Estimating Relative Abundance of Young of Year American Eel, *Anguilla rostrata,* in the Virginia Tributaries of Chesapeake Bay (Spring 2008)

Final Report

Submitted by

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Introduction

American eel (*Anguilla rostrata*) is a valuable commercial species along the Atlantic coast of North America from New Brunswick to Florida. In recent years, harvest along the U.S. Atlantic Coast has declined, with similar patterns occurring in the Canadian Maritime Provinces (Meister and Flagg 1997). Landings from Chesapeake Bay typically represent 63% of the annual United States commercial harvest (ASMFC 2000). In 2008, Virginia commercial landings were 154,451 lbs with the average annual landings since mandatory reporting began in 1993 at 218,037 lbs (VMRC 2008).

A decline in abundance of American eel has been observed in recent years with conflicting evidence regarding spatial synchrony throughout their range (Richkus and Whalen 1999; Sullivan et al. 2006). Limited knowledge about fundamental biological characteristics of glass eels has complicated interpretation of juvenile abundance trends (Sullivan et al. 2006). Hypotheses for the decline in abundance include shifts in location of the Gulf Stream, pollution, overfishing, parasites, altered oceanic conditions, and barriers to fish passage (Castonguay et al. 1994; Haro et al. 2000; Knights 2003). Additionally, factors such as unfavorable wind-driven currents may affect glass eel recruitment on the continental shelf and may have a greater impact than fishing mortality or continental climate change (Knights 2003).

The Atlantic States Marine Fisheries Commission (ASMFC) adopted the Interstate Fishery Management Plan (FMP) for the American eel in November 1999. The FMP focuses on increasing coastal states' efforts to collect American eel data through both fishery-dependent and fishery-independent studies. Consequently, member jurisdictions agreed to implement an annual survey for young-of-year (YOY) American eels. The survey is intended to "…characterize trends in annual recruitment of the YOY eels over time [to produce a] qualitative appraisal of the annual recruitment of American eel to the U.S. Atlantic Coast" (ASMFC 2000). The development of these surveys began in 2000 with full implementation by 2001. Survey results should provide necessary data on coastal recruitment success and further understanding of American eel population dynamics. A recent American eel stock assessment report (ASMFC 2006) emphasized the importance of the coast-wide survey as an index of sustained recruitment over the historical coastal range and an early warning of potential range contraction of the species. In 2008, the Virginia Institute of Marine Science continued its spring sampling to estimate relative abundance of YOY American eels in Virginia tributaries of Chesapeake Bay.

Life History

The American eel is a catadromous species that occurs along the Atlantic and Gulf coasts of North America and inland in the St. Lawrence Seaway and Great Lakes (Murdy et al. 1997). The species is panmictic and supported throughout its range by a single spawning population (Haro et al. 2000; Meister and Flagg 1997). Spawning takes place during winter to early spring in the Sargasso Sea. Eggs hatch into leaf-shaped transparent ribbon-like larvae called leptocephali, which are transported by ocean currents (over 9-12 months) in a generally northwesterly direction and can grow to 85 mm TL (Jenkins and Burkhead 1993). Within a year, metamorphosis into the next life stage (glass eel) occurs in the Western Atlantic near the east coast of North America. A reduction in length to about 50 mm TL occurs prior to reaching the continental shelf (Jenkins and Burkhead 1993). Coastal currents and active migration transport the glass eels (= YOY) into Maryland and Virginia rivers and estuaries from February to June (Able and Fahay 1998). As growth continues, the glass eel becomes pigmented (elver stage) and within 12 to14 months acquires a dark color with underlying yellow (yellow eel stage). Many eels migrate upriver into freshwater rivers, streams, lakes, and ponds, while others remain in estuaries. Most of the eel's life is spent in these habitats as a yellow eel. Metamorphosis into the silver eel stage occurs during the seaward migration that occurs from late summer through autumn. Age at maturity varies greatly with location and latitude and in Chesapeake Bay may range from 8 to 24 years, with most mature eels being less than 10 years old (Owens and Geer 2003). American eel from Chesapeake Bay mature and migrate at an earlier age than eels from northern areas (Hedgepeth 1983). Upon maturity, eels migrate back to the Sargasso Sea to spawn and die (Haro et al. 2000).

It has been suggested that glass eel migration has a fortnightly periodicity related to tidal currents and stratification of the water column (Ciccotti et al. 1995). Additionally, alterations in freshwater flow (timing and magnitude) to bays and estuaries may affect the size, timing, and spatial patterns of upstream migration of glass eels and elvers (Facey and Van Den Avyle 1987). YOY eel may use freshwater "signals" to enhance recruitment to local estuaries, thereby influencing year-class strength (Sullivan et al. 2006).

Objectives

1. Monitor the glass eel migration, or run, into the Virginia Chesapeake Bay tributaries to determine the spatial and temporal components of recruitment.

2. Examine environmental factors, which may influence young-of-year eel recruitment.

3. Collect basic biological information on recruiting eels, including length, weight, and pigment stage.

Methods

Minimum criteria for YOY American eel sampling has been established in the ASMFC American Eel FMP, with the Technical Committee approving sampling gear. The timing and placement of gear must coincide with periods of peak YOY shoreward migration. At a minimum, the gear must fish during flood tides during nighttime hours. The sampling season is designated as a minimum of four days per week for at least six weeks or for the duration of the run. At least one site must be sampled in each jurisdiction. The entire catch of YOY eels must be counted from each sampling event and a minimum of 60 glass eels (if present per system) must be examined for length, weight, and pigmentation stage weekly.

Due to the importance of the eel fishery in Virginia, the methods used must ensure proper temporal and spatial sampling coverage, and provide reliable recruitment estimates. To provide the necessary spatial coverage and to assess suitable locations, numerous sites were evaluated previously (Geer 2001). Final site selection was based on known areas of glass eel concentrations, accessibility, and specific physical criteria (e.g., proper habitat) suitable for glass eel recruitment to the sampling gear. Four sites were selected with two on the York River and one each on the Rappahannock and James rivers. Two sites on the York River are Bracken's Pond and Wormley Pond (Figure 1). Bracken's Pond is located along the Colonial Parkway at the base of the Yorktown Naval Weapons Station Pier and is less than 100 m from the York River with the tide often reaching the spillway. This site was chosen as a primary site in 2000 with gear comparisons performed throughout the sampling season. Wormley Pond is located on the Yorktown Battlefield and drains into Wormley Creek which has a tidal range that routinely reaches 50 cm depth at the spillway. This site was not sampled in Spring 2000. Kamp's Millpond drains into the Eastern Branch of the Corrotoman River, a tributary to the Rappahannock River (Figure 1). Kamp's Millpond covers approximately 80 acres and is located upstream of Route 790, just north of Kilmarnock. The final collection site on the James River is Wareham's Pond, which is located in Kingsmill in James City County. Wareham's Pond drains directly into the James River, which is about 100 m away, though a high tide may reach the end of the spillway (Figure 1).

Irish eel ramps were used to collect eels at all sites. The ramp configuration successfully attracts and captures small eels in tidal waters of Chesapeake Bay. Ramp operation requires a continuous flow of water over the climbing substrate and the collection device, which was accomplished through a gravity feed. Hoses, with adapters, were attached to the ramp and collection buckets to allow for quick removal of eels for sampling. Enkamat™ erosion control material on the ramp floor provided a textured climbing surface and extended into the water below the trap. The ramps were placed on an incline (15-45^{o}) with the ramp entrance and textured mat extending into the water. The ramp entrance was placed in shallow water (< 25 cm) to prevent submersion of the entire ramp. The inclined ramp and an additional 4^{o} incline of the substrate inside the ramp provided sufficient slope to create attractant flow. A hinged lid provided access for cleaning and flow adjustments.

