Monitoring relative abundance of Young of Year American Eel, *Anguilla rostrata,* in the Virginia tributaries of Chesapeake Bay

By

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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. Evaluate various gears and methods of collecting glass eels to determine the most effective and efficient sampling method.

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

4. Collect basic biological information on recruiting eels to include 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 Flagg, 1997). Since 1964, Chesapeake Bay 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). 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 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 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 spawning grounds of the Sargasso Sea.

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 states' efforts to collect data on the resource and the fishery it supports through both fishery dependent and 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.

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 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 10 years old (Owens and Geer, in press). *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.

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. A minimum of 60 specimens must be collected for length, weight, and pigment stage information weekly.

Due to the importance of the eel fishery in Virginia and the Chesapeake Bay, 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 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 recruitment. During the 2002 sampling season, sampling was conducted daily on the York River (Brackens and

Wormley Ponds) and four days a week on the Rappahannock R. (Kamps Millpond) and the James R. (Lake Maury).

The two sites on the York River were Brackens Pond and Wormley Pond (Figure 1). Brackens Pond is located along the Colonial Parkway at the base of the Yorktown Naval Weapon Station Pier (Figure 2). Its proximity to the York River is less than 100 m with the tide often reaching the spillway. 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 could not be 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 4). The reservoir is approximately 80 acres and drains into the Eastern Branch of the Corrotoman River, tributary to the Rappahannock River. Lake Maury provided an ideal location immediately adjacent to the James River (Figures 1 and 5). Sampling with an Irish ramp was attempted in 2001. However, the lake level was dropped nearly two meters by the Virginia Department of Transportation to conduct road repairs which made it difficult to obtain the proper flow for the Irish ramp.

Once presence of eels was determined at a site, sampling began. 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 considerably higher 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^{TM} 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^{o}), 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 angles, in combination with the 4^{o} angle of the substrate inside the ramp, provided sufficient slope to create attractant

flow. A hinged lid provided access for cleaning and for flow adjustments. Flow over the textured climbing surface was adjusted to maintain a depth of 5-10 mm.

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 Rappahannock R. (Kamps Mill Pond) and James R. (Lake Maury). 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 = good, 4 = not functioning) with water temperature, salinity, pH, air temperature, wind direction and speed, and precipitation recorded during most site visits. 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'. This corresponded to the observation of two distinct modes in the 2000 length frequencies, which likely reflects differing year classes (Geer, 2001). Lengths, weights, and pigment stage (according to Haro and Krueger, 1988) were collected from sixty eels weekly from each system. In addition to the ramps, dip nets (45x21cm, 800 *u*m mesh) were used to provide information on the eel presence.

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. 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 full moon starting on the day of the full moon and (4) the week of the waning moon.

Results

Thus far, three years of juvenile eel data have been collected in Virginia. The eel YOY CPUE decreased in the York River at both Brackens and Wormley Ponds, while at Kamps Millpond, the YOY CPUE increased (Table 1; Figure 7A and 7B). Elver CPUE decreased at Brackens Pond over the past three years, but increased at Wormley Pond

over the past two (Table 1; Figure 8A). Elver CPUE increased at both Kamps Millpond and Lake Maury (Table 1; Figure 8B).

Eel YOY at Wormley Pond were first collected on February 22nd (Figure 9). Three major peaks in YOY CPUE were found during March 9th through March 19th, with smaller peaks occurring before (February 24th) and after (March 21st and April 3rd) that period (Figure 9). YOY were first collected at Brackens Pond on March 4th, with most of the YOY collected during March (Figure 9). About 4 times as many YOY were collected at Wormley compared to Brackens Pond (Table 1).

Elvers at Wormley Pond were first collected on February 20th, with high abundances collected through March 18th, and except for a minor peak April 4th, remained low (CPUE less than 5) for the rest of the survey (Figure 10). Elver CPUE at Brackens Pond was always less than 5, except for March 24th and March 26th (Figure 10). About 6 times as many elvers were collected at Wormley compared to Brackens Pond (Figure 10 and Table 1).

