

Evaluating Recruitment of American Eel, *Anguilla rostrata*, to the Potomac River  
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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 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, 2000). Some fishery independent indices have shown a decline in American eel abundance in recent years (Richkus and Whalens, 1999). 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).

Fisheries management techniques aren't 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). 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 the 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 the resource 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, 2000). The development of these surveys began as pilot surveys in 2000 with full implementation by the 2001 season. Results from these surveys 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. As growth continues, the eel becomes pigmented (elver stage) and within 12–14 months acquires 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. 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 in a fortnightly periodicity related to selective tidal stream transport (Ciccotti et al., 1995).

## 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 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 60 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. suitable habitat), which are suitable for glass eel concentrations. The Maryland sampling of the Potomac River 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 (Gardy's Millpond and Clark's Millpond; see Figure 1) from 2001 – 2003, which exceeds the FMP requirements.

Eels were collected with Irish eel ramps at all locations (Figure 2). Irish eel ramps are an approved gear as stated in the FMP (ASMFC, 2000). The configuration of these ramps (as described below) proved successful for attracting and capturing small 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, thus requiring a considerable amount 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°), often on land, with the ramp entrance and textured mat extending into the water. Submersion of the ramp entrance was considered undesirable and thus was placed in shallow water (< 25 cm). The above inclination, in combination with the 4° 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 (Monday-Wednesday-Friday, and alternating weekend days). Only eels found in the ramp's collection bucket were recorded. Trap performance was rated on a scale of 1 to 4 (1= gear 100% efficient, 2 = gear > 50% efficient, 3 = gear < 50% efficient, 4= gear not functioning). Water temperature, pH, air temperature, wind direction, wind speed, and precipitation were recorded during site visits. In addition, starting in 2002, Hobo™ temperature data loggers were employed which allowed for a mean temperature to be recorded for a 24 hr. period. All eels were enumerated and returned to the water above the impediment, with any sub-sample information appropriately recorded. Specimens less than or equal to 85 mm total length (TL) were classified as 'young of year', while those greater than 85 mm TL were considered elvers. This corresponds to the observation of two distinct modes in the 2000 length frequencies, likely reflecting differing year classes (Geer, 2001). Lengths, weights, and pigment stage (as described by Haro and Krueger, 1988) were collected from at least sixty eels (when feasible) on a weekly basis.

Clark's Millpond (Coan River – Northumberland County) was sampled from March 11<sup>th</sup> to May 16<sup>th</sup> 2003. The spillway remained at least one meter above the creek with a strong and steady stream flow. To increase the eel's chances of traversing the spillway, a modified ramp extension (G. Wippelhauser, pers. comm.) was used each year (Figure 3). Gardy's Millpond (Yeocomico River – Northumberland County) was also sampled on a regular basis from March 11<sup>th</sup> to May 16<sup>th</sup> 2003 (Figure 4). The site contains a spillway that drains through five box culverts, across riprap into a coarse sand area of the Yeocomico River. The Virginia Department of Game and Inland Fisheries maintains the site.

For analyses, a daily catch per unit effort (CPUE) was established for each site. 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 lunar stage, we performed ANOVA with lunar quarter as the factor and CPUE as the response. Lunar quarter was divided into four stages (according to van Montfrans et al., 1995): (1) the week of the new moon beginning on the day of the new moon, (2) the week of the waxing moon, (3) the week of the full moon starting on the day of the full moon and (4) the week of the waning moon.

## Results

The overall (both sites combined) CPUE for YOY in 2003 was lower than the previous three years, though elver CPUE increased (Figure 5; Table 1). For the four years sampled thus far, CPUE's for YOY have exhibited a decreasing trend, while those for elvers have increased (Figure 5). Individually in 2003, CPUE for YOY was three times greater at Gardy's than Clark's (1.08 and 0.36 respectively; Table 2) with slightly more elvers collected at Gardy's (Table 2).

The CPUE for YOY at Gardy's Millpond was lower than the three previous years (Table 2; Brooks et al., 2002). The CPUE for elvers was slightly greater than last year (Table 2). YOY were captured from April 7<sup>th</sup> through May 16<sup>th</sup> (Figure 6) with minor peaks occurring from April 22<sup>nd</sup> and April 30<sup>th</sup>. Elvers were captured throughout the survey beginning March 13<sup>th</sup> and continuing through May 14<sup>th</sup> (Figure 6) with major peaks in CPUE March 21<sup>st</sup>, March 27<sup>th</sup> through March 29<sup>th</sup> and May 3<sup>rd</sup>.