Only eels in the ramp's collection bucket (not on the climbing surface) were recorded. Trap performance was rated on a scale of 0 to 3 (0 = new set; 1 = gear fishing; 2 = gear fishing, but not efficiently; 3 = gear not fishing). Water temperature, air temperature, wind direction and speed, and precipitation were recorded during most site visits. All eels were enumerated and placed above the impediment, with any subsample information recorded, if applicable. Specimens less than or equal to ~ 85 mm total length (TL) were classified as YOY, while those between 85 and 254 mm TL were considered elvers. These lengths correspond to the two distinct length-frequency modes observed in the 2000 survey, which likely reflects differing year classes (Geer 2001). Length, weight, and pigmentation stage (see Haro and Krueger 1988) were collected from 60 eels from each system weekly. Daily catch (raw number of eels caught per day) and annual geometric mean catch per unit effort (CPUE) were calculated for each site. Annual CPUEs for each site were standardized to a 24-hour soak time and geometric means were calculated using the time period in which 95% of the cumulative total catch was sampled (i.e., dates in which 0%-2.5% and 97.5%-100% of the cumulative total catch was collected were excluded), in an effort to account for the interannual variability in the period of maximum recruitment.

Results

Eel traps at Wormley Pond and Bracken's Pond were deployed from 27 February to 30 May, 2008 and at Wareham's Pond on the James River from 6 March to 30 May. The eel trap at Kamp's Millpond was deployed from 19 March to 20 June, 2008. Counts of glass eels in 2008 were the lowest number recorded at Wormley Pond (n = 9,012 glass eels) and Bracken's Pond (n = 1,165 glass eels) since collections began (Table 1). Counts of glass eels captured at Wareham's Pond were relatively high with 2,456 eels, while counts of glass eels at Kamp's Millpond (n = 481 glass eels) were relatively low for the time series (Table 1). Indices of abundance for glass eels from the two York River sites showed different patterns with greater variability found in Wormley Pond compared with Bracken's Pond (Figure 2). In the James River, recent glass eel abundance estimates have been stable, whereas those from the Rappahannock River remained low (Figure 3).

The number of elvers captured at Wormley Pond (n = 139 elvers), Bracken's Pond (n = 262), and Kamp's Millpond (n = 37) were below the historic average for each site, but the number of elvers captured at Wareham's Pond (n = 511) was above average (Table 2). Abundance estimates of elvers from Wormley Pond and Bracken's Pond in the York River exhibit different patterns, although both show a peak in 2007 (Figure 4). Abundance indices of elvers in the James and Rappahannock rivers have been low aside from the peak observed in 2003 in the Rappahannock River (Figure 5).

A total of 641 glass eels from Wormley and Bracken's Ponds were returned to the lab for staging and length and weight measurements. Lengths of glass eels ranged from 49.7 to 68.4 mm total length with a mean length of 57.86 mm (3.53 standard deviation, SD). Weights of individual glass eels ranged from 0.063 to 0.268 g and averaged 0.137 g (0.033 SD; Figure 6). Mean TL of glass eels recruiting to Wormley Pond and Bracken's Pond on the York River has remained consistent since 2001 (Figure 7). The level of pigmentation of glass eels increased each month from March to May with most eels at stage 3 or 4 (Figure 8).

Water temperature increased throughout the study period in 2008 and peak counts of glass eels typically occurred when water temperatures were between 12 – 15 ^{o}C (Figure 9). Catches of elver eels were more variable in relation to water temperature (Figure 10). Peak counts of glass eels tend to occur first in the York River, followed by the James and Rappahannock rivers (Figure 11).

Discussion

Overall, the time series shows that the total number of glass eels captured among all sites differs by several orders of magnitude with most caught at the two sites in the York River. The greatest number of glass eels captured in the York River peaked at nearly 91,000 glass eels in 2007, while the lowest number caught was 1,165 glass eels in 2008. Out of nine years of eel collections in the York River, the fewest number of glass eels were captured during 2008, an order of magnitude decrease from the previous year. Although fewer glass eels are typically captured on the James and Rappahannock rivers compared with the York River, 2008 ranked as the second highest catch for the James River site with the total catch greater than that observed at Bracken's Pond on the York River. Catches of glass eels for the Rappahannock River in 2008 ranked sixth out of nine years of survey data. Variability of glass eel catches has been found in other systems with no clear pattern related to water temperature or lunar phase, and conflicting results related to water flow or precipitation (Overton and Rulifson 2009).

The number of elvers captured with Irish eel ramps was well below that of glass eels and ranged from as few as 5 elvers (Kamp's Millpond, 2000) to as many as 1,968 elvers per year (Kamp's Millpond 2003). Peak collections of elvers occurred during 2007 at both sites in the York River and the James River, but in the Rappahannock River 2007 ranked second lowest. The number of elvers captured during 2008 was very low in the Rappahannock River, low in the York River, and high in the James River compared with historic averages for these systems.

The timing of recruitment of glass eels in each pond appears to be related to the distance between each sampling site and the mouth of Chesapeake Bay. Earliest recruitment is observed at Wormley Pond on the York River (55.7 km from the mouth of the Bay), followed by Bracken's Pond (59.4 km), Wareham's Pond in the James River (77.8 km), and finally Kamp's Millpond on the Rappahannock River (101 km). Additionally, two sites located on the Virginia side of the Potomac River (> 101 km from the mouth of the bay) show much later recruitment peaks compared with the other Virginia locations. The few elvers captured in 2008 do not show any pattern related to distance from the mouth of the Bay.

Conclusions and Recommendations

1. Irish eel ramps are an effective, passive gear for sampling YOY American eel in coastal Virginia. The traps fish continuously meeting the ASMFC mandates for sample collections during peak recruitment.

2. Sampling should continue at the primary sites on the York, James and Rappahannock rivers and should start at least as early as the previous year and continue later, if necessary. Given the great variability associated with spring temperatures in the Chesapeake Bay region, sampling must be over a wide water temperature range to ensure that sampling encompasses peak migration of YOY eels.

3. The ultimate goal of this survey is to provide annual estimates of recruitment for YOY eels and elvers. Considering the unique nature of each site, and the performance variability of the sampling gear at these sites, it may be necessary to develop an "index" for each site. Parameters such as pond drainage area, distance from the ocean, discharge, and other physical parameters should continue to be evaluated to provide a relative value for each site. This value may then be used to weight the catch rates at each site to provide an overall estimate of juvenile eel recruitment to Virginia waters.

4. Additional years of data are necessary to solve the American eel recruitment puzzle. Anomalies that occur offshore (e.g., Gulf Stream changes) should also be investigated.

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Table 1. Total number of glass eels collected, the number of glass eels used for 95% index calculations, dates corresponding to 95% index period, the number of days of the index period, and the geometric mean and standard error by site and year.

