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By

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Objectives

1. Determine number and size of eels recruiting to the Potomac River watershed.

2. Examine the diel, tidal, lunar, and water quality factors, which may influence young of year eel recruitment.

3. Collect basic biological information on recruiting eels including but not limited to: length, weight, and pigment stage.

Introduction

Measures of juvenile recruitment success have long been recognized as valuable fisheries management tools. In Chesapeake Bay, these measures provide reliable indicators for future year class strength for species such as blue crabs (Lipcius and Van Engel, 1990), striped bass (Goodyear, 1985), and several other recreationally and commercially important species (Geer and Austin, 1999).

The American eel, *Anguilla rostrata,* is a valuable commercial species along the entire Atlantic coast from New Brunswick to Florida. Landings along the U.S. Atlantic coast have varied from 290 MT in 1962 to a high of 1600 MT in 1975 (NMFS, 1999). In recent years, harvests along the U.S. Atlantic Coast seemingly declined, with similar patterns occurring in the Canadian Maritime Provinces, and in Europe with its congener *A. anguilla* (Ciccotti et al., 1995). The Mid-Atlantic states (New York, New Jersey, Delaware, Maryland, and Virginia) comprised the largest portion of the East Coast catch (88% of the reported landings) since 1988 (NMFS,1999). The Chesapeake Bay jurisdictions of Virginia, Maryland, and the Potomac River Fisheries Commission (PRFC) alone represent 30,15, and 18% respectively, of the annual United States commercial harvest for 1987-1996 (ASMFC, 1999). Fishery independent indices have shown a decline in American eel abundance in recent years as well (Richkus and Whalens, 1999; Geer, 2003; Montane and Lowery, 2005). Hypotheses for this decline include locational shifts in the Gulf Stream, pollution, overfishing, parasites, and barriers to fish passage (Castonguay et al., 1994; Haro et al., 2000). Local factors such as unfavorable wind-driven currents may affect glass eel recruitment on continental shelves and may have a greater impact than fishing mortality or continental climate change (Knights, 2003).

Fisheries management techniques are not often applied to American eels because basic biological information is not well known. Unknown biological parameters such as variation in growth rates and length at age have complicated stock assessment and management efforts. Though American eel are not usually considered a sport fish, their ubiquity and readiness to take a bait leads them to be caught by recreational fishermen (Collette and Klein-MacPhee, 2002). Young American eel are also used as a baitfish in coastal areas (Jenkins and

Burkhead, 1993.) Absence of basic population dynamics data has hampered attempts at evaluation of regional exploitation rates (Social Research for Sustainable Fisheries, 2002). Additionally, relatively few studies have addressed the recruitment of glass eels to Atlantic coast estuaries from the Sargasso Sea spawning grounds.

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 the states' efforts to collect data on American eel and the fishery it supports through both fishery dependent and fishery independent studies. To this end, member jurisdictions (including the PRFC) agreed to implement an annual abundance survey for young of year (YOY) American eels. The survey is intended to "…characterize trends in annual recruitment of young of year eels over time [to produce a] qualitative appraisal of the annual recruitment of American eel to the U.S. Atlantic coast (ASMFC, 1999). These surveys began as pilot surveys in 2000 with full implementation by the 2001 season. Survey results will provide critical data on eel coastal recruitment success and further understanding of American eel population dynamics.

Life History

The American eel is a catadromous species, present 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. The eggs hatch into leaf-shaped ribbon-like larvae called leptocephali, which are transported by the ocean currents (over 9-12 months) in a generally northwesterly direction. Within a year, metamorphosis into the next life stage (glass eel) occurs in the Western Atlantic near the East Coast of North America. Coastal currents and active migration transport the glass eels into rivers and estuaries from February to June in Virginia and Maryland. As growth continues, the eel becomes pigmented (elver stage) and within 12 –14 months acquires a dark color with underlying yellow (yellow eel stage; Facey and Van Den Avyle, 1987). 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. Age at maturity varies greatly with location and latitude, and in Chesapeake Bay may range from 8 to 24 years, with most being less than ten years old (Owens and Geer, 2003). *A. rostrata* 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). Metamorphosis into the silver eel stage occurs during the seaward migration that occurs from late summer through autumn.

It has been suggested that glass eel migration consists of waves of invasion (Boetius and Boetius, 1989 as reported by Ciccotti et al., 1995), and perhaps a fortnightly periodicity related to selective tidal stream transport (Ciccotti et al., 1995). Additionally, alterations in freshwater inflow (patterns and magnitudes) to bays and estuaries may alter flow regimes and consequently affect the size, timing and spatial patterns of upstream migration of glass eels and elvers (Facey and Van Den Avyle, 1987).

Methods

The American Eel FMP created by the ASMFC established minimum criteria for YOY American eel sampling, with the ASMFC Technical Committee approving sampling gear. The timing and placement of gear must coincide with periods of peak YOY eel onshore migration. At a minimum, the gear must fish during flood tides occurring during the 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. On a weekly basis, a minimum of sixty specimens must be taken for length, weight, and pigment stage information.

Due to the importance of the eel fishery in Virginia and the Potomac River, additional methods have been implemented to insure proper temporal and spatial coverage, and to provide reliable estimates of recruitment success. 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. proper habitat), which were suitable for glass eel recruitment to our gear. The Maryland sampling of the Potomac River (northern shore site) was discontinued in 2001, due in part to the low catch rates observed the previous year (Geer, 2001). At the request of PRFC, VIMS sampled two sites on the Potomac River (i.e. southern shore sites, Gardy's Millpond and Clark's Millpond; see Figure 1) from 2000 – 2006, exceeding the FMP requirements.

Eels were collected with Irish eel ramps (Figure 2) at all locations. Irish eel ramps are an approved gear as stated in the FMP (ASMFC, 1999). The configuration of these ramps (as described below) proved successful for attracting and capturing YOY and juvenile eels in tidal waters of Chesapeake Bay. Ramp operation required continuous flow of water over the climbing substrate and through the collection device. The water supply for the Irish ramp is through gravity feed, requiring at least one foot (30.5 cm) of head above the trap. Hoses were attached to the ramp and collection buckets with adapters, which allowed quick removal and replacement during collection. Enkamat™ erosion control material on the floor of the ramp and extending into the water below the ramp provided a textured climbing surface for eels. The ramps were placed on an incline (15-45^{o}), often on land, with the ramp entrance and textured mat extending into the water. The above inclination, in combination with the 4^o elevation of the substrate inside the ramp, resulted in sufficient slope to create attractant flow. A hinged lid provided access for cleaning and flow adjustments. Flow over the textured climbing surface was adjusted to maintain minimal depths.

Traps were checked four days per week (generally Monday, Tuesday, Thursday and Friday). Only eels found in the ramp's collection bucket 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, pH, air temperature, wind direction, wind speed, and precipitation were recorded. In addition, starting in 2002, temperature data loggers (Stowaway Tidbits™) were deployed which recorded hourly water temperature at each site. All eels were enumerated and returned to the water above the impediment, with any sub-sample information appropriately recorded. YOY eels were distinguished from elvers by their different pigmentation. Eels less than or equal to 85 mm total length (TL) were classified as YOY, while those greater than 85 mm TL were classified as elvers. These two distinct length frequency modes likely represent different year classes (Geer, 2001). Lengths, weights, and pigment stage (as described by Haro and Krueger, 1988) were collected from up to sixty eels weekly.

