Estimating Relative Abundance of Young-of-Year American Eel, *Anguilla rostrata,* in the Virginia Tributaries of Chesapeake Bay (Spring 2011)

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 2011, 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), though glass eels have been captured as early as December (VIMS, unpublished data). 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 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^{TM} 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

Collections of young-of-year American eel (*Anguilla rostrata*) began on 14 February 2011 at Wormley Pond and Brackens Pond on the York River and on 28 February 2011 at Wareham's Pond on the James River. The trap at Kamp's Millpond on the Rappahannock River was deployed on 16 March 2011. Traps were pulled on 2 June 2011 at the York and James River sites, and the Rappahannock River trap was removed on 28 June 201. A total of 12,871 glass eels were collected at Wareham's Pond on the James River, 69,660 glass eels were collected at Brackens Pond and 66,953 at Wormley Pond on the York River, while 1,860 glass eels were collected at Kamp's Millpond on the Rappahannock River in 2011 (Table 1).

Elver indices increased at all sites compared with last year with Bracken's Pond recording the second highest number of elvers in the time series (Table 2; Figures 4

and 5). Catch rates 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 increases in 2010 and 2011 (Figure 4). Elvers collected 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 657 glass eels from Wormley Pond were returned to the lab for weight, length, and pigment stage determination. Total length (TL) of these glass eels ranged from 48.7 to 69.0 mm, with a mean length of 57.8 mm (3.14 standard deviation, SD). Weights of individual glass eels ranged from 0.058 to 0.284 g and averaged 0.143 g (0.032 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 February and May (Figure 8).

Water temperature increased throughout the study period in 2011 with the arrival of glass eels in late February at Wormley and Brackens Ponds and early- to mid-March at Wareham's Pond and Kamp's Millpond (Figure 9). Peak catches of glass eels occurred between 14 and 26 March at Wormley Pond. Catches of elver eels were more variable and occurred throughout the monitoring period (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

Glass eel indices observed at all Virginia sites showed average or above average recruitment in 2011. While recruitment of glass eels at any one site can vary from year to year, increases in recruitment at all sites is a positive sign of a potentially strong year class. Whether solid recruitment of glass eels translates into increases in juvenile eel production and subsequent increases in spawning stock biomass remains unknown.

The timing of recruitment of glass eels continues to support the hypothesis of a single recruitment pulse entering Chesapeake Bay and dispersing throughout the Bay in

relation to the monitoring sites proximity to the Bay mouth. Earliest recruitment of glass eels 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, glass eels arrive at two sites located on the Virginia side of the Potomac River (> 101 km from the mouth of the bay) much later than locations nearer the mouth. The first appearance of glass eels at sites within Chesapeake Bay is after their arrival at sites closer to the coast in MD and DE.

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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
	2011	66953	62410.25
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
	2011	69660	62697.45
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
	2011	12871	14318.00
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
	2011	1860	1980.40

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
	2011	79	104.85
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
	2011	525	644.22
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
	2011	463	523.00
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
	2011	104	213.72

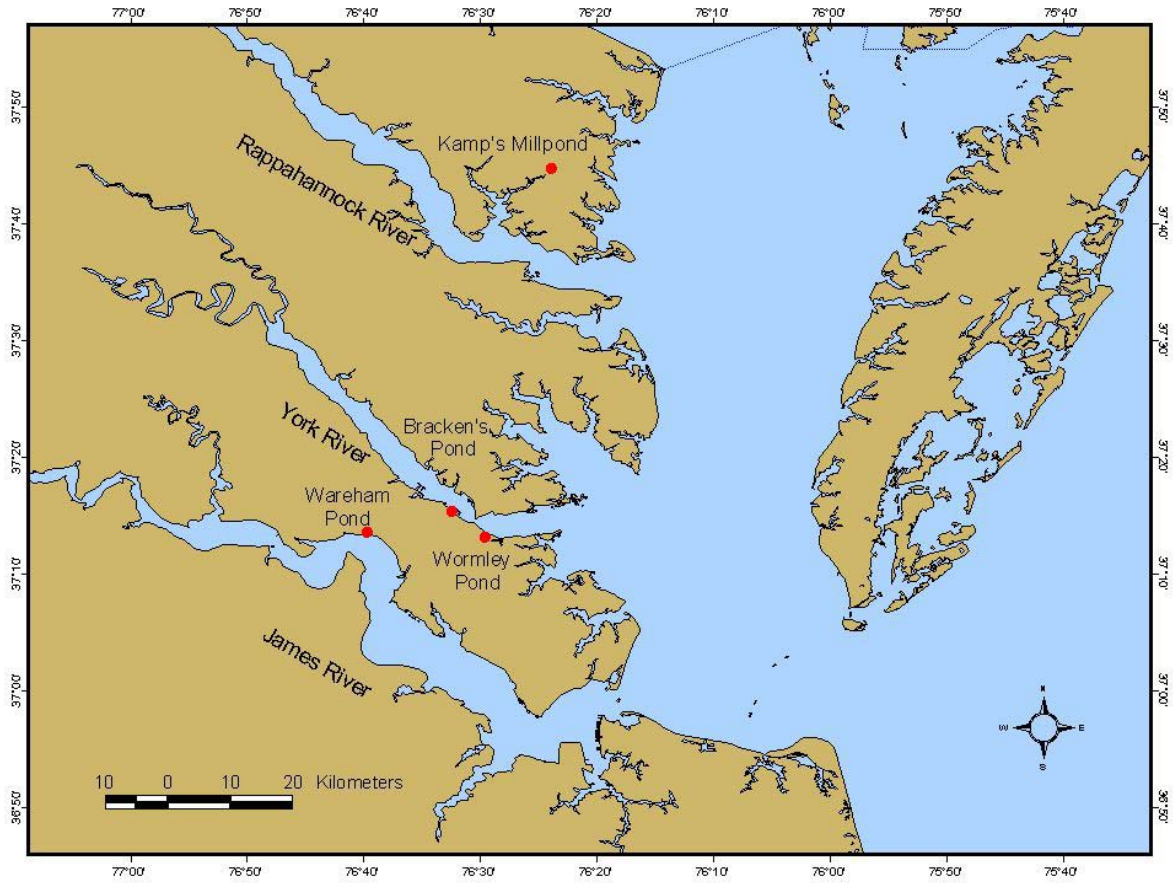


Figure 1. American eel sampling sites in the Rappahannock (Kamp's Millpond), York (Wormley Pond and Bracken's Pond), and James (Wareham's Pond) rivers, Virginia, 2011.

