE between 1991 and 2002 (Figure 5-50, Table 5-39). Therefore, there was a significant decrease in white sucker CPUE from the general electrofishing program conducted throughout lower Vernon Pool during the period 1991 through 2002 in both areas exposed and not exposed to Vermont Yankee's thermal plume.

Partitioning the white sucker CPUE data obtained by general electrofishing in the Vernon Dam tailrace into the most upstream sampling stations found between the foot of the dam (Station 2) and Stebbins Island (Figure 5-1), and stations at least four miles downstream from the dam revealed a significant decreasing trend nearest to the dam and no trend further downstream (Figure 5-49, Table 5-38). Stations 0.1 miles south of Vernon Dam, Station 3 and Stebbins Island (Figure 5-1), were all in the most upstream portion of the tailrace and closest to the influence of Vermont Yankee's thermal plume, and the trend in the combined general electrofishing CPUE from these upstream locations exhibited a significant decreasing trend with a Kendall Tau b correlation coefficient of -0.667 and a significance probability of p=0.003 (Figure 5-49c). Station 2 was located about four miles downstream from Vernon Dam (Figure 5-1), and the trend in the combined general electrofishing CPUE from this downstream location exhibited no significant trend with a Kendall Tau b correlation coefficient of -0.107 and a significance probability of p=0.630 (Figure 5-49d). Therefore, there was a significant decrease in white sucker CPUE from the general electrofishing program in the tailrace area immediately below Vernon Dam during the period 1991 through 2002, but no significant decrease was observed further downstream in upper Turners Falls Pool.

Based on the two limiting or exclusionary thermal effects threshold temperatures cited in Table 5-40 for white sucker (maximum and avoidance), and the predicted plume temperature contours for the average case and extreme case occurrence of flow and temperature (Figures 5-51 and 5-52), the increase in river water temperature due to the new permit limits would not exclude white sucker from any existing benthic habitat under the proposed new Vermont Yankee thermal limits that they presently have access to under the existing permit limits. No habitat exclusion is predicted for the

maximum survival or avoidance temperature based on reported upper incipient lethal temperature (UILT) and avoidance temperature (Table 5-40). The UILT representing the maximum temperature permissible for summer survival of white sucker is reported to be 88°F; the thermal avoidance temperature is 86°F.

With respect to the indicator thermal effects parameters for white sucker, there is no change in the predicted habitat volume or bottom area under the proposed new summer temperature limits compared to the existing discharge conditions for both average case and extreme case conditions for spawning and early life history. Additionally, there is no meaningful change in habitat or volume under the average case scenario for optimum growth or preferred temperatures. The reported spawning temperature is about 60°F, and the mid-to upper incubation temperature for egg and larval development is 65°F (Table 5-40). The reported optimum temperatures for growth and thermal preference are both 81°F. The predicted changes in habitat exposure with respect to the preferred and growth indicator temperatures in the thermally effected portion of lower Vernon Pool are small in plume volume (-0.5% or - 89 $ft^3 * 10^4$) and in plume area (-0.2% or –0.8 acres) compared to the total available habitat (19,400 $ft^3 * 10^4$ or 324 acres) in lower Vernon Pool. Therefore, the thermal plume affects only a small portion of the habitat because the highest plume temperatures typically occur at the surface near the Vermont Yankee discharge weir, habitat not favored by the bottom feeding white sucker.

There is no predicted increase in the time the mixed Connecticut River water in the Vernon Dam tailrace down to Station 3 will be at or above the maximum temperature for summer survival (UILT) or avoidance for white sucker under the proposed new thermal discharge limits because those water temperatures are never reached (Table 5-40). With respect to the indicator temperatures, the optimum temperature for growth and preference is predicted to be exceeded for about 188 hours or 5.1% more of the time under the proposed new limits compared to the existing limits. The change predicted for the time at or above the spawning temperature is 2.3% (about 83 hours), and the predicted increase in time the Connecticut River water at Station 3 will be at or above the incubation and larval development temperature under the proposed new discharge limits is 4.6 % or 167 hours compared to the existing limits (Table 5-40).

There is little potential under the proposed new temperature limits for the Vermont Yankee thermal plume to adversely affect the spawning of white sucker as evidenced by recent increases in ichthyoplankton collections in the most recent (since 1998) years (Tables 5-13 and 5-41). The percent of catch for white sucker has also increased from 0.5% in 1997 to a peak of 37.9% of the total ichthyoplankton catch in 2001 (Table 5-13). Additionally, white sucker generally migrate into gravelly tributaries to spawn when water temperatures approach 50°F (Scott and Crossman). Therefore, they likely would not spawn in the thermally influenced portion of the project and spawning is likely to occur prior to the summer permit period.

The proposed new summer temperature limits for the Vermont Yankee thermal plume are expected to have no adverse effects on the omnivore trophic guild of fish species that are reported to be tolerant members of the fish community that are represented by white sucker in lower Vernon Pool and the Vernon Dam tailrace waters. Although a significant decreasing trend was observed during 1991 through 2002 in white sucker electrofishing CPUE in the portion of lower Vernon Pool exposed to Vermont Yankee's thermal plume, and in the Vernon Dam tailrace area immediately downstream from the dam, electrofishing CPUE trends also decreased in the sampling stations in Vernon Pool

located clearly upstream from the influence of Vermont Yankee's plume. Therefore, the decrease was throughout lower Vernon Pool and not directly linked to Vermont Yankee's thermal discharge. Furthermore, white sucker larval abundance has increased in the nearfield ichthyoplankton collections during the 1997 through 2001 period, and this fish species is relatively robust with respect to its thermal tolerance and habitat requirements. It is likely, therefore, that the decreasing trend in white sucker electrofishing CPUE is related to food web dynamics and not to Vermont Yankee's thermal discharge. In addition to significant increases in the abundance of smallmouth bass and walleye in the recent time series (Figures 5-33c and 5-39b), one relatively new piscivore in Vernon Pool is the black crappie (*Pomoxis nigromaculatus*), which first appeared in 1996 in lower Vernon Pool in the general electrofishing survey and has increased in abundance annually since then.

Among the non-RIS represented by white sucker, common carp, goldfish, and golden shiner are found in very low numbers in the fish community of lower Vernon Pool and in the Vernon Dam tailwaters (Tables 5-9 through 5-12), and their abundance is expected to remain low under the proposed new thermal limits. Regardless of the gear type used in lower Vernon Pool and in the Vernon Dam tailwaters, the non-RIS species represented by white sucker are less than 5% of the proportional catch.

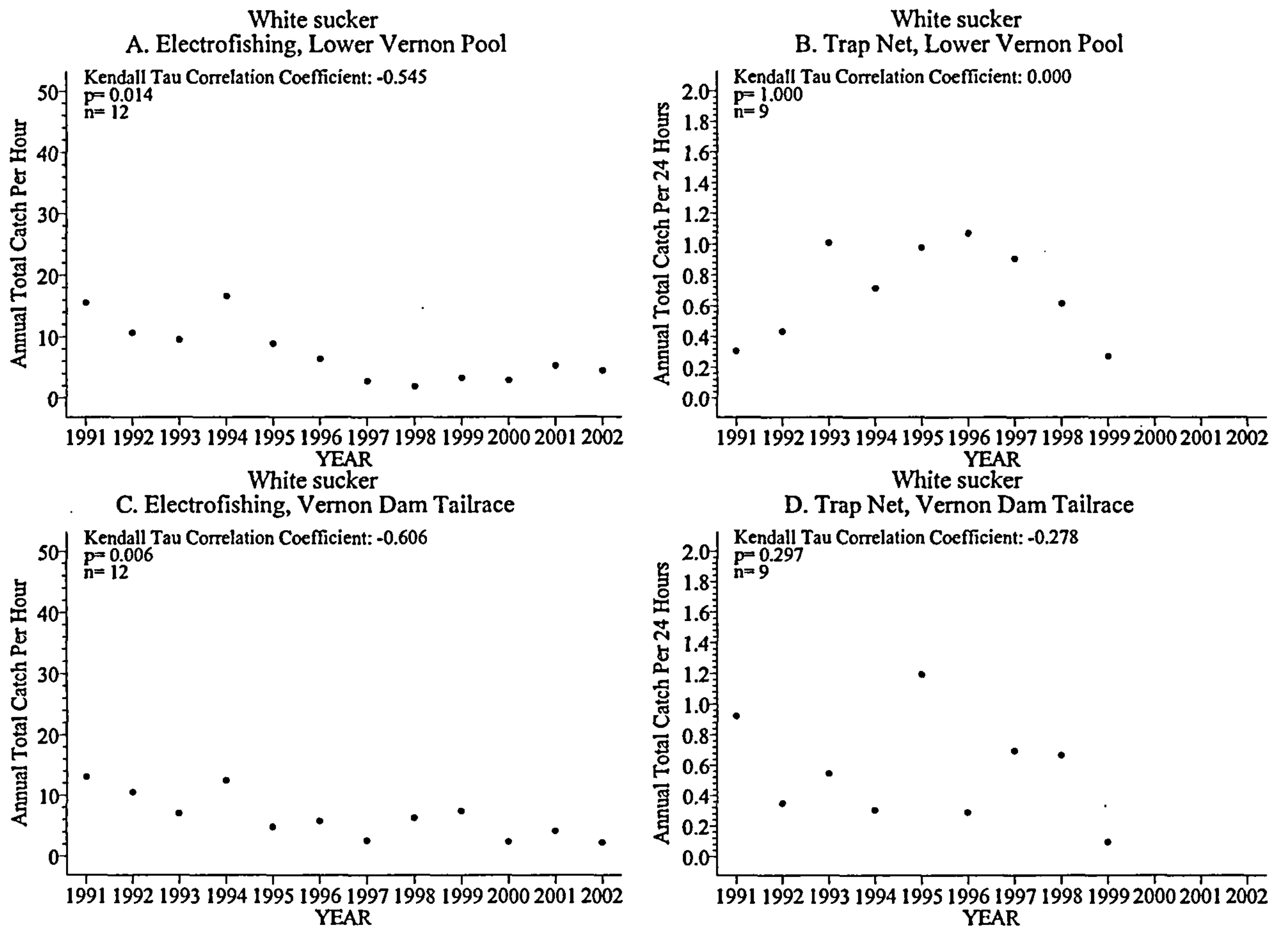


Figure 5-48. Scatter plots comparing white sucker annual total catch per hour for electrofishing and catch per 24 hours for trap nets during 1991 through 2002 in lower Vernon Pool and the Vernon Dam tailrace of the Connecticut River near Vernon, Vermont.

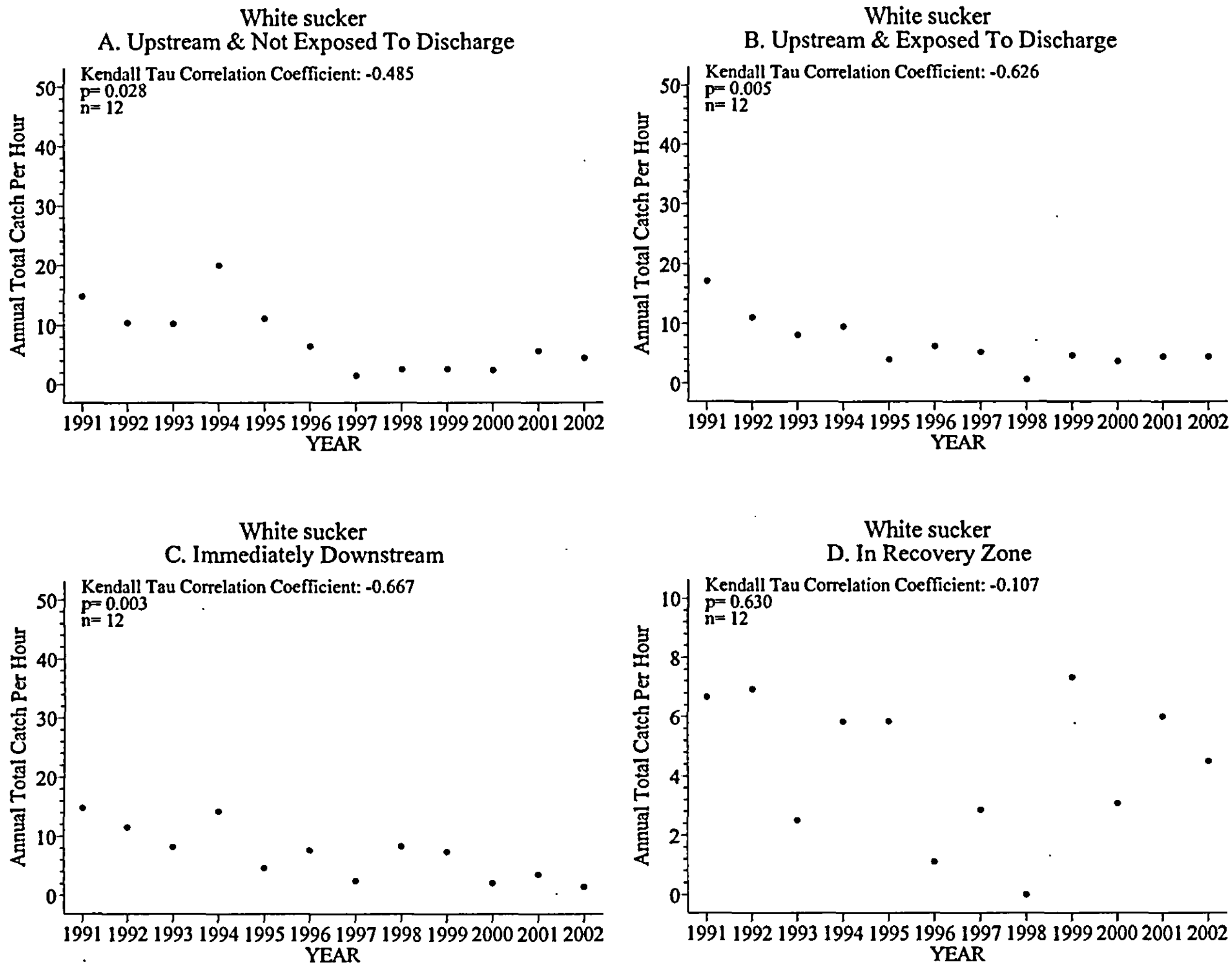


Figure 5-49. Annual total catch per unit effort of white sucker collected by general electrofishing in the Connecticut River, in the vicinity of Vernon, Vermont during 1991-2002.

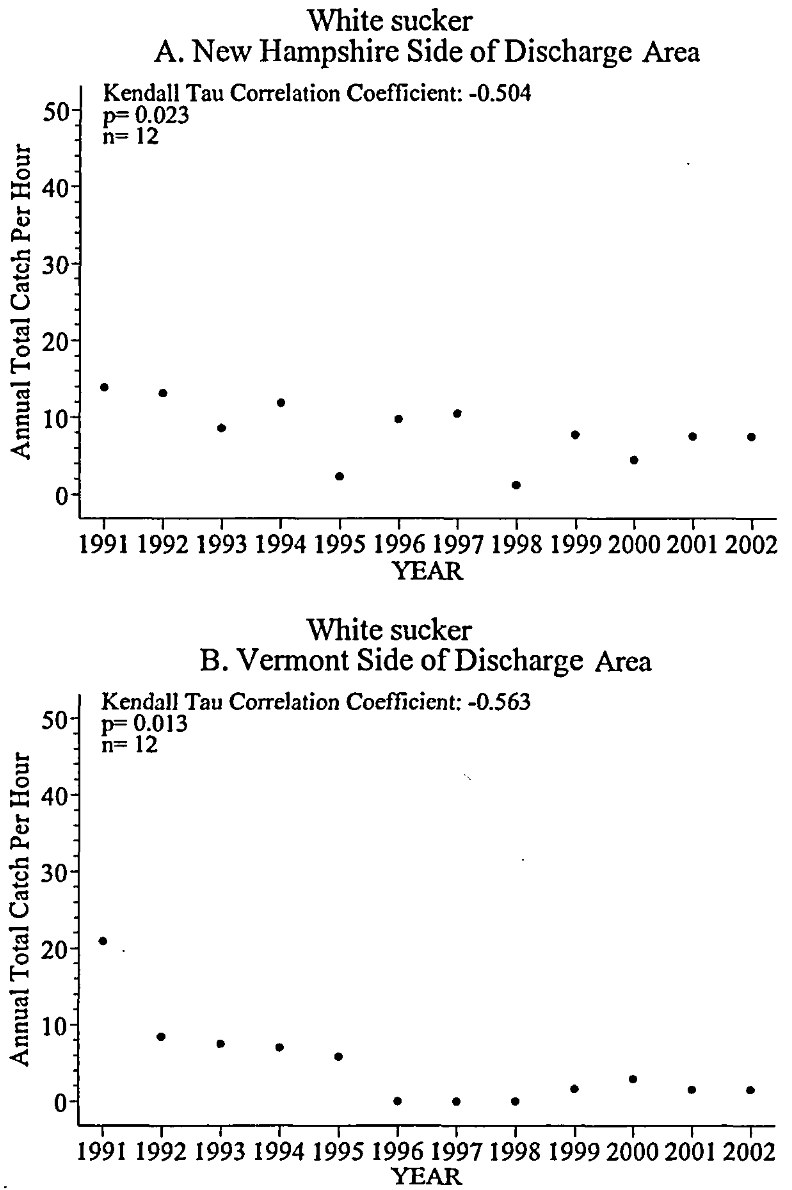
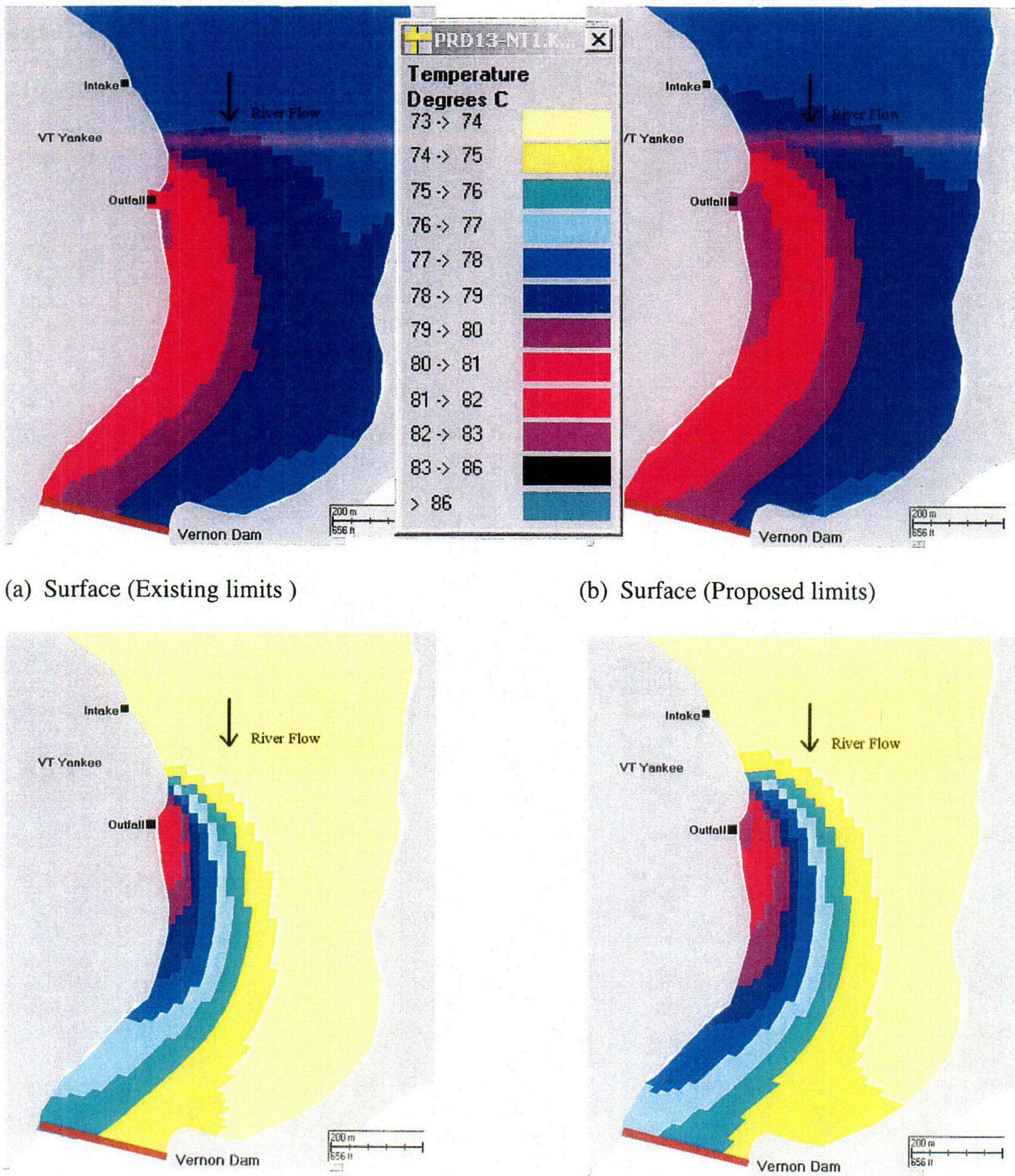


Figure 5-50. Annual total catch per unit effort of white sucker collected by general electrofishing in the discharge area upstream of Vernon Dam, Connecticut River, in the vicinity of Vernon, VT during 1991-2002.



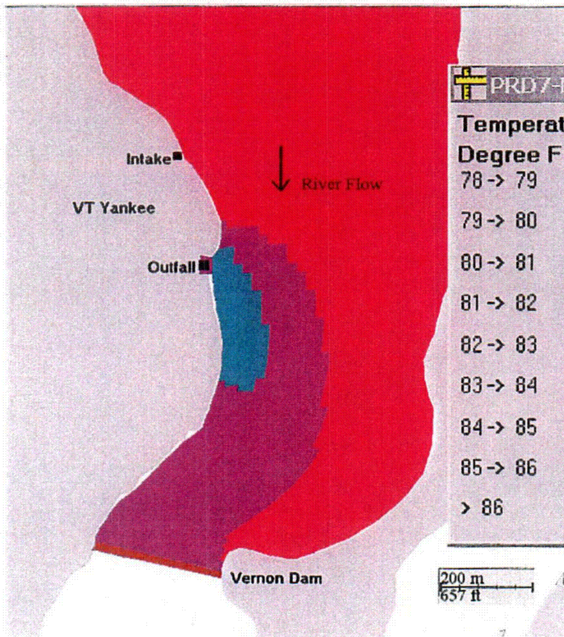
(a) Surface (Existing limits)

(b) Surface (Proposed limits)

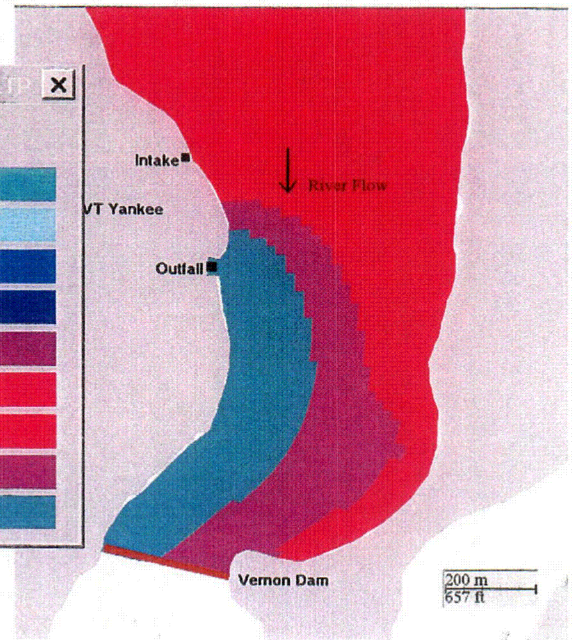
(c) Bottom (Existing limits)

(d) Bottom (Proposed limits)

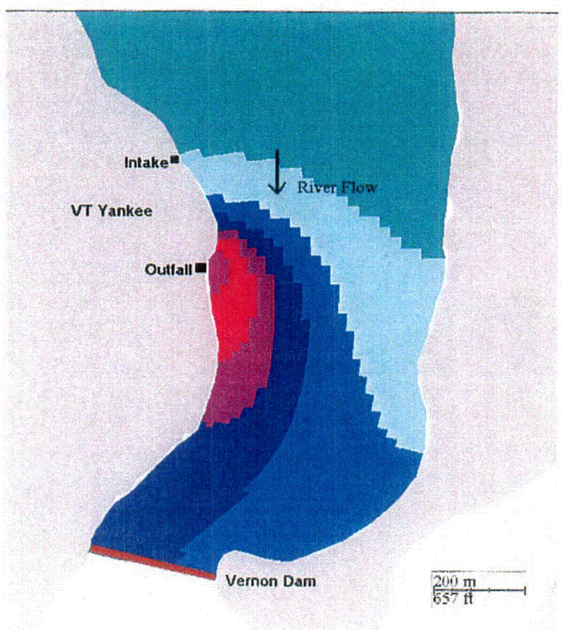
Figure 5-51. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the average case (50% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the white sucker avoidance temperature of 86°F.



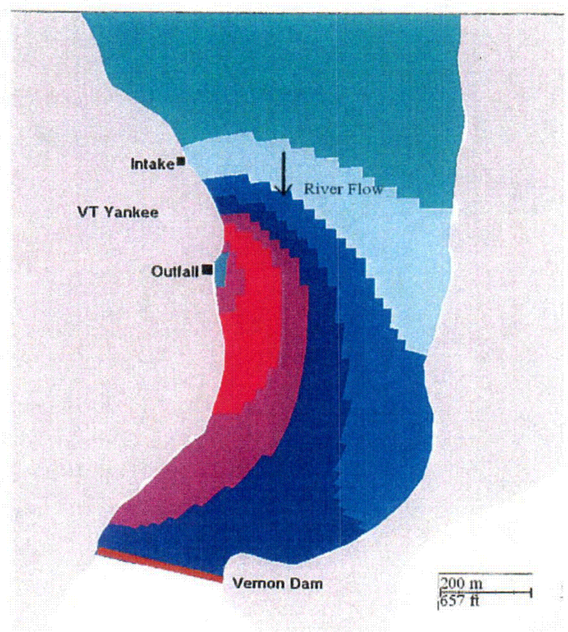
(a) Surface (Existing limits)



(b) Surface (Proposed limits)



(c) Bottom (Existing limits)



(d) Bottom (Existing limits)

Figure 5-52. Predicted changes in Vermont Yankee's thermal plume surface or bottom area in lower Vernon Pool of the Connecticut River exposed to the extreme case (1% occurrence) of flow and ambient temperature under existing and proposed new summer thermal discharge limits for the white sucker avoidance temperature of 86°F.

Table 5-38. Annual total catch per unit effort of white sucker collected by general electrofishing in Connecticut River, in the vicinity of Vernon, VT during 1991-2002.

	Upstream of Vernon Dam & not exposed to discharge				Upstream of Vernon Dam & exposed to discharge				Immediately downstream of Vernon Dam				Downstream of Vernon Dam at Station 2				Total			
	N	Count	Effort	CPUE	N	Count	Effort	CPUE	N	Count	Effort	CPUE	N	Count	Effort	CPUE	N	Count	Effort	CPUE
1991	16	80	5.40	14.81	8	41	2.40	17.08	16	65	4.40	14.77	4	8	1.20	6.67	44	194	13.40	14.48
1992	16	54	5.20	10.38	8	32	2.90	11.03	16	53	4.60	11.52	4	9	1.30	6.92	44	148	14.00	10.57
1993	16	54	5.30	10.19	8	21	2.60	8.08	16	37	4.50	8.22	4	3	1.20	2.50	44	115	13.60	8.46
1994	16	88	4.40	20.00	8	20	2.10	9.52	16	64	4.50	14.22	4	7	1.20	5.83	44	179	12.20	14.67
1995	16	63	5.70	11.05	8	10	2.50	4.00	16	23	5.00	4.60	4	7	1.20	5.83	44	103	14.40	7.15
1996	14	16	2.50	6.40	6	6	0.97	6.21	12	17	2.22	7.67	4	1	0.90	1.11	36	40	6.58	6.08
1997	16	4	2.67	1.50	8	7	1.33	5.25	12	5	2.02	2.48	4	2	0.70	2.86	40	18	6.72	2.68
1998	16	7	2.77	2.53	8	1	1.55	0.65	12	17	2.03	8.36	4	0	0.67	0.00	40	25	7.02	3.56
1999	16	7	2.72	2.58	8	6	1.28	4.68	12	15	2.02	7.44	4	5	0.68	7.32	40	33	6.70	4.93
2000	16	6	2.50	2.40	8	5	1.35	3.70	12	4	1.90	2.11	4	2	0.65	3.08	40	17	6.40	2.66
2001	16	15	2.67	5.63	8	6	1.33	4.50	12	7	2.00	3.50	4	4	0.67	6.00	40	32	6.67	4.80
2002	16	12	2.70	4.44	8	6	1.33	4.50	12	3	2.00	1.50	4	3	0.67	4.50	40	24	6.70	3.58

Table 5-39. Annual total catch per unit effort of white sucker collected by general electrofishing in the discharge area upstream of Vernon Dam, Connecticut River, in the vicinity of Vernon, VT during 1991-2002.

	Vermont side				New Hampshire side				Total			
	N	Count	Effort	CPUE	N	Count	Effort	CPUE	N	Count	Effort	CPUE
1991	4	23	1.10	20.91	4	18	1.30	13.85	8	41	2.40	17.08
1992	4	11	1.30	8.46	4	21	1.60	13.13	8	32	2.90	11.03
1993	4	9	1.20	7.50	4	12	1.40	8.57	8	21	2.60	8.08
1994	4	7	1.00	7.00	4	13	1.10	11.82	8	20	2.10	9.52
1995	4	7	1.20	5.83	4	3	1.30	2.31	8	10	2.50	4.00
1996	2	0	0.35	0.00	4	6	0.62	9.73	6	6	0.97	6.21
1997	4	0	0.67	0.00	4	7	0.67	10.50	8	7	1.33	5.25
1998	4	0	0.72	0.00	4	1	0.83	1.20	8	1	1.55	0.65
1999	4	1	0.63	1.58	4	5	0.65	7.69	8	6	1.28	4.68
2000	4	2	0.68	2.93	4	3	0.67	4.50	8	5	1.35	3.70
2001	4	1	0.67	1.50	4	5	0.67	7.50	8	6	1.33	4.50
2002	4	1	0.67	1.50	4	5	0.67	7.50	8	6	1.33	4.50

Table 5-40. Comparison of predicted habitat change in Vernon Pool of the Connecticut River for white sucker between the existing and the proposed new summer permit limits.

A. Percent Difference						
Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[1] in % Time Station 3 is At or Above Temp °F
Exclusionary Temperatures		Change[3] in % Plume Volume ≥ Temperature		Change[3] in % Bottom Area ≥ Temperature		
Max. for summer survival, or UILT	88	0.0	0.0	0.0	0.0	0.0
Avoidance	86	0.0	-0.3	0.0	-0.1	0.0
Indicator Temperatures		Change[3] in % Plume Volume ≥ Temperature		Change[3] in % Bottom Area ≥ Temperature		
Optimum for growth	81	-0.5	-6.3	-0.2	-7.7	5.1
Preferred	81	-0.5	-6.3	-0.2	-7.7	5.1
Spawning	60	0.0	0.0	0.0	0.0	2.3
Early life history	65	0.0	0.0	0.0	0.0	4.6
B. Numeric Difference						
Thermal Effects Parameter	Temp (°F)	Average (50%) Case	Extreme (1%) Case	Average (50%) Case	Extreme (1%) Case	Increase[2] in Hours Station 3 is At or Above Temp °F
Exclusionary Temperatures		Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature		Change[3] in Bottom Area (acres) ≥ Temperature		
Max. for summer survival, or ULT	88	0.0	0.0	0.0	0.0	0.0
Avoidance	86	0.0	-64.0	0.0	-0.3	0.0
Indicator Temperatures		Change[3] in Plume Volume ($ft^3 * 10^4$) ≥ Temperature		Change[3] in Bottom Area (acres) ≥ Temperature		
Optimum for growth	81	-89.0	-1220.1	-0.8	-24.9	187.5
Preferred	81	-89.0	-1220.1	-0.8	-24.9	187.5
Spawning	60	0.0	0.0	0.0	0.0	82.8
Early life history	65	0.0	0.0	0.0	0.0	167.4

[1]Increase in % time = Station 3 proposed % exceedance - Station 3 existing % exceedance
[2]Increase in hours = increase in % time * 3648 hours in summer period
[3]Change in % plume volume, % bottom area, plume volume or plume area is calculated as [existing – proposed new] so that losses are shown as negative values

Table 5-41. Earliest and latest dates of capture of ichthyoplankton for white sucker, 1991-2002. Also shown are mean daily ambient Connecticut River temperatures recorded at Station 7 for the dates of capture. Note that sampling does not begin before May 1.

Year	Earliest	Temp (F)	Latest	Temp (F)
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	11 Jun	63	11 Jun	63
1997	-	-	-	-
1998	27 May	65	02 Jul	66
1999	21 May	60	27 May	58
2000	29 May	57	13 Jun	61
2001	31 May	59	22 Jun	71
2002	28 May	50	19 Jun	58
Temp Range:		50-65		58-71
Notes:	Fairly common in recent years			

6.0 SUMMARIES OF THE PREVIOUS §316(a) DEMONSTRATIONS

Extensive environmental monitoring has been performed annually in the Connecticut River in the vicinity of Vermont Yankee since 1967. These monitoring studies have covered a wide range of river temperature and flow conditions, and have included all the major aquatic community components, including phytoplankton, zooplankton, benthic macroinvertebrates, and both resident and migratory fish. They have been performed over all thermal discharge conditions ranging from pre-operation (1967-1973), closed-cycle, hybrid-cycle (partial use of cooling towers) and once-through cooling.

Vermont Yankee was originally permitted in 1973 to operate solely in closed cycle cooling mode until determinations could be made concerning possible environmental impact from the discharge of heat, and they operated in this mode until February 1974, when the first of several open-cycle testing modes was begun. Subsequently, Vermont Yankee submitted successive requests for alternative thermal discharge limits that ultimately resulted in the limits presently contained in their NPDES permit. These requests were supported by information presented in two comprehensive §316(a) demonstrations, Binkerd et al. (1978) and Downey et al. (1990). Each of the previous §316(a) demonstrations described the results of monitoring studies performed in the vicinity of the station and examined the potential for adverse environmental impact due to the proposed changes in the thermal discharge limits. As background for this current request, a summary of the information regarding thermal discharge issues in each of these two previous assessments is provided in the following sections.

6.1 MARCH 1978 §316(a) DEMONSTRATION

Binkerd et al. (1978) presented engineering, hydrological, and biological information that supported a request for alternate thermal effluent limitations to increase net power output by providing relief from the full-time closed-cycle mode of operation. This 1978 §316(a) demonstration included the results of baseline or pre-operational field studies begun in 1967, as well as hydrological and biological studies performed during selected periods of open-cycle operations between 1974 and 1977.

Based on this 1978 §316(a) assessment, Vermont Yankee was issued a NPDES permit allowing operation in open-cycle mode during the winter period from October 15 through May 15 under the following constraints:

- A not-to-exceed temperature limit of 65°F at Station 3;
- A rate of temperature change at Station 3 not exceeding 5°F per hour;
- A Station 3 temperature not to exceed 13.4°F above ambient.

Relief from operating in closed-cycle mode during the summer period from May 16 through October 14 was not requested by the 1978 §316(a) demonstration.

The 1978 §316(a) demonstration was based largely on the results of a series of field studies (Phase I–IV) performed under periods of open-cycle and hybrid operation beginning in February 1974. During the Phase I ecological studies, River temperatures were low and flows were relatively high, and heat rejection rate was increased in 20% increments to 80% of the maximum. In Phase II and III, from December 1974 through June 1976, heat rejection was limited to 10 to 50% of the maximum rate (in order to comply with applicable water quality limits and Nuclear Regulatory Commission operating restrictions) when river flows fluctuated about periods of minimum flow. Based on finding no

adverse environmental impact during these studies, application was made to the VANR for permission to study the effects of open-cycle 100% heat load to the river under all flow conditions. Approval was granted, and the Phase IV studies were conducted from September 1976 through May 1977 to assess the impact of maximum heat rejection during all river flow conditions. No adverse ecological effects were observed during any of these studies, which resulted in this assessment being based, in large part, on a "Lack of Prior Appreciable Harm" or Type I demonstration approach as per USEPA (1977) draft §316(a) guidance.

The 1978 §316(a) demonstration concluded that operation of the Vermont Yankee Station in open-cycle mode during October 15 through May 15 would assure protection of the balanced indigenous aquatic community. Key information highlighted in the assessment is summarized below.

6.1.1 Downstream Temperature Patterns

The thermal plume from Vermont Yankee was observed to sink or rise dependent on ambient river temperature (density), and the extent of plume dispersion away from the Vermont shore was dependent on river flow. At an ambient river temperature of less than 39.2°F, the plume would sink, and above this temperature it would spread over the River surface. In both cases, the stratified water mixed with ambient water during passage through the turbines or spill gates at Vernon Station, and the downstream water was thermally well-mixed.

Two temperature patterns were observed in the mixed water column sampled at Station 3. A rise in temperature was observed after minimum flows due to accumulation of warm water in Vernon Pool. The warm water mass moves rapidly downstream when flows at Vernon Station are subsequently increased. The second pattern occurred during periods of high and relatively stable flow rates. Under these conditions, the temperatures at Station 3 varied little from ambient conditions, usually less than 2°F.

6.1.2 Equation Used to Predict Temperature Rise at Station 3

To ascertain the plant-induced temperature rise at Station 3, the heat load allowed to be rejected to the River is estimated by use of a predictive equation, and Vermont Yankee operations are controlled to achieve the desired heat load. The equation, referred to as Equation 1.1 in Binkerd et al. (1978), calculates the plant-induced temperature increase at Station 3 as follows:

$$\Delta Tr = H/(p\ Cp\ Qr)$$

H is the heat rejection rate to the river, p is the density of water, Cp is the specific heat of water, and Qr is the river flow rate. In 1997 this equation was rearranged for ease of computer computation using input from the plant environmental thermal sensor network.

Binkerd et al. (1978) found that Equation 1.1 overestimated anticipated temperature increases, particularly at low flows during the winter period, as a result of surface cooling and dispersion characteristics in Vernon Pool and between Vernon Dam and Station 3 for which Equation 1.1 does not account.

6.2 JUNE 1990 §316(a) DEMONSTRATION

The second thermal discharge assessment for Vermont Yankee was contained in Downey et al. (1990) and covered the field monitoring period from 1981 through 1989. Like the 1978 §316(a)

demonstration, the 1990 §316(a) demonstration presented engineering, hydrological and biological information in support of a Vermont Yankee request for increased mixed river temperature limits. This assessment was the culmination of a nearly 10-year effort referred to as Project SAVE (Save Available Vermont Energy), which sought to maximize the plant's energy production without an increase in environmental impact. In contrast to the earlier request for change in the thermal discharge limits, the alternate limits requested in the 1990 §316(a) demonstration were for the summer compliance period, May 16 - October 14.

The alternate temperature limits requested as a result of the information presented in the 1990 §316(a) demonstration were for calculated (Equation 1.1, Binkerd et al. 1978) increases of 2 to 5°F in mixed river temperatures at Station 3 based on upstream ambient temperatures, as follows:

Station 7 Ambient Temperature	***Calculated Increase in Temperature Above Ambient at Station 3***
Above 63°F	2°F
>59°F, ≤63°F	3°F
≥55°F, ≤59°F	4°F
Below 55°F	5°F

As background, in 1981 Vermont Yankee proposed a program and study plan to the VANR for evaluating the effects on aquatic resources of once-through (open) and hybrid (partial open) cycle cooling as an alternative to totally closed-cycle operation during the period May 16 through October 14. Biological data obtained as part of Project SAVE (from 1982 – 1989), and results from 20 years of monitoring and "objective-specific" studies, formed the basis of the bioassessment of the aquatic community contained in the 1990 §316(a) demonstration (Downey et al. 1990). The intensive biological studies for Project SAVE focused on the potential effects of open or hybrid cycle operation within the constraints of the applicable temperature standards, which at that time were established to protect the warm water fish community, and which allowed a 1°F to 5°F increase in mixed river temperature, dependent on upriver ambient water temperature.

During the early years of Project SAVE (1982 – 1985), Vermont Yankee was operated in either once-through or hybrid mode during the summer period from May 16 through October 14. However, with the increased frequency of movement of the recirculation gate used to divert heated water back through the cooling system prior to discharge, as required by the thermal discharge limitations in effect during Project SAVE, operational difficulties reduced the reliability of the gate and limited the planned thermal discharges. Nevertheless, an increased energy production for Vermont of 5,000 to 18,000 MW hours per year was realized during 1982 to 1985.

Project SAVE was reassessed in 1985, in part due to a revision of the Vermont Water Quality Standards that changed the habitat designation of this reach of the Connecticut River from warm water to coldwater fish habitat. The change in habitat status was likely in response to the establishment of restoration goals for the anadromous Atlantic salmon to the Connecticut River, and was not entirely supported by an analysis of the actual observed upstream Connecticut River water temperatures in Vernon Pool during the summer period. The Vermont coldwater fish habitat temperature standards limited the increase in water temperature due to the Vermont Yankee cooling water discharge to 1°F above ambient.

In the 1986 NPDES Permit for Vermont Yankee, the temperature limitations for the winter period of October 15 through May 15 remained as follows:

- The temperature at Station 3 during open-cycle operation shall not exceed 65°F;
- The rate of temperature change at Station 3 shall not exceed 5°F per hour; and
- The increase in temperature above ambient at Station 3 shall not exceed 13.4°F.

However, the 1986 NPDES permit allowed a 1°F temperature increase for the summer period from May 16 through October 14. The 1986 NPDES permit also separated biological monitoring requirements into two sections, Part I- "task-oriented" monitoring and Part II- "goal-oriented" or "objective-specific" studies. Many of the goal-oriented studies focused on topics associated with re-establishing anadromous fish to this section of the Connecticut River. The results of these goal-oriented studies have been presented in a series of nearly 80 Analytical Bulletins (see Appendix 1 for a list of the Bulletins). Also in 1986, Vermont Yankee replaced the mechanical gate operators on the recirculation gate, as well as two cooling tower bypass gates and an intake gate to withstand repeated cycling between once-through and hybrid operation, which was continued for Project SAVE in 1987 to 1989.

The 1990 §316(a) demonstration noted that the Vermont Yankee had discharged heat to the river since 1982 without exceeding the limits permitted for Project SAVE, and attributed this excellent compliance record, in part, to a computerized simulation of plant operation. The thermal discharge management program underwent extensive verification and subsequently formed the basis for an operating manual that continues to be used to control the quantity of heat discharged to the River in compliance with applicable permit limits.

6.2.1 Modifications at Vernon Dam and Vernon Station

Downey et al. (1990) reported in the 1990 §316(a) demonstration that, since the 1978 §316(a) demonstration (Binkerd et al. 1978), some significant changes were made at Vernon Dam and Vernon Station. One was the construction of an upstream fishway near the Vermont bank at Vernon Dam. The Vernon Dam fishway commenced operation in 1981 and provided passage for American shad, Atlantic salmon and other species into Vernon Pool. In 1984, the height of the wooden flashboards along the crest of the dam was increased by 2 feet. In 1987 most of the wooden flashboards were converted to hydraulically operated gates. These devices reduced the frequency with which pool elevation was drawn down to dam crest height and allowed more control of spillage along the dam's crest. Although these changes affected the shape of the plume in Vernon Pool, the differences appeared to be relatively minor. The River at Station 3 continued to be well-mixed at all flows.

Water temperatures in the Vernon Dam fishway were described as being equal to, or less than, those at Station 3 during high river flows. At lower flows they were often 1°F to 2°F higher than at Station 3 and on occasion up to 3°F to 4°F higher.

6.2.2 Biological Assessment

In 1986, there was concurrence among the regulatory agencies and the EAC that the potential for adverse thermal impacts from Vermont Yankee's discharge was negligible on the phytoplankton, zooplankton, and macroinvertebrate communities in the Connecticut River study area. However, routine sampling and analyses of these communities was conducted throughout the Project SAVE

period. In agreement with the results presented in the 1978 §316(a) demonstration, the findings of the studies performed in 1981 through 1989 also did not detect any negative changes attributable to Vermont Yankee's thermal discharge in these three "low potential impact" communities.

Resident fish were not excluded from any habitats in the river due to thermal enrichment, nor was growth of any species adversely affected by open or hybrid operations during Project SAVE. In 18 years of monitoring, Downey et al. (1990) reported in the 1990 §316(a) demonstration that no fish mortality due to rapid thermal change (e.g., cold shock) was ever observed. There was no blockage of upstream migrating adult Atlantic salmon or American shad either through the fishway at Vernon Dam or in the river past the plant. Radio telemetry studies summarized in the 1990 §316(a) demonstration documented that downstream migrating Atlantic salmon smolts moved unimpeded through Vernon Pool. (The more recent studies reported by Finck et al. (1995) and Normandeau (1994a, 1995a and 1996) confirm that American shad and Atlantic salmon have successfully migrated past Vernon Dam and Vermont Yankee in both upstream and downstream directions).