YOY CPUE at Clark's Millpond were 80% lower in 2003 than in 2002 (Table 2). Elver CPUE was twice that of 2002 (Table 2). YOY were captured from April 25<sup>th</sup> through May 16<sup>th</sup> (Figure 7) with most collected on April 28<sup>th</sup>. Elvers were captured throughout the survey beginning March 14<sup>th</sup> and continuing through May 16<sup>th</sup> (Figure 7).

We never collected enough eels in a single day that made it feasible to transport back to the lab and stage (the most caught on a single day were 4 at Clarks and 12 at Gardy's). YOY and elver recruitment comparisons for Gardy's and Clark's Millponds show that our sampling regime captured recruitment peaks in all years sampled (Figures 8 and 9).

Presently it is unknown whether a particular environmental parameter was a driving force or hindrance to the recruitment migration of eels to fresh water. Water temperature at Gardy's and Clark's Millponds varied between 8.6°C and 21.7°C (Figure 10) but showed no significant relationship with YOY or elver CPUE. In 3 of 4 cases, mean CPUE for Clarks YOY, Gardy's YOY, and Gardy's Elver was highest during the period of the waning moon, suggesting a lag period for up to a week after the full moon. There was a significant difference between elver CPUE during the week of the waxing moon than the week of the waning moon for Gardy's elvers, with significantly higher CPUE during the week of the waning moon (Tukeys Pairwise Comparisons Test, MINITAB, 1998).

There was no relationship between CPUE of YOY and elvers at Clarks, though there was a positive trend between YOY and elver CPUE at Gardy's ( $r^2 = 0.09$ ,  $P = 0.058$ ).

## **Discussion**

Most Atlantic Coast states had lower than normal recruitment this year, possibly a result of the increased precipitation (pers. comm., ASMFC Eel Committee). In general, CPUE for YOY eels was lower at the Potomac sites than other years, though elver CPUE increased slightly. Initial migration may be mediated by temperature and precipitation (proxy for salinity), and then be associated with a lunar periodicity. If the run is highly variable from year to year (as is suspected), a very productive site one year may be unproductive in future

years. Conversely, poor sites in one year may be very productive in others, hence the need for continual time series data.

With only four years of data most of the variability associated with eel recruitment remains an unknown, therefore, an estimate of recruitment success may only be preliminary at this time. Questions remain as to the exact timing of the run and the influence physical parameters of a site may have on recruitment. These estimates will undergo further revisions as the survey becomes better established and more of the inherent variability is considered.

We found highest recruitment during the week of the waning moon (during the week after the full moon). Similar relationships were found in Wormley Pond in the York River during 2002 (Montane et al, 2002).

### **Conclusions and Recommendations**

1. Most Atlantic Coast states had lower than normal recruitment this year, possibly a result of the increased precipitation (pers. comm., ASMFC Eel Committee). In general, CPUE for YOY eels was lower at the Potomac sites than other years, though elver CPUE increased slightly. Initial migration may be mediated by temperature and precipitation (proxy for salinity), and then be associated with a lunar periodicity.
2. Irish eel ramps are an effective gear for sampling YOY eels in coastal Virginia.
3. Sampling should start on or around March 1, and continue through June 1, if necessary, 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 eel 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. Parameters such as 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 an overall estimate of abundance.



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Table 1. Potomac River YOY and Elver CPUE by year (both sites combined)

Year	YOY			Elver			Sampling Days
	Total	CPUE	Max.	Total	CPUE	Max.	
2000	306	3.78	107	20	0.25	6	81
2001	733	6.26	499	829	7.09	72	117
2002	244	2.22	51	363	3.30	39	110
2003	95	0.72	12	525	3.98	49	132

Table 2. Potomac River catch statistics by site and year (2000 – 2003).

**2000**

Site Name	Site Code	Start Date	End Date	Gear	YOY			Elver			Sampling Days
					Total	CPUE	Max.	Total	CPUE	Max.	
Clark's Millpond	CM	30-Mar-00	16-May-00	Irish Eel Ramp	15	0.32	7	5	0.11	2	47
Gardy's Millpond	GA	12-Apr-00	16-May-00	Irish Eel Ramp	291	8.56	107	15	0.44	6	34
<b>Potomac River 2000 Overall Summary</b>					<b>306</b>	<b>3.78</b>	<b>107</b>	<b>20</b>	<b>0.25</b>	<b>6</b>	<b>81</b>