Clark's Millpond (Coan River – Northumberland County) was sampled from February 28th to May 25th 2006. The spillway was approximately one meter above the creek with a strong and steady stream flow, requiring a modified ramp extension to allow the eels to traverse the spillway (Figure 3). Gardy's Millpond (Yeocomico River – Northumberland County) was sampled during the same period (February 28th to May 25th 2006; Figure 4). The site contains a spillway that drains through four box culverts, across riprap into a coarse sand area of the Yeocomico River. The Virginia Department of Game and Inland Fisheries maintains the site.

A daily catch per unit effort (geometric mean CPUE) was calculated for each site as well as both sites combined. CPUE for the Irish eel ramp was calculated as catch per 24 hours of soak time. To examine whether a relationship existed between YOY or elver CPUE and environmental parameters, a series of regressions were performed. Glass eel length, weight and condition index (Fulton Condition Factor or K, see Anderson and Neumann, 1996) were analyzed (both sites combined).

Results

The overall (both Clark's and Gardy's Millponds combined) YOY CPUE in 2006 was greater than 2005 and the highest in seven years (Table 1; Figure 5). Elver CPUE for 2006 was nearly six times higher than 2005 and was the highest since the start of the survey in 2000. For the seven years sampled thus far, combined YOY CPUE's have exhibited a very slight increasing trend, while combined elver CPUE has increased (Figure 5). In 2006, YOY CPUE at Clark's Millpond was the highest since 2000 and slightly greater than Gardy's Millpond in 2006 (1.63 and 1.43, respectively; Figure 6, top and bottom). Elver CPUE was higher at Gardy's than Clark's Millponds (4.26 and 2.18, respectively; Figure 6, top and bottom).

YOY CPUE at Clark's Millpond since 2000 has shown a significant increase ($r^2 = 0.7$, $P = 0.02$; Figure 6A). Elver CPUE at Clark's Millpond did not exhibit a trend (Figure 6, top). A large spike in YOY occurred April 15th 2006, though YOY were collected earlier in smaller numbers (Figure 7, top). In either case, there was no relationship between catch and lunar period (Figure 7, top). Elvers were captured throughout the survey beginning March 13th and continuing through May 25th 2006 with an elver peak on March 15th (Figure 7, bottom),

The YOY CPUE at Gardy's Millpond decreased from 2000 to 2005 and then increased in 2006 (Figure 6, bottom). The 2006 CPUE for elvers increased four-fold compared to the previous year and exhibited an increasing trend (Figure 6, bottom). YOY were captured from March 13th through May 15th (Figure 8, top) with major peaks March 31st and May 12th. Elvers were captured throughout the survey beginning March 8th and continuing through May 25th (Figure 8, bottom) with a spike March 13th. YOY and elver recruitment comparisons for Gardy's and Clark's Millponds show that the sampling regime employed captured recruitment peaks during Spring 2006 (Figures 7 and 8).

As water temperature increased, the number of YOY eels at Clark's Millpond increased significantly ($r^2 = 0.21$, $P = 0.001$), though a spike in catch did not occur until the water temperature hit 18^{o} C (Figure 9, top). A large increase in elver CPUE occurred after a temperature spike of 16^{o} C and in general, as water temperature increased, elver catch increased (Figure 9, bottom). As water temperature increased, glass eel CPUE increased at Gardy's Millpond, while elver CPUE decreased with increasing temperature (Figure 10, top and bottom). Glass eels began to recruit to the gear once water temperature was above 16^{o}C and a large spike in catch occurred at the same temperature for elvers also (Figure 10, top and bottom).

Every glass eel pigmentation stage was collected (Figure 11). Toward the end of the survey, mostly stages 5 through 7 were collected and overall most (97%) of the eels staged were stages 3 through 7 (Figure 11). Later staged eels were collected at Clark's compared to Gardy's Millponds (Figure 12).

Pigmentation stages for the Potomac sites were more advanced than those collected from the James and York Rivers (VIMS American Eel Survey, unpublished data) possibly a result of the longer migration period necessary to reach the middle Chesapeake Bay. Glass eel weight significantly increased in 2006 (r^2 = 0.62, P = 0.0005) with glass eel length (Figure 13), similar to previous years (Montane et al., 2005). Since 2002, length of YOY eels has exhibited a decreasing trend, while weight and condition index have increased (Figure 14). However, it must be noted that in general, later stage eels (particularly stages 4 and 5) are usually shorter than early stage eels.

Discussion

Overall (Clark's and Gardy's Millponds combined) YOY and elver CPUE increased. Separately, YOY and elvers increased at each site. Initial migration may be mediated by temperature for the YOY, and possibly the elvers. The run is highly variable from year to year, as is total YOY CPUE . Thus, a very productive site one year may be unproductive the next. Conversely, poor sites in one year may be very productive in others, hence the need for long term continual time series data.

Questions remain as to the exact timing of the run and the influence physical parameters of a site may have on recruitment. Initial arrival of juvenile eels may be correlated to large increases in water temperature (Sorensen and Bianchini, 1986). Increases in water temperature resulted in increased recruitment in mid April for Clark's and Gardy's Millponds YOY and Clark's Millponds elvers. Elvers may also delay upstream migration at freshwater interfaces until certain behavioral and physiological changes have occurred (Sorensen and Bianchini, 1986).

Long term (20+ year) glass eel recruitment studies in both North Carolina and New Jersey have suggested glass eel lengths have been decreasing (M. Sullivan, pers. comm.). Similar decreasing trends in glass eel length have been found in this study as well (Figure 14). In general, glass eel size increases with increasing distance from the breeding grounds (Boetius, 1976). On the North American eastern coast, glass eels from Nova Scotia were on average, 6 mm longer than those from Florida (Vladykov, 1966 as reported by Boetius, 1976).

With only seven years of data, most of the variability associated with eel recruitment in Chesapeake Bay remains an unknown, though with a few more years of data and comprehensive analysis of the Potomac and other Virginia tributaries sampled (sites sampled by VIMS for VMRC), some of the trends may become more apparent. These data were incorporated into the recently completed American Eel Stock Assessment.

Conclusions and Recommendations

1. In general, CPUE for YOY eels and elvers increased at the Potomac River sites during 2006 compared to 2005. Initial migration may be mediated by temperature. In 2006, there did not appear to be a consistent lunar effect.

2. Irish eel ramps remain an effective gear for sampling YOY eels in coastal Virginia.

3. Sampling should start early March and continue through end of May to capture peak recruitment. Given the great variability associated with spring temperatures in the Chesapeake region, sampling must be over a wide range of temperatures ensuring sampling occurs during optimal temperature regimes.

