AMERICAN EEL ABUNDANCE AND DISTRIBUTION ALONG THE SPILLWAYS OF THE LAKE WATEREE DAM ON THE WATEREE RIVER AND THE COLUMBIA DAM ON THE BROAD RIVER

COMPLETION REPORT

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Summary

During 2010-2012 we evaluated American eel *Anguilla rostrata* abundance and distribution along the spillways of the Columbia and Wateree dams. Eel ramp traps were fished at up to four locations along each dam for a total effort of 4,890 ramp days. Backpack electrofishing was conducted on 37 dates with a total electrofishing effort of 9 hours at each Wateree and Columbia dams. During 2010 - 2012 twenty-five American eels were captured; 12 at Wateree Dam and 13 at Columbia Dam. Based on ramp trap collections and backpack electrofishing along the spillways of the dams there appeared to be very few eels in the vicinity of the two dams during 2010 - 2012. Based on very limited observations it appears that the best placement for future passage facilities at Wateree Dam would be near the powerhouse on the west side of the spillway and for Columbia Dam near the existing fish passage facility on the east side of the dam.

Introduction

Since the 1980's a decrease in American eel *Anguilla rostrata* catch rates has heightened concerns over the status of the population (ASMFC 2000; Haro et al. 2000). The cause of this decline is unknown, but several factors (e.g. migration barriers, habitat loss and degradation, overfishing, etc.) have been identified that could affect abundance and distribution (Haro et al. 2000). American eel were historically abundant along the Atlantic slope where their range extended into the Wateree and Broad rivers and their tributaries. Dams constructed along those rivers and tributaries have impeded the inland migration of juvenile eels and the seaward migration of adults altering eel distribution within the Santee River Basin. Facilitating passage around migration barriers should benefit American eel populations and augment restoration efforts. Juvenile eels may exhibit specific habitat preferences that could influence where along

the dam they attempt upstream passage. Maximizing eel passage will require effective placement of passage facilities. The objectives of this study were to quantify the migrational timing and abundance of American eels at various locations along the spillways of the Lake Wateree Dam on the Wateree River and the Columbia Dam on the Broad River, evaluate factors that effect this distribution, and identify areas where American eel passage would be maximized.

Materials and Methods

Eel Collection

Eel ramp traps, backpack electrofishing, box traps, eel pots, and visual surveys were used to identify when and where eel passage and collection devices should be placed at the Wateree and Columbia dams to maximize passage of American eels.

The design of the ramp traps was similar to those that worked very well at Roanoke Rapids, North Carolina (Dominion 2009). Ramp traps were constructed from ¾ inch plywood, or aluminum cable trays, and ranged from roughly 7 ft to 13 ft in length and were 12 inches wide. The ramp deck was covered with 1-in polyethylene Akwadrain strip drain (AWD, Inc., Monroe, North Carolina) and terminated at a covered collection bucket (Figure 1). Water was supplied to each ramp and collection bucket through gravity fed supply lines. Attraction flow was added to ramp traps at Wateree Dam during 2011 by adding an additional water supply line to each trap that gently agitated the water surface at the ramp entrance. The entrance to each trap was submerged at all water generation levels.

Three ramp traps were installed at Wateree Dam during spring 2010 and a fourth trap, trap 0, was added during 2011 (Figure 2). At Columbia Dam 3 ramp traps were installed during spring 2010 and a fourth trap, a box-style, trap was added during 2011 (Figures 1 and 2), during 2012 this box style trap was removed and replaced with a ramp trap. During 2011 all the ramp

traps, except for trap 1 at Columbia Dam, were replaced with aluminum ramps with similar dimensions and water supply features as the original wooden ramps. During 2010 – 2012 eel ramp traps, as well as baited traps, were monitored at least monthly until April, and then typically every Monday, Wednesday, and Friday through June. After June eel traps were monitored biweekly for the remainder of the year. The base of each dam was visually surveyed each sampling day to identify congregations of eels in areas not sampled with traps.

Ramp trap collections were supplemented with other passive gear and backpack electrofishing was used to evaluate the presence and abundance of eels in the vicinity of the Wateree and Columbia dams. Two types of passive eel pots were used, a tubular (80 cm x 15 cm) Fukui eel trap (FT-108; Fukui North America, Ontario, Canada) and a minnow trap (Eagle Claw Fishing Tackle Co., Denver, Colorado) that was 41 cm x 23 cm with a funnel that terminated in a 0.3 cm opening. The Eagle Claw minnow traps were covered with nylon stocking material to prevent escapement of eels. Both traps were baited with cut gizzard shad or cat food and fished continuously at 4 and 6 locations at Columbia Dam and Wateree Dam, respectively. Electrofishing was conducted by two person teams using a LR-24 backpack electrofishing unit (Smith-root, Inc., Vancouver, Washington). An attempt was made to backpack electrofish most month's spring - summer for 10 minutes at each ramp trap location, except trap 0 at Wateree Dam where water depth was too great for wading. Backpack electrofishing was delayed at Columbia Dam during 2010 until a "right of entry" agreement could be reached with the City of Columbia.

Collected eels were enumerated, measured, examined for visual implant elastomer (VIE) tags with a VI light (Northwest Marine Technology Inc., Shaw Island, Washington) and released

above the dams. One eel captured on 18 October 2012, was retained and sacrificed so that its elastomer tag could be removed and the tag color confirmed.