Seven RIS were selected in the 1990 §316(a) demonstration for more detailed discussion of their distribution in the River near Vermont Yankee, migration relative to the thermal plume, and growth. The RIS selected were Atlantic salmon, American shad, smallmouth bass, walleye, yellow perch, white perch, and spottail shiner. The same finding of lack of adverse impact due to Vermont Yankee's thermal discharge was concluded for these seven fish species.

The results of the various studies documented that plant operation during Vermont Yankee Project SAVE for the summer period from May 16 through October 14 did not alter the distribution, abundance or diversity of aquatic biota of the Connecticut River near Vernon. Downey et al. (1990) concluded in the 1990 §316(a) demonstration that continued Vermont Yankee thermal discharge under the requested sliding scale of temperature limits would assure the protection and propagation of a balanced indigenous community of aquatic life in the Connecticut River.

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APPENDIX 1

Analytical Bulletins

Appendix Table 1-1. List of Vermont Yankee Analytical Bulletins 1984 – 2003.

Bulletin	Author(s)	Year	Title
1	Downey, Philip C.	1984	Notes on the health of fishes of the Connecticut River near Vernon, Vermont
2	Johnston, H. Gregory	1984	Thermal experience of the Connecticut River near Vernon, Vermont
3	Binkerd, Roger C.	1984	Synopsis of 1983 Environmental Programs
4	Johnston, H. Gregory and Roger C. Binkerd	1984	Determination of optimal settings of condenser cooling system facilities
5	Downey, Philip C.	1984	Age and growth of walleye (*Stzistedion vitreum vitreum* (Mitchill)) of the Connecticut River near Vernon, Vermont
6	Downey, Philip C.	1985	Growth of 1984 juvenile American shad (*Alosa sapidissima* (Wilson)) of the Connecticut River near Vernon, Vermont
7	Downey, Philip C.	1985	Age and growth of smallmouth bass (*Micropterus dolomieui* Lacepede) of the Connecticut River near Vernon, Vermont
8	Downey, Philip C.	1985	Age and growth of white perch (*Morone americana* (Gmelin)) of the Connecticut River near Vernon, Vermont
9	Downey, Philip C.	1985	Age and growth of yellow perch (*Perca flavescens* (Mitchill)) of the Connecticut River near Vernon, Vermont
10	King, David E.	1985	Vermont Yankee environmental temperature system
11	Binkerd, Roger C.	1985	Temperature patterns near Vernon Dam fish passage during high river discharge
12	Binkerd, Roger C.	1985	Connecticut River water quality near Vernon, Vermont, 1969-1984
13	Luxenberg, Roland R.	1985	Connecticut river temperature increase
14	Downey, Philip C. and Alexander J. Haro	1985	Fish impingement on intake screens at Vermont Yankee, 1974-1984
15	Downey, Philip C.	1986	Growth of 1985 juvenile American shad (*Alosa sapidissima* (Wilson)) of the Connecticut River near Vernon, Vermont
16	Downey, Philip C.	1987	Spatial distribution of 1986 juvenile shad (*Alosa sapidissima* (Wilson)) of the Connecticut River near Vernon, Vermont
17	Luxenberg, Roland R.	1987	Temporal and spatial distribution of water quality parameters in Upper Turners Falls Pool

(continued)

Appendix Table 1-1 (Continued)

Bulletin	Author(s)	Year	Title
18	Shambaugh, Angela D.	1987	Temporal and spatial distribution of phytoplankton in Upper Turners Falls Pool
19	Wood, Susan M.	1988	Temporal and spatial distribution of macroinvertebrates in Upper Turners Falls Pool
20	Timmons, Maria J.	1988	Temporal and spatial distribution of zooplankton in Upper Turners Falls Pool
21	Downey, Philip C.	1988	Age and growth of 1986 juvenile American shad (*Alosa sapidissima* (Wilson)) of the Connecticut River near Vernon, Vermont
22	Downey, Philip C.	1990	Microhabitats of juvenile American shad (*Alosa sapidissima* (Wilson)) of the Connecticut River near Vernon, Vermont
23	Downey, Philip C., Nicholas R. Staats, and Mark B. Biercevicz	1990	Age and growth of juvenile American shad (*Alosa sapidissima* (Wilson)) of the Connecticut River near Vernon, Vermont
24	Staats, Nicholas R.	1990	Age and sex composition of adult American shad (*Alosa sapidissima* (Wilson)) at Vernon Dam fishway, 1989
25	Shambaugh, Angela D., Philip C. Downey, and Nicholas R. Staats	1990	Evaluation of shad otolith aging techniques: scanning electron microscopy and light microscopy
26	Briggs, Errol C. and Philip C. Downey	1990	Fish impingement on intake screens at Vermont Yankee, 1985-1989
27	Shambaugh, Angela D.	1989	Algal growth in the cooling towers and spray pond of Vermont Yankee, late summer 1988
28	Shambaugh, Angela D. and Philip C. Downey	1990	The occurrence of *Leptodora kindii* in the Connecticut River near Vernon, Vermont during early summer 1988
29	Downey, Philip C. Nicholas R. Staats, and Roger C. Binkerd	1990	Downstream movement of Atlantic Salmon (*Salmo salar* Linnaeus) smolts in Vernon pool
30	Binkerd, Roger C., Michael T. Hewlett, and Philip C. Downey	1990	Tag and recapture studies of smallmouth bass (*Micropterus dolomieui,* Lacepede), 1981-1989
31	Downey, Philip C.	1990	Age and growth of selected resident fish of the Connecticut River near Vernon, Vermont
32	Downey, Philip C.	1990	Abundance, density, and composition of ichthyoplankton of the Connecticut River near Vernon, Vermont

(continued)

Appendix Table 1-1 (Continued)

Bulletin	Author(s)	Year	Title
33	Binkerd, Roger C., Roland R. Luxenberg, and Stephen P. Farrington	1990	Thermal plumes in the lower Vernon pool, 1989
34	Luxenberg, Roland R.	1990	Thermal history of the Connecticut River, 1984-1989
35	Downey, Philip C.	1990	Composition of the fish community of the Connecticut River near Vernon, Vermont
36	Downey, Philip C.	1990	Adult American shad (*Alosa sapidissima* (Wilson)) migration in the Connecticut River near Vernon, Vermont
37	Park, Janice H.	1990	Acquisition of biological data and their translation to a computer database
38	King, David E.	1990	The Vermont Yankee environmental data acquisition systems; An update
39	Luxenberg, Roland R.	1990	Analysis of the thermal history of the Connecticut River 1970-1989
40	Downey, Philip C. and Nicholas R. Staats	1990	Composition of the Adult American shad (*Alosa sapidissima* (Wilson)) population at Vernon Dam and Turners Falls Fishways, 1990
41	Downey, Philip C.	1991	Sexual maturity of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1990
42	Downey, Philip C. and Mark P. Biercevicz	1991	Relative density and growth of juvenile American Shad in the Connecticut River Near Vernon, Vermont, 1990.
43	Downey, Philip C. and Mark P. Biercevicz	1994	Composition of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1991
44	Downey, Philip C. and Robert L. Smith	1995	Sexual maturity of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1991
45	Biercevicz, Mark P. and Philip C. Downey	1995	Relative density and growth of Juvenile American Shad in the Connecticut River near Vernon, Vermont, 1991
46	Smith, Robert L., Philip C. Downey, and Gary R. Miles	1995	Composition of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1992
47	Downey, Philip C. and Robert L. Smith	1995	Sexual maturity of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1992

(continued)

Appendix Table 1-1 (Continued)

Bulletin	Author(s)	Year	Title
48	Smith, Robert L. and Philip C. Downey	1995	Relative density and growth of Juvenile American Shad in the Connecticut River near Vernon, Vermont, 1992
49	Smith, Robert L., Philip C. Downey, and Gary R. Miles	1995	Composition of Adult American shad at Turners Falls and Vernon Dam Fishways, 1993
50	Downey, Philip C. and Robert L. Smith	1995	Sexual maturity of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1993
51	Smith, Robert L. and Philip C. Downey	1995	Relative density and growth of Juvenile American Shad in the Connecticut River near Vernon, Vermont, 1993
52	Smith, Robert L. and Philip C. Downey	1995	Composition of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1994
53	Downey, Philip C. and Robert L. Smith	1995	Sexual maturity of Adult American Shad at Turners Falls and Vernon Dam Fishways, 1994
54	Smith, Robert L. and Philip C. Downey	1995	Relative density and growth of Juvenile American Shad in the Connecticut River near Vernon, Vermont, 1994
55	Smith, Robert L. and Philip C. Downey	1995	Evaluation of gross energy content in selected Adult American shad tissue by proximate analysis
56	Finck, Laura L. and Philip C. Downey	1995	Adult American shad (*Alosa sapidissima* (Wilson)) passage efficiency through Vernon fishway, 1981 to 1994
57	Downey, Philip C. and Robert L. Smith	1995	Biology of American shad, 1990 to 1995
58	Finck, Laura L.	1995	Zebra Mussel and asiatic clam monitoring, 1994
59	Finck, Laura L. and Philip C. Downey	1995	Tag and recapture of Smallmouth Bass (*Micropterus dolomieui* Lacepede) in the Connecticut River near Vernon, Vermont, 1990 to 1994
60	Smith, Robert L. and Philip C. Downey	1995	Age and growth of White Perch (*Morone americana* (Gmelin)) in the Connecticut River near Vernon, Vermont 1968-1994
61	Smith, Robert L. and Philip C. Downey	1995	Age and growth of Walleye (*Stzostedion vitreum* (Mitchill)) in the Connecticut River near Vernon, Vermont, 1968 to 1994

(continued)

Appendix Table 1-1 (Continued)

Bulletin	Author(s)	Year	Title
62	Smith, Robert L. and Philip C. Downey	1995	Age and growth of Yellow Perch (*Perca flavescens* (Mitchill)) in the Connecticut River near Vernon, Vermont 1968 to 1994
63	Smith, Robert L. and Philip C. Downey	1995	Age and growth of Smallmouth Bass (*Micropterus dolomieui* Lacepede) in the Connecticut River near Vernon, Vermont, 1968 to 1994
64	Smith, Robert L. and Philip C. Downey	1995	Fish composition at Turners Falls and Vernon Dam, 1968 to 1994
65	Finck, Laura L., Robert L. Smith, and Philip C. Downey	1995	Atlantic Salmon (*Salmo salar*) smolt impingement at Vermont Yankee on the Connecticut River from 1981 to 1995
66	Smith, Robert L. and Philip C. Downey	1995	Phytoplankton and zooplankton entrainment at Vermont Yankee, 1990-1995
67	Smith, Robert L. and Philip C. Downey	1995	Composition of Adult American shad at Turners Falls and Vernon Dam Fishways, 1995
68	Downey, Philip C. and Robert L. Smith	1995	Sexual maturity of Adult American shad at Turners Falls and Vernon Dam Fishways, 1995
69	Smith, Robert L. and Philip C. Downey	1995	Relative density and growth of Juvenile American shad in the Connecticut River near Vernon, Vermont, 1995
70	Normandeau Associates Inc.	1998	Composition of adult American shad at the Vernon Hydroelectric Dam Fishway During Spring 1997
71	Normandeau Associates Inc.	1998	Abundance of juvenile American shad in the Vernon Pool during 1997
72	Normandeau Associates Inc.	1999	Composition of Adult American Shad at the Vernon Hydroelectric Dam Fishway During Spring 1998
73	Normandeau Associates Inc.	1999	Abundance of Juvenile American Shad In the Vernon Pool During 1998
74	Normandeau Associates Inc.	2000	Composition of Adult American at the Vernon Hydroelectric Dam Fishway During Spring 1999
75	Normandeau Associates Inc.	2000	Abundance of Juvenile American Shad In the Vernon Pool During 1999
76	Normandeau Associates Inc.	2001	Abundance of Juvenile American Shad In the Vernon Pool During 2000
77	Normandeau Associates Inc.	2002	Composition of Adult American Shad at the Vernon Hydroelectric Dam Fishway, During Spring 2001
78	Normandeau Associates Inc.	2002	Abundance of Juvenile American Shad in the Vernon Pool During 2001

(continued)

Appendix Table 1-1 (Continued)

Bulletin	Author(s)	Year	Title
79	Normandeau Associates Inc.	2003	Abundance of Juvenile American Shad in the Vernon Pool During 2002
80	Normandeau Associates Inc.	2003	Evaluation of the Macroinvertebrate Community in Lower Vernon Pool During 2002 Using Artificial Multiplate Samplers

APPENDIX 2

Thermal Effects Parameters

Appendix Table 2-1. Temperatures at which thermal effects have been reported for the nine Representative Important Species of fish, with rationale for temperatures selected for modeling the thermal effects of Vermont Yankee's proposed Delta T increase.

Species: American shad

Parameter	Temperature (F) Critical	Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	90.5	75.2-82.4	Young experience rapid mortality.	Moss (1970)	90: single value available
Optimum for growth	50-88		Juv's found over this range in Conn. R. Apparent wide temp tolerance in rivers	Marcy et al. (1972) Stier and Crance (1985)	70: approximate mid-point of range
Avoidance	86		Avoided thermal plume, Conn. R.	Marcy (1976b)	86: single value available is reasonable considering max. for summer survival and temperatures at which juveniles were found by Marcy et al. (1972)
	46		Juveniles generally avoid temps. less than this. Juveniles begin emigrating from river when temps. drop below 60°F.	Marcy (1976b) Crance (1985)	
	50		Juveniles absent below this temp., had outmigrated from Conn. R.	Marcy (1976b)	
Preferred	60-70		Spend majority of time at these temps.	Leggett and Whitney (1972)	65: mid-point of range
Spawning	near 65		Peak movement of spawning run into rivers.	Leggett and Whitney (1972)	65: spawning, lower mid-range
	60-75		Approx. range- during passage by Vermont Yankee, fishway daily mean temps., 1998-2002.	Vernon Dam fishway data	
	46-79		Range- during spawning	Scott and Crossman (1973)	
	57-70		Peak spawning activity	Stier and Crance (1985)	
Early life history	50-86		Range- egg incubation, development	Scott and Crossman (1973)	70: egg, larval development
	60-80		Optimum for egg, larval development; Conn. R.	Marcy (1976b)	

(continued)

Appendix Table 2-1. (Continued)

Species: Atlantic salmon

Parameter	Temperature (F) Critical	Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	82	81.5	Juveniles (parr) No mortality below this temp.	Stanley and Trial (1995)	82: single value. Note that optimum parr habitat is not found in lower Vernon Pool
Optimum for growth	59-66 72.5		Juveniles (parr) Maximum limit for feeding, parr	Stanley and Trial (1995)	Not Applicable: Preferred parr habitat not present.
Avoidance	N/A		No appropriate data found		78: It is assumed that the fish will avoid near-lethal temperatures.
Preferred	58		Juveniles (parr)	Stanley and Trial (1995)	Not Applicable: Preferred habitat not present.
Spawning	60-74		Approx. range- upriver passage at Vernon, fishway daily mean temps., 1998-2002.	Vernon Dam fishway data	Not Applicable: Do not spawn in Conn. R. near Vermont Yankee
	<73		Adults generally found to migrate to spawning grounds at or below temp.	Stanley and Trial (1995)	

(continued)

Appendix Table 2-1. (Continued)

Species: Spottail shiner

Parameter	Temperature (F) Critical	Temperature (F) Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	95-100	79	UILT, high acclimation temp.	Wismer and Christie (1987)	95: minimum selected; tolerant of high temperatures
Optimum for growth	86 73-91		MWAT, young Range, no growth >95	Wismer and Christie (1987) Wismer and Christie (1987)	86: within range of acceptable growth
Avoidance	95-102			Wismer and Christie (1987)	95: minimum
Preferred	86	77	Young	Wismer and Christie (1987)	86: single value, optimal temperatures for growth often similar to preferred
Spawning	59-68		Range, spawning and successful incubation	Wismer and Christie (1987)	64: mid-range for spawning, incubation
Early life history	56-78		Ichthyoplankton collected over this range at Vermont Yankee, 1998-2001		70: hatching, early development; just below optimal juvenile growth range

(continued)

Appendix Table 2-1. (Continued)

Species: Smallmouth bass

Parameter	Temperature (F) Critical	Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	98.6	95	UILT, young and adults	Armour (1993a)	98: suggested UILT
Optimum for growth	89.6-91.4		MWAT for adequate juvenile and adult growth.	Armour (1993a)	90: mid-range
Avoidance	95-100	70-90	Juveniles	Peterson and Schutsky (1977)	95: Minimum of range
Preferred	73-82	80-82	Juveniles	Peterson and Schutsky (1977)	81: conservative temperature
	80.6		Adults	Armour (1993a)	
	86-87.8	75.2-86	Juveniles	Cherry et al. (1975)	
Spawning	59-70		Spawning, daily mean	Armour (1993a)	63: spawning,lower mid-range; incubation
	61-65		Most egg deposition	Scott and Crossman (1973)	
Early life history	59-77		Favorable hatching success	Armour (1993a)	70: hatching, early development

(continued)

Appendix Table 2-1. (Continued)

Species: Yellow perch

Parameter	Temperature (F) Critical	Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	84-95		UILT- juveniles	Krieger et al. (1983)	90: UILT typically higher than upper avaoidance and MWAT tolerance reported by Eaton and Scheller (1996)
	90		UILT- adults	Krieger et al. (1983)	
	84	77	UILT- adults, juveniles.	Wismer and Christie (1987)	
	85	72-75	UILT- larvae	Wismer and Christie (1987)	
Optimum for growth	72		MWAT	Wismer and Christie (1987)	74: within optimum range
	73-76		Optimum	Krieger et al. (1983)	
	50		Near the upper limit of low temp. period needed for maturation of eggs.	Krieger et al. (1983)	
Avoidance	79-84			Krieger et al. (1983)	83: upper mid-range
	84		MWAT tolerance	Eaton and Scheller (1996)	
	84-88	75-77	Upper avoidance	Wismer and Christie (1987)	
Preferred	64-77		Range- young, adults	Krieger et al. (1983)	77: approximate mid-range
	77-81		Range- young of year	Wismer and Christie (1987)	
Spawning	45-59		Range- spawning	Wismer and Christie (1987)	50: lower mid-range spawning
Early life history	45-68		Range- good incubation, hatching	Krieger et al. (1983)	65: incubation, hatching
	46-70		Ichthyoplankton collected over this range at Vermont Yankee, 1990-2001		

(continued)

Appendix Table 2-1. (Continued)

Species: Walleye

Parameter	Temperature (F) Critical	Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	94		UUILT	Armour (1993b)	89: plume does not attain this high a temperature
	89	75	UILT	Wismer and Christie (1987)	
Optimum for growth	76		Physiological optimum	Armour (1993b)	74: conservative optimal growth temperature
	86		Zero net growth	Armour (1993b)	
	68-75		range- optimum temps. for growth	McMahon et al. (1984)	
	77		MWAT	Wismer et al. (1987)	
Avoidance	70-81		Over geographic range	Armour (1993b)	76: lower mid-range
	84		MWAT tolerance	Eaton et al. (1996)	
Preferred	69-74		Great Lakes area	Wismer et al. (1987)	72: mid-range
Spawning	43-52		Most spawning occurs	McMahon et al. (1984)	48: mid-range
Early life history	48-59		Optimum incubation	McMahon et al. (1984)	54: incubation, mid range
	66		Near lethal limit for embryos	McMahon et al. (1984)	
	52-64		Ichthyoplankton collected over this range at Vermont Yankee, 1991-2001 except at 70F in 1999.		

(continued)

Appendix Table 2-1. (Continued)

Species: Largemouth Bass

Parameter	Temperature (F) Critical	Temperature (F) Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	95-98	85	95F sublethal 98F lethal to 50% in <3 hours	Peterson and Schutsky (1977)	95: minimum of range
Optimum for growth	75-86 81-86		Adults, very little growth, <59 >97 Optimal for fry	Stuber et al. (1982)	83: slightly below maximum, lower than preferred
Avoidance	87-91	77		Meldrim and Gift (1971)	90: conservatively low
	90-99	80-84	Juveniles	Peterson and Schutsky (1977)	
	96		MWAT tolerance	Eaton and Scheller (1996)	
Preferred	86-89	79-82	Juveniles	Peterson and Schutsky (1977)	86: minimum of range in lab tests
	81		Final preferred temp. determined by sonic tagging	Coutant (1974)	
Spawning	68-70		Optimal	Stuber et al. (1982)	70: spawning
Early life history	55-79		Acceptable range Survival very low, <50 >86		75: incubation, early development

(continued)

Appendix Table 2-1. (Continued)

Species: Fallfish

Parameter	Temperature (F) Critical	Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	90		UILT	Trial et al. (1983)	90: single value
Optimum for growth	50-68		Apparent highest suitability; avg. temp. during warmest time of year	Trial et al. (1983)	68: reasonable to select maximum to evaluate warmest period of year
Avoidance	82		Seldom occur in waters with average above this temp.	Trial et al. (1983)	82: consensus temperature
	82		Upper avoidance	Scott and Crossman (1973)	
Preferred	Not Available				
Spawning	54		Nest building	Wismer and Christie (1987)	
	59-64		Spawning, usual range	Trial et al. (1983)	60: spawning
Early life history	61-64		Embryo incubation usually occurs		65: hatching, early development

(continued)

Appendix Table 2-1. (Continued)

Species: White sucker

Parameter	Temperature (F) Critical	Temperature (F) Acclimation	Comments	References	Temperature Selection Rationale
Max. for summer survival, or UILT	88	79	Adults, juveniles	Twomey et al. (1984)	88: at high acclimation temperature
Optimum for growth	75		Summer. Optimum temps may vary geographically; broad temp. tolerances.	Twomey et al. (1984)	81: within range, approximates preferred temperature
	54-84		Range	Wismer and Christie (1987)	
Avoidance	81		Larvae	Twomey et al. (1984)	86: approximate mid-range
	81		MWAT tolerance	Eaton and Scheller (1996)	
	90	75	Juveniles, lab tests	Peterson and Schutsky (1977)	
Preferred	73-77		Larvae	Twomey et al. (1984)	81: reasonable based on acclimation temperature
	81	77	Juveniles, lab tests	Peterson and Schutsky (1977)	
Spawning & early life history	50-68		Usual spawning range	Trautman (1957)	60: approximate mid-range, spawning, hatching
	59		Max. hatching success; diminished <48 >63	Twomey et al. (1984)	65: early development
	57-71		Ichthyoplankton collected over this range at Vermont Yankee, 1996-2001		

Appendix Table 2-2. Summary of temperature effects (volumes and areas) on the Representative Important Species and other selected fishes for four model scenarios for the May 16 - October 14 compliance period.

Average Case = occurs 50% of the time
Extreme Case = occurs <1% of the time

Existing = 2 deg. F limit
Proposed = 3 deg. F limit

Total Lower Vernon Pool Volume = 193.7 x10^6 cu. ft.
Total Lower Vernon Pool Bottom Area = 324 acres

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Volume Average Case Proposed	Volume Extreme Case Existing	Volume Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Bottom Area Average Case Proposed	Bottom Area Extreme Case Existing	Bottom Area Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Hours of Exceedance at Station 3[a] Proposed
American Shad											
Max. for summer survival, or UILT	90	0	0	0	0	0	0	0	0	0	0
Optimum for growth (eggs & larvae)	70	19366	19366	19366	19366	14132	14132	14132	14132	2361	2524
Avoidance	86	0	0	26	90	0	0	21	36	0	0
Preferred	65	19366	19366	19366	19366	14132	14132	14132	14132	2792	2959
Spawning	65	19366	19366	19366	19366	14132	14132	14132	14132	2792	2959
Early life history	70	19366	19366	19366	19366	14132	14132	14132	14132	2361	2524

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Volume Exceeding Temp. Average Case Proposed	Volume Exceeding Temp. Extreme Case Existing	Volume Exceeding Temp. Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Bottom Area Exceeding Temp. Average Case Proposed	Bottom Area Exceeding Temp. Extreme Case Existing	Bottom Area Exceeding Temp. Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Hours of Exceedance at Station 3[a] Proposed
Atlantic Salmon											
Max. for summer survival (parr)	82	6	20	2031	4123	2	8	726	1808	59	181
Optimum for growth (parr)	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										
Avoidance	78	559	1021	19366	19366	299	538	14132	14132	563	926
Preferred (parr)	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										
Spawning	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										
Early life history	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Proposed
Spottail Shiner											
Max. for summer survival, or UILT	95	0	0	0	0	0	0	0	0	0	0
		(Zero value indicates plume does not exceed this temperature.)									
Optimum for growth	86	0	0	26	90	0	0	21	36	0	0
Avoidance	95	0	0	0	0	0	0	0	0	0	0
Preferred	86	0	0	26	90	0	0	21	36	0	0
Spawning, incubation	64	19366	19366	19366	19366	14132	14132	14132	14132	2888	3085
Early life history	70	19366	19366	19366	19366	14132	14132	14132	14132	2361	2524

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Volume Exceeding Temp. Average Case Proposed	Volume Exceeding Temp. Extreme Case Existing	Volume Exceeding Temp. Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Bottom Area Exceeding Temp. Average Case Proposed	Bottom Area Exceeding Temp. Extreme Case Existing	Bottom Area Exceeding Temp. Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Hours of Exceedance at Station 3[a] Proposed
Smallmouth Bass											
Max. for summer survival, or UILT	98	0	0	0	0	0	0	0	0	0	0
Optimum for growth	90	0	0	0	0	0	0	0	0	0	0
Avoidance	95	0	0	0	0	0	0	0	0	0	0
Preferred	81	65	154	5061	6281	39	74	2093	3177	147	335
Spawning	63	19366	19366	19366	19366	14132	14132	14132	14132	3006	3184
Early life history	70	19366	19366	19366	19366	14132	14132	14132	14132	2361	2524

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3)				Bottom Area Exceeding Temp. (1000s of ft^2)				Hours of Exceedance at Station 3[a]	
		Average Case		Extreme Case		Average Case		Extreme Case			
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Yellow Perch											
Max. for summer survival, or UILT	90	0	0	0	0	0	0	0	0	0	0
Optimum for growth	74	6829	7557	19366	19366	2302	2978	14132	14132	1568	1809
Avoidance	83	0	0	890	1621	0	0	294	674	11	76
Preferred	77	1212	2030	19366	19366	517	929	14132	14132	794	1191
Spawning	50	19366	19366	19366	19366	14132	14132	14132	14132	3648	3648
Early life history	65	19366	19366	19366	19366	14132	14132	14132	14132	2792	2959

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Volume Exceeding Temp. (10000s of ft^3) Average Case Proposed	Volume Exceeding Temp. (10000s of ft^3) Extreme Case Existing	Volume Exceeding Temp. (10000s of ft^3) Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Extreme Case Existing	Bottom Area Exceeding Temp. (1000s of ft^2) Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Hours of Exceedance at Station 3[a] Proposed
Walleye											
Max. for summer survival, or UILT	89	0	0	0	0	0	0	0	0	0	0
Optimum for growth	74	6829	7557	19366	19366	2302	2978	14132	14132	1568	1809
Avoidance	76	2357	3335	19366	19366	932	1394	14132	14132	1039	1459
Preferred	72	19366	19366	19366	19366	14132	14132	14132	14132	1895	2238
Spawning	48	19366	19366	19366	19366	14132	14132	14132	14132	3648	3648
Early life history	54	19366	19366	19366	19366	14132	14132	14132	14132	3614	3643

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Proposed
Largemouth Bass											
Max. for summer survival, or UILT	95	0	0	0	0	0	0	0	0	0	0
Optimum for growth	83	0	0	890	1621	0	0	294	674	11	76
Avoidance	90	0	0	0	0	0	0	0	0	0	0
Preferred	86	0	0	26	90	0	0	21	36	0	0
Spawning & incubation	70	19366	19366	19366	19366	14132	14132	14132	14132	2361	2524
Early life history	75	4163	4990	19366	19366	1459	1933	14132	14132	1315	1650

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft^3) Average Case Existing	Volume Exceeding Temp. Average Case Proposed	Volume Exceeding Temp. Extreme Case Existing	Volume Exceeding Temp. Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft^2) Average Case Existing	Bottom Area Exceeding Temp. Average Case Proposed	Bottom Area Exceeding Temp. Extreme Case Existing	Bottom Area Exceeding Temp. Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Hours of Exceedance at Station 3[a] Proposed
Fallfish											
Max. for summer survival, or UILT	90	0	0	0	0	0	0	0	0	0	0
Optimum for growth	68	19366	19366	19366	19366	14132	14132	14132	14132	2559	2681
Avoidance	82	6	20	2031	4123	2	8	726	1808	59	181
Preferred	Not Available										
Spawning & incubation	60	19366	19366	19366	19366	14132	14132	14132	14132	3388	3471
Early life history	65	19366	19366	19366	19366	14132	14132	14132	14132	2792	2959

(continued)

Appendix Table 2-2. (Continued)

Thermal Effects Parameter	Temp (F)	Volume Exceeding Temp. (10000s of ft³) Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	Bottom Area Exceeding Temp. (1000s of ft²) Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	Hours of Exceedance at Station 3[a] Existing	Proposed
White Sucker											
Max. for summer survival, or UILT	88	0	0	0	0	0	0	0	0	0	0
Optimum for growth	81	65	154	5061	6281	39	74	2093	3177	147	335
Avoidance	86	0	0	26	90	0	0	21	36	0	0
Preferred	81	65	154	5061	6281	39	74	2093	3177	147	335
Spawning & incubation	60	19366	19366	19366	19366	14132	14132	14132	14132	3388	3471
Early life history	65	19366	19366	19366	19366	14132	14132	14132	14132	2792	2959

Note a: The hours of temperature exceedance at Station 3 under existing and proposed NPDES Permit limits for the operation of Vermont Yankee were calculated from temperatures observed at Station 3 during the summer period in 1998-2002 and the difference between existing and proposed Delta Ts.

Appendix Table 2-3. Summary of temperature effects (percentages of volume and area) on the Representative Important Species and other selected fishes for four model scenarios for the May 16 - October 14 compliance period.

Average Case = occurs 50% of the time
Extreme Case = occurs <1% of the time

Existing = 2 deg. F limit
Proposed = 3 deg. F limit

Total Lower Vernon Pool Volume = 193.7 x10^6 cu. ft.
Total Lower Vernon Pool Bottom Area = 324 acres

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature: Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	% Bottom Area Exceeding Temperature: Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	% Probability of Exceedance at Station 3[a] Existing	Proposed
American Shad											
Max. for summer survival, or UILT	90	0	0	0	0	0	0	0	0	0	0
Optimum for growth (eggs & larvae)	70	100	100	100	100	100	100	100	100	64.7	69.2
Avoidance	86	0	0	0.1	0.5	0	0	0.2	0.3	0	0
Preferred	65	100	100	100	100	100	100	100	100	76.5	81.1
Spawning	65	100	100	100	100	100	100	100	100	76.5	81.1
Early life history	70	100	100	100	100	100	100	100	100	64.7	69.2

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature: Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	% Bottom Area Exceeding Temperature: Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	% Probability of Exceedance at Station 3[a] Existing	Proposed
Atlantic Salmon											
Max. for summer survival (parr)	82	0	0.1	10.5	21.3	0	0.1	5.1	12.8	1.6	5.0
Optimum for growth (parr)	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										
Avoidance	78	2.9	5.3	100	100	2.1	3.8	100	100	15.4	25.4
Preferred (parr)	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										
Spawning	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										
Early life history	Not Applicable (preferred spawning and nursery habitat absent near Vermont Yankee)										

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature: Average Case Existing	% Volume Exceeding Temperature: Average Case Proposed	% Volume Exceeding Temperature: Extreme Case Existing	% Volume Exceeding Temperature: Extreme Case Proposed	% Bottom Area Exceeding Temperature: Average Case Existing	% Bottom Area Exceeding Temperature: Average Case Proposed	% Bottom Area Exceeding Temperature: Extreme Case Existing	% Bottom Area Exceeding Temperature: Extreme Case Proposed	% Probability of Exceedance at Station 3[a] Existing	% Probability of Exceedance at Station 3[a] Proposed
Spottail Shiner											
Max. for summer survival, or UILT	95	0	0	0	0	0	0	0	0	0	0
		(Zero value indicates plume does not exceed this temperature.)									
Optimum for growth	86	0	0	0.1	0.5	0	0	0.2	0.3	0	0
Avoidance	95	0	0	0	0	0	0	0	0	0	0
Preferred	86	0	0	0.1	0.5	0	0	0.2	0.3	0	0
Spawning, incubation	64	100	100	100	100	100	100	100	100	79.2	84.6
Early life history	70	100	100	100	100	100	100	100	100	64.7	69.2

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature: Average Case		% Volume Exceeding Temperature: Extreme Case		% Bottom Area Exceeding Temperature: Average Case		% Bottom Area Exceeding Temperature: Extreme Case		% Probability of Exceedance at Station 3[a]	
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Smallmouth Bass											
Max. for summer survival, or UILT	98	0	0	0	0	0	0	0	0	0	0
Optimum for growth	90	0	0	0	0	0	0	0	0	0	0
Avoidance	95	0	0	0	0	0	0	0	0	0	0
Preferred	81	0.3	0.8	26.1	32.4	0.3	0.5	14.8	22.5	4.0	9.2
Spawning	63	100	100	100	100	100	100	100	100	82.4	87.3
Early life history	70	100	100	100	100	100	100	100	100	64.7	69.2

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature				% Bottom Area Exceeding Temperature				% Probability of Exceedance at Station 3[a]	
		Average Case		Extreme Case		Average Case		Extreme Case			
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Yellow Perch											
Max. for summer survival, or UILT	90	0	0	0	0	0	0	0	0	0	0
Optimum for growth	74	35.3	39.0	100	100	16.3	21.1	100	100	43.0	49.6
Avoidance	83	0	0	4.6	8.4	0	0	2.1	4.8	0.3	2.1
Preferred	77	6.3	10.5	100	100	3.7	6.6	100	100	21.8	32.7
Spawning	50	100	100	100	100	100	100	100	100	100	100
Early life history	65	100	100	100	100	100	100	100	100	76.5	81.1

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature				% Bottom Area Exceeding Temperature				% Probability of Exceedance at Station 3[a]	
		Average Case		Extreme Case		Average Case		Extreme Case			
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Walleye											
Max. for summer survival, or UILT	89	0	0	0	0	0	0	0	0	0	0
Optimum for growth	74	35.3	39.0	100	100	16.3	21.1	100	100	43.0	49.6
Avoidance	76	12.2	17.2	100	100	6.6	9.9	100	100	28.5	40.0
Preferred	72	100	100	100	100	100	100	100	100	51.9	61.4
Spawning	48	100	100	100	100	100	100	100	100	100	100
Early life history	54	100	100	100	100	100	100	100	100	99.1	99.9

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature: Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	% Bottom Area Exceeding Temperature: Average Case Existing	Average Case Proposed	Extreme Case Existing	Extreme Case Proposed	% Probability of Exceedance at Station 3[a] Existing	Proposed
Largemouth Bass											
Max. for summer survival, or UILT	95	0	0	0	0	0	0	0	0	0	0
Optimum for growth	83	0	0	4.6	8.4	0	0	2.1	4.8	0.3	2.1
Avoidance	90	0	0	0	0	0	0	0	0	0	0
Preferred	86	0	0	0.1	0.5	0	0	0.2	0.3	0	0
Spawning & incubation	70	100	100	100	100	100	100	100	100	64.7	69.2
Early life history	75	21.5	25.8	100	100	10.3	13.7	100	100	36.0	45.2

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature				% Bottom Area Exceeding Temperature				% Probability of Exceedance at Station 3[a]	
		Average Case		Extreme Case		Average Case		Extreme Case			
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Fallfish											
Max. for summer survival, or UILT	90	0	0	0	0	0	0	0	0	0	0
Optimum for growth	68	100	100	100	100	100	100	100	100	70.2	73.5
Avoidance	82	0	0.1	10.5	21.3	0	0.1	5.1	12.8	1.6	5.0
Preferred	Not Available										
Spawning & incubation	60	100	100	100	100	100	100	100	100	92.9	95.1
Early life history	65	100	100	100	100	100	100	100	100	76.5	81.1

(continued)

Appendix Table 2-3. (Continued)

Thermal Effects Parameter	Temp (F)	% Volume Exceeding Temperature: Average Case Existing	% Volume Exceeding Temperature: Average Case Proposed	% Volume Exceeding Temperature: Extreme Case Existing	% Volume Exceeding Temperature: Extreme Case Proposed	% Bottom Area Exceeding Temperature: Average Case Existing	% Bottom Area Exceeding Temperature: Average Case Proposed	% Bottom Area Exceeding Temperature: Extreme Case Existing	% Bottom Area Exceeding Temperature: Extreme Case Proposed	% Probability of Exceedance at Station 3[a]: Existing	% Probability of Exceedance at Station 3[a]: Proposed
White Sucker											
Max. for summer survival, or UILT	88	0	0	0	0	0	0	0	0	0	0
Optimum for growth	81	0.3	0.8	26.1	32.4	0.3	0.5	14.8	22.5	4.0	9.2
Avoidance	86	0	0	0.1	0.5	0	0	0.2	0.3	0	0
Preferred	81	0.3	0.8	26.1	32.4	0.3	0.5	14.8	22.5	4.0	9.2
Spawning & incubation	60	100	100	100	100	100	100	100	100	92.9	95.1
Early life history	65	100	100	100	100	100	100	100	100	76.5	81.1

Note a: The probability of temperature exceedance at Station 3 under existing and proposed NPDES Permit limits for the operation of Vermont Yankee is calculated from temperatures observed at Station 3 during the summer period, 1998-2002.

APPENDIX 3

Hydrothermal Modeling

Prepared for Normandeau Associates, Inc., Bedford, NH as Appendix 3 to their report: ***316(a) Demonstration in Support of a Request for Increased Discharge Temperature Limits at Vermont Yankee Nuclear Power Station During May Through October***

Hydrothermal Modeling of the Cooling Water Discharge from the Vermont Yankee Power Plant to the Connecticut River

ASA Report 02-088 **Final Report**
April 2004

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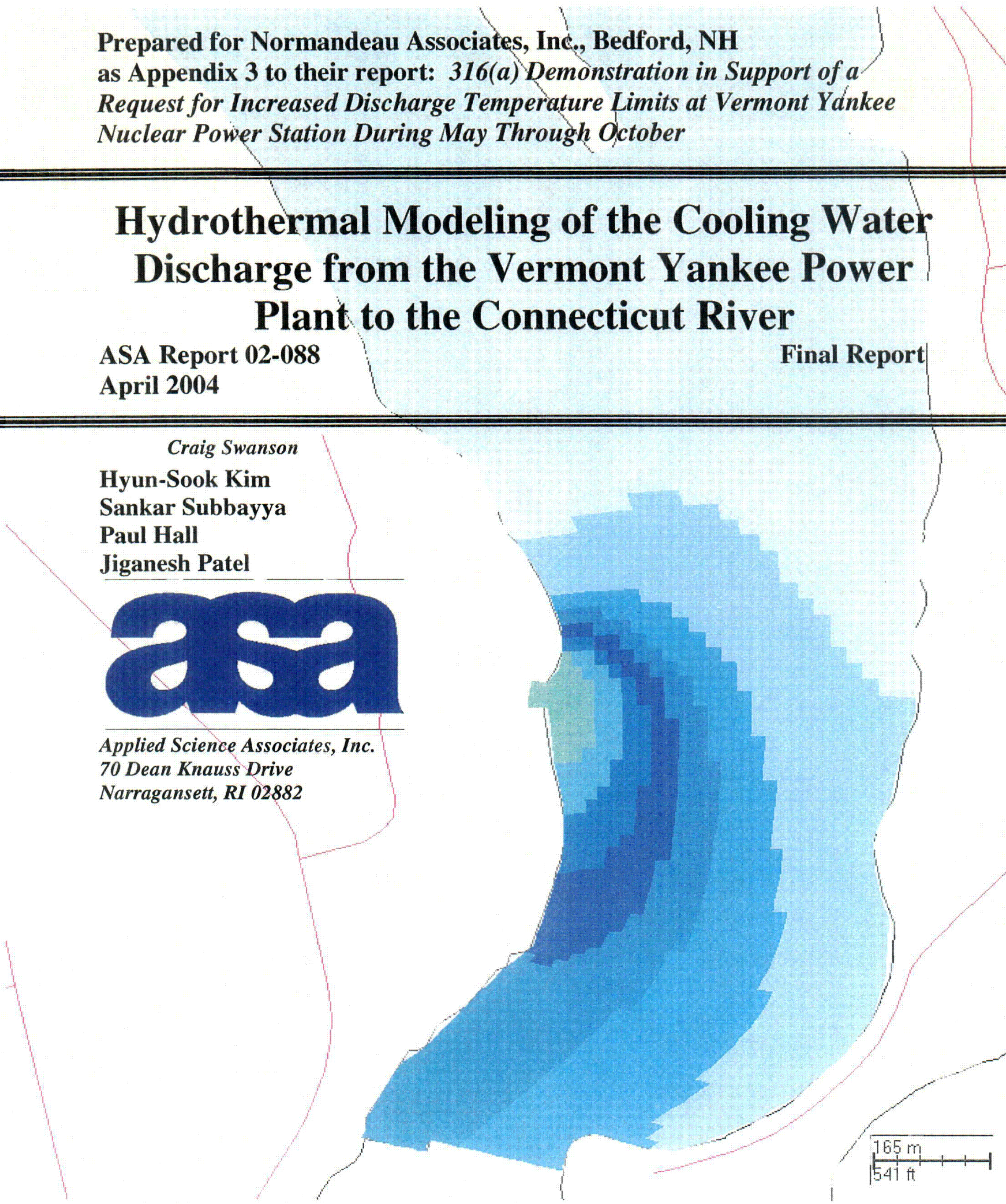

APPENDIX 4

Macroinvertebrate and Fish Study Design Chronology 1991–2002

The following Appendix 4 sections describe each annual program performed from 1991 through 2002 to monitor the benthic macroinvertebrate community and the fish community according to the specifications of Vermont Yankee's NPDES permit, Part III Environmental Monitoring Studies, Connecticut River. Three different NPDES permits governed sampling requirements during the 1991 through 2002 period (1991, 1996, and 2001). Some sampling requirements have changed from permit to permit, or within a permit period, at the direction of Vermont Yankee's EAC. Additionally, high or low river flows and other natural variations may have affected completion of the specified sampling programs within a given year. The purpose of Appendix 4 is to describe the differences (if any) among years to assist interpretation of cross-year trends that were presented in Section 5 of this Demonstration Report.

Permit required monitoring was performed for Vermont Yankee by two environmental services contractors. Aquatec, Inc. (called Inchcape Testing Services after 1993) performed all environmental monitoring from 1967 through 1995. Normandeau Associates, Inc. (Normandeau) began providing all of Vermont Yankee's environmental monitoring services in 1996, and has continued to do so to date. Normandeau took over a monitoring program with largely undocumented field and laboratory procedures. Guidance for field sampling requirements was provided by the specifications of Vermont Yankee's NPDES permit (Part III Environmental Monitoring Studies, Connecticut River) and by the annual monitoring reports. Normandeau prepared Standard Operating Procedures to document the specifics of the field monitoring program performed annually since 1996.

BENTHIC MACROINVERTEBRATES

Macroinvertebrate samples were collected at four locations in the Connecticut River from 1991 through 2001 and two stations in 2002. Two locations (Stations 2 and 3) are downstream of Vernon Dam and two (Stations 4 and 5) are upstream of the Dam (Figures 1-1 and 5-1). Two sampling methods were employed: grab sampling and "rock basket" colonization samplers. An Ekman grab (Aquatec, Inc. unspecified dimensions, but probably the standard Ekman grab with a 6-inch by 6-inch opening) was used from 1991 through 1995, and a 9-inch by 9-inch Ponar grab was used (by Normandeau) from 1996 through 2002. Rock baskets used prior to 1996 were actually minnow traps (Aquatec, Inc. unspecified dimensions, but probably 9-inch diameter by 16-inch long cylinders) consisting of 0.25-inch galvanized wire mesh filled with 1-2 inch stones. Standard rock baskets were used (by Normandeau) from 1996 through 2002, consisting of 7-inch diameter by 10-inch long cylindrical barbeque baskets with a 5/8-inch by 3-inch mesh openings that were filled with 2-4 inch bank run stones.

Due to a reporting error in 1992 on the part of Aquatec, Inc. (formerly providing monitoring services for Vermont Yankee prior to 1996), data from that year on the rock basket sampling design is lacking from this analysis. Sampling effort has varied during the 1991-2002 period due to equipment loss, changes in gear, and changes in permit monitoring requirements (Appendix Table A4-1 and A4-2). In an attempt to adjust or standardize these data for the sampling gear and deployment variability, count data from Ponar grabs were standardized into organisms collected per grab, and count data for rock baskets was standardized as the number of invertebrates collected per rock basket per 30 days of deployment. However, these adjustments do not fully standardize for the gear differences, so statistical trend analysis was only performed on the 1996 through 2002 data collected by Normandeau using fully documented procedures.