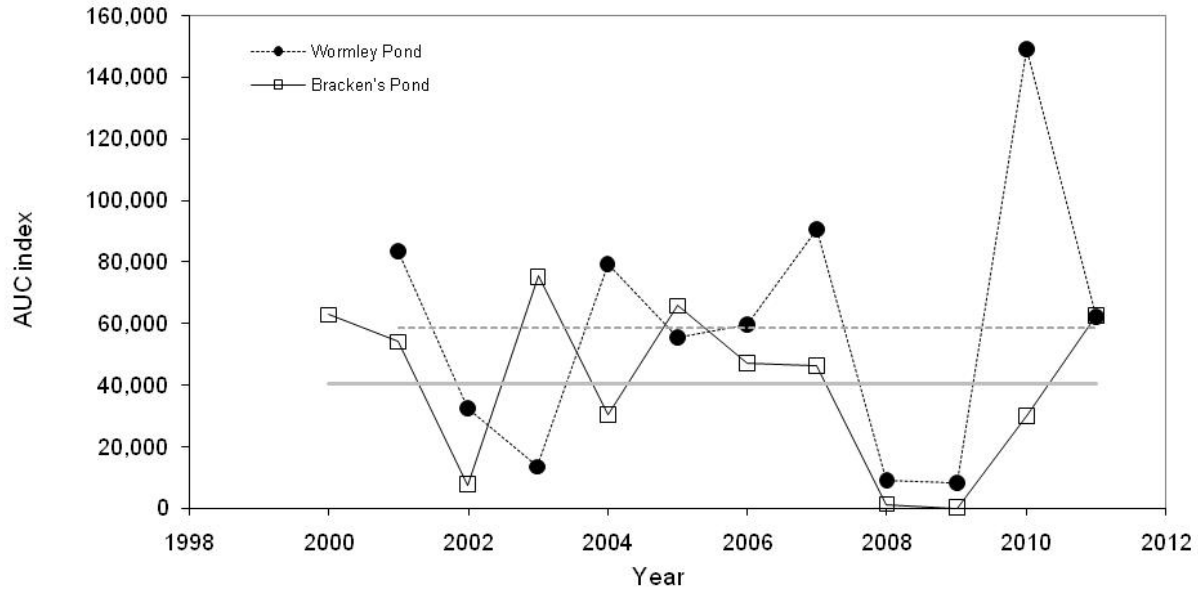


Figure 2. Abundance indices and time series average calculated by area-under-the-curve method for glass eels from Wormley Pond and Bracken's Pond (York River system). Time series averages are shown as solid (Bracken's Pond) and dotted (Wormley Pond) lines.

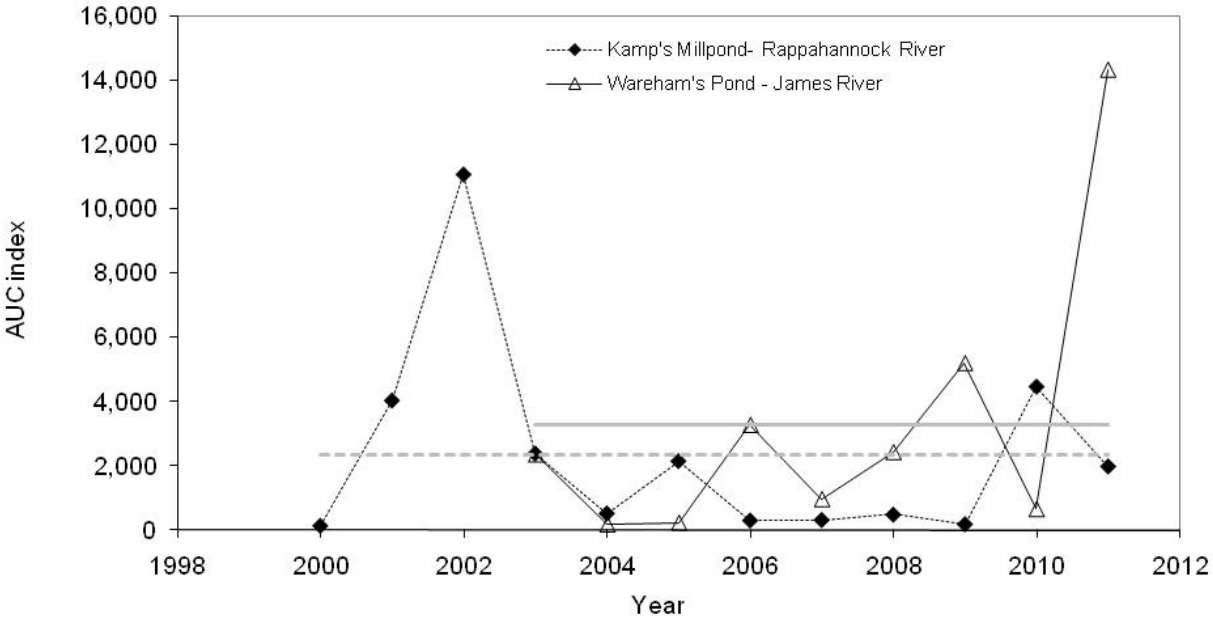


Figure 3. Abundance indices and time series average calculated by the area-under-the-curve method for glass eels from Wareham's Pond (James River system) and Kamp's Millpond (Rappahannock River system). Time series averages are shown as solid (Wareham's Pond) and dotted (Kamp's Millpond) lines.

