EDM

A60 071212 007
Env. Document Type: NPDES Correspondence

January 2, 2008

Mr. Paul E. Davis, Director
Division of Water Pollution Control
Tennessee Department of Environment and Conservation
6th Floor, L&C Annex
401 Church Street
Nashville, Tennessee 37243-1534

Dear Mr. Davis:

TENNESSEE VALLEY AUTHORITY (TVA) – ALLEN FOSSIL PLANT (ALF) – NPDES PERMIT NO. TN0005355 – BULL RUN FOSSIL PLANT (BRF) – NPDES PERMIT NO. TN0005410 – CUMBERLAND FOSSIL PLANT (CUF) – NPDES PERMIT NO. TN0005789 – GALLATIN FOSSIL PLANT – NPDES PERMIT NO. TN0005428 – JOHN SEVIER FOSSIL PLANT (JSF) – NPDES PERMIT NO. TN0005436 – JOHNSONVILLE FOSSIL PLANT (JOF) – NPDES PERMIT NO. TN0005444 – KINGSTON FOSSIL PLANT (KIF) – NPDES PERMIT NO. TN0005452 – SUBMISSION OF 316(B) BIOLOGICAL MONITORING DATA

TVA is herewith submitting the biological monitoring data for the subject facilities that were collected in accordance with the Proposal for Information Collection (PIC) plans as developed under the 316(b) requirements prior to their suspension by EPA on March 20, 2007. The specific permit references for this requirement are given below. Please note that the KIF permit was issued prior to the effective date of the 316(b) Phase II rule and does not include the requirement to submit 316(b) monitoring data.

Plant	NPDES Permit No.	Requirement Reference
ALF	TN0005355	Part V
BRF	TN0005410	Part III, L.
CUF	TN0005789	Part V
GAF	TN0005428	Part III, L.
JSF	TN0005436	Part V
JOF	TN0005444	Part III, M.
KIF	TN0005452	N/A

With the exception of JSF, TVA has concluded that the cooling water intakes at these facilities have not adversely impacted fish and shellfish communities in the source water bodies. For JSF, no changes in the fish community upstream of the plant have been observed or detected other than those previously identified under the detention dam mitigation indicating no further adverse environmental impact from plant operations.

If you need further information, please contact Mike Stiefel at (423) 751-6844 in Chattanooga or by email at mbstiefel@tva.gov.

I certify, under penalty of law, that I have personally examined and am familiar with the information submitted herein; and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. See 18 U.S.C. 1001 and 33 U.S.C. 1319. (Penalties under these statutes may include fines up to $10,000 and or maximum imprisonment of between 6 months and 5 years.)

Sincerely,

Preston D. Swafford
Executive Vice President
Fossil Power Group
3K Lookout Place

GGP:CMA:MBS:PAB
Enclosures
cc (Enclosures):

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Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402-2801

Preston D. Swafford
Executive Vice President
Fossil Power Group

January 2, 2008

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Sincerely,

Preston D. Swafford
Executive Vice President
Fossil Power Group
3K Lookout Place

Enclosures

Review/Concurrence Form

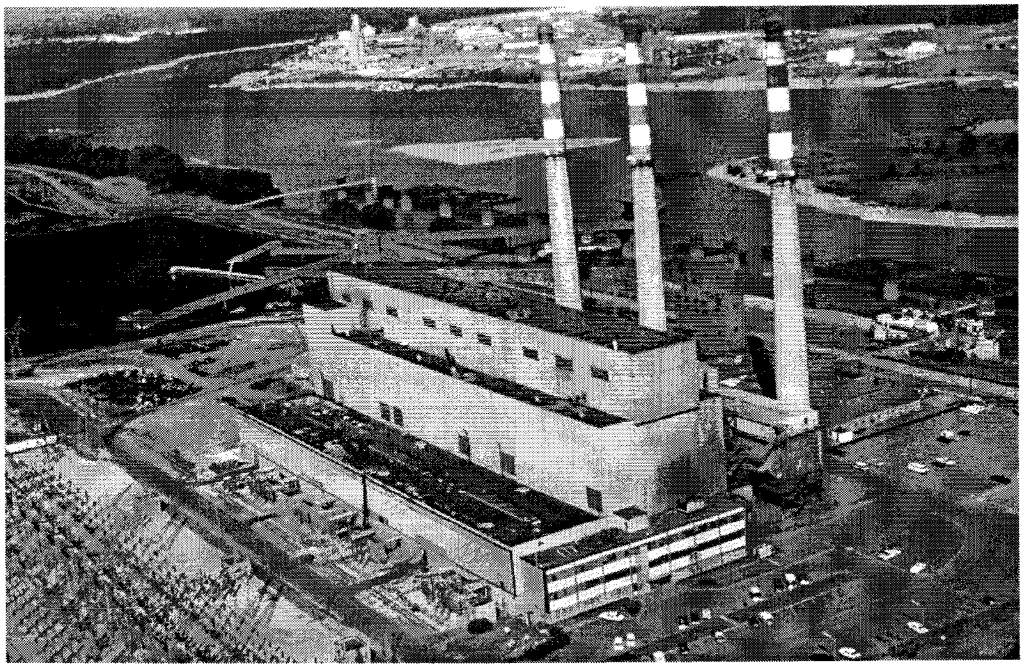
Subject: Letter to TDEC - ALF, BRF, CUF, GAF, JSF, JOF, and KIF NPDES Permit Biological Monitoring Data			
Document to be signed by: Preston D. Swafford			
Document summary/purpose: • ALF, BRF, CUF, GAF, JSF, JOF, and KIF NPDES Permit submission of 316(b) Biological Monitoring Data			
Originating Organization	Environmental Compliance		
Document Prepared By	Michael B. Stiefel		
EDMS No. A60 071212 007		Date December 14, 2007	CTS Number
File No.	1/2/2008 DUE DATE: ~~12/24/2007~~		
INSTRUCTIONS: Please call Pat Bell when signed at 3357. Thanks.			

CONCURRENCES		
Name	Signature - Comment	Date
Mike Stiefel	Michael B. Stiefel	12/17/07
Cynthia Anderson	Cynthia Anderson	12/17/07
Gordon Park		
John Kammeyer	[signature]	12/19/07

TENNESSEE VALLEY AUTHORITY

ALLEN FOSSIL PLANT
NPDES PERMIT NO. TN0005355
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT ALLEN FOSSIL PLANT DURING 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

ALF	Allen Fossil Plant
CCW	Condenser Cooling Water
CWA	Clean Water Act
EA	Equivalent Adult
EPA	Environmental Protection Agency
EPRI	Formerly known as the Electric Power Research Institute
PF	Production Foregone
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

Introduction

Allen Fossil Plant (ALF), placed into operation in 1959, withdraws condenser cooling water (CCW) from McKellar Lake near Memphis, Tennessee, 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 potential mechanism for adverse impacts and is defined as the condition in which fish and/or shellfish 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 a Proposal for Information Collection submitted to the Tennessee Department of Environment and Conservation (TDEC) in 2005, Tennessee Valley Authority (TVA) conducted impingement monitoring at ALF from March 2005 through March 2007 to assess the effects of impingement on the aquatic community of McKellar Lake and the adjacent Mississippi River. This report presents impingement data collected from the CCW intake screens during 2005-2007 with comparisons to historical data collected during 1974-1976.

Plant Description

ALF, located on the south shore of McKellar Lake near Memphis, Tennessee (Figure 1), is a three-unit, coal-fired plant having a maximum generating capacity of 990 megawatts. CCW is withdrawn directly from McKellar Lake at a maximum rate of approximately 22 m^3/s (777 cfs). McKellar Lake is an oxbow lake approximately 12.6 km (7.8 miles) long which empties into the Mississippi River at Mississippi River Kilometer 1168 (MRM 726). Surface elevation varies with the Mississippi River between 52.5 m (172 ft) and 70.5 m (231 ft) above MSL. Accordingly, surface area of McKellar Lake ranges from approximately 364 (899.5 acres) to 1,133 ha (2,799.7 acres).

Circulating Water System

River water is used as the main coolant in the station, carrying off rejected heat from various items of station equipment. The CCW entrains a large amount of debris which must be removed; this is especially true in the high-water season. The raw water entering the circulating water pump house passes through a trashrack which removes all the larger pieces of flotsam which might damage the pump mechanisms. The partially screened water flows through the sluice gates into the circulating water intake chamber where all remaining refuse large enough to clog the condenser is removed by traveling water screens, sized to prevent passage of particles greater than 9.5 mm (3/8 in) in size. The refuse caught on the screen is lifted up to the operating floor level where it is washed into a sluice trough by high pressure from the screen wash pumps. This water is drawn from the pump house discharge manifold and is strained before use by the screen wash water strainers.

Circulating Water Pumps

Depending on river level, water temperature, and the number of units in service, circulating water demands are met by one to six circulating water pumps operating in parallel.

Traveling Screens

Nine Link-Belt Company BEJ Model 54A traveling water screens are installed in the circulating water intake tunnel to remove refuse and other material. They are arranged in groups of threes, each group serving a single pump intake chamber. Twin spray systems are provided for screen washing so that should failure occur in one system due to nozzle closing or other malfunctioning, the second system will be immediately available. The spray is used to wash impinged fish and debris accumulated on the screen into the refuse trough. The screens have a capacity of 151 m^3/min (40,000 gpm) through a clean screen at the low water elevation of 179 feet (55 m) (depth of 3 m [10 ft]) with a maximum water velocity of 1.9 fps (0.6 m^3/s). The refuse caught on the screen is lifted up to the operating floor level where it is washed into a sluice trough by a high pressure from the screen wash pumps. This water is drawn from the pump house discharge manifold and is strained before use by the screen wash water strainers.

Methods

Weekly impingement monitoring for this investigation began on March 16, 2005, and continued through March 6, 2007. To simplify comparisons in this report, data from March 16, 2005 through March 08, 2006 will be referred to as Year-One, and from March 15, 2006 through March 06, 2007 as Year-Two. To collect each sample, the plant intake screens were rotated and washed by the assistant unit operator to remove all fish and debris. After 24 hours, screens were again rotated and washed with Aquatic Monitoring and Management crew on site. Fish were collected in the catch basket constructed of 9.5 mm (3/8 in) mesh at the end of the sluice channel 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 2, 1974 through July 30, 1976 (TVA 1976).

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 impinged after death or in a moribund state (Griffith and Tomljanovich 1975, Griffith 1978). If these 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. Additionally, if threadfin shad were observed dying in McKellar Lake from cold-shock, this was documented to indicate cold-shock as the primary cause of unusually high impingement of this species. Any fish collected alive were returned to the lake after processing.

Data Analysis

Impingement data from weekly 24-hr samples were extrapolated to a weekly total from the one day sample to provide estimates of total fish impinged by week and a total value for Year-One and Year-Two of the study. In rare situations when less than a 24-hr sample was possible, data were normalized to 24 hours.

To facilitate the implementation of and compliance with EPA's regulations for Section 316(b) of the CWA (Federal Register Vol. 69, No. 131; July 9, 2004), impingement losses of fish were evaluated by converting the losses to equivalent reductions of adult fish, or of biomass production available to predators. EPRI (formerly 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 was applied to forage fish species to quantify the loss from entrainment and impingement in terms of potential forage available 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 also used these models to determine the "biological liability" of the CCW intake structure.

Results and Discussion

Numbers collected by species and year are presented in Table 1. During Year-One and Year-Two of the current impingement monitoring, 51,115 and 13,217 fish were collected, respectively, from weekly screen-wash samples. The number of species impinged was 37 and 28 during the first and second year, respectively (Table 1).

Gizzard shad comprised 37% of the total number of fish collected for both years combined, followed by skipjack herring (25%), freshwater drum (14%), silver carp, and threadfin shad at (11%) each (Table 2). Estimated fish impingement for Year-One was 357,805. During Year-Two sampling, the estimated total number of impinged fish decreased to 92,519 (Table 2). The estimated total numbers of fish impinged and percent by month for both years are presented in Table 3. At ALF, peak impingement occurred during December through March (Figure 2). The proportion of total fish impinged during December through March each year was 80% in Year-One and 68% in Year-Two. The highest total estimated number impinged in one sample (91,602) was observed on December 21, 2005, (Figure 2) and was comprised predominately (81%) of skipjack herring.

Plotted daily ambient intake temperatures for ALF (24-hour average) during each of the two years sampled (Figure 3) appear to be generally correlated with peak impingement as previously reported by numerous studies (EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978, McLean et al., 1980). Figure 3 also presents average ALF intake temperatures from 1986 through 2006 for comparison.

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). A recent study by Fost (2006) indicated that cold-stressed threadfin and gizzard shad can be classified as either <u>impaired</u> or <u>moribund</u>. 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). Intake temperatures at ALF during December through February both years fell below Fost's threshold (Figure 3); however, large numbers of threadfin shad were not impinged. Unlike species composition observed at most other TVA fossil sites, threadfin shad ranked third behind gizzard shad and skipjack herring in numbers impinged at ALF (Table 2). Cove rotenone surveys conducted by TVA in 1979 and 1980 (Kay and Lowery 1981) found only two and 15 threadfin shad per hectare in the two years, respectively. The authors suggested that fish populations in McKellar Lake are likely influenced significantly by seasonal water level fluctuations and migration of riverine fishes into and out of McKellar Lake from and to the Mississippi River.

Application of the EA and PF models reduced the total estimated impingement liability to 63,166 and 15,050 fish during Year-One and Year-Two, respectively (Table 4).

Comparison with Historical Impingement Data

Impingement monitoring as part of the initial 316(b) demonstration at ALF was conducted during August 2, 1974, through July 30, 1976 (TVA 1976). Estimated mean annual impingement for the two years was 769,431 fish (TVA 1976). Results of historical impingement monitoring are summarized and compared with results of this study in Table 4. Gizzard shad dominated the composition during 1974-1975 and 1975-1976, (63% and 60%) respectively, followed by threadfin shad and freshwater drum (Table 5). The conclusion from the original 316(b) investigation (TVA 1976) was that impingement levels observed at ALF would not be expected to adversely impact the fish population in the Mississippi River and/or McKellar Lake.

Summary and Conclusions

Impingement of fish by ALF CCW was monitored during 2005-2007 and compared with historical data collected during 1974 -1976. The average of the two year study for annual estimated impingement for Year-One and Year-Two (225,162) was significantly lower than the average (795,967) for two years of historical monitoring conducted during 1974-1976. The application of the EA and PF models resulted in a significant reduction of the total estimated impingement liability to 63,166 and 15,050 fish during Year-One and Year-Two, respectively.

Impingement of fish at ALF over the 48-year period of operation has not had an apparent adverse impact on the fish community of McKellar Lake. The fact that McKellar Lake is continuously open to fish migration into and out of the Mississippi River would likely obscure any effect from plant impingement.

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Table 1. List of Fish Species by Family, Scientific and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Allen Fossil Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Petromyzontidae	*Ichthyomyzon castaneus*	Chestnut lamprey	1	1
Acipenseridae	*Scaphirhynchus platorynchus*	Shovelnose sturgeon	1	0
Polyodontidae	*Polyodon spathula*	Paddlefish	76	31
Lepisosteidae	*Lepisosteus platostomus*	Shortnose gar	2	0
	Lepisosteus osseus	Longnose gar	1	0
Clupeidae	*Dorosoma cepedianum*	Gizzard shad	19,980	3,955
	Dorosoma petenense	Threadfin shad	4,297	4,400
	Alosa chrysochloris	Skipjack herring	15,480	551
Cyprinidae	*Campostoma oligolepis*	Largescale stoneroller	0	1
	Pimephales promelas	Fathead minnow	52	2
	Pimephales notatus	Bluntnose minnow	26	0
	Cyprinus carpio	Common carp	1	0
	Hypophthalmichthys molitrix	Silver carp	5,572	41
	Notropis atherinoides	Emerald shiner	102	8
	Notemigonus crysoleucas	Golden shiner	7	33
	Macrhybopsis storeriana	Silver chub	97	3
Catostomidae	*Ictiobus bubalus*	Smallmouth buffalo	2	2
	Carpiodes carpio	River carpsucker	4	15
	Carpiodes cyprinus	Quillback	7	0
Ictaluridae	*Ictalurus punctatus*	Channel catfish	140	643
	Ictalurus furcatus	Blue catfish	742	91
	Pylodictis olivaris	Flathead catfish	14	4
	Ameiurus melas	Black bullhead	1	0
	Ameiurus natalis	Yellow bullhead	4	1
Atherinidae	*Labidesthes sicculus*	Brook silverside	4	4
Moronidae	*Morone chrysops*	White bass	25	4
	Morone mississippiensis	Yellow bass	72	27
	Morone saxatilis	Striped bass	15	0

Table 1. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Centrarchidae	*Micropterus salmoides*	Largemouth bass	4	0
	Micropterus dolomieu	Smallmouth bass	0	8
	Micropterus punctulatus	Spotted bass	1	0
	Lepomis cyanellus	Green sunfish	2	0
	Lepomis megalotis	Longear sunfish	33	10
	Lepomis gulosus	Warmouth	10	0
	Lepomis macrochirus	Bluegill	125	159
	Pomoxis nigromaculatus	Black crappie	1	0
	Pomoxis annularis	White crappie	74	13
	Centrarchus macropterus	Flier	0	2
Percidae	*Sander canadense*	Sauger	161	0
	Percina caprodes	Logperch	0	141
	Sander vitreus	Walleye	0	4
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	3,979	3,063
		Total number of fish	**51,115**	**13,217**
		Total number of species	**37**	**28**

Table 2. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Allen Fossil Plant During 2005-2007.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Gizzard shad	139,860	27,685	**83,773**	1,071,567	510,006	**790,787**	**37**
Skipjack herring	108,360	3,857	**56,109**	738,843	117,250	**428,047**	**25**
Threadfin shad	30,079	30,800	**30,440**	135,317	239,897	**187,607**	**14**
Freshwater drum	27,853	21,441	**24,647**	484,932	200,193	**342,563**	**11**
Silver carp	39004	287	**19,646**	847637	64414	**456,026**	**9**
Blue catfish	5194	637	**2,916**	66633	30576	**48,605**	**1**
Channel catfish	980	4,501	**2,741**	32,760	50,883	**41,822**	**1**
Bluegill	875	1,113	**994**	22,120	9,695	**15,908**	**T**
Sauger	1,127	0	**564**	102,536	0	**51,268**	**T**
Logperch	0	987	**494**	0	6,692	**3,346**	**T**
Emerald shiner	714	56	**385**	2,380	287	**1,334**	**T**
Paddlefish	532	217	**375**	56,770	50,708	**53,739**	**T**
Silver chub	679	21	**350**	6,846	140	**3,493**	**T**
Yellow bass	504	189	**347**	8,589	3,661	**6,125**	**T**
White crappie	518	91	**305**	78,442	16,758	**47,600**	**T**
Fathead minnow	364	14	**189**	1050	56	**553**	**T**
Longear sunfish	231	70	**151**	8,757	4,452	**6,605**	**T**
Golden shiner	49	231	**140**	154	2,240	**1,197**	**T**
White bass	175	28	**102**	9,226	3,402	**6,314**	**T**
Bluntnose minnow	182	0	**91**	392	0	**196**	**T**
River carpsucker	28	105	**67**	182	24,850	**12,516**	**T**
Flathead catfish	98	28	**63**	25,872	22,862	**24,367**	**T**
Striped bass	105	0	**53**	1,092	0	**546**	**T**
Warmouth	70	0	**35**	735	0	**368**	**T**
Brook silverside	28	28	**28**	42	126	**84**	**T**
Smallmouth bass	0	56	**28**	0	462	**231**	**T**
Quillback	49	0	**25**	350	0	**175**	**T**
Yellow bullhead	28	7	**18**	238	196	**217**	**T**
Smallmouth buffalo	28	0	**14**	26,600	0	**13,300**	**T**
Largemouth bass	14	14	**14**	34,440	4,410	**19,425**	**T**
Walleye	0	28	**14**	0	420	**210**	**T**
Chestnut lamprey	7	7	**7**	280	658	**469**	**T**
Shortnose gar	0	14	**7**	0	126	**63**	**T**
Green sunfish	14	0	**7**	196	0	**98**	**T**

Table 2. (continued)

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Flier	14	0	**7**	16,604	0	**8,302**	T
Shovelnose sturgeon	7	0	**4**	42	0	**21**	T
Longnose gar	7	0	**4**	406	0	**203**	T
Common carp	7	0	**4**	4074	0	**2,037**	T
Black bullhead	7	0	**4**	1,414	0	**707**	T
Spotted bass	7	0	**4**	14	0	**7**	T
Black crappie	7	0	**4**	2,954	0	**1,477**	T
Largescale stoneroller	0	7	**4**	0	294	**147**	T
Totals	**357,805**	**92,519**		**3,790,486**	**1,365,714**		**98**

T = Trace < one percent

Table 3. Numbers of Fish Impinged at Allen Fossil Plant by Month and Percent of Annual Total During Year-One, 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
Jan	1,722	3	1,843	14	3,565	6
Feb	10,169	20	5,716	43	15,885	25
Mar	9259	18	912	7	10,171	16
Apr	2366	5	39	0	2,405	4
May	132	0	60	0	192	0
Jun	76	0	48	0	124	0
Jul	1260	2	174	1	1,434	2
Aug	1149	2	2970	22	4,119	6
Sep	4125	8	223	2	4,348	7
Oct	198	0	269	2	467	1
Nov	629	1	458	3	1,087	2
Dec	20,030	39	505	4	20,535	32
Total	**51,115**		**13,217**		**64,332**	

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

	1974-1975	1975-1976	2005-2006	2006-2007
Extrapolated Annual Number Impinged	192,283	1,399,650	357,805	92,519
Number Liable for after EA & PF Reduction	28,557	154,306	63,166	15,050

Table 5. Percent Composition (By Number and after EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Allen Fossil Plant During 1974-1976 and 2005-2007.

	1974-1975*		1975-1976*		2005-2006		2006-2007	
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**
Gizzard shad	63	21	21	9	39	19	30	17
Skipjack herring	-	-	1	-	30	15	4	2
Threadfin shad	10	7	74	79	8	4	33	18
Freshwater drum	19	21	3	5	8	7	23	17
Catfish	-	-	-	-	-	-	6	5
Silver carp	-	-	-	-	11	31	-	-
Paddlefish	2	16	0	0	-	13	-	31
Sauger	-	-	-	-	-	4	-	-
Logperch	-	-	-	-	-	-	1	4
Bluegill	-	-	-	-	-	-	1	2
Yellow bass	-	-	-	-	-	-	-	1
White crappie	-	-	-	-	-	-	-	1
Total	**94**	**65**	**98**	**93**	**96**	**93**	**98**	**98**

Dash denotes not a major species during that year.

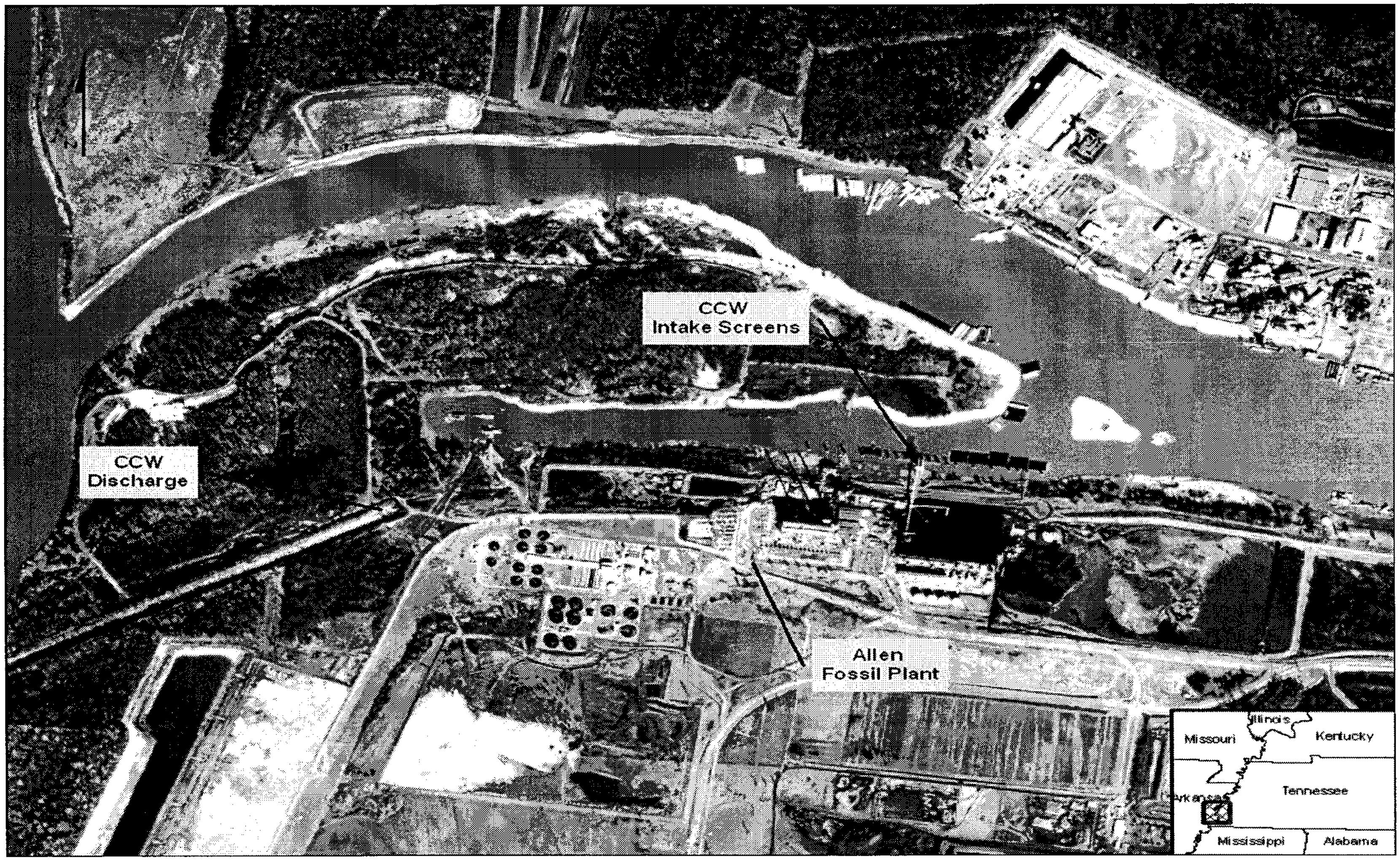


Figure 1. Aerial photograph of Allen Fossil Plant including condenser cooling water intake structure and discharge channel.

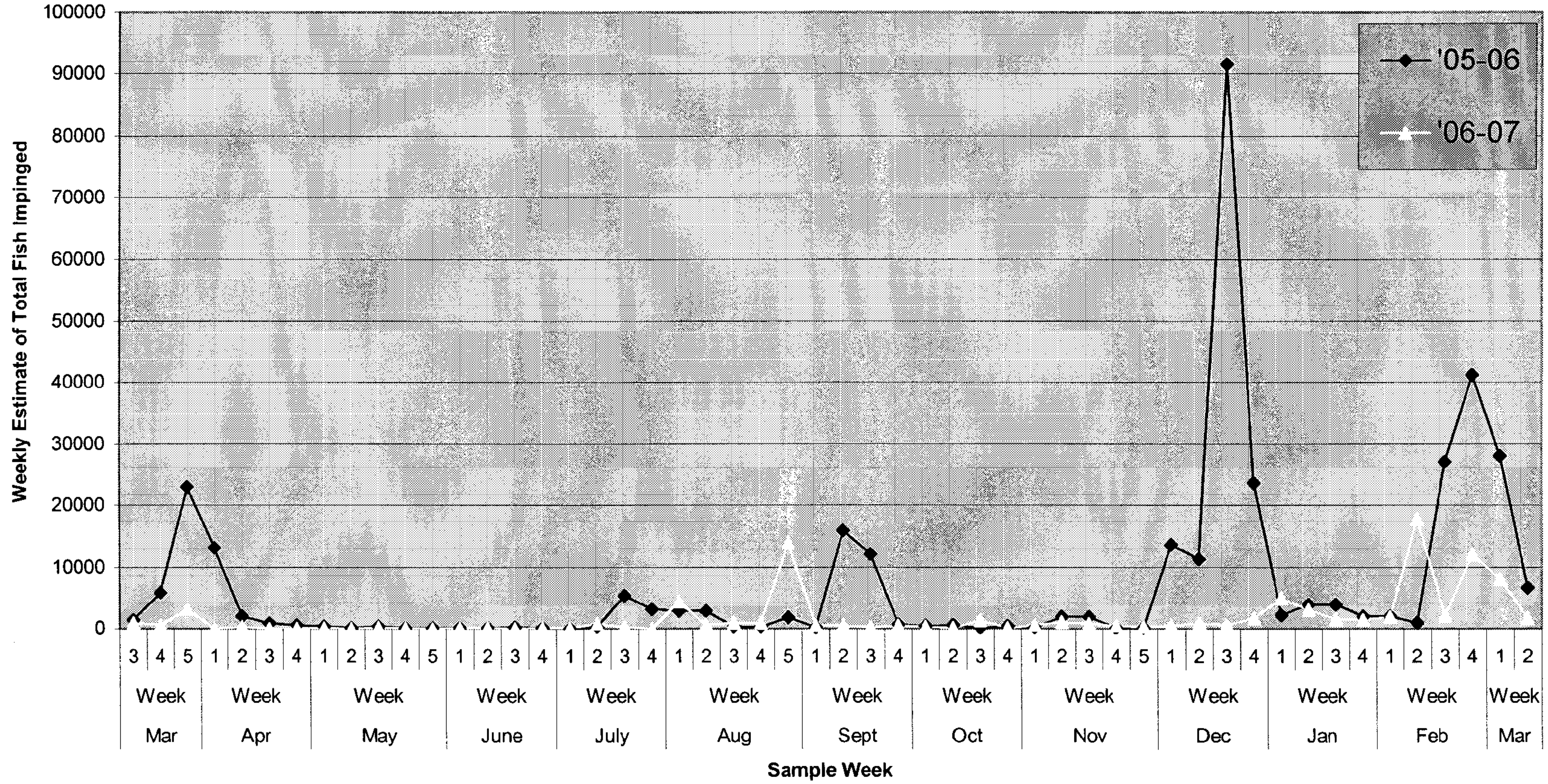


Figure 2. Estimated weekly fish impingement at TVA's Allen Fossil Plant during 2005-2007.

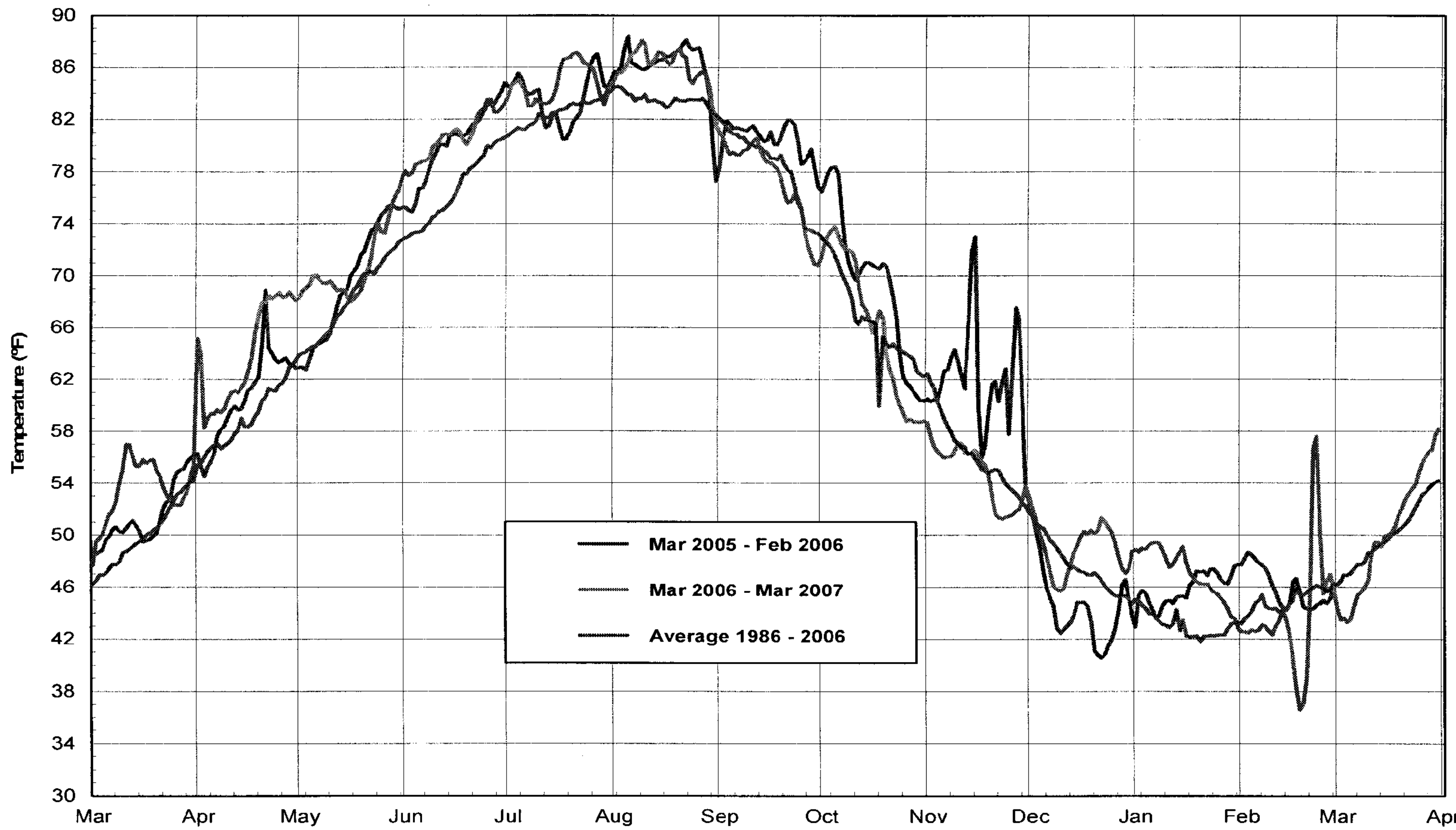


Figure 3. Ambient daily (24-hr avg) water temperature at Allen Fossil Plant intake during historical (1986-2006) and recent (2005-2007) impingement monitoring.

