

**Evaluating Recruitment of American Eel, *Anguilla rostrata*,  
in the Potomac River (Spring 2010)**

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**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. Landings from Chesapeake Bay typically represent 63% of the annual United States commercial harvest (ASMFC 2000). In 2007, Virginia commercial landings (196,853 lbs) were 70% of the average annual landings in VA since mandatory reporting began (1993) and 23.6% of the US landings (ASMFC 2008; VMRC 2008). Since the 1980s, however, harvest along the U.S. Atlantic Coast has declined, with similar patterns occurring in the Canadian Maritime Provinces (Meister and Flagg 1997).

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. A recent American eel stock assessment report (ASMFC 2006) 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 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 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 (= YOY) into Maryland and Virginia rivers and 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). YOY eel 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 takes place 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-the-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 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.

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 continuous flow of water over the climbing substrate and the collection device, and was accomplished through a gravity feed. Hoses were attached to the ramp and collection buckets 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 ramps were placed on an incline (15-45°), often on land, 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.

Sampling on the Potomac River (Clark's Millpond and Gardy's Millpond) was conducted from 19 March to 21 July 2010. Clark's Millpond (Coan River – Northumberland County) spillway is situated approximately one meter above the creek with a steady stream flow that requires a modified ramp extension to allow the eels to access the spillway. Gardy's Millpond (Yeocomico River – Northumberland County) contains a spillway that drains through four box

culverts, across a riffle constructed of riprap and into a lotic area of the Yeocomico River.

Only eels in the ramp's collection bucket (not on the climbing surface) were recorded. Trap performance was rated on a scale of 0 to 3 (0 = new set; 1 = gear fishing; 2 = gear fishing, but not efficiently; 3 = gear not fishing). Water temperature, air temperature, wind direction and speed, and precipitation were recorded during most site visits. All eels were counted 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 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 differing year classes (Geer 2001). Individual length, weight, and pigmentation stage information (see Haro and Krueger 1988) were collected weekly from 60 eels. Daily catch (raw number of eels caught per day) and annual area-under-the-curve (AUC) indices were calculated for each site (Olney and Hoenig 2001). Annual AUC at each site was standardized to a 24-hour soak time.

## **Results and Discussion**

In 2010, glass eels were first observed at Gardy's Millpond on 26 March and at Clark's Millpond on 29 March (Figure 2). Peak collections of glass eels occurred on two occasions in Gardy's Millpond: early April and mid-June. In Clark's Millpond glass eels were captured in peak numbers in early May. More than 4.5 times as many glass eels were captured at Clark's Millpond compared with Gardy's Millpond in 2010 (Table 1). Timing of glass eel recruitment to rivers in Chesapeake Bay follows a pattern related to the proximity of the sampling locations to the Atlantic Ocean. Stations in Virginia tributaries nearer the mouth of Chesapeake Bay show recruitment peaks earlier in the year compared with sites from the Potomac River (Tuckey and Fabrizio 2009).

Elvers were captured in greatest numbers early in the sampling period at both sites and catches decreased towards the end of the survey (Figure 3). As in

previous years, more elvers were observed at Gardy's Millpond than at Clark's Millpond (Table 2). 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).

Recruitment of glass eels in Clark's Millpond in 2010 exceeded the 10-year average (avg. = 179.47). Whereas recruitment of glass eels at Gardy's Millpond was below the 10-year average (mean = 184.60; Figure 4). Average recruitment of elvers continues at both sites with greater numbers consistently captured at Gardy's Millpond (Figure 5).

Contrary to findings in previous years, no glass eels with stage 1 pigmentation were captured in 2010 and few glass eels with pigment stages 2 - 4 were captured during the extensive recruitment window (Figure 6). Pigmentation stages for Potomac River sites were, in general, more advanced than those for YOY eels collected from the James and York River sites (VIMS American Eel Survey, unpublished data) during 2010. Furthermore, larger glass eels were captured in 2010 compared with previous years with an average length of 61.74 mm TL and an average weight of 0.24 g (Figure 7). Compared with eels sampled nearer the mouth of the bay, larger size and later pigment stages indicate that the Chesapeake Bay system receives a single recruitment pulse.