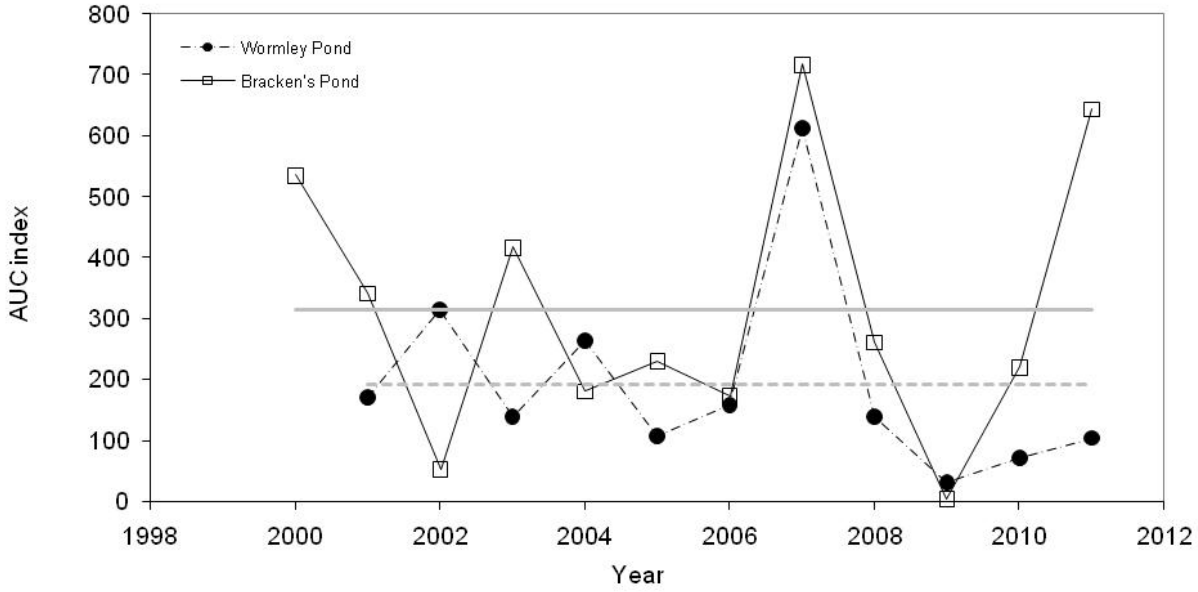


Figure 4. Abundance indices and time series average calculated by the area-under-the-curve method for elvers from Wormley Pond and Bracken's Pond (York River System). Time series averages are shown as solid (Bracken's Pond) and dotted (Wormley Pond) lines.

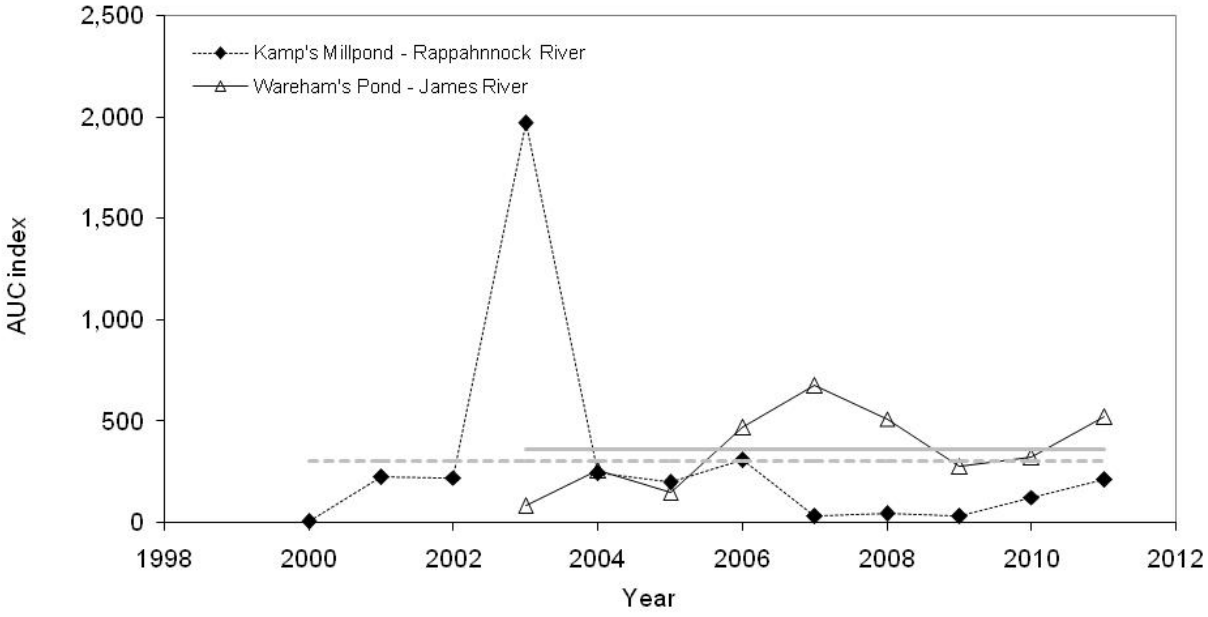


Figure 5. Abundance indices and time series average calculated by the area-under-the-curve method for elvers from Wareham's Pond (James River system) and Kamp's Millpond (Rappahannock River system). Time series averages are shown as solid (Wareham's Pond) and dotted (Kamp's Millpond) lines.