**2001**

Site Name	Site Code	Start Date	End Date	Gear	YOY			Elver			Sampling Days
					Total	CPUE	Max.	Total	CPUE	Max.	
Clark's Millpond	CM	16-Mar-01	12-May-01	Irish Eel Ramp	4	0.07	1	205	3.60	23	57
Gardy's Millpond	GA	12-Mar-01	12-May-01	Irish Eel Ramp	729	11.95	499	624	10.23	89	61
<b>Potomac River 2001 Overall Summary</b>					<b>733</b>	<b>6.21</b>	<b>499</b>	<b>829</b>	<b>7.03</b>	<b>89</b>	<b>118</b>

**2002**

Site Name	Site Code	Start Date	End Date	Gear	YOY			Elver			Sampling Days
					Total	CPUE	Max.	Total	CPUE	Max.	
Clark's Millpond	CM	9-Mar-02	2-May-02	Irish Eel Ramp	115	2.09	16	90	1.64	9	55
Gardy's Millpond	GA	9-Mar-02	2-May-02	Irish Eel Ramp	129	2.35	51	273	4.96	39	55
<b>Potomac River 2002 Overall Summary</b>					<b>224</b>	<b>2.22</b>	<b>51</b>	<b>363</b>	<b>3.30</b>	<b>39</b>	<b>110</b>

**2003**

Site Name	Site Code	Start Date	End Date	Gear	YOY			Elver			Sampling Days
					Total	CPUE	Max.	Total	CPUE	Max.	
Clark's Millpond	CM	11-Mar-03	16-May-03	Irish Eel Ramp	24	0.36	4	225	3.41	49	66
Gardy's Millpond	GA	11-Mar-03	16-May-03	Irish Eel Ramp	71	1.08	12	300	4.55	41	66
<b>Potomac River 2003 Overall Summary</b>					<b>95</b>	<b>0.72</b>	<b>12</b>	<b>525</b>	<b>3.98</b>	<b>49</b>	<b>132</b>

## Figure List

Figure 1 . Potomac River Sampling Sites.

Figure 2. Irish Ramp at Gardy's Millpond showing its configuration.

Figure 3. Irish Ramp at Clark's Millpond.

Figure 4. Spillway at Gardy's Millpond.

Figure 5. Potomac River CPUE for YOY and Elvers (both sites combined), 2000 - 2003.