Ponar or Ekman grab samples were collected in June, August, and October in each year from 1991 until 2001 when grab sampling was discontinued pursuant to the EAC's direction. Three replicate Ponar or Ekman grab samples were collected in each year, 1991-2000, at each of three sub-locations, one each near the New Hampshire and Vermont banks of the River, and one at mid-river, on a transect located at each of the four stations (Stations 2, 3, 4, and 5) per sample date.

Rock basket samples were collected after 30 to 60 days (average 48 ± 11, N=77) River exposure on two occasions during the interval June through October in each year, except in 2001 when ANR directed in the current NPDES permit that an additional sampling effort be undertaken at Stations 2 and 3, and that sampling at Stations 4 and 5 be eliminated.

After collection, all Ponar grab samples were rinsed over U.S. Standard No. 30 sieves (mesh opening 0.595 mm) in the field. Sample residue retained on the sieves was preserved with 70% ethanol prior to laboratory processing. In the laboratory, the contents of each replicate grab sample from each station were combined and then sub-sampled to an aliquot of at least 100 organisms (if present) before the macroinvertebrates were sorted under 2X magnification. The macroinvertebrates sorted from each sub-sample were examined with a stereomicroscope, identified to the lowest practical level, and enumerated. Where subsampling occurred counts by taxonomic category (taxon) were extrapolated to total numbers for entire sample, based on the fraction of each composite sample analyzed.

Each rock basket sample was either transported in an individual bucket to the laboratory where the samplers were disassembled and the rocks were rinsed over U.S. Standard No. 30 sieves, or placed into individual buckets and immediately processed in the boat. From 2001 on, samples were rinsed and preserved in the field with 70% ethanol for later identification. All organisms found attached to the rocks in each sample were removed and preserved along with the sample residue retained on the sieves. From 1991 to 1995, rock basket samples from each station and date were combined and sorted in their entirety. The residue from one of each pair of rock basket samples collected at each station per sample date was randomly selected for macroinvertebrate sorting under 2X magnification from 1996 to 2000 and extrapolated to 2 baskets. From 2001 on, each rock basket was sorted and identified in its entirety. At least 100 macroinvertebrates were sorted from each sample (if present), and the sorted organisms were examined with a stereomicroscope, identified, and enumerated. Counts by taxon were extrapolated to total numbers for entire sample based on the fraction of each sample analyzed.

The macroinvertebrates in each sorted fraction were identified to the lowest practical taxonomic level, given their life stage and condition, using dissecting (45X magnification) and compound (1,000X magnification) microscopes. Chironomids and oligochaetes were separated by subfamily, tribe, or recognizable type prior to identification to the genus/species level. All or representative sub-samples from each grouping were prepared by clearing and mounting, and identified with a compound microscope. Where sub-sampled, the number of specimens identified to genus/species was used to proportion the remaining individuals from each group into specific taxa. In instances where chironomids or Oligochaetes could be identified to genus or species without the aid of a compound microscope, no preparation was necessary. Taxonomic keys used to identify all macroinvertebrates were Brinkhurst (1986), Brown (1976), Burch (1975), Burks (1953), Hitchcock (1974), Jokinen (1992), Klemm (1985), McCafferty (1975), Merritt and Cummins (1996), Peckarsky (1990), Roback (1985), Simpson and Bode (1980), Wiederholm (1983), Wiggins (1996). In short, the protocol, sampling methodology and analysis ensure comprehensive review and well-supported conclusions.

FISH

General electrofishing and trap net sampling occurred during May, June, September and October of each year, unless excessively high or low water levels or extremely dense vegetation rendered sampling dangerous or ineffective. Electrofishing was performed throughout the 12-year period, while trap net sampling was discontinued at the direction of the U.S. Fish and Wildlife Service (USFWS), VANR, and the EAC after 1999. Fish collected by both methods were identified to species, enumerated, weighed to the nearest gram (wet weight), and measured for total length to the nearest millimeter.

Electrofishing was performed with a boat electroshocker employing a bow-mounted cathode array and a Coffelt Electronics Model VVP-15 variable voltage pulsator. Sampling was carried out in the evening beginning approximately 0.5 hour after sunset. Both Aquatec and Normandeau used a Coffelt Electronics Model VVP-15 variable voltage pulsator for electrofishing. Eight stations with a total of 10 sub-locations (six located upstream and four downstream of Vernon Dam) were sampled (Appendix Table A4-3). Electrofishing is an active sampling method wherein the boat moves through a sampling site. Fish encountering the electrical field in front of the boat are stunned, netted from the water, temporarily held in a livewell for processing and then released at the collection location.

Trap nets consisted of a steel frame covered with 1.3-cm square-mesh knotless nylon. Each net had a 1 x 2-meter mouth opening, two 8-m long wings and a 30-cm center lead. Trap nets were deployed for approximately 48 hours for each monthly sampling event and all fish collected were removed and processed after about 24 hours and at the conclusion of sampling. Eight nets were deployed at six locations upstream of Vernon Dam and six were set downstream at five locations (Appendix Table A4-4). The trap net is a passive gear that depends on moving fish to encounter the wings and center lead, which guide them into the trap section of the net.

Documentation of Fish Data Sets for Vermont Yankee's General Electrofishing & Trap Net Programs 1991-2002

Potential impacts of thermal discharge from Vermont Yankee on nine RIS of fish were evaluated using data from 1991 through 2002 in a non-parametric time-series trend analysis. Number of samples, fish counts, and CPUE were calculated for May, June, September and October at each station sampled with trap nets and general electrofishing during 1991-1995 by Aquatec. Trap net and general electrofishing collections were made by Normandeau Associates during 1996-2002 at the same stations and sampling frequency as the previous period of 1991-1995. Data from both periods were compiled following the sample design in Appendix Tables 4-3 and 4-4, but there were some missing samples for some stations during some months or years (Appendix Tables 4-5 and 4-6). However, the sample design for both periods exceeded the minimum sampling effort established by Part III of Vermont Yankee's NPDES Permit. Although some inconsistencies in the design of the data used for analysis, the NPDES Permit monitoring requirements were met in all 12 years. Discrepancies in total number of samples, fish and effort between the data used in the time-series analysis and in each annual report are explained herein.

1991 Through 1995 General Electrofishing and Trap Nets

Total catch and effort by species collected by general electrofishing and trap net during 1991-1995 were compiled from report tables (Aquatec, Inc. 1992, 1993, 1994, 1995, and 1996). In addition,

individual sample data for American shad and white sucker were compiled for analysis of trends on a smaller spatial scale.

1996 General Electrofishing

A total of three samples from elecrofishing collections in July at Stations 3, Stebbins Island-NH, and 0.1 mile south of Vernon Dam were included in Table 5-2 of the annual report (Normandeau 1997) but excluded from the analytical data design. Two samples collected in the anadromous fish electrofishing program from another location at 0.1 mile south of Vernon (station code=725) in September and Stebbins-NH (613) in October were also excluded from the analysis. Beginning in 1996, and continuing through the present, the Stebbins Island-VT Station was dropped from the general electrofishing program and maintained as an anadromous fish collecting station only. The exclusion of these electrofishing samples reduced the total effort from 7.50 to 6.58 hours and total catch from 1591 to 1541 fish. At Station 5-NH, general electrofishing samples were not collected in May and June 1996. At Station 4-VT, general electrofishing samples were not collected in May and June 1996.

1996 Trap Nets

Total number of samples, catch and effort for trap net were the same as reported in the 1996 annual report. Extra trap net samples were collected in June and September for a portion of the stations to compensate for missed samples in May due to high water flows (Normandeau 1997). Beginning in September 1996, sampling was increased to other stations to match the sample design from prior years (Normandeau 1997).

Station 4 was coded without N (6) and S (7) locations. These samples were assumed to be station 4-NH-N (416), but after further investigation should have been assigned to code 417. An extra sample was collected at Station 4-NH-N (416) in Sep 96 based on this assignment. If corrected, stratitifed and annual total CPUE remains unchanged. Pull dates (times) during September were 04 Sep (10:52) for undefined station (station 4, state=1, sub=.), 04 Sep (11:05) for station code 416, and 05 Sep (10:10) for station code 416.

Station 4-NH-S had two 24-h samples in June and one 24-h sample in Sep 96 that were not collected. Again, only two 24-h samples were collected in June (19 and 20 Sep) at an undefined station 4. One 24-h sample in Sep was specifically coded (417) on pull date (time) of 05 Sep (9:55) and set date (time) of 04 Sep (10:52).

Station 4-VT-S had no samples collected in June 1996.

Station 3 had an extra sample collected in June and no samples were collected October 1996. The three pull dates in June were 7 June, 8 June and 19 June 1996.

Station Stebbins-VT was not sampled in 1996.

Station 2 VT4 was not sampled for both 24-hour sets in June and October 1996.

Station 2 VT4.2 was not sampled for both 24-hour sets in October 1996.

1997 General Electrofishing

In 1997, three empty samples for general electrofishing were erroneously excluded from Table 5-2 in the annual report (Normandeau 1998) which accounted for the difference in effort. Also, September electrofishing collections began on 30 September and ended on 1 October 1997. The empty sample collected by electrofishing on 30 October at Station 3 was excluded because it was a second sample collected for the anadromous fish electrofishing program. Another anadromous fish sample collected on 26 September at Stebbins Island-NH (613) was also excluded from analysis.

1997 Trap Nets

In 1997, the sampling design was met with the collection of all required trap net samples in all months at all locations. However, 17 empty samples for trap net were erroneously excluded from Table 5-2 in the annual report (Normandeau 1998) which accounted for the difference in effort.

1998 General Electrofishing

In 1998, Station 2 in September was sampled by general electrofishing on the NH side and was not reported in the annual report. This sample was included to meet the NPDES permit sampling frequency criteria for Station 2. Also, an empty sample at one of the substations at Stebbins Island-NH Station in September was excluded because it was an anadromous fish sample. These corrections explained the higher total catch and effort in 1998 electrofishing compared to the 1998 annual report (Normandeau 1999).

1998 Trap Nets

The trap net data in 1998 were updated by correcting station code from 051 to 426 on a sample set on 11 June 1998 and correctly reassigning 1 fish to the correct sample (set 11 June 1998, station 051). Also, a void 24-h trap net sample was excluded from Station 4-VT-S and Station 2-VT-S in May.

Station 4-VT-S had a void 24-h trap net sample pulled on 08 May 1998 that was excluded from analysis.

Station 2-VT-S had a void 24-h trap net sample pulled on 05 May 1998 that was excluded from analysis.

1999 General Electrofishing

In 1999, electrofishing data for 1999 were the same as the data summarized in the annual report (Normandeau 2000).

1999 Trap Nets

Some trap net data in 1999 was not recovered because of gear loss in the September due to Hurricane Floyd.

Station Stebbins-NH trap net was not deployed in June due to shallow water (< 10 inches), thus two 24-h samples were not collected. This trap net site was exposed above the water line again in September, thus two 24-h samples were not collected. The trap net sample collected for the first 24-h of net deployed on 03 May 1999 at 12:30 was in low water and a lot of mud was in it. The second 24-h or 48-h sample was not collected because net was not reset due to low water.

Station 2- VT4.2 trap net had the second 24-h sample that was not collected on 16 Sepember 1999 because of high water from Hurricane Floyd.

Station NH Setback had a trap net that was not deployed on 13 September 1999 because the station was inaccessible due to low water and presence of a bald eagle.

Station 4 NH-S had a trap net that was not deployed on 13 September 1999 because of low water and presence of a bald eagle.

2000 General Electrofishing

In 2000, electrofishing data were consistent with the 2000 annual report (Vermont Yankee and Normandeau 2001).

2000 Trap Nets

The trap net program was discontinued after 1999 and no sampling was conducted during 2000 (Vermont Yankee and Normandeau 2001).

2001 General Electrofishing

In 2001, a total of 1,760 fish from 40 general electrofishing samples were the same values reported in the 2001 annual report. Total effort (6.7 h) was similar to the reported effort (7.0 h) in the annual report and the slight difference was due to rounding (Vermont Yankee and Normandeau 2002).

2001 Trap Nets

The trap net program was discontinued after 1999 and no sampling was conducted during 2001 (Vermont Yankee and Normandeau 2002).

2002 General Electrofishing

The electrofishing data used for 2002 were the same as the data summarized in Table 5-3 of the annual report (Vermont Yankee and Normandeau 2003).

2002 Trap Nets

The trap net program was discontinued after 1999 and no sampling was conducted during 2002 (Vermont Yankee and Normandeau 2003).

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Appendix Table 4-1. Number of Ponar and Rock Basket Samples collected in each month from the Connecticut River upstream and downstream of Vernon Dam, 1991 through 2002.

Location/ Station	Gear	1991				1992			1993			1994			1995			1996			1997			1998			1999				2000					2001					2002		
		June	Aug	Sept	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	July	Aug	Oct	June	July	Aug	Sept	Oct	June	July	Aug	Sept	Nov	June	Aug	Oct
Downstream Station 2	Ponar[1]	9	9	ns	9	9	9	9	9	9	9	9	9	9	9	9	9	0	3	9	9	9	9	9	9	9	9	0	9	9	9	0	9	0	9	9	ns	ns	ns	ns	ns	ns	ns
Downstream Station 3	Ponar[1]	9	9	ns	9	9	9	9	9	9	9	9	9	9	9	9	9	1	3	9	9	9	9	9	9	9	9	0	9	9	9	0	9	0	9	9	ns	ns	ns	ns	ns	ns	ns
Upstream Station 4	Ponar[1]	9	9	ns	9	9	9	9	9	9	9	9	9	9	9	9	9	1	3	9	9	9	9	9	9	9	9	0	9	9	9	0	9	0	9	9	ns	ns	ns	ns	ns	ns	ns
Upstream Station 5	Ponar[1]	9	9	ns	9	9	9	9	9	9	9	9	9	9	9	9	9	1	3	9	9	9	9	9	9	9	9	0	9	9	9	0	9	0	9	9	ns	ns	ns	ns	ns	ns	ns
Downstream Station 2	Rock Basket[2]	ns	ns	2	2	NA	NA	NA	ns	2	2	ns	2	2	ns	2	2	ns	2	ns	ns	2	2	ns	2	2	ns	2	ns	2	ns	2	ns	2	ns	ns	2	ns	3	3	3	3	3
Downstream Station 3[3]	Rock Basket[2]	ns	ns	2	ns	NA	NA	NA	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	ns	2	ns	ns	ns	2	ns	ns	2	ns	3	3	3	3	3
Upstream Station 4	Rock Basket[2]	ns	2	ns	2	NA	NA	NA	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	ns	2	2	ns	2	2	ns	ns	2	ns	ns	ns	ns	ns	ns
Upstream Station 5	Rock Basket[2]	ns	ns	2	2	NA	NA	NA	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	2	ns	2	ns	2	2	ns	2	2	ns	ns	2	ns	ns	ns	ns	ns	ns
Downstream Station 2 Sampling Duration	Rock Basket[2]	ns	ns	36	58	NA	NA	NA	ns	55	48 or 50	ns	55	48-50	ns	56-58	56-58	ns	58	ns	ns	47	58	ns	78	45	ns	49	ns	36	ns	50	ns	42	ns	ns	38	ns	37	37	30	30	30
Downstream Station 3[3] Sampling Duration	Rock Basket[2]	ns	ns	36	ns	NA	NA	NA	ns	55	48 or 50	ns	55	48-50	ns	56-58	56-58	ns	58	49	ns	47	55	ns	78	45	ns	49	ns	36	ns	ns	ns	42	ns	ns	38	ns	37	37	30	30	30
Upstream Station 4 Sampling Duration	Rock Basket[2]	ns	55	ns	58	NA	NA	NA	ns	55	48 or 50	ns	55	48-50	ns	56-58	56-58	ns	41	43	ns	46	62	ns	76	46	ns	50	ns	37	51	ns	37	42	ns	ns	38	ns	ns	ns	ns	ns	ns
Upstream Station 5 Sampling Duration	Rock Basket[2]	ns	ns	36	58	NA	NA	NA	ns	55	48 or 50	ns	55	48-50	ns	56-58	56-58	ns	41	43	ns	46	62	ns	76	46	ns	50	ns	37	51	ns	37	42	ns	ns	38	ns	ns	ns	ns	ns	ns

ns = not sampled

[1]Ponars - three grabs per site at each of three quarter points across river at each of four stations. Triplicate samples composited and analyzed. Ponar sampling was discontinued after 2000.

[2]Rock Baskets - two rock baskets are set at each of four stations. From 1991 to 1996, rockbaskets from each station were combined into one sample to be analyzed. From 1997 to 2000 one rock basket is randomly picked and analyzed from each station and month. After 2000, stations 4 and 5 were eliminated from the rockbasket program.

[3]Downstream Station 3 for rock baskets was relocated from a deep pool (10-12 ft) on the Vermont shore to a shallow riffle on the New Hampshire shore beginning in August 2001.

NA - Reporting error found in Aquatecs 1992 Annual Report. A total of 7 samples were collected and analyzed, date and location of these samples cannot be determined.

Appendix Table 4-2. Number of Ponar and Rock Basket Samples analyzed in the laboratory in each month from the Connecticut River upstream and downstream of Vernon Dam, 1991 through 2002.

Location/Station	Gear	1991				1992			1993			1994			1995			1996			1997			1998			1999				2000					2001					2002		
		June	Aug	Sept	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	Aug	Oct	June	July	Aug	Oct	June	July	Aug	Sept	Oct	June	July	Aug	Sept	Nov	June	Aug	Oct
Downstream Station 2	Ponar[1]	9	9	0	9	9	9	9	9	9	9	9	9	9	9	9	9	0	3	9	3	3	3	3	3	3	3	0	3	3	3	0	3	0	3	3	ns	ns	ns	ns	ns	ns	ns
Downstream Station 3	Ponar[1]	9	9	0	9	9	9	9	9	9	9	9	9	9	9	9	9	1	3	9	3	3	3	3	3	3	3	0	3	3	3	0	3	0	3	3	ns	ns	ns	ns	ns	ns	ns
Upstream Station 4	Ponar[1]	9	9	0	9	9	9	9	9	9	9	9	9	9	9	9	9	1	3	9	3	3	3	3	3	3	3	0	3	3	3	0	3	0	3	3	ns	ns	ns	ns	ns	ns	ns
Upstream Station 5	Ponar[1]	9	9	0	9	9	9	9	10[4]	9	9	9	9	9	9	9	9	1	3	9	3	3	3	3	3	3	3	0	3	3	3	0	3	0	3	3	ns	ns	ns	ns	ns	ns	ns
Downstream Station 2	Rock Basket[2]	0	0	1	1	NA	NA	NA	ns	1	1	ns	1	1	ns	1	1	ns	1	0	ns	1	1	ns	1	1	ns	1	ns	1	ns	1	ns	1	ns	ns	2	ns	3	3	3	3	3
Downstream Station 3[3]	Rock Basket[2]	0	0	1	0	NA	NA	NA	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	ns	1	ns	ns	ns	1	ns	ns	2	ns	3	3	3	3	3
Upstream Station 4	Rock Basket[2]	0	1	0	1	NA	NA	NA	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	ns	1	1	ns	1	1	ns	ns	2	ns	ns	ns	ns	ns	ns
Upstream Station 5	Rock Basket[2]	0	0	1	1	NA	NA	NA	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	1	ns	1	ns	1	1	ns	1	1	ns	ns	2	ns	ns	ns	ns	ns	ns

ns = not sampled

[1]Ponars - three grabs per site at each of three quarter points across river at each of four stations. Each grab was analyzed separately from 1991 to 1996. Triplicate samples were composited and subsampled from 1997 to 2002.

Rock Baskets - two rock baskets are set at each of four stations. From 1991 to 1996, rockbaskets from each station were combined into one sample to be analyzed. From 1997 to 2000 one rock basket is randomly picked and analyzed from each station and month. After 2000, stations 4 and 5 were eliminated from the rockbasket program.

[3]Downstream Station 3 for rock baskets was relocated from a deep pool (10-12 ft) on the Vermont shore to a shallow riffle on the New Hampshire shore beginning in August 2001.

[4]109 samples were collected and analysed, date and location of extra sample is unknown so assigned randomly.

NA - Reporting error found in Aquatecs 1992 Annual Report. A total of 7 samples were collected and analyzed, date and location of these samples cannot be determined.

Appendix Table 4-3. Sampling design and the number of samples scheduled for collection by general electrofishing at each Station in lower Vernon Pool and in the Vernon Dam tailrace of the Connecticut River during May, June, September and October 1991-2002.

		Number of Electrofishing Samples by Month				
NPDES Station	**Station**	**May**	**Jun**	**Sep**	**Oct**	**Total**
Upstream from Vernon Dam						
Rum Point	Rum Point	1	1	1	1	4
Station 5	Station 5-NH	1	1	1	1	4
	Station 5-VT	1	1	1	1	4
NH Setback	NH Setback	1	1	1	1	4
Station 4	Station 4-VT	1	1	1	1	4
	Station 4-NH	1	1	1	1	4
Upstream Subtotal		6	6	6	6	24
Downstream from Vernon Dam						
0.1 mi S Vernon Dam	0.1 mi S Vernon Dam	1	1	1	1	4
Station 3	Station 3	1	1	1	1	4
Stebbins Island	Stebbins Island-NH	1	1	1	1	4
	Stebbins Island-VT	1	1	1	1	4
Station 2	Station 2	1	1	1	1	4
Downstream Subtotal		5	5	5	5	20
	Total	**11**	**11**	**11**	**11**	**44**

Appendix Table 4-4. Sampling design and the number of samples scheduled for collection by trap net at each Station in lower Vernon Pool and in the Vernon Dam tailrace of the Connecticut River during May, June, September and October 1991-2002.

		Number of 24 h Trap Net Samples by Month				
NPDES Station	**Station**	**May**	**Jun**	**Sep**	**Oct**	**Total**
Upstream from Vernon Dam						
Rum Point	Rum Point	2	2	2	2	8
Station 5	Station 5-NH	2	2	2	2	8
	Station 5-VT	2	2	2	2	8
NH Setback	NH Setback	2	2	2	2	8
Rum Point	Rum Point	2	2	2	2	8
Station 4	Station 4-VT-N	2	2	2	2	8
	Station 4-VT-S	2	2	2	2	8
	Station 4-NH-N	2	2	2	2	8
	Station 4-NH-S	2	2	2	2	8
Upstream Subtotal		18	18	18	18	72
Downstream from Vernon Dam						
0.1 mi S Vernon Dam	0.1 mi S Vernon Dam	2	2	2	2	8
Station 3	Station 3	2	2	2	2	8
Stebbins Island	Stebbins Island-NH	2	2	2	2	8
	Stebbins Island-VT	2	2	2	2	8
Station 2	Station 2-VT-N	2	2	2	2	8
	Station 2-VT-S	2	2	2	2	8
Downstream Subtotal		12	12	12	12	48
	Total	**30**	**30**	**30**	**30**	**112**

Appendix Table 4-5. Number of samples in the data collected by general electrofishing in the Connecticut River near Vernon, Vermont during 1991-2002 used in the non-parametric time-series analysis.

		1991					1992					1993					1994				
		Number of Samples by Month				Total	Number of Samples by Month				Total	Number of Samples by Month				Total	Number of Samples by Month				Total
		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct	
Upstream from Vernon Dam	Rum Point	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 5-NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 5-VT	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	NH Setback	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 4 NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 4 VT	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Total	6	6	6	6	24	6	6	6	6	24	6	6	6	6	24	6	6	6	6	24
Downstream from Vernon Dam	0.1 mi S Vernon	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 3	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Stebbins NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Stebbins VT	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 2	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Total	5	5	5	5	20	5	5	5	5	20	5	5	5	5	20	5	5	5	5	20
Total		11	11	11	11	44	11	11	11	11	44	11	11	11	11	44	11	11	11	11	44

(continued)

Appendix Table 4-5. Continued.

		1995					1996					1997					1998				
		Number of Samples by Month				Total	Number of Samples by Month				Total	Number of Samples by Month				Total	Number of Samples by Month				Total
		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct	
Upstream from Vernon Dam	Rum Point	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 5-NH	1	1	1	1	4	n/s	n/s	1	1	*2*	1	1	1	1	4	1	1	1	1	4
	Station 5-VT	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	NH Setback	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 4 NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 4 VT	1	1	1	1	4	n/s	n/s	1	1	*2*	1	1	1	1	4	1	1	1	1	4
	Total	6	6	6	6	24	*4*	*4*	6	6	*20*	6	6	6	6	24	6	6	6	6	24
Downstream from Vernon Dam	0.1 mi S Vernon	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 3	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Stebbins NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Stebbins VT	1	1	1	1	4	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
	Station 2	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Total	5	5	5	5	20	4	4	4	4	16	4	4	4	4	16	4	4	4	4	16
Total		**11**	**11**	**11**	**11**	**44**	***8***	***8***	**10**	**10**	***36***	**10**	**10**	**10**	**10**	**40**	**10**	**10**	**10**	**10**	**40**

(continued)

Appendix Table 4-5. Continued.

		1999					2000					2001					2002				
		Number of Samples by Month				Total	Number of Samples by Month				Total	Number of Samples by Month				Total	Number of Samples by Month				Total
		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct	
Upstream from Vernon Dam	Rum Point	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 5-NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 5-VT	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	NH Setback	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 4 NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 4 VT	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Total	6	6	6	6	24	6	6	6	6	24	6	6	6	6	24	6	6	6	6	24
Downstream from Vernon Dam	0.1 mi S Vernon	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Station 3	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Stebbins NH	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Stebbins VT	n/s	n/s	n/s	n/s		n/s	n/s	n/s	n/s		n/s	n/s	n/s	n/s		n/s	n/s	n/s	n/s	
	Station 2	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
	Total	4	4	4	4	16	4	4	4	4	16	4	4	4	4	16	4	4	4	4	16
Total		**10**	**10**	**10**	**10**	**40**	**10**	**10**	**10**	**10**	**40**	**10**	**10**	**10**	**10**	**40**	**10**	**10**	**10**	**10**	**40**

Appendix Table 4-6. **Number of samples in the data collected by trap net in the Connecticut River near Vernon, Vermont during 1991-2002 used in the non-parametric time-series analysis.**

		1991					1992					1993				
		Number of 24-h Samples by Month				Total	Number of 24-h Samples by Month				Total	Number of 24-h Samples by Month				Total
		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct	
Upstream from Vernon Dam	Rum Point	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 5-NH	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 5-VT	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	NH Setback	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 4 NH-N	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 4 NH-S	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 4 VT-N	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 4 VT-S	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Total	16	16	16	16	64	16	16	16	16	64	16	16	16	16	64
Downstream from Vernon Dam	0.1 mi S Vernon	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 3	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Stebbins NH	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Stebbins VT	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 2 VT4	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 2 VT4.2	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Total	12	12	12	12	48	12	12	12	12	48	12	12	12	12	48
Total		**28**	**28**	**28**	**28**	**112**	**28**	**28**	**28**	**28**	**112**	**28**	**28**	**28**	**28**	**112**

(continued)

Appendix Table 4-6. Continued.

		1994					1995					1996				
		Number of 24-h Samples by Month				Total	Number of 24-h Samples by Month				Total	Number of 24-h Samples by Month				Total
		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct	
Upstream from Vernon Dam	Rum Point	2	2	2	2	8	2	2	2	2	8	n/s	2	2	2	6
	Station 5-NH	2	2	2	2	8	2	2	2	2	8	n/s	2	3	2	7
	Station 5-VT	2	2	2	2	8	2	2	2	2	8	n/s	2	2	2	6
	NH Setback	2	2	2	2	8	2	2	2	2	8	n/s	2	2	2	6
	Station 4 NH-N	2	2	2	2	8	2	2	2	2	8	n/s	2	3	2	7
	Station 4 NH-S	2	2	2	2	8	2	2	2	2	8	n/s	n/s	1	2	3
	Station 4 VT-N	2	2	2	2	8	2	2	2	2	8	n/s	2	2	2	6
	Station 4 VT-S	2	2	2	2	8	2	2	2	2	8	n/s	n/s	2	2	4
	Total	16	16	16	16	64	16	16	16	16	64		12	17	16	45
Downstream from Vernon Dam	0.1 mi S Vernon	2	2	2	2	8	2	2	2	2	8	n/s	2	2	2	6
	Station 3	2	2	2	2	8	2	2	2	2	8	n/s	3	2	n/s	5
	Stebbins NH	2	2	2	2	8	2	2	2	2	8	n/s	2	2	2	6
	Stebbins VT	2	2	2	2	8	2	2	2	2	8	n/s	n/s	2	n/s	2
	Station 2 VT4	2	2	2	2	8	2	2	2	2	8	n/s	n/s	2	n/s	2
	Station 2 VT4.2	2	2	2	2	8	2	2	2	2	8		2	2	n/s	4
	Total	12	12	12	12	48	12	12	12	12	48		9	12	4	25
Total		**28**	**28**	**28**	**28**	**112**	**28**	**28**	**28**	**28**	**112**		***21***	***29***	***20***	***70***

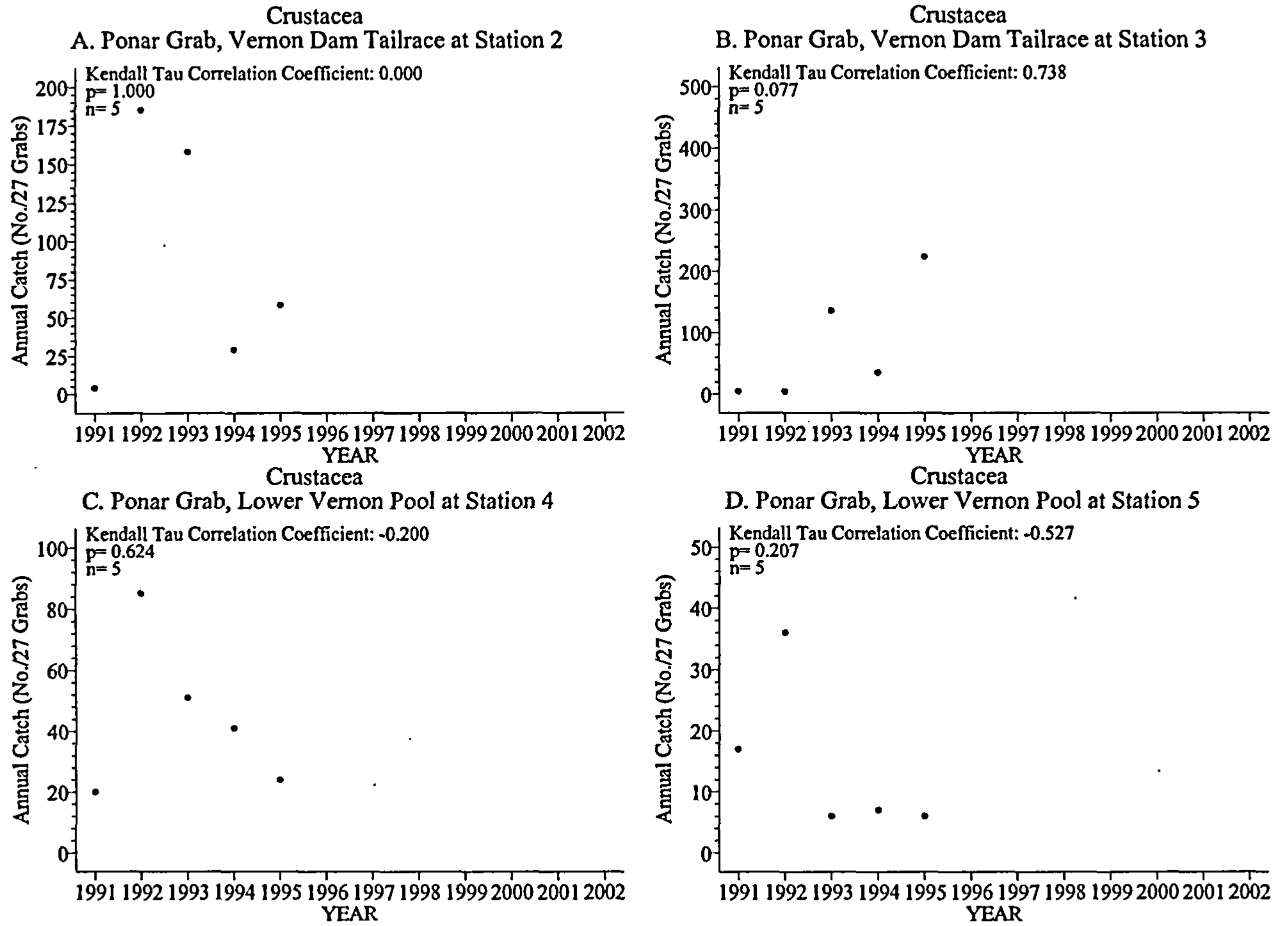
(continued)

Appendix Table 4-6. Continued.

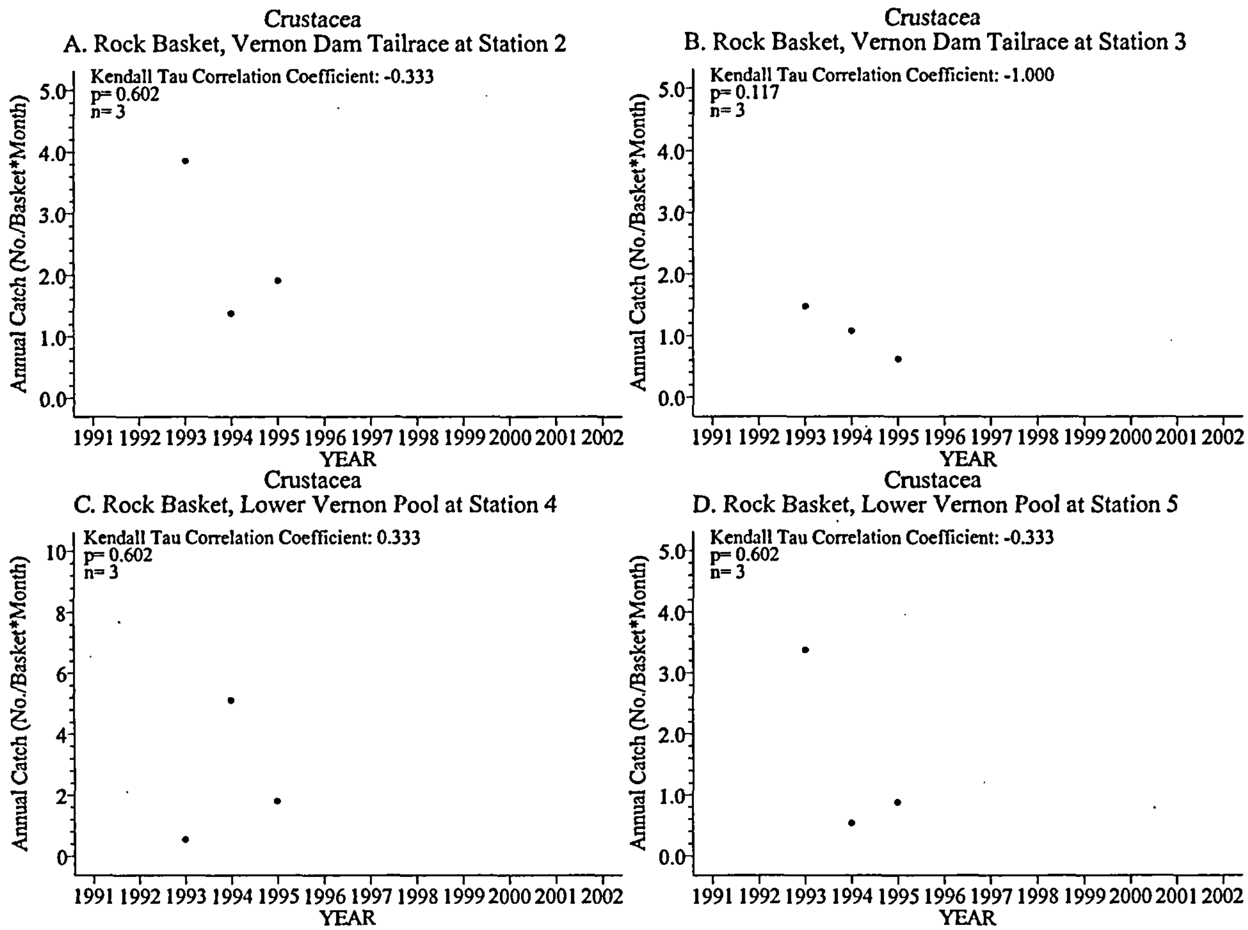
		1997					1998					1999				
		Number of 24-h Samples by Month				Total	Number of 24-h Samples by Month				Total	Number of 24-h Samples by Month				Total
		May	Jun	Sep	Oct		May	Jun	Sep	Oct		May	Jun	Sep	Oct	
Upstream from Vernon Dam	Rum Point	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 5-NH	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 5-VT	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	NH Setback	2	2	2	2	8	2	2	2	2	8	2	2		2	6
	Station 4 NH-N	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 4 NH-S	2	2	2	2	8	2	2	2	2	8	2	2		2	6
	Station 4 VT-N	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 4 VT-S	2	2	2	2	8	*1*	2	2	2	*7*	2	2	2	2	8
	Total	16	16	16	16	64	*15*	16	16	16	*63*	16	16	12	16	60
Downstream from Vernon Dam	0.1 mi S Vernon	2	2	2	2	8	2	2	2	2	8	2	2	1	2	*7*
	Station 3	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Stebbins NH	2	2	2	2	8	2	2	2	2	8	*1*			2	*3*
	Stebbins VT	2	2	2	2	8	2	2	2	2	8	2	2	2	2	8
	Station 2 VT4	2	2	2	2	8	2	2	2	2	8	2	2	*1*	2	*7*
	Station 2 VT4.2	2	2	2	2	8	*1*	2	2	2	*7*	2	2	2	2	8
	Total	12	12	12	12	48	*11*	12	12	12	*47*	11	10	8	12	41
Total		**28**	**28**	**28**	**28**	**112**	***26***	**28**	**28**	**28**	***110***	***27***	***26***	***20***	**28**	***101***

APPENDIX 5

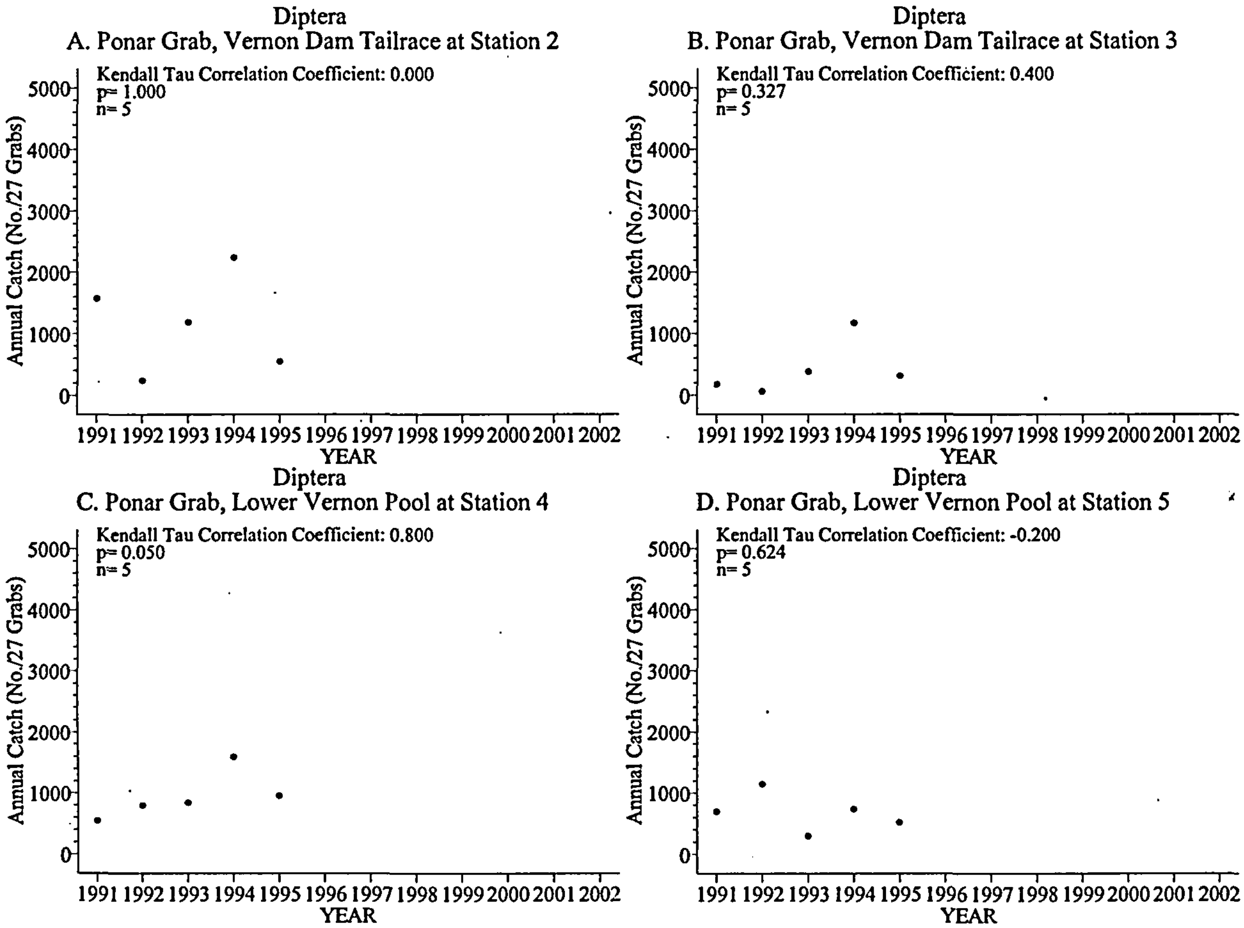
Macroinvertebrate Time Series Plots



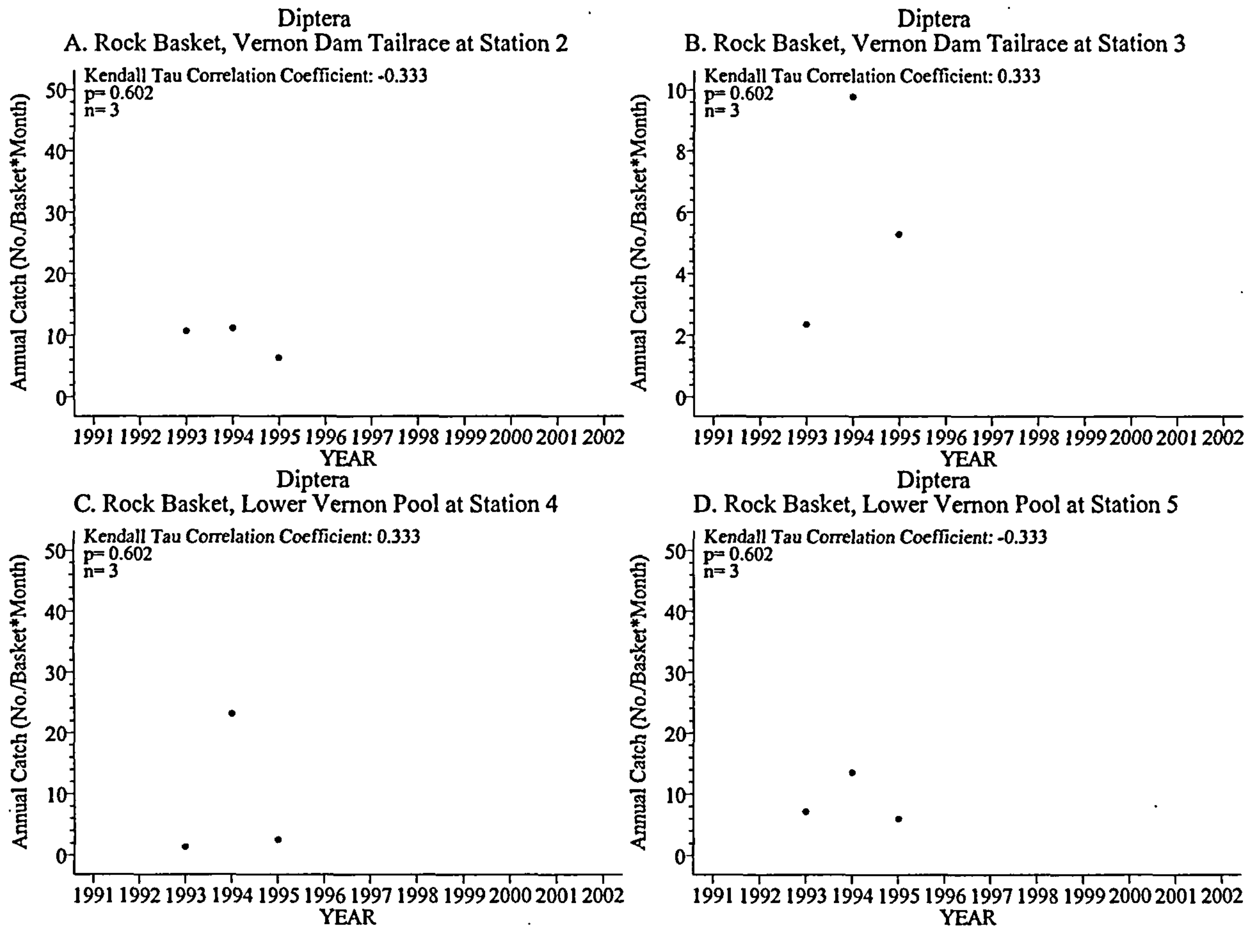
Appendix Figure 5-1. Kendall-Tau correlation for Crustaceans collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



