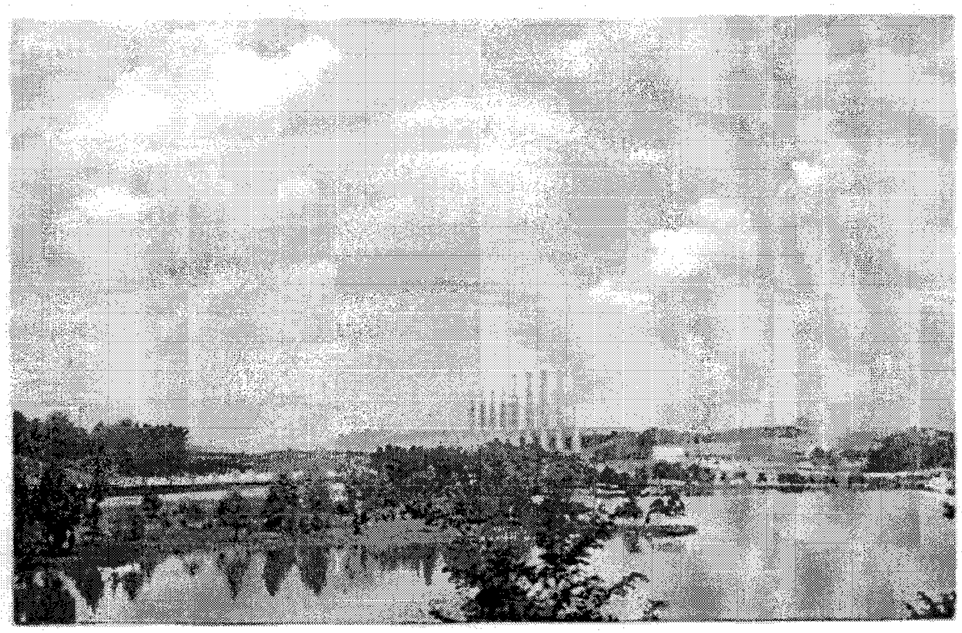
TENNESSEE VALLEY AUTHORITY

KINGSTON FOSSIL PLANT
NPDES PERMIT NO. TN0005452
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT KINGSTON FOSSIL PLANT DURING 2004 THROUGH 2006



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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BIP	Balanced Indigenous Population
CCW	Condenser Cooling Water
CWA	Clean Water Act
EA	Equivalent Adult
EPA	Environmental Protection Agency
EPRI	Formerly known as the Electric Power Research Institute
KIF	Kingston Fossil Plant
PF	Production Foregone
RFAI	Reservoir Fish Assemblage Index
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

Introduction

Kingston Fossil Plant (KIF), placed into operation in 1955, withdraws condenser cooling water (CCW) from Watts Bar Reservoir and is subject to compliance with the Tennessee Water Quality Act and the federal Clean Water Act (CWA). Section 316(b) of the CWA requires the location, design, construction, and capacity of cooling water intake structures to reflect the best technology available for minimizing adverse environmental impact. Impingement mortality is a component of 316(b) and is defined as an impact in which fish and/or shelfish are trapped or impinged against an intake screen and often killed in the process. In response to the Environmental Protection Agency (EPA) issuance of a 2004 rule for implementing Section 316(b) (a rule subsequently suspended in 2007) and in accordance with the Proposal for Information Collection submitted to the Tennessee Department of Environment and Conservation (TDEC) in 2005, Tennessee Valley Authority (TVA) conducted impingement monitoring at KIF from November 2004 through November 2006 to assess the effects of impingement on the aquatic community of Watts Bar Reservoir. This report presents impingement data collected from the CCW intake screens during 2004-2006 with comparisons to historical data collected during 1974-1978.

Per an agreement reached in September 2001 with TDEC, Division of Water Pollution Control, TVA performs Reservoir Fish Assemblage Index (RFAI) (Hickman and Brown 2002) sampling once every two years to demonstrate that KIF operation is not impacting the balanced indigenous population (BIP). TVA conducted these RFAI studies to evaluate fish communities in areas immediately upstream and downstream of KIF during the 2001, 2003, and 2005 (Scott 2006). The primary reason for gathering these data is to support the continuation of Section 316(a) thermal variance for KIF. However, the RFAI monitoring also gives an indication of the overall impact of plant operations on the reservoir fish assemblage and benthic community, including potential impacts from the plant's cooling water intake.

Plant Description

KIF is located on a peninsula formed by the Clinch and Emory River embayments of Watts Bar Reservoir approximately 4.4 km (2.7 miles) above the confluence of the Clinch and Tennessee Rivers (Figure 1). The final unit of the nine-unit plant was placed in commercial operation December 2, 1955, bringing the total capacity to 1,700 megawatts. With an average summer water temperature of 23.9°C (75.02°F), Units 1-4 each require 6.6 m^3/s (241 cfs) CCW and Units 5-9 each require 9.2 m^3/sec (324.8 cfs) for an approximate plant total flow of 73.3 m^3/s (2,587 cfs) for condenser cooling purposes.