Figure 6. YOY and CPUE at Gardy's Millpond for 2003

Figure7. YOY and CPUE at Clarks Millpond for 2003

Figure 8. YOY and Elver CPUE at Gardy's Millpond for 2000-2003

Figure 9. YOY and Elver CPUE at Clark's Millpond for 2000-2003

Figure 10. Physical parameters measured at Clark's and Gardy's Millponds

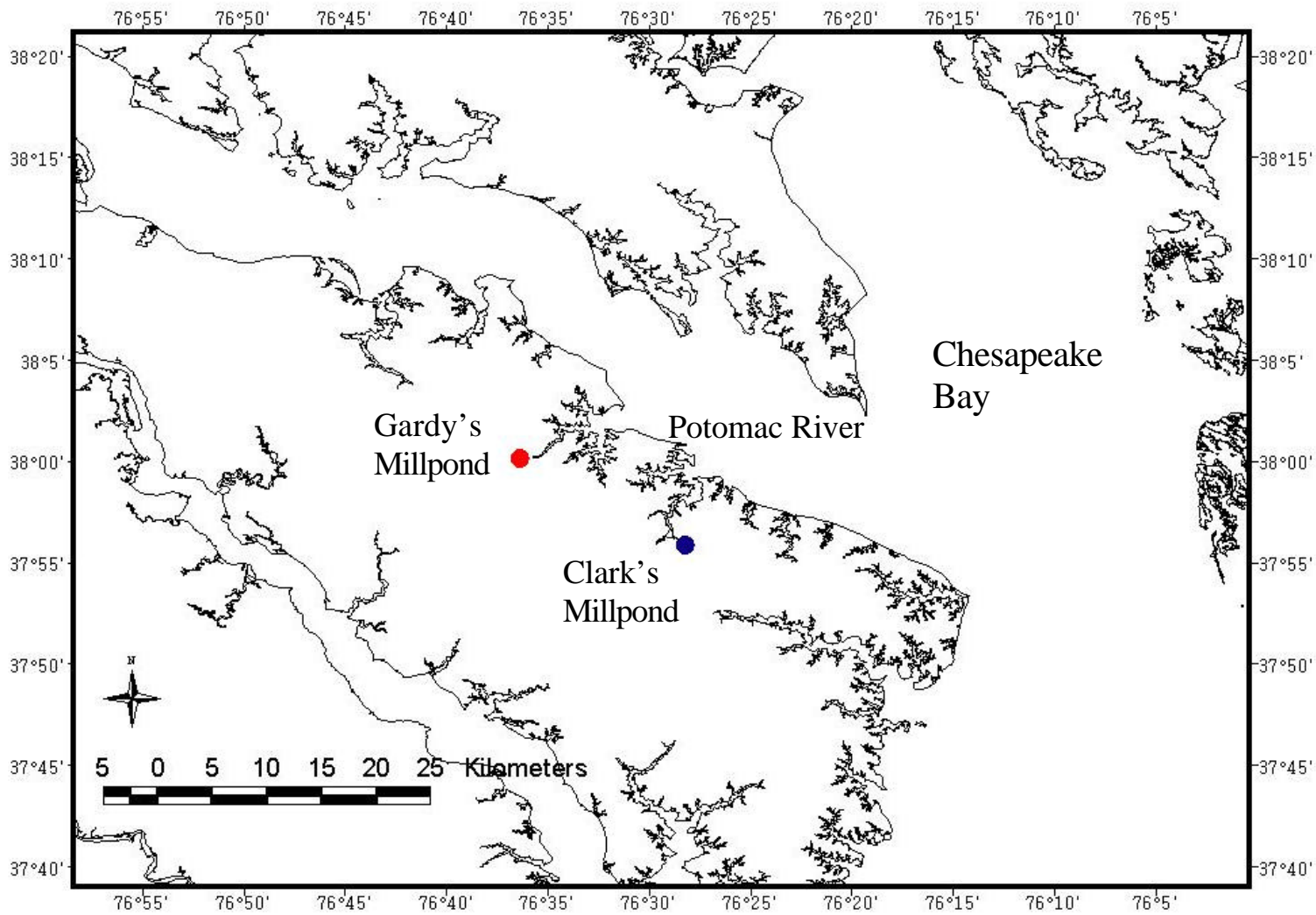


Figure 1. Potomac River Sampling Site in 2003.



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



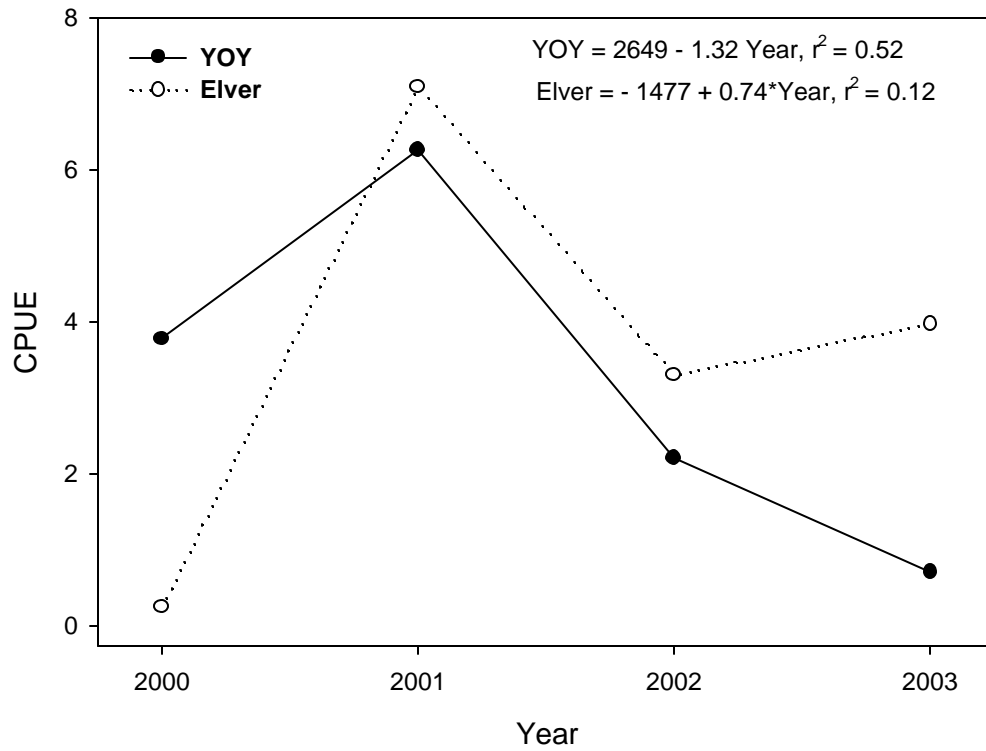


Figure 3. The Irish ramp at Clark's Millpond (Coan River). The green tube in the foreground is the modified ramp extension.