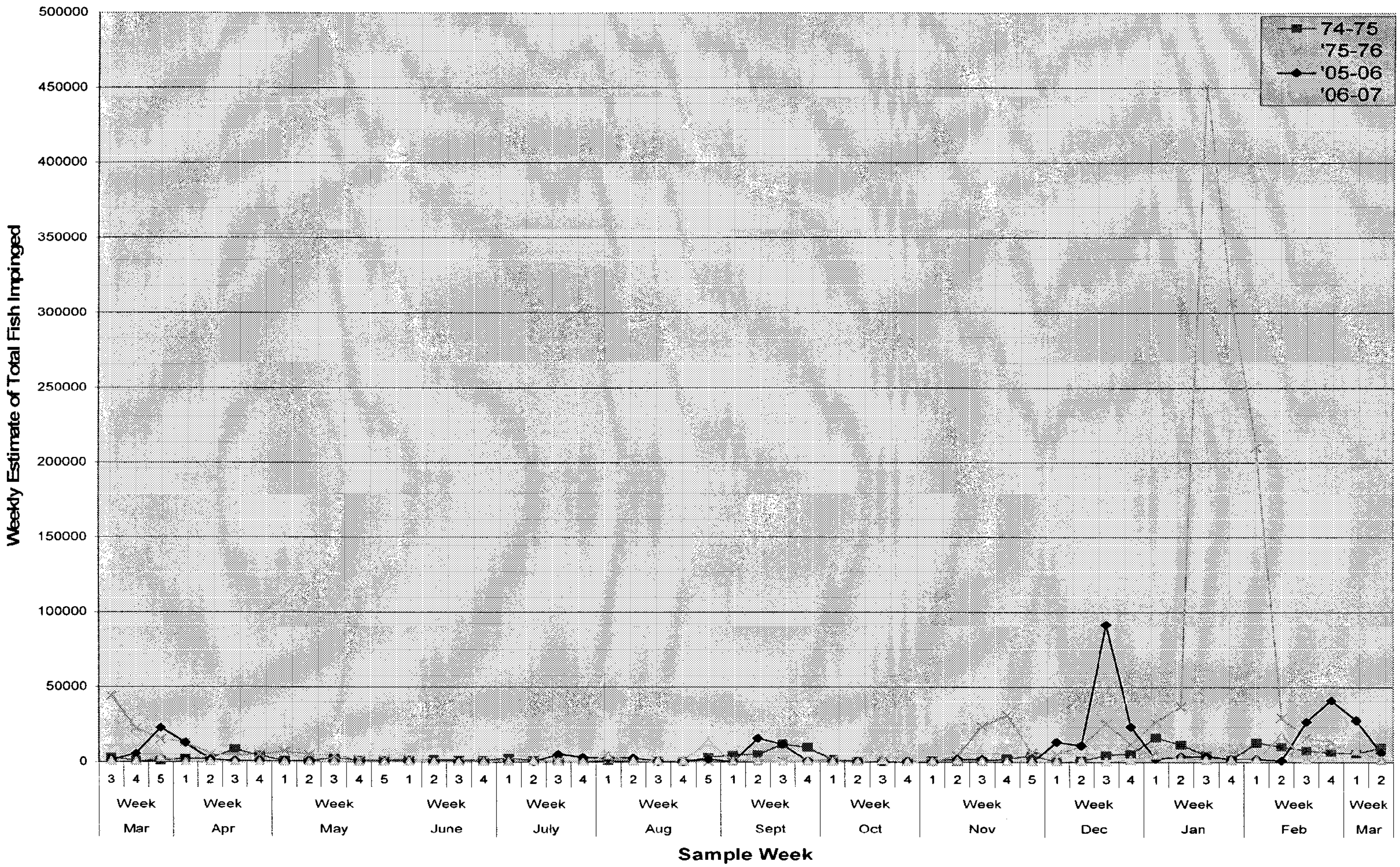
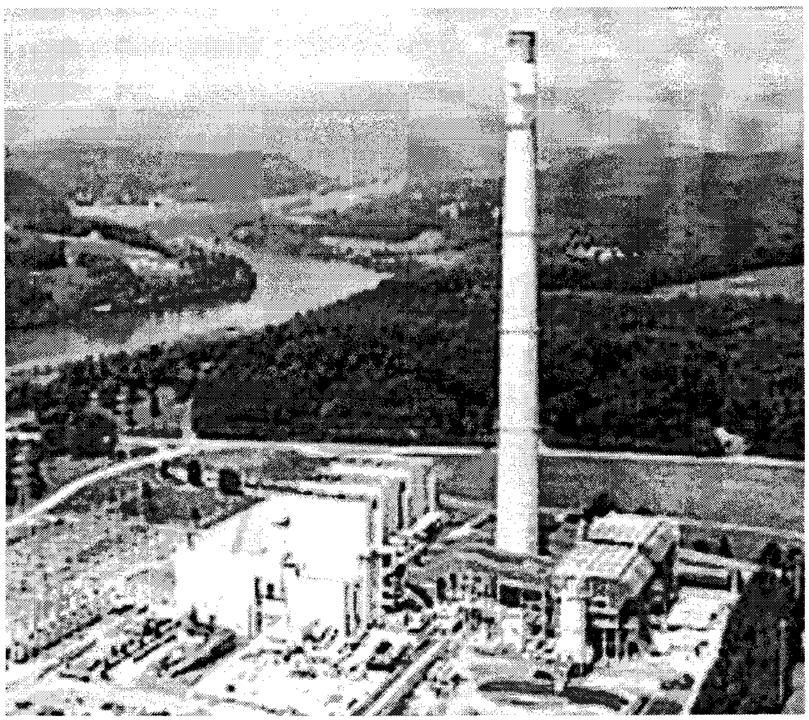


Figure 4. Comparison of estimated weekly fish impingement at TVA's Allen Fossil Plant during historical and recent monitoring periods.

TENNESSEE VALLEY AUTHORITY

BULL RUN FOSSIL PLANT
NPDES PERMIT NO. TN0005410
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT BULL RUN FOSSIL PLANT DURING 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

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

Introduction

Bull Run Fossil Plant (BRF), placed into operation in 1967, withdraws condenser cooling water (CCW) from the Clinch River 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 shellfish 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 a Proposal for Information Collection submitted to Tennessee Department of Environment and Conservation (TDEC) in 2005, Tennessee Valley Authority (TVA) conducted impingement monitoring at BRF from February 09, 2005 through February 07, 2007 to assess the effects of impingement on the aquatic community of Melton Hill Reservoir. This report presents impingement data collected from the CCW intake screens during 2005-2007 with comparisons to historical data collected during August 1974 through April 1975.

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

Plant Description and Condenser Circulating Water System

BRF is located on Melton Hill Reservoir at Clinch River Kilometer (CRK) 76.9 (Clinch River Mile 47.8) (Figure 1). The average annual temperature of the reservoir is 12.7°C (55°F) and maximum temperature is 22.2°C (72°F). These temperatures were used in the design of the condenser. The condenser circulation water system consists of a combined intake structure and pumping station, supply conduits between pumps and the condenser, and discharge conduits between the condenser and discharge structure. Water flows to the intake channel from Melton Hill Reservoir and is discharged back to the reservoir downstream from the intake structure. The intake structure and pumping station, a reinforced concrete structure, is located west of the powerhouse at the end of the intake channel from the reservoir. It houses the necessary equipment for screening the debris and fish from the circulating water and pumping the water through the condenser. Each of the three circulating water pumps is installed in a separate suction well and entering water is strained by trashracks and 9.5 mm (3/8 in) mesh traveling screens. The smallest openings in the circulating water system are in the 2.2 cm (7/8 in) condenser tubes; therefore, everything passing the screens should pass the entire system. Differential pressure gauges are installed to indicate the loss of head across each rack and screen combination. The loss of head will gradually increase as the screens and racks become clogged. When the loss reaches a predetermined amount, a contact on the differential gauge will cause the corresponding high-differential window to light on the annunciator board and sound an audible alarm showing that the screens and/or racks must be cleaned. Debris and fish are washed from the screens by water from the screen wash pumps. The screen washing nozzles wash the debris into a sluice trench that extends the length of the pumping station deck and connects to a pipe that carries the trash to the condenser water discharge channel. Two 20.3 cm (8 in) flushout valves connected to the screen wash pumps discharge header are provided to move the trash down the sluice trench.

Intake Channel and Skimmer Wall

The intake channel (Figure 1) was designed to furnish condenser water at the rate of 104.8 m/s (3,700 cfs) with a velocity of 1 m/s (3.3 fps) for four 900,000-kw units and is located west of the powerhouse. A channel 207.2 m (680 ft) long was excavated from the pumping station to Melton Hill Reservoir with a minimum width of 12.1 m (40 ft).

The channel extends upstream approximately 914.4 m (3000 ft) and is formed by the east shore of the reservoir and dikes, built on Black Island in the reservoir. A skimmer wall was built across the entrance to this channel to keep the warmer surface water from entering the channel.

Adjacent to the skimmer wall, two underwater dams were constructed across the main channel of the river. They divert the cooler bottom water into the intake channel and still permit navigation in the main channel at minimum pool stage. At the same time, the skimmer wall across the intake channel prevents recirculation of warm water from the discharge channel (Figure 1). Together they reduce the amount of time during the year that the inlet temperature is above 12.7°C (55°F). The skimmer wall is a series of 12.1 m (40 ft) pre-cast concrete beams stacked in vertical slots between cast-in-place piers. Extending across the entrance to the intake channel they form a complete barrier except for a 1.8 m (6 ft) high continuous opening between piers across the bottom of the channel.

Methods

Weekly impingement monitoring began on February 09, 2005 and continued through February 8, 2007. To simplify comparisons in this report, data from February 09, 2005 through January 31, 2006 will be referred to as Year-One, and from February 07, 2006 through February 08, 2007 as Year-Two. To collect each sample, 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 Aquatic Monitoring and Management crew on site. A catch basket constructed of 9.5 mm (3/8 in) mesh was installed at the end of the sluice pipe where the monitoring crew collected, 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. Estimates of weekly impingement rates were calculated and compared with historical data. In rare situations when less than a 24-hr sample was possible, data were normalized to 24 hrs.

In response to the agreement with the TDEC, resident fish communities were sampled in Melton Hill Reservoir upstream and downstream of BRF during the years 2001, 2003, and 2005 (Scott 2006).

Moribund/Dead Fish

The majority of fish collected from a 24-hr screen wash were dead when processed. Incidental numbers of fish which appeared (i.e., exhibiting pale gills, cloudy eyes, fungus, or partial decomposition) to have been dead for more than 24 hours were not included in the sample. Also, during winter, threadfin shad occasionally suffer die-offs and are impinged after death or in a moribund state (Griffith and Tomljanovich 1975, Griffith 1978). If these 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 samples were extrapolated to provide estimates of total fish impinged by week and total for each year of the study. To facilitate the implementation of and compliance with EPA's regulations for Section 316(b) of the CWA (Federal Register Vol. 69, No. 131; July 9, 2004), impingement losses of fish were evaluated by extrapolating the losses to equivalent reductions of adult fish, or of biomass production available to predators. EPRI (Formerly known as the Electric Power Research Institute) 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 and quantifies the loss from entrainment and impingement in terms of potential available forage for consumption by predators. Requirements of the models are site-specific data on the distribution and abundance of fish populations vulnerable to impingement. TVA also used these models to determine the "biological liability" of the BRF CCW intake structure.

Results and Discussion

During Year-One and Year-Two of impingement monitoring at BRF, 8,006 and 22,390 fish were collected, respectively, from weekly screen-wash samples. Total numbers collected in impingement samples by species and year are presented in Table 1. Number of species collected was 23 and 21 during the first and second year of sampling respectively. Estimated total fish impinged for each year extrapolated from weekly samples was 56,042 for Year-One and 156,730 for 2006 (Table 2). This increase between years was a reflection of threadfin shad impingement tripling from 41,769 in Year-One samples to 152,971 in 2006 (Table 2). A significant portion (7,389, 33%) of fish impinged in Year-Two (22,390) was from one sample collected on October 31, 2006 (Figure 3). Percent composition for Year-One and Year-Two combined was 92% threadfin shad and 8% gizzard shad (Table 2). All other species comprised less than one percent each.

Plotted daily (24-hour average) ambient intake water temperatures for BRF during each of the two years sampled are presented in Figure 3. Lowest temperatures do not appear to be strongly correlated with peak impingement as previously reported by numerous studies (EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978, McLean et al., 1980). A recent study by Fost (2006) indicated that cold-stressed threadfin and gizzard shad can be classified as either <u>impaired</u> or <u>moribund</u>. 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 2 also presents average BRF intake temperatures from 1986 through 2006 for comparison. Winter (January through March) temperatures during both Year-One and Year-Two, dropped below the threshold temperature of 7.5°C (45.5°F) described by Fost (2006) as when threadfin shad become impaired.

Seasonal impingement during Year-One was not only significantly lower than in Year-Two, but peaks were observed during August (42%), April (23%) and May (14%) instead of between October and January as in Year-Two (Figure 3) (Table 3).

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).

Application of the EA and PF models to the estimated total numbers of impinged fish indicated that 3,174 and 6,216 of those, in Years-One and Two respectively, (Table 4) would have been expected to survive to either harvestable (EA) size/age or to provide forage (PF). These reduced numbers are considered the "biological liability" resulting from plant CCW impingement.

Results of fish community (RFAI) sampling indicated "Good" fish communities at both sites (Scott 2006) and indicated that impingement at BRF has not impacted the fish community of Melton Hill Reservoir. No state or federal protected fish species were collected or are known to occur in the vicinity of BRF.

Comparison with Historical Data

During historical sampling from August 1974 through April 1975, 2,599 fish representing 24 species were collected (TVA 1975) compared to the average of 15,198 fish collected during 2005-2007 represented 23 species. During 1974-1975 sampling threadfin shad (88%) were dominant followed by gizzard shad at 4.1%. Similarly, during 2005-2007 threadfin shad were dominant (92%) followed by gizzard shad (8%). The extrapolated annual total for number of fish impinged during 1974-1975 and 2005-2007 was 26,976 and 30,396, respectively. Peak impingement of 844 fish occurred on November 27, 1974, (TVA 1975) compared to 7,509 occurring October 31, 2006 during 2005-2007.

It was concluded that based on data collected during 1974-1975 that impingement of fish at BRF resulted in no adverse environmental impact to the Melton Hill fish community (TVA 1975).

Summary and Conclusions

Impingement of fish by BRF CCW was monitored during February 2005-January 2007 and compared with historical data collected during August 1974-April 1975. Total numbers of fish estimated impinged annually were higher during 2005-2007 than during 1974-1975. Average number estimated impinged during 2005-2007 (two years) was 106,386 compared to 26,976 during 1974-1975. Threadfin shad, which comprised 92%

of the total impinged, are known as prolific spawners, seldom live more than two or three years and often spawn during the first year of life (Johnson 1969). Favorable RFAI scores for the Melton Hill Reservoir fish community indicate that the BRF CCW intake has not adversely impacted the Melton Hill Reservoir fish community and that a BIP exists.

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Table 1. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Bull Run Fossil Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-One
Clupeidae	*Alosa pseudoharengus*	Alewife	26	5
	Dorosoma cepedianum	Gizzard shad	1,861	448
	Dorosoma petenense	Threadfin shad	5,967	21,853
	D. petenense x *D. cepedianum*	Hybrid shad	1	0
Cyprinidae	*Pimephales vigilax*	Bullhead minnow	1	1
	Pimephales promelas	Fathead minnow	5	1
	Pimephales notatus	Bluntnose minnow	0	4
	Cyprinus carpio	Common carp	0	1
	Carassius auratus	Goldfish	0	1
	Notemigonus crysoleucas	Golden shiner	1	0
Catostomidae	*Ictiobus bubalus*	Smallmouth buffalo	1	0
	Ictiobus niger	Black buffalo	1	0
	Moxostoma duquesnei	Black redhorse	0	1
	Moxostoma erythrurum	Golden redhorse	1	0
	Hypentelium nigricans	Northern hogsucker	2	0
Ictaluridae	*Ictalurus punctatus*	Channel catfish	2	9
	Ameiurus melas	Black bullhead	1	0
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	0	1
Cottidae	*Cottus carolinae*	Banded sculpin	17	20
Moronidae	*Morone chrysops*	White bass	3	0
	Morone mississippiensis	Yellow bass	12	6
Centrarchidae	*Lepomis macrochirus*	Bluegill	4	3
	Lepomis microlophus	Redear sunfish	0	1
	Pomoxis nigromaculatus	Black crappie	1	3
	Pomoxis annularis	White crappie	1	3
Percidae	*Percina caprodes*	Logperch	81	25
	Perca flavescens	Yellow perch	13	0
	Sander canadense	Sauger	1	1
	Sander vitreus	Walleye	0	2
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	3	1
		Total number of fish	**8,006**	**22,390**
		Total number of species	**23**	**21**

Table 2. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Bull Run Fossil Plant During 2005-2007.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Threadfin shad	41,769	152,971	**97,370**	172,347	219,863	**196,105**	92
Gizzard shad	13,027	3,136	**8,082**	164,640	19,551	**92,096**	8
Logperch	567	175	**371**	5,306	1,134	**3,220**	T
Banded sculpin	119	140	**130**	896	336	**616**	T
Alewife	182	35	**109**	3,143	483	**1,813**	T
Yellow bass	84	42	**63**	9,310	3,598	**6,454**	T
Yellow perch	91	0	**46**	3,045	0	**1,523**	T
Channel catfish	14	63	**39**	336	1,799	**1,068**	T
Bluegill	28	21	**25**	1904	672	**1,288**	T
Fathead minnow	35	7	**21**	140	14	**77**	T
Black crappie	7	21	**14**	644	4,851	**2,748**	T
Bluntnose minnow	0	28	**14**	0	98	**49**	T
Freshwater drum	21	7	**14**	6,475	959	**3,717**	T
White crappie	7	21	**14**	35	1,120	**578**	T
White bass	21	0	**11**	3,850	0	**1,925**	T
Bullhead minnow	7	7	**7**	21	28	**25**	T
Northern hog sucker	14	0	**7**	70	0	**35**	T
Sauger	7	7	**7**	3,675	63	**1,869**	T
Walleye	0	14	**7**	0	3,143	**1,572**	T
Black buffalo	7	0	**4**	28	0	**14**	T
Black bullhead	7	0	**4**	35	0	**18**	T
Black redhorse	0	7	**4**	0	1,176	**588**	T
Common carp	0	7	**4**	0	5,054	**2,527**	T
Golden redhorse	7	0	**4**	6,335	0	**3,168**	T
Golden shiner	7	0	**4**	147	0	**74**	T
Goldfish	0	7	**4**	0	672	**336**	T
Hybrid shad	7	0	**4**	70	0	**35**	T
Rainbow trout	0	7	**4**	0	490	**245**	T
Redear sunfish	0	7	**4**	0	70	**35**	T
Smallmouth buffalo	7	0	**4**	9,765	0	**4,883**	T
Totals	**56,042**	**156,730**		**392,217**	**265,174**		

T = Trace < one percent

Table 3. Numbers of Fish Impinged at Bull Run Fossil Plant by Month and Percent of Annual Total During 2005-2006, 2006-2007, 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 1 and 2 Combined	Percent of Two-year Total
Nov	118	1	5,298	24	5,416	18
Dec	81	1	2,610	12	2,691	9
Jan	86	1	3,517	16	3,603	12
Feb	186	2	538	2	724	2
Mar	481	6	0	0	481	2
Apr	1,869	23	0	0	1,869	6
May	1,142	14	87	0	1,229	4
Jun	58	1	11	0	69	0
Jul	48	1	429	2	477	2
Aug	3,342	42	1,582	7	4,924	16
Sep	219	3	72	0	291	1
Oct	376	5	8,246	37	8,622	28
Total	**8,006**		**22,390**		**30,396**	

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

	1974-1975	2005-2006	2006-2007
Extrapolated Annual Number Impinged	26,976	56,042	156,730
Number Liable for after EA & PF Reduction	*	3,174	6,216

***EA and PF not calculated for historical data**

Table 5. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Bull Run Fossil Plant during 1974-1975 and 2005-2007.

	1974-1975		2005-2006		2006-2007	
Species Composition	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**
Threadfin shad	88	64	75	66	98	96
Gizzard shad	4	3	23	20	2	2
Logperch	4	19	1	7	-	1
Freshwater drum	1	3	-	-	-	-
Bluegill	-	2	-	-	-	-
Yellow bass	-	-	-	2	-	-
Yellow perch	-	-	-	2	-	-
Alewife	-	-	-	1	-	-
Sauger	-	-	-	1	-	-

Dash denotes not a major species during that year.

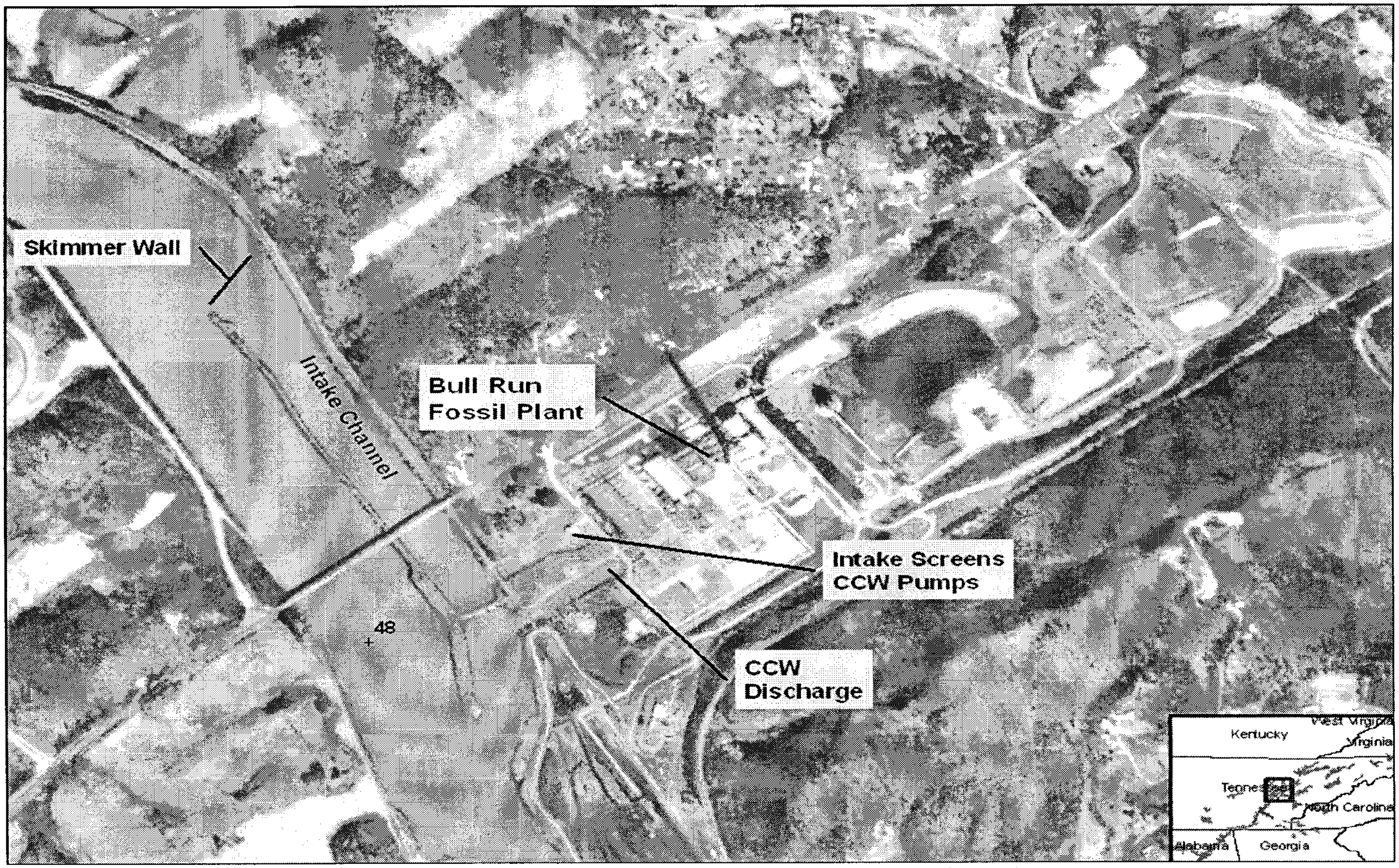


Figure 1. Aerial photograph of Bull Run Fossil Plant CCW intake structure including skimmer wall, intake basin, and discharge channel.

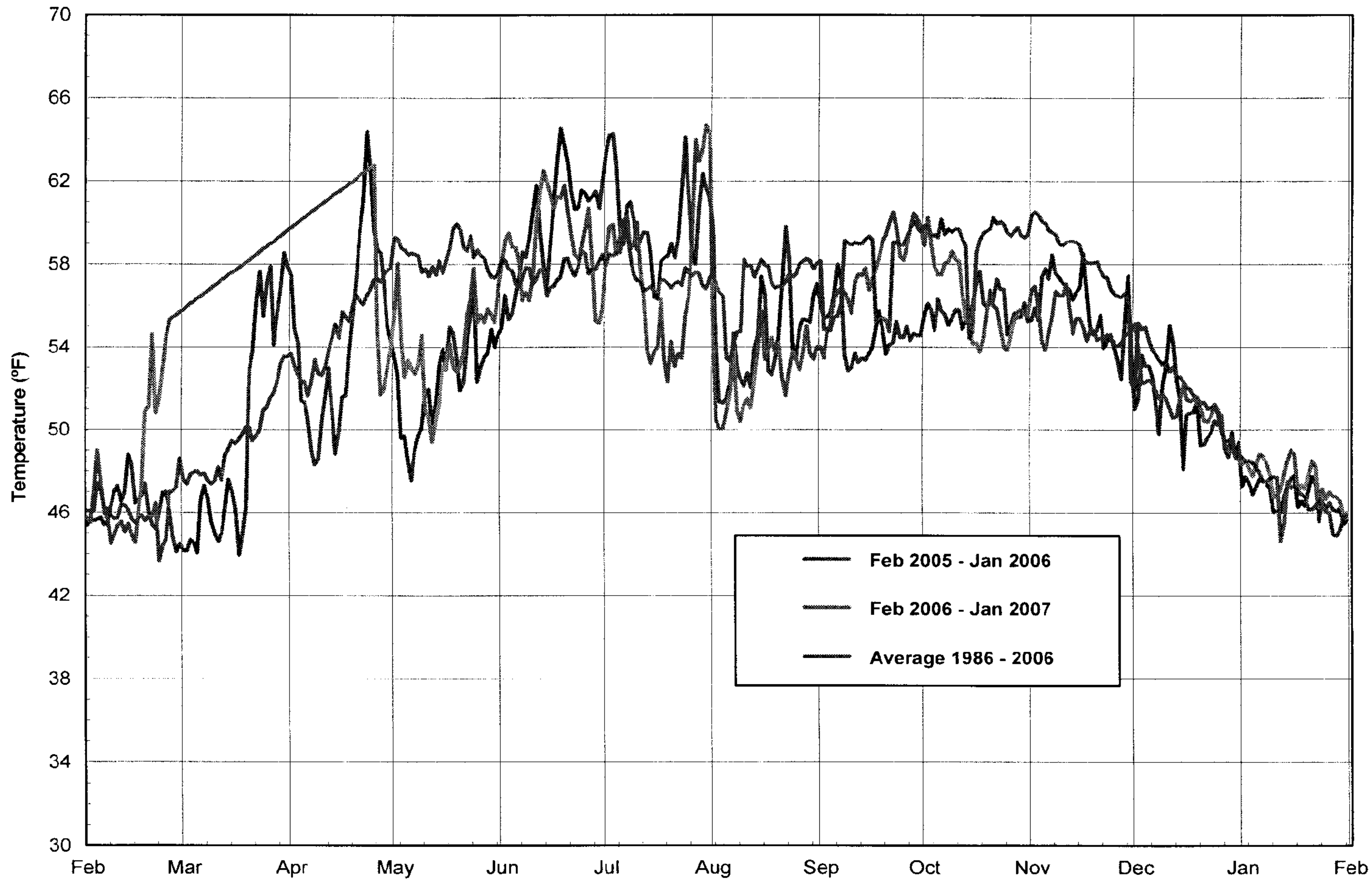


Figure 2. Ambient daily (24-hr avg) water temperature at Bull Run Fossil Plant intake during historical (1974-1975) and recent (2005-2007) impingement monitoring.

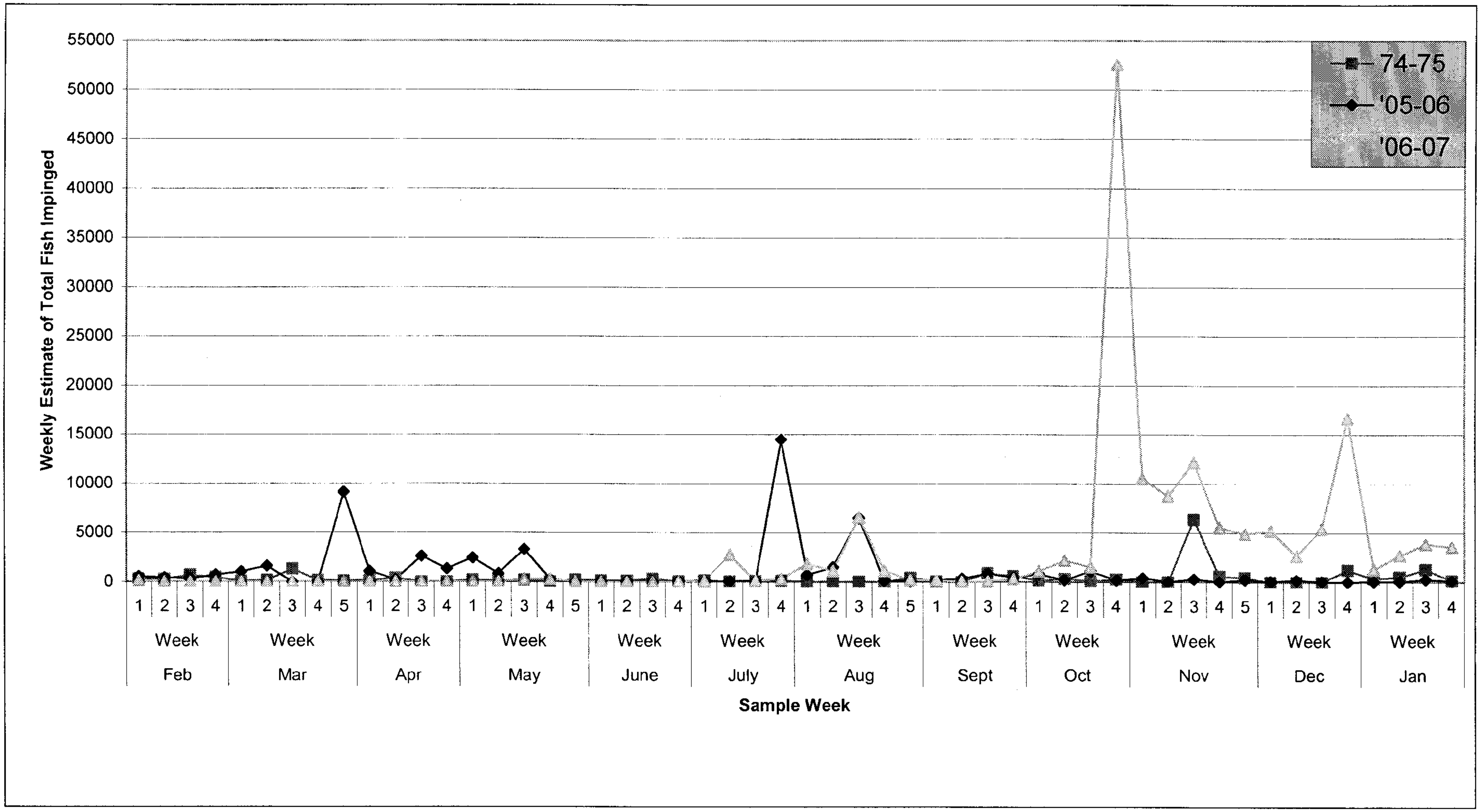
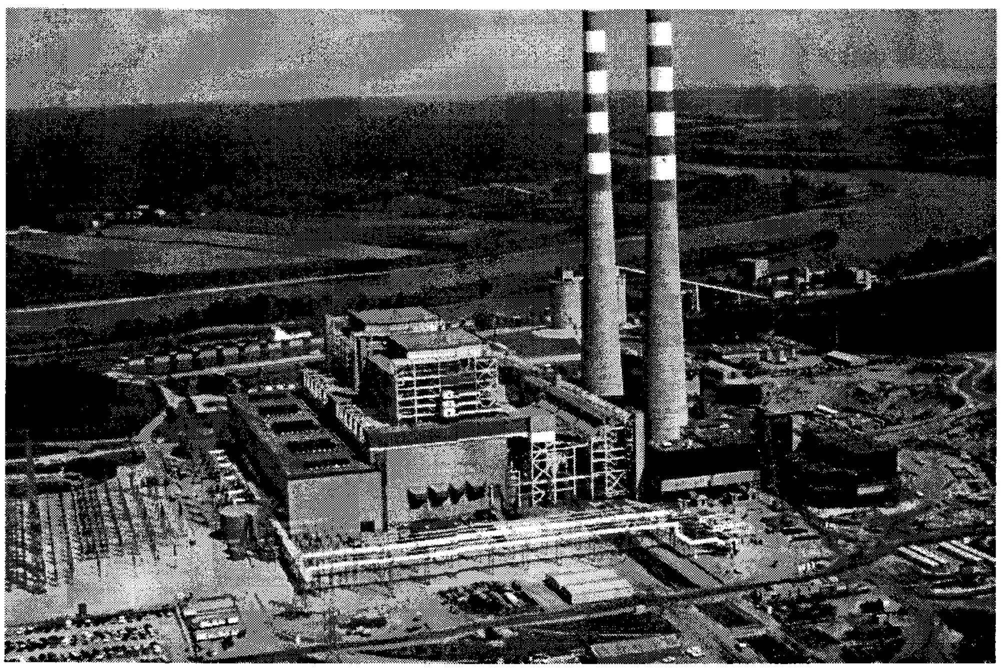


Figure 3. Comparison of estimated weekly fish impingement at TVA's Bull Run Fossil Plant during historical and recent monitoring periods.

