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THE INFLUENCE OF SAVANNAH RIVER DISCHARGE AND CHANGING SRS COOLING WATER REQUIREMENTS ON THE POTENTIAL ENTRAINMENT OF ICHTHYOPLANKTON AT THE SRS SAVANNAH RIVER INTAKES (U)

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ABSTRACT

Entrainment (i.e., withdrawal of fish larvae and eggs in cooling water) at the SRS Savannah River intakes is greatest when periods of high river water usage coincide with low river discharge during the spawning season. American shad and striped bass are the two species of greatest concern because of their recreational and/or commercial importance and because they produce drifting eggs and larvae vulnerable to entrainment. In the mid-reaches of the Savannah River, American shad and striped bass spawn primarily during April and May. An analysis of Savannah River discharge during April and May 1973-1989 indicated the potential for entrainment of 4-18% of the American shad and striped bass larvae and eggs that drifted past the SRS. Average April and May entrainment rates would have consistently exceeded 12% during the low water years of 1985-1989. This analysis assumed the concurrent operation of L-, K-, and P-Reactors. Additional scenarios investigated were: 1) shutting down L- and P-Reactors, maintaining minimum flows to Steel Creek (required to protect aquatic habitat), and operating K-Reactor with a recycle cooling tower; and 2) shutting down L- and P-Reactors, eliminating minimum flows to Steel Creek, and operating K-Reactor with a recycle cooling tower. The former scenario reduced potential entrainment to 0.7-3.3%, and the latter scenario reduced potential entrainment to 0.2-0.8%. Thus, the currently favored scenario of operating K-Reactor with a cooling tower and not operating L- and P-Reactors represents a significant lessening of the impact of SRS operations. Entrainment can be further reduced by reducing the minimum flow requirements to Steel Creek.

INTRODUCTION

Cooling water for Savannah River Site (SRS) reactors and makeup water for Par Pond is pumped from the Savannah River at the 1G and 3G pumphouses (Figure 1). Ichthyoplankton (drifting fish larvae and eggs) from the river are entrained with the river water and passed through the reactor heat exchangers where temperatures may reach 70° C (Halverson et al. 1987) during full power operation. Ichthyoplankton mortality under such conditions is assumed to be 100%. The amount of ichthyoplankton entrained into the reactor cooling systems depends on the density and distribution of ichthyoplankton in the river, river discharge levels, and the volume of water withdrawn for cooling.

Savannah River discharge in the vicinity of the SRS (approximately RM 130 - 160) is largely determined by the release of water from J. Strom Thurmond Reservoir, an Army Corp of Engineers mainstream impoundment located at RM 237.7. During droughts, such as the one that occurred in late 1987 and in 1988, discharge from Lake Thurmond is very low resulting in low flows near the SRS. Under such conditions, the SRS is capable of removing a greater proportion of the river discharge and, therefore, a greater proportion of the ichthyoplankton drifting past the SRS. The greatest entrainment losses occur when periods of low flow are concurrent with periods of peak ichthyoplankton abundance.

The amount of cooling water needed for SRS operations is determined by the number of reactors in operation and by the operational mode of the reactors. During former times, the concurrent operation of L-, K-, and P-Reactors resulted in a total cooling water requirement of approximately 23.7 cubic meters per second (cms). Shutdown of L- and P-Reactors and conversion of the K-Reactor once-through cooling system to a recycle cooling system (upon completion of the K-cooling tower and tie in with K-Reactor) will reduce this quantity to approximately 2.6-4.1 cms. This quantity consists of approximately 1.1 cms for K-cooling tower operation and and 1.5-3.0 cms for the maintenance of fish habitat in Steel Creek. Three cms is provided during March through June to maintain spawning and nursery areas, and 1.5 cms is provided during the rest of the year.

