

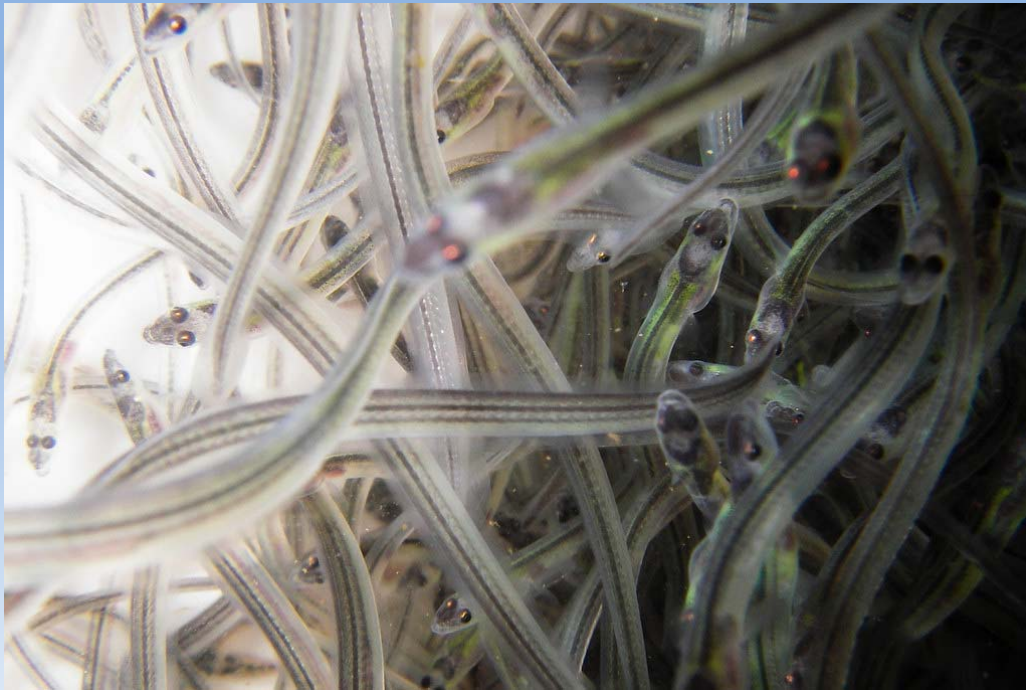
**Evaluating Recruitment of American Eel,
Anguilla rostrata, in the Potomac River
(Spring 2021)**



Submitted to:

Potomac River Fisheries Commission

January 2021 – September 2021



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DOI: 10.25773/5xmt-b850

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Acknowledgments

We thank the individuals that participated in field sampling including Wendy Lowery, Jack Buchanan, Katie Nickerson, and Daniel Royster. We also thank Virginia Marine Resources Commission (VMRC) law enforcement officers for monitoring the survey gear during the study. A special thanks to Ms. Joanne Northern and family (Gardy’s Millpond), who granted permission to sample on their property. This project was funded by the Potomac River Fisheries Commission.

Introduction

American Eel (*Anguilla rostrata*) is a valuable commercial species along the Atlantic coast of North America from New Brunswick to Florida. Landings from Chesapeake Bay typically represent 60% of the annual United States commercial harvest (ASMFC 2012). American Eel is also important to the recreational fishery as it is often used live as bait for Striped Bass (*Morone saxatilis*) and Cobia (*Rachycentron canadum*). In 2020, Chesapeake Bay commercial landings of American Eel (218,005 lbs) were 80% of the U.S. landings (personal communication from the National Marine Fisheries Service, Fisheries Statistics Division). Since the 1980s, harvest along the U.S. Atlantic Coast has declined, with similar patterns occurring in the Canadian Maritime Provinces (Meister and Flagg 1997). The American Eel Benchmark Stock Assessment report (ASMFC 2012) established that the American Eel is depleted in U.S. waters; the 2017 stock assessment update (ASMFC 2017) confirmed that this population remains depleted.

Hypotheses for the decline in abundance of American Eel in recent years include locational shifts in the Gulf Stream, pollution, overfishing, parasites, and barriers to fish passage (Castonguay et al. 1994; Haro et al. 2000). The decline in abundance may or may not exhibit spatial synchrony (Richkus and Whalen 1999; Sullivan et al. 2006); 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). Limited knowledge about fundamental biological characteristics of juvenile American Eel 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 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. The American Eel Benchmark Stock Assessment report (ASMFC 2012) emphasized the importance of the coast-wide survey for providing data useful in calculating an index of recruitment over the historical coastal range and for serving as an early warning of potential range contraction of the species. Funding for the Virginia Institute of Marine Science’s spring survey in the Potomac River was provided by the Potomac River Fisheries Commission, thereby ensuring compliance with the 1999 ASMFC Interstate Fishery Management Plan for American Eels.

Life History

The American Eel is a facultative 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 (for 9-12 months) in a generally northwesterly direction and can grow to 85 mm total length (TL; Jenkins and Burkhead 1993). Within one 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 (= young of the year, or YOY) into Maryland and Virginia estuaries from February to June (Able and Fahay 1998). Ciccotti et al. (1995) suggested that glass eel migration occurs as waves of invasion with perhaps a fortnightly periodicity related to tidal currents and stratification of the water column. Alterations in the timing and magnitude of freshwater flow to bays and estuaries may affect the magnitude, timing, and spatial patterns of upstream migration of glass eels (Facey and Van Den Avyle 1987). Young-of-year eels may use freshwater “signals” to enhance

recruitment to local estuaries, thereby influencing year-class strength in a particular estuary (Sullivan et al. 2006).