Eel YOY were first collected at Kamps Millpond March 15th with CPUE exhibiting a single major peak around March 27th (Figure 11). Elver CPUE exhibited greater variability with three major peaks (March 17th March 28th and April 17th; Figure 11). Eel YOY were first collected at Lake Maury March 10th, with CPUE exhibiting a single major peak at that time, followed by two minor peaks around March 17th and March 20th (Figure 12). Elver CPUE exhibited a single major peak April 14th preceded by two minor peaks (March 18th and March 30th ; Figure 12), though few eels were collected.

Lengths of YOY measured ranged from 50 – 69 mm TL (Figure 13A). The York River, which captured 77.5 % of the YOY, exhibited the widest size range (Figure 13A). There was a significant positive relationship between YOY length and weight ($r^2 = 0.56$, $P < 0.0005$; Figure 13B). Pigmentation stages of York River glass eels began as mainly stages 2 and 3, progressed to later stages (stages 4, 5, and 6) two to four weeks later and then returned to mainly stages 1 and 2 (Figure 14). There were nearly significant trends between lunar quarter and elver CPUE at Wormley Pond, with the week of the waning moon having greater CPUE than the other three categories ($F = 2.20$; $df = 3, 65$; $P = 0.097$).

Wormley YOY CPUE was significantly negatively related to both water and air temperature ($r^2 = 0.09$; $P = 0.021$ and $r^2 = 0.08$; $P = 0.035$, respectively), as was elver CPUE ($r^2 = 0.18$; $P = 0.001$ and $r^2 = 0.12$; $P = 0.009$, respectively). Brackens YOY CPUE was also significantly negatively related to water temperature ($r^2 = 0.08$; $P = 0.044$).

Discussion

The high recruitment at Brackens Pond and Wormley Pond the past two years indicates that the criteria for YOY sampling sites, which were derived by VIMS and MDNR personnel based on ASMFC guidelines, were valid. Unfortunately, finding suitable sites is often difficult, especially after Hurricane Floyd had destroyed many of the existing sites in September 1999. Many of the sites visited in 2000 and 2001 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.

The shallow fast moving water of the culvert at Kamps Millpond presented some difficulties in maintaining flow over the ramp in 2001. However, a modification to the intake hose corrected the problem. Additionally, extremely strong flow rates occur at Lake Maury especially after heavy rains, such that the entire eel ramp is displaced. This occurs frequently throughout the sampling period, and may be cause for future elimination of this site.

Air and water temperature can significantly affect eel YOY catches (Brooks et al., 2002). During 2002, as temperature increased, CPUE decreased. However, this may be more of a temporal factor as elver "runs" usually occur toward the beginning of the surveys.

Conclusions and Recommendations

- Irish eel ramps continue to be an effective gear in coastal Virginia. This passive gear appears to be cost and time-effective for sampling Virginia waters. 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 (Wormley, Brackens, and Kamps), though sampling at Lake Maury (James River) may need to be re-evaluated due to the low, sporadic catches observed, and frequent movement of the trap via the strong water currents in the spillway outflow.
- 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 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.

Literature Cited

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

Brooks, H., M. T. Mathes and M. M. Montane. 2002. Evaluating recruitment of American eel, *Anguilla rostrata,* to the Potomac River-Spring 2002. Report to Potomac River Fisheries Commission. 22 pp.

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.

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

Geer, P.J. *In press*. Distribution, relative abundance, and habitat preferences of American eel, (Anguilla rostrata) in the Virginia portion of Chesapeake Bay. Pages XXX-XXX *In* D. A. Dixon (Editor), Biology, Management and Protection of Catadromous Eels. American Fisheries Society Symposium Series 33, Bethesda, MD, USA.

Geer, P.J., and H.M. Austin. 1996. 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.

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

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. 1998. Pigmentation, size and migration of elvers, *Anguilla rostrata* (Lesuer), in a coastal Rhode Island stream. Can. Journal of Zoology. 66:2528-2533.

Hedgepeth, M. Y. 1983. Age, growth and reproduction of American eels, *Anguilla rostrata* (Lesuer), from the Chesapeake Bay Area. Masters Thesis. College of William and Mary. 61 pp.

Lipcius, R.N. and W.A. Van Engel. 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 eastern North America. Focus 22(l): 25-26

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.

