ZEBRA MUSSELS

in South Carolina: The Potential Risk of Infestation

by

Steven de Kozlowski and **Chris Page**

S.C. Department of Natural Resources

and

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This report was initiated by the
South Carolina Zebra Mussel Task Force
and supported by
South Carolina Department of Natural Resources
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and
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2002

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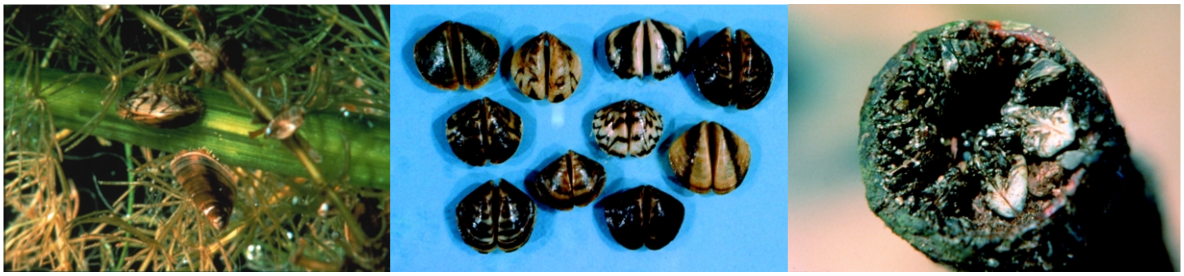

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Introduction:

Non-native invasive species, such as zebra mussels, cost the U.S. economy an estimated $137 billion annually in lost production and control costs (Pimentel et al., 2000). In the absence of native predators and diseases, exotic organisms may develop very large populations that create severe ecological and economic problems. When such invasions occur in our lakes and rivers they can disrupt whole aquatic ecosystems and impair important municipal, industrial, agricultural, and recreational uses of our waterways.

The S.C. Department of Natural Resources (SCDNR) attempts to prevent and manage aquatic invasive species problems through its Aquatic Nuisance Species Program. Following the introduction of zebra mussels in the Great Lakes, the SCDNR and S.C. Sea Grant Consortium formed the Zebra Mussel Task Force to help identify interested parties and to bring focus to this issue. Composed of representatives from the public and private sector, the task force has served as an effective communication and education network for those entities most at risk of being impacted by zebra mussel infestations.

The main objective of this study was to determine the relative risk of zebra mussel infestations in public waters throughout the state. Although several excellent risk assessments have been conducted independently by electric and water utilities in South Carolina, these studies focused primarily on water bodies used by the utilities, which left large areas of the state unstudied. In addition, water quality criteria used to assess the potential for zebra mussel colonization were not consistent among all the studies, so the results were not directly comparable. A secondary objective was to develop a risk assessment that was not only useful to South Carolina but complimented existing assessments in the region. Fortunately, North Carolina conducted an excellent statewide zebra mussel assessment in 1997 that has served as a model for several states. Because three of our largest rivers, the Broad, Catawba, Pee Dee, and several smaller rivers originate in North Carolina, we adopted their methodology for this assessment. Together, the North Carolina and South Carolina assessments provide a uniform zebra mussel risk assessment for three major river basins in the South Atlantic Slope Drainage.

Hopefully, this document will serve as a valuable resource for public and private water use interests to plan for and prevent major adverse impacts from zebra mussels when they finally arrive.

Zebra Mussel Biology and Dispersal:

The zebra mussel, *Dreissena polymorpha*, is a freshwater bivalve mollusk (mussel) native to the drainage basins of the Aral, Black and Caspian Seas in Eastern Europe and western Asia. They can reach lengths of up to two inches but are usually about the size of a fingernail (10-20 mm).

Adult zebra mussels have conspicuous dark parallel stripes across the shell, hence the common name “zebra” mussel. While these zebra stripes are usually in regular striped patterns, a variety of patterns can occur in local populations (Fig. 1).

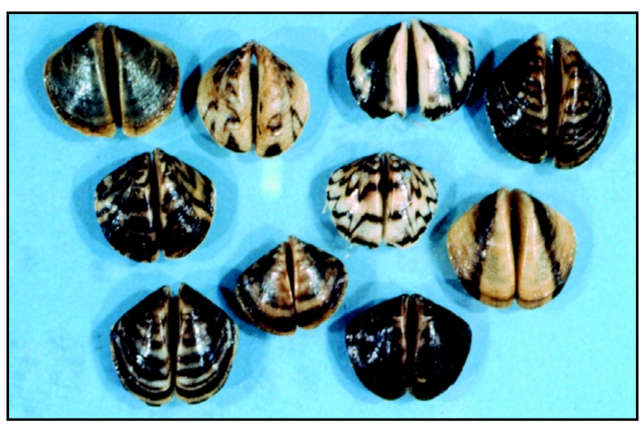

Figure 1. Variations in zebra mussel shell patterns.

Adult zebra mussels have conspicuous byssal threads extending from the lower portion of the shell, which are used to attach to hard, submerged substrates (Fig. 2). The mussels often attach to each other creating “barnacle-type” colonies. Reproduction is sexual with females producing up to one-half million eggs per year. After fertilization, eggs hatch into veliger larvae, which disperse with other plankton in the water column. Veliger larvae change into postlarvae, remain planktonic for a while, and then settle on and attach to smooth, hard objects where they develop into adults. Zebra mussels feed by filtering plankton from the water. They are well known for their filtering efficiency and ability to clarify water.

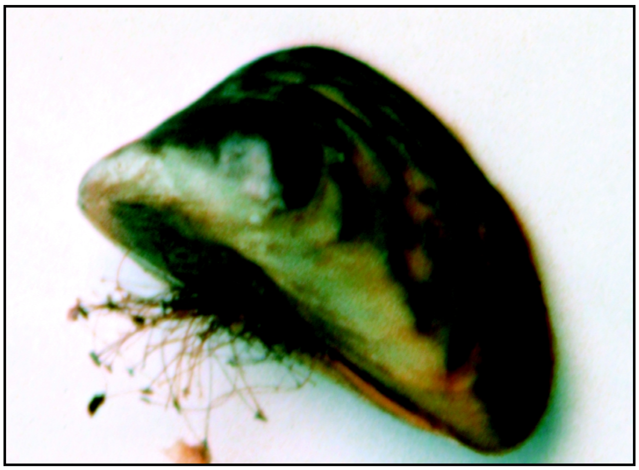

Figure 2. Byssal threads used to anchor to substates.

