Estimating Relative Abundance of Young-of-Year American Eel, *Anguilla rostrata,* in the Virginia Tributaries of Chesapeake Bay (Spring 2010)

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, US coastal harvests have declined, with similar patterns occurring in the Canadian Maritime Provinces (Meister and Flagg 1997). Landings from Chesapeake Bay typically represent 63% of the annual US commercial harvest (ASMFC 2000). In 2008, Virginia commercial landings were 154,451 lbs; since mandatory reporting began in 1993, the average annual landings have been 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 2010, 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 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 an underlying yellow hue (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 takes place from late summer through autumn. Age at maturity varies greatly with location and latitude and in Chesapeake Bay may range from 2 to 18 years, but most eels reach maturity between age 2 and 6 (Owens and Geer 2003). American eels 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 measures of 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

Field Methods

Minimum criteria for YOY American eel sampling were established in the ASMFC American Eel FMP, with the Technical Committee approving sampling gear and methods. 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: two on the York River and one each on the Rappahannock and James rivers. The James River site is located in the Kingsmill area of James City County (Wareham's Pond). Wareham's Pond drains directly into the James River, which is about 100 m away, though high tides may reach the end of the spillway (Figure 1). The 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; the tide often reaches the spillway. This site was chosen as a primary site in 2000 with gear comparisons performed throughout the sampling season. Wormley Pond, located on the Yorktown Battlefield, 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. The final collection site is at Kamp's Millpond, which 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, north of Kilmarnock.

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; continuous flow was accomplished through a gravity feed. Hoses 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. 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, 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 > 85 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; note: eels longer than 254 mm TL are considered yellow phase eels, although this is not explicitly stated in Geer 2001). Length, weight, and pigmentation stage (see Haro and Krueger 1988) were recorded from 60 eels weekly. Indices of abundance were calculated using the area-under-the-curve approach (Olney and Hoenig 2001).

Results

In 2010, eel traps were deployed from 4 March to 9 June at Wormley and Bracken's ponds on the York River and Wareham's Pond on the James River. The trap at Kamp's Millpond on the Rappahannock River was deployed on 19 March and pulled on 21 July, 2010. Record counts of glass eels at Wormley Pond were observed this year totaling more than 139,000 individuals. The previous record of nearly 91,000 individuals was observed in 2007 (Table 1; Figure 2). In contrast, the count of glass eels at Wareham's Pond (672 glass eels) was the third lowest on record for that site (Figure 3). The count of glass eels at Brackens Pond was 23,044, a large increase compared with the previous two years. However, the low counts in 2008 and 2009 may have been due to the presence a standing pool of water at the mouth of the creek (standing water is less attractive to migrating glass eels). In 2010, the beaver dam at Bracken's Pond burst and the resulting flood flushed sediment from the mouth of the creek that connects Bracken's Pond to the York River, thereby eliminating the standing pool of water that had been present for the previous two years. The run of glass eels at Kamp's Millpond on the Rappahannock River resulted in more than 4,700 glass eels.

Elver counts at all sites were below historic averages (Table 2; Figures 4 and 5). Abundance estimates of elvers from Wormley Pond and Bracken's Pond in the York

River exhibit similar patterns in recent years with a peak in 2007, declines in 2008 and 2009 and an increase in 2010 (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 487 glass eels from Wormley Pond was returned to the lab for weight, length, and pigment stage determination. Total length (TL) of these glass eels ranged from 46.2 to 65.0 mm, with a mean length of 55.7 mm (3.31 standard deviation, SD). Weights of individual glass eels ranged from 0.054 to 0.220 g and averaged 0.125 g (0.031 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). As expected, pigmentation stages of glass eels increased monthly between March and May (Figure 8).

Water temperature increased throughout the study period in 2010 with the arrival of glass eels in early March at Wormley and Wareham's Ponds and mid- to late-March at Bracken's Pond and Kamp's Millpond (Figure 9). Peak catches of glass eels occurred between 15 and 26 March at Wormley Pond. Catches of elver eels were more variable and occurred throughout the monitoring period although peak catches tended to occur in mid-March (Figure 10). Peak counts of glass eels tend to occur first in the York River, followed by the James, Rappahannock, and Potomac rivers (Figure 11).

Discussion

Record numbers of glass eels at Wormley Pond and above average counts of glass eels at Kamp's Millpond demonstrate that successful spawning and recruitment to near-shore habitats is occurring. 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).

As noted in Tuckey and Fabrizio (2009), the extremely low catch of glass eels and elvers at Bracken's Pond in 2008 and 2009 may have been the result of changes to flow dynamics at that site. A sediment barrier at the mouth of the creek connecting Bracken's Pond with the York River resulted in the formation of a pool. This impoundment of water may have prevented the freshwater signal from reaching glass eels in the main portion of the York River. The change in hydrology at this site following the beaver dam breach in 2010 was immediately followed by a peak in glass eel recruitment observed between 30 April and 3 May. It is likely that in the past, glass eels were recruiting to the pool formed by the sediment barrier but not moving beyond that area. Previously, the trap at Bracken's Pond was not creating attractant flow because it had been submerged and was therefore not fishing effectively during 2008 and 2009. In 2010, the trap at Bracken's Pond was raised out of the water in an attempt to create attractant flow. However, we did not observe an increase in glass eel counts until the dam breached, indicating that glass eels were not moving beyond the impounded water (and hence, were not vulnerable to capture by our gear). The fact that Wormley Pond shows a similar declining index in 2008 and 2009 suggests that the data from Bracken's Pond may still be of value, so we continue to report it here.

The timing of recruitment of glass eels in each pond appears to be related to the distance between the 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 other Virginia locations.

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Table 1. Total number of glass eels captured and the index of abundance using Area Under the Curve method (AUC).

Site	Year	Total Caught	AUC index
Wormley Pond	2001	82267	83492.52
	2002	31518	32638.74
	2003	14385	13725.63
	2004	78258	79293.45
	2005	56259	55660.70
	2006	61211	59854.95
	2007	90988	90705.01
	2008	9012	9220.64
	2009	8367	8404.22
	2010	139391	149154.20
Bracken's Pond	2000	61228	62884.68
	2001	52838	54113.09
	2002	7413	7590.79
	2003	77592	75405.36
	2004	29914	30281.74
	2005	65983	65885.25
	2006	45738	47093.62
	2007	46758	46266.78
	2008	1165	1150.34
	2009	69	67.53
	2010	23044	30087.78
Wareham's Pond	2003	2230	2350.62
	2004	158	165.29
	2005	225	224.05
	2006	3280	3266.29
	2007	953	959.29
	2008	2456	2417.16
	2009	5322	5192.30
	2010	672	648.46
Kamp's Millpond	2000	139	129.91
	2001	3956	4030.22
	2002	11217	11064.48
	2003	2387	2377.49
	2004	524	516.16
	2005	2084	2144.97
	2006	302	298.58
	2007	313	311.48
	2008	481	478.99
	2009	179	179.03
	2010	4734	4461.99

Table 2. Total number of elvers captured and the index of abundance using Area Under the Curve method (AUC).

