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**Estimating Relative Abundance of Young of Year American Eel,  
*Anguilla rostrata*, in the Virginia Tributaries of Chesapeake Bay.  
Final Report (2003 Reporting Year)**

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**Estimating Relative Abundance of Young of Year American Eel, *Anguilla rostrata*, in the  
Virginia Tributaries of Chesapeake Bay.**

Final Report  
(2003 Reporting Year)

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Submitted to  
Virginia Marine Resources Commission  
Marine Recreational Fishing Advisory Board  
Project # RF03-10

July 30, 2004

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## **Objectives**

1. Monitor the glass eel migration, or run, into the Virginia Chesapeake Bay tributaries to determine the spatial and temporal components of recruitment.
2. Examine the diel, tidal, lunar, and water quality parameters 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 a valuable fisheries management tool. In the Chesapeake Bay, these measures provide reliable indicators for future year class strength for blue crabs (Lipcius and Van Engel, 1990), striped bass (Goodyear, 1985), as well as 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 (Meister and Flag, 1997). Since 1964, Chesapeake Bay eel landings have significantly decreased ( $r^2 = 0.13$ ,  $P = 0.03$ ). 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; Geer, 2003). 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). 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).

Fisheries management techniques often are not 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 methodologies and management efforts. 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 (hereafter referred to as FMP) for the American Eel in November 1999. The FMP focuses on increasing the state's 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 Virginia) 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 the 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 necessary data on coastal recruitment success and further the understanding of American eel population dynamics.

The Virginia Institute of Marine Science's American Eel Monitoring Survey (VIMS AEMS) continued its spring sampling to estimate relative abundance of YOY American eels in Virginia tributaries of Chesapeake Bay. Funding was provided by the VMRC MRFAB and CFAB, which ensured compliance with the 1999 ASMFC Interstate American Eel FMP.

### **Life History**

The American eel is a catadromous species which 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. The eggs hatch into leaf-shaped ribbon-like larvae called leptocephali, which are transported by 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 (or young of year, YOY) into Maryland and Virginia rivers and estuaries from February to June, though they are most common in February and March (Able and Fahay, 1998). As growth continues, the glass 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 10 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**

Minimum criteria for YOY American eel sampling has been established in the ASMFC Eel FMP, with the Technical Committee approving sampling gear. The timing and placement of gear must coincide with those periods of peak 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.

To provide the necessary spatial coverage and to assess suitable locations, numerous sites in Virginia were initially sampled in 2000 (Geer, 2001). Final site selection was based on known areas of glass eel recruitment, accessibility, and specific physical criteria, (*e.g.* suitable habitat), which promote glass eel concentration.

Two sites on the York River were Brackens Pond and Wormley Pond (Figure 1), located within the Colonial National Historical Park (National Park Service). Brackens Pond is located along the Colonial Parkway at the base of the Yorktown Naval Weapon Station Pier. Its proximity to the York River is less than 100 m with the tide often reaching the spillway (Figure 2). Wormley Pond is located on the Yorktown Battlefield grounds, and drains into Wormley Creek which has a tidal range that routinely reaches a depth of 50 cm at the spillway (Figure 3). This site was not sampled in 2000 because the road crossing over the spillway was destroyed by Hurricane Floyd and repairs were not completed until the fall of 2000.

Kamps Millpond is located upstream of Route 790, just north of Kilmarnock, in Lancaster County (Figure 1). The reservoir is approximately 80 acres and drains into the Eastern Branch of the Corrotoman River, tributary to the Rappahannock River (Figures 1 and 4). Warehams Pond is located adjacent to Kingsmill in James City County and drains directly into the James River which is only about 100 m away, though a high tide may reach the end of the spillway (Figures 1 and 5).

Once presence of eels was determined at a site, Irish eel ramps were used to collect eels at all sites (Figure 6). The ramp configuration successfully attracts and captures small eels in tidal waters of Chesapeake Bay. Ramp operation required the continuous flow of water over the climbing substrate and through the collection device. The passive supply of water to the traps through gravity feed required that the water level be at least one foot above the trap than below it, or that water traveling at high velocity be available nearby (Figure 6). Hoses were attached to the ramp and collection buckets with adapters were used to allow for quick removal for collecting. Enkamat<sup>TM</sup> erosion control material on the floor of the ramp 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. Submersion of the ramp entrance was considered undesirable, and as such was placed in shallow water (< 25 cm). These inclines, in combination with the 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. Flow over the textured climbing surface was adjusted to maintain a depth of 5-10 mm.

In addition to the ramps, dip nets (45x21cm, 800  $\mu$ m mesh) were used to provide information on the presence and abundance of eels. Dip nets were deployed by sweeping either a set distance (culverts and other concrete substrates) or a set time of 30 seconds (gravel, mud, and sand bottoms). Once eel recruitment had begun, traps were checked daily on the York River (Wormley and Brackens Ponds) and four days per week (Monday-Wednesday-Friday, and alternating weekend days) on the Rappahannock (Kamps Mill Pond) and James Rivers (Warehams Pond). Only eels found in the ramp's collection bucket (not on the climbing surface) were recorded. Trap performance was rated on a scale of 1 to 4 (1 = 100% efficient, 2 = >50% efficient, 3 = <50% efficient and 4 = not functioning) with water temperature, pH, air temperature, wind direction and speed, and precipitation recorded. Starting in 2002, temperature data loggers were deployed and an hourly water temperature recorded. All eels were enumerated and placed above the impediment, with any subsample information recorded, if applicable. Specimens less than or equal to ~85 mm total length (TL) were classified as "YOY", while those 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). Lengths, weights, and pigment stage (see Haro and Krueger, 1988) were collected from sixty eels weekly from each system. Sampling was conducted from 21 February to 16 May 2003. The previous James River site (Lake Maury) was replaced by Warehams Pond in 2003 due to low catches and the Irish eel trap being continuously swept away.

For analyses, a daily and annual catch per unit effort (CPUE) was established for each site. CPUE for the Irish eel ramp was catch per 24 hours of soak time and were calculated as geometric means. To examine whether a relationship existed between YOY or elver CPUE and lunar stage, we performed ANOVA with lunar stage as the factor and CPUE as the response. Lunar stage was divided into four quarters (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. Tukeys Pairwise comparisons (MINITAB, 1998) were run on the data, if appropriate.