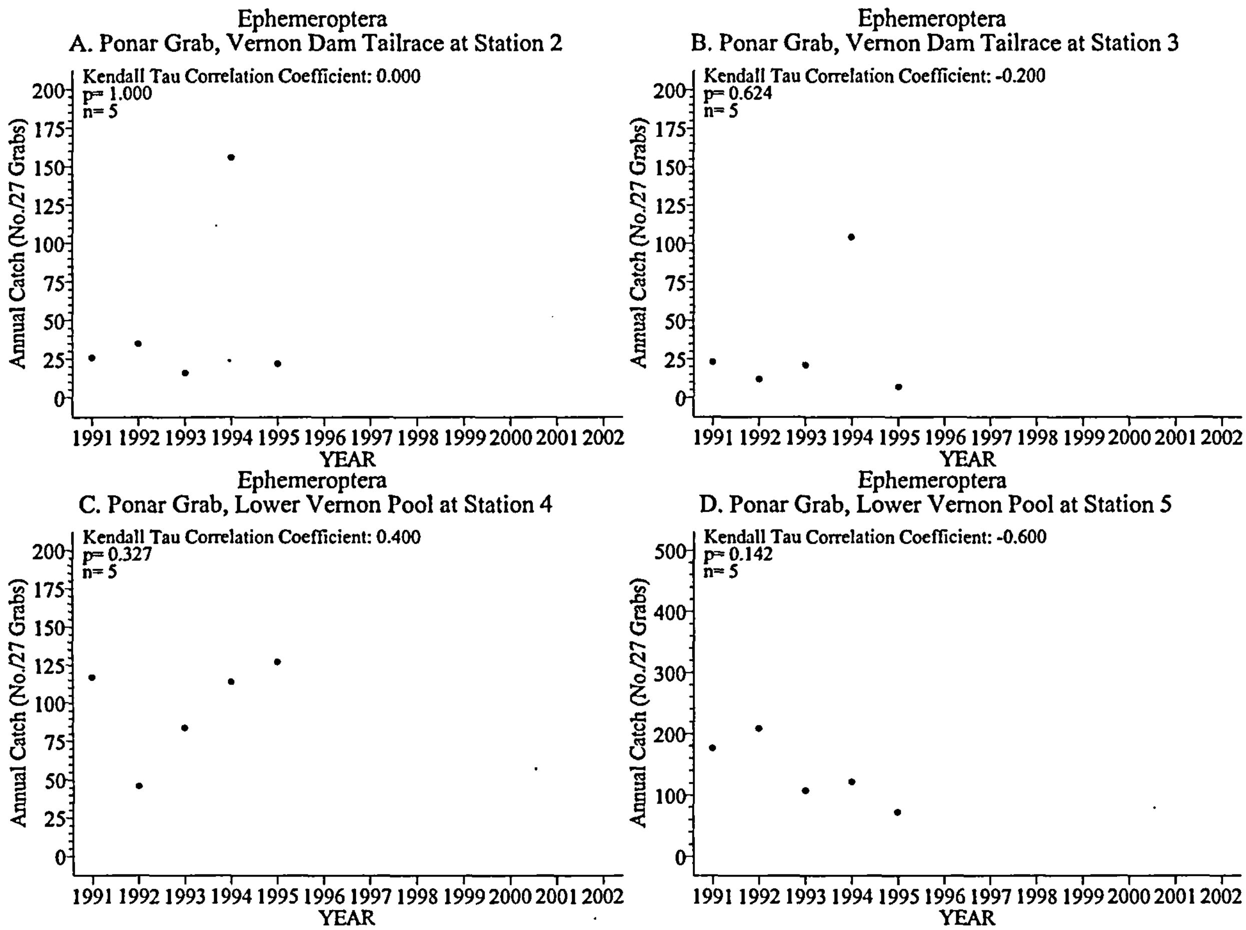
Appendix Figure 5-2. Kendall-Tau correlation for Crustaceans collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



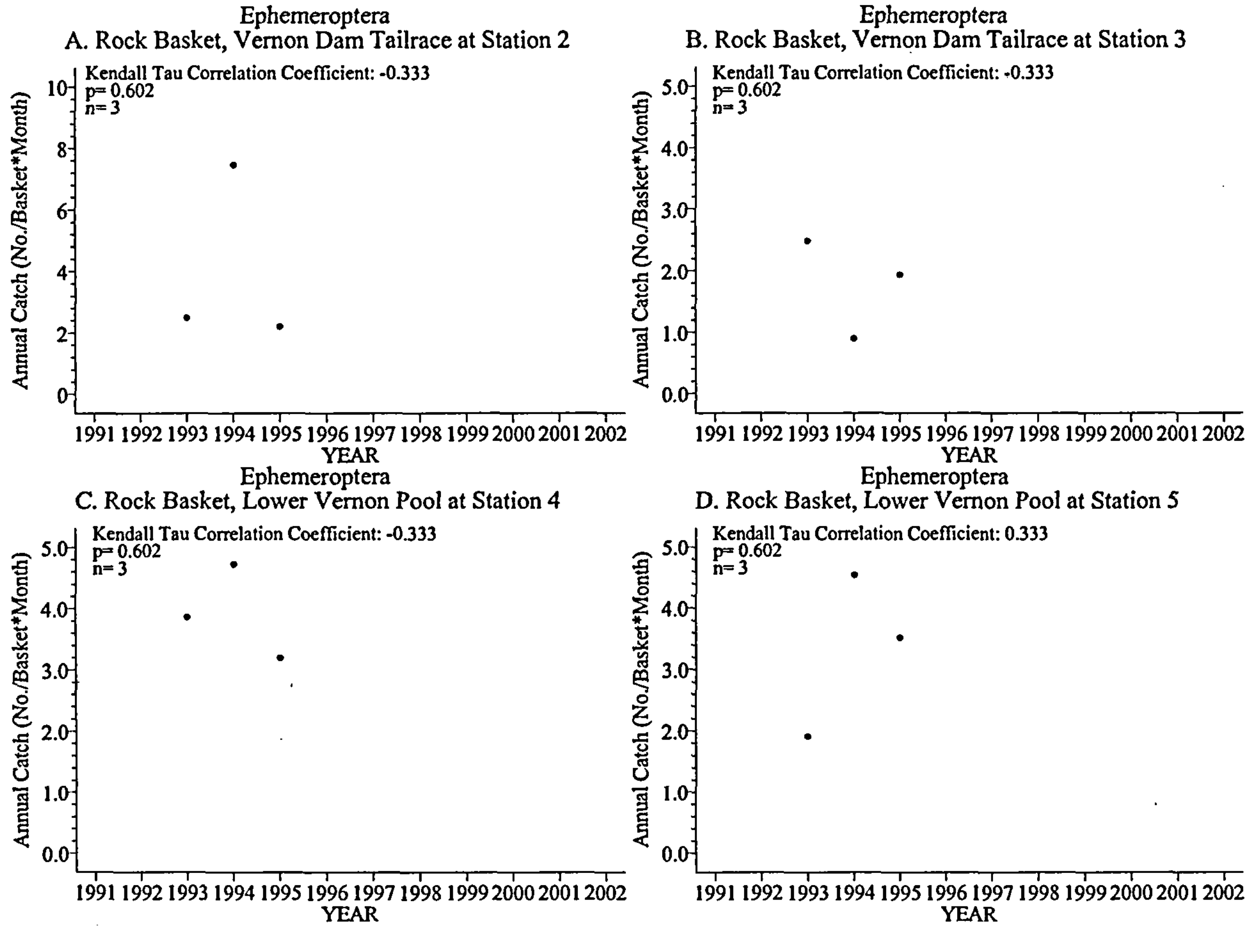
Appendix Figure 5-3. Kendall-Tau correlation for Dipterans collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



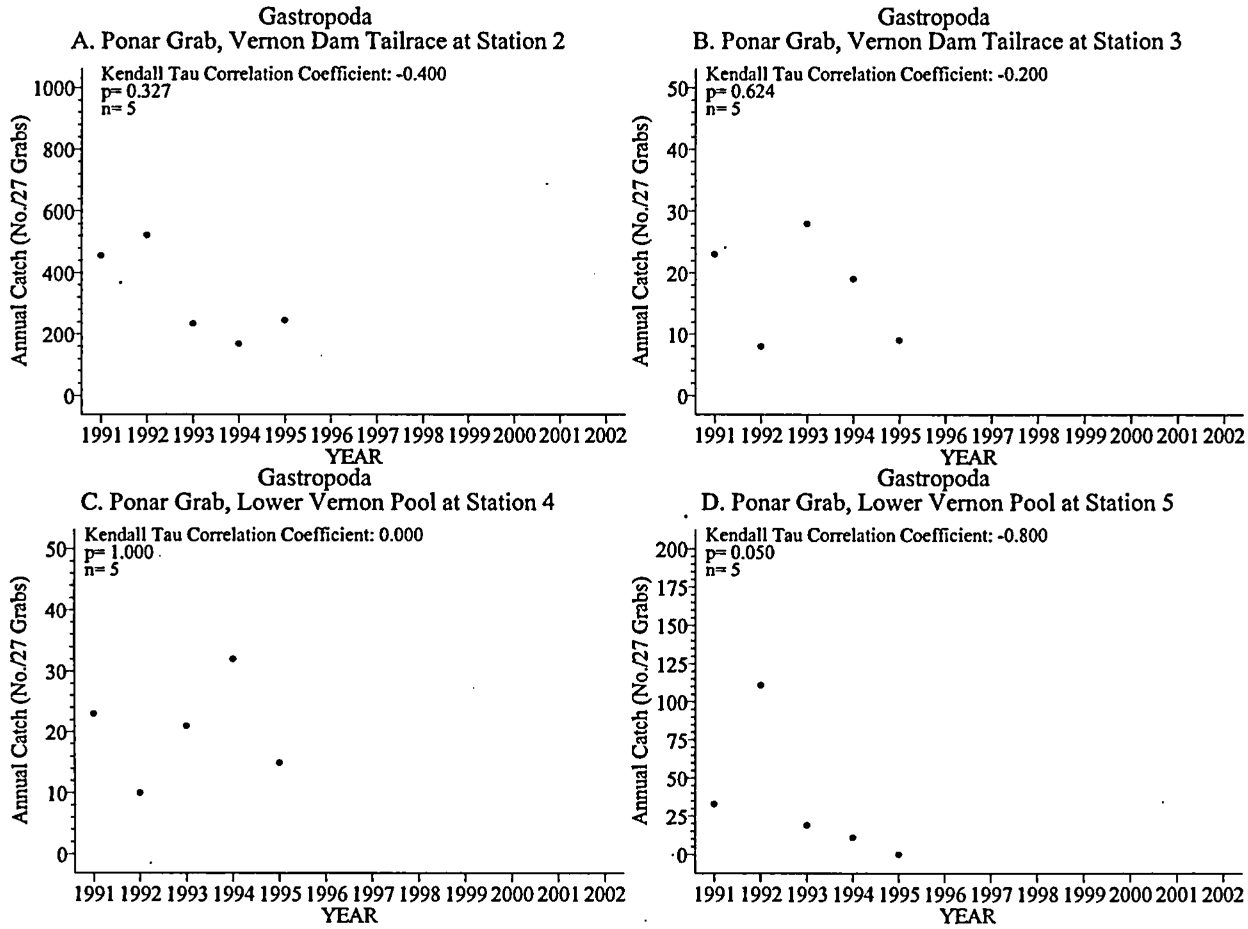
Appendix Figure 5-4. Kendall-Tau correlation for Dipterans collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



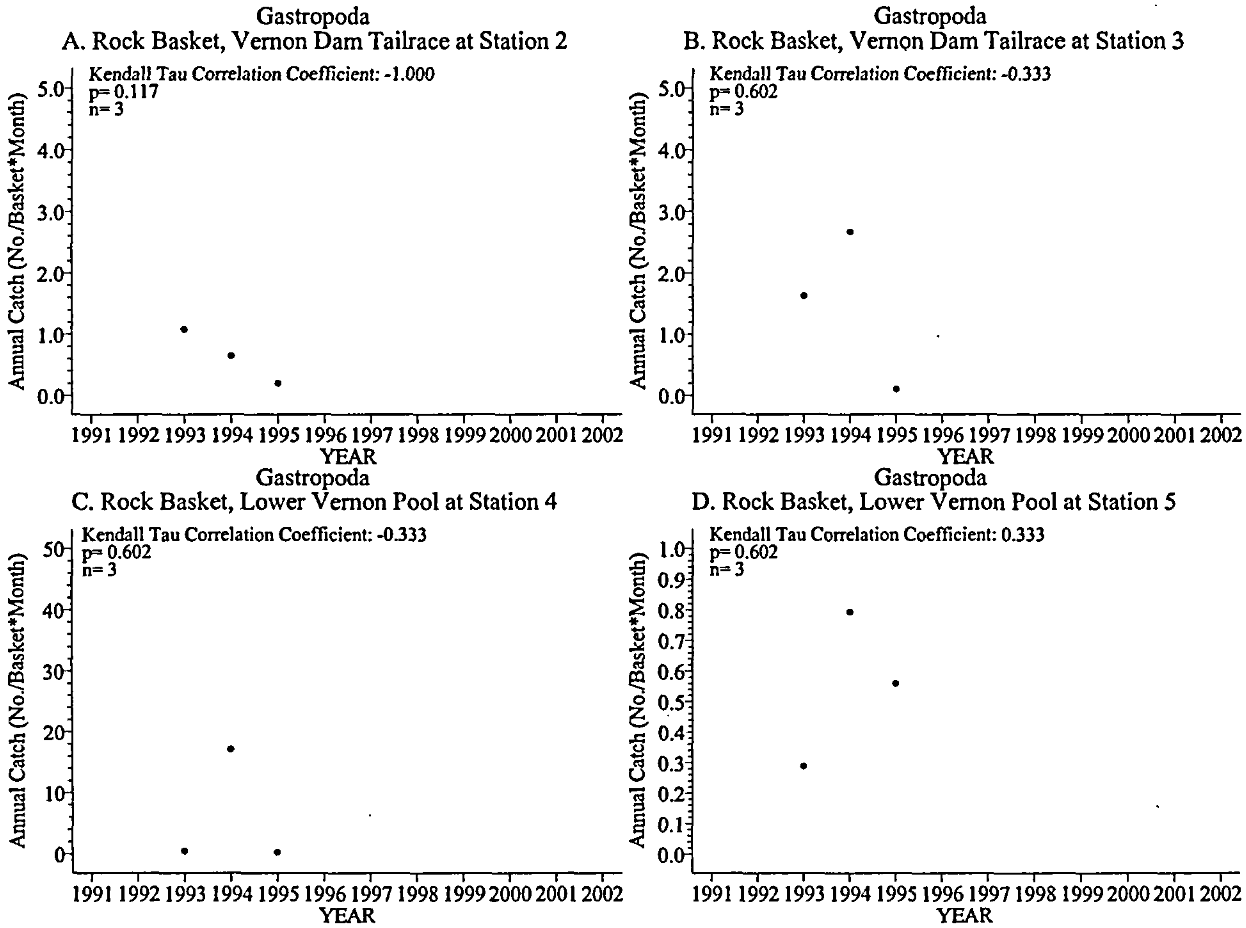
Appendix Figure 5-5. Kendall-Tau correlation for Ephemeropterans collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



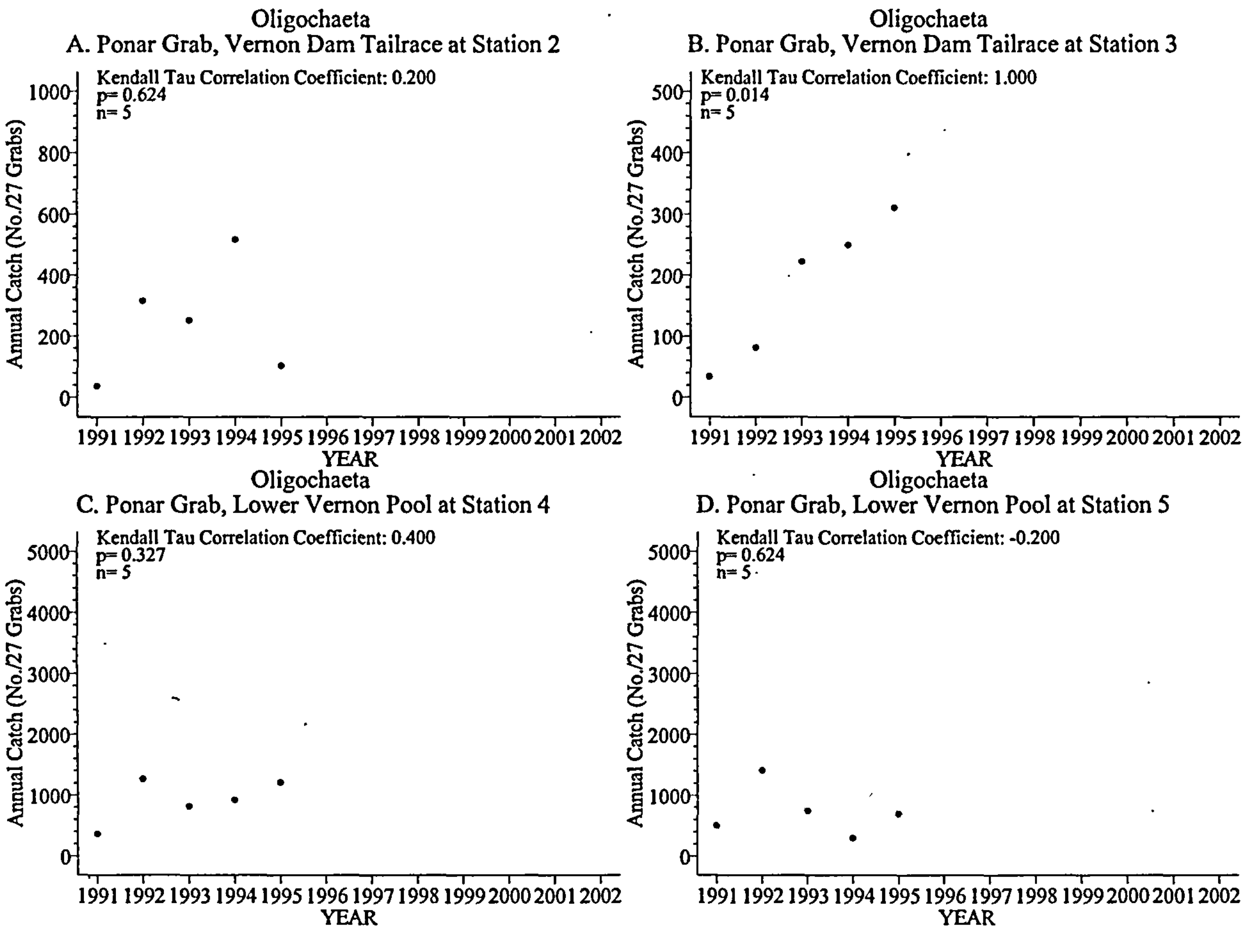
Appendix Figure 5-6. Kendall-Tau correlation for Ephemeropterans collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



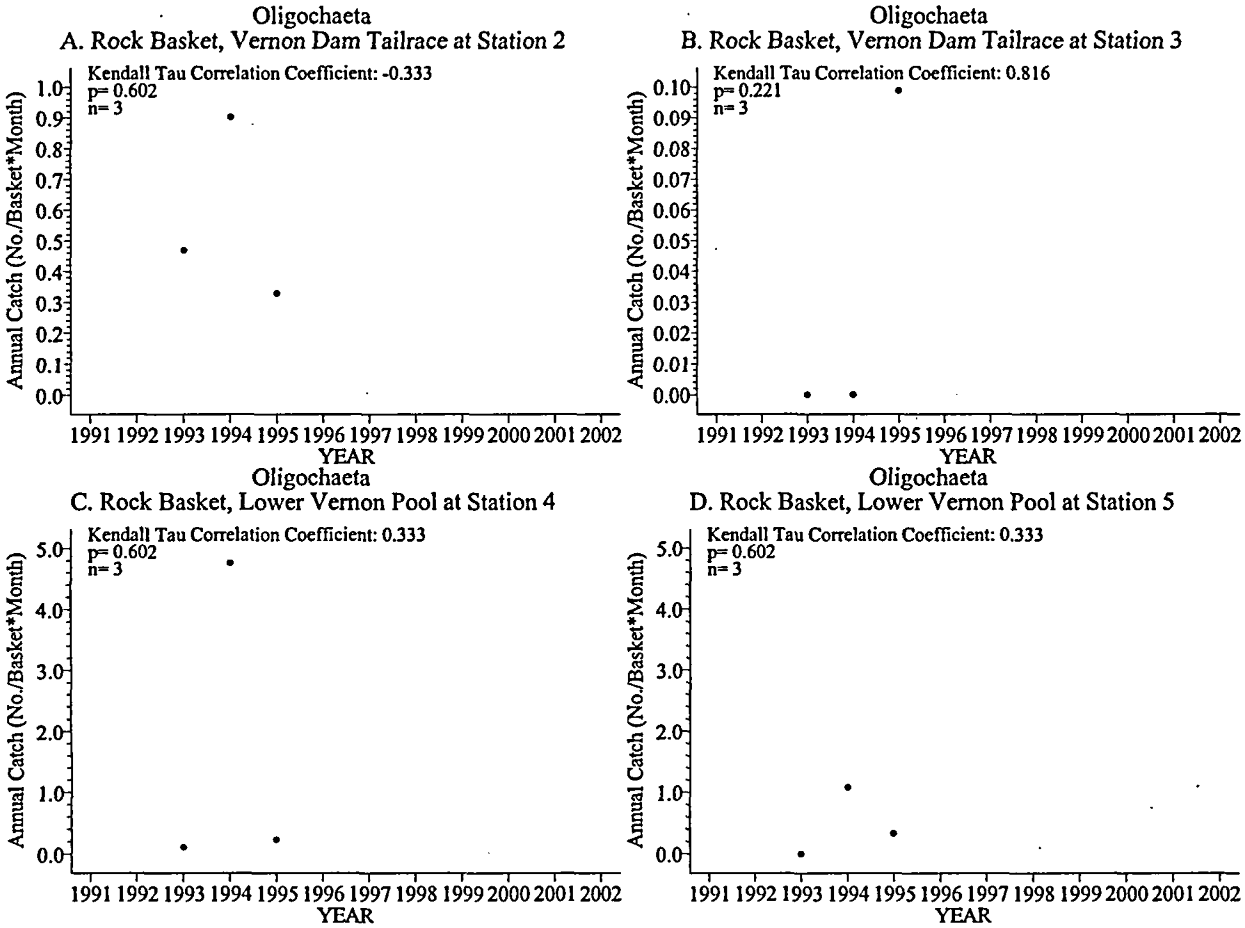
Appendix Figure 5-7. Kendall-Tau correlation for gastropods collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



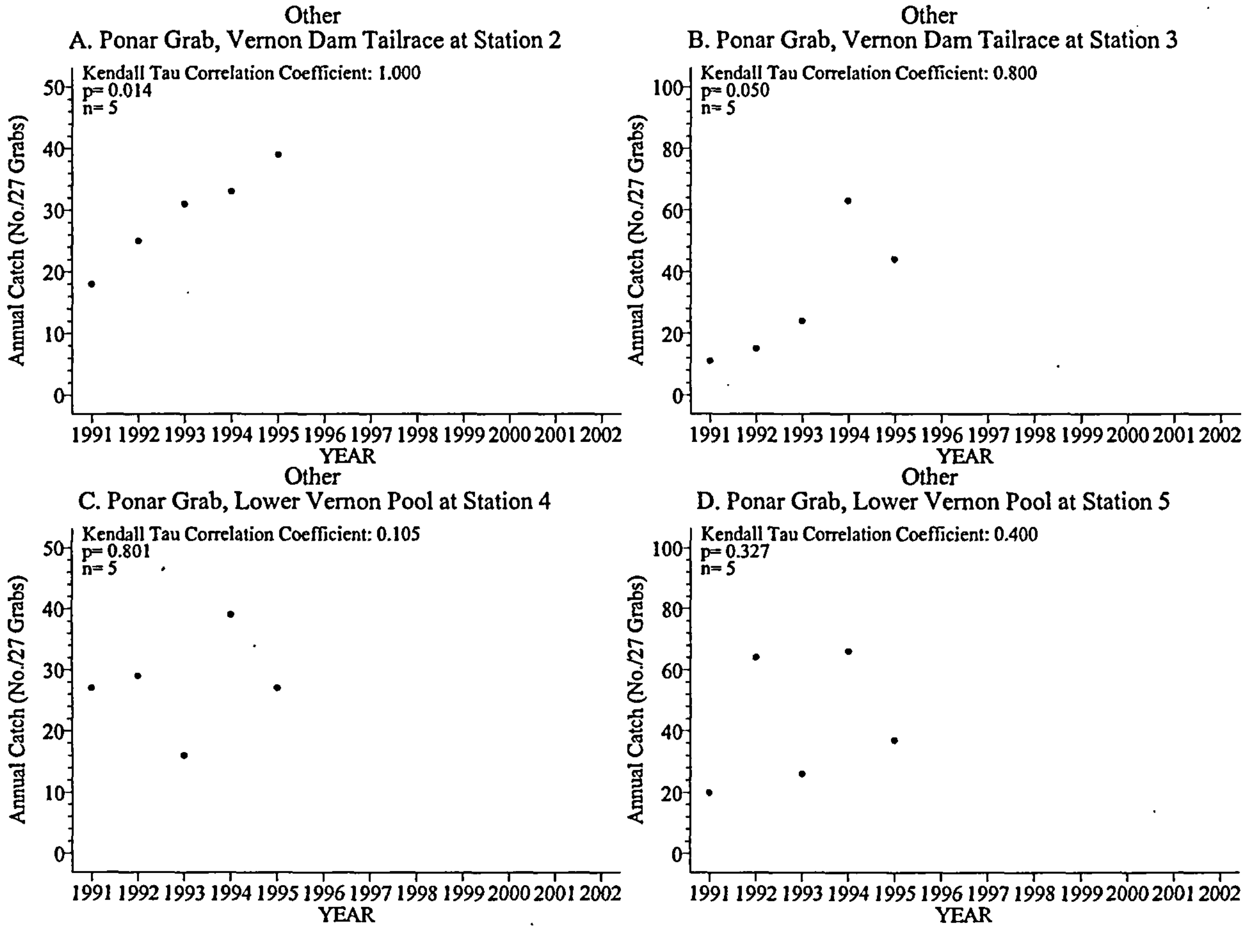
Appendix Figure 5-8. Kendall-Tau correlation for gastropods collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



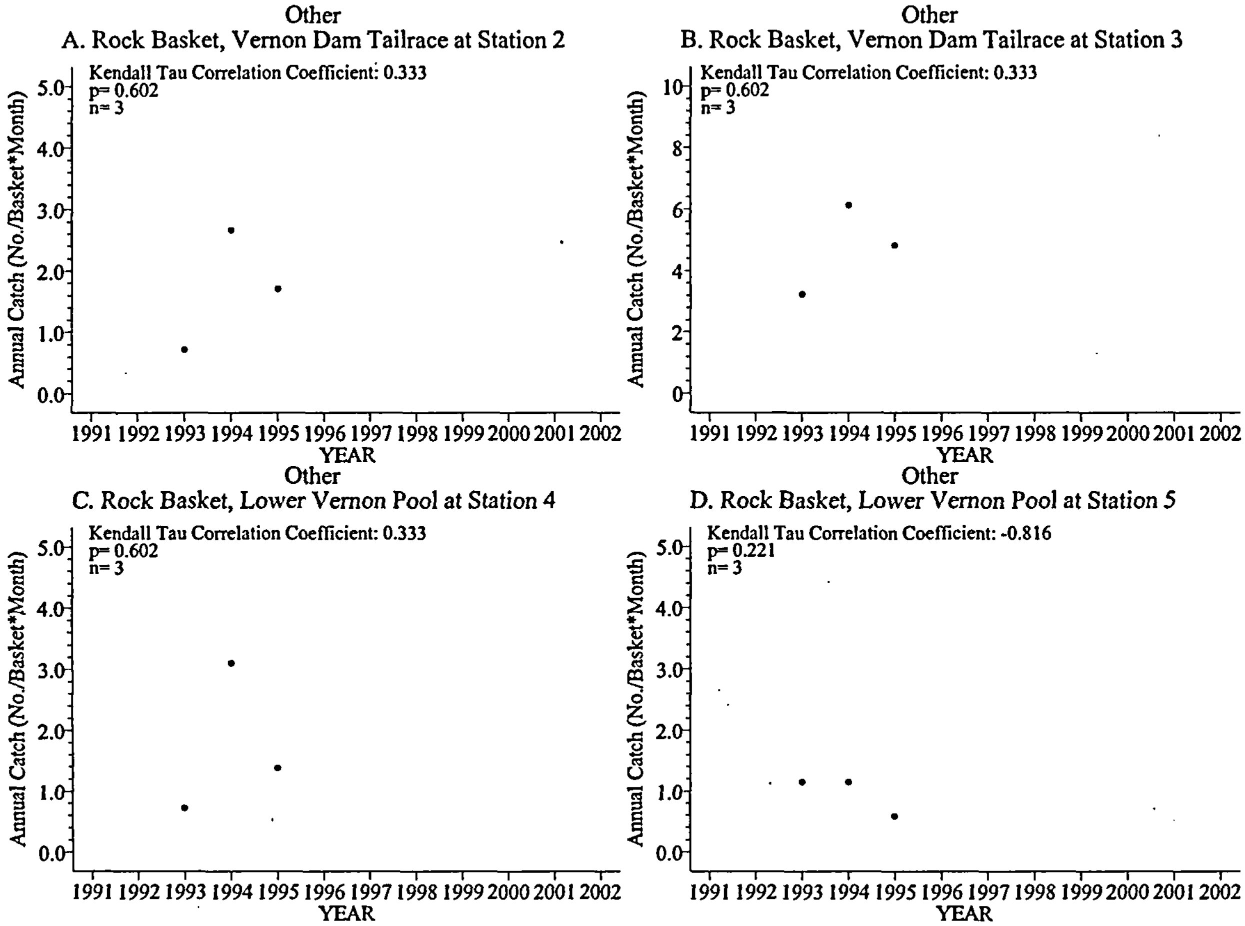
Appendix Figure 5-9. Kendall-Tau correlation for Oligochaets collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



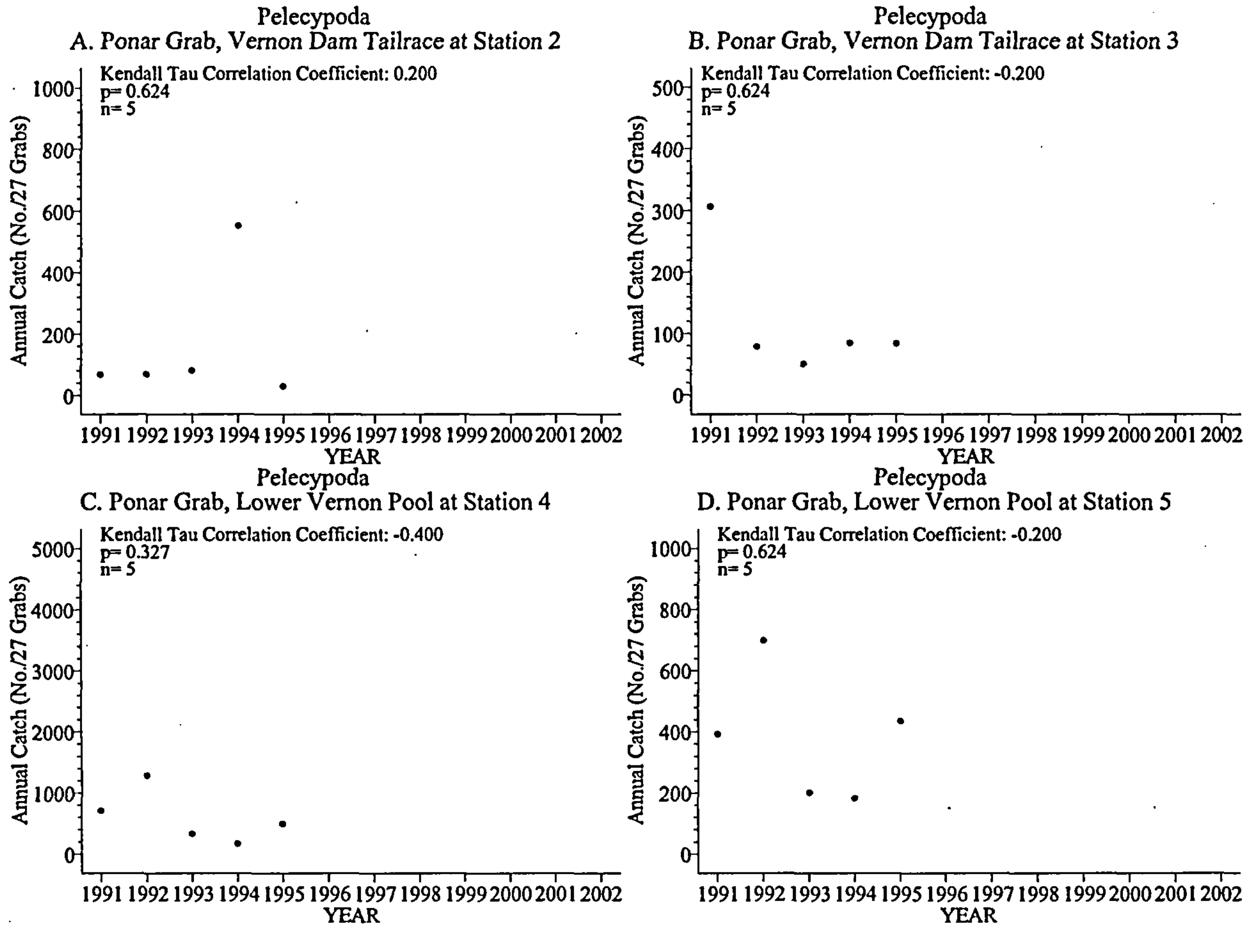
Appendix Figure 5-10. Kendall-Tau correlation for Oligochaets collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



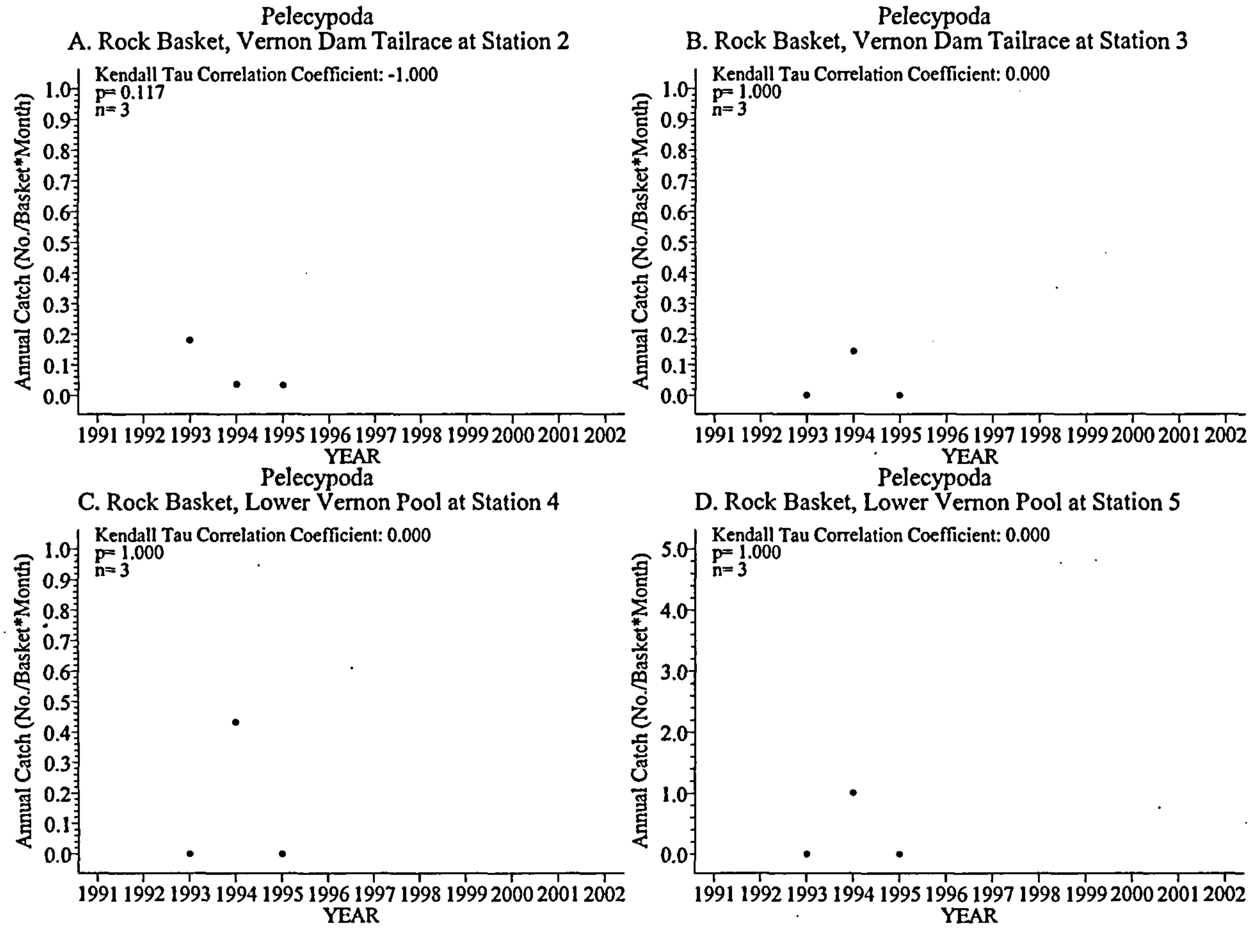
Appendix Figure 5-11. Kendall-Tau correlation for other invertebrate taxa collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



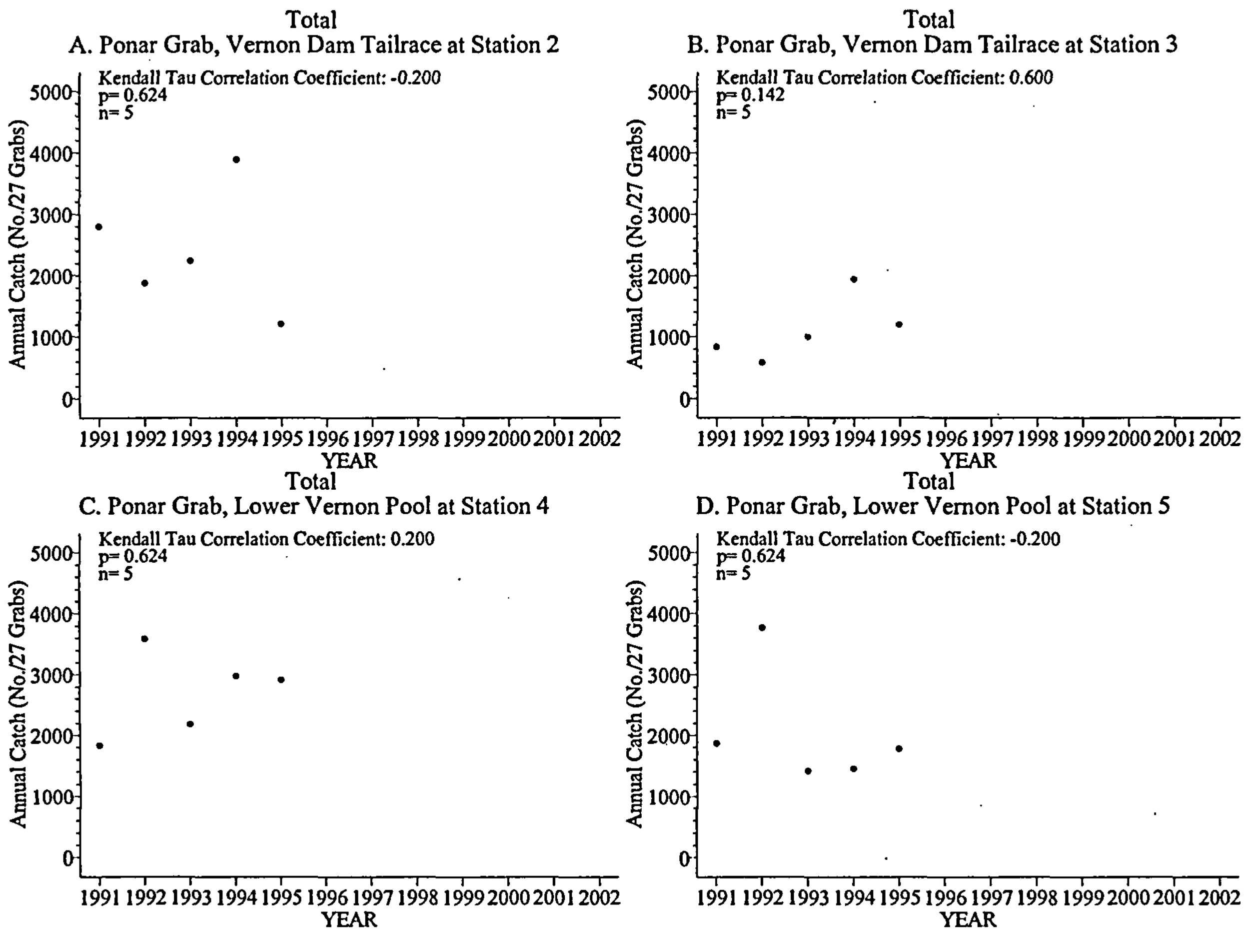
Appendix Figure 5-12. Kendall-Tau correlation for other invertebrate taxa collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



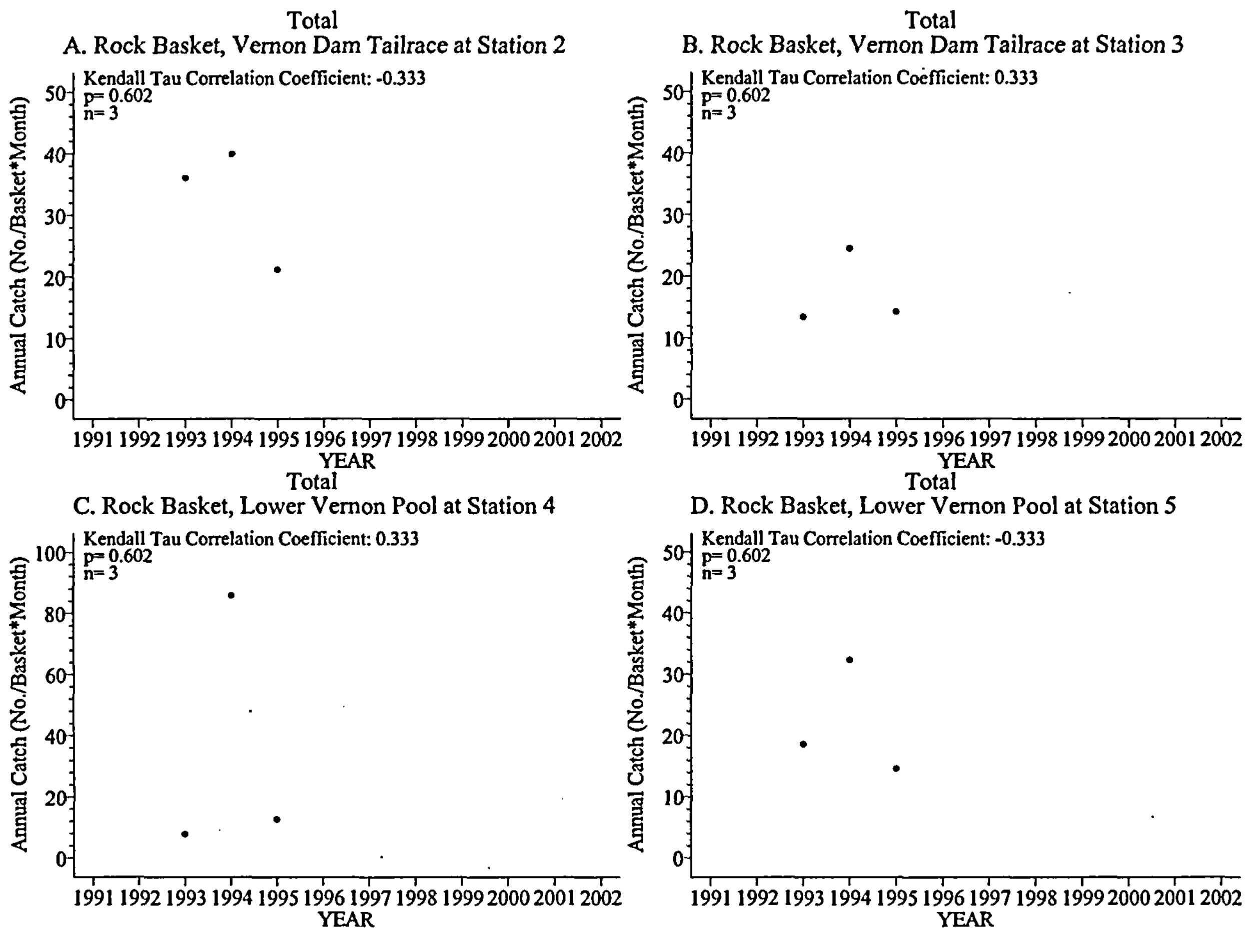
Appendix Figure 5-13. Kendall-Tau correlation for Pelecypods collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