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 the Paq'tnkek Fish and Wildlife Society.

van Montfrans, J., C. E. Epifanio, D. M. Knott, R. N. Lipcius, D. J. Mense, K. S. Metcalf, E. J. Olmi 111, R. J. Orth, M. H. Posey, E. L. Wenner and T. L. West. Settlement of blue crab postlarvae in Western North Atlantic Estuaries. Bull. Mar. Sci. 57(3):834-854.

Table 1. CPUE for YOY and Elvers by site, 2000-2002.

2002

River	Site Name	Site	Start Date	End Date	Total	CPUE	Max.	Total	CPUE	Max.	Sampling Events
					Young of Year			Elvers			
York	Brackens Pond	BP	1-Mar-02	3-May-02	7,413	117.67	487	52	0.83	6	63
	Wormley Pond	WC	20-Feb-02	3-May-02	31,518	443.92	5,490	315	4.44	37	71
	System Summary				38,931	290.53	5,490	367	2.74	37	134
Rapp.	Kamps Millpond	KM	8-Mar-02	2-May-02	11,213	203.87	3,704	224	4.07	31	55
James	Lake Maury	LM	5-Mar-02	3-May-02	108	2.04	53	41	0.77	19	53
	Virginia 2002 Overall Summary				50,252	207.65	5,490	632	2.61	37	242

2001

River	Site Name	Site	Start Date	End Date	Total	CPUE	Max.	Total	CPUE	Max.	Events
					Young of Year			Elvers			
York	Brackens Pond	BP	23-Feb-01	29-Jun-01	52,838	419.35	3,519	334	2.65	70	126
	Wormley Pond	WC	27-Feb-01	17-May-01	81,836	1035.90	19,205	171	2.16	28	79
	System Summary				134,674	656.95	19,205	505	2.46	70	205
Rapp.	Kamps Millpond	KM	12-Mar-01	12-May-01	3,956	64.85	2,184	222	3.64	36	61
James	Lake Maury	LM	9-Mar-02	13-Mar-01	0	0.00	0	0	0.00	0	4
	Virginia 2001 Overall Summary				138,630	513.44	19,205	727	2.69	70	270

2000

River	Site Name	Site	Start Date	End Date	Total	CPUE	Max.	Total	CPUE	Max.	Events
					Young of Year			Elvers			
York	Brackens Pond	BP	16-Mar-00	16-May-00	61,225	1003.69	8,025	531	8.70	99	61
Rapp.	Kamps Millpond	KM	12-Apr-00	16-May-00	139	4.09	79	5	0.15	2	34
	Virginia 2000 Overall Summary				61,364	645.94	8,025	536	5.64	99	95

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Figure 1. 2002 American Eel Sampling Sites.

