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Estimating Relative Abundance of Young-of-the-year American Eel, Anguilla rostrata, in the Virginia Tributaries of Chesapeake Bay, Spring 2016

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Estimating Relative Abundance of Young-of-Year American Eel, *Anguilla rostrata,* in the Virginia Tributaries of Chesapeake Bay (Spring 2016)

Final Report for Project No. RF/CF 15-01

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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 the U.S., harvests have declined, with similar patterns occurring in the Canadian Maritime Provinces (Meister and Flagg 1997). An average of 62% of the annual landings of U.S. commercial harvest since 1993 have come from the Chesapeake Bay (personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, 9 February 2015). In 2013, Virginia commercial landings were approximately 100,298 lbs; since mandatory reporting began in 1993, average annual landings in Virginia have been 193,200 lbs or 19% of the U.S. American Eel harvest (personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, 9 February 2015).

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). 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). However, limited knowledge about fundamental biological characteristics of glass eels has complicated interpretation of juvenile abundance trends (Sullivan et al. 2006).

The Atlantic States Marine Fisheries Commission (ASMFC) adopted the Interstate Fishery Management Plan (FMP) for the American Eel in November 1999. The FMP calls for efforts to collect American Eel data through both fishery-dependent and fishery-independent studies in coastal states. Consequently, member jurisdictions agreed to implement an annual survey for young-of-year (YOY or glass) 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 provide necessary data on coastal recruitment success and further understanding of American Eel population dynamics. A recent American Eel benchmark stock assessment report found that the American Eel stock status is depleted and emphasized the importance of the coast-wide survey as an index of recruitment over the historical coastal range in the U.S. and an early warning of potential range contraction of the species (ASMFC 2012). In 2016, 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 in the York River estuary as early as December (VIMS, unpublished data). As growth continues, the glass eel becomes pigmented (elver stage) and within 12 to 14 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 into estuarine habitats 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, (Sullivan et al. 2006), or may respond to conspecific cues, such that the presence of glass eels in a particular water body attracts the recruitment of other glass eels to the same location (Schmucker et al. 2016).

Objectives

The objectives of this study were to:

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 jurisdiction) must be examined for length, weight, and pigmentation stage weekly.

Due to the importance of the eel fishery in Virginia, the methods used to monitor glass eel recruitment 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 estuary and one each on the Rappahannock and James river estuaries. The James River site (Wareham's Pond) is located in the Kingsmill area of James City County, VA. Wareham's Pond drains directly into the James River, which is about 100 m away, though high tides may affect water levels at 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. 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. The final collection site is 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, VA.

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 ramp was placed on an incline (15 - 45°) 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° 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 different year classes (Geer 2001; note: eels larger than 254 mm TL are not considered elvers, 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 for each site were calculated using the area-under-the-curve approach (Olney and Hoenig 2001).

Results

Collections of young-of-year American Eel began on 22 February 2016 at Bracken's Pond and Wormley Pond in the York River estuary, on 29 February 2016 at Wareham's Pond in the James River estuary, and on 22 March 2016 at Kamp's Millpond in the Rappahannock River estuary. Traps were removed on 13 June 2016 from Wareham's Pond (105 days of continuous sampling), and Wormley Pond and Bracken's Pond (112 days of continuous sampling at each site) in the York River estuary. The Rappahannock River estuary trap was removed on 29 June 2016 after 99 days of sampling. In all, we collected 358 glass eels at Bracken's Pond, 40,154 glass eels at Wormley Pond (York River system), 915 glass eels at Wareham's Pond (James River system), and 947 glass eels at Kamp's Millpond (Rappahannock River system; Table 1). Glass eel catch rates in 2016 were below-average in all sampled estuaries in Virginia.

Small numbers of glass eels were first captured in late February at Wormley Pond and early March at Bracken's and Wareham's Ponds. Glass eels were first captured in late-March at

Kamp's Millpond (Figure 9). The majority of glass eels recruiting to Wormley and Wareham's Ponds occurred over a 30-day period from 4 March to 4 April and a similar recruitment pulse lasting about 30 days occurred at Kamp's Millpond nearly a month later (late March to late April). There was an increase in glass eel recruitment at Bracken's Pond at the end of May. Peak counts of glass eels typically occur first in the York River estuary, followed by the James, Rappahannock, and Potomac river estuaries (Figure 11).

Elver indices were above-average at all sites in 2016 with record numbers being captured at Bracken's and Wareham's ponds (Table 2; Figures 4 and 5). Catches of elver eels occurred throughout the monitoring period at all sites (Figure 10). In the York River estuary, there were two large pulses of elvers that occurred at both sites, one during late February into early March and one occurring in late May. We continued to capture elvers at Wormley and Bracken's ponds between the peak catches, but at reduced numbers. In the James River estuary there was one pulse of elver eels captured as soon as the trap was set that tapered off as the sampling season progressed (Figure 10C). The capture of elvers in the Rappahannock River estuary was continuous throughout the sampling period with an increase occurring from mid- to late-May (Figure 10D).

The area below the spillway at Wareham's Pond was redesigned in 2013 and the three highest catches of elvers were observed in 2014, 2015, and 2016 suggesting that changes to the site may have positively influenced the catch of elvers in Wareham's Pond. Catch rates of elvers from Wormley Pond increased in 2016 after eight years of below-average observations (Figure 4).

We examined 608 glass eels from Wormley Pond for weight, length, and pigment stage determination in 2016. Total length (TL) of these glass eels ranged from 47.0 to 69.5 mm, with a mean length of 55.6 mm (3.60 standard deviation, SD). Weights of individual glass eels ranged from 0.063 to 0.257 g and averaged 0.127 g (0.032 SD; Figure 6). Mean TL of glass eels recruiting to Wormley Pond on the York River has remained consistent since 2002 (Figure 7). As expected, glass eel pigment stages increased monthly from February to April, 2016 (Figure 8).

Conclusions

Glass eel recruitment was below-average at all sites in 2016. The timing of recruitment was consistent among sites with peak recruitment occurring from early March to early April at sites in the York and James rivers, and a delay of one month in the Rappahannock River, which is furthest from the mouth of Chesapeake Bay.

The timing of recruitment of glass eels to monitoring sites in Virginia supports the hypothesis of several pulses of glass eels entering and dispersing throughout Chesapeake Bay. Earliest arrival of glass eels is typically observed at Wormley Pond in the York River estuary (55.7 km from the mouth of the Bay), followed by Bracken's Pond in the York system (59.4 km), Wareham's Pond in the James River estuary (77.8 km), and finally Kamp's Millpond in the Rappahannock River estuary (101 km). Additionally, glass eels arrive at two sites located on the Virginia side of the Potomac River estuary (> 101 km from the mouth of the Bay) much later than at locations near the mouth of Chesapeake Bay. It is interesting to note that relative abundance indices at sites closer to the mouth of Chesapeake Bay tend to show greater variation than those further from the mouth of the Bay (Potomac River sites; Tuckey and Fabrizio 2016).