Site	Year	Total Caught	AUC index
Wormley Pond	2001	171	171.39
	2002	315	314.56
	2003	138	140.51
	2004	257	264.70
	2005	105	108.61
	2006	160	158.44
	2007	619	612.77
	2008	139	139.97
	2009	31	32.01
	2010	80	71.92
Bracken's Pond	2000	528	535.38
	2001	334	341.14
	2002	52	52.22
	2003	411	416.74
	2004	171	179.96
	2005	231	229.92
	2006	166	172.72
	2007	723	717.81
	2008	262	260.92
	2009	3	3.02
	2010	190	219.88
Wareham's Pond	2003	84	84.72
	2004	260	256.44
	2005	148	148.61
	2006	469	471.24
	2007	682	676.74
	2008	511	512.75
	2009	275	275.74
	2010	306	323.43
Kamp's Millpond	2000	5	4.89
	2001	222	225.36
	2002	224	222.92
	2003	1968	1972.62
	2004	250	246.06
	2005	196	198.55
	2006	312	310.03
	2007	32	31.66
	2008	37	45.09
	2009	33	34.49
	2010	132	125.89

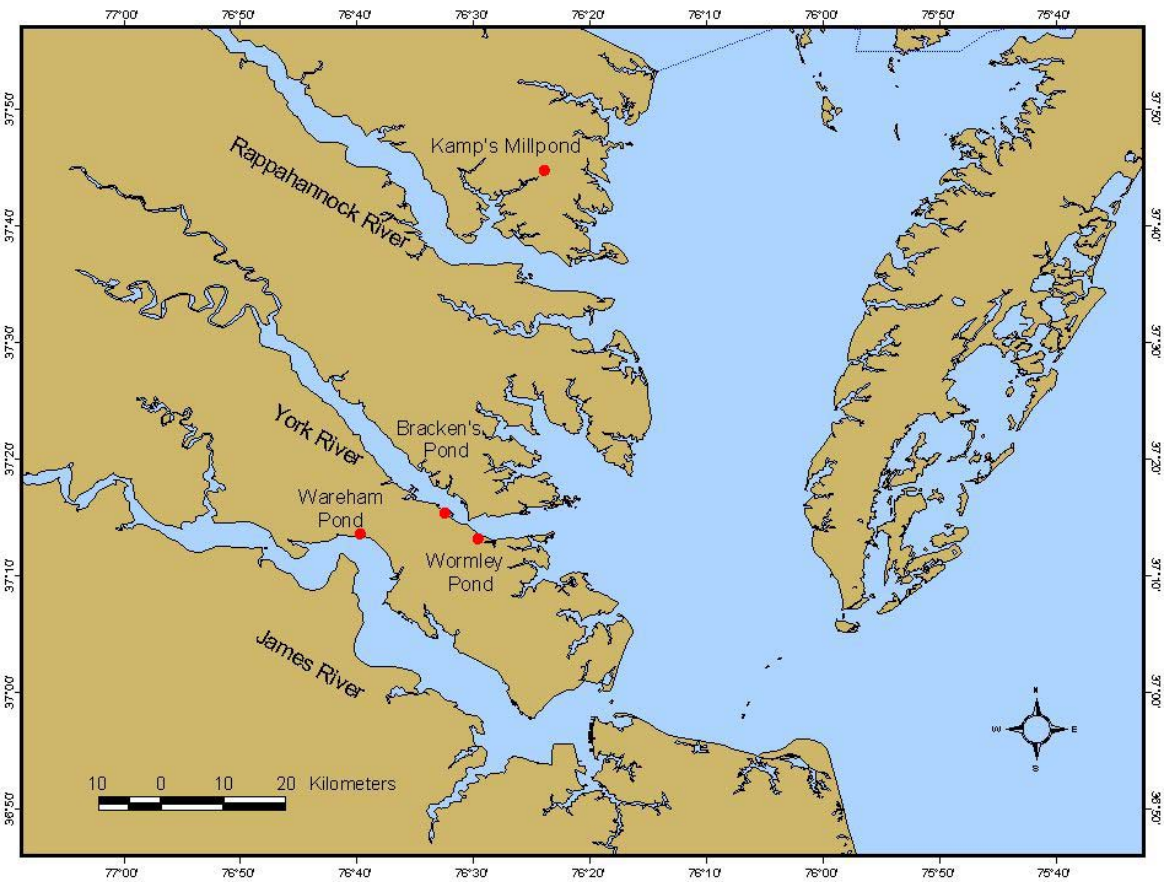


Figure 1. American eel sampling sites in the Rappahannock (Kamp's Millpond), York (Wormley Pond and Bracken's Pond), and James (Wareham's Pond) rivers, Virginia, 2010.

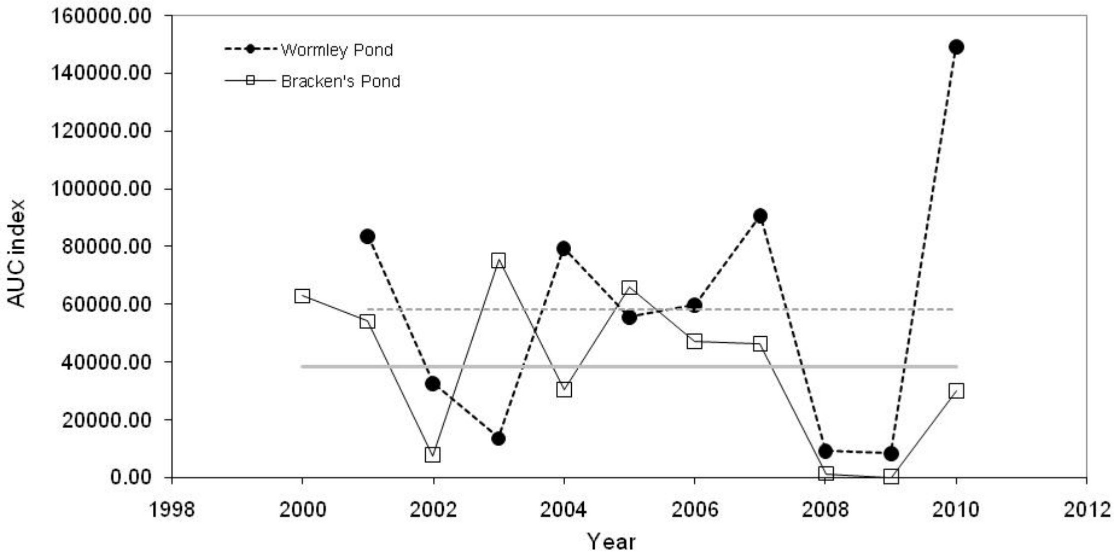


Figure 2. Abundance indices and time series average calculated by area-under-the-curve method for glass eels from Wormley Pond and Bracken's Pond (York River system). Time series averages are shown as solid (Bracken's Pond) and dotted (Wormley Pond) lines.