In South Carolina, adult zebra mussels may be confused with two other small bivalves, *Corbicula* (Asiatic clam) and *Mytilopsis*. Corbicula can be distinguished from zebra mussels by their larger size, oval-shaped shell and lack of byssal threads. Corbicula are only found as individuals as opposed to the barnacle-type colonies formed by zebra mussels. *Mytilopsis* is more similar in appearance to zebra mussels; however, they are only found in brackish water environments where zebra mussels are unlikely to thrive.

Zebra mussels are native to Eastern Europe and western Asia, but in the 1800’s as international shipping developed and canals were constructed, their range spread throughout Europe and into Great Britain. Zebra mussels were successfully introduced into North America in the 1980’s in Lake St. Clair in the Great Lakes through ballast water discharge. Once established, they spread rapidly throughout the Great Lakes, Hudson River and upper Mississippi River systems by 1991. Zebra mussels have exhibited strong genetic plasticity and have tolerated hostile environments beyond their traditional environmental ranges in their native area. It was initially thought that water temperatures in the southern United States would prohibit colonization in this area but by the mid 1990’s zebra mussel colonies were documented as far south as Louisiana on the Mississippi River, as far west as Oklahoma on the Arkansas River, and as far east as Knoxville on the Tennessee River (Fig. 3). Currently, they do not occur in the Atlantic slope drainages from Virginia south to Florida.

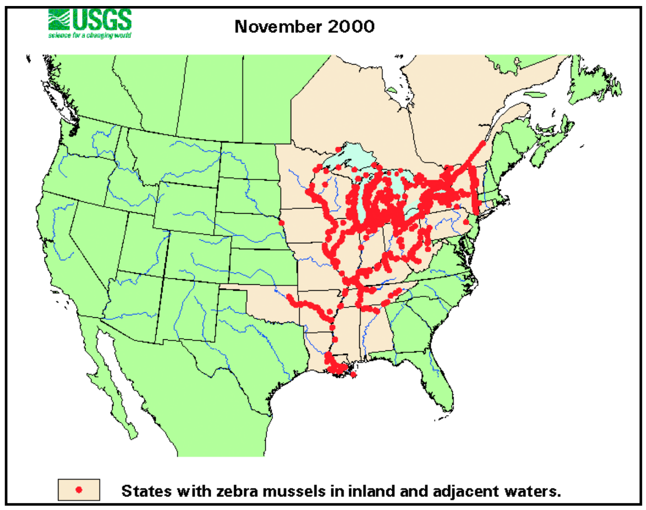

Figure 3. Documented zebra mussel range in the United States as of November 2000.

If left to natural water movements, zebra mussel dispersal would be very limited. However, commercial and recreational boating activities have greatly expanded the range of zebra mussels. High-speed oceanic crossings increase the likelihood of successful transport far from their home range. Adults can hitchhike on the hulls of ships and drop off in new locations or produce gametes in new waters while attached. Adults also have a tendency to attach to aquatic wells of boats using infested waters, to be discharged later into uninfested waters. The rapid dispersal of zebra mussels in the Mississippi River Basin between 1991 and 1993 is attributed to the extensive commercial barge traffic in that river system. Overland transport by recreational boats and trailers is believed to be a primary method of introduction to isolated inland lakes within the Great Lakes Region, and a serious potential method of zebra mussel introduction to water bodies outside their current range.

Impacts of Zebra Mussel Infestations:

Zebra mussels are a relatively recent aquatic introduction to North America, but their impacts

Figure 4. Zebra mussels readily attach to aquatic vegetation.

have been widespread, diverse, and costly. With the introduction of any non-native, invasive species, comes the inherent possibility of rapid population explosions in the absence of native predators, competitors, and diseases in native environments. Just such a scenario has occurred with zebra mussels. Populations in North America have achieved unheard of densities compared to its native range. Zebra mussels in North America have reached densities of 750,000 individuals per square meter and formed layers one foot thick.

Zebra mussels have a propensity for entering and clogging water intake pipes of any size (Fig. 5). In time, water flow is restricted and eventually curtailed resulting in facility closures and expensive corrective measures. A 1995 study by the New York Sea Grant quantified the economic impact of zebra mussels in North America. Zebra mussel related expenses totaled $69 million for the 339 facilities reporting with expenses at one facility reaching $5.95 million. The greatest economic impacts occurred at electric power plants ($35 million), followed by drinking water treatment plants ($21 million) and various industries ($5.8 million).

When present in large numbers, zebra mussels can dramatically alter the ecology of

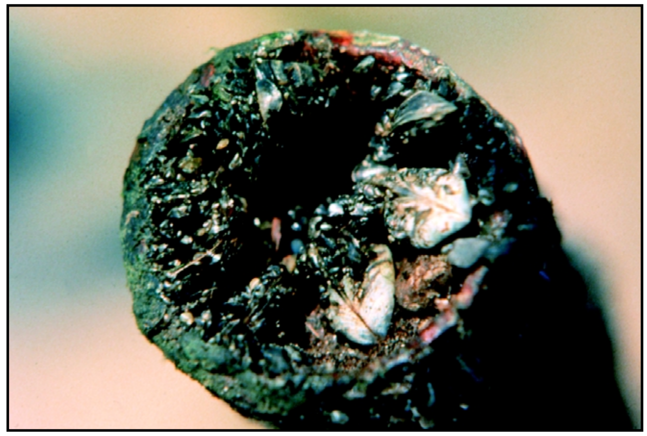

Figure 5. Water intake pipe clogged with adult zebra mussels.

freshwaters by dramatically reducing phytoplankton populations and adversely impacting native bivalves. Zebra mussels, like all bivalves, feed by filtering phytoplankton (microscopic plants) and detritus from the water. It is well documented that zebra mussels have incredible filtering capacities and have reduced phytoplankton populations in large lakes and rivers by as much as 90%. As a consequence, higher level organisms, such as zooplankton and fish, that feed directly on phytoplankton can experience similar population declines. Reductions in plankton result in increased water clarity, which may be beneficial. However, along with greater light penetration comes increases in benthic algae and submersed aquatic vegetation, which may result in additional ecological and water use problems.