How recruitment of glass eels translates into yellow-phase eel production and subsequent changes in spawning stock biomass remains unknown. However, we are collecting American Eel sub-adults from the VIMS Juvenile Fish Trawl Survey and also obtaining eel samples from the Virginia Department of Game and Inland Fisheries in a cooperative effort to compare the age distribution of sub-adult American Eels with the recruitment indices of glass eels in each watershed. This unfunded project is underway and we have collected and processed more than 800 eels from the various sources.

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Table 1. Total number of glass American Eels captured and the index of abundance using Area Under the Curve method (AUC). 'NA' indicates that data are not available due to construction at this site in 2013.

Site	Year	Total Caught	AUC index	Site	Year	Total Caught	AUC index
Wormley Pond	2001	82,267	83,492.5				
	2002	31,518	32,638.7				
	2003	14,385	13,725.6	Wareham's Pond	2003	2,230	2,350.6
	2004	78,258	79,293.5		2004	158	165.3
	2005	56,259	55,660.7		2005	225	224.1
	2006	61,211	59,855.0		2006	3,280	3,266.3
	2007	90,988	90,705.0		2007	953	959.3
	2008	9,012	9,220.6		2008	2,456	2,417.2
	2009	8,367	8,404.2		2009	5,322	5,192.3
	2010	139,391	149,154.2		2010	672	648.5
	2011	66,953	62,410.3		2011	12,871	14,318.0
	2012	65,312	65,271.7		2012	3,933	4,042.1
	2013	42,415	42,362.2		2013	NA	NA
	2014	36,894	38,447.9		2014	1,979	1,969.8
	2015	40,071	46,619.6		2015	5,218	5,737.6
	2016	40,154	44,829.6		2016	915	936.2
Bracken's Pond	2000	61,228	62,884.7	Kamp's Millpond	2000	139	129.9
	2001	52,838	54,113.1		2001	3,956	4,030.2
	2002	7,413	7,590.8		2002	11,217	11,064.5
	2003	77,592	75,405.4		2003	2,387	2,377.5
	2004	29,914	30,281.7		2004	524	516.2
	2005	65,983	65,885.3		2005	2,084	2,145.0
	2006	45,738	47,093.6		2006	302	298.6
	2007	46,758	46,266.8		2007	313	311.5
	2008	1,165	1,150.3		2008	481	479.0
	2009	69	67.5		2009	179	179.0
	2010	23,044	30,087.8		2010	4,734	4,462.0
	2011	69,660	62,697.5		2011	1,860	1,980.4
	2012	62,738	85,747.3		2012	67,045	43,654.3
	2013	29,272	28,486.3		2013	2,426	2,457.2
	2014	3,376	3,863.9		2014	4,167	3,693.9
	2015	35,328	38,294.8		2015	508	485.1
	2016	358	399.5		2016	947	950.8

Table 2. Total number of elver American Eels captured and the index of abundance using Area Under the Curve method (AUC). 'NA' indicates that data are not available due to construction at this site in 2013.

Site	Year	Total Caught	AUC index	Site	Year	Total Caught	AUC index
Wormley Pond	2001	171	171.4				
	2002	315	314.6				
	2003	138	140.5	Wareham's Pond	2003	84	84.7
	2004	257	264.7		2004	260	256.4
	2005	105	108.6		2005	148	148.6
	2006	160	158.4		2006	469	471.2
	2007	619	612.8		2007	682	676.7
	2008	139	140.0		2008	511	512.8
	2009	31	32.0		2009	275	275.7
	2010	80	71.9		2010	306	323.4
	2011	79	104.9		2011	463	523.0
	2012	79	69.9		2012	496	516.0
	2013	99	112.1		2013	NA	NA
	2014	64	74.7		2014	1,368	1,399.9
	2015	107	103.1		2015	946	1,173.4
	2016	248	340.4		2016	2,061	1,976.5
Bracken's Pond	2000	528	535.4	Kamp's Millpond	2000	5	4.9
	2001	334	341.1		2001	222	225.4
	2002	52	52.2		2002	224	222.9
	2003	411	416.7		2003	1,968	1,972.6
	2004	171	180.0		2004	250	246.1
	2005	231	229.9		2005	196	198.6
	2006	166	172.7		2006	312	310.0
	2007	723	717.8		2007	32	31.7
	2008	262	260.9		2008	37	45.1
	2009	3	3.0		2009	33	34.5
	2010	190	219.9		2010	132	125.9
	2011	525	644.2		2011	104	213.7
	2012	462	542.8		2012	891	730.7
	2013	354	398.4		2013	218	222.5
	2014	163	174.5		2014	259	246.5
	2015	358	548.0		2015	119	239.1
	2016	685	800.3		2016	364	452.8

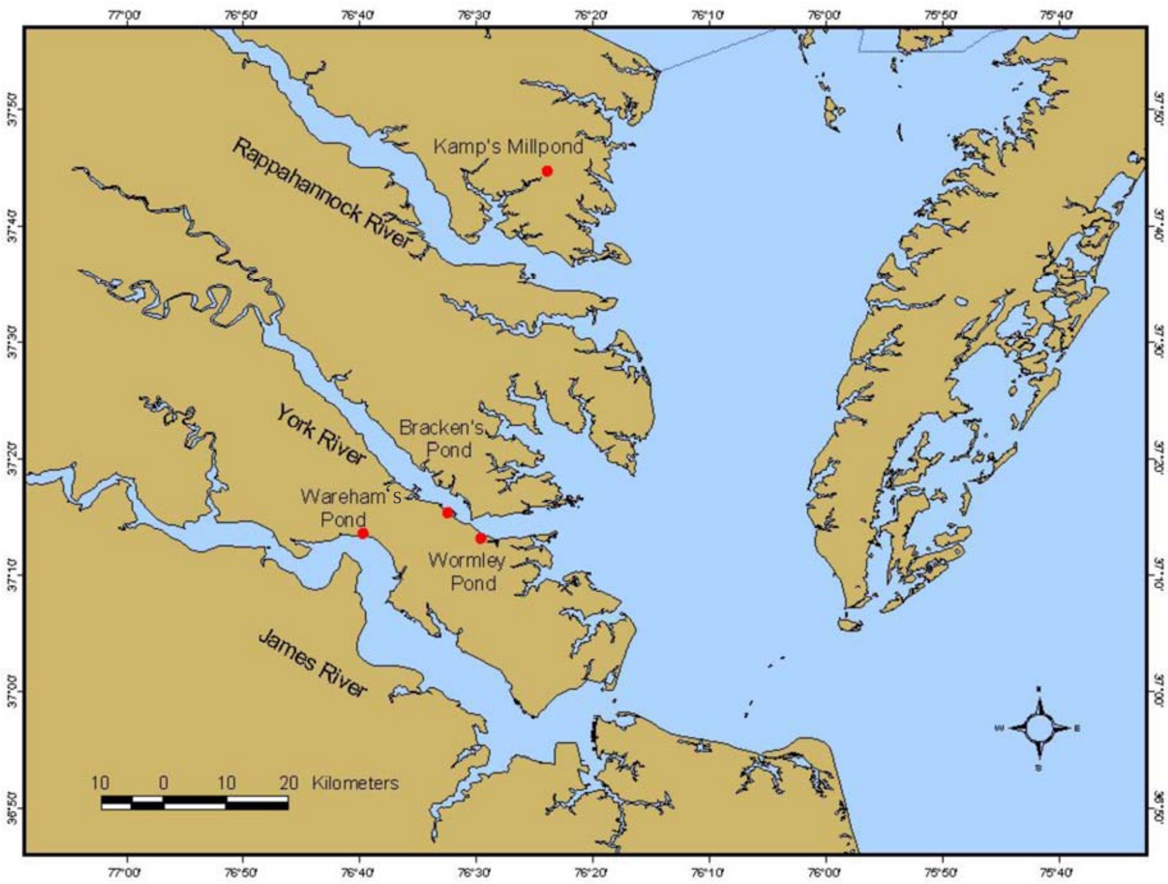

Figure 1. American Eel sampling sites in sub-estuaries of the Chesapeake Bay: the Rappahannock (Kamp's Millpond), York (Wormley Pond and Bracken's Pond), and James (Wareham's Pond) estuaries, Virginia, 2016.