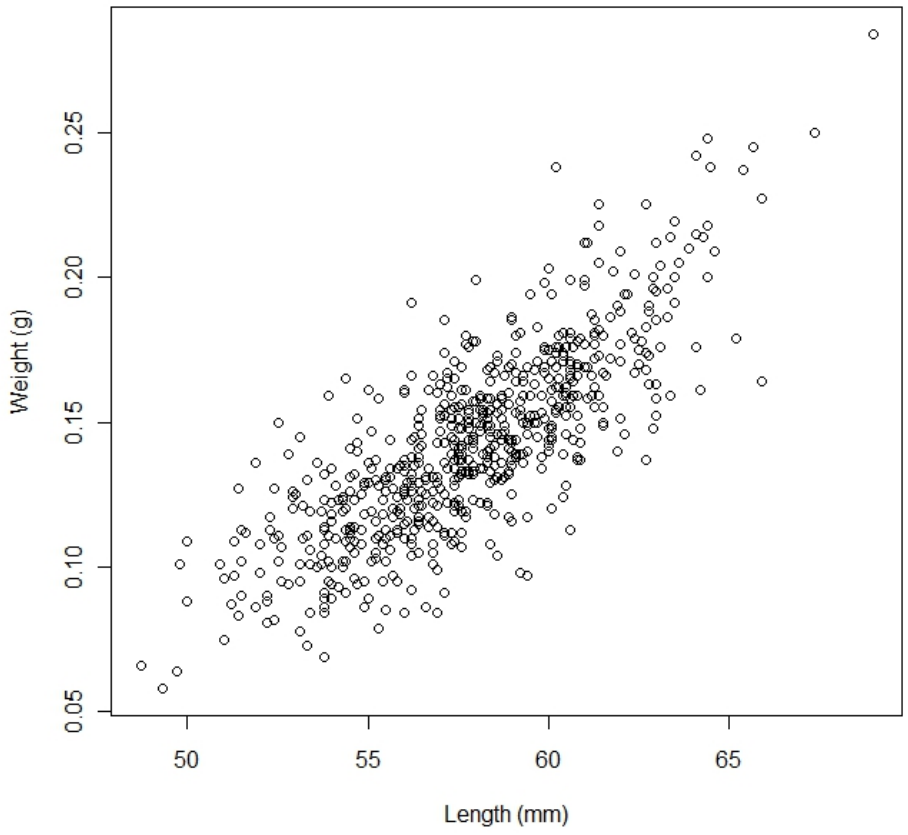


Figure 6. Length-weight relationship for glass eels from the York River, 2011 (n = 657).

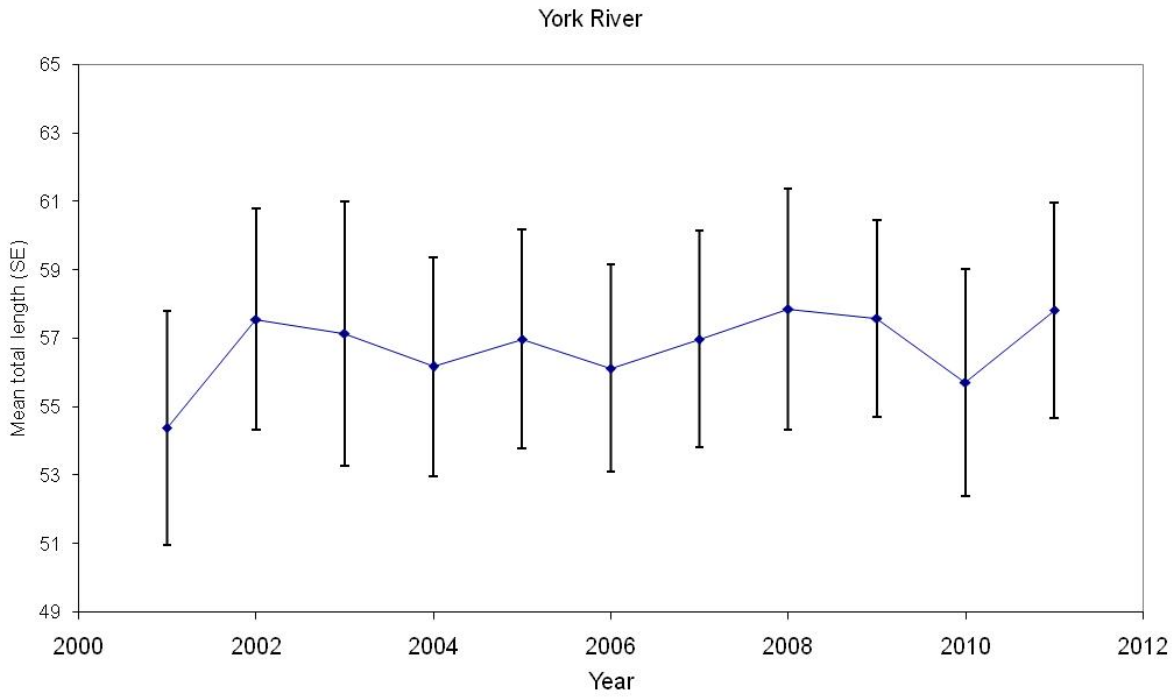


Figure 7. Mean total length (mm; SD) of glass eels collected with Irish eel ramps from 2002 to 2011 from two sites combined (Wormley and Bracken's Ponds) in the York River, Virginia.

