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ALABAMA POWER COMPANY

COOSA AND WARRIOR RIVER PROJECTS

E11 – Impingement, Entrainment, and Turbine Mortality Study Progress Report

May, 2002

Prepared by:

KLEINSCHMIDT ASSOCIATES
Energy and Water Resource Consultants

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E11 - IMPINGEMENT, ENTRAINMENT, AND TURBINE MORTALITY STUDY PROGRESS REPORT

1.0 INTRODUCTION

Stakeholders of the Coosa and Warrior Relicensing Teams have identified fish impingement, entrainment, and turbine mortality as an issue to address during relicensing of the Coosa (FERC No. 2146 – Weiss, Neely Henry, Logan Martin, Lay, and Bouldin), Mitchell (FERC No. 82) and Jordan (FERC No. 618) Projects (Coosa River Projects), and the Warrior Project (FERC No. 2165 – Smith and Bankhead). Therefore, the E11 Issue Action Group (IAG) was formed to identify methods to address this issue.

The IAG met on January 30, 2002 to discuss potential methods to address the issue and agreed to evaluate the potential magnitude of fish impingement, entrainment, and turbine mortality using a combination of existing entrainment and turbine mortality literature and site-specific information. On March 7, 2002, APC distributed the Draft E11 Entrainment Study Plan (Study Plan). The IAG met on March 12, 2002 to discuss the proposed methodology outlined in the draft Study Plan. The IAG members indicated that, after some minor changes, the Study Plan is acceptable.

This report is a summary of the study progress to date.

2.0 STUDY PROGRESS

2.1 Impingement

Analysis of potential impingement at the projects will require several inputs: trash rack spacing, intake velocity, and species-size composition. Trash rack spacing and intake velocities are currently being verified by Alabama Power personnel. Fish species-size composition will be based on information from ADCNR management reports or other fisheries reports in conjunction with the entrainment estimates for each project.

Once these inputs have been developed, intake velocities and trash rack spacing will then be compared with the swimming speeds and body widths of fish species at the projects to determine which species and sizes of fish, if any, are susceptible to impingement. This qualitative analysis may be supplemented by plant operator observations, as stated in the Study Plan.

2.1 Entrainment

2.2.1 Entrainment Database

At the March 13, 2002 meeting, IAG members discussed the entrainment database provided in the Study Plan. Some IAG members requested additional information about several studies listed in the entrainment database. Summaries of those studies are provided in Appendix A of this report.

Additional information on studies in the entrainment database has been gathered and organized. Specifically, entrainment rates from most of the studies in the database have been converted to volumetric rates (i.e., fish per million cubic feet of water) and organized by month. This information is presented in Table 1. This information will be used to determine the average entrainment rates by season and year for each project.

2.2.3 Calculation of the Entrainment Estimate

After the IAG has agreed upon the appropriate monthly or annual entrainment rates that will be used at each of the projects, a stepwise calculation process will be employed to estimate fish entrainment. This process consists of the following steps:

Step 1 – Total number of fish entrained by month

The total number of fish entrained by each project is based on two parameters: seasonal fish entrainment rate (fish per million cubic feet (mcf) of water) and project operation (mcf of water passed through the turbines – average flow during normal water years). To calculate the total number of fish entrained by month, multiply the appropriate seasonal rate by the appropriate monthly flow.

*Example: 5.0 fish/mcf of water * 1,000 mcf = 5,000 fish*

Step 2 – Total number of fish entrained by season

To calculate the total number of fish entrained by Season, sum the total number of fish entrained per month (from Step 1) for each season according to the following:

Winter = December, January, February
Spring = March, April, May
Summer = June, July, August
Fall = September, October, November

Step 3 – Number of entrained fish within each family/genus-group by Season

The percentages for each family/genus-group will be based on ADCNR fish collection data, species composition from the entrainment

database, and IAG recommendations. The composition of entrained fish will be represented as a percentage (e.g., Lepomids = 25%, Micropterans = 10%, Ictalurids = 9%, etc.) for each season. To calculate the number of entrained fish within each family/genus-group by season, the total number of entrained fish by season (from Step 2) will be multiplied by the family/genus-group composition percentages.

Example: *Total number of fish entrained in Spring = 100,000*
Spring composition percentage of Lepomids = 25%
*100,000 * 0.25 = 25,000 Lepomids entrained in Spring*

Step 4 – Number of entrained fish within each 25mm (1-inch) length-group for each family/genus-group by season

The size composition breakdown for each family/genus-group will be based on ADCNR fish collection data, size breakdown from the entrainment database, and IAG recommendations. The size composition of each family/genus-group of entrained fish will be represented as a percentage (e.g., Lepomids: 0-25mm = 20%, 26-50mm = 30%, 51-75mm = 30%, 76-100mm = 10%, and 101-125mm = 10%) for each season. To calculate the number of entrained fish within each 25mm length-group for each family/genus-group by season, the total number of fish in each family/genus-group for each season will be multiplied by the appropriate seasonal size composition percentage.

EXAMPLE	*Lepomids – Estimated Spring Entrainment = 25,000 fish*	
Length Group	*Spring Size Composition*	*Number of Fish*
0 – 25mm	*0.20*	*5,000*
26 – 50mm	*0.30*	*7,500*
51 – 75mm	*0.30*	*7,500*
76 – 100mm	*0.10*	*2,500*
101-125mm	*0.10*	*2,500*
Totals	*1.0 (100%)*	*25,000*

Step 5 – Total number of entrained fish by family/genus-group by length-group by year

To calculate the number of entrained fish in each family/genus-group and length-group by year, the results of Step 4 will simply be summed for each species for the entire year.

2.3 Turbine Mortality

At the March 13, 2002 meeting, IAG members discussed the mortality database provided in the study plan. Some IAG members identified additional studies and suggested they be included in the database. Although turbine mortality analysis can not be performed until the entrainment estimates are completed, additional information on identified turbine mortality studies in the database are provided in Tables 2 and 3 of this document. Additional information on mortality studies in the database will be gathered as the study moves forward.