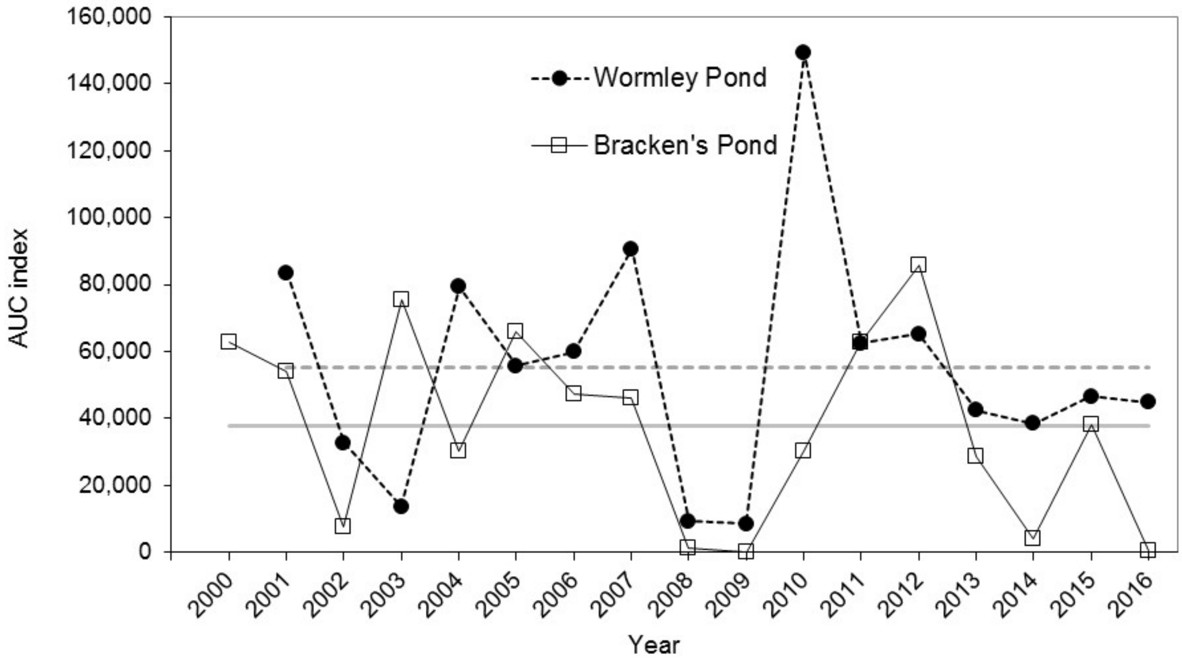

Figure 2. Abundance indices and time series average calculated by the area-under-the-curve method for glass American Eels from Wormley Pond and Bracken's Pond (York River estuary). Time series averages are shown as solid (Bracken's Pond) and dotted (Wormley Pond) lines.

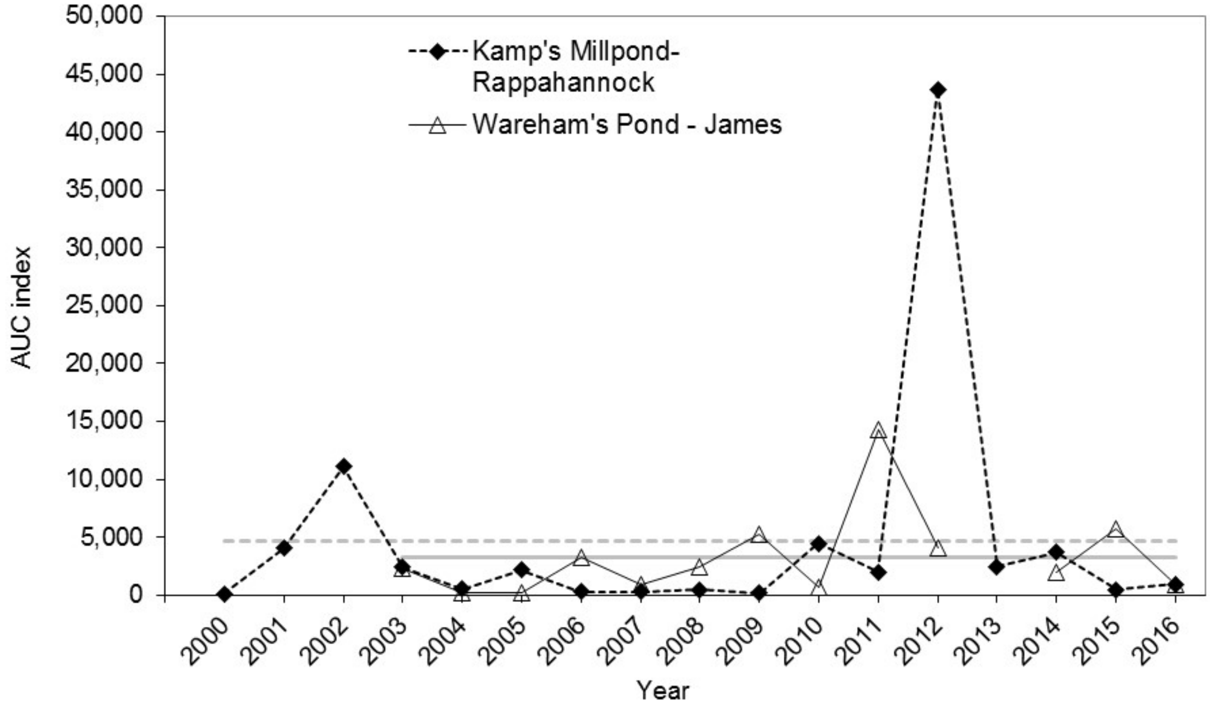

Figure 3. Abundance indices and time series average calculated by the area-under-the-curve method for glass American Eels from Wareham's Pond (James River estuary) and Kamp's Millpond (Rappahannock River estuary). Time series averages are shown as solid (Wareham's Pond) and dotted (Kamp's Millpond) lines. Wareham's Pond was not sampled in 2013 due to dam construction at our sampling site.