Site	Year	Total Caught	Total Used	Start Date	End Date	Days	GEOMEAN	STDERR
Wormley Pond	2001	82267	79485	15-Mar	13-Apr	30	737.125	0.464
	2002	31518	30299	24-Feb	9-Apr	45	272.130	0.292
	2003	14385	13678	14-Mar	15-Apr	33	95.949	0.399
	2004	78258	73834	1-Mar	19-Apr	50	980.639	0.161
	2005	56259	53378	23-Feb	19-Apr	56	172.220	0.306
	2006	61211	57698	8-Mar	12-Apr	36	841.993	0.239
	2007	90988	85414	5-Mar	23-Apr	50	184.356	0.499
	2008	9012	8705	4-Mar	17-Apr	45	86.918	0.256
Bracken's Pond	2000	61228	58288	27-Mar	2-May	36	482.177	0.381
	2001	52838	50146	14-Mar	5-Jun	84	261.503	0.156
	2002	7413	7000	8-Mar	20-Apr	44	106.465	0.169
	2003	77592	73431	11-Mar	12-May	63	119.631	0.340
	2004	29914	28403	6-Mar	12-May	68	173.152	0.207
	2005	65983	63009	13-Mar	14-May	63	188.142	0.283
	2006	45738	43268	27-Feb	5-May	68	297.585	0.201
	2007	46758	44637	12-Mar	10-May	60	211.588	0.227
	2008	1165	1113	5-Mar	26-May	83	4.560	0.145
Wareham's Pond	2003	2230	2150	19-Mar	29-Apr	37	12.819	0.244
	2004	158	154	8-Mar	16-May	69	1.032	0.113
	2005	225	214	21-Mar	8-Apr	19	6.312	0.300
	2006	3280	3145	3-Mar	19-Apr	48	29.770	0.216
	2007	953	920	5-Mar	3-May	60	7.547	0.158
	2008	2456	2333	17-Mar	17-Apr	32	32.615	0.259
Kamp's Millpond	2000	139	134	16-Apr	12-May	27	1.531	0.185
	2001	3956	3788	6-Apr	3-May	28	31.468	0.281
	2002	11217	10589	17-Mar	16-Apr	31	136.605	0.251
	2003	2387	2254	26-Mar	8-May	44	28.606	0.222
	2004	524	497	13-Apr	23-May	41	4.993	0.210
	2005	2084	2016	30-Mar	3-May	35	14.942	0.289
	2006	302	283	10-Mar	24-May	76	1.806	0.112
	2007	313	299	30-Mar	1-Jul	94	2.201	0.077
	2008	481	459	31-Mar	4-Jun	62	3.938	0.129

Table 2. Total number of elver eels collected, the number of elver eels used for 95% index calculations, dates corresponding to the index period, the number of days of the index period, and the geometric mean and standard error by site and year.

Site	Year	Total Caught	Total Used	Start Date	End Date	Days	GEOMEAN	STDERR
Wormley Pond	2001	171	162	12-Mar	4-May	54	1.564	0.129
	2002	315	298	22-Feb	17-Apr	55	3.279	0.135
	2003	138	130	4-Mar	12-May	70	1.099	0.093
	2004	257	239	24-Feb	16-May	83	1.631	0.101
	2005	105	100	22-Feb	19-May	87	0.715	0.073
	2006	160	156	20-Feb	6-May	76	0.985	0.094
	2007	619	559	26-Feb	14-May	78	3.704	0.102
	2008	139	135	2-Mar	28-May	88	0.715	0.081
Bracken's Pond	2000	528	481	28-Mar	9-May	42	2.811	0.253
	2001	334	314	4-Mar	17-Jun	106	1.119	0.099
	2002	52	49	16-Mar	28-Apr	44	0.673	0.102
	2003	411	399	6-Mar	12-May	68	2.263	0.145
	2004	171	158	22-Feb	13-May	82	1.022	0.098
	2005	231	224	23-Feb	15-May	82	1.525	0.099
	2006	166	152	23-Feb	6-May	73	1.305	0.092
	2007	723	692	23-Feb	13-May	80	5.389	0.116
	2008	262	247	4-Mar	26-May	84	1.354	0.105
Wareham's Pond	2003	84	79	19-Mar	24-Apr	32	1.296	0.156
	2004	260	252	8-Mar	9-May	62	1.839	0.131
	2005	148	137	20-Mar	12-May	54	1.791	0.101
	2006	469	442	24-Feb	17-May	83	2.134	0.132
	2007	682	641	15-Mar	17-May	64	5.207	0.150
	2008	511	487	12-Mar	18-May	67	3.261	0.156
Kamp's Millpond	2000	5	4	16-Apr	25-Apr	10	0.390	0.039
	2001	222	215	16-Mar	8-May	54	2.415	0.125
	2002	224	216	13-Mar	19-Apr	38	4.387	0.117
	2003	1968	1907	13-Mar	9-May	58	13.669	0.200
	2004	250	230	10-Mar	20-May	72	2.023	0.094
	2005	196	188	23-Mar	17-May	56	2.331	0.087
	2006	312	301	10-Mar	14-May	66	2.478	0.112
	2007	32	25	15-Mar	27-Jun	105	0.209	0.029
	2008	37	33	24-Mar	8-Jun	73	0.424	0.037

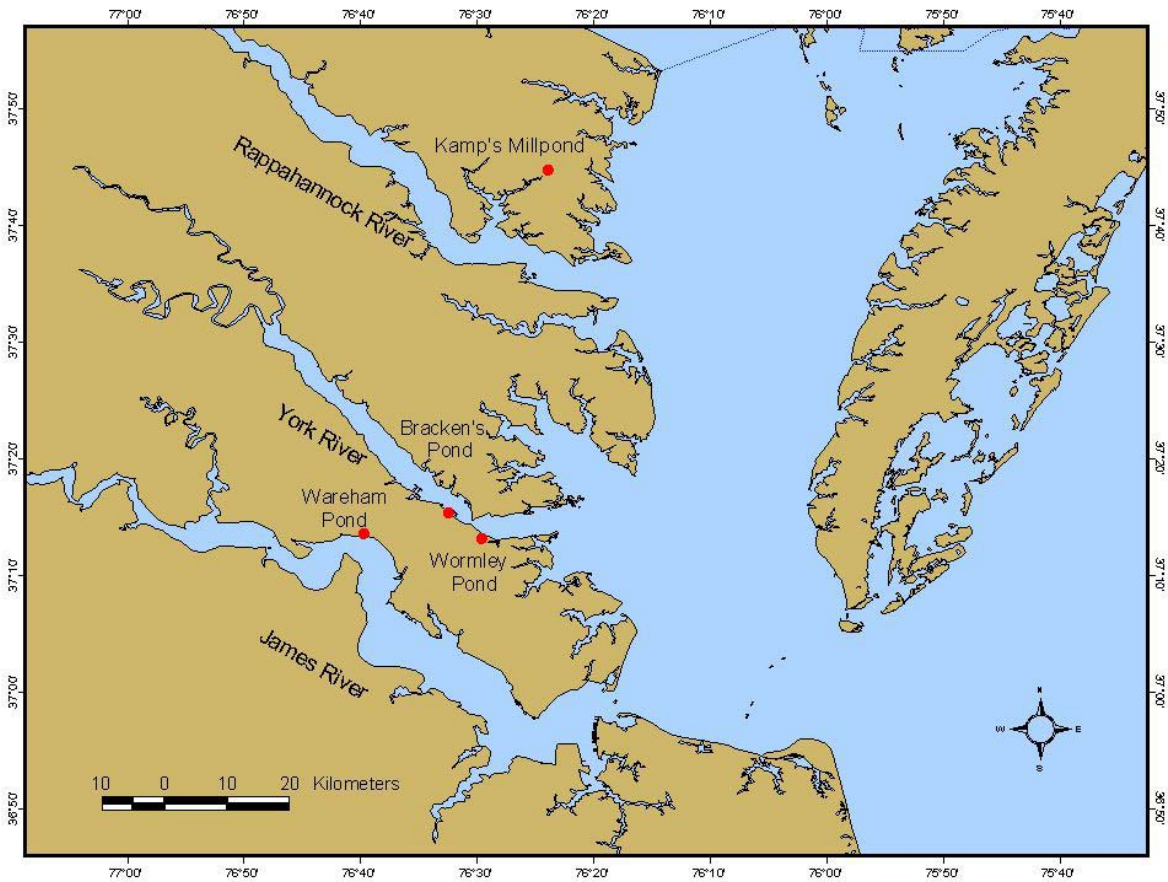

Figure 1. American eel sampling sites in the Rappahannock (Kamp's Millpond), York (Wormley Pond and Bracken's Pond), and James (Wareham's Pond) rivers, Virginia, 2008.