Only fish that produce drifting eggs and larvae are likely to be impacted by entrainment. Most of the drifting eggs and larvae in the Savannah River are produced by two anadromous species, American shad (Alosa sapidissima) and striped bass (Morone saxatilis) (Paller et al. 1984, Paller et al 1985, Paller et al 1986). Both species are of high commercial and/or recreational value. The striped bass, in particular, is a highly esteemed sport fish. Because striped bass reproduction is decreasing in the tidal Savannah River, interest in mid Savannah River striped bass stocks is currently increasing (M. Van Den Avyle, personal communication). Current efforts to improve American shad populations in the Savannah River has generated considerable interest in this species as well.

The objectives of this report are to:

1) investigate the relationship between Savannah River discharge and the entrainment of American shad and striped bass at the SRS Savannah River intakes with special reference to the low flow conditions that existed during 1985 - 1989.
2) investigate the effects of declining cooling water requirements on the entrainment of striped bass and American shad at the SRS Savannah intakes.

SAVANNAH RIVER DISCHARGE LEVELS

The United States Geological Survey (USGS) maintains several gaging stations on the Savannah River. The Jackson Gaging Station (RM 156.8) is closest to the SRS intake canals (RMs 157.3 and 155.4) and provides the best measure of water flow past the intake canals. However, Savannah River discharges exceeding 616 cms (cubic meters per second) [22000 cfs(cubic feet per second)] cannot be accurately measured at the Jackson Gaging Station. Such flows inundate the broad Savannah River floodplain and are not tightly coupled with river stage. In this report, flows too high to measure were assumed to equal 616 cms, thus providing a conservatively low estimate of Savannah River discharge during high flow periods.

Figure 2 depicts yearly average and minimum discharges at the Jackson Gaging Station during 1973 - 1989. Minima are the lowest daily values recorded during each year. Average and, to a lesser extent, minimum discharges exhibit a general trend of decrease during 1973 - 1989. Particularly low flows occurred during 1981 - 1982 and during 1985 - 1989. Minimum yearly discharges were approximately 20 to 160 cms less than average yearly discharges; the largest differences occurred during high discharge years.

Figure 3 depicts average monthly, minimum monthly, and minimum daily discharges at the Jackson Gaging Station during 1973 - 1989. The minimum monthly discharge for each month is the lowest average monthly discharge observed for the month. The minimum daily discharge for each month is the lowest average daily discharge observed for the month. Minimum daily and minimum monthly discharges exhibited less seasonal change than average monthly discharges (Figure 2). The coefficients of variation for minimum daily and minimum monthly discharges were 10.0 and 9.6, respectively, in contrast to 23.9 for the average monthly discharge. Minimum daily flows are only slightly (average of 14.4%) lower than minimum monthly flows. The period of highest flow in the Savannah River extends from February through April.

TEMPORAL TRENDS IN AMERICAN SHAD AND STRIPED BASS ICHTHYOPLANKTON ABUNDANCE

American shad and striped bass ichthyoplankton were collected from the Savannah River on a weekly basis from February - July during 1982, 1983, 1984, and 1985 (ECS 1983, Paller et al. 1984, Paller et al 1985, Paller et al 1986) as part of an effort to assess the impacts of SRS operations on Savannah River fisheries resources. Ichthyoplankton were collected from a number of locations, including RM 155.4 and RM 157.3 which are located just upstream from the 1G and 3G intake canals, respectively. Over 90% of the ichthyoplankton of both species consisted of eggs rather than larvae.

Median monthly densities of American shad and striped bass ichthyoplankton at RMs 155.4 and 157.3 are shown in Figures 4 and 5, respectively. American shad densities peaked in April and May; relatively low densities were observed in March and June, and virtually no American shad were collected in other months. Striped bass densities peaked in May; relatively low densities were observed in April and no striped bass were collected in the remaining months. These data demonstrate that April and May are the months of maximum potential entrainment of American shad and striped bass ichthyoplankton at the SRS Savannah River water intakes.