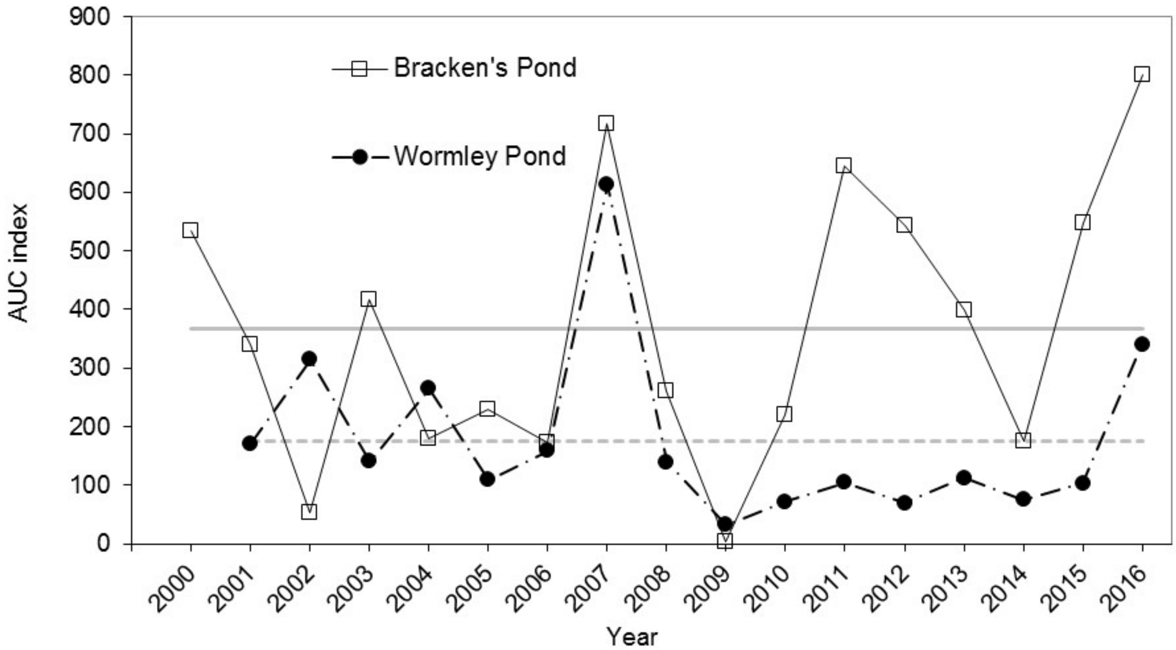

Figure 4. Abundance indices and time series average calculated by the area-under-the-curve method for elver American Eels from Wormley Pond and Bracken's Pond (York River estuary). Time series averages are shown as solid (Bracken's Pond) and dotted (Wormley Pond) lines.

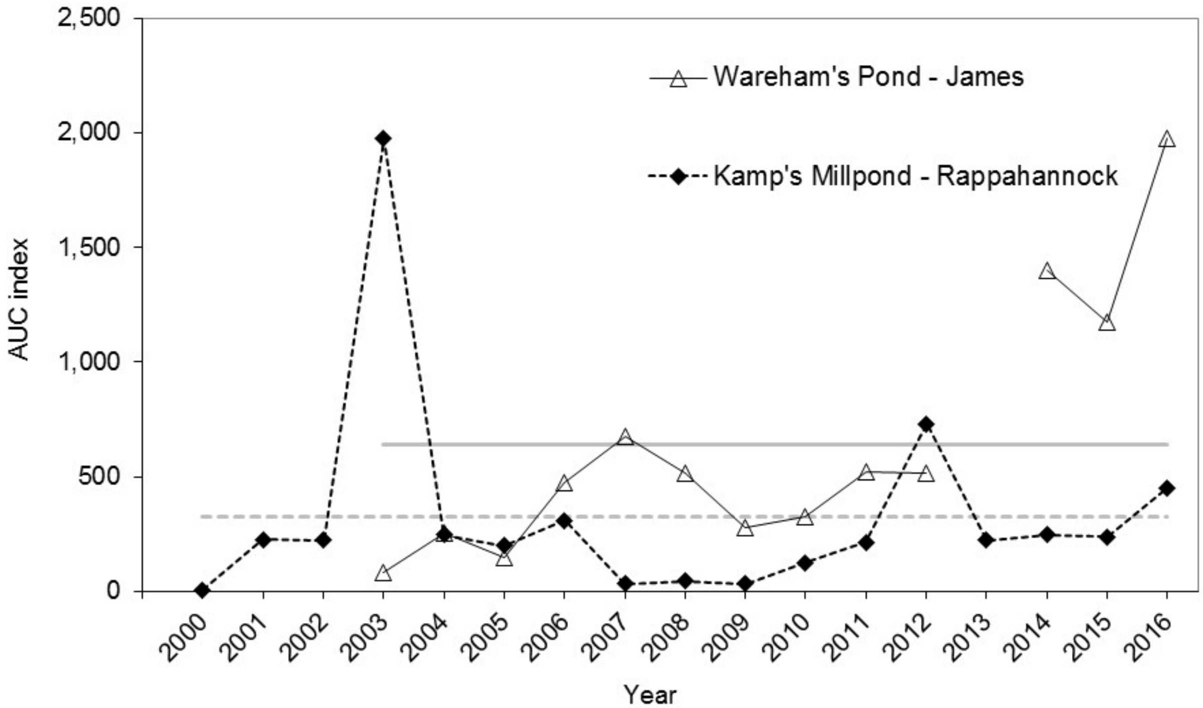

Figure 5. Abundance indices and time series average calculated by the area-under-the-curve method for elver American Eels from Wareham's Pond (James River estuary) and Kamp's Millpond (Rappahannock River estuary). Time series averages are shown as solid (Wareham's Pond) and dotted (Kamp's Millpond) lines. Wareham's Pond was not sampled in 2013 due to dam construction at our sampling site.

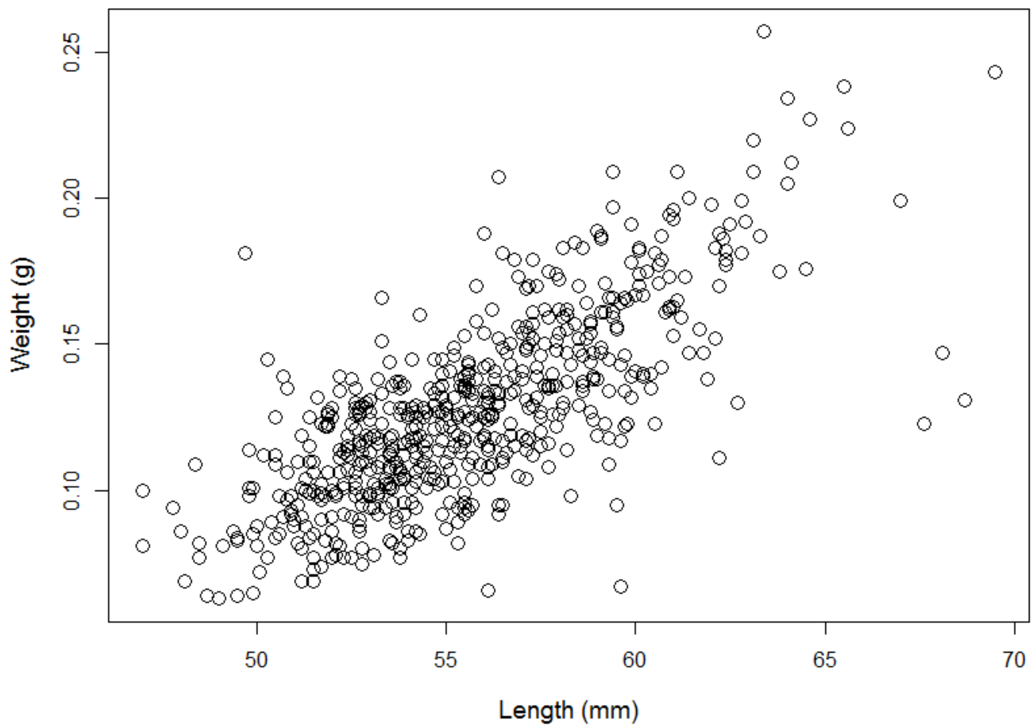

Figure 6. Length-weight relationship for glass American Eels from the York River estuary, 2016. Average TL = 55.6 mm, average weight = 0.127 g, N = 608 eels.