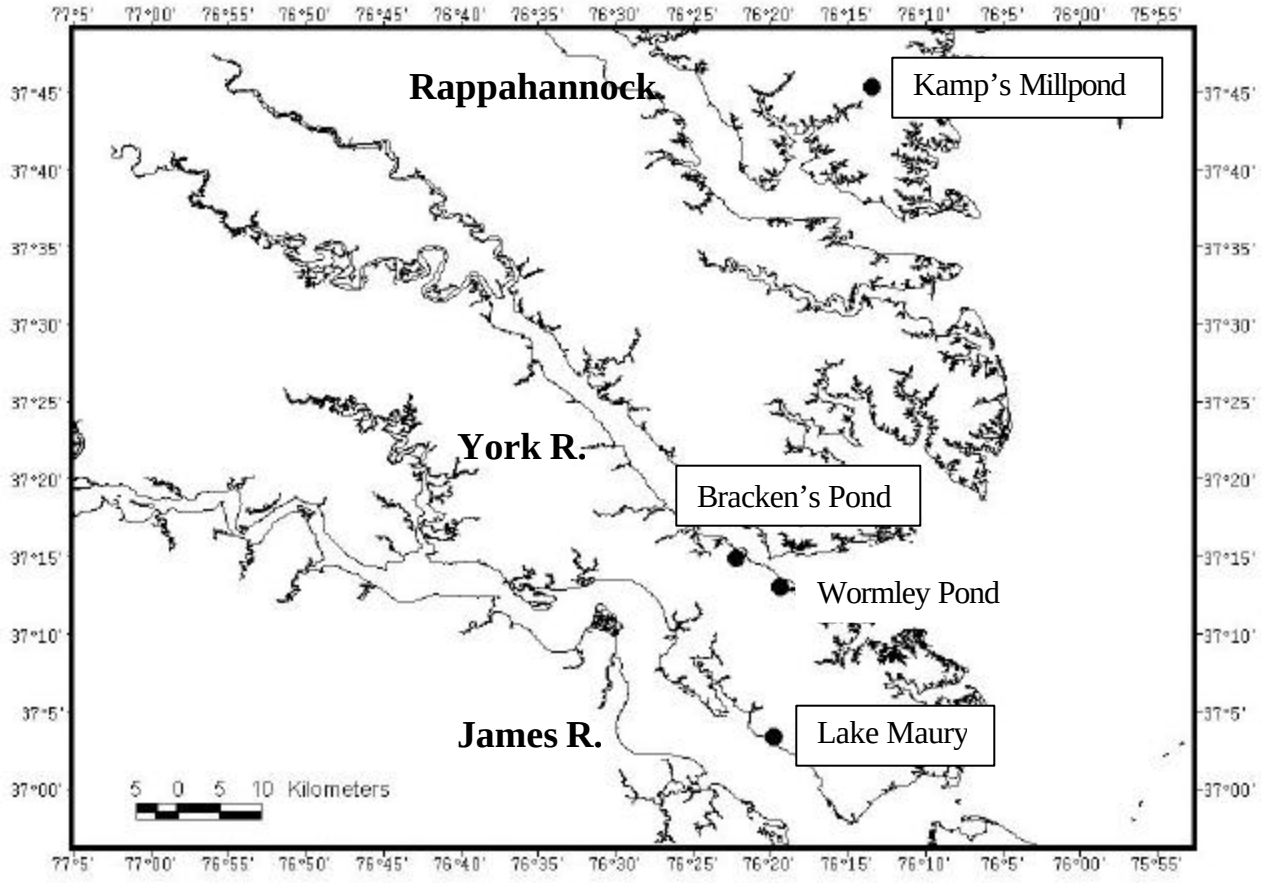

Figure 2. Brackens Pond spillway and tailrace. Irish ramp was set against the right wall on upstream end of culvert.

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.

Figure 5. Outflow of Lake Maury spillway. Irish ramp was near head

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

Figure 7. Eel YOY CPUE.