### **Conclusions and Recommendations**

1. Recruitment of glass eels in 2010 occurred earlier at Gardy's Millpond, but at lower abundances than at Clark's Millpond.
2. Similar to 2009, recruitment of elvers occurred early in the 2010 sampling season and decreased as sampling progressed at each site.
3. Recruitment of glass eels at these sites consists of more developed glass eels compared with stations located nearer the mouth of Chesapeake Bay.



4. We recommend continued sampling of glass eels from the Potomac River sites because recruitment estimates from Clark's and Gardy's Millponds display consistency (low variation) through time, a characteristic that will enhance detection of change. Time series of glass eel abundances from the James, York, and Rappahannock rivers are more variable (more 'noise' in the data) and are less likely to provide early and definitive signals of change.

## **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, New Jersey. 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 2006. Terms of Reference and Advisory Report to the American Eel Stock Assessment Peer Review. Stock Assessment Report No. 06-01. 23p.
- ASMFC 2008. Review of the Atlantic States Marine Fisheries Commission fishery management plan for American eel (*Anguilla rostrata*). Washington, D.C. 15 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. Intra-seasonal 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* (Lesueur), 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.
- 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. 2009. Estimating relative abundance of young of year American eel, *Anguilla rostrata*, in the Virginia Tributaries of Chesapeake Bay (Spring 2008). Final Report to the Virginia Marine Resources Commission. Virginia Institute of Marine Science, Gloucester Point, VA. 27 p.

Virginia Marine Resources Commission (VMRC). 2008. Virginia Landings Bulletin. Virginia Marine Resources Commission, Newport News, Virginia, 5p.

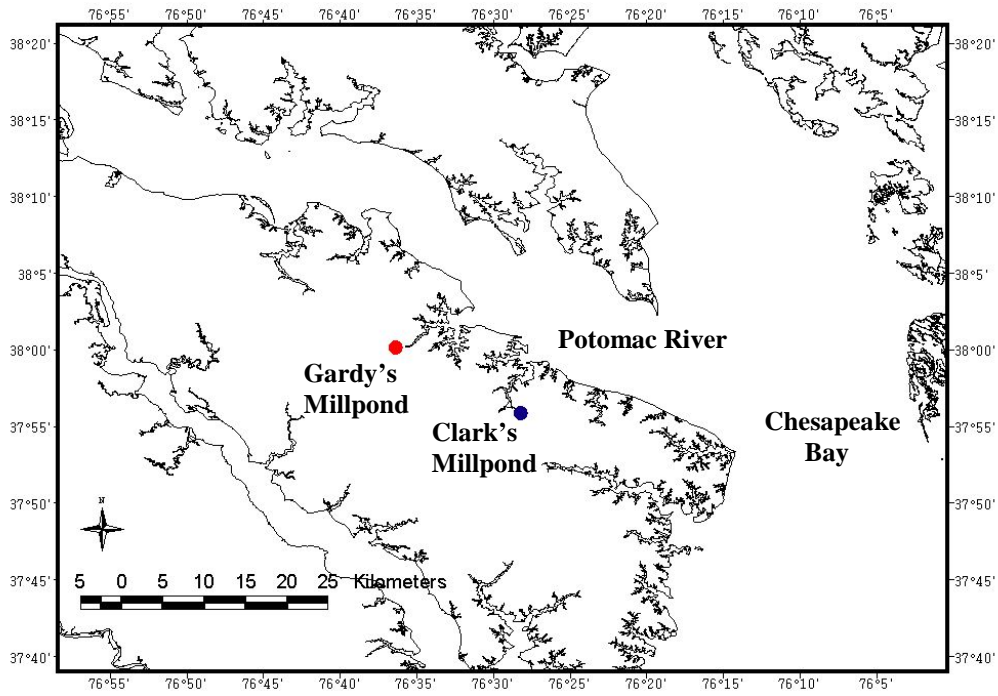
Table 1. Summary of glass eel collections on the Potomac River at Clark's Millpond, Gardy's Millpond, and for the combined sites (2000 – 2010). CPUE is calculated as the Area Under the Curve (AUC).