4. The ultimate goal of this survey is to provide estimates of recruitment for YOY eels and elvers. Considering the unique nature of each site, and the performance variability of the sampling gear at each site, it may be necessary to develop an index for each sampling site. Drainage area, distance from the ocean, discharge, and other physical parameters should be evaluated in an attempt to provide a relative value for each site. This value can then be used to weight the catch rates at each site, to provide a more reliable abundance estimate.

References

Anderson, R. O. and R. M. Neumann. 1996. Length, weight and associated structural indices. Pages 447-482 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

ASMFC, 1999. Fishery Management Plan for American Eel, *Anguilla rostrata*.

Boetius, J. 1976. Elvers, *Anguilla anguilla* and *Anguilla rostrata* from two Danish localities. Size, body weight, developmental stage and number of vertebrae related to time of descent. Meddr Danm. Fisk- og Havundersw N.S. 7:199-220.

Castonquay, 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.

Collette, B. B. and G. Klein-MacPhee. 2002. Bigelow and Schroeders Fishes of the Gulf of Maine. 3rd Ed. Smithsonian Institution Press. Washington, D.C. 748 pp.

Facey, D. E. and M. J. Van Den Avyle. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)—Americen eel. U. S. Fish Wildl. Serv. Biol. Rep. 82(11.74). U. S. Army Corps of Engineers, TR EL-82-4. 28 pp.

Geer, P.J. 1997. Evaluation of the Potomac River American eel, *Anguilla rostrata*, pot fishery based on commercial landings. Virginia Marine Resources Report 97-06.

Geer, P.J. 2001. Evaluating recruitment of American eel, *Anguilla rostrata*, to the Potomac River ---Spring 2001. Report prepared for Potomac River Fisheries Commission. Virginia Institute of Marine Science Gloucester Point, Virginia 23062. 21 pp.

Geer, P. J. 2003. Distribution, relative abundance, and habitat use of American eel *Anguilla rostrata* in the Virginia portion of the Chesapeake Bay. Pages 101-115 *in* D. A. Dixon (Editor). Biology, Management and Protection of Catadromous Eels. American Fisheries Society, Sympoium 33, Bethesda, MD, USA.

Geer, P.J., and H.M. Austin. 1999. Estimation of relative abundance of recreationally important finfish in the Virginia portion of Chesapeake Bay. Annual Report to VMRC/USFWS Sportfish Restoration Project F104R9. July 1998 to June 1999. Virginia Institute of Marine Science, Gloucester Point, Virginia 23062. 139 pp.

Goodyear, C.P. 1985. Relationship between reported commercial landings and abundance of young striped bass in Chesapeake Bay, Maryland. Trans. Amer. Fish. Soc. 114(1):92-96.

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 pp.

Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society. Bethesda, MD. 1079 pp.

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.

Lipcius, R. N. and W. A. Van Engel. 1990. Blue crab population dynamics in Chesapeake Bay: variation in abundance (York River, 1972 – 1988) and stock-recruit functions. Bull. Mar. Sci. 46(1): 180-194.

Meister, A. L. and L. N. Flagg. 1997. Recent developments in the American eel fisheries of North America. FOCUS 22(1):1-4.

MINITAB. 1998. Release 12. State College, PA.

Montane, M.M. and W.A. Lowery. 2005. Estimating Relative Juvenile Abundance of Ecologically Important Finfish and Invertebrates in the Virginia Portion of Chesapeake Bay, Project # NA03NMF4570378, July 2004 - June 2005. Annual Report to NOAA Chesapeake Bay Office. Virginia Institute of Marine Science, Gloucester Point, VA 23062. 123 pp.

Montane, M.M., W.A. Lowery, H. Brooks and A. D. Halvorson. 2005. Evaluating recruitment of American eel, Anguilla rostrata, to the Potomac River (Spring 2005). Final Report to the Potomac River Fisheries Commission. 27 pp.

Murdy, E.O., R.S. Birdsong and J.A. Musick. 1997. Fishes of Chesapeake Bay. Smithsonian Institution Press. 324 pp.

NMFS, 1999. February 21, 1999. "Annual commercial landings statistics. National Marine Fisheries Service Fisheries Statistics Division Annual Landings Query". http://remora.ssp.nmfs.gov/MFPUBLIC/owa/mrfss.ft_HELP.SPECIES.

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, Sympoium 33, Bethesda, MD, USA.

Richkus, W. and K. Whalen. 1999. American eel, *Anguilla rostrata*, scooping 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.

Social Research for Sustainable Fisheries. 2002. The Paq'tnkek Mi'kmaq and Kat (American eel-*Anguilla rostrata*). A Preliminary Report of Research Results, Phase I. SRSF Research Report #4. Social Research for Sustainable Fisheries, St. Francis Xavier University, in collaboration with Paq'tnkek Fish and Wildlife Society.

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.

Table 1. Potomac River catch statistics by site and year (2000-2006).

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	30-Mar-00	16-May-00	15	0.11	5	0.04	13
Gardy's	12-Apr-00	16-May-00	291	1.28	15	0.17	10
Potomac River 2000 Totals			306	0.62	20	0.10	23

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	16-Mar-01	12-May-01	4	0.03	205	0.88	32
Gardy's	12-Mar-01	12-May-01	729	0.88	624	1.46	33
Potomac River 2001 Totals			733	0.46	829	1.17	65

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	9-Mar-02	2-May-02	115	0.53	90	0.49	31
Gardy's	9-Mar-02	2-May-02	129	0.52	273	1.03	31
Potomac River 2002 Totals			244	0.52	363	0.76	62

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	11-Mar-03	16-May-03	24	0.11	225	0.67	39
Gardy's	11-Mar-03	16-May-03	71	0.28	300	0.90	39
Potomac River 2003 Totals			95	0.20	525	0.78	78

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	8-Mar-04	30-May-04	447	0.68	314	0.71	45
Gardy's	8-Mar-04	24-May-04	39	0.17	483	1.17	42
Potomac River 2004 Totals			486	0.43	797	0.93	87

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	10-Mar-05	25-May-05	223	0.69	62	0.27	38
Gardy's	10-Mar-05	25-May-05	94	0.35	313	0.98	38
Potomac River 2005 Totals			317	0.52	375	0.63	76

Site	Start Date	End Date	YOY		Elver		Sampling Events
			Total	CPUE	Total	CPUE	
Clark's	28-Feb-06	25-May-06	80	1.63	153	2.18	46
Gardy's	28-Feb-06	25-May-06	46	1.43	692	4.26	46
Potomac River 2006 Totals			126	1.53	845	3.05	92

Figure List

Figure 1. 2006 Potomac River sampling sites.