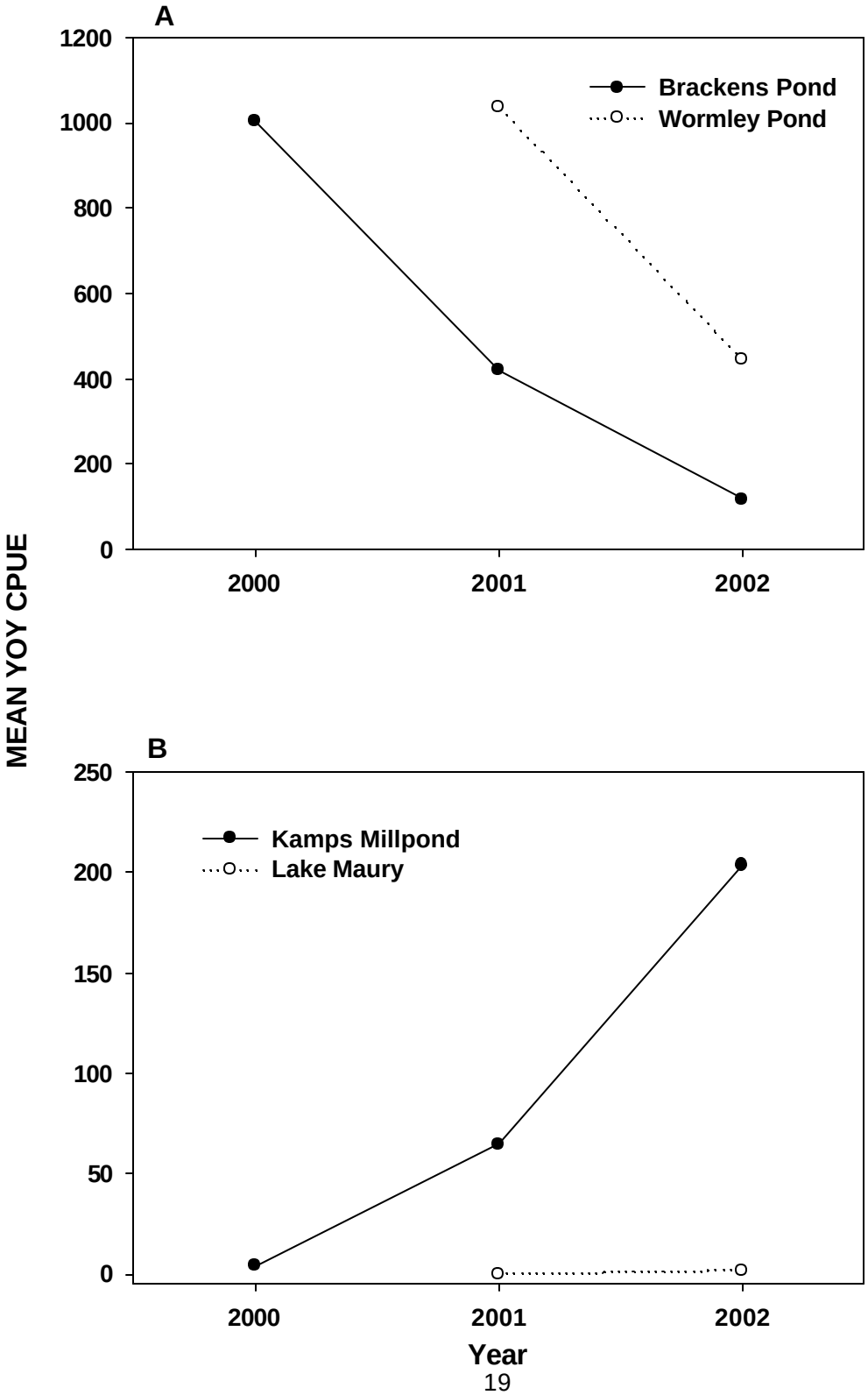

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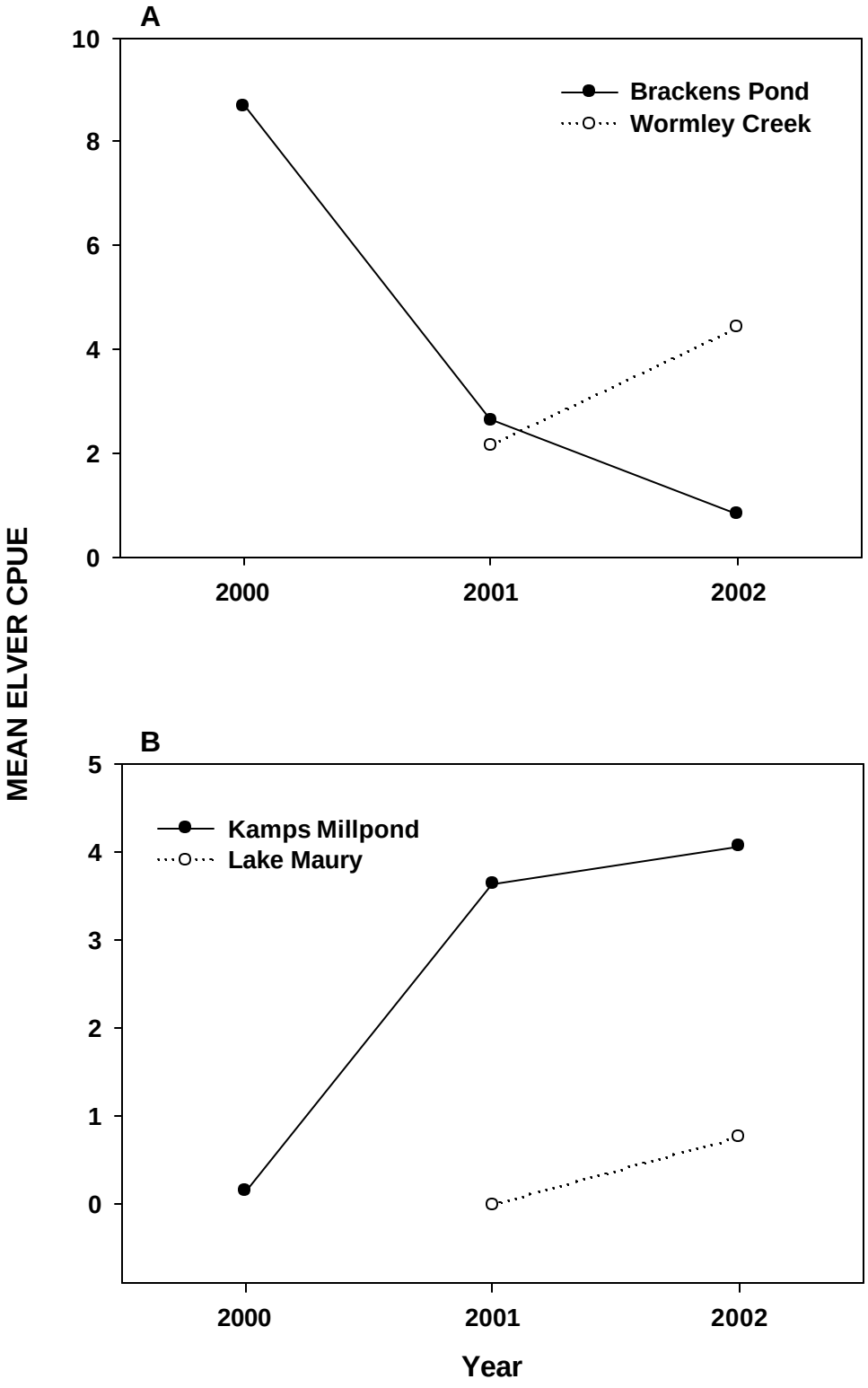
Figure 8. Eel Elver CPUE.