Table 1. Entrainment rate information from studies entrainment database

	Entrainemnt Rates (fish/million cubic feet of water)												
Site Name	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG.
Ninety-nine Islands	2.8	5.6	0.8	2.1	4.5	4.5	4.5	4.5	2.7	5.5	3.3	0	3.4
Gaston Shoals	1.3	1.4	0.6	5	1.5	8.8	9	8.3	3.6	2.3	0.4	0.5	3.6
Neals Shoals	-	-	6.7	-	9.5	7.7	-	4.6	-	4.0	-	0.9	5.6
Hollidays Bridge	2.2	0.8	6.5	3.7	11.6	7.1	7.1	7.1	2.9	3.1	1.2	3.3	4.7
Saluda Hydro.	2.2	5.4				10.1	8.1	5.8	5.5	12.6	4.8	5.4	6.7
High Falls	-	-	-	-	-	-	-	-	-	-	-	-	-
Richard B. Russell	6.8	33.6	1.0	1.2	0.5	0.3	0.5	1.3	0.6	0.4	2.6	1.1	4.1
Steven's Creek	-	-	-	-	-	-	-	-	-	-	-	-	-
King Mill	-	-	7.3	4.0	5.2	3.1	3.4	3.6		8.2	4.7		4.9
Moore's Park	0.2	0.8	3.5	7.6	2.9	3.2	5.7	15.6	6.4	3.8	0.2	0.6	4.2
La Barge	-	-	-	-	-	-	-	-	-	-	-	-	-
Kleber		0.82	0.44	51.6	2.89	2.31	3.04	5.38	11.03	14.74	5.16	1.38	9.0
Average	2.6	6.9	3.4	10.7	4.8	5.2	5.2	6.2	4.7	6.1	2.8	1.7	5.1

Table 2. Physical and Hydraulic Characteristics of all Hydroelectric Dams Equipped with Kaplan/Propeller Type Turbines for Which Survival Data are Available

Station	Sampling Method	Species Tested	Treatment Sample Size	Control Sample Size	Avg. Fish Length (mm)	Turbine Flow (cfs)	No. of Blades	Runner Speed (rpm)	Head (ft)	Runner Dia. (in)	Est. Percent Survival
Annapolis, NS	Radio telemetry	American shad	20	39	Adult	14,287	-	50	22	267	53.7
Chalk Hill, MI-WI	HI-Z Turb'N Tag	Bluegill	60	43	103	1,330	4	150	29	102	97.0
Chalk Hill, MI-WI	HI-Z Turb'N Tag	Bluegill	50	67	153	1,330	4	150	29	102	98.0
Chalk Hill, MI-WI	HI-Z Turb'N Tag	W. Sucker/R. Trout	77	70	119	1,330	4	150	29	102	91.0
Chalk Hill, MI-WI	HI-Z Turb'N Tag	W. Sucker/R. Trout	38	45	261	1,330	4	150	29	102	97.0
Conowingo, MD	HI-Z Turb'N Tag	American Shad	108	108	125	8,000	6	120	90	225	94.9
Craggy Dam, NC	HI-Z Turb'N Tag	Channel Catfish	43	28	180	600	4	229	21	69	93.0
Craggy Dam, NC	HI-Z Turb'N Tag	Channel Catfish	63	28	180	200	4	229	-	69	90.0
Craggy Dam, NC	HI-Z Turb'N Tag	Channel Catfish	39	22	277	200	4	229	-	69	81.0
Craggy Dam, NC	HI-Z Turb'N Tag	Bluegill	33	40	100	200	4	229	-	69	96.0
Craggy Dam, NC	HI-Z Turb'N Tag	Channel Catfish	32	22	277	600	4	229	-	69	93.0
Craggy Dam, NC	HI-Z Turb'N Tag	Bluegill	72	54	155	200	4	229	-	69	86.0
Crescent, NY	HI-Z Turb'N Tag	Blueback Herring	125	125	91	1,520	5	144	27	108	96.0
Greenup Dam, OH	Radio telemetry	Sauger	48	NA	231	11,866	5	90	30	240	85.4
Hadley Falls, MA	Radio telemetry	American Shad	36	69	560	4,200	5	128	52	170	78.2
Hadley Falls, MA	HI-Z Turb'N Tag	American Shad	100	100	82	4,200	5	128	52	170	97.3
Hadley Falls, MA	HI-Z Turb'N Tag	American Shad	100	100	82	1,550	5	128	-	170	100.0
Hadley Falls, MA	HI-Z Turb'N Tag	American Shad	120	120	82	4,200	5	150	-	170	89.1
Herrings, NY	Full discharge netting	Centrarchid	74	65	<100	1,200	-	138	19	113	98.3
Herrings, NY	Full discharge netting	Centrarchid	77	63	175	1,200	-	138	19	113	97.3
Herrings, NY	Full discharge netting	Centrarchid	80	65	>250	1,200	-	138	19	113	93.2
Herrings, NY	Full discharge netting	Percid	46	51	<100	1,200	-	138	19	113	91.1
Herrings, NY	Full discharge netting	Centrarchid	90	65	<100	1,200	-	138	19	113	95.0
Herrings, NY	Full discharge netting	Centrarchid	90	69	100-250	1,200	-	138	19	113	96.4
Herrings, NY	Full discharge netting	Centrarchid	90	77	>250	1,200	-	138	19	113	92.5
Herrings, NY	Full discharge netting	Percid	185	78	<100	1,200	-	138	19	113	94.9
Herrings, NY	Full discharge netting	Percid	179	139	100-250	1,200	-	138	19	113	98.2
Herrings, NY	Full discharge netting	Percid	138	137	>250	1,200	-	138	19	113	96.2
Herrings, NY	Full discharge netting	Soft ray	188	144	<100	1,200	-	138	19	113	97.5
Herrings, NY	Full discharge netting	Soft ray	201	159	100-250	1,200	-	138	19	113	91.7
Herrings, NY	Full discharge netting	Soft ray	175	125	>250	1,200	-	138	19	113	85.1
Herrings, NY	Full discharge netting	Clupeids	196	166	<100	1,200	-	138	19	113	92.8
Marshall, NC	Partial netting	Resident	2,544	2,544	-	1,250	-	212	31.4	149.4	92.3
Morrow, MI (EPRI)	Full discharge netting	Resident	764	220	-	235	-	175	12	54	92.1
Morrow, MI	Full discharge netting	Bluegill	218	59	Adult\YOY	235	-	175	12	54	70.0
Morrow, MI	Full discharge netting	Brown Bullhead	117	39	Adult	235	-	175	12	54	97.0
Morrow, MI	Full discharge netting	Pumpkinseed	88	22	Adult\YOY	235	-	175	12	54	90.0
Morrow, MI	Full discharge netting	Black Crappie	90	33	Adult\YOY	235	-	175	12	54	74.0
Morrow, MI	Full discharge netting	White Sucker	64	29	Adult\YOY	235	-	175	12	54	67.0
Morrow, MI	Full discharge netting	Yellow Perch	39	5	Adult	235	-	175	12	54	78.0
Morrow, MI	Full discharge netting	Redhorse	31	10	Adult	235	-	175	12	54	71.0
Morrow, MI	Full discharge netting	Largemouth Bass	24	5	Adult	235	-	175	12	54	81.0
Morrow, MI	Full discharge netting	Northern Pike	21	1	Adult	235	-	175	12	54	45.0
Morrow, MI	Full discharge netting	Yellow Bullhead	39	5	Adult	235	-	175	12	54	92.0
Raymondville, NY	Full discharge netting	Eel	-	-	625	1,640	6	120	21	131	63.0
Thornapple, WI	Full discharge netting	Indigenous sp	3,378	-	-	700	6	120	15	110	95.3