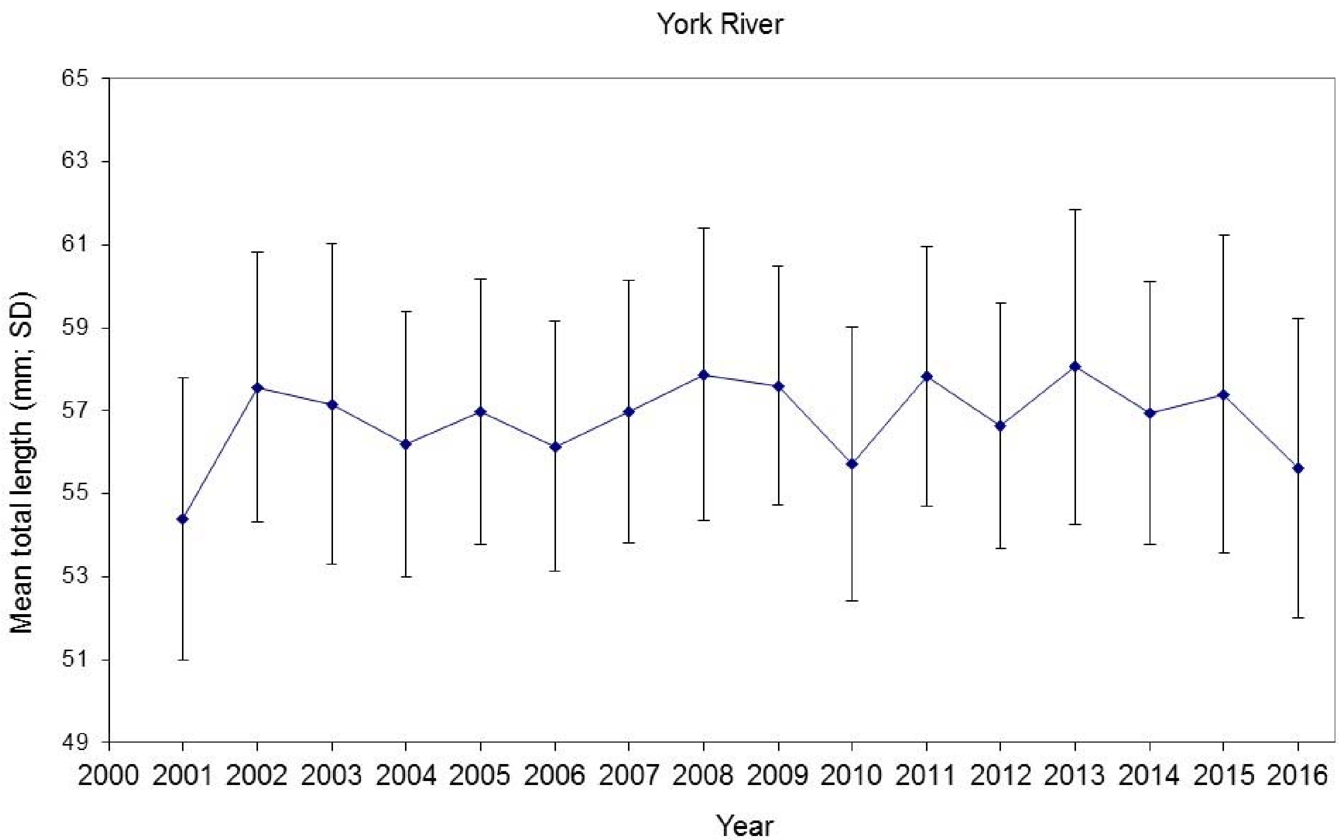

Figure 7. Mean total length (mm; SD) of glass American Eels collected with Irish Eel ramps from 2001 to 2016 from two sites combined (Wormley and Bracken's Ponds) in the York River estuary, Virginia. Long-term mean 56.8 mm (n = 16 years).