| Source  | YEAR   | Start Date | End Date | Total Catch | AUC CPUE24h |
|---------|--------|------------|----------|-------------|-------------|
| Clark's | 2000   | 28-Apr     | 15-May   | 15          | 14.50       |
|         | 2001   | 9-Apr      | 22-Apr   | 4           | 4.05        |
|         | 2002   | 1-Apr      | 27-Apr   | 115         | 115.79      |
|         | 2003   | 25-Apr     | 15-May   | 24          | 23.30       |
|         | 2004   | 21-Apr     | 27-May   | 447         | 459.19      |
|         | 2005   | 13-Apr     | 26-May   | 223         | 222.37      |
|         | 2006   | 6-Apr      | 22-May   | 80          | 79.96       |
|         | 2007   | 26-Apr     | 1-Jul    | 435         | 437.96      |
|         | 2008   | 14-Apr     | 19-Jun   | 22          | 20.30       |
|         | 2009   | 6-Apr      | 11-Jun   | 42          | 42.68       |
| 2010    | 19-Mar | 21-Jul     | 421      | 389.06      |             |
| Gardy's | 2000   | 16-Apr     | 27-Apr   | 291         | 286.85      |
|         | 2001   | 8-Apr      | 24-Apr   | 729         | 730.25      |
|         | 2002   | 29-Mar     | 25-Apr   | 129         | 129.50      |
|         | 2003   | 7-Apr      | 13-May   | 71          | 70.08       |
|         | 2004   | 2-Apr      | 18-May   | 39          | 38.86       |
|         | 2005   | 28-Mar     | 5-May    | 94          | 93.52       |
|         | 2006   | 17-Mar     | 11-May   | 46          | 45.39       |
|         | 2007   | 23-Apr     | 27-Jun   | 248         | 249.26      |
|         | 2008   | 20-Mar     | 11-Jun   | 187         | 178.94      |
|         | 2009   | 30-Mar     | 3-Jun    | 231         | 229.92      |
| 2010    | 19-Mar | 21-Jul     | 90       | 80.25       |             |