The 18 condenser circulating water pumps each withdraw from separate suction pits. Water enters the intake structure through trashracks constructed of vertical 1.59 cm (5/8 in) steel bars with 9.21 cm (3-5/8 in) openings. The racks are periodically cleaned by a rake operated by the intake gantry crane. Following the trashracks, the CCW passes through the vertical traveling screens. These are constructed of 0.6 X 3 m (2 X 10 ft) screen panels of 12-gauge galvanized wire with 9.5 mm (3/8 in) square openings. The panels are fastened top to bottom to form an endless belt and attached to chains operating between sprockets at the bottom and drive sprockets supported on the intake deck. Debris and fish collected on the traveling screens are washed off into a sluice trench that extends the length of the pumping station deck and empties into a 68.6 cm (27 in) concrete pipe which conveys the screen backwash discharge underground in a southerly direction for 440 m (1,442 ft) to empty into the CCW discharge basin.

Intake Channel and Skimmer Wall

An intake channel extends 1,372 m (4,500 ft) from the pumping station to the original streambed of the Emory River in the Swan Pond Embayment of Watts Bar Reservoir (Figure 1). A 126 m (413 ft) long skimmer wall is positioned across the intake channel and extends 7.5 m (24 ft) below the water surface. The maximum depth of the intake channel is 12.5 m (40 ft).

The skimmer wall provides water at a substantially lower temperature to the plant's condensers during the summer months. A still further significant temperature reduction was obtained by the construction of a submerged dam or barrier on the Clinch River near kilometer 6.3 (mile 3.9), downstream from the mouth of the Emory River. The computed reduction in intake temperatures has been as much as 2.5°C (4.5°F), resulting in a substantial saving in fuel consumption at KIF. The dam is built of quarry-run limestone dumped into position from barges. The 1.8 m (6 ft) wide submerged dam crest is at an approximate elevation of 220 m (722 ft), which ensures an adequate navigation depth at all times.

Methods

Weekly impingement monitoring began on November 16, 2004, and continued through November 6, 2006. To simplify comparisons in this report, data from November 16, 2004, through November 8, 2005, will be referred to as Year-One, and from November 16, 2005, through November 6, 2006, as Year-Two.

To collect each sample, the plant intake screens were rotated and washed on a prearranged schedule by the plant Assistant Unit Operator to remove all fish and debris. After 24 hours, screens were again rotated and washed with an Aquatic Monitoring and Management crew on site. Fish and debris were collected in a catch basket constructed of 9.5 mm (3/8 in) mesh at the end of the sluice pipe where the monitoring crew removed and processed the sample. Fish were sorted from debris, identified, separated into 25 mm (1 in) length classes, enumerated, and weighed. Data were recorded by one member of the crew and checked and verified (signed) by the other for quality control. Quality Assurance/Quality Control procedures for impingement sampling (TVA 2004) were followed to ensure samples were comparable with historical impingement mortality data.

Historical impingement sampling was conducted by TVA from August 1974 through April 1975 (TVA 1976). Additional sampling was conducted three days per week by Oak Ridge National Laboratory personnel during the periods November 1976 through April 1977 and September 1977 through April 1978 (TVA 1981).

Moribund/Dead Fish

The majority of fish collected from a 24-hr screen wash were dead when processed. Incidental numbers of fish which appeared to have been dead for more than 24 hours (i.e., exhibiting pale gills, cloudy eyes, fungus, or partial decomposition) were not included in the sample. Also, during winter, threadfin shad occasionally suffer die-offs and are often impinged after death or in a moribund state (Griffith and Tomljanovich 1975, Griffith 1978). If these die-off incidents were observed, they were documented to specify that either all, or a portion of impinged threadfin shad during the sample period were due to cold-shock and would not have been impinged otherwise. Any fish collected alive were returned to the reservoir after processing.

Data Analysis

Impingement data from weekly 24-hour samples were extrapolated for each week to provide estimates of total fish impinged by week and an estimate for each year of the study. In rare situations when less than a 24-hr sample occurred, data were normalized to 24 hrs.

Historical data collected during 1976-1978 (TVA 1981) were collected during three days per week and weekly estimates were extrapolated accordingly. For annual estimates, data collected from September or November through April were extrapolated to annual totals impinged. These annual estimates, even though based on less than full-year samples, should be relatively comparable to current data presented here (2004-2006) since sampling covered the period of peak impingement.

To facilitate the implementation of and compliance with the EPA regulations for Section 316(b) of the CWA prior to its suspension by EPA, impingement losses of fish were evaluated by extrapolating the losses to equivalent reductions of adult fish, or of biomass production available to predators. In conformance with methods utilized by EPA in its Technical Development Documents in support of the Phase II Rule (EPA 2004), EPRI (formerly known as the Electric Power Research Institute) has identified two models (Barnthouse 2004) for extrapolating losses of fish eggs, larvae, and juveniles at intake structures to numbers or production of older fish. The Equivalent Adult (EA) model quantifies entrainment and impingement losses in terms of the number of fish that would have survived to a given future age. The Production Foregone (PF) model applies to forage fish species to quantify the loss from entrainment and impingement in terms of potential available forage for consumption by predators. Required inputs to the models are site-specific data on the distribution and abundance of fish populations vulnerable to entrainment and impingement. TVA in turn also used these models to determine the "biological liability" of the CCW intake structure.