As glass eels grow, they become pigmented (elver stage) and within 12 to 14 months eels acquire 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, mature eels range from 8 to 24 years, with most 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 to the Sargasso Sea to spawn and die (Haro et al. 2000).

Objectives

The objectives of our study in the Potomac River were to:

1. monitor the young-of-year (glass eel) migration into the Potomac River watershed to determine spatial and temporal components of American Eel recruitment; and
2. collect basic biological information on recruiting glass eels, including length, weight, and pigment stage.

Methods

Minimum criteria for YOY American Eel sampling used in our survey were established in the ASMFC American Eel FMP and used in our survey. Specifically, the timing and placement of gear must coincide with periods of peak YOY onshore migration. At a minimum, the gear must be deployed during nighttime flood tides. 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 at least 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 and the Potomac River, 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 in both Virginia and Maryland were evaluated previously (Geer 2001). Final site selection was based on known areas of glass eel concentrations, accessibility, and specific physical criteria (e.g., appropriate habitat) suitable for glass eel recruitment to the sampling gear. The Maryland sampling of the Potomac River (northern shore site) was discontinued in 2001, due in part to the low catch rates in 2000 (Geer 2001). At the request of PRFC, the Virginia Institute of Marine Science (VIMS) began sampling two sites on the southern shore of the Potomac River (Gardy's Millpond and Clark's Millpond; Figure 1) in 2000.

One site (Gardy's Millpond, Northumberland County) was sampled on the Potomac River in 2021. Gardy's Millpond contains a spillway that drains through four box culverts, across a riffle constructed of riprap and into a lotic area of the Yeocomico River. Clark's Millpond had also been sampled in previous years, however, conditions at the site have changed and there have been few glass eels and elvers in recent years (Tables 1 and 2). Furthermore, the conditions on the millpond spillway, where the trap was deployed, have deteriorated and are no longer safe. Thus sampling was terminated at Clark's Millpond in 2016.

An Irish eel ramp was used to collect eels. The ramp configuration successfully attracts and captures small eels in tidal waters of Chesapeake Bay. Ramp operation requires continuous flow of water over the climbing substrate and the collection device, and was accomplished through gravity feed. A hose was attached to the ramp and to the collection bucket with adapters to allow for quick removal for sampling. Enkamat™ erosion control material on the ramp floor provided a textured climbing surface and extended into the water below the trap. 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. 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 site visits. All eels were counted and placed above the impediment, with any subsample information recorded, if applicable. Specimens less than or equal to ~ 85 mm TL were classified as YOY, while those greater than 85 mm TL were considered elvers. These lengths correspond to the two distinct length-frequency modes observed in the 2000 survey, which likely reflects two year classes (Geer 2001). Individual length, weight, and pigmentation stage information (see Haro and Krueger 1988) were collected weekly. Daily catch (raw number of eels captured per day) and annual area-under-the-curve (AUC; Olney and Hoenig 2001) indices are presented. Annual AUC indices were standardized to a 24-hour sampling time.

This year, in addition to the glass eels collected in the trap, we used dip nets to opportunistically collect glass eels in the spillway, well away from the trap location. This was done to gather a larger sample size of glass eels to compare with other sites within Chesapeake Bay. These glass eels were not included in the index calculations and length, weight, and pigment stage is discussed in a separate paragraph to maintain consistency among years.

Results and Discussion

Glass eels were sampled at Gardy's Millpond between 19 March and 14 June 2021; the study period encompassed 89 days. Glass eel recruitment at Gardy's Millpond resulted in the collection of 369 glass eels in 2021 (Table 1). Glass eels were not captured until May, which is well after first arrival at this site in previous years (Figure 2). Despite the late arrival of glass eels, relative abundance was above-average at Gardy's Millpond in 2021 ($\text{index}_{2021} = 388.85$; mean long-term index = 200.2; Figure 4).

Elvers were first captured on 19 March 2021 at Gardy's Millpond and continued throughout the sampling period with multiple peaks throughout the survey (Figure 3). We observed a below-average catch of elvers in 2021 (index = 480.54; Table 2; Figure 5). Initial arrival and migration of elvers may be correlated with increases in water temperature, however, elver migration may be delayed at freshwater interfaces until certain behavioral and physiological changes have occurred (Sorensen and Bianchini 1986).

Pigmentation stages of Potomac River glass eels consisted of mostly stage 6 (48% of the number examined) and stage 7 (24%; Figure 6). Glass eels captured in the Potomac River exhibit late-stage pigmentation patterns typically beginning with stage 3 and darker individuals, however this year we observed mostly late stages coinciding with the late arrival of glass eels at this site (Figure 7). Lengths of glass eels captured in 2021 ranged from 48.6 to 73.2 mm TL (average length = 57.5 mm TL, SD = 4.49) and weights ranged from 0.05 to 0.39 g (mean = 0.16 g, SD = 0.06; Figure 8). Lengths of glass eels captured in 2021 were similar to previous years (Figure 9).

Glass eels from the Potomac River are more developed and are likely older than those at sites closer to the mouth of Chesapeake Bay. Total catch of glass eels at sites on the Potomac River are typically below those in other VA tributaries, which may be due to natural mortality or a dilution effect as glass eels migrate into a variety of habitats available in lower Chesapeake Bay. Although recruitment of glass eels is low at Potomac River sites, variation in recruitment levels is also lower than that found at other sites in lower Chesapeake Bay (Tuckey and Fabrizio 2020). Reduced variation in recruitment indices in the Potomac River may allow for the earlier detection of change because there is less noise in the signal compared with widely varying recruitment pulses observed in other lower Chesapeake Bay systems. Additionally, the relatively stable abundance of elvers observed at sites on the Potomac River are consistent with the abundance of elvers found in other sites in VA and suggest that the carrying capacity of small, impounded water bodies appears relatively stable across years. This hypothesis relies on the similar abundance of elvers found in the James, York, and Rappahannock

rivers despite orders of magnitude greater abundances of glass eels at these sites (Tuckey and Fabrizio 2020).