Table 2. Physical and Hydraulic Characteristics of all Hydroelectric Dams Equipped with Kaplan/Propeller Type Turbines for Which Survival Data are Available
Continued

Station	Sampling Method	Species Tested	Treatment Sample Size	Control Sample Size	Avg. Fish Length (mm)	Turbine Flow (cfs)	No. of Blades	Runner Speed (rpm)	Head (ft)	Runner Dia. (in)	Est. Percent Survival
Thornapple, WI	Full discharge netting	Bullheads & Catfish	-	-	-	-	6	120	-	110	91.9
Thornapple, WI	Full discharge netting	Suckers & Redhorse	-	-	-	-	6	120	-	110	93.4
Thornapple, WI	Full discharge netting	Panfish & Y. Perch	-	-	-	-	6	120	-	110	93.5
Thornapple, WI	Full discharge netting	N. Pike & Muskllng	-	-	-	-	6	120	-	110	94.1
Thornapple, WI	Full discharge netting	Burbot	-	-	-	-	6	120	-	110	96.9
Thornapple, WI	Full discharge netting	Minnow/Dace/Darter	-	-	-	-	6	120	-	110	97.1
Thornapple, WI	Full discharge netting	Small/ Largemth Bass	-	-	-	-	6	120	-	110	97.4
Thornapple, WI	Full discharge netting	Walleye	-	-	-	-	6	120	-	110	97.6
Townsend Dam, PA	HI-Z Turb'N Tag	Largemouth Bass	31	NA	217	1,500	3	152	16	113	96.8
Townsend Dam, PA	HI-Z Turb'N Tag	Largemouth Bass	51	50	102	800	3	152	16	113	100.0
Townsend Dam, PA	HI-Z Turb'N Tag	Largemouth Bass	50	50	217	800	3	152	16	113	86.0
Twin Branch, IN	Full discharge netting	Bluegill	300	300	126	411	4	241	21.4	NA	94.7

Table 3. Physical and Hydraulic Characteristics of all Hydroelectric Dams Equipped with Francis Type Turbines for Which Survival Data are Available

Station	Sampling Method	Species Tested	Treatment Sample Size	Control Sample Size	Avg. Fish Length (mm)	Turbine Flow (cfs)	No. of Blades	Runner Speed (rpm)	Head (ft)	Runner Dia. (in)	Est. Percent Survival
Alcona, MI	Full Discharge Netting	bluegill	-	-	58 - 154	615	16	90	43	100	90.0
Alcona, MI	Full Discharge Netting	bluegill	-	-	95 - 206	615	16	90	43	100	84.0
Alcona, MI	Full Discharge Netting	white sucker	-	-	111 - 278	615	16	90	43	100	94.0
Alcona, MI	Full Discharge Netting	white sucker	-	-	161 - 395	615	16	90	43	100	90.0
Alcona, MI	Full Discharge Netting	golden shiner	-	-	65 - 129	615	16	90	43	100	81.0
Alcona, MI	Full Discharge Netting	golden shiner	-	-	101 - 188	615	16	90	43	100	85.0
Alcona, MI	Full Discharge Netting	spottail shiner	-	-	81 - 128	615	16	90	43	100	59.0
Alcona, MI	Full Discharge Netting	white sucker	-	-	111 - 278	615	16	90	43	100	94.0
Alcona, MI	Full Discharge Netting	white sucker	-	-	161 - 395	615	16	90	43	100	90.0
Columbia, SC	HI-Z Turb'N Tag	blueback herring	100	100	140	833	14	164	28	64	88.1
Columbia, SC	HI-Z Turb'N Tag	Lepomids	100	100	107	833	14	164	28	64	95.9
Columbia, SC	HI-Z Turb'N Tag	channel catfish	95	65	143	833	14	164	28	64	92.5
E.J. West, NY	Full Discharge Netting	centrarchiforms	-	-	small	2,700	15	113	63	131	72.0
E.J. West, NY	Full Discharge Netting	centrarchiforms	-	-	medium	2,700	15	113	63	131	85.0
E.J. West, NY	Full Discharge Netting	centrarchiforms	-	-	large	2,700	15	113	63	131	60.0
E.J. West, NY	Full Discharge Netting	percid	-	-	small	2,700	15	113	63	131	51.0
E.J. West, NY	Full Discharge Netting	soft ray	-	-	small	2,700	15	113	63	131	32.0
E.J. West, NY	Full Discharge Netting	soft ray	-	-	medium	2,700	15	113	63	131	71.0
E.J. West, NY	Full Discharge Netting	soft ray	-	-	large	2,700	15	113	63	131	68.0
Finch Pruyn, NY (Unit 4)	Full Discharge Netting	smallmouth bass	-	-	<191	920	-	225	48	41	95.0
Finch Pruyn, NY (Unit 4)	Full Discharge Netting	smallmouth bass	-	-	191 - 229	920	-	225	48	41	91.0
Finch Pruyn, NY (Unit 4)	Full Discharge Netting	smallmouth bass	-	-	236 - 305	920	-	225	48	41	93.0
Finch Pruyn, NY (Unit 5)	Full Discharge Netting	smallmouth bass	-	-	<191	920	-	225	48	41	94.0
Finch Pruyn, NY (Unit 5)	Full Discharge Netting	smallmouth bass	-	-	191 - 229	920	-	225	48	41	91.0
Finch Pruyn, NY (Unit 5)	Full Discharge Netting	smallmouth bass	-	-	236 - 305	920	-	225	48	41	71.0
Five Channels, MI	Full Discharge Netting	centrarchiforms	-	-	72 - 189	1,034 - 1,167	16	150	36	55	94.0
Five Channels, MI	Full Discharge Netting	centrarchiforms	-	-	113 - 244	1,034 - 1,167	16	150	36	55	89.0
Five Channels, MI	Full Discharge Netting	percid	-	-	<152	1,034 - 1,167	16	150	36	55	72.0
Five Channels, MI	Full Discharge Netting	percid	-	-	>152	1,034 - 1,167	16	150	36	55	76.9
Five Channels, MI	Full Discharge Netting	golden shiner	-	-	62 - 153	1,034 - 1,167	16	150	36	55	82.0
Five Channels, MI	Full Discharge Netting	golden shiner	-	-	111 - 207	1,034 - 1,167	16	150	36	55	85.0
Five Channels, MI	Full Discharge Netting	white sucker	-	-	81 - 241	1,034 - 1,167	16	150	36	55	89.0
Five Channels, MI	Full Discharge Netting	white sucker	-	-	225 - 442	1,034 - 1,167	16	150	36	55	71.0
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	bluegill	-	-	76	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	bluegill	-	-	127	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	bluegill	-	-	178	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	white sucker	-	-	76	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	white sucker	-	-	127	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	white sucker	-	-	178	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	white sucker	-	-	229	645	16	90	-	-	91.4
Grand Rapids, WI (Units 1,2, & 4 comb.)	Full Discharge Netting	white sucker	-	-	292	645	16	90	-	-	91.4
Hardy, MI (Unit 2)	Full Discharge Netting	bluegill	-	-	79 - 149	510	16	163.6	100.2	83.75	89.0
Hardy, MI (Unit 2)	Full Discharge Netting	bluegill	-	-	120 - 186	510	16	163.6	100.2	83.75	91.0