## **Results**

In 2003, 97,655 YOY and 2601 elvers were collected (Table 1). Abundances and CPUE for both YOY and elvers varied over the four years sampled (Tables 1 and 2). Overall abundance of both YOY and elvers decreased through 2002 and then increased in 2003. Most Atlantic Coast states experienced a decrease in CPUE for YOY eels in 2003 (ASMFC, pers. comm.); the overall YOY and elver CPUE for Virginia actually increased from the previous year. Catch statistics by river and site for 2003 show Brackens Pond and Wormley Creek to be the most productive sites (Table 2), similar to previous sampling years (Montane et al., 2003).

In the York River (Brackens and Wormley Ponds combined), YOY decreased from 2002 while the elver CPUE remained the same (Figure 7, top and bottom, respectively). Eel YOY CPUE in the York River continued to decrease at Wormley Pond, but increased in 2003 at Brackens Pond (Figure 8A). Elver CPUE decreased at Brackens Pond from 2000 to 2002, but increased in 2003. Wormley Pond elver CPUE decreased in 2003 (Figure 8B). Eel YOY CPUE at Kamps Millpond decreased while lever CPUE increased in 2003 (Figure 9).

Eel YOY at Wormley Pond were first collected 13 March (Figure 10). A single peak in YOY CPUE occurred 26 March, followed by three minor peaks. YOY were first collected at Brackens Pond on March 4th, with four major peaks occurring 14 March, 26 March, 4 April and 15 April (Figure 10). Unlike previous years, more YOY eels were collected at Brackens Pond than Wormley Pond. Last year, about 1.5 times as many YOY eels were collected at Wormley compared to Brackens Pond (Montane et al., 2003).

Elvers at Wormley Pond were first collected on 26 February, with three major peaks occurring 4 April, 13 April, and 17 April (Figure 11). Elvers were first collected 5 March at Brackens Pond, and increased to a major peak 16 April, and then dropped off (Figure 11). Elver CPUE at Brackens Pond was greater than Wormley Pond in 2003 (Figure 11).

Eel YOY were first collected at Kamps Millpond (Rappahannock River) 14 March with CPUE exhibiting a major peak 3 April and minor peaks 29 March, 15 April, 22 April- 24 April, 30 April and 4 May (Figure 12). Elver CPUE exhibited major peaks early in the survey (14 March, 19 March and 25 March and then decreased thereafter (Figure 12). Eel YOY were first collected at Warehams Pond (James River) 15 March, with CPUE exhibiting a single major peak 19 March and within a week, catches remained low for the rest of the season (Figure 13). Elver CPUE exhibited a single major peak 21 March and was variable thereafter, though few eels were collected (Figure 13).

Lengths of YOY eels measured ranged from 45 – 70 mm TL (Figure 14). The York River, which captured most of the YOY eels, exhibited the widest size range (Figure 14). There was a significant positive relationship between YOY length and weight ( $r^2 = 0.73$ ,  $P < 0.0005$ ; Figure 15). Pigmentation stages of York River glass eels began as mainly stages 1 and 2, progressed to a point (31 March) where only stages 3, 4, and 5 were collected and then nearly all stages except for Stage 7 were collected during the remainder of the study (Figure 16).

During 2003, significantly more YOY were collected at Wormley Pond and Kamps Millpond during the week of the waning moon and the week of the new moon (Kamps only;  $F = 4.03$ ,  $df = 3,81$ ,  $P = 0.010$  and  $F = 5.83$ ,  $df = 3,62$ ,  $P = 0.001$ , respectively). At Warehams Pond, significantly more YOY and elvers were collected during the week of the full moon ( $F = 5.55$ ,  $df = 3,60$ ,  $P = 0.002$  and  $F = 7.32$ ,  $df = 3,62$ ,  $P < 0.0005$ , respectively). When the data are log transformed, significantly less elvers were collected at Wormley Pond during the week of the full moon than the other three lunar quarters ( $F = 3.15$ ,  $df = 3,81$ ,  $P = 0.029$ ). Significantly more YOY were collected at Brackens Pond during the week of the waxing moon than the week of the waning moon ( $F = 4.93 = 3,76$ ,  $P = 0.003$ ). Significantly less YOY were collected at Kamps Millpond during the week of the waxing moon than the other three lunar quarters ( $F = 3.15$ ,  $df = 3,81$ ,  $P = 0.029$ ). ). At Warehams Pond, significantly more YOY and elvers were collected during the week of the full moon ( $F = 14.29$ ,  $df = 3,60$ ,  $P = 0.0005$  and  $F = 12.03$ ,  $df = 3,62$ ,  $P < 0.0005$ , respectively) than the other lunar quarters. Lunar effects on YOY and elver recruitment vary in this study. For example, at Brackens Pond, dramatic spikes in YOY recruitment occurred after the waxing, waning and full moons, though the spikes occurred 12, 7 and 12 days apart (Figure 17, top). Highest elver recruitment occurred during the full moon (Figure 17,

bottom). Brackens Pond YOY CPUE (log transformed) significantly increased with increasing water temperature ( $r^2 = 0.14$ ,  $P = 0.001$ ). Warehams Pond YOY and elver CPUE and Kamps Millpond elver CPUE (all log-transformed) significantly decreased with increasing water temperature ( $r^2 = 0.15$ ,  $P = 0.002$ ;  $r^2 = 0.14$ ,  $P = 0.002$  and  $r^2 = 0.10$ ,  $P = 0.011$ ).

## **Discussion**

The continued high recruitment at Brackens Pond and Wormley Pond since 2001 indicates that the criteria for YOY sampling sites, based on ASMFC guidelines, were valid. Many of the sites previously visited may have historically provided good eel runs, but destruction of habitat in and around these millponds may have restricted recruitment. With some ingenuity, sites that appear to be marginal for eel recruitment with the Irish eel ramp may prove successful. The run appears to be highly variable from year to year (as is suspected); thus a very productive site one year may be unproductive in future years, and vice versa. Successful sites and gears have been identified, and with consistent funding, the ASMFC sampling requirements should be easily achieved in future years.

Air and water temperature can significantly affect eel YOY catches (Brooks et al., 2002). During 2002, as temperature increased, CPUE decreased (Montane et al., 2003). In 2003, increased water temperature resulted in both increased and decreased catches of YOY and elvers. However, this may be more of a temporal factor as elver “runs” usually occur toward the beginning of the surveys. At most sites during 2003, eels were collected throughout the duration of the study, once they began to recruit.

Lunar effects on YOY and elver recruitment vary in this study, but this variability occurs in other Virginia rivers as well (Montane et al., 2004), and may be related to the proximity of the traps to the larger adjacent river systems.