Eel Marking

During April 2012 we marked eels collected in ramp traps below the St. Stephen's fish passage in the Santee-Cooper rediversion canal with VIE tags and stocked them below the Columbia and Wateree dams. The eels were tagged and stocked in an effort to increase the number of eels in the vicinity of the dams so that we could better address our objective of determining where along the spillways of the two dams eels attempt to pass. On 20 April 2012 staff from the South Carolina Department of Natural Resources (SCDNR) Fisheries Section, Duke Power, and United States Fish and Wildlife Service (USFWS) implanted 863 eel elvers (Mean TL = 93 mm; Range 48 – 151 mm TL) with pink VIE tags. The eels were divided equally and stocked 25 April 2012 into the Broad River approximately 1 mile below Columbia Dam and into the Wateree River approximately 2 miles below Wateree Dam.

Water Quality

Water temperature at multiple trap locations was recorded at 15-minute intervals with temperature loggers (HOBO Pendant; Onset Computer Corporation, Inc., Pocasset, Massachusetts). Temperature, dissolved oxygen, and conductivity were recorded at each ramp trap location during each sampling visit with a Pro Plus mutlitparameter meter (YSI, Inc. Yellow Springs, Ohio).

Results/Discussion

Eel Collection

The minimum number of days eel ramp traps were in operation varied by site and trap location from 24 to 340 days/year (Table 1). Ramp traps at Wateree Dam were in operation relatively consistently while those at Columbia Dam often lost prime due to the small elevation change from the reservoir to the ramp traps. Ramp traps at Columbia Dam were also dislodged during high water events while those at Wateree Dam remained in place for the duration of the study. Ramp traps 2 and 3 at Columbia Dam were frequently dislodged during spring and summer 2010, and during 2011 often lost prime due to low water levels. During 2012 we had much better success keeping ramp traps at Columbia Dam operational due largely to more favorable flow conditions and the installation of aluminum ramps that were less likely to be damaged or dislodged during high flow events.

Backpack electrofishing was used to supplement ramp trap effort and was conducted during spring through fall at each site during 2010 - 2012 (Table 2). Monthly electrofishing effort varied by site and year and ranged from 0 to 90 minutes (Table 2). An effort was made to sample for 10 minutes at each ramp trap location; however, occasionally environmental factors limited our ability to effectively sample some of the locations at each site. For example, May electrofishing collections were not possible at Columbia Dam during 2012 due to high water, and ramp trap 3 at Wateree Dam could not be sampled effectively after June 2012 due to excessive growth of aquatic vegetation. We discontinued sampling on the West side of Columbia Dam during 2012 due to the extremely slick bedrock and broken terrain that caused a personnel safety issue. During July and August 2011 we increased our backpack electrofishing sampling at Columbia Dam to account for poor ramp trap performance due to low water levels. During the

three year study we expended 18 hours of effort backpack electrofishing in the vicinity of ramp trap locations at the two dams.

During 2010-2012 twenty-five eels (Mean Total Length [TL] = 216 mm; range 84 – 394 mm TL) were collected from the two dams (Table 3). Thirteen eels were collected from Columbia Dam and 12 eels were collected from Wateree Dam. Electrofishing was more productive at Columbia dam where 10 eels were captured during backpack electrofishing, while only three eels were captured in traps (2 in ramp traps and 1 in a Fukui trap). Conversely, ramp traps were more effective at Wateree dam where 11 of 12 eels captured were collected from ramp traps. Baited minnow traps were not effective collecting eels. One eel was collected in a Fukui trap at Columbia Dam and no eels were collected in baited minnow traps. There was no difference in mean TL of American eel between collection method or site (t-test; $P > 0.05$). Although eels were captured throughout the year, the majority (18 of 25) were captured between April and June once water temperatures reached 20 ºC; most of the remaining eels were captured after water temperatures began to cool during fall (Figures 3 and 4).

All eels collected from Wateree Dam were captured on the west side of the spillway near the powerhouse in ramps 0 – 2; no eels were captured from ramp 3 on the east side of the Dam. At Columbia Dam all eels were captured on the east side of the dam near the fish passage facility at ramp locations 1 and 4, and the Fukui trap that was located near ramp 1.

Mean annual backpack electrofishing catch rate (number/hour) of eels at Columbia Dam was 1.28/h (range; 0.61 - 2.35) during 2010-2012 (Table 4). Only one eel was collected while backpack electrofishing at Wateree Dam during 2010-2012. Annual mean ramp trap catch rates (number/trap day) were 0.0012 (range; 0.000 – 0.0019) and 0.0033 (range; 0.0018 – 0.0055) at Columbia Dam and Wateree Dam, respectively (Table 4).

Eel Marking

Three of the VIE marked and stocked eels were recaptured (Table 3). Two of the marked eels were recaptured in ramp traps at Wateree Dam and one eel was recaptured in a ramp trap at Columbia Dam. The first marked eel was recaptured at Wateree Dam on 1 June 2012; 42 days after it was stocked 2 miles below the dam. The other two eels were recaptured on 11 September 2012 (Columbia Dam) and 18 October 2012 (Wateree Dam).

Water Quality

Water temperature was recorded every 15 minutes at three Wateree Dam ramp sites and one ramp site at Columbia Dam (Figure 5). Mean daily water temperature exceeded 32 ºC at Wateree Ramp 2 (15 days) and Wateree Ramp 3 (5 days) during 2010 - 2012. At Columbia Dam water temperatures exceed 32 ºC on 5 dates all occurring during 2010. Shallow water likely resulted in water temperatures exceeding 32 ºC. Wateree Dam ramps 2 and 3 were located in areas where limited water exchange occurs at low generation and no water exchange occurs during no generation. The high water temperatures at Columbia ramp location 1 were likely due to the shallow water depths where the temperature logger was only a few cm below the water, or out of the water, at low flows.