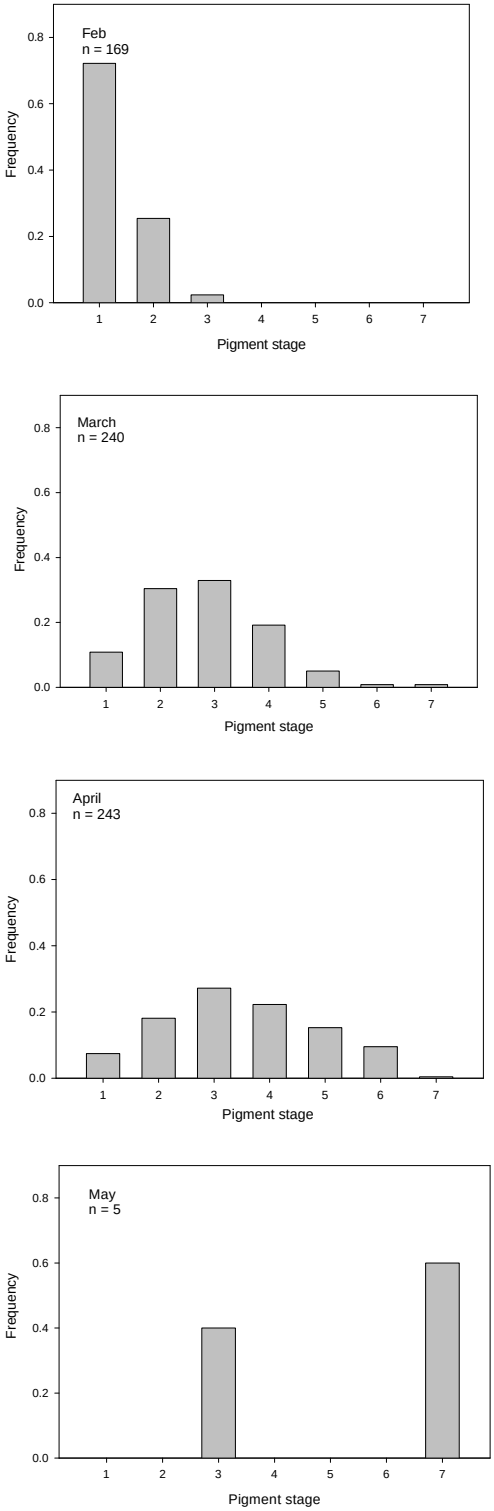


Figure 8. Frequency of glass eel pigment stages by month for the York River system, 2011.

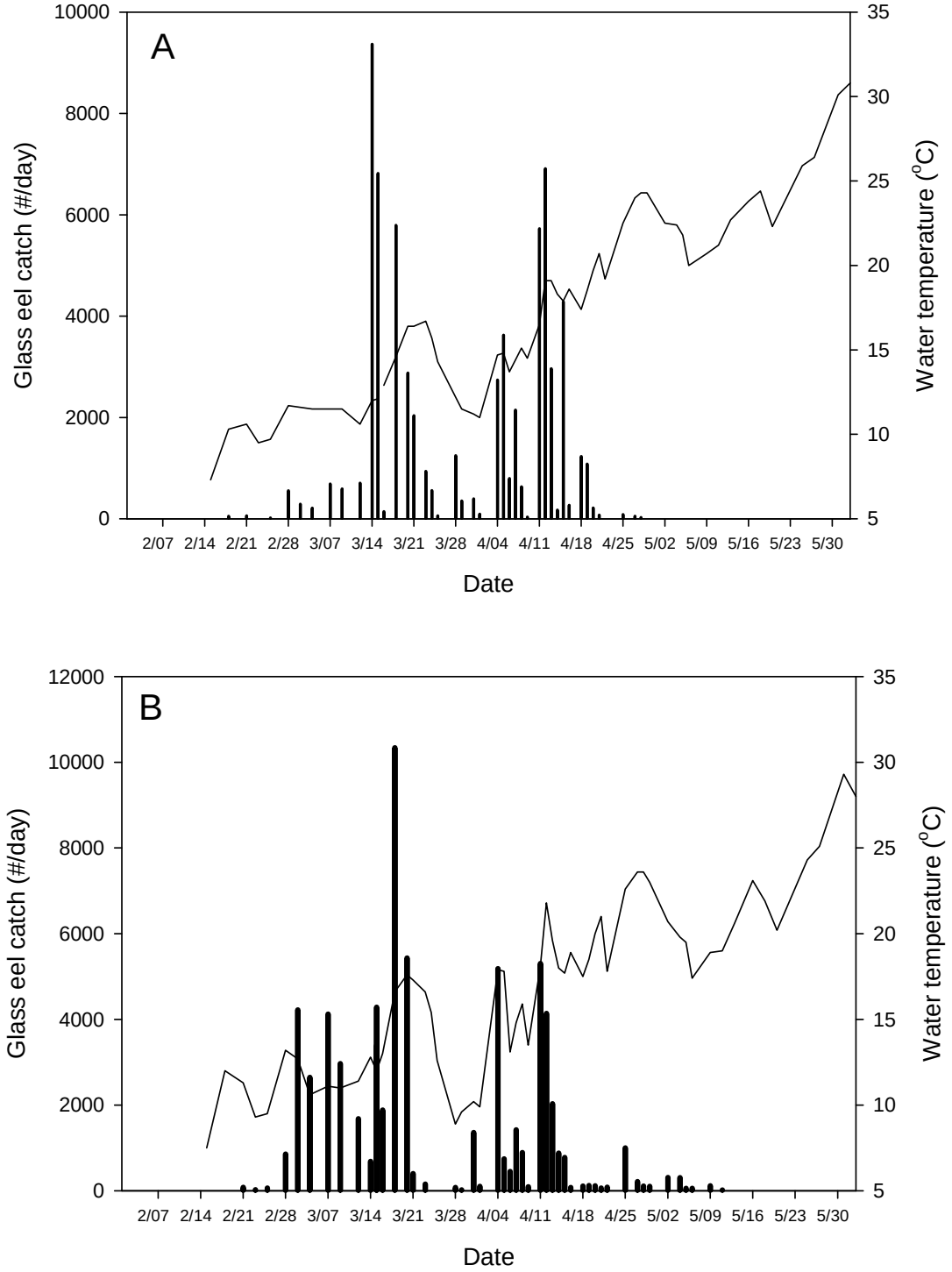
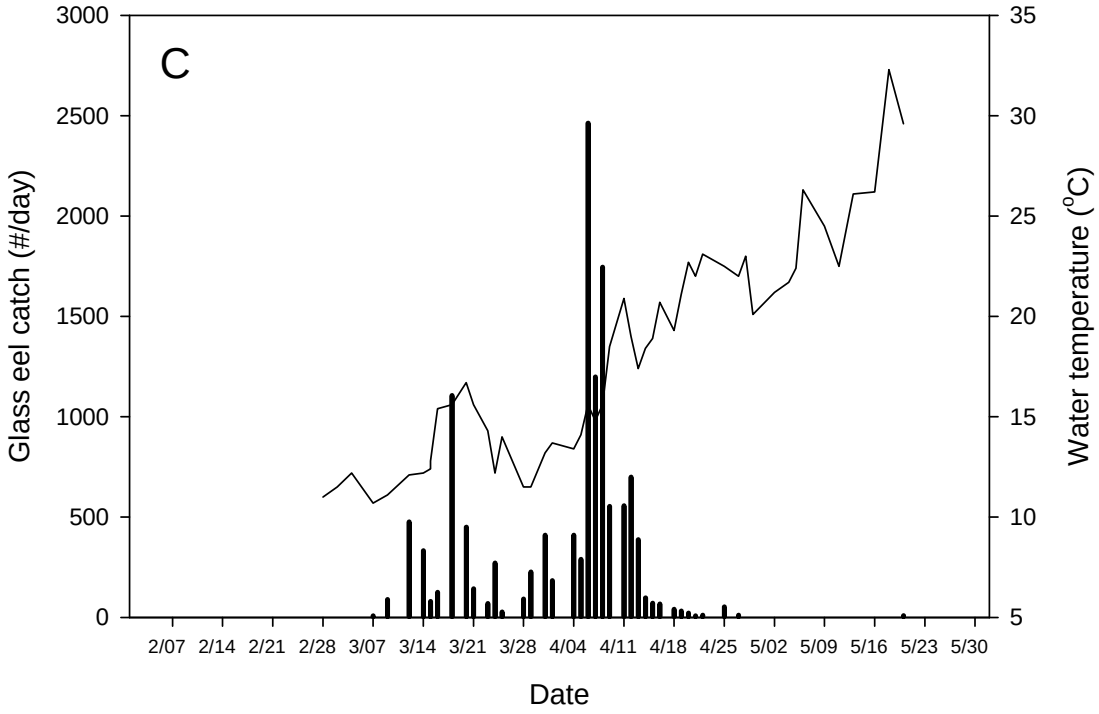


