IMPINGEMENT AND ENTRAINMENT AT THE RIVER WATER INTAKES OF THE SAVANNAH RIVER PLANT

Submitted by: U.S. Department of Energy
Savannah River Operations Office
Aiken, South Carolina

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SRC-90-0520
August 8, 1990

Dr. James D. Arnett
Task Order Manager
Environmental Division
Savannah River Operations Office
U.S. Department of Energy
Post Office Box A
Aiken, South Carolina 29802

REFERENCE: Contract No. DE-AC09-87SR15107, March 30, 1987; Task Assignment 001, Environmental Studies Support

SUBJECT: NUS Review: Agency Letters on Draft Environmental Impact Statement, "Continued Operation of K-, L-, and P- Reactors" (ATS 1055)

Dear Dr. Arnett:

Pursuant to your request, NUS has reviewed the subject agency letters and we have comments that are provided in the enclosed review report.

Should you have any questions or wish to discuss these comments, please call P. R. Moore or me at 649-7963.

Sincerely,

William R. Weiss
Principal Investigator
Task Assignment 001

WRW:deh

Enclosure

cc w/ encl.:
J. N. Knox, DOE-SR/ED
M. I. Goldman, NUS-HQ (Cat. 3)
B. C. Marcy, NUS-SRC
J. L. Oliver, NUS-SRC
P. R. Moore, NUS-SRC
S. M. Bartlett, NUS-SRC
File 001-3.7-055

cc w/o encl.:
A. B. Gould, Jr., DOE-SR/ED
S. S. Norton, DOE-SR/ED
R. L. Shoup, NUS-SRC
File 001-2.2, 1.1.1

P.R. Moore Name Initials Date ... 8/7/90
REVIEW W.R. Weiss WRW 8/7/90
CONCUR
APPROVE J.L. Oliver JLO 8/8/90
SCOPE OF REVIEW
FULFILLS WORKSCOPE
SOUNDNESS OF RESULTS
COMMUNICATION EFFECTIVENESS
OTHER DOE Sensitivity

NUS REVIEW OF REGULATORY AGENCY COMMENTS ON THE DRAFT EIS "CONTINUED OPERATION OF K-, L-, AND P-REACTORS"

INTRODUCTION

At the request of the U.S. Department of Energy-Savannah River Operations Office (DOE-SR), NUS has reviewed letters from four natural resource management agencies on the Reactor Operation Environmental Impact Statement (ROEIS). The agencies commenting on the ROEIS were the U.S. Department of the Interior, the South Carolina Wildlife and Marine Resources Department, the National Oceanic and Atmospheric Administration (National Marine Fisheries Service), and the U. S. Environmental Protection Agency. This review was intended to focus on the issues of impingement and entrainment and to offer suggestions on possible approaches to mitigation and future research.

GENERAL COMMENTS

The regulatory agencies all expressed the same concerns: that predicted levels of impingement and entrainment associated with the operation of three reactors were unacceptably high, and that losses of this magnitude could very well damage the fisheries resource. The main concern of the agencies appeared to be anadromous species such as the American shad, striped bass, and the endangered shortnose sturgeon. None of the comment letters disputed the facts of the ROEIS and none questioned the validity of the data it contained. The regulators simply drew conclusions from the data that were diametrically opposed to those advanced in the ROEIS.

Notwithstanding the comments of the regulatory agencies, numbers of fish impinged annually at the Savannah River Site (SRS) cooling water intakes were very low, particularly when compared to numbers impinged at commercial power plants. Moreover, the bulk of the fish impinged over the 1983-1985 study period were either slow-growing lepomids (bluespotted sunfish, warmouth, and spotted sunfish) that provide little or no recreational fishery or forage species, such as threadfin shad and gizzard shad, with high reproductive potentials. There is simply no evidence that the predicted impingement rate will harm the commercial or recreational fisheries of the Savannah River.

If impingement studies are conducted in the future, an effort should be made to weigh and measure all fish collected from traveling screens. Length frequency distributions should be provided for commonly-impinged species. This will enable DOE to better assess potential impacts, as impingement of sexually-mature fish and "trophy" fish is more significant than impingement of young-of-the-year fish and small fish. Weight measurements will permit an estimate of total biomass impinged, an important piece of information for impact assessment purposes. It would be informative to know, for example, if the average bluegill or redbreast impinged weighed 30 grams or 300 grams.

The regulatory agency biologists argue that rates of entrainment seen at the SRS cooling water intakes are excessive, basing their arguments on (1) percentage of river flow diverted as cooling water and (2) percentage of ichthyoplankton entrained, which averaged 11 percent over the course of a four-year study. This argument ignores the resilience of fish populations and twenty years of research on density-dependent regulation (or "compensatory mechanisms") of stocks of anadromous fish.

The 1987 DOE study "Impingement and Entrainment at the River Water Intakes of the Savannah River Plant" contains data on relative abundance of ichthyoplankton in the Savannah River. Data on selected species are presented below:

Percent Composition of Fish Eggs and Larvae Collected in the Savannah River, 1983-1985

Species	1983	1984	1985
American Shad	1.4	14.0	50.7
Striped Bass	0.2	3.0	5.4
Blueback Herring	12.1	4.5	2.2
Gizzard/Threadfin Shad	19.9	10.8	9.9

Relative abundance of American shad and striped bass ichthyoplankton in the Savannah River samples increased steadily from 1983-1985. These data strongly suggest that populations of two commercially and recreationally-important fish species using the middle reaches of the Savannah River are stable, if not expanding, despite "cropping" of eggs and larvae at the cooling water intakes of the Savannah River Site.

The status of the other clupeids (blueback herring, gizzard shad, threadfin shad, and hickory shad) is more problematic. Relative abundance of blueback herring ichthyoplankton in samples declined steadily from 1983-1985, while relative abundance of gizzard/threadfin shad appeared to drop off to some degree after 1983. Paller, in the 1986 ECS/Normandeau report, attributed this decline in blueback herring numbers to low river water levels which "reduced access to swamp and backwater spawning sites." This may be true of gizzard shad as well, for they often spawn in oxbows and sloughs of big rivers. Hickory shad appear to be a minor component of the anadromous fishery in the Savannah River, never appearing in significant numbers.

Densities of ichthyoplankton in Savannah River samples taken over the 1983-1985 period showed a similar pattern:

Mean Ichthyoplankton Densities (No./1000 m^3) in Savannah River Samples, 1983-1985

Species	1983	1984	1985
American Shad	8.45	4.83	27.86
Striped Bass	2.16	2.76	3.25
Blueback Herring	10.44	1.92	1.40
Other Shad	16.78	3.96	5.93

Again, the data suggest that populations of two important anadromous species have not been harmed in an obvious way by impingement and entrainment at the SRS intakes. Densities of other clupeid species decreased over the course of the study. Whether this decrease in abundance relative to American shad is the result of plant operations, inter-specific competition, natural year-to-year variation, or some habitat factor is unknown. It is hoped that the planned Westinghouse Savannah River Company-Savannah River Laboratory (WSRC/SRL) studies will shed some light on this problem.

The fact that no striped bass eggs or larvae were collected in the vicinity of SRS until 1982 and were collected in every subsequent sampling year is additional evidence for a recovering or expanding striped bass population in the middle reaches of the Savannah River. The data suggest that entrainment of striped bass eggs and larvae at the SRS cooling water intakes has not had a significant impact on recruitment of adult fish into the population. However, University of Georgia researchers have apparently suggested that striped bass in the Savannah River have, to some extent, abandoned traditional down-river and estuarine spawning areas and moved upstream to spawn in less heavily-fished and polluted areas. If this is true, striped bass eggs and larvae may be more vulnerable to entrainment, and there could be some population-level effects. Research on Savannah River striped bass stocks currently being conducted by Dr. Mike Van den Ayvle and his graduate students at the University of Georgia should resolve some of these issues.

Mr. John Crane of the South Carolina Wildlife and Marine Resources Department (SCWMRD) is currently studying striped bass population dynamics in the Santee River drainage (Wateree and Congaree rivers). This study promises to generate some interesting information on timing and synchronicity of spawning, differential survival rates of eggs and larvae, and possible compensatory (density-dependent) mechanisms regulating recruitment of striped bass.

Numbers of spawning striped bass ascending coastal rivers in the eastern United States have increased dramatically over the last three or four years from the Hudson River in New York to the Roanoke River in North Carolina. Striped bass stocks in the Chesapeake Bay have shown pronounced increases over the last several years. This resurgence has been attributed to improvements in water quality resulting from Clean Water Act/National Pollutant Discharge Elimination System regulatory action and widespread restrictions on sport fishing and commercial harvest of striped bass. Whatever the reason, Atlantic coast striped bass populations are recovering in the mid-Atlantic region and we can only assume that this is the case in the Savannah River as well.

RECOMMENDATIONS

There are a number of gaps and anomalies in the ECS/Normandeau ichthyoplankton data that WSRC-SRL should address and seek to eliminate in its 1991 studies.

First, WSRC researchers should sample ichthyoplankton more frequently than Ecological and Chemical Sciences, Inc. (ECS)/Normandeau Associates, Inc. (NA) did in 1983-1985. Weekly sampling is probably sufficient to mark the beginning and end of the spawning season, but it is inadequate to define the intensity and timing of spawning during the peak period of April through mid-June. Ichthyoplankton should be sampled no less than twice weekly (or as often as resources permit) during the April-June period. The rather spectacular fluctuations in relative abundance of clupeid larvae seen by ECS/NA may well be the result of low sampling intensity, as peaks and valleys of abundance could easily be missed in the one week interval between sample collections.

Second, river transects should be sampled randomly with respect to time in order to obtain reasonable estimates of larval fish densities and entrainment rates. Unfortunately, the 1983-1985 ECS/NA data are based on (systematic) daytime samples and adjusting the sampling scheme would make comparisons difficult. DOE-SR/ED is, thus, faced with a dilemma: whether to continue using a sampling strategy that is flawed, but will yield comparable results, or to employ a sampling scheme that yields more meaningful data and does not lend itself to comparison with historical data. The solution may be to sample larval fish exactly as before, but to collect supplemental (randomly-assigned) nighttime samples to permit an analysis of the degree to which daytime samples underestimate abundance of larval fish.

Third, it would be extremely helpful to have estimates, even crude estimates, of numbers of adult spawners of species of interest. ECS/NA researchers did a commendable job of estimating ichthyoplankton densities in the river and numbers of eggs and larval fish entrained. This approach produced estimates of percentage of available ichthyoplankton entrained. The operative assumption was that a high percentage of larvae entrained (say 20 percent or more) was "bad," whereas a lower percentage of fish entrained was acceptable or "insignificant."

If WSRC-SRL researchers were able to come up with population estimates of the species in question, the issue of larval losses could be resolved in short order. If, for example, there were 100,000 mature female American shad in the spawning run, each containing upwards of 200,000 eggs, then the loss of 1.0×10^6 eggs would indeed be insignificant. If, on the other hand, there were an estimated 1,000 striped bass adults in the run (50 percent female, one assumes) and an estimated 2.0×10^7 larvae were entrained, the population could very well be at risk.

Numbers of migrating adults could be estimated with state-of-the-art hydroacoustic gear, with Peterson mark and recapture techniques, or both. BioSonics, of Seattle, Washington claims that its hydroacoustic gear is sensitive enough not only to count fish, but to measure the size of fish passing through the sonar beam. Different species have different sonic "signatures." A hydroacoustic survey in conjunction with netting or electrofishing (to ground truth data) could provide some reasonably accurate data on sizes of spawning runs. Peterson mark and recapture techniques are extremely labor intensive, but could be used to estimate numbers of more abundant species like American shad and gizzard/threadfin shad.

Mark and recapture studies in rivers typically involve electrofishing upstream to collect fish for tagging and drifting gill nets downstream for recaptures. If pilot studies result in the capture of striped bass and sturgeon in nets, then this work should be discontinued. These species are too valuable, and in the case of shortnose sturgeon, too rare, to jeopardize by accidental collecting. If proper mesh sizes are selected, this should not be a problem.

Mr. Doug Cooke of the SCWMRD's Dennis Wildlife Center (Bonneau, South Carolina) has for several years conducted hydroacoustic surveys and mark and recapture studies of blueback herring in the Cooper and Santee rivers and would be an excellent source of advice regarding this proposed work.

The most viable mitigation option appears to be the placement of wire screens or barrier nets across the mouths of the 1G and 3G intake canals. This would greatly reduce impingement losses and reduce entrainment losses to some extent, because fish would no longer be able to enter the intake canal to spawn. A permanent wire-mesh barrier with removeable screens (for cleaning) would be expensive to build and to maintain. Block nets would be considerably less expensive, but would require frequent inspections and cleaning during certain times of the year. A number of commercial utilities use barrier nets to prevent the impingement of fish at power plant intakes, among them Potomac Electric Power (Chalk Point Steam Station, Maryland), Detroit Edison (Ludington Pumped-Storage Plant, Michigan), and Orange & Rockland Utilities (Bowline Point Power Plant, New York). Impingement rates at all three plants have been reduced significantly.

Fish stocking was mentioned as an alternative in the 1987 DOE report, but the same report conceded that shad and herring were not readily available from commercial fish hatcheries. Striped bass could be stocked, but solid estimates of impingement and entrainment losses to the sport and commercial fishery would be required to set stocking rates. As no data are available on egg-to-adult mortality rates of striped bass in the Savannah River, calculating replacement rates would be little more than an educated guess. Further, SCWMRD has historically rejected stocking as a mitigation option. South Carolina Electric & Gas Company offered to replace adult fish killed by thermal discharges at V. C. Summer Nuclear Station by stocking adult fish and was turned down flatly by SCWMRD. Finally, there is a widely-held belief among fishermen and fisheries professionals that hatchery-bred fish are inferior to native fish. There is no doubt that hatchery-bred fish are initially more vulnerable to predation and are less efficient feeders than wild fish. The transition from hatchery pond to river is not an easy one, and often leads to high mortality among stocked fish.

NUS CORPORATION

INTERNAL CORRESPONDENCE

TO: Distribution

DATE: August 3, 1990

FROM: R. M. Burd/B. H. Bradford

COPIES: Files 023-2.3, 023-3.3.7.7

SUBJECT: Time of Travel of a Slug Contaminant in the Savannah River from SRS to Beaufort/Jasper Water Intakes (Lift Station)

I. The following information and data were used to calculate the time of travel:

1. Average flow rate of river = $295 m^3/s$

2. Cross sectional area, (75m x 3m) = $225 m^2$

   Estimated to range to (146m x 3m) = $440 m^2$

3. $\text{Velocity}_1 \ \frac{295 m^3/s}{225 m^2} = 1.3 m/s$

   $\text{Velocity}_2 \ \frac{295 m^3/s}{440 m^2} = 0.67 \ m/s$

4. Distance from SRS to Beaufort/Jasper is about 100 miles

   = 160 km = $1.6 \times 10^5 m$

5. Time of travel (of leading edge of slug)

   a. $\frac{160{,}000 m}{1.3 m/s} = \frac{123{,}077 s}{86{,}400 s/d} =$ 1.4 days (34 hours)

   b. $\frac{160{,}000 m}{0.67 m/s} = \frac{238{,}806 s}{86{,}400 s/d} =$ 2.8 days (68 hours)

[Response to comment L-49-09 says 1.5 to 3.0 days and asks DOE/WSRC to verify.]

II. The 0.67 m/s velocity is documented in "The Water Encyclopedia" (2 ed.) 1990, as the mean velocity for rivers in the southeast, occurring during low flow periods. ($71 m^3/s$)

III. Calculations by B. H. Bradford using the Manning equation which uses slope (4 ft/mile above the Fall Line and 1 ft/mile in the Coastal Plain), river width, depth, and a roughness factor; and other flow equation calculations indicate velocities in the river range from 0.71 m/s to 1.2 m/s.

IV. Based on the above, it is likely that Beaufort/Jasper Water Authority would have at least 34 hours advance warning of a spill at SRS.

V. Time of passage of a slug past the Beaufort/Jasper water (lift station) intakes is estimated to require 2 to 3 days depending on:

1. Volume of spill, or distance of leading edge to trailing edge
2. Dispersion or mixing rate in the river (believed to be low, i.e., poor mixing)
3. Velocity of river at the time of spill
4. Tidal influences in the lower reaches of the river

VI. Lift stations for Beaufort/Jasper and Port Wentworth are on the river upstream from Savannah. A 20-30 mile canal and pipeline lead from the lift station east to the Beaufort/Jasper Water Treatment Plant. Beaufort/Jasper lift station is about 30 miles above the mouth of the Savannah River.

VII. Manning equation:

$$Q = \frac{1}{n \times A \times R^{2/3} \times s^{1/2}}$$

n = roughness coefficient = 0.03 in natural streams

W = width, 100 meters

s = slope = 1.89×10^{-4}

Q = 295 m^3/s (annual mean flow in Savannah River)

A = cross sectional area

V = velocity

d = depth

m	m^2	m	m^3/s	m/s
d	A	R	Q	V
15	1500	11.5	3514	2.3
5	500	4.5	629	1.3
3	300	2.8	275	0.9
3.14	314	3.0	297	0.9

Cross checks:

At Augusta, dam length = 110 m
(Savannah River Bluff depth = 2.8 m
Lock and Dam) area = 308 m^2
Q = 295 m^3/s
V = 0.96 m/s

Water Encyclopedia: Southeast streams

mean V = 1.5 miles/hr = 0.67 m/s
Q = 2500 cfs = 71 m^3/s (low flow conditions)

Adjustment for Q = 295 m^3/s (Linsley, Kohler & Paulhus)

$V = kq^m$ m = 0.2 semi-arid U.S.
m = 0.1 midwestern U.S.
assume m = 0.1 southeastern U.S.
$V = (295/71)^{0.1}$ = 1.2 m/s

Estimated velocity range 0.67-1.3 m/s

DISTRIBUTION:

M. I. Goldman
B. C. Marcy
~~J. L. Oliver~~
P. R. Moore
W. R. Weiss

New & improved version incorporating new sources.

Table 1. Sizes of Eggs and Larvae of Representative Altamaha R. Fishes

Species	Egg Size (mm)	Larval size (prolarvae/protolarvae)
Atlantic sturgeon	~2.5 mm	11 mm ("newly-hatched fry")
Shortnose sturgeon	~3.0 mm ✓	
Longnose gar	2.1-3.2 mm	
Blueback herring	.87-1.1 mm	
American shad	2.5-3.5 mm	9-10 mm ("when hatched")
Threadfin shad	0.75 mm	
Gizzard shad	0.75 mm	
Carp	1.0 mm	
Silvery minnow	1.0 mm	6 mm
Golden shiner	1.0 mm	
Ironcolor shiner	0.8-0.9 mm	
Spottail shiner	0.8 mm	5 mm
Spotted sucker	2.3-2.6 mm	
White catfish	~4.2 ("fertilized"); 4.0-4.5 mm ("ripe")	
Channel catfish	3.5-4.0 mm	
White bass	0.8	4-14 mm
Striped bass	1.0-1.35 mm (unfertilized); 2.4-3.9 mm (fertilized) ✓	> 5 mm
Redbreast	~1.0 mm	
Warmouth	~1.0 mm	
Bluegill	~1.1 mm	
Largemouth bass	1.5-1.7 mm	
White crappie	<1.0 mm	
Black crappie	0.8-0.9 mm	

Sources: Scott and Crossman's ***Freshwater Fishes of Canada***, Jones et al's ***Development of Fishes of the Mid-Atlantic Bight***, Carlander's ***Handbook of Freshwater Fishery Biology***, and Auer's ***Identification of Larval Fishes of the Great Lakes Basin with Emphasis on the Lake Michigan Drainage.***

BACKGROUND

Ichthyoplankton samples were collected from the Altamaha River in 1974, 1975, 1976, 1979, and 1980 as part of pre- and post-operational studies of entrainment at the Plant Hatch intake. Samples were collected using a standard 0.5 meter (diameter) Wildco plankton nets with a mesh size of 760 microns (0.760 mm).

IMPINGEMENT AND ENTRAINMENT AT THE RIVER WATER INTAKES OF THE SAVANNAH RIVER PLANT

Submitted by: U.S. Department of Energy
Savannah River Operations Office
Aiken, South Carolina

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#426
EPB
ED

JAN 2 3 1987

Lieutenant Colonel Stewart H. Bornhoft
District Engineer
South Atlantic Division
Charleston District
P.O. Box 919
Charleston, SC 29402

Dear Colonel Bornhoft:

SPECIAL CONDITION B OF SECTION 404 PERMIT #84-2X-088 for L-LAKE EMBANKMENT

Enclosed for your review are three copies of the report required to answer "Special Condition B of Permit #84-2X-088". The Department of Energy, Savannah River Operations Office does not believe that mitigation of impingement/entrainment losses from the restart of L-Reactor is required since a three, not a four, reactor operation is still in effect at the Savannah River Plant. Thus, we have not increased the quantity of cooling water withdrawals from the Savannah River which were expected with the restart of L-Reactor.

Questions from your staff may be directed to W. G. McMillan (FTS 239-1447).

Sincerely,
Original Signed by
S. R. Wright

S. R. Wright, Director
Environmental Division

EEP:DSD:adm

Enclosure (3 cys)

bcc w/encl:
J. A. Porter, Du Pont, SRP
E. A. Campbell, NUS
PED
OCC (Concur)
ECB (Concur)
PROD (Concur)

1/21/87

CONCURRENCES		
RTG SYMBOL	INITIALS/SIG.	DATE
ED	DSD	1/21/87
ED	WEW	1/21/87
ED		1/21/87
ED	SRW	1/21/87
OCC	JB	1/22/87
PROD		1/23/87

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SUMMARY

In July 1984 the Savannah River Plant (SRP) received a permit from the U.S. Army Corps of Engineers to construct an embankment on Steel Creek to create a 1000-acre cooling reservoir which would receive cooling water discharged from the restart of L Reactor. As a condition of that permit, SRP was required to submit this report which discusses the feasibility and desirability of appropriate means to mitigate the impingement of fish and entrainment losses of fish eggs and larvae that result from the restart of L Reactor.

At the time the permit was issued, it was anticipated that the restart of L Reactor would bring the total number of reactors operating simultaneously to four. This would have resulted in an increase of about 42% in the amount of water withdrawn from the Savannah River by the SRP. However, reactor operating schedules changed, which resulted in only two reactors operating from June to November 1985, with a maximum of three reactors operating from November 1985 to the present. Thus, no significant change in pumping has occurred since the restart of the L Reactor in November 1985. It is not anticipated that there will be significant increases in water withdrawn during subsequent years, because current plans are for a continuation of the operation of three reactors.