Zebra mussels tend to attach readily to other clams and mussels and form large colonies. When zebra mussel encrustations become too large, they prevent native clams from feeding and breathing, which results in death. Unfortunately, many of our native clam species are already threatened, so increased competition from zebra mussels, either by direct contact or indirectly through reductions in phytoplankton, may lead to their eventual elimination in some waters.

Assessment Method:

This risk assessment is based on that developed in 1997 by North Carolina Sea Grant for assessing the risk of zebra mussel colonization in North Carolina. Most of the large rivers in South Carolina originate in North Carolina, so a consistent assessment method based on similar water quality parameters made sense and provided a uniform assessment for most of the basins draining the South Atlantic slope of the United States.

This study evaluates the relative suitability of water bodies to support zebra mussel populations based on five water quality parameters important to their survival and propagation; average summer temperature, dissolved oxygen, pH, calcium, and salinity. These parameters were divided into three major categories that reflect their colonization potential; Definite, Maybe, and Unlikely. Water quality parameters that were in the range known to support reproducing zebra mussel populations elsewhere in North America were labeled “Definite”. Parameters that were in the range in which zebra mussels are known to survive but not well were labeled “Maybe”. Finally, water quality parameters that were outside the range in which zebra mussels are known to occur were labeled “Unlikely.”

Suitability criteria for the following key water quality parameters were evaluated for 256 primary water quality sampling stations throughout the state. These stations are monitored monthly by the S.C. Department of Health and Environmental Control and have produced at least 10 years of water quality data. Data from the past 5 years were used in this assessment.

Water Quality Parameters and Associated Suitability Criteria

Dissolved Oxygen

Sufficient dissolved oxygen is necessary for respiration. Larval zebra mussels appear to be less tolerant of low dissolved oxygen conditions than adults. Zebra mussels like other bivalves are able to tightly close their shells and survive for short periods of low dissolved oxygen.

Dissolved Oxygen Suitability Criteria:

Definite .... 8-12 ppm
Maybe .... 4-8 ppm
Unlikely .... <4 ppm

Temperature

Zebra mussels are typically considered a cool water species. Since South Carolina has a temperate climate, warmer than the native range for zebra mussels, lower temperatures were not considered as a limiting factor, so a low temperature limit was not established for South Carolina. The upper temperature limit appears to be above 32 degrees Celsius for a period of time. The temperature criteria evaluated in this study was the average water temperature for June, July, August and September.

Temperature Suitability Criteria:

Definite .... 15-31º C
Maybe .... 31-32º C
Unlikely .... >32º C

pH

pH regulates calcium uptake in freshwater shellfish. Acidic waters reduce growth and reproduction in aquatic species. Acidic waters can cause shell dissolution in excess of calcium uptake in zebra mussels at moderate pH levels.

pH Suitability Criteria:

Definite 7.4-8.7
Maybe 6.8-7.4
Unlikely ....<6.8 or >9.5

Calcium

Calcium is the major component of shells, so is a critical element for freshwater bivalve growth and reproduction. This element is especially important to zebra mussel survival because they require a higher level of calcium than most other bivalves. The S.C. Department of Health and Environmental Control does not routinely monitor for calcium, therefore, calcium values were estimated from known alkalinity values (Claudi and Mackie, 1993) using the formula:

Ca (mg/L) = Alkalinity (mg $CaCO_3$/L)/3.49

To verify the accuracy of this formula in estimating calcium for South Carolina waters, water samples from 18 water bodies throughout the state were collected and analyzed specifically for calcium and alkalinity. Calcium values were estimated from measured alkalinity then compared to measured calcium values. Actual calcium values showed a reasonably close correlation with estimated values (Fig. 6). Although the correlation coefficient was not very high (R^2=0.638), 94% of the sites (17) yielded the same suitability category (i.e., unlikely, maybe, or definite) for both the measured and estimated values.

Calcium Suitability Criteria:

Definite .... >15 mg/L
Maybe .... 9-15 mg/L
Unlikely .... <9 mg/L

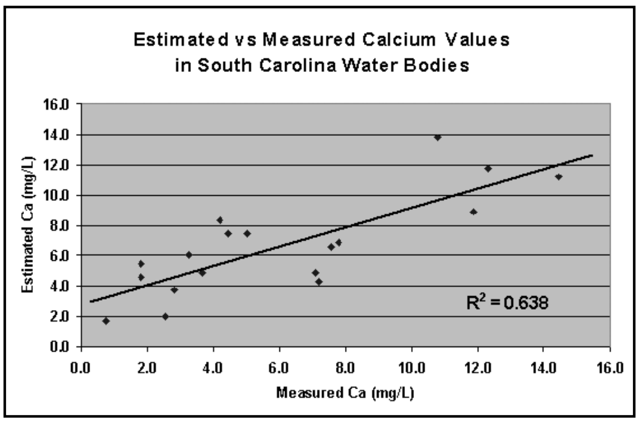

Figure 6. Comparison of measured and estimated calcium values.

Salinity

Salinity can be a limiting factor to zebra mussel colonization in estuarine areas since zebra mussels are freshwater bivalves. Zebra mussels can withstand relatively low salinity, but are unable to tolerate higher levels of salinity for extended periods. Salinity was only evaluated for coastal sites where saltwater movement upstream may impact the suitability of zebra mussel survival. Salinity would not be a limiting factor in inland sites.

Salinity Suitability Criteria:

Definite .... 0-5 ppt
Maybe .... 5-10 ppt
Unlikely .... >10 ppt

Results and Discussion:

Results of the analysis are presented graphically in Figure 7 (located inside pocket on back cover) and presented in detail by sampling station in the Appendix. In Figure 7, the relative suitability of each water quality parameter to support zebra mussels is presented by color in a pie diagram for each station. Only coastal streams where salinity levels fluctuate due to saltwater mixing included a "salinity ring" around the pie diagram. Overall, the greater the amount and intensity of red in the pie diagram the greater the risk of zebra mussel colonization.