Results and Discussion

Numbers of fish collected by year and species are presented in Table 1. During Year-One and Year-Two of recent impingement monitoring, 26,511 and 32,171 fish were collected, respectively (Table 1). The total number of species collected each year was similar with 30 species in Year-One and 33 in Year-Two (Table 1).

Total numbers estimated impinged by extrapolation by species and year for Year-One and Year-Two are presented in Table 2. Threadfin shad comprised 95% of the two-year total followed by gizzard shad, freshwater drum, and channel catfish at 1% each (Table 2).

In Table 3, the estimated total fish impinged and percent of the annual total by month for both years are presented. The estimated annual impingement extrapolated from weekly samples was 185,577 during Year-One and 225,197 during Year-Two (Table 4). Peak impingement occurred during October through December at KIF (Table 3 and Figure 2). The proportion of total fish impinged during October through December each year was 86% in Year-One and 69% in Year-Two.

A plot of daily (24-hour average) ambient intake water temperatures for KIF during each of the two years sampled is presented in Figure 3. Lower temperatures appear to be generally correlated with peak impingement as previously reported in numerous studies

(EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978, McLean et al., 1980). A recent study by Fost (2006) also indicated that cold-stressed threadfin and gizzard shad can be classified as either impaired or moribund. Impaired shad could recover if environmental conditions improved and would therefore not die if not impinged. Moribund fish, on the other hand, are assumed to not be able to recover and die regardless of impingement. Fost's data indicated that threadfin shad began to exhibit reduced or impaired swimming performance at 7.5°C (45.5°F). Figure 3 also presents average KIF intake temperatures from 1986-2006 for comparison. While winter temperatures during both Year-One and Year-Two dropped below the Fost threshold, these temperatures did not appear to coincide with specific impingement peaks in this study period (Figure 2).

Threadfin and/or gizzard shad typically comprise over 90% of fish impinged on cooling-water intake screens of thermal power stations in the Southeastern U. S. (EPRI 2005). They also comprise an average of 35%-56% of total fish biomass where they occur (Jenkins 1967). No state or federal protected fish species were collected or are known to occur in the vicinity of KIF.

Application of the EA and PF models to the estimated total numbers of impinged fish indicated that 7,893 and 8,216 in Year-One and Year-Two, respectively (Table 4), would have been expected to survive to either harvestable (EA) size/age or to provide forage (PF). This reduced number is considered the "biological liability" resulting from plant CCW impingement mortality based on the guidance developed for the now suspended 316(b) regulations.

As part of TVA's Vital Signs Monitoring Program (Scott 2006), resident fish communities were sampled in Watts Bar Reservoir upstream and downstream of KIF in 2001, 2003, and 2005. Results indicated "Good" fish communities at both sites and TVA concluded that operations at KIF are not impacting the fish community of Watts Bar Reservoir.

Comparison with Historical Data

Estimated impingement from historical sampling conducted during 1974-1978 (including the extrapolated annual totals for number of fish impinged) and the numbers estimated after EA and PF reduction are presented in Table 4. The extrapolated total for 1974-1975 was 335,076; for 1976 was 1,163,232; and for 1977-1978 was 2,881,039. Table 5 presents the percent composition by number of major species impinged during 1974-1978 and 2004-2006. Threadfin shad dominance was consistent at between 95% and 98% except during 1977-1978 when threadfin shad comprised only 48% of the total. Peak impingement during October through January for the historical data (Figure 4) agrees with that observed during 2004-2006 (Figure 3). For the historical study it was concluded that based on data collected during 1974-1975, impingement of fish at KIF resulted in no adverse environmental impact (TVA 1976).

The Watts Bar Reservoir area experienced an unusually cold winter during 1976-1977 which caused a significant die-off of threadfin shad from cold shock. McLean, et al. (1979, 1980) conducted studies at KIF to determine (1) the physical and biological causes of impingement of threadfin shad and (2) the effects of impingement on the threadfin shad population and on the threadfin shad-predator population of Watts Bar Reservoir. Impingement samples taken three times per week from mid-November 1976 through April 1977 produced an estimate of 240,000 threadfin shad impinged during this 5-1/2 month period. The impingement rate for threadfin shad was strongly associated

with temperature. Approximately 3,000 threadfin shad were impinged per day during November. On December 7, water temperature decreased from 7°C (44.6°F) to 4°C (39.2°F) and the following day 42,000 threadfin were impinged. Water temperature later decreased to 2.7°C (36.86°F) which is below the lower lethal limit for threadfin shad (Griffith and Tomljanovich 1975) and stressed shad were observed in large numbers in the KIF intake channel. Dead and moribund threadfin shad were observed in shallow embayments and along the reservoir shoreline during this period. The heated CCW discharge channel at KIF was the only place that healthy threadfin shad were observed throughout the winter (Schneider and Tuberville 1981).

Despite the obvious significant mortality in the threadfin shad population that was estimated at 95% in Watts Bar Reservoir, more than twice as many threadfin shad were impinged the following winter (1977-1978). From late September 1977 through the end of April 1978, an estimated 560,000 threadfin shad were impinged at KIF (McLean et al., 1980). As observed during the previous year, almost all threadfin shad were impinged before January 25.