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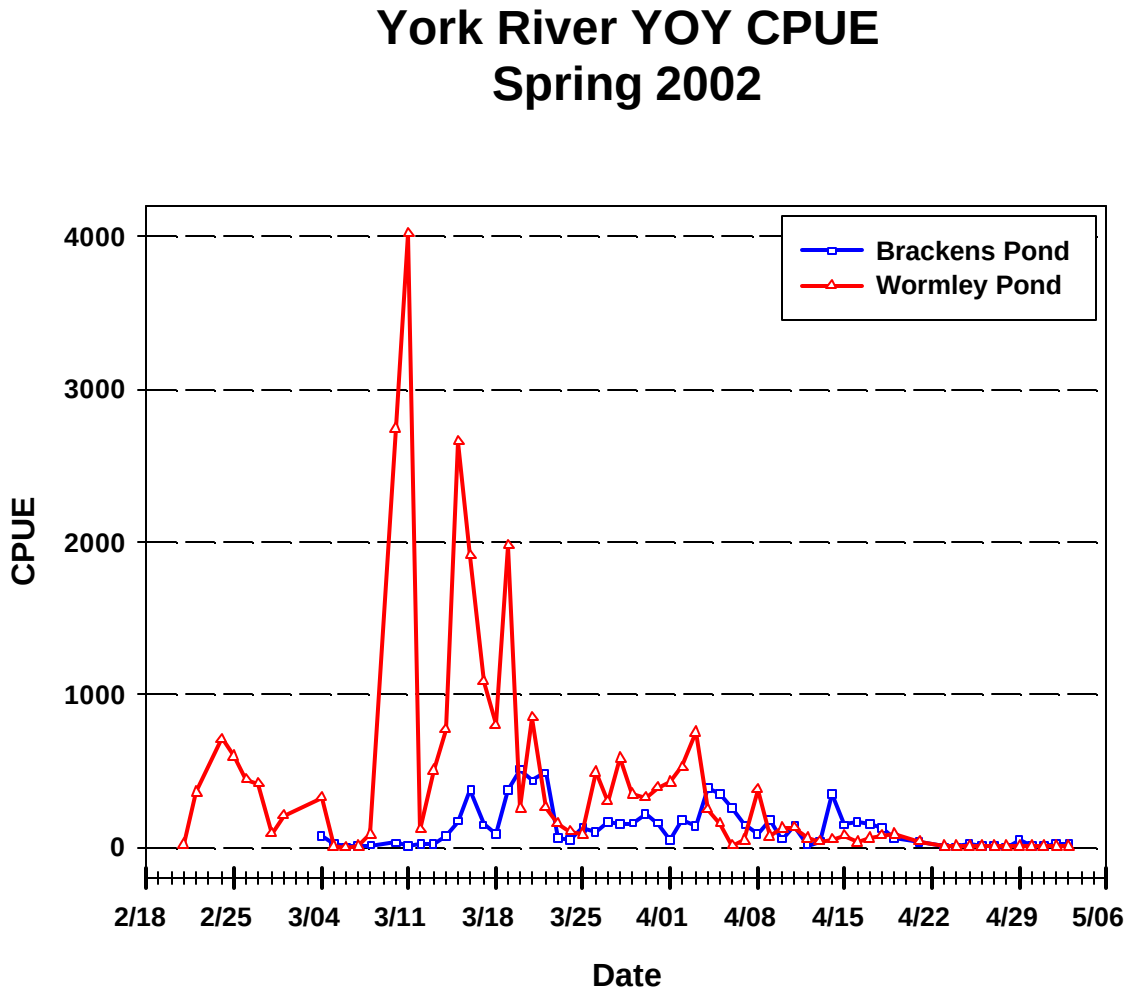