Potential for Colonization

No stations indicated water quality conditions that were ideal for the growth and propagation of zebra mussels. Ninety percent of the stations had at least one water quality constituent that made it "unlikely" for zebra mussel colonization. Of those stations about half had two constituents that made colonization unlikely. None of the stations reflected "definite" potential for colonization for all water quality constituents. Calcium and pH appear to be the most limiting factors to zebra mussel colonization in the state. In general, surface waters in South Carolina are too soft and pH levels are too low to allow for good shell formation. Calcium concentrations in surface waters rarely exceed 15 mg/L except in brackish waters along the coast, and pH values are typically below 6.8, so are too acidic for good shell development, a critical activity for growth and propagation.

However, there seem to be two regions of the state where water quality characteristics are more favorable for zebra mussel colonization. One area is a band in the middle piedmont region extending from York County near Charlotte, NC southwest to McCormick County near the Georgia border. This region includes several streams in the Catawba River drainage in York and Chester Counties; in the Savannah River drainage in McCormick, Greenwood, and Abbeville Counties; and a couple of streams in the Saluda and Broad River Basins in Newberry County.

The other area of suitable zebra mussel

habitat occurs in several streams inland along the coast. These include the Intracoastal Waterway near Little River Inlet at the border with North Carolina, the Sampit River at Georgetown, portions of the Cooper and Ashepoo Rivers near Charleston, and the Savannah River at Savannah, Georgia. These latter sites are of particular concern because they are also near commercial ports so are at increased risk of zebra mussel introductions from ballast water discharge and detachment of adults from ship hulls.

Potential Sources of Introduction

The probability of zebra mussel introductions to South Carolina by commercial vessels appears low but should not be completely dismissed. Unlike the Great Lakes and Mississippi River ports, deep draft commercial vessels entering the state must arrive directly through saltwater routes. Therefore, mussels attached to the outside of hulls would be subject to severe environmental conditions and would probably not survive. However, water quality conditions in some ports, such as Georgetown and Savannah (Georgia), and in the Cooper River just north of Charleston may be suitable for zebra mussel colonization if veligers or small adults were discharged from ballast water. Port Royal appears to be the only port in which zebra mussels would not survive due to salinity conditions.

Smaller commercial barges that enter the state via the Intracoastal Waterway (ICWW) are an unlikely source of zebra mussel introduction. Salinity in the waterway along the southern portion of the coast from Savannah to the Santee River is too high (>10 ppt) for zebra mussel survival. While salinities in the northern portion of the ICWW from Georgetown to North Carolina are low enough for zebra mussel survival, barges would still need to pass through higher salinity conditions in the North Carolina portion of the ICWW before entering the state.

The inland movement of zebra mussels via commercial vessels to more suitable freshwater habitat would be very limited. While some states have commercially navigable waters that extend far inland, commercial boat traffic in South Carolina is restricted to coastal waterways. Historically, the most extensive commercial traffic was on the Savannah River between Savannah and Augusta, Georgia, but that has all but stopped in the past 10 years. Commercially navigable waters with salinity levels low enough to support zebra mussels include the upper portion of Winyah Bay and the ICWW north to Little River Inlet, the Cooper River from Lake Moultrie south to the confluence with Back River (at Back River Reservoir dam), and the Savannah River north of Savannah. Just as the navigability to inland waters from commercial ports is limited, water quality conditions that support zebra mussels in these upstream waters is also limited. Even if zebra mussel populations were established in these ports, seaward flows and excessively soft water upstream would probably restrict their movement inland.

The greatest threat of introductions to inland waters comes from recreational boaters; especially those who leave their boats in the water for most of the year then travel to South Carolina from states known to have zebra mussels. Such boaters may include individuals with dual residence (“snowbirds”), tournament anglers, or boaters simply traveling here on vacation and enjoying our inland lakes and rivers. Fortunately, our large reservoirs do not appear to be suitable habitat for zebra mussel colonization. However, as a precaution, South Carolina has posted prominent signs at major public boat ramps reminding boaters to check for and remove zebra mussels and aquatic vegetation from their boats prior to entering our public waterways.

Recommendations:

Although South Carolina has a relatively low risk of experiencing serious zebra mussel infestations and impacts, the probability is still present. Based on this assessment, the following precautions are recommended.

1. Prevention measures focused on public education and awareness of zebra mussels specifically, and aquatic nuisance species in general, should be continued by the public and private sector. These should include brochures, public service announcements, and trade show presentations.

2. Signs should be posted and maintained at all boat launch sites on public waterways instructing boaters to check for and remove aquatic vegetation and take precautions to prevent the introduction of zebra mussels.

3. Water dependent industries located in the higher risk areas of the state identified above should monitor for the presence of zebra mussels on a regular basis and prepare management plans to respond to zebra mussel infestations if and when they occur.

4. Precautions should be taken to prevent ballast water discharge by commercial vessels at the ports of Georgetown, Charleston, and Savannah.

5. The State Zebra Mussel Task Force should continue to meet periodically to maintain an effective network of interested parties and keep current on the status of zebra mussel colonization and control nationwide.

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References:

Baker, P., S. Baker and R. Mann. 1993. Virginia Sea Grant Marine Resource Advisory No. 50. Virginia Sea Grant Advisory No. VSG-93-03, and Virginia Institute of Marine Science Contribution No. 1821.

Claudi, R. and G.L. Mackie. 1993. Practical Manual for Zebra Mussel Monitoring and Control. Boca Raton, FL: Lewis Publishers. 227 pp.

Cohen, A.N. and A. Weinstein. 1998. The Potential distribution and Abundance of Zebra Mussels in California. Technical Report. CALFED Category III Steering Committee California Urban Water Agencies. San Francisco Estuary Institute, Richmond, CA.

Doll, B. 1997. Zebra Mussel Colonization: North Carolina's Risks. North Carolina Sea Grant College Program. UNC SG-97-01, University of North Carolina, Raleigh, NC.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and Economic Costs of Nonindigenous Species in the United States. BioScience 50 (1): 53-65.