Figure 9. Glass eel catches (bars) and water temperature (line) in 2011 from (A) Wormley Pond, and (B) Bracken's Pond. Note axis scales are not uniform.



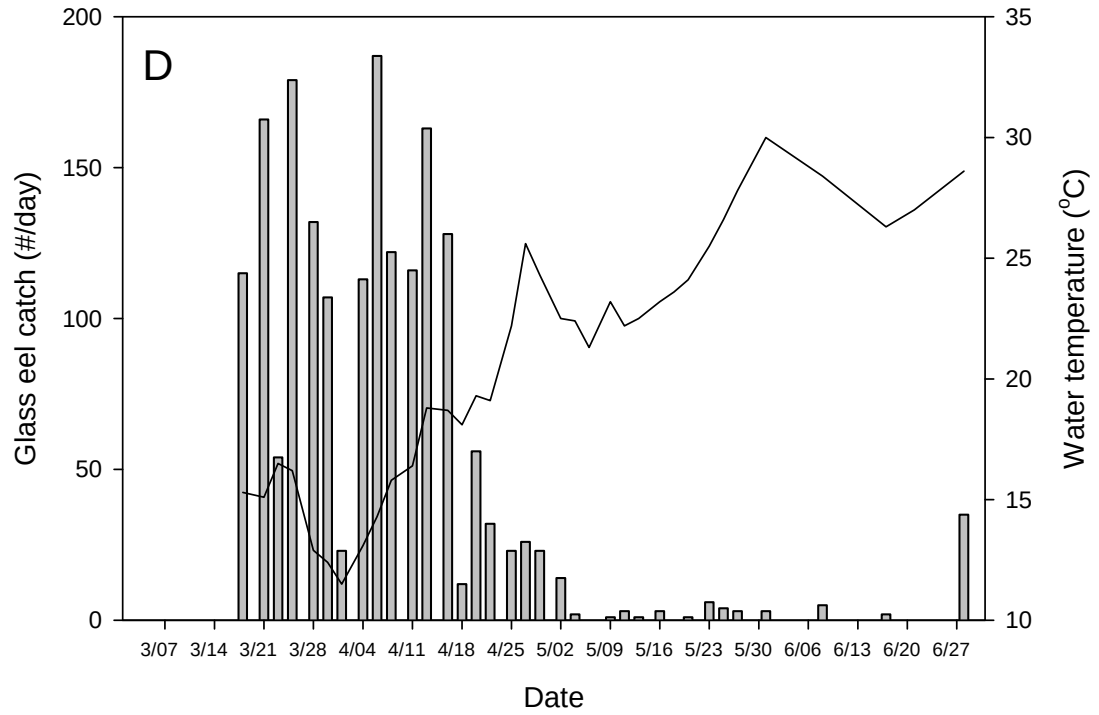


Figure 9 continued. Glass eel catches (bars) and water temperature (line) in 2011 from (C) Wareham's Pond, and (D) Kamp's Millpond. Note axis scales are not uniform.