TENNESSEE VALLEY AUTHORITY

CUMBERLAND FOSSIL PLANT
NPDES PERMIT NO. TN0005789
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT CUMBERLAND FOSSIL PLANT DURING 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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ACRONYMS

AM&M	Aquatic Monitoring and Management
BIP	Balanced Indigenous Population
CUF	Cumberland Fossil Plant
CuRM	Cumberland River Mile
CCW	Condenser Cooling Water
CWA	Clean Water Act
EA	Equivalent Adult
EPRI	Formerly known as the Electric Power Research Institute
PF	Production Foregone
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

Introduction

Cumberland Fossil Plant (CUF) is subject to compliance with the Tennessee Water Quality Act and the federal Clean Water Act (CWA). Section 316(b) of the CWA requires facilities to demonstrate that the condenser cooling water (CCW) withdrawal is having no significant impact on the aquatic community. Impingement mortality is a component of Section 316(b) and is defined as an impact of which fish and/or shellfish 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 a Proposal for Information Collection submitted to the Tennessee Department of Environment and Conservation (TDEC) in 2005, the Tennessee Valley Authority (TVA) conducted impingement monitoring at CUF from February 2005 through February 2007 to assess the effects of impingement on the aquatic community of Barkley Reservoir. This report presents impingement data collected from the CCW intake screens during 2005-2007 with comparisons to historical data collected during 1974-1976 (TVA 1977).

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 CUF operation is not impacting the balanced indigenous population (BIP) in Barkley Reservoir. The primary reason for gathering these data is to support the continuation of a Section 316(a) thermal variance for CUF. However, the RFAI monitoring gives an indication of the overall impact of plant operations on the reservoir fish assemblage, including impacts from the plant's cooling water intake.

Plant Description

CUF is located on the south bank of the Cumberland River in Stewart County, Tennessee, at Cumberland River Kilometer 165.8 (Cumberland River Mile [CuRM] 103) (Figure 1). This is a two-unit, once-through cooling, coal-fired plant with a maximum generator nameplate rating of 2,600 megawatts. Commercial operation of Unit 1 began in July 1972 and Unit 2 was added in April 1973. Maximum total condenser and auxiliary flow is 120 m^3/sec (4,328 cfs). The plant is approximately 116 km (72 miles) upstream of Barkley Dam and approximately 74 km (46 miles) below Cheatham Dam. River flow in the plant vicinity is primarily controlled by releases from these two dams in addition to tributary inflows upstream of the plant.

Pumping Station

The intake pumping station at CUF contains 16 separate intake chambers, each with a trashrack and conventional vertical traveling screen. Eight CCW pumps withdraw water through the 16 chambers and screens. The trashracks consist of 1.6 cm (5/8 in) thick steel bars arranged vertically with 9.2 cm (3 5/8 in) clear openings between bars. After passing through the trashracks, the water passes through the vertical traveling screens. The screen panels consist of 12-gauge galvanized wire having 9.5 m (3/8 in) square openings.

Circulating water for the plant is provided through a 168 m (650 ft) long intake channel. A 339 m (1,112 ft) long skimmer wall (Figure 1) at the mouth of the intake channel allows selective withdrawal of cooling water from the lower reaches of the water column.

Methods

Weekly impingement monitoring began on February 23, 2005, and continued through February 13, 2007. To simplify comparisons in this report, data from February 23, 2005 through February 16, 2006 will be referred to as Year-One, and from February 23, 2006 through February 13, 2007 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 (AM&M) crew on site. Samples were collected according to TVA's Quality Assurance Procedure (NR OPS-FO-0BR-23.11) for Impingement Counts (TVA 2004). During periods of heavy debris load, it occasionally became necessary for the plant operators to wash more frequently than once per 24 hours; in this situation, daily counts of fish impinged were adjusted to account for the actual time between screen backwash operations.

After each screen (or groups of screens) was washed, all fish (and debris) were removed from a catch basket constructed of 9.5 mm (3/8 in) mesh at the end of the screen wash sluice pipe. Fish were sorted by species in 25 mm (1 in) length groups, then counted, weighed and recorded. Any fish that could not be positively field-identified was preserved in 10% formalin and taken to the TVA Aquatic Biology Laboratory in Norris for identification or verification. Quality Assurance/Quality Control procedures for impingement sampling (TVA 2004) were followed to ensure samples were comparable with historical impingement mortality data.

In response to the agreement with TDEC, TVA initiated RFAI studies to evaluate fish communities in areas immediately upstream and downstream of CUF during the years 2001-2003, and 2005 (Scott 2006).

Moribund/Dead Fish

Fish collected from a 24-hr screen wash were usually all dead when processed. 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 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

Weekly impingement samples were extrapolated to provide estimates of total fish impinged by week and during each year of the study. In rare situations when less than a 24-hr sample occurred, data were normalized to 24 hrs.

To facilitate the implementation of and compliance with the EPA regulations for Section 316(b) of the CWA (Federal Register Vol. 69, No. 131; July 9, 2004), 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 also used these models to determine the "biological liability" of the CCW intake structure based on the EPA guidance developed under the suspended rule.

Results and Discussion

During Year-One and Year-Two of impingement monitoring, 595,632 and 126,190 fish were collected from weekly screen-wash samples (Table 1). Number of species collected was 53 in Year-One and 44 in Year-Two. Total number and biomass estimated impinged by species and year are presented in Table 2. Threadfin shad comprised 88% of the total for both years combined followed by gizzard shad (5%), freshwater drum (4%), and skipjack herring (2%) (Table 2). Estimated total numbers of fish impinged and percent by month for both years are presented in Table 3. Peak impingement during Year-One occurred during January 2005 (61% of annual total) followed by 14% in December and 12% in September (Table 4, Figure 2). During Year-Two, peak impingement was recorded in July (43%) and August (14%). The estimated annual impingement extrapolated from weekly samples was 4,169,424 during Year-One and 883,330 during Year-Two (Table 4). Higher impingement during the warmer months at CUF as well as four other TVA plants had been previously reported by Griffith and Tomljanovich (1975). McDonough and Hackney (1978) examined relationships between impingement and both physical and biological factors at CUF. They reported numbers of skipjack herring impinged were positively correlated with air temperature. They also found total numbers impinged and numbers of each species tested except freshwater drum were found to increase with a rise in water level. Daily (24-hour average) ambient intake water temperatures for CUF during each of the two years sampled and historical average temperatures for 1986-2006 are presented in Figure 3.

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).

A recent study by Fost (2006) 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). Winter temperatures at CUF during both Year-One and Year-Two, remained above the Fost threshold temperature (Figure 2). No die-offs of threadfin shad were observed during the two years of monitoring by Aquatic Monitoring and Management crews or were reported by power plant personnel.

Application of the EA and PF models to the total numbers of impinged fish indicated that 156,272 and 41,064 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, resident fish communities were sampled using RFAI in Barkley Reservoir upstream and downstream of CUF in 2001, 2002, 2003, and 2005 (Scott 2006). In 2005, RFAI scores were 43 and 44 ("Good") at the upstream and downstream sites respectively. Average scores of 40 at both sites over the four years sampled, also indicated the fish communities were "Good" and that that impingement at CUF is not adversely impacting the fish community of Barkley Reservoir in the vicinity of CUF. No state or federal protected fish species were collected or are known to occur in the vicinity of CUF.

Comparison with Historical Data

Estimated impingement from historical sampling during1974 through 1978 (including the extrapolated annual totals for number of fish impinged) and the number liable for after EA and PF reduction are presented in Table 4. The total estimated numbers of fish impinged for 1974-1975 were 2,060,478, for 1975-1976 1,083,173, for 1976-1977, 1,124,060, and for 1977-1978, 1,873,298. Table 5 presents the percent composition by number and biological liability of major species impinged during 1974-1978 and 2005-2007. Threadfin shad dominance varied from 55% in 1977-1978 to a high of 93% in 1974-1975 (Table 5). Gizzard shad, skipjack herring, and freshwater drum were consistently the next three most dominant species (Table 5).

Summary and Conclusions

RFAI scores in 2005 of 43 and 44 for upstream and downstream samples, respectively, indicated "Good" fish communities at both sites (Table 5). Because RFAI scores were within the 6 point acceptable variation, it can be concluded that the CUF heated effluent is not adversely impacting the resident fish community in the Cumberland River in the vicinity of the plant discharge. Resident fish communities at these locations reached 71.1% and 73.3% of their potential for downstream and upstream sites, respectively.

Impingement of fish by the CUF CCW was monitored during 2005-2007 and compared with historical data collected during 1974-1978. Average number estimated impinged during 2005-2007 (two years) was 2,526,377 compared to 1,535,252 per year during 1974-1978. Both annual estimated impingement and bioliability for fish impinged were higher during 2005-2006 (Table 4) than during 2006-2007 or the historical monitoring period (1974-1978). The consistent annual impingement of significant numbers of threadfin shad at CUF after thirty-four years of operation indicates that this species is capable of sustaining a viable population in spite of occasional high mortality from impingement. This prolific species seldom lives more than two or three years and is capable of spawning during the first year of life (Johnson 1969). Dryer and Benson

(1957) and Kimsey et al., (1957) noted the explosive reproductive potential of threadfin shad. Lowest total estimated impingement during the most recent year sampled (2006-2007) and the evidence of a BIP, suggest that the CUF CCW intake is not adversely affecting the Barkley Reservoir fishery.

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Table 1. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Cumberland Fossil Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year One	Year Two
Petromyzontidae	*Ichthyomyzon castaneus*	Chestnut lamprey	1	8
Acipenseridae	*Acipenser fulvescens*	Lake sturgeon	0	1
Polyodontidae	*Polyodon spathula*	Paddlefish	26	2
Hiodontidae	*Hiodon tergisus*	Mooneye	7	1
Clupeidae	*Alosa pseudoharengus*	Alewife	35	4
	Dorosoma cepedianum	Gizzard shad	31,349	3,856
	Alosa chrysochloris	Skipjack herring	7,217	5,706
	Dorosoma petenense	Threadfin shad	533,393	103,602
Cyprinidae	*Pimephales vigilax*	Bullhead minnow	5	8
	Pimephales notatus	Bluntnose minnow	2	0
	Pimephales promelas	Fathead minnow	1	0
	Notropis atherinoides	Emerald shiner	102	127
	Cyprinella spiloptera	Spotfin shiner	2	1
	Carassius auratus	Goldfish	0	3
	Notemigonus crysoleucas	Golden shiner	7	2
	Macrhybopsis storeriana	Silver chub	1,281	395
	Semotilus atromaculatus	Creek chub	4	0
Catostomidae	*Carpiodes carpio*	River carpsucker	0	1
	Carpiodes cyprinus	Quillback	2	0
	Hypentelium nigricans	Northern hogsucker	2	1
	Ictiobus bubalus	Smallmouth buffalo	1	0
	Ictiobus niger	Black buffalo	0	1
	Minytrema melanops	Spotted sucker	16	12
	Moxostoma duquesnii	Black redhorse	21	0
	Moxostoma erythrurum	Golden redhorse	43	3
	Moxostoma macrolepidotum	Shorthead redhorse	4	0
Ictaluridae	*Ictalurus furcatus*	Blue catfish	1,714	1,293
	Ictalurus punctatus	Channel catfish	479	253
	Pylodictis olivaris	Flathead catfish	20	21
	Noturus gyrinus	Tadpole madtom	3	0
	Noturus spp.	Unidentified madtom	1	0
	Ameiurus natalis	Yellow bullhead	1	2
	Ameiurus melas	Black bullhead	1	0

Table 1. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year One	Year Two
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	2	2
Aphredoderidae	*Aphredoderus sayanus*	Pirate perch	4	6
Atherinopsidae	*Labidesthes sicculus*	Brook silverside	0	1
		Unidentified silverside	0	1
Belonidae	*Strongylura marina*	Atlantic needlefish	1	0
Cottidae	*Cottus carolinae*	Banded sculpin	0	1
Moronidae	*Morone saxatilis*	Striped bass	49	45
	Morone chrysops	White bass	21	22
	Morone mississippiensis	Yellow bass	1,682	498
	Morone saxatilis x M. chrysops	Hybrid striped bass	6	0
Centrarchidae	*Lepomis macrochirus*	Bluegill	453	140
	Lepomis microlophus	Redear sunfish	38	22
	Lepomis gulosus	Warmouth	1	7
	Lepomis humilis	Orangespotted sunfish	14	1
	Lepomis megalotis	Longear sunfish	78	39
	Lepomis cyanellus	Green sunfish	28	6
	Ambloplites rupestris	Rock bass	2	0
	Micropterus dolomieu	Smallmouth bass	2	0
	Micropterus salmoides	Largemouth bass	6	14
	Micropterus punctulatus	Spotted bass	10	6
	Pomoxis annularis	White crappie	11	4
	Pomoxis nigromaculatus	Black crappie	1	0
Percidae	*Percina shumardi*	River darter	27	12
	Percina caprodes	Logperch	213	78
	Sander canadense	Sauger	3	6
	Sander vitreus	Walleye	3	0
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	17,233	9,977
		Total number of fish	**595,632**	**126,190**
		Total number of species	**53**	**44**

Table 2. Estimated Annual Numbers, Biomass and Percent Composition of Fish Impinged by Species at Cumberland Fossil Plant During 2005-2007.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Threadfin shad	3,733,751	725,214	**2,229,483**	18,370,114	2,663,857	**10,516,986**	**88**
Gizzard shad	219,443	26,992	**123,218**	2,096,668	346,381	**1,221,525**	**5**
Freshwater drum	120,631	69,839	**95,235**	4,028,619	2,090,102	**3,059,361**	**4**
Skipjack herring	50,519	39,942	**45,231**	621,782	913,990	**767,886**	**2**
Blue catfish	11,998	9,051	**10,525**	99,946	137,725	**118,836**	**T**
Yellow bass	11,774	3,486	**7,630**	242,018	99,428	**170,723**	**T**
Silver chub	8,967	2,765	**5,866**	196,252	60,865	**128,559**	**T**
Channel catfish	3,353	1,771	**2,562**	118,993	67,011	**93,002**	**T**
Bluegill	3,171	980	**2,076**	69,622	44,296	**56,959**	**T**
Logperch	1,491	546	**1,019**	14,014	5,117	**9,566**	**T**
Emerald shiner	714	889	**802**	4,032	4,935	**4,484**	**T**
Longear sunfish	546	273	**410**	7,994	6,713	**7,354**	**T**
Striped bass	343	315	**329**	28,084	14,371	**21,228**	**T**
Redear sunfish	266	154	**210**	24,731	9,037	**16,884**	**T**
Golden redhorse	301	21	**161**	13,391	1,904	**7,648**	**T**
White bass	147	154	**151**	5,971	39,242	**22,607**	**T**
Flathead catfish	140	147	**144**	30,527	2,674	**16,601**	**T**
Alewife	245	28	**137**	4,032	483	**2,258**	**T**
Sauger	189	84	**137**	59,857	25,291	**42,574**	**T**
Green sunfish	196	42	**119**	1,302	210	**756**	**T**

Table 2. (continued)

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Paddlefish	182	14	**98**	44,163	651	**22,407**	T
Spotted sucker	112	84	**98**	74,494	27,601	**51,048**	T
Black redhorse	147	0	**74**	637	0	**319**	T
Largemouth bass	42	98	**70**	182	350	**266**	T
Spotted bass	70	42	**56**	945	5,873	**3,409**	T
Orangespotted sunfish	98	7	**53**	462	21	**242**	T
White crappie	77	28	**53**	301	441	**371**	T
Bullhead minnow	35	56	**46**	210	329	**270**	T
Pirate perch	28	42	**35**	140	203	**172**	T
Chestnut lamprey	7	56	**32**	665	2,170	**1,418**	T
Golden shiner	49	14	**32**	301	266	**284**	T
River darter	21	42	**32**	98	84	**91**	T
Mooneye	49	7	**28**	1,365	1,036	**1,201**	T
Warmouth	7	49	**28**	35	308	**172**	T
Hybrid striped bass	42	0	**21**	36,036	0	**18,018**	T
Black buffalo	28	0	**14**	140	0	**70**	T
Creek chub	28	0	**14**	140	0	**70**	T
Rainbow trout	14	14	**14**	2,170	2,611	**2,391**	T
Shorthead redhorse	28	0	**14**	140	0	**70**	T
Goldfish	0	21	**11**	0	84	**42**	T

Table 2. (continued)

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Northern hogsucker	14	7	**11**	63	42	**53**	T
Spotfin shiner	14	7	**11**	112	28	**70**	T
Tadpole madtom	21	0	**11**	126	0	**63**	T
Walleye	21	0	**11**	175	0	**88**	T
Yellow bullhead	7	14	**11**	280	294	**287**	T
Bluntnose minnow	14	0	**7**	105	0	**53**	T
Quillback	14	0	**7**	63	0	**32**	T
Rock bass	14	0	**7**	140	0	**70**	T
Smallmouth bass	14	0	**7**	70	0	**35**	T
Atlantic needlefish	7	0	**4**	546	0	**273**	T
Banded sculpin	0	7	**4**	0	112	**56**	T
Black bullhead	7	0	**4**	28	0	**14**	T
Black crappie	7	0	**4**	315	0	**158**	T
Brook silverside	0	7	**4**	0	21	**11**	T
Fathead minnow	7	0	**4**	35	0	**18**	T
Lake sturgeon	0	7	**4**	0	420	**210**	T
River carpsucker	0	7	**4**	0	8,505	**4,253**	T
Smallmouth buffalo	7	0	**4**	42	0	**21**	T
Unidentified madtom	7	0	**4**	35	0	**18**	T
Unidentified silverside	0	7	**4**	0	35	**18**	T
Totals	**4,169,424**	**883,330**	**2,526,377**	**26,202,708**	**6,585,117**	**16,393,913**	

Table 3. Numbers of Fish Impinged at Cumberland Fossil Plant by Month and Percent of Annual Total During Year-One, 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
Jan	363,808	61	2,381	2	366,189	51
Feb	5,406	1	4,276	3	9,682	1
Mar	465	0	12,358	10	12,823	2
Apr	604	0	2,283	2	2,887	0
May	1144	0	2,659	2	3,803	1
Jun	2448	0	3014	2	5,462	1
Jul	35655	6	54256	43	89,911	12
Aug	11130	2	17854	14	28,984	4
Sep	72929	12	11935	9	84,864	12
Oct	3,687	1	6,696	5	10,383	1
Nov	14735	2	6953	6	21,688	3
Dec	83,621	14	1,525	1	85,146	12
Total	**595,632**		**126,190**		**721,822**	

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

	1974-1975	1975-1976	1976-1977	1977-1978	2005-2006	2006-2007
Extrapolated Annual Number Impinged	2,060,478	1,083,173	1,124,060	1,873,298	4,169,424	883,330
Number Liable for after EA & PF Reduction	21,448	45,514	18,396	30,926	156,272	41,064

Table 5. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Cumberland Fossil Plant During 1974-1978 and 2005-2007.

	1974-1975		1975-1976		1976-1977		1977-1978		2005-2006		2006-2007	
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**	**% by Number**	**% after PA and EF**
Threadfin shad	93	87	63	40	74	64	55	49	90	81	82	68
Gizzard shad	2	2	3	2	2	1	19	17	5	5	3	3
Skipjack herring	1	1	10	7	18	16	21	18	1	1	5	4
Freshwater drum	2	4	19	26	5	9	3	7	3	6	8	14
Silver chub	-	-	2	1	-	-	-	-	-	-	-	-
Paddlefish	-	4	-	17	-	4	-	3	-	1	-	-
Bluegill	-	-	-	-	-	-	-	-	-	3	-	3
Yellow/White bass	-	-	-	-	-	-	-	-	-	2	-	3
Blue catfish	-	-	-	-	-	-	-	-	-	-	1	2
Sauger	-	1	-	3	-	-	-	1	-	-	-	-
Total	**98**	**99**	**97**	**96**	**99**	**94**	**98**	**95**	**99**	**99**	**99**	**97**

Dash denotes not a major species during that year.

Table 6. RFAI Scores for the Fish Community Sampled at Stations Upstream and Downstream of Cumberland Steam Plant During 2001, 2003, and 2005 Including Recent and Historical Scores for Other Stations on Barkley Reservoir.

Station	River Mile	2001	2002	2003	2005	AVG
Cumberland downstream	**P-CURM102**	42	38	36	44	40.00
Cumberland upstream	**P-CURM107**	42	38	39	43	40.50

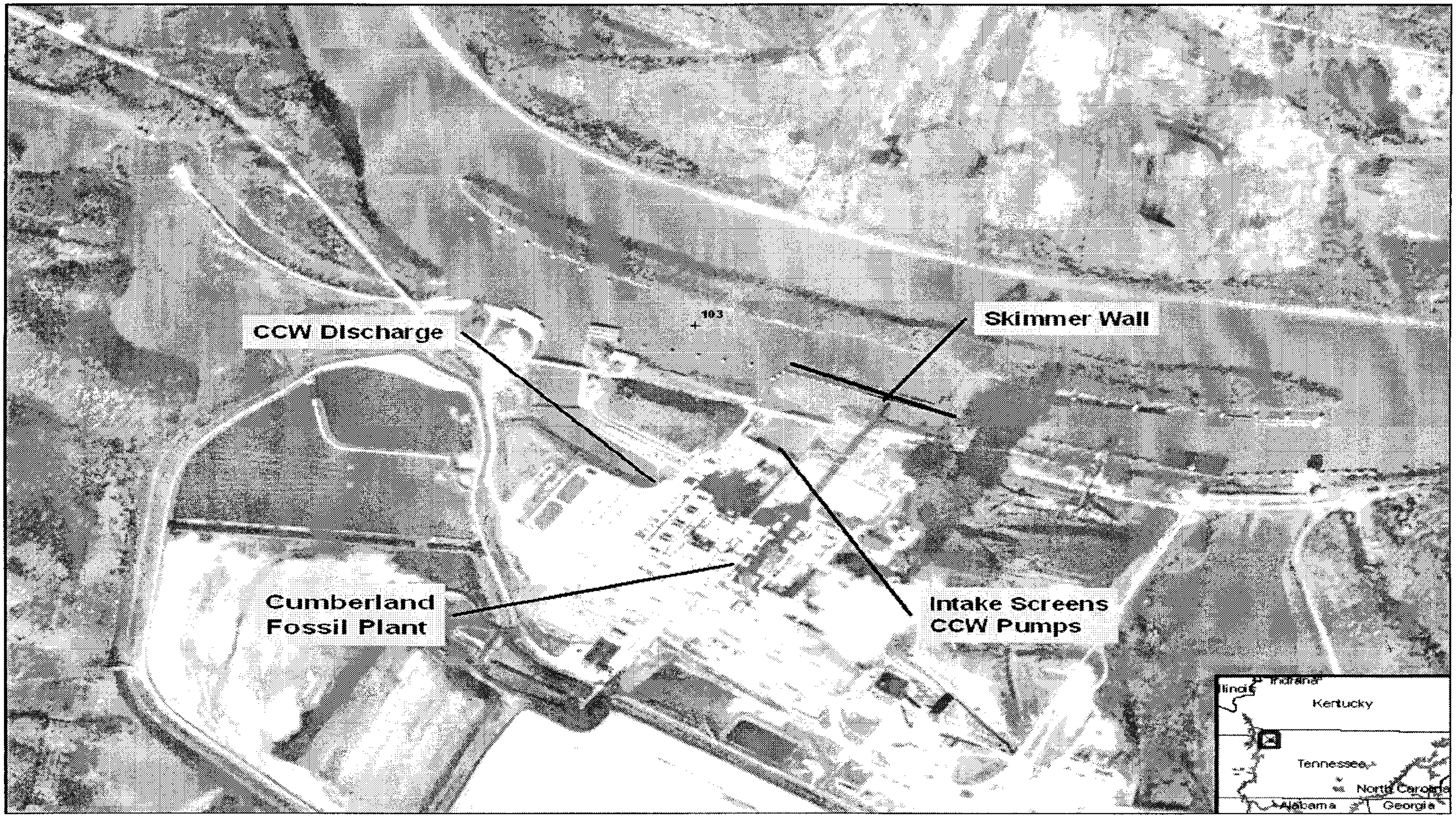


Figure 1. Aerial photograph of Cumberland Fossil Plant including CCW intake structure, skimmer wall, intake basin, and discharge channel.

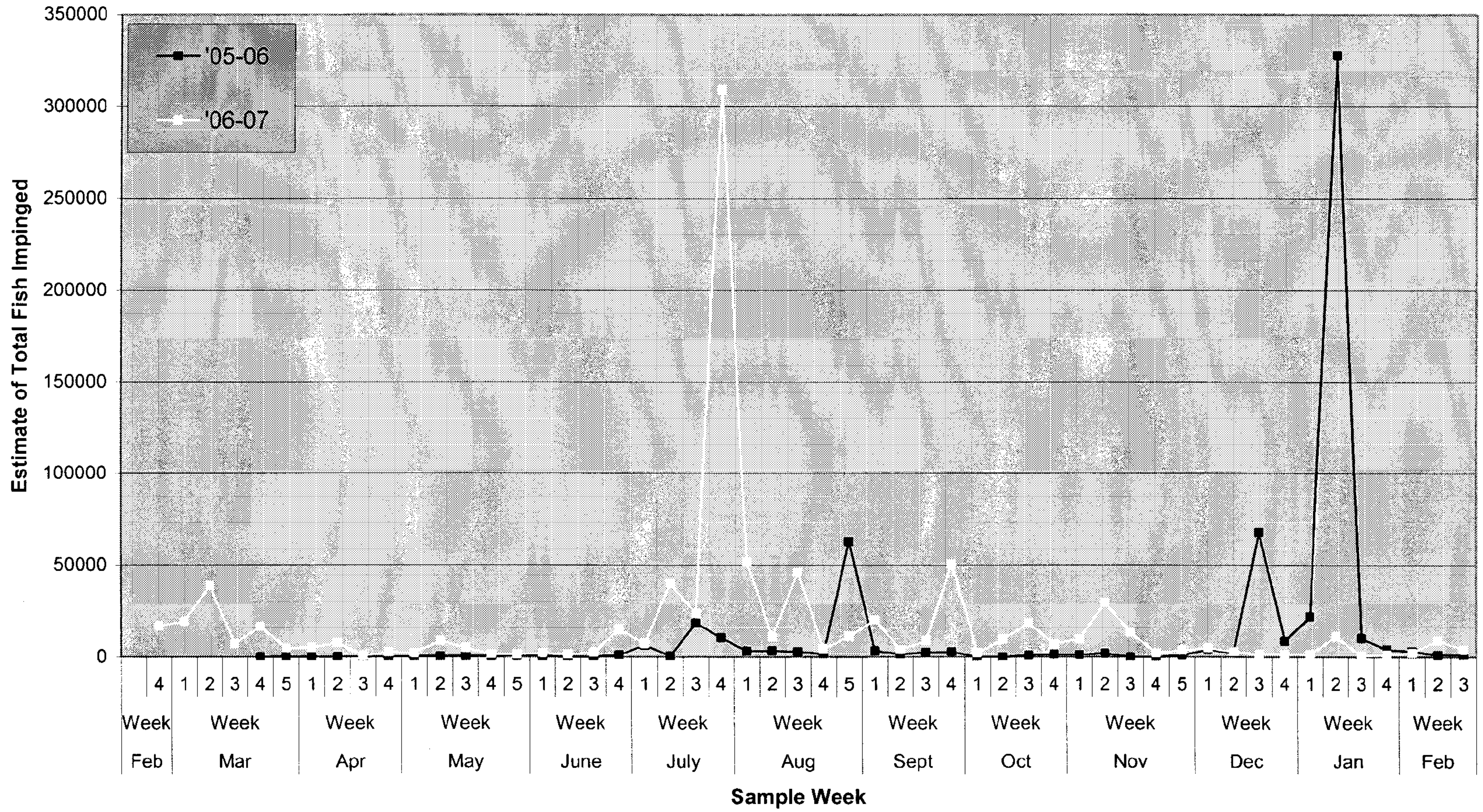


Figure 2. Estimated weekly fish impingement at TVA's Cumberland Fossil Plant during 2005-2007.

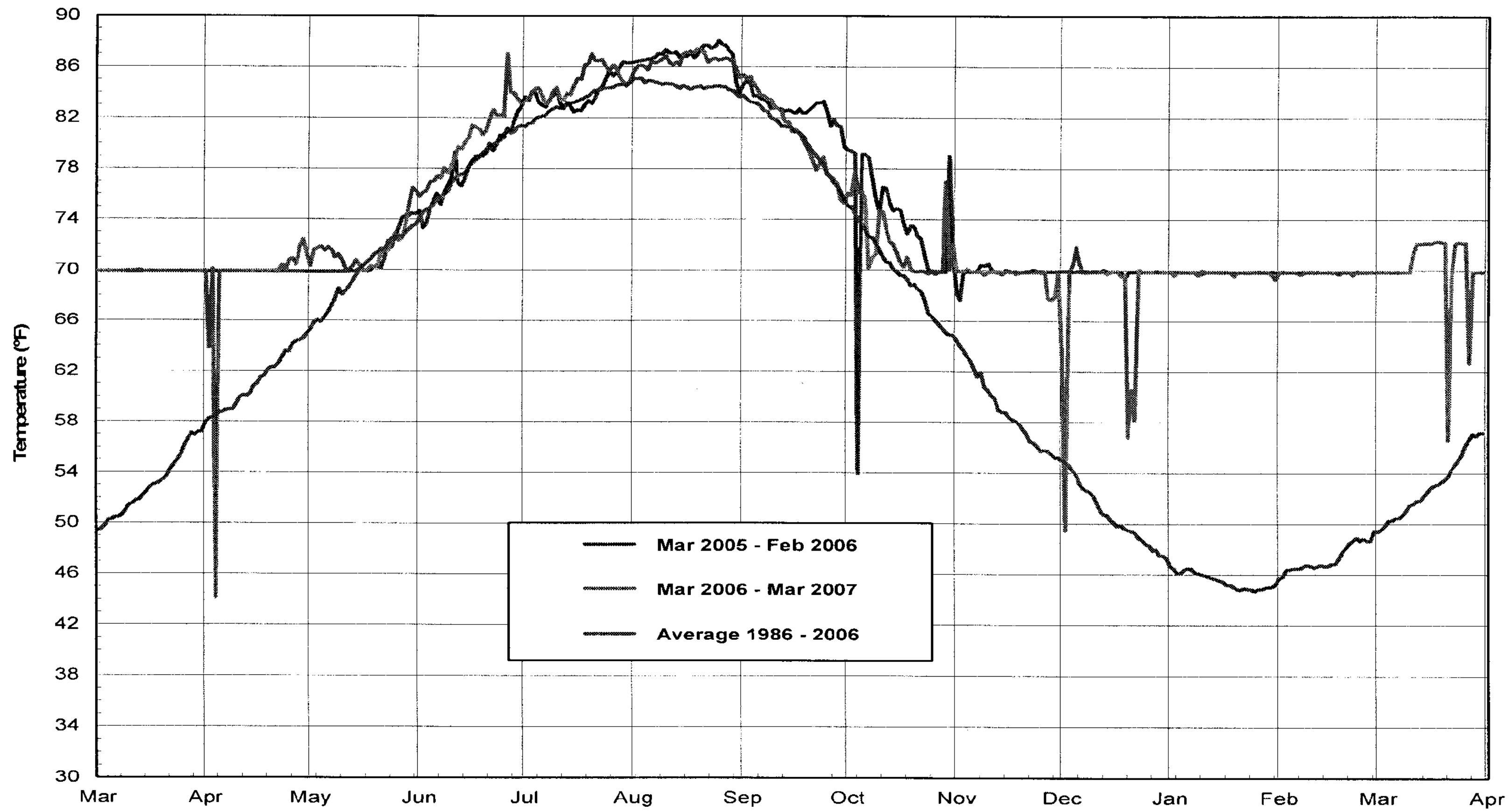


Figure 3. Ambient weekly water temperature at Cumberland Fossil Plant during historical (1986-2006) and recent (2005-2007) impingement monitoring.