Conductivity during 2010 and 2011 varied by site, ramp location, and season (Figure 6). Conductivity was highest during summer. Conductivity was similar among ramp locations at Columbia Dam (Mean = 87 µS/cm; range = 56 -186 µS/cm) and lower than Wateree Dam (mean = 147 µS/cm; range = 80 – 267 µS/cm), where conductivity varied among sites (Table 5, Figure 6). At Wateree Dam mean conductivities were similar at ramps 0 – 2, but higher at ramp location 3 where conductivity was highly variable and frequently exceed 200 µS/cm (Figure 6).

Dissolved oxygen was marginally higher at Columbia Dam ramp locations (mean = 7.2 mg/l; range = 3.5 – 11.0 mg/l) than Wateree Dam ramp locations (mean = 6.4 mg/l; range = 2.5 – 13.6 mg/l) during 2010 and 2011 (Table 6, Figure 7). Dissolved oxygen at all ramp locations exceeded 4mg/l on most dates. At Columbia Dam low dissolved oxygen (< 4mg/l) was observed on only one date at ramp 3. At Wateree Dam low dissolved oxygen (< 4mg/l) was observed more frequently, especially at ramp location 3 (8 dates) and ramp location 1 (5 dates) (Figure 7).

In general, the water quality parameters we collected at most ramp locations were consistent with the freshwaters of South Carolina and should not have negatively influenced eel use of the Broad River below Columbia Dam or the Wateree River below Wateree Dam. The low dissolved oxygen levels and high and variable conductivity at ramp location 3, in the bypassed reach below Wateree Dam, are likely due to the limited exchange of water in the bypassed area. Aquatic habitat in the bypassed reach directly below the dam is primarily small shallow pools, which are filled by dam seepage, separated by bedrock.

Recommendations

Catch of eels was very low at both dams during 2010-2012. It does not appear that many eels utilized the bypassed area below Wateree Dam, nor were eels abundant below Columbia Dam during 2010 - 2012. The low catch rates of eels below Columbia and Wateree dams are consistent with backpack electrofishing catch rates of eels in wadeable streams within the Congaree and Wateree drainages (Figure 8). Lower in the Santee Drainage, below the Santee-Cooper lakes, catch rates of eels in wadeable streams are much higher ranging from 9 to 14 eels per hour (Figure 8). Additionally, many more eels are captured in ramp traps below the St. Stephen's Fish Passage in the rediversion canal than below Columbia and Wateree dams. During 2012 over 17,000 eel elvers were collected below St. Stephen's while only 13 eels were

collected at our sample sites below Columbia and Wateree dams. It is clear, based on backpack electrofishing catch rates in wadeable streams and ramp trap catch rates below St Stephen's, that eels are more abundant lower in the system, below Pinopolis Dam on the Cooper River, St Stephen's Dam on the rediversion canal, and Wilson Dam on the Santee River. Future efforts should focus on getting eels past those migration barriers lower in the system so that passage higher in the system at Columbia and Wateree dams can be evaluated.

The low eel catch rates below both dams has limited our ability to recommend a suitable location for future passage facilities. All the eels collected at Wateree Dam have been collected on the west side of the dam nearest the powerhouse. We have expended over 2.8 hours of backpack electrofishing effort along the east side of the dam, and have had and eel ramp trap fishing for nearly three years in that location, but no eels have been collected. At Columbia Dam all the eels have been collected on the east side of the dam, near the fish passage facility; however, our collection effort has been much greater in that area. The west side of the dam is not accessible when water is spilling which has decreased our opportunities for electrofishing and water flowing over the dam has frequently dislodged our traps in that area. At the conclusion of this project, based on limited data, it is difficult to recommend an eel passage facility location for either dam. At Columbia Dam there is an existing eel passage on the west bank and all our eel captures have occurred on the east bank so an eel passage facility on the east bank near the existing fish passage would seem to make the most sense. At Wateree Dam the most sensible location appears to be just to the east of the power house. Further evaluation is warranted in the future when the density of eels increases in the vicinity of these dams.

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Dominion. 2009. Roanoke Rapids and Gaston Hydropower Project FERC No. 2009: American Eel studies-2009. Dominion Electric Environmental Services, Richmond, Virginia.

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Tables

Table 1. Installation date of each eel ramp trap at each site and the minimum number of days each ramp trap was running each year through November 2012.

Site	Trap	Installation Date	Trap Days 2010	2011	2012
Wateree	0	3/17/2011	*	268	301
	1	3/10/2010	291	298	304
	2	3/10/2010	224	295	340
	3	3/10/2010	236	265	320
Columbia	1	5/20/2010	161	222	220
	2	5/20/2010	24	113	299
	3	6/8/2010	63	95	191
	4	5/11/2011	*	61	299

Table 2. Backpack electrofishing effort in minutes at each site by month during 2010 - 2012.

		Site		
Year	Month	Columbia	Wateree	Total Effort
2010				
	April	-	46	46
	May	-	36	36
	June	35	18	53
	July	29	27	57
	August	10	27	38
	October	24	27	51
	November	0	21	21
2011				
	March	10	28	38
	April	10	30	40
	May	50	28	78
	June	31	52	82
	July	79	0	79
	August	97	23	120
	November	28	28	57
	December	33	31	64
2012				
	February	30	25	55
	April	29	28	57
	June	15	15	30
	July	11	12	23
	September	6	18	24
	December	11	20	31
Total Effort		538	540	1080

Table 3. Total length of American eel collected by date from each site and ramp location, method of capture, and color of VIE tag if present during 2010-2012.