Figure 9. Daily York River YOY CPUE.

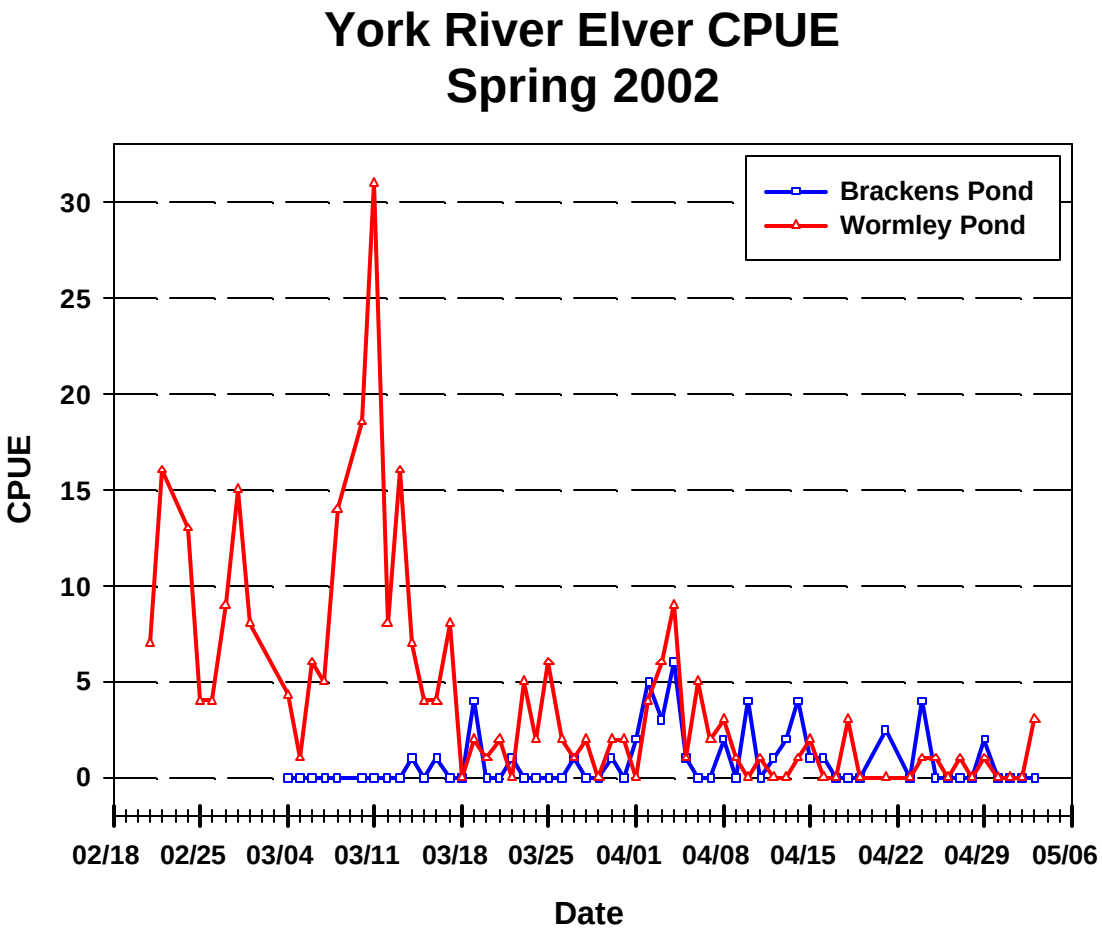


Figure 10. Daily York River Elver CPUE.