RELATIONSHIP BETWEEN SAVANNAH RIVER DISCHARGE, COOLING WATER NEEDS AND PERCENT WATER WITHDRAWAL

Entrainment impacts at the SRS intakes are dependent upon the proportion of Savannah River water withdrawn during the period of ichthyoplankton occurrence. The proportion of Savannah River water withdrawn is dependent upon SRS water requirements in relation to Savannah River discharge levels. Three SRS water requirements were investigated in the following analysis:

1) 23.7 cms, the approximate amount of water required to operate K-Reactor and L-Reactor at full power in a once through cooling mode (approximately 11.2 cms each) and supply Par Pond with make-up water during the operation of P-Reactor (approximately 1.3 cms),

2) 4.1 cms, the approximate amount of water required to operate K-Reactor in a recycle cooling mode and meet the Steel Creek flow requirements,
3) 1.1 cms, the approximate amount of water required to operate K-Reactor with a recycle cooling tower.

Water requirement 1 prevailed in the past, water requirement 2 will prevail in the future upon completion of the K-cooling tower, and water requirement 3 is possible if minimum flow requirements for Steel Creek are renegotiated. The analysis includes only the months of April and May since striped bass and American shad ichthyoplankton are comparatively rare or absent at other times.

Figure 6 depicts the frequency of occurrence of different Savannah River discharge levels during April and May based on records taken from the Jackson gaging station during 1973 - 1989. It also depicts the percentage of river water that would be withdrawn at the SRS intakes (1G and 3G canals) at each Savannah River discharge level assuming water withdrawals of 23.7, 4.1, and 1.1 cms. Average monthly values rather than average daily values were used to construct Figure 6. The frequency of low average monthly discharges indicates the potential for prolonged periods of high withdrawal which are likely to have more serious impacts than short (i.e., daily) periods of high withdrawal. The use of average daily rather than average monthly discharges in Figure 6 would only have increased maximum withdrawal rates by a small proportion (from 16% to 18% in April and from 18% to 19% in May) due to the relatively small difference between minimum monthly discharges and minimum daily discharges (Figure 3).

Average monthly Savannah River discharges ranged from 153 cms to 572 cms in April and from 132 cms to 397 cms in May. The high values in the preceding ranges underestimate actual discharge levels because of the use of a conservative value to represent discharges in excess of 616 cms. Discharge was generally higher in April than in May as indicated by a comparison of the grand mean discharge for each month (349 cms in April and 251 cms in May). The maximum percentage of the Savannah River discharge that would be withdrawn at the SRS intakes at a water usage rate of 23.7 cms is 16% in April and 18% in May Figure 6). Relatively high withdrawals (≥ 12%) occurred when average monthly discharges were below 200 cms. Average discharges below 200 cms were observed during 5 out of the 17 years (29%) in April and during 7 out of the 17 years (41%) in May. Average April and May discharges below 200 cms occurred consistently during the low rainfall years of 1985 - 1989 (Figure 6). Average withdrawals during all 17 years included in the analysis were approximately 8.4% in April and 10.9% in May. Note that the preceding percent withdrawal rates are also equal to percent entrainment rates assuming that the larvae and eggs are homogeneously distributed vertically and horizontally near the intake canals.

Reduction of SRS water requirements to 4.1 cms by shutting down L- and P-Reactors, operating K-Reactor with a recycle cooling tower, and maintaining minimum flow requirements to Steel Creek decreased percentage withdrawals to a maximum of 2.7%% in April and 3.3% in May. Average withdrawals for all 17 years assuming a water requirement of 4.1 cms were 1.5% in April and 1.9% in May. Further reduction of Savannah River water withdrawals to 1.1 cms by eliminating Steel Creek flow requirements reduced the withdrawal percentage to a maximum of approximately 0.7% in April and 0.8% in May. Average withdrawals for all 17 years assuming a water requirement of 1.1 cms were approximately 0.4% in April and 0.5% in May.