## **Conclusions and Recommendations**

- Irish eel ramps are a passive gear that continue to be an efficient, and cost and time-effective gear

for sampling in coastal Virginia. Drainages with high densities of eels (perhaps identified from other surveys) could be targeted for YOY sampling. Sites in these drainages may have as yet unquantified characteristics which make them particularly attractive to immigrating YOY.

- Sampling should continue at the primary sites on the York, James and Rappahannock Rivers.
- Sampling should start at least as early as the previous year and continue later, if necessary. Given the great variability associated with spring temperatures in the Chesapeake Bay region, sampling must be over a wide water temperature range to ensure that sampling occurs at optimal temperature regimes.
- Dip netting may be an expedient way to determine the presence or absence of eels and act as a barometer indicating when passive gear (Irish eel ramp) should be deployed.
- The ultimate goal of this survey is to provide annual estimates of recruitment for YOY eels and elvers. Considering the unique nature of each site, and the performance variability of the sampling gear at these sites, it may be necessary to develop an "index" for each site. Parameters such as pond 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 may then be used to weigh the catch rates at each site to provide an overall estimate of juvenile eel recruitment.

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Table 1. Eel abundance for 2000-2003 sampling seasons. CPUE is shown as catch per 24 hours of soak time.

Year	YOY		Elver		Sites	Sampling Days
	Total	Max.	Total	Max.		
2000	61,346	8,025	536	99	BP, KM	95
2001	138,630	19,205	727	70	BP, WC, KM, LM	270
2002	50,252	5,490	632	37	BP, WC, KM, LM	242
2003	97,655	10,937	2,601	360	BP, WC, KM, WA	293

Table 2. Catch statistics by site for 2000-2003. CPUE is catch per 24 hours of soak time and is calculated as a geometric mean.

Yr.	Brackens & Wormley YOY	Brackens & Wormley Elver	Brackens YOY	Brackens Elver	Wormley YOY	Wormley Elver	Kamps YOY	Kamps Elver	Warehams YOY	Warehams Elver
2000	136.83	3.95	136.83	3.95	*	*	2.54	1.12	*	*
2001	88.92	2.14	124.72	2.19	55.17	2.07	11.35	3.36	*	*
2002	79.37	2.31	63.63	1.50	96.43	3.37	45.65	3.46	*	*
2003	40.88	2.31	86.71	2.78	19.80	1.94	15.71	12.78	7.41	1.59



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Figure 3. Wormley Creek spillway.

Figure 4. Kamp's Millpond spillway and tailrace.

Figure 5. Warehams Pond spillway.

Figure 6. The Irish eel ramp showing its configuration. The arrows indicate the flow of water as well as eel movement.

Figure 7. Mean Eel YOY and Elver CPUE (2000-2003) for Brackens Pond and Wormley Creek, combined.

Figure 8. Mean Eel YOY and Elver CPUE for Brackens Pond and Wormley Creek (2000-2003).

Figure 9. Mean Eel YOY and Elver CPUE for Kamps Millpond (2000-2003) and Warehams Pond (2003).

Figure 10. Daily York River YOY CPUE, Spring 2003, by site.

Figure 11. Daily York River Elver CPUE, Spring 2003, by site.

Figure 12. Daily Rappahannock River YOY and Elver CPUE, Spring 2003, by site.

Figure 13. Daily James River YOY and Elver CPUE, by site.

Figure 14. Glass eel length frequency for 2003, by river.

Figure 15. Linear regression of weight vs. length YOY eels collected in 2003.

Figure 16. Frequency of York River pigmentation stages over the course of the study.

Figure 17. YOY and Elver CPUE at Brackens Pond vs. Lunar Phase.

Figure 1. 2003 American Eel Sampling Sites

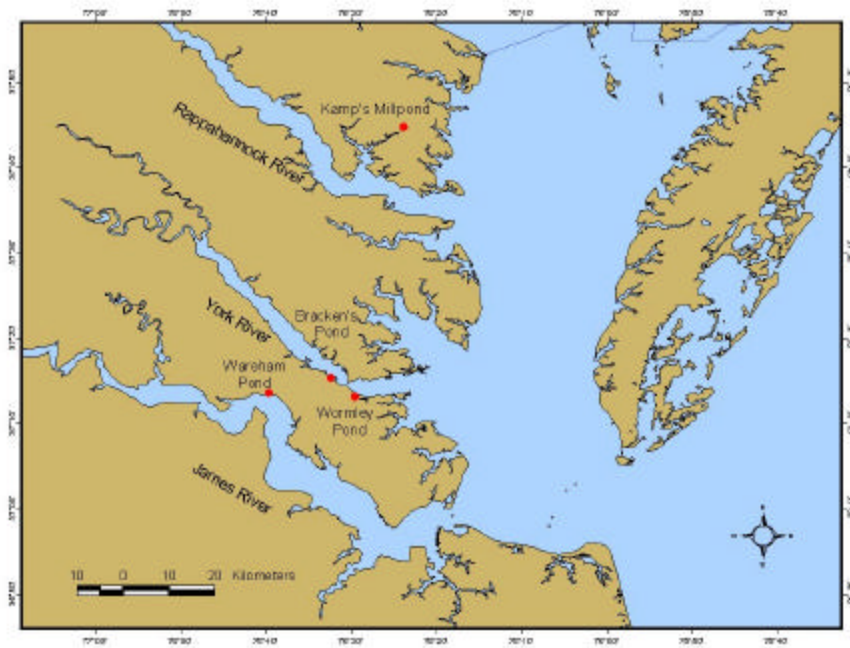


Figure 2. Brackens Pond spillway and tailrace. Irish ramp was set against the right wall on upstream end of culvert.



Figure 3. Bridge over Wormley Creek with Wormley Pond in background. Irish ramp was set under upstream edge of bridge at the base of the dam.