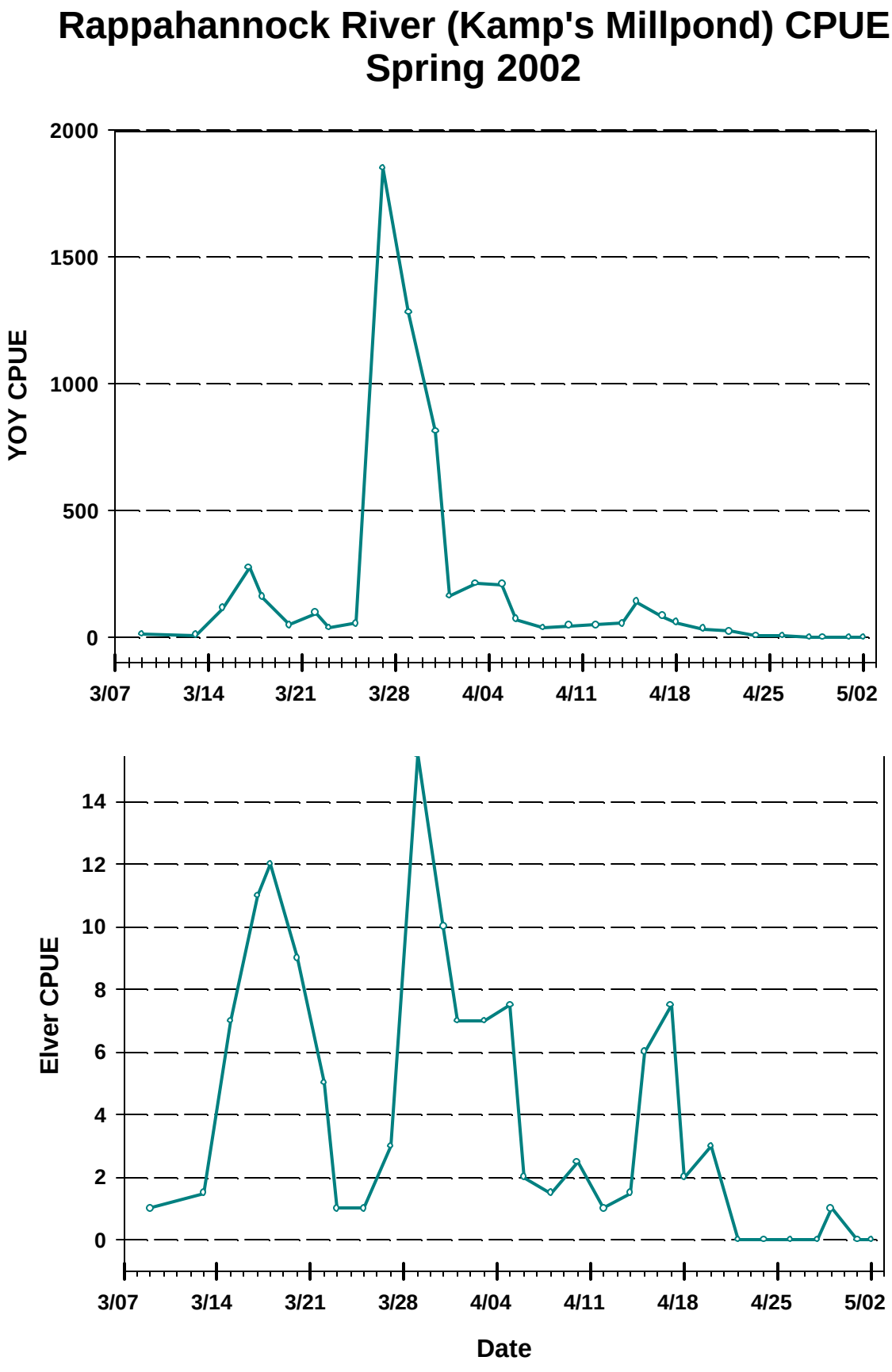


Figure 11. Rappahannock River (Kamps Millpond) CPUE.