Conclusions

1. Recruitment of glass eels was above-average at Gardy's Millpond in 2021 despite a delay in the arrival of glass eels compared with previous years.
2. The length of glass eels captured at Gardy's Millpond remains relatively consistent across years.
3. We found a relatively greater proportion of late-pigment stage eels in 2021 compared with previous years.
4. The index for elvers was below average in 2021 returning to levels observed prior to the recent record highs observed in 2019 and 2020.

References

- Able, K. W. and M. P. Fahay. 1998. The first year in the life of estuarine fishes in the Middle Atlantic Bight. Rutgers University Press, New Brunswick, NJ. 342 p.
- Atlantic States Marine Fisheries Commission (ASMFC). 2000. Interstate Fishery Management Plan for American Eel. Fishery Management report No. 36. Washington, D.C. 79p.
- ASMFC 2012. American Eel Stock Assessment for peer review. ASMFC, Stock Assessment Report No. 12-01, Washington, D.C. 254 p.
- ASMFC 2017. American Eel Stock Assessment Update. ASMFC, Washington, D.C. 123 p.
- Castonguay, M., P.V. Hodson, C.M. Couillard, M.J. Eckersley, J.D. Dutil and G. Verreault. 1994. Why is recruitment of American Eel, *Anguilla rostrata*, declining in the St. Lawrence River and Gulf? Can. J. Fish. Aquat. Sci. 51:479-488.
- Ciccotti, E, T. Ricci, M. Scardi, E. Fresi and S. Cataudella. 1995. Intraseasonal characterization of glass eel migration in the River Tiber: space and time dynamics. J. Fish Biol. 47:248-255.
- Facey, D. E. and M. J. Van Den Avyle. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)—American eel. U. S. Fish Wildl. Serv. Biol. Rep. 82(11.74). U. S. Army Corps of Engineers, TR EL-82-4. 28 p.

- Geer, P.J. 2001. Evaluating recruitment of American eel, *Anguilla rostrata*, to the Potomac River -- Spring 2001. Final Report to the Potomac River Fisheries Commission. Virginia Institute of Marine Science, Gloucester Point, Virginia. 21 p.
- Haro, A. J. and W. H. Kreuger. 1988. Pigmentation, size and migration of elvers, *Anguilla rostrata* (Lesuer), in a coastal Rhode Island stream. Can. J. Zool. 66:2528-2533.
- Haro, A., W. Richkus, K. Whalen, W.-Dieter Busch, S. Lary, T. Brush, and D. Dixon. 2000. Population decline of the American eel: Implications for research and management. Fisheries 25(9): 7-16.
- Hedgepeth, M. Y. 1983. Age, growth and reproduction of American eels, *Anguilla rostrata* (Lesueur), from the Chesapeake Bay area. Masters Thesis. College of William and Mary. 61 p.
- Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society. Bethesda, MD. 1079 p.
- Knights, B. 2003. A review of the possible impacts of long-term oceanic and climate changes and fishing mortality on recruitment of anguillid eels of the Northern Hemisphere. The Science of the Total Environment 310(1-3):237-244.
- Meister, A. L. and L. N. Flagg. 1997. Recent developments in the American eel fisheries of North America. FOCUS 22(1):1-4.
- Murdy, E.O., R.S. Birdsong and J.A. Musick. 1997. Fishes of Chesapeake Bay. Smithsonian Institution Press. 324 p.
- Olney, J. E. and J. M. Hoenig. 2001. Managing a fishery under moratorium: Assessment opportunities for Virginia's stocks of American shad. Fisheries 26: 6-11.
- Owens, S. J. and P. J. Geer. 2003. Size and age structure of American eels in tributaries of the Virginia portion of the Chesapeake Bay. Pages 117-124 in D. A. Dixon (Editor). Biology, Management and Protection of Catadromous Eels. American Fisheries Society, Symposium 33, Bethesda, MD, USA.
- Richkus, W. and K. Whalen. 1999. American eel, *Anguilla rostrata*, scoping study. A literature review and data review of the life history, stock status, population dynamics, and hydroelectric impacts. Final Report, March 1999 by Versar, Inc., Prepared for EPRI.

- Sorensen, P. W. and M. L. Bianchini. 1986. Environmental correlates of the freshwater migration of elvers of the American eel in a Rhode Island brook. *Trans. Amer. Fish. Soc.* 115:258-268.
- Sullivan, M. C., K. W. Able, J. A. Hare, and H. J. Walsh. 2006. *Anguilla rostrata* glass eel ingress into two, U. S. east coast estuaries: patterns, processes and implications for adult abundance. *Journal of Fish Biology* 69:1081-1101.
- Tuckey, T. D. and M. C. Fabrizio. 2020. Estimating relative abundance of young of year American Eel, *Anguilla rostrata*, in the Virginia Tributaries of Chesapeake Bay (Spring 2017). Final Report to the Virginia Marine Resources Commission. Virginia Institute of Marine Science, Gloucester Point, VA. 24 p.
<https://doi.org/10.25773/f7km-zx23>

Table 1. Summary of glass eel collections in the Potomac River at Clark’s Millpond (2000 – 2016) and Gardy’s Millpond (2000 – 2021). Sampling at Clark’s Millpond was discontinued after 2016 due to a change at that site that no longer attracted glass eels. Catch per unit effort is calculated as the Area Under the Curve (AUC).