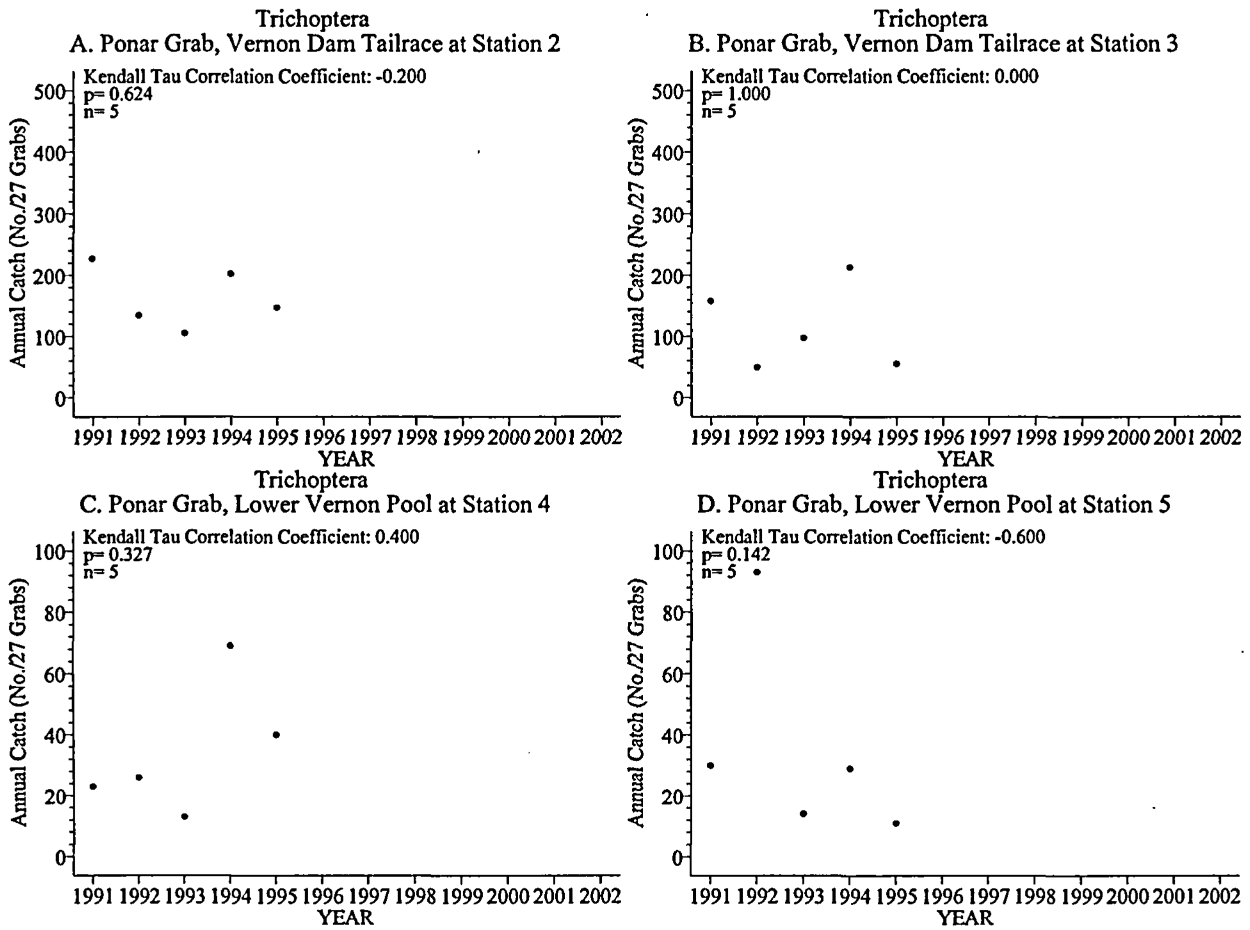
Appendix Figure 5-14. Kendall-Tau correlation for Pelecypods collected from 1993 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



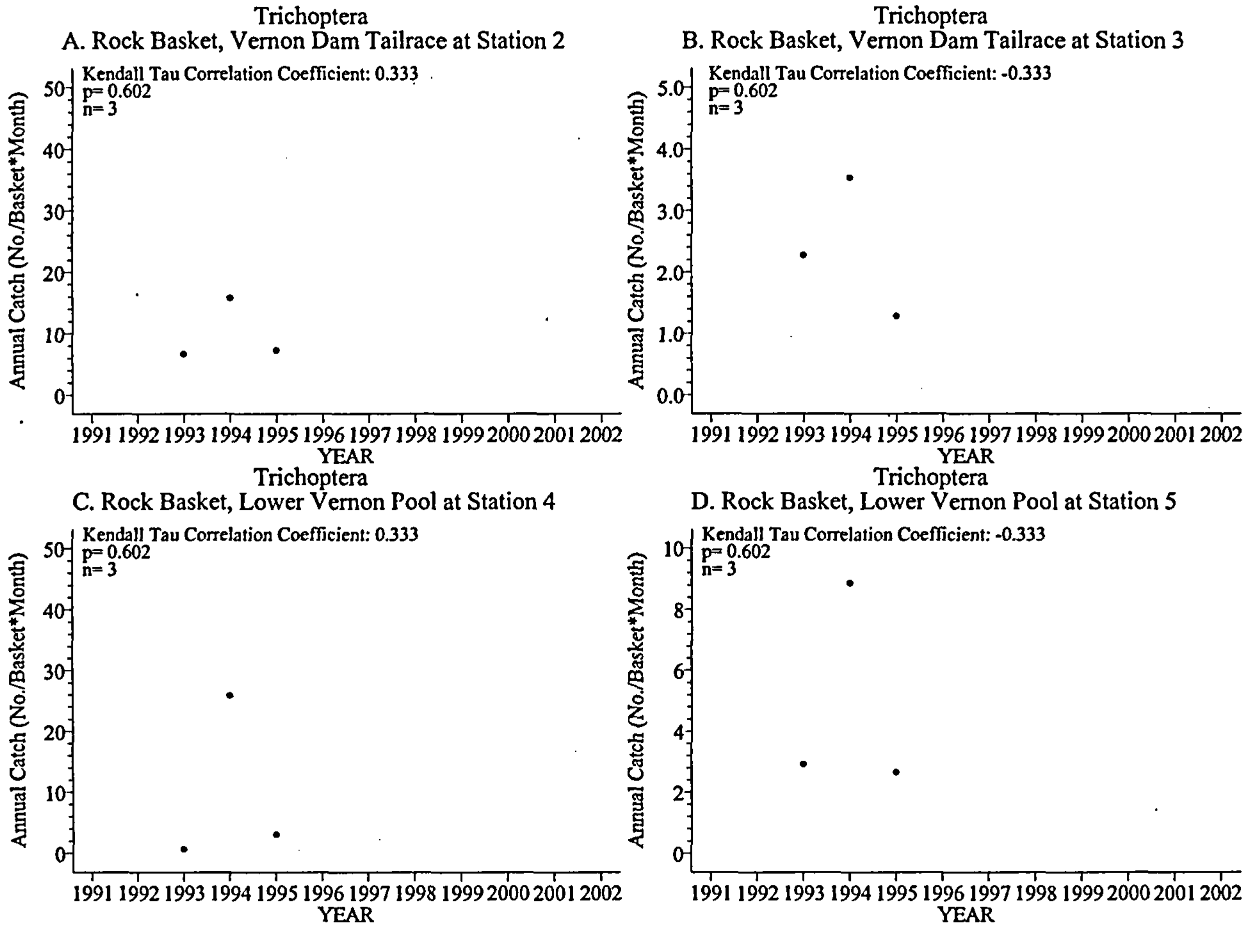
Appendix Figure 5-15. Kendall-Tau correlation for all macroinvertebrates collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



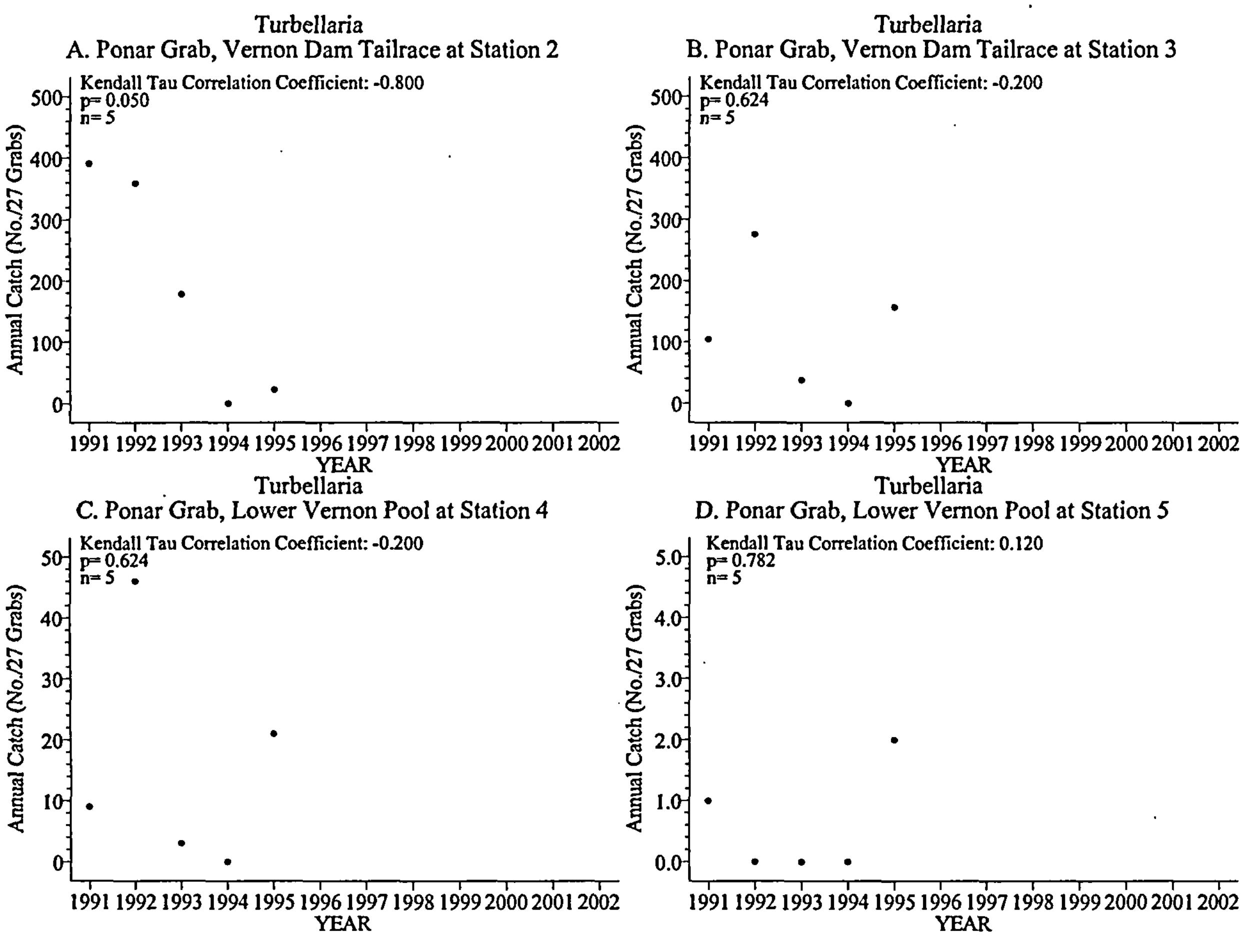
Appendix Figure 5-16. Kendall-Tau correlation for all macroinvertebrates collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



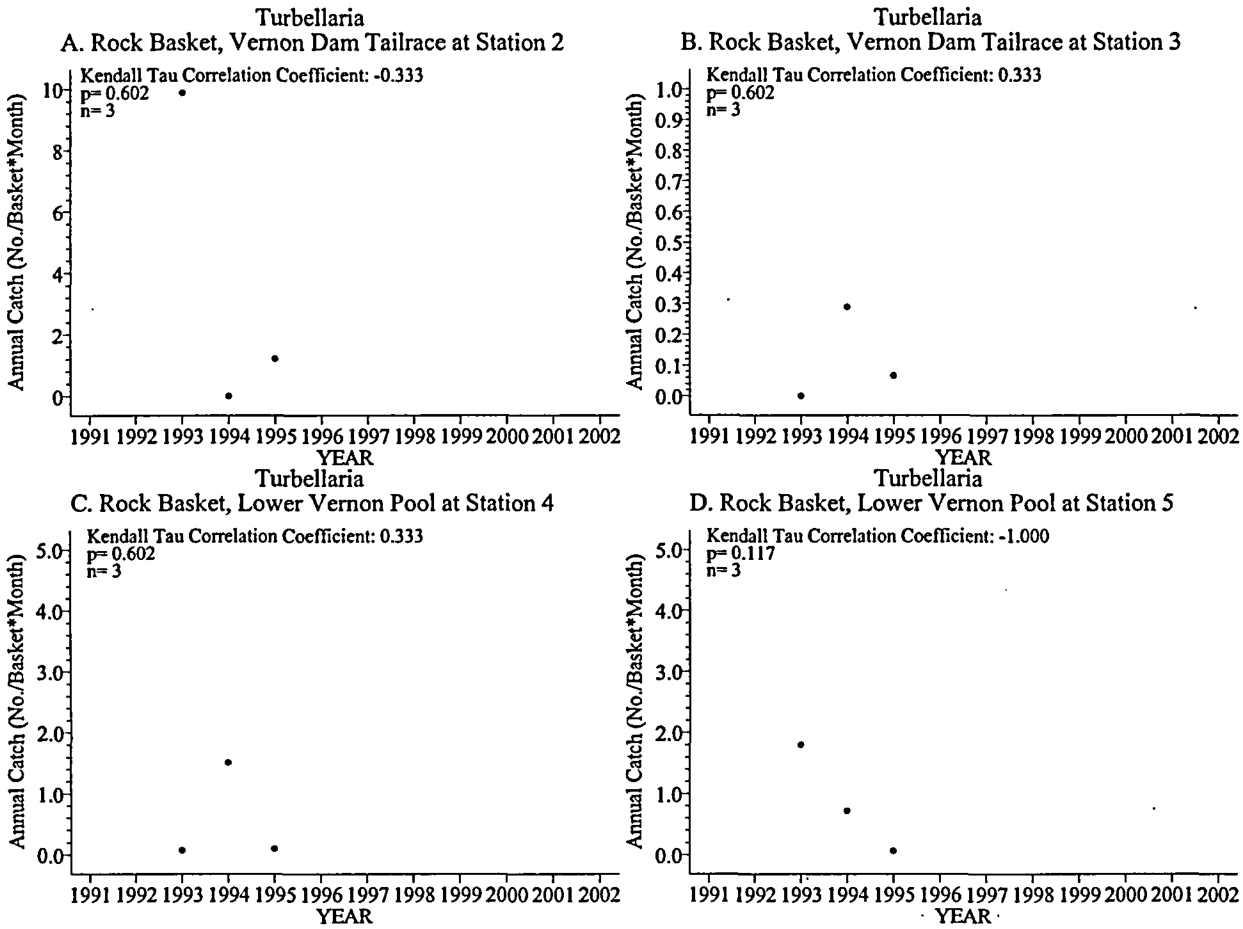
Appendix Figure 5-17. Kendall-Tau correlation for Trichopterans collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



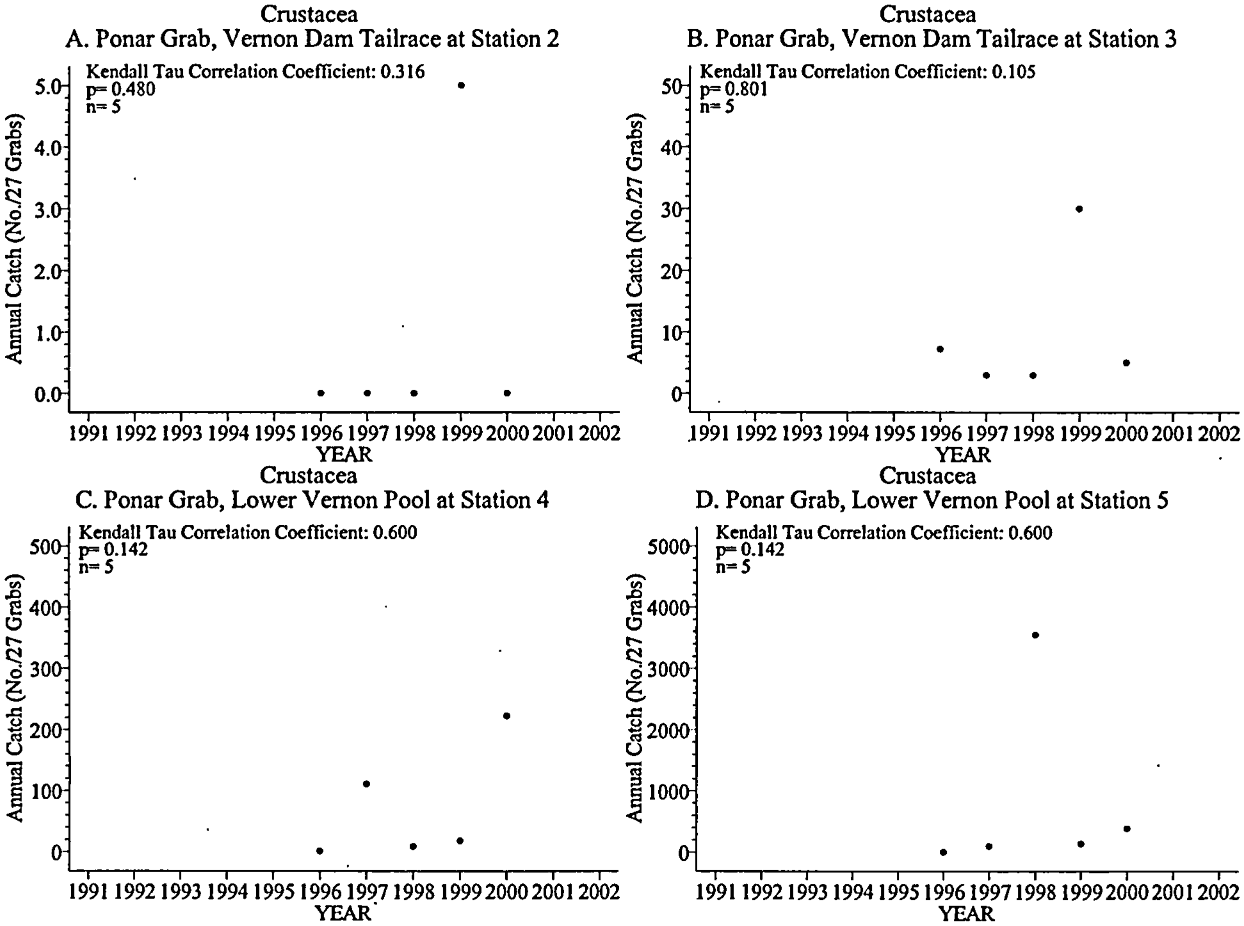
Appendix Figure 5-18. Kendall-Tau correlation for Trichopterans collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



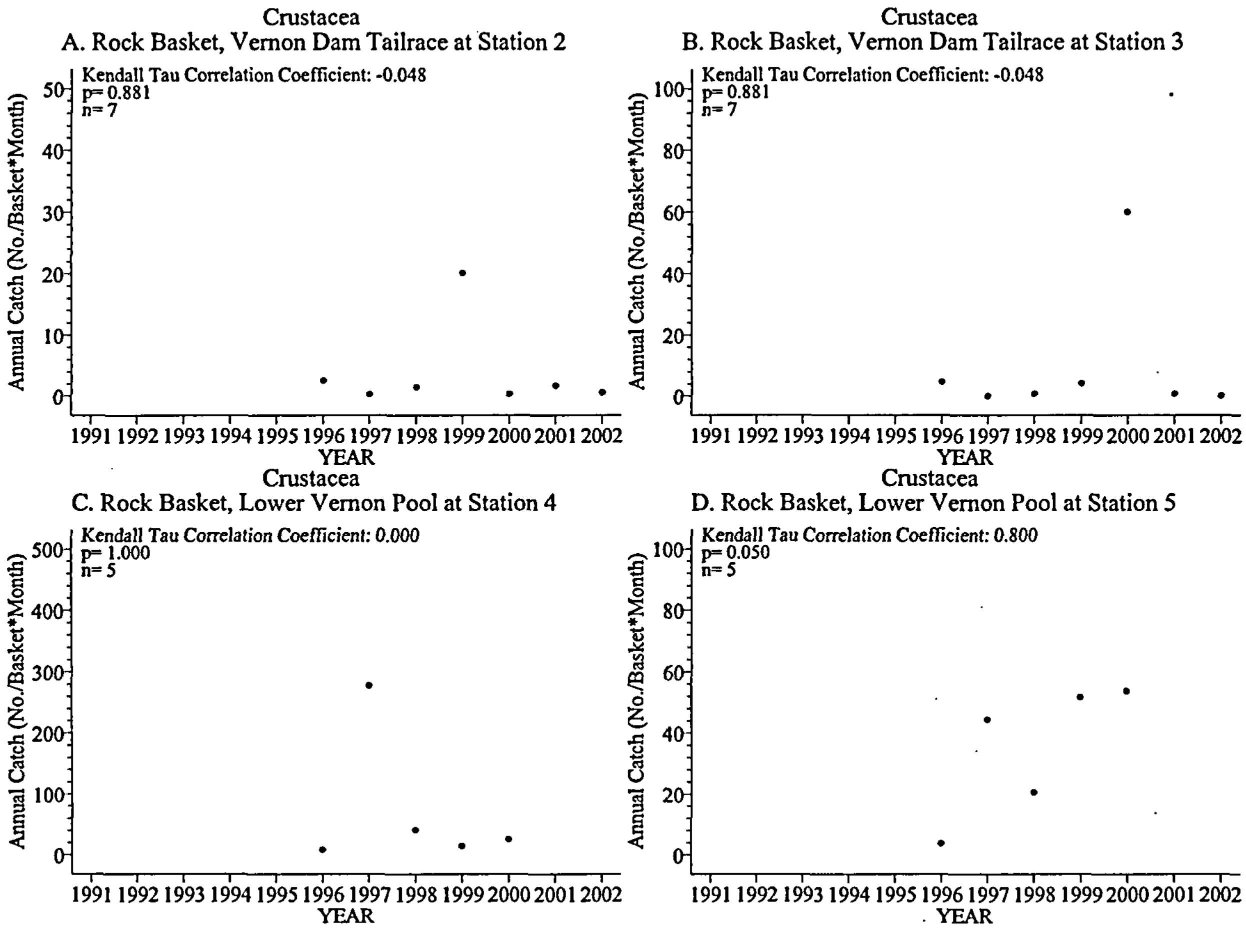
Appendix Figure 5-19. Kendall-Tau correlation for Turbellarians collected from 1991 to 1995 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



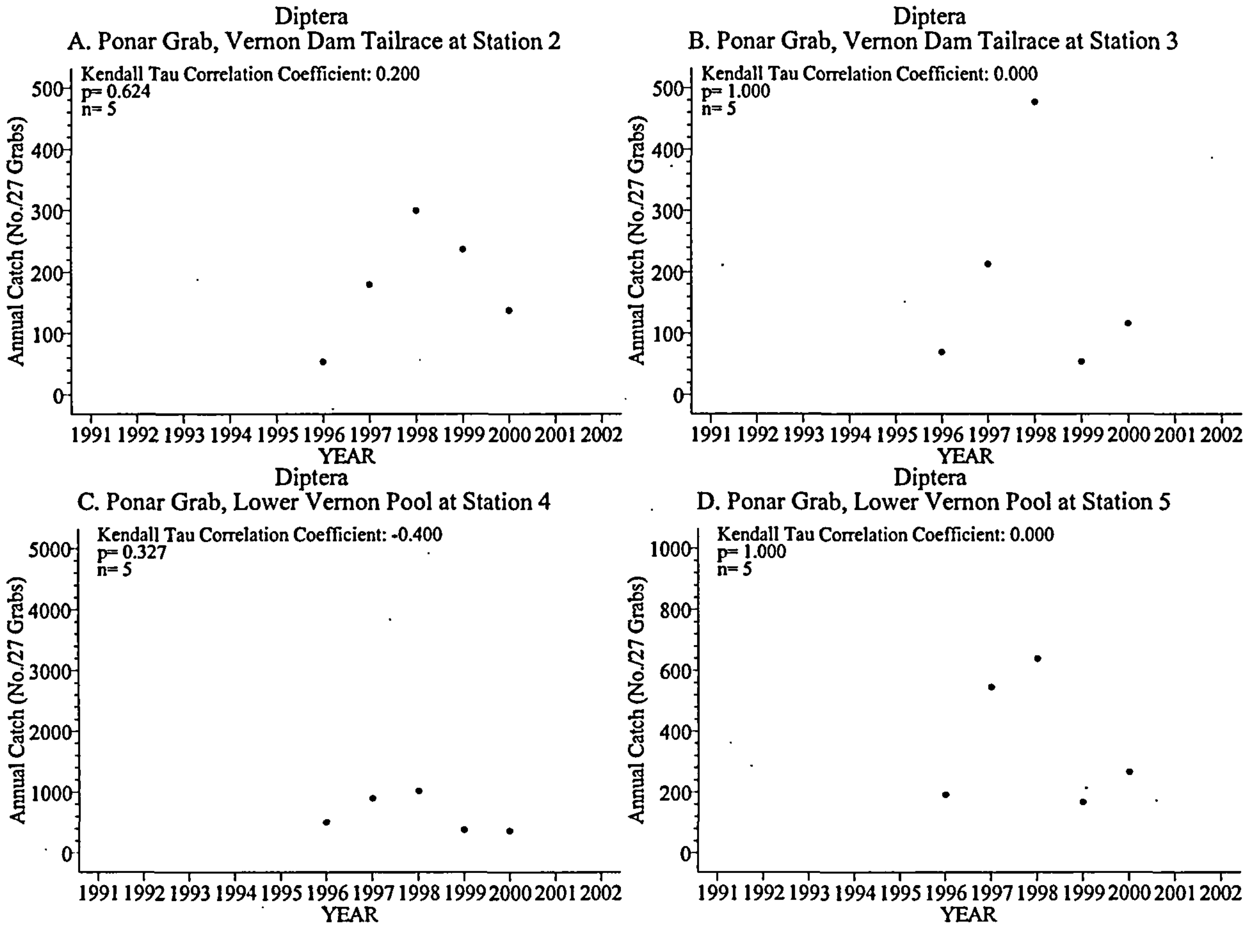
Appendix Figure 5-20. Kendall-Tau correlation for Turbellarians collected from 1993 to 1995 by rock basket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



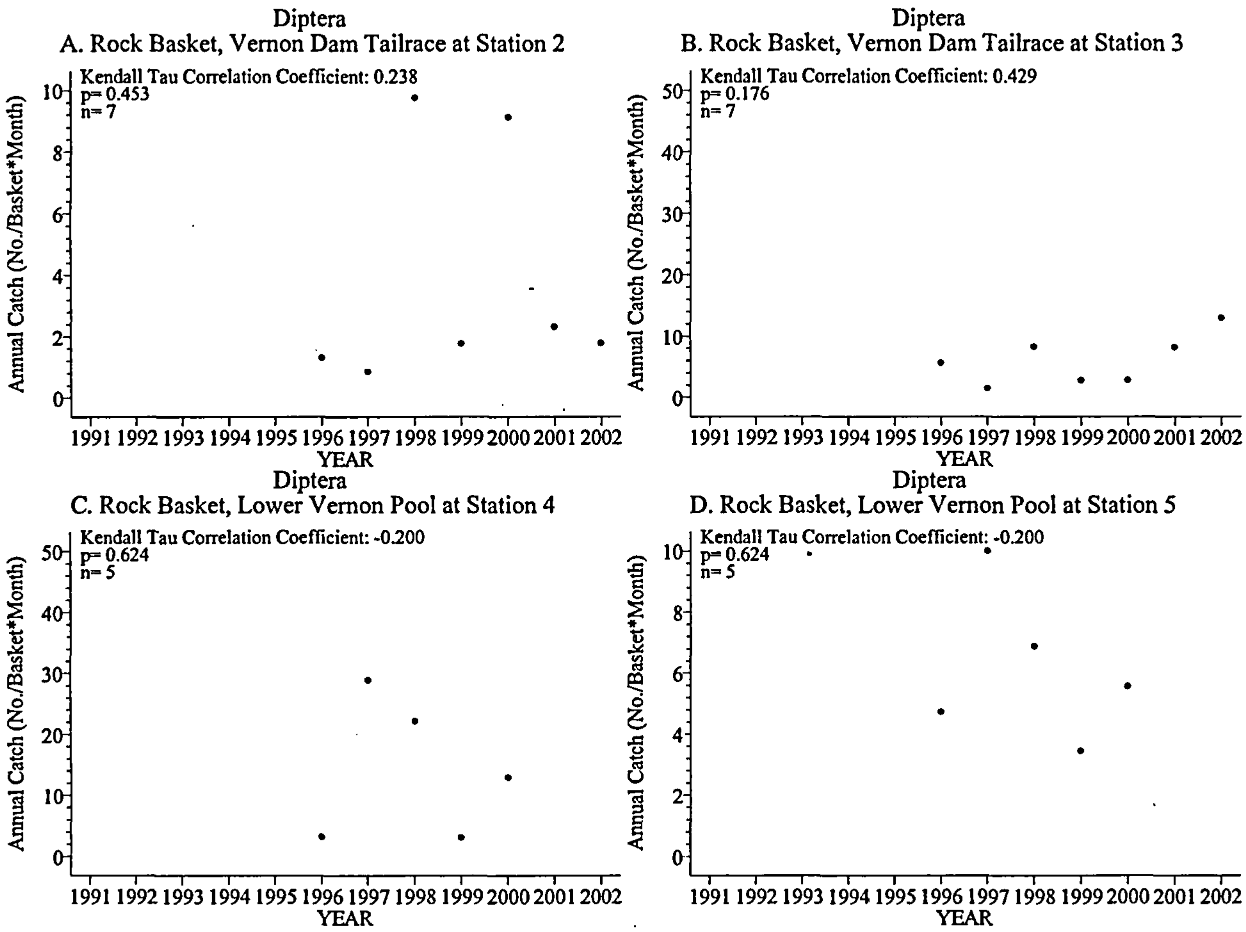
Appendix Figure 5-21. Kendall-Tau correlation for Crustaceans collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



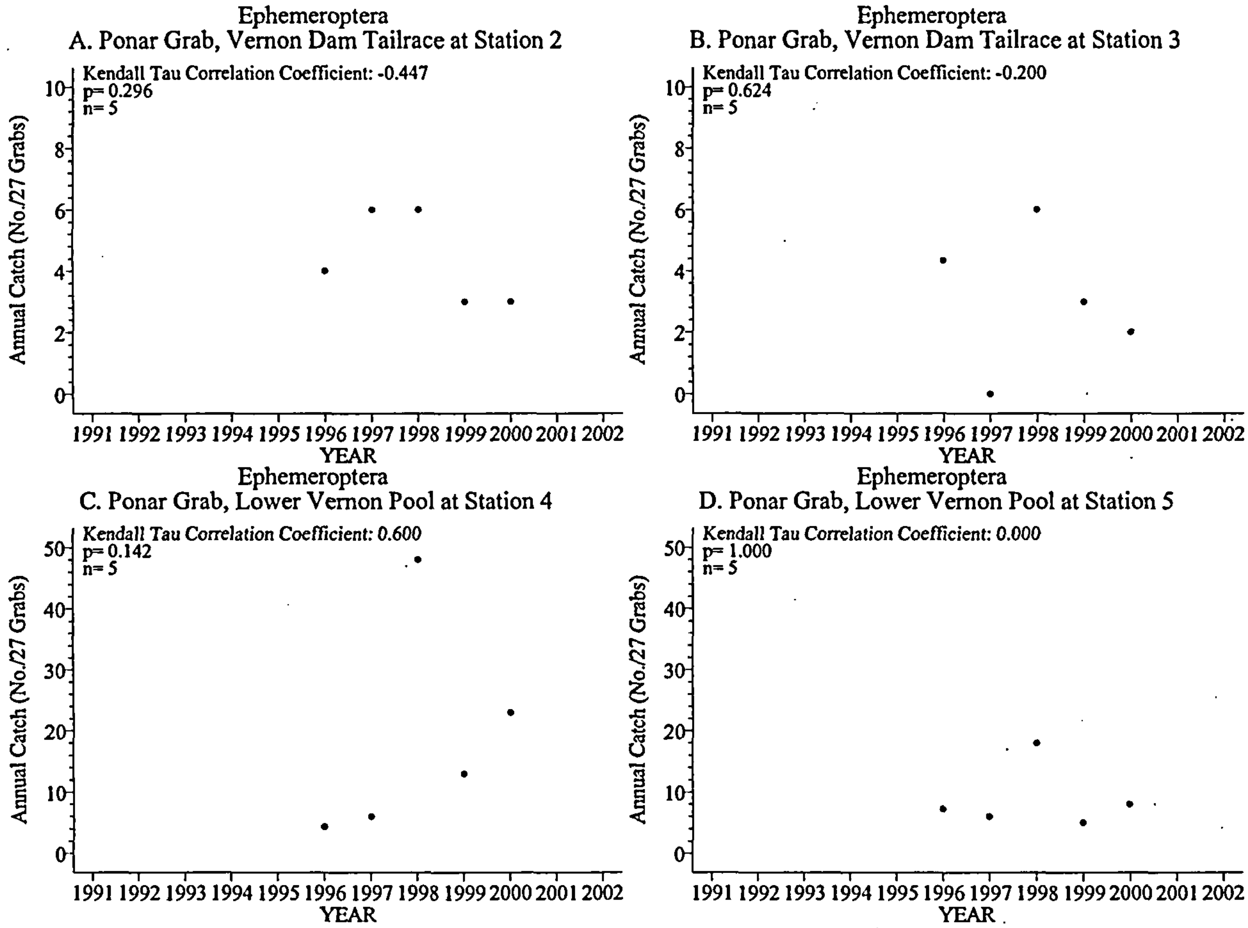
Appendix Figure 5-22. Kendall-Tau correlation for Crustaceans collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



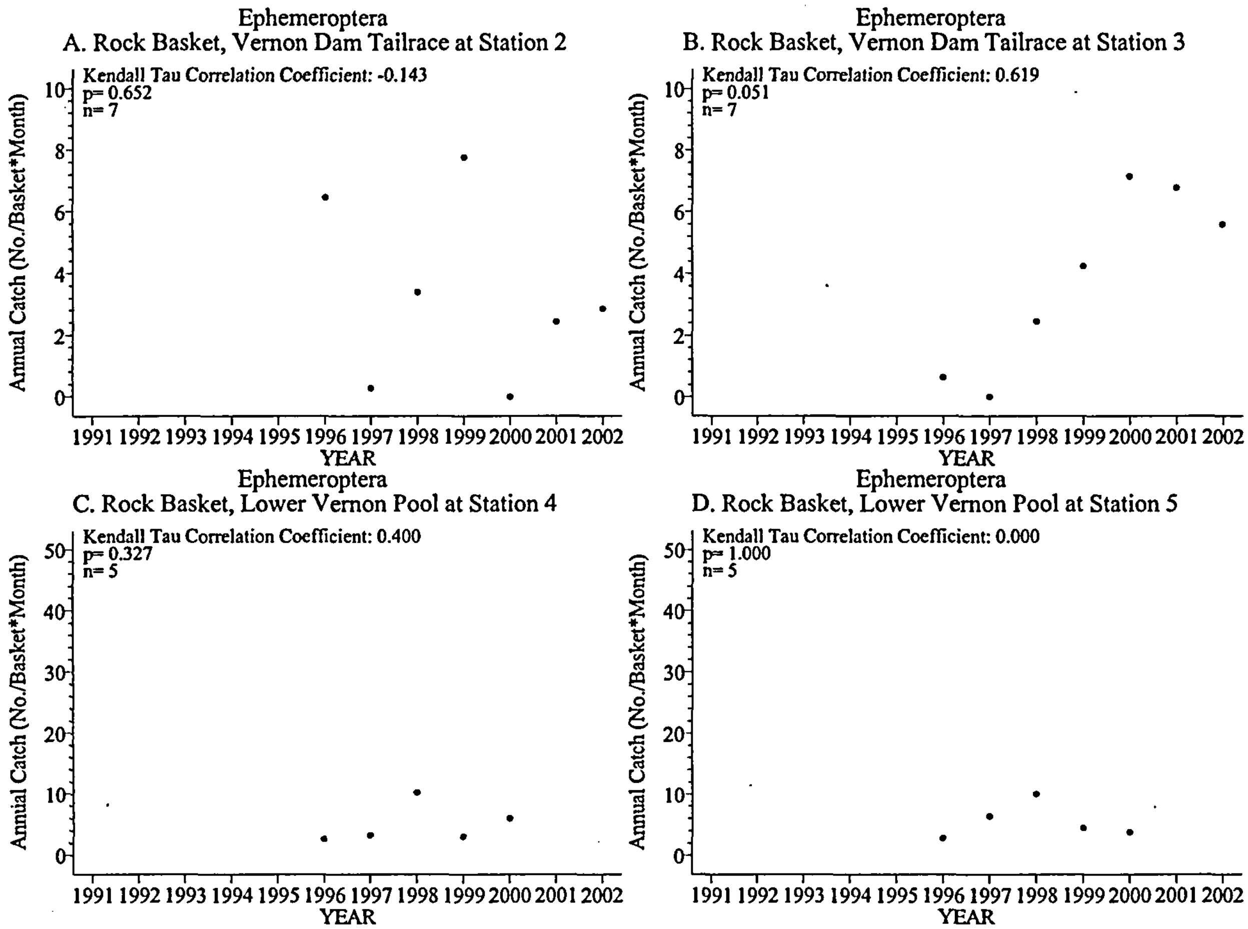
Appendix Figure 5-23. Kendall-Tau correlation for Dipterans collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



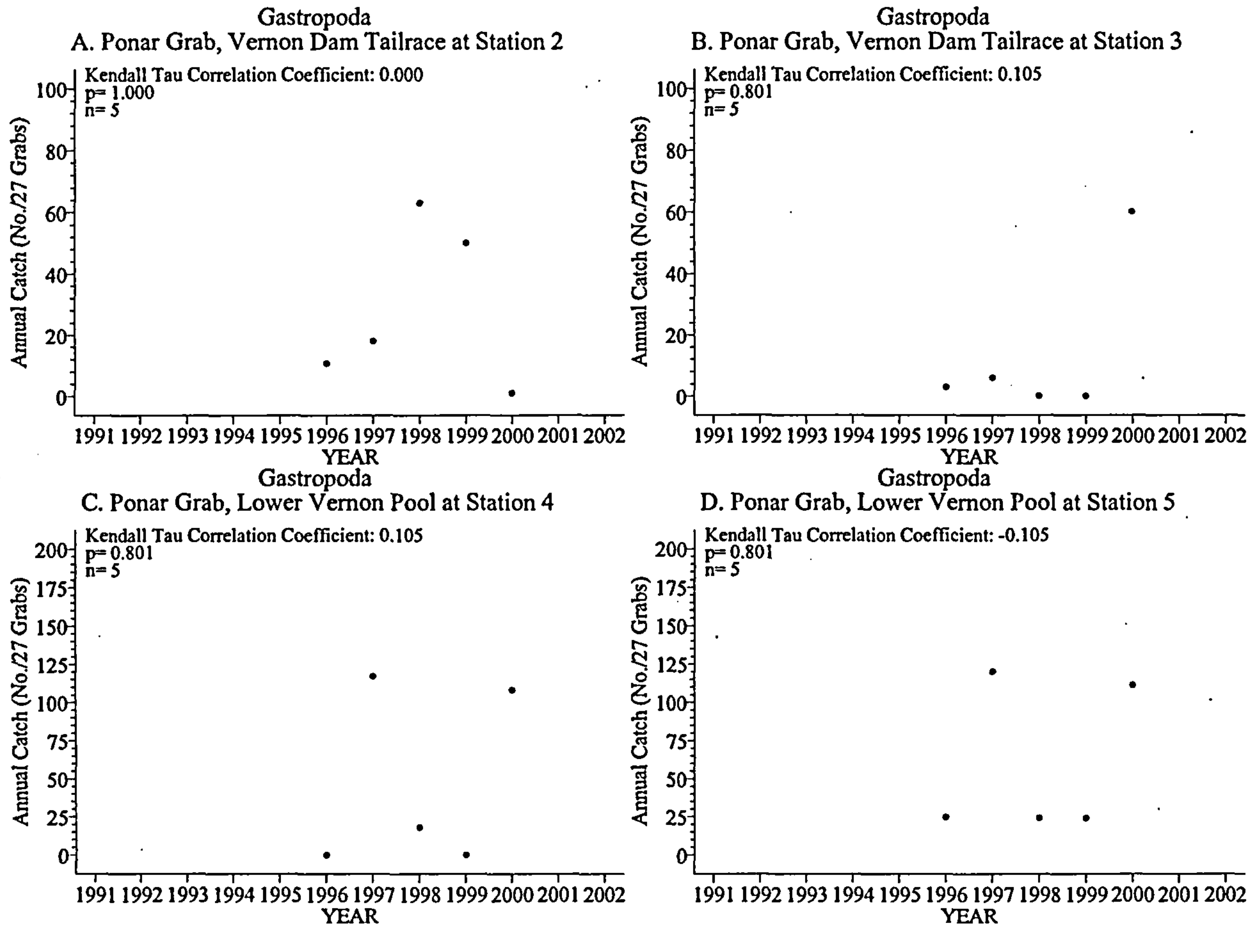
Appendix Figure 5-24. Kendall-Tau correlation for Dipterans collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



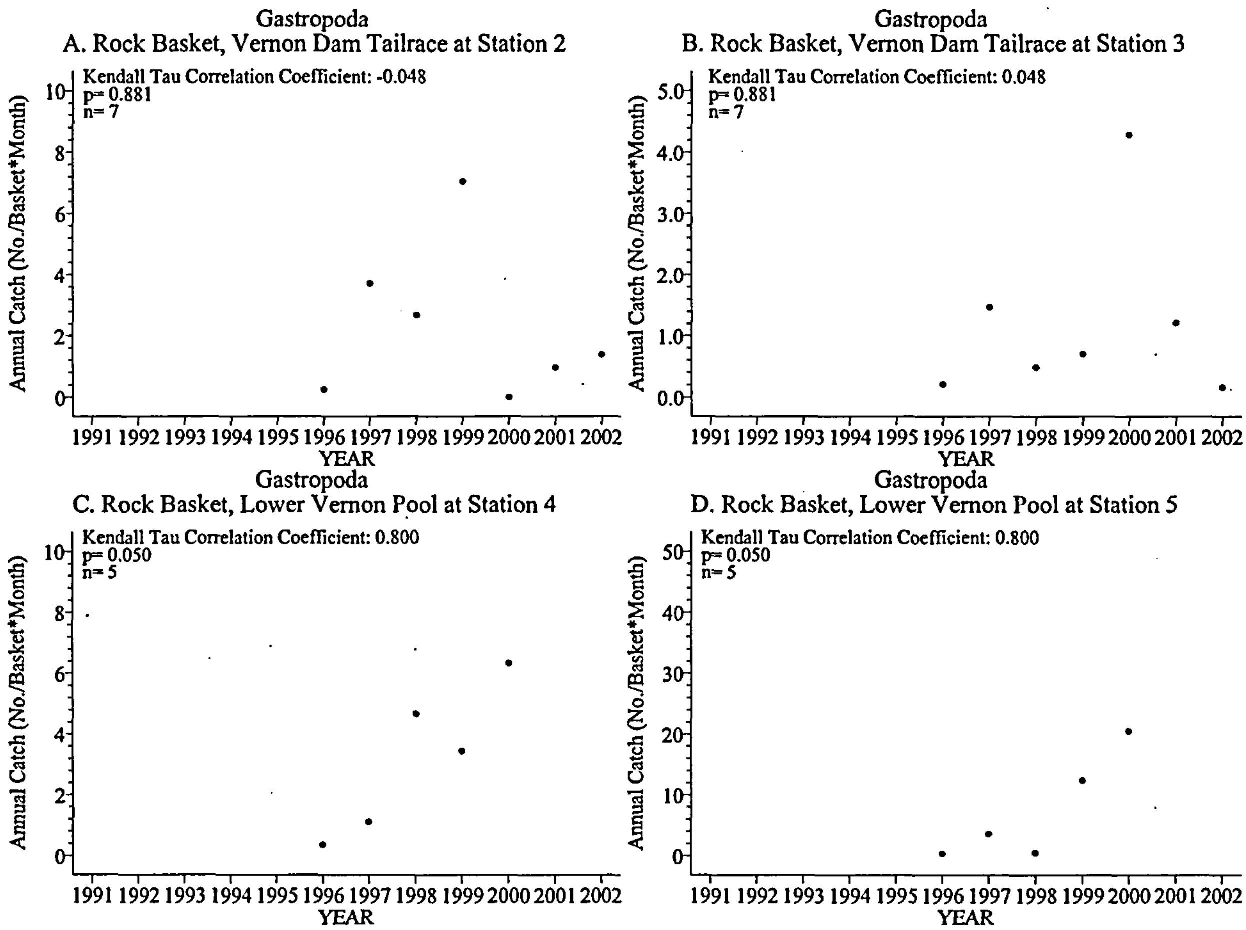
Appendix Figure 5-25. Kendall-Tau correlation for Ephemeropterans collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