Figure 4. View of Kamp's Millpond spillway and tailrace. Irish ramp is on far side of creek

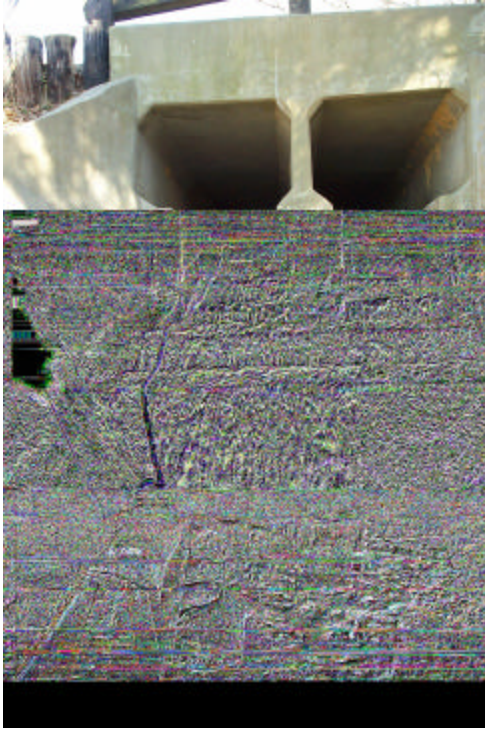


Figure 5. Warehams Pond spillway and tailrace. Irish ramp is in the f

Figure 6. An Irish eel ramp showing its configuration. The arrows indicate the flow of water as well as eel movement.



Figure 7. VIMS AEMS (A) Eel YOY and (B) Elver CPUE for Brackens Pond and Wormley Creek (York River, VA) combined, 2000-2003.

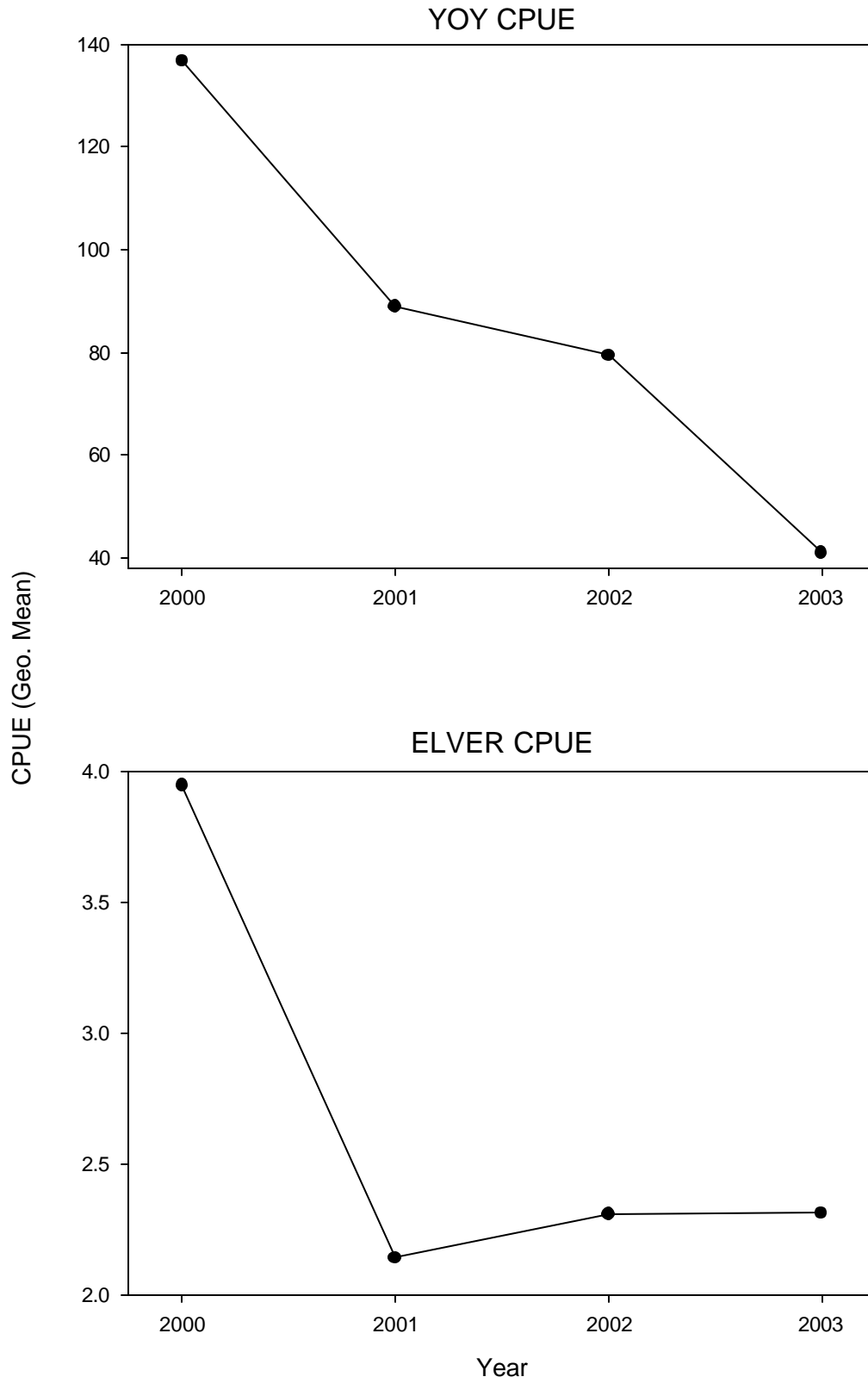


Figure 8. VIMS AEMS (A) Eel YOY and (B) Elver CPUE for Brackens Pond and Wormley Creek (York River, VA), 2000-2003.