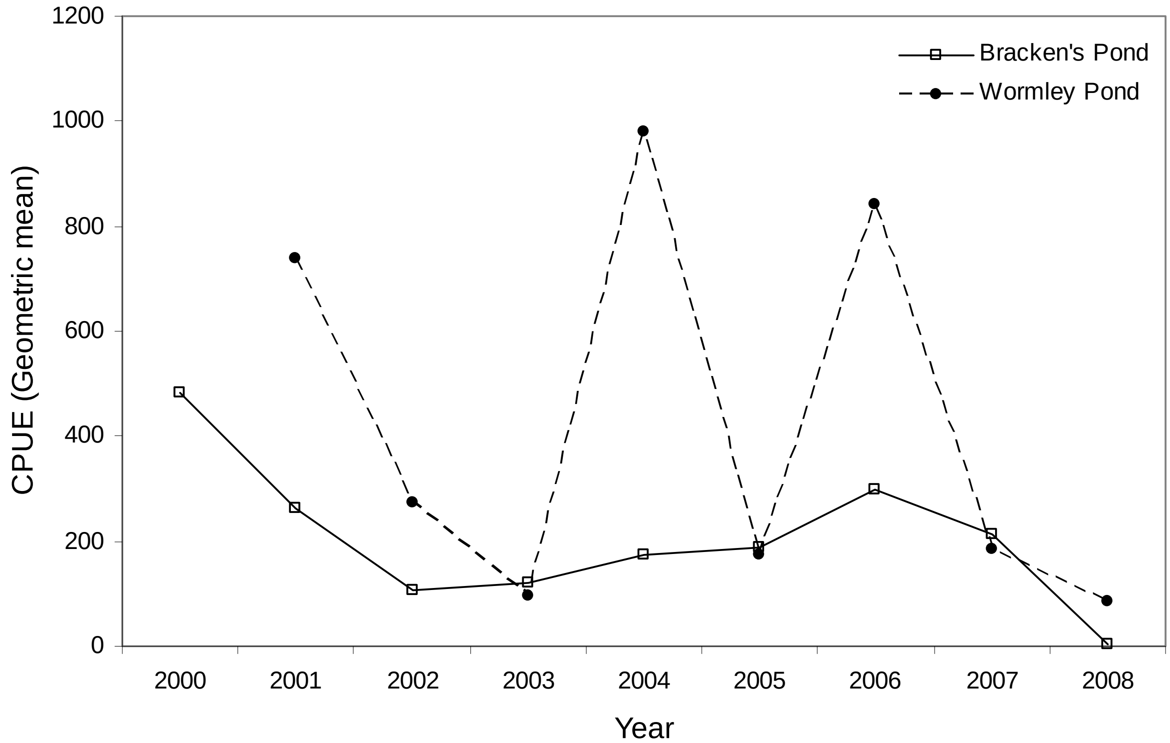

Figure 2. Index of abundance estimates of glass eels from two stations on the York River, Virginia.

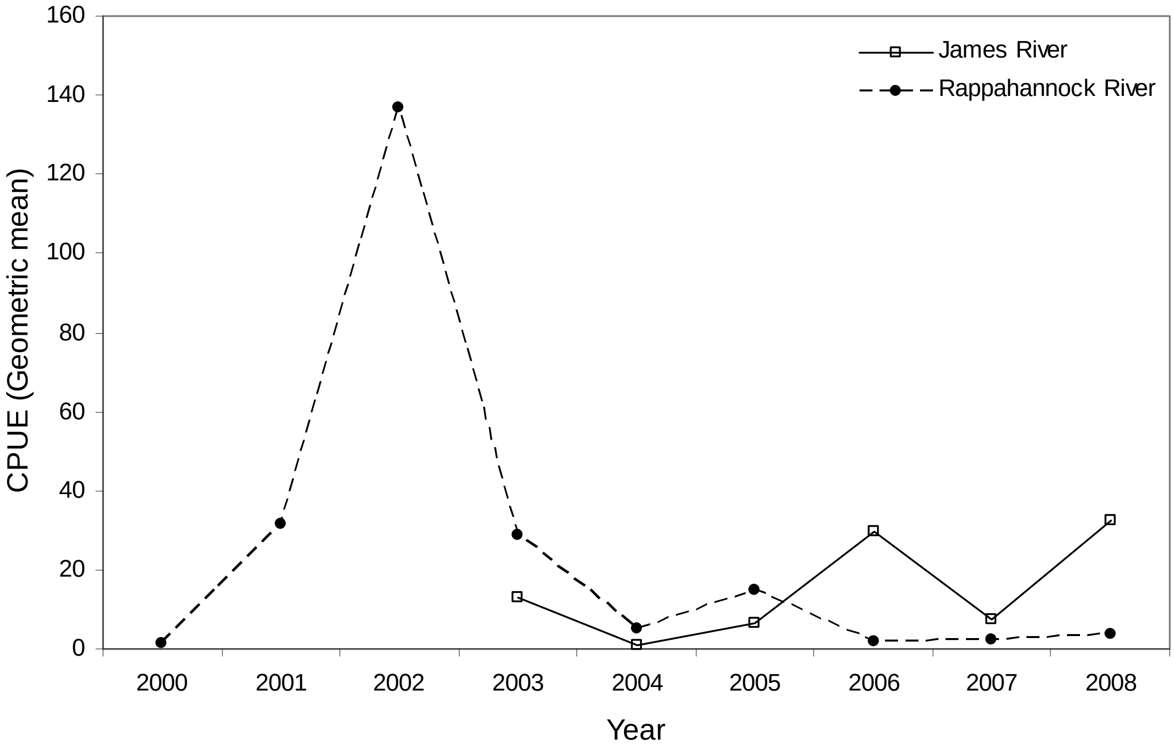

Figure 3. Index of abundance estimates of glass eels from the James River (Wareham's pond) and the Rappahannock River (Kamp's Millpond), Virginia.

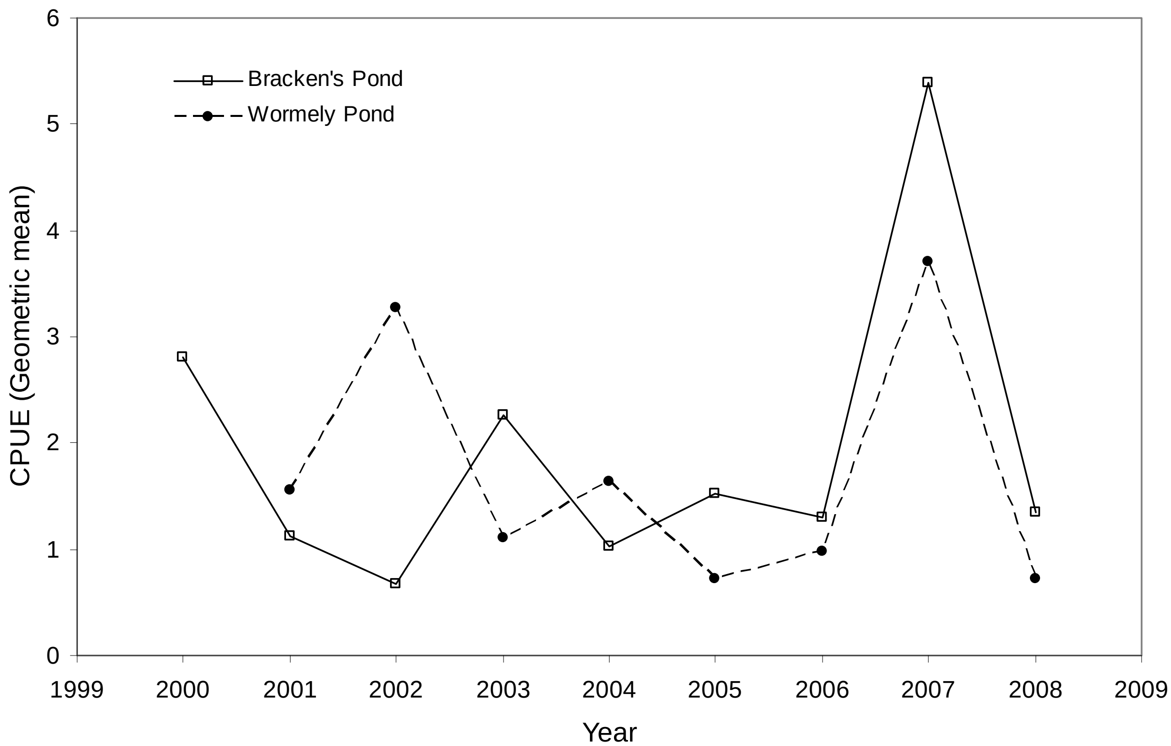

Figure 4. Index of abundance estimates of elvers from two stations on the York River, Virginia.