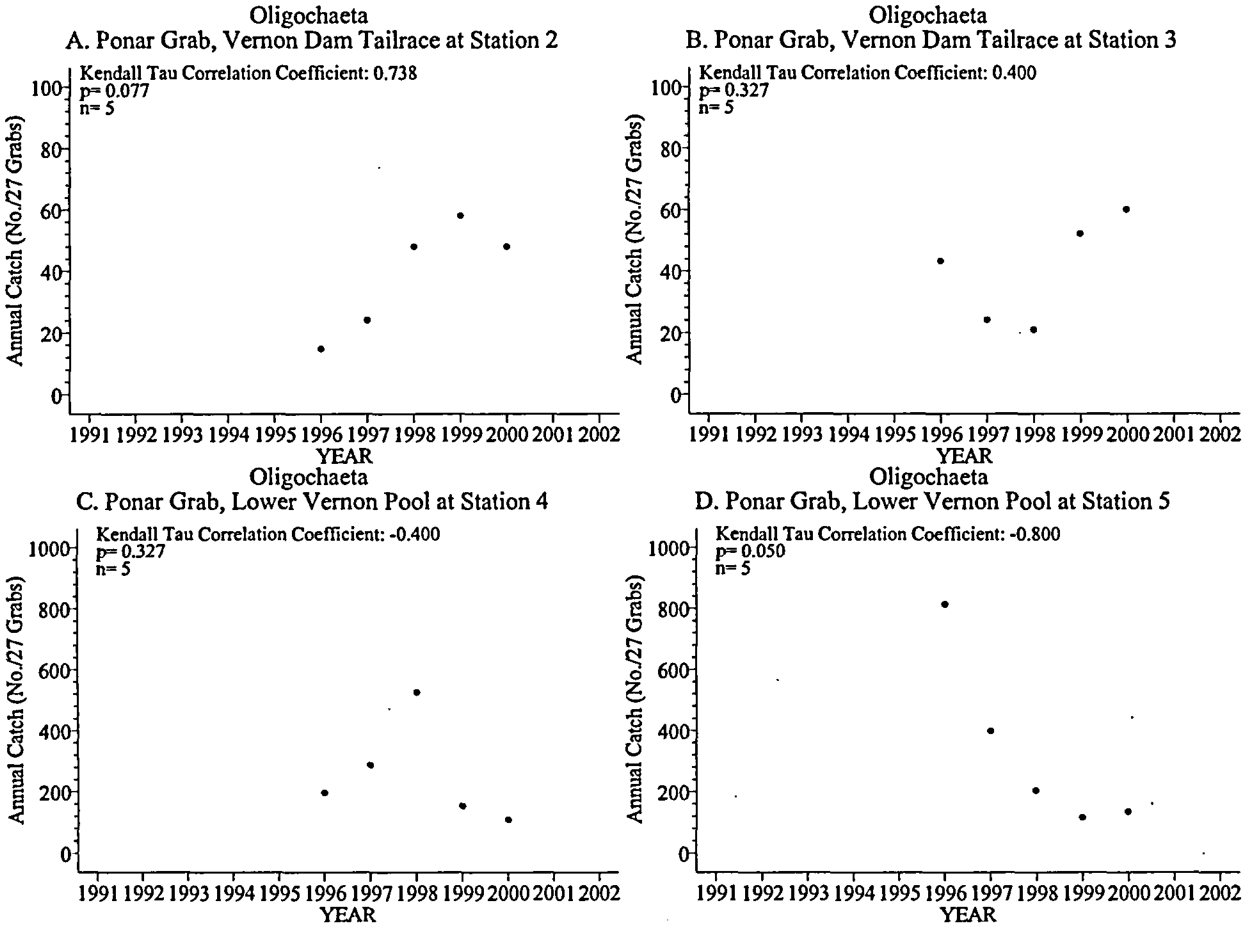
Appendix Figure 5-26. Kendall-Tau correlation for Ephemeropterans collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



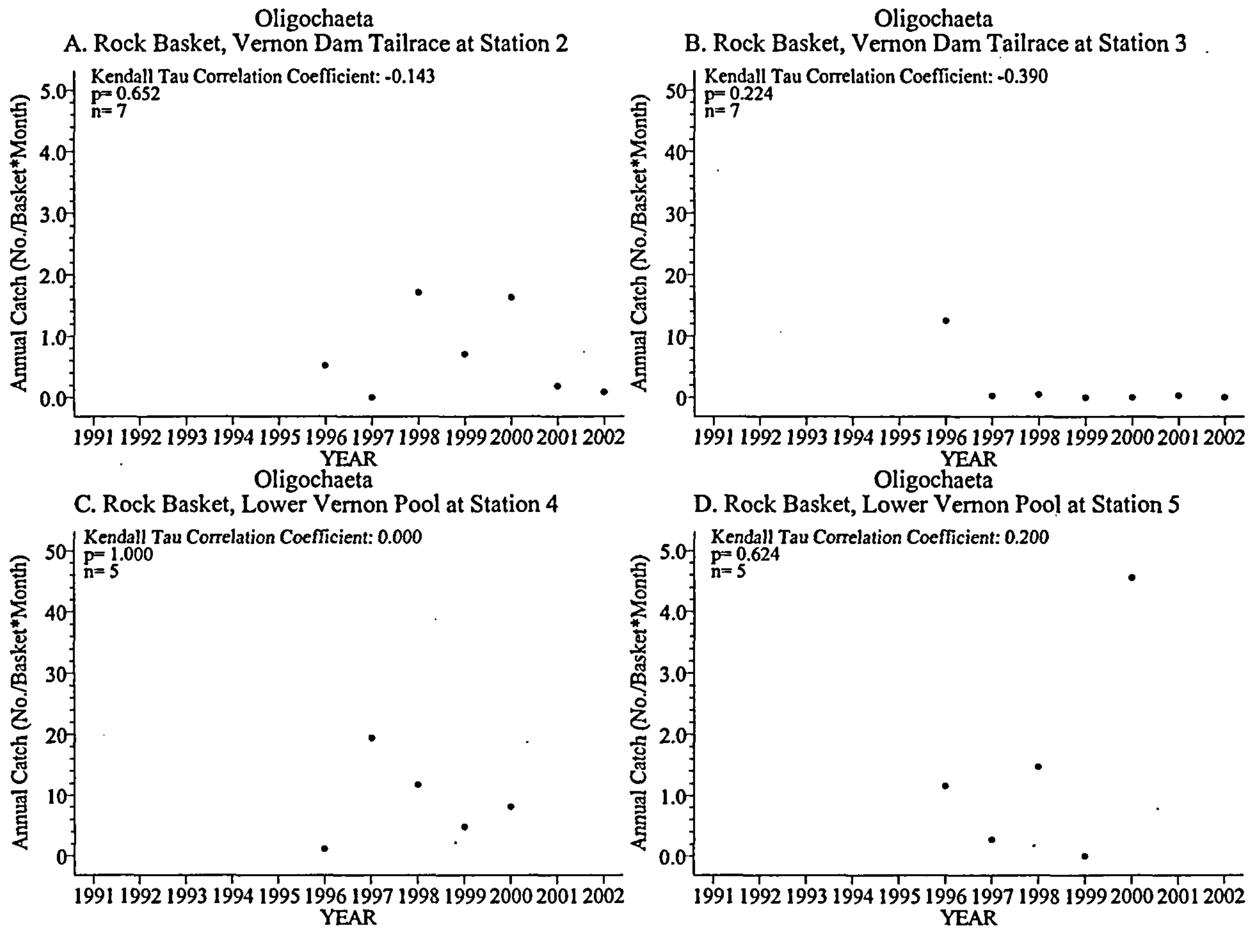
Appendix Figure 5-27. Kendall-Tau correlation for Gastropods collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



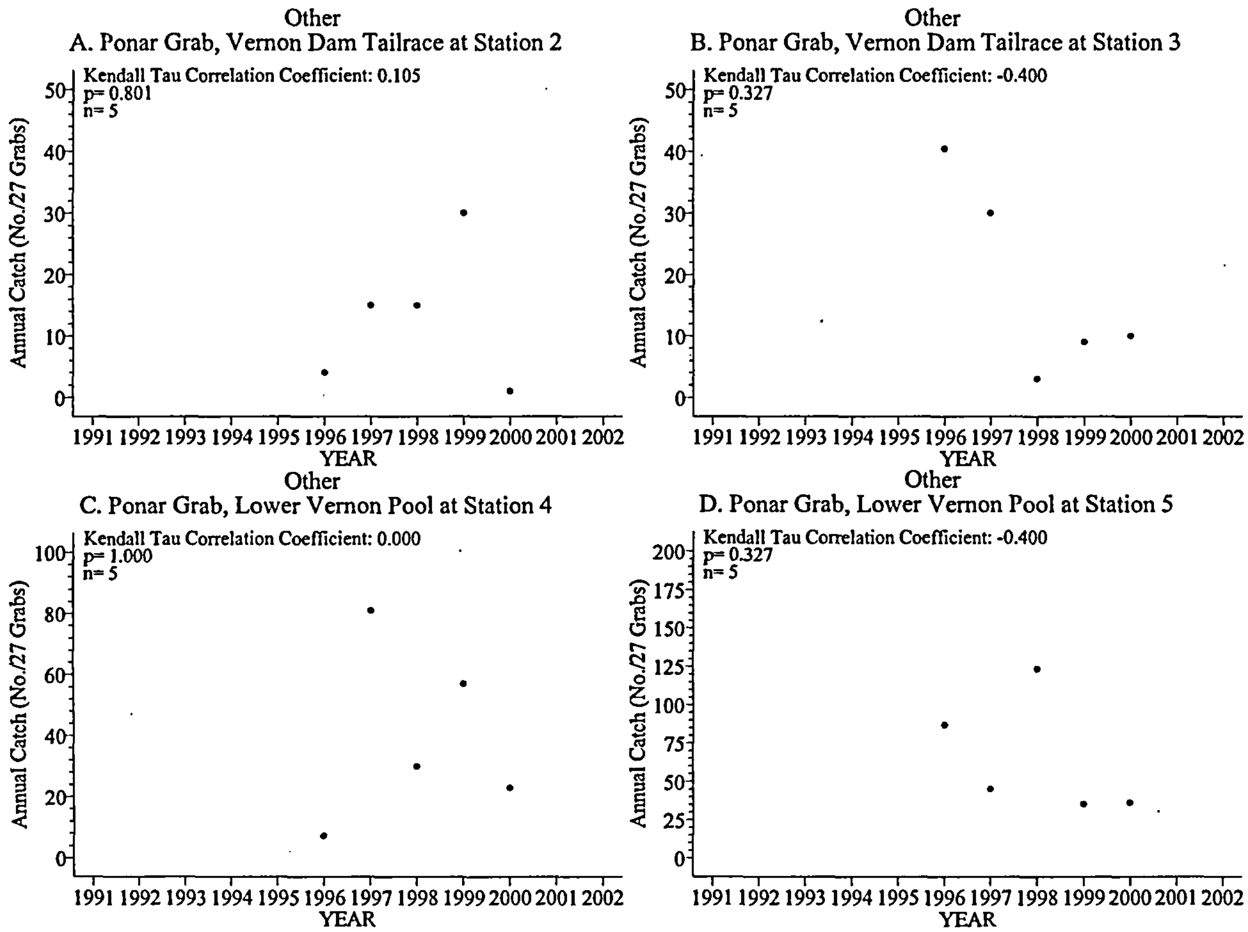
Appendix Figure 5-28. Kendall-Tau correlation for Gastropods collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



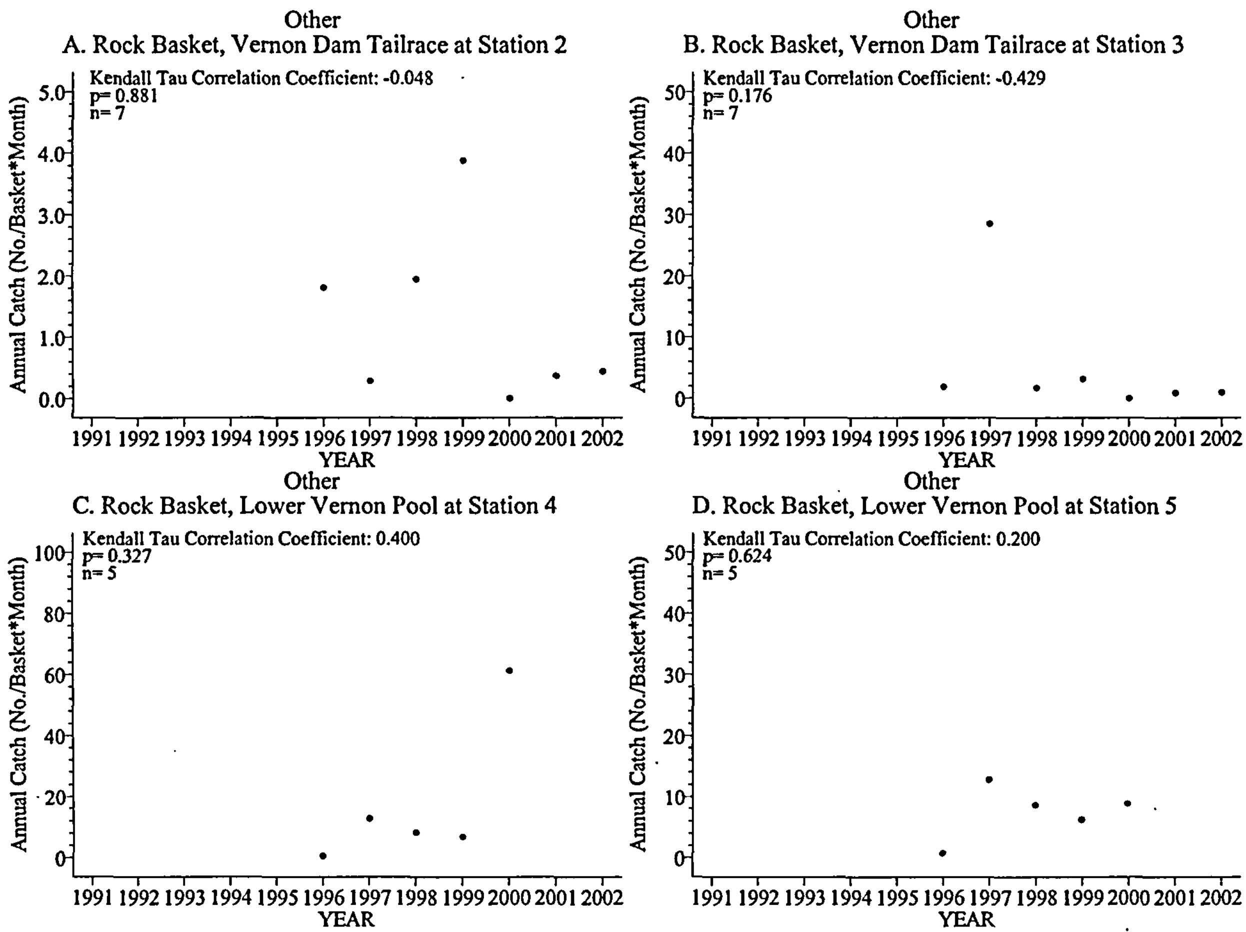
Appendix Figure 5-29. Kendall-Tau correlation for Oligochaets collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



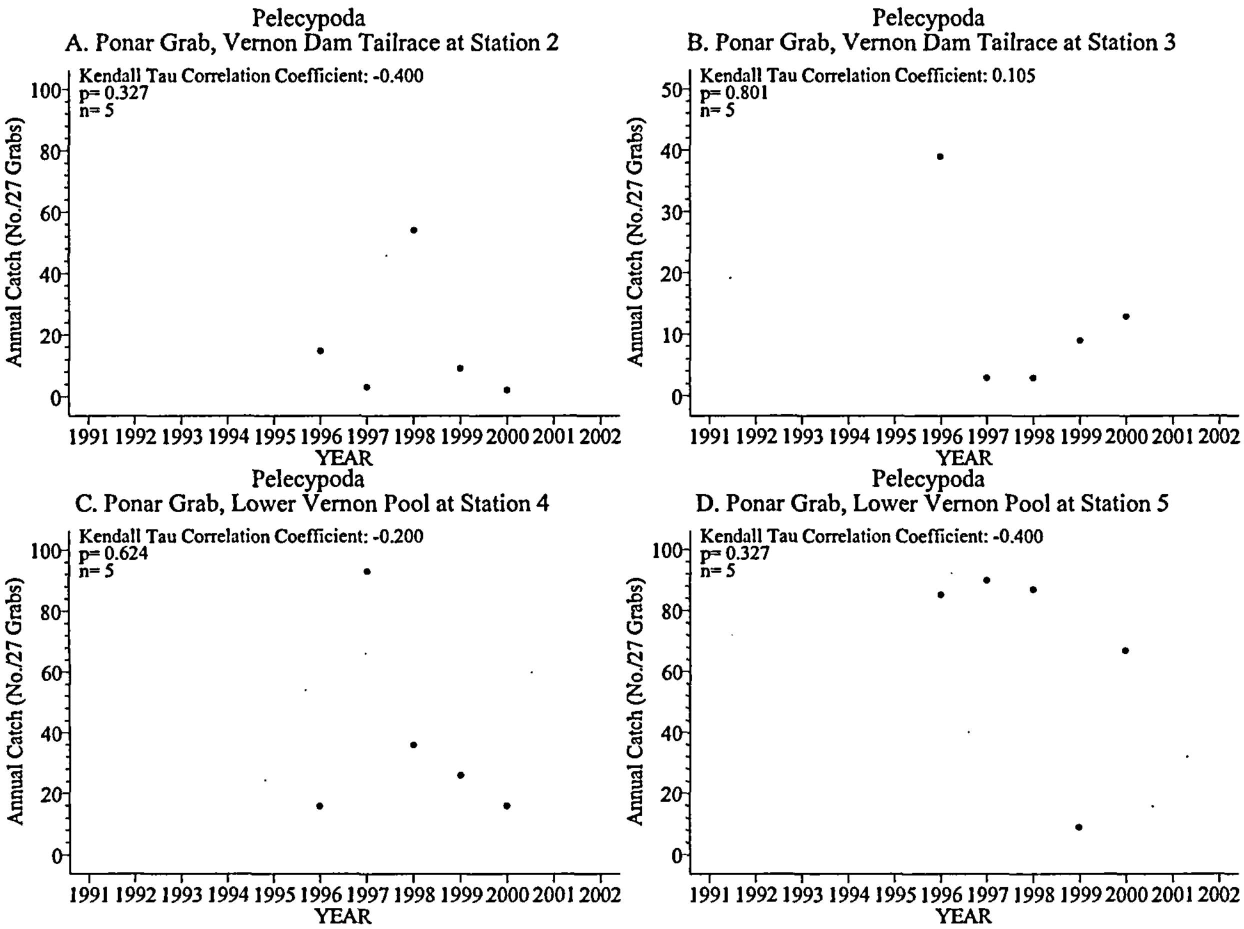
Appendix Figure 5-30. Kendall-Tau correlation for Oligochaets collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



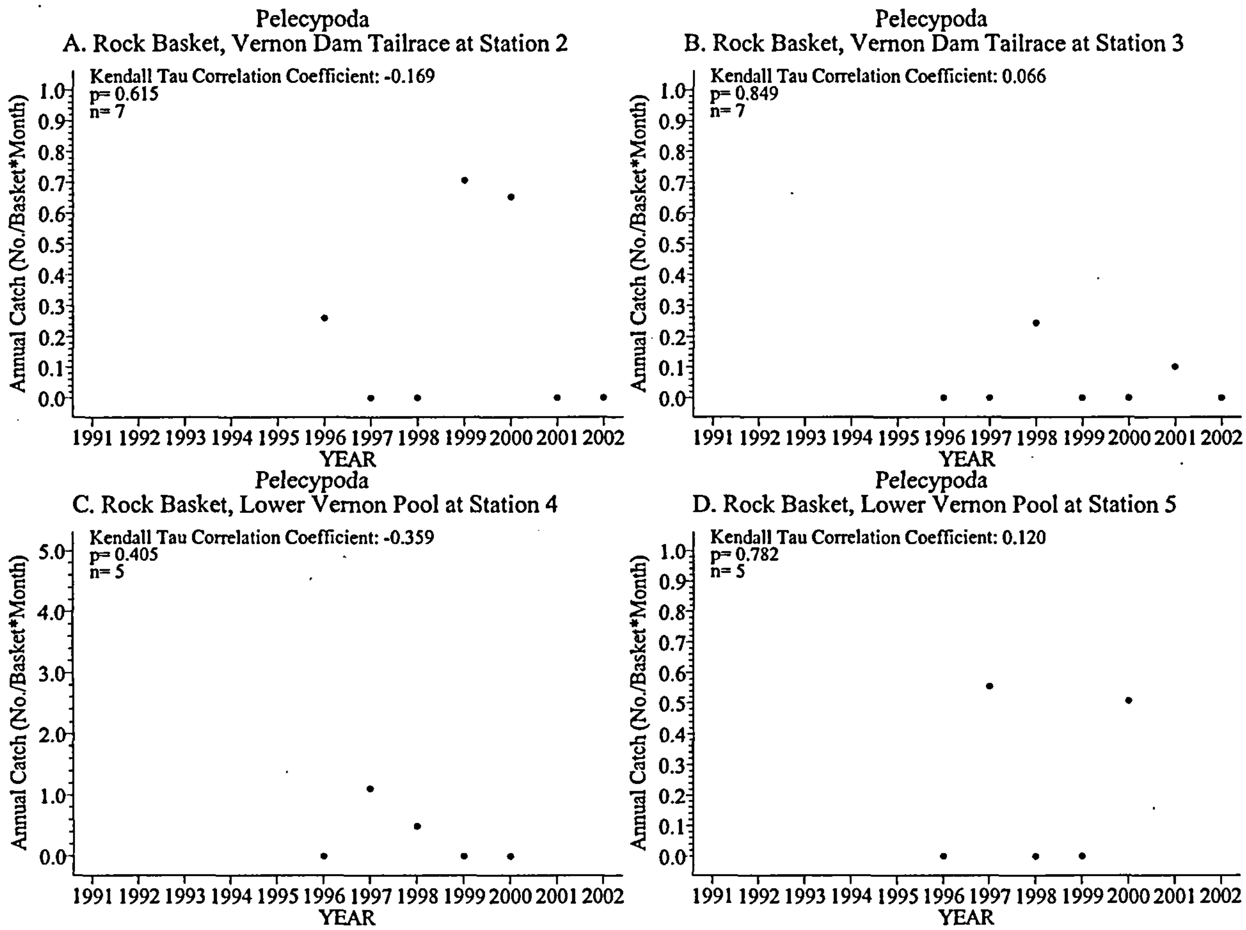
Appendix Figure 5-31. Kendall-Tau correlation for all other taxa collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



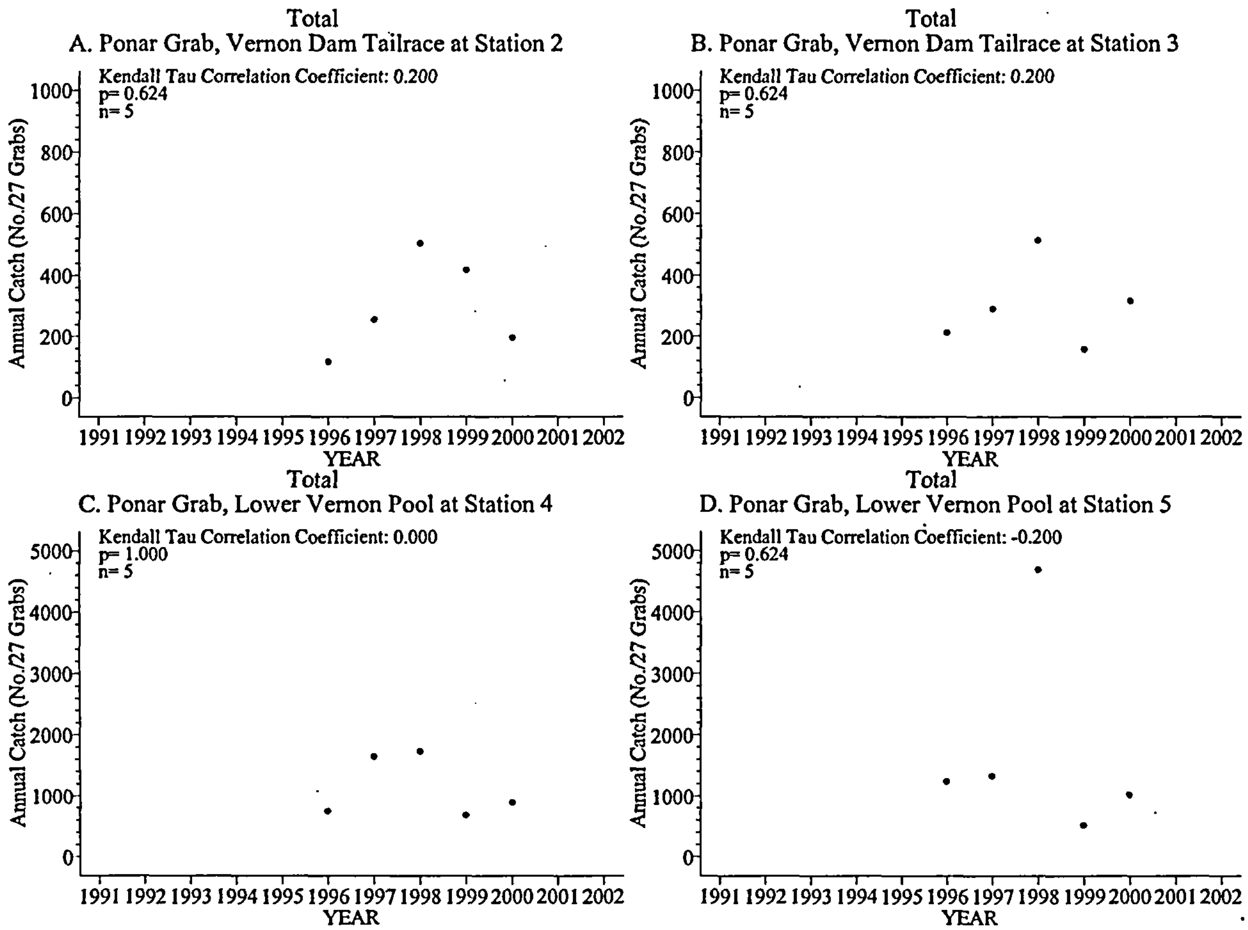
Appendix Figure 5-32. Kendall-Tau correlation for all other taxa collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



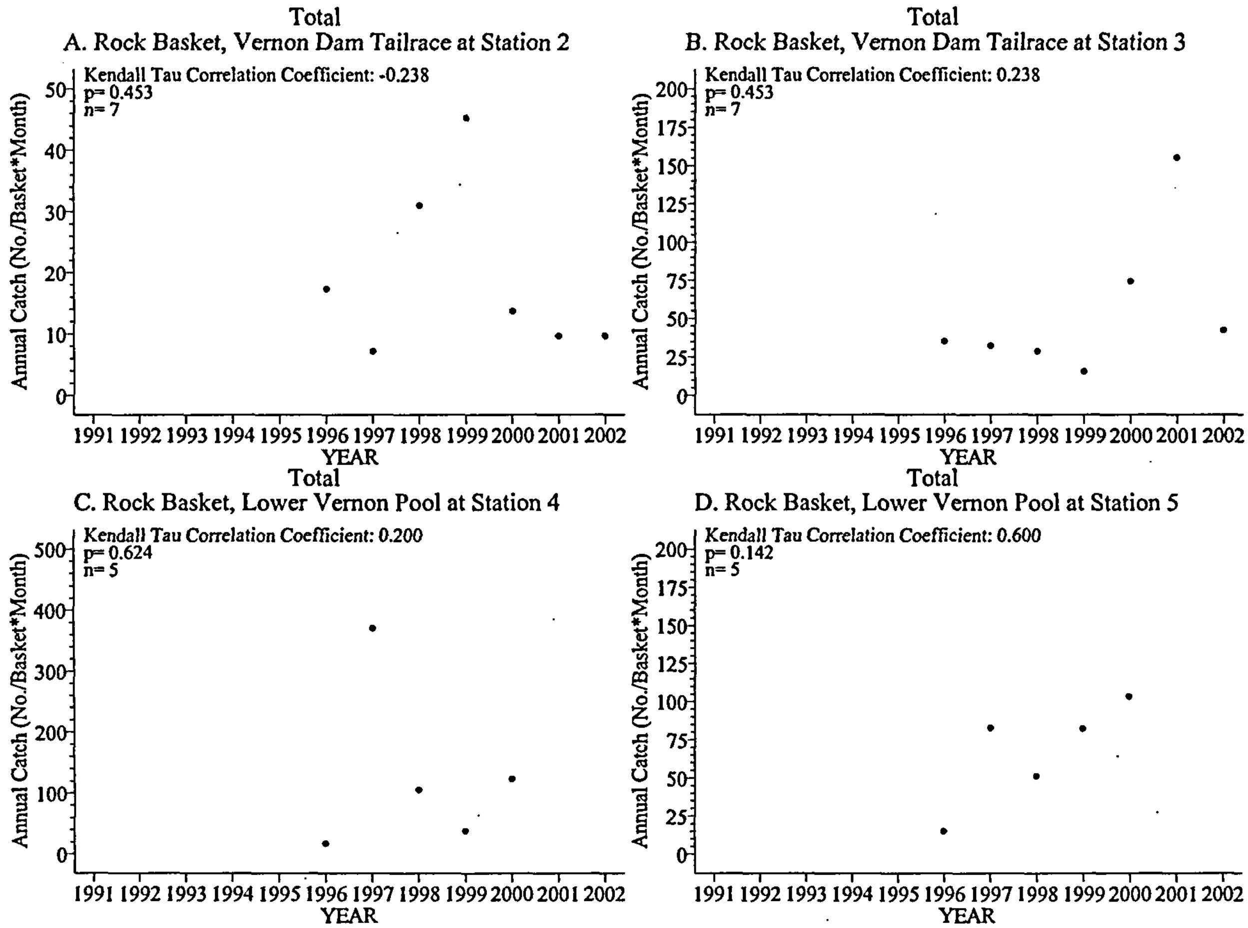
Appendix Figure 5-33. Kendall-Tau correlation for Pelecypods collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



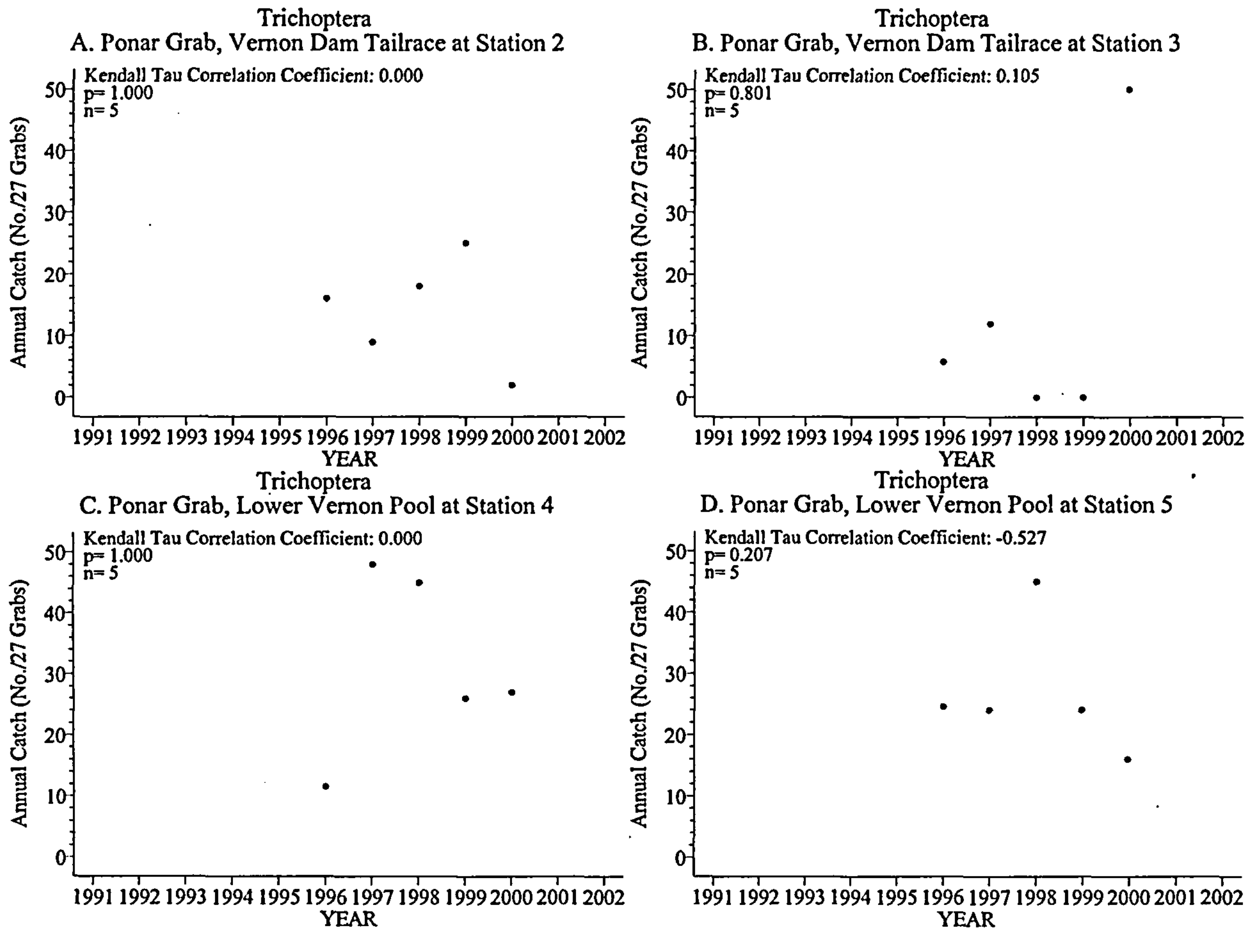
Appendix Figure 5-34. Kendall-Tau correlation for Pelecypods collected from 1996 to 2002 by rockbasket grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



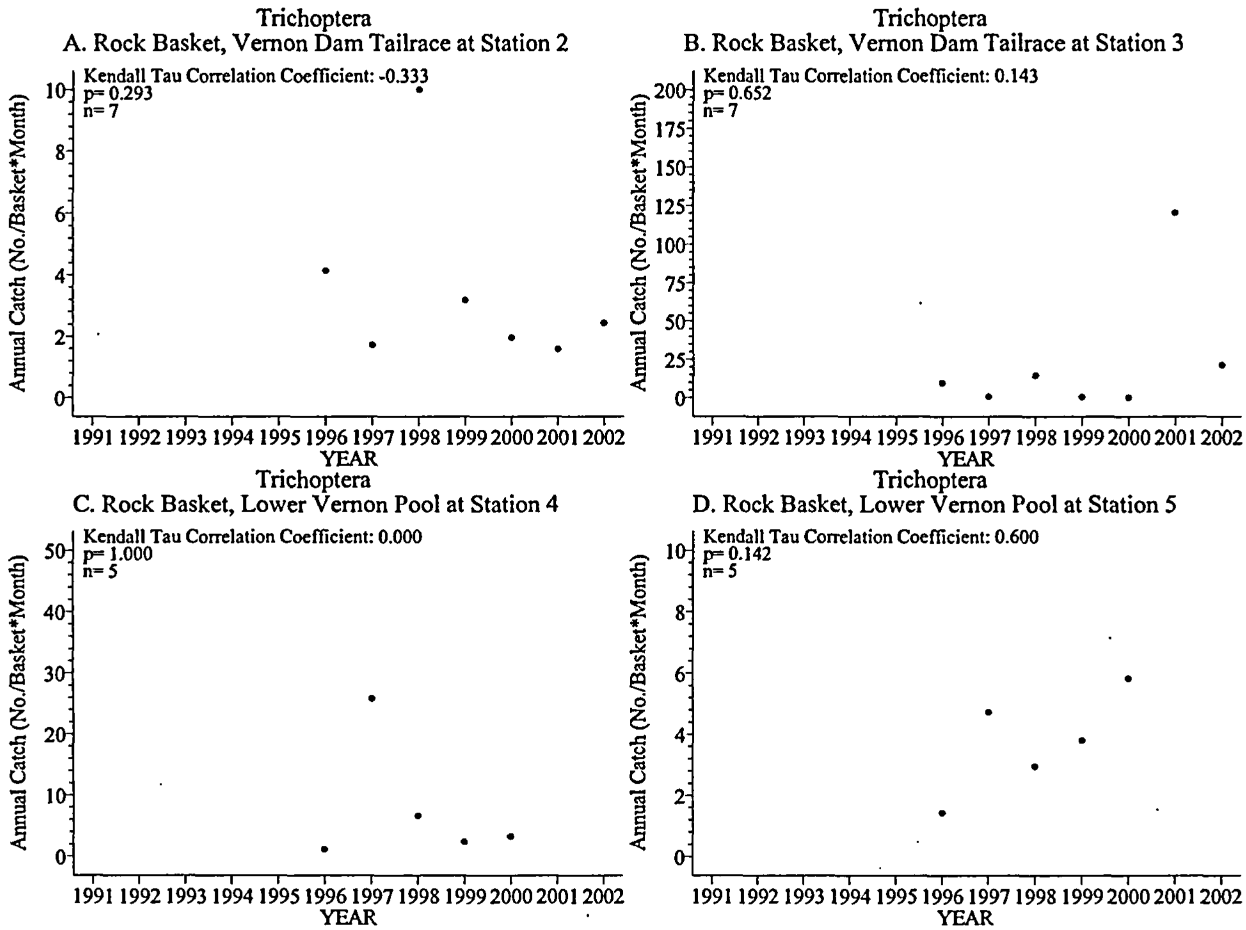
Appendix Figure 5-35. Kendall-Tau correlation for all macroinvertebrates collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



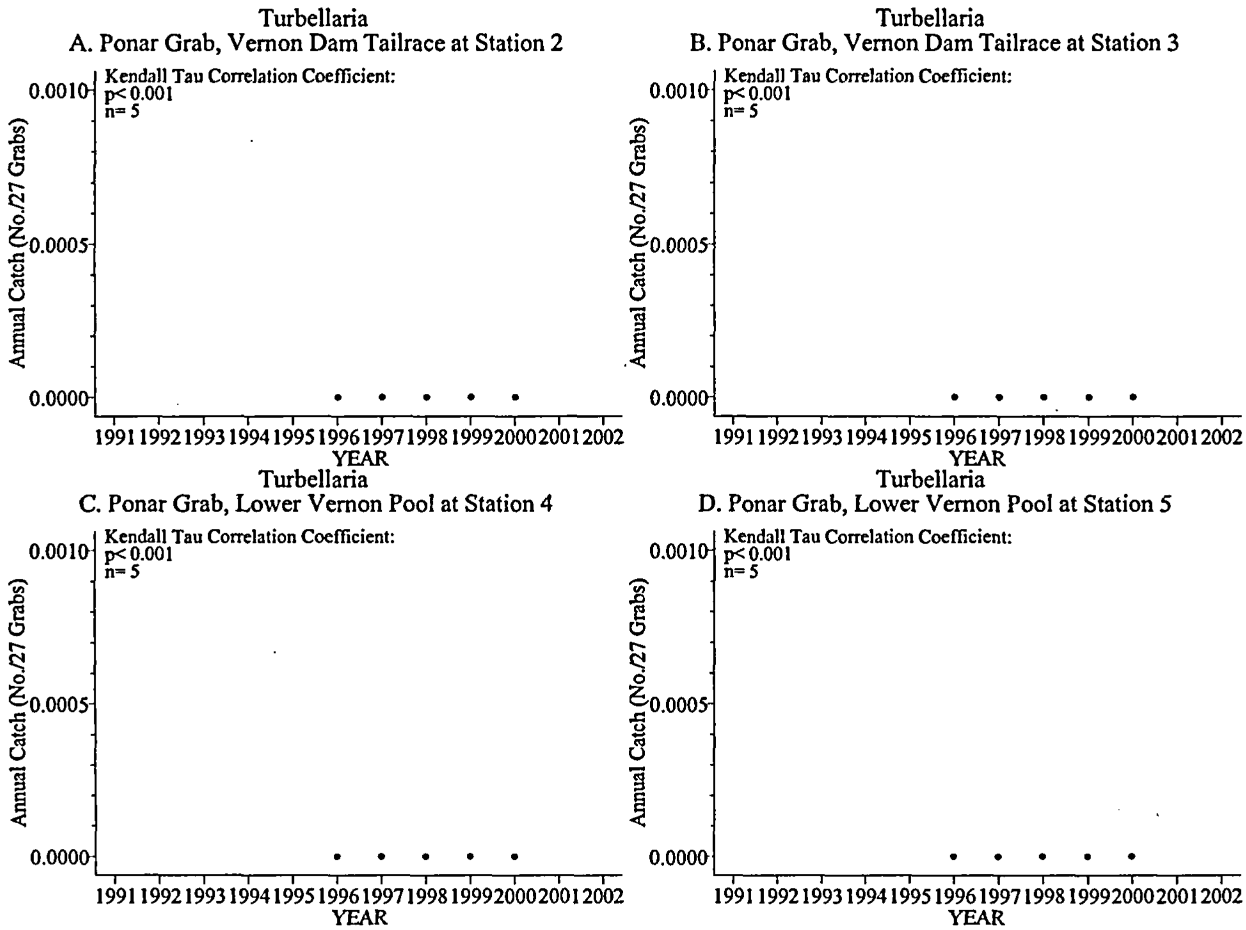
Appendix Figure 5-36. Kendall-Tau correlation for all macroinvertebrates collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



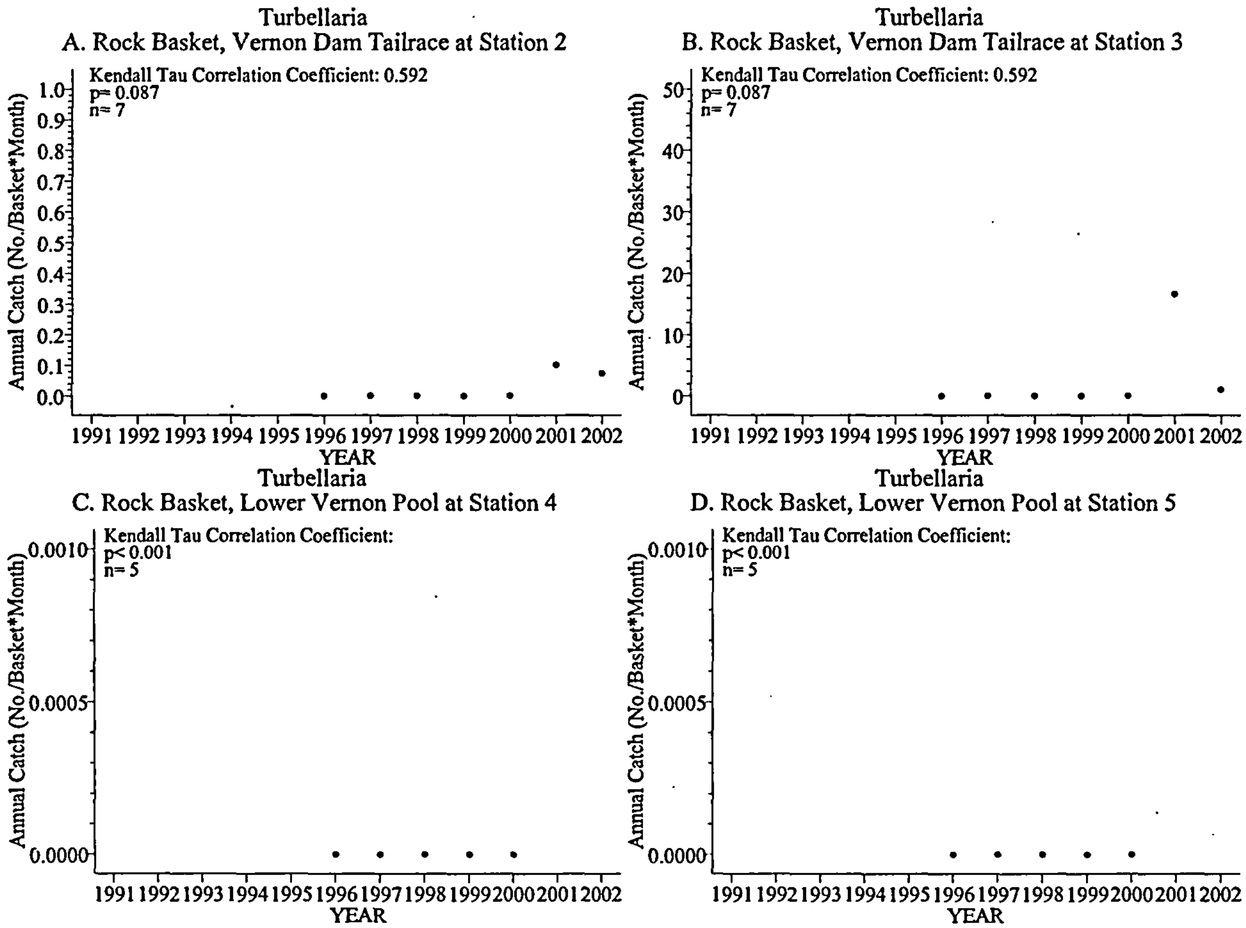
Appendix Figure 5-37. Kendall-Tau correlation for Trichopterans collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



Appendix Figure 5-38. Kendall-Tau correlation for Trichopterans collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.