Table 3. Physical and Hydraulic Characteristics of all Hydroelectric Dams Equipped with Francis Type Turbines for Which Survival Data are Available (Continued)

Station	Sampling Method	Species Tested	Treatment Sample Size	Control Sample Size	Avg. Fish Length (mm)	Turbine Flow (cfs)	No. of Blades	Runner Speed (rpm)	Head (ft)	Runner Dia. (in)	Est. Percent Survival
Hardy, MI (Unit 2)	Full Discharge Netting	largemouth bass	-	-	80 - 162	510	16	163.6	100.2	83.75	76.0
Hardy, MI (Unit 2)	Full Discharge Netting	white sucker	-	-	96 - 237	510	16	163.6	100.2	83.75	77.0
Hardy, MI (Unit 2)	Full Discharge Netting	white sucker	-	-	137 - 375	510	16	163.6	100.2	83.75	64.0
Hardy, MI (Unit 2)	Full Discharge Netting	golden shiner	-	-	74 - 165	510	16	163.6	100.2	83.75	85.0
Hardy, MI (Unit 2)	Full Discharge Netting	golden shiner	-	-	113 - 204	510	16	163.6	100.2	83.75	89.0
Hollidays Bridge, SC	balloon tag	catfish	25	25	152 - 228	-	-	200	42	-	100.0
Hollidays Bridge, SC	balloon tag	catfish	25	25	229 - 305	-	-	200	42	-	100.0
Hollidays Bridge, SC	balloon tag	catfish	28	25	152 - 228	-	-	200	42	-	93.0
Hollidays Bridge, SC	balloon tag	catfish	25	25	229 - 305	-	-	200	42	-	96.0
Holtwood, PA (Unit 3 - double runner)	Full Discharge Netting	American shad	-	-	95 - 163	3,500	17	102.8	62	112	60.0
Minetto, NY (Unit 3)	Full Discharge Netting	bluegill	92	112	80 - 116	1,500	16	72	17	139	81.4
Minetto, NY (Unit 3)	Full Discharge Netting	largemouth bass	108	101	141 - 310	1,500	16	72	17	139	90.7
Minetto, NY (Unit 3)	Full Discharge Netting	largemouth bass	88	84	165 - 348	1,500	16	72	17	139	87.4
Minetto, NY (Unit 3)	Full Discharge Netting	yellow perch	44	66	64 - 119	1,500	16	72	17	139	65.3
Minetto, NY (Unit 3)	Full Discharge Netting	white sucker	89	115	114 - 215	1,500	16	72	17	139	99.1
Minetto, NY (Unit 3)	Full Discharge Netting	white sucker	87	119	177 - 280	1,500	16	72	17	139	81.5
Minetto, NY (Unit 4)	Full Discharge Netting	largemouth bass	126	130	150 - 205	1,500	16	72	17	139	73.7
Minetto, NY (Unit 4)	Full Discharge Netting	largemouth bass	77	130	236 - 323	1,500	16	72	17	139	83.4
Minetto, NY (Unit 4)	Full Discharge Netting	yellow perch	89	138	51 - 93	1,500	16	72	17	139	85.4
Minetto, NY (Unit 4)	Full Discharge Netting	walleye	121	131	132 - 215	1,500	16	72	17	139	94.5
Minetto, NY (Unit 4)	Full Discharge Netting	walleye	122	87	135 - 210	1,500	16	72	17	139	95.7
Minetto, NY (Unit 4)	Full Discharge Netting	white sucker	128	127	70 - 111	1,500	16	72	17	139	90.7
Minetto, NY (Unit 4)	Full Discharge Netting	white sucker	122	135	71 - 105	1,500	16	72	17	139	74.0
Minetto, NY (Unit 4)	Full Discharge Netting	white sucker	125	128	141 - 260	1,500	16	72	17	139	89.3
Minetto, NY (Unit 4)	Full Discharge Netting	white sucker	90	131	212 - 285	1,500	16	72	17	139	87.4
Minetto, NY (Unit 4)	Full Discharge Netting	American eel	107	172	547 - 705	1,500	16	72	17	139	93.6
Ninety-Nine Islands, SC	balloon tag	catfish	27	25	152 - 228	665	-	225	72	-	89.0
Ninety-Nine Islands, SC	balloon tag	catfish	26	25	229 - 305	665	-	225	72	-	88.0
Ninety-Nine Islands, SC	balloon tag	catfish	26	25	152 - 228	665	-	225	72	-	100.0
Ninety-Nine Islands, SC	balloon tag	catfish	24	27	229 - 305	665	-	225	72	-	100.0
Peshtigo, WI (Unit 4)	Full Discharge Netting	centrarchiforms	-	-	<152	460	-	100	13	80	99.5
Peshtigo, WI (Unit 4)	Full Discharge Netting	centrarchiforms	-	-	>152	460	-	100	13	80	100.0
Peshtigo, WI (Unit 4)	Full Discharge Netting	percid	-	-	<152	460	-	100	13	80	99.5
Peshtigo, WI (Unit 4)	Full Discharge Netting	percid	-	-	>152	460	-	100	13	80	100.0
Peshtigo, WI (Unit 4)	Full Discharge Netting	cyprinid	-	-	<152	460	-	100	13	80	93.9
Peshtigo, WI (Unit 4)	Full Discharge Netting	cyprinid	-	-	>152	460	-	100	13	80	90.1
Peshtigo, WI (Unit 4)	Full Discharge Netting	ictalurid	-	-	<152	460	-	100	13	80	93.9
Peshtigo, WI (Unit 4)	Full Discharge Netting	ictalurid	-	-	>152	460	-	100	13	80	90.1
Peshtigo, WI (Unit 4)	Full Discharge Netting	catastomid	-	-	<152	460	-	100	13	80	93.9
Peshtigo, WI (Unit 4)	Full Discharge Netting	catastomid	-	-	>152	460	-	100	13	80	90.1
Potato Rapids, WI	Full Discharge Netting	centrarchiforms	-	-	<152	500	-	123	17	84	90.5
Potato Rapids, WI	Full Discharge Netting	centrarchiforms	-	-	>152	500	-	123	17	84	91.3
Potato Rapids, WI	Full Discharge Netting	percid	-	-	<152	500	-	123	17	84	90.5