Total numbers of all fish estimated impinged during the winter of 1977-1978 (2,881,039) were also higher (Table 4). While the percent composition of threadfin shad was lower (48%) during this period, skipjack herring composition (28%) as well as gizzard shad at 22% was significantly higher during 1977-1978 (Table 5). The fact that threadfin shad demonstrated the ability to rebound from a reservoir-wide, non-plant induced mortality (cold stress) indicates that impingement mortality at KIF does not represent an adverse impact to the threadfin shad population of Watts Bar Reservoir.

Summary and Conclusions

Impingement of fish by the KIF CCW was monitored during 2004-2006 and compared with historical data collected during 1974-1978. Total numbers of fish estimated to be impinged annually were lower during 2004-2006 than during 1974-1978. The average number estimated to be impinged during 2004-2006 (two years) was 205,387, compared to 1,459,782 per year during 1974-1978. Annual fish impingement totals were noticeably lower during 2005-2006 than during historical monitoring periods (1974-1978). RFAI scores in 2003 and 2005 of 43 and 44 for downstream and upstream samples, respectively, indicated good fish communities at both sites. Resident fish communities at these locations reached 71.1% and 73.3% of their potential scores for downstream and upstream sites, respectively. All the score averages for the Tennessee River stations in the vicinity of KIF indicate "Good" fish communities, and the nearest downstream Watts Bar Reservoir average met the adjusted 70% screening criteria for designation as BIP.

These factors as described above provide evidence of a balanced and healthy fish community and indicate that the KIF CCW intake has not adversely impacted the Watts Bar Reservoir biota.

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Table 1. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2004-2006 at TVA's Kingston Fossil Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Petromyzontidae	*Ichthyomyzon castaneus*	Chestnut lamprey	2	0
Clupeidae	*Alosa pseudoharengus*	Alewife	65	36
	Dorosoma cepedianum	Gizzard shad	514	308
	Alosa chrysochloris	Skipjack herring	2	68
	Dorosoma petenense	Threadfin shad	25,320	30,491
	D. petenense x *D. cepedianum*	Hybrid shad	1	0
Cyprinidae	*Pimephales notatus*	Bluntnose minnow	1	6
	Pimephales vigilax	Bullhead minnow	0	3
	Pimephales promelas	Fathead minnow	1	0
	Cyprinella spiloptera	Spotfin shiner	0	1
	Campostoma oligolepis	Largescale stoneroller	1	0
	Notropis atherinoides	Emerald shiner	0	3
	Notropis photogenis	Silver shiner	1	0
Catostomidae	*Hypentelium nigricans*	Northern hogsucker	5	3
	Minytrema melanops	Spotted sucker	1	0
Ictaluridae	*Ictalurus furcatus*	Blue catfish	13	38
	Ictalurus punctatus	Channel catfish	210	137
	Pylodictis olivaris	Flathead catfish	26	5
	Ameiurus natalis	Yellow bullhead	3	0
Atherinidae	*Labidesthes sicculus*	Brook silverside	0	1
Moronidae	*Morone saxatilis*	Striped bass	18	29
	Morone chrysops	White bass	0	3
	Morone mississippiensis	Yellow bass	58	129
Centrarchidae	*Lepomis cyanellus*	Green sunfish	4	0
	Lepomis macrochirus	Bluegill	61	211
	Lepomis gulosus	Warmouth	0	3
	Lepomis megalotis	Longear sunfish	0	5
	Lepomis auritus	Redbreast sunfish	2	7
	Lepomis microlophus	Redear sunfish	0	1

Table 1. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Centrarchidae	*Ambloplites rupestris*	Rock bass	9	2
	Micropterus dolomieu	Smallmouth bass	1	2
	Micropterus punctulatus	Spotted bass	14	13
	Micropterus salmoides	Largemouth bass	1	4
	Pomoxis annularis	White crappie	2	8
	Pomoxis nigromaculatus	Black crappie	0	6
Percidae	*Percina sciera*	Dusky darter	0	2
	Etheostoma blennioides	Greenside darter	0	1
	Percina caprodes	Logperch	22	20
	Perca flavescens	Yellow perch	0	1
	Sander canadense	Sauger	2	4
	Sander vitreus	Walleye	1	0
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	150	620
		Total number of fish	**26,511**	**32,171**
		Total number of species	**30**	**33**