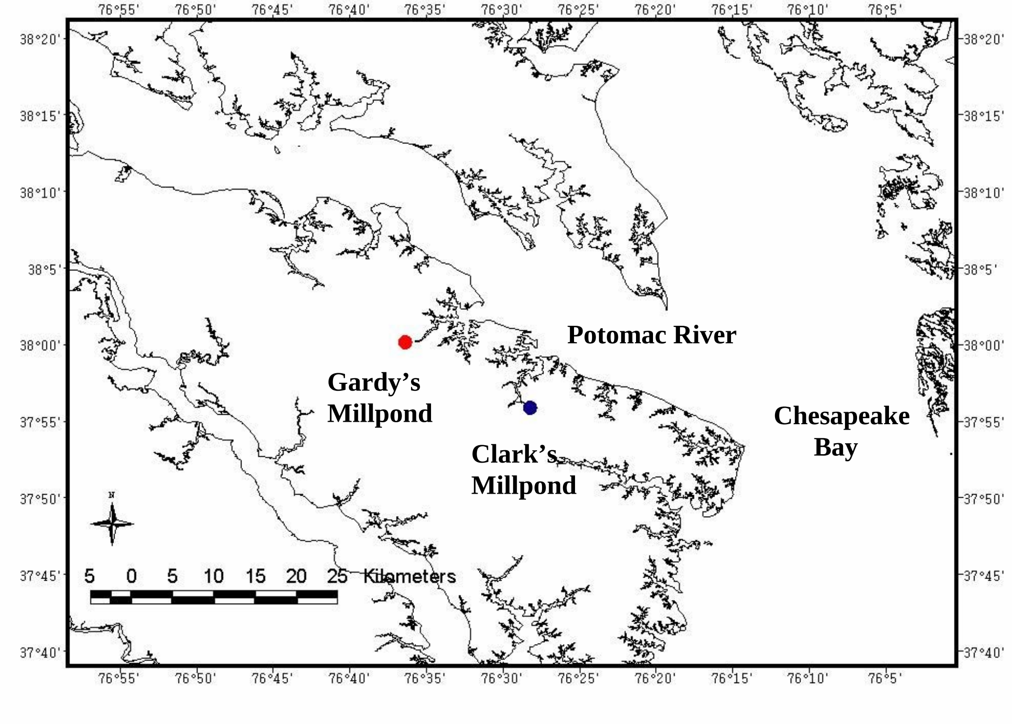


Figure 2. The Irish ramp at Gardy's Millpond showing its configuration.
The arrows indicate the flow of water as well as eels.

Figure 3. The Irish ramp at Clark's Millpond (Coan River). The green tube in the foreground was initially used as the modified ramp extension. In 2004, the "tube" was replaced with ¼" Delta knotless nylon placed in layers in the same location.

Figure 4. The spillway at Gardy's Millpond (Yeocomico River). The Irish ramp was located in the culvert on the left.

Figure 5. Potomac River CPUE (geometric mean) for YOY and Elvers (both sites combined), 2000 - 2006.

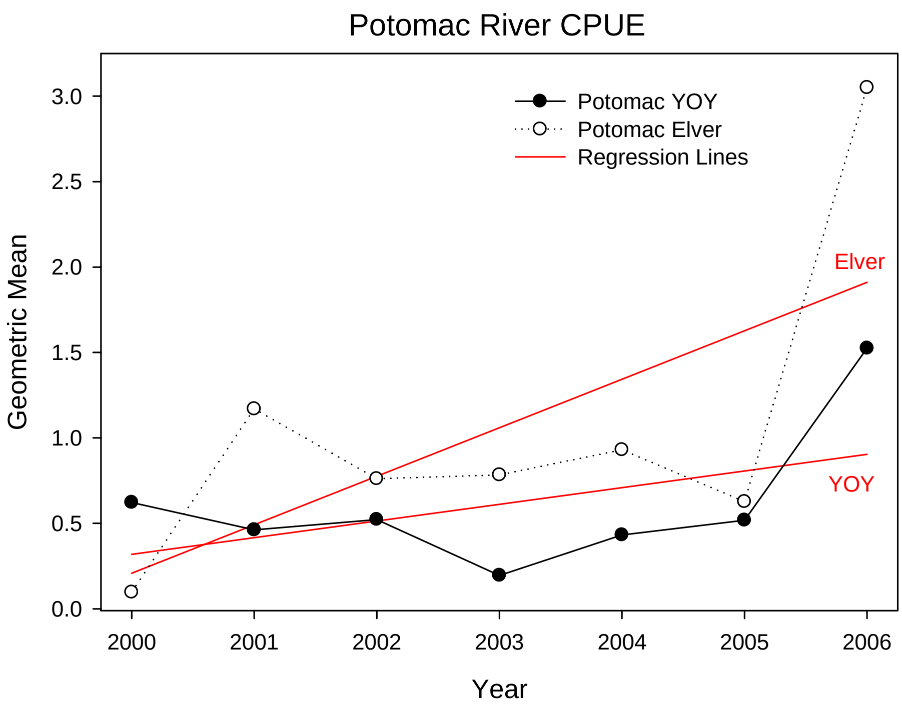


Figure 6. YOY and Elver CPUE at Clark's and Gardy's Millponds for 2000-2006.