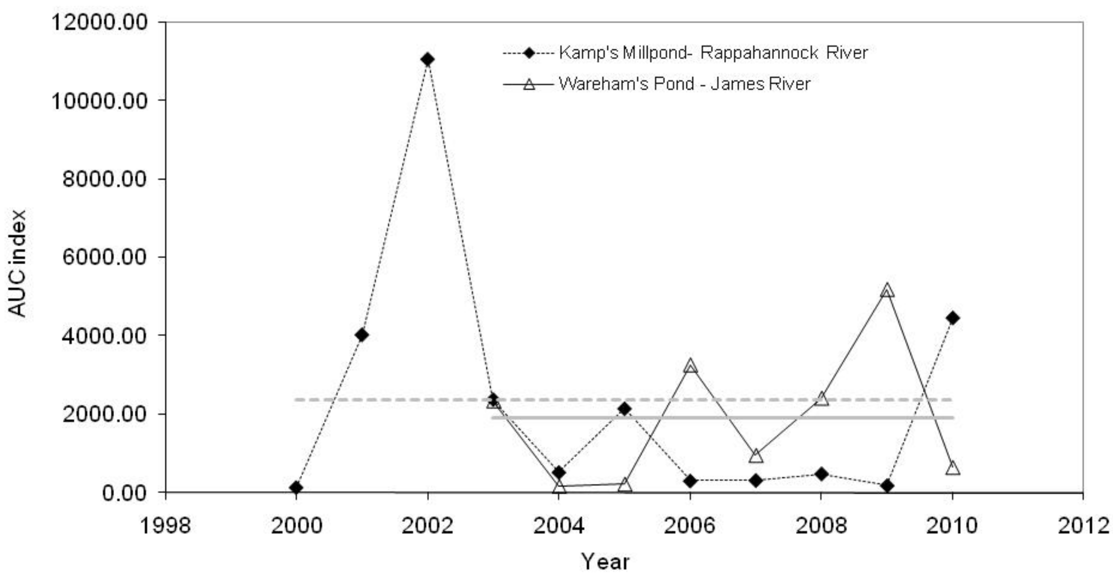


Figure 3. Abundance indices and time series average calculated by the area-under-the-curve method for glass eels from Wareham's Pond (James River system) and Kamp's Millpond (Rappahannock River system). Time series averages are shown as solid (Wareham's Pond) and dotted (Kamp's Millpond) lines.

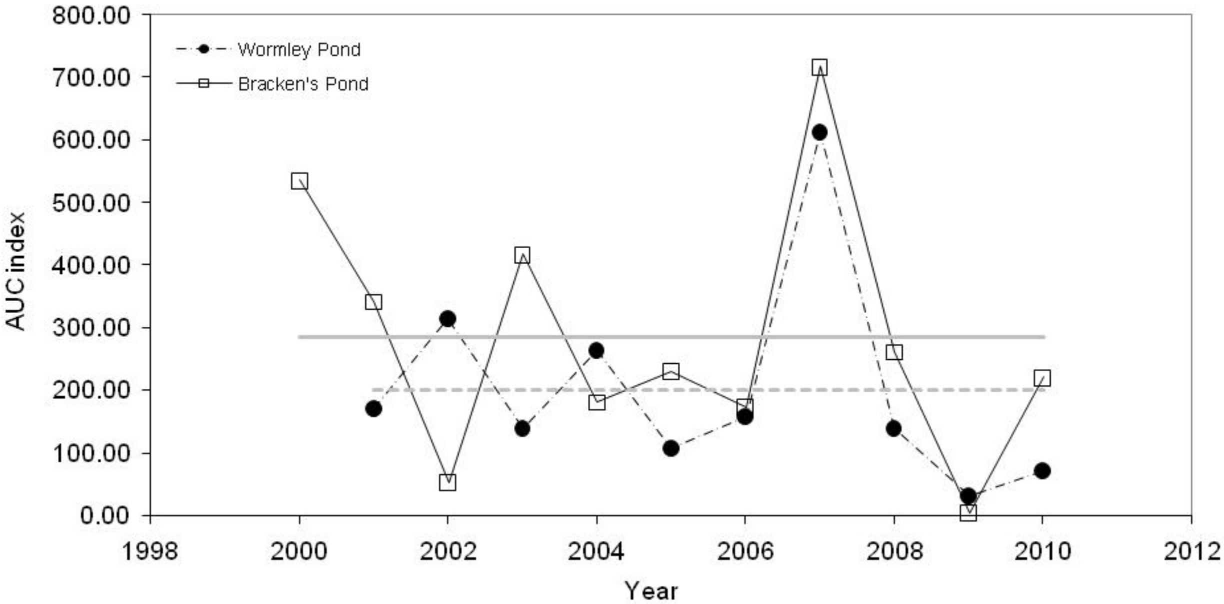


Figure 4. Abundance indices and time series average calculated by the area-under-the-curve method for elvers from Wormley Pond and Bracken's Pond (York River System). Time series averages are shown as solid (Bracken's Pond) and dotted (Wormley Pond) lines.