Table 2. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Kingston Fossil Plant During 2004-2006.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	**Year-One**	**Year-Two**	**Average**	**Year-One**	**Year-Two**	**Total**	
Threadfin shad	177,240	213,451	**195,346**	525,959	511,644	**1,037,603**	95
Freshwater drum	1,050	4,361	**2,706**	39,326	204,736	**244,062**	1
Gizzard shad	3,598	2,149	**2,874**	40,656	26,922	**67,578**	1
Channel catfish	1,470	959	**1,215**	7,112	9,751	**16,863**	1
Bluegill	427	1,477	**952**	5,061	9,345	**14,406**	T
Yellow bass	406	854	**630**	8,610	14,924	**23,534**	T
Alewife	455	231	**343**	9,261	1,652	**10,913**	T
Skipjack herring	14	476	**245**	8,260	5,110	**13,370**	T
Striped bass	126	217	**343**	1,050	1,400	**2,450**	T
Blue catfish	91	217	**308**	1,001	6,818	**7,819**	T
Logperch	154	140	**294**	2,030	1,652	**3,682**	T
Spotted bass	238	0	**238**	1,162	0	**1,162**	T
Flathead catfish	182	35	**217**	2,674	224	**2,898**	T
Rock bass	63	14	**77**	1,435	322	**1,757**	T
White crappie	14	56	**70**	56	4,165	**4,221**	T
Redbreast sunfish	14	49	**63**	42	105	**147**	T
Northern hogsucker	35	21	**56**	245	147	**392**	T
Bluntnose minnow	7	42	**49**	7	168	**175**	T
Sauger	14	28	**42**	11,375	21,119	**32,494**	T
Black crappie	0	42	**42**	0	854	**854**	T
Largemouth bass	7	28	**35**	35	483	**518**	T
Longear sunfish	0	35	**35**	0	1,939	**1,939**	T
White bass	0	35	**35**	0	3,773	**3,773**	T
Green sunfish	28	0	**28**	91	0	**91**	T
Smallmouth bass	7	21	**28**	35	147	**182**	T
Yellow bullhead	21	0	**21**	315	0	**315**	T
Emerald shiner	0	21	**21**	0	63	**63**	T
Warmouth	0	21	**21**	0	1,218	**1,218**	T
Chestnut lamprey	14	0	**14**	875	0	**875**	T
Bullhead minnow	0	14	**14**	0	70	**70**	T
Dusky darter	0	14	**14**	0	420	**420**	T
Fathead minnow	7	0	**7**	35	0	**35**	T
Hybrid shad	7	0	**7**	35	0	**35**	T

Table 2. (continued)

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Total	
Largescale stoneroller	7	0	**7**	35	0	**35**	T
Silver shiner	7	0	**7**	70	0	**70**	T
Spotted sucker	7	0	**7**	4,410	0	**4,410**	T
Walleye	7	0	**7**	4,305	0	**4,305**	T
Brook silverside	0	7	**7**	0	56	**56**	T
Greenside darter	0	7	**7**	0	56	**56**	T
Redear sunfish	0	7	**7**	0	70	**70**	T
Spotfin shiner	0	7	**7**	0	7	**7**	T
Yellow perch	0	7	**7**	0	315	**315**	T
Total	**185,577**	**225,197**		**675,563**	**829,675**		

T = Trace < one percent

Table 3. Numbers of Fish Impinged at Kingston Fossil Plant by Month and Percent of Annual Total During Year-One and Year-Two and for Both Years Combined.

Month	Total Number of Fish Impinged Year-One	Percent of Annual Total	Total Number of Fish Impinged Year-Two	Percent of Annual Total	Years One and Two Combined	Percent of Two-Year Total
Nov	9,009	34	4,291	14	13,300	23
Dec	10,623	40	12,980	42	23,603	41
Jan	322	1	1,023	3	1,345	2
Feb	128	0	1,729	6	1,857	3
Mar	148	1	6,132	20	6,280	11
Apr	88	0	252	1	340	1
May	51	0	62	0	113	0
Jun	25	0	94	0	119	0
Jul	630	2	242	1	872	2
Aug	1,989	8	1,702	5	3,691	6
Sep	563	2	534	2	1,097	2
Oct	2,935	11	3,130	10	6,065	11
Total	**26,511**		**32,171**		**58,682**	

Table 4. Total Numbers of Fish Estimated Impinged by Year at Kingston Fossil Plant and Numbers Following Application of Equivalent Adult and Production Foregone Models.

	1974-1975	1976*	1977-1978	2004-2005	2005-2006
Extrapolated Annual Number Impinged	335,076	1,163,232	2,881,039	185,577	225,197
Number after EA and PF Reduction	5,862	7,077	20,622	7,893	8,216

*1976 data extrapolated from seven samples between 11/19/76–12/01/76

Table 5. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Kingston Fossil Plant During 1974-1978 and 2004-2006.

	1974-1975		1976*		1977-1978		2004-2005		2005-2006	
Species Composition	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**
Threadfin shad	95	89	98	94	48	45	96	89	95	86
Skipjack herring	2	2	-	-	28	26	-	-	-	-
Gizzard shad	-	-	-	-	22	20	-	-	1	1
Freshwater drum	1	2	2	3	1	3	1	1	2	5
Channel catfish	-	-	-	-	-	-	1	1	-	1
Bluegill	1	2	-	-	-	-	-	1	1	2
Logperch	-	2	-	-	-	-	-	1	-	-
White bass	-	1	-	-	-	2	-	-	-	-
Yellow bass	-	-	-	-	-	1	-	2	-	2
White crappie	-	-	-	-	-	1	-	-	-	-
Striped bass	-	-	-	-	-	-	-	1	-	1
Alewife	-	-	-	-	-	-	-	1	-	-
Sauger	-	-	-	1	-	-	-	1	-	1
Total	**99**	**99**	**100**	**98**	**99**	**98**	**100**	**100**	**99**	**99**

***1976 data from seven samples between 11/19/76–12/01/76**

Dash denotes not a major species during that year.