This report summarizes the impact of withdrawing Savannah River water for secondary cooling of SRP nuclear reactors and a large, coal-fired, steam generation facility on the Savannah River fisheries. Report findings are based primarily on the results of a three year impingement/entrainment study conducted by the Department of Energy from 1983 to 1985. The results of this study adequately define the impingement/entrainment losses associated with three reactor operation, even though they do not specifically cover the first year of L-Reactor operation.

The results of that study showed that during that period, an average of 7603 fish were impinged on river water pump intake screens each year. Entrainment losses averaged 10.0×10^6 eggs and 18.8×10^6 larvae annually. Species affected most by impingement were blue-spotted sunfish and threadfin shad. Entrainment losses were primarily American shad and other clupeids. These losses do not appear to have a significant impact on the Savannah River fisheries, therefore no mitigation seems justified. However, to comply with the permit request, several mitigation alternatives are discussed.

1. INTRODUCTION

The Savannah River Plant (SRP) is a facility of the U.S. Department of Energy (DOE) that produces special nuclear materials. The SRP is located on the middle reaches of the Savannah River (Figure 1-1) and withdraws cooling water from the river for nuclear production reactors, fossil fuel steam and electric generators, and other facilities. Flow in the Savannah River is regulated by the operation of a series of dams upstream of the SRP, particularly the Clarks Hill Dam and Reservoir that is operated by the U.S. Army Corps of Engineers. The intake of river water at the SRP results in the impingement and entrainment of some resident and migratory fishes at the SRP pumping facilities (DOE, 1984, McFarlane et al., 1978).

In July, 1984 the SRP received a permit from the U.S. Army Corps of Engineers (Permit No. 84-2Z-088) to construct an embankment on Steel Creek of the SRP to form a 1000 acre cooling reservoir (Figure 1-2). The reservoir was constructed to receive cooling waters from the recently reactivated L Reactor on the SRP and thereby mitigate the effects of the thermal effluents on the downstream reaches of Steel Creek. As a condition of that permit (Special Conditions, Item b.), the DOE agreed to:

> ". . . submit within twelve months of the restart of the L-Reactor a report to the District Engineer that discusses the feasibility and desirability of a restocking plan or other appropriate means to mitigate impingement of fish and entrainment losses of fish eggs, and larvae, and to implement the measures deemed necessary by the District Engineer at that time after he has consulted with appropriate State and Federal resources agencies."

The L Reactor operates with once-through cooling. Savannah River water is pumped to the reactors through existing intake structures at the pumphouses and released into onsite streams or reservoirs after passage through the reactor heat exchangers. It was anticipated that the increased pumpage of river water to support the resumption of L-Reactor operation would result in a 42 percent increase in withdrawal of Savannah River water (DOE, 1984). Assessments of the resulting impact on fishery resources of the Savannah River from impingement and entrainment were based on linear extrapolations of available data for impingement and entrainment rates prior to L-Reactor restart. Using worst case assumptions, DOE (1984) estimated that an additional 5840 fish would be impinged annually and an additional 7.7×10^6 eggs and 11.9×10^6 larvae would be entrained as a result of the increase in river pumping.

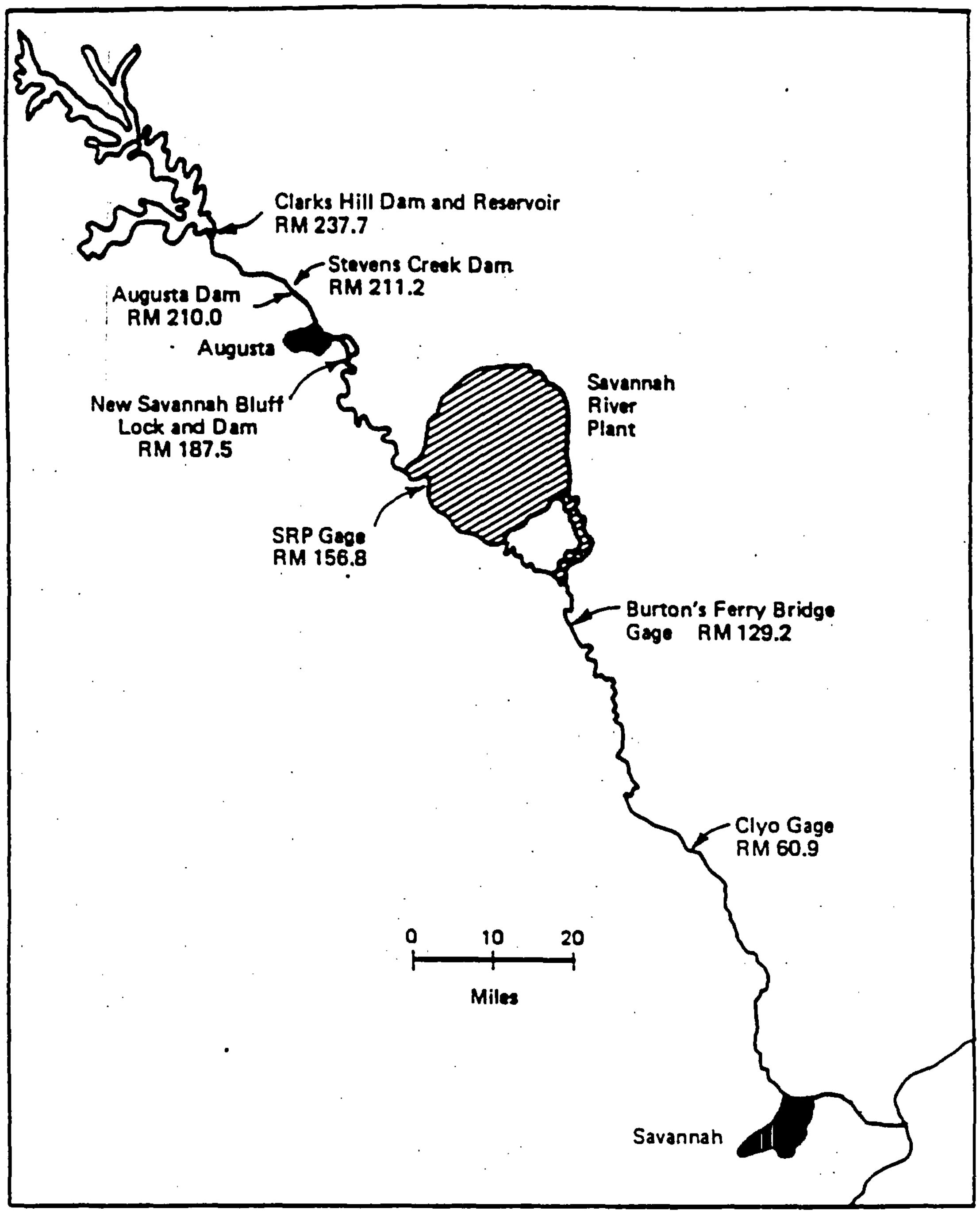

FIGURE 1-1. The Savannah River and Selected Reference Points

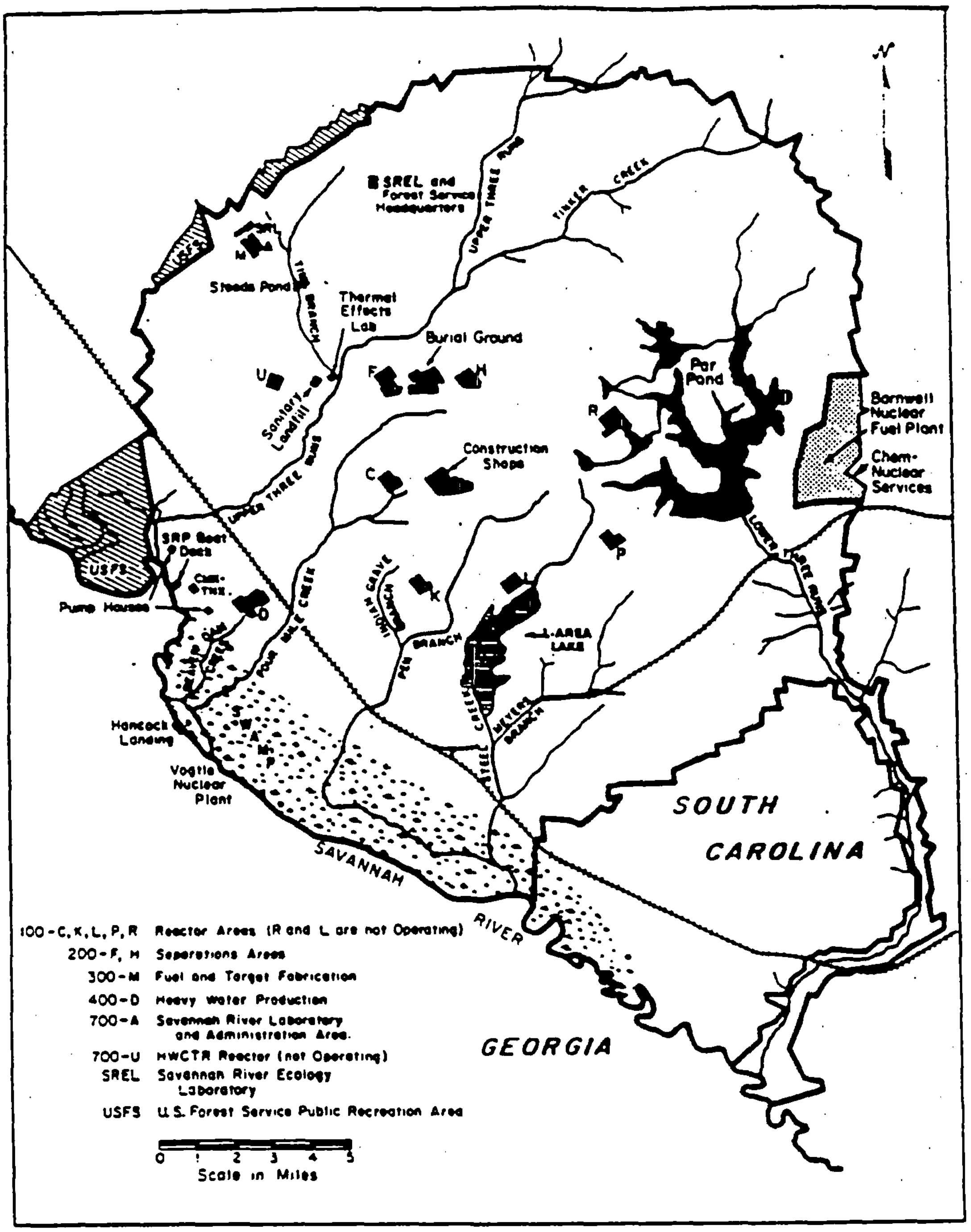

FIGURE 1-2. Map of the SRP Indicating Locations of L Lake and the Pumping Stations on the Savannah River

This report presents information relevant for the consideration of the potential impact of SRP cooling water utilization on the fishery resources of the Savannah River including:

A description of the Savannah River in the vicinity of the SRP, with recent and historic flows in the Savannah River, Plant operating data with design of the SRP cooling water intakes and distribution system, and actual and potential cooling water pumping volumes at the 1G, 3G, and 5G intakes.

Recent and historic data on the fisheries resources of the Savannah River, with data on species composition, relative abundance and changes in abundance among years.

An evaluation of the consequences of the intake of reactor cooling water from the Savannah River by the SRP on fishery resources in the river, particularly as related to incremental impacts associated with the operation of the L Reactor.

A consideration of mitigation alternatives that could reduce the rates of impingement and entrainment and/or improve the and recommendations concerning the implementation of mitigation alternatives.

2. PLANT OPERATING DATA

2.1 Cooling Water Requirements

The Savannah River Plant operates three pumping stations on the Savannah River (Figure 2-1). Two of these, designated 1G and 3G, are identical ten-pump units each located at the terminus of a long intake canal. The third station, 5G, operates six smaller pumps on a small inlet cove of the river. Only the 1G and 3G pumphouses provide water to cool SRP reactors, but this evaluation will consider impingement and entrainment effects at all three facilities.

The rated capacities of the pumping stations are given in Table 2-1. Operation of any of these pumping stations at maximum capacity is rare under current requirements because all reactors seldom operate concurrently.

TABLE 2-1

Savannah River Plant Pumping Station Capacities

Pumping Station	Number of Operable Pumps	Rated Pump Capacity, gal/min	Maximum Sustained Station Flow	
			m^3/sec	$m^3 \times 10^6$ day
1G	10	32,500	20.5	1.8
3G	10	32,500	20.5	1.8
5G	6	12,500	4.7	0.4
Total SRP capacity			41.6	4.0

Secondary cooling water for the SRP production reactors is supplied by the 1G and 3G intakes on the Savannah River (Figure 2-2). The 5G pumphouse supplies cooling water exclusively to the 400-D Area steam generation facility. Four of the five nuclear reactors on the SRP are currently operational. The R Reactor was placed on stand-by status in 1964 and has not operated since that time. Cooling water for the P Reactor is supplied from Par Pond in a recirculating mode; approximately ten percent of its total cooling water (~1 m^3/s) is pumped from the Savannah River to replace evaporative and seepage losses from the Par Pond system. C, K, and L Reactors operate in a once-through mode and their total cooling water requirements (10-11 m^3/s per reactor) are met by pumping Savannah River water.

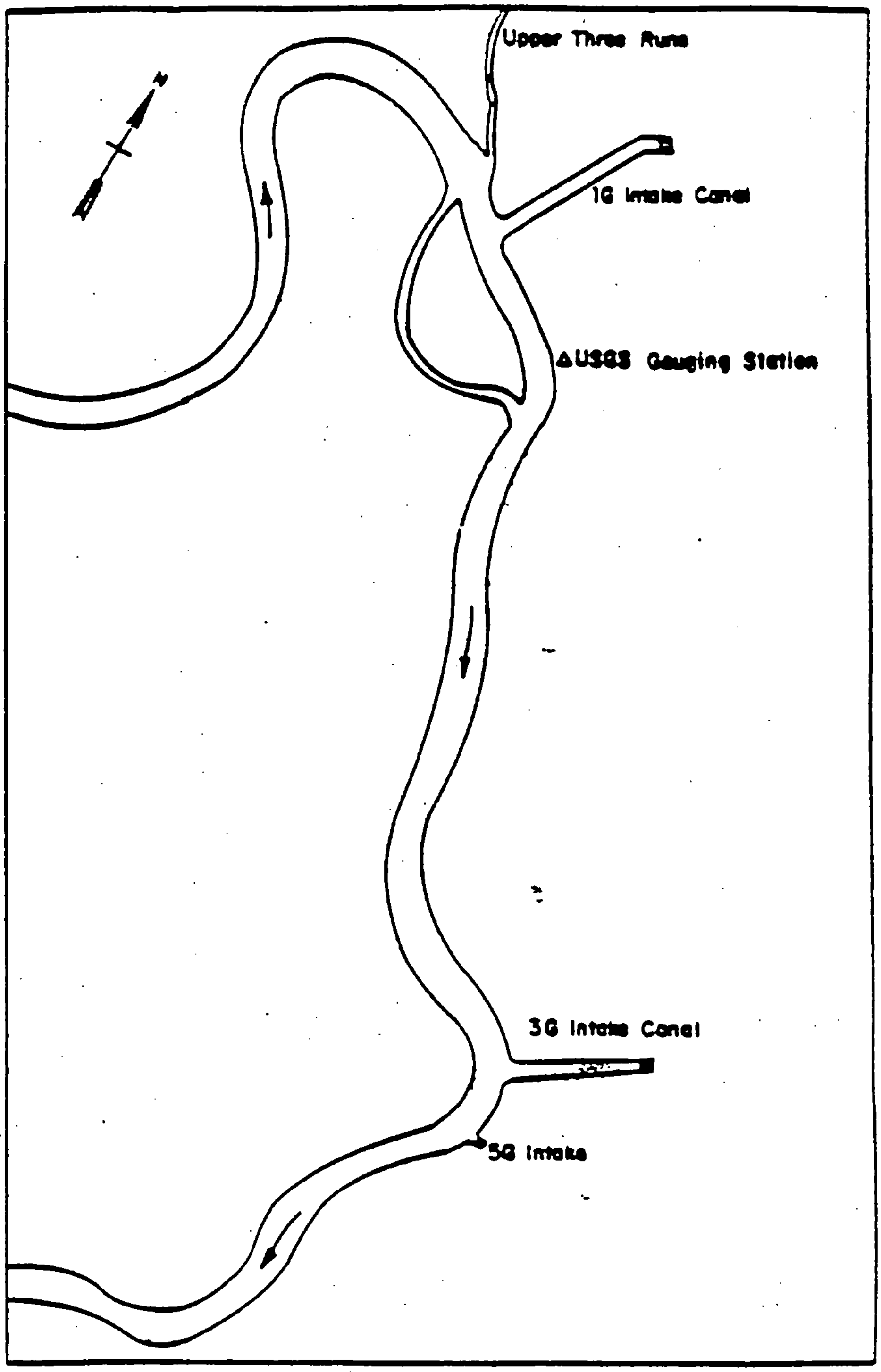

FIGURE 2-1. SRP Pumping Station Locations

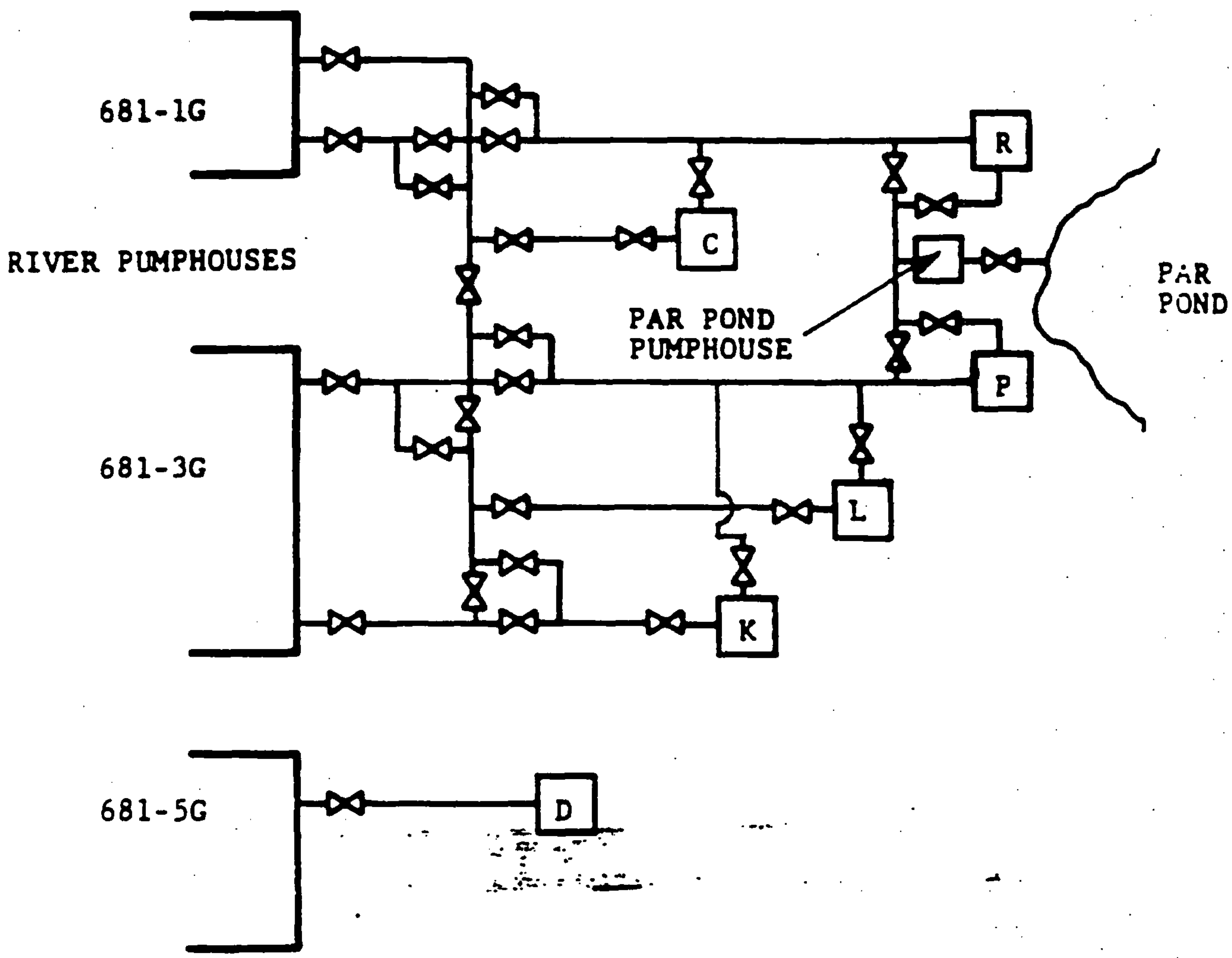

FIGURE 2-2. Schematic of the SRP Cooling Water Supply System

2.2 Cooling Water Intake Structures

The general orientation of the pumping stations and intake canals is shown in Figure 2-1.

The 1G intake canal is 550 m long with a broad, shallow cross-sectional profile (Figures 2-3 and 2-4). The Savannah River fluctuates over 4 m in elevation seasonally and the width of the canal thus varies from 30 to 70 m in response to river level, with a minimum preferred depth of 2 m.

The 3G intake canal is 410 m long with a broad, shallow cross-sectional profile similar to 1G at low river elevations (Figures 2-5 and 2-6). A more extensive berm permits greater lateral expansion at high water and width varies from 27 to more than 90 m, with a minimum depth of 2 m.

The 5G intake is located on a small cove 12 m wide and 20 m from the river to the trash gate on the pumphouse (Figure 2-7). The minimum depth of the cove is 2 m.

Information on canal morphometry should be considered as approximate, however. The canals must be dredged periodically because reduced water velocities in the intake canals (relative to the river) result in substantial sediment accumulation in the canals. Dredging and sedimentation result in periodic changes in canal morphometry.

Water enters the 1G and 3G pumphouses through individual bays for each pump (Figures 2-8 and 2-9). The water is drawn from each bay via a 1.8 x 3.0 m rectangular gate in a lower rear corner of the bay, passes through a vertical trash screen, and enters the conduit to the pump. Water enters the 5G pumphouse through a vertical traveling screen into a bay containing three pumps (Figure 2-10).

2.3 Screening Devices

All of the SRP pumping stations use vertical traveling screens to remove trash from the cooling water. Each pump at the 1G and 3G stations has a separate traveling screen. One screen suffices for three of the smaller pumps at the 5G station. The screen panels are 1.82 m long, 0.59 m high, with 11-mm-square mesh and a 10-cm-wide trash tray. The relative locations of screens and pumps are shown in Figures 2-8, 2-9, and 2-10.