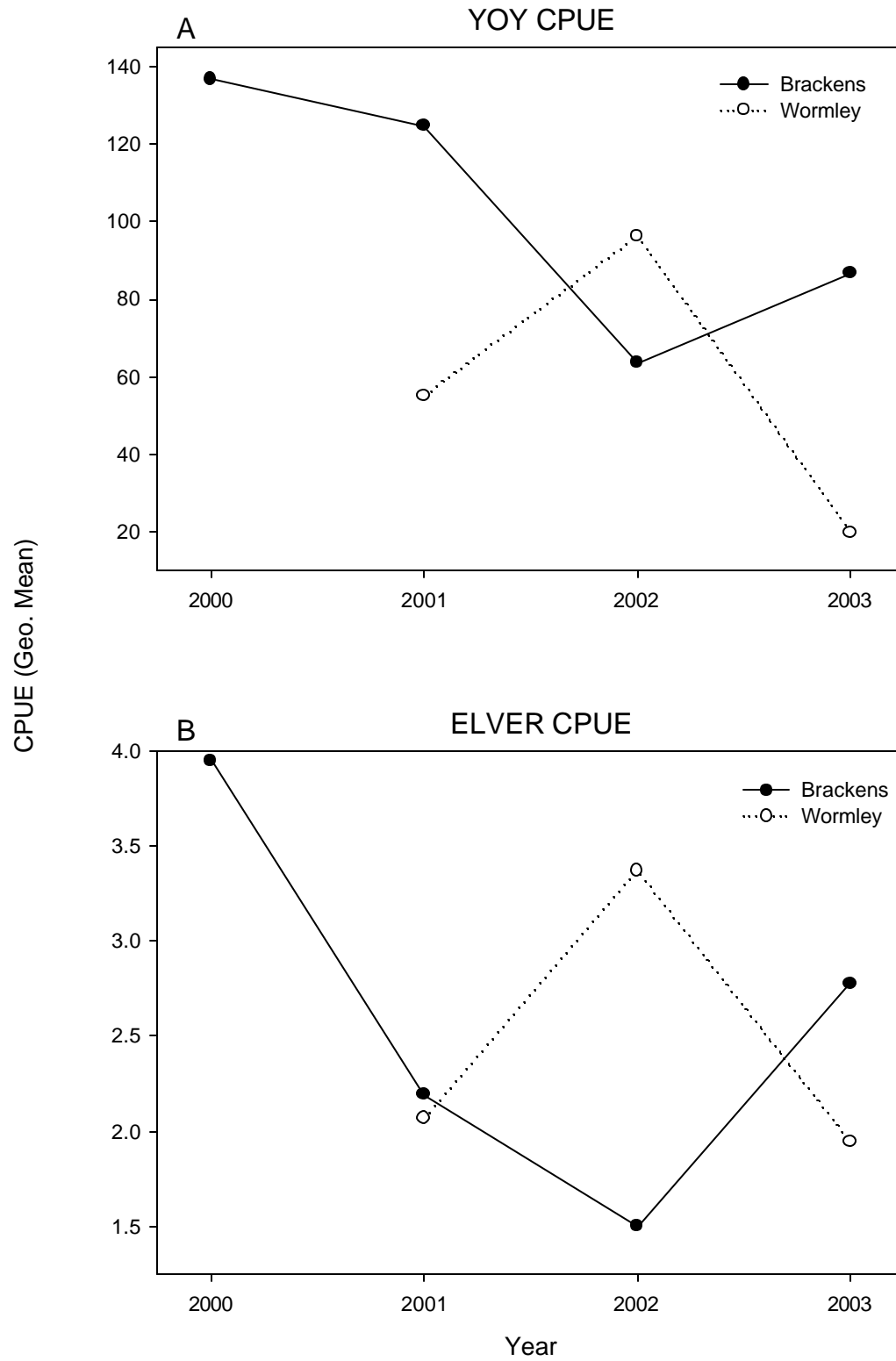


Figure 9. VIMS AEMS Eel YOY and Elver CPUE for Kamps Millpond (Rappahannock River, VA), 2000-2003 and Warehams Pond (James River, VA), 2003.

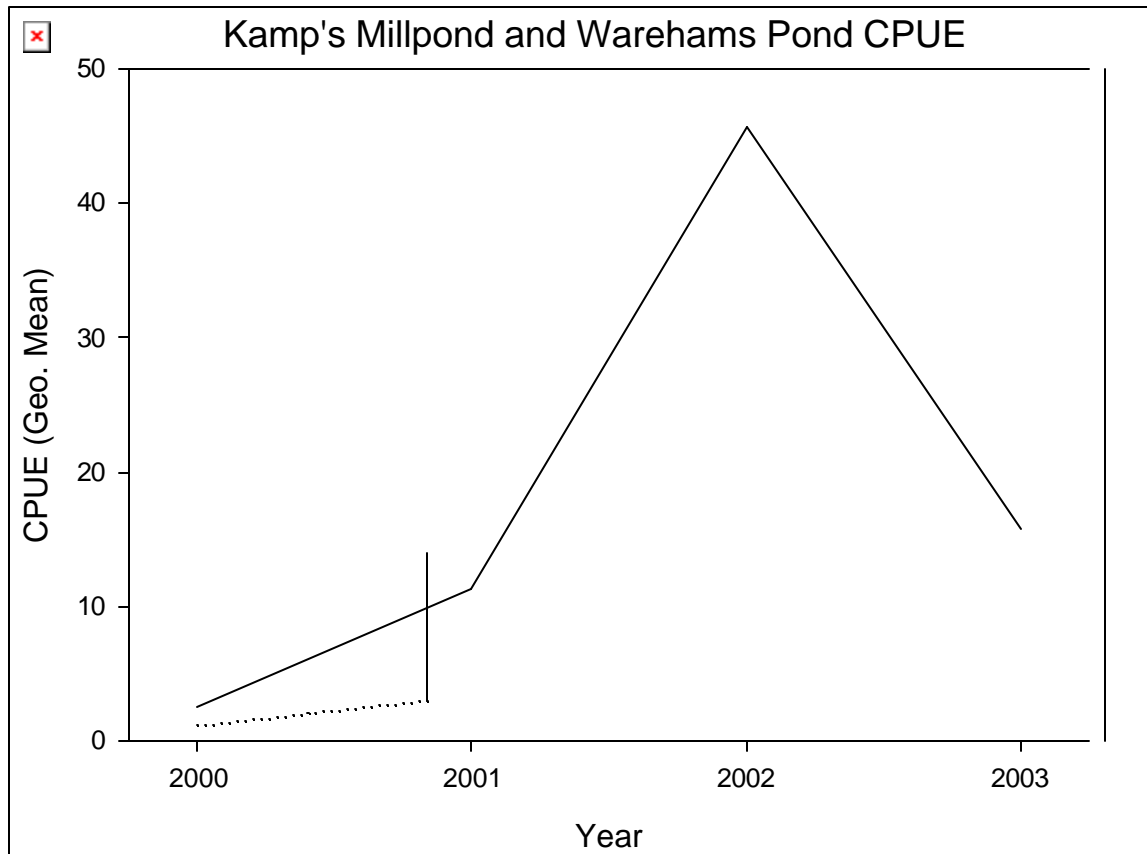


Figure 10. York River Eel YOY CPUE, for duration of study, by site (Spring 2003).