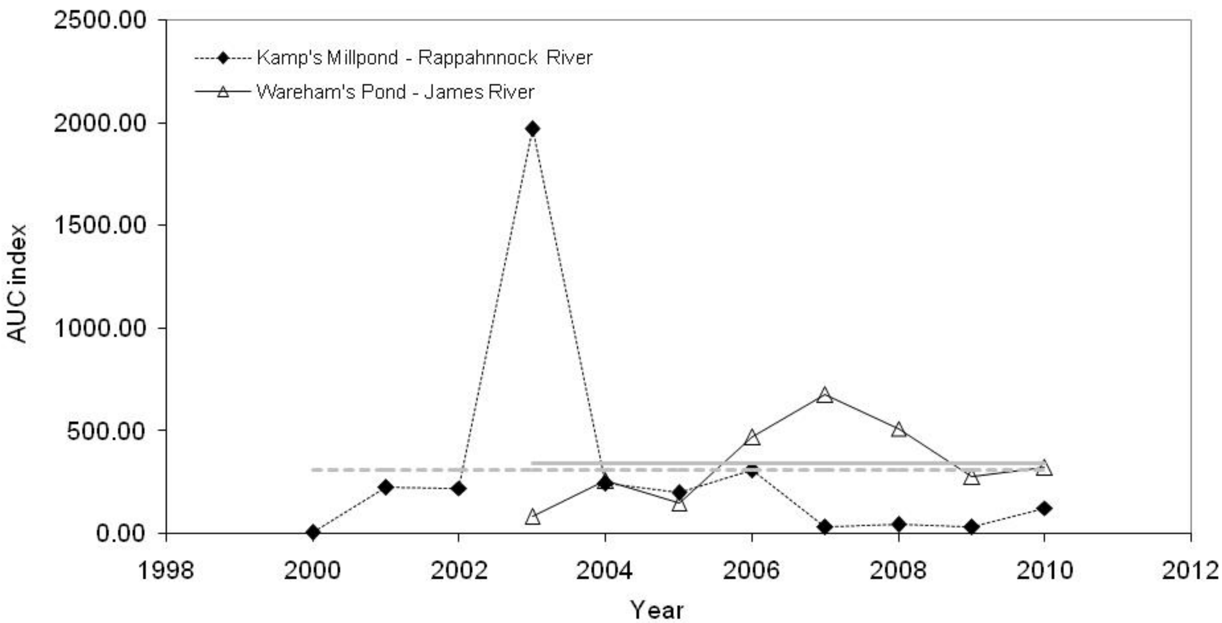


Figure 5. Abundance indices and time series average calculated by the area-under-the-curve method for elvers from Wareham's Pond (James River system) and Kamp's Millpond (Rappahannock River system). Time series averages are shown as solid (Wareham's Pond) and dotted (Kamp's Millpond) lines.

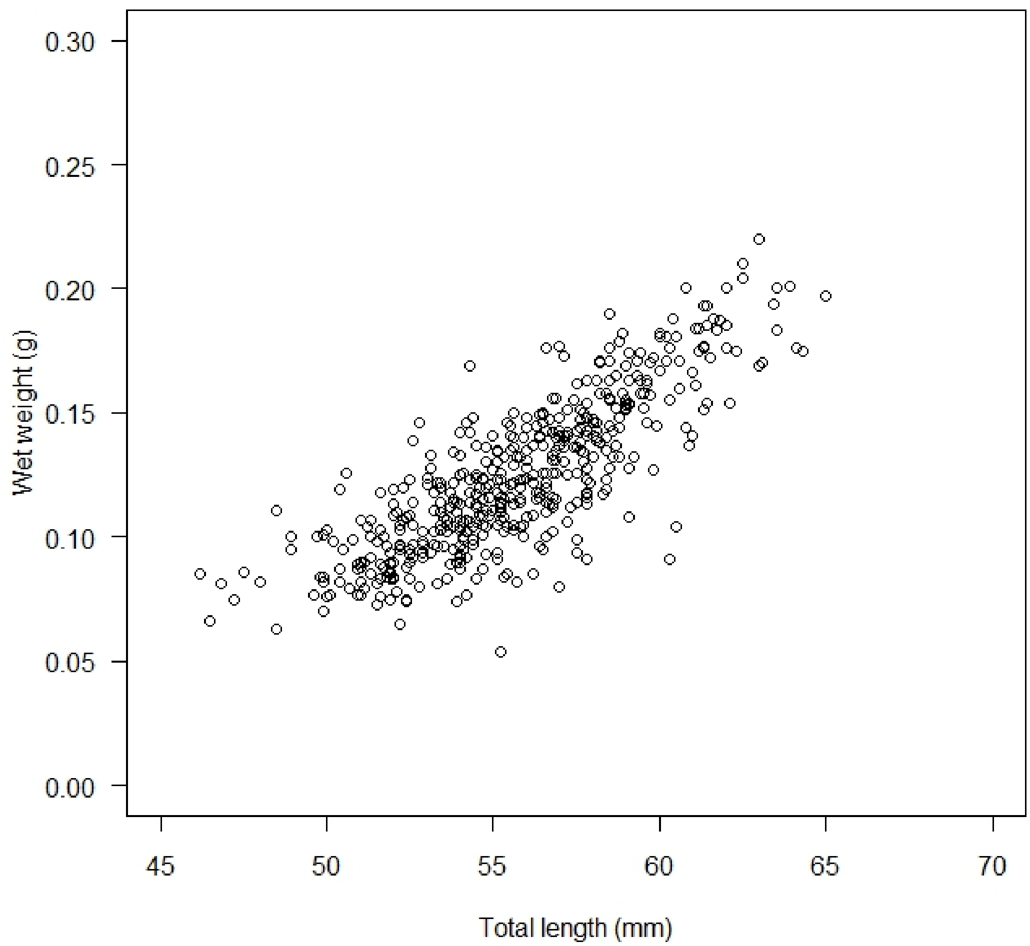


Figure 6. Length-weight relationship for glass eels from the York River, 2010 (n = 487).