The screens are normally cleaned once per day, a procedure requiring 15 to 30 minutes. High-pressure water jets are used to wash accumulated trash and impinged fish into a trough and thence to a 0.3-m-diameter pipe which empties on the ground in a swale some distance away. There is no opportunity for impinged organisms to return to the river.

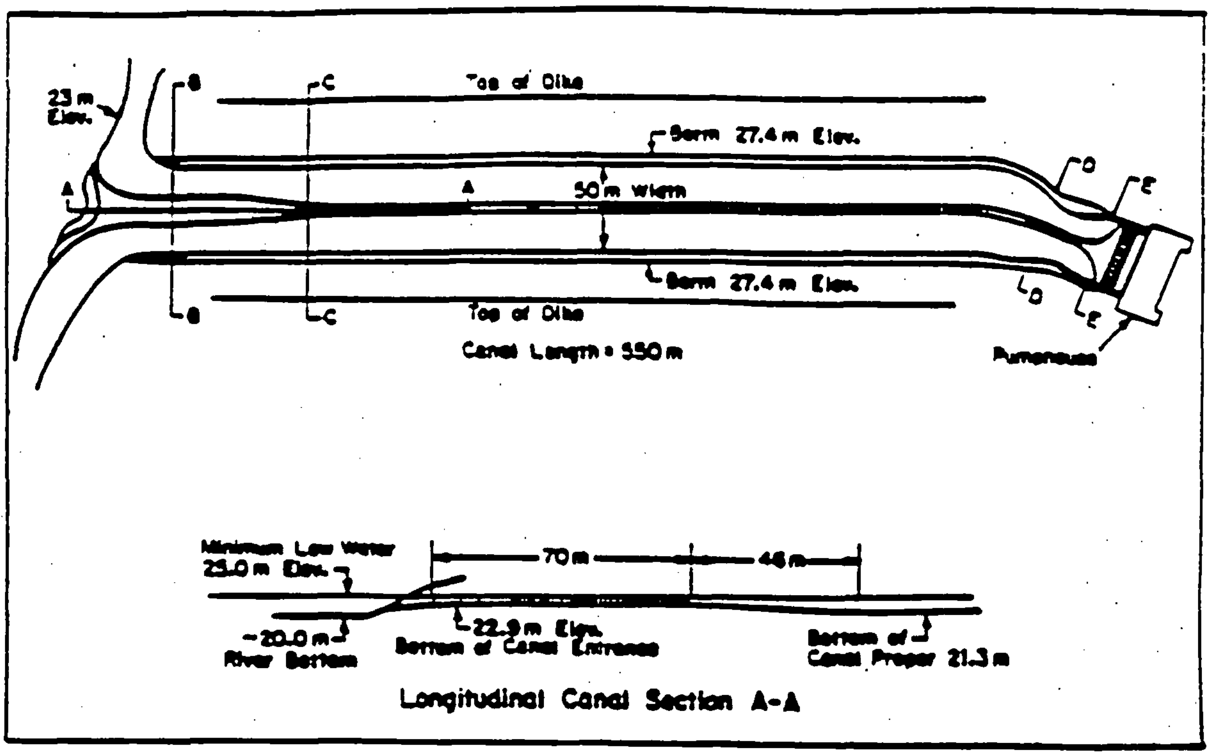

FIGURE 2-3. Plan View and Longitudinal Section of Entrance of 1G Canal

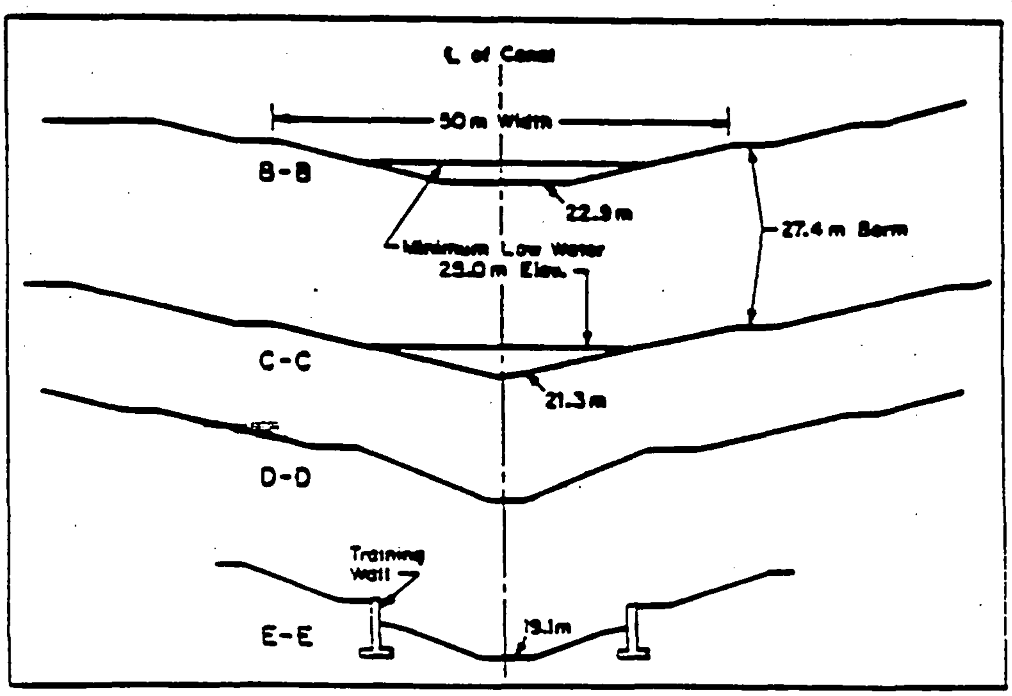

FIGURE 2-4. Cross Sections of 1G Canal at Points Designated in Figure 2-3

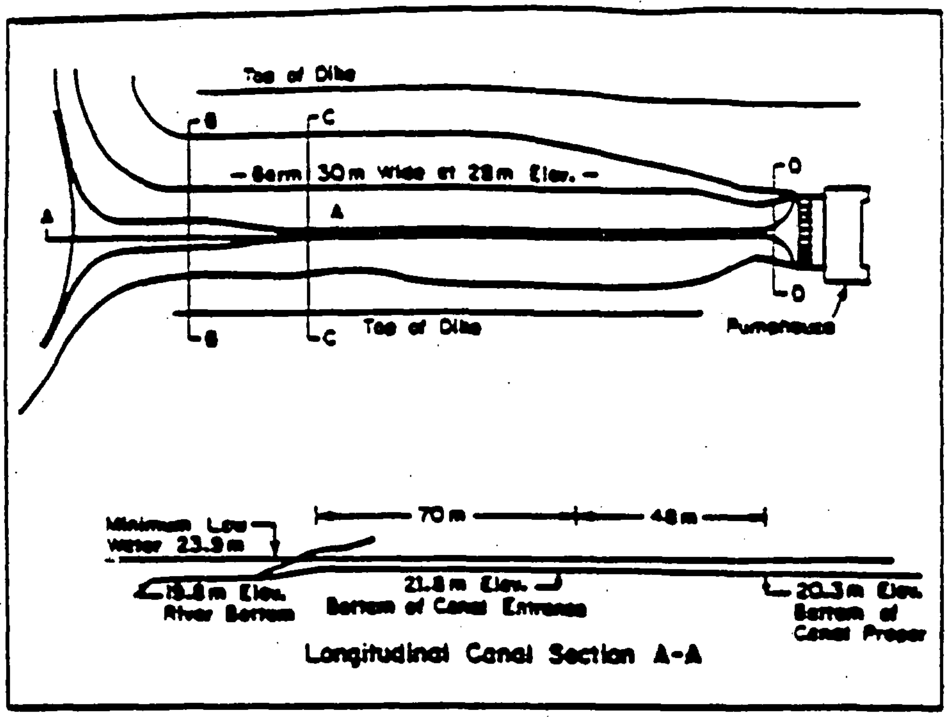

FIGURE 2-5. Plan View and Longitudinal Section of Entrance of 3G Canal

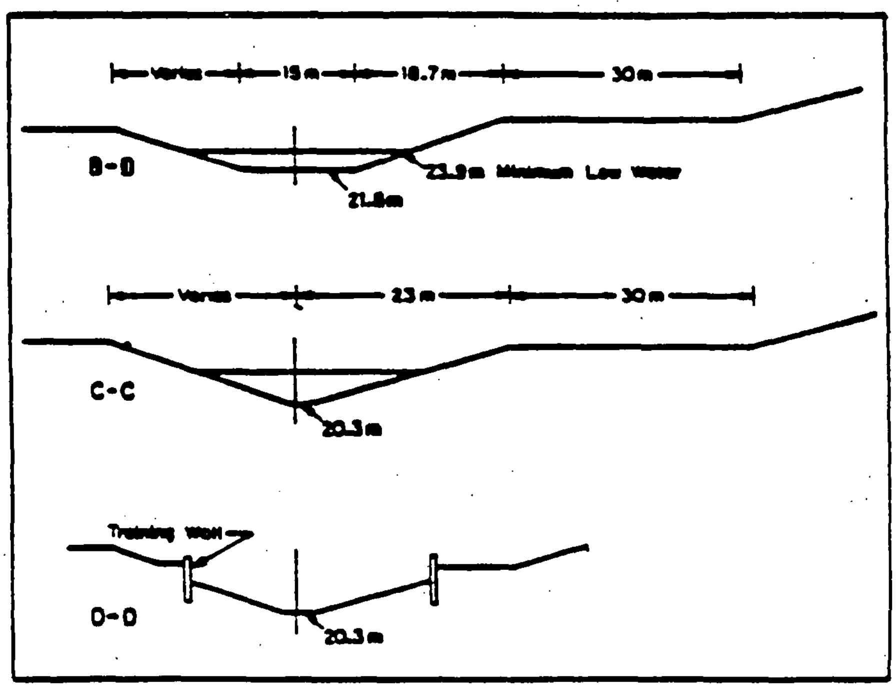

FIGURE 2-6. Cross Sections of 3G Canal at Points Designated in Figure 2-5

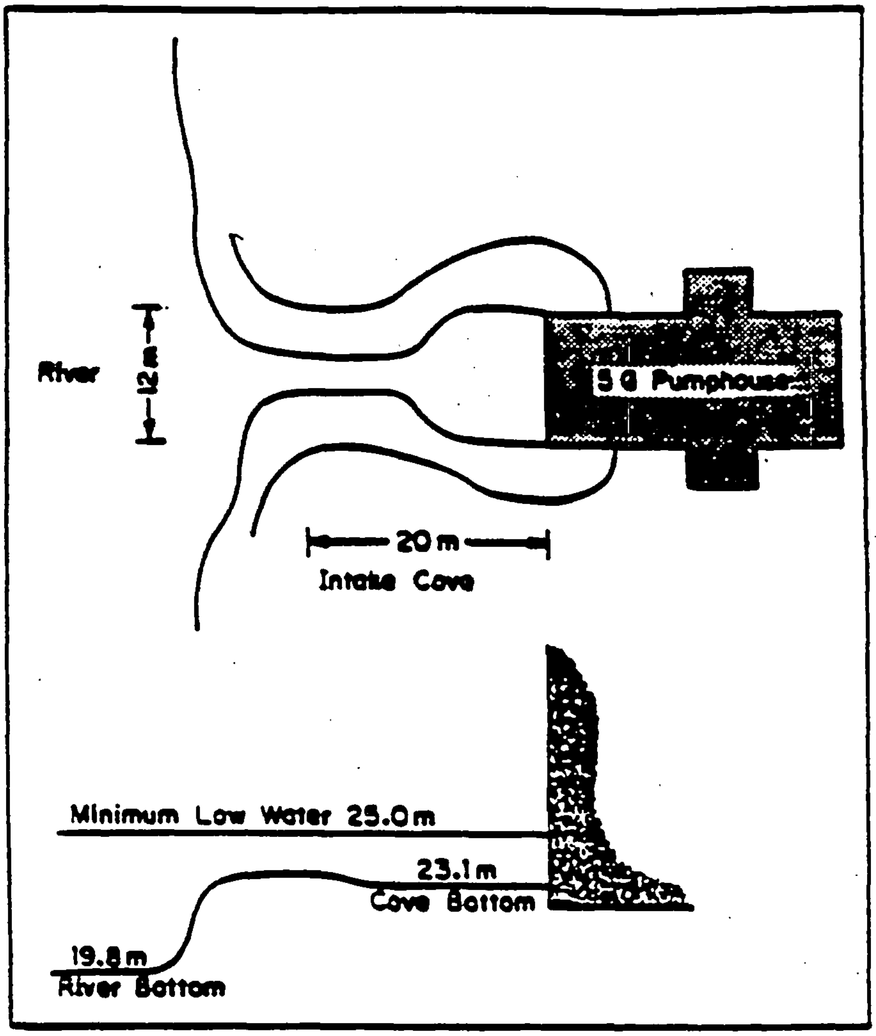

FIGURE 2-7. Plan View and Profile of 5G Intake Cove

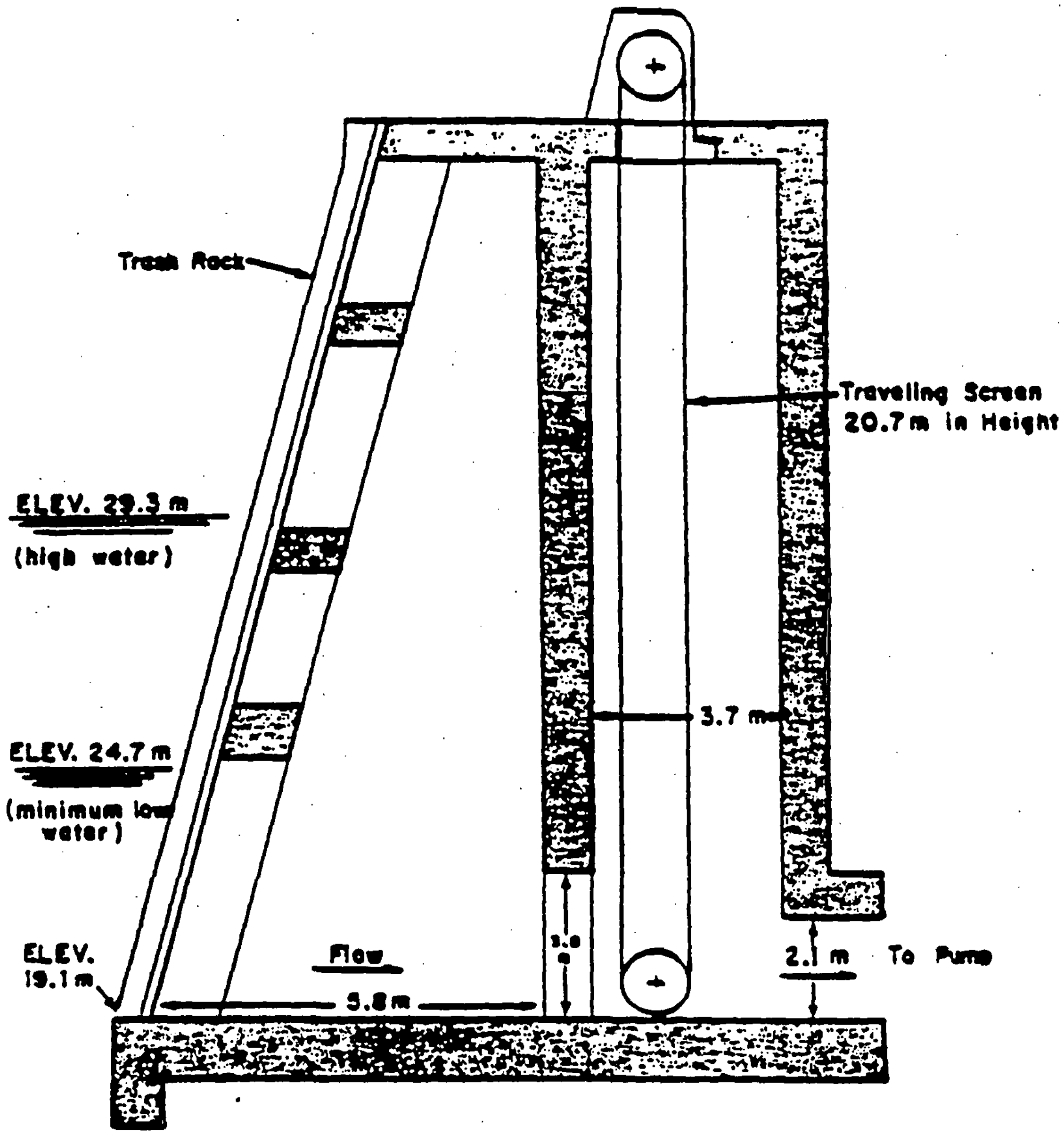

FIGURE 2-8. Schematic of 1G and 3G Pumphouse Intake, Elevation View

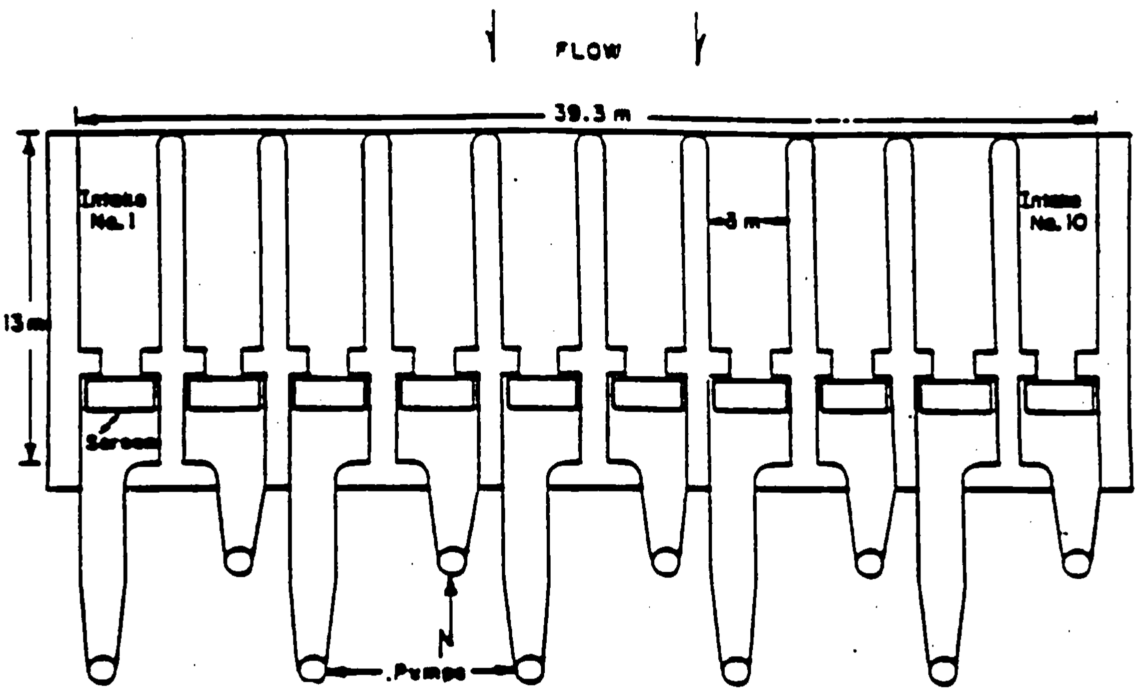

FIGURE 2-9. Schematic of 1G and 3G Pumphouse Intake, Plan View

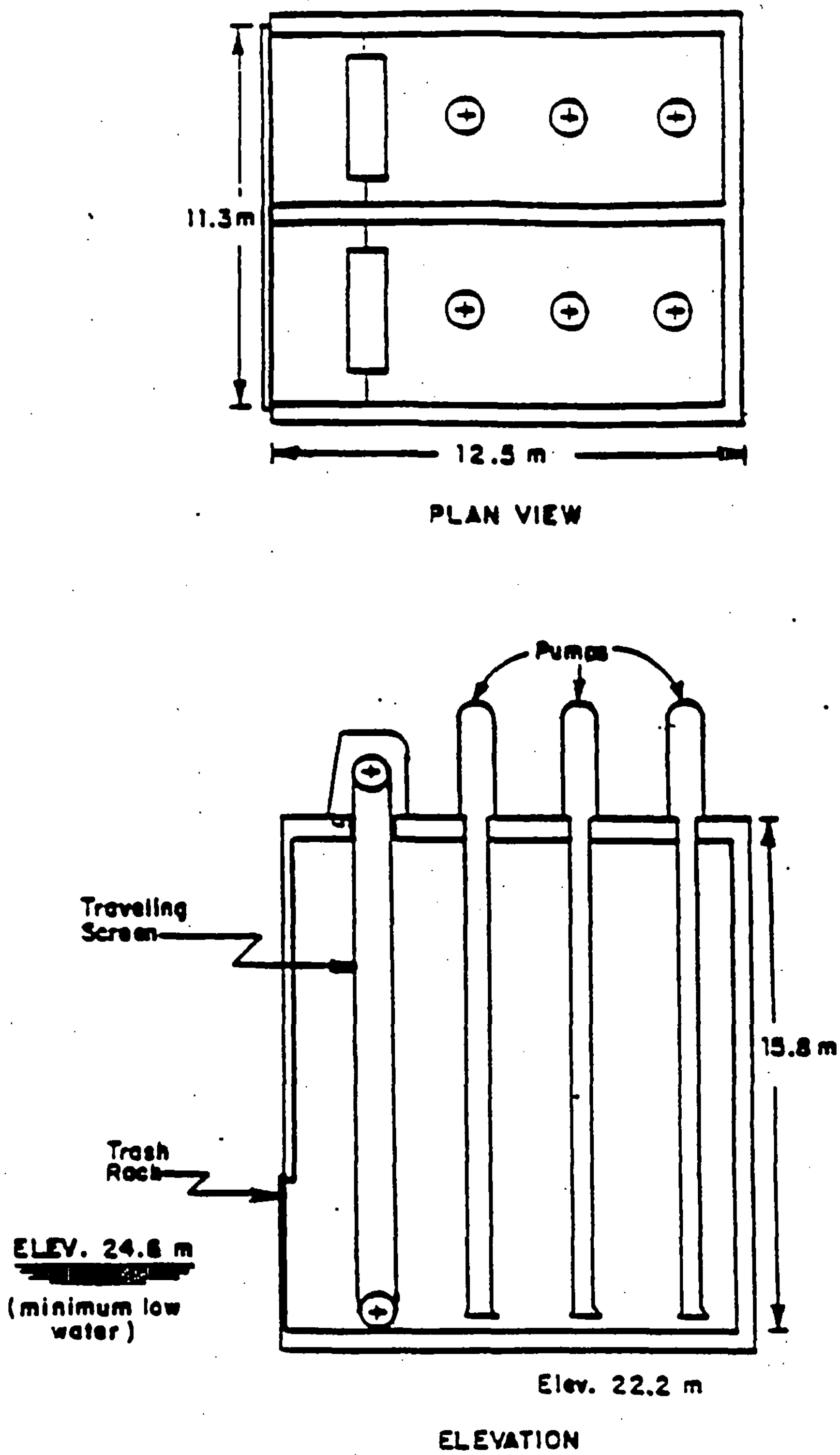

FIGURE 2-10. Schematic of 5G Pumphouse Intake

3. SAVANNAH RIVER FLOW AND SRP WITHDRAWALS

The Savannah River drains approximately 27,400 sq km in North Carolina, South Carolina and Georgia. Through most of its length, it forms the border between Georgia and South Carolina. Flow in the lower reaches of the Savannah River is regulated by three large reservoirs upstream of Augusta, GA (Table 3-1). Downstream of the Clarks Hill Dam are three smaller dams that have minimal influence on river flow characteristics of the Savannah River (Figure 1-1).