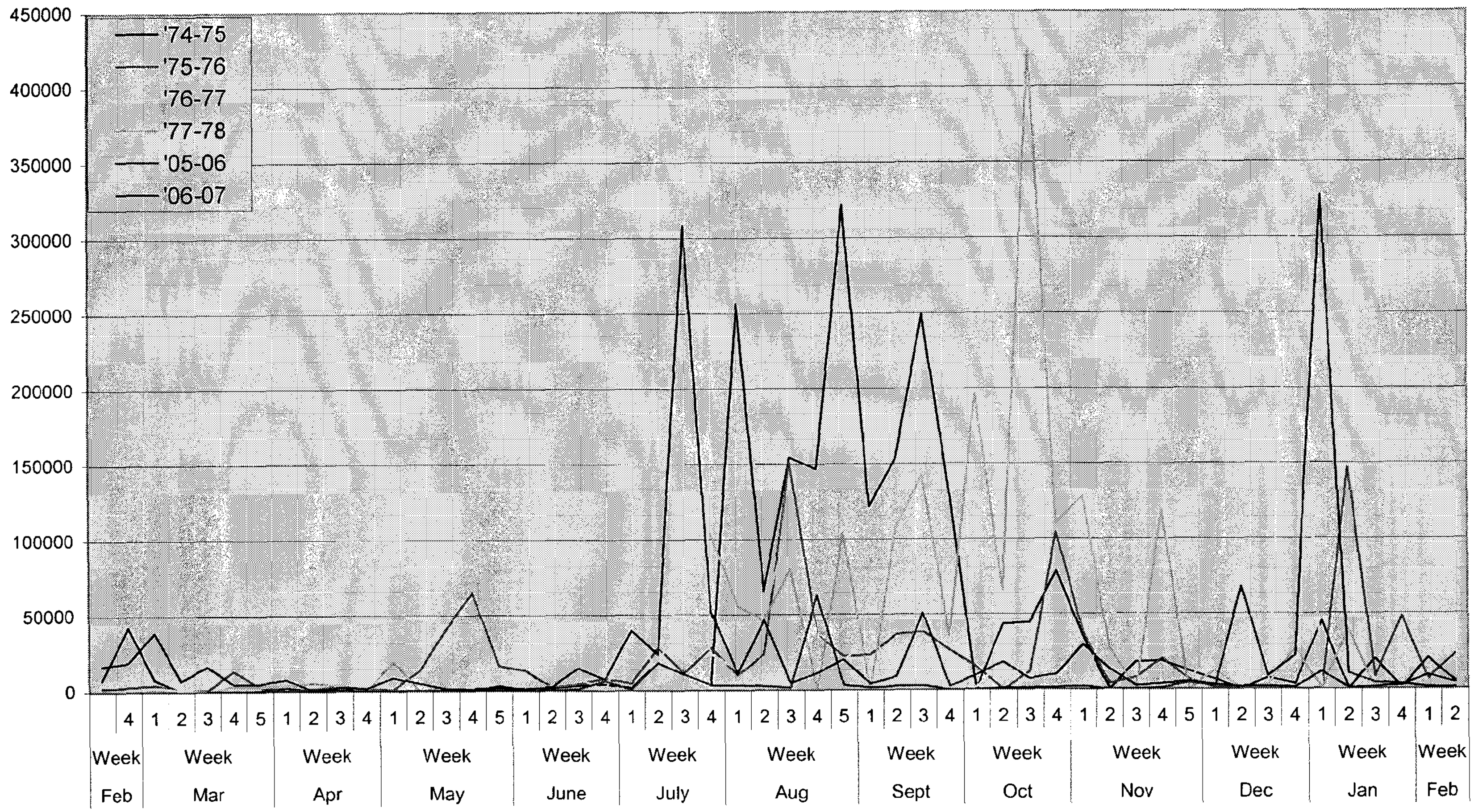
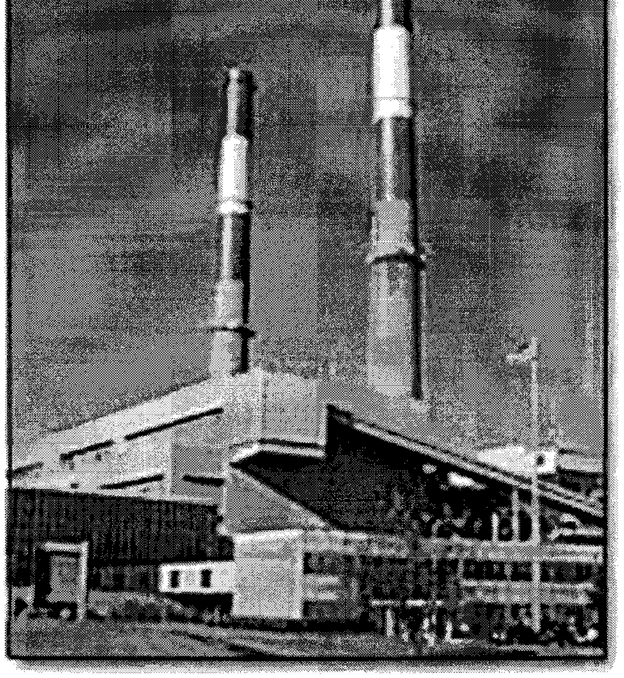


Figure 4. Comparison of estimated weekly fish impingement at TVA's Cumberland Fossil Plant during historical and recent monitoring periods.

TENNESSEE VALLEY AUTHORITY

GALLATIN FOSSIL PLANT
NPDES PERMIT NO. TN0005428
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT GALLATIN FOSSIL PLANT FROM 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

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
GAF	Gallatin Fossil Plant
PF	Production Foregone
RFAI	Reservoir Fish Assemblage Index
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

Introduction

Gallatin Fossil Plant (GAF) withdraws condenser cooling water (CCW) from Old Hickory 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 a Proposal for Information Collection submitted to the Tennessee Department of Environment and Conservation (TDEC) in 2005, Tennessee Valley Authority (TVA) conducted impingement monitoring at GAF from February 2005 through February 2007 to assess the effects of impingement on the aquatic community of Old Hickory Reservoir. This report presents impingement data collected from the CCW intake screens during 2005-2007 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 GAF operation is not impacting the balanced indigenous population (BIP) of Old Hickory Reservoir. The primary reason for gathering these data is to support the continuation of Section 316(a) thermal variances. However, the RFAI monitoring gives an indication of the overall impact of plant operations on the reservoir fish assemblage, including potential impacts from the plant's cooling water intake.

Plant Description

GAF is located on the north shore of Old Hickory Reservoir (Figure 1) between Cumberland River Kilometer (CuRK) 389.5 (Cumberland River Mile [CuRM] 242) and 392.7 CuRK (244 CuRM) and is approximately 43.4 km (27 miles) above Old Hickory Dam and 112.6 km (70 miles) below Cordell Hull Dam. Old Hickory Reservoir was impounded in 1957 and at full pool covers approximately 9,100 hectares (22,500 acres). Units 1 and 2 at GAF were placed in operation in 1956. Two more units were added in 1959 which raised the total capacity of the plant to 1,255 megawatts.

The condenser circulating water system supplies water at the rate of 9.7 m^3/s (343 cfs) per unit for Units 1 and 2 and 10.3 m^3/s (365 cfs) per unit for Units 3 and 4, or 40.1 m^3/s (1,416 cfs) for the 4-unit plant.

Water is brought from the reservoir through an excavated channel 838.2 m (2750 ft) long to the intake structure, where it is pumped through tunnels approximately 213.3 m (700 ft) to the condenser. From the condenser, discharge tunnels approximately 131 m (430 ft) long take the water to the discharge channel. The discharge channel is 1006 m (3300 ft) long and empties into the reservoir approximately 2.4 km (1.5 river miles) downstream from the mouth of the intake channel.

Skimmer Wall and Traveling Screens

River water is used as the main cooling source for the station, carrying off rejected heat from equipment. The GAF skimmer wall was designed to allow colder water to enter the intake channel underneath the wall while keeping out the warmer water in the upper stratum of the reservoir. This cold water enables the condenser to effect greater reduction in backpressure at the turbine, thereby resulting in reduction of the Btu/kwh requirements.

Eight traveling screens at the intake pumping station remove trash and debris from the plant water supply after larger pieces are removed by trashracks located in front of the screens. The traveling screens filter any debris or fish that will not pass through the 2.4 cm^2 (3/8 in^2) openings in the screens. When the head differential between the intake and discharge sides of a screen reaches about 6 in, an alarm sounds and the screens are started by the operator. The screen drives are electrically interlocked with a refuse spray system so the screen drives will not start until the spray water reaches the required pressure. When screens are rotated and washed, spray water removes the trash and debris from the screens and carries it to the CCW discharge.

Methods

Weekly impingement monitoring for this investigation began on February 3, 2005 and continued through January 23, 2007. To simplify comparisons in this report, data from February 3, 2005 through January 25, 2006 will be referred to as Year-One, and from February 1, 2006, through January 23, 2007, as Year-Two. Intake screens were rotated and washed by the Assistant Unit Operator to remove all fish and debris. After twenty-four hours, screens were again rotated and washed with an Aquatic Monitoring and Management crew on site. Fish were collected in the 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.

Moribund/Dead Fish

Fish collected from a 24-hr screen wash were usually all dead when processed. 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 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. Additionally, if threadfin shad were observed dying in the reservoir from cold-shock, this was documented and presented in the report to indicate cold-shock as the primary cause of unusually high impingement of this species.

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-hour sample was possible, data were normalized to 24 hours.

To facilitate the implementation of and compliance with EPA's regulations for Section 316(b) of the CWA 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 forage available 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 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, 17,261 fish were collected from weekly screen-wash samples. Impingement was over twice as high (38,374 fish) during Year-Two. Number of species impinged was 29 and 26 during Year-One and Year-Two, respectively (Table 1).

During Year-One, threadfin shad comprised 82% of the total followed by gizzard shad (15%), freshwater drum (2%), and skipjack herring at 1% (Table 2) before the EPRI models were applied. Percent composition during Year-Two was similar to the first with 87% threadfin shad and 12% gizzard shad (Table 2).

In Table 3, the estimated total fish impinged for Year-One extrapolated from weekly samples was 120,848. Early in Year-Two, one sample collected on February 15, 2006, contained a total of 18,961 fish from the 24-hr screen wash. The extrapolated weekly estimate from this sample was 132,727 fish, which is greater than the extrapolated total for the entire Year-One (Table 3).

Peak impingement during Year-One at GAF occurred during January, September, and November (Table 4 and Figure 2). During Year-Two, 95% of the total fish impinged was during February, March and April. A plot of daily (24-hr average) ambient intake water temperatures for GAF during Year-One and Year-Two is presented in Figure 3. Lower temperatures during winter were generally correlated with peak impingement as previously reported by numerous studies (EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978, McLean et al., 1980). A recent study by Fost (2006) 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). Winter temperatures during both years dropped below the Fost threshold. Figure 3 also presents historical average GAF intake temperatures from 1986-2006 for comparison. No die-offs of threadfin shad were observed during the two years of monitoring by AMM crews or were reported by power plant personnel.

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).

Application of the EA and PF models to the estimated total numbers of impinged fish indicated that 4,737 and 7,210 fish during Year-One and Year-Two, respectively (Table 5), 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, resident fish communities were sampled in Old Hickory Reservoir upstream and downstream of GAF in 2001, 2003, and 2005. Results indicated "Good" fish communities at both the upstream and downstream sites and TVA concluded that operations at GAF are not impacting the fish community of Old Hickory Reservoir (Scott 2006). The RFAI scores of 47 and 46 ("Good") for the site downstream and upstream, respectively, of GAF during autumn 2005 exceeded the 70% BIP criterion indicating that the resident fish community above and below GAF was above the conservative screening level.

The slightly higher average RFAI score downstream of GAF further indicates impingement mortality is not adversely impacting the fish community below the plant discharge.

No state or federal protected fish species were collected in the vicinity of GAF.

Comparison with Historical Impingement Data

Impingement monitoring as part of the initial 316(b) demonstration at GAF was conducted from August 1974 through July 1976 (TVA 1976). Relatively high impingement of paddlefish resulted in additional monitoring from August 1977 through April 1980. Results of historical impingement monitoring from 1974-1978 are summarized and compared with results of the current monitoring study in Table 5 and Figure 4. Impingement estimates were highest and relatively consistent, numbering between 200,000 and 300,000 during the first three years of historical monitoring (August 1974 through July 1978). The original 316(b) demonstration based on impingement data from August 1974 through July 1976 concluded that there was no evidence that impingement of fish at GAF constituted a significant adverse impact to the fish assemblage in Old Hickory Reservoir.

Summary and Conclusions

Impingement of fish by the GAF CCW was monitored during 2005-2007 and compared with historical data collected during 1974-1978. Total numbers of fish estimated impinged annually were lower during 2005-2007 than during 1974-1978. The average number estimated impinged during the two years 2005-2007 was 194,737 compared to 240,244 per year during 1974-1978. Annual impingement totals for fish impinged were noticeably lower during 2005-2006 than during historical monitoring periods (1974-1978). Relatively low impingement rates and the evidence of a balanced and healthy fish community from the 316(a) studies suggest that the GAF CCW intake is not adversely affecting the Old Hickory Reservoir fish community.

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Table 1. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Gallatin Fossil Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Petromyzontidae	*Ichthyomyzon castaneus*	Chestnut lamprey	1	0
Polyodontidae	*Polyodon spathula*	Paddlefish	2	0
Hiodontidae	*Hiodon tergisus*	Mooneye	0	1
Clupeidae	*Alosa pseudoharengus*	Alewife	16	9
	Dorosoma cepedianum	Gizzard shad	2,618	4,620
	Alosa chrysochloris	Skipjack herring	91	98
	Dorosoma petenense	Threadfin shad	14,107	33,418
Cyprinidae	*Pimephales vigilax*	Bullhead minnow	1	15
	Notropis atherinoides	Emerald shiner	0	1
	Carassius auratus	Goldfish	1	0
	Notemigonus crysoleucas	Golden shiner	0	2
	Macrhybopsis storeriana	Silver chub	14	5
Catostomidae	*Ictiobus bubalus*	Smallmouth buffalo	1	0
	Ictiobus cyprinellus	Bigmouth buffalo	1	0
Ictaluridae	*Ictalurus furcatus*	Blue catfish	3	2
	Ictalurus punctatus	Channel catfish	10	6
	Pylodictis olivaris	Flathead catfish	3	1
	Ameiurus natalis	Yellow bullhead	4	0
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	0	1
Moronidae	*Morone saxatilis*	Striped bass	23	13
	Morone chrysops	White bass	0	3
	Morone mississippiensis	Yellow bass	43	63
Centrarchidae	*Lepomis macrochirus*	Bluegill	22	28
	Lepomis auritus	Redbreast sunfish	1	0
	Lepomis microlophus	Redear sunfish	10	4
	Lepomis gulosus	Warmouth	0	1
	Lepomis humilis	Orangespotted sunfish	1	0
	Lepomis megalotis	Longear sunfish	1	4
	Lepomis spp.	Hybrid sunfish	1	0
	Micropterus salmoides	Largemouth bass	2	0
	Micropterus punctulatus	Spotted bass	0	2
	Pomoxis annularis	White crappie	2	1

Table 1. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Percidae	*Etheostoma caeruleum*	Rainbow darter	4	3
	Percina caprodes	Logperch	4	1
	Sander canadense	Sauger	0	1
	Sander vitreus	Walleye	3	0
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	274	72
		Total number of fish	**17,261**	**38,374**
		Total number of species	**29**	**26**

Table 2. Percent Composition (By Number and after EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Gallatin Fossil Plant During 1974-1976 and 2005-2007.

	1974-1976*	2005-2006		2006-2007	
Species Composition	% by Number	% by Number	% after PA and EF	% by Number	% after PA and EF
Threadfin shad	67	82	74	87	85
Gizzard shad	15	15	14	12	12
Freshwater drum	11	2	4	0	1
Skipjack herring	4	1	0	-	-
Yellow bass	-	-	2	0	1
Paddlefish	3	-	1	-	-
Sauger	-	-	1	-	-
Striped bass	-	-	1	-	-
Total	**100**	**100**	**97**	**99**	**99**

***EA and PF not calculated for historical data.**
Dash denotes not a major species that year.

Table 3. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Gallatin Fossil Plant During 2005-2007.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Threadfin shad	98,749	233,926	**166,338**	351,736	855,113	**603,425**	**85**
Gizzard shad	18,326	32,340	**25,333**	108,969	164,213	**136,591**	**13**
Freshwater drum	1,918	504	**1,211**	127,981	34,692	**81,337**	**1**
Skipjack herring	637	686	**662**	7,917	51,681	**29,799**	**T**
Yellow bass	301	441	**371**	12,782	21,532	**17,157**	**T**
Bluegill	154	196	**175**	2,282	2,548	**2,415**	**T**
Striped bass	161	91	**126**	1,547	4,025	**2,786**	**T**
Alewife	112	63	**88**	1,491	1,288	**1,390**	**T**
Silver chub	98	35	**67**	3,150	1,155	**2,153**	**T**
Bullhead minnow	7	105	**56**	28	413	**221**	**T**
Channel catfish	70	42	**56**	413	112	**263**	**T**
Redear sunfish	70	28	**49**	4,193	392	**2,293**	**T**
Sauger	28	21	**25**	6,314	4,445	**5,380**	**T**
Blue catfish	21	14	**18**	140	42	**91**	**T**
Logperch	28	7	**18**	511	168	**340**	**T**
Longear sunfish	7	28	**18**	385	1,211	**798**	**T**
Flathead catfish	21	7	**14**	161	7	**84**	**T**
Yellow bullhead	28	0	**14**	189	0	**95**	**T**
Walleye	21	0	**11**	140	0	**70**	**T**
White bass	0	21	**11**	0	434	**217**	**T**
White crappie	14	7	**11**	3731	154	**1,943**	**T**
Golden shiner	0	14	**7**	0	168	**84**	**T**
Largemouth bass	14	0	**7**	70	0	**35**	**T**
Paddlefish	14	0	**7**	1,400	0	**700**	**T**
Spotted bass	0	14	**7**	0	98	**49**	**T**
Bigmouth buffalo	7	0	**4**	49	0	**25**	**T**
Chestnut lamprey	7	0	**4**	385	0	**193**	**T**
Emerald shiner	0	7	**4**	0	14	**7**	**T**

Table 3. (continued)

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	**Year-One**	**Year-Two**	**Average**	**Year-One**	**Year-Two**	**Average**	
Goldfish	7	0	**4**	70	0	**35**	**T**
Hybrid sunfish	7	0	**4**	350	0	**175**	**T**
Mooneye	0	7	**4**	0	2,877	**1,439**	**T**
Orangespotted sunfish	7	0	**4**	35	0	**18**	**T**
Rainbow darter	0	7	**4**	0	14	**7**	**T**
Rainbow trout	0	7	**4**	0	2,450	**1,225**	**T**
Redbreast sunfish	7	0	**4**	175	0	**88**	**T**
Smallmouth buffalo	7	0	**4**	56	0	**28**	**T**
Warmouth	0	7	**4**	0	434	**217**	**T**
Total	**120,848**	**268,625**	**194,737**	**636,650**	**1,149,400**		

T = Trace < one percent

Table 4. Numbers of Fish Impinged at Gallatin 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
Jan	6,467	37	283	1	6,750	12
Feb	136	1	22,244	58	22,380	40
Mar	67	0	11,696	30	11,763	21
Apr	81	0	2,655	7	2,736	5
May	61	0	169	0	230	0
Jun	52	0	107	0	159	0
Jul	1120	6	28	0	1,148	2
Aug	328	2	77	0	405	1
Sep	4183	24	114	0	4,297	8
Oct	1,163	7	510	1	1,673	3
Nov	2014	12	233	1	2,247	4
Dec	1,592	9	259	1	1,851	3
Total	**17,264**		**38,375**		**55,639**	

Table 5. Total Numbers of Fish Estimated Impinged by Year at Gallatin Fossil Plant and Numbers Following Application of Equivalent Adult and Production Foregone Models.

	1974-1975	1975-1976	1977-1978	2005-2006	2006-2007
Extrapolated Annual Number Impinged	267,978	225,209	227,544	120,848	268,625
Number Liable for after EA & PF Reduction	20,603	32,851	17,648	4,737	7,210

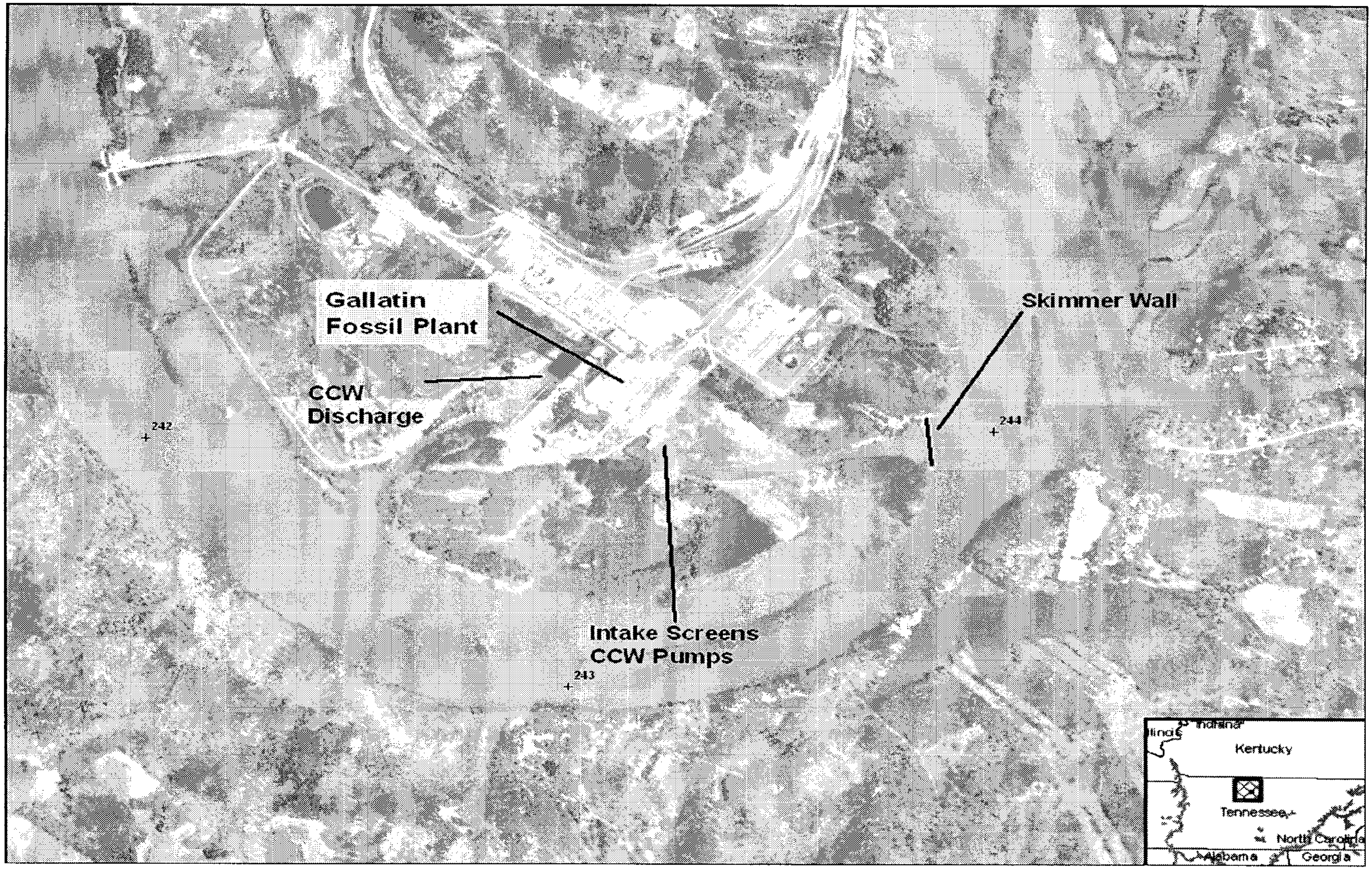


Figure 1. Aerial photograph of Gallatin Fossil Plant including CCW intake structure, skimmer wall, and discharge channel.

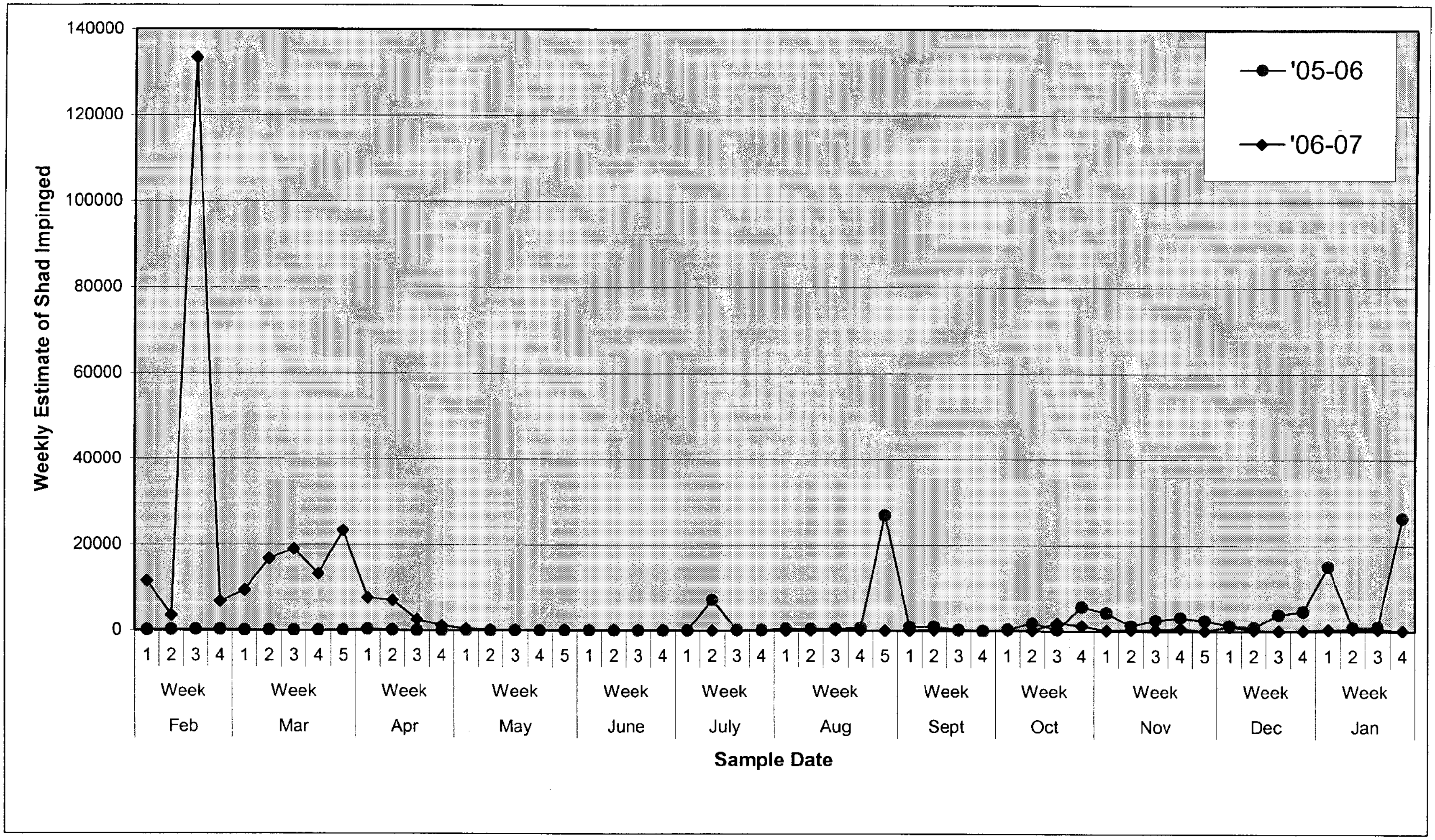


Figure 2. Estimated weekly fish impingement at Gallatin Fossil Plant during 2005-2007.

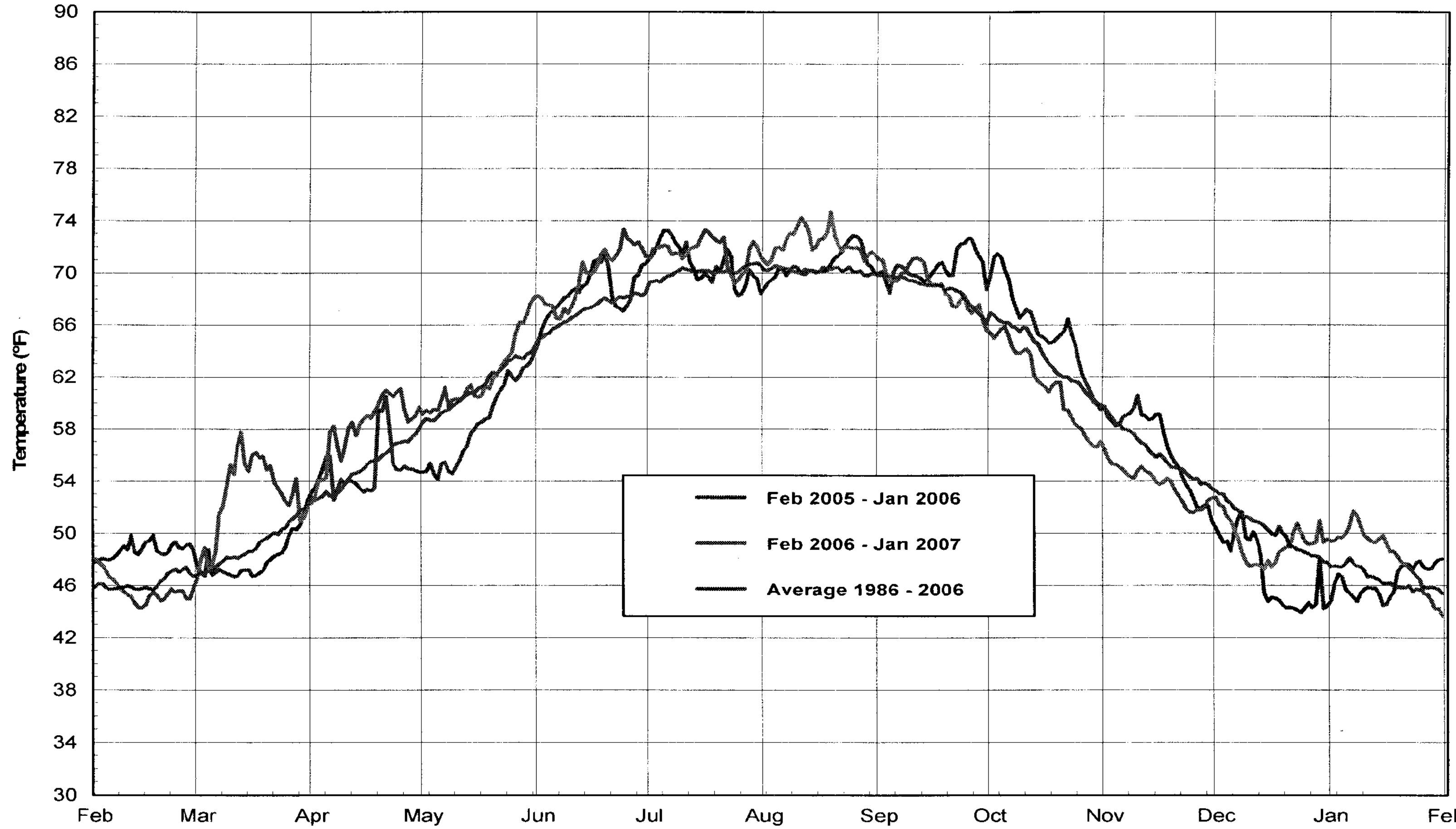


Figure 3. Ambient daily (24-hr avg) water temperature at Gallatin Fossil Plant during historical (1986-2006) and recent (2005-2007) impingement monitoring.