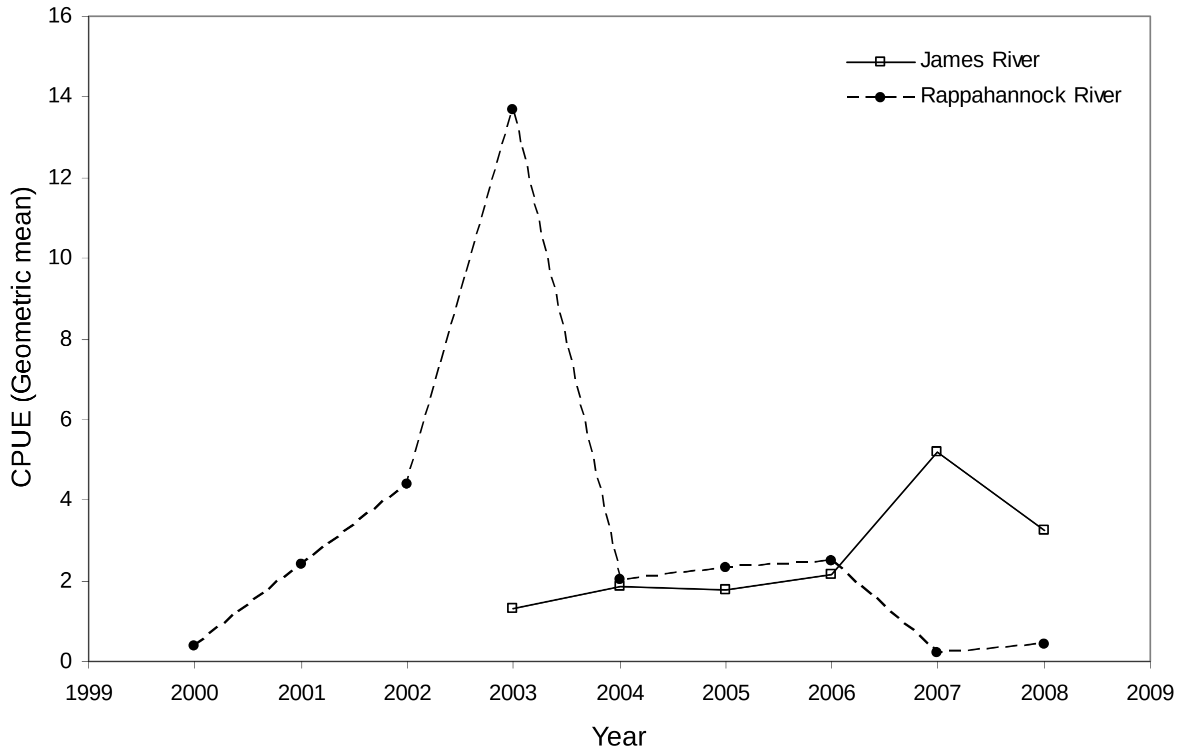

Figure 5. Index of abundance estimates of elvers from the James River (Wareham's Pond) and the Rappahannock River (Kamp's Millpond), Virginia.

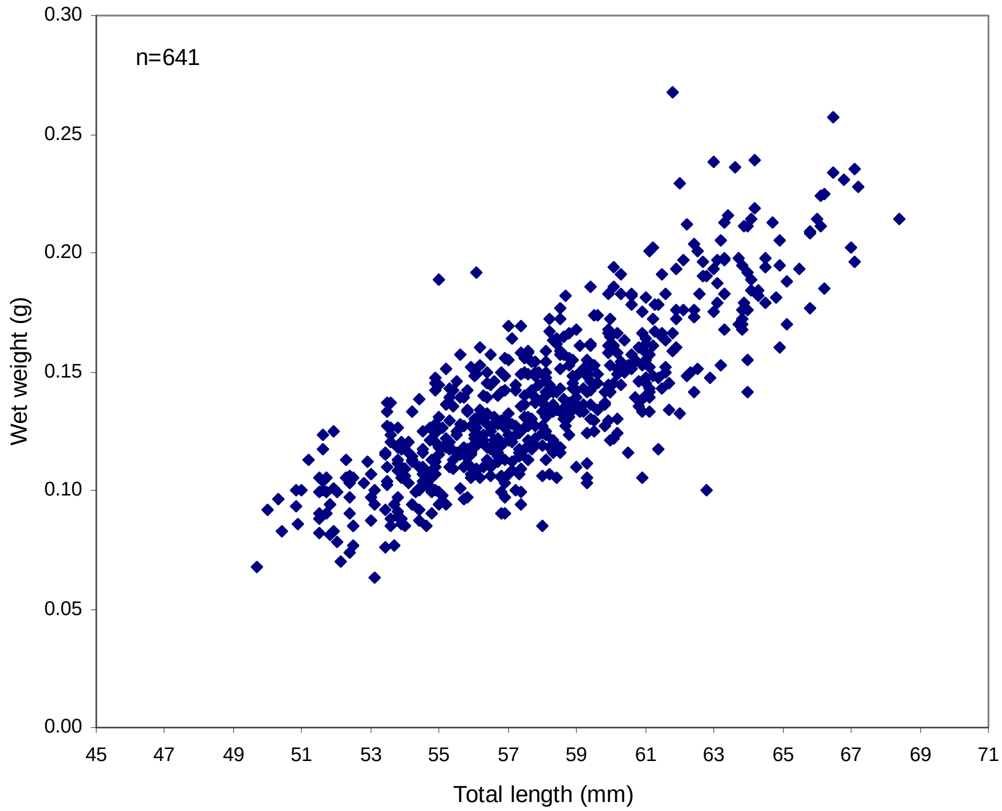

Figure 6. American eel total length and wet weight from the York River, 2008.