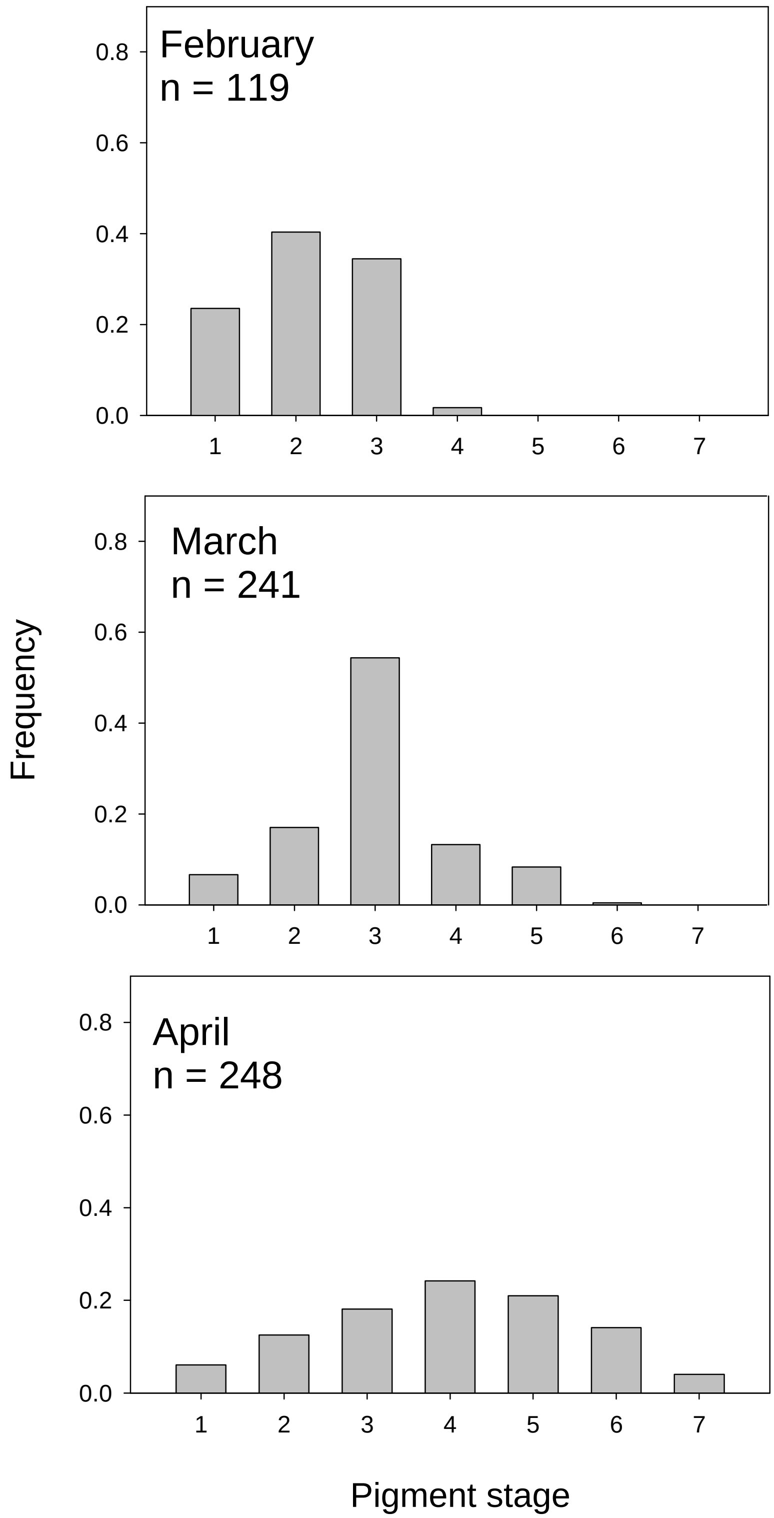

Figure 8. Frequency of pigment stages for glass eels by month for the York River estuary, 2016.

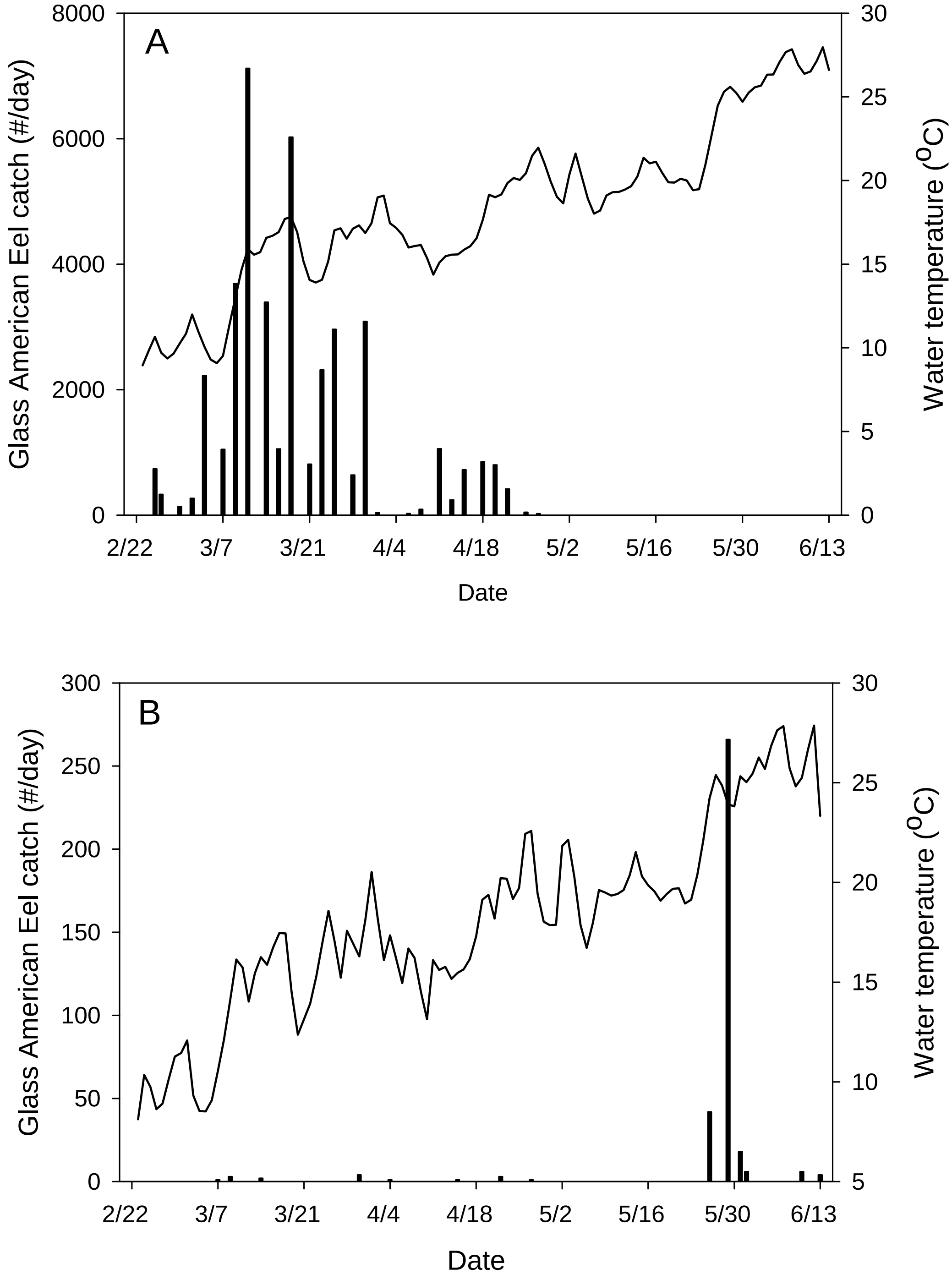

Figure 9. Glass American Eel catches (bars) and water temperature (line) in 2016 from (A) Wormley Pond, and (B) Bracken's Pond. Note axis scales are not uniform.