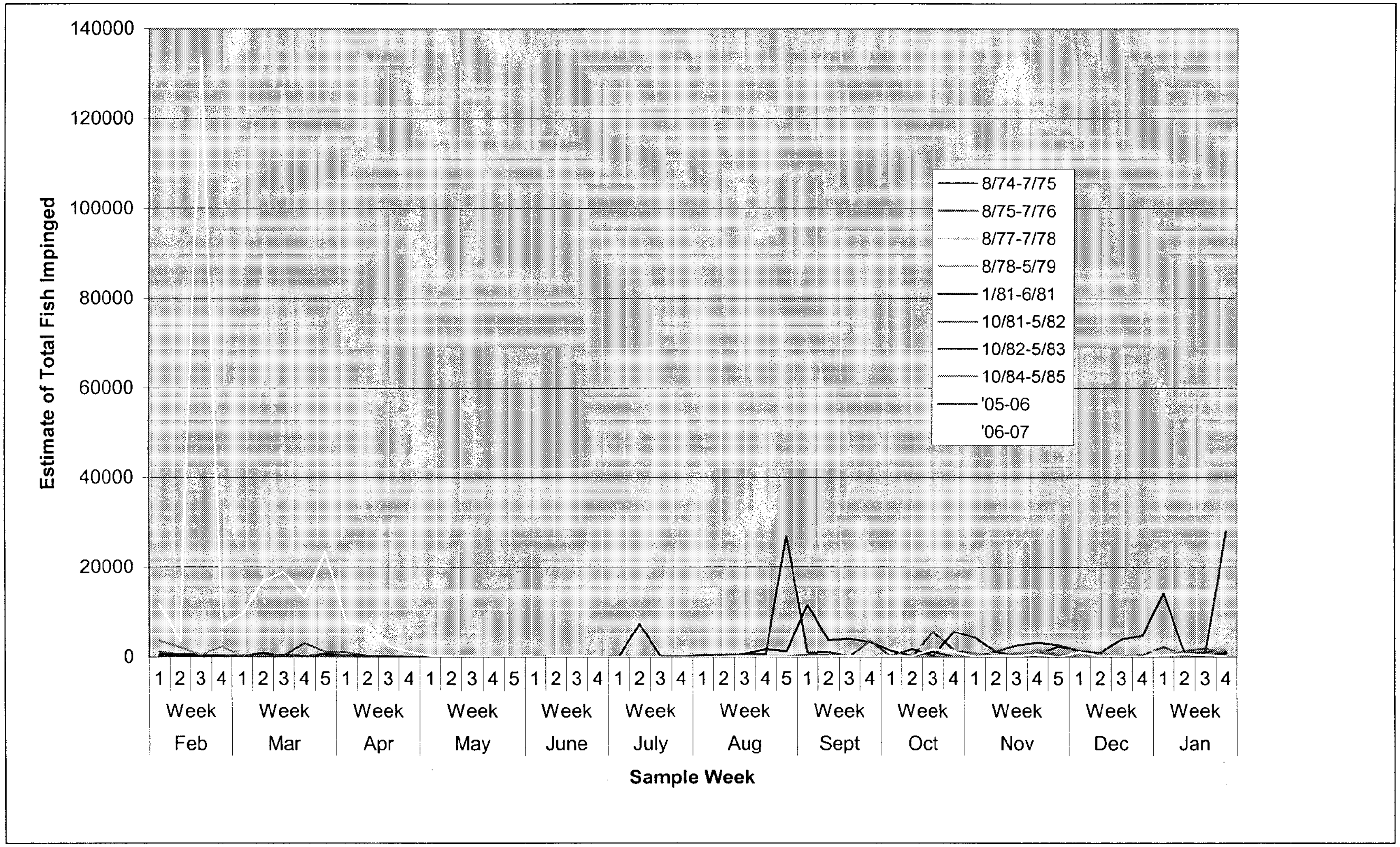
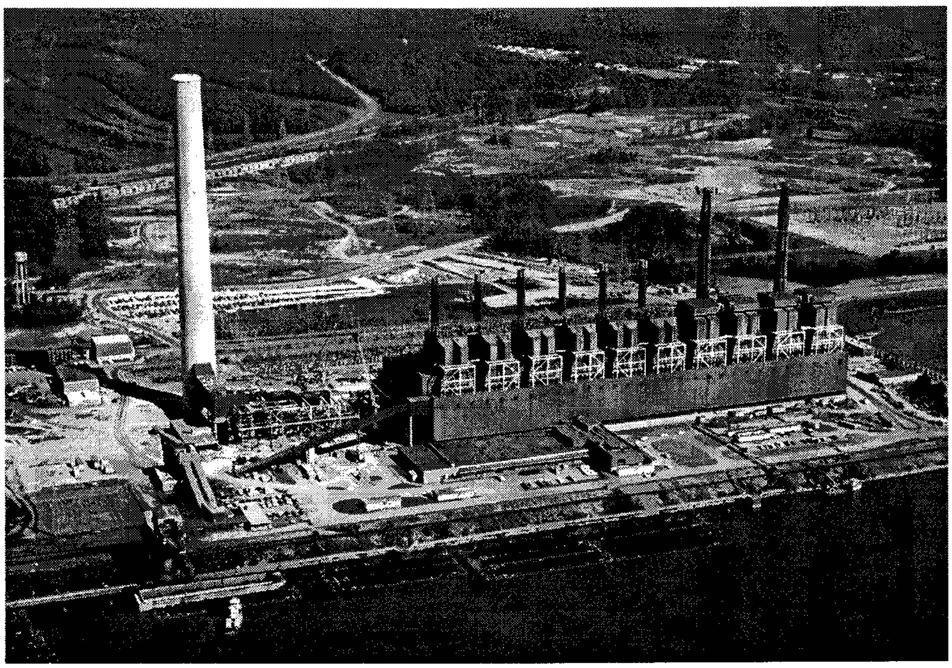


Figure 4. Comparison of estimated weekly fish impingement at TVA's Gallatin Fossil Plant during historical and recent monitoring periods.

TENNESSEE VALLEY AUTHORITY

JOHNSONVILLE FOSSIL PLANT
NPDES PERMIT NO. 0005444
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT JOHNSONVILLE FOSSIL PLANT DURING 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

AM&M	Aquatic Monitoring and Management
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
JOF	Johnsonville Fossil Plant
PF	Production Foregone
RFAI	Reservoir Fish Assemblage Index
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

Introduction

Johnsonville Fossil Plant (JOF), placed into operation in 1951, withdraws condenser cooling water (CCW) from Kentucky 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 shellfish 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 a Proposal for Information Collection submitted to the Tennessee Department of Environment and Conservation (TDEC) in 2005, Tennessee Valley Authority (TVA) conducted impingement monitoring during March 2005 through February 2007 to assess the effects of impingement on the aquatic community of Kentucky Reservoir. This report presents impingement data collected from the CCW intake screens during 2005-2007 with comparisons to historical data collected during 1974-1976 and 1980-1982.

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 JOF operation is not impacting the balanced indigenous population (BIP). The primary reason for gathering these data is to support the continuation of Section 316(a) thermal variance for JOF. However, the RFAI monitoring also gives an indication of the overall impact of plant operations on the reservoir fish assemblage, including impacts from the plant's cooling water intake.

Plant Description

JOF is located on the eastern shore of Kentucky Reservoir at Tennessee River Kilometer 161 (Tennessee River Mile 100). JOF began operation in 1951 with six units, then in 1959 added four more for a total generating capacity of 1,485 megawatts. The condenser cooling water for JOF is pumped from Kentucky Reservoir via a 480 m (1574 ft) long intake channel located southwest of the plant (Figure 1). At full operating capacity, JOF has a total flow through the condensers of 70.8 m^3/sec (2500 cfs).

Water enters the intake structure through trashracks consisting of vertical steel bars spaced so that the clear opening is 9.2 cm (3 5/8 in). The trashracks are cleaned by a rake operated from the deck gantry crane. The trashracks cover the openings below the curtain walls, the bottoms of which are below normal water level. The low elevation of the bottom edge of the curtain wall aids in maintaining stratification of the water, thus drawing from the cooler lower depths in summer and sealing the screen chamber from freezing weather in the winter.

There are two traveling screens per unit, each 3 m (10 ft) wide with 9.5 mm (3/8 in) square openings. Debris and fish impinged against the screens are washed off by spraying into a sluice trench that extends the length of the intake structure deck and connects to a 61 cm (24 in) underground concrete pipe then conveyed 549 m (1,800 ft) to the reservoir downstream from the intake channel.

Methods

Weekly impingement monitoring began on March 8, 2005 and continued through February 27, 2007. To simplify comparisons in this report, data from March 8, 2005 through February 28, 2006 will be referred to as Year-One, and from March 7, 2006 through February 27, 2007 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 (AM&M) 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 at JOF was initially conducted by TVA from July 30, 1974 through March 30, 1976 (TVA 1976). Two years of additional impingement monitoring were conducted at JOF during mid-August, 1980 through mid-August, 1982 (Hackney et al., 1984) to reevaluate impacts of fish impingement in response to relocation of the JOF ashpond discharge from the Tennessee River (Kentucky Reservoir) to the plant CCW intake channel. [NOTE: The ash pond discharge was subsequently re-routed to the Tennessee River.]

In response to an agreement with TDEC, TVA initiated RFAI studies to evaluate fish communities in areas immediately upstream and downstream of JOF during the years 2003 and 2005 (Scott 2006).

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

To facilitate the implementation of and compliance with the EPA regulations for Section 316(b) of the CWA (Federal Register Vol. 69, No. 131; July 9, 2004), 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 also used these models to determine the "biological liability" of the CCW intake structure.

Results and Discussion

During Year-One and Year-Two of impingement monitoring, 10,711 and 116,894 fish were collected, respectively, from weekly screen-wash samples (Table 1). Threadfin shad comprised 92% of the total impinged for both years combined followed by bluegill (3%), freshwater drum (2%), and gizzard shad, largemouth bass, redear sunfish and skipjack herring at 1% each (Table 2). Estimated total numbers collected by year and percent composition (both years combined) in impingement samples by species are presented in Table 2. Number of species collected during Year-One was 40 and 28 in Year-Two (Table 1). Estimated total numbers impinged extrapolated from weekly samples was 74,944 during Year-One and 818,258 during Year-Two (Table 2). Total fish collected in impingement samples and percent by month for Year-One and Two are presented in Table 3. Peak impingement (81%) occurred during November through February during Year-One while 82% of all fish sampled during Year-Two were collected during February alone (Table 3) (Figure 2). One sample period (February 13, 2007) alone accounted for 59% (68,781) of all fish impinged during Year-Two (Figure 2) and 98% of this sample was threadfin shad.

Plotted daily (24-hr average) ambient intake water temperatures (Figure 3) for JOF during each of the two years sampled appear to be correlated with peak impingement as previously reported by numerous studies (EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978, McLean et al., 1980). The lowest temperature recorded during Year-Two was 5.6°C (42°F) during mid-February (Figure 3) when the peak impingement was recorded. Figure 3 also presents average JOF intake temperatures from 1986 through 2006 for comparison. The low temperatures recorded during February 2007 were noticeably below the historical average.

A recent study by Fost (2006) 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.

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 die-offs of threadfin shad were observed during the two years of monitoring by AM&M crews or were reported by power plant personnel.

Application of the EA and PF models to the total numbers estimated impinged resulted in the reduced numbers of fish (Table 4) which 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 impingement. The numbers of fish representing JOF's biological liability for Year-One and Year-Two were 10,731 and 23,486 respectively (Table 4).

As part of TVA's Vital Signs Monitoring Program (Scott 2006), resident fish communities were sampled in Kentucky Reservoir upstream and downstream of JOF in 2003 and 2005. Resulting RFAI scores indicated "Good" fish communities at both sites and scores at the downstream station were higher (46 and 47 in 2003 and 2005, respectively) at JOF both years than at the upstream station (43 and 45 in 2003 and 2005, respectively). TVA concludes from these data that impingement at JOF is not adversely impacting the fish community of Kentucky Reservoir and that a BIP exists in the vicinity of JOF. No State or Federal protected fish species were collected or are known to occur in the vicinity of JOF.

Comparison with Historical Data

Estimated annual numbers impinged from historical sampling during 1974-1976 and 1980-1982 including the reduced numbers after EA and PF application are presented in Tables 4. The estimated total of fish impinged during 1974-975 and 1975-1976 was 193,781 and 1,391,558, respectively. Impingement estimate was highest during 1980-1981 (5,168,065) but dropped to 1,879,675 during 1981-1982 (Table 4). Higher intake temperature in the winters of 1974-1975 and 1975-1976 compared to 1980-1981 and 1981-1982 corresponded to lower numbers of threadfin shad impinged (Hackney et al., 1984). It was concluded from the 1980-1982 study that impingement of fish by JOF increased in total numbers following relocation of the ashpond discharge to the intake channel. Threadfin shad were primarily responsible for this increase, and a relationship between ashpond discharge volume and increased impingement of threadfin shad was confirmed with a high degree of statistical confidence (Hackney et al., 1984). [NOTE: The ash pond discharge was subsequently re-routed to the Tennessee River.] The JOF thermal discharge has been reported (Dycus et al., 1978) to affect seasonal distribution of fish, especially threadfin shad, sauger, catfish, and skipjack herring in Kentucky Reservoir. Survival of significant threadfin shad broodstock during extremely cold winters may depend on the presence of this thermal discharge as a refuge (Dryer and Benson 1957).

Table 5 presents the percent composition by number and by biological liability for major (>1%) species impinged at JOF by year during 1974-1976, 1980-1982, and 2005-2007. Threadfin shad dominance ranged from 60% in 2005-2006 to 98% in 1980-1981.

Summary and Conclusions

Impingement rates during the most recent monitoring period were lower than the average annual impingement recorded from four years of historical monitoring. Favorable ("Good") RFAI scores above and below JOF indicate the presence of a BIP in the vicinity of the plant and no evidence of adverse environmental impact from the CCW. Since threadfin shad remain the dominant species impinged at JOF, and have been subjected to impingement by full, ten-unit operation for 48 years, it seems this species is obviously able to maintain a viable population in spite of CCW impingement.

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

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Petromyzontidae	*Ichthyomyzon castaneus*	Chestnut lamprey	3	0
Lepisosteidae	*Lepisosteus platostomus*	Shortnose gar	1	0
Hiodontidae	*Hiodon tergisus*	Mooneye	1	0
Clupeidae	*Dorosoma cepedianum*	Gizzard shad	943	717
	Alosa chrysochloris	Skipjack herring	248	479
	Dorosoma petenense	Threadfin shad	6,447	110,656
Cyprinidae	*Pimephales notatus*	Bluntnose minnow	19	0
	Pimephales vigilax	Bullhead minnow	1	0
	Pimephales promelas	Fathead minnow	5	0
	Notropis atherinoides	Emerald shiner	29	37
	Notemigonus crysoleucas	Golden shiner	2	1
	Clinostomus funduloides	Rosyside dace	2	0
	Macrhybopsis storeriana	Silver chub	29	3
Catostomidae	*Carpiodes carpio*	River carpsucker	0	1
	Minytrema melanops	Spotted sucker	0	8
Ictaluridae	*Ictalurus furcatus*	Blue catfish	125	153
	Ictalurus punctatus	Channel catfish	138	60
	Pylodictis olivaris	Flathead catfish	12	6
	Ameiurus natalis	Yellow bullhead	6	0
Esocidae	*Esox masquinongy*	Muskellunge	0	1
Atherinidae	*Labidesthes sicculus*	Brook silverside	3	2
	Menidia beryllina	Inland silverside	3	1
Belonidae	*Strongylura marina*	Atlantic needlefish	1	2
Cottidae	*Cottus carolinae*	Banded sculpin	5	0

Table 1. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Moronidae	*Morone saxatilis*	Striped bass	2	1
	Morone chrysops	White bass	57	1
	Morone mississippiensis	Yellow bass	367	153
Centrarchidae	*Ambloplites rupestris*	Rock bass	1	0
	Lepomis macrochirus	Bluegill	504	3,612
	Lepomis auritus	Redbreast sunfish	4	0
	Lepomis microlophus	Redear sunfish	23	20
	Lepomis cyanellus	Green sunfish	1	0
	Lepomis megalotis	Longear sunfish	35	17
	Lepomis humilis	Orangespotted sunfish	8	0
	Lepomis gibbosus	Pumpkinseed sunfish	1	0
Centrarchidae	*Lepomis gulosus*	Warmouth	7	0
	Micropterus salmoides	Largemouth bass	6	5
	Micropterus punctulatus	Spotted bass	5	1
	Micropterus dolomieu	Smallmouth bass	2	11
	Pomoxis annularis	White crappie	17	11
Percidae	*Sander canadense*	Sauger	2	1
	Percina caprodes	Logperch	18	15
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	1,629	919
	Total number of fish		**10,711**	**116,894**
	Total number of species		**40**	**28**

Table 2. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Johnsonville Fossil Plant During 2005-2006 and 2006-2007.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
Species	**Year-One**	**Year-Two**	**Average**	**Year-One**	**Year-Two**	**Average**	
Threadfin shad	45,129	774,592	409,861	209,286	2,783,585	1,496,436	92
Bluegill	3,528	25,284	14,406	19,768	88,235	54,002	3
Freshwater drum	11,403	6,433	8,918	826,819	491,036	658,928	2
Gizzard shad	6,601	5,019	5,810	323,330	288,652	305,991	1
Largemouth bass	42	35	39	5,152	5,600	5,376	1
Redear sunfish	161	140	151	16,191	14,182	15,187	1
Skipjack herring	1,736	3,353	2,545	30,527	131,754	81,141	1
Yellow bass	2,569	1,071	1,820	56,133	36,596	46,365	T
Blue catfish	875	1,071	973	47,712	62,671	55,192	T
Channel catfish	966	420	693	76,699	120,932	98,816	T
Emerald shiner	203	259	231	973	2,226	1,600	T
White bass	399	7	203	16,198	2,772	9,485	T
Longear sunfish	238	119	179	9,044	5,964	7,504	T
Logperch	126	105	116	756	812	784	T
Silver chub	203	21	112	5,012	168	2,590	T
White crappie	119	77	98	4,711	5,740	5,226	T
Bluntnose minnow	133	0	67	455	0	228	T
Flathead catfish	84	42	63	959	4,760	2,860	T
Smallmouth bass	14	77	46	154	6,258	3,206	T
Orangespotted sunfish	56	0	28	1,400	0	700	T
Spotted sucker	0	56	28	0	32,130	16,065	T
Warmouth	49	0	25	1,526	0	763	T
Spotted bass	35	7	21	154	56	105	T
Yellow bullhead	42	0	21	280	0	140	T
Banded sculpin	35	0	18	140	0	70	T
Brook silverside	21	14	18	35	56	46	T

Table 2. (continued)

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Fathead minnow	35	0	18	532	0	266	T
Inland silverside	21	7	14	84	28	56	T
Redbreast sunfish	28	0	14	658	0	329	T
Atlantic needlefish	7	14	11	294	840	567	T
Chestnut lamprey	21	0	11	266	0	133	T
Golden shiner	14	7	11	84	42	63	T
Sauger	14	7	11	1,414	1,806	1,610	T
Striped bass	14	7	11	1,456	1,456	1,456	T
Rosyside dace	14	0	7	84	0	42	T
Bullhead minnow	7	0	4	28	0	14	T
Green sunfish	7	0	4	28	0	14	T
Mooneye	7	0	4	1,274	0	637	T
Muskellunge	0	7	4	0	4,466	2,233	T
Pumpkinseed	7	0	4	238	0	119	T
River carpsucker	0	7	4	0	1,134	567	T
Rock bass	7	0	4	14	0	7	T
Shortnose gar	7	0	4	3,864	0	1,932	T
Total	**74,977**	**818,258**		**1,663,732**	**4,093,95**		

T = Trace < one percent

Table 3. Numbers of Fish Impinged at Johnsonville Fossil Plant by Month and Percent of Annual Total During Year-One, 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	Total Year-One and Year-Two	Percent of Two-year Total
Mar	842	8	563	0	1,405	1
Apr	405	4	346	0	751	1
May	106	1	73	0	179	0
Jun	38	0	11	0	49	0
Jul	150	1	39	0	189	0
Aug	72	1	258	0	330	0
Sep	126	1	249	0	375	0
Oct	379	4	1,555	1	1,934	2
Nov	2,003	19	2,596	2	4,599	4
Dec	1,489	14	8,779	8	10,268	8
Jan	2,021	19	6,576	6	8,597	7
Feb	3,080	29	95,849	82	98,929	78
Total	**10,711**		**116,894**		**127,605**	

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

	1974-1975	1975-1976	1980-1981	1981-1982	2005-2006	2006-2007
Extrapolated Annual Number Impinged	193,781	1,391,558	5,168,065	1,879,675	74,944	818,258
Number Liable for after EA & PF Reduction	22,404	62,055	551,567	124,248	10,731	23,486

Table 5. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Johnsonville Fossil Plant During 1974-1976 and 2005-2007.

	1974-1975		1975-1976		1980-1981		1981-1982		2005-2006		2006-2007	
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	% by Number	% after PA and EF
Threadfin shad	65	47	91	84	98	96	91	83	60	35	95	87
Gizzard shad	9	6	5	5	-	-	2	2	9	5	1	1
Freshwater drum	7	12	2	5	0	1	6	13	15	23	1	2
Skipjack herring	13	9	-	-	1	1	-	-	2	1	-	-
Bluegill	2	4	-	-	-	-	-	-	5	7	3	7
Yellow/White bass	-	-	-	-	-	-	-	-	3	14	0	1
Ictalurids	1	1	-	-	-	-	-	-	-	-	-	-
Total	**97**	**79**	**98**	**94**	**99**	**98**	**99**	**98**	**94**	**85**	**100**	**98**

Dash denotes not a major species that year.

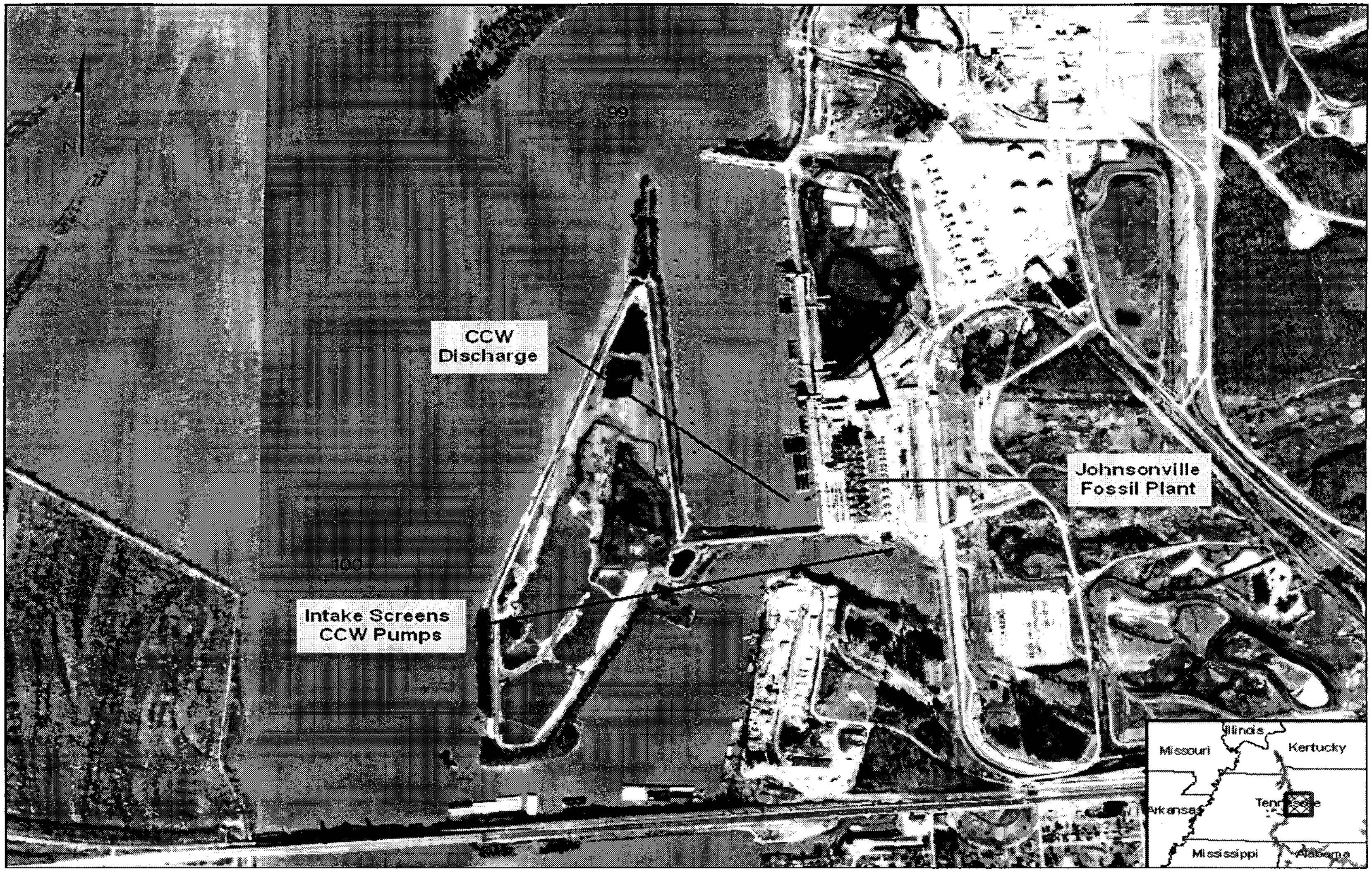


Figure 1. Aerial photograph of Johnsonville Fossil Plant including CCW intake structure and discharge.

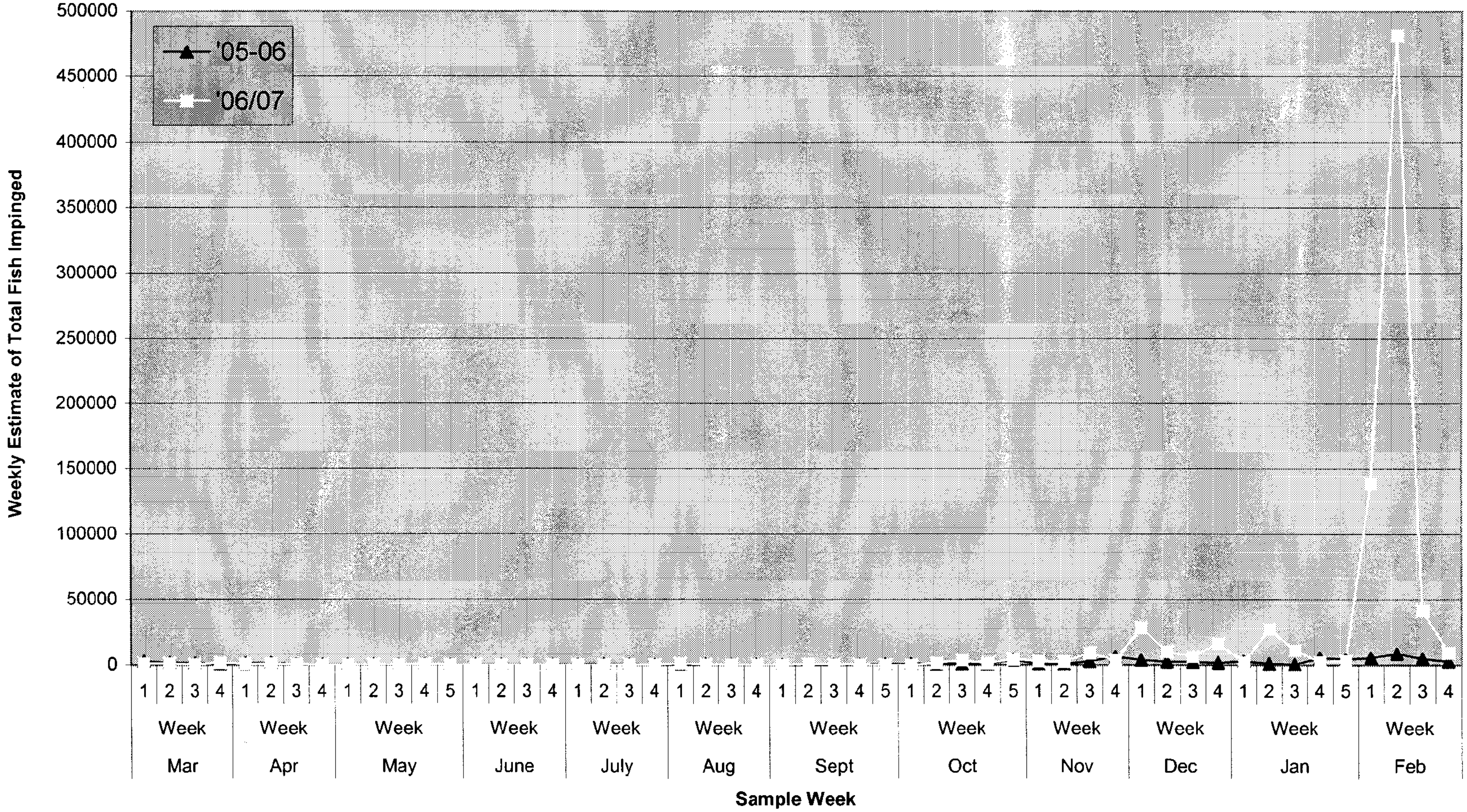


Figure 2. Estimated weekly fish impingement at TVA's Johnsonville Fossil Plant during 2005-2007.

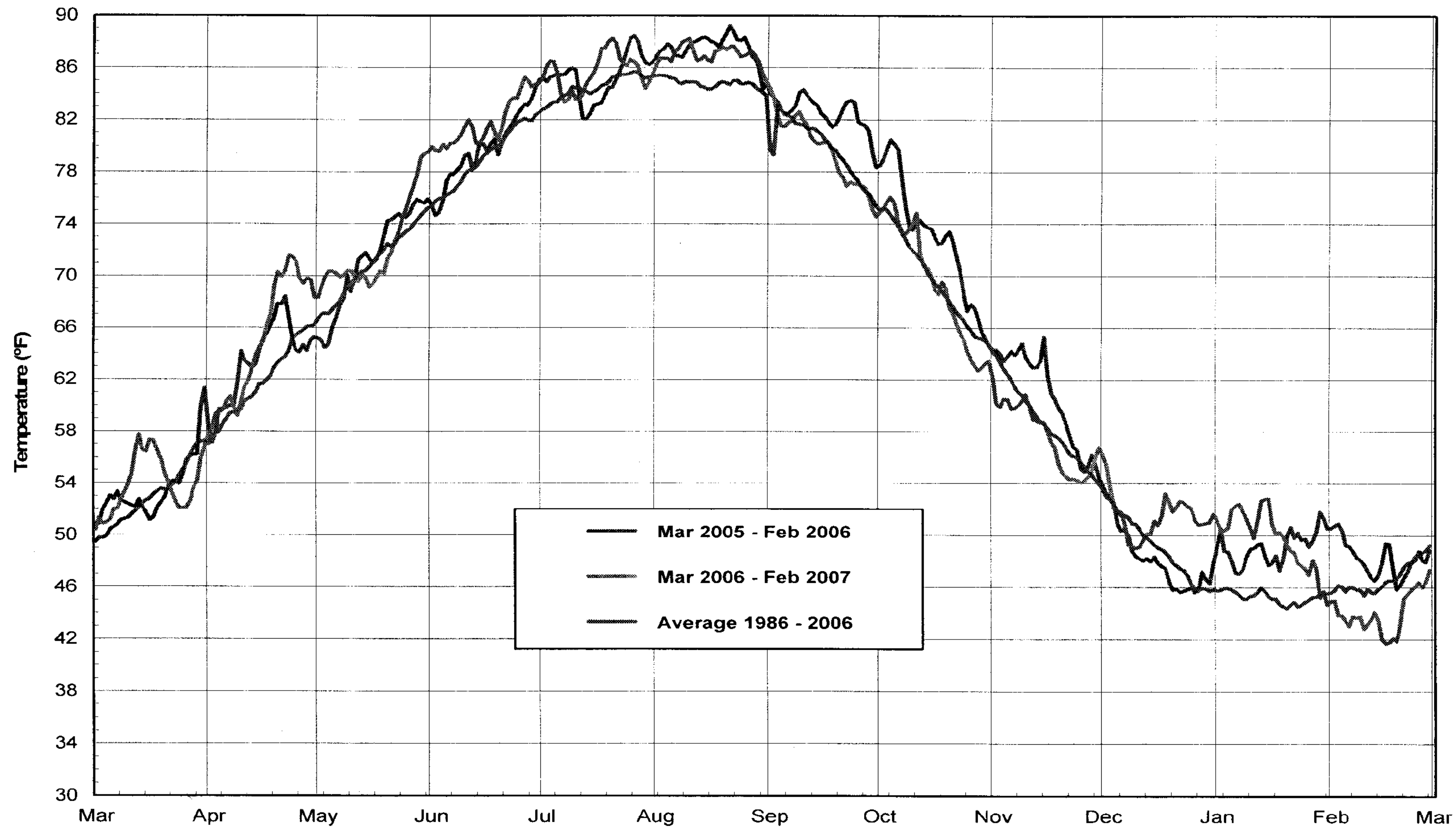


Figure 3. **Ambient daily (24-hr avg) water temperature at Johnsonville Fossil Plant intake during historical (1986-2006) and recent (2005-2007) impingement monitoring.**

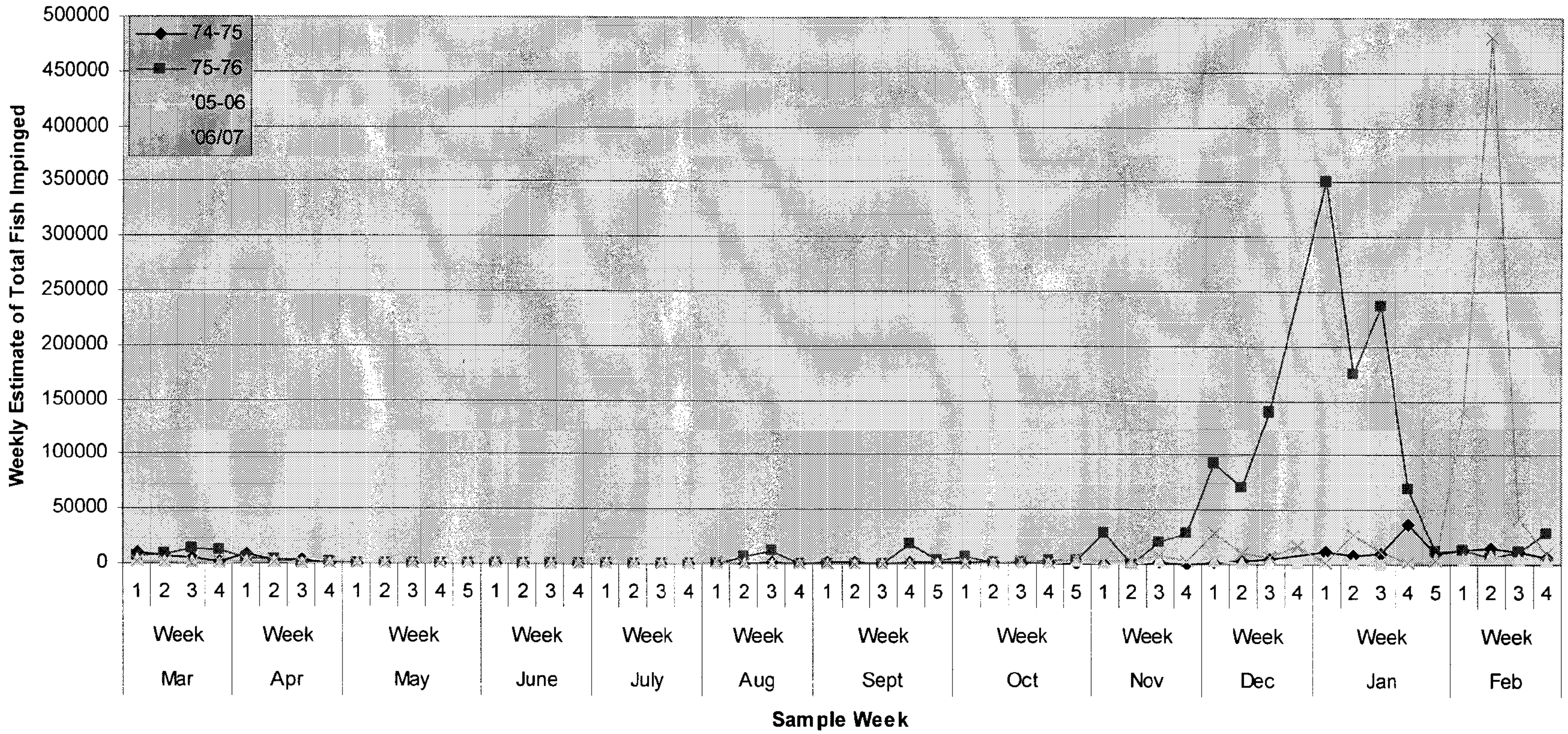
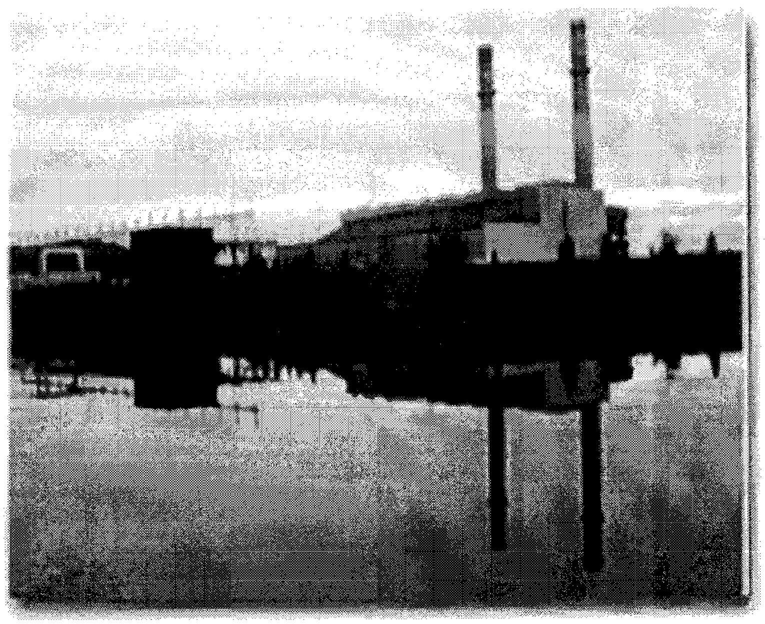


Figure 4. Comparison of estimated weekly fish impingement at TVA's Johnsonville Fossil Plant during historical and recent monitoring periods.