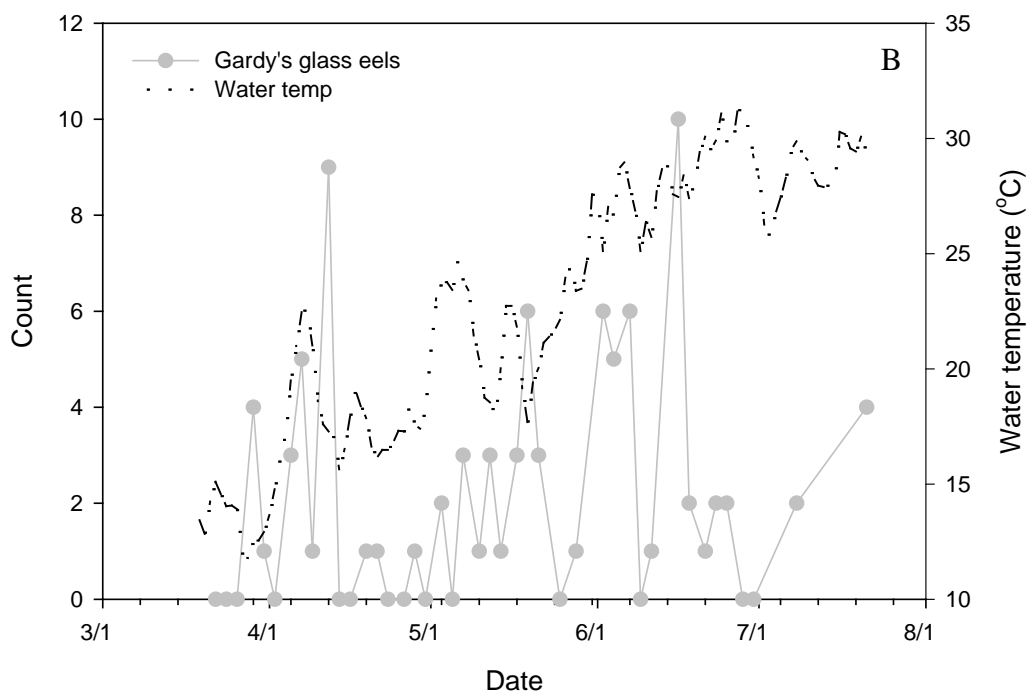
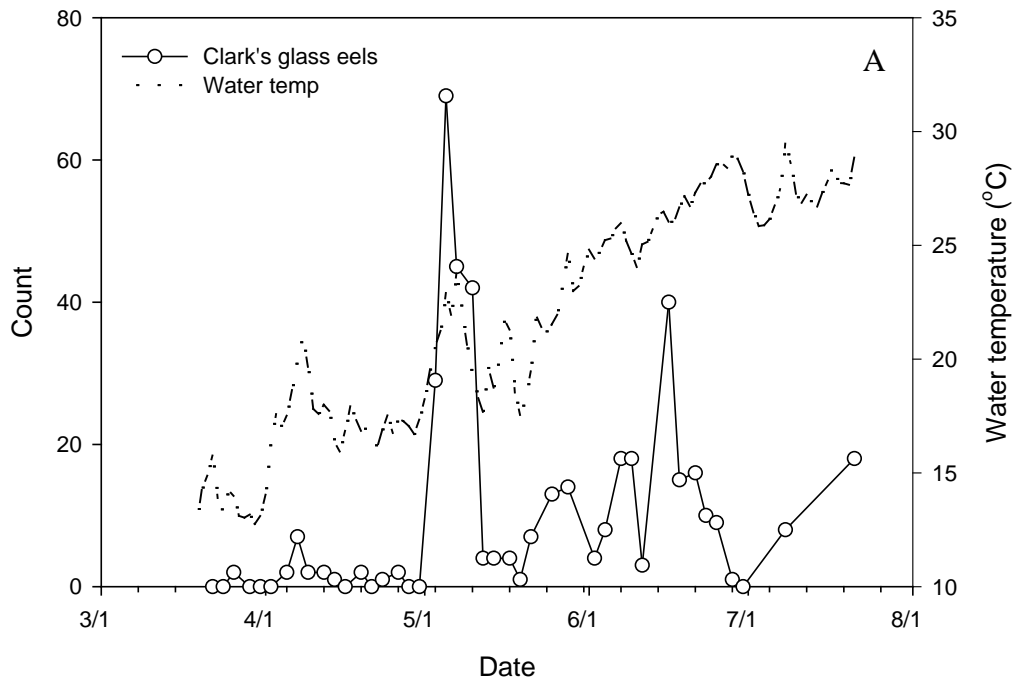
Table 2. Summary of elver collections on the Potomac River at Clark's Millpond, Gardy's Millpond, and for the combined sites (2000 – 2010). CPUE is calculated as the Area Under the Curve (AUC).