Appendix

Summary of Water Quality Data from Primary Monitoring Stations by Major River Basins

South Carolina
River Basins

ACE Basin:

STATION #	Hydrologic Unit Code	STREAM NAME	Average Calcium	Average Dissolved Oxygen	Average pH	Average Salinity	Averag Summer Temp.
MD-043	03050201	COOPER RVR	12.69	6.81	7.43	8.19	28.68
MD-044	03050201	COOPER RVR	15.38	6.69	7.52	11.13	28.45
MD-248	03050201	COOPER RVR	17.43	6.65	7.47	11.64	28.50
MD-045	03050201	COOPER RVR	19.63	6.64	7.64	16.34	28.50
MD-046	03050201	COOPER RVR	24.51	7.00	7.78	21.45	27.54
CSTL-079	03050201	DIVERSION CANAL	6.19	8.12	7.13	0.14	27.01
MD-217	03050201	DURHAM CK	6.69	7.03	7.02	0.02	26.82
MD-240	03050201	FOSTER CK	13.91	3.48	6.75	0.02	26.99
MD-114	03050201	GOOSE CK	14.86	2.13	6.38	0.02	25.06
MD-039	03050201	GOOSE CK	14.68	6.54	7.02	2.28	27.43
MD-243	03050201	SHIPYARD CK	20.62	7.18	7.66	16.06	27.70
CSTL-062	03050201	TAIL RACE CANAL BELOW LAKE MOULTRIE	5.61	8.11	7.11	0.00	27.01
MD-047	03050201	TOWN CK, COOPER RVR	22.45	6.67	7.74	20.09	28.70
MD-115	03050201	WANDO RVR	22.66	6.30	7.44	16.88	27.27
MD-198	03050201	WANDO RVR	23.12	6.85	7.75	19.03	28.39
MD-049	03050202	ASHLEY RVR	17.62	6.46	7.08	5.28	25.35
MD-052	03050202	ASHLEY RVR	24.63	6.70	7.62	18.72	28.15
MD-034	03050202	ASHLEY RVR	24.85	6.89	7.68	21.61	28.59
MD-247	03050202	CHARLESTON HARBOR	27.32	6.93	7.94	25.61	28.22
MD-048	03050202	CHARLESTON HARBOR	26.88	6.98	7.91	24.09	28.23
MD-165	03050202	CHARLESTON HARBOR	24.96	7.19	7.84	21.83	28.22
MD-246	03050202	CHURCH CK	21.57	6.24	7.28	9.64	28.82
CSTL-013	03050202	DORCHESTER CK	16.88	7.81	7.46	0.02	27.05
CSTL-099	03050202	EAGLE CK	16.27	6.93	7.14	0.47	27.28
MD-069	03050202	ICWW	28.75	6.87	7.85	25.88	28.32
MD-203	03050202	JEREMY CK	21.18	6.67	7.41	16.59	28.27
MD-071	03050202	SHEM CK	27.03	5.86	7.69	23.84	28.21
MD-202	03050202	STONO RVR	24.55	6.59	7.33	20.70	27.30
MD-026	03050202	STONO RVR	25.59	6.42	7.43	21.42	28.08
MD-020	03050202	WAPPOO CK	25.23	6.92	7.73	20.36	28.29
CSTL-063	03050202	WASSAMASSAW SWAMP	9.00	5.57	6.70	0.00	24.57
E-091	03050203	CHINQUAPIN CK	3.91	8.67	6.54	0.00	24.10
E-092	03050203	N FORK EDISTO RVR	1.83	8.61	6.17	0.00	24.13
E-099	03050203	N FORK EDISTO RVR	1.89	8.22	6.17	0.00	24.34
E-007	03050203	N FORK EDISTO RVR	1.89	8.48	6.22	0.00	23.60
E-007C	03050203	N FORK EDISTO RVR	2.63	8.16	6.28	0.00	24.72
E-008	03050203	N FORK EDISTO RVR	2.46	8.51	6.31	0.00	24.97
E-090	03050204	S FORK EDISTO RVR	2.75	8.89	6.43	0.00	24.78
E-094	03050204	SHAW CK	2.26	8.55	6.23	0.00	23.82
MD-209	03050205	BOHICKET CK	29.88	6.09	7.56	23.35	28.46
MD-195	03050205	CHURCH CK	26.78	5.93	7.42	21.82	28.16
MD-120	03050205	DAWHO RVR	17.88	6.89	7.17	13.09	25.73
E-013	03050205	EDISTO RVR	2.72	7.81	6.30	0.00	25.70
E-086	03050205	EDISTO RVR	3.39	7.49	6.52	0.00	25.69
E-015	03050205	EDISTO RVR	4.73	7.37	6.63	0.00	26.19
E-016	03050205	POLK SWAMP	12.28	5.42	6.66	0.00	24.58
E-059	03050206	FOUR HOLE SWAMP	7.21	7.08	6.50	0.00	24.31
E-100	03050206	FOUR HOLE SWAMP	9.93	6.81	6.82	0.00	24.95
E-051	03050206	PROVIDENCE SWAMP	6.73	6.47	6.42	0.00	25.33
CSTL-028	03050207	SALKEHATCHIE RVR	4.35	8.29	6.53	0.00	24.33
CSTL-003	03050207	SALKEHATCHIE RVR	5.64	7.74	6.52	0.00	24.40
CSTL-006	03050207	SALKEHATCHIE RVR	6.58	7.21	6.71	0.00	24.47
MD-003	03050208	BEAUFORT RVR	30.44	6.36	7.60	27.25	28.56
MD-005	03050208	BEAUFORT RVR	31.55	6.83	7.86	28.45	28.34
MD-174	03050208	BROAD CK	29.95	6.29	7.71	25.93	28.40
MD-116	03050208	BROAD RVR	29.39	7.22	7.77	25.42	28.28
MD-175	03050208	CALIBOGUE SOUND	29.37	6.94	7.90	27.16	28.10
MD-245	03050208	COLLETON RVR	29.84	6.73	7.71	26.54	28.29
MD-168	03050208	COOSAW RVR	26.13	6.84	7.63	22.21	28.59
CSTL-110	03050208	COOSAWHATCHIE RVR	6.95	7.03	6.53	0.00	24.67
CSTL-109	03050208	COOSAWHATCHIE RVR	7.28	5.39	6.40	0.00	24.66
MD-118	03050208	NEW RVR	2.18	5.78	5.67	2.54	26.81
MD-007	03050208	POCOTALIGO RVR	15.21	5.41	6.77	10.44	28.19