Source	Year	Start Date	End Date	Total Catch	AUC
Clark's	2000	1-Apr	16-May	15	23.74
	2001	16-Mar	12-May	4	4.05
	2002	8-Mar	2-May	115	115.79
	2003	11-Mar	16-May	24	40.21
	2004	8-Mar	30-May	447	468.93
	2005	10-Mar	27-May	223	295.78
	2006	28-Feb	25-May	80	90.53
	2007	27-Feb	5-Jul	435	470.33
	2008	19-Mar	20-Jun	22	31.98
	2009	25-Mar	18-Jun	42	42.68
	2010	19-Mar	21-Jul	421	389.06
	2011	16-Mar	28-Jun	46	104.51
	2012	23-Feb	16-Jul	419	495.38
	2013	21-Feb	7-Jun	196	208.07
	2014	10-Mar	13-Jun	1	1.00
	2015	25-Mar	30-Jun	1	1.00
2016	28-Mar	29-Jun	3	3.00	
Gardy's	2000	12-Apr	16-May	291	286.85
	2001	12-Mar	12-May	729	730.25
	2002	8-Mar	2-May	129	129.50
	2003	11-Mar	16-May	71	70.01
	2004	8-Mar	24-May	39	38.86
	2005	10-Mar	27-May	94	102.68
	2006	28-Feb	25-May	46	45.39
	2007	27-Feb	5-Jul	248	260.09
	2008	19-Mar	20-Jun	187	178.94
	2009	25-Mar	18-Jun	231	229.92
	2010	19-Mar	21-Jul	90	80.25
	2011	16-Mar	28-Jun	35	36.78
	2012	23-Feb	16-Jul	261	259.83
	2013	21-Feb	13-Jun	333	383.86
	2014	10-Mar	13-Jun	243	253.10
	2015	25-Mar	30-Jun	113	118.42
	2016	25-Mar	29-Jun	42	42.12
	2017	21-Mar	28-Jul	402	544.16
	2018	27-Feb	1-Jun	101	98.79
	2019	19-Mar	18-Jul	130	173.30
2020	6-Mar	29-Jun	185	227.66	
2021	17-Mar	14-Jun	369	388.85	

Table 2. Summary of elver collections in the Potomac River at Clark’s Millpond (2000 – 2016) and Gardy’s Millpond (2000 – 2021). Sampling at Clark’s Millpond was discontinued after 2016 due to a change at that site that no longer attracted eels. Catch per unit effort is calculated as the Area Under the Curve (AUC).

Source	Year	Start Date	End Date	Total Catch	AUC
Clark's	2000	1-Apr	16-May	5	10.69
	2001	16-Mar	12-May	205	253.67
	2002	8-Mar	2-May	90	90.95
	2003	11-Mar	16-May	225	237.72
	2004	8-Mar	30-May	314	316.36
	2005	10-Mar	27-May	62	62.33
	2006	28-Feb	25-May	153	195.68
	2007	27-Feb	5-Jul	90	90.31
	2008	19-Mar	20-Jun	276	289.16
	2009	25-Mar	18-Jun	90	90.46
	2010	19-Mar	21-Jul	208	209.59
	2011	16-Mar	28-Jun	84	114.09
	2012	23-Feb	16-Jul	268	256.69
	2013	21-Feb	7-Jun	148	158.23
	2014	10-Mar	13-Jun	13	14.63
	2015	25-Mar	30-Jun	11	11.09
2016	28-Mar	29-Jun	18	18.08	
Gardy's	2000	12-Apr	16-May	15	16.46
	2001	12-Mar	12-May	624	660.76
	2002	8-Mar	2-May	273	277.15
	2003	11-Mar	16-May	300	300.78
	2004	8-Mar	24-May	483	476.76
	2005	10-Mar	27-May	313	330.15
	2006	28-Feb	25-May	692	827.71
	2007	27-Feb	5-Jul	198	198.23
	2008	19-Mar	20-Jun	393	385.88
	2009	25-Mar	18-Jun	360	358.27
	2010	19-Mar	21-Jul	375	317.53
	2011	16-Mar	28-Jun	507	527.09
	2012	23-Feb	16-Jul	411	406.59
	2013	21-Feb	13-Jun	664	1564.73
	2014	10-Mar	13-Jun	967	982.11
	2015	25-Mar	30-Jun	591	656.03
	2016	25-Mar	29-Jun	124	208.23
	2017	21-Mar	28-Jul	546	655.35
	2018	27-Feb	1-Jun	396	450.10
	2019	19-Mar	18-Jul	1684	3554.12
2020	6-Mar	29-Jun	1044	2428.21	
2021	17-Mar	14-Jun	489	480.54	

Figure 1. Sampling sites in the Potomac River. Sampling at Clark's Millpond was discontinued after 2016.