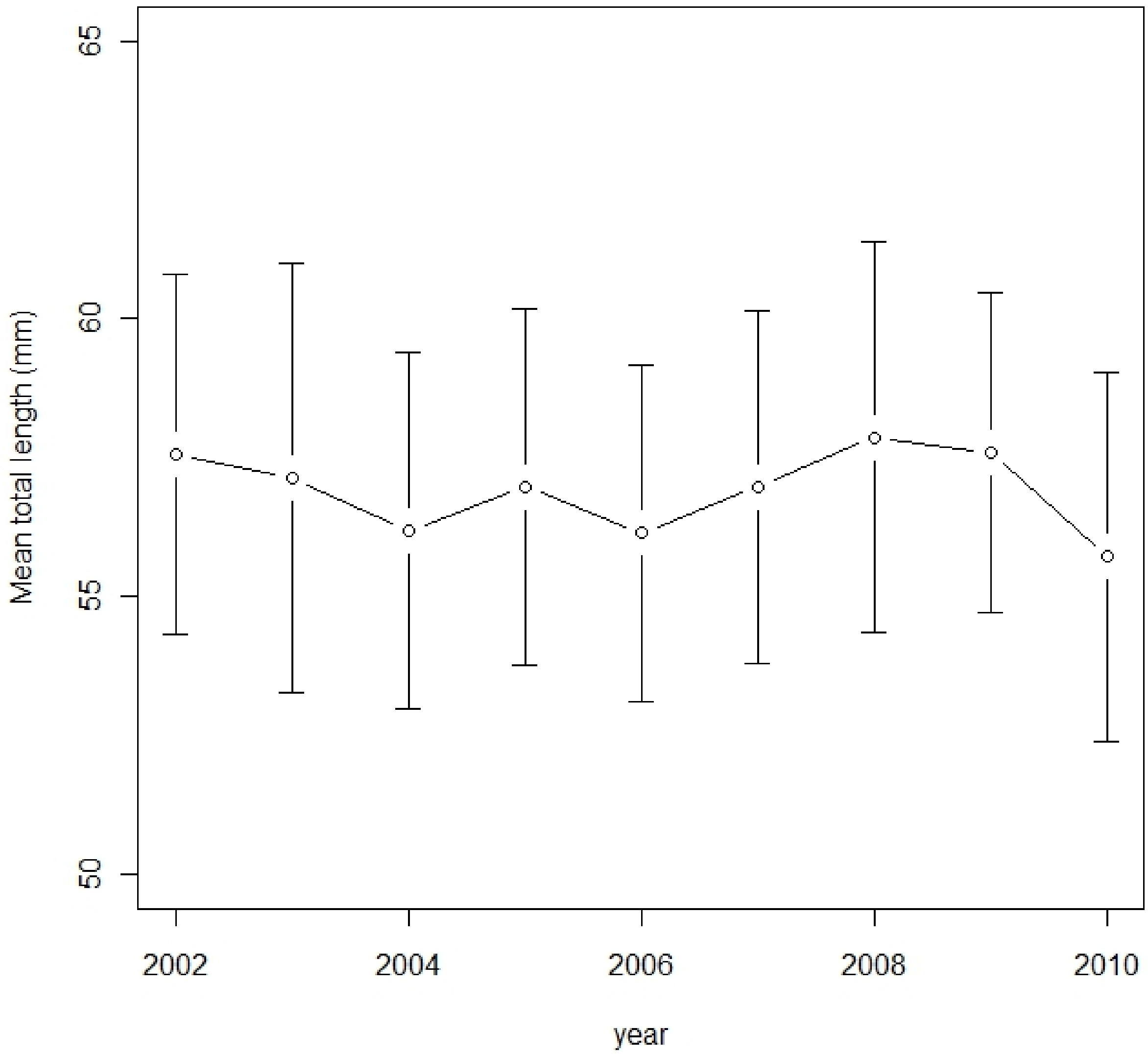


Figure 7. Mean total length (mm; SD) of glass eels collected with Irish eel ramps from 2002 to 2010 from two sites combined (Wormley and Bracken's Ponds) in the York River, Virginia.

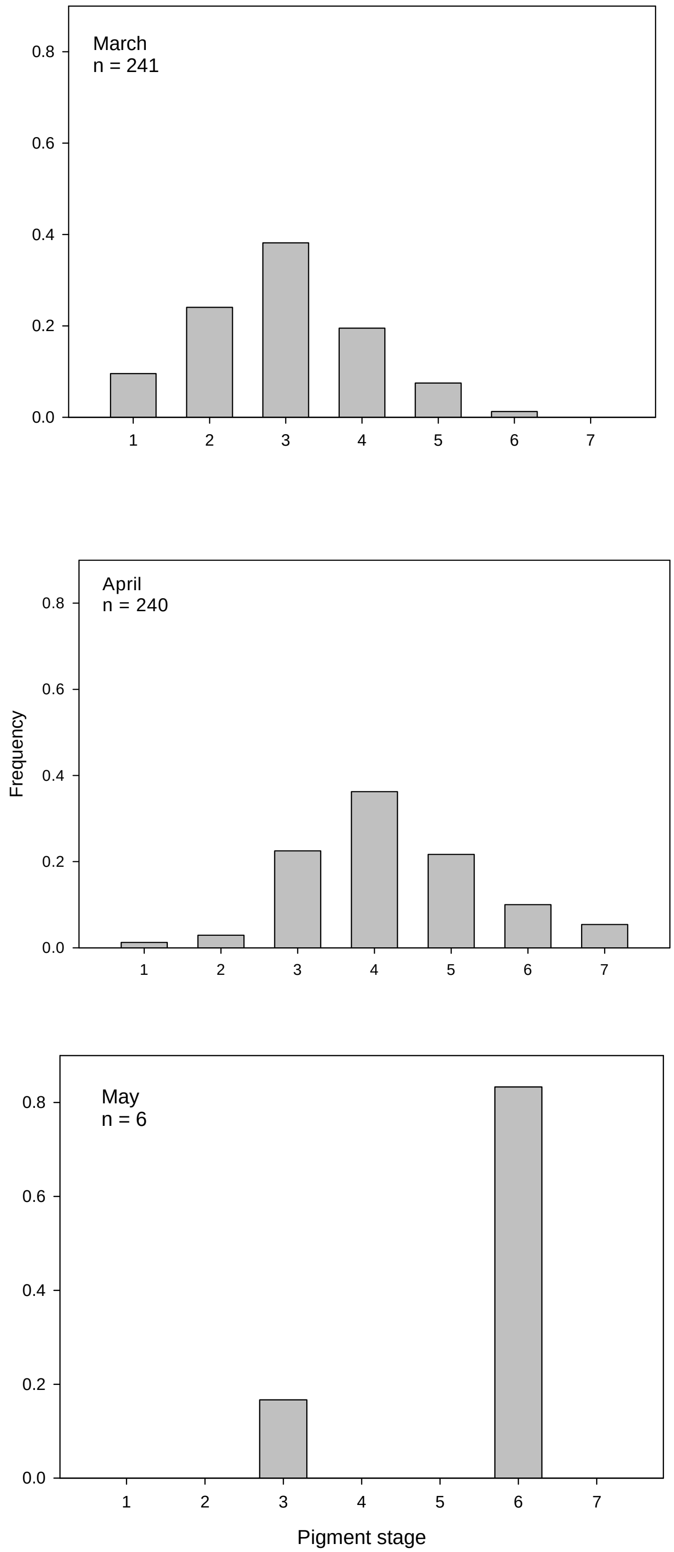
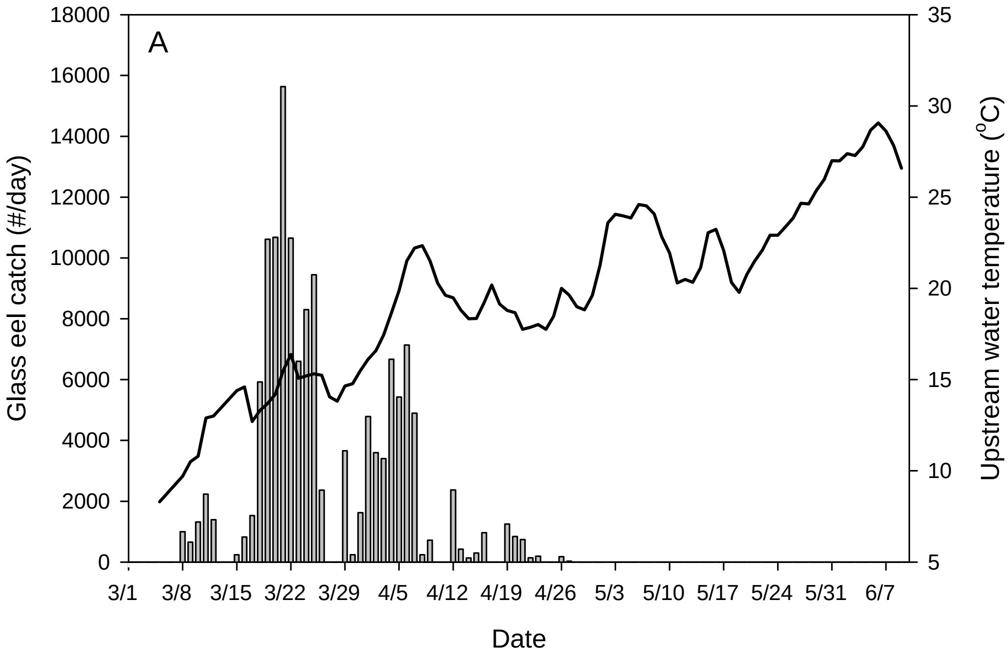