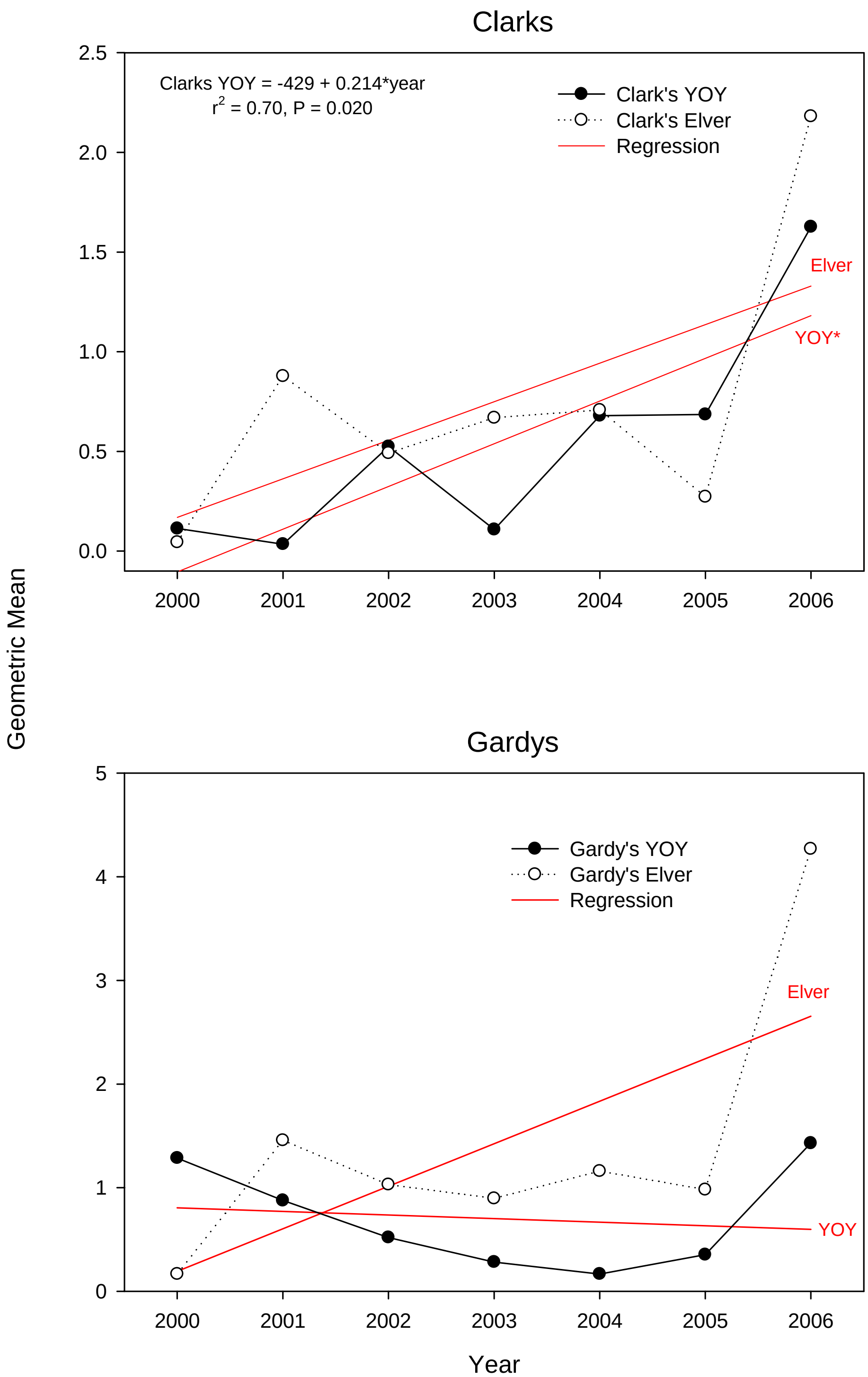


Figure 7. 2006 CPUE for YOY and Elvers at Clarks Millpond.

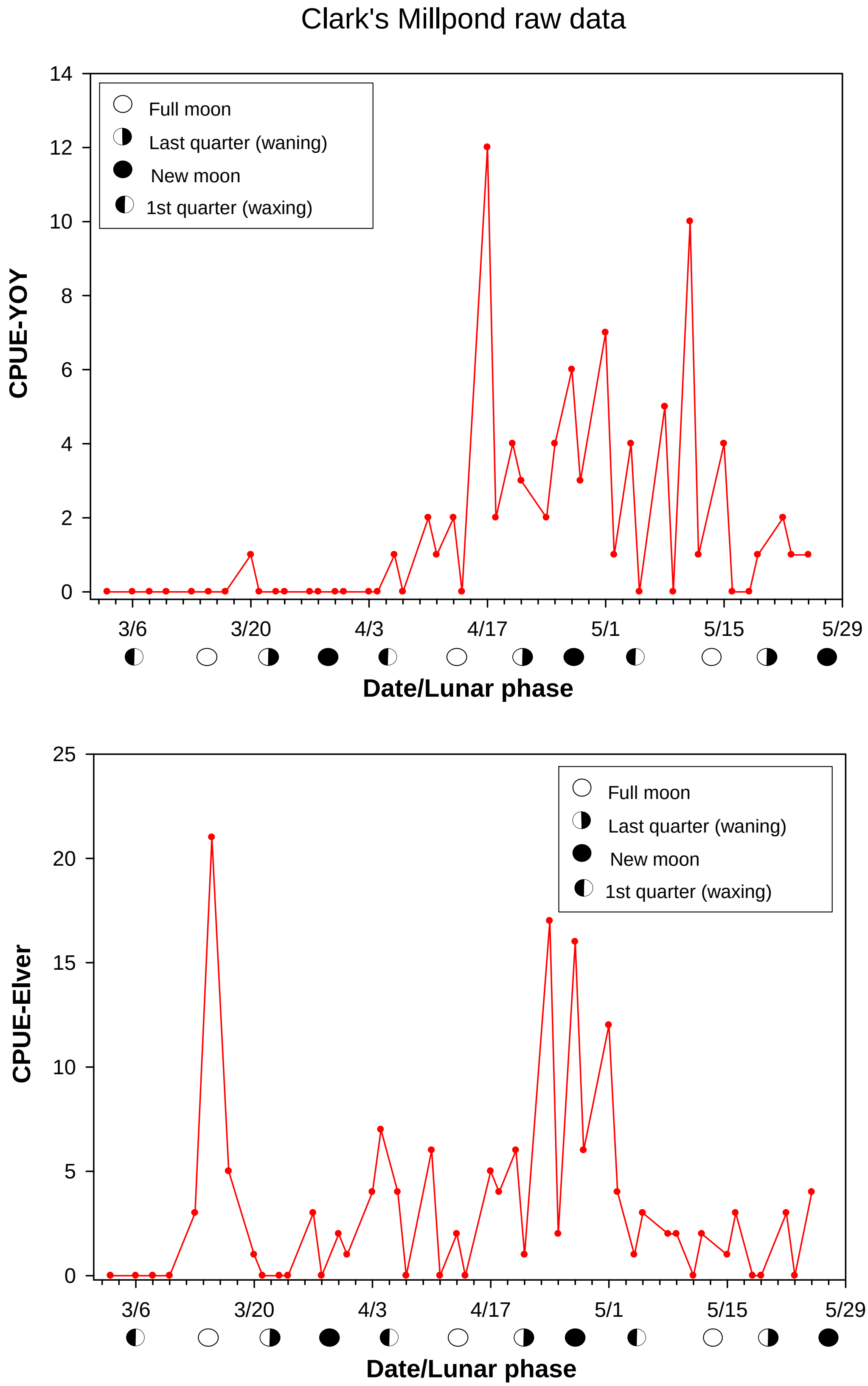
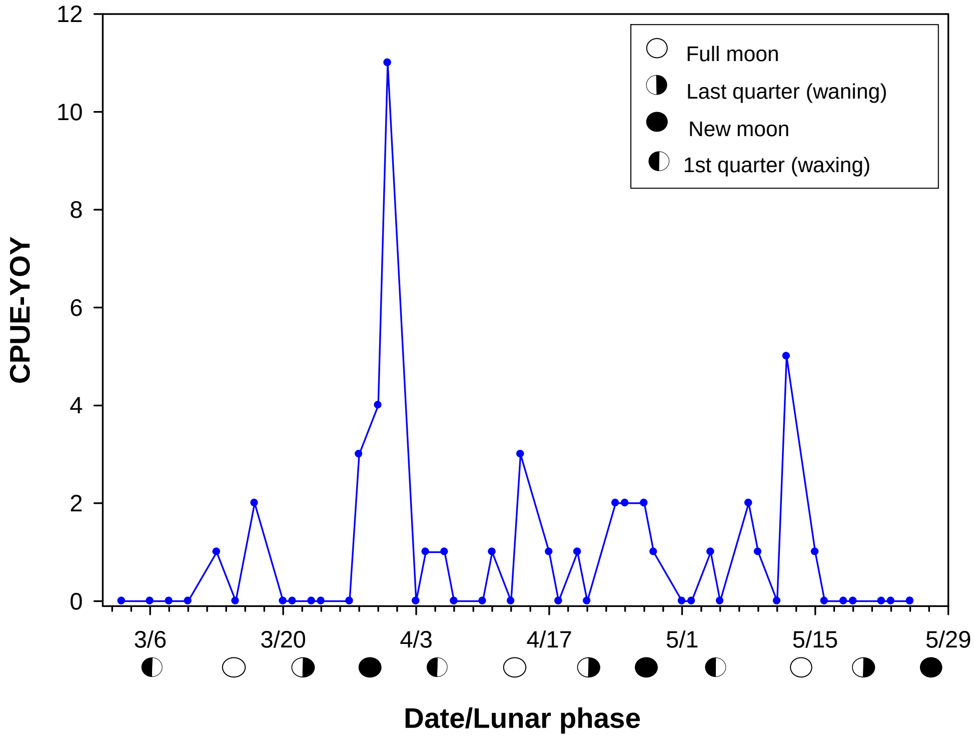


Figure 8. 2006 CPUE for YOY and Elvers at Gardy's Millpond.