Date	Site	Location	TL (mm)	Method	Tag
4/21/2010	Wateree	1	108	Ramp	
8/10/2010	Wateree	2	394	Ramp	
8/25/2010	Columbia	1	314	E.F.	
5/2/2011	Wateree	1	235	Ramp	
5/25/2011	Columbia	1	203	E.F.	
6/17/2011	Wateree	1	249	E.F.	
6/17/2011	Wateree	2	272	Ramp	
6/17/2011	Columbia	1	203	E.F.	
6/17/2011	Columbia	1	217	E.F.	
6/29/2011	Columbia	Fukui 1	251	Fukui	
12/14/2011	Columbia	1	223	E.F.	
12/14/2011	Columbia	1	162	E.F.	
2/1/2012	Columbia	1	200	E.F.	
4/23/2012	Wateree	0	189	Ramp	
4/23/2012	Columbia	1	167	E.F.	
4/27/2012	Wateree	0	176	Ramp	
5/14/2012	Wateree	0	208	Ramp	
5/23/2012	Wateree	2	200	Ramp	
5/23/2012	Wateree	0	286	Ramp	
6/1/2012	Wateree	2	84	Ramp	Pink
6/13/2012	Columbia	1	245	E.F.	
6/13/2012	Columbia	1	335	E.F.	
6/22/2012	Columbia	1	138	Ramp	
9/11/2012	Columbia	4	128	Ramp	Pink
10/18/2012	Wateree	0	224	Ramp	Pink

Table 4. Catch per unit effort (CPUE) expressed as number of American eels captured per hour for backpack electrofishing (Eel/h) and number of American eels captured per day for ramp traps at two sites during 2010 – 2012 in the Broad River below the Columbia Dam and in the Wateree River below Wateree Dam.

		CPUE	
Dam	Year	Backpack (Eel/h)	Ramp Traps (Eel/day)
Columbia	2010	0.61	0.0000
Columbia	2011	0.89	0.0019
Columbia	2012	2.35	0.0016
Wateree	2010	0.00	0.0027
Wateree	2011	0.27	0.0018
Wateree	2012	0.00	0.0055

Table 5. Mean Conductivity (µs/cm), minimum and maximum observed values at each ramp location at Columbia and Wateree dams during 2010 and 2011.

		2010				2011			
Site	Ramp	N	Mean	Min	Max	N	Mean	Min	Max
Columbia	1	24	90	73	186	51	81	57	104
Columbia	2	9	82	71	131	36	86	65	105
Columbia	3	10	91	78	115	22	103	76	143
Columbia	4	-	-	-	-	26	84	65	96
Wateree	0	-	-	-	-	56	144	90	186
Wateree	1	41	129	80	165	59	146	122	220
Wateree	2	44	129	83	183	55	147	102	188
Wateree	3	45	149	92	215	59	175	136	269

Table 6. Mean dissolved oxygen (mg/l), minimum, and maximum observed values at each ramp location at Columbia and Wateree dams during 2010 and 2011.

		2010				2011		
Site	Ramp	N	Mean	Min	Max	N	Mean	Min	Max
Columbia	1	24	7.28	4.60	10.30	52	7.39	4.42	11.00
Columbia	2	10	8.23	5.80	9.93	35	7.47	5.35	10.97
Columbia	3	10	5.84	4.30	7.00	22	6.40	3.46	9.88
Columbia	4	-	-	-	-	26	7.33	4.42	10.69
Wateree	0	-	-	-	-	56	6.06	3.58	10.19
Wateree	1	43	6.84	3.69	13.60	59	5.95	3.31	10.70
Wateree	2	44	7.29	4.95	12.44	56	6.42	3.76	11.50
Wateree	3	45	6.90	4.00	13.03	59	5.87	2.54	11.04

Figures

Figure 1. Ramp trap (top panel) and box-style trap (bottom panel) installed at Columbia Dam, South Carolina.

Figure 2. Eel ramp trap locations at Columbia Dam (top panel) and Wateree Dam (bottom panel) during 2012.