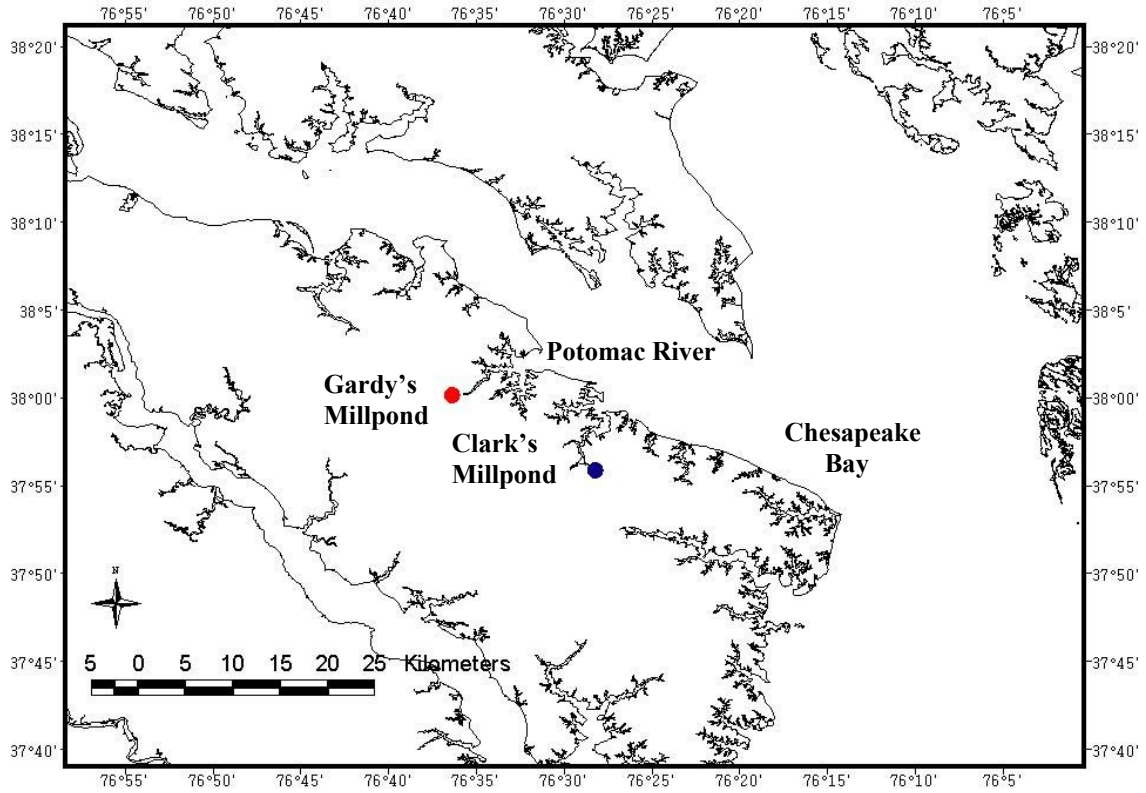


Figure 2. Number of glass eels captured during each sampling event and water temperature ($^{\circ}\text{C}$) at Gardy's Millpond, 2021.

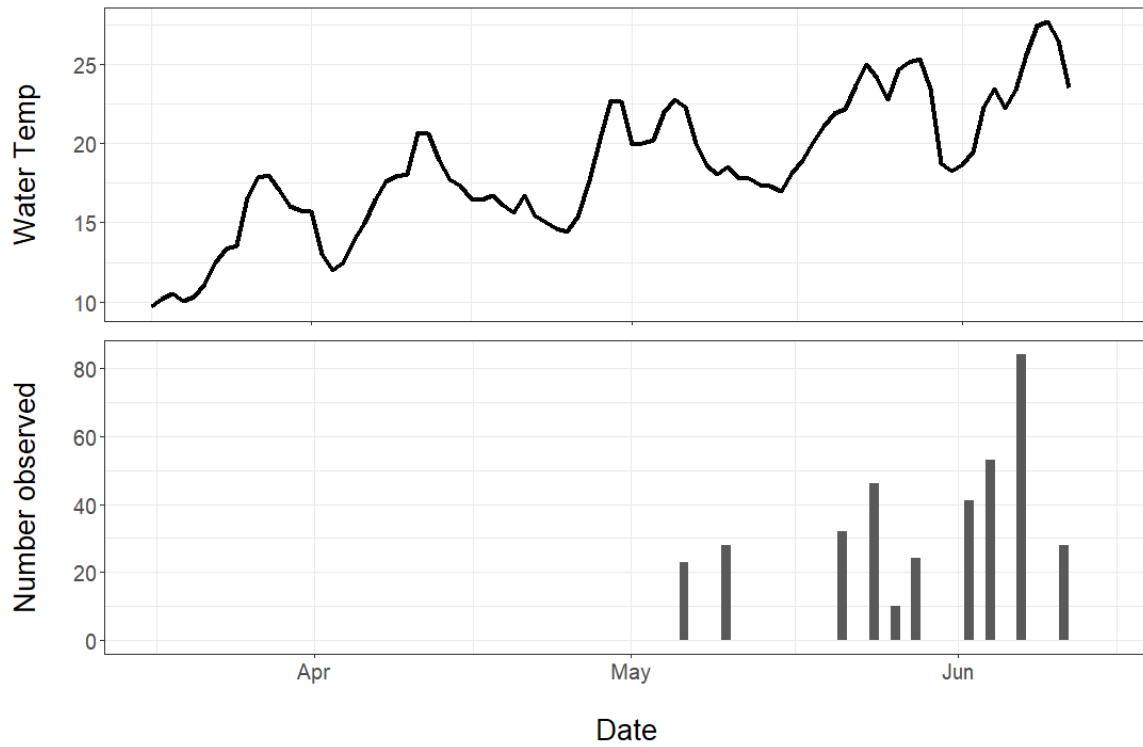


Figure 3. Number of elvers captured during each sampling event and water temperature (°C) at Gardy's Millpond, 2021.