Gardy's Millpond raw data



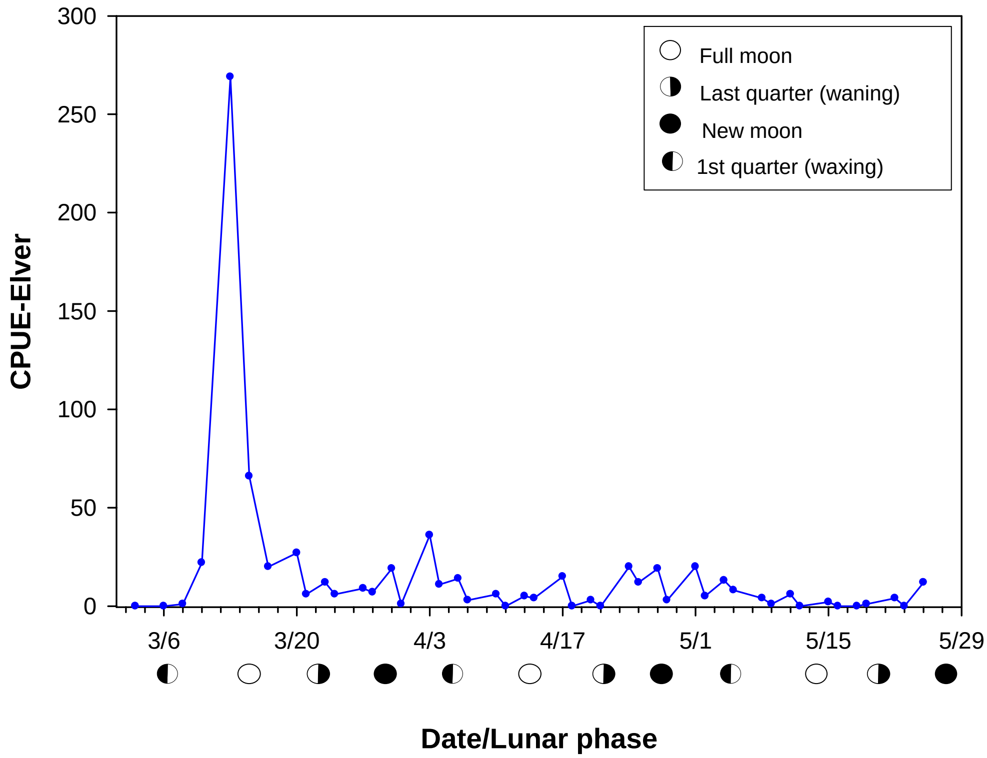


Figure 9. YOY and Elver CPUE vs. Water Temperature (downstream) at Clark's Millpond.

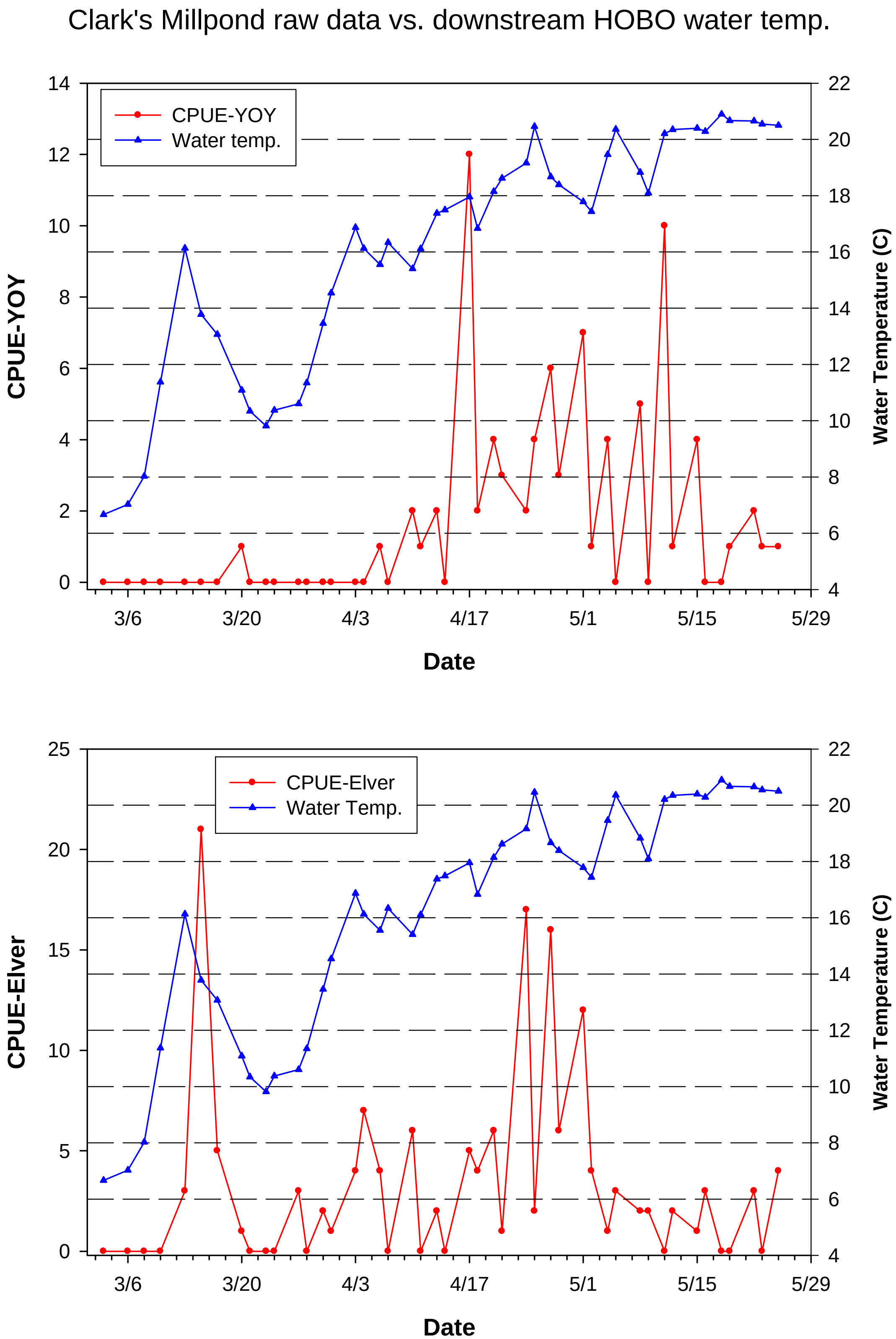
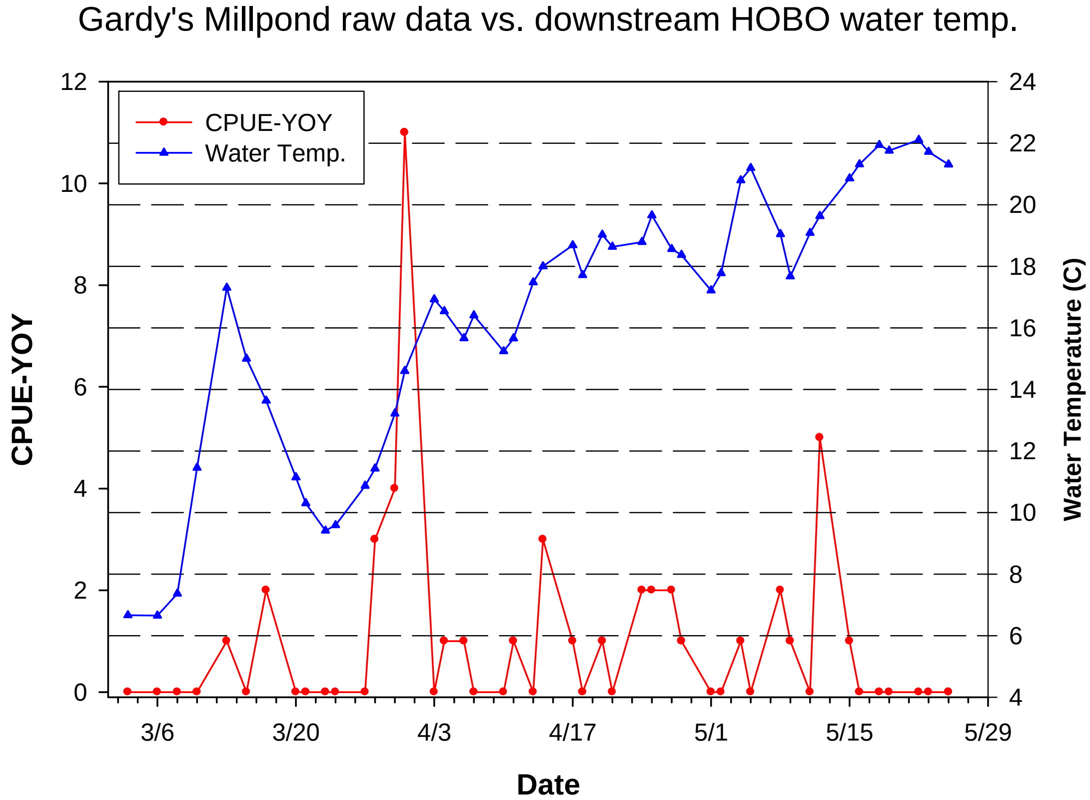