Understanding the relationship between SRS water requirements, Savannah River discharge, and percent withdrawal permits entrainment to be estimated but does not provide a complete understanding of entrainment impacts on American shad and striped bass stocks because population level impacts are influenced by a variety of factors. However, it is obvious that any mitigation measure that reduces entrainment is likely to make the continued operation of the SRS water intakes more acceptable from an environmental perspective. The currently favored scenario of operating K-Reactor with a cooling tower and not operating L- and P-Reactors reduces entrainment far below previous levels and represents a significant lessening of the impact of SRS operations. Entrainment can be further reduced by eliminating the minimum flow requirements to Steel Creek. The latter step would necessitate a predictive assessment of the impacts of reduced flows on aquatic organisms in Steel Creek and, if warranted by the results of the predictive assessment, renegotiation of the 1984 agreement between DOE and SCDHEC.

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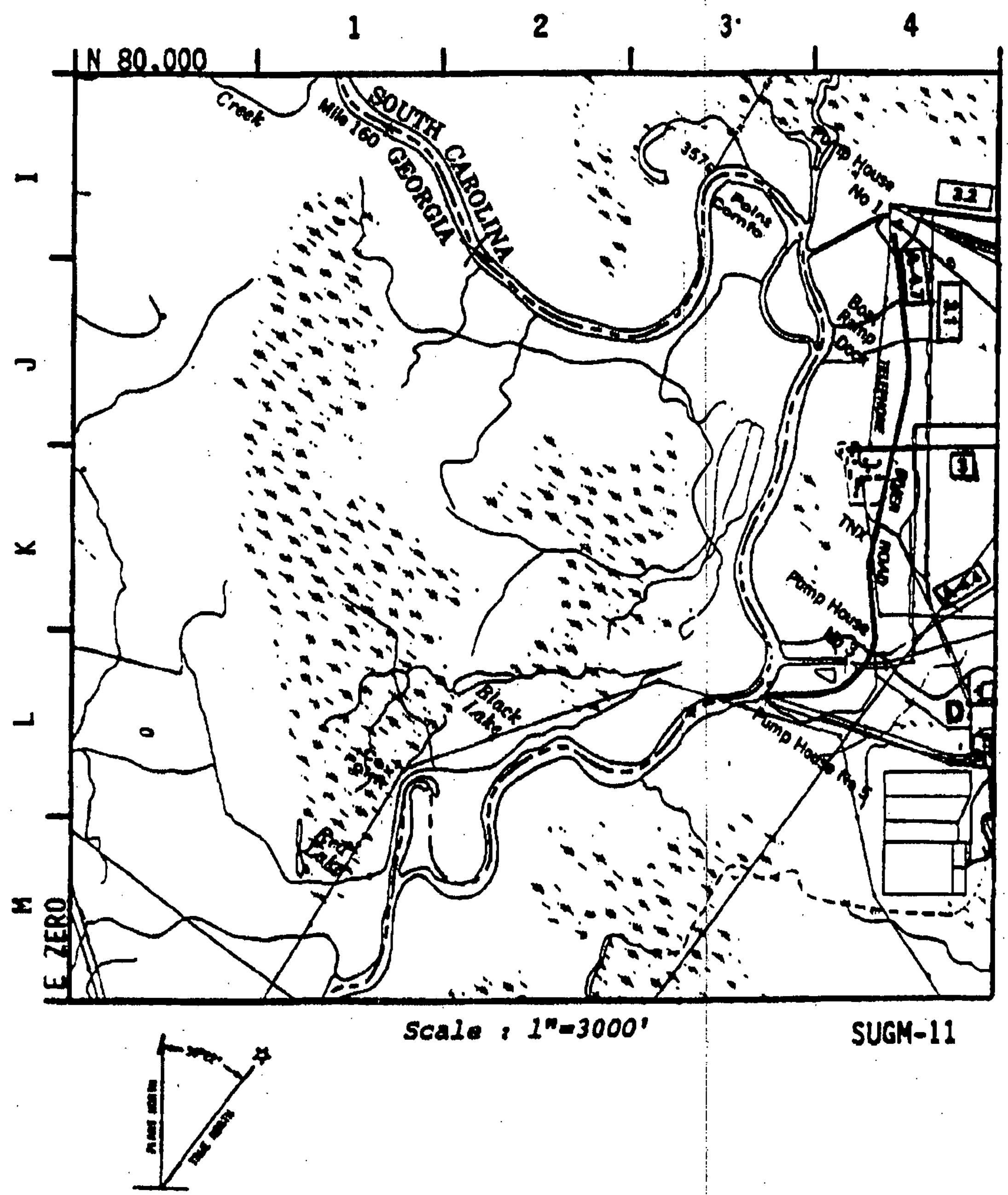