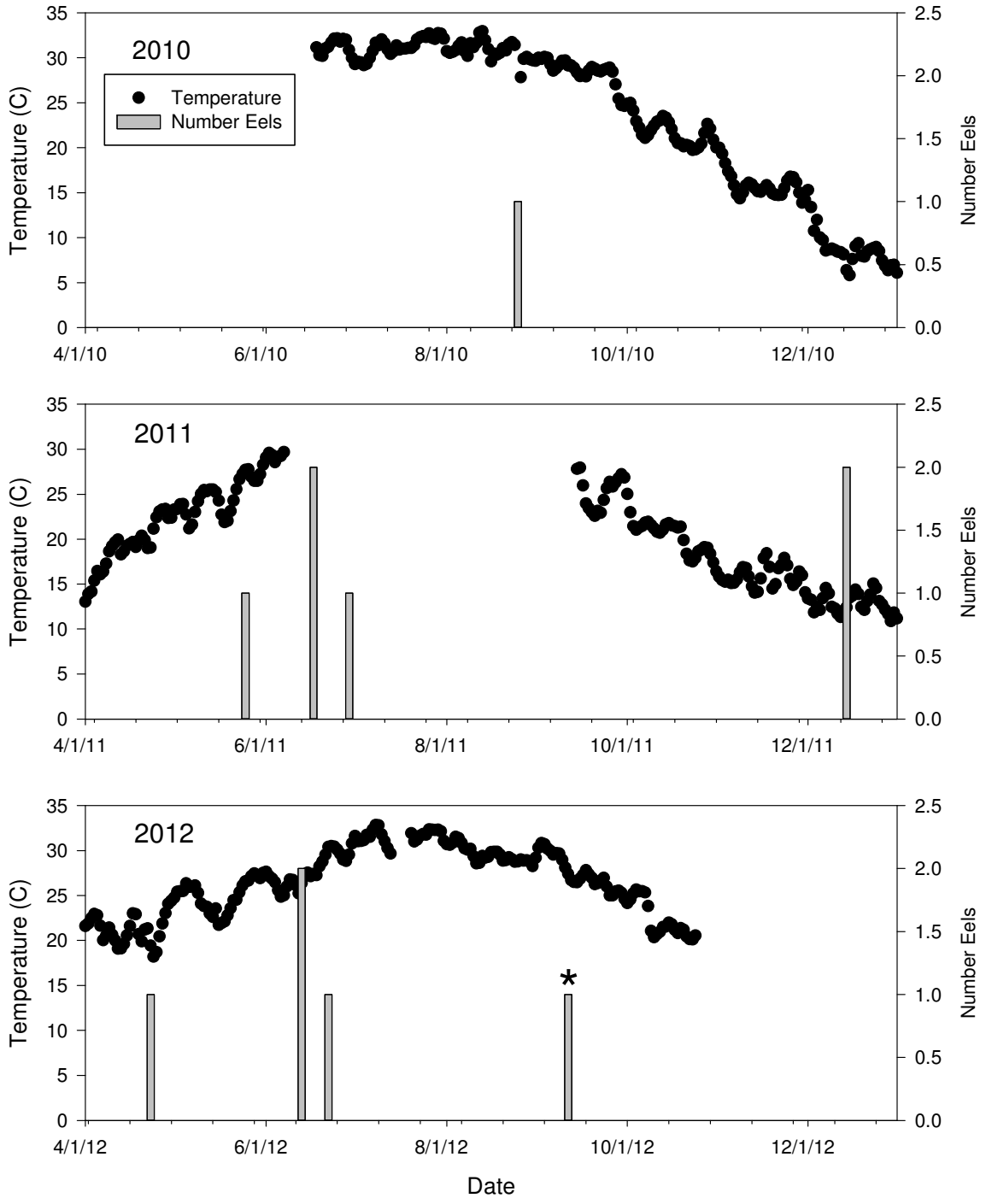

Figure 3. Water temperature at Columbia Dam ramp site 1 and the number of eels collected at all Columbia Dam sites during April – December of each study year. Astericks indicates recapture of tagged and stocked eel.