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 for YOY and Elvers (both sites combined) 2000-2003



## Gardy's Millpond Spring 2003

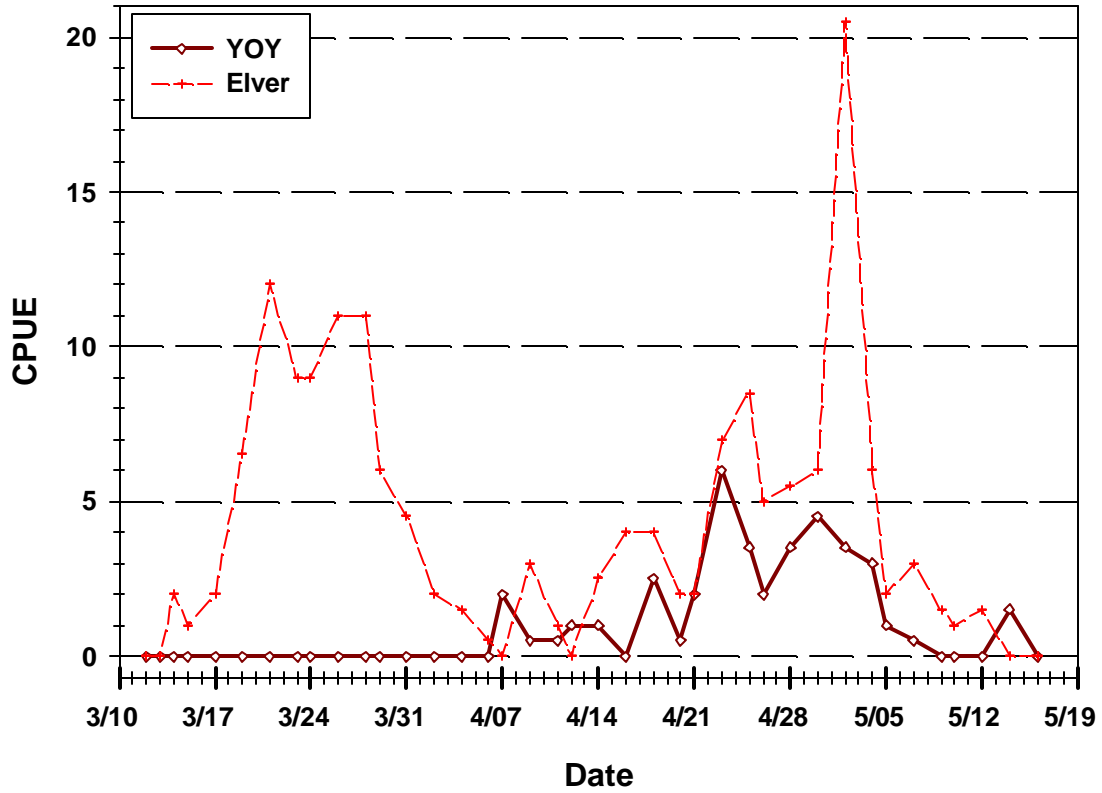


Figure 6. YOY and elver CPUE over time at Gardy's Millpond.