| Source  | YEAR   | Start Date | End Date | Total Catch | AUC CPUE24h |
|---------|--------|------------|----------|-------------|-------------|
| Clark's | 2000   | 5-Apr      | 15-May   | 5           | 4.97        |
|         | 2001   | 19-Mar     | 10-May   | 205         | 207.26      |
|         | 2002   | 13-Mar     | 21-Apr   | 90          | 90.95       |
|         | 2003   | 17-Mar     | 8-May    | 225         | 229.27      |
|         | 2004   | 2-Apr      | 23-May   | 314         | 316.36      |
|         | 2005   | 28-Mar     | 24-May   | 62          | 62.33       |
|         | 2006   | 15-Mar     | 24-May   | 153         | 153.41      |
|         | 2007   | 15-Mar     | 27-Jun   | 90          | 90.31       |
|         | 2008   | 24-Mar     | 15-Jun   | 276         | 259.96      |
|         | 2009   | 30-Mar     | 31-May   | 90          | 90.46       |
| 2010    | 19-Mar | 21-Jul     | 208      | 185.89      |             |
| Gardy's | 2000   | 16-Apr     | 15-May   | 15          | 13.49       |
|         | 2001   | 16-Mar     | 1-May    | 624         | 613.87      |
|         | 2002   | 15-Mar     | 27-Apr   | 273         | 277.15      |
|         | 2003   | 19-Mar     | 6-May    | 300         | 300.78      |
|         | 2004   | 10-Mar     | 11-May   | 483         | 476.76      |
|         | 2005   | 23-Mar     | 17-May   | 313         | 311.83      |
|         | 2006   | 10-Mar     | 14-May   | 692         | 700.96      |
|         | 2007   | 15-Mar     | 27-Jun   | 198         | 198.23      |
|         | 2008   | 20-Mar     | 11-Jun   | 393         | 385.88      |
|         | 2009   | 30-Mar     | 2-Jun    | 360         | 358.27      |
| 2010    | 19-Mar | 21-Jul     | 375      | 317.53      |             |

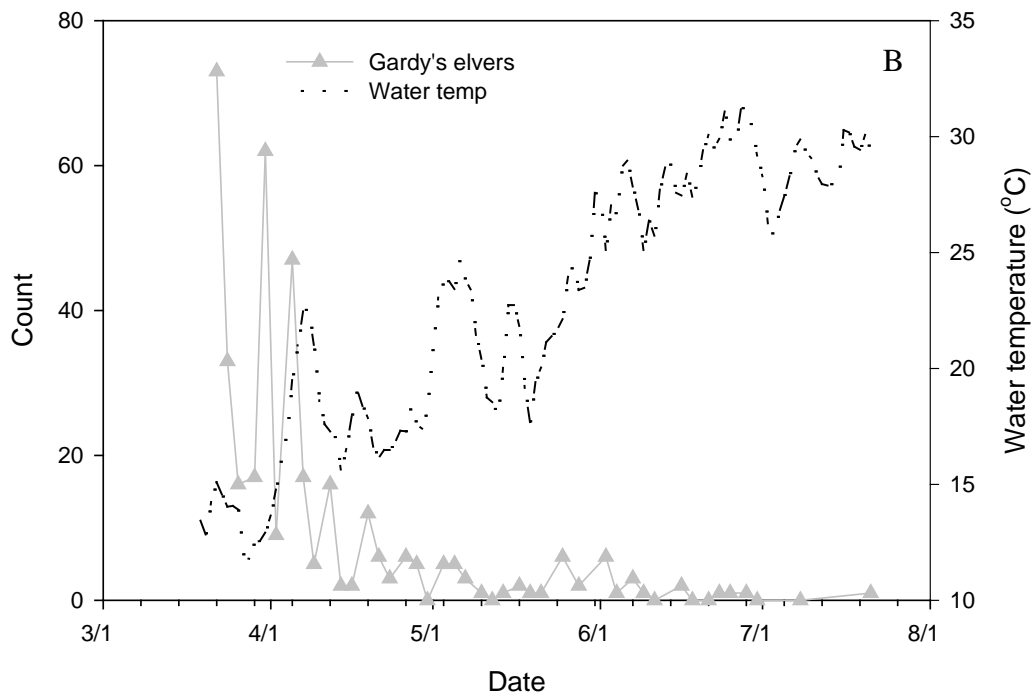
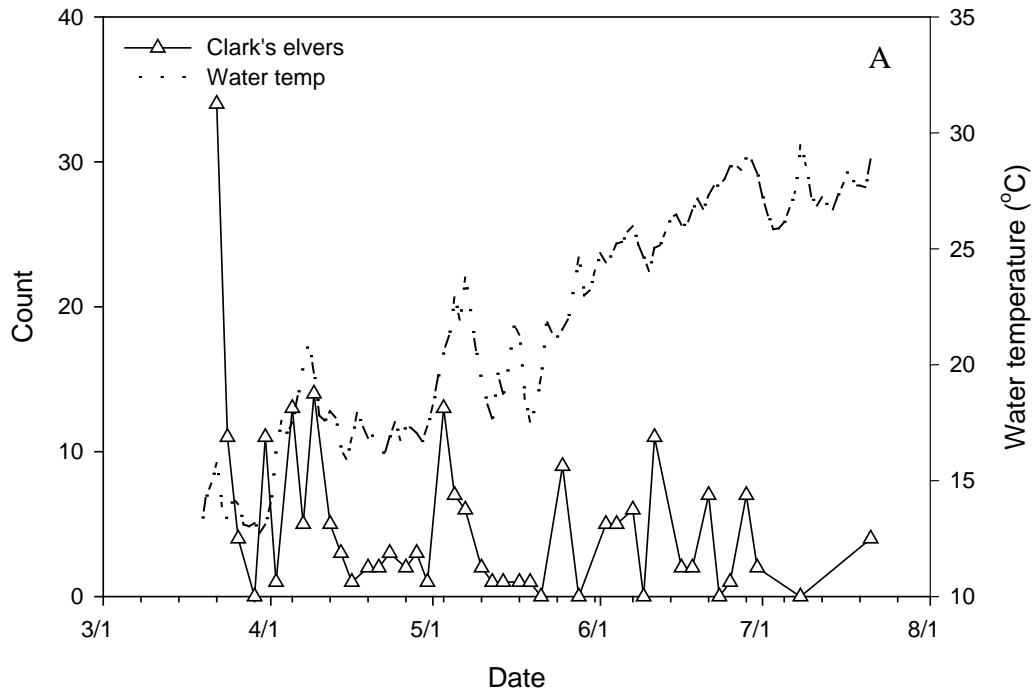
**Figure 1.** Sampling sites in the Potomac River.