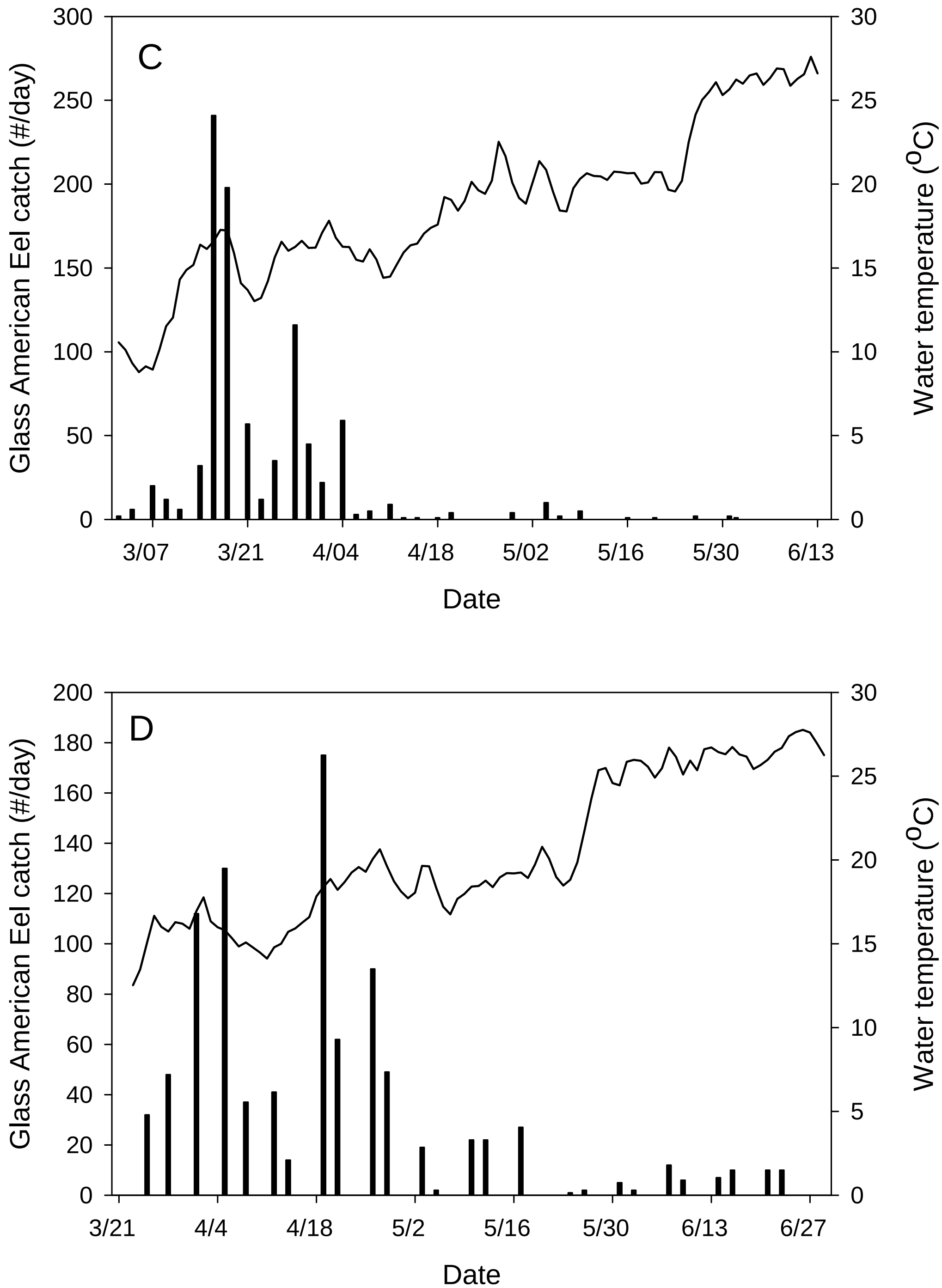

Figure 9 continued. Glass American Eel catches (bars) and water temperature (line) in 2016 from (C) Wareham's Pond, and (D) Kamp's Millpond. Note axis scales are not uniform.

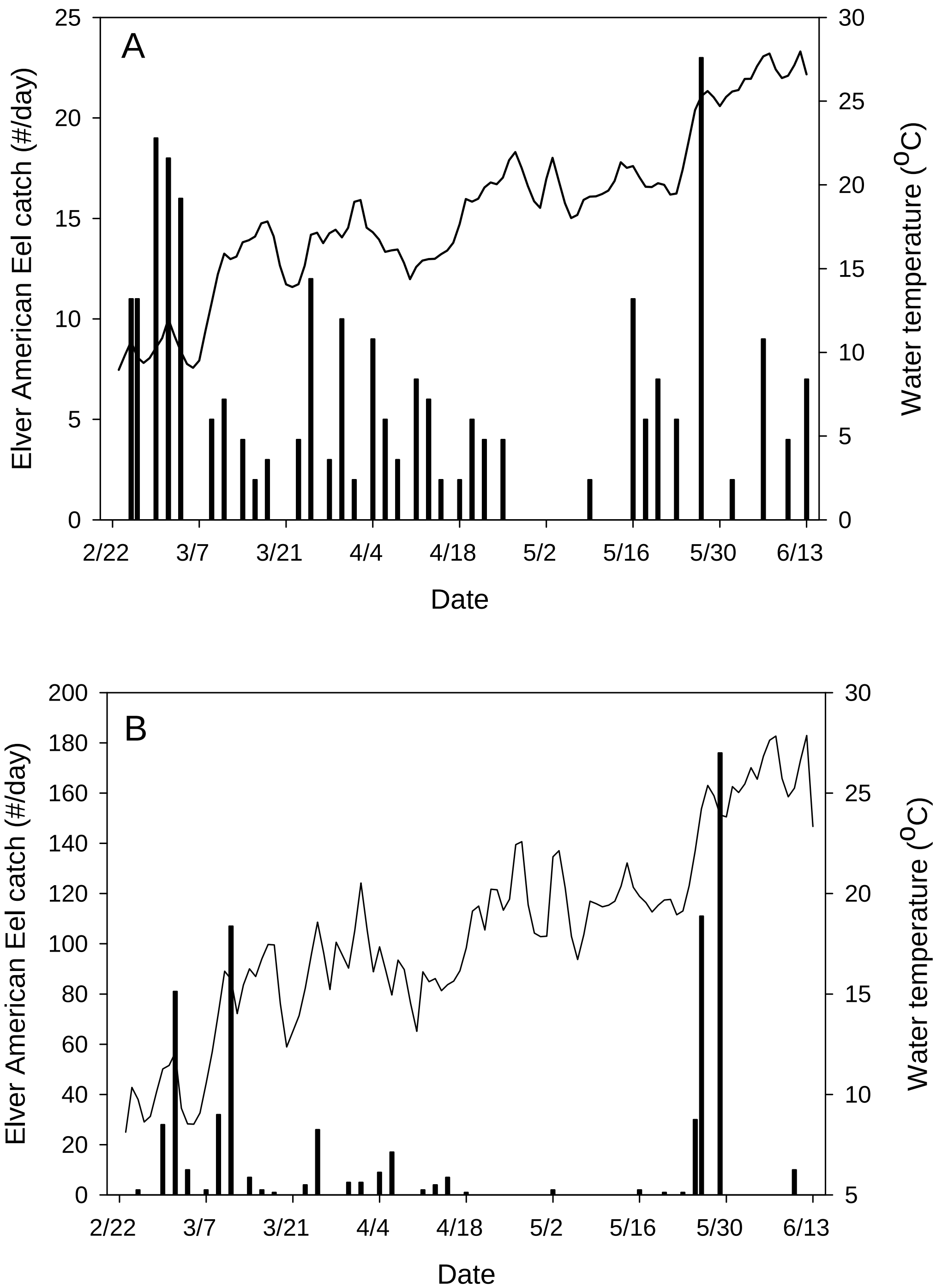

Figure 10. Elver American Eel catches (bars) and water temperature (line) in 2016 from (A) Wormley pond, and (B) Bracken's Pond. Note axis scales are not uniform.