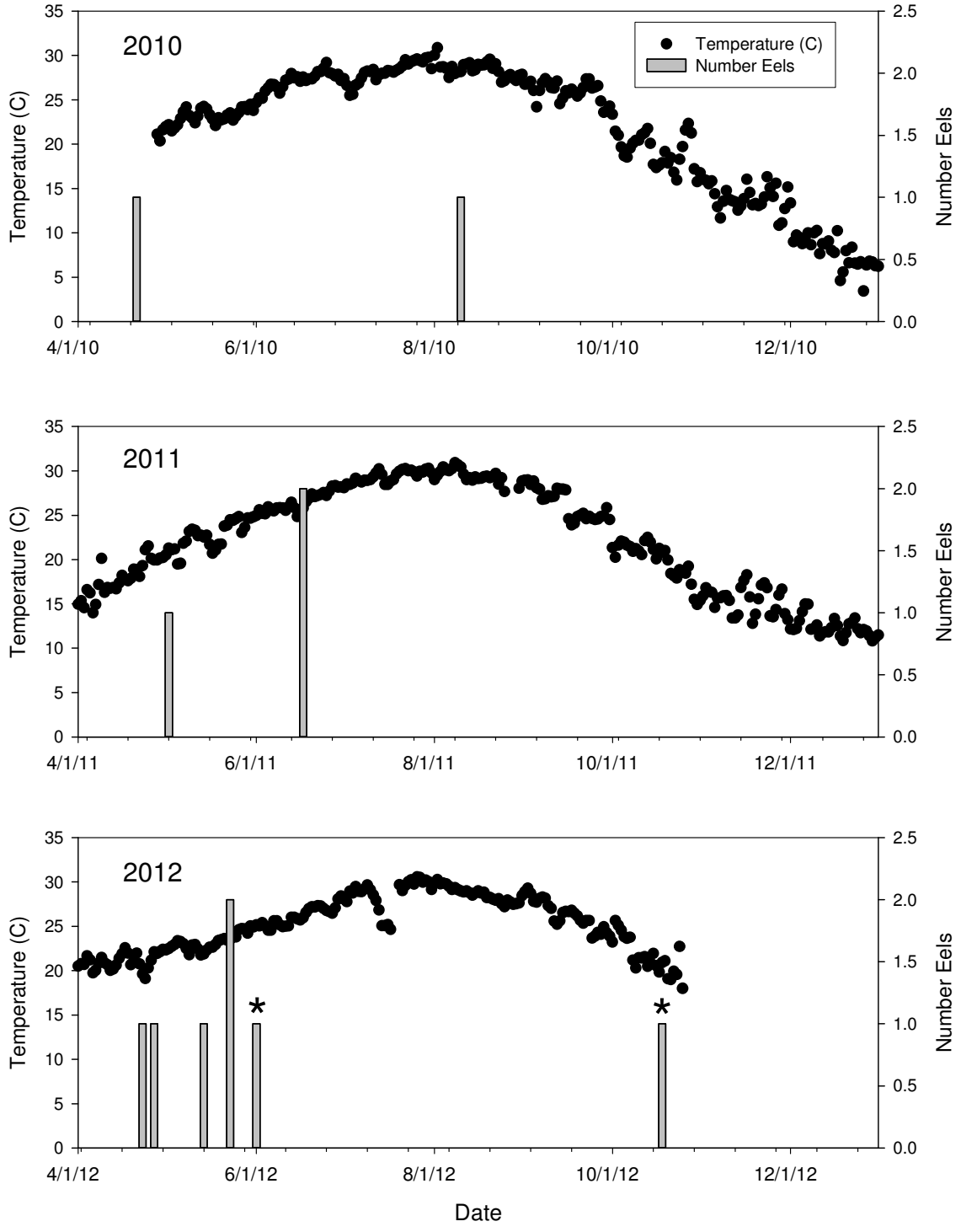

Figure 4. Water temperature at Wateree Dam ramp site 1 and the number of eels collected at all Wateree Dam sites during April – December of each study year. Astericks indicates recapture of tagged and stocked eel.

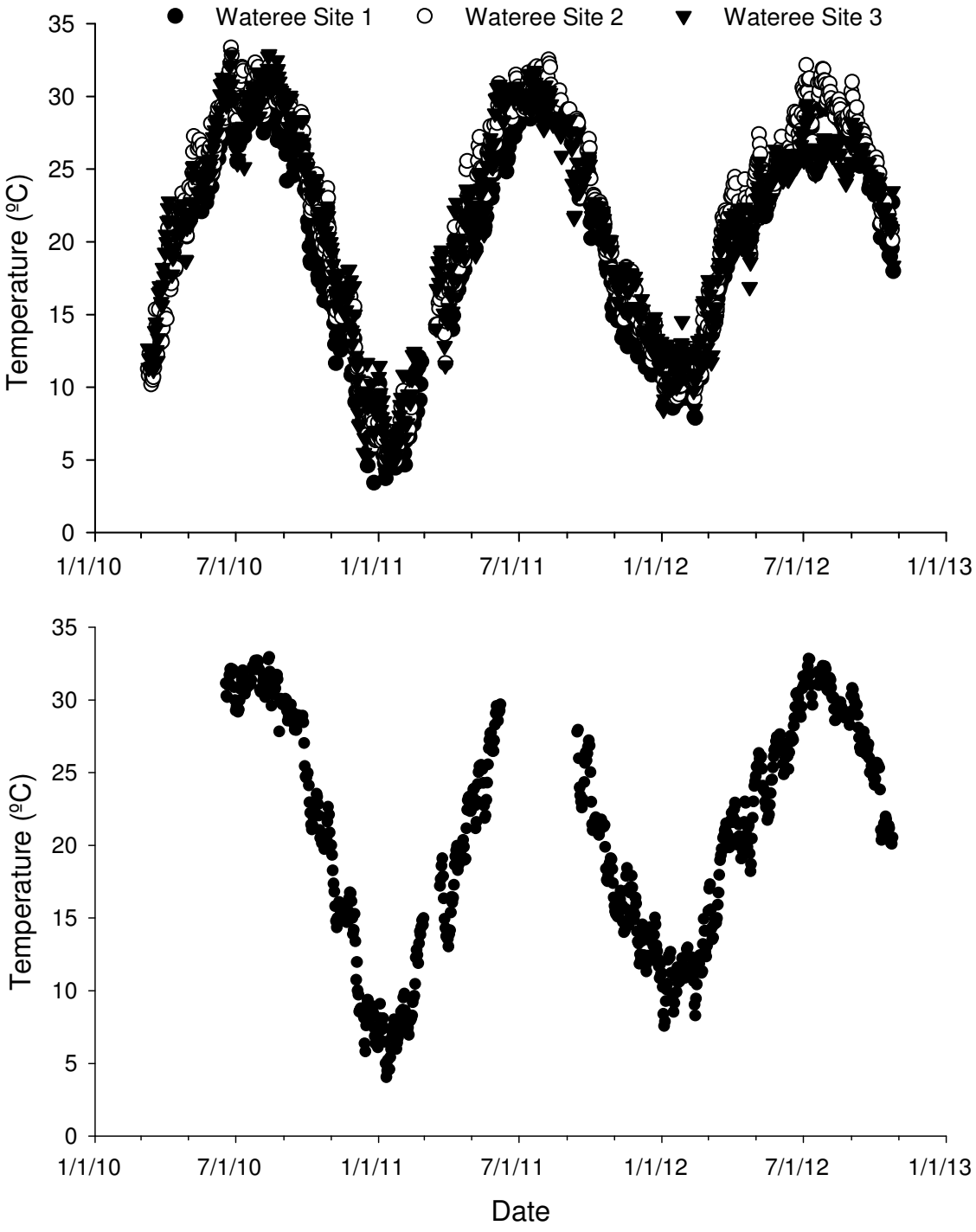

Figure 5. Mean daily water temperature at Wateree Dam (top panel) and Columbia Dam (bottom panel) collected with Onset temperature loggers during 2010 – 2012.