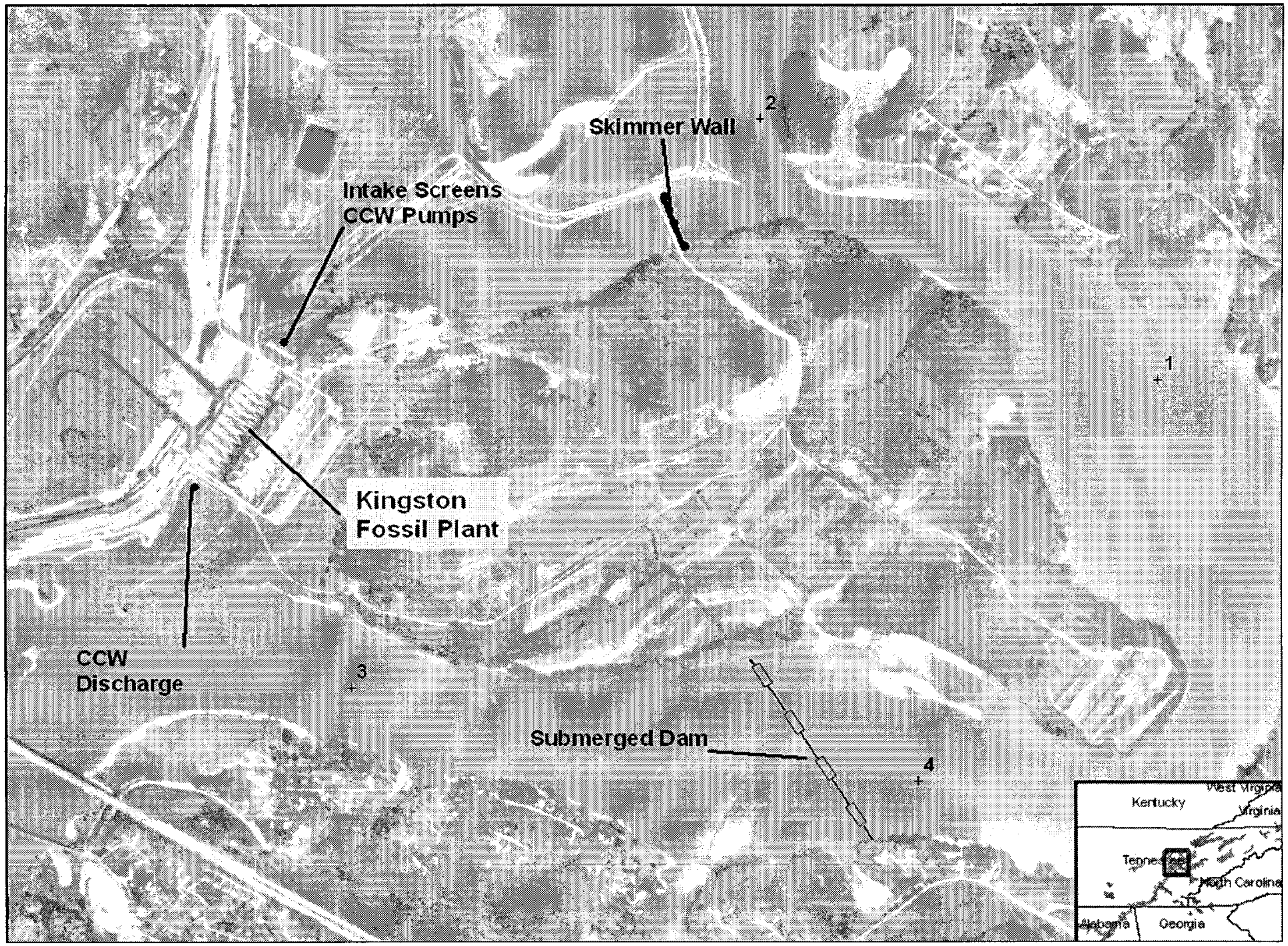

Figure 1. Aerial photograph of Kingston Fossil Plant including CCW intake structure, skimmer wall, intake basin, and discharge channel.