TENNESSEE VALLEY AUTHORITY

JOHN SEVIER FOSSIL PLANT
NPDES PERMIT NO. TN0005436
316(b) MONITORING PROGRAM

ENTRAINMENT AND IMPINGEMENT OF FISH AT JOHN SEVIER FOSSIL PLANT DURING 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

AM&M	Aquatic Monitoring and Management
CCW	Condenser Cooling Water
CWA	Clean Water Act
EA	Equivalent Adult
EPA	Environmental Protection Agency
EPRI	Formerly known as the Electric Power Research Institute
HRK	Holston River Kilometer
HRM	Holston River Mile
JSF	John Sevier Fossil Plant
PF	Production Foregone
TVA	Tennessee Valley Authority

Introduction

John Sevier Fossil Plant (JSF), placed into operation in 1955, is located on the south bank of the upper Holston River (Holston River Kilometer [HRK] 171/Holston River Mile [HRM] 106.3) at the head of Cherokee Reservoir and is subject to the Tennessee Water Quality Act and the Clean Water Act (CWA). Section 316(b) of the CWA requires the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing environmental impacts.

Entrainment and impingement mortality are two components of 316(b). Entrainment is defined as the incorporation of all life stages of fish and shellfish with intake water flow entering and passing through a cooling water intake and into a cooling water system. Impingement mortality is defined as an impact in which fish and shellfish are trapped or impinged against an intake screen and often killed in the process. This report presents results of entrainment and impingement sampling conducted at JSF during 2005-2007 with comparisons to historical data collected during 1974-1975.

Plant Description

JSF is located 86.9 river km (53.9 miles) upstream from Cherokee Dam and 57.9 river km (35.9 miles) downstream from the confluence of the North and South Forks of the Holston River. The plant operates four coal-fired steam-electric generating units with a rated capacity of 846 megawatts. The first unit began operation in July 1955 and the last unit in October 1957.

During certain periods of short duration, natural river flows and flows provided by regulation of upstream dams are insufficient to meet circulating water demand of 28.7 m^3/s (1,013 ft^3/s). Flow past JSF is primarily a function of water released from TVA's Fort Patrick Henry Dam 27.2 km (16.9 mi) upstream and inflow from the North Fork of the Holston River 14 kilometers (8.7 m) upstream. During periods of low runoff from the North Fork and zero releases from Fort Patrick Henry, JSF requires more volume for condenser cooling water (CCW) than typically flows past the plant. In those situations, the plant depends on water impounded by John Sevier Detention Dam. This detention dam (Figure 1) was constructed on the Holston River between the JSF CCW intake and discharge channel for the sole purpose of providing a reservoir of water to supply the condensers during low flow conditions. An excavated channel above the dam leads the water under a floating trash boom and into the JSF intake basin. From the intake structure the water flows to the condenser and then to the discharge channel which empties into the river below the dam.

Each of the eight circulating water pumps, two per unit, is installed in a separate suction well with entering water being strained by trashracks and 9.5 mm (3/8 in) mesh traveling screens. Two traveling screens, each 3 m (10 ft) wide are provided per unit. The smallest openings in the circulating water system are the 22 cm (7/8 in) outside diameter condenser tubes; therefore, everything passing through the traveling screens should pass through the entire system.

Differential pressure gauges are installed to indicate the loss of head across each pair of racks and screens. The loss of head is a measure of screen and rack cleanliness and indicates when screens should be cleaned. Debris that is caught on the screens is washed off by spraying it into a sluice trench that extends the length of the pumping station deck and then conveys the debris to the discharge channel. Heavy debris conditions during certain periods of the year may make it necessary to run the screens continuously.

Methods

Entrainment

Larval sampling began on March 23, 2005, and continued through January 31, 2007. Weekly sampling was conducted during the normal spawning season (March through August) and continued once monthly throughout the remainder of the year (September through February). To simplify comparisons in this report, data from March 23, 2005, through February 13, 2006, will be referred to as Year-One, and from March 15, 2006, through January 31, 2007, as Year-Two. Each week, daytime and nighttime ichthyoplankton samples provided temporal abundance of larval fish and eggs at three stations along a transect perpendicular to river flow just upstream of the plant intake channel at HRK 172.5 (HRM 107.2) (Figure 1). Four ten-minute samples were collected weekly in the reservoir during both day and night. Samples consisted of one full-stratum sample from both left and right overbanks, two samples from the mid-channel area with one full-stratum, and one towed near bottom for the duration of the sample. To estimate densities of eggs and larvae entrained with the CCW, four replicate, seven-minute full-stratum samples were also collected along and parallel to the intake trash boom.

Samples were collected with a beam net (0.5 m square, 1.8 m long, with 505 micron "nitex" mesh netting) which was towed upstream at a speed of 1.0 m/s for 6-7 minutes. The volume of water filtered through the net was measured with a large-vaned General Oceanics flowmeter®. Approximately 75 m^3 of water was filtered during each reservoir and intake sample.

Laboratory Analysis - Entrainment

Larval fish and eggs were removed from the samples, identified to the lowest possible taxon, counted and measured to the nearest millimeter total length following standard procedures outlined in S & F OPS-FO-BR-24.1 (TVA 1985). Taxonomic decisions were based on TVA's "Preliminary Guide to the Identification of Larval Fishes in the Tennessee River," (Hogue et al., 1976) and other pertinent literature.

The term "unidentifiable larvae" as used below applies to specimens too damaged or mutilated to identify, while "unspecifiable" before a taxon implies a level of taxonomic resolution that currently cannot be identified to a lower taxon. For example, "unspecifiable catostomids" designates larvae within the family Catostomidae that cannot be specified to a lower taxonomic level. The category "unidentifiable eggs" applies to specimens that cannot be identified due to damage or lack of taxonomic knowledge. Taxonomic refinement is a function of specimen size, condition, and developmental stage. Throughout this report, the designation "unspecifiable clupeids" refers to clupeids less than 20 mm (~ ¾ in) in total length and could include *Dorosoma cepedianum* (gizzard shad), *D. petenense* (threadfin shad), *Alosa chrysochloris* (skipjack herring) and/or *Alosa pseudoherengus* (alewife). Any clupeid specimens identified to species level represent postlarvae which are 20 mm (~ ¾ in) or longer in total length.

The developmental stage of moronids also determines level of taxonomic resolution. *Morone saxatilis* (striped bass) hatch at a larger size than either *M. chrysops* (white bass) or *M. mississippiensis* (yellow bass). Although it is currently impossible to distinguish between larvae of the latter two species, *M. saxatilis* can be eliminated as a possibility based on developmental characteristics of specimens 6 mm (~ ¼ in) or less in total length (hence, the taxonomic designation *Morone*, not *saxatilis*). Specimens identified as *Morone spp.* are greater than 6 mm (~ ¼ in) total length.

Data Analysis - Entrainment

Temporal occurrence and relative abundance of eggs and larvae by taxon are presented and discussed for the two-year monitoring period. Densities of fish eggs and larvae are expressed as numbers per 1000 m^3 of water sampled.

Estimated entrainment of fish eggs and larvae at JSF was calculated by the following method: densities of eggs and larvae transported past the plant were estimated for each sample period by averaging densities (all stations) of eggs and larvae from HRK 172.5 (HRM 107.2) and multiplying by the corresponding 24-hour flow past the plant. Percentage of transported ichthyofauna entrained by the plant was estimated from the formula:

$$E = \frac{D_i}{D_r}\frac{Q_i}{Q_r} X100$$

where D_i = mean density (N/1000 m^3) of eggs or larvae in intake samples;

Dr = mean density (N/1000 m3) of eggs or larvae in river (HRM 107.2 (172.5 km) transect);

Q_i = plant intake water demand (m^3/d);

Q_r = river flow (m^3/d).

Impingement

Weekly impingement monitoring began on February 28, 2005, and continued through February 19, 2007. Entrainment sampling data from March 2005 through February 2006 will be referred to as Year-One and from March 2006 through February 2007 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 (AM&M) crew on site. Fish were collected in the 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 following TVA's Quality Assurance Procedure No. RSO&E-BR-23.11, Rev 1 (TVA 2004). Data were recorded by one member of the crew and checked and verified (signed) by the other for quality control. Estimates of weekly impingement rates were calculated and compared with historical data. In rare situations when less than a 24-hr sample was possible, data were normalized to 24 hours.

Moribund/Dead Fish

The majority of fish collected from a 24-hr screen wash were usually all dead when processed. 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 could be impinged after death or in a moribund state (Griffith and Tomljanovich 1975, Griffith 1978). If these incidents were observed, it was documented that due to ambient temperatures, either all, or a portion of impinged threadfin were due to cold-shock and would not have been impinged otherwise. Additionally, if threadfin shad were observed dying in the reservoir from cold-shock, this would be documented and presented in the report to indicate cold-shock as the primary cause of unusually high impingement of this species. Any fish collected alive were returned to the reservoir after processing.

Data Analysis - Impingement

Impingement data from weekly 24-hr 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-hour sample was possible, data were normalized to 24 hours. Historical impingement data at JSF were collected weekly between August 6, 1974, and April 22, 1975, (TVA 1975) using the same standard procedures employed during the current study.

To facilitate the implementation of and compliance with the Environmental Protection Agency's (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. EPRI (formerly 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 and quantifies the loss from entrainment and impingement in terms of potential available forage for consumption by predators. Requirements of the models are site-specific data on the distribution and abundance of fish populations vulnerable to entrainment and impingement. TVA in turn used these models to determine the "biological liability" of the intake structure.

Results and Discussion

Hydraulic Entrainment

The percentage of Holston River flow entrained as CCW at JSF estimated by sample period during Year-One averaged 45% and 41% during Year-Two, respectively (Table 1).

Weekly entrainment samples collected at JSF filtered an average of 600 m^3 for intake samples and 610 m^3 for reservoir samples. Volume of water filtered weekly (16 samples) during larval sampling at JSF in 1975 averaged 612 m^3 for intake samples and 613 m^3 for reservoir samples. Daily (24-hr avg) ambient water temperatures at JSF intake during 2004-2006 and historical (1986-2006) data are plotted in Figure 2.

Fish Eggs and Larvae

A list of families of fish collected at JSF including common names and lowest level of taxonomic resolution identified is presented in Table 2. A total of 75 fish eggs were collected in entrainment samples during Year-One and 19 were collected during Year-Two (Table 3). All but one of the eggs from Year-One were clupeid eggs and the remaining egg was ictiobine (probably carpsucker). Sixty-five of the eggs were collected in intake samples and ten from reservoir samples (Table 4). During Year-Two all 19 eggs were collected from intake samples. Sixteen of the eggs were cyprinid, two clupeid and one percid (Table 4).

During Year-One sampling, a total of 2,025 larval fish was collected in reservoir and intake samples combined and was comprised of 50% clupeids (shad and alewife), 21% centrarchids (black bass, crappie, and sunfish) and 12% cyprinids (minnows and carp) (Table 3). Other significant (over 1%) taxa included catostomids (suckers, carpsuckers) (7%), percids (darters, logperch) (6%) and ictalurids (catfish) (3%). During Year-Two, 1,136 fish were collected and composition was 55% centrarchids, 27% clupeids and 10% cyprinids. Other significant taxa included catostomids (5%), percids (2.4%) and ictalurids (1.3%) (Table 3).

Temporal occurrence and densities of larvae by family and year are plotted in Figures 3 through 8. Occurrence of clupeid larvae (shad and alewife) was basically limited to April through July (Figure 3). Clupeid densities during Year-One peaked at close to $300/1000m^3$ in late-May and again in mid-June through early July. During Year-Two, a single peak of nearly $400/1000m^3$ occurred on April 19 (Figure 3). Cyprinid (minnows, carp) larvae were present in samples from March through August (Figure 4). Densities both years peaked at near $90/1000m^3$ during April of Year-One and in June of Year-Two. Catostomid (redhorse suckers, buffalo, and carpsuckers) larvae occurred in samples from April through July (Figure 5). Densities were relatively consistent between years peaking at near $20/1000m^3$ on several sample periods. However, on May 16 of Year-One, catostomid density peaked at $111/1000m^3$ (Figure 5). Ictalurid (catfish) larvae were present in samples from mid-June through early September (Figure 6). Peak density of $37/1000m^3$ was observed on July 11, 2005, and $13/1000m^3$ on June 28, 2006. Centrarchid (sunfish, bass) larvae occurred in JSF samples from late April through mid-August both years (Figure 7) and the overall peak density of $908/1000m^3$ occurred on May 31, 2006 (Year-Two). On this date, the density of centrarchid larvae in intake and reservoir samples was 865 and $43/1000m^3$, respectively. Percid (logperch, darters) larvae were collected in samples beginning in mid-March both years and continued occurring through late-July or early-August (Figure 8). Peak density during Year-One was $83/1000m^3$ on April 19, 2005, and during Year-Two, $22/1000m^3$ on April 19, 2006.

Proportion of larvae collected from intake samples compared to reservoir samples during Year-One was nearly equal with 50.3% from reservoir samples and 49.7% from intake samples (Table 4). During Year-Two however, 62.5% of all larvae were collected from intake samples and only 37.5% from reservoir samples.

Entrainment of fish eggs during Year-One was calculated at 322% of the eggs passing JSF. Percent entrainment for Year-Two could not be calculated because all 19 eggs were collected from intake samples. Estimating entrainment percentage for eggs or larvae when numbers are greater in intake samples than in reservoir samples is either not possible (when all eggs or larvae are collected from intake samples) or not reliable (when higher numbers are collected from intake samples) due to anomalies in horizontal distribution of eggs and or larvae. Estimated entrainment of fish larvae at JSF during Year-One was 82.1% and 111.7% during Year-Two (Table 5) of the total population drifting past the plant. Estimated entrainment was highest during Year-One for clupeids (144%) and catostomids (143%) and during Year Two for centrarchids (378%) catostomids (92%) and percids (76%). As noted for estimated entrainment of eggs, higher densities of fish larvae collected in intake samples compared to reservoir samples resulted in questionable or infeasible entrainment estimates. Estimated entrainment of 378% of centrarchids during Year-Two was a prime example of how one perhaps anomalous sample period with higher densities in intake samples than in reservoir samples can influence results.

Catostomids, which include both redhorse suckers (*Moxostoma*) and carpsuckers (*Cyprinus*) were the most abundant taxon collected in the intake (84%) and plant (56%) transect samples during Year-One (Table 4).

Entrainment percentages of eggs and larvae estimated from historical samples collected during 1975 were reported in TVA 1977a. Sample methods differed between 1975 and the present study and comparisons of data should consider those differences. Sampling in 1975 was biweekly (every other week) and intake samples were collected with stationary nets (passive as opposed to active sampling in 2005-2007). Lower numbers/densities of larvae would normally be collected with stationary nets than with towed nets. Annual entrainment of Catostomids in 1975 was estimated to be 16.1% of the transported population. Cyprinids (30%) and clupeids (2.3%) were the only other taxa with estimated entrainment over 1%. Total estimated entrainment of all larvae was 15.7%, essentially a reflection of that of catostomids. Additional sampling was conducted during 1977 above and below John Sevier Detention Dam (Graser et al., 1979) primarily to determine the fate of larvae drifting past JSF and over the detention dam. Clupeids comprised 89% and catostomids 9.4% of larvae collected at the plant transect during the 1977 sampling. No intake samples were collected.

Graser et al., (1979) concluded that significant mortality likely occurs from dam passage and that some larvae/post-larvae are apparently able to resist transport over the dam. The fish community above John Sevier Detention Dam is considered relatively poor and does not contribute significantly to the Cherokee Reservoir community via passage of viable larvae over the dam. All water passing JSF and entering Cherokee Reservoir is either entrained by the plant or passes over John Sevier Detention Dam.

Results of application of the EA and PF models to the JSF entrainment data including reduced numbers by family are presented in Table 6. Estimated numbers of fish eggs entrained during Year-One and Year-Two were 270 and 100 million, respectively. Corresponding numbers after EA and PF reduction representing estimated eggs which would have hatched and survived to a given age were 3,600 and 9,200 during Year-One and Year-Two, respectively. During Year-One, clupeid eggs dominated those entrained while in Year-Two, cyprinid eggs were the dominant taxon (Tables 3 and 6).

The high percentages of entrainment estimated for both fish eggs and larvae, especially for certain taxa, were shown to have resulted from one or more anomalous samples. Horizontal distribution caused more eggs or larvae to be collected in intake than in reservoir samples. In the case of centrarchids, it is likely that spawning occurred on the overbank just upstream of the intake and drifting larvae were concentrated at the intake during one sample period (May 31, 2006).

Impingement

Numbers of fish collected in impingement samples by year and by species are presented in Table 7. During Year-One a total of 2,949 fish representing 40 species was collected from CCW intake screen wash samples. During Year-Two, 2,050 fish (39 species) were collected in impingement samples.

Extrapolation of these totals resulted in an estimated 20,643 fish impinged for the Year-One and 14,350 for Year-Two (Tables 7 and 8). During Year-One, the samples were dominated by threadfin shad (40.7%); gizzard shad were (13.6%), channel catfish (14%), and alewife (11.1%) (Tables 7 and 9). Other species collected representing greater than 1% of the total included rock bass, bullhead minnow, bluegill, golden redhorse and silver shiner. Percent composition during Year-Two was similar with threadfin shad (68%), gizzard shad (14%), channel catfish (3%) and sunfish (3%).

Table 8 lists the percent composition by species (1% or greater) for biological liability calculated for fish impinged during the current monitoring. Biological liability during Year-One was dominated by threadfin shad (25%), alewife (21%) and channel catfish (12%). Year-Two was dominated by threadfin shad (50%), gizzard shad and sunfish at 10% each (Table 9).

Total numbers of fish impinged and percent per month for both years sampled are presented in Table 10. For both years combined, peak impingement (56%) occurred during November through February. A plot of daily (24-hour avg) ambient intake water temperatures for JSF during each of the two years sampled (Figure 2) appears to be generally correlated with peak impingement as previously reported in numerous studies at other generation facilities (EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978, McLean et al., 1980). Figure 2 also presents average JSF intake temperatures from 1986-2006 for comparison.

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).

A recent study by Fost (2006) 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. No die-offs of threadfin shad were observed at JSF during the two years of monitoring by AM&M crews or were reported by power plant personnel.

Application of the EA and PF models to the total numbers estimated impinged resulted in reduced numbers of fish (Table 11) which 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. The numbers of fish representing JSF's biological liability for Year-One and Year-Two were 1,889 and 1,841 respectively (Table 11).

Comparison with Historical Data

During 1974-1975 impingement monitoring, gizzard shad comprised 71.2% and threadfin shad 27.0% of the total impinged (TVA 1977b). Channel catfish and bluegill were the two next most abundant species impinged. Estimated annual impingement of all species was 151,465 fish weighing 647 kg (TVA 1977b). Gizzard and threadfin shad decreased to only 54.3% of fish sampled during Year-One of the current study and 82% during Year-Two. The historical estimated impingement total was significantly greater than the 20,643 and 14,350 fish estimated impinged during Year-One and Year-Two of the current investigation.

Summary and Conclusions

Entrainment of fish eggs and larvae and impingement of juvenile and adult fish at JSF were monitored during 2005-2007 to determine potential impacts of the CCW intake to the fish community of John Sevier Detention Reservoir. Comparison with historical data was made to the extent possible. Estimated rates of entrainment through the plant and impingement against the plant's cooling water intake screens after the application of the EA and PF models did not indicate adverse impact to the Holston River fish community particularly since most fish eggs and larvae not entrained by the plant are passed over the detention dam and would be lost to John Sevier Detention Reservoir.

A relatively low-value fishery exists above JSF Detention Dam (TVA 1977b) resulting from chronic pollution of the Holston River and the presence of the detention dam which prevents repopulation of upstream areas by fish swimming upstream to spawn from Cherokee Reservoir. It was determined from the initial 316(b) demonstration (1977b) that the John Sevier Detention Dam had prevented the upstream spawning migration of at least two species (paddlefish and sauger) and a mitigation settlement was reached between Tennessee Valley Authority and the Tennessee Department of Environment and Conservation. JSF has been in operation for 52 years, and no changes in the fish community upstream of the plant have been observed or detected other than those previously identified under the detention dam mitigation indicating no further adverse environmental impact from plant operation.

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Table 1. Holston River Flow Past John Sevier Fossil Plant Estimated by Sample Period During Year-One and Year-Two and Percentage Entrained as Condenser Cooling Water.

Volume									
Year-One					Year-Two				
Sample	Intake	Detention Dam	Total Reservoir		Sample	Intake	Detention Dam	Total Reservoir	
Date	m^3 day	m^3 day	m^3 day	Entrained	Date	m^3 day	m^3 day	m^3 day	Entrained
	Q_i	Q_r	Q_t	%		Q_i	Q_r	Q_t	%
03/23/2005	7.90E+07	2.65E+08	3.44E+08	23.0	01/23/2006	7.54E+07	4.37E+08	5.12E+08	14.7
03/29/2005	7.87E+07	2.50E+08	3.28E+08	23.9	02/13/2006	7.63E+07	1.39E+08	2.15E+08	35.5
04/05/2005	9.42E+07	7.34E+08	8.28E+08	11.4	03/15/2006	9.71E+07	1.85E+08	2.82E+08	34.4
04/12/2005	7.79E+07	5.04E+08	5.82E+08	13.4	03/22/2006	9.91E+07	1.08E+08	2.07E+08	47.9
04/19/2005	9.87E+07	1.36E+08	2.35E+08	42.0	03/29/2006	9.73E+07	5.21E+07	1.49E+08	65.1
04/25/2005	1.05E+08	1.49E+08	2.53E+08	41.4	04/05/2006	1.11E+08	1.19E+08	2.30E+08	48.3
05/02/2005	9.85E+07	6.56E+08	7.55E+08	13.1	04/12/2006	1.11E+08	1.63E+08	2.74E+08	40.4
05/09/2005	9.14E+07	2.30E+08	3.22E+08	28.4	04/19/2006	1.12E+08	1.25E+08	2.37E+08	47.3
05/16/2005	1.04E+08	7.22E+07	1.76E+08	59.0	04/25/2006	1.11E+08	4.99E+08	6.10E+08	18.2
05/23/2005	8.97E+07	7.44E+07	1.64E+08	54.7	05/03/2006	1.12E+08	3.11E+08	4.24E+08	26.5
05/31/2005	8.42E+07	7.61E+07	1.60E+08	52.5	05/10/2006	1.12E+08	2.10E+08	3.22E+08	34.7
06/06/2005	1.03E+08	2.20E+08	3.23E+08	31.8	05/17/2006	1.11E+08	3.96E+07	1.51E+08	73.7
06/14/2005	1.03E+08	2.20E+08	3.24E+08	31.9	05/24/2006	1.10E+08	1.77E+08	2.87E+08	38.3
06/20/2005	1.02E+08	6.22E+07	1.65E+08	62.2	05/31/2006	1.07E+08	3.11E+08	4.18E+08	25.6
06/29/2005	1.01E+08	7.64E+07	1.77E+08	56.9	06/07/2006	9.93E+07	9.19E+07	1.91E+08	51.9
07/05/2005	9.76E+07	7.42E+07	1.72E+08	56.8	06/12/2006	9.91E+07	1.18E+08	2.17E+08	45.6
07/11/2005	9.57E+07	1.36E+08	2.32E+08	41.3	06/21/2006	9.70E+07	6.89E+07	1.66E+08	58.5
07/21/2005	1.03E+08	1.31E+08	2.34E+08	43.9	06/28/2006	1.01E+08	1.78E+08	2.79E+08	36.1

Table 1. (continued)

Volume									
Year-One					Year-Two				
Sample	Intake	Detention Dam	Total Reservoir		Sample	Intake	Detention Dam	Total Reservoir	
Date	m^3 day	m^3 day	m^3 day	Entrained	Date	m^3 day	m^3 day	m^3 day	Entrained
	Q_i	Q_r	Q_t	%		Q_i	Q_r	Q_t	%
07/25/2005	1.02E+08	5.13E+07	1.53E+08	66.6	07/03/2006	1.09E+08	1.52E+08	2.61E+08	41.9
08/02/2005	1.01E+08	1.67E+08	2.68E+08	37.8	07/12/2006	1.08E+08	1.11E+08	2.19E+08	49.2
08/10/2005	1.04E+08	7.27E+07	1.76E+08	58.7	07/19/2006	1.11E+08	6.26E+07	1.73E+08	63.9
08/16/2005	1.00E+08	7.18E+07	1.72E+08	58.3	07/26/2006	1.08E+08	8.14E+07	1.89E+08	57.0
08/23/2005	9.69E+07	8.05E+07	1.77E+08	54.6	08/02/2006	1.08E+08	8.72E+07	1.95E+08	55.2
08/29/2005	9.31E+07	8.63E+07	1.79E+08	51.9	08/09/2006	1.06E+08	2.05E+08	3.11E+08	34.2
09/20/2005	1.01E+08	1.33E+08	2.34E+08	43.1	08/16/2006	1.07E+08	1.05E+08	2.12E+08	50.3
10/17/2005	1.04E+08	4.06E+07	1.45E+08	71.9	08/23/2006	1.07E+08	1.62E+08	2.68E+08	39.8
11/21/2005	1.05E+08	2.23E+07	1.27E+08	82.5	09/07/2006	9.77E+07	2.86E+08	3.84E+08	25.4
12/19/2005	7.77E+07	5.60E+07	1.34E+08	58.1	10/25/2006	1.11E+08	2.32E+08	3.43E+08	32.2
Average	**9.62E+07**	**1.89E+08**	**7.13E+09**	**45.4**	11/15/2006	1.05E+08	4.63E+08	5.68E+08	18.5
					12/20/2006	7.64E+07	1.41E+08	2.18E+08	35.1
					01/31/2007	7.29E+07	2.41E+08	3.14E+08	23.2
					Average	**1.02E+08**	**1.89E+08**	**8.83E+09**	**40.9**

Table 2. List of Scientific and Common Names of Fish Eggs and Larvae by Family and Lowest Level of Taxonomic Identification.

Scientific Name	Common Name	Lowest Level of Taxonomic Identification
Clupeidae	**Shad**	**Family** - all larvae <20 mm TL. **Genus or Species** - larger individuals to *Alosa* spp., alewife, skipjack, gizzard and threadfin shad.
Cyprinidae	**Minnows and Carps**	**Family** - most minnows, shiners, and chubs. **Genus or Species** - common carp, golden shiner, and larger individuals to emerald shiner, mimic shiner, *Pimephales* spp.
Catostomidae	**Suckers**	**Subfamily** - ictiobines (buffalo and carpsuckers) **Genus** - Larger individual to buffalo
Ictaluridae	**Catfishes**	**Species** - Blue, Channel, Flathead, Bullhead
Centrarchidae	**Sunfishes**	**Genus** - crappie, lepomids (sunfishes), and black bass. **Species** - larger individuals to largemouth bass.
Percidae	**Darters**	**Genus** - *Etheostoma* type, *P.caprodes* type, not *P. caprodes* type.
Poeciliidae	**Livebearers**	**Species** - Western Mosquitofish

Table 3. Number and Percent Composition of Fish Eggs and Larvae by Family Collected from Samples at John Sevier Fossil Plant During 2005-2007.

	Number Collected		Percent Composition	
	Year-One	Year-Two	Year-One	Year-Two
Eggs				
Clupeidae	74	2	98.5	9.4
Ictiobinae	1	0	1.5	0.0
Cyprinidae	0	16	0.0	84.4
Percidae	0	1	0.0	6.3
Totals	**75**	**19**	**100.0**	**100.1**
Larvae				
Clupeidae	1,013	320	50.1	26.9
Cyprinidae	245	115	12.1	9.7
Catostomidae	140	58	6.9	4.9
Ictaluridae	68	16	2.9	1.3
Centrarchidae	426	609	21.3	54.8
Percidae	127	28	6.4	2.4
Poeciliidae	6	0	T	0.0
Totals	**2,025**	**1,146**	**99.7**	**100.0**

Table 4. Number, Density, and Percentage of Fish Eggs and Larvae by Family Collected in Intake and Reservoir Samples at John Sevier Fossil Plant During 2005-2007.