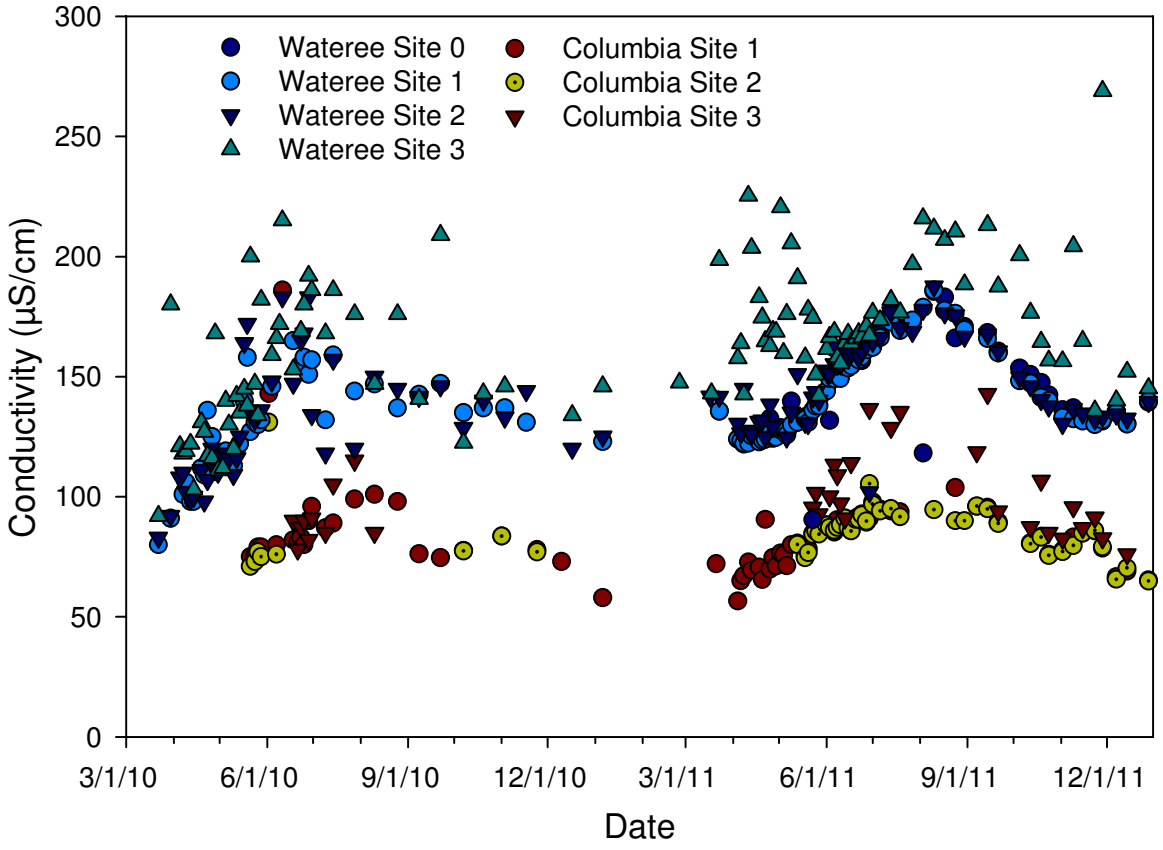

Figure 6. Conductivity (µS/cm) on each sample date at each site and ramp location during 2010-2011.