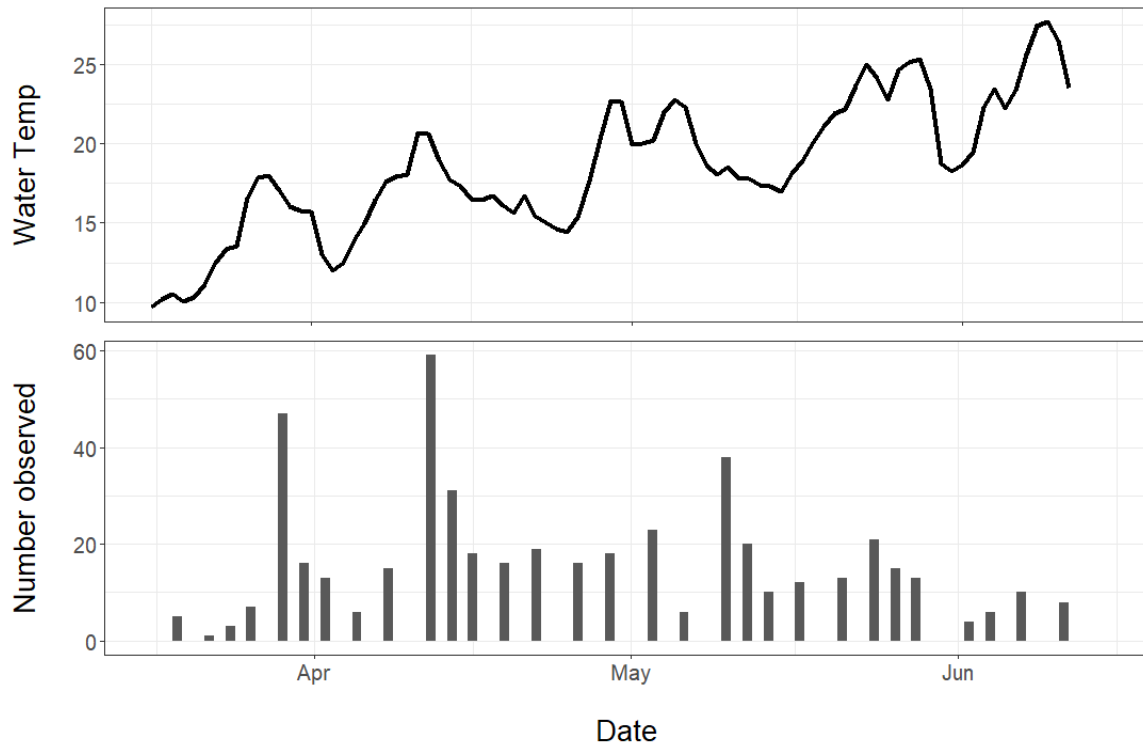


Figure 4. Glass eel index (area-under-the-curve method) from 2000 to 2021. Collections in 2000 followed different protocols and are not directly comparable to collections in later years. Time-series average for 2021 consists of data from 2001 to 2020. Sampling at Clark's Millpond was discontinued after 2016.

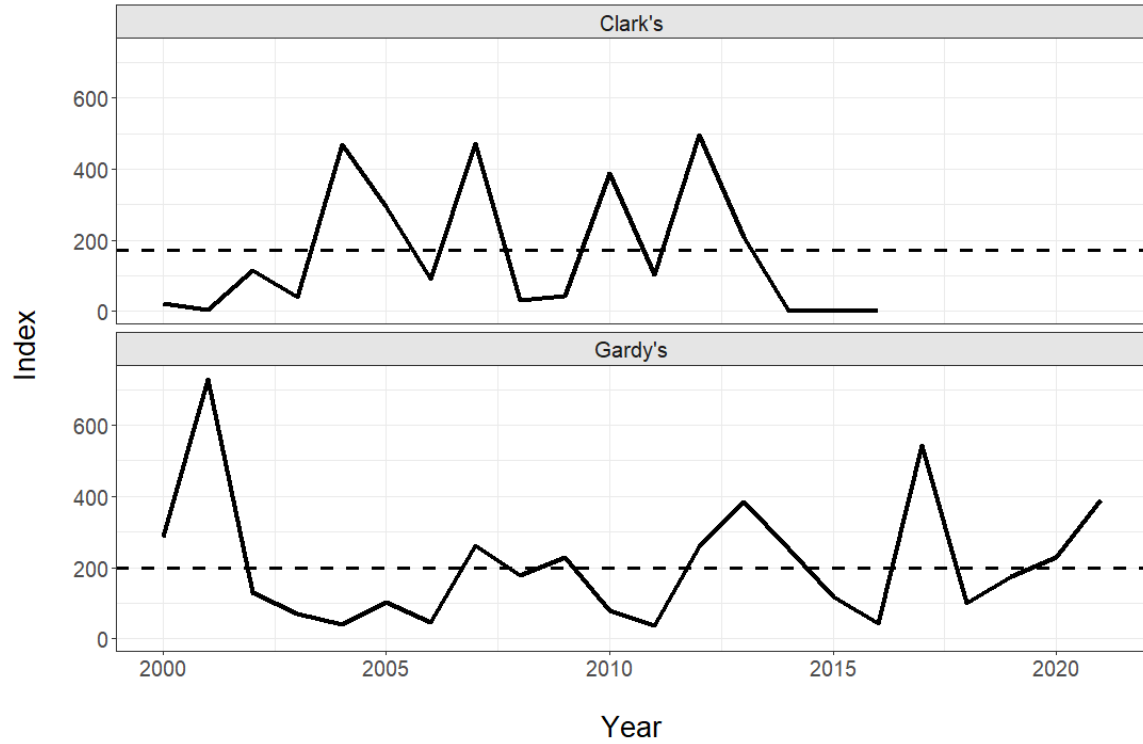


Figure 5. Elver eel index (area-under-the-curve method) from 2000 to 2021. Collections in 2000 followed different protocols and are not directly comparable to collections in later years. Time-series average for 2021 consists of data from 2001 to 2020. Sampling at Clark's Millpond was discontinued after 2016.