Santee Basin:

STATION #	Hydrologic Unit Code	STREAM NAME	Average Calcium	Average Dissolved Oxygen	Average pH	Average Salinity	Averag Summer Temp.
CW-152	03050101	CROWDERS CK	20.06	9.32	7.03	0.00	22.52
CW-023	03050101	CROWDERS CK	13.47	8.67	6.85	0.00	21.86
CW-197	03050101	LAKE WYLIE	4.49	8.67	6.87	0.00	28.68
CW-198	03050101	LAKE WYLIE	5.03	8.66	7.07	0.00	28.30
CW-201	03050101	LAKE WYLIE	4.97	8.60	7.10	7.00	28.01
CW-014	03050103	CATAWBA RVR	5.24	7.98	6.95	0.00	25.94
CW-041	03050103	CATAWBA RVR	5.49	8.42	6.89	0.00	26.13
CW-016	03050103	CATAWBA RVR	7.29	8.50	7.05	0.00	27.40
CW-029	03050103	FISHING CK	7.85	9.31	6.91	0.00	21.71
CW-005	03050103	FISHING CK	10.05	8.93	6.84	0.00	22.14
CW-008	03050103	FISHING CK	10.85	9.52	6.96	0.00	23.95
CW-016F	03050103	LAKE, FISHING CK RESERVOIR	7.85	8.47	7.09	0.00	27.73
CW-057	03050103	LAKE, FISHING CK RESERVOIR	7.94	8.86	7.10	0.00	28.50
CW-226	03050103	MCALPINE CK	14.68	7.85	6.76	0.00	25.54
CW-002	03050103	ROCKY CK	20.52	7.92	7.06	0.00	23.43
CW-176	03050103	SIXMILE CK	11.63	8.45	6.81	0.00	23.13
CW-013	03050103	SUGAR CK	14.96	7.98	6.92	0.00	24.63
CW-229	03050104	BEAR CK	4.99	8.50	7.05	0.00	21.53
CW-208	03050104	LAKE WATEREE	7.89	8.62	7.33	0.00	28.42
CW-207	03050104	LAKE WATEREE	7.83	8.48	7.29	0.00	28.26
CW-209	03050104	LAKE WATEREE	7.47	8.52	7.29	0.00	28.32
CW-228	03050104	SAWNEYS CK	7.70	8.86	6.99	0.00	21.80
CW-155	03050104	SPEARS CK	0.84	8.40	6.43	0.00	23.33
CW-206	03050104	WATEREE RVR	6.80	7.51	6.75	0.00	27.77
CW-222	03050104	WATEREE RVR	7.39	7.86	6.86	0.00	29.00
B-042	03050105	BROAD RVR	4.50	9.51	7.06	0.00	24.38
B-044	03050105	BROAD RVR	5.76	9.37	6.97	0.00	25.05
BL-001	03050105	LAWSONS FORK CK	5.20	9.41	6.84	0.00	22.31
B-026	03050105	N PACOLET RVR	5.51	9.10	6.69	0.00	23.04
B-048	03050105	PACOLET RVR	5.24	8.97	6.96	0.00	24.45
B-046	03050106	BROAD RVR	6.21	9.31	7.11	0.00	25.10
B-236	03050106	BROAD RVR	6.19	8.16	6.88	0.00	27.13
B-316	03050106	CRANE CK	3.86	7.95	6.81	0.00	24.38
B-328	03050106	LAKE, MONTICELLO	6.69	8.87	7.10	0.00	27.65
B-327	03050106	LAKE, MONTICELLO	6.60	8.93	7.40	0.00	28.26
B-280	03050106	SMITH BRANCH	8.98	8.27	6.83	0.00	24.55
B-021	03050107	FAIRFOREST CK	7.31	8.65	6.68	0.00	22.50
B-321	03050107	FAIRFOREST CK TRIB	5.62	8.21	6.38	0.00	21.28
B-148	03050107	MIDDLE TYGER RVR	3.61	9.35	6.62	0.00	19.98
B-317	03050107	MUSH CK	3.85	9.02	6.63	0.00	21.02
B-008	03050107	TYGER RVR	5.71	9.49	6.80	0.00	23.50
B-051	03050107	TYGER RVR	6.74	9.16	6.97	0.00	23.60
B-072	03050108	DUNCAN CK	10.39	8.67	7.03	0.00	23.26
B-097	03050108	DURBIN CK	4.32	9.04	6.63	0.00	22.10
BE-001	03050108	ENOREE RVR	3.62	9.02	6.43	0.00	20.98
BE-017	03050108	ENOREE RVR	4.95	8.97	6.70	0.00	22.94
B-041	03050108	ENOREE RVR	5.34	9.02	6.72	0.00	24.00
B-054	03050108	ENOREE RVR	6.76	8.61	6.91	0.00	25.29
B-192	03050108	PRINCESS CK	2.60	9.11	6.31	0.00	20.70
S-042	03050109	BUSH RVR	13.44	6.51	6.75	0.00	23.75
S-290	03050109	CAMPING CK	14.95	8.66	7.01	0.00	22.90
S-131	03050109	LAKE GREENWOOD	5.14	9.01	6.95	0.00	28.19
S-274	03050109	LAKE MURRAY	4.64	8.73	7.17	0.00	27.85
S-223	03050109	LAKE MURRAY	5.54	9.34	7.35	0.00	28.04
S-279	03050109	LAKE MURRAY	5.16	8.68	7.17	0.00	28.15
S-280	03050109	LAKE MURRAY	4.68	8.65	7.27	0.00	28.03
S-273	03050109	LAKE MURRAY	4.75	8.66	7.19	0.00	27.20
S-204	03050109	LAKE MURRAY	5.11	8.59	7.38	0.00	27.35
S-292	03050109	LAKE, N SALUDA RESERVOIR	2.14	9.03	6.92	0.00	24.92
S-291	03050109	LAKE, TABLE ROCK RESERVOIR	1.37	8.89	6.77	0.00	25.17
S-034	03050109	LITTLE RVR	7.58	9.53	6.75	0.00	25.56
S-123	03050109	LITTLE SALUDA RVR	8.42	7.36	6.62	0.00	23.58
S-315	03050109	MILL CK	8.08	8.23	6.24	0.00	20.44
S-088	03050109	N SALUDA RVR	3.29	9.80	6.49	0.00	17.41