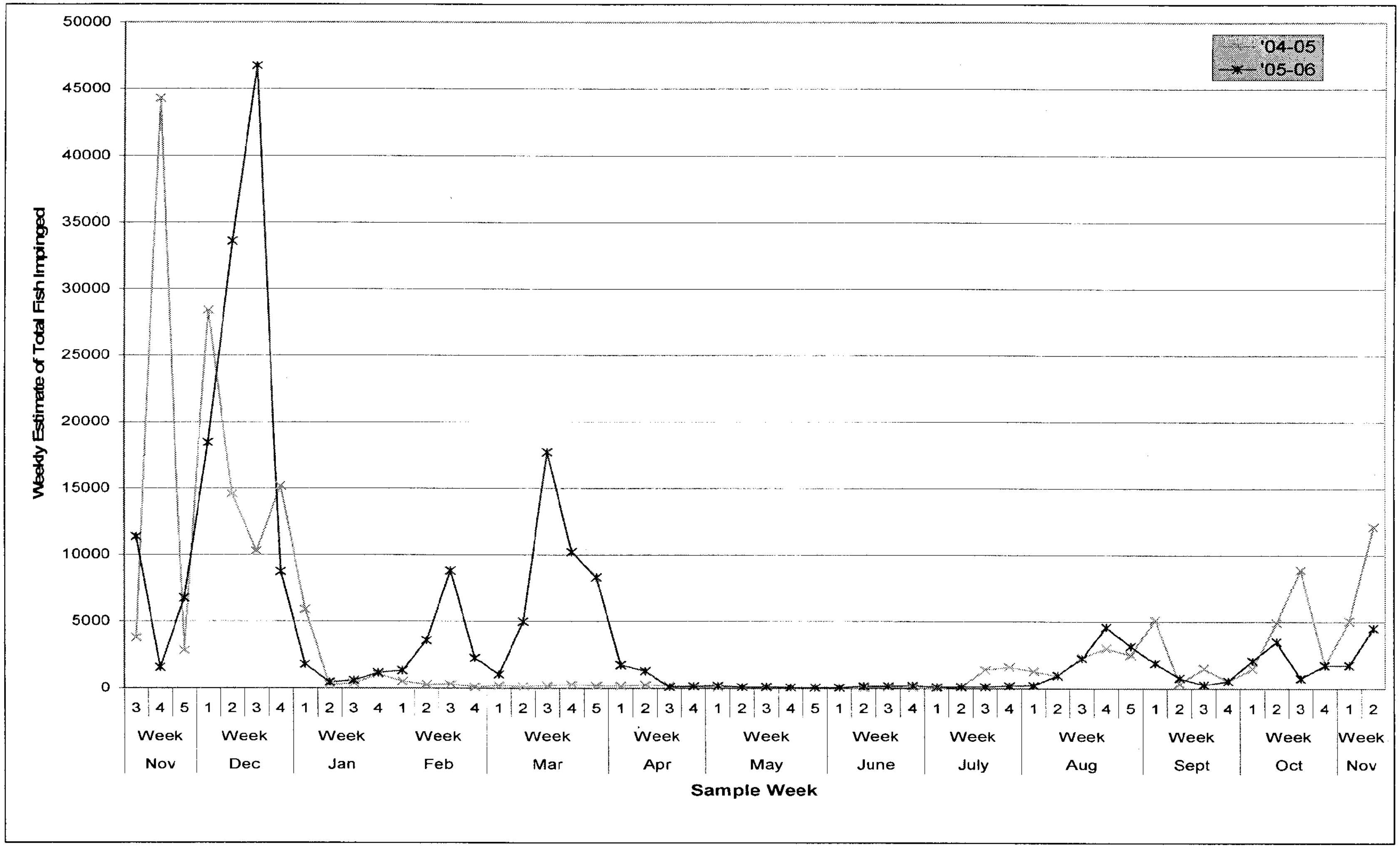

Figure 2. Estimated weekly fish impingement at TVA's Kingston Fossil Plant during 2004-2006.