TABLE 3-1

Impoundments on the Savannah River

Impoundment	Year Completed	Storage Capacity* (full pool-10^9 m^3)
Hartwell	1961	3.147
Richard B. Russell	1983	1.271
Clarks Hill	1952	3.023

* Source: James et al., 1985.

3.1 Savannah River Flows

The discharge volume of the Savannah River downstream of Augusta, GA has been continuously monitored by the U.S. Geological Survey (USGS) at Augusta (New Savannah Bluff Lock and Dam), Jackson, SC (near SRP intakes), Burton's Ferry (U.S. Highway 301), and Clyo, GA, for several years. Average river discharge at these locations in shown in Table 3-2.

TABLE 3-2

Average Discharge at Locations on the Lower Savannah River*

Location Name	River Mile	Mean Discharge** (m^3/sec)	Years of Record
Augusta	187.5	289.1	77
Jackson	156.8	NA†	15
Burton's Ferry	129.2	301.6	33
Clyo	60.9	342.4	51

* Source: USGS (1986).
** Through Water Year 1984.
† Discharge greater than approx. 625 m^3/sec not reported.

Monthly average Savannah River discharge at Jackson is shown in Table 3-3. Generally, river discharge is lowest and least variable during the summer and fall months. Maximum discharge normally occurs during winter and spring months. Average monthly discharge during Water Years (WY) 1983-85, the period of greatest interest for this evaluation, did not deviate substantially from the longer term average monthly discharge values.

Within individual months and years during October 1982 to September 1985, river discharge exhibited wide variations, however. Discharge during WY's 1983 and 1984 were generally similar, with winter flows being somewhat higher in WY 1983 than in 1984 (Table 3-3). Discharge in May and August of WY 1984 was notably higher than during the previous year. However, the greatest deviations occurred during WY 1985 when average discharge for virtually every month was below that observed in either of the two previous years. The actual differences in winter-spring discharge are likely greater than apparent from Table 3-3 because discharge greater than approximately 625 m^3/sec cannot be estimated reliably at the Jackson station. Consequently, winter-spring discharge during years with high river discharge is underestimated.

3.2 SRP Cooling Water Withdrawal

3.2.1 Volume of Water Withdrawal, 1G and 3G Intakes

The monthly average volume of Savannah River water withdrawn at the 1G and 3G intakes ranged from 14.4 m^3/sec to 25.3 m^3/sec during 1983-85 (Table 3-4). There was no strong seasonal trend in the volume of river water withdrawn, nor was there any obvious trend for intake withdrawal volume to change among the three years.

Intake withdrawal volumes exhibited no exceptional increase during October-December 1985 (Table 3-4), when L Lake was filling and L Reactor began operation. Intake volumes following the L-Reactor restart were slightly higher than during the previous few months, but well within the range observed for the three year period.

3.2.2 Percent of Savannah River Withdrawal, 1G and 3G Intakes

The percentage of Savannah River water that was withdrawn at the 1G and 3G intakes remained relatively constant during 1983 through 1985. SRP reactor cooling water requirements resulted in the withdrawal of 4.1% to 14.4% of the river volume in 1983, 4.1% to 13.1% in 1984, and 6.7% to 14.6% in 1985 (Table 3-4). The percentage of river water withdrawn by the two pumphouses tended to be larger in summer and fall during 1983 and 1984, but no distinct seasonal pattern was apparent for 1985.

TABLE 3-3

Monthly Average* Savannah River Discharge (m^3/sec) at the Jackson Gauge, Water Years 1972-85**

	1972-82 Average	1972-82 Maxium	1972-82 Minimum	1983 Average	1984 Average	1985 Average†	1983-85 Average
October	208.7	247.7	143.6	190.1	173.8	184.1	182.7
November	249.7	410.2	129.2	170.4	164.2	182.7	172.4
December	285.7	395.7	162.4	247.9	258.5	172.3	226.3
January	359.1	461.6	190.8	418.6	366.8	183.6	323.0
February	412.6	533.6	221.9	493.4	403.2	375.4	424.0
March	332.9	529.2	195.4	513.3	469.3	211.8	398.1
April	338.3	561.0	188.1	503.3	412.3	177.9	364.5
May	300.5	394.5	160.9	257.0	396.5	157.7	270.4
June	305.7	560.8	190.0	297.3	250.9	151.5	266.6
July	231.7	391.5	154.8	196.9	234.1	165.3	198.8
August	204.5	241.5	161.1	187.7	343.8	162.1	231.2
September	199.5	232.0	241.5	189.8	216.8	155.4	187.3

* Average discharge underestimated during high flow, maximum discharge reliably measured is approx. 625 m^3/sec, which was used in calculations when discharge exceeded that value.

** Water Year is October-September, e.g., Water Year 1985 is October 1984-September 1985.

† Provisional data.

TABLE 3-4

Monthly Volume and Percent of Savannah River Water Withdrawn at the 1G and 3G Intakes at the SRP, 1983-85

		1983	1984	1985
January	Volume(m^3/sec)	23.7	25.3	23.0
	Percent of River*	5.8	5.6	12.9
February	Volume(m^3/sec)	22.5	15.2	22.8
	Percent of River	4.6	4.1	6.7
March	Volume(m^3/sec)	22.6	18.0	21.6
	Percent of River	4.4	4.4	10.5
April	Volume(m^3/sec)	22.8	23.7	21.8
	Percent of River	4.1	6.3	12.4
May	Volume(m^3/sec)	22.8	23.6	22.8
	Percent of River	9.3	6.4	14.6
June	Volume(m^3/sec)	16.9	22.0	18.7
	Percent of River	6.4	9.2	12.6
July	Volume(m^3/sec)	19.5	22.2	15.7
	Percent of River	10.2	9.8	9.5
August	Volume(m^3/sec)	23.4	23.1	15.3
	Percent of River	12.7	7.8	9.5
September	Volume(m^3/sec)	22.6	23.8	16.4
	Percent of River	12.1	11.3	10.7
October	Volume(m^3/sec)	23.1	18.8	19.9
	Percent of River	13.5	10.5	-**
November	Volume(m^3/sec)	22.9	14.4	21.3
	Percent of River	14.4	7.9	-
December	Volume(m^3/sec)	23.6	22.0	18.2
	Percent of River	9.8	13.1	-

* Percentage over-estimated during months of high river discharge.
** River discharge volume not available.

3.3.3 Volume of Water Withdrawal, 5G Intake

The volume of water withdrawn at the 5G intake cannot be estimated as reliably as for the 1G and 3G intakes. Estimates of intake volumes are derived from the number of pumps operating (usually 3) and the rated pump capacity. Intake volume at the 5G pumphouse is relatively constant at approximately 2.2 m^3/sec.

4.0 ADULT AND JUVENILE FISH - IMPINGEMENT

Streams of the southeastern Atlantic Coastal Plain generally contain a diverse fish fauna. Dahlberg and Scott (1971) reported 106 fish species from the Savannah River drainage basin. Bennett and McFarlane (1983) have summarized available literature and found 71 species of anadromous and fresh water fishes to be reported from the Savannah River in the vicinity of the SRP.

The Savannah River supports both recreational and commercial fisheries. Bream and largemouth bass are the species most sought after by sport fishermen in freshwater sections of the river downstream of the New Savannah Bluff Lock and Dam (Schmitt and Hornsby, 1985). Channel catfish are taken by both sport and commercial fishermen. Anadromous species of importance in the Savannah River include American shad (Alosa sapidissima), hickory shad (Alosa mediocris), Atlantic sturgeon (Acipenser oxyrhynchus), shortnose sturgeon (Acipenser brevirostrum), and striped bass (Morone saxatilis). Both shortnose sturgeon and striped bass are protected from commercial harvest, and the shortnose sturgeon is listed as an endangered species. The catadromous American eel (Anguilla rostrata) is harvested commercially in some sections of the river.

Several factors have been identified as potentially affecting the productivity of Savannah River fish populations. Schmitt and Hornsby (1985) identified two areas of the lower Savannah River where water quality is substantially degraded as a result of wastewater input: below the New Savannah Bluff Lock and Dam from Butler Creek to downstream of Spirit Creek and the Savannah Harbor area. Rulifson et al. (1982) cite dams and impoundments, inadequate fishway facilities, reduction in spawning habitat, reduction in nursery areas, dredge and fill projects, poor food availability, and the location, type and magnitude of effluents into the Savannah River as potential contributors to declining anadromous fish stocks.

This report section will evaluate the composition of the Savannah River fish community, relationships between fish abundance and angler harvest and the magnitude and composition of impingement as a source of mortality for those populations. Using these data, potential impacts of SRP impingement on angler harvest can be evaluated.

4.1 Species Composition and Relative Abundance

The species composition and relative abundance of Savannah River fish in the vicinity of the SRP were examined during 1982-85 (ECS, 1983, Paller et al., 1984, Paller and Osteen, 1985, Paller and Saul, 1986). Collections were made along transects in the Savannah River and in the 1G and 3G intake canals using both electrofishing and hoop-netting techniques. Savannah River collections from four transects near the SRP intakes between RM 152.2 and 157.3 were analyzed for this evaluation. Collections were made quarterly from March 1982 to September 1985.

The dominant species collected in the Savannah River and the SRP intake canals during 1982-85 are presented in Table 4-1. Other species comprising less than one percent of reported catches for either location or sampling gear are presented in Table 4-2.

4.2 Impingement -

Impingement data were summarized from the reports prepared by Environmental & Chemical Sciences, Inc. (ECS, 1983, Paller et al., 1984, Paller and Osteen, 1985, Paller and Saul, 1986). Although impingement samples were collected from March 1982 to September 1985, the samples used in this evaluation are primarily from September 1982 through September 1985 because methodologies were consistent during this interval. Additional unpublished data from October to December 1985 were also included as appropriate.

In a preliminary biological measurement program, collections of impinged fishes on the travelling screens at the 1G, 3G, and 5G intakes were made biweekly between April and August 1982. Between September 1982 and August 1985 collections were made on approximately 100 randomly selected sampling dates yearly. The data collected after August 1982 more accurately represent impingement over an annual cycle because the frequency of collection was higher and more consistent.

Impingement at the 1G and 3G intakes varied substantially among years. The maximum annual impingement collections occurred at the 1G intake in 1983 (1462 fish, Table 4-3). Extrapolating the estimated daily impingement for this period to an entire year provides an estimate of 5336 fish per year impinged at the 1G intake during 1983. The highest annual impingement collections at the 3G (1150 fish) and 5G (1282 fish) intakes also occurred in 1983 with an estimated annual impingement of 4198 and 4679 fish per year, respectively. Although the sampling effort remained constant from 1983 through 1985, both the actual (measured) impingement and the estimated annual impingement declined through time at both the 1G and 3G intakes. The minimum estimated annual impingement occurred in 1985 at the 1G (1670 fish) and 3G (1316 fish) intakes; minimum annual impingement occurred in 1984 at the 5G intake (213 fish). Average estimated annual impingement for the three year period was 3124 fish (8.56 fish/day) at the 1G intake, 2761 fish (7.56 fish/day) at the 3G intake, and 1718 fish (4.70 fish/day) at the 5G intake.

TABLE 4-1

Percent Composition of Abundant* Fish Species Collected in the Savannah River and SRP Intake Canals, 1982-85**

	Savannah River		Intake Canals	
Taxa	Electro-Fishing Percent	Hoop-Netting Percent	Electro-Fishing Percent	Hoop-Netting Percent
Flier	0.30	1.21	0.09	1.55
Redbreast sunfish	26.73	7.09	10.04	12.69
Bluegill	8.44	4.32	24.07	19.95
Spotted sunfish	5.22	0.86	1.83	1.55
Warmouth	1.25	1.04	0.85	0.26
Pumpkinseed	0.17	0.35	2.30	1.04
Redear sunfish	1.63	0.95	4.13	1.81
Dollar sunfish	2.74	0.00	8.38	0.26
Bluespotted sunfish	0.98	0.00	2.34	0.00
Largemouth bass	7.69	0.00	6.04	0.00
Black crappie	2.07	4.75	0.89	27.20
Yellow perch	1.08	0.00	6.47	0.78
Bowfin	3.83	1.04	1.91	1.04
Blueback herring	1.73	0.17	0.51	0.00
American shad	1.25	0.26	0.00	0.00
Gizzard shad	2.44	0.86	2.76	2.59
Threadfin shad	1.96	0.00	0.94	0.00
Spotted sucker	11.21	0.78	5.23	3.37
Lined topminnow	0.00	0.00	1.20	0.00
Pirate perch	1.49	0.00	0.47	0.00
Chain pickerel	3.29	0.00	10.97	0.26
Grass pickerel	1.08	0.00	1.70	0.00
Longnose gar	0.81	2.51	0.26	0.52
White catfish	0.07	8.47	0.00	0.26
Flat bullhead	0.24	31.98	0.04	11.92
Brown bullhead	0.00	1.47	0.00	0.00
Channel catfish	0.41	24.29	0.09	8.55
Brook silverside	1.29	0.00	0.94	0.00
Striped mullet	1.42	0.00	2.00	0.00
American eel	3.32	3.11	0.13	2.33
Other species	5.86	4.49	3.42	2.07

* Species comprising greater than one percent of collections for either sampling method or location.

** Scientific and common names of Savannah River fish species are presented in Appendix A.

TABLE 4-2

Fish Species* Collected in Low Abundance in the Savannah River or SRP Intake Canals, 1982-85**

Mud sunfish	Eastern silvery minnow
Redeye bass	Ohoopee shiner
White crappie	Notropis spp.
Striped bass	Unidentified minnow
White bass	Golden shiner
Hybrid bass	Hogchoker
Tesselated darter	Redfin pickerel
Logperch	Esox spp.
Blackbanded darter	Spotted gar
Lake chubsucker	Florida gar
Chubsucker	Snail bullhead
Highfin carpsucker	Speckled madtom
Silver redhorse	Eastern mudminnow
Quillback carpsucker	Mosquitofish

* Scientific and common names of Savannah River fish species are presented in Appendix A.

** Less than one percent of collections for any sampling method or location identified in Table 4-1.

TABLE 4-3

Total Annual Impingement at 1G, 3G and 5G Intakes

Year		Intake 1G	3G	5G
1982	Total fish collected	73	284	84
	Number of days sampled	43	43	43
	Average impingement/day	1.70	6.60	1.95
	Estimated annual impingement	619.7	2410.7	713.0
1983	Total fish collected	1462	1150	1282
	Number of days sampled	100	100	100
	Average impingement/day	14.62	11.50	12.82
	Estimated annual impingement	5336.3	4197.5	4679.3
1984	Total fish collected	655	766	59
	Number of days sampled	101	101	101
	Average impingement/day	6.48	7.58	0.58
	Estimated annual impingement	2367.0	2768.2	213.2
1985*	Total fish collected	430	339	67
	Number of days sampled	94	94	94
	Average impingement/day	4.57	3.61	0.71
	Estimated annual impingement	1669.7	1316.3	260.2
1983-85** average	Total fish collected	849.0	751.7	469.3
	Number of days sampled	98.3	98.3	98.3
	Average impingement/day	8.56	7.56	4.70
	Estimated annual impingement	3124.3	2760.7	1717.6

* Includes unpublished data from October-December 1985.
** Only 1983-85 data were used for these calculations because sampling was limited in 1982.

Impingement at the SRP intakes is strongly seasonal. Approximately 60 percent of the fish impingement at 1G and 3G during 1983-85 occurred from March through May (63.3% at 1G; 58.4% at 3G: Figure 4-1). Almost 93 percent of impingement at the 5G intake occurred during these months. The largest number of impinged fish were collected in May, when approximately one-third of the annual impingement occurred over the three year period at 1G and 3G, while 65 percent of annual impingement at the 5G intake occurred during April. No month other than March, April, and May exhibited greater than ten percent of the annual average impingement at the 1G intake. Substantial impingement occurred during January (11.1%) and December (12.3%) at the 3G intake, however. Impingement was low during the late summer and fall months at all intakes.

At least 62 species of fish representing 17 families were impinged at the SRP intakes from March 1982 to December 1985 (Tables 4-4 and 4-5). Twenty species were collected in sufficient abundance that the species collection represented over one percent of the total collections between September 1982 and September 1985 (Table 4-4). Blue-spotted sunfish (23.29%) and threadfin shad (11.39%) were clearly the most abundant species in impingement samples at all intakes over this three year period. Among the remaining species only gizzard shad (6.31), redbreast sunfish (5.49%), and warmouth (5.30%) exceeded five percent of the total collections. Thus, overall impingement losses from the Savannah River were concentrated among fish identified as forage species (see categories of Schmitt and Hornsby (1985) that have little commercial or recreational value.

Species specific impingement varied substantially among the three intakes and among years, however. For the period September 1982 through August 1983, blue-spotted sunfish dominated impingement collections at the 1G and 5G intakes while threadfin shad dominated collections at 3G (Figure 4-2a). From September 1983 through August 1984 threadfin shad dominated collections at the 1G intake and blue-spotted sunfish were relatively minor component of the 1G collections (Figure 4-2b). Blue-spotted sunfish dominated collections at the 3G and 5G intakes during this latter period. From September 1984 through September 1985 impingement collections were relatively low at all intakes and gizzard shad were most abundant in 1G intake collections, threadfin shad dominated collections at 3G, and American shad were most abundant at the 5G intake (Figure 4-2c). Centrarchids did not dominate the collections at any of the three intakes during this last period.

The impingement of fish at the SRP intakes appears to be strongly selective relative to the abundance of fish in the intake canals. Quarterly electrofishing of the intake canals revealed that the fish community in the canals is strongly dominated by centrarchids (Figures 4-2a, 4-2b, and 4-2c). Through the sampling

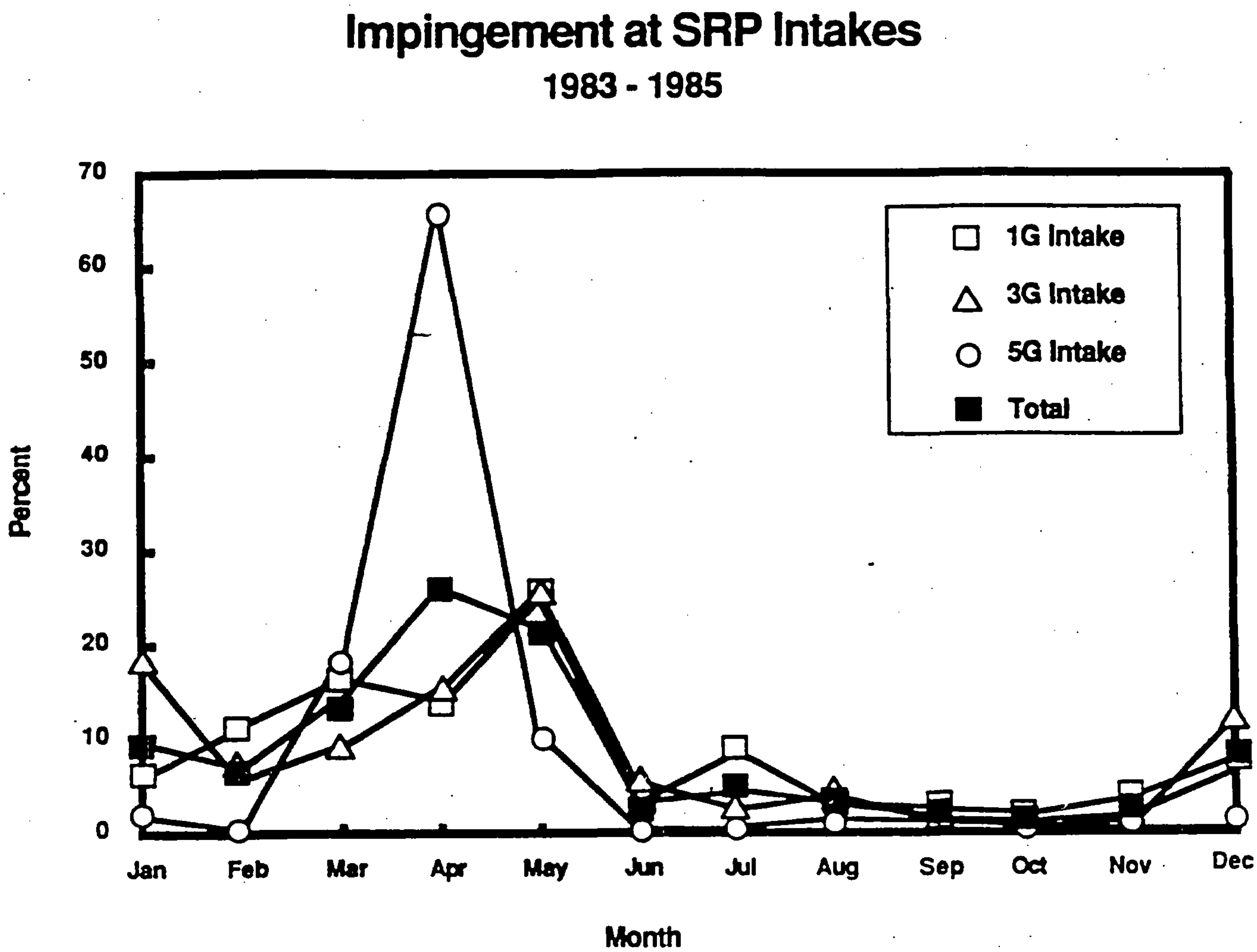

FIGURE 4-1. Monthly Percentage of Total Annual Impingement at 1G, 3G, and 5G Intakes. Average Values for 1983-85.