Santee Basin Continued:

STATION #	Hydrologic Unit Code	STREAM NAME	Average Calcium	Average Dissolved Oxygen	Average pH	Average Salinity	Averag Summer Temp.
S-093	03050109	NINETY SIX CK	11.25	8.68	6.96	0.00	23.75
S-073	03050109	REEDY RVR	3.55	9.21	6.46	0.00	18.58
S-013	03050109	REEDY RVR	5.42	8.89	6.63	0.00	22.98
S-018	03050109	REEDY RVR	13.83	8.75	6.93	0.00	23.77
S-021	03050109	REEDY RVR	8.39	8.59	6.77	0.00	25.44
S-250	03050109	SALUDA RVR	3.25	8.87	6.54	0.00	22.24
S-007	03050109	SALUDA RVR	3.41	9.07	6.59	0.00	23.77
S-125	03050109	SALUDA RVR	4.04	9.08	6.74	0.00	25.70
S-295	03050109	SALUDA RVR	5.18	7.96	6.62	0.00	25.73
S-186	03050109	SALUDA RVR	4.65	7.87	6.63	0.00	25.51
S-298	03050109	SALUDA RVR	5.23	8.30	6.75	0.00	18.32
S-294	03050109	TWELVEMILE CK	3.37	8.61	6.80	0.00	23.90
B-080	03050110	BROAD RVR	6.46	8.73	7.16	0.00	27.83
C-008	03050110	CONGAREE CK	0.87	8.13	6.15	0.00	24.50
CSB-001R	03050110	CONGAREE RVR	6.02	8.86	7.03	0.00	24.63
CSB-001L	03050110	CONGAREE RVR	5.22	9.05	7.05	0.00	21.90
C-007	03050110	CONGAREE RVR	5.40	8.33	6.81	0.00	24.84
C-001	03050110	GILLS CK	2.48	8.08	6.49	0.00	26.47
C-017	03050110	GILLS CK	2.72	7.53	6.37	0.00	25.11
C-068	03050110	LAKE, FOREST	1.83	8.66	6.62	0.00	27.50
C-072	03050110	TOMS CK	0.81	8.02	5.74	0.00	23.69
ST-024	03050111	LAKE MARION	7.17	8.56	7.11	0.00	28.04
ST-025	03050111	LAKE MARION	8.15	9.28	7.00	0.00	27.29
ST-031	03050112	REDIVERSION CANAL	5.45	8.38	7.23	0.00	27.73
ST-016	03050112	SANTEE RVR	6.99	7.56	6.82	0.00	27.84
ST-001	03050112	SANTEE RVR	7.97	6.67	7.02	0.00	27.41

Savannah Basin:

STATION #	Hydrologic Unit Code	STREAM NAME	Average Calcium	Average Dissolved Oxygen	Average pH	Average Salinity	Averag Summer Temp.
SV-230	03060101	BIG EASTATOE CK	2.47	9.89	6.71	0.00	20.28
SV-333	03060101	CONEROSS CK	4.20	9.21	6.62	0.00	21.95
SV-004	03060101	CONEROSS CK	6.33	8.71	6.63	0.00	23.96
SV-135	03060101	EIGHTEEN MILE CK	5.39	9.28	6.67	0.00	21.24
SV-268	03060101	EIGHTEEN MILE CK	6.25	8.85	6.88	0.00	26.95
SV-236	03060101	LAKE HARTWELL	3.48	8.91	7.17	0.00	28.39
SV-288	03060101	LAKE HARTWELL	3.32	8.41	6.95	0.00	27.97
SV-339	03060101	LAKE HARTWELL	3.23	8.62	6.90	0.00	27.72
SV-335	03060101	LAKE JOCASSEE	1.88	8.88	6.76	0.00	25.95
SV-337	03060101	LAKE JOCASSEE	1.91	8.59	6.81	0.00	25.90
SV-336	03060101	LAKE JOCASSEE	1.89	8.68	6.76	0.00	25.75
SV-334	03060101	LAKE JOCASSEE	1.85	8.76	6.82	0.00	25.88
SV-338	03060101	LAKE KEOWEE	2.26	8.17	6.72	0.00	27.16
SV-312	03060101	LAKE KEOWEE	2.30	8.56	6.82	0.00	27.98
SV-311	03060101	LAKE KEOWEE	2.28	8.71	6.82	0.00	27.78
SV-249	03060101	SENECA RVR	2.35	8.41	6.59	0.00	27.24
SV-227	03060102	CHATTOOGA RVR	1.31	9.98	6.70	0.00	20.55
SV-199	03060102	CHATTOOGA RVR	1.45	9.91	6.75	0.00	21.84
SV-340	03060103	LAKE HARTWELL	2.95	8.61	6.90	0.00	27.83
SV-100	03060103	LAKE RUSSELL	3.16	8.03	6.59	0.00	19.91
SV-098	03060103	LAKE RUSSELL	3.39	9.01	6.97	0.00	26.47
SV-291	03060103	J. STROM THURMOND LAKE	4.40	9.00	6.78	0.00	26.88
SV-294	03060103	J. STROM THURMOND LAKE	4.22	8.66	6.69	0.00	24.37
SV-318	03060103	LONG CANE CK	10.62	8.87	6.87	0.00	22.78
SV-031	03060103	ROCKY RVR	6.29	8.67	6.61	0.00	23.11
SV-052	03060103	SAWNEY CK	20.07	8.21	6.81	0.00	23.10
SV-326	03060106	FOUR MILE CK	3.62	8.55	6.40	0.00	23.23
SV-329	03060106	HORSE CK	1.81	9.06	6.32	0.00	25.40
SV-071	03060106	HORSE CK	1.74	8.77	6.27	0.00	25.31
SV-096	03060106	HORSE CK	2.07	8.70	6.24	0.00	24.57
SV-250	03060106	HORSE CK	1.79	8.68	6.23	0.00	25.54
SV-328	03060106	LOWER THREE RUNS CK	7.95	8.37	6.75	0.00	24.08
SV-069	03060106	SAND RVR	2.00	8.76	5.96	0.00	22.14