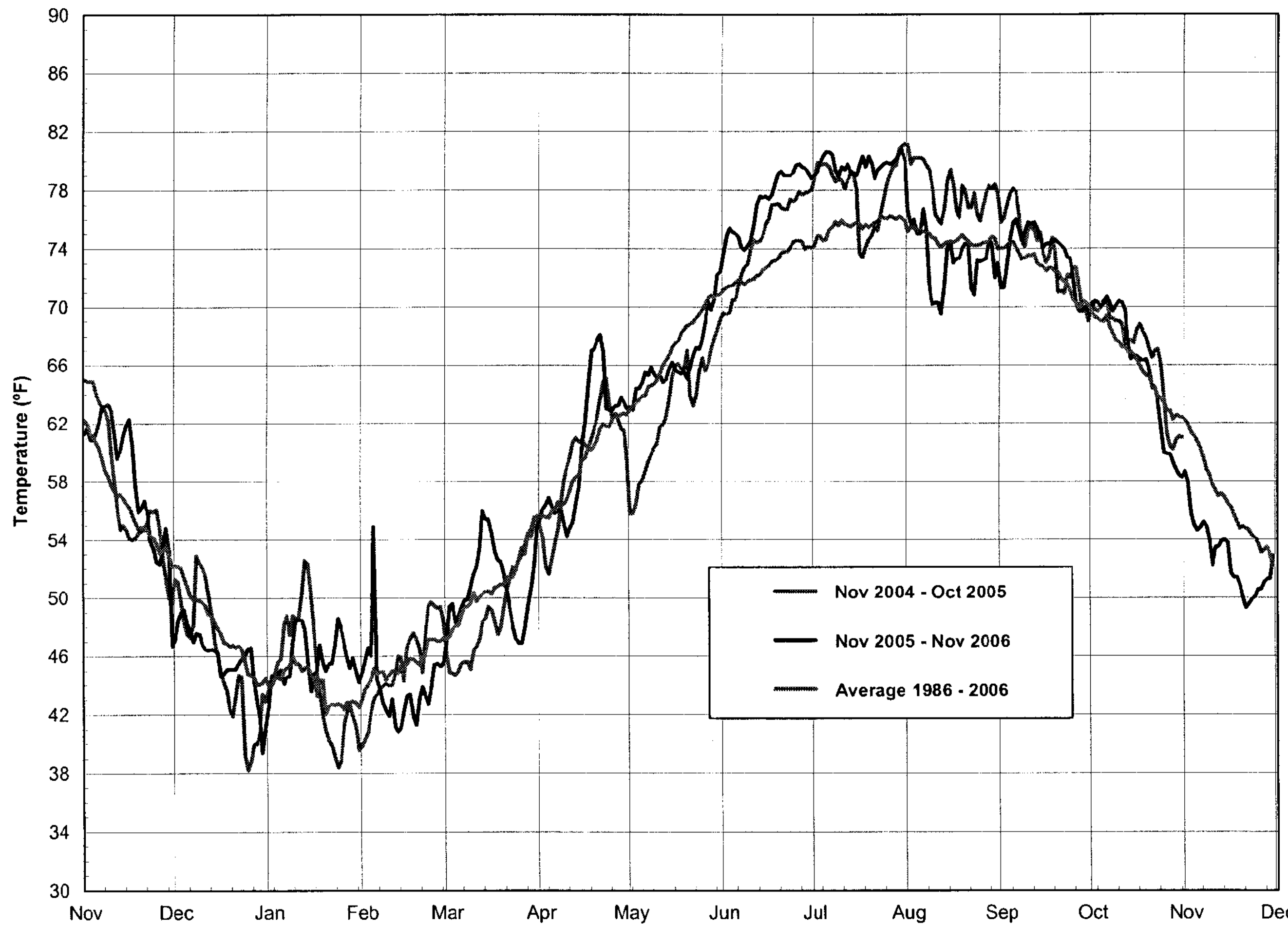

Figure 3. Ambient daily (24-hr avg) water temperature at Kingston Fossil Plant intake during historical (1986-2006) and recent (2004-2006) impingement monitoring.

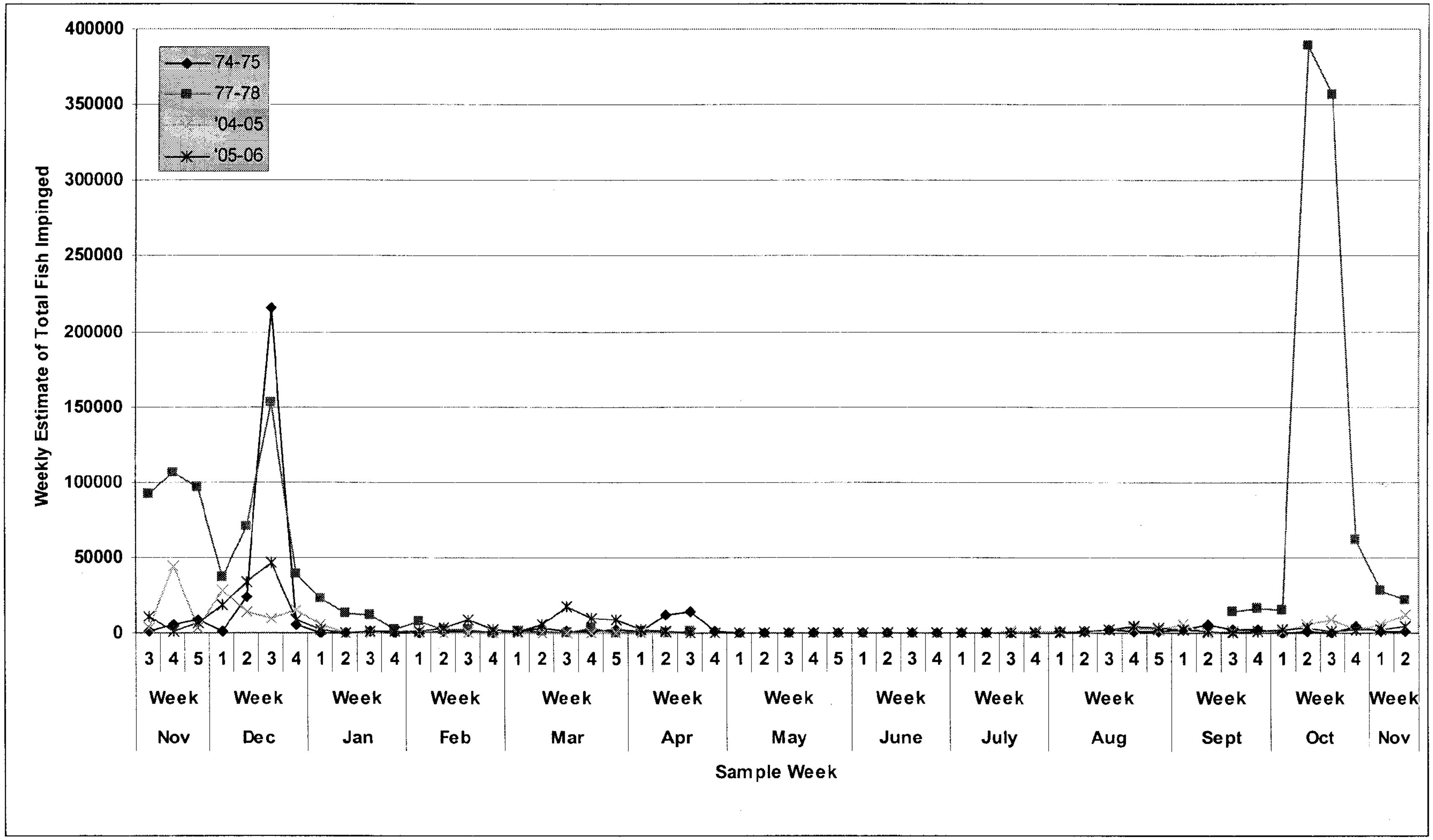

Figure 4. Comparison of estimated weekly fish impingement at TVA's Kingston Fossil Plant during historical and recent monitoring periods.