Figure 8. Frequency of glass eel pigment stages by month for the York River system, 2010.



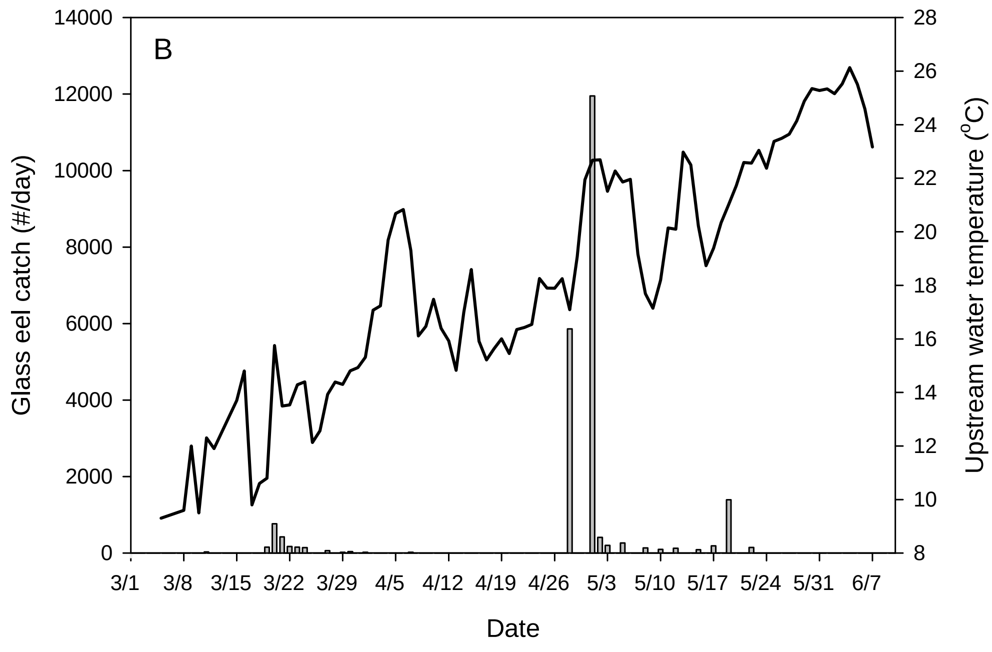


Figure 9. Glass eel catches (bars) and water temperature (line) in 2010 from (A) Wormley Pond, and (B) Bracken's Pond. Note axis scales are not uniform.