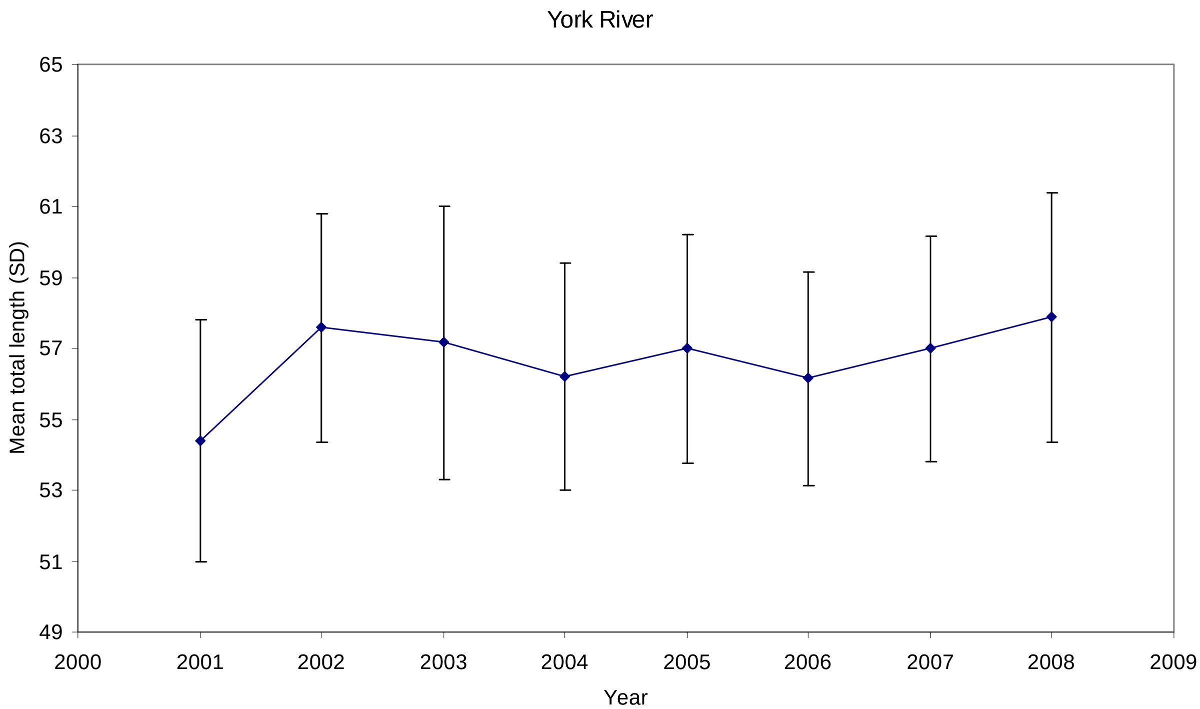

Figure 7. Mean total length (mm; SD) of glass eels collected with Irish eel ramps from 2001 to 2008 from two sites combined (Wormley and Bracken's ponds) in the York River, Virginia.

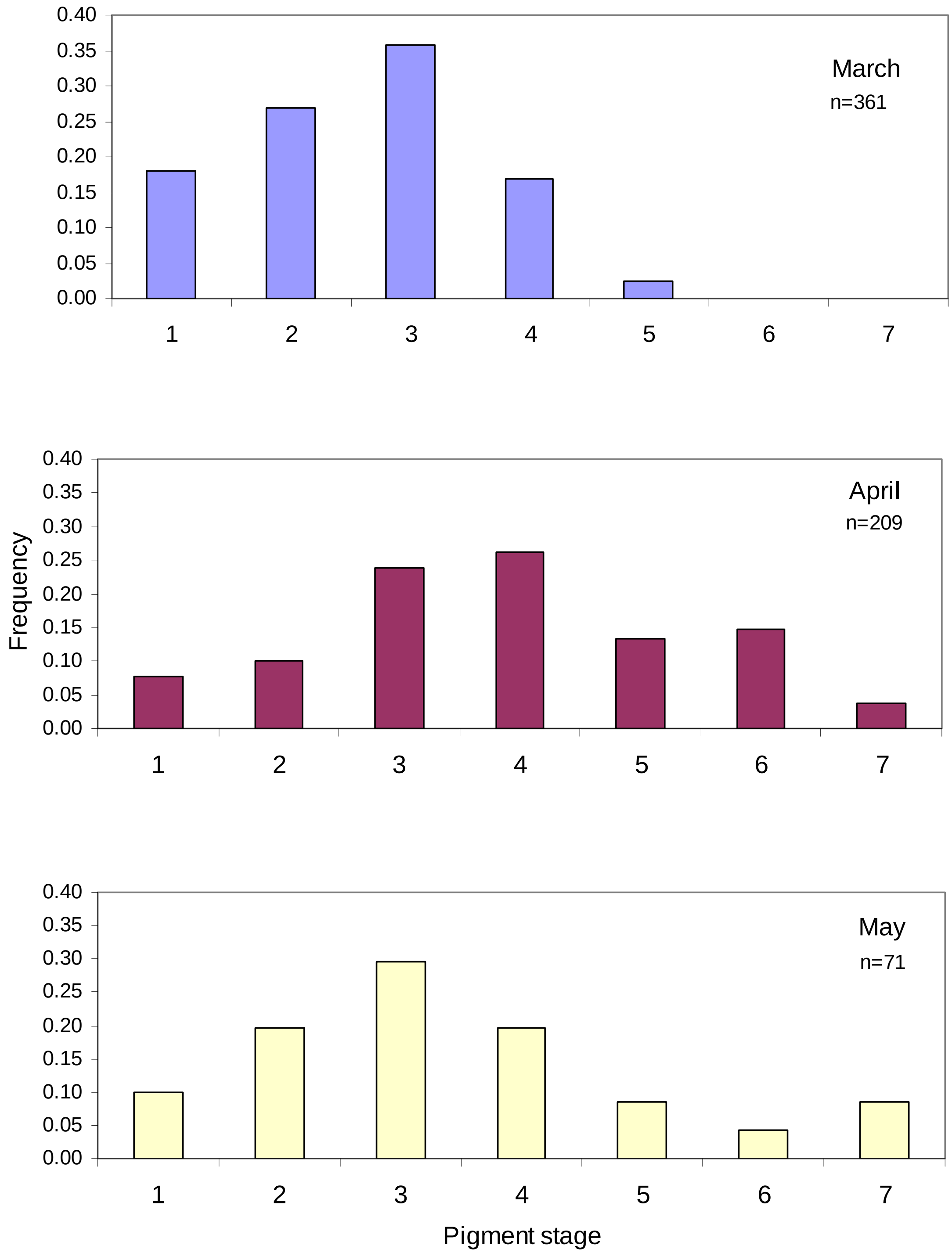

Figure 8. Frequency of glass eel pigment stages by month for the York River system.

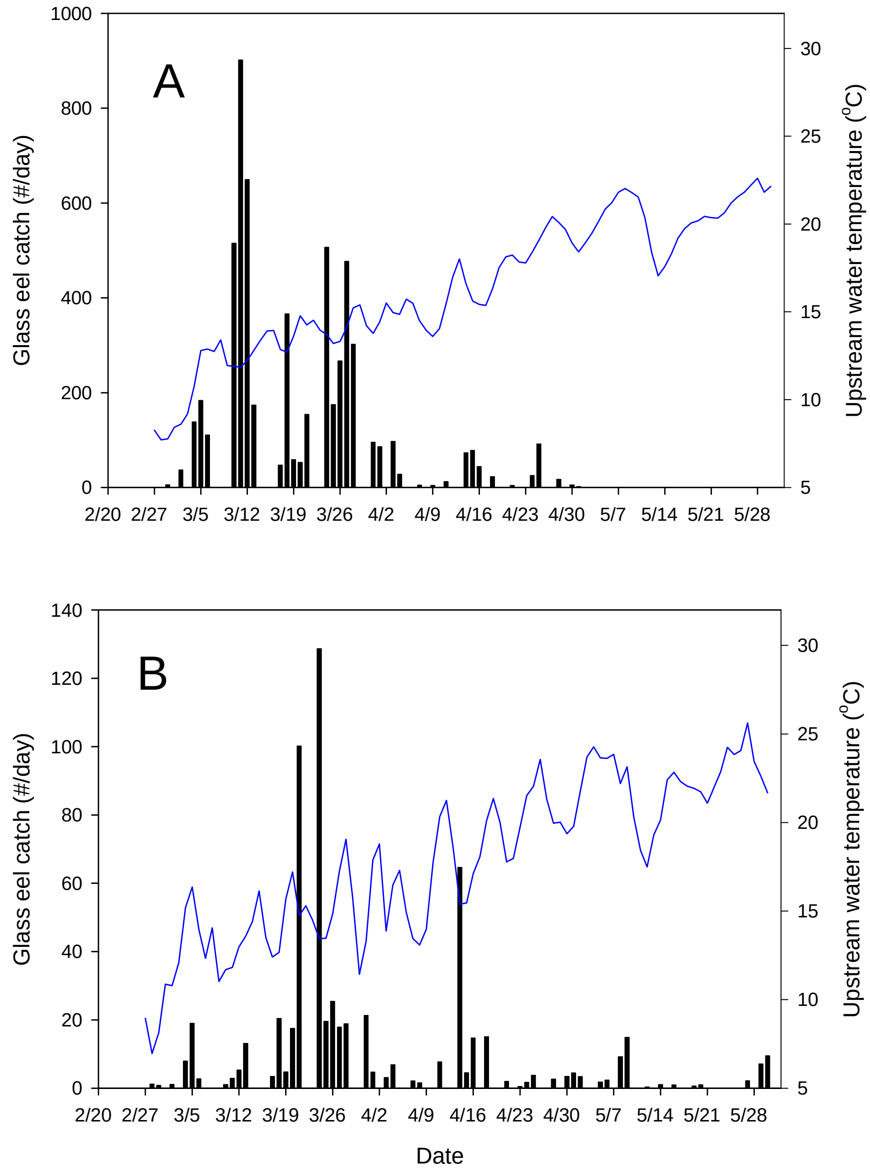

Figure 9. Glass eel catches (bars) and water temperature (line) during 2008 from A) Wormley pond, B) Bracken's Pond, C) Wareham's Pond, and D) Kamp's Millpond. Note y-axis scale for glass eel catches are not uniform.