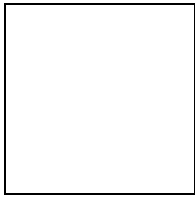
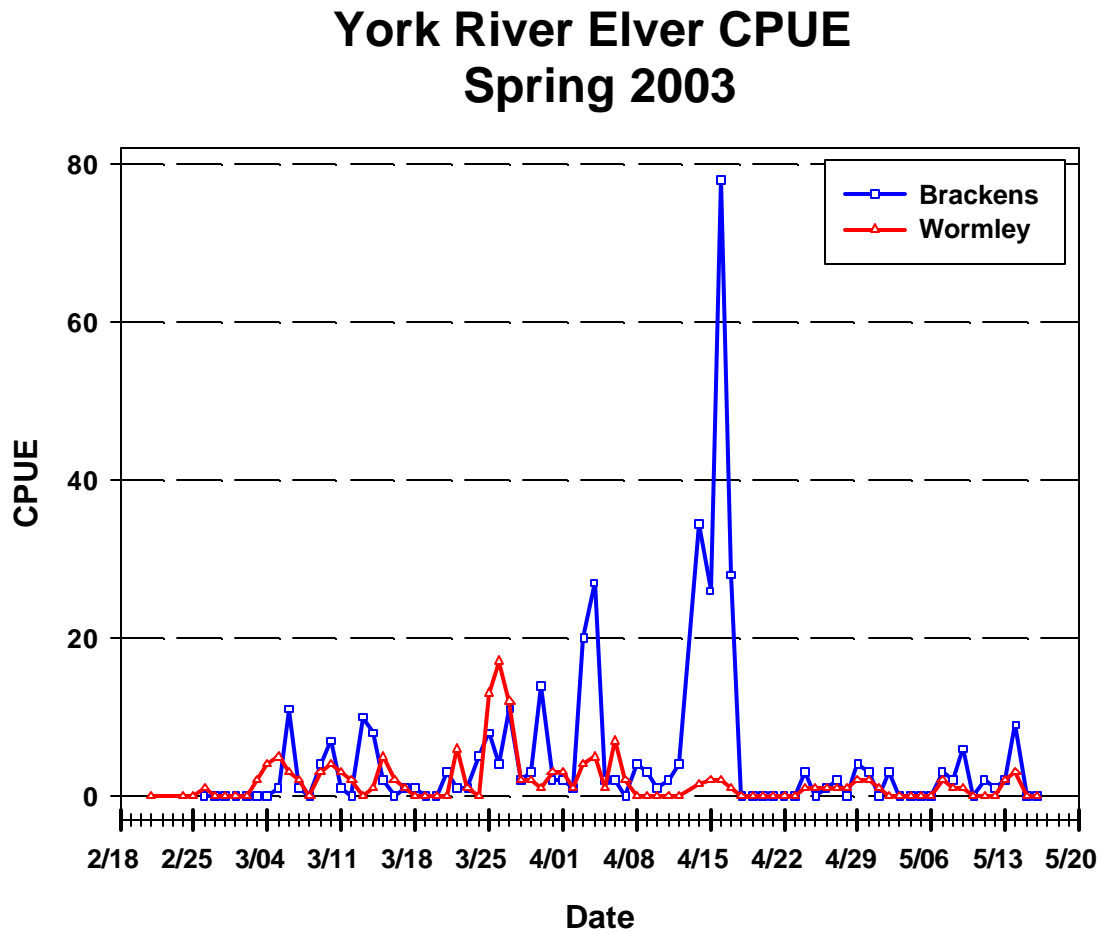




Figure 11. York River Eel Elver CPUE for duration of study, by site (Spring 2003).



## Rappahannock River (Kamp's Millpond) CPUE Spring 2003

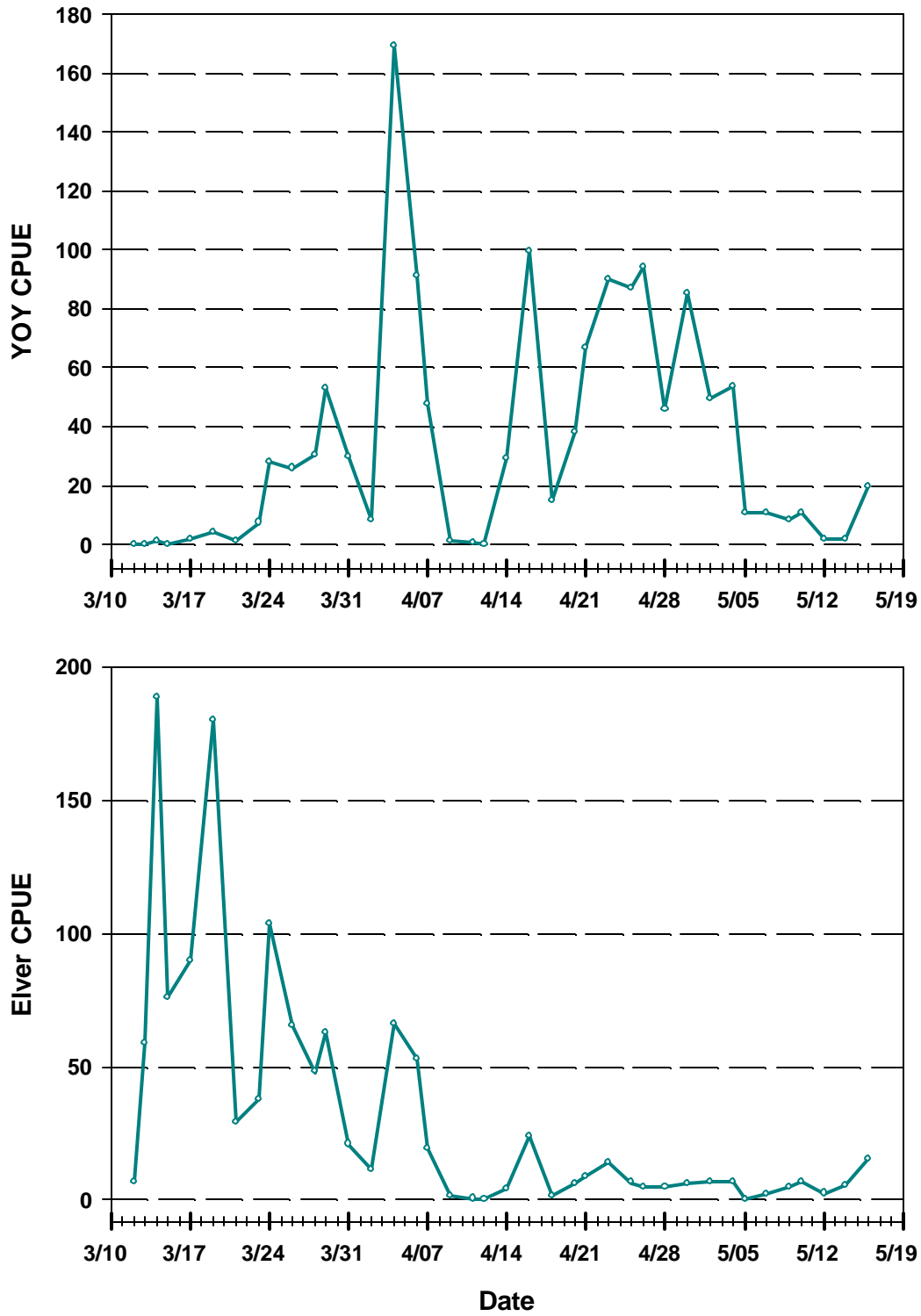


Figure 12. Rappahannock River Eel YOY and Elver CPUE for duration of study (Spring 2003).