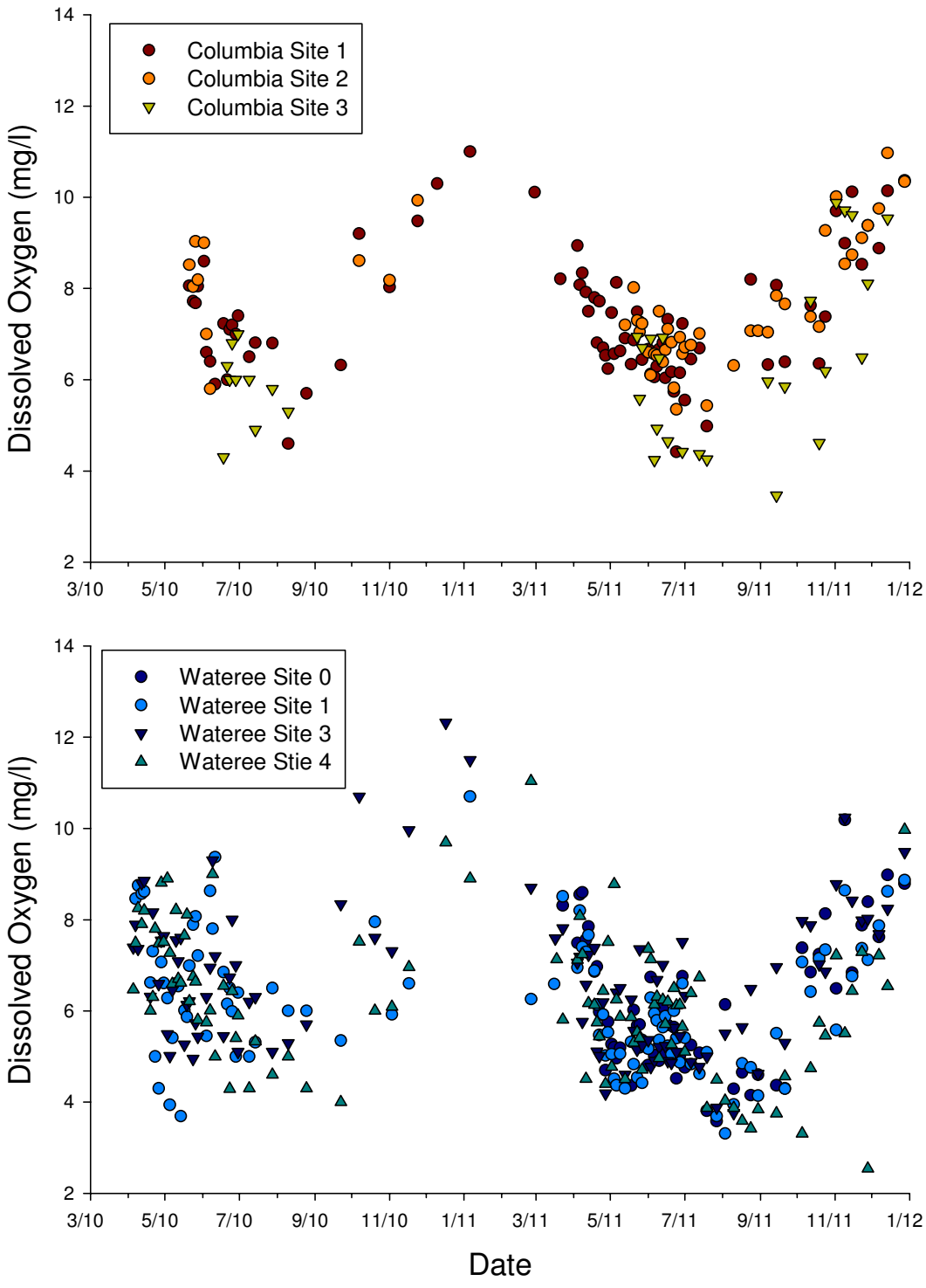

Figure 7. Dissolved oxygen (mg/l) at Columbia Dam ramp locations (top panel) and Wateree Dam ramp locations (bottom panel) during 2010 and 2011.

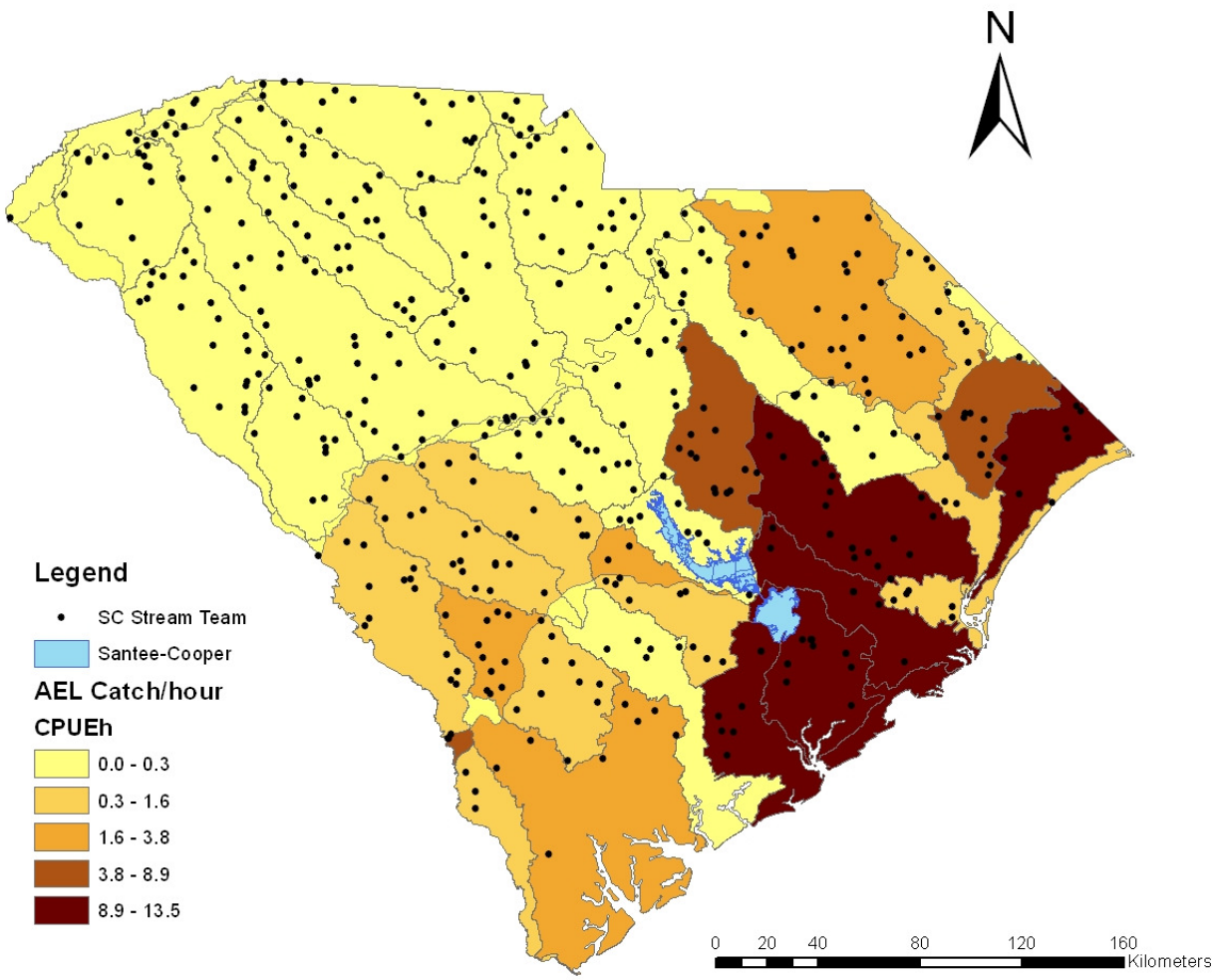

Figure 8. Mean backpack electrofishing catch rates (number/hour) of American eel in South Carolina wadeable streams by drainage. Mean catch rates calculated from data collected by the SCDNR stream team during 2005-2011.