**Figure 2.** Number of glass eels captured during each sampling event and water temperature at A) Clark's Millpond and B) Gardy's Millpond, 2010.

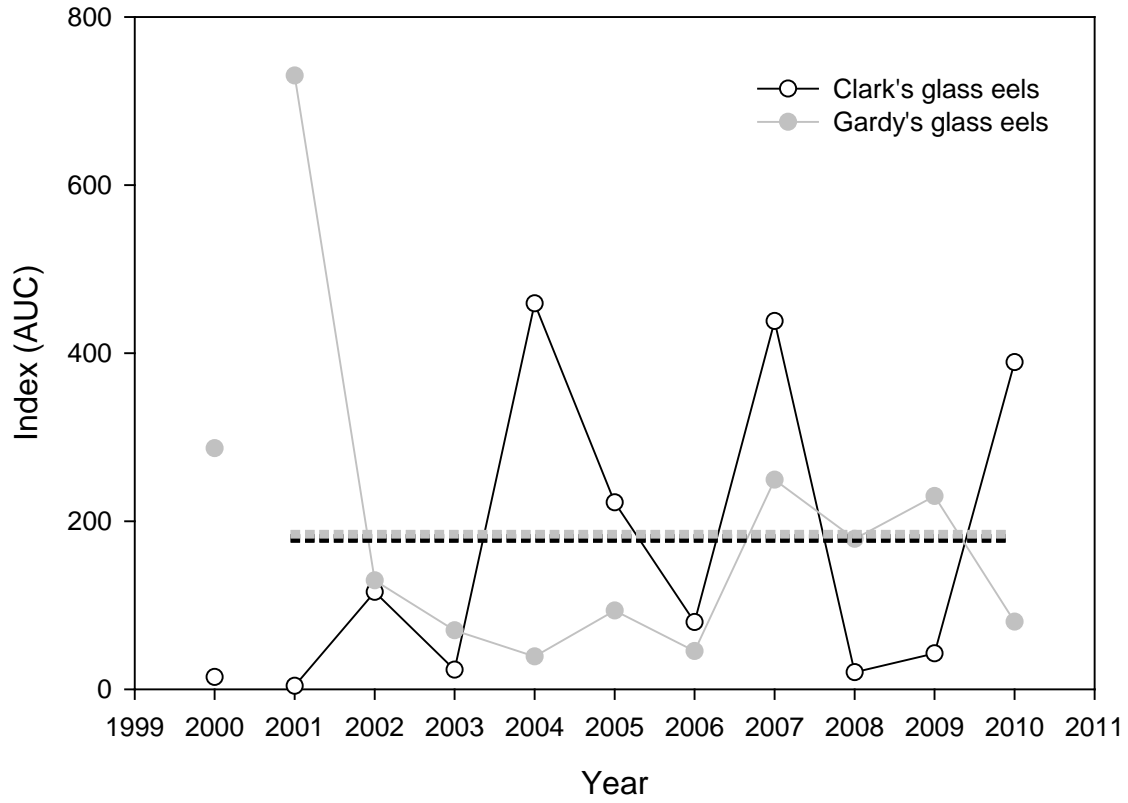


**Figure 3.** Number of elver eels captured during each sampling event and water temperature at A) Clark's Millpond and B) Gardy's Millpond, 2010.