Figure 10. YOY and Elver CPUE vs. Water Temperature (downstream) at Gardy's Millpond.



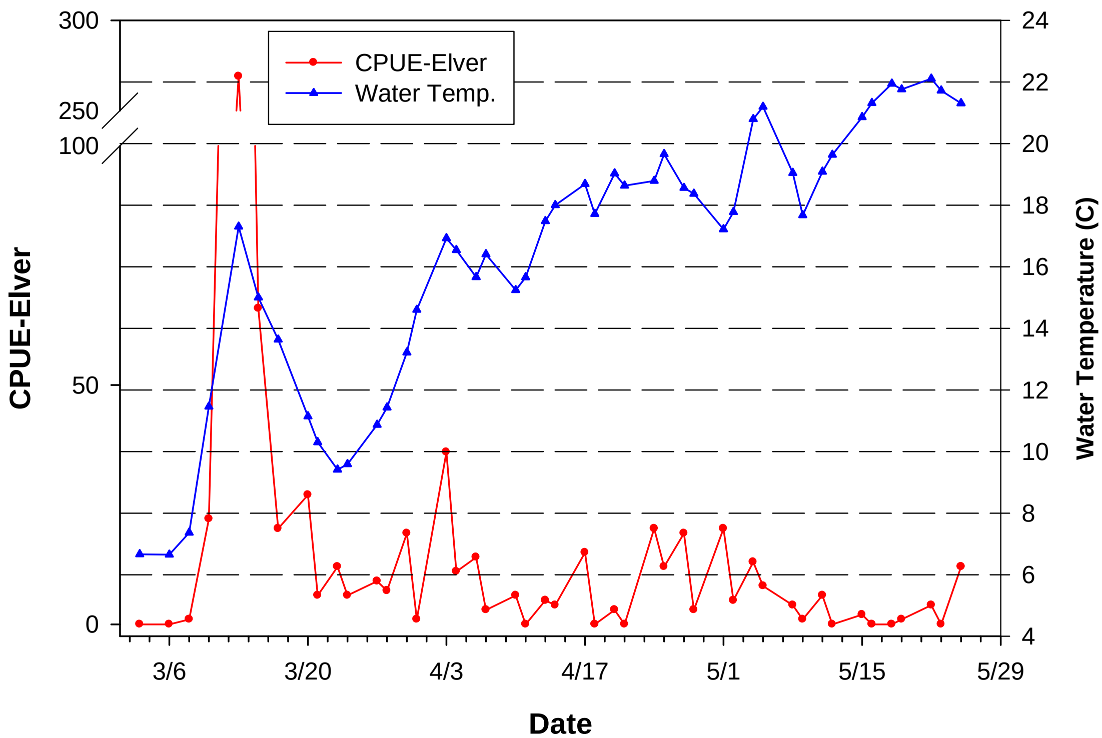


Figure 11. 2006 Potomac River Pigmentation Stages (Gardy's and Clark's combined).