TABLE 4-4

Count and Percentages of Fish Species Representing Greater Than One Percent of Impingement Collections at the 1G, 3G, and 5G Intakes. September 1982-September 1985

Species	Number	Percent
Bluespotted sunfish	1465	23.29
Threadfin shad	716	11.39
Gizzard shad	397	6.31
Redbreast sunfish	345	5.49
Warmouth	333	5.30
Flier	313	4.98
Hogchoker	252	4.01
Spotted sunfish	218	3.47
Bluegill	179	2.85
Black crappie	171	2.72
Bowfin	162	2.58
Blueback herring	141	2.24
Spottail shiner	122	1.94
Pirate perch	119	1.89
Dollar sunfish	112	1.78
Pumpkinseed	85	1.35
White catfish	82	1.30
Redfin pickerel	77	1.22
Flat bullhead	70	1.11
Mud sunfish	69	1.10
Total of minor species	860	13.68
Total	6288	100.00

TABLE 4-5

Species of Fish Collected at the 1G, 3G, and 5G Intakes Representing Less Than One Percent of Total Collections. September 1982–September 1985

Hickory shad	Speckled madtom
American shad	Margined madtom
Chain pickerel	Redear sunfish
Golden shiner	Blackbanded sunfish
Pugnose minnow	Largemouth bass
Ohoopee shiner	Banded sunfish
Coastal shiner	White crappie
Bannerfin shiner	Green sunfish
Carp	Yellow perch
Whitefin shiner	Blackbanded darter
Eastern silvery minnow	Tesselated darter
Spotted sucker	Swamp darter
Creek chubsucker	Mudminnow
Lake chubsucker	Eastern mudminnow
Chubsucker	Atlantic sturgeon
Silver redhorse	American eel
Channel catfish	Unidentified killifish
Snail bullhead	Mosquitofish
Brown bullhead	Brook silverside
Yellow bullhead	Striped bass
Tadpole madtom	Atlantic needlefish

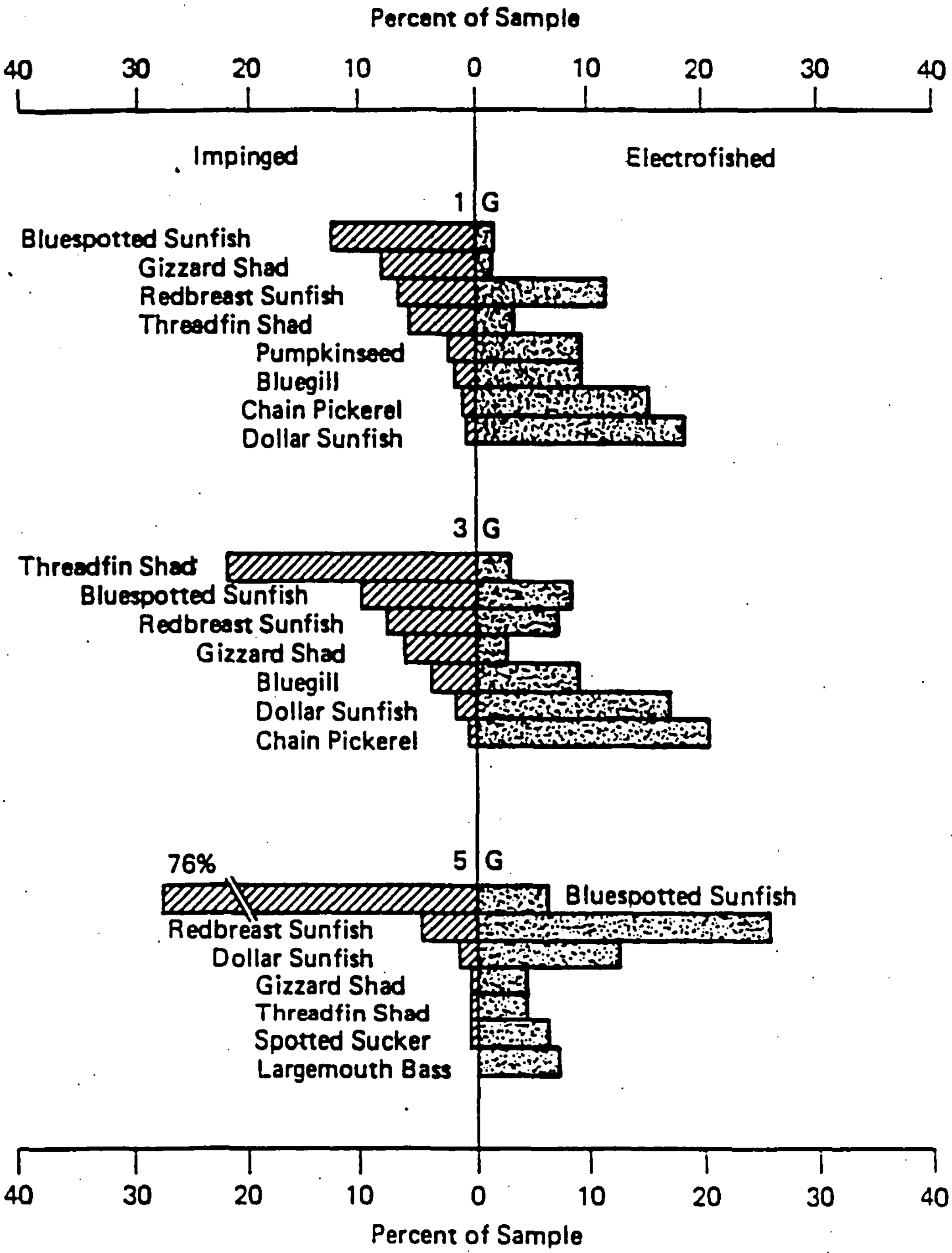

FIGURE 4-2a. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouse by Electrofishing. September 1982-August 1983 (from Paller et al., 1984)

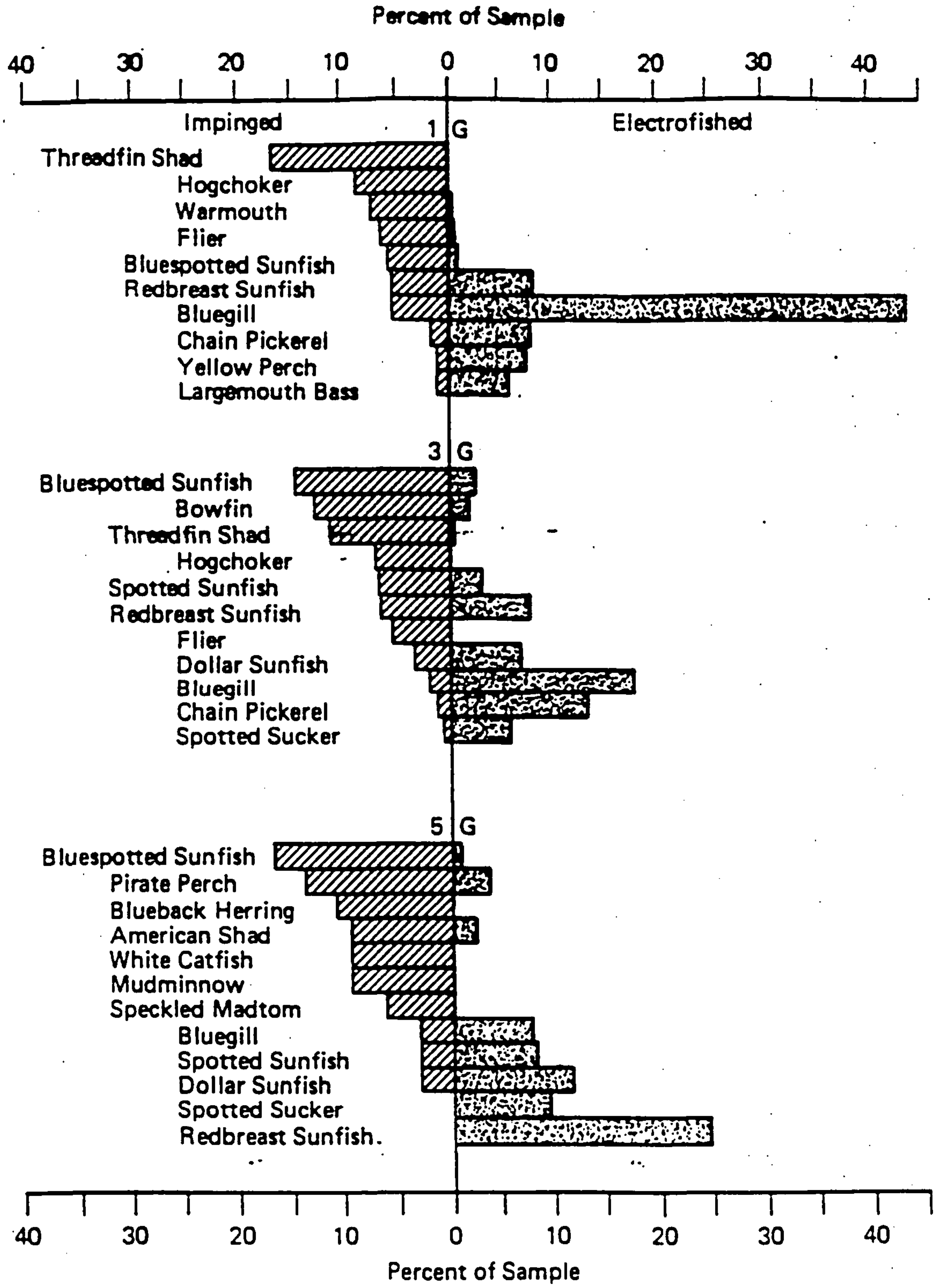

FIGURE 4-2b. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouses by Electrofishing. September 1983-August 1984 (from Paller and Osteen, 1985)

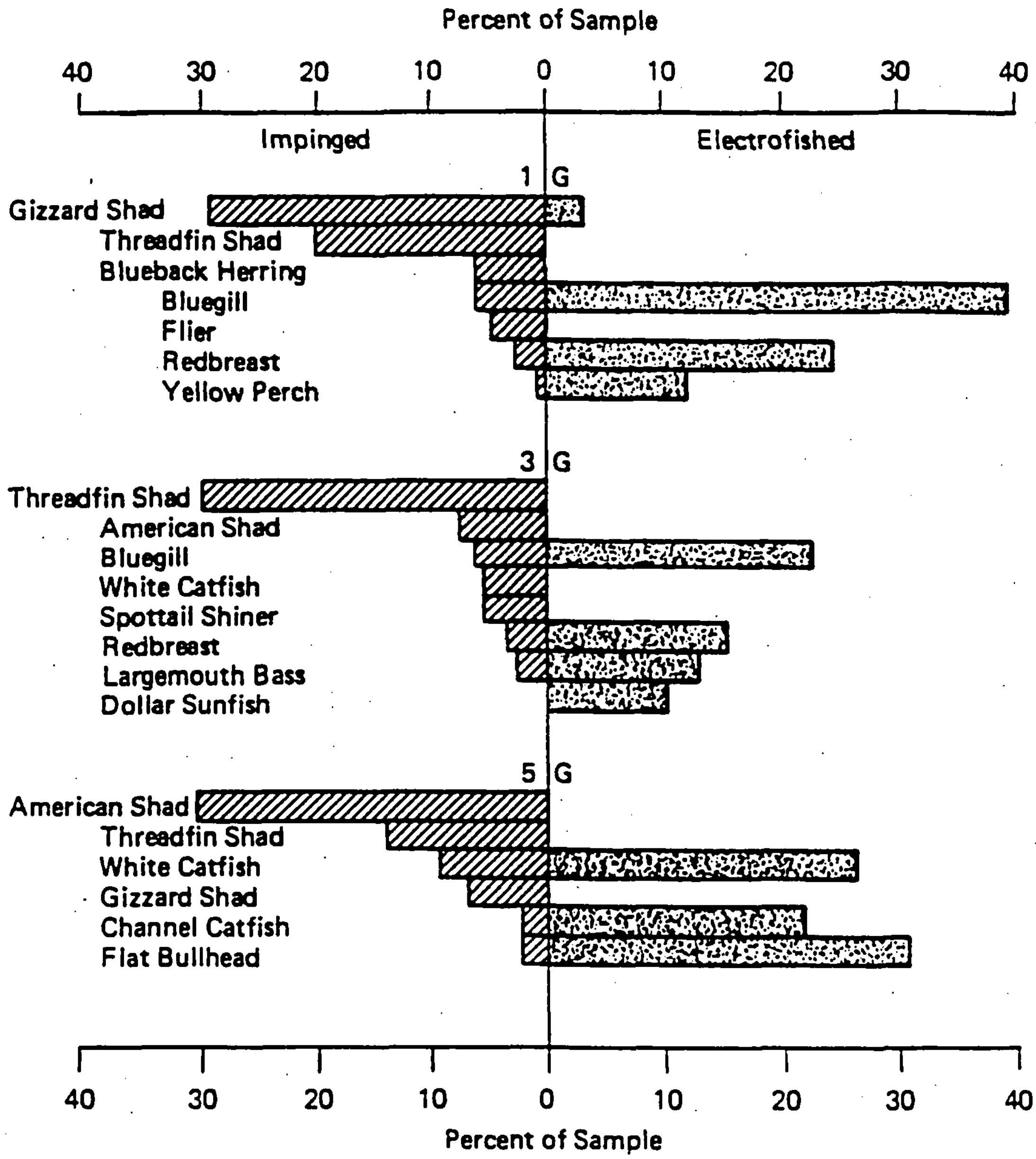

FIGURE 4-2c. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected in the Vicinity of the Pumphouses by Electrofishing. September 1984-September 1985. (from Paller and Saul, 1986)

period from September 1982 through September 1985, the electrofishing collections were dominated by a mixture of bluegill, redbreast and dollar sunfish at all intake areas. Chain pickerel were collected routinely, while yellow perch, suckers, largemouth bass and spotted sunfish appeared less routinely in collections, but occasionally in substantial numbers. The most notable exception to this pattern is the dominance of flat bullhead, white catfish and channel catfish in collections near the 5G intake during September 1984 through September 1985. Generally, those species that were dominant in electrofishing collections were not species that were most abundant in impingement collections.

4.3 Sport Fishing in the Savannah River

Schmitt and Hornsby (1985) evaluated the fishery resources in the Savannah River downstream of the New Savannah Bluff Lock and Dam during 1980-82. Average annual sport fishing harvest from the freshwater portions of the river (approximately RM 21-187) was estimated to range from 171,561 fish/yr in 1982 to 550,282 fish/yr in 1980 (3 year average = 305,778 fish/yr). Dominant species in the sport harvest were redbreast sunfish (27.2%) and bluegill (24.1%, Table 4-6). The composite category of "bream" accounted for 64.0 percent of the total angler catch. The composite category of "catfish" also represented a substantial portion of the sport harvest (14.6%), with bullhead spp. (8.2%) the major reported taxon within this category. Crappie (8.0%) represented a substantial component of the sport harvest and was comparable to warmouth (7.3%). No other species (or species group) represented greater than five percent of the sport harvest. Notably, anadromous species (striped bass, 0.2%; American shad, 1.7%) did not contribute substantially to the angler's harvest. However, the authors noted that American shad harvest may be underestimated because of the development of a fishery for this species near the New Savannah Bluff Lock and Dam, while the assessment for this species emphasized downstream areas of the river.

The proportions of fish species caught by anglers were frequently in sharp contrast to angler preferences. Approximately 35 percent of angler fishing effort was directed toward bream (composite reporting category plus individual species), while 64 percent of the harvest was from this category (Table 4-6). The relationship between effort and harvest was even more disparate for largemouth bass; 25.7 percent of fishing effort was targeted toward this species, while it constituted only 3.2 percent of the catch. Overall, catfish were not highly desired (approx. 7% of effort), but were caught in slightly greater proportion (14.6%). American shad (7.8% of effort) and striped bass (4.7% of effort) were caught in substantially lower abundances than desired by sport fishermen, the disparity being comparable to that exhibited for largemouth bass.

TABLE 4-6

Fish Species Preferred and Caught by Savannah River Sport Fisherman*

Taxon	Percent Angler Effort	Percent Angler Catch
Bream	24.9	64.0**
Redbreast sunfish	8.7	27.2
Bluegill	1.0	24.1
Warmouth	0.1	7.3
Redear sunfish	0.4	4.4
Largemouth bass	25.7	3.2
Crappie	10.7	8.0
Yellow Perch	1.3	3.0
Catfish	7.0	14.6**
Bullhead spp.	0.4	8.2
Channel catfish	<0.1	4.2
White catfish	0.5	2.1
Chain pickerel	0.5	0.9
American shad	7.8	1.7
Striped bass	4.7	0.2
Hybrid bass	4.4	0.3
Other	1.9	4.1
Total	100.0	100.0

* Adapted from Schmitt and Hornsby (1985).
** Sum of taxa within category.

4.4 Relationship of Sport Fishery to Abundance and SRP Impingement

The findings on the relative abundance of fish in the Savannah River near the SRP intakes (Section 4.1) and in the impingement collections (Section 4.2) were analyzed relative to the angler catches in freshwater sections of the Savannah River (Section 4.3). Information on fish relative abundance collected concurrently with the creel survey (Schmitt and Hornsby, 1985) were also evaluated because these data are directly comparable in both space (length of river) and time (years).

Fish species caught by anglers in the Savannah River represent an extremely limited set of those species that are available. Electrofishing collections by Schmitt and Hornsby (1985) throughout the freshwater sections of the lower Savannah River indicated that the taxa caught by anglers represented only 33.1 percent of the relative abundance (numerical) collected in their electrofishing effort. Similarly, those species that constitute 95.8 percent of the angler catch constitute only 27.8 percent of total impingement at the SRP intakes. The species caught by anglers represent 59.8 percent of the numbers of fish caught by electrofishing and 86.9 percent of hoop-net sampling from the Savannah River near the SRP intakes. However, Paller and Osteen (1985) noted that the electrofishing collections near the SRP do not accurately reflect the abundance of minnows and other small species and the same caution undoubtedly applies to hoop-net collections because the hoop-nets used for the SRP collections had a maximum mesh size of 37 mm.

"Bream" represent the largest component of the anglers' catch in the Savannah River. Although centrarchids were a substantial component of SRP impingement collections, the species impinged were not predominantly those caught by anglers (Figure 4-3). Although redbreast sunfish are abundant in the creel (27.1%) and in the river near the intakes (26.7%), they represented only 5.5 percent of impingement. Bluegill also show much higher relative abundance in the anglers' catch than in the river (all methods) and impingement. Among the "bream" caught by anglers, only the spotted sunfish represents a higher relative abundance in impingement (3.5%) than in the creel (1.1%), but the species relative abundance in impingement is less than the relative abundance in electrofishing collections (5.2%).

Crappie, yellow perch, and largemouth bass all exhibit higher relative abundances in the creek (8.0%, 3.0%, and 3.2%, respectively) than in impingement (2.9%, 0.8%, and 0.5%, respectively, Figure 4-3). All three species exhibit higher relative abundance in the river (by at least one collection method) than in impingement, and largemouth bass exhibits higher relative abundance in the

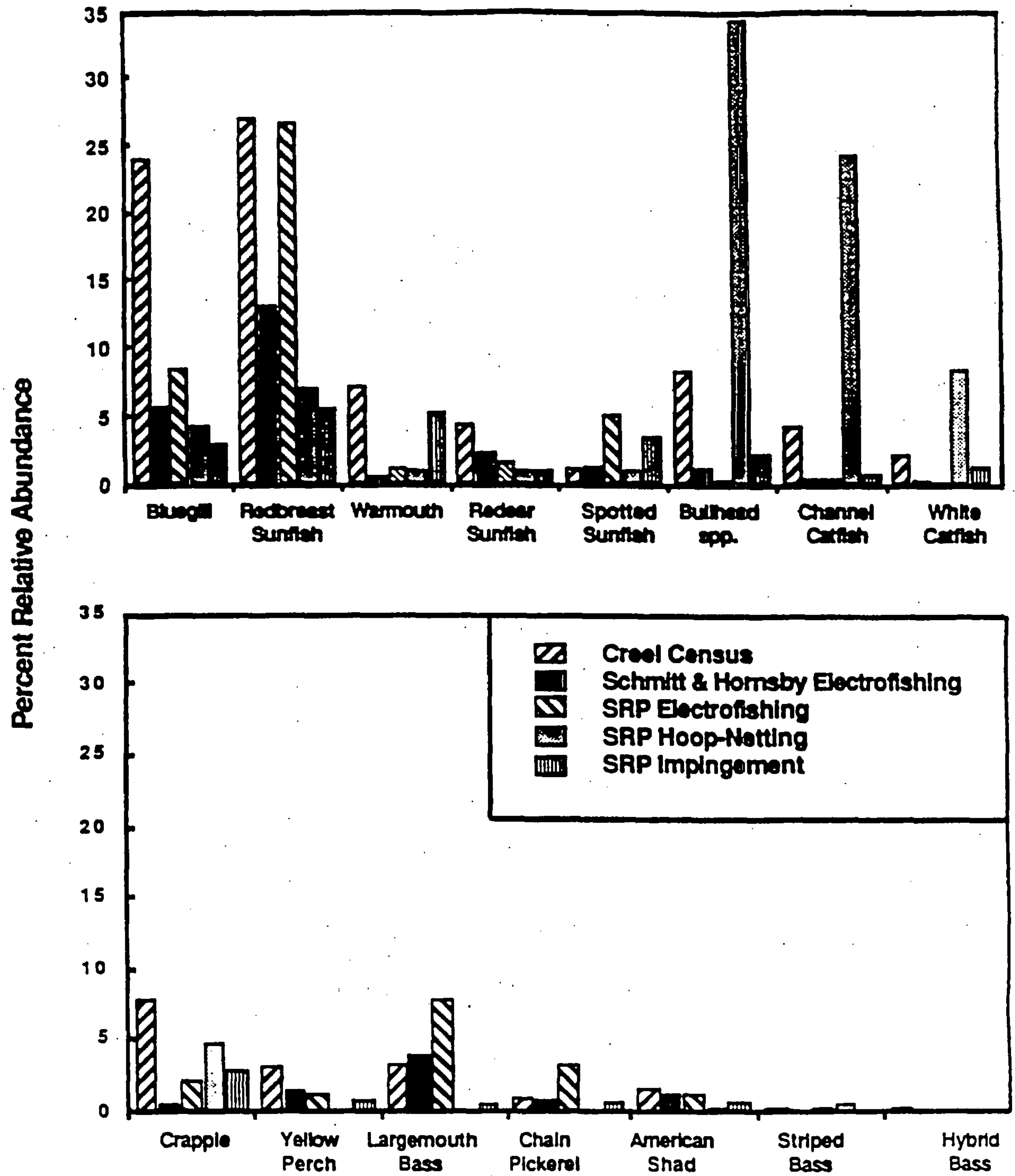

FIGURE 4-3. Relative Abundance of Fish Taxa in Creel, Electrofishing and Hoop-Net Collections, and SRP Impingement

river than in the creel. Chain pickerel is a minor component of the creel (0.9%) and has comparable abundance in impingement (0.7%).