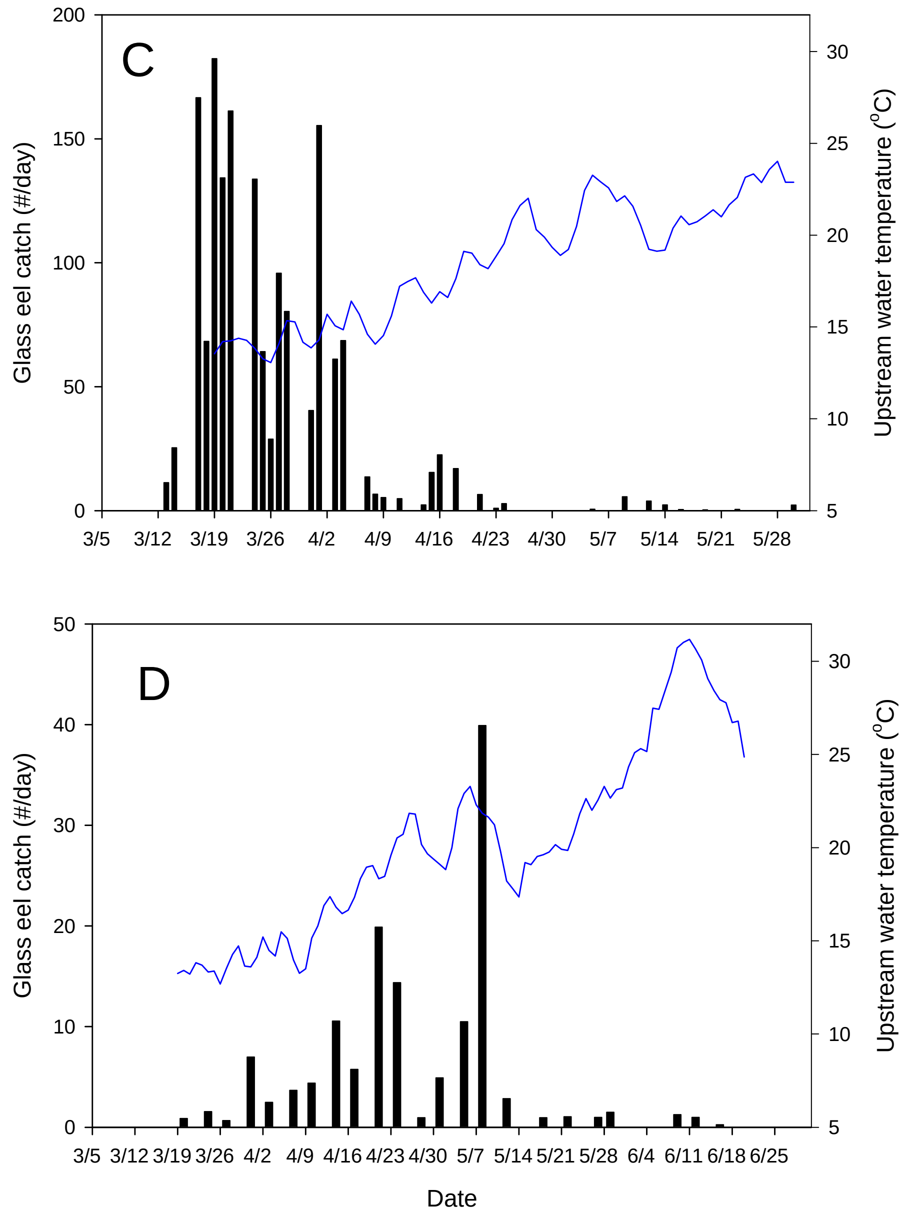

Figure 9 continued. Glass eel catches (bars) and water temperature (line) during 2008 from A) Wormley pond, B) Bracken's Pond, C) Wareham's Pond, and D) Kamp's Millpond. Note y-axis scale for glass eel catches are not uniform.

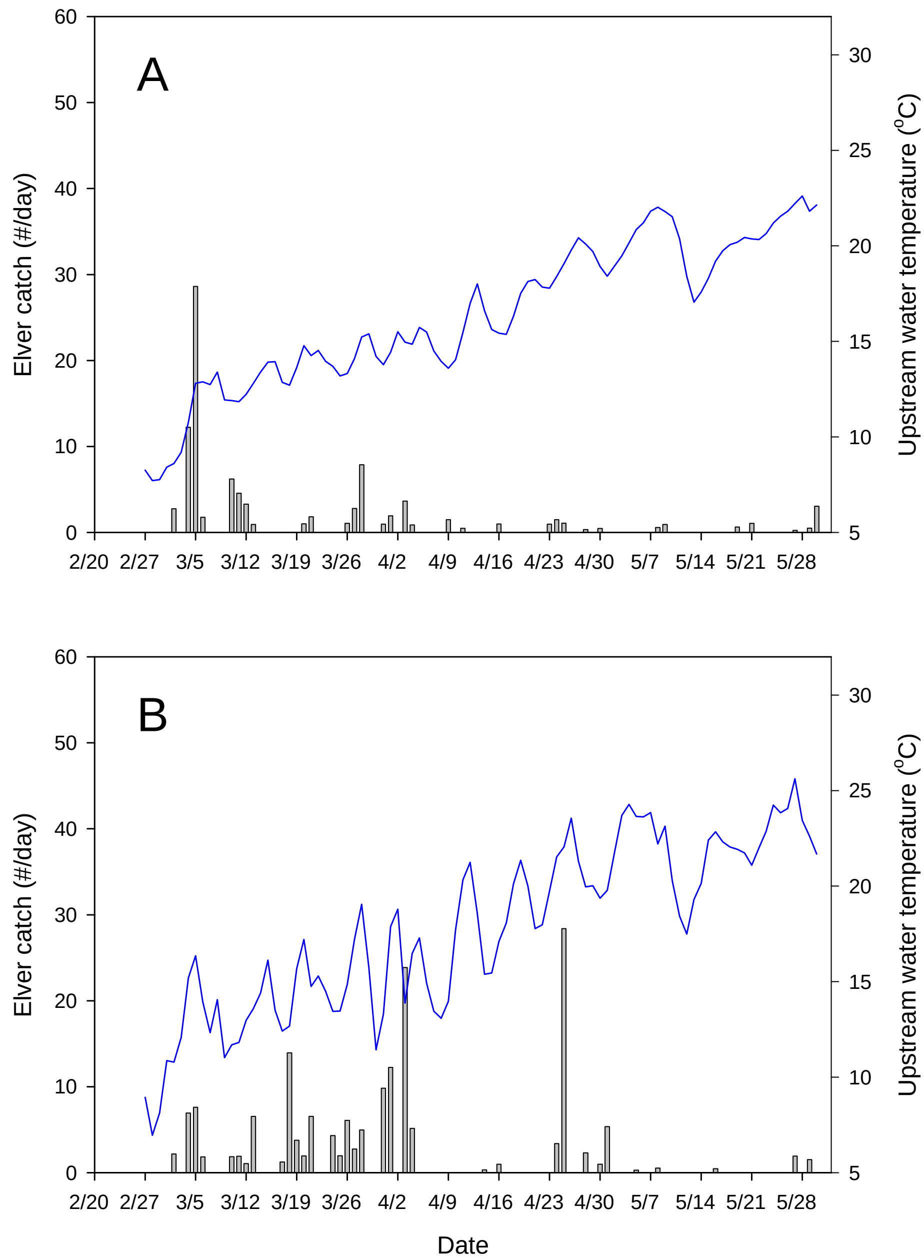

Figure 10. Elver catches (bars) and water temperature (line) during 2008 from A) Wormley pond, B) Bracken's Pond, C) Wareham's Pond, and D) Kamp's Millpond.