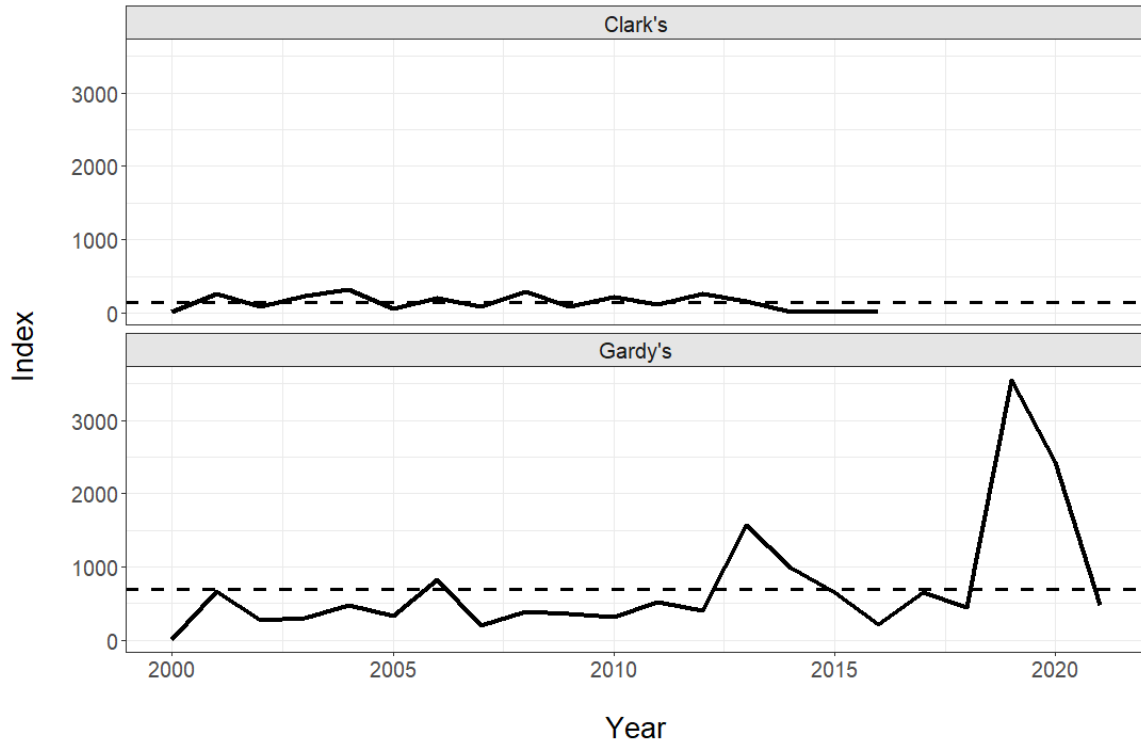


Figure 6. Glass eel pigment stage frequency distribution for the Potomac River, 2021 (N = 264).

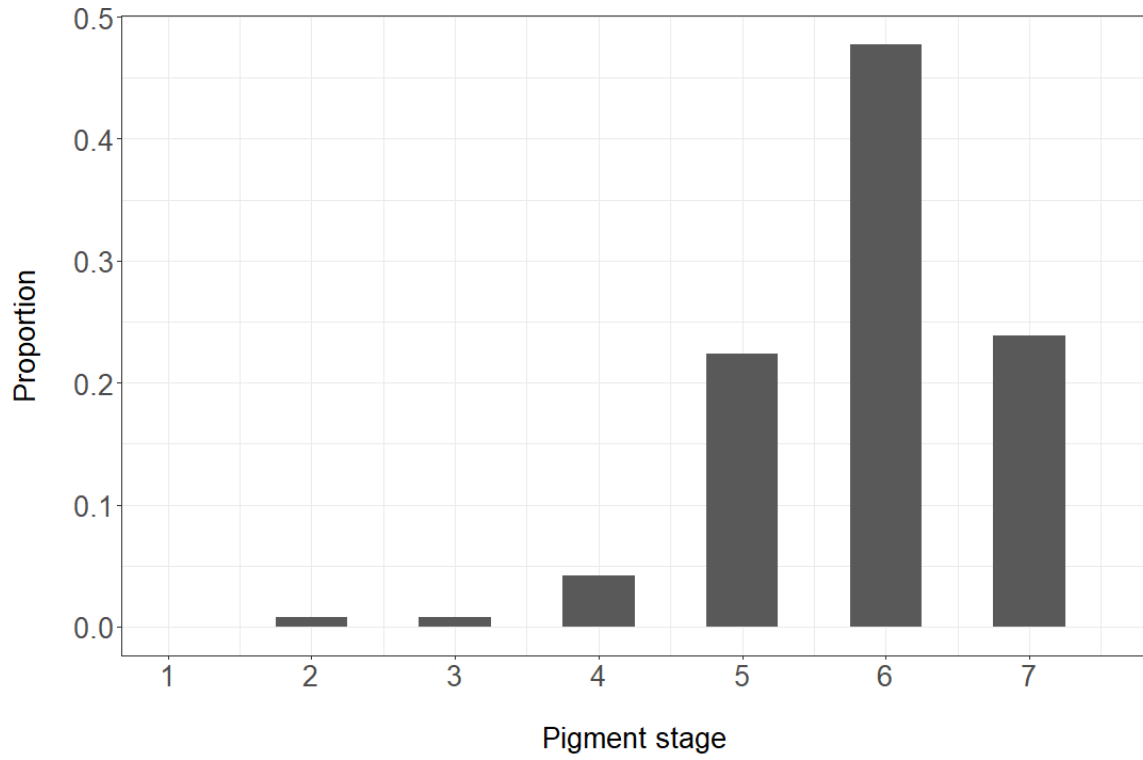


Figure 7. Glass eel pigment stage frequency distribution for the Potomac River, 2002 – 2021 (except 2003, which was not assessed that year).