Impingement relative abundances for all taxa of catfish [bullhead spp. (2.1%), channel catfish (0.8%) and white catfish (1.3%)] were lower than relative abundances for those taxa in the creel (8.2%, 4.2%, and 2.1%, respectively Figure 4-3). However, the relative abundances of these taxa in hoop-net collections from the river were substantially higher than for either impingement or angler catches. The disparity between relative abundances of catfish taxa in electrofishing and hoop-net collections suggests that catfish are a substantial component of the Savannah River ichthyofauna, and that electrofishing provides poor estimates of the abundance of these taxa.

American shad, striped bass and hybrid bass were minor components in all of the collection methods (angling, electrofishing, hoop-netting, impingement, Figure 4-3). The abundance of the migratory American shad and striped bass in the Savannah River near the SRP was undoubtedly underestimated during the quarterly sampling program. Nevertheless, the low frequency of these species in impingement collections (approximately 100 collections throughout the year) is highly encouraging because it indicates that adults and juveniles of these species are minimally influenced by impingement mortality associated with SRP operations.

4.5 Relationship of SRP Impingement to Other Facilities

Freeman and Sharma (1977) summarized impingement data from power plants in the United States. Information for ten of these facilities in the southeastern United States is summarized in Table 4-7. Although the pumping capacity at the SRP intakes is near the middle range for the facilities considered, the annual impingement rate is the lowest (8 thousand fish per year). Only the Widows Creek (15 thousand) and Bull Run (11 thousand) Steam Plants had comparably low annual impingement rates. Three of the facilities considered (Arkansas Nuclear One, Browns Ferry and Wateree) had reported impingement rates in excess of three million fish per year.

The species composition of impingement at the SRP intakes was somewhat unique among the facilities considered, however. Whereas impingement at most of these facilities was strongly dominated by clupeids (primarily threadfin and/or gizzard shad), bluespotted sunfish were most abundant in collections at the SRP (Table 4-4). Over the three year period considered, threadfin and gizzard shad comprised less than 18 percent of total impingement collections at the three SRP intakes (Table 4-4).

TABLE 4-7

Summary of Fish Impingement Rates at Electrical Generating Facilities in the Southeastern United States[a] and the Savannah River Plant

Facility	Location (water source)	Intake Capacity (m^3/sec)	Estimated Annual Impingement (thousands)	Abundant Species
Arkansas Nuclear One	Lake Dardanelle	49.2	15,949	Threadfin shad Gizzard shad Freshwater drum
Allen Station	Catawba River	37.8	450	Threadfin shad Gizzard shad Bluegill
Browns Ferry Nuclear Plant	Wheeler Reservior	83.3	3,111	Shad and herring Freshwater drum Catfish
Colbert Steam Plant	Pickwick Reservior	NA	101	Threadfin shad Skipjack herring Gizzard shad
Watts Bar Steam Plant	Watts Bar Reservoir	17.7	50	Threadfin shad Freshwater drum Bluegill
Widows Creek Steam Plant	Guntersville Reservoir	68.9	15	Threadfin shad Freshwater drum Gizzard shad
Bull Run Steam Plant	Melton Hill Reservoir	26.3	11	Threadfin shad Gizzard shad Logperch
Kingston Steam Plant	Watts Bar Reservoir	61.0	221	Threadfin shad Freshwater drum Bluegill
Wateree Station	Wateree River	21.5	3,059	Threadfin shad Channel catfish Yellow perch
John Sevier Steam Plant	Holston River	28.7	76	Gizzard shad Threadfin shad Channel catfish
Savannah River Plant	Savannah River	41.6	8	Bluespotted sunfish Threadfin shad Gizzard shad

[a] Adapted from Freeman and Sharma (1977).

5. FISH EGGS AND LARVAE - ENTRAINMENT

The entrainment of fish eggs and larvae (ichthyoplankton) at intake structures is affected by a variety of factors including overall ichthyoplankton abundance in waters adjacent to the intake and percentage of river water withdrawn. The total magnitude and species composition of entrainment can also be influenced by aspects of intake design, the spatial distribution of ichthyoplankton relative to the intakes, and fish species behavioral and life history characteristics. The ultimate result of entrainment-related mortality on fish population persistence depends on the magnitude of species-specific mortality rates and the population level responses of the species to this added source of mortality.

5.1 Ichthyoplankton Abundance in the Savannah River

Recent studies on ichthyoplankton of the mid- and lower reaches of the Savannah River began in 1982 and ended in 1985 (ECS, 1983, Paller et al., 1984, Paller et al., 1985, Paller et al., 1986). The 1982 studies were restricted in scope, and included seven river transects between RM 141.5 and 157.3 and the two SRP intake canals (1G and 3G: Figure 5-1, Table 5-1). The 1983 and 1984 studies included 26 river transects between RM 29.3 and 187.1, and the two intake canals. The 1985 study was slightly truncated, and included 21 river transects between RM 89.3 and 187.1 and the two intake canals. Sampling in 1982 was conducted on alternate weeks from March through August, while in subsequent years, sampling was conducted weekly from February through July. This consideration of entrainment at the SRP will emphasize ichthyoplankton collections in the vicinity of the SRP intake canals during 1983-1985.

The ichthyoplankton assemblage in the Savannah River consists of a variety of species which differ in recreational, economic and ecological importance. Among the most abundant ichthyoplankton taxa in the Savannah River are gizzard and/or threadfin shad, American shad, blueback herring, sunfishes, crappie, minnows and suckers (Table 5-2). Generally, the cluepids (including anadromous American shad and blueback herring, and resident gizzard and threadfin shad) dominated collections in the Savannah River during 1983-1985. The blueback herring, while somewhat less abundant, is another anadromous species used for commercial purposes in some coastal areas. Some species, such as the largemouth bass and other centrarchids, were comparatively abundant as adults in the Savannah River, but scarce in the ichthyoplankton collections because their eggs and larvae reside in sheltered areas where they are unlikely to become entrained in currents and carried into open water. Such species are less susceptible to SRP entrainment impacts than those that produce drifting eggs and larvae.

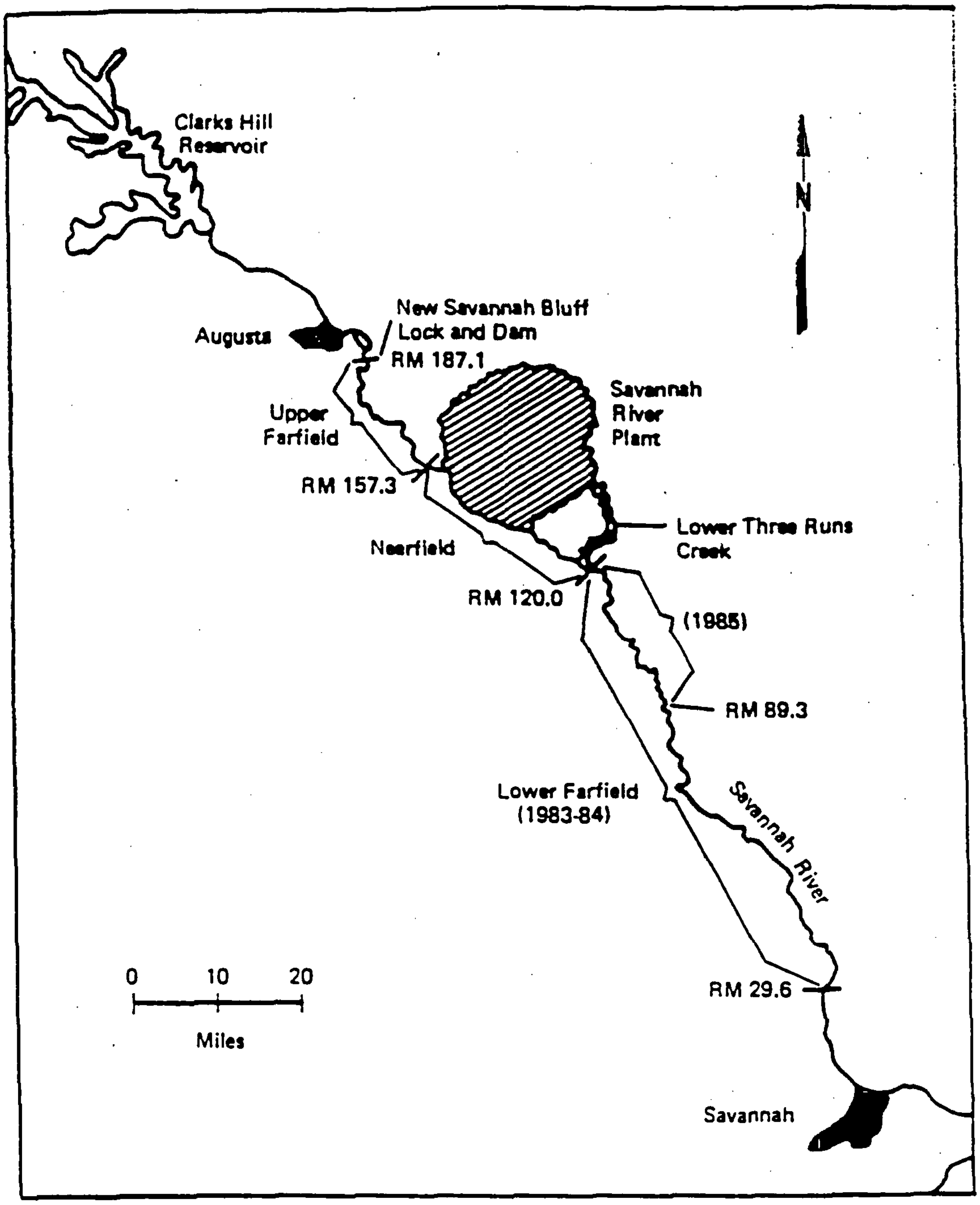

FIGURE 5-1. Map of the Savannah River Showing the Location of the Savannah River Plant, Lower Farfield, Nearfield, and Upper Farfield Sections of the River

TABLE 5-1

Summary of Sampling Locations and Sampling Times for the Savannah River Ichthyoplankton Program

River Mile	Year 1982	1983	1984	1985
Upper Farfield				
187.1		X	X	X
176.0		X	X	X
166.6		X	X	X
Nearfield				
157.3	X	X	X	X
157.1*	X	X	X	
157.0	X	X	X	X
155.4	X	X	X	X
155.3*	X	X	X	
155.2	X	X	X	X
152.2		X	X	X
152.0		X	X	X
150.8	X	X	X	X
150.4	X	X	X	X
145.7				X
141.7		X	X	X
141.5	X	X	X	X
137.7		X	X	X
129.1		X	X	X
128.9		X	X	X
Lower Farfield				
120.0		X	X	X
110.0		X	X	X
97.5		X	X	X
89.3		X	X	X
79.9		X	X	
69.9		X	X	
60.0		X	X	
50.2		X	X	
40.2		X	X	
29.6		X	X	
Duration	March -August	February -July	February -July	February -July
Frequency	Biweekly	Weekly	Weekly	Weekly

* SRP Intake Canals.

TABLE 5-2

Percent Composition of Fish Eggs and Larvae Collected in the Savannah River, 1983-85

Taxa	1983*	1984*,**	1985**,†
American shad	1.4	14.0	50.7
Blueback herring	12.1	4.5	2.2
Gizzard and/or threadfin shad	19.9	10.8	9.9
Unid. clupeid	6.7	7.6	3.3
Striped bass	0.2	3.0	5.4
Spotted sucker	5.0	4.3	8.1
Unid. sucker	0.8	0.7	0.4
Pirate perch	8.0	0.3	0.1
Yellow perch	3.5	1.1	0.2
Darter	2.6	2.7	0.7
Sunfish (Lepomis)	2.1	6.9	0.7
Unid. sunfish	1.1	4.0	0.3
Crappie	16.6	13.5	0.3
Mudminnow	<0.1	<0.1	0.0
Swampfish	<0.1	<0.1	<0.1
Minnow (Cyprinid)	14.0	13.5	3.7
Carp	3.6	3.2	4.6
Mosquitofish	<0.1	<0.1	<0.1
Topminnow		<0.1	<0.1
Needlefish	<0.1	0.1	<0.1
Silverside	0.2	0.2	0.1
Catfish and/or bullhead	0.1	<0.1	0.1
Pickerel	0.3	0.1	<0.1
Sturgeon	<0.1	<0.1	<0.1
Gar	<0.1	<0.1	0.0
Unidentified	1.7	9.8	9.2
Total numbers	36,941	18,267	22,698

* Based on 26 transects between RM 29.6 and 187.1.
** Does not include intake canals.
† Based on 21 transects between RM 89.3 and 187.1.

All clupeid taxa exhibited considerable variations in abundance among years. American shad eggs and larvae increased in relative abundance from 1.4 percent to 50.7 percent of collections between 1983 and 1985. Concurrently, blueback herring decreased from 12.1 percent (1983) to 2.2 percent (1985) of collections. Gizzard and/or threadfin shad relative abundance paralleled the decline in blueback herring.

Some of the decline in the relative abundance of blueback herring from 1984 to 1985 could be attributable to the reduction of sampling effort in the lower reaches of the Savannah River, because this section of the river appears to be a major spawning area for the species (Table 5-3a). However, the decrease in density from 1983 through 1985 was also observed in the mid-reaches of the river (Tables 5-3b and 5-3c), and is more likely related to variations in spawning stock abundance or the availability of spawning sites. Low river water levels, especially during the 1985 spawning season, likely reduced access to swamp and backwater spawning sites utilized by blueback herring (Paller et al., 1986). The sharp increase in American shad ichthyoplankton abundance from 1983 to 1985 may also be related to variations in spawning stock abundance.

Striped bass spawning in the upper reaches of the Savannah River had not been documented prior to 1982 (ECS, 1982). Dudley et al. (1977) reported that striped bass spawning was restricted to the lower reaches of the river and McFarlane et al. (1978) collected no striped bass ichthyoplankton during their sampling in 1977. However, striped bass eggs and/or larvae were collected during each year of this survey (ECS, 1982, Table 5-2) and, the highest densities occurred between approximately RM 166 to RM 120 during 1983-1985 (Tables 5-3a, 5-3b and 5-3c). Although total striped bass ichthyoplankton abundance was substantially lower than found for American shad, striped bass showed a similar trend in abundance with a substantial increase from 1983 to 1985.

Ichthyoplankton relative abundance and densities for many of the abundant resident fish taxa (e.g., gizzard and/or threadfin shad, pirate perch, crappie and minnows) declined from 1983 to 1985 (Tables 5-2, 5-3a, 5-3b, and 5-3c). Suckers exhibited a slight increase and sunfish ichthyoplankton relative abundance was somewhat higher in 1984 than in either 1983 or 1985.

Sturgeon larvae were collected from the Savannah River in the vicinity of the SRP during 1982. Examination of these specimens by Mr. Darrell Snyder (Larval Fish Laboratory, Colorado State University) indicated that both Atlantic sturgeon and the endangered shortnose sturgeon were present (Table 5-4). Both sturgeon species have been collected in all subsequent years. Total sturgeon larvae collections (number of specimens) were highest in 1982, although sampling intensity was lowest during that year

TABLE 5-3a

Mean Ichthyoplankton Densities (No./1000 m^3) at Savannah River Transects During February-July 1983

River Mile	American Shad	Blueback Herring	Striped Bass	Other Shad*	Minnows	Sunfish	Crappie	Total Ichthyoplankton**
				Lower Farfield				
29.6	5.3	11.7	2.7	8.3	4.8	1.5	13.6	67.8
40.0	4.5	16.1	1.4	17.2	6.1	1.1	15.6	89.2
50.2	6.4	20.8	0.5	21.3	12.1	1.9	21.0	118.1
60.0	7.1	32.4	5.1	18.7	11.8	3.4	26.8	144.0
69.9	4.7	19.7	0.5	20.1	6.1	2.0	12.1	87.2
79.9	4.5	26.9	0.8	40.7	6.3	2.0	16.9	124.9
89.3	7.6	32.7	2.3	59.2	9.0	2.4	25.4	171.5
97.5	12.3	39.2	1.1	54.1	10.9	2.6	29.8	191.1
110.0	18.3	13.4	1.3	15.7	17.7	2.5	21.7	136.6
120.0	8.2	8.6	11.3	7.7	12.8	3.0	16.4	98.7
				Nearfield				
128.9	5.4	5.9	0.7	5.4	14.9	4.7	16.3	84.4
129.1	6.9	5.8	4.1	5.3	18.1	4.2	16.2	95.2
137.7	10.0	3.8	0.1	3.7	22.3	7.5	15.5	105.1
141.5	6.8	4.2	0.0	4.2	14.7	9.7	13.7	102.2
141.7	12.1	4.0	0.0	4.9	12.2	10.1	14.9	110.2
150.4	8.7	2.5	1.3	4.3	12.9	1.7	5.5	54.0
150.8	8.9	3.6	0.1	4.9	11.1	0.9	7.8	53.2
152.0	7.8	1.9	2.4	6.9	12.1	1.7	5.9	62.1
152.2	10.5	2.5	10.2	8.0	14.7	1.1	6.1	90.3
155.2	11.9	1.9	5.1	9.5	12.2	0.3	4.3	65.4
155.3†	0.8	6.5	0.0	33.1	5.9	1.1	9.3	76.8
155.4	10.5	2.6	5.9	11.9	19.2	0.2	6.0	82.3
157.0	12.9	2.9	0.0	8.7	8.3	0.5	6.1	61.5
157.1†	1.0	7.9	0.1	23.7	4.4	1.9	11.9	71.5
157.3	17.8	1.7	0.0	9.6	12.1	1.0	5.4	73.6
				Upper Farfield				
166.6	25.6	2.4	6.3	24.7	11.8	2.0	3.7	96.6
176.0	8.9	1.3	0.1	12.8	11.7	1.0	2.9	52.5
187.1	1.6	0.3	0.0	25.2	4.9	0.9	0.7	47.7

* Gizzard and/or threadfin shad.
** Totals include taxa shown plus taxa not shown.
† Intake canals.

TABLE 5-3b

Mean Ichthyoplankton Densities (No./1000 m^3) at Savannah River Transects During February–July 1984

River Mile	American Shad	Blueback Herring	Striped Bass	Other Shad*	Minnows	Sunfish	Crappie	Total Ichthyo-plankton**
				Lower Farfield				
29.6	1.2	0.7	0.0	2.1	1.0	8.3	5.5	24.5
40.0	1.3	0.8	0.0	2.8	0.9	9.1	8.4	30.8
50.2	1.7	0.9	0.0	3.2	2.7	12.6	4.8	32.5
60.0	1.3	2.4	0.0	4.4	1.9	6.1	10.3	33.0
69.9	0.8	0.9	0.0	3.9	3.1	3.2	5.3	24.2
79.9	1.5	2.6	0.0	4.2	2.3	1.8	4.1	25.2
89.3	3.8	1.6	0.6	4.7	4.3	2.5	3.9	30.2
97.5	6.2	4.1	0.7	11.3	3.1	4.0	5.1	44.8
110.0	10.5	1.3	1.6	1.1	5.2	4.6	3.9	35.8
120.0	5.6	1.7	4.1	2.5	5.8	3.2	3.6	34.9
				Nearfield				
128.9	3.6	0.9	3.7	2.1	6.6	3.4	3.1	32.3
129.1	5.2	0.9	3.1	1.3	7.8	5.1	2.8	34.3
137.7	8.0	1.1	6.4	1.7	9.6	6.4	4.1	49.0
141.5	7.4	2.2	3.4	2.1	13.6	10.0	6.7	57.1
141.7	11.2	1.0	14.3	2.5	12.1	10.4	6.4	67.6
150.4	2.8	3.1	6.7	3.8	5.2	2.7	6.0	41.4
150.8	5.8	2.9	5.2	4.5	4.8	1.7	5.8	39.7
152.0	5.8	1.6	2.1	4.8	4.4	1.5	6.4	34.7
152.2	9.8	1.1	2.8	3.5	5.1	0.9	4.5	38.6
155.2	5.6	1.9	6.1	3.7	3.8	0.6	4.9	35.5
155.3†	0.2	6.6	1.6	4.9	3.0	0.8	10.9	43.1
155.4	4.0	1.1	6.1	3.8	4.2	1.0	5.9	36.8
157.0	9.9	1.5	4.0	3.5	4.6	1.9	6.1	45.3
157.1†	0.2	4.6	1.4	5.2	2.4	1.9	10.1	42.5
157.3	11.8	2.6	3.2	4.0	6.5	1.7	4.6	47.4
				Upper Farfield				
166.6	3.3	2.5	0.0	8.2	5.6	0.4	1.1	28.7
176.0	4.0	0.8	0.0	7.0	6.1	1.1	0.3	26.2
187.1	3.6	0.2	0.1	4.0	5.7	0.9	0.4	23.6

* Gizzard and/or threadfin shad.
** Totals include taxa shown plus taxa not shown.
† Intake canals.

TABLE 5-3c

Mean Ichthyoplankton Densities (No./1000 m^3) at Savannah River Transects During February–July 1985

River Mile	American Shad	Blueback Herring	Striped Bass	Other Shad*	Minnows	Sunfish	Crappie	Total Ichthyo-plankton**
				Lower Farfield				
89.3	47.4	0.9	2.0	2.2	2.5	1.4	0.1	67.8
97.5	26.6	1.7	1.2	4.7	1.6	0.2	0.1	44.1
110.0	39.6	0.6	1.5	1.2	3.2	0.2	0.1	55.6
120.0	35.3	0.8	1.3	1.7	2.2	0.7	0.4	51.7
				Nearfield				
128.9	41.7	1.4	5.3	2.2	4.1	1.0	0.2	64.2
129.1	31.3	0.8	6.3	1.9	2.9	1.4	0.2	54.7
137.7	34.1	1.8	0.4	2.9	1.9	1.4	0.1	55.2
141.5	30.0	1.4	0.1	3.4	1.5	1.1	0.1	50.9
141.7	54.6	0.9	0.5	3.7	1.8	1.8	0.3	83.2
145.7	63.2	0.7	0.6	3.0	1.6	1.5	0.5	84.3
150.4	22.0	1.0	2.4	2.1	0.8	0.2	0.3	44.7
150.8	12.6	1.9	0.3	3.0	1.0	0.1	0.0	31.8
152.0	10.6	1.4	3.7	3.2	1.6	0.1	0.1	28.7
152.2	14.2	2.2	3.3	3.6	2.0	0.1	0.1	43.1
155.2	18.2	2.6	16.0	3.1	1.0	0.0	0.2	67.1
155.3†	0.3	0.9	2.5	7.0	1.0	0.1	0.2	30.7
155.4	19.3	0.8	13.6	4.8	1.6	0.1	0.0	57.0
157.0	24.6	0.4	0.5	3.8	1.7	0.2	0.1	47.5
157.1†	0.8	1.1	0.1	3.0	0.7	0.2	0.1	22.2
157.3	36.0	0.5	2.1	3.8	1.6	0.2	0.2	81.6
				Upper Farfield				
166.6	59.4	3.2	10.7	22.3	2.5	0.2	0.1	149.3
176.0	15.7	2.4	0.1	27.2	4.5	0.4	0.2	70.9
187.1	3.3	2.8	0.1	22.7	5.4	0.6	0.4	58.6

* Gizzard and/or threadfin shad.
** Totals include taxa shown plus taxa not shown.
† Intake Canals.