Family	NUMBER				DENSITY				PERCENTAGE			
	Year-One Number		Year-Two Number		Year-One No./1000m^3		Year-Two No./1000m^3		Year-One Percentage		Year-Two Percentage	
	Intake	Res	Intake	Res	Intake	Res	Intake	Res	Intake	Res	Intake	Res
Eggs												
Clupeidae	64	10	2	0	103	16	3	0	85.9	14.1	100.0	0.0
Ictiobinae	1	0	0	0	2	0	0	0	100.0	0.0	0.0	0.0
Cyprinidae	0	0	16	0	0	0	27	0	0.0	0.0	100.0	0.0
Percidae	0	0	1	0	0	0	2	0	0.0	0.0	100.0	0.0
TOTAL	**65**	**10**	**19**	**0**	**105**	**16**	**32**	**0**	**86.1**	**13.9**	**100.0**	**0.0**
Larvae												
Clupeidae	576	437	96	224	938	703	165	381	56.9	43.1	30.0	70.0
Cyprinidae	114	131	55	60	184	210	95	101	46.5	53.5	47.8	52.2
Catostomidae	84	56	32	26	137	90	56	44	60.0	40.0	55.2	44.8
Ictaluridae	8	60	4	12	0	96	7	19	11.8	88.2	25.0	75.0
Percidae	28	99	15	13	46	162	26	23	22.0	78.0	53.6	46.4
Centrarchidae	190	236	514	95	312	384	942	171	44.6	55.4	84.4	15.6
Poeciliidae	6	0	0	0	10	0	0	0	100.0	0.0	0.0	0.0
TOTAL	**1,006**	**1,019**	**716**	**430**	**1,627**	**1,645**	**1291**	**739**	**49.7**	**50.3**	**62.5**	**37.5**

Table 5. Seasonal Entrainment Estimates for Numerically Significant Fish Taxa Collected at John Sevier Fossil Plant During 2005-2007.

Taxa		Intake Number Entrained per day $Q_i \times D_i$		Reservoir Total Number per day $Q_r \times D_r$		Entrainment Estimate		
		Year-One	Year-Two	Year-One	Year-Two	% Year-One	% Year-Two	1975
Eggs								
Clupeidae		9.50E+09	3.42E+08	3.00E+09	0.00E+00	316.7	*	
Ictiobinae		1.70E+08	0.00E+00	0.00E+00	0.00E+00	*	*	
Cyprinidae		0.00E+00	3.00E+09	0.00E+00	0.00E+00	0.0	*	
Percidae		0.00E+00	1.88E+08	0.00E+00	0.00E+00	0.0	*	
	Totals	**9.67E+09**	**3.53E+09**	**3.00E+09**	**0.00E+00**	322.3	*	
Larvae								
Clupeidae		9.00E+10	1.84E+10	6.30E+10	5.19E+10	142.9	35.4	2.3
Cyprinidae		1.90E+10	1.04E+10	2.40E+10	3.20E+10	79.2	32.5	30
Catostomidae		1.30E+10	6.06E+09	9.00E+09	6.60E+09	144.4	91.8	16.7
Ictaluridae		0.00E+00	6.70E+08	1.10E+10	3.33E+09	0.0	20.1	
Percidae		4.40E+09	2.89E+09	3.00E+10	3.79E+09	14.7	76.3	
Centrarchidae		3.10E+10	1.00E+11	5.60E+10	2.65E+10	55.4	378.3	
Poeciliidae		9.80E+08	0.00E+00	0.00E+00	0.00E+00	*	0.0	
	Totals	**1.58E+11**	**1.39E+11**	**1.93E+11**	**1.24E+11**	82.1	111.7	15.7

*All eggs in Year-Two were collected in intake samples; therefore entrainment estimates could not be calculated.

Table 6. Numbers of Fish Eggs and Larvae by Family Estimated Entrained by John Sevier Fossil Plant, Equivalent Adult and Production Foregone Model Results, and Biological Liability During 2005-2007.

		Intake Number Entrained $Q_i \times D_i$		Total After EA and PF Reduction	
Taxa		**Year-One**	**Year-Two**	**Year-One**	**Year-Two**
Eggs					
Clupeidae		2.7E+08	9.7E+06	3.6E+03	1.3E+02
Ictiobinae		4.7E+06	0.0E+00	1.0E+01	0.0E+00
Cyprinidae		0.0E+00	8.5E+07	0.0E+00	4.8E+03
Percidae		0.0E+00	5.3E+06	0.0E+00	4.3E+03
Totals		**2.7E+08**	**1.0E+08**	**3.6E+03**	**9.2E+03**
Larvae					
Clupeidae		2.5E+09	5.2E+08	1.8E+07	3.7E+06
Cyprinidae		5.3E+08	2.9E+08	2.1E+07	1.2E+07
Catostomidae		3.8E+08	1.7E+08	2.4E+07	7.8E+06
Ictaluridae		0.0E+00	1.9E+07	0.0E+00	1.3E+05
Percidae		1.3E+08	8.2E+07	1.1E+06	7.0E+05
Centrarchidae		8.9E+08	2.8E+09	3.1E+06	9.8E+06
Poeciliidae		2.7E+07	0.0E+00	7.4E+02	0.0E+00
Totals		**4.5E+09**	**3.9E+09**	**6.7E+07**	**3.4E+07**

Qi = CCW flow (m3/day)
Di = Number of eggs/larvae calculated from densities in intake samples

Table 7. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's John Sevier Fossil Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Lepisosteidae	*Lepisosteus osseus*	Longnose gar	1	0
Clupeidae	*Alosa pseudoharengus*	Alewife	328	19
	Dorosoma cepedianum	Gizzard shad	402	289
	Alosa chrysochloris	Skipjack herring	0	20
	Dorosoma petenense	Threadfin shad	1201	1404
Cyprinidae	*Pimephales vigilax*	Bullhead minnow	95	9
	Pimephales notatus	Bluntnose minnow	1	14
	Pimephales promelas	Fathead minnow	2	0
	Notropis atherinoides	Emerald shiner	0	9
	Carassius auratus	Goldfish	0	2
	Notemigonus crysoleucas	Golden shiner	7	2
	Cyprinella spiloptera	Spotfin shiner	26	12
	Notropis micropteryx	Highland shiner	1	0
	Notropis spectrunculus	Sawfin shiner	1	0
	Notropis photogenis	Silver shiner	40	0
	Luxilus chrysocephalus	Striped shiner	9	1
	Notropis telescopus	Telescope shiner	2	3
	Macrhybopsis storeriana	Silver chub	0	1
	Cyprinus carpio	Common carp	0	1
	Nocomis micropogon	River chub	0	1
	Erimystax dissimilis	Streamline chub	1	7
	Notropis amblops	Bigeye chub	50	0
Catostomidae	*Ictiobus bubalus*	Smallmouth buffalo	1	0
	Moxostoma duquesnei	Black redhorse	4	3
	Moxostoma erythrurum	Golden redhorse	50	12
	Moxostoma carinatum	River redhorse	0	1
	Moxostoma spp.	Unidentified redhorse	1	1
	Hypentelium nigricans	Northern hogsucker	7	0
	Carpiodes cyprinus	Quillback	1	0
	Carpiodes carpio	River carpsucker	4	0

Table 7. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Ictaluridae	*Ictalurus furcatus*	Blue catfish	4	4
	Ictalurus punctatus	Channel catfish	411	67
	Pylodictis olivaris	Flathead catfish	5	4
	Ameiurus natalis	Yellow bullhead	3	0
	Ameiurus melas	Black bullhead	2	0
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	0	3
Atherinopsidae	*Labidesthes sicculus*	Brook silverside	6	0
Cottidae	*Cottus carolinae*	Banded sculpin	6	24
Centrarchidae	*Lepomis macrochirus*	Bluegill	77	67
	Lepomis auritus	Redbreast sunfish	24	4
	Lepomis microlophus	Redear sunfish	3	0
	Lepomis gulosus	Warmouth	0	8
	Lepomis sp.	Unidentifiable sunfish	0	3
	Lepomis megalotis	Longear sunfish	0	5
	Lepomis cyanellus	Green sunfish	8	0
	Ambloplites rupestris	Rock bass	123	5
	Micropterus dolomieu	Smallmouth bass	28	7
	Micropterus salmoides	Largemouth bass	3	0
	Micropterus punctulatus	Spotted bass	0	1
	Pomoxis annularis	White crappie	3	27
	Pomoxis nigromaculatus	Black crappie	5	3
Percidae	*Etheostoma camurum*	Bluebreast darter	0	1
	Percina caprodes	Logperch	3	3
	Sander canadense	Sauger	0	
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	0	2
		Total number of fish	**2,949**	**2,050**
		Total number of species	**40**	**39**

Table 8. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at John Sevier Fossil Plant During 2005-2007.

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number Years-One and Two
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Threadfin shad	8,407	9,828	**9,118**	29,967	30,590	**30,279**	**52**
Gizzard shad	2,814	2,023	**2,419**	45,521	33,082	**39,302**	**14**
Channel catfish	2,877	469	**1,673**	25,473	10,836	**18,155**	**10**
Alewife	2,296	133	**1,215**	13,468	1,582	**7,525**	**7**
Bluegill	539	469	**504**	11,977	5,096	**8,537**	**3**
Rock bass	861	35	**448**	2,387	98	**1,243**	**3**
Bullhead minnow	665	63	**364**	882	84	**483**	**2**
Golden redhorse	350	84	**217**	136,556	46,872	**91,714**	**1**
Bigeye chub	350	0	**175**	399	0	**200**	**1**
Silver shiner	280	0	**140**	3,024	0	**1,512**	**1**
Spotfin shiner	182	84	**133**	525	259	**392**	**1**
Smallmouth bass	196	49	**123**	987	1,848	**1,418**	**1**
Banded sculpin	42	168	**105**	630	588	**609**	**1**
White crappie	21	189	**105**	98	140	**119**	**1**
Redbreast sunfish	168	28	**98**	707	665	**686**	**1**
Skipjack herring	0	140	**70**	0	4,445	**2,223**	**T**
Bluntnose minnow	7	98	**53**	35	175	**105**	**T**
Striped shiner	63	7	**35**	1,596	161	**879**	**T**
Emerald shiner	0	63	**32**	0	308	**154**	**T**
Flathead catfish	35	28	**32**	2,856	357	**1,607**	**T**

Table 8. (continued)

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number Years-One and Two
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Golden shiner	49	14	**32**	6,440	105	**3,273**	T
Black crappie	35	21	**28**	140	77	**109**	T
Blue catfish	28	28	**28**	672	917	**795**	T
Green sunfish	56	0	**28**	280	0	**140**	T
Streamline chub	7	49	**28**	35	287	**161**	T
Warmouth	0	56	**28**	0	560	**280**	T
Black redhorse	28	21	**25**	1,715	9,611	**5,663**	T
Northern hogsucker	49	0	**25**	378	0	**189**	T
Brook silverside	42	0	**21**	91	0	**46**	T
Logperch	21	21	**21**	98	105	**102**	T
Longear sunfish	0	35	**18**	0	637	**319**	T
Telescope shiner	14	21	**18**	14	49	**32**	T
River carpsucker	28	0	**14**	31,605	0	**15,803**	T
Largemouth bass	21	0	**11**	182	0	**91**	T
Unidentifiable sunfish	0	21	**11**	0	70	**35**	T
Rainbow trout	0	21	**11**	0	8,610	**4,305**	T
Redear sunfish	21	0	**11**	301	0	**151**	T
Yellow bullhead	21	0	**11**	1,267	0	**634**	T

Table 8. (continued)

	Estimated Number			Estimated Biomass (g)			Percent Composition by Number Years-One and Two
Species	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Black bullhead	14	0	**7**	6,664	0	**3,332**	**T**
Fathead minnow	14	0	**7**	70	0	**35**	**T**
Freshwater drum	0	14	**7**	0	5,362	**2,681**	**T**
Goldfish	0	14	**7**	0	84	**42**	**T**
Unidentified redhorse	7	7	**7**	7	70	**39**	**T**
Bluebreast darter	0	7	**4**	0	28	**14**	**T**
Common carp	0	7	**4**	0	9,394	**4,697**	**T**
Longnose gar	7	0	**4**	875	0	**438**	**T**
Quillback	7	0	**4**	7,504	0	**3,752**	**T**
River chub	0	7	**4**	0	294	**147**	**T**
River redhorse	0	7	**4**	0	4,984	**2,492**	**T**
Highland shiner	7	0	**4**	7	0	**4**	**T**
Sauger	0	7	**4**	0	14	**7**	**T**
Sawfin shiner	7	0	**4**	14	0	**7**	**T**
Silver chub	0	7	**4**	0	35	**18**	**T**
Smallmouth buffalo	7	0	**4**	49	0	**25**	**T**
Spotted bass	0	7	**4**	0	14	**7**	**T**
Totals	**20,643**	**14,350**		**335.496**	**178,493**		

Table 9. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's John Sevier Fossil Plant During 2005-2007.

	Year-One		Year-Two	
Species Composition	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**
Threadfin shad	41	25	68	50
Gizzard shad	14	8	14	10
Alewife	11	21	1	2
Channel catfish	14	12	3	5
Sunfish	-	-	3	10
Bluegill	3	7	-	-
Rock bass	4	7	-	-
Redhorse	2	3	-	-
Shiners	3	4	1	2
Golden redhorse	-	-	1	2
Smallmouth bass	1	4	0	5
Bullhead minnow	3	1	-	-
Skipjack herring	-	-	1	1
White crappie	-	-	1	3
Banded sculpin	-	-	1	1
Minnows	-	-	1	0
Rainbow trout	-	-	0	4
Logperch	-	-	0	1
Total	**96**	**92**	**95**	**96**

Dash denotes not a major species during that year.

Table 10. Numbers of Fish Impinged at John Sevier Fossil Plant by Month and Percent of Annual Total During Year-One, Year-Two, and for Both Years Combined.

Month	Total Number of Fish Impinged Year-One	Percent of Annual Total	Number of Fish Impinged Year-Two	Percent of Annual Total	Years-One and Two Combined	Percent of Two-Year Total
Jan	480	16	303	15	783	16
Feb	191	6	596	29	787	16
Mar	55	2	263	13	318	6
Apr	43	1	140	7	183	4
May	60	2	60	3	120	2
Jun	12	0	20	1	32	1
Jul	51	2	32	2	83	2
Aug	427	14	51	2	478	10
Sep	403	14	118	6	521	10
Oct	378	13	111	5	489	10
Nov	316	11	277	14	593	12
Dec	533	18	79	4	612	12
Total	**2,949**		**2,050**		**4,999**	

Table 11. Total Numbers of Fish Impinged by Year at John Sevier Fossil Plant and Numbers Following Application of Equivalent Adult and Production Foregone Models.

	Year-One	Year-Two
Extrapolated Annual Number Impinged	20,643	14,350
Number Liable for after EA & PF Reduction	1,889	1,841

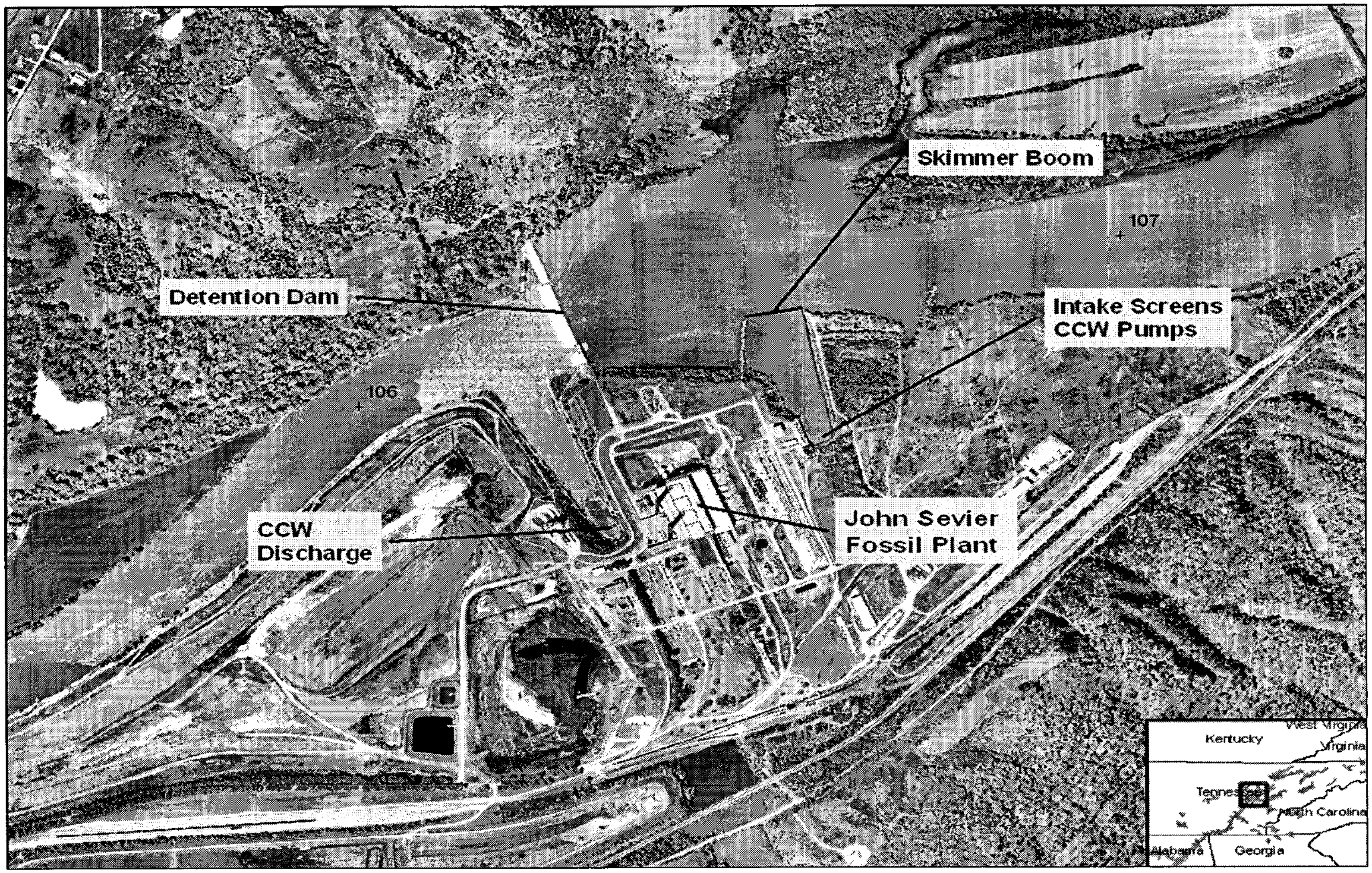

Figure 1. Aerial photograph of John Sevier Fossil Plant including CCW intake structure, skimmer boom, intake basin, detention dam, and discharge channel.

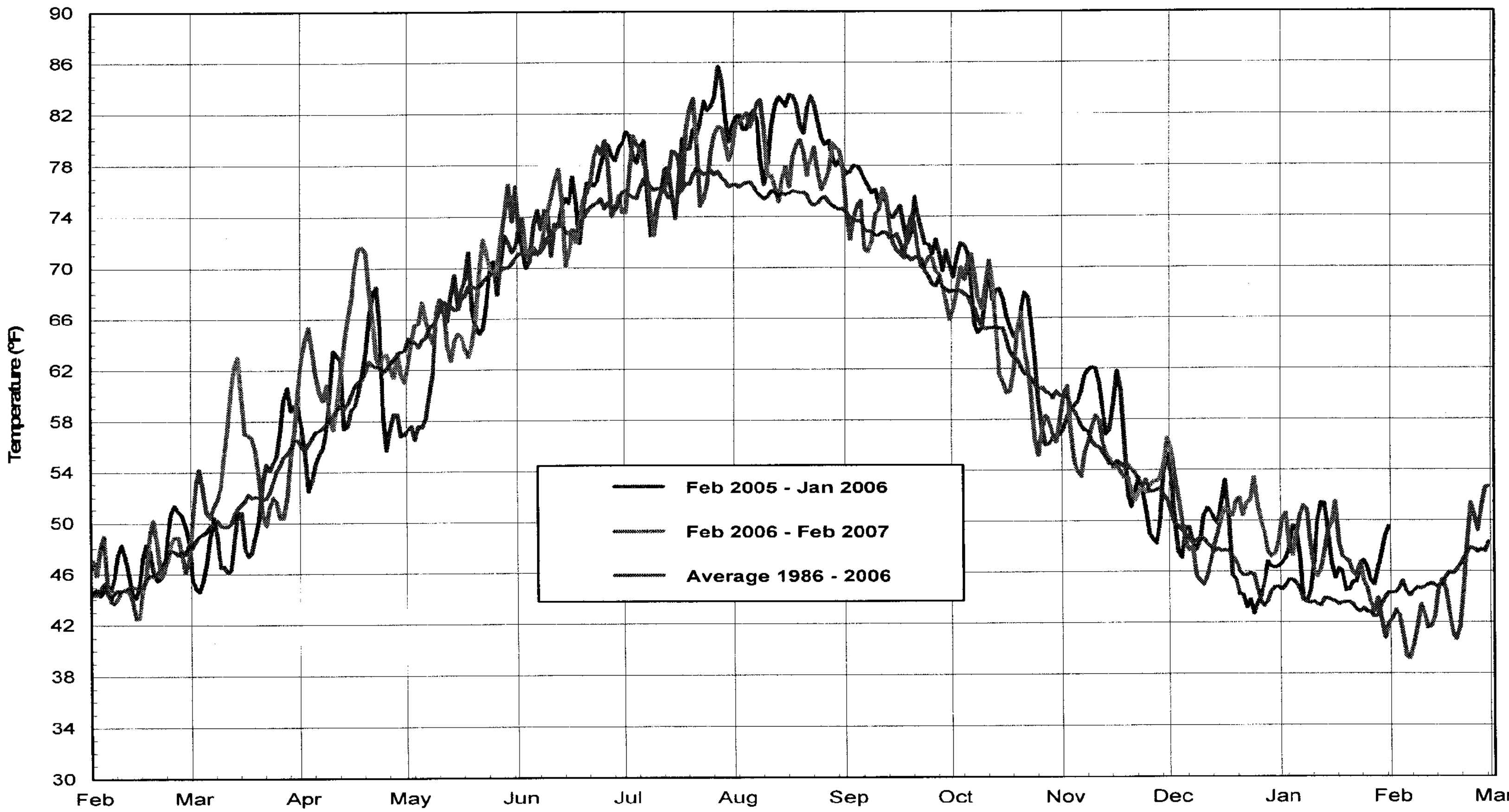

Figure 2. Ambient daily (24-hr avg) water temperature at John Sevier Fossil Plant intake during historical (1986-2006) and recent (2005-2007) entrainment and impingement monitoring.

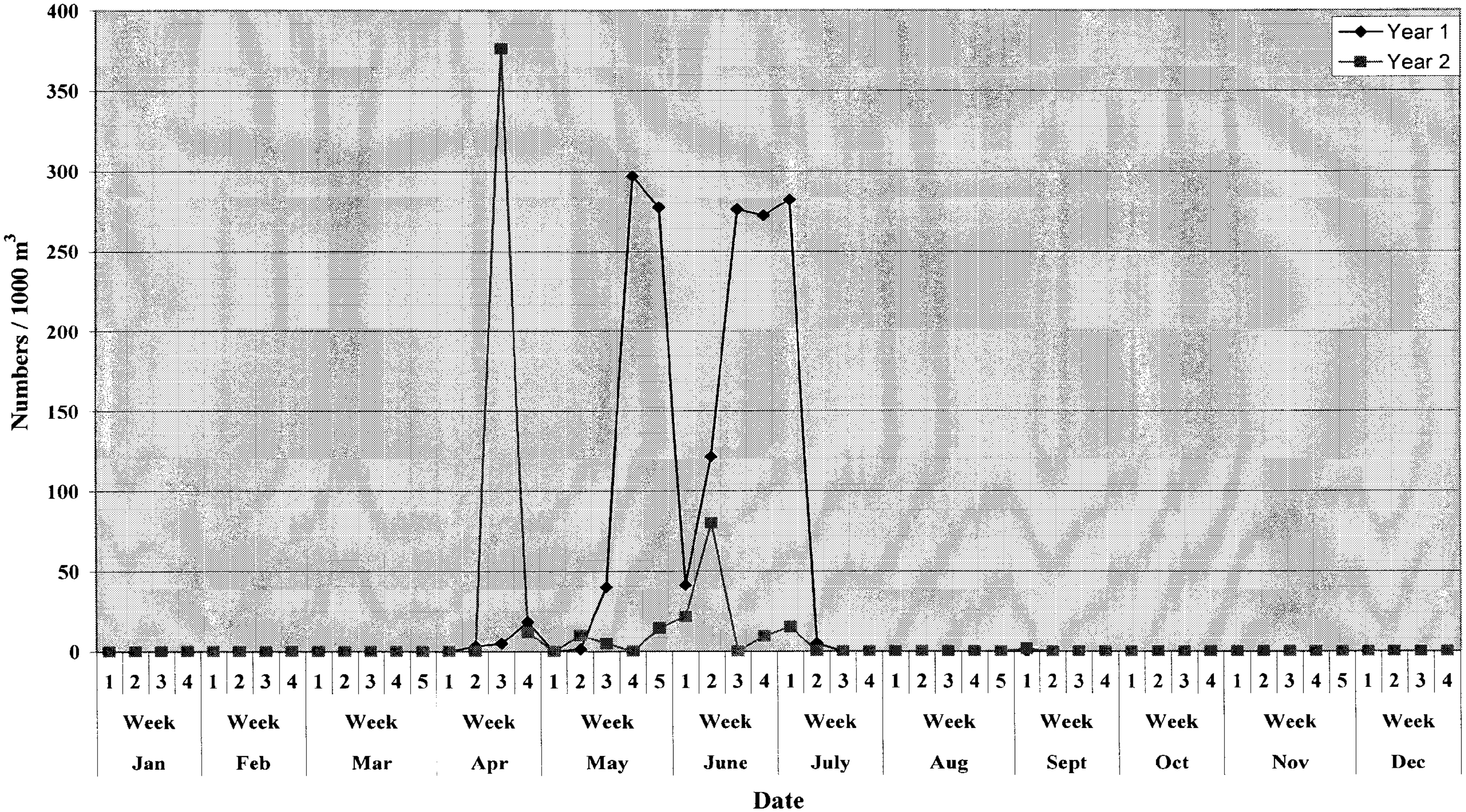

Figure 3. Densities of clupeid larvae collected in entrainment samples at John Sevier Fossil Plant during 2005-2007.

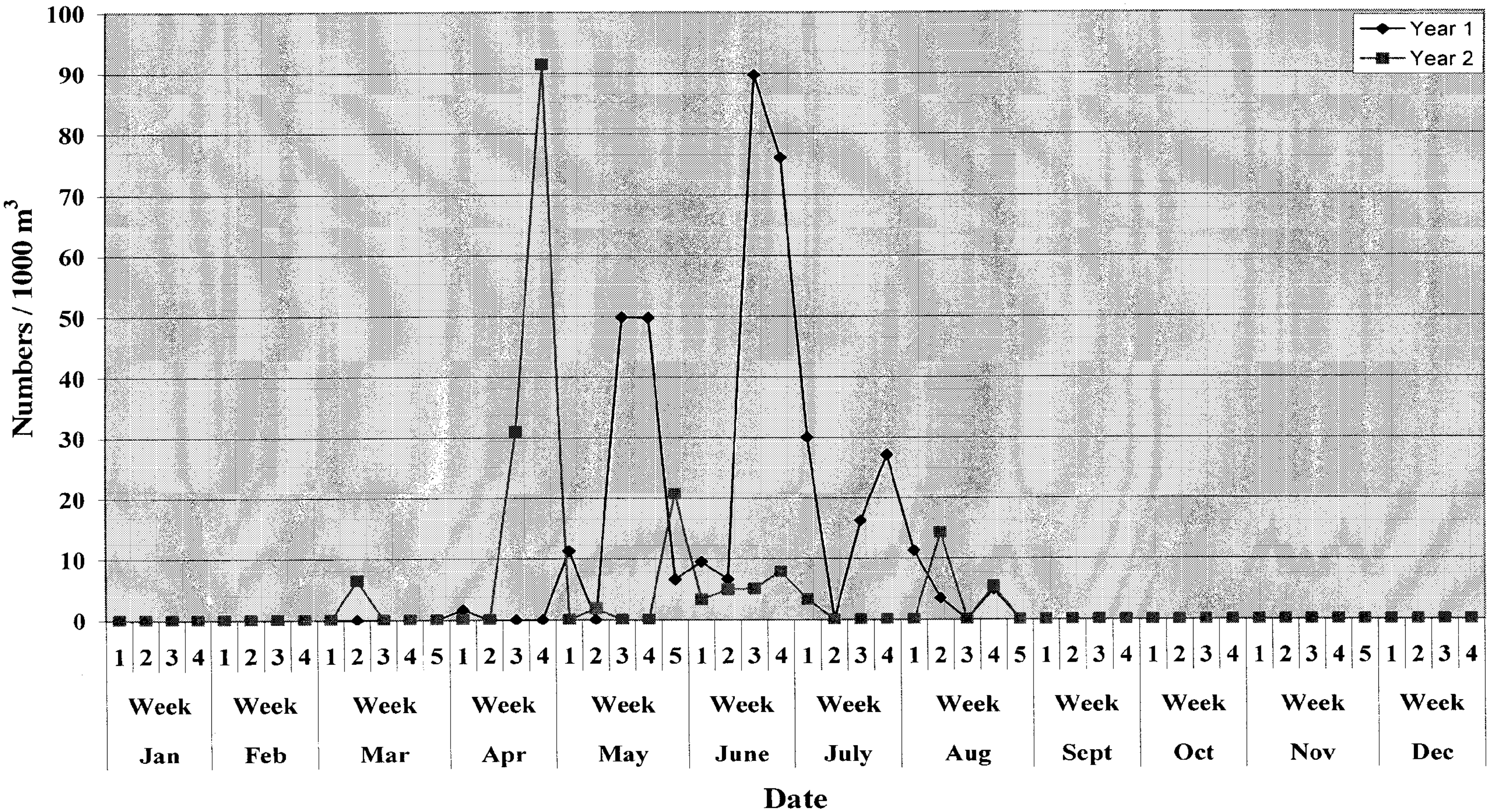

Figure 4. Densities of cyprinid larvae collected in entrainment samples at John Sevier Fossil Plant during 2005-2007.

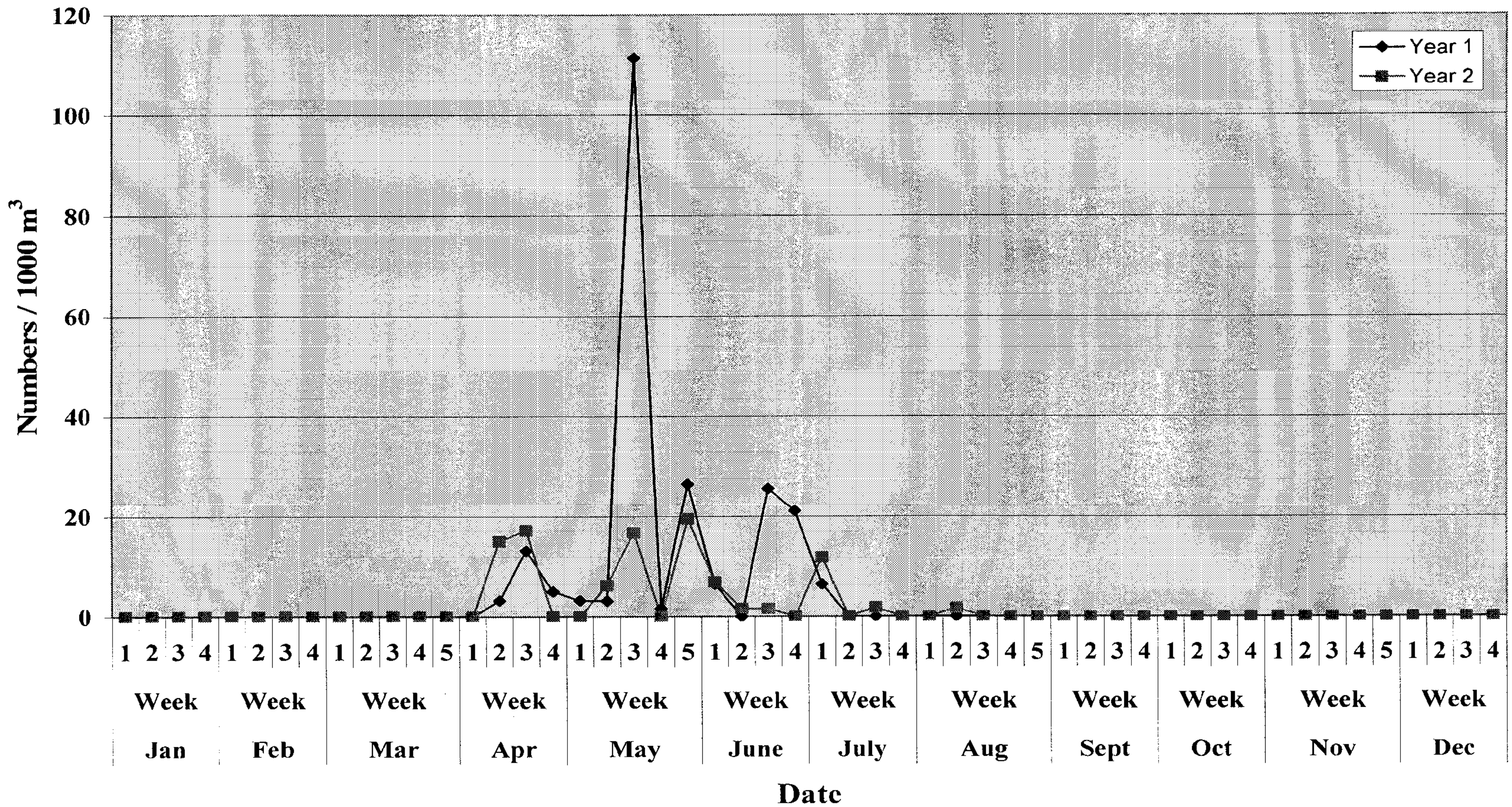

Figure 5. Densities of catostomid larvae collected in entrainment samples at John Sevier Fossil Plant during 2005-2007.