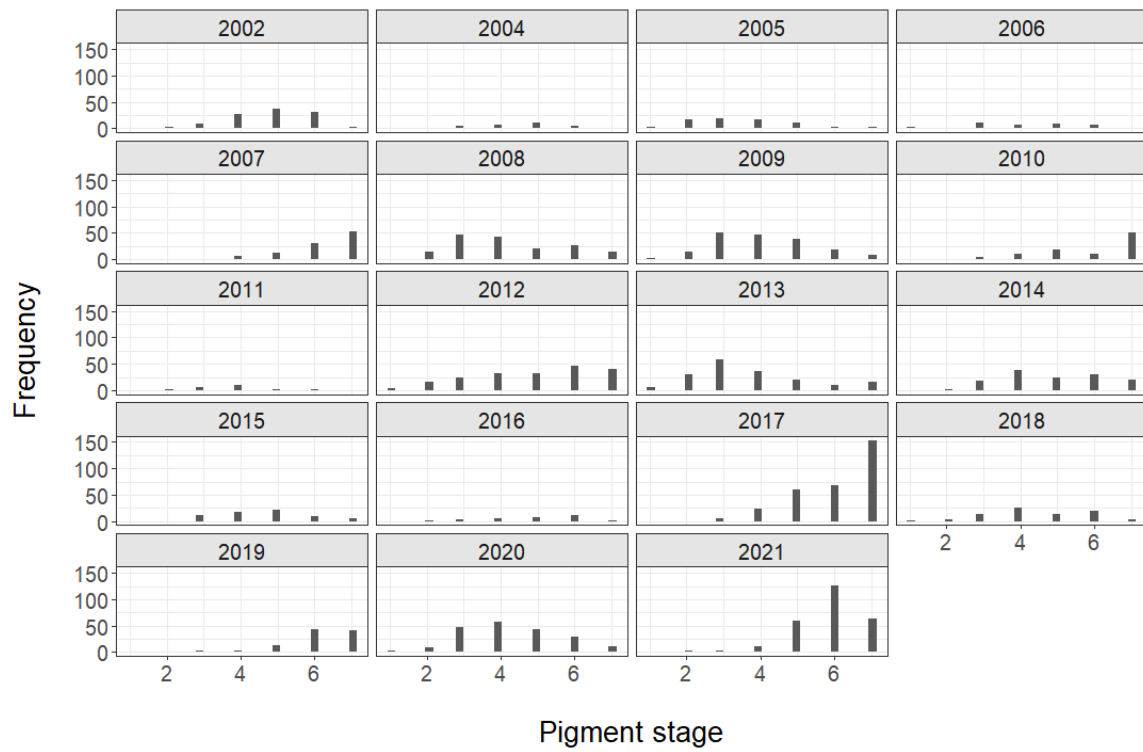


Figure 8. Total length and wet weight of glass eels captured at Gardy's Millpond, 2021. Average TL = 57.5 mm, average weight = 0.16 g, N = 264 eels.

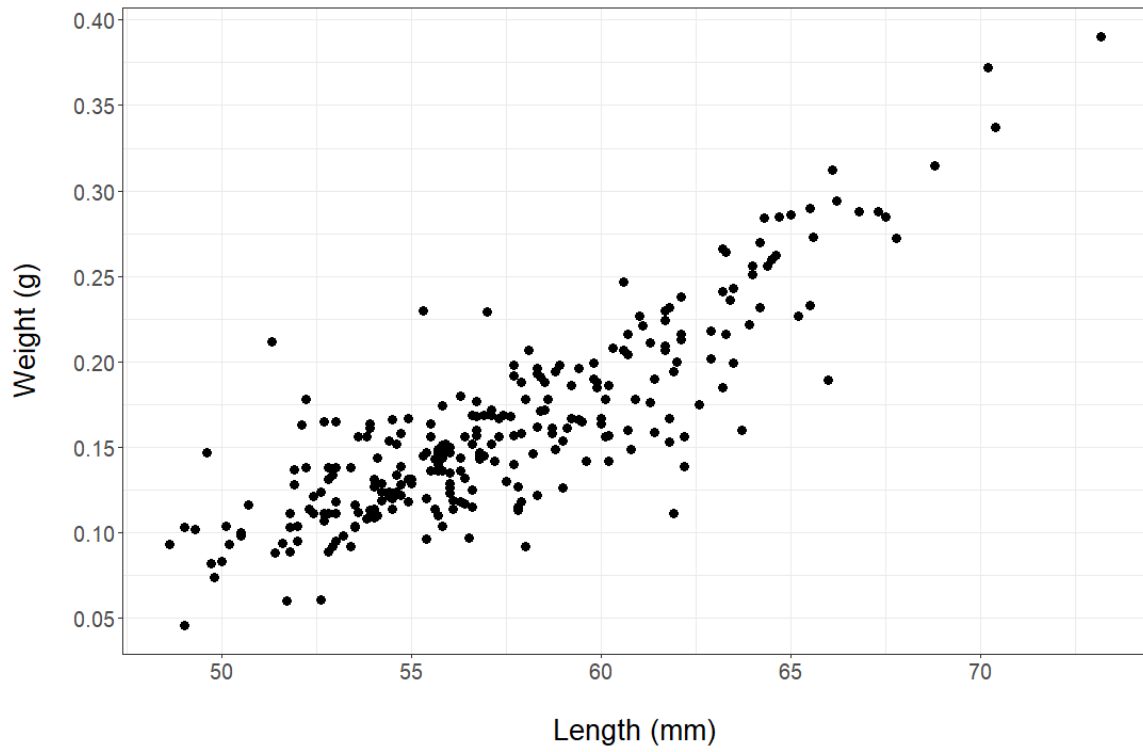


Figure 9. Annual length distribution of glass eels captured at Gardy's Millpond from 2002 to 2021 (excluding 2003).