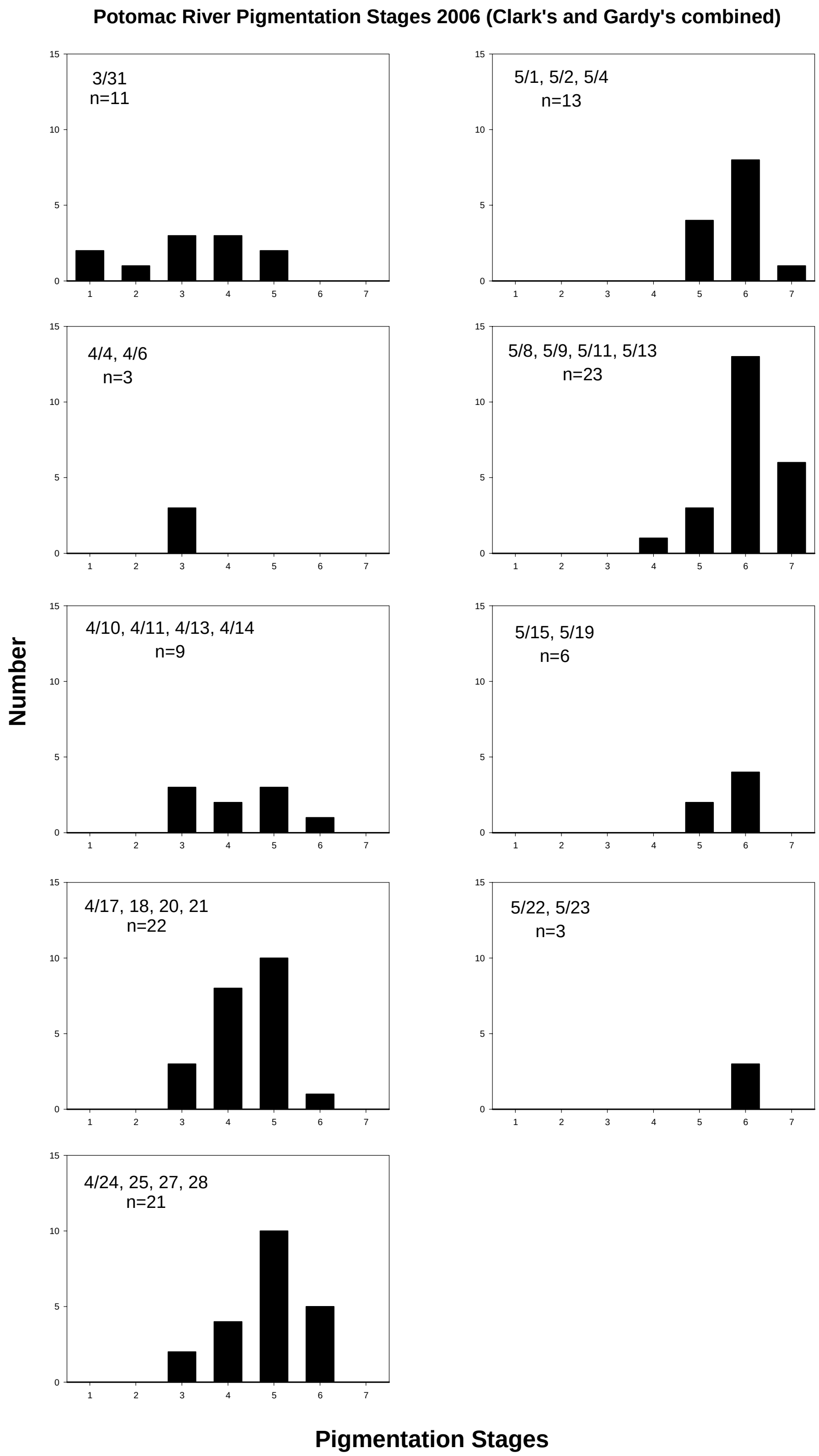


Figure 12. Frequency distribution of glass eel pigmentation stages during 2006 at Clark's and Gardy's Millponds.

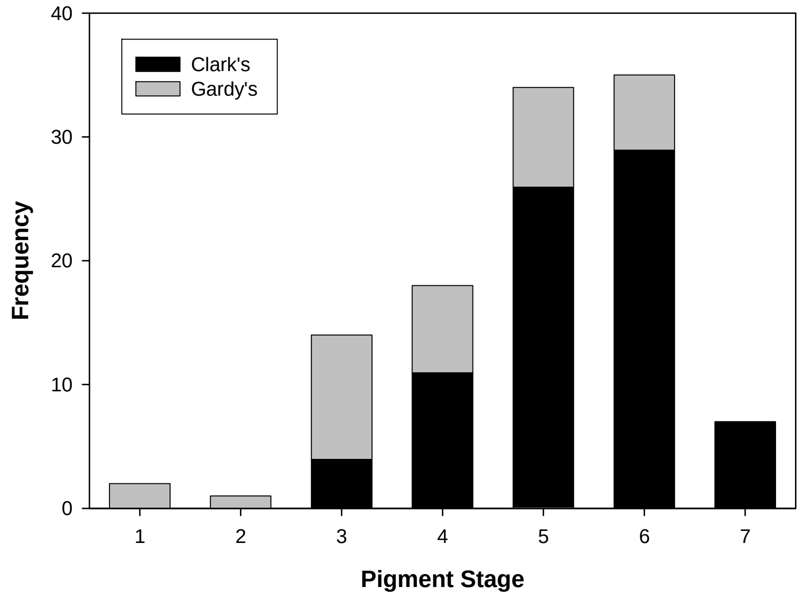


Figure 13. Glass eel length-weight regression (Clark's and Gardy's Millponds combined). (Note: Solid line denotes regression line)

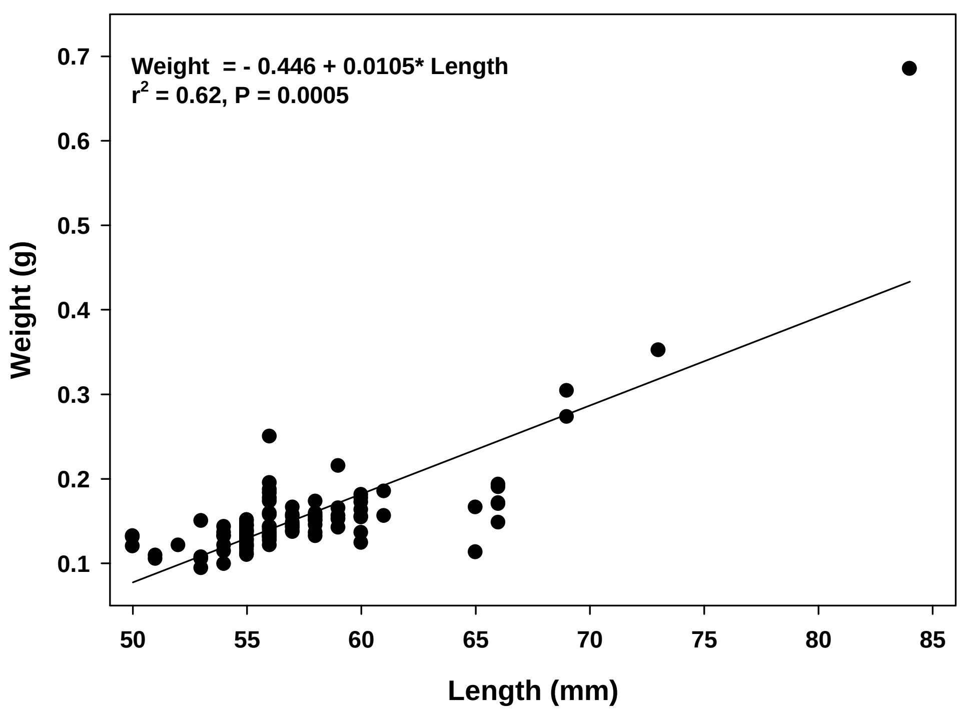


Figure 14. Length, weight and condition index (K) for glass eels examined from the Potomac River, 2002-2006. Note: Due to low numbers of YOY eels collected in 2003, no biological data was available.