Table 3. Physical and Hydraulic Characteristics of all Hydroelectric Dams Equipped with Francis Type Turbines for Which Survival Data are Available (Continued)

Station	Sampling Method	Species Tested	Treatment Sample Size	Control Sample Size	Avg. Fish Length (mm)	Turbine Flow (cfs)	No. of Blades	Runner Speed (rpm)	Head (ft)	Runner Dia. (in)	Est. Percent Survival
Potato Rapids, WI	Full Discharge Netting	percid	-	-	>152	500	-	123	17	84	91.3
Potato Rapids, WI	Full Discharge Netting	cyprinid	-	-	<152	500	-	123	17	84	78.0
Potato Rapids, WI	Full Discharge Netting	cyprinid	-	-	>152	500	-	123	17	84	63.1
Potato Rapids, WI	Full Discharge Netting	catastomid	-	-	<152	500	-	123	17	84	78.0
Potato Rapids, WI	Full Discharge Netting	catastomid	-	-	>152	500	-	123	17	84	63.1
Potato Rapids, WI	Full Discharge Netting	ictalurid	-	-	<152	500	-	123	17	84	78.0
Potato Rapids, WI	Full Discharge Netting	ictalurid	-	-	>152	500	-	123	17	84	63.1
Rogers, MI (Units 1 & 2)	Full Discharge Netting	bluegill	-	-	46 - 155	383	15	150	39	60	96.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	bluegill	-	-	108 - 180	383	15	150	39	60	85.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	largemouth bass	-	-	74 - 139	383	15	150	39	60	77.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	percid	-	-	<152	383	15	150	39	60	91.8
Rogers, MI (Units 1 & 2)	Full Discharge Netting	percid	-	-	>152	383	15	150	39	60	87.2
Rogers, MI (Units 1 & 2)	Full Discharge Netting	golden shiner	-	-	70 - 114	383	15	150	39	60	54.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	golden shiner	-	-	103 -173	383	15	150	39	60	92.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	spottail shiner	-	-	58 - 174	383	15	150	39	60	73.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	white sucker	-	-	82 - 219	383	15	150	39	60	81.0
Rogers, MI (Units 1 & 2)	Full Discharge Netting	white sucker	-	-	162 - 413	383	15	150	39	60	86.0
Sandstone Rapids, WI	Full Discharge Netting	centrarchiforms	-	-	<152	-	-	150	42	87	89.9
Sandstone Rapids, WI	Full Discharge Netting	centrarchiforms	-	-	>152	-	-	150	42	87	79.9
Sandstone Rapids, WI	Full Discharge Netting	cyprinid	-	-	<152	-	-	150	42	87	75.0
Sandstone Rapids, WI	Full Discharge Netting	cyprinid	-	-	>152	-	-	150	42	87	62.8
Sandstone Rapids, WI	Full Discharge Netting	ictalurid	-	-	<152	-	-	150	42	87	75.0
Sandstone Rapids, WI	Full Discharge Netting	ictalurid	-	-	>152	-	-	150	42	87	62.8
Sandstone Rapids, WI	Full Discharge Netting	catastomid	-	-	<152	-	-	150	42	87	75.0
Sandstone Rapids, WI	Full Discharge Netting	catastomid	-	-	>152	-	-	150	42	87	62.8
Stevens Creek, SC	Balloon tag	blueback herring	-	-	131 - 200	1,000	14	75	28	135	94.3
White Rapids, WI	Balloon tag	centrarchiforms	-	-	<152	900	14	100	29	134	97.0
White Rapids, WI	Balloon tag	centrarchiforms	-	-	>152	900	14	100	29	134	80.0
White Rapids, WI	Balloon tag	percid	-	-	<152	900	14	100	29	134	96.0
White Rapids, WI	Balloon tag	percid	-	-	>152	900	14	100	29	134	80.0
White Rapids, WI	Balloon tag	cyprinid	-	-	<152	900	14	100	29	134	96.0
White Rapids, WI	Balloon tag	cyprinid	-	-	>152	900	14	100	29	134	80.0
White Rapids, WI	Balloon tag	ictalurid	-	-	<152	900	14	100	29	134	96.0
White Rapids, WI	Balloon tag	ictalurid	-	-	>152	900	14	100	29	134	80.0
White Rapids, WI	Balloon tag	catastomid	-	-	<152	900	14	100	29	134	96.0
White Rapids, WI	Balloon tag	catastomid	-	-	>152	900	14	100	29	134	80.0

Appendix A

Summary of Selected Entrainment Studies

Ninety-nine Islands (FERC No. 2331)

Gaston Shoals (FERC No. 2332)

Neal Shoals (FERC No. 2315)

Hollidays Bridge (FERC No. 2465)

Saluda Hydro (FERC No. 2406)

Richard B. Russell Project (USACOE project)

SUMMARY OF FIVE ENTRAINMENT PROJECTS
PERFORMED ON THE BROAD AND SALUDA RIVERS, SC

1.0 NINETY-NINE ISLANDS

Hydroacoustic and full recovery netting were performed on Unit 4 (a 3 MW horizontal twin-runner Francis-type turbine) of the Ninety-nine Islands project during February - December of 1990.

1.1 Full Recovery Entrainment Netting

Full recovery entrainment netting was performed on Unit 4 of the Ninety-nine Islands project during the daylight hours of 0800 - 1700 hrs. Netting was performed on a monthly basis with a 2 hour sample taken 2 times a day for 2 consecutive days per month yielding a total of 68 sampling hours for the year (Table 1). "Initial and steady-state" sampling was performed, but no apparent trends were observed; therefore all monthly netting data was combined to yield a total number of fish (by species) entrained per hour of sampling. Monthly netting efficiencies were calculated and each monthly data set was corrected for net losses. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the six turbine units at the project and multiplying by the monthly entrainment netting rate. The sum of the estimated monthly entrainment yields a total estimated annual entrainment of 238,447 fish for the project. Investigators indicated that these estimates may be inflated due to suspected net intrusion in the tailrace collections.