Figure 1. Map of the Savannah River Site (SRS) showing the location of the pump house intakes on the Savannah River.

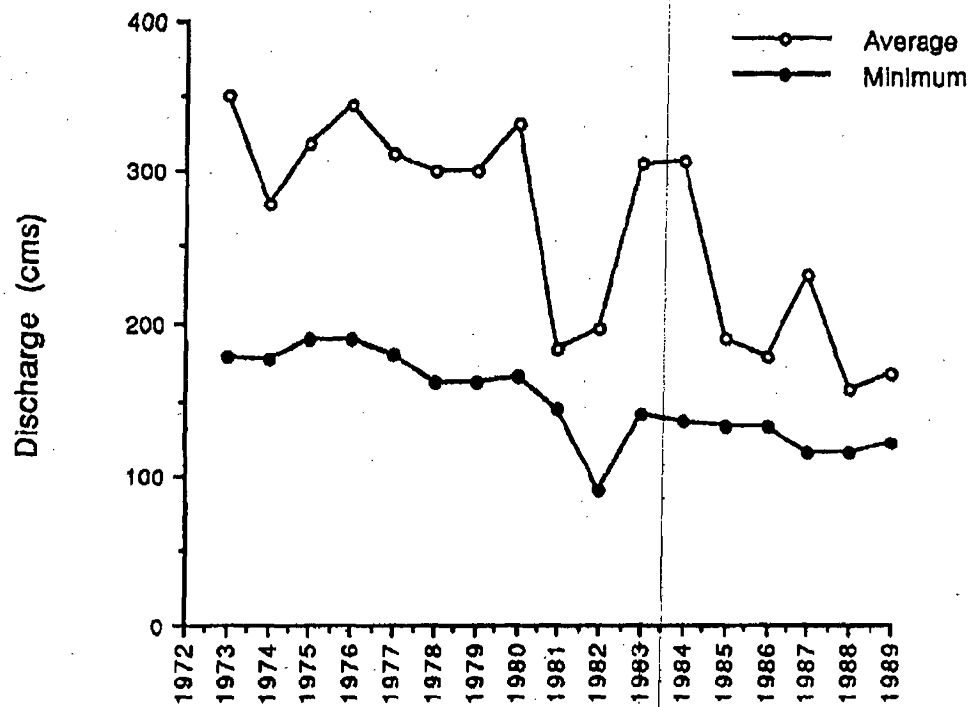

Figure 2. Average yearly and minimum daily flows in the Savannah River near the Jackson gaging station (RM 156.8) during 1973 - 1989.