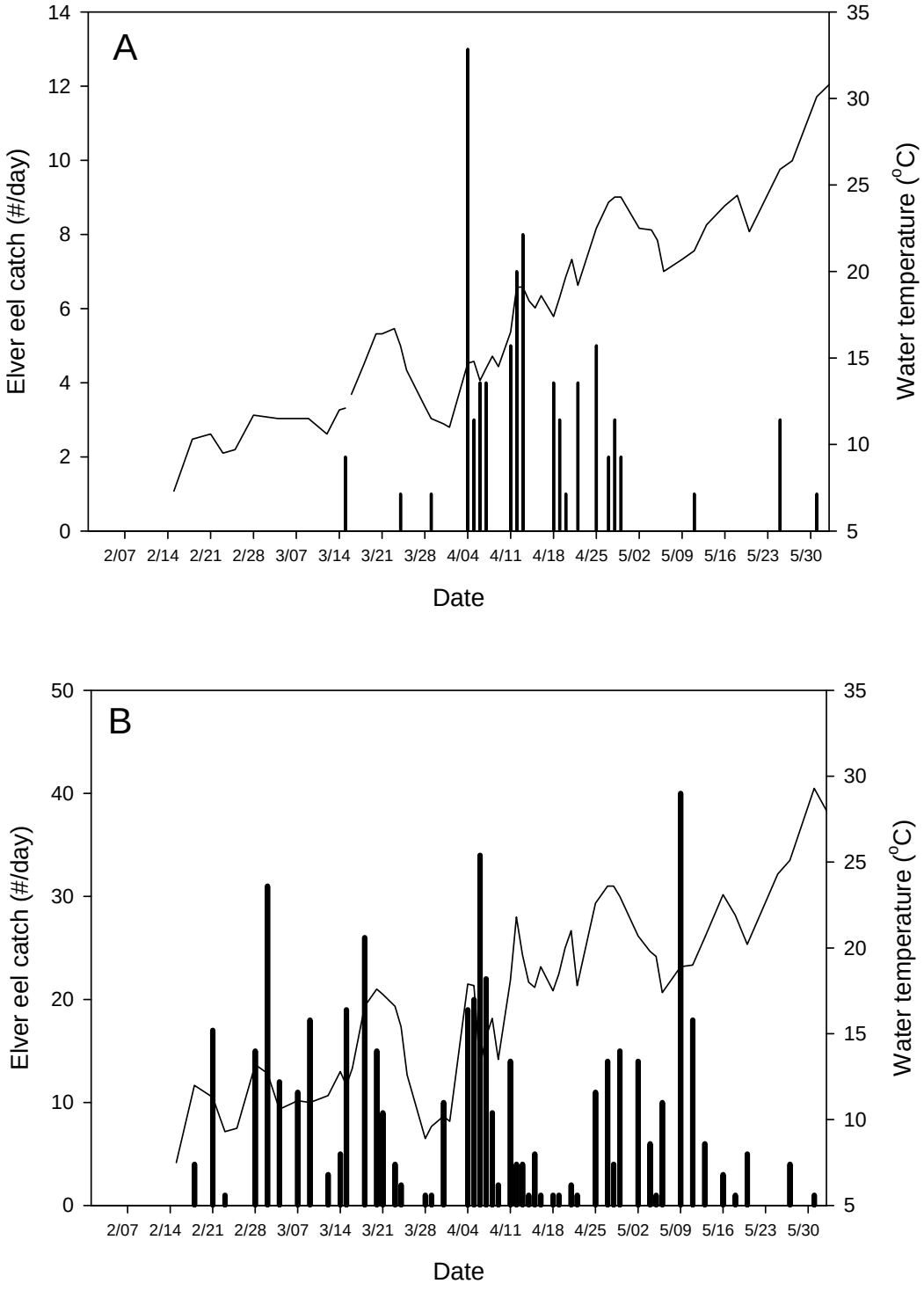
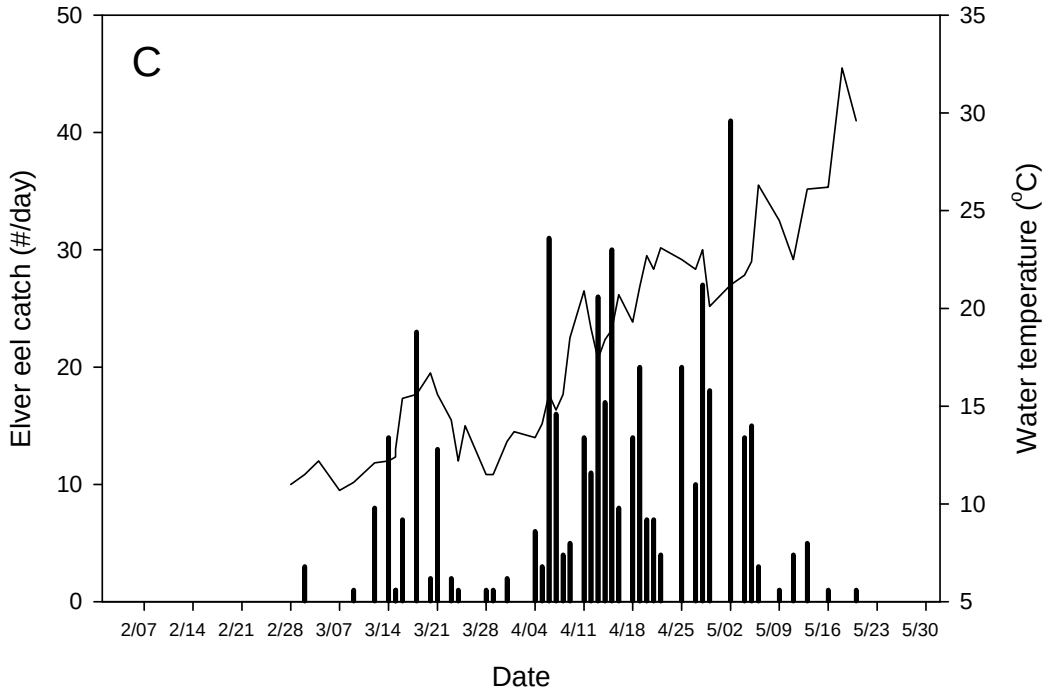


Figure 10. Elver catches (bars) and water temperature (line) in 2011 from (A) Wormley pond, and (B) Bracken's Pond. Note axis scales are not uniform.