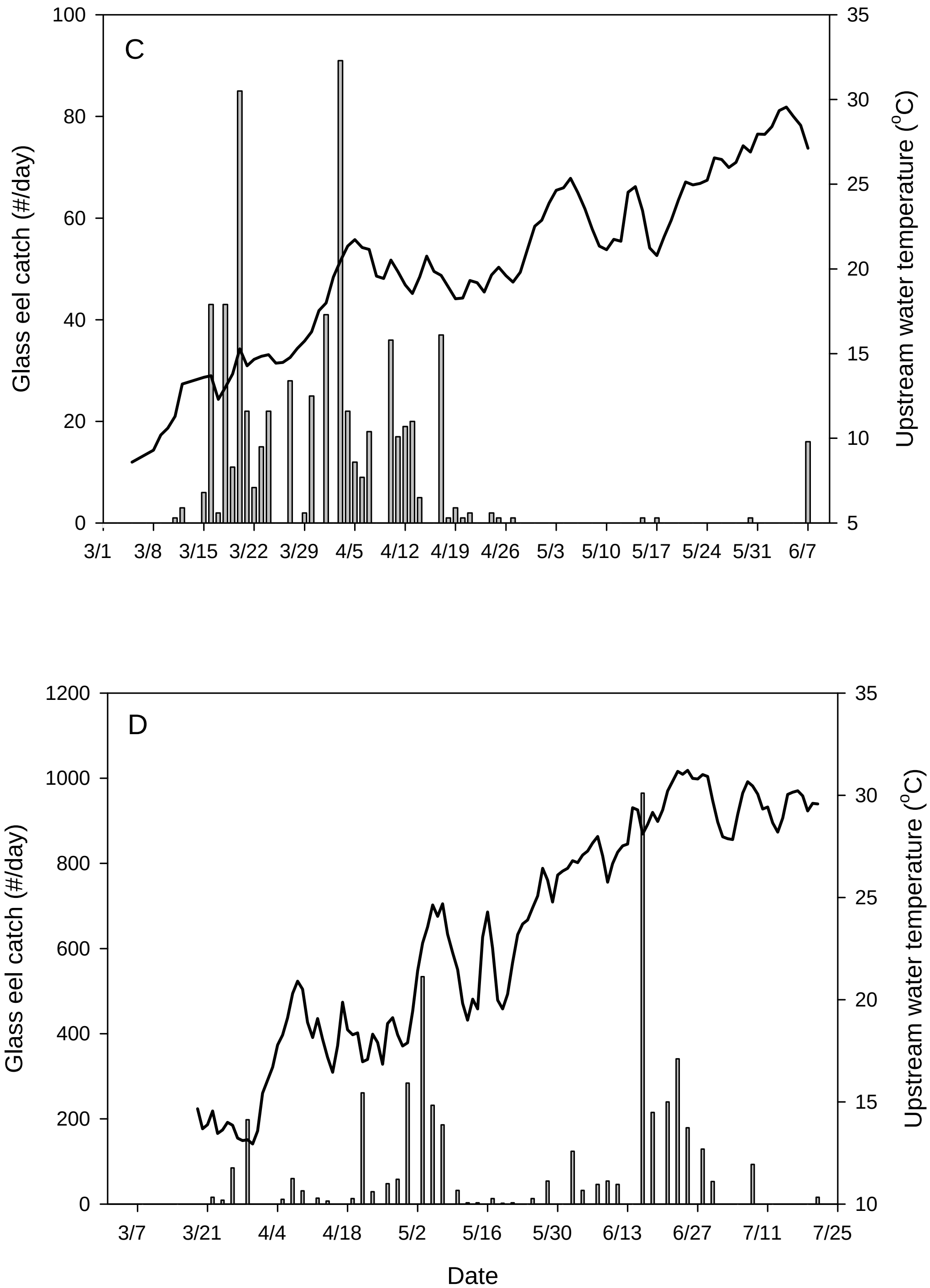


Figure 9 continued. Glass eel catches (bars) and water temperature (line) in 2010 from (C) Wareham's Pond, and (D) Kamp's Millpond. Note axis scales are not uniform.

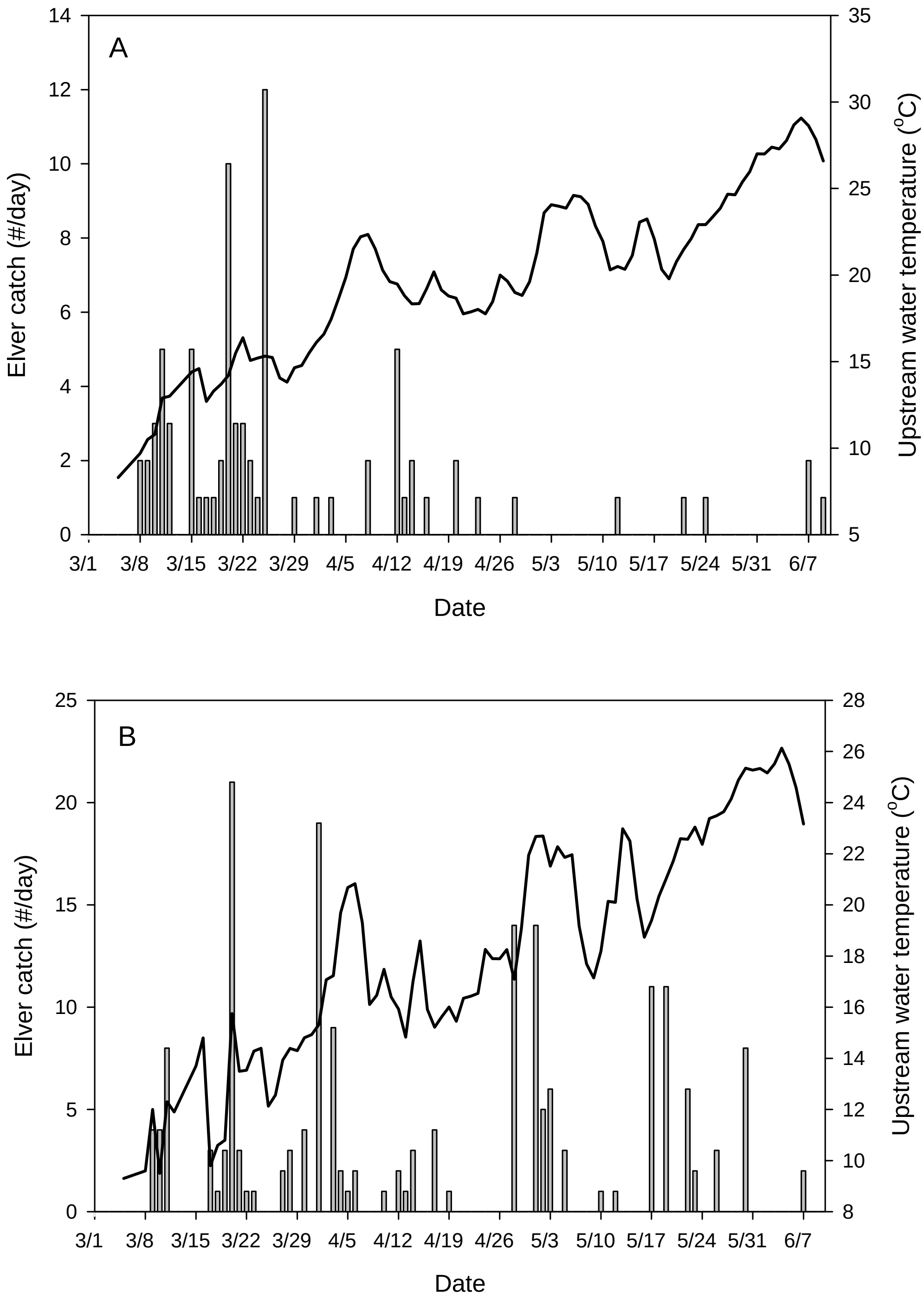
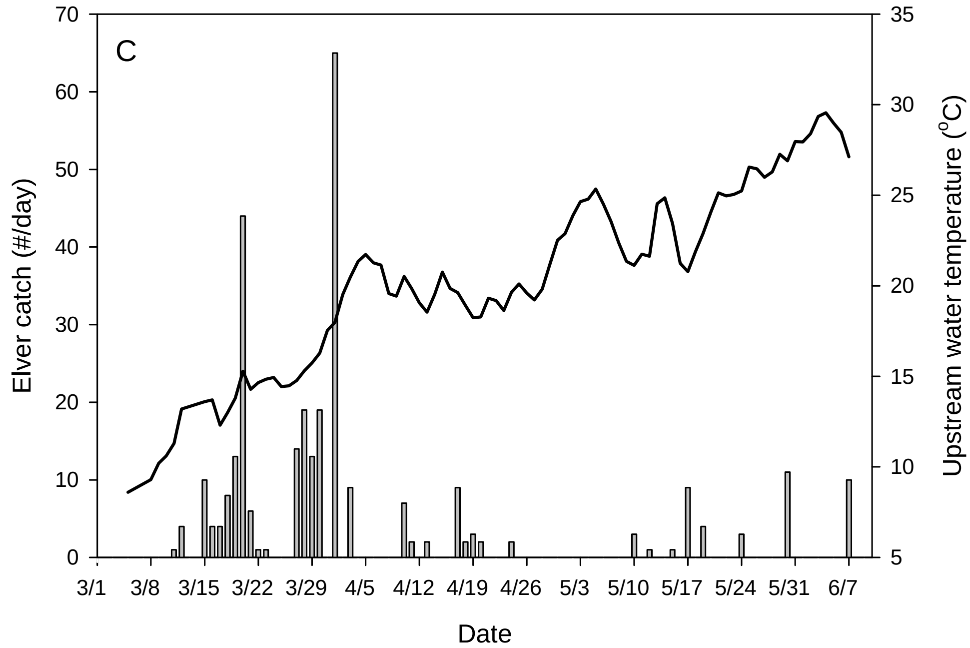


Figure 10. Elver catches (bars) and water temperature (line) in 2010 from (A) Wormley pond, and (B) Bracken's Pond. Note axis scales are not uniform.