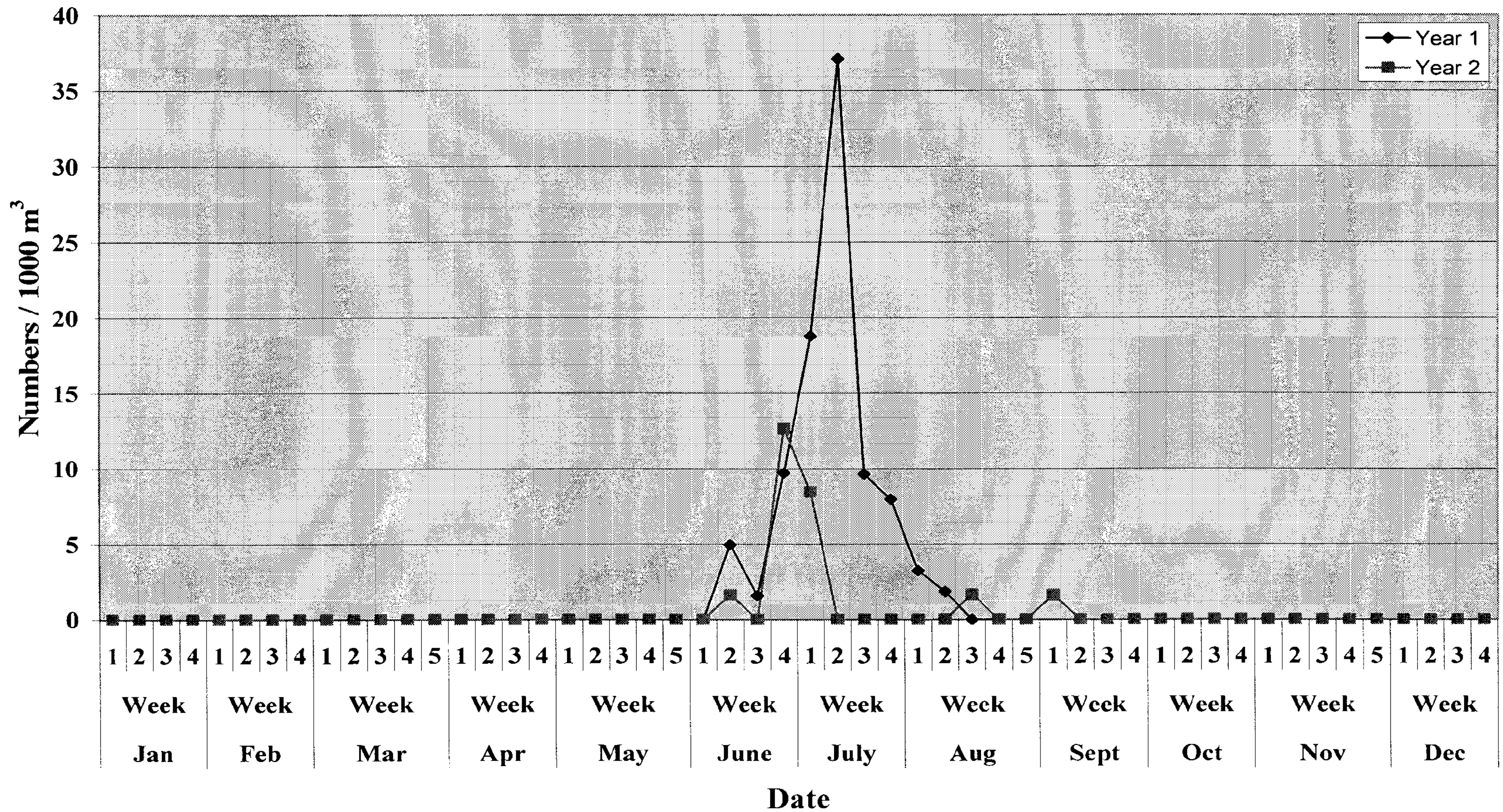

Figure 6. Densities of ictalurid larvae collected in entrainment samples at John Sevier Fossil Plant during 2005-2007.

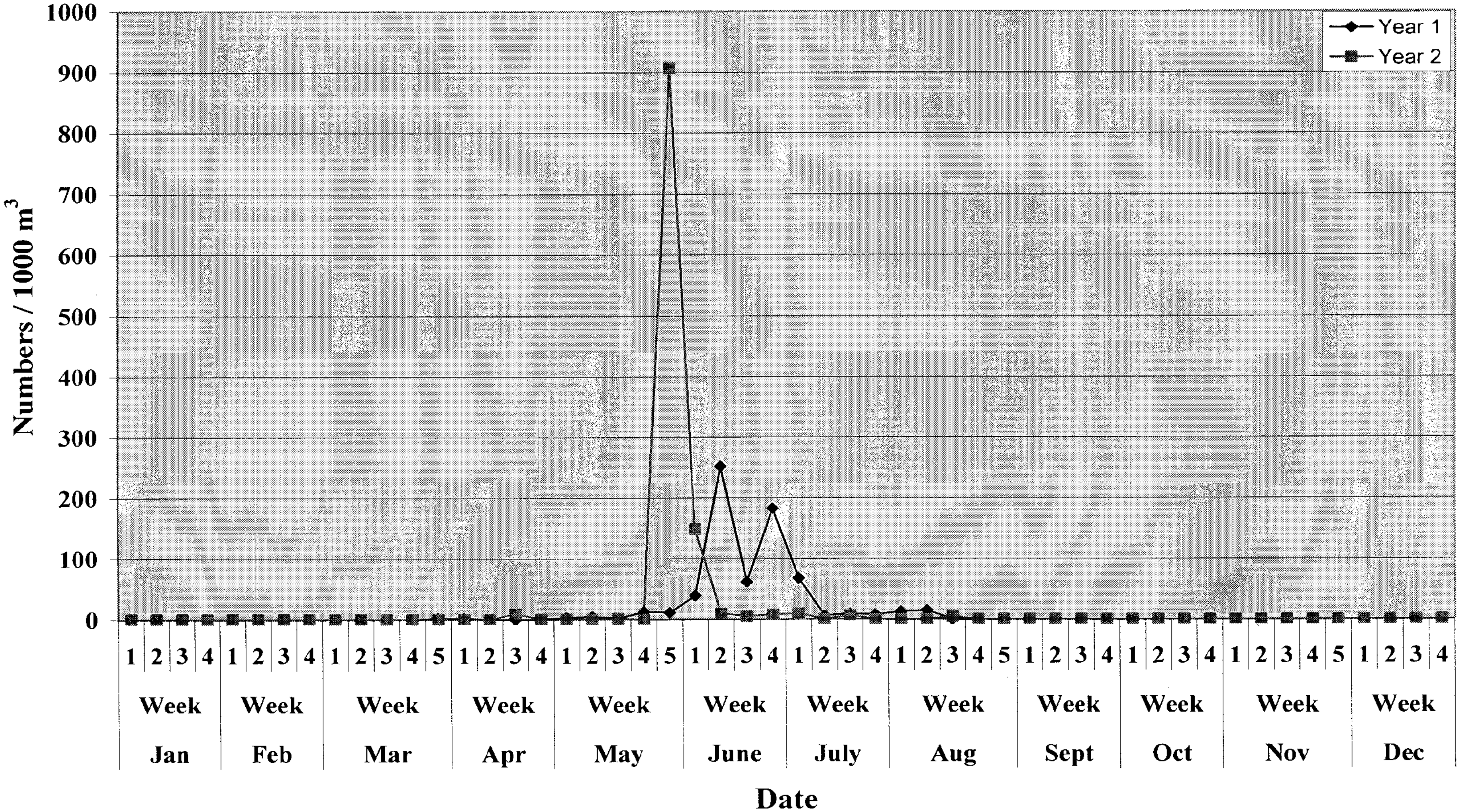

Figure 7. Densities of centrachid larvae collected in entrainment samples at John Sevier Fossil Plant 2005-2007.

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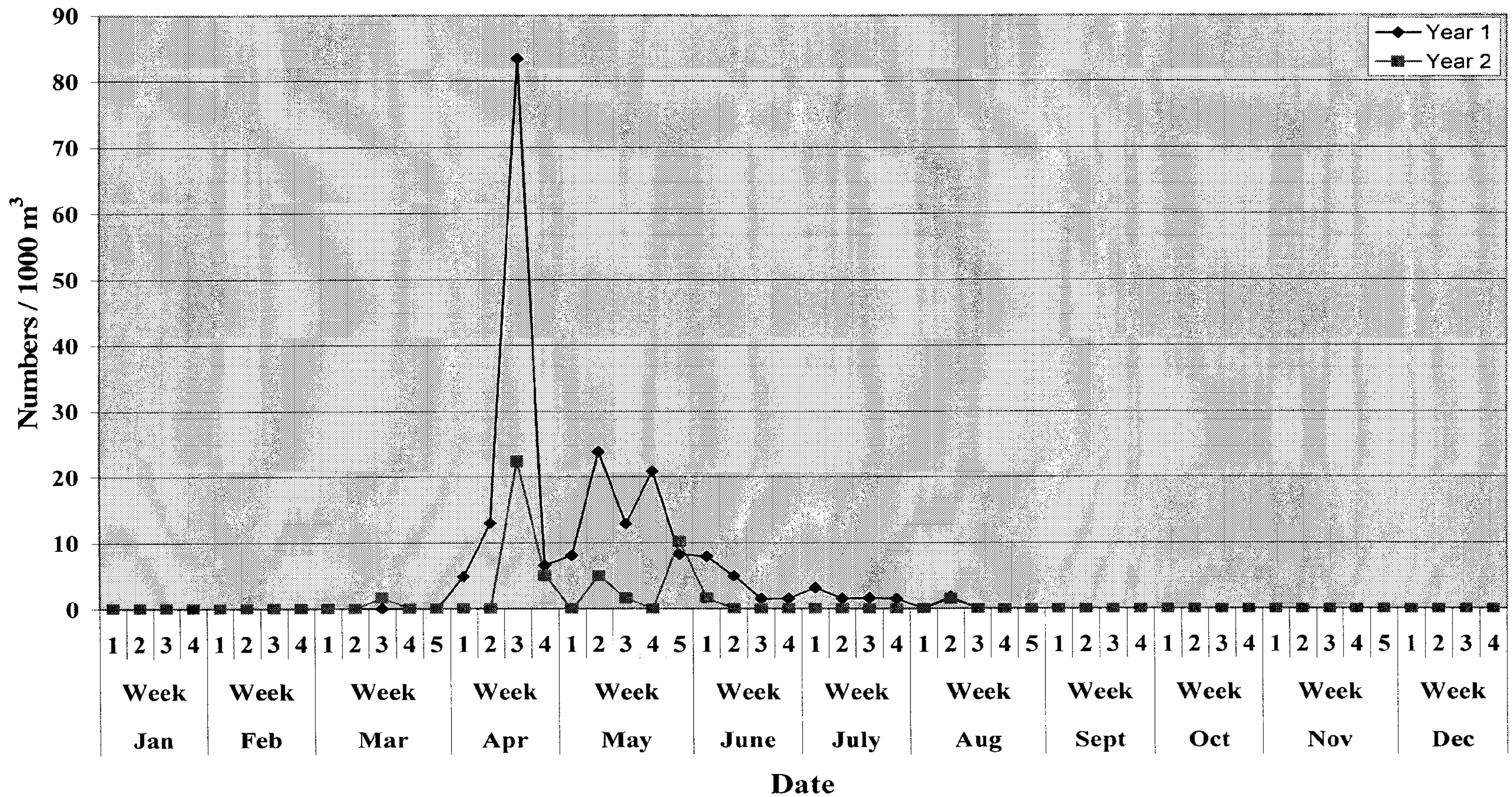


Figure 8. Densities of percid larvae collected in entrainment samples at John Sevier Fossil Plant during 2005-2007.

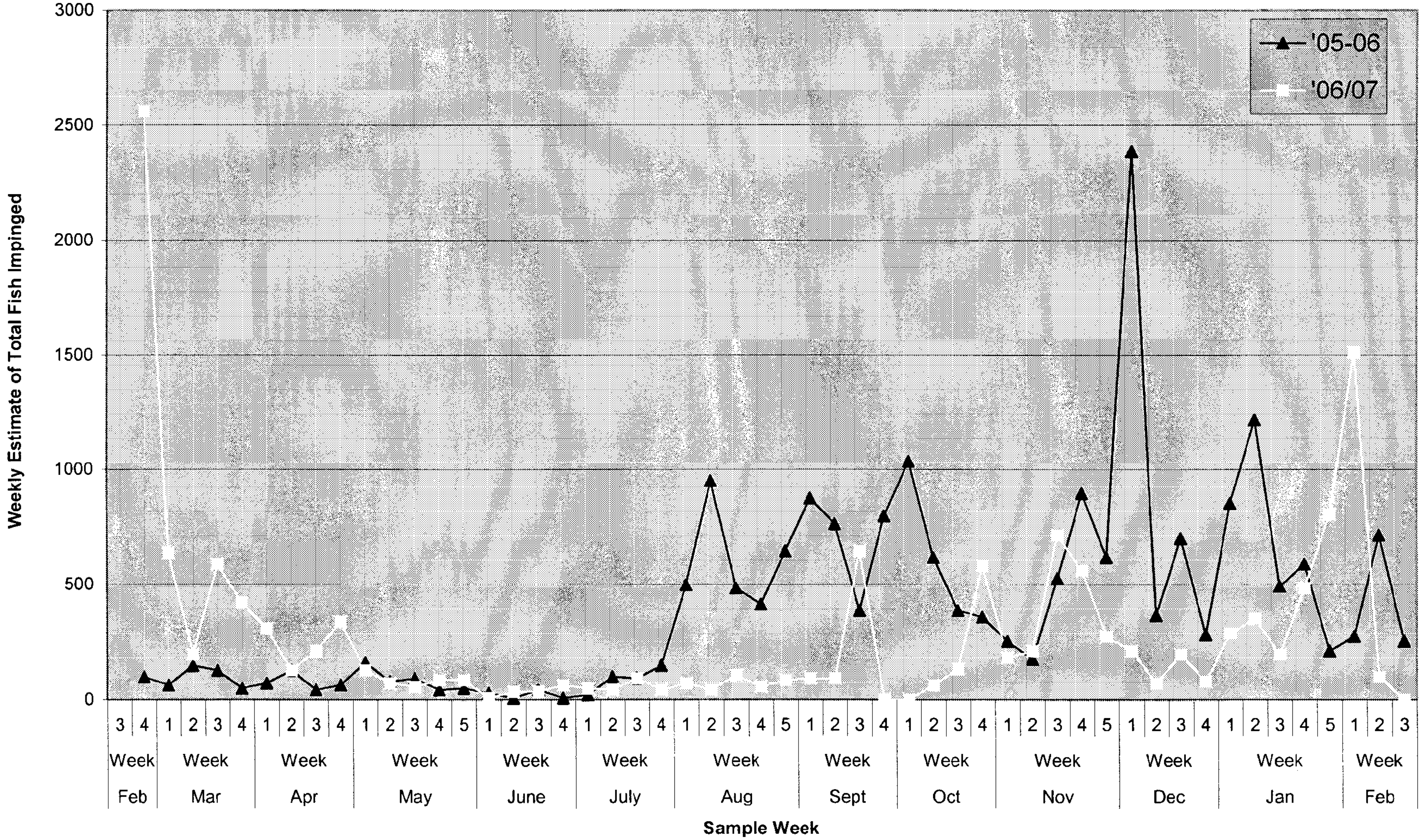
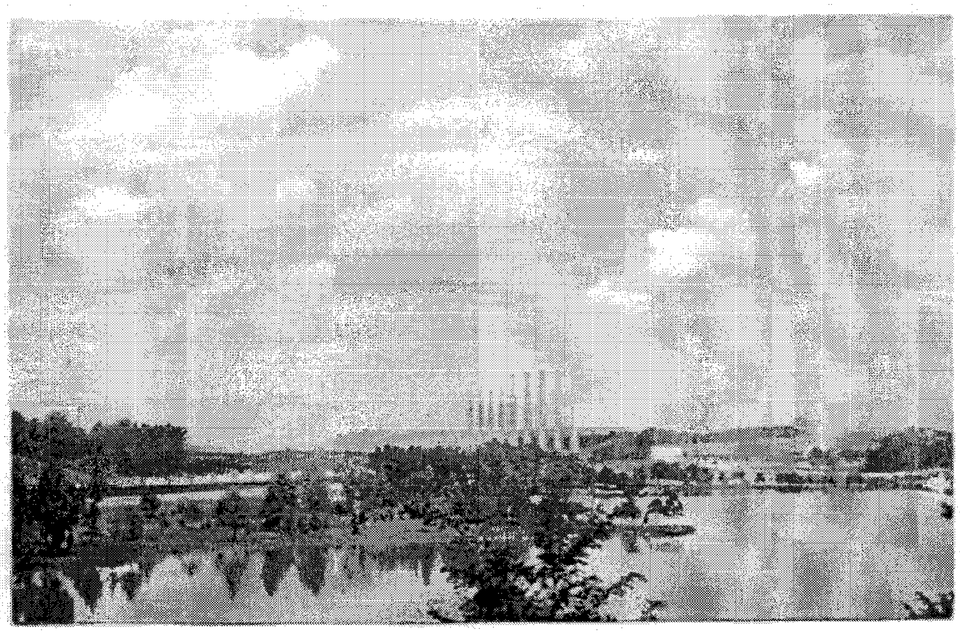


Figure 9. Estimated weekly fish impingement at TVA's John Sevier Fossil Plant during 2005-2007.

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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LIST OF ACRONYMS

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.

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	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.

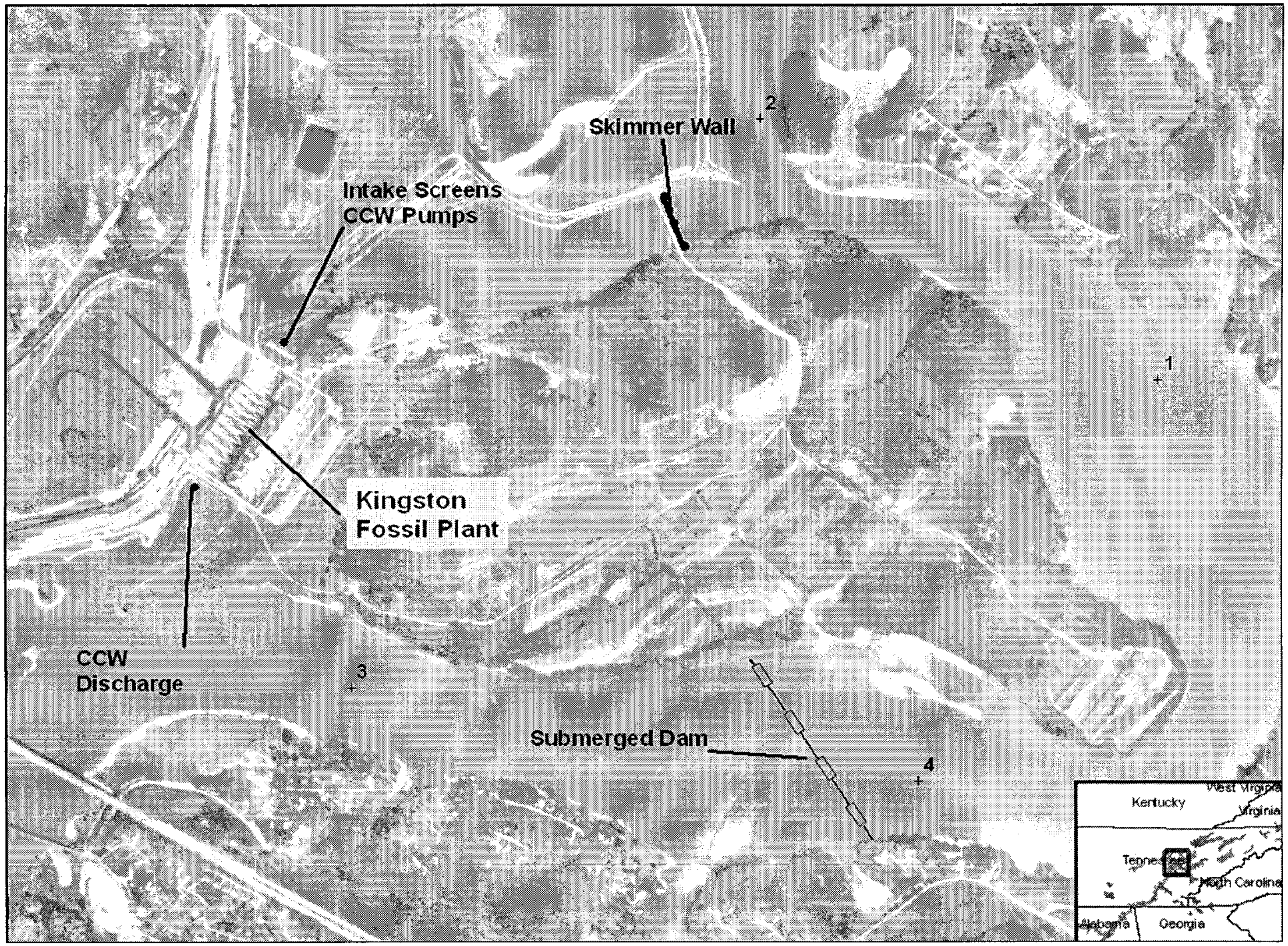

Figure 1. Aerial photograph of Kingston Fossil Plant including CCW intake structure, skimmer wall, intake basin, and discharge channel.

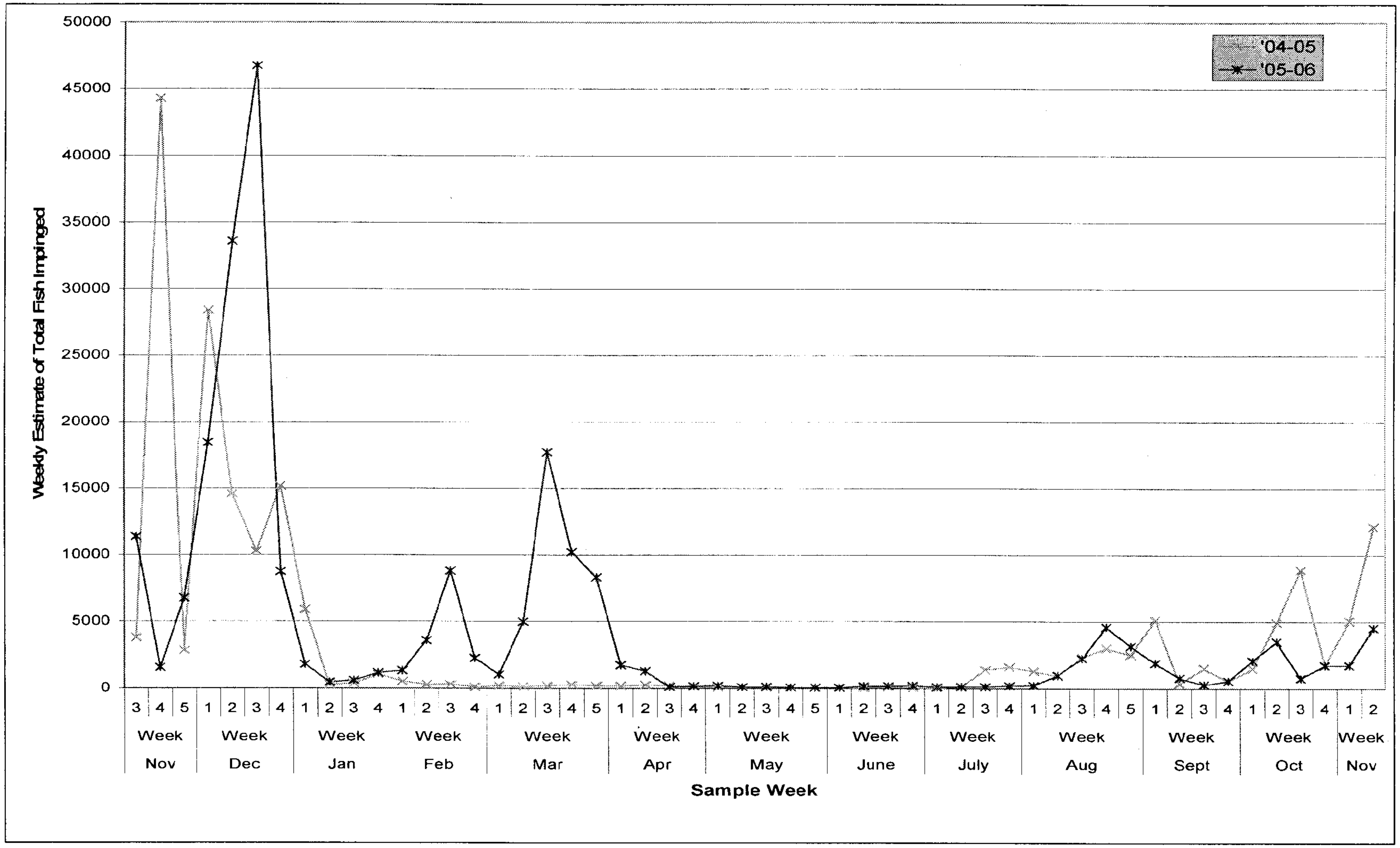

Figure 2. Estimated weekly fish impingement at TVA's Kingston Fossil Plant during 2004-2006.

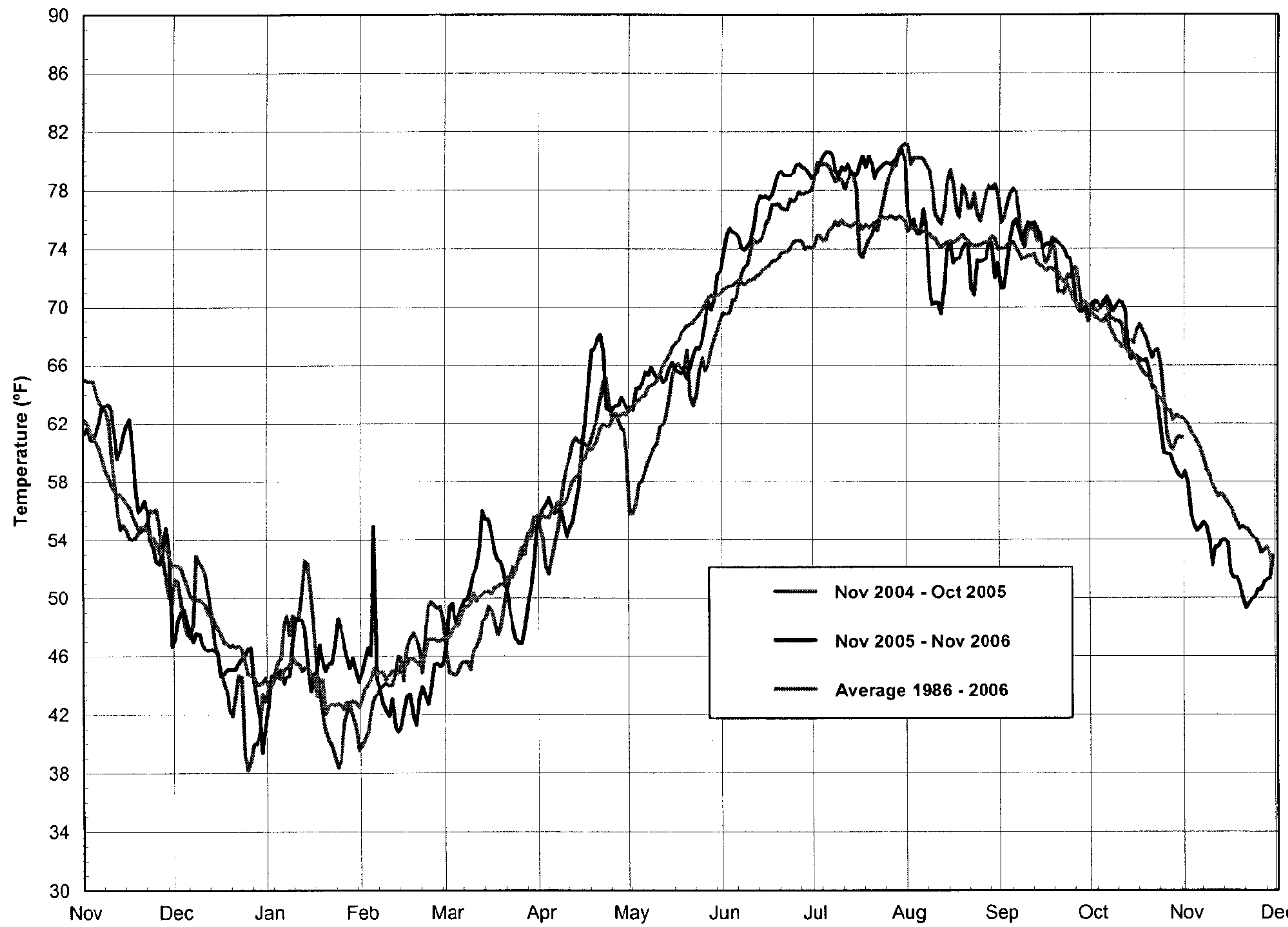

Figure 3. Ambient daily (24-hr avg) water temperature at Kingston Fossil Plant intake during historical (1986-2006) and recent (2004-2006) impingement monitoring.

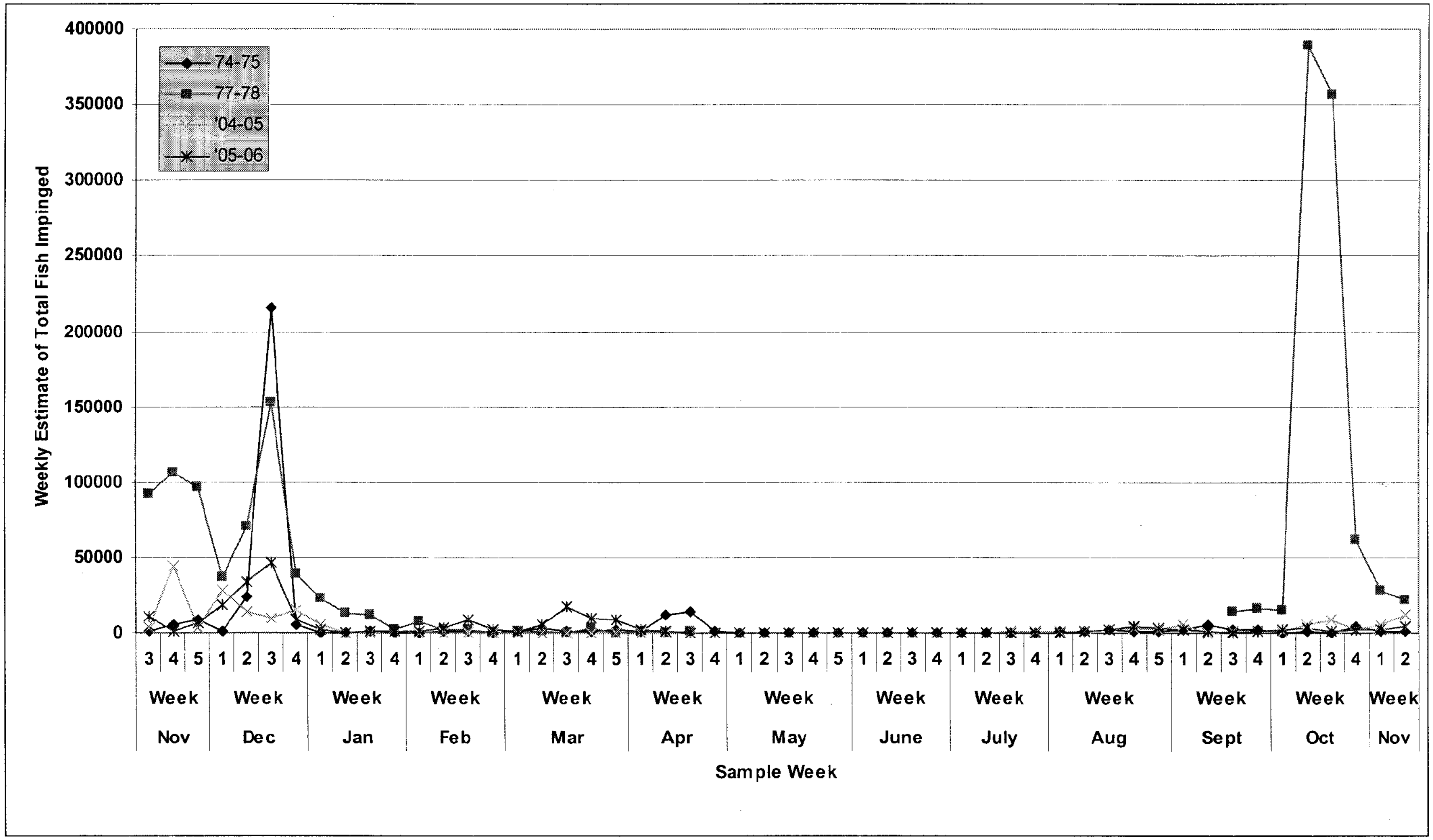

Figure 4. Comparison of estimated weekly fish impingement at TVA's Kingston Fossil Plant during historical and recent monitoring periods.