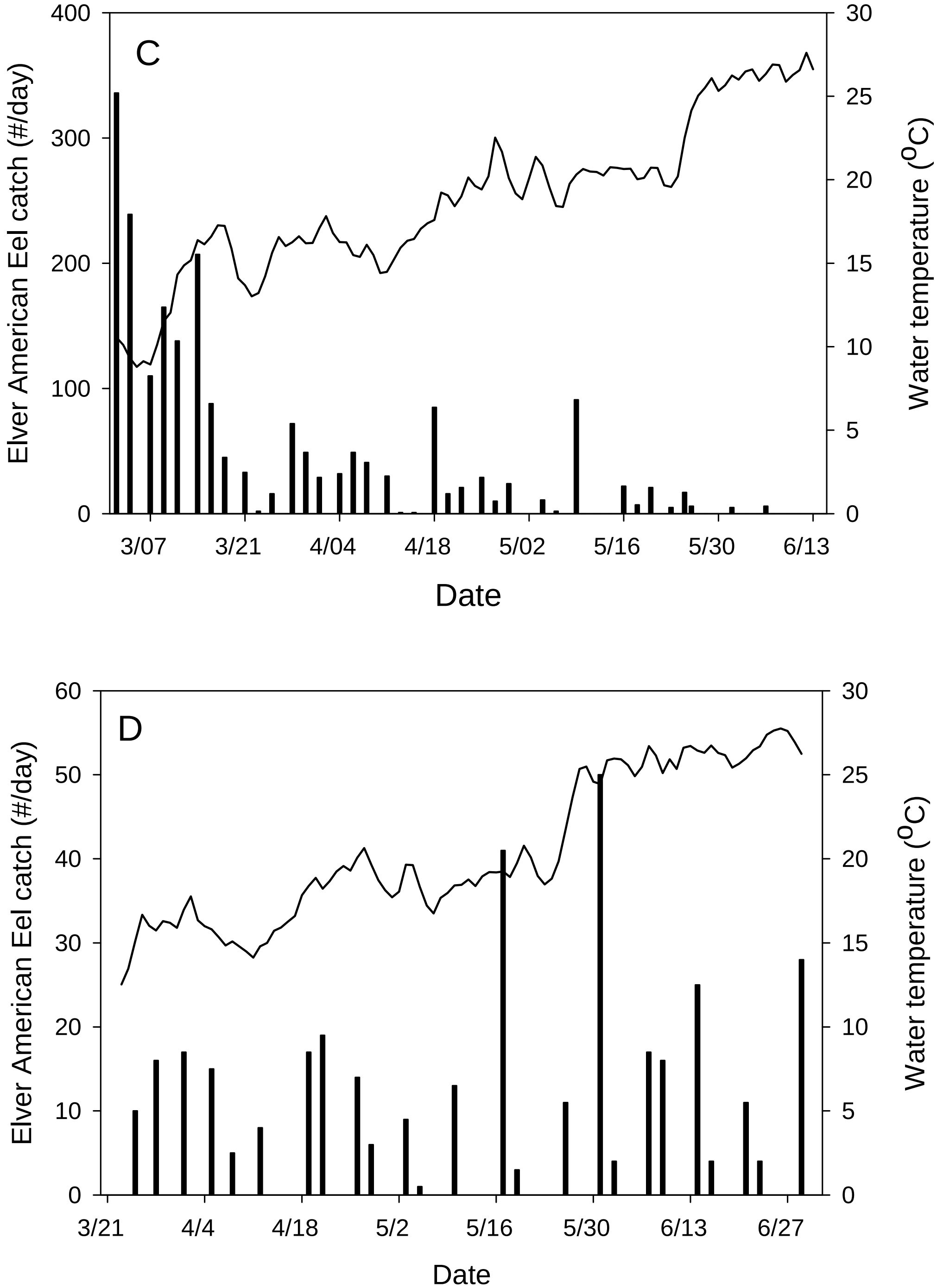

Figure 10 continued. Elver catches (bars) and water temperature (line) in 2016 from (C) Wareham's Pond, and (D) Kamp's Millpond. Note axis scales are not uniform.

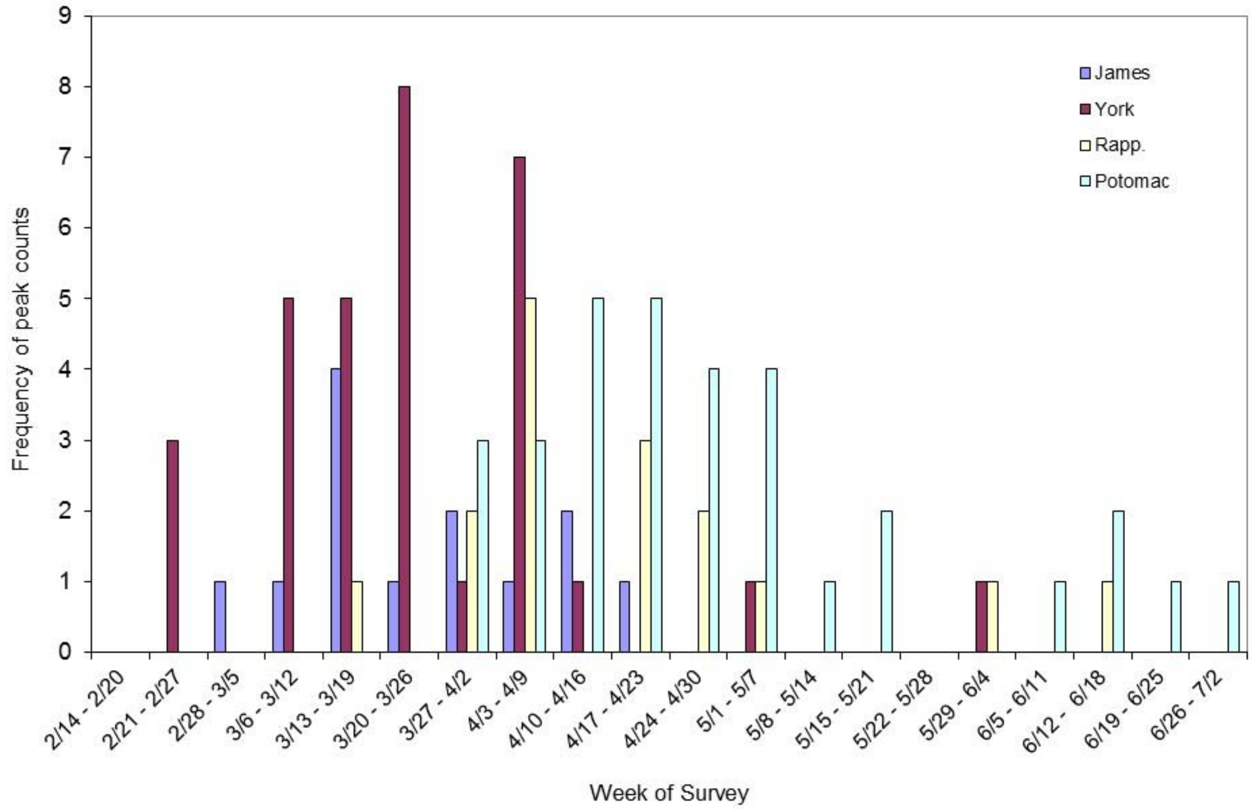

Figure 11. Survey week during which peak counts of glass eels were observed at each site from 2001 to 2016. Two sites are monitored in the York and Potomac estuaries each year (n = 32 observations per river). In the James River estuary, one site was monitored continuously since 2003, though this site was not accessible in 2013 (n = 13 observations). In the Rappahannock River estuary, one site was monitored each year (n = 16 observations). Potomac River data are from Tuckey and Fabrizio (2016).