1.2 Hydroacoustic Entrainment Sampling

Hydroacoustic sampling was performed on Unit 4 of the Ninety-nine Islands project on a monthly basis during both daytime and nighttime project operation with a

total of 2,042 hours of data collected over 101 days (Table 2). Fish entrainment is reported as the number of fish entrained per hour of sampling. Reported monthly rates are the mean of all hourly sampling rates for the collection month. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the six turbine units at the project and multiplying by the monthly hydroacoustic entrainment rate for Unit 4. The sum of the monthly fish entrainment estimates yields a total estimated annual entrainment of 205,585 fish for the project. Based on background noise levels, it was calculated that the smallest fish target "acoustically visible" was 100 mm in length. By comparing simultaneous netting and hydroacoustic samples, it was determined that there was fairly good agreement between the netting and hydroacoustic entrainment estimates for the Ninety-nine Islands Project.

Table 1. Entrainment Netting Recovery Data collected at the Ninety-Nine Islands Project during February - December of 1990.

Month	Hours Sampled	Hourly Entrainment Rate	Total Hours of Turbine Operation	Projected Number of Fish Entrained
January	No Data	Ave. of Dec. and Feb. rates = 6.8	3,140	21,352
February	8	13.5	3,656	49,355
March	8	1.9	3,937	7,479
April	8	5.1	3,362	17,145
May	8	10.8	2,862	30,911
June	8	10.9	1,708	18,618
July	No Data	June rate = 10.9	1,655	18,042
August	No Data	June rate = 10.9	1,489	16,233
September	8	6.5	1,357	8,821
October	4	13.2	2,605	34,390
November	8	7.8	2,064	16,101
December	8	0	2,026	0
TOTAL	68 hrs	Mean = 8 fish/hr	29,861 hrs	238,447 fish

Table 2. Fish Entrainment at the Ninety-nine Islands Project based on Hydroacoustic sampling during February - December of 1990.

Month	Days Sampled	Hourly Entrainment Rate	Total Hours of Turbine Operation	Projected Number of Fish Entrained
January	No Data	Used Feb = 0.4	3,140	1,256
February	13	0.4	3,656	1,487
March	13	4.6	3,937	18,150
April	9	4	3,362	13,474
May	7	12.8	2,862	36,701
June	15	11	1,708	18,722
July	15	5.9	1,655	9,838
August	9	14.8	1,489	22,037
September	12	8	1,357	10,788
October	No Data	Ave. of Sept. and Nov. rates = 13.2	2,605	34,386
November	9	18.4	2,064	37,936
December	No Data	Feb. rate = 0.4	2,026	810
TOTAL	101 days	Mean =6.9 fish/hr	29,861 hrs	205,585 fish

2.0 GASTON SHOALS

Hydroacoustic and full recovery netting were performed on Unit 6 (a 2.5 MW vertical Francis-type turbine) of the Gaston Shoals Hydroelectric project during January - December of 1990.

2.1 Full Recovery Entrainment Netting

Full recovery entrainment netting was performed on Unit 6 of the Gaston Shoals project during the daylight (0800 - 1600) and the nighttime hours (2000 - 0400). Netting was performed on a monthly basis with a 2 hour sample taken 4 times a day (one 24 hr period) once per month yielding a total of 64 (32 daytime and 32 nighttime) sampling hours for the year (Table 3). "Initial and steady-state", daytime, and nighttime sampling was performed, but no apparent trends were observed; therefore all monthly netting data was combined to yield a total number of fish (by species) entrained per hour of sampling. Monthly netting efficiencies were calculated and each monthly data set was corrected for net losses. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the three operational turbine units at the project and multiplying by the monthly entrainment netting rate. The sum of the estimated monthly entrainment yields a total estimated annual entrainment of 156,619 fish for the project. Investigators indicated that these estimates may be inflated due to suspected net intrusion in the tailrace collections.

2.2 Hydroacoustic Entrainment Sampling

Hydroacoustic sampling was performed on Unit 6 of the Gaston Shoals on a monthly basis during both daytime and nighttime project operation with a total of 112 days of data collected (Table 4). Fish entrainment is reported as the number of fish entrained per hour of sampling. Reported monthly rates are the mean of all hourly sampling rates for the collection month. The total number of fish entrained by month was

determined by totaling the number of generation hours for each of the three turbine units at the project and multiplying by the monthly hydroacoustic entrainment rate for Unit 6. The sum of the monthly fish entrainment estimates yields a total estimated annual entrainment of 91,753 fish for the project. Based on background noise levels, it was calculated that the smallest fish target "acoustically visible" was 100 mm in length. By comparing simultaneous netting and hydroacoustic samples, it was determined that there was no acceptable correlation between the entrainment netting estimates and the hydroacoustic entrainment estimates for the Gaston Shoals project.

Table 3. Entrainment Netting Recovery Data collected at the Gaston Shoals project during February - December of 1990.

Month	Hours Sampled	Hourly Entrainment Rate	Total Hours of Turbine Operation	Projected Number of Fish Entrained
January	No Data	Ave. of Dec. and Feb. rates = 2.9	2,021	5,859
February	8	3.3	2,012	6,639
March	8	1.4	2,224	3,113
April	8	11.5	2,152	24,749
May	8	3.4	2,182	7,418
June	8	20.9	1,568	32,773
July	No Data	June rate = 20.9	1,382	28,882
August	No Data	June rate = 20.9	1,260	26,334
September	8	9.0	1,080	9,720
October	No Data	Ave. of Sep. and Nov. rates = 5.6	1,352	7,569
November	8	1.0	1,253	1,255
December	8	1.3	1,776	2,308
TOTAL	64 hrs	Mean = 7.7 fish/hr	20,262 hrs	156,619 fish

Table 4. Fish Entrainment at the Gaston Shoals project based on Hydroacoustic sampling during February - December of 1990.

Month	Days Sampled	Hourly Entrainment Rate	Project Turbine Operation	Projected Number of Fish Entrained
January	8	8.5	2,021	17,199
February	10	2.3	2,012	4,628
March	5	3.6	2,224	7,984
April	8	2.7	2,152	5,875
May	13	0.3	2,182	715
June	15	10.5	1,568	16,495
July	16	2.5	1,382	3,455
August	6	1.4	1,260	1,701
September	9	1.8	1,080	1,948
October	6	5.2	1,352	7,059
November	16	8.0	1,253	10,042
December	No Data	Ave of Nov.& Jan. rates = 8.25	1,776	14,652
TOTAL	112 days	Mean = 4.5 fish/hr	20,262 hrs	91,753 fish

3.0 NEAL SHOALS

Hydroacoustic and full recovery netting were performed on Unit 3 (1.1 MW horizontal Francis-type turbine) of the Neal Shoals Hydroelectric project during February 1991 through January 1990.