Appendix Figure 5-39. Kendall-Tau correlation for Turbellarians collected from 1996 to 2000 by Ponar grab sampler in the Vernon Dam tailrace and Lower Vernon Pool.



Appendix Figure 5-40. Kendall-Tau correlation for Turbellarians collected from 1996 to 2002 by rockbasket sampler in the Vernon Dam tailrace and Lower Vernon Pool.

APPENDIX 6

Adult American Shad Hourly Count Data and the Corresponding Hourly Water Temperature Data for the Vernon Dam Fishway on the Connecticut River, 1991-2001

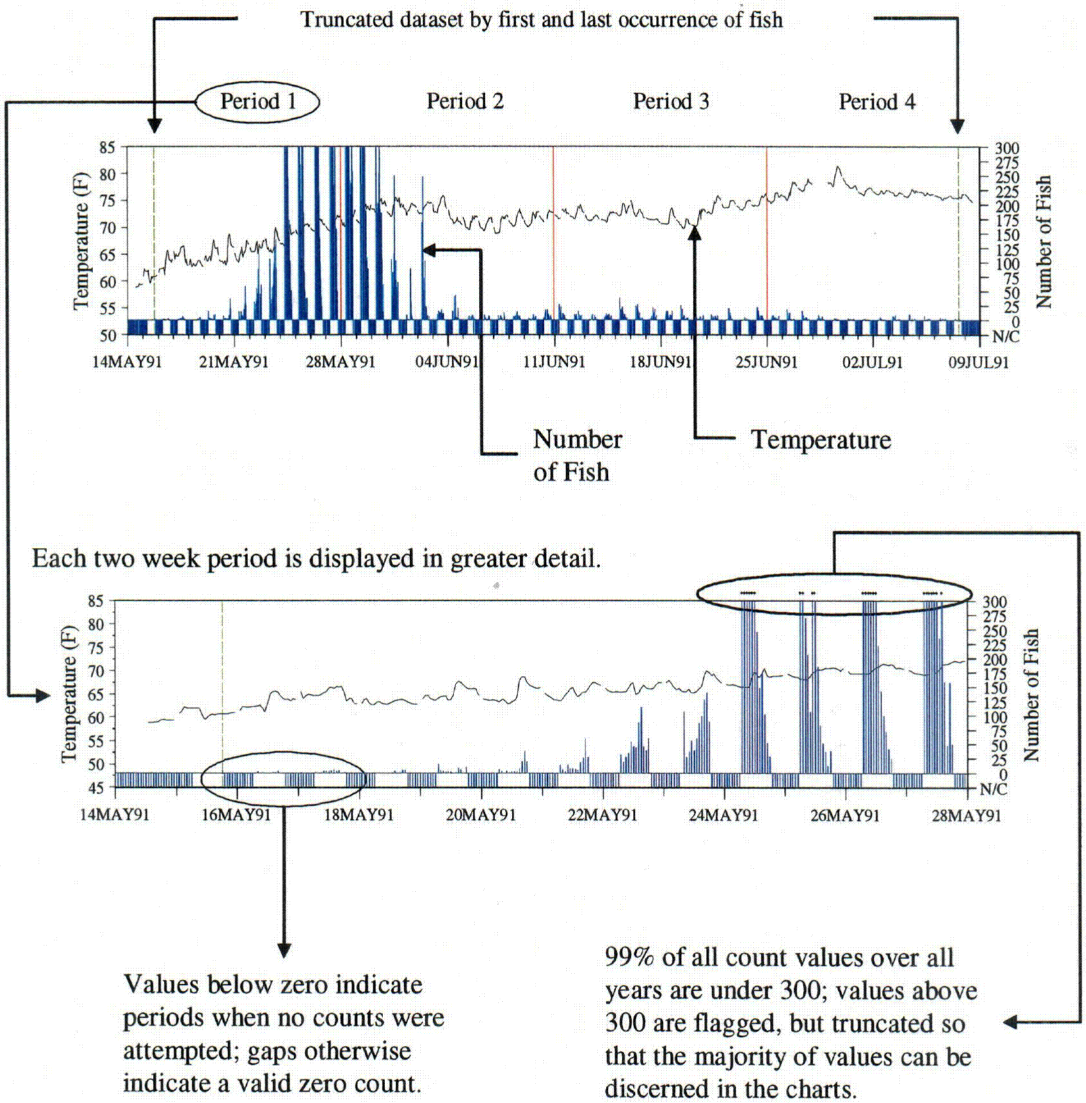
Normandeau received VANR's original, handwritten field data sheets on 29 September 2003, double keyed 5,691 records (lines) of Fishway count data, and resolved any discrepancies in these data where we could. We then double keypunched the corresponding hourly Fishway water temperature data from Vermont Yankee's Annual Monitoring Reports for the period 1991-1996, combined these data with digital records of Fishway water temperatures for the period 1997-2001, and merged this water temperature data set back into the American shad hourly count data set so that the data file represents each date, hour, American shad hourly count, and the corresponding hourly average water temperature for each of the 5,691 records of data available for the 1991-2001 period of Vernon Dam Fishway operations. This original data file containing 5,691 records was then subjected to a statistical quality control inspection in which 80 randomly selected records from each year were checked against the source documents to insure that the average outgoing quality level of the original data file had fewer than 1 error out of every 100 observations (AOQL < 1%). This original data file was delivered Mr. Kenneth Cox of VANR on 7 January 2004. In telephone conversations with Mr. Cox on 1 March and again on 8 March, Mr. Cox recommended changes to 173 records of original data file based on his review of the 7 January data listing and his notes and other documentation describing differences in the data recording conventions used among VANR's Fishway counting crew. The changes to the original data file related to either 1) eliminating a total of 73 count records at the beginning or end of counting days because the VANR counting crew had terminated their shift and had pre-filled in times when they were not present, 2) adding 11 count records for hours when no crew was present and a camera was used record hourly counts, or 3) changing the count or comment code on 89 records. Normandeau subsequently changed 173 records of the original data file based on Mr. Cox's review, and we now provide this document as the final summary of Vernon Dam Fishway hourly shad counts for the operational periods during 1991-2001.

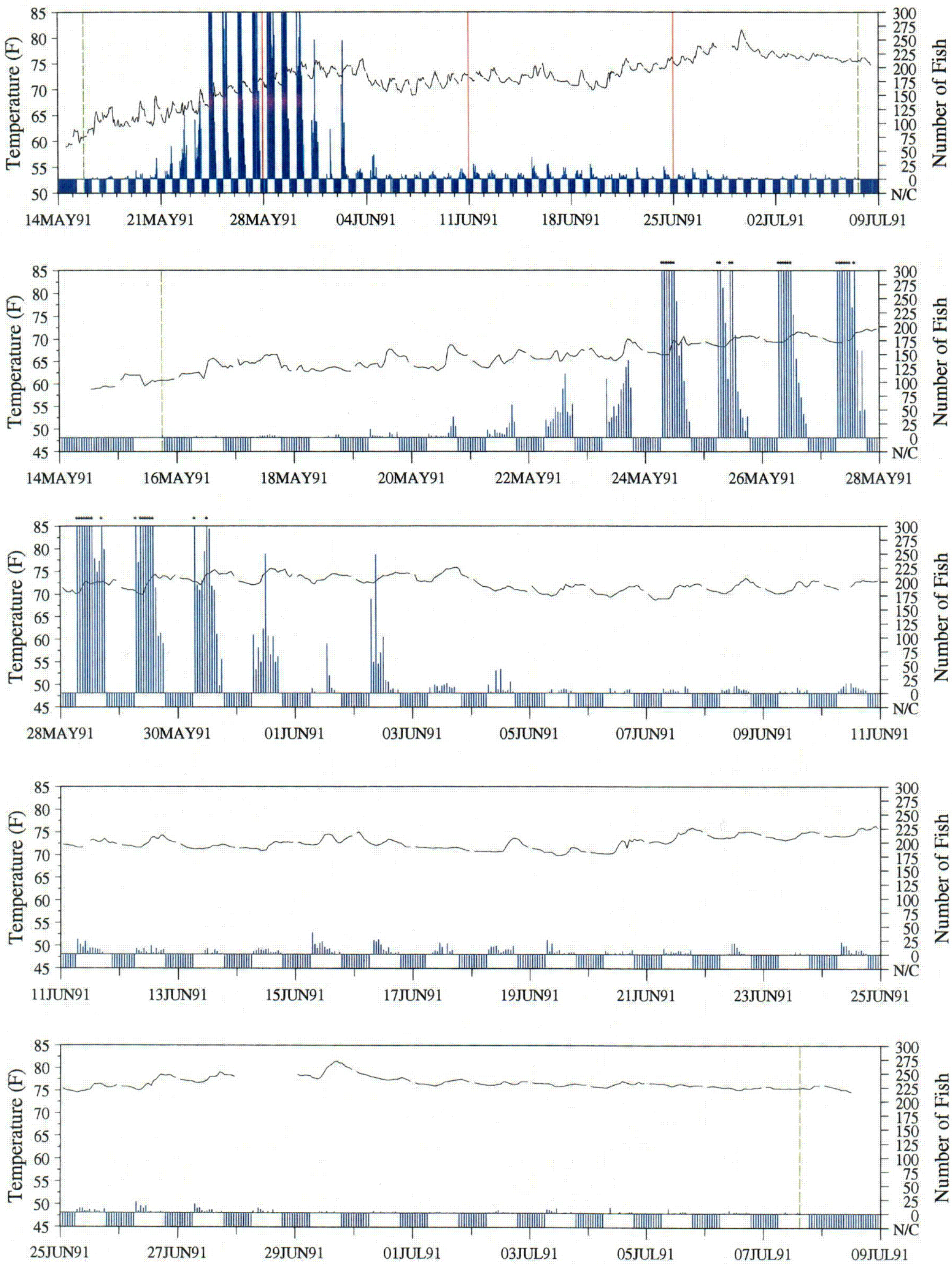
The final data file, as edited with the information provided by Mr. Cox on 1 and 8 March 2004, has 5,628 records of data compared to the original file with 5,691 data records. The final data file is included at the end of this document following the statistical summary tables and figures. Comment codes of 1, 2, 3 or 4 were assigned to each data record in this final data file to explain the criteria that we used if a data value other than the one shown on the original data sheet was assigned to the record in the final data file. We used the definitions for comments that were supplied by VANR to me on 1 December 2003, and subsequently clarified on 1 and 8 March 2004. A total of 64 data records out of the 5,628 total count records in the final data file could not be assigned a count value based on the original information provided, an additional 547 data records out of the 5,628 total records in the final data file were assigned a zero count when a negative count or "*" appeared in the original data, and 28 data records out of the 5,628 total records in the final data file had a count value greater than zero assigned when no count was shown.

Also provided are two tabular summaries of each year's data set, 1991 through 2001, and two graphical summaries. A legend figure describes the notations used on the corresponding time series plots of hourly fishway count data for each year. The tabular summaries for each year (and for all years combined) shows the maximum, minimum, mean and frequency information for the time period of fishway operation, temperature data, and American shad hourly count data. The first summary table is referred to as the "Full Data Set" and represents all hourly count observations available for that year. The second summary table is referred to as the "Truncated Data Set", and provides a subset of each annual full data set that was truncated to exclude consecutive hours with zero shad counts at the beginning or end of each annual time series. Each truncated data set represents the annual time series of hourly counts beginning with the first hour in which American shad were observed at the

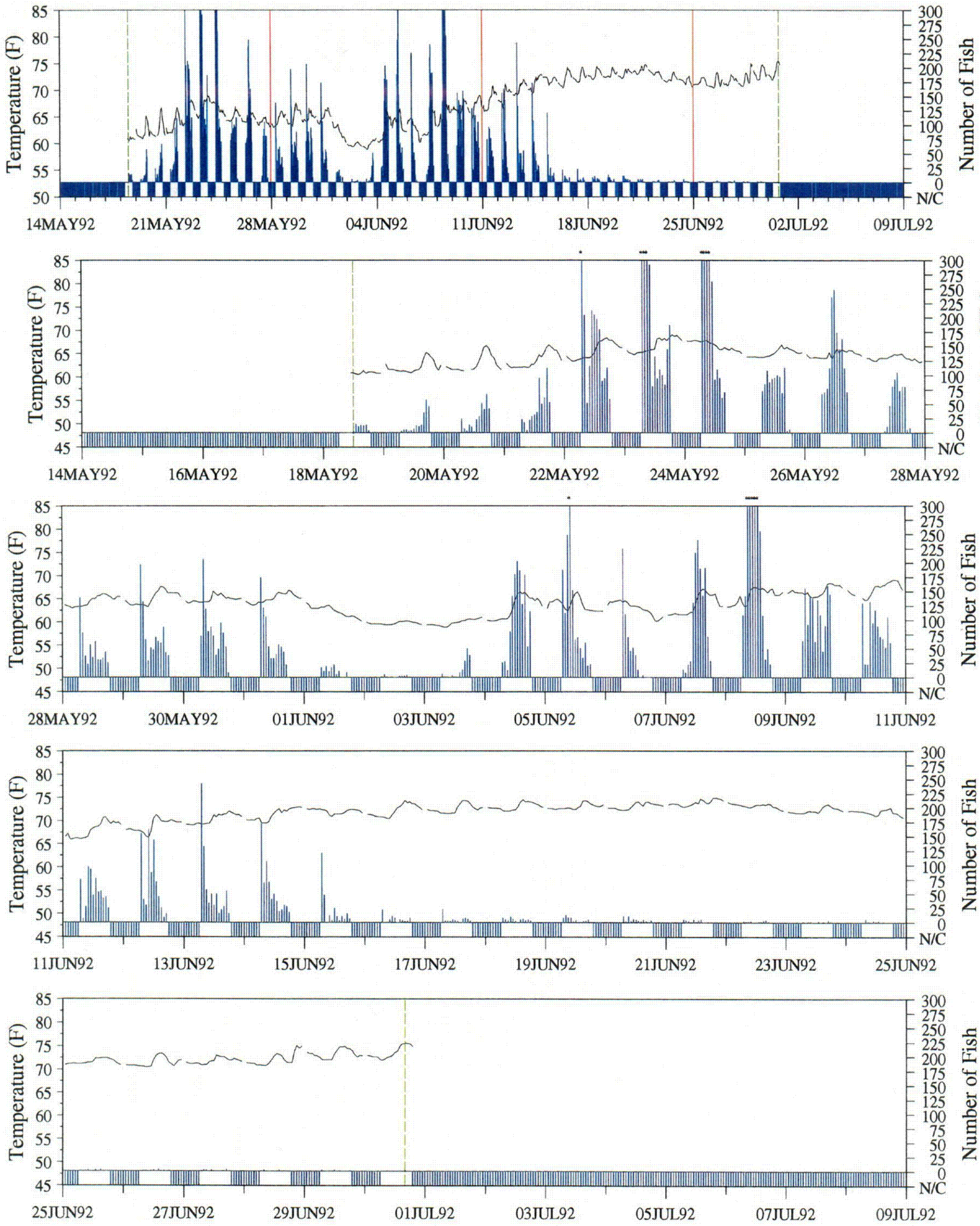
Vernon fishway, and continuing until the last shad was counted. The color graph presents the real time sequence of hourly counts and the corresponding hourly mean Fishway water temperature values for each year based on all of the valid data available for that year. A dashed vertical line demarcates the beginning and end of the truncated data set. The second graph is a scatter plot for each year showing the relationship between the hourly average Fishway water temperature and the corresponding number of American shad passing upstream through the Vernon fishway during that hour. The top panel of each scatter plot shows the scatter of all hourly observations in the full data set, and the bottom panel shows the scatter of the hourly observations represented by the truncated data set. Also shown on each of the two scatter plots is the linear regression line, the Pearson product-moment correlation coefficient (r), and the associated significance probability (p) for the Pearson statistic. The Pearson statistic describes the direction and degree of statistical correlation between the hourly American shad counts and the associated hourly average Fishway water temperatures. A negative Pearson statistic means that shad counts decreased with increasing water temperature, and a positive Pearson statistic means that counts increased with increasing water temperature. The magnitude of the Pearson statistic ranges from –1 to +1 for a perfect negative or positive correlation, respectively. If a perfect negative or positive correlation was observed, all of the points in the scatter plot would fall exactly on the regression line. A horizontal line produces a Pearson statistic of zero (0), indicating no positive or negative relationship. The significance probability is a test showing if the Pearson statistic describes a relationship among the scatter of points that is significantly different from zero. A Pearson statistic with a probability (p) less than 0.05 is considered significantly different from zero.

Legend for Times Series Charts

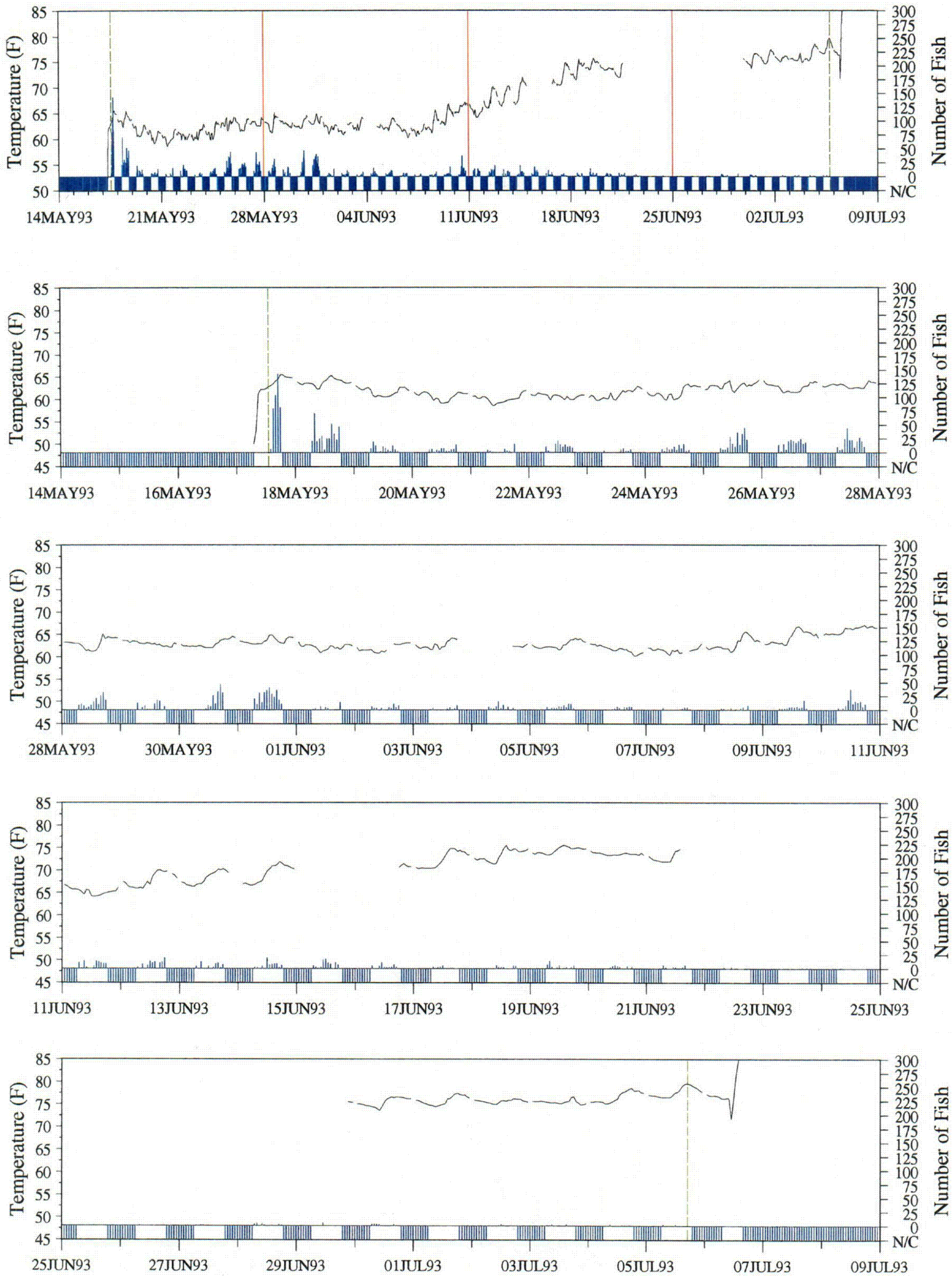




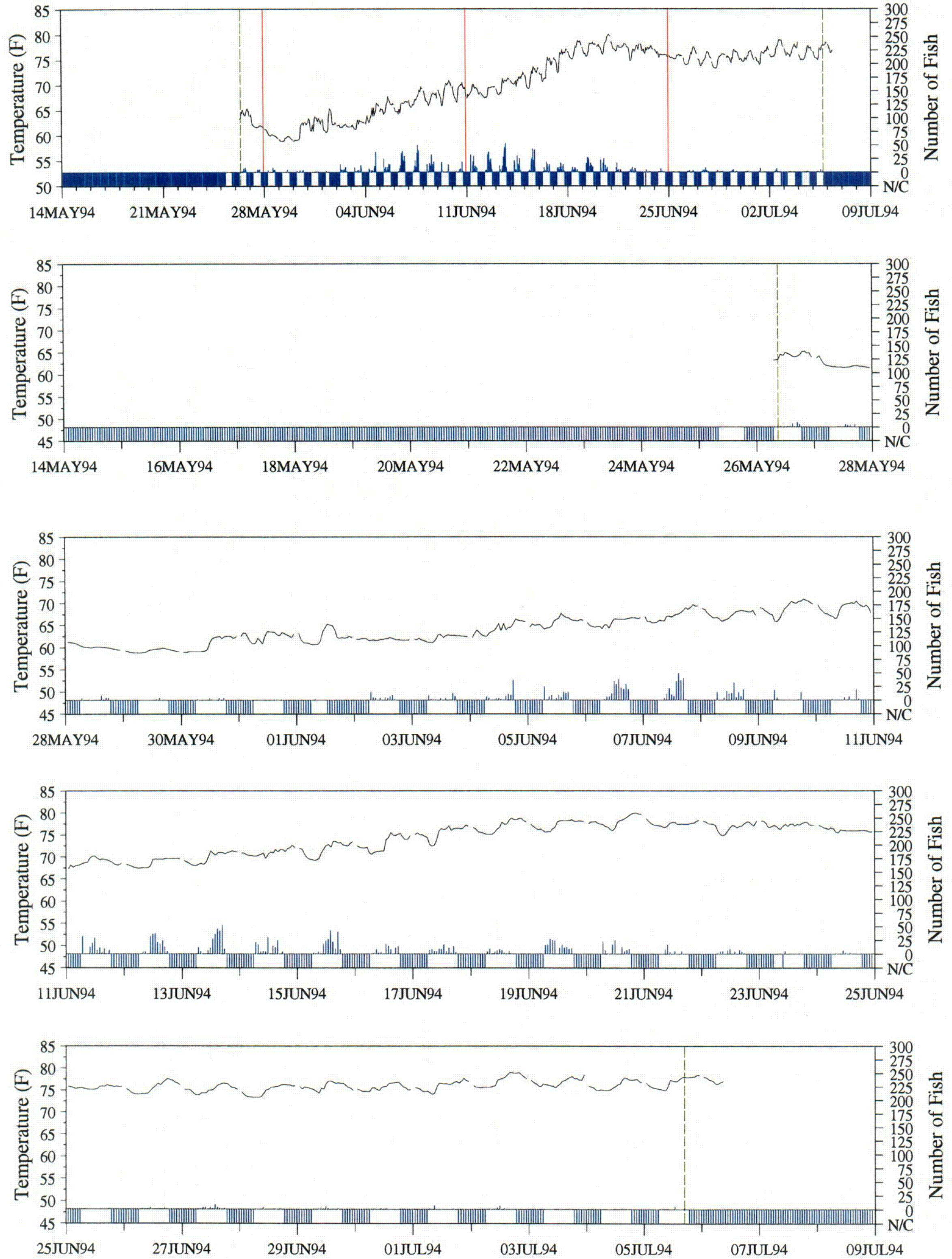
Appendix Figure 6-1. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1991.



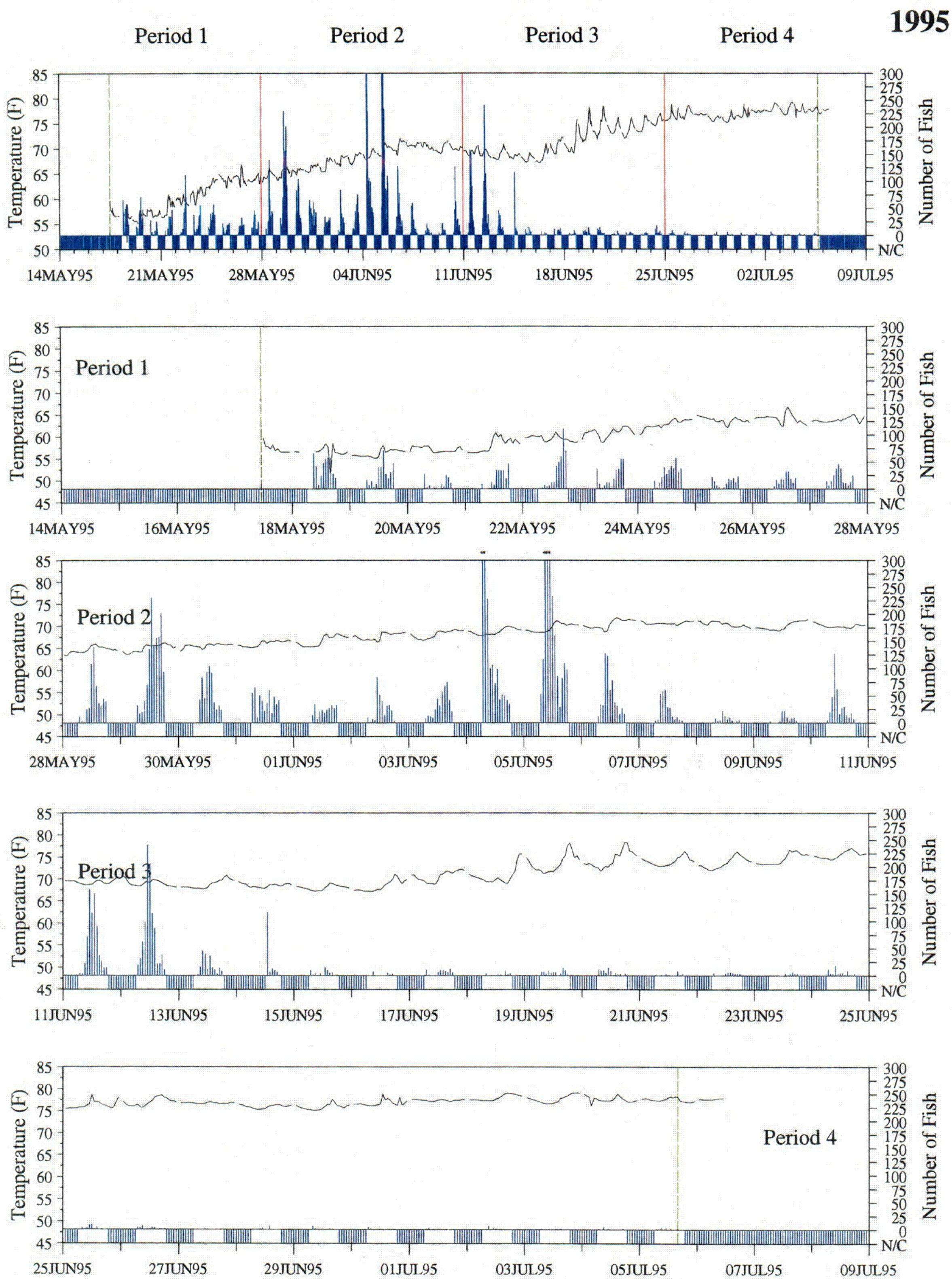
Appendix Figure 6-2. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1992.



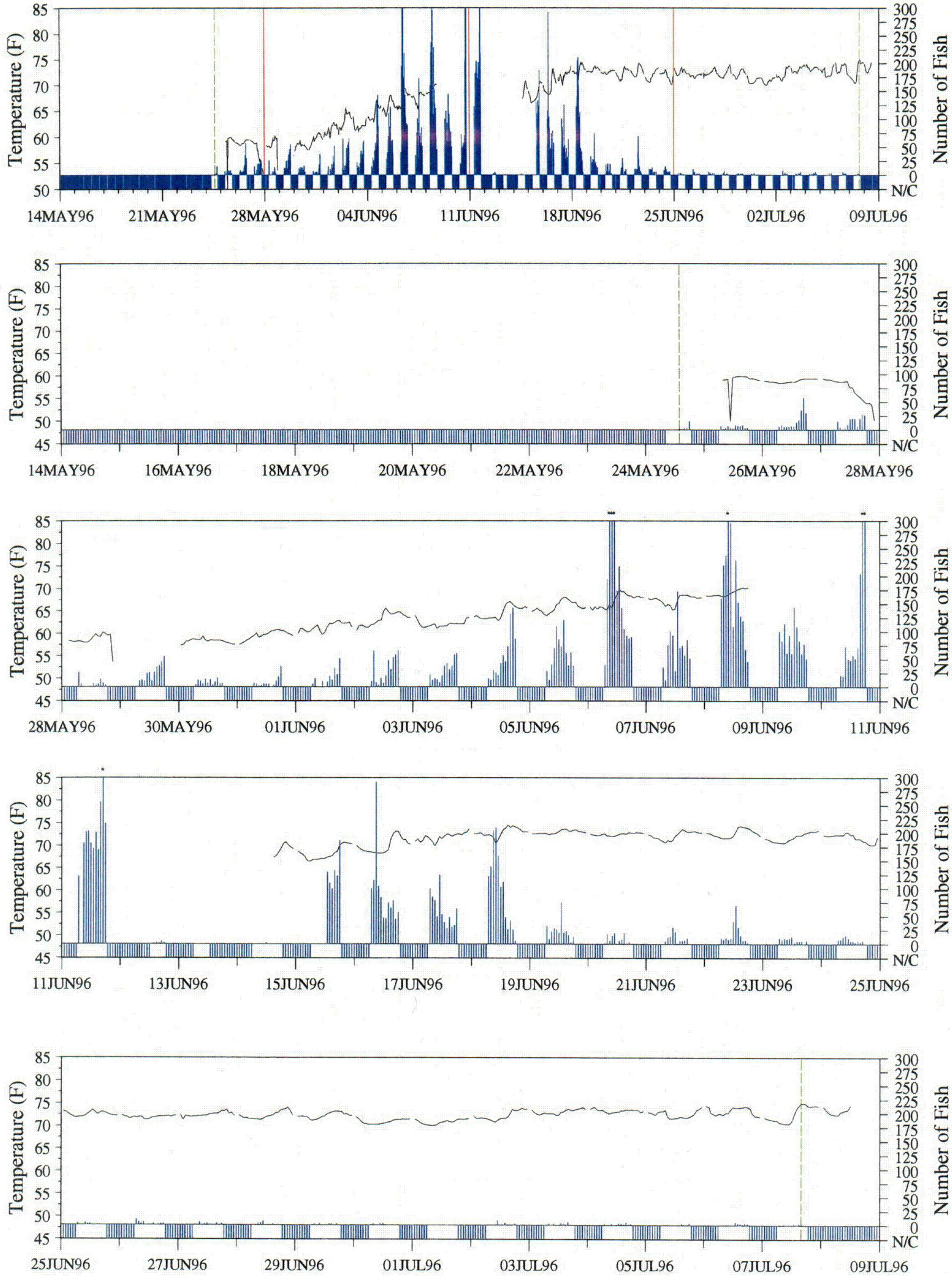
Appendix Figure 6-3. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1993.



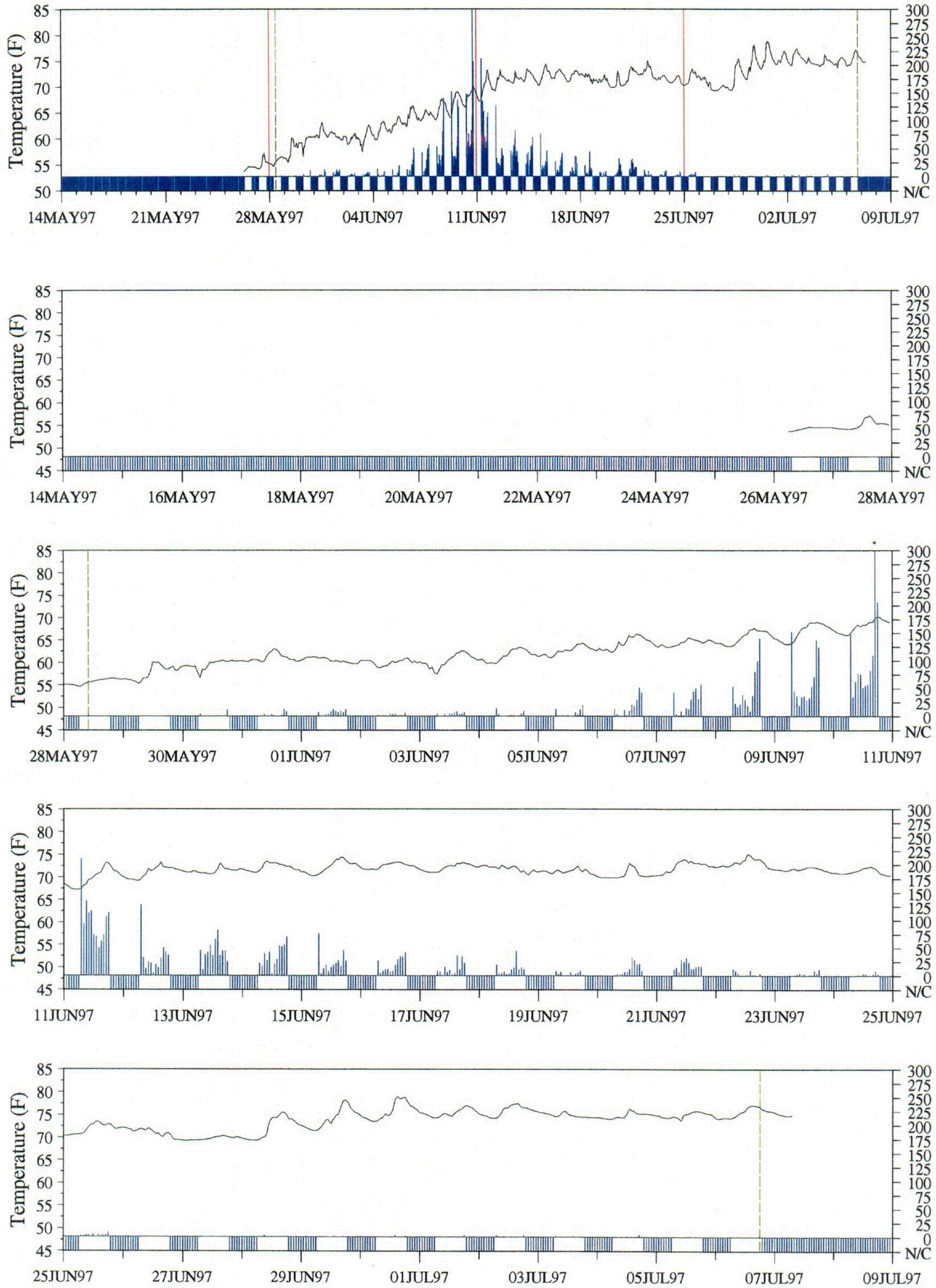
Appendix Figure 6-4. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1994.



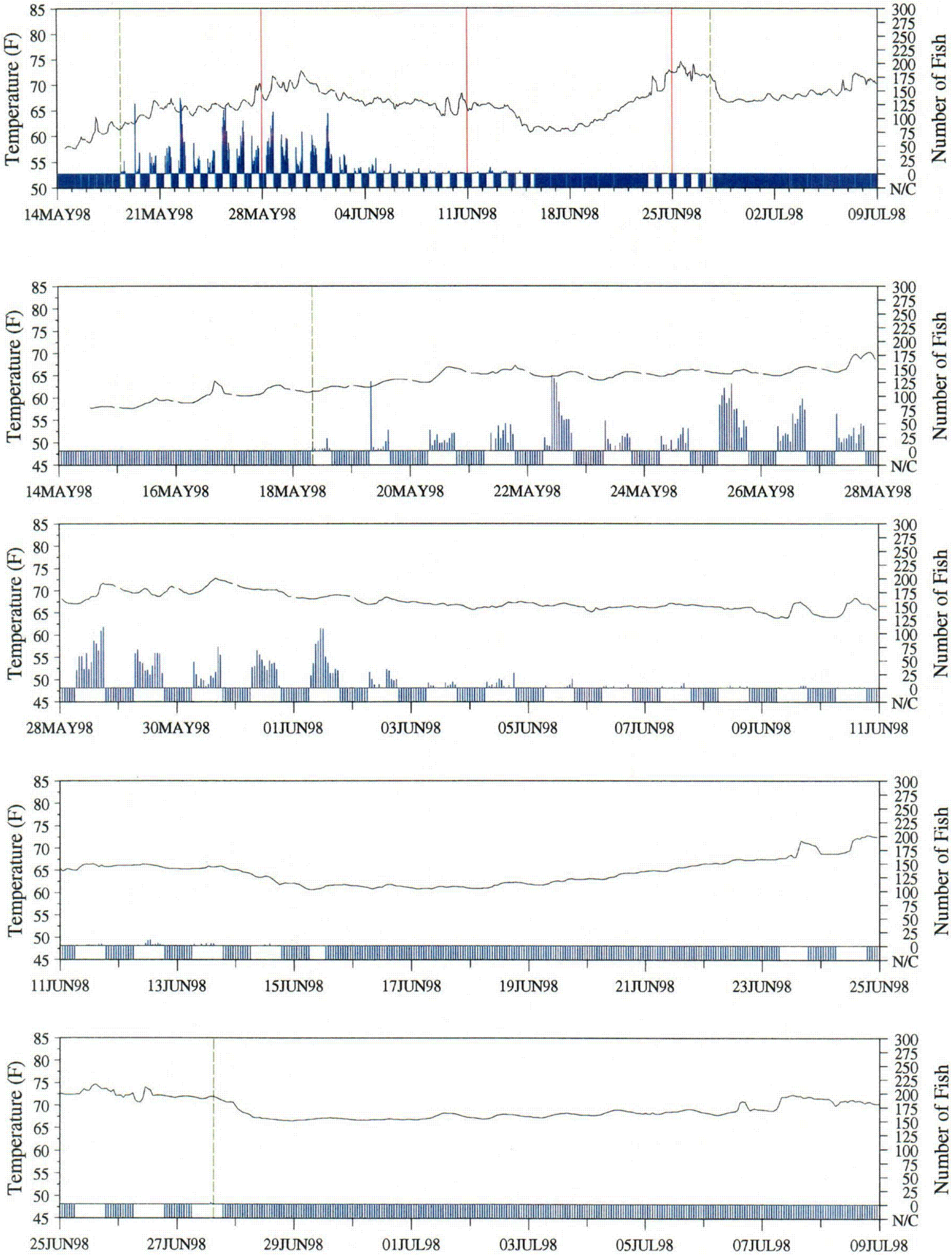
Appendix Figure 6-5. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1995.



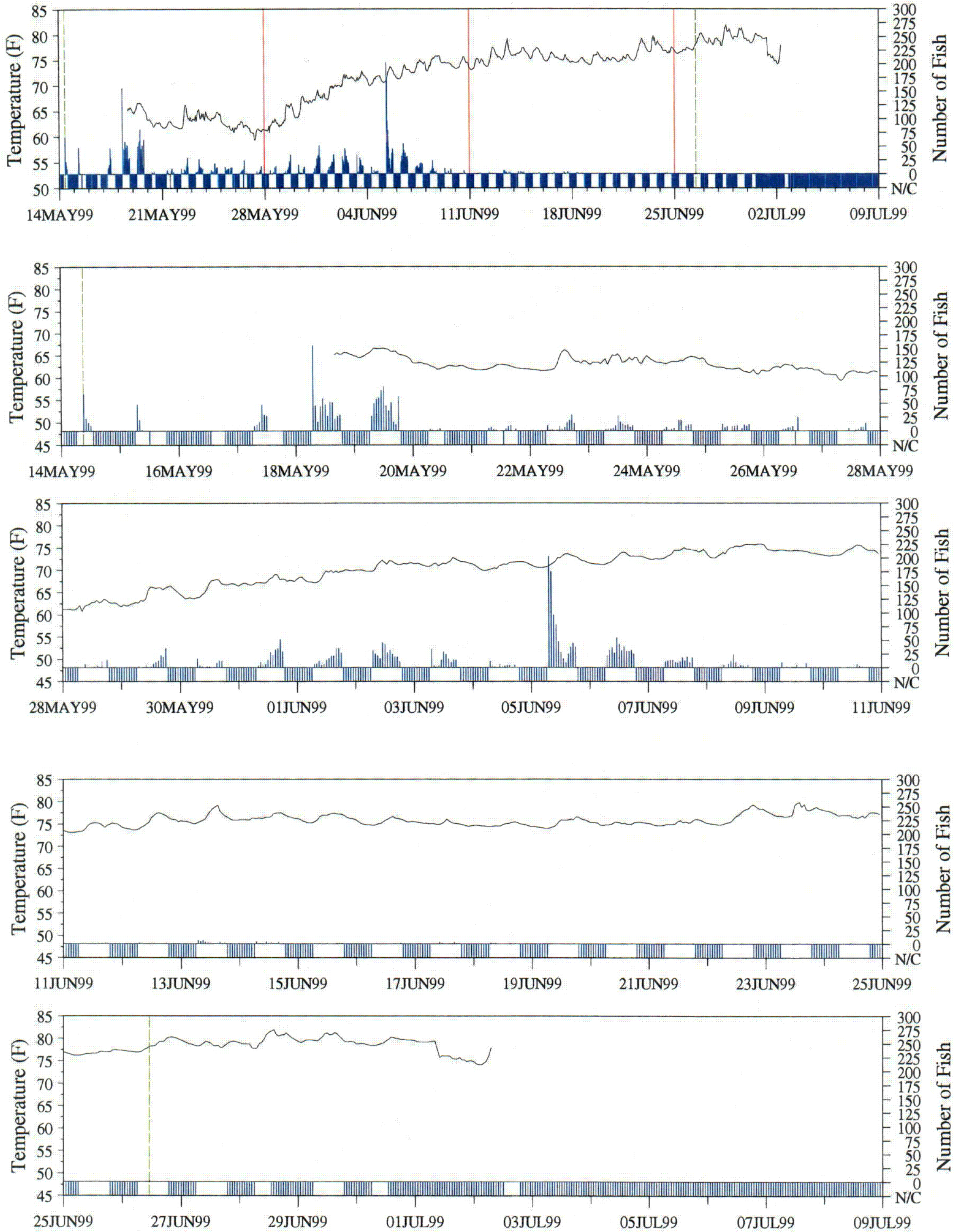
Appendix Figure 6-6. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1996.