## Clark's Millpond Spring 2003

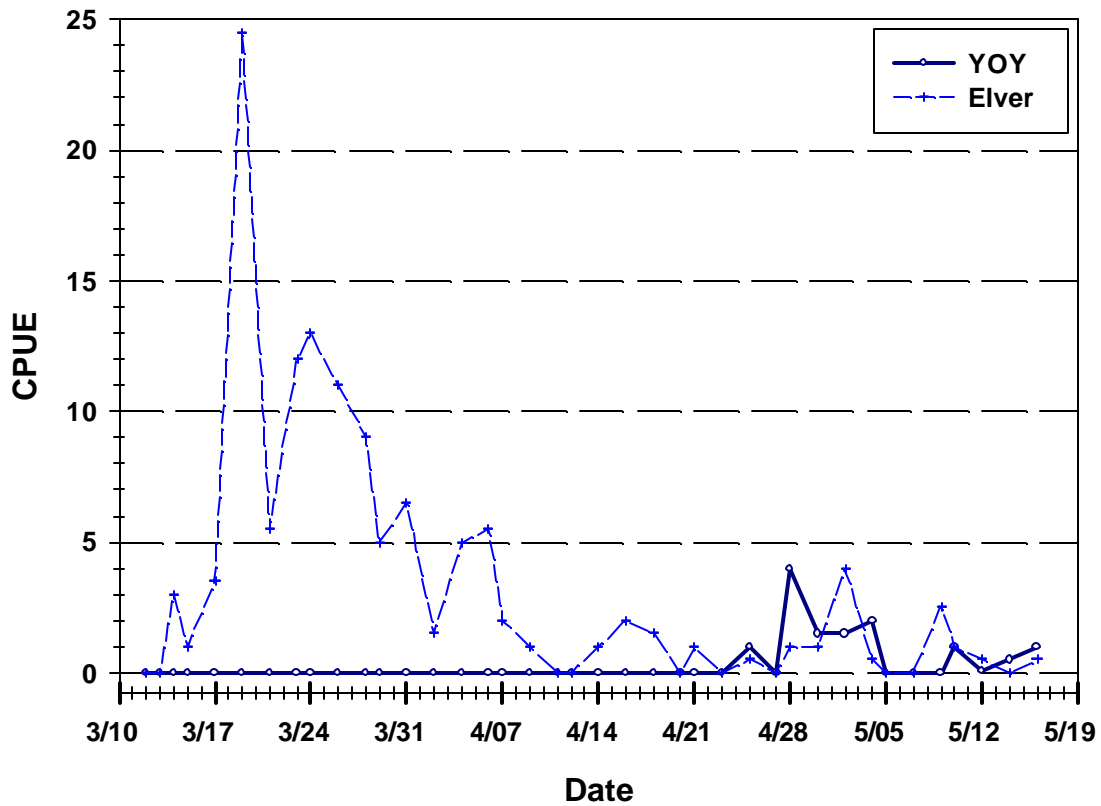


Figure 7. YOY and Elver CPUE over time at Clark's Millpond.