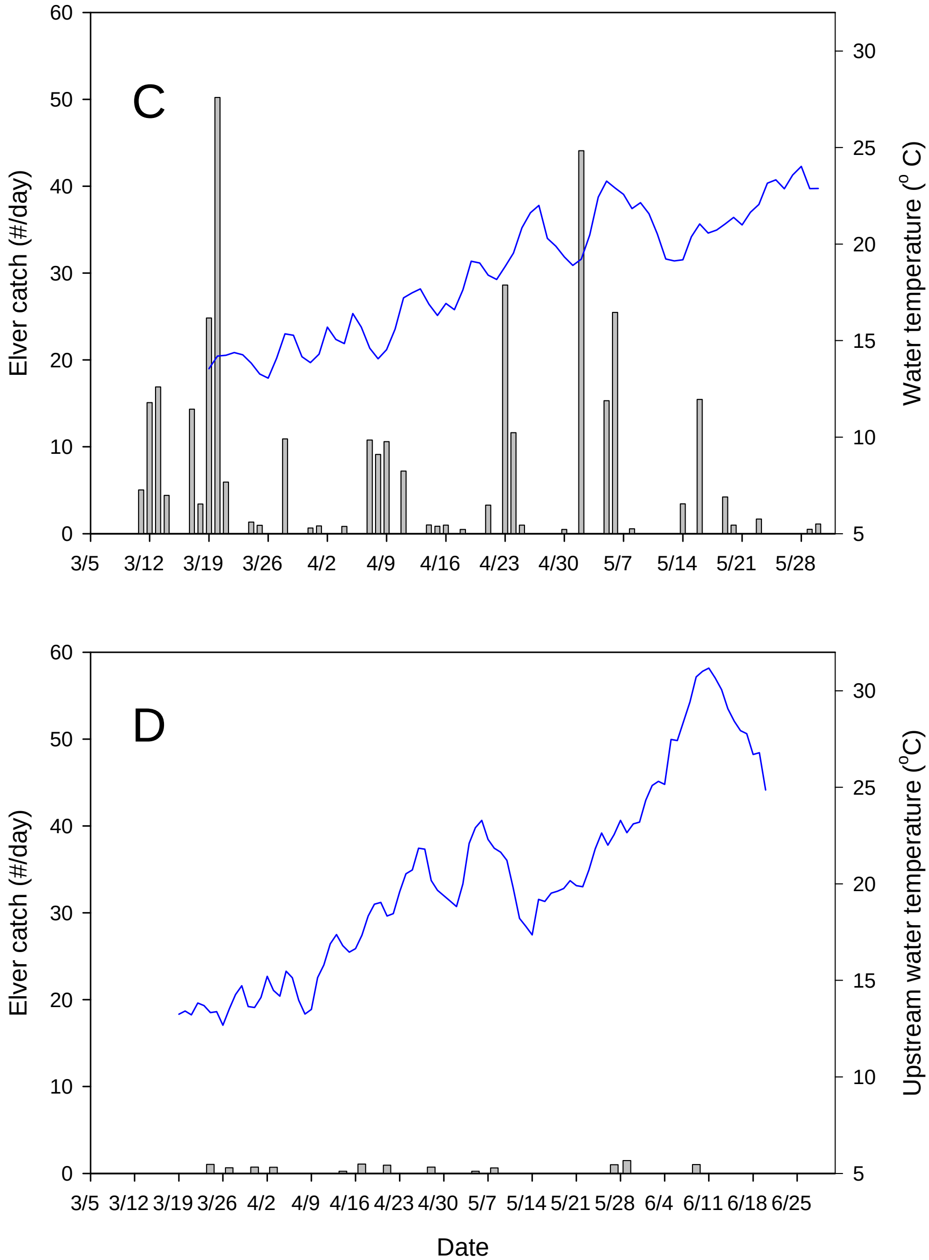

Figure 10 continued. Elver catches (bars) and water temperature (line) during 2008 from A) Wormley pond, B) Bracken's Pond, C) Wareham's Pond, and D) Kamp's Millpond.

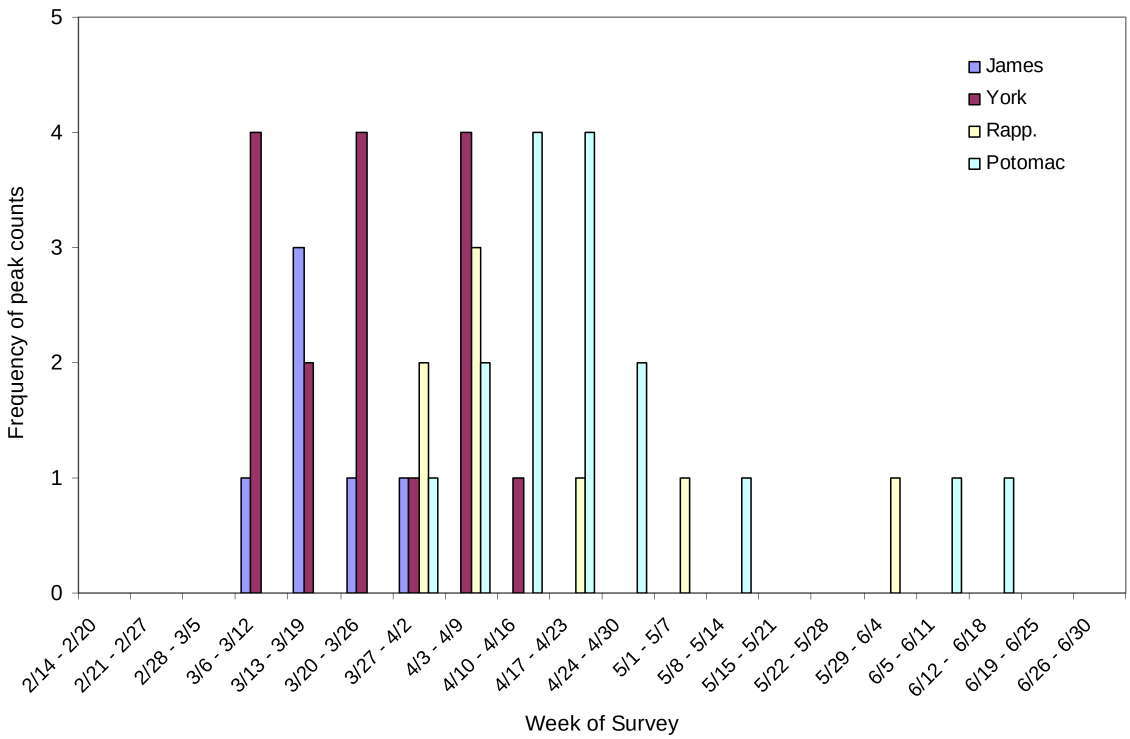

Figure 11. Week of survey when peak counts of glass eels were observed in each river from 2001 to 2008. Two sites are monitored in the York and Potomac rivers each year (n = 16 observations per river). In the James River, one site was monitored beginning in 2003 (n=6 observations). In the Rappahannock River, one site was monitored each year (n=8 observations). Potomac River data are from Fabrizio and Tuckey, 2008.