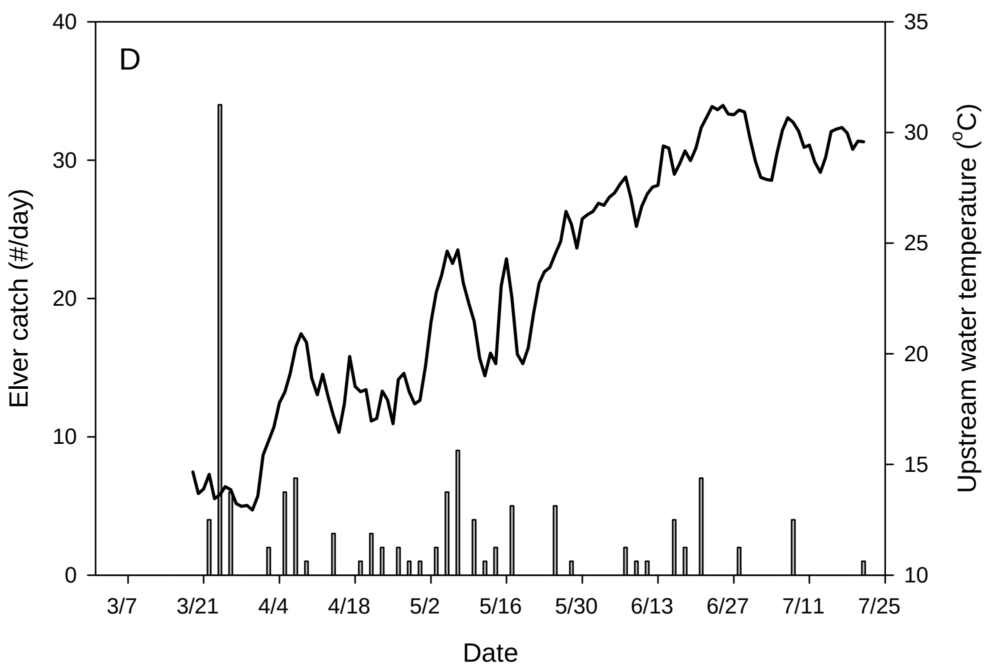


Figure 10 continued. Elver catches (bars) and water temperature (line) in 2010 from (C) Wareham's Pond, and (D) Kamp's Millpond. Note axis scales are not uniform.

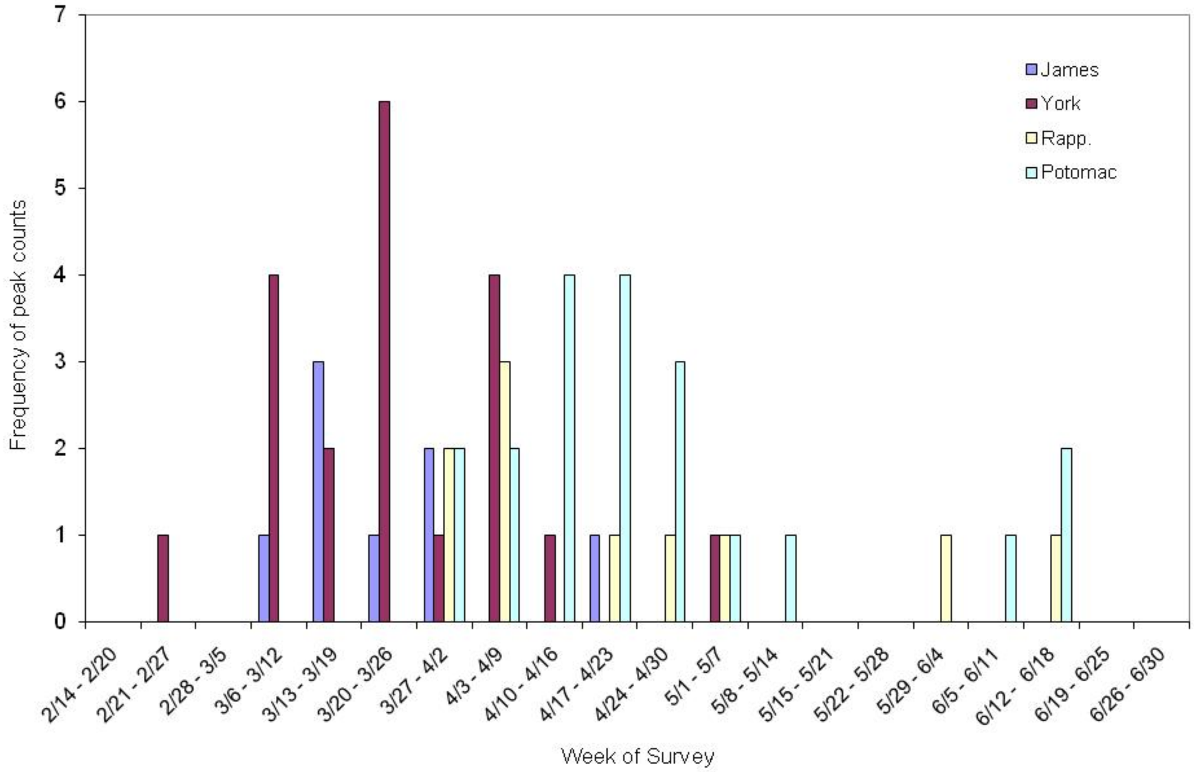


Figure 11. Survey week during which peak counts of glass eels were observed for each river from 2001 to 2010. Two sites are monitored in the York and Potomac rivers each year (n = 20 observations per river). In the James River, one site was monitored beginning in 2003 (n = 8 observations). In the Rappahannock River, one site was monitored each year (n = 10 observations). Potomac River data are from Tuckey and Fabrizio (2010).