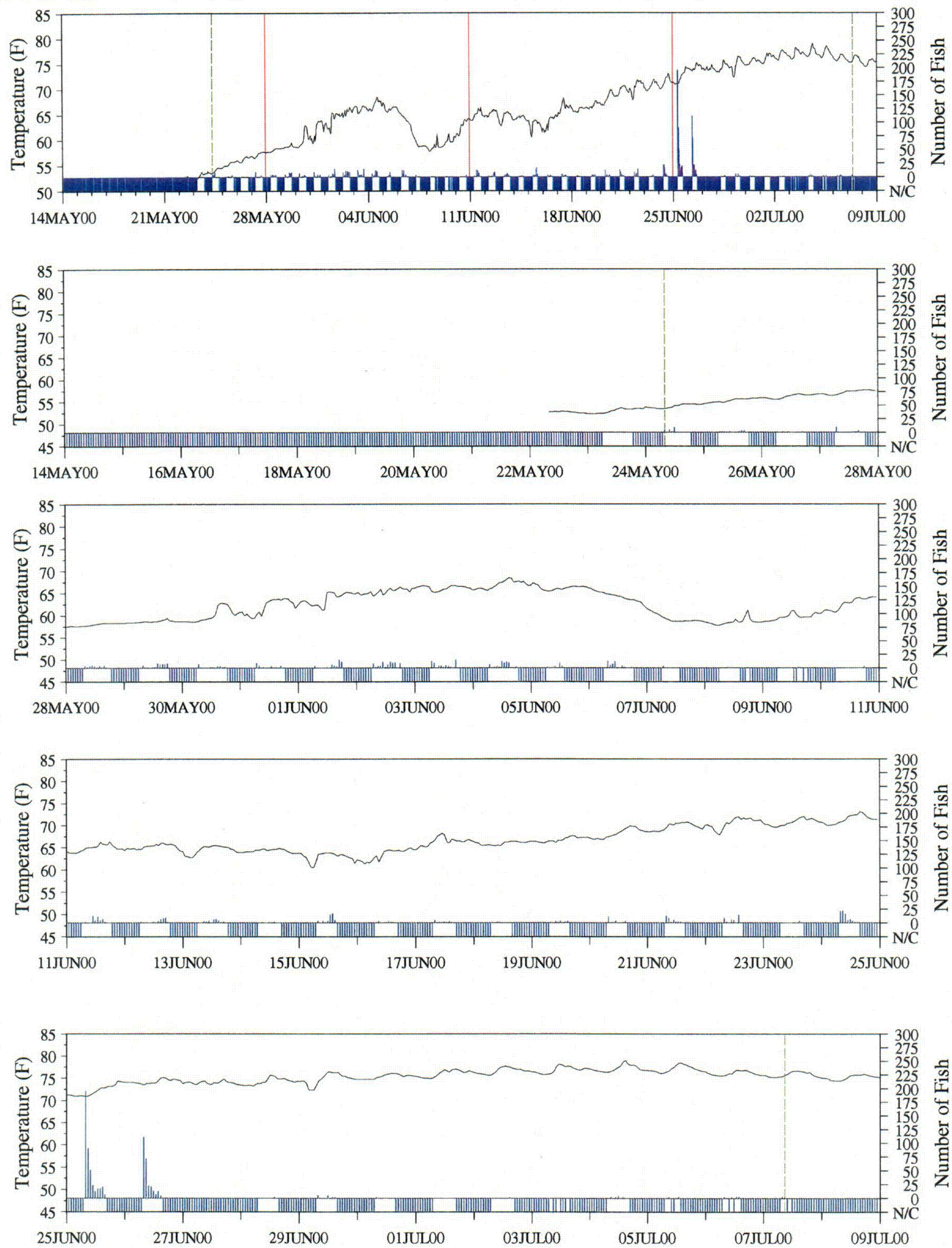
Appendix Figure 6-7. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1997.



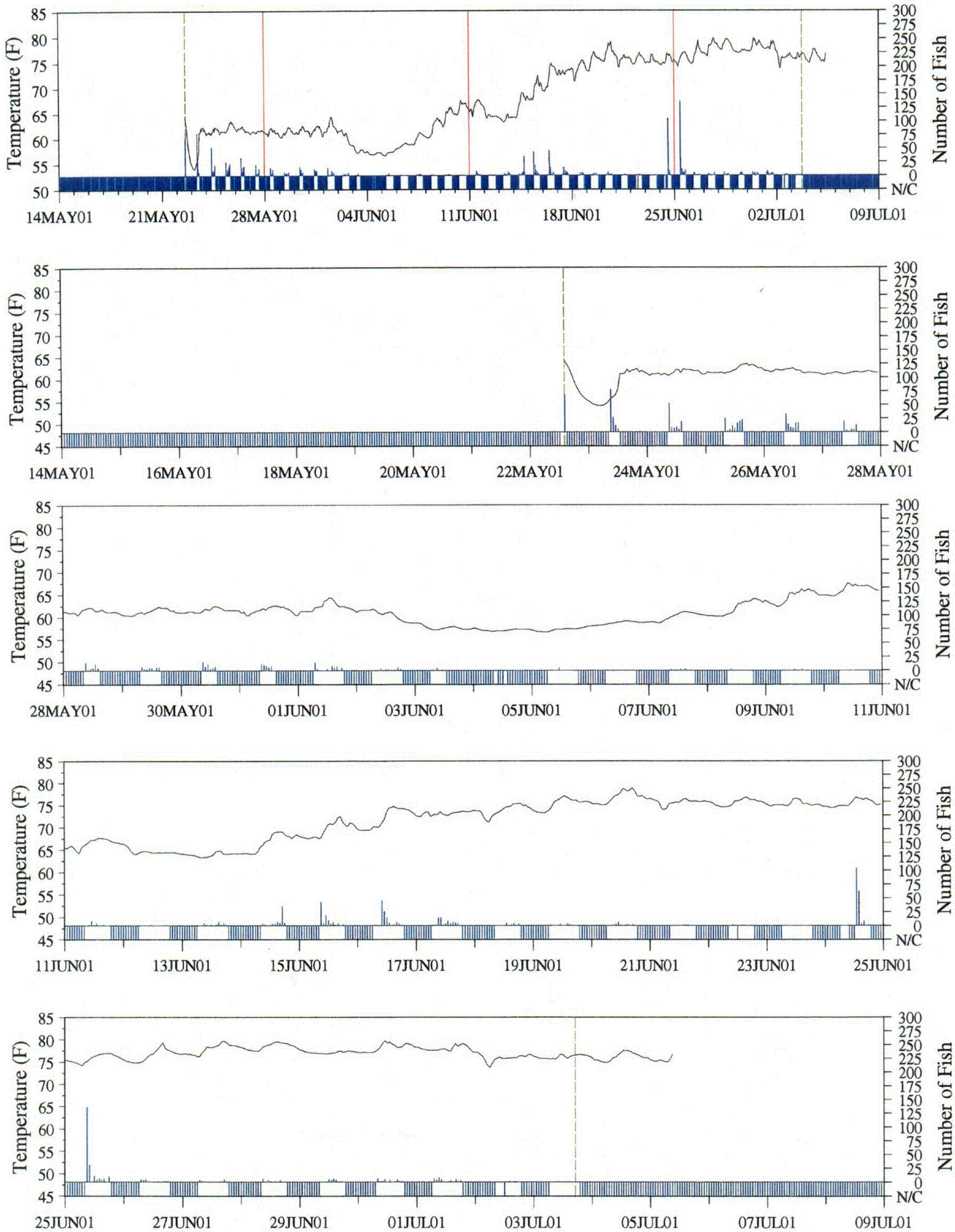
Appendix Figure 6-8. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1998.



Appendix Figure 6-9. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 1999.



Appendix Figure 6-10. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 2000.



Appendix Figure 6-11. Hourly count of adult American shad passing upstream through the Vernon Dam Fishway on the Connecticut River, Vernon, Vermont and the corresponding hourly average fishway water temperature, 14 May – 9 July, 2001.

Appendix Table 6-1. Statistical summary for hourly fishway counts and temperatures.

Full Data Set	
Parameter	**1991**
Time Summary[1]	
Start Date and Time	15-May-91 07:00
End Date and Time	07-Jul-91 18:00
First Date and Time With Shad Count > 0	15-May-91 18:00
Last Date and Time With Shad Count > 0	07-Jul-91 15:00
N Hrs With Shad Count Data	650
Max Hrs With Shad Count Data	651
N Hrs With Shad Count Data and Temperature Data	631
Total Hrs With Temperature Data	632
Maximum Possible Hours With Temperature Data	651
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	62.0
Min Temperature on Start Date During Hrs When Shad First Counted	59.6
Mean Temperature on Start Date During Hrs When Shad First Counted	60.8
Max Temperature on End Date During Hrs When Shad Last Counted	75.7
Min Temperature on End Date During Hrs When Shad Last Counted	75.4
Mean Temperature on End Date During Hrs When Shad Last Counted	75.5
Max Temperature From All Hours of Shad Counts	81.5
Min Temperature From All Hours of Shad Counts	59.6
Mean Temperature From All Hours of Shad Counts	71.9
SD of Mean Temperatures From All Hours of Shad Counts	4.2
SE of Mean Temperatures From All Hours of Shad Counts	0.2
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	148
N Hrs With At Least One Shad Counted	502
N Hrs Where No Count Was Taken	1
N Hrs With Zero Shad, Comment Code 1	51
N Hrs With Zero Shad, Comment Code 2	45
N Hrs With Missing Count Value, Comment Code 3	1
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	1788
90% Hourly Count	152.5
75% Hourly Count	15
Median Hourly Count	4
25% Hourly Count	1
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	57.1
SD of Mean Hourly Counts	178.4
SE of Mean Hourly Counts	7.0

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in intervals even. Summary statistics exclude dates before start date or after end date in each year.
[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.
[3] Comment Codes:
1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1991**
Time Summary[1]	
Start Date and Time	15-May-91 18:00
End Date and Time	07-Jul-91 15:00
First Date and Time With Shad Count > 0	15-May-91 18:00
Last Date and Time With Shad Count > 0	07-Jul-91 15:00
N Hrs With Shad Count Data	636
Max Hrs With Shad Count Data	637
N Hrs With Shad Count Data and Temperature Data	617
Total Hrs With Temperature Data	618
Maximum Possible Hours With Temperature Data	637
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	60.8
Min Temperature on Start Date During Hrs When Shad First Counted	60.8
Mean Temperature on Start Date During Hrs When Shad First Counted	60.8
Max Temperature on End Date During Hrs When Shad Last Counted	75.5
Min Temperature on End Date During Hrs When Shad Last Counted	75.4
Mean Temperature on End Date During Hrs When Shad Last Counted	75.5
Max Temperature From All Hours of Shad Counts	81.5
Min Temperature From All Hours of Shad Counts	60.8
Mean Temperature From All Hours of Shad Counts	72.1
SD of Mean Temperatures From All Hours of Shad Counts	3.9
SE of Mean Temperatures From All Hours of Shad Counts	0.2
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	134
N Hrs With At Least One Shad Counted	502
N Hrs Where No Count Was Taken	1
N Hrs With Zero Shad, Comment Code 1	50
N Hrs With Zero Shad, Comment Code 2	44
N Hrs With Missing Count Value, Comment Code 3	1
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	1788
90% Hourly Count	158
75% Hourly Count	16.5
Median Hourly Count	5
25% Hourly Count	1
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	58.3
SD of Mean Hourly Counts	180.2
SE of Mean Hourly Counts	7.1

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1992**
Time Summary[1]	
Start Date and Time	18-May-92 07:00
End Date and Time	30-Jun-92 18:00
First Date and Time With Shad Count > 0	18-May-92 12:00
Last Date and Time With Shad Count > 0	30-Jun-92 16:00
N Hrs With Shad Count Data	522
Max Hrs With Shad Count Data	528
N Hrs With Shad Count Data and Temperature Data	520
Total Hrs With Temperature Data	522
Maximum Possible Hours With Temperature Data	528
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	61.3
Min Temperature on Start Date During Hrs When Shad First Counted	60.5
Mean Temperature on Start Date During Hrs When Shad First Counted	60.9
Max Temperature on End Date During Hrs When Shad Last Counted	75.5
Min Temperature on End Date During Hrs When Shad Last Counted	71.9
Mean Temperature on End Date During Hrs When Shad Last Counted	73.9
Max Temperature From All Hours of Shad Counts	75.5
Min Temperature From All Hours of Shad Counts	58.9
Mean Temperature From All Hours of Shad Counts	67.9
SD of Mean Temperatures From All Hours of Shad Counts	4.4
SE of Mean Temperatures From All Hours of Shad Counts	0.2
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	77
N Hrs With At Least One Shad Counted	445
N Hrs Where No Count Was Taken	6
N Hrs With Zero Shad, Comment Code 1	0
N Hrs With Zero Shad, Comment Code 2	22
N Hrs With Missing Count Value, Comment Code 3	6
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	1936
90% Hourly Count	143
75% Hourly Count	71
Median Hourly Count	15.5
25% Hourly Count	2
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	59.6
SD of Mean Hourly Counts	135.2
SE of Mean Hourly Counts	5.9

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1992**
Time Summary[1]	
Start Date and Time	18-May-92 12:00
End Date and Time	30-Jun-92 16:00
First Date and Time With Shad Count > 0	18-May-92 12:00
Last Date and Time With Shad Count > 0	30-Jun-92 16:00
N Hrs With Shad Count Data	519
Max Hrs With Shad Count Data	521
N Hrs With Shad Count Data and Temperature Data	517
Total Hrs With Temperature Data	519
Maximum Possible Hours With Temperature Data	521
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	61.3
Min Temperature on Start Date During Hrs When Shad First Counted	60.5
Mean Temperature on Start Date During Hrs When Shad First Counted	60.9
Max Temperature on End Date During Hrs When Shad Last Counted	75.5
Min Temperature on End Date During Hrs When Shad Last Counted	71.9
Mean Temperature on End Date During Hrs When Shad Last Counted	73.6
Max Temperature From All Hours of Shad Counts	75.5
Min Temperature From All Hours of Shad Counts	58.9
Mean Temperature From All Hours of Shad Counts	67.9
SD of Mean Temperatures From All Hours of Shad Counts	4.4
SE of Mean Temperatures From All Hours of Shad Counts	0.2
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	74
N Hrs With At Least One Shad Counted	445
N Hrs Where No Count Was Taken	2
N Hrs With Zero Shad, Comment Code 1	0
N Hrs With Zero Shad, Comment Code 2	22
N Hrs With Missing Count Value, Comment Code 3	2
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	1936
90% Hourly Count	144
75% Hourly Count	71
Median Hourly Count	16
25% Hourly Count	2
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	60.0
SD of Mean Hourly Counts	135.5
SE of Mean Hourly Counts	5.9

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1993**
Time Summary[1]	
Start Date and Time	17-May-93 08:00
End Date and Time	06-Jul-93 15:00
First Date and Time With Shad Count > 0	17-May-93 13:00
Last Date and Time With Shad Count > 0	05-Jul-93 17:00
N Hrs With Shad Count Data	599
Max Hrs With Shad Count Data	607
N Hrs With Shad Count Data and Temperature Data	462
Total Hrs With Temperature Data	469
Maximum Possible Hours With Temperature Data	607
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	65.5
Min Temperature on Start Date During Hrs When Shad First Counted	61.3
Mean Temperature on Start Date During Hrs When Shad First Counted	63.2
Max Temperature on End Date During Hrs When Shad Last Counted	76.4
Min Temperature on End Date During Hrs When Shad Last Counted	76.3
Mean Temperature on End Date During Hrs When Shad Last Counted	76.4
Max Temperature From All Hours of Shad Counts	79.7
Min Temperature From All Hours of Shad Counts	58.6
Mean Temperature From All Hours of Shad Counts	66.5
SD of Mean Temperatures From All Hours of Shad Counts	5.9
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	208
N Hrs With At Least One Shad Counted	391
N Hrs Where No Count Was Taken	8
N Hrs With Zero Shad, Comment Code 1	79
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	8
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	143
90% Hourly Count	17
75% Hourly Count	7
Median Hourly Count	2
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	6.1
SD of Mean Hourly Counts	11.9
SE of Mean Hourly Counts	0.5

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1993**
Time Summary[1]	
Start Date and Time	17-May-93 13:00
End Date and Time	05-Jul-93 17:00
First Date and Time With Shad Count > 0	17-May-93 13:00
Last Date and Time With Shad Count > 0	05-Jul-93 17:00
N Hrs With Shad Count Data	592
Max Hrs With Shad Count Data	593
N Hrs With Shad Count Data and Temperature Data	455
Total Hrs With Temperature Data	456
Maximum Possible Hours With Temperature Data	593
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	65.5
Min Temperature on Start Date During Hrs When Shad First Counted	62.8
Mean Temperature on Start Date During Hrs When Shad First Counted	63.9
Max Temperature on End Date During Hrs When Shad Last Counted	79.7
Min Temperature on End Date During Hrs When Shad Last Counted	76.6
Mean Temperature on End Date During Hrs When Shad Last Counted	77.8
Max Temperature From All Hours of Shad Counts	79.7
Min Temperature From All Hours of Shad Counts	58.6
Mean Temperature From All Hours of Shad Counts	66.4
SD of Mean Temperatures From All Hours of Shad Counts	5.9
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	201
N Hrs With At Least One Shad Counted	391
N Hrs Where No Count Was Taken	1
N Hrs With Zero Shad, Comment Code 1	78
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	1
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	143
90% Hourly Count	17
75% Hourly Count	7
Median Hourly Count	2
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	6.2
SD of Mean Hourly Counts	12.0
SE of Mean Hourly Counts	0.5

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1994**
Time Summary[1]	
Start Date and Time	25-May-94 09:00
End Date and Time	05-Jul-94 18:00
First Date and Time With Shad Count > 0	26-May-94 09:00
Last Date and Time With Shad Count > 0	05-Jul-94 17:00
N Hrs With Shad Count Data	501
Max Hrs With Shad Count Data	501
N Hrs With Shad Count Data and Temperature Data	491
Total Hrs With Temperature Data	491
Maximum Possible Hours With Temperature Data	501
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	65.0
Min Temperature on Start Date During Hrs When Shad First Counted	63.3
Mean Temperature on Start Date During Hrs When Shad First Counted	64.2
Max Temperature on End Date During Hrs When Shad Last Counted	78.0
Min Temperature on End Date During Hrs When Shad Last Counted	74.9
Mean Temperature on End Date During Hrs When Shad Last Counted	76.7
Max Temperature From All Hours of Shad Counts	79.4
Min Temperature From All Hours of Shad Counts	58.8
Mean Temperature From All Hours of Shad Counts	70.7
SD of Mean Temperatures From All Hours of Shad Counts	6.1
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	195
N Hrs With At Least One Shad Counted	306
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	75
N Hrs With Zero Shad, Comment Code 2	16
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	13
Highest Hourly Count	53
90% Hourly Count	17
75% Hourly Count	7
Median Hourly Count	1
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	5.6
SD of Mean Hourly Counts	9.2
SE of Mean Hourly Counts	0.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1994**
Time Summary[1]	
Start Date and Time	26-May-94 09:00
End Date and Time	05-Jul-94 17:00
First Date and Time With Shad Count > 0	26-May-94 09:00
Last Date and Time With Shad Count > 0	05-Jul-94 17:00
N Hrs With Shad Count Data	489
Max Hrs With Shad Count Data	489
N Hrs With Shad Count Data and Temperature Data	489
Total Hrs With Temperature Data	489
Maximum Possible Hours With Temperature Data	489
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	65.0
Min Temperature on Start Date During Hrs When Shad First Counted	63.4
Mean Temperature on Start Date During Hrs When Shad First Counted	64.3
Max Temperature on End Date During Hrs When Shad Last Counted	78.0
Min Temperature on End Date During Hrs When Shad Last Counted	74.9
Mean Temperature on End Date During Hrs When Shad Last Counted	76.6
Max Temperature From All Hours of Shad Counts	79.4
Min Temperature From All Hours of Shad Counts	58.8
Mean Temperature From All Hours of Shad Counts	70.7
SD of Mean Temperatures From All Hours of Shad Counts	6.1
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	183
N Hrs With At Least One Shad Counted	306
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	75
N Hrs With Zero Shad, Comment Code 2	16
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	13
Highest Hourly Count	53
90% Hourly Count	17
75% Hourly Count	7
Median Hourly Count	2
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	5.7
SD of Mean Hourly Counts	9.3
SE of Mean Hourly Counts	0.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1995**
Time Summary[1]	
Start Date and Time	17-May-95 11:00
End Date and Time	05-Jul-95 18:00
First Date and Time With Shad Count > 0	17-May-95 11:00
Last Date and Time With Shad Count > 0	05-Jul-95 16:00
N Hrs With Shad Count Data	580
Max Hrs With Shad Count Data	580
N Hrs With Shad Count Data and Temperature Data	576
Total Hrs With Temperature Data	576
Maximum Possible Hours With Temperature Data	580
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	58.4
Min Temperature on Start Date During Hrs When Shad First Counted	51.4
Mean Temperature on Start Date During Hrs When Shad First Counted	56.6
Max Temperature on End Date During Hrs When Shad Last Counted	78.3
Min Temperature on End Date During Hrs When Shad Last Counted	77.1
Mean Temperature on End Date During Hrs When Shad Last Counted	77.7
Max Temperature From All Hours of Shad Counts	79.1
Min Temperature From All Hours of Shad Counts	51.4
Mean Temperature From All Hours of Shad Counts	69.4
SD of Mean Temperatures From All Hours of Shad Counts	6.1
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	103
N Hrs With At Least One Shad Counted	477
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	26
N Hrs With Zero Shad, Comment Code 2	2
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	2
Highest Hourly Count	1100
90% Hourly Count	60.5
75% Hourly Count	28
Median Hourly Count	7
25% Hourly Count	1
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	26.8
SD of Mean Hourly Counts	70.6
SE of Mean Hourly Counts	2.9

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1995**
Time Summary[1]	
Start Date and Time	17-May-95 11:00
End Date and Time	05-Jul-95 16:00
First Date and Time With Shad Count > 0	17-May-95 11:00
Last Date and Time With Shad Count > 0	05-Jul-95 16:00
N Hrs With Shad Count Data	578
Max Hrs With Shad Count Data	578
N Hrs With Shad Count Data and Temperature Data	574
Total Hrs With Temperature Data	574
Maximum Possible Hours With Temperature Data	578
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	58.4
Min Temperature on Start Date During Hrs When Shad First Counted	51.4
Mean Temperature on Start Date During Hrs When Shad First Counted	56.6
Max Temperature on End Date During Hrs When Shad Last Counted	78.3
Min Temperature on End Date During Hrs When Shad Last Counted	77.3
Mean Temperature on End Date During Hrs When Shad Last Counted	77.8
Max Temperature From All Hours of Shad Counts	79.1
Min Temperature From All Hours of Shad Counts	51.4
Mean Temperature From All Hours of Shad Counts	69.4
SD of Mean Temperatures From All Hours of Shad Counts	6.1
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	101
N Hrs With At Least One Shad Counted	477
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	26
N Hrs With Zero Shad, Comment Code 2	2
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	2
Highest Hourly Count	1100
90% Hourly Count	61
75% Hourly Count	28
Median Hourly Count	7
25% Hourly Count	1
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	26.8
SD of Mean Hourly Counts	70.7
SE of Mean Hourly Counts	2.9

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1996**
Time Summary[1]	
Start Date and Time	24-May-96 11:00
End Date and Time	07-Jul-96 18:00
First Date and Time With Shad Count > 0	24-May-96 14:00
Last Date and Time With Shad Count > 0	07-Jul-96 16:00
N Hrs With Shad Count Data	492
Max Hrs With Shad Count Data	534
N Hrs With Shad Count Data and Temperature Data	437
Total Hrs With Temperature Data	447
Maximum Possible Hours With Temperature Data	534
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	60.0
Min Temperature on Start Date During Hrs When Shad First Counted	49.9
Mean Temperature on Start Date During Hrs When Shad First Counted	58.8
Max Temperature on End Date During Hrs When Shad Last Counted	75.0
Min Temperature on End Date During Hrs When Shad Last Counted	70.4
Mean Temperature on End Date During Hrs When Shad Last Counted	72.4
Max Temperature From All Hours of Shad Counts	75.0
Min Temperature From All Hours of Shad Counts	49.9
Mean Temperature From All Hours of Shad Counts	68.4
SD of Mean Temperatures From All Hours of Shad Counts	5.4
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	91
N Hrs With At Least One Shad Counted	401
N Hrs Where No Count Was Taken	42
N Hrs With Zero Shad, Comment Code 1	24
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	42
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	735
90% Hourly Count	110
75% Hourly Count	45.5
Median Hourly Count	8
25% Hourly Count	1
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	38.3
SD of Mean Hourly Counts	75.3
SE of Mean Hourly Counts	3.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1996**
Time Summary[1]	
Start Date and Time	24-May-96 14:00
End Date and Time	07-Jul-96 16:00
First Date and Time With Shad Count > 0	24-May-96 14:00
Last Date and Time With Shad Count > 0	07-Jul-96 16:00
N Hrs With Shad Count Data	487
Max Hrs With Shad Count Data	529
N Hrs With Shad Count Data and Temperature Data	435
Total Hrs With Temperature Data	445
Maximum Possible Hours With Temperature Data	529
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	60.0
Min Temperature on Start Date During Hrs When Shad First Counted	49.9
Mean Temperature on Start Date During Hrs When Shad First Counted	58.8
Max Temperature on End Date During Hrs When Shad Last Counted	74.9
Min Temperature on End Date During Hrs When Shad Last Counted	70.4
Mean Temperature on End Date During Hrs When Shad Last Counted	71.9
Max Temperature From All Hours of Shad Counts	74.9
Min Temperature From All Hours of Shad Counts	49.9
Mean Temperature From All Hours of Shad Counts	68.4
SD of Mean Temperatures From All Hours of Shad Counts	5.4
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	86
N Hrs With At Least One Shad Counted	401
N Hrs Where No Count Was Taken	42
N Hrs With Zero Shad, Comment Code 1	24
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	42
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	735
90% Hourly Count	112
75% Hourly Count	46
Median Hourly Count	8
25% Hourly Count	1
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	38.7
SD of Mean Hourly Counts	75.5
SE of Mean Hourly Counts	3.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

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2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1997**
Time Summary[1]	
Start Date and Time	26-May-97 08:00
End Date and Time	06-Jul-97 18:00
First Date and Time With Shad Count > 0	28-May-97 10:00
Last Date and Time With Shad Count > 0	06-Jul-97 18:00
N Hrs With Shad Count Data	503
Max Hrs With Shad Count Data	503
N Hrs With Shad Count Data and Temperature Data	503
Total Hrs With Temperature Data	503
Maximum Possible Hours With Temperature Data	503
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	54.6
Min Temperature on Start Date During Hrs When Shad First Counted	53.8
Mean Temperature on Start Date During Hrs When Shad First Counted	54.3
Max Temperature on End Date During Hrs When Shad Last Counted	77.2
Min Temperature on End Date During Hrs When Shad Last Counted	74.4
Mean Temperature on End Date During Hrs When Shad Last Counted	76.0
Max Temperature From All Hours of Shad Counts	79.0
Min Temperature From All Hours of Shad Counts	53.8
Mean Temperature From All Hours of Shad Counts	68.6
SD of Mean Temperatures From All Hours of Shad Counts	6.4
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	180
N Hrs With At Least One Shad Counted	323
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	18
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	308
90% Hourly Count	45
75% Hourly Count	14
Median Hourly Count	2
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	14.9
SD of Mean Hourly Counts	31.0
SE of Mean Hourly Counts	1.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

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2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1997**
Time Summary[1]	
Start Date and Time	28-May-97 10:00
End Date and Time	06-Jul-97 18:00
First Date and Time With Shad Count > 0	28-May-97 10:00
Last Date and Time With Shad Count > 0	06-Jul-97 18:00
N Hrs With Shad Count Data	477
Max Hrs With Shad Count Data	477
N Hrs With Shad Count Data and Temperature Data	477
Total Hrs With Temperature Data	477
Maximum Possible Hours With Temperature Data	477
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	56.4
Min Temperature on Start Date During Hrs When Shad First Counted	55.6
Mean Temperature on Start Date During Hrs When Shad First Counted	56.0
Max Temperature on End Date During Hrs When Shad Last Counted	77.2
Min Temperature on End Date During Hrs When Shad Last Counted	74.4
Mean Temperature on End Date During Hrs When Shad Last Counted	76.0
Max Temperature From All Hours of Shad Counts	79.0
Min Temperature From All Hours of Shad Counts	55.5
Mean Temperature From All Hours of Shad Counts	69.4
SD of Mean Temperatures From All Hours of Shad Counts	5.7
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	154
N Hrs With At Least One Shad Counted	323
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	18
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	308
90% Hourly Count	45
75% Hourly Count	16
Median Hourly Count	3
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	15.7
SD of Mean Hourly Counts	31.6
SE of Mean Hourly Counts	1.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

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Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1998**
Time Summary[1]	
Start Date and Time	18-May-98 08:00
End Date and Time	27-Jun-98 16:00
First Date and Time With Shad Count > 0	18-May-98 08:00
Last Date and Time With Shad Count > 0	27-Jun-98 15:00
N Hrs With Shad Count Data	381
Max Hrs With Shad Count Data	381
N Hrs With Shad Count Data and Temperature Data	381
Total Hrs With Temperature Data	381
Maximum Possible Hours With Temperature Data	381
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	62.4
Min Temperature on Start Date During Hrs When Shad First Counted	61.4
Mean Temperature on Start Date During Hrs When Shad First Counted	61.8
Max Temperature on End Date During Hrs When Shad Last Counted	72.0
Min Temperature on End Date During Hrs When Shad Last Counted	71.4
Mean Temperature on End Date During Hrs When Shad Last Counted	71.7
Max Temperature From All Hours of Shad Counts	74.6
Min Temperature From All Hours of Shad Counts	61.4
Mean Temperature From All Hours of Shad Counts	67.3
SD of Mean Temperatures From All Hours of Shad Counts	2.7
SE of Mean Temperatures From All Hours of Shad Counts	0.1
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	123
N Hrs With At Least One Shad Counted	258
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	34
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	1
Highest Hourly Count	137
90% Hourly Count	58
75% Hourly Count	30
Median Hourly Count	4
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	19.3
SD of Mean Hourly Counts	28.1
SE of Mean Hourly Counts	1.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

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2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1998**
Time Summary[1]	
Start Date and Time	18-May-98 08:00
End Date and Time	27-Jun-98 15:00
First Date and Time With Shad Count > 0	18-May-98 08:00
Last Date and Time With Shad Count > 0	27-Jun-98 15:00
N Hrs With Shad Count Data	380
Max Hrs With Shad Count Data	380
N Hrs With Shad Count Data and Temperature Data	380
Total Hrs With Temperature Data	380
Maximum Possible Hours With Temperature Data	380
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	62.4
Min Temperature on Start Date During Hrs When Shad First Counted	61.4
Mean Temperature on Start Date During Hrs When Shad First Counted	61.8
Max Temperature on End Date During Hrs When Shad Last Counted	72.0
Min Temperature on End Date During Hrs When Shad Last Counted	71.4
Mean Temperature on End Date During Hrs When Shad Last Counted	71.7
Max Temperature From All Hours of Shad Counts	74.6
Min Temperature From All Hours of Shad Counts	61.4
Mean Temperature From All Hours of Shad Counts	67.3
SD of Mean Temperatures From All Hours of Shad Counts	2.7
SE of Mean Temperatures From All Hours of Shad Counts	0.1
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	122
N Hrs With At Least One Shad Counted	258
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	34
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	1
Highest Hourly Count	137
90% Hourly Count	59
75% Hourly Count	30
Median Hourly Count	4
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	19.3
SD of Mean Hourly Counts	28.2
SE of Mean Hourly Counts	1.4

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

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4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**1999**
Time Summary[1]	
Start Date and Time	14-May-99 09:00
End Date and Time	29-Jun-99 18:00
First Date and Time With Shad Count > 0	14-May-99 09:00
Last Date and Time With Shad Count > 0	26-Jun-99 11:00
N Hrs With Shad Count Data	517
Max Hrs With Shad Count Data	524
N Hrs With Shad Count Data and Temperature Data	487
Total Hrs With Temperature Data	487
Maximum Possible Hours With Temperature Data	524
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	65.6
Min Temperature on Start Date During Hrs When Shad First Counted	65.1
Mean Temperature on Start Date During Hrs When Shad First Counted	65.3
Max Temperature on End Date During Hrs When Shad Last Counted	81.3
Min Temperature on End Date During Hrs When Shad Last Counted	79.4
Mean Temperature on End Date During Hrs When Shad Last Counted	80.5
Max Temperature From All Hours of Shad Counts	81.4
Min Temperature From All Hours of Shad Counts	59.3
Mean Temperature From All Hours of Shad Counts	71.9
SD of Mean Temperatures From All Hours of Shad Counts	5.7
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	205
N Hrs With At Least One Shad Counted	312
N Hrs Where No Count Was Taken	7
N Hrs With Zero Shad, Comment Code 1	73
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	7
N Hrs With Non-Zero Count, Comment Code 4	12
Highest Hourly Count	203
90% Hourly Count	29
75% Hourly Count	11
Median Hourly Count	1
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	10.3
SD of Mean Hourly Counts	22.5
SE of Mean Hourly Counts	1.0

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:
- 1 = a recorded "*" was assigned a value of zero
- 2 = a negative recorded value was assigned a value of zero
- 3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
- 4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**1999**
Time Summary[1]	
Start Date and Time	14-May-99 09:00
End Date and Time	26-Jun-99 11:00
First Date and Time With Shad Count > 0	14-May-99 09:00
Last Date and Time With Shad Count > 0	26-Jun-99 11:00
N Hrs With Shad Count Data	481
Max Hrs With Shad Count Data	488
N Hrs With Shad Count Data and Temperature Data	451
Total Hrs With Temperature Data	451
Maximum Possible Hours With Temperature Data	488
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	65.6
Min Temperature on Start Date During Hrs When Shad First Counted	65.1
Mean Temperature on Start Date During Hrs When Shad First Counted	65.3
Max Temperature on End Date During Hrs When Shad Last Counted	78.2
Min Temperature on End Date During Hrs When Shad Last Counted	77.0
Mean Temperature on End Date During Hrs When Shad Last Counted	77.5
Max Temperature From All Hours of Shad Counts	79.8
Min Temperature From All Hours of Shad Counts	59.3
Mean Temperature From All Hours of Shad Counts	71.3
SD of Mean Temperatures From All Hours of Shad Counts	5.5
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	169
N Hrs With At Least One Shad Counted	312
N Hrs Where No Count Was Taken	7
N Hrs With Zero Shad, Comment Code 1	70
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	7
N Hrs With Non-Zero Count, Comment Code 4	12
Highest Hourly Count	203
90% Hourly Count	29
75% Hourly Count	12
Median Hourly Count	2
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	11.0
SD of Mean Hourly Counts	23.1
SE of Mean Hourly Counts	1.1

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**2000**
Time Summary[1]	
Start Date and Time	23-May-00 07:00
End Date and Time	07-Jul-00 11:00
First Date and Time With Shad Count > 0	24-May-00 08:00
Last Date and Time With Shad Count > 0	07-Jul-00 09:00
N Hrs With Shad Count Data	413
Max Hrs With Shad Count Data	413
N Hrs With Shad Count Data and Temperature Data	413
Total Hrs With Temperature Data	413
Maximum Possible Hours With Temperature Data	413
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	53.7
Min Temperature on Start Date During Hrs When Shad First Counted	52.4
Mean Temperature on Start Date During Hrs When Shad First Counted	53.1
Max Temperature on End Date During Hrs When Shad Last Counted	76.3
Min Temperature on End Date During Hrs When Shad Last Counted	75.4
Mean Temperature on End Date During Hrs When Shad Last Counted	75.8
Max Temperature From All Hours of Shad Counts	79.0
Min Temperature From All Hours of Shad Counts	52.4
Mean Temperature From All Hours of Shad Counts	65.8
SD of Mean Temperatures From All Hours of Shad Counts	6.9
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	192
N Hrs With At Least One Shad Counted	221
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	26
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	195
90% Hourly Count	9
75% Hourly Count	3
Median Hourly Count	1
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	3.8
SD of Mean Hourly Counts	13.0
SE of Mean Hourly Counts	0.6

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:

1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**2000**
Time Summary[1]	
Start Date and Time	24-May-00 08:00
End Date and Time	07-Jul-00 09:00
First Date and Time With Shad Count > 0	24-May-00 08:00
Last Date and Time With Shad Count > 0	07-Jul-00 09:00
N Hrs With Shad Count Data	400
Max Hrs With Shad Count Data	400
N Hrs With Shad Count Data and Temperature Data	400
Total Hrs With Temperature Data	400
Maximum Possible Hours With Temperature Data	400
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	54.5
Min Temperature on Start Date During Hrs When Shad First Counted	53.5
Mean Temperature on Start Date During Hrs When Shad First Counted	54.0
Max Temperature on End Date During Hrs When Shad Last Counted	75.7
Min Temperature on End Date During Hrs When Shad Last Counted	75.4
Mean Temperature on End Date During Hrs When Shad Last Counted	75.5
Max Temperature From All Hours of Shad Counts	79.0
Min Temperature From All Hours of Shad Counts	53.5
Mean Temperature From All Hours of Shad Counts	66.1
SD of Mean Temperatures From All Hours of Shad Counts	6.7
SE of Mean Temperatures From All Hours of Shad Counts	0.3
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	179
N Hrs With At Least One Shad Counted	221
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	26
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	195
90% Hourly Count	9
75% Hourly Count	3
Median Hourly Count	1
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	3.9
SD of Mean Hourly Counts	13.2
SE of Mean Hourly Counts	0.7

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

[3] Comment Codes:
1 = a recorded "*" was assigned a value of zero
2 = a negative recorded value was assigned a value of zero
3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**2001**
Time Summary[1]	
Start Date and Time	22-May-01 13:00
End Date and Time	03-Jul-01 18:00
First Date and Time With Shad Count > 0	22-May-01 14:00
Last Date and Time With Shad Count > 0	03-Jul-01 17:00
N Hrs With Shad Count Data	406
Max Hrs With Shad Count Data	406
N Hrs With Shad Count Data and Temperature Data	405
Total Hrs With Temperature Data	405
Maximum Possible Hours With Temperature Data	406
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	64.4
Min Temperature on Start Date During Hrs When Shad First Counted	64.4
Mean Temperature on Start Date During Hrs When Shad First Counted	64.4
Max Temperature on End Date During Hrs When Shad Last Counted	76.7
Min Temperature on End Date During Hrs When Shad Last Counted	75.5
Mean Temperature on End Date During Hrs When Shad Last Counted	76.2
Max Temperature From All Hours of Shad Counts	79.7
Min Temperature From All Hours of Shad Counts	55.5
Mean Temperature From All Hours of Shad Counts	69.4
SD of Mean Temperatures From All Hours of Shad Counts	7.3
SE of Mean Temperatures From All Hours of Shad Counts	0.4
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	172
N Hrs With At Least One Shad Counted	234
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	56
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	136
90% Hourly Count	8
75% Hourly Count	4
Median Hourly Count	1
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	4.3
SD of Mean Hourly Counts	11.8
SE of Mean Hourly Counts	0.6

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

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Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**2001**
Time Summary[1]	
Start Date and Time	22-May-01 14:00
End Date and Time	03-Jul-01 17:00
First Date and Time With Shad Count > 0	22-May-01 14:00
Last Date and Time With Shad Count > 0	03-Jul-01 17:00
N Hrs With Shad Count Data	404
Max Hrs With Shad Count Data	404
N Hrs With Shad Count Data and Temperature Data	404
Total Hrs With Temperature Data	404
Maximum Possible Hours With Temperature Data	404
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	64.4
Min Temperature on Start Date During Hrs When Shad First Counted	64.4
Mean Temperature on Start Date During Hrs When Shad First Counted	64.4
Max Temperature on End Date During Hrs When Shad Last Counted	76.7
Min Temperature on End Date During Hrs When Shad Last Counted	75.5
Mean Temperature on End Date During Hrs When Shad Last Counted	76.1
Max Temperature From All Hours of Shad Counts	79.7
Min Temperature From All Hours of Shad Counts	55.5
Mean Temperature From All Hours of Shad Counts	69.3
SD of Mean Temperatures From All Hours of Shad Counts	7.3
SE of Mean Temperatures From All Hours of Shad Counts	0.4
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	170
N Hrs With At Least One Shad Counted	234
N Hrs Where No Count Was Taken	0
N Hrs With Zero Shad, Comment Code 1	55
N Hrs With Zero Shad, Comment Code 2	0
N Hrs With Missing Count Value, Comment Code 3	0
N Hrs With Non-Zero Count, Comment Code 4	0
Highest Hourly Count	136
90% Hourly Count	8
75% Hourly Count	4
Median Hourly Count	1
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	4.3
SD of Mean Hourly Counts	11.9
SE of Mean Hourly Counts	0.6

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in
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Appendix Table 6-1 (Continued)

Full Data Set	
Parameter	**All Years**
Time Summary[1]	
Start Date and Time	15-May-91 07:00
End Date and Time	03-Jul-01 18:00
First Date and Time With Shad Count > 0	15-May-91 18:00
Last Date and Time With Shad Count > 0	03-Jul-01 17:00
N Hrs With Shad Count Data	5564
Max Hrs With Shad Count Data	5628
N Hrs With Shad Count Data and Temperature Data	5306
Total Hrs With Temperature Data	5326
Maximum Possible Hours With Temperature Data	5628
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	62.0
Min Temperature on Start Date During Hrs When Shad First Counted	59.6
Mean Temperature on Start Date During Hrs When Shad First Counted	60.8
Max Temperature on End Date During Hrs When Shad Last Counted	76.7
Min Temperature on End Date During Hrs When Shad Last Counted	75.5
Mean Temperature on End Date During Hrs When Shad Last Counted	76.2
Max Temperature From All Hours of Shad Counts	81.5
Min Temperature From All Hours of Shad Counts	49.9
Mean Temperature From All Hours of Shad Counts	69.0
SD of Mean Temperatures From All Hours of Shad Counts	6.0
SE of Mean Temperatures From All Hours of Shad Counts	0.1
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	1694
N Hrs With At Least One Shad Counted	3870
N Hrs Where No Count Was Taken	64
N Hrs With Zero Shad, Comment Code 1	462
N Hrs With Zero Shad, Comment Code 2	85
N Hrs With Missing Count Value, Comment Code 3	64
N Hrs With Non-Zero Count, Comment Code 4	28
Highest Hourly Count	1936
90% Hourly Count	54
75% Hourly Count	14
Median Hourly Count	3
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	23.8
SD of Mean Hourly Counts	84.2
SE of Mean Hourly Counts	1.1

(continued)

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

[2] In 1994, 1995, 1996 and 1999 there were no temperatures recorded on the first day of counts, so the temperature summary is based on records from the first day after the start of counts that temperatures were recorded.

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3 = a recorded "*" or other value was assigned a missing value when a number could not could not be assigned
4 = a recorded "*" was resolved to a non-zero count

Appendix Table 6-1 (Continued)

Truncated Data Set	
Parameter	**All Years**
Time Summary[1]	
Start Date and Time	15-May-91 18:00
End Date and Time	03-Jul-01 17:00
First Date and Time With Shad Count > 0	15-May-91 18:00
Last Date and Time With Shad Count > 0	03-Jul-01 17:00
N Hrs With Shad Count Data	5551
Max Hrs With Shad Count Data	5615
N Hrs With Shad Count Data and Temperature Data	5293
Total Hrs With Temperature Data	5313
Maximum Possible Hours With Temperature Data	5615
Temperature Summary[2]	
Max Temperature on Start Date During Hrs When Shad First Counted	60.8
Min Temperature on Start Date During Hrs When Shad First Counted	60.8
Mean Temperature on Start Date During Hrs When Shad First Counted	60.8
Max Temperature on End Date During Hrs When Shad Last Counted	76.7
Min Temperature on End Date During Hrs When Shad Last Counted	75.5
Mean Temperature on End Date During Hrs When Shad Last Counted	76.1
Max Temperature From All Hours of Shad Counts	81.5
Min Temperature From All Hours of Shad Counts	49.9
Mean Temperature From All Hours of Shad Counts	69.1
SD of Mean Temperatures From All Hours of Shad Counts	6.0
SE of Mean Temperatures From All Hours of Shad Counts	0.1
American Shad Count Summary[3]	
N Hrs With Zero Shad Counted	1681
N Hrs With At Least One Shad Counted	3870
N Hrs Where No Count Was Taken	64
N Hrs With Zero Shad, Comment Code 1	461
N Hrs With Zero Shad, Comment Code 2	85
N Hrs With Missing Count Value, Comment Code 3	64
N Hrs With Non-Zero Count, Comment Code 4	28
Highest Hourly Count	1936
90% Hourly Count	55
75% Hourly Count	14
Median Hourly Count	3
25% Hourly Count	0
10% Hourly Count	0
Lowest Hourly Count	0
Mean Hourly Count	23.9
SD of Mean Hourly Counts	84.3
SE of Mean Hourly Counts	1.1

[1] For charts, the Fishway Period was defined as May 14th Through July 9th. The earliest start of counts was May 14th in 1999, while the latest completion of counts was July 7th in 1991, 1996 and 2000. The period was carried to July 9th to keep graphing in

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