TABLE 5-4

Larval Sturgeon Collected From the Savannah River During 1982, 1983, 1984 and 1985.

1982

Collection Date	River Mile	Sample Location*	Identity**	River Temp. (°C)	River Elev. (ft)†
3/12	157.3	CT	Sh	12.5	85.9
3/26	157.3	CB	Sh	13.2	84.2
4/21	150.8	CB	Atl	17.8	83.5
4/22	155.2	EB	Atl	15.2	86.3
4/22	155.2	ET	Atl	15.2	86.3
4/22	155.2	EB	Atl	15.2	86.3
4/22	157.0	WB	Atl	15.2	86.3
4/22	157.0	EB	Atl	15.3	86.3
5/21	155.4	CB	Atl	20.3	83.2
5/21	155.4	CB	Atl	20.3	83.2
5/21	157.0	CB	Atl	20.2	83.2
5/21	157.3	CT	Atl	20.2	83.2
5/21	157.3	CB	Atl	20.2	83.2
8/21	157.3	CT	Atl	21.0	84.7

1983

Collection Date	River Mile	Sample Location*	Identity**	River Temp. (°C)	River Elev. (ft)†
3/09	79.9	WB	Sh	16.0	94.9
3/22	155.4	CB	Sh	12.5	91.9
3/22	157.1	WT	Sh	11.5	92.5
3/22	155.3	ET	Sh	11.5	92.5
3/22	155.2	ET	Sh	11.3	92.5
3/23	97.5	WT	Sh	12.6	92.5
3/29	155.2	CT	Atl	12.5	90.6
4/26	129.1	CB	Atl	14.4	94.0
5/03	157.0	WB	Atl	18.1	86.5
5/10	155.4	CB	Atl	17.5	84.5
5/17	150.4	EB	Atl	22.5	84.3
5/18	69.9	EB	Atl	21.5	84.6
6/14	150.8	CB	Atl	20.5	83.8

* Samples were taken in mid-channel (C), near the South Carolina bank (E) and near the Georgia bank (W); samples were also taken near the top (T) and near the bottom (B) of the water column.

** Sh = shortnose sturgeon; Atl = Atlantic sturgeon.

† River elevation at Jackson, SC.

TABLE 5-4 (Contd)

1984

Collection Date	River Mile	Sample Location*	Identity**	River Temp. (°C)	River Elev. (ft)†
3/28	120.0	EB	Sh	15.0	89.3
4/04	110.0	CB	Sh	15.5	88.6
4/23	176.0	WB	Atl	14.0	92.9
4/24	152.0	CB	Atl	14.5	93.3
5/02	176.0	WB	Atl	15.8	94.5
5/23	110.0	WB	Atl	20.5	86.6
5/29	157.0	WB	Atl	20.4	86.1
5/29	152.2	WB	Atl	20.5	86.1
5/29	152.2	EB	Atl	20.5	86.1

1985

Collection Date	River Mile	Sample Location*	Identity**	River Temp. (°C)	River Elev. (ft)†
3/19	155.4	WB	Sh	12.0	83.6
3/26	166.6	EB	Sh	12.8	83.3
4/09	157.3	EB	Atl	14.1	83.3
4/16	141.7	EB	Atl	16.5	83.3
4/16	157.0	WB	Atl	16.0	83.3
4/24	120.0	CB	Atl	20.5	84.1
4/30	176.0	WT	Atl	18.6	82.8

* Samples were taken in mid-channel (C), near the South Carolina bank (E) and near the Georgia bank (W); samples were also taken near the top (T) and near the bottom (B) of the water column.

** Sh = shortnose sturgeon; Atl = Atlantic sturgeon.

† River elevation at Jackson, SC.

(Table 5-1). Generally, it appears that both species spawn upstream or near the SRP and that shortnose sturgeon spawn earlier and at cooler water temperature than Atlantic sturgeon.

Atlantic and shortnose sturgeon are demersal in nature and consequently most larvae are collected in samples near the river bottom. The National Marine Fisheries Service has concurred with DOE that increased pumping associated with the operation of L Reactor will not jeopardize the population of shortnose sturgeon in the Savannah River (Oravetz, 1983).

5.2 Entrainment

Entrainment of ichthyoplankton into the SRP cooling water intake pumps removes them from the Savannah River population. Entrainment of ichthyoplankton is dependent on several factors including the density of organisms in the river, the amount of spawning in the intake canals, the volume of water withdrawn by each pump and, in the case of 1G intake, the density of organisms in Upper Three Runs Creek which enters the river immediately upstream of the 1G intake canal (Figure 2-1).

When fish larvae enter the intake canals from the river, they move from rapid currents to slow currents which may enable larger larvae to swim to protected shoreline areas. This behavior could reduce the mortality rate of larvae entrained from the river. However, there is evidence from the larval collections made during 1982 (ECS, 1983) that the intake canals are used as spawning sites by several species. Accordingly, loss of larvae for some species by entrainment may be greater than is indicated by the ichthyoplankton densities in the river water entering the canal. Consequently, larval entrainment at the 1G and 3G intakes was calculated using the larval density in the intake canals since these organisms are the ones most likely to be lost from the total Savannah River ichthyoplankton population, regardless of whether they were spawned in the canal or moved in on river currents. Larval densities in the Savannah River were used to calculate entrainment at the 5G intake because of the short length of this canal.

The calculation of entrainment of fish eggs from the Savannah River into the three pumphouses was not as direct as the calculation of larval entrainment. Few eggs were actually collected in the canals. Generally, fish that spawn in freshwater have demersal rather than planktonic eggs. The only exceptions to this in the Savannah River drainage are the anadromous American shad (Jones et al., 1978) and striped bass (Hardy, 1978). The reduced current velocity in the intake canals allows the suspended eggs to settle out of the water column (McFarlane, 1982). Silt settles over these eggs and they die. The entrainment losses were calculated such that fish eggs that settle out of the water column and those actually entrained by the pumps are assumed to be lost. Consequently, the average egg densities used in the entrainment calculations were from the immediate upstream river transect. The egg densities for 3G and 5G are the same because they were calculated from the river transect immediately upstream of the 3G intake canal.

The density of eggs entering 1G canal was not calculated directly from the upstream river transect because a portion of the water entering 1G canal comes from Upper Three Runs Creek. The relative percent contribution of Upper Three Runs Creek and the river to the 1G intake canal water was estimated by measuring the sodium concentrations in the river upstream of the 1G canal, in Upper Three Runs Creek and in the mixed water coming out of the pump. These percentages were multiplied by the density of eggs from each source to get an average density of fish eggs entering the 1G canal.

To estimate total entrainment of ichthyoplankton during a spawning season, the daily entrainment rates were multiplied by the number of days between samples, generally a week, and summed. Annual entrainment is considered to be equal to that which occurs during the February-July spawning season. There is generally very little ichthyoplankton in the river to be entrained from September to January.

5.2.1 Larvae

A minimum of 17 species of larval fishes were entrained at the three intake structures at the SRP during 1983 (Table 5-5). Because larval fish are difficult to identify, there were probably unidentified species in these collections. The most abundant family of fish collected was Clupeidae, the herring family, which comprised 59 percent of the total ichthyoplankton entrainment. The single most abundant taxon was the genus Dorosoma (gizzard shad and threadfin shad), with 10.5×10^6 larvae (37.4 percent). Other abundant taxa were crappie, blueback herring and minnows, which represented 14.1, 9.5 and 9.0 percent, respectively.

Total larval fish entrainment for the SRP from February-July 1983 was calculated to be 28.0×10^6, of which 12.9×10^6 larvae (46.2 percent) were from the 1G pumphouse, 13.2×10^6 larvae (47.3 percent) were from the 3G pumphouse and 1.8×10^6 (6.5 percent) were from the 5G pumphouse (Table 5-6).

At least 17 taxa of larval fish were entrained at the SRP pumphouses during the 1984 spawning season (Table 5-7). As in 1983, the most common family found in the entrainment samples was Clupeidae, the herring and shad family, which comprised 50 percent

TABLE 5-5

Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses. February-July 1983

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Composition
Clupeidae					
American shad	90	80	4	174	0.6
Blueback herring	1434	1146	68	2648	9.5
Other shad	4315	5782	365	10,462	37.4
Unident. clupeids	1641	1572	90	3303	11.8
Esocidae					
Unident. pickerel	129	53	9	191	0.7
Cyprinidae					
Carp	26	80	17	123	0.4
Unident. cyprinids	814	1026	690	2530	9.0
Catostomidae					
Spotted sucker	853	573	237	1663	5.9
Other suckers		13	20	33	0.1
Ictaluridae					
Unident. catfish		13		13	<0.1
Aphredoderidae					
Pirate perch	388	400	28	816	2.9
Atherinidae					
Brook silverside			7	7	<0.1
Percichthyidae					
Striped bass	13		2	15	<0.1
Centrarchidae					
Unident. crappie	2170	1599	184	3953	14.1
Unident. sunfish	233	40	2	275	1.0
Other centrarchids	129	133	7	269	1.0
Percidae					
Yellow perch	142	320	33	495	1.8
Other percids	388	187	52	627	2.2
Other	129	213	26	368	1.3
Total	12,894	13,230	1,841	27,965	100.0

TABLE 5-6

Estimated Entrainment of Larval Fish at SRP Intakes

		1G	3G	5G	Total
1977*	Number ($x10^6$)	7.1	11.9	0.6	19.6
	Percent	36.2	60.7	3.1	
1982**	Number ($x10^6$)	5.2	12.0	0.7	17.9
	Percent	28.8	67.1	4.0	
1983†	Number ($x10^6$)	12.9	13.2	1.8	28.0
	Percent	46.2	47.3	6.5	
1984††	Number ($x10^6$)	7.7	8.8	1.0	17.6
	Percent	44.0	50.3	5.6	
1985¶	Number ($x10^6$)	3.8	6.4	0.7	10.9
	Percent	34.9	58.7	6.4	
Average number ($x\ 10^6$)		8.1	9.5	1.2	18.8
(1983-85) percent		43.4	50.3	6.3	

* April-June, McFarlane et al. (1978).
** March-August, ECS (1983).
† February-July, Paller et al. (1984).
†† February-July, Paller et al. (1985).
¶ February-July, Paller et al. (1986).

TABLE 5-7

Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses. February–July 1984

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Compo-sition
Clupeidae					
American shad	36	26	-	62	0.4
Blueback herring	891	1398	39	2328	13.2
Other shad	1010	1085	139	2234	12.7
Unident. clupeids	2102	1975	116	4193	23.9
Esocidae					
Unident. pickerel	23	7	-	30	0.2
Cyprinidae					
Carp	175	203	46	424	2.4
Unident. cyprinids	449	679	167	1295	7.4
Catostomidae					
Spotted sucker	495	506	118	1119	6.4
Other suckers	-	23	12	35	0.2
Aphredoderidae					
Pirate perch	-	-	3	3	<0.1
Percichthyidae					
Striped bass	33	73	17	123	0.7
Centrarchidae					
Unident. crappie	1908	2181	233	4322	24.5
Unident. sunfish	147	100	22	269	1.5
Other centrarchids	200	59	16	275	1.6
Percidae					
Yellow perch	77	218	5	300	1.7
Other percids	84	219	39	342	1.9
Lepisosteidae					
Gar	19	-	-	19	0.1
Other	99	87	19	205	1.2
Total	7,748	8,839	991	17,578	100.0

of the larval fish that were entrained. The single most abundant taxon was crappie with 4.3 x 10^6 larvae (24.5 percent). Other abundant taxa were unidentified clupeids, blueback herring and other shad (gizzard and/or threadfin shad), which comprised 23.9, 13.2 and 12.7 percent of the total larvae entrained, respectively. Generally, there were no differences in the species composition among the three pumphouses.

Total larval fish entrainment for the SRP from February-July 1984 was calculated to be 17.6 x 10^6. The 1G pumphouse entrained 7.7 x 10^6 larvae (44 percent), 8.8 x 10^6 larvae (50.3 percent) were entrained at the 3G pumphouse and 1.0 x 10^6 larvae (5.6 percent) at the 5G pumphouse (Table 5-6).

At least 6 taxa of larvae were entrained at the SRP pumphouses in 1985 (Table 5-8). The most common larval fish entrained were suckers, which comprised 43% of the larval fish entrained. The single most abundant taxon was spotted sucker with a total of 4.6 x 10^6 larvae (42.7%) entrained at the three pumphouses. Other abundant taxa were gizzard and/or threadfin shad (22.0%), unidentified Clupeidae (11.4%), and carp (10.3%). Generally, there were no substantive differences in the species composition between three pumphouses.

Total larval fish entrained due to SRP activities from February-July 1985 was calculated to be 10.9 x 10^6 (Table 5-6). The 1G pumphouse entrained 3.8 x 10^6 larvae (35%); 6.4 x 10^6 larvae (59%) were entrained at the 3G pumphouse and 0.7 x 10^6 larvae (6%) at the 5G pumphouse (Table 5-6).

For the five years for which data are available, estimated entrainment of larval fish was highest in 1983 when 28.0 x 10^6 larvae were entrained (Table 5-6). Minimum larval entrainment (10.9 x 10^6 larvae) occurred in 1985. The 1983 estimated larval entrainment is almost fifty percent higher than the average entrainment (18.8 x 10^6 larvae) for the three year period (1983-85) during which sampling methodologies were consistent. The 1983-85 average entrainment is comparable to entrainment estimates for 1977 and 1982.

The highest percentage of larval entrainment occurred at the 3G intake during 1983-85 (9.5 x 10^6 larvae, 50.3 percent of total; Table 5-6). Larval entrainment was substantially lower at the 1G intake (8.1 x 10^6 larvae, 43.4 percent of total). Larval entrainment at the 5G intake was consistently low (1.2 x 10^6 larvae, 6.3 percent), and never exceeded 6.5 percent of the total entrainment at the SRP river water intakes during 1983-85. Thus, the magnitude of larval entrainment at the SRP is primarily determined by losses at the 1G and 3G intakes.

TABLE 5-8

Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses. February-July 1985

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Composition
Clupeidae					
American shad	46	9	5	60	0.6
Blueback herring	195	198	21	414	3.8
Other shad	563	1660	171	2394	22.0
Unident. clupeids	379	797	69	1245	11.4
Cyprinidae					
Carp	341	687	89	1117	10.3
Unident. cyprinids	122	225	61	408	3.8
Catostomidae					
Spotted sucker	1835	2585	223	4643	42.7
Unident. sucker	0	24	6	30	0.4
Others	341	195	39	575	5.1
Total	3,822	6,380	684	10,886	100.1

The relative abundance of larval taxonomic groups entrained varies substantially from year-to-year, however. McFarlane et al. (1978) reported that clupeids (48 percent), primarily blueback herring (29.1 percent), were most abundant among entrained larvae in 1977. Cyprinid (10.0 percent) and catastomid (11.2 percent) larvae were also relatively abundant. No striped bass eggs or larvae were collected during sampling in 1977.

Clupeid larvae also dominated entrainment collections during 1983-85. This group accounted for over fifty percent of larval entrainment in 1983 (Table 5-5) and 1984 (Table 5-7), but only approximately thirty-eight percent in 1985 (Table 5-8). Among the clupeids, gizzard and/or threadfin shad larvae were most abundant, representing 37.3, 12.7 and 22.0 percent of total larval entrainment in 1983, 1984 and 1985, respectively. Blueback herring represented 9.5, 13.2 and 3.8 percent of collections in those years. American shad larvae were a minor component of entrainment, ranging from 0.4 to 0.6 percent of entrainment from 1983-85.

Abundances of other larval taxa were also variable among years in entrainment. Cyprinids ranged from 9.4 to 14.1 percent of entrained larvae (Tables 5-5, 5-7, and 5-8). However, the greatest change in relative composition occurred among catastomid larvae, with spotted sucker larvae increasing from 5.9 and 6.4 percent of larval entrainment in 1983 and 1984, to 42.7 percent in 1985.

5.2.2 Eggs

The total egg entrainment during February-July 1983 was calculated to be 9.2 x 10^6 eggs of which 4.3 x 10^6 eggs were entrained at 1G, 4.2 x 10^6 eggs at 3G and 0.7 x 10^6 eggs at 5G (Table 5-9). The most abundant species was American shad which represented 55.0 percent of the total eggs entrained (Table 5-10). The other abundant groups were "other" eggs and striped bass eggs, which represent 28.0 and 14.2 percent of the total egg entrainment, respectively.

The total fish egg entrainment during February-July 1984 was estimated to be 5.8 x 10^6 eggs, of which 2.7 x 10^6 eggs (46.6%) were entrained at the 1G pumphouse, 2.6 x 10^6 eggs (45.4%) at the 3G pumphouse and 0.5 x 10^6 eggs (8.0 %) at the 5G pumphouse (Table 5-9). The most abundant egg species was American shad, which represented 50.3 percent of the total eggs entrained (Table 5-10). The other abundant groups of eggs entrained were striped bass and "other" eggs which represented 30.6 and 15.2 percent of the total eggs entrained, respectively.

The total fish egg entrainment during February-July 1985 was estimated to be 15.1 x 10^6, of which 7.8 x 10^6 eggs (51.4%) were entrained at the 1G pumphouse, 6.2 x 10^6 (41.4%) at the 3G pumphouse, 1.1 x 10^6 eggs (7.3%) at the 5G pumphouse (Table 5-9). American shad eggs were most abundant in entrainment and represented 46.7% of the total eggs entrained (Table 5-10). The other abundant groups of eggs entrained were striped bass and "other" eggs which represented 26.2% and 24.8% of the total entrained, respectively.

Total fish egg entrainment varied considerably among the years for which data are available. Average total entrainment from 1983-85 was 10.0 x 10^6 eggs at the three SRP intakes (Table 5-9). However, egg entrainment varied almost three fold during those years from 5.8 x 10^6 in 1984 to 15.1 x 10^6 in 1985. The highest estimated egg entrainment occurred in 1982 (18.1 x10^6), while estimated entrainment in 1977 (6.9 x 10^6) was near the low end of the range of values.

The proportions of total eggs entrained at each of the three intakes remained relatively constant from year to year. Highest egg entrainment occurred at the 1G intake during all years except 1977 when entrainment was highest at the 3G intake (Table 5-9). The 1G intake averaged 49.1 percent of the total eggs entrained from 1983 to 1985. The 3G intake averaged 43.3 percent of total egg entrainment from 1983 to 1985, while the 5G intake averaged 7.6 percent of egg entrainment during this period.

American shad eggs dominated entrainment collections from 1983 to 1985 and the percentage of total egg entrainment attributable to this species was relatively constant (Table 5-10). American shad eggs averaged 50.0 percent of egg entrainment and ranged from 46.7 percent (1985) to 55.0 percent (1983) of all eggs entrained. The number of American shad eggs entrained annually varied substantially, however, as total egg entrainment varied. The highest number of American shad eggs entrained was 7.1 x 10^6 in 1985 although this species represented only 46.7 percent of total egg entrainment in that year.

Striped bass eggs were less than half as abundant as American shad eggs in entrainment, averaging 23.4 percent (2.4 x 10^6 eggs/year) from 1983 to 1985 (Table 5-10). However, striped bass eggs varied widely among years both as a percentage of total egg entrainment (14.2 - 30.6 percent) and as numbers of eggs entrained annually (1.3 x 10^6 - 4.0 x 10^6 eggs/year). Eggs of blueback herring, Dorosoma spp. (gizzard and/or threadfin shad) and percids were relatively minor components in entrainment. The undifferentiated component of "other" eggs represented a substantial component of egg entrainment, but likely included a wide variety of taxa, few of which represented substantial individual contributions to total egg entrainment.

TABLE 5-9

Estimated Egg Entrainment at SRP Intakes

		1G	3G	5G	Total
1977*	Number ($x10^6$)	2.4	4.0	0.5	6.9
	Percent	34.8	58.0	7.2	
1982**	Number ($x10^6$)	8.7	8.2	1.2	18.1
	Percent	48.3	45.1	6.6	
1983†	Number ($x10^6$)	4.3	4.2	0.7	9.2
	Percent	46.7	45.7	7.6	
1984††	Number ($x10^6$)	2.7	2.6	0.5	5.8
	Percent	46.6	44.8	8.6	
1985¶	Number ($x10^6$)	7.8	6.2	1.1	15.1
	Percent	51.7	41.1	7.3	
Average number ($x10^6$)		4.9	4.3	0.8	10.0
(1983-85) percent		48.3	43.8	7.8	

* April-June, McFarlane et al. (1978).
** March-August, ECS (1983).
† February-July, Paller et al. (1984).
†† February-July, Paller et al. (1985).
¶ February-July, Paller et al. (1986).

TABLE 5-10

Estimated Entrainment and Taxonomic Composition of Fish Eggs at SRP Intakes, 1983-85

Taxa		1983*	1984**	1985†	Average
American shad	Number (x10^6)	5.07	2.91	7.06	5.01
	Percent	55.0	50.3	46.7	50.0
Blueback herring	Number (x10^6)	0.09	0.07	0.14	0.10
	Percent	1.0	1.2	0.9	1.0
Dorosoma spp.	Number (x10^6)	-††	0.13	0.21	-¶
	Percent	-††	2.2	1.4	-¶
Striped bass	Number (x10^6)	1.31	1.77	3.96	2.35
	Percent	14.2	30.6	26.2	23.4
Unident. percids	Number (x10^6)	0.16	0.02	-††	-¶
	Percent	1.7	0.3	-††	-¶
Other eggs	Number (x10^6)	2.58	0.88	3.74	2.4¶¶
	Percent	28.0	15.2	24.8	25.6¶¶
Total number (x10^6)		9.21	5.78	15.11	10.03

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* Paller et al. (1984).
** Paller et al. (1985).
† Paller et al. (1986).
†† Not provided in source document.
¶ Not calculated because of partial data.
¶¶ Includes *Dorosoma* spp. and unident. percids.