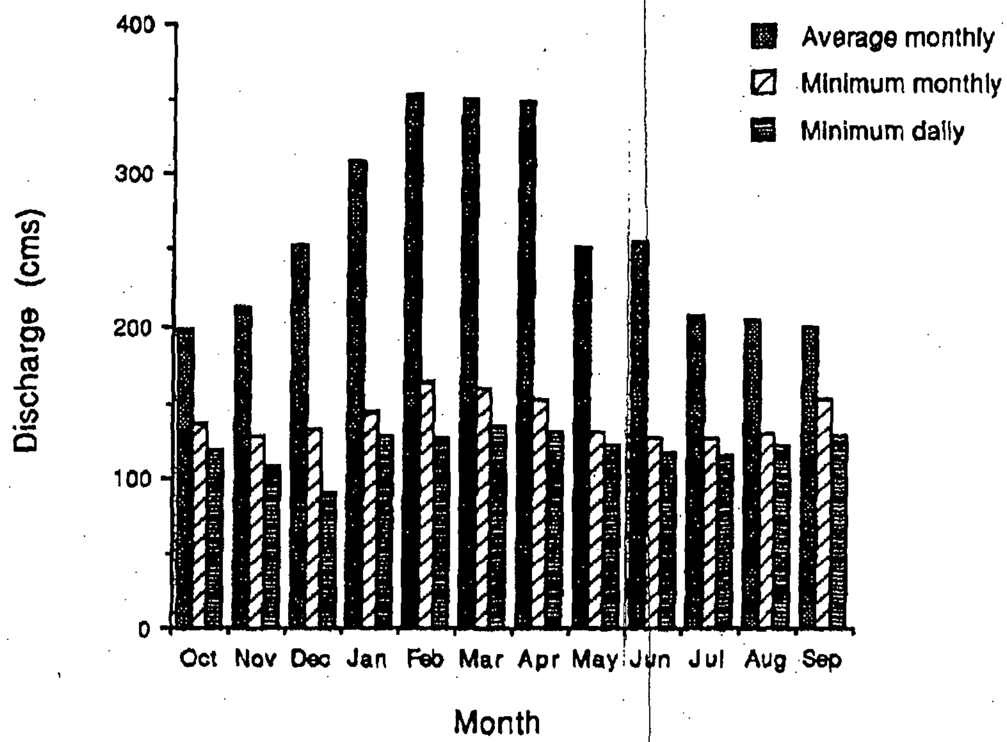

Figure 3. Average monthly, minimum monthly, and minimum daily discharges in the Savannah River near the Jackson gaging station (RM 156.8) during 1973 - 1989.

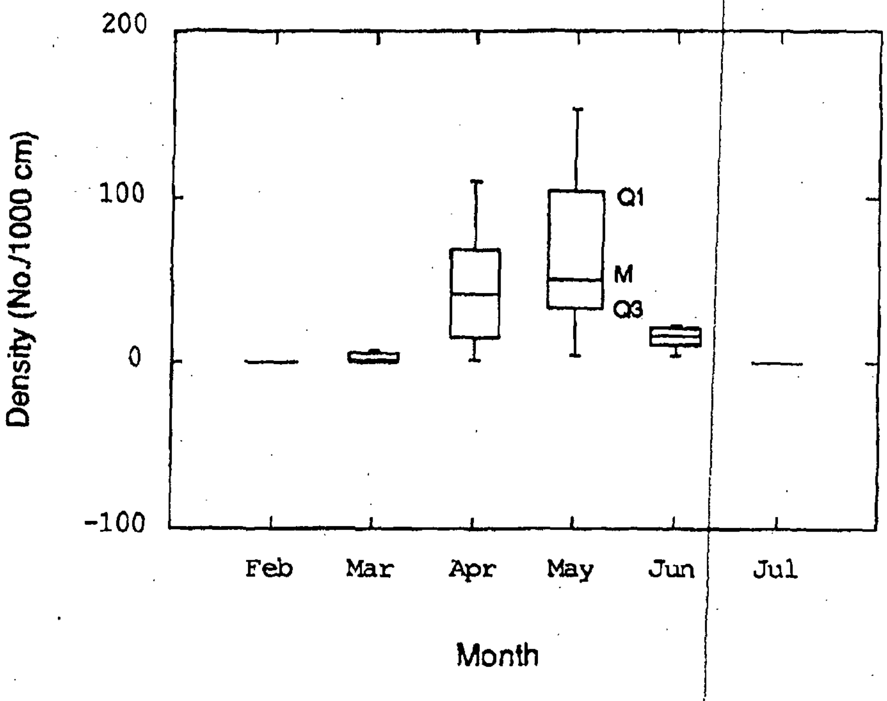

Figure 4. Box plot showing monthly median (M), first quartile (Q1), third quartile (Q3), and range of American shad ichthyoplankton densities (number/1000 cubic meters) during 1982 - 1985.