Savannah Basin Continued:

STATION #	Hydrologic Unit Code	STREAM NAME	Average Calcium	Average Dissolved Oxygen	Average pH	Average Salinity	Averag Summer Temp.
SV-251	03060106	SAVANNAH RVR	4.16	8.59	6.55	0.00	22.11
SV-252	03060106	SAVANNAH RVR	4.41	8.86	6.64	0.00	23.49
SV-323	03060106	SAVANNAH RVR	4.48	8.94	6.65	0.00	23.60
SV-118	03060106	SAVANNAH RVR	5.12	8.18	6.65	0.00	24.93
SV-327	03060106	STEEL CK	4.17	8.79	6.61	0.00	25.79
SV-324	03060106	TIMS BRANCH	3.27	9.07	6.40	0.00	21.86
SV-325	03060106	UPPER THREE RUNS CK	2.08	8.90	6.28	0.00	22.48
SV-151	03060107	HARD LABOR CK	12.30	8.32	6.84	0.00	23.45
SV-330	03060107	STEVENS CK	11.38	9.39	7.10	0.00	23.64
SV-191	03060109	SAVANNAH RVR	11.86	6.94	6.92	1.36	27.00

Pee Dee Basin:

STATION #	Hydrologic Unit Code	STREAM NAME	Average Calcium	Average Dissolved Oxygen	Average pH	Average Salinity	Averag Summer Temp.
PD-004	03040201	BLACK CK	3.03	8.62	6.75	0.00	27.34
PD-023	03040201	BLACK CK	4.37	7.01	6.46	0.00	26.67
PD-021	03040201	BLACK CK	1.35	8.40	5.91	0.00	27.23
PD-025	03040201	BLACK CK	3.64	7.87	6.61	0.00	25.61
PD-027	03040201	BLACK CK	4.13	7.97	6.63	0.00	25.15
PD-065	03040201	GULLEY BR	9.02	8.54	6.74	0.00	25.72
PD-327	03040201	LAKE ROBINSON	0.74	7.64	6.76	0.00	32.26
PD-012	03040201	PEE DEE RVR	6.88	8.70	6.93	0.00	26.37
PD-015	03040201	PEE DEE RVR	7.41	8.23	6.90	0.00	27.00
PD-028	03040201	PEE DEE RVR	7.57	8.00	6.85	0.00	26.53
PD-337	03040201	PEE DEE RVR	7.49	7.70	6.69	0.00	26.21
PD-076	03040201	PEE DEE RVR	8.22	7.66	6.73	0.00	27.04
PD-061	03040201	PEE DEE RVR	6.81	6.91	6.57	0.00	27.25
PD-187	03040201	SMITH SWAMP	16.31	4.22	6.58	0.00	24.44
MD-080	03040201	WINYAH BAY	8.97	7.54	6.82	3.34	26.24
PD-006	03040202	LITTLE LYNCHES RVR	5.64	9.63	6.78	0.00	23.21
PD-109	03040202	LITTLE LYNCHES RVR	3.51	8.73	6.59	0.00	23.65
PD-113	03040202	LYNCHES RVR	7.48	9.28	6.90	0.00	23.02
PD-080	03040202	LYNCHES RVR	2.97	8.46	6.63	0.00	24.64
PD-071	03040202	LYNCHES RVR	3.08	7.90	6.50	0.00	23.85
PD-364	03040202	LYNCHES RVR	3.65	7.89	6.51	0.00	25.63
PD-041	03040202	LYNCHES RVR	4.14	7.75	6.55	0.00	25.52
PD-319	03040202	LYNCHES RVR	4.20	7.65	6.64	0.00	25.67
PD-093	03040202	LYNCHES RVR	3.92	7.99	6.62	0.00	25.40
PD-281	03040202	LYNCHES RVR	4.48	7.23	6.59	0.00	24.58
PD-332	03040202	SPARROW SWAMP	4.79	7.04	6.51	0.00	24.09
PD-038	03040203	LUMBER RVR	4.39	7.27	6.47	0.00	25.27
PD-069	03040204	LITTLE PEE DEE RVR	2.18	7.64	6.30	0.00	24.33
PD-052	03040204	LITTLE PEE DEE RVR	2.06	7.49	6.26	0.00	24.71
PD-042	03040204	LITTLE PEE DEE RVR	3.91	7.02	6.38	0.00	25.63
PD-189	03040204	LITTLE PEE DEE RVR	3.62	6.55	6.27	0.00	26.03
PD-227	03040205	BLACK RVR	6.11	6.67	6.62	0.00	25.39
PD-170	03040205	BLACK RVR	5.88	6.18	6.62	0.00	27.02
PD-325	03040205	BLACK RVR	7.41	6.70	6.68	1.24	26.83
PD-091	03040205	POCOTALIGO RVR	4.19	4.31	6.35	0.00	25.31
PD-202	03040205	POCOTALIGO RVR	12.75	3.44	6.54	0.00	25.58
PD-043	03040205	POCOTALIGO RVR	8.96	6.41	6.77	0.00	25.22
MD-127	03040206	ICWW	4.74	5.65	6.22	0.00	26.98
MD-124	03040206	WACCAMAW RVR	3.35	6.29	6.33	0.00	26.71
MD-138	03040206	WACCAMAW RVR	6.20	6.66	6.46	0.02	26.88
MD-146	03040206	WACCAMAW RVR, ICWW	5.08	5.73	6.30	0.00	26.25
MD-087	03040207	ICWW	5.63	5.74	6.37	0.00	26.94
MD-162	03040207	LITTLE RVR	15.59	7.43	7.10	7.92	28.02
MD-075	03040207	SAMPIT RVR	10.82	5.99	6.81	3.38	27.15
MD-073	03040207	SAMPIT RVR	10.23	6.73	6.88	3.38	26.96
MD-077	03040207	SAMPIT RVR	10.33	6.60	6.78	3.40	27.00
MD-149	03040207	WHITES CK	10.62	6.34	6.83	3.43	26.33

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