5.3 Ichthyoplankton Withdrawal

The percentage of ichthyoplankton withdrawn from the Savannah River is determined by dividing the number of fish eggs and larvae entrained by the number of eggs and larvae transported past the intake canals in the Savannah River. The number of ichthyoplankton entrained at each intake is derived by summing the numbers of eggs and larvae that were entrained during each year (Table 5-11). The number of ichthyoplankton that were vulnerable to entrainment was estimated by multiplying ichthyoplankton densities in the river near the canals times the river discharge on that date. Ichthyoplankton densities at RM 157.3 were used for entrainment at the 1G intake, and densities at Rm 155.4 were used for estimates at the 3G and 5G intakes. Annual ichthyoplankton transport was derived by extrapolating the weekly measurements through the sampling season (February-July).

The total number of ichthyoplankton entrained was consistently highest at the 3G intake and ranged from 11.4×10^6 ichthyoplankton in 1984 to 17.4×10^6 in 1983 (Table 5-11). Entrainment at the 1G intake was only slightly less than at 3G, while a much smaller number of ichthyoplankton was entrained at the 5G intake.

Total number of ichthyoplankton entrained was highest in 1983, with substantially lower numbers of eggs and larvae entrained in 1984 and 1985 (Table 5-11). Total numbers of ichthyoplankton entrained were also similar in 1984 and 1985.

Estimates of ichthyoplankton transport varied among years and between transects at which transport was calculated (Table 5-11). Highest ichthyoplankton transport occurred during 1983 when densities (Table 5-3a) and river discharge (Table 3-3) were both relatively high. Ichthyoplankton transport past the SRP intakes was substantially lower in 1984 and 1985. In 1984 ichthyoplankton densities were relatively low (Table 5-3b), while river discharge was slightly below that observed in 1983 (Table 3-3). Ichthyoplankton densities in 1985 (Table 5-3c) were comparable to densities observed in 1983, but river discharge was extremely low as a result of low winter rainfall and relatively low releases of water from Clarks Hill Reservoir.

The combined effects of changes in ichthyoplankton density and river water discharge among years resulted in differences in estimates of the percentages of ichthyoplankton entrained from the river each year (Table 5-11). The percentage of ichthyoplankton entrained at all intakes was lowest in 1984 (8.3%) and only slightly higher in 1983 (9.6%). The highest percentage of river ichthyoplankton entrained was in 1985 (12.3%) when Savannah River discharge was low during the spawning season (Table 3-3).

TABLE 5-11

Percentage of Savannah River Ichthyoplankton Entrained at SRP Intakes, 1983-85.

		1983*	1984**	1985†
Number entrained (x10°)	1G	17.2	10.4	11.6
	3G	17.4	11.4	12.6
	5G	2.5	1.5	1.8
	Total	37.1	23.3	26.0
Number transported in River ($x10^6$)	RM 157.3	388	282	212
	RM 155.4	405	216	133
Percent entrained	1G	4.4	3.7	5.5
	3G	4.3	5.3	9.5
	5G	0.6	0.7	1.4
	Total††	9.6	8.3	12.3
Percent river withdrawn¶		7.7	7.0	12.2

* Paller et al. (1984).
** Paller et al. (1985).
† Paller et al. (1986).
†† based on transport at RM 157.3.
¶ all intakes combined, February-July.

The primary factor that appears to influence the percentage of river ichthyoplankton entrained in the SRP intakes is the percentage of river water withdrawn (Table 5-11). Although the volume of river water withdrawn by the SRP remained relatively constant during the spawning season among the three years (Table 3-4), river discharge varied substantially and the percentage of river water withdrawn during the spawning season was higher in 1985 than in 1983 or 1984.

6.0 ASSESSMENT OF IMPACTS OF SRP INTAKES

6.1 Impingement

Impingement at the three SRP intakes averaged approximately 7600 fish annually. Approximately 77 percent of the total impingement occurs at the 1G and 3G intakes that provide secondary cooling water for SRP reactors. However, impingement rates vary substantially seasonally and among years. Highest impingement usually occurs during late winter-early spring, and Paller and Osteen (1985) have suggested that high and variable water levels may result in elevated impingement rates.

The taxonomic composition of impingement is variable, but centrarchids are the dominant group in collections at the SRP intakes. During 1983-85 blue-spotted sunfish was the dominant species in impingement collections, followed by threadfin shad, gizzard shad, redbreast sunfish and warmouth. These taxa exceeded five percent of collections over the three year period. The overall rates of impingement at the SRP intakes are low relative to other cooling water intake facilities in the southeastern region, and impingement losses are concentrated among species of low commercial or recreational value.

6.2 Entrainment

An average of 10.0 x 10^6 eggs and 18.8 x 10^6 larvae were entrained annually at the SRP intakes during 1983-85. Entrainment rates are a function of ichthyoplankton abundance in the Savannah River, the volume of water withdrawn at the intakes, and river discharge volume. Paller et al. (1984) indicated that entrainment is also influenced by fish spawning in the intake canals.

Entrainment losses of fish eggs were primarily from the anadromous species, American shad and striped bass. Although estimated numbers of American shad eggs varied widely, among years during 1983-85, the percent of American shad eggs in fish egg collections remained relatively constant. Numbers and percent composition of striped bass in eggs collections varied somewhat more than for American shad. The highest entrainment of eggs of these species occurred in 1985 when densities were high and river discharge rates were low.

Entrainment losses of fish larvae were concentrated among clupeids, predominantly gizzard and/or threadfin shad. Blueback herring were entrained in moderate abundance while few larvae of American shad occurred in the intake canals. Crappie larvae were relatively abundant in entrainment collection in 1983 and 1984, while spotted sucker larvae were abundant in 1985.

Overall entrainment losses average approximately ten percent of the ichthyoplankton passing the SRP intakes. Egg losses are concentrated among two anadromous species, American shad and striped bass, but only populations spawning in the 30 miles of the river between the New Savannah Bluff Lock and Dam and the SRP are affected. Striped bass and American shad spawn throughout the Savannah River, but Gilbert et al. (1986) have concluded that the primary region for striped bass spawning is in the tidally influenced portions of the river near Savannah. Entrainment of ichthyoplankton of fresh water species primarily affects the eggs and larvae of individuals that spawn in the vicinity of the intake canals, either in the river, or in the 1G and 3G canals. Consequently, the effect of entrainment of fish eggs and larvae should be small and restricted to local fish species populations.

6.3 Status of Savannah River Fish Populations

Relatively little is known concerning the current status of fishery stocks in the Savannah River and the overall levels of mortality sustained by individual species populations. The creel survey of Schmitt and Hornsby (1985) represents a significant addition to the knowledge of sports fishing pressure on individual species in freshwater and estuarine areas of the lower Savannah River. Concurrent sampling of the creel censused areas using electrofishing and rotenone also provided information on abundance and species composition of resident species.

American shad stocks appear to be healthy and productive in the Savannah River. Music (1981) reported on commercial catches by Georgia shad fishermen in 1980 and found that the Savannah River produced the greatest catches (in pounds of fish and income), representing 51 percent of Georgia shad landings in that year, while only 13 percent of Georgia's commercial shad fishermen operated in the Savannah. Thus, American shad stocks in the Savannah River may be less heavily exploited and relatively more abundant than stocks in other Georgia rivers. Additionally, Schmitt and Hornsby (1985) reported the development of a previously undocumented sport fishery for American shad in the vicinity of the New Savannah Bluff Lock and Dam, and recommended that the magnitude of this fishery be evaluated.

Less is known concerning the status of striped bass in the Savannah River, however. Only recently has spawning upstream of tidally influenced regions of the river been documented (ECS, 1983, Paller et al., 1984, Paller et al., 1985, Paller et al., 1986). Nevertheless, Gilbert et al. (1986) suggested that striped bass spawning occurs primarily in the tidally influenced portions of the river. It is not clear whether the current spawning of striped bass in upstream regions of the river represents a re-establishment of a spawning stock in this area, or is a result of the increased intensity of sampling efforts during 1982-85 relative to prior sampling programs.

Although relatively little is known concerning fish stocks, the quality of fish habitat in the river near the SRP has likely improved. The recent improvement of the sewage treatment facilities in Aiken County, South Carolina, have undoubtedly resulted in improvement of water quality in Horse Creek, which enters the Savannah River at RM 197.4. The continuing upgrading of sewage treatment facilities for the Augusta, Georgia area will result in improved water quality in Butler Creek (RM 187.2) which enters the river near the new Savannah Bluff Lock and Dam. The river section from the New Savannah Bluff Lock and Dam to downstream of Spirit Creek (RM 182.2) was identified by Schmitt and Hornsby (1985) as an area of degraded water quality.

Overall, there is currently no basis for concluding that fish stocks in the Savannah River are adversely affected by SRP operations. Although direct assessment of recent changes in fish stocks is currently not feasible, the losses of fish resulting from SRP operations are small and localized. Such small losses should not result in a significant risk to the abundance or persistence of fish stocks in the lower Savannah River.

7.0 MITIGATION ALTERNATIVES AND EVALUATION

This section of the report describes mitigation alternatives for impingement/entrainment losses to comply with the request made in the 404 permit. However, after studying the impact of water withdrawal from the Savannah River by SRP, there seems to be little justification for taking mitigative action at this time. This conclusion is supported earlier in the text and is summarized below.

- Losses to the Savannah River fish populations attributable to impingement or entrainment at the SRP intakes have a negligible impact on total river populations,
- There is no indication that the Savannah River fish populations are declining as a whole,
- SRP intake effects are probably small in comparison to the combined effects of other industries and municipalities on water quality and habitat availability and the operation of locks and dams on the river; however it is difficult to compare relative impacts with the information available,
- The restart of L Reactor did not significantly change the amount of water withdrawn from the Savannah River by SRP as was previously forecast because the SRP continues to operate only three reactors.

Despite the conclusion that mitigation of intake effects is not warranted, several mitigation alternatives are presented to illustrate what options are available.

Mitigation alternatives are considered in relation to the overall operation of the SRP and the Savannah River fishery resource, particularly for fish populations in the region of the SRP. Consequently, implementation of many of the alternatives that are presented here are not necessarily within the control of the Department of Energy.

7.1 Impingement

Mitigation alternatives considered in this section are directed toward potential reductions in impingement rates at the SRP.

7.1.1 Diversion of Trash Sluice

Trash from the pumphouse traveling screens, which contains organic debris as well as impinged fish, is presently discharged into a small slough near the pumphouse. Although impingement on the screens does not result in 100 percent mortality for fish, it is not possible for surviving fish to return to the river because the slough is physically isolated from the river and swamp. Impinged fish are consumed by racoons, large snakes and other scavengers. Diversion of the screen trash to the Savannah River or the intake canals would return any surviving fish to the river and reduce the number of fish lost by impingement. Although no quantitative data are available on survival rates of impinged fish at the SRP intakes, live fish are routinely observed in the impingement samples and the biologists responsible for the impingement sampling estimate that approximately 20 percent of the impinged fish are alive at the time of collection. However, many of these fish had abrasions and injuries that would reduce the probability of long-term survival. Among the fish collected, juvenile centrarchids appeared to be most likely to survive impingement, while clupeids were least likely to survive. Thus, the diversion of the pumphouse trash sluice to the river or canal would likely reduce total impingement losses less than 20 percent, returning an average of ~1500 fish to the river each year.

7.1.2 Screening of Intake Canals

Some reduction in impingement losses could possibly be achieved by placement of fine mesh screens or nets across the intake canals near the point of entry for river water. Such blocking devices would reduce the movement of adult and juvenile fish into the canal areas near the traveling screens on which fish are impinged. This approach might also result in some reductions in entrainment losses for those species that appear to spawn in the intake canals by eliminating access to these habitats for spawning. However, high organic debris loads in the Savannah River, particularly during winter and spring flooding when impingement is high, could reduce the efficiency of this approach. It is likely that large floating debris, such as logs, would tear the nets, while smaller debris would clog the nets or require frequent cleaning. The potential for these nets to reduce the amount of cooling water available to the reactors would need to be evaluated before this option could be fully considered.

7.2 Entrainment

Mitigation alternatives considered in this section relate not only to the reduction of entrainment losses of fish eggs and larvae at the SRP intakes, but also include approaches that could enhance the productivity of fish populations in the nearby regions of the Savannah River.

7.2.1 Access to Spawning Sites Upstream from the New Savannah Bluff Lock and Dam

The New Savannah Bluff Lock and Dam (RM 187.5) constitutes a physical barrier to the upstream migration of anadromous fish. However, Osteen et al. (1984) collected anadromous fish in the vicinity of the Augusta City Dam (RM 210.0), indicating that the New Savannah Bluff Lock and Dam permits some upstream movement of some fish species.

The migration of anadromous fish could be aided by the installation of a fish ladder at RM 187.5 or operation of the dam locks so that fish could move through the locks during the spring spawning run. Increased movement of fish through the lock and dam could result in increased spawning of anadromous fish in the section of the river upstream of the New Savannah Bluff Lock and Dam and below the Clarks Hill Dam. However, the overall impact of the dam on anadromous fish spawning has not been assessed and it is not known if anadromous fish that encounter the dam find suitable spawning areas below the dam, move downstream in search of more suitable spawning sites, or spawn unsuccessfully in unsuitable habitats. However, results from ichthyoplankton collections taken immediately downstream from the lock and dam (RM 187.1) do not indicate that increased spawning of anadromous fish occurs in this area of the river (Paller et al., 1984, Paller et al., 1985, Paller et al., 1986).

7.2.2 Spawning Season Flow Enhancement

The percentage of river flow that is withdrawn by the SRP directly affects the proportion of fish eggs and larvae that are entrained from the Savannah River. The increased percentage of eggs and larvae that were entrained from the river during 1985 was primarily a result of reduced river discharge during that period. Maintenance of higher discharge volumes from Clarks Hill Reservoir during peak spawning periods would decrease the proportion of Savannah River flow that is taken in at the SRP intakes, and thereby decrease the percentage of eggs and larvae that are lost by entrainment at the SRP intakes. Such an approach would also increase the habitat available for spawning if discharge was sufficient to inundate floodplain areas adjacent to the river. Paller et al. (1986) have suggested that reduced spring flooding during 1985 may have adversely affected the spawning of such species as blueback herring and gizzard/threadfin shad by reducing the area of floodplain habitat that was available for spawning.

7.2.3 Fish Stocking

Fish stocking programs in the Savannah River are presently limited to the shortnose sturgeon. Neither the Georgia Game and Fish Division nor the South Carolina Wildlife and Marine Resources Department plan to implement stocking programs for any other fish species in the near future.

To assess the feasibility of fish stocking as a mitigation alternative for entrainment losses, the 1983-1985 entrainment data were evaluated to determine which taxa are most frequently entrained, the feasibility of initiating stocking programs for these species, and the number of adult fish that would be required annually to produce numbers of ichthyoplankton equivalent to the number entrained annually at the Savannah River Plant.

The following assumptions were made in calculating the number of adults required to replace entrainment losses:

1. All stocked adults will successfully mate and spawn.
2. Stocked adults will spawn only once. (It is recognized that this is a very conservative estimate, since many adults will live to spawn for several years.)
3. Fish released in the vicinity of the SRP will not emigrate from the area prior to spawning.
4. All eggs spawned by stocked adults will be viable.
5. Egg mortality will be minimal. (It is recognized that Assumptions #'s 4 and 5 are not valid, but egg viability and mortality data for the species of interest were not readily available.)

Of the ichthyoplankton entrained at the Savannah River Plant in 1983-1985, four groups accounted for 80% of the total entrainment. Clupeids (52%) were the most frequently entrained ichthyoplankters, followed by centrarchids (11.3%), suckers (9%) and striped bass (8%).

The American shad, which is the only clupeid in the Savannah River that has significant value as a commerical or recreational species, accounted for 18% of total entrainment. Since hatcheries have not been able to successfully rear American shad nor other species of clupeids, stocking of clupeids is not a viable option at this time.

Suckers are an important forage fish, but have little value as commercial or sport fish and are not routinely reared by hatcheries, although it may be possible to rear them, if deemed necessary.

However, due to the minimal importance of this family to commercial and recreational fishing, stocking of suckers would be of little value.

Striped bass are an important sport fish in the Savannah River and can be successfully reared in hatcheries. Using a mean fecundity of 700,000 egg/female (Hardy, 1978), approximately four adult female striped bass per year would be required to replace the 2.32 million striped bass eggs and larvae entrained annually at the Savannah River Plant.

Although the species composition of centrarchid ichthyoplankters was not finely delineated, centrarchids, in general, are readily reared in commercial hatcheries. Bluegills, largemouth bass, or other appropriate species could be included in a stocking program. Using a mean entrainment rate of 3.3 million centrarchid eggs and larvae per year and conservatively estimating the fecundity of centrarchids at 20,000 eggs/female (Scott and Crossman, 1973), approximately 165 adult female centrarchids would be required to replace annual entrainment losses resulting from Savannah River Plant operations.

Thus, although the number of ichthyoplankton entrained at the Savannah River Plant averages approximately 28.9 million per year, the number is quite small when the fecundities of the dominant species and the size of the Savannah River fish populations are considered. In addition, there is no evidence that fisheries stocks in the Savannah River are declining as a result of SRP operations. Thus, the initiation of a stocking program does not appear to be warranted at this time.

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APPENDIX A

Common and Scientific Names and Taxonomic Affiliations of Fish Collected or Known to Occur in the Savannah River Near the SRP

Order	Family	Species	Common Name
Acipenseriformes	Acipenseridae	*Acipenser oxyrhynchus*	Atlantic sturgeon
		Acipenser brevirostrum	Shortnose sturgeon
Semionotiformes	Lepisosteidae	*Lepisosteus osseus*	Longnose gar
		Lepisosteus platyrhincus	Florida gar
		Lepisoteus oculatus	Spotted gar
Amiiforms	Amiidae	*Amia calva*	Bowfin
Anguilliformes	Anguillidae	*Anguilla rostrata*	American eel
Clupeiformes	Clupeidae	*Alosa aestivalis*	Blueback herring
		Alosa sapidissima	American shad
		Dorosoma capediaum	Gizzard shad
		Alosa mediocris	Hictory shad
		Dorosoma petenense	Threadfin shad
Salmoniformes	Umbridae	*Umbra pygmaea*	Eastern mudminnow
	Esocidae	*Esox niger*	Chain pickerel
		Esox americanus	Redfin pickerel Grass pickerel
Cypriniformes	Cyprinidae	*Cyprinus carpio*	Carp
		Hybognathus nuchalis	Silvery minnow
		Hybopsis rubrifrons	Rosyface chub
		Nocomis leptocephalus	Bluehead chub
		Notemigonus crysoleucas	Golden shiner

APPENDIX A, Contd

Order	Family	Species	Common Name
Cypriniformes	Cyprinidae (Cont.)	*Notropis chalybaeus*	Ironcolor shiner
		Notropis cummingsae	Dusky shiner
		Notropis leedsi	Ohoopee shiner
		Notropis emiliae	Pugnose minnow
		Notropis hudsonius	Spottail shiner
		Notropis hypselopterus	Sailfin shiner
		Notropis leedsi	Bannerfin shiner
		Notropis lutipinnis	Yellowfin shiner
		Notropis maculatus	Taillight shiner
		Notropis petersoni	Coastal shiner
		Notropis niveus	Whitefin shiner
	Catostomidae	*Carpiodes cyprinus*	Quillback carpsucker
		Erimyzon oblongus	Creek chubsucker
		Emimyzon sucetta	Lake chubsucker
		Minytrema melanops	Spotted sucker
		Moxostoma anisurum	Silver redhorse
Cyprinidontiformes	Cyprinodontidae		Unid. killifish
Siluriformes	Ictaluridae	*Ictalurus brunneus*	Snail bullhead
		Ictalurus catus	White catfish
		Ictalurus natalis	Yellow bullhead
		Ictalurus nebulosus	Brown bullhead

APPENDIX A, Contd

Order	Family	Species	Common Name
Siluriformes	Ictaluridae (cont.)	Ictalurus platycephalus	Flat bullhead
		Ictalurus punctatus	Channel catfish
		Noturus gyrinus	Tadpole madtom
		Noturus insignis	Margined madtom
		Noturus leptacanthus	Speckled madtom
		Pylodicitis olivaris	Flathead catfish
Percopsiformes	Amblyopsidae	Chologaster cornuta	Swampfish
	Aphredoderidae	Aphredoderus sayanus	Pirate perch
Atheriniformes	Belonidae	Strongylura marina	Atlantic needlefis
	Cyprinodontidae	Fundulus lineolatus	Lined topminnow
		Fundulus chrysotus	Golden topminnow
		Fundulus notti	Starhead topminnow
	Poeciliidae	Gambusia affinis	Mosquitofish
	Atherinidae	Ladidesthes sicculus	Brook silverside
Perciformes	Percichthyidae	Morone chrysops	White bass
		Morone saxatilis	Striped bass
	Centrarchidae	Acantharchus pomotis	Mud sunfish
		Centrarchus macropterus	Flier
		Elassoma zonatum	Banded pygmy sunfi
		Enneacanthus chaetodon	Blackbanded sunfis

APPENDIX A, Contd

Order	Family	Species	Common Name
Perciformes	Centrarchidae (cont.)	Enneacanthus gloriosus	Bluespotted sunfish
		Lepomis auritus	Redbreast sunfish
		Lepomis cyanellus	Green sunfish
		Lepomis gibbosus	Pumpkinseed
		Lepomis gulosus	Warmouth
		Lepomis macrochirus	Bluegill
		Lepomis marginatus	Dollar sunfish
		Lepomis microlophus	Redear sunfish
		Lepomis punctatus	Spotted sunfish
		Mcropterus salmoides	Largemouth bass
		Micropterus coosae	Redeye bass
		Pomoxis annularis	White crappie
		Pomoxis nigromaculatus	Black crappie
	Percidae	Etheostoma fricksium	Savannah darter
		Etheostoma fusiforme	Swamp darter
		Etheostoma hopkinsi	Christmas darter
		Etheostoma inscriptum	Turquoise darter
		Etheostoma olmstedi	Tessellated darter
		Etheostoma serriferum	Sawcheeker darter
		Perca flavescens	Yellow perch
		Percina nigrofasciata	Blackbanded darter

APPENDIX A, Contd

Order	Family	Species	Common Name
Perciformes	Percidae	Percina caprodes	Logperch
	Mugilidae	Mugil cephalus	Striped mullet
	Agonidae	Agonostomos monticola	Mountain mullet
	Gobidae	Awaous tajasica	River goby
Pleuronectiformes	Soleidae	Trinectes maculatus	Hogchoker