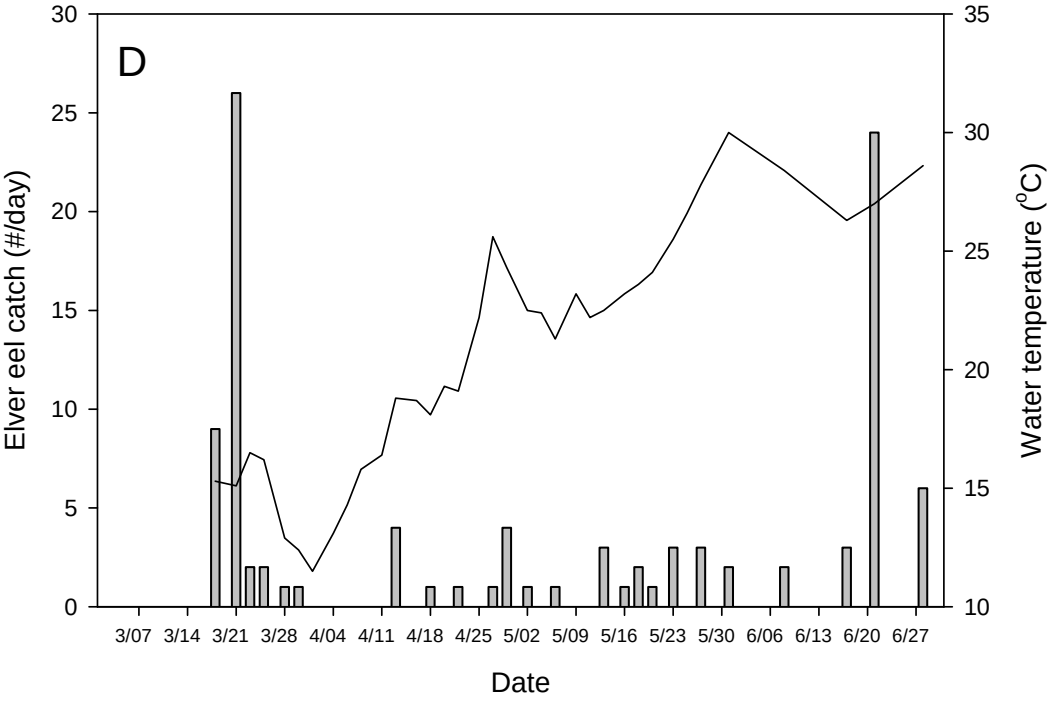


Figure 10 continued. Elver catches (bars) and water temperature (line) in 2011 from (C) Wareham's Pond, and (D) Kamp's Millpond. Note axis scales are not uniform.

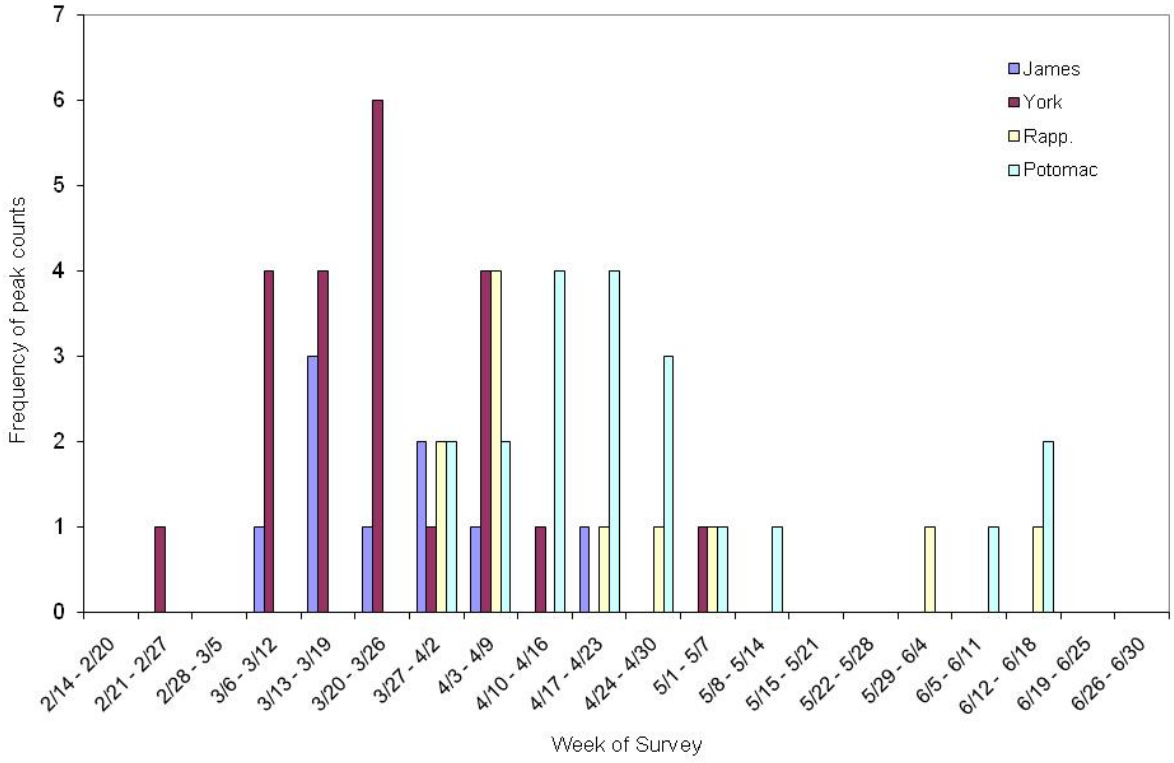


Figure 11. Survey week during which peak counts of glass eels were observed for each river from 2001 to 2011. Two sites are monitored in the York and Potomac rivers each year (n = 22 observations per river). In the James River, one site was monitored beginning in 2003 (n = 9 observations). In the Rappahannock River, one site was monitored each year (n = 11 observations). Potomac River data are from Tuckey and Fabrizio (2010b).