# YOY and Elver CPUE at Gardy's Millpond (2000 - 2003)

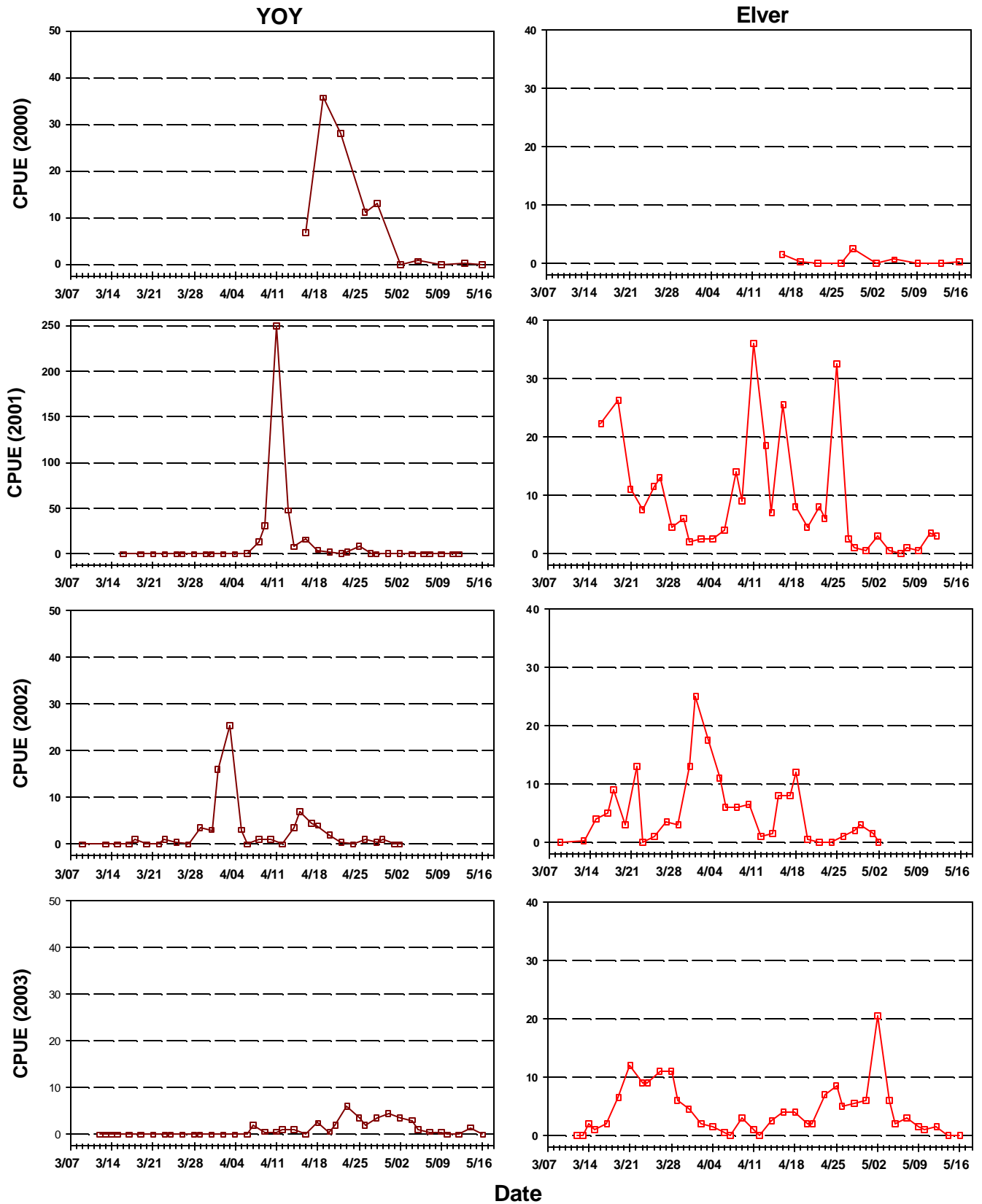


Figure 8. YOY and Elver CPUE over time at Gardy's Millpond for 2000-2003.