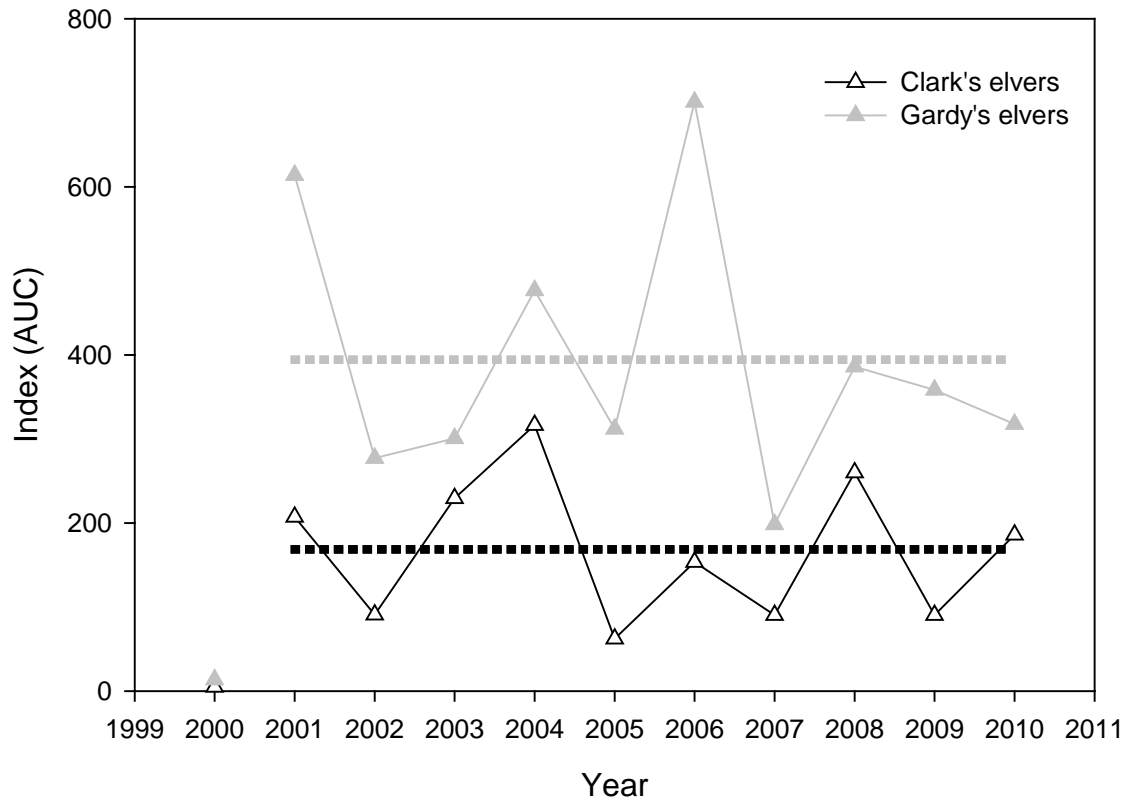




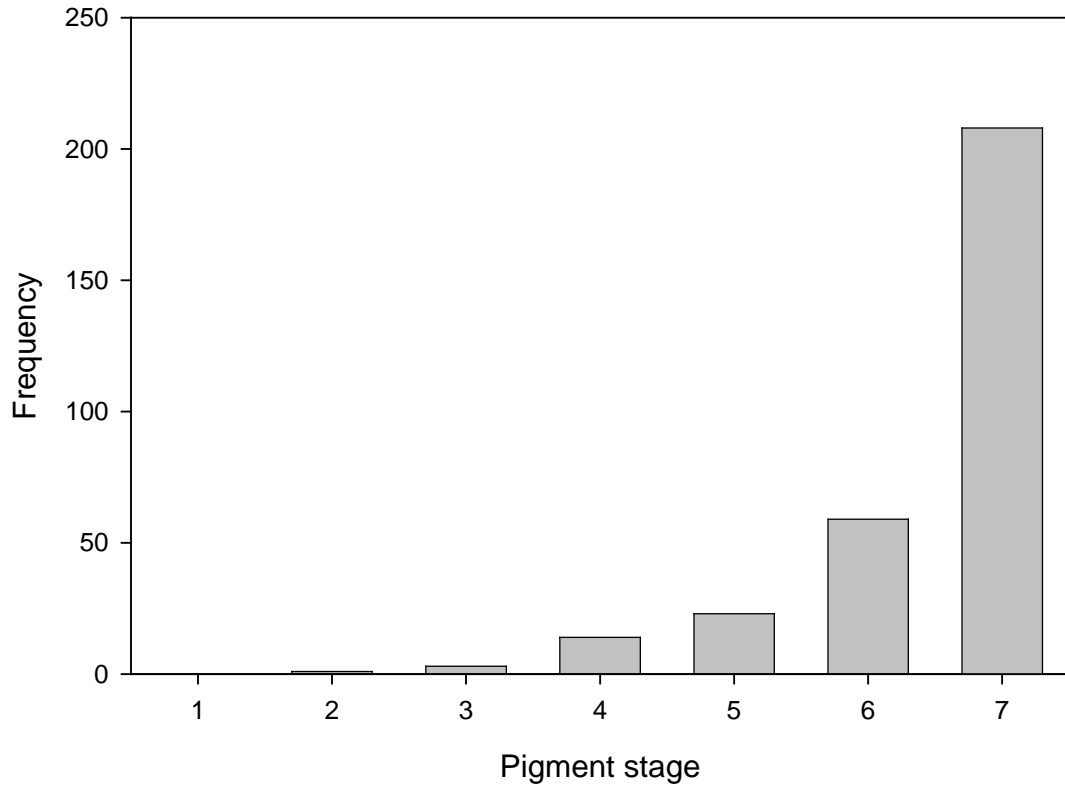
**Figure 4.** Glass eel index (area-under-the-curve method) from 2000 to 2010. Collections in 2000 followed different protocols and are not directly comparable to collections in later years.



**Figure 5.** Elver eel index (area-under-the-curve method) from 2000 to 2010. Collections in 2000 followed different protocols and are not directly comparable to collections in later years.



**Figure 6.** Glass eel pigment stage frequency distribution for the Potomac River, 2010.



**Figure 7.** Total length and wet weight of glass eels captured at Clark's and Gardy's Millponds, 2010. Average TL = 61.74 mm, average weight = 0.24 g.