## James River (Warehams Pond) CPUE Spring 2003

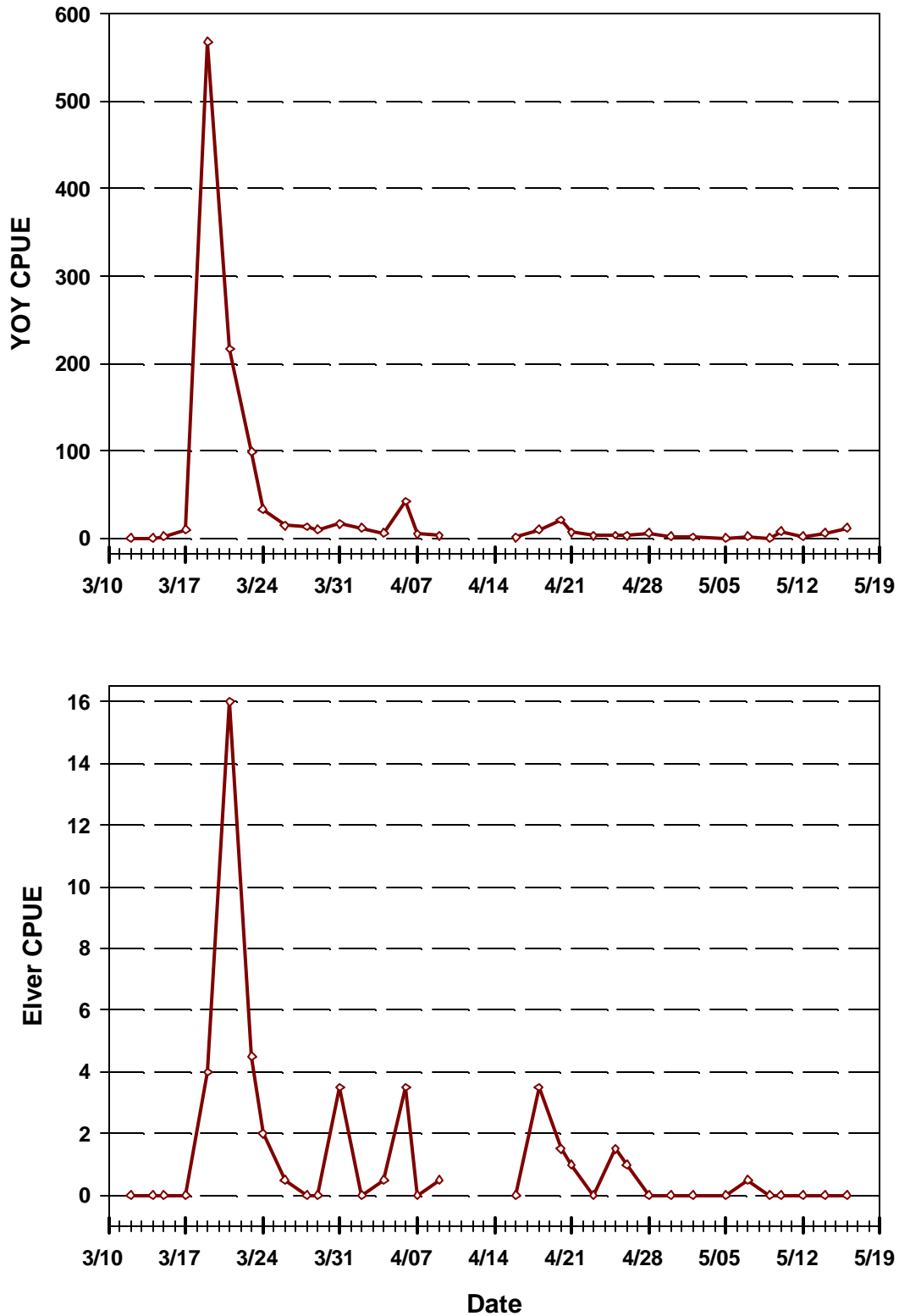


Figure 13. James River Eel YOY and Elver CPUE for duration of study (Spring 2003).

Figure 14. Glass eel length frequency.

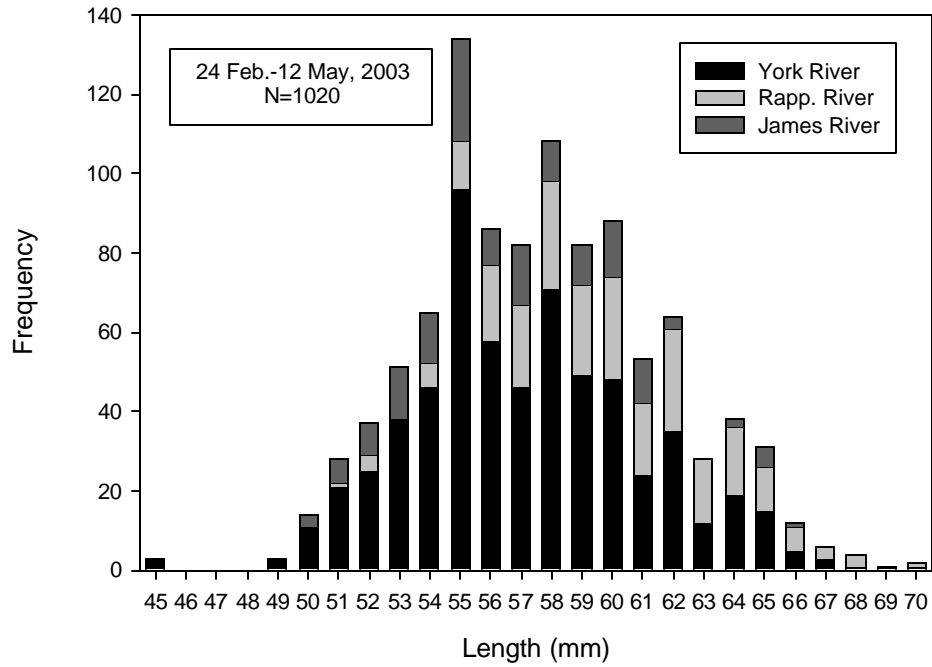


Figure 15. Linear regression of weight vs. length for glass eels.