## YOY and Elver CPUE at Clark's Millpond (2000 - 2003)

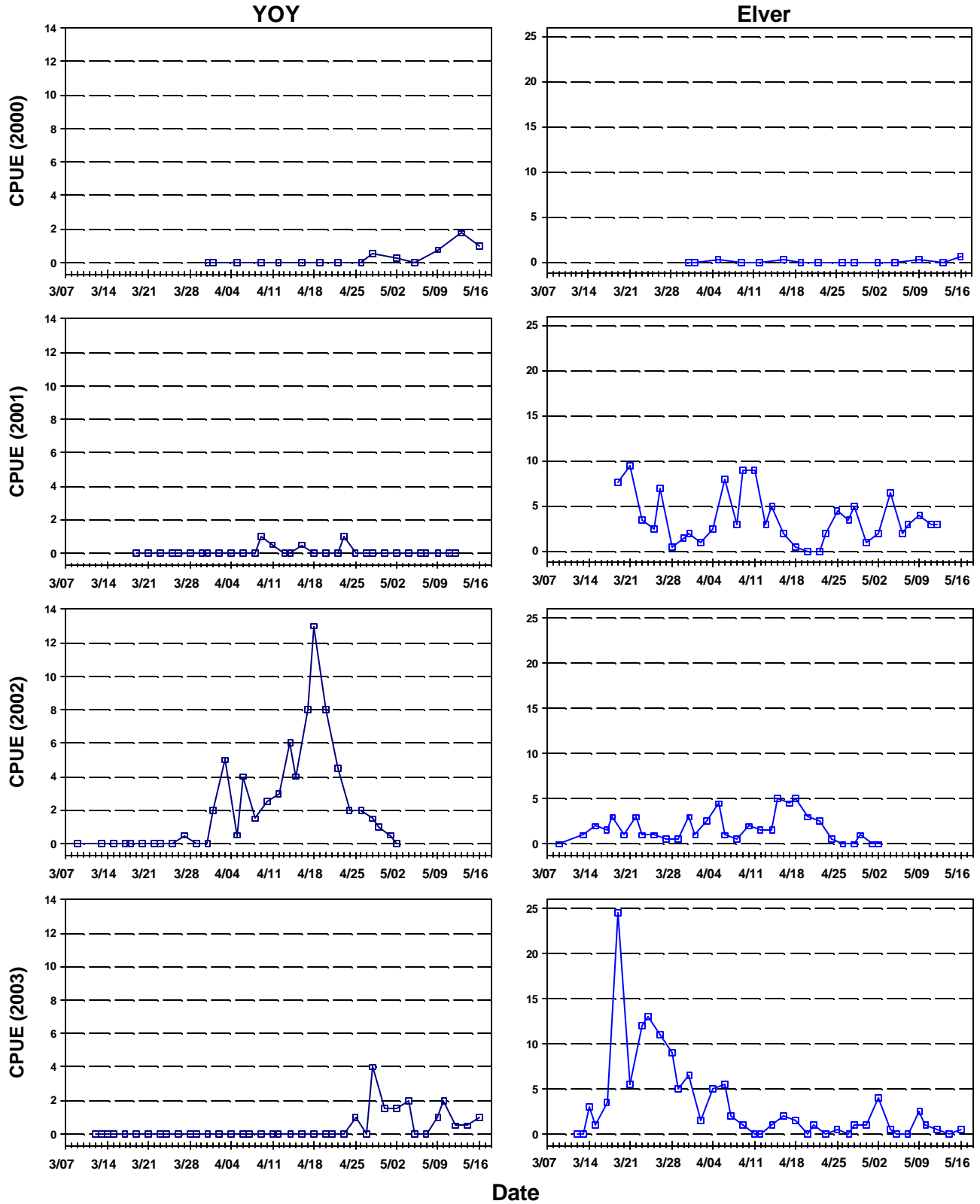


Figure 9. YOY and Elver CPUE over time at Clarks Millpond for 2000-2003

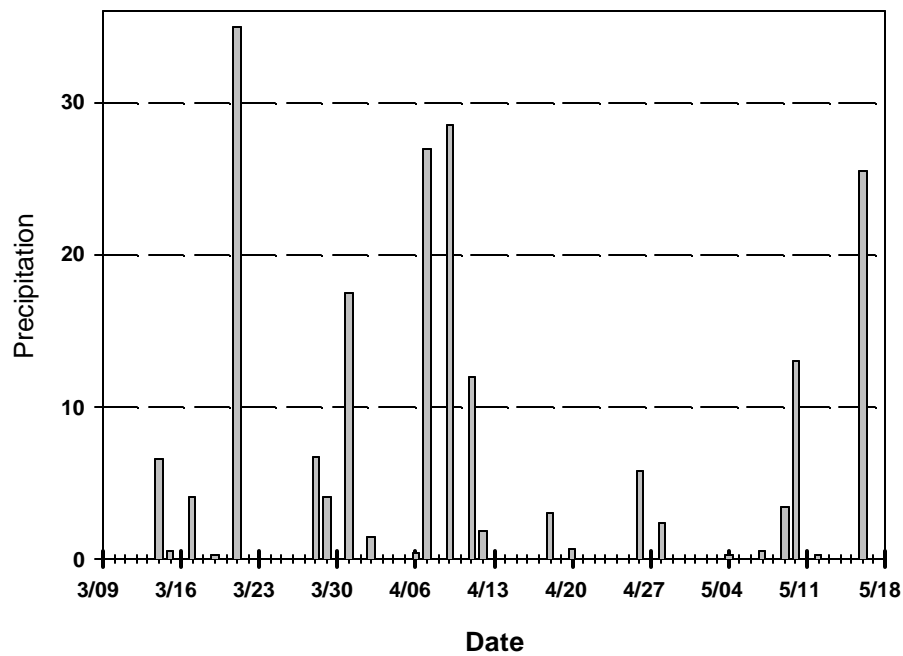
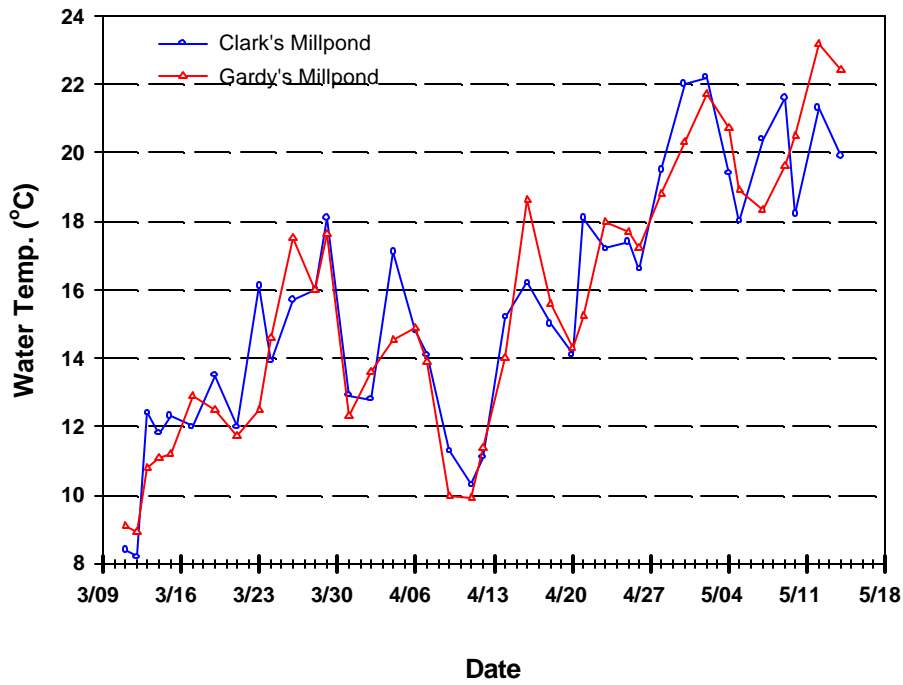


Figure 10. Physical parameters measured at Gardy's and Clark's Millponds. (Note: Precipitation data collected from rain gauge at Gardy's Millpond).