3.1 Full Recovery Entrainment Netting

Full recovery entrainment netting was performed on Unit 3 of the Neal Shoals project during the daylight hours (0600 - 1200 or 1600 - 2200 hrs). During each netting-month, a 6 hour sample taken once a day for 2 consecutive days per month (12 hrs/month). There were six successful netting events during March, May, June, August, October, and December yielding a total of 45.75 sampling hours for the year (Table 5). Entrainment netting collection efficiencies were determined for fish < 100 mm (96%) and for fish > 100 mm (71%). Reported entrainment rates were not corrected for these net losses but assumed 100% net efficiency. The total number of fish entrained annually was determined by totaling the number of generation hours for each of the four operational turbine units at the project and multiplying by the mean annual entrainment netting rate of 13.7 fish/hr. Based on the annual project operation time of 19,819.3 hours, the estimated annual entrainment for the project was 271,524.4 fish.

Discussions with Gerrit Jöbsis (South Carolina Department of Natural Resources) determined that the netting rates were adjusted for a 73% netting recovery rate which increased the annual entrainment rate to 345,510 fish for the project.

3.2 Hydroacoustic Entrainment Sampling

Hydroacoustic entrainment sampling was performed on Unit 3 of the Neal Shoals project on a monthly basis during both daytime and nighttime project operation. The hydroacoustic data was analyzed through July of 1991 with poor or no correlation with

the entrainment netting data. Based on these results, the number of fish entrained at the site was based solely on entrainment netting.

Table 5. Entrainment Netting Recovery Data collected at the Neal Shoals project during March - December of 1991.

Month	Hours Sampled	Number of Fish Collected	Initial Hourly Entrainment Rate	Adjusted Hourly Entrainment Rate	Projected Number of Fish Entrained
January	NA	-------	NA	NA	
February	NA	-------	NA	NA	
March	10.25	171	16.7	21.2	
April	NA	-------	NA	NA	
May	11	259	23.5	29.9	
June	3	58	19.3	24.5	Project
July	NA	-------	NA	NA	Operation =
August	10	109	10.9	13.8	19819.3 hrs
Septembe r	NA	-------	NA	NA	times the annual
October	0.5	5	10.0	12.7	entrainment rate
November	NA	-------	NA	NA	of 17.4 fish/hr =
December	11	25	2.3	2.9	
TOTAL	45.75 hrs	627 fish	Mean = 13.7 fish/hr	Mean = 17.4 fish / hr	345,510 fish/ yr

4.0 SALUDA HYDRO

Hydroacoustic and full recovery netting were performed on Unit 1 (a 0.6 MW horizontal twin-runner Francis-type turbine) of the Saluda Hydroelectric project during January - December of 1990 and January of 1991.

4.1 Full Recovery Entrainment Netting

Full recovery entrainment netting was performed on Unit 1 of the Saluda Hydroelectric project during the daylight hours of 0800 - 1700 hrs. Netting was performed on a monthly basis with a 2 hour sample taken 2 times a day for 2 consecutive days per month (8 hrs/month) yielding a total of 48 sampling hours for the year (Table 6). "Initial and steady-state" sampling was performed, but no apparent trends were observed; therefore all the monthly netting data was combined to yield a total number of fish (by species) entrained per hour of sampling. Monthly netting efficiencies were calculated and each monthly data set was corrected for net losses. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the four operational turbine units at the project and multiplying by the monthly entrainment netting rate. The sum of the estimated monthly entrainment for 9 months of operation yields a total estimated entrainment of 87,274 fish for the project. Investigators indicated that these estimates may be inflated due to suspected net intrusion in the tailrace collections.

4.2 Hydroacoustic Entrainment Sampling

Hydroacoustic entrainment sampling was performed on both Unit 1 and Unit 2 of the Saluda Hydroelectric project a monthly basis during both daytime and nighttime project operation with a total of 1587 hours of data collected over 95 days (Table 7). Unit 1 was sampled during January through October 1990 and Unit 2 was sampled during November of 1990 through January of 1991. Fish entrainment is reported as the number

of fish entrained per hour of sampling. Reported monthly rates are the mean of all hourly sampling rates for the collection month. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the four turbine units at the project and multiplying by the monthly hydroacoustic entrainment rate for either Unit 1 or Unit 2. The sum of the monthly fish entrainment estimates yields a total estimated annual entrainment of 31,811 fish for the project. Based on background noise levels, it was calculated that the smallest fish target "acoustically visible" was 100 mm in length. By comparing simultaneous netting and hydroacoustic samples, it was determined that there was limited agreement between the entrainment netting estimates and the hydroacoustic entrainment estimates for the Saluda Hydroelectric project.

Table 6. Entrainment Netting Recovery Data collected at the Saluda Hydroelectric project during January - December of 1990.

Month	Hours Sampled	Hourly Entrainment Rate	Total Hours of Turbine Operation	Projected Number of Fish Entrained
January	No Data	Dec. rate = 6.2	1917	11,885
February	No Data	Dec. rate = 6.2	2244	13,913
March	No Data	No estimate	2238	---------
April	No Data	No estimate	1963	---------
May	No Data	No estimates	1624	---------
June	8	11.6	1097	12,725
July	No Data	Ave. of June & Aug. rates = 9.3	855	7,952
August	8	6.7	780	5,226
September	8	6.3	720	4,536
October	8	14.5	1350	19,575
November	8	5.5	932	5,126
December	8	6.2	1022	6,336
TOTAL	48 hrs	Mean = 5.2 fish/hr	16742	87,274 fish
Adjusted for 9 months of sampling		Mean = 8.0 fish/hr	10,917	87,274 fish

Table 7. Fish Entrainment at the Saluda Hydroelectric project based on hydroacoustic sampling during January 1990 to January of 1991.

Month	Days Sampled	Hourly Entrainment Rate	Total Hours of Turbine Operation	Projected Number of Fish Entrained
January	4	1.1	1,917	2,032
February	4	0.0	2,244	0
March	12	0.6	2,238	1,388
April	23	0.8	1,963	1,570
May	1	0.4	1,624	585
June	9	0.8	1,097	823
July	No Data	3.3	855	2,822
August	4	5.8	780	4,547
September	2	2.3	720	1,663
October	9	7.7	1,350	10,449
November	2	5.1	932	4,716
December	11	1.2	1,022	1,216
January	14	3.0	No Data	No Data
TOTAL	95 days	Mean = 2.4 fish/hr	16,742	31,811 fish

5.0 HOLLIDAYS BRIDGE

Hydroacoustic and full recovery netting were performed on Unit 3 (a 0.9 MW horizontal triple-runner Francis-type turbine) during January - December of 1990 and on Unit 2 during April - June of 1992 of the Hollidays Bridge Hydroelectric project.