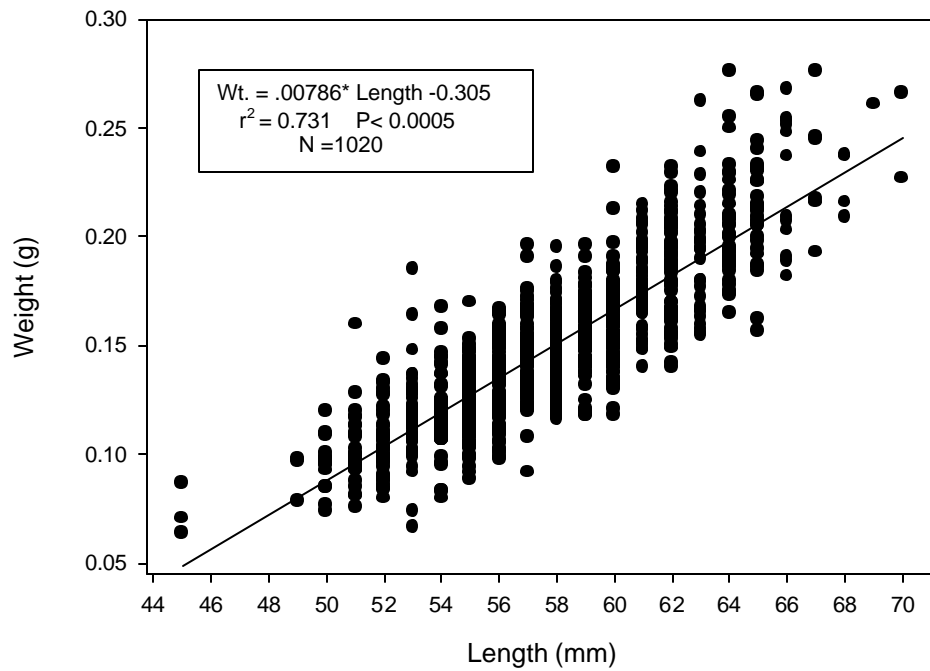


Figure 16. Pigmentation stages of York River glass eels during the 2003 survey.

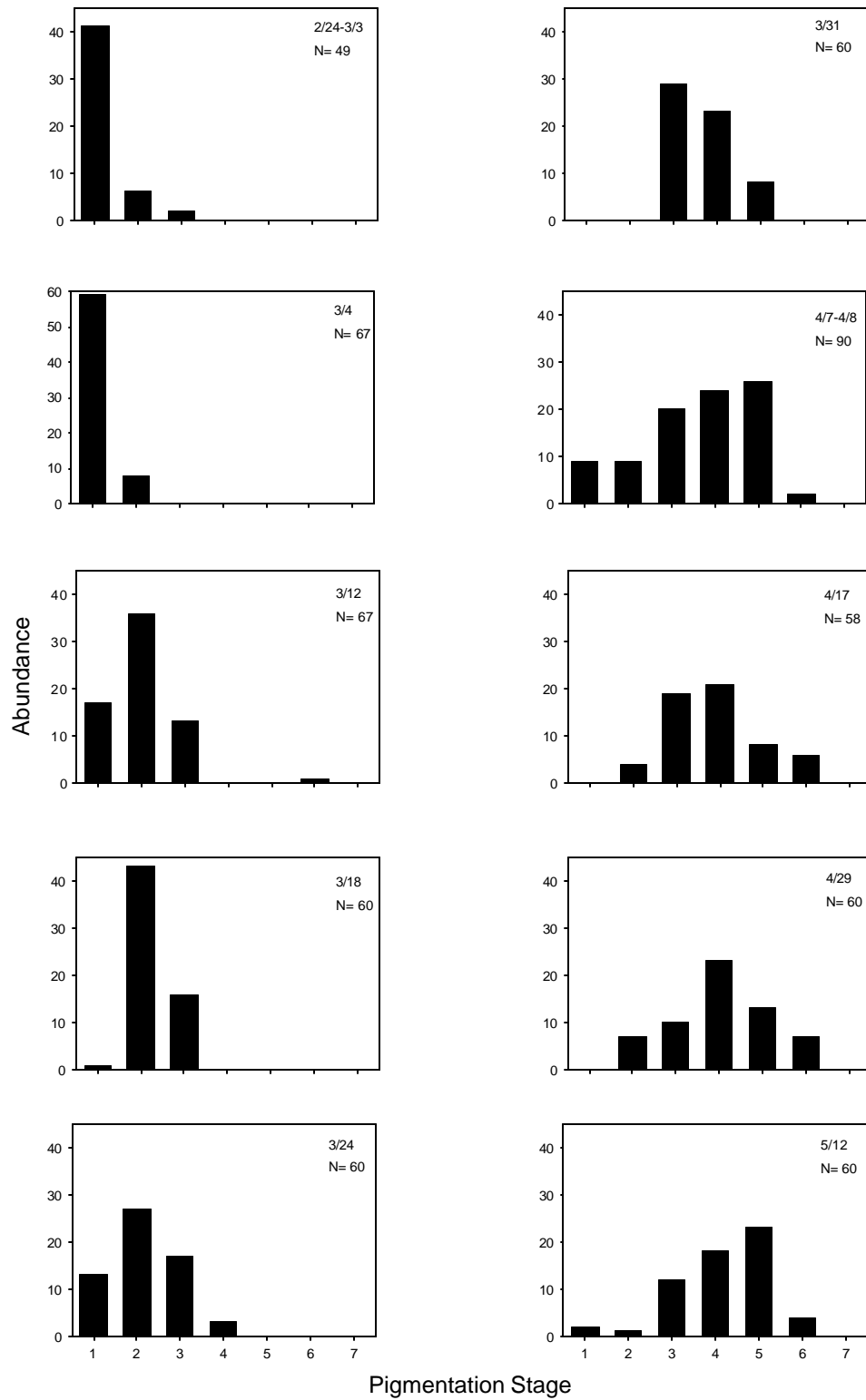


Figure 17. YOY and Elver CPUE at Brackens Pond vs. Lunar Phase.