5.1 Full Recovery Entrainment Netting

Full recovery entrainment netting was performed on Unit 3 of the Hollidays Bridge project during the daylight hours of 0800 - 1700 hrs. Netting was performed on a monthly basis with a 2 hour sample taken 2 times a day for 2 consecutive days per month (8 hrs/month) yielding a total of 40 sampling hours for the year (Table 8). "Initial and steady-state" sampling was performed, but no apparent trends were observed; therefore all the monthly netting data was combined to yield a total number of fish (by species) entrained per hour of sampling. Monthly netting efficiencies were calculated and each monthly data set was corrected for net losses. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the four operational turbine units at the project and multiplying by the monthly entrainment netting rate. The sum of the estimated monthly entrainment for 5 months of project operation yields a total estimated entrainment of 28,489 fish for the project.

To satisfy a FERC AIR, additional entrainment net sampling was performed during April - June of 1992 to fill in missing months of project entrainment. Unit 2 was sampled during this period using the same sampling methodology employed during the 1990 studies. The similarities between the configuration of Unit 3 and Unit 2 were deemed appropriate to assume similar entrainment rates. A total of 32 hours of entrainment netting were performed during the 1992 study bringing the total project entrainment netting to 72 hrs. The total estimated annual fish entrainment of 112,345 fish is based on project operation hours during 1992. Investigators indicated that these estimates may be inflated due to suspected net intrusion in the tailrace collections.

5.2 Hydroacoustic Entrainment Sampling

Hydroacoustic entrainment sampling was performed on a monthly basis during January, February, and September - December of 1990 with a total of 720 hours of data collected over 38 days (Table 9). Unit 1 was sampled during January - October 1990 and Unit 2 was sampled during November of 1990 - January of 1991. Fish entrainment is reported as the number of fish entrained per hour of sampling. Reported monthly rates are the mean of all hourly sampling rates for the collection month. The total number of fish entrained by month was determined by totaling the number of generation hours for each of the three turbine units at the project and multiplying by the monthly hydroacoustic entrainment rate for Unit 1 or Unit 2. The sum of the monthly entrainment estimates yields an estimated entrainment of 14,330 fish for 8 months of project operation. Based on background noise, it was calculated that the smallest fish target "acoustically visible" was 100 mm in length. There was no report of additional hydroacoustics sampling performed in 1992. This is probably due to the limited agreement between the entrainment netting estimates and the hydroacoustic entrainment estimates for the Hollidays Bridge project.

Table 8. Entrainment Netting Recovery Data collected at the Hollidays Bridge project during January - December of 1990 and April-June of 1992.

Month	Hours Sampled	Hourly Entrainment Rate	Hours of Turbine Operation (1992)	Projected Number of Fish Entrained
January	NA	Dec. rate = 3.8	1,468	5,578
February	8	1.4	1,419	1,987
March (92)	8	11.1	1,475	16,373
April (92)	8	6.3	1,382	8,707
May (92)	8	19.9	1,290	25,671
June (92)	8	12.1	1,179	14,266
July	NA	June rate = 12.1	1,015	12,282
August	NA	June rate = 12.1	941	11,386
September	8	4.9	751	3,680
October	8	5.3	729	3,864
November	8	2.1	845	1,775
December	8	5.6	1,210	6,776
TOTAL	72 hrs	Mean = 8.2 fish/hr	13,704	112,345 fish

Table 9. Fish Entrainment at the Hollidays Bridge project based on hydroacoustic sampling during January 1990 to January of 1991.

Month	Days Sampled	Hourly Entrainment Rate	Total Hours of Turbine Operation	Projected Number of Fish Entrained
January	9	0.3	1,749	507
February	13	0.3	2,102	631
March	No Data	Feb. rate = 0.3	1,179	354
April	No Data	ND	0	0
May	No Data	ND	0	0
June	No Data	ND	0	0
July	No Data	ND	0	0
August	No Data	1.3	475	618
September	4	1.4	782	1,103
October	2	1.2	1,312	1,561
November	6	4.8	852	4,124
December	4	5.3	1,023	5,432
TOTAL	38 days	Mean = 1.5 fish/hr	9,474 hrs	14,330 fish

6.0 RICHARD B. RUSSELL

Full recovery netting was performed on Unit 5 (an 80MW Francis-type turbine) at the Richard B. Russell Project.

6.1 Full Recovery Entrainment Netting

Full discharge recovery netting was performed during conventional generation on Unit 5 of the Richard B. Russell Project as part of a mid-1980s study to analyze the effects of pumpback turbines on the fisheries of Lakes Russell and Thurmond. Sampling was conducted over a full 12-month cycle. Entrainment was dominated by threadfin shad (87.3%), blueback herring (6.6%), and yellow perch (4.2%). Entrainment rates from the Richard B. Russell entrainment study were presented by month and species. For the purpose of summarizing this study, Table 10 presents the average entrainment rate by month and Table 11 presents the average annual entrainment rate for each entrained fish species.

Table 10. Monthly average entrainment rates for the Richard B. Russell Project conventional generation netting study

Month	Entrainment Rate (fish/hr)
January	1,458.22
February	7,251.67
March	224.91
April	251.83
May	108.46
June	71.63
July	101.21
August	269.67
September	127.45
October	91.64
November	556.56
December	228.72
Average	**894.23**

Table 10. Mean annual entrainment rates of fish entrained during conventional generation netting at the Richard B. Russell Project.

Name	Mean Annual Entrainment (fish/hr)
threadfin shad	781.363
blueback herring	58.397
yellow perch	36.635
white catfish	6.354
bluegill	2.939
white perch	2.080
black crappie	2.010
channel catfish	0.613
spottail shiner	0.379
white crappie	0.378
carp	0.265
gizzard shad	0.159
warmouth	0.085
yellow bullhead	0.084
flathead catfish	0.062
hybrid bass	0.060
black bullhead	0.036
spotted bass	0.026
green sunfish	0.016
striped bass	0.015
snail bullhead	0.014
golden shiner	0.013
largemouth bass	0.012
redbreast sunfish	0.012
silver redhorse	0.012
tesselated darter	0.010
blackbanded darter	0.007
whitefin shiner	0.007
longnose gar	0.007
rainbow trout	0.006
walleye	0.006
smallmouth bass	0.005
northern hogsucker	0.004
white bass	0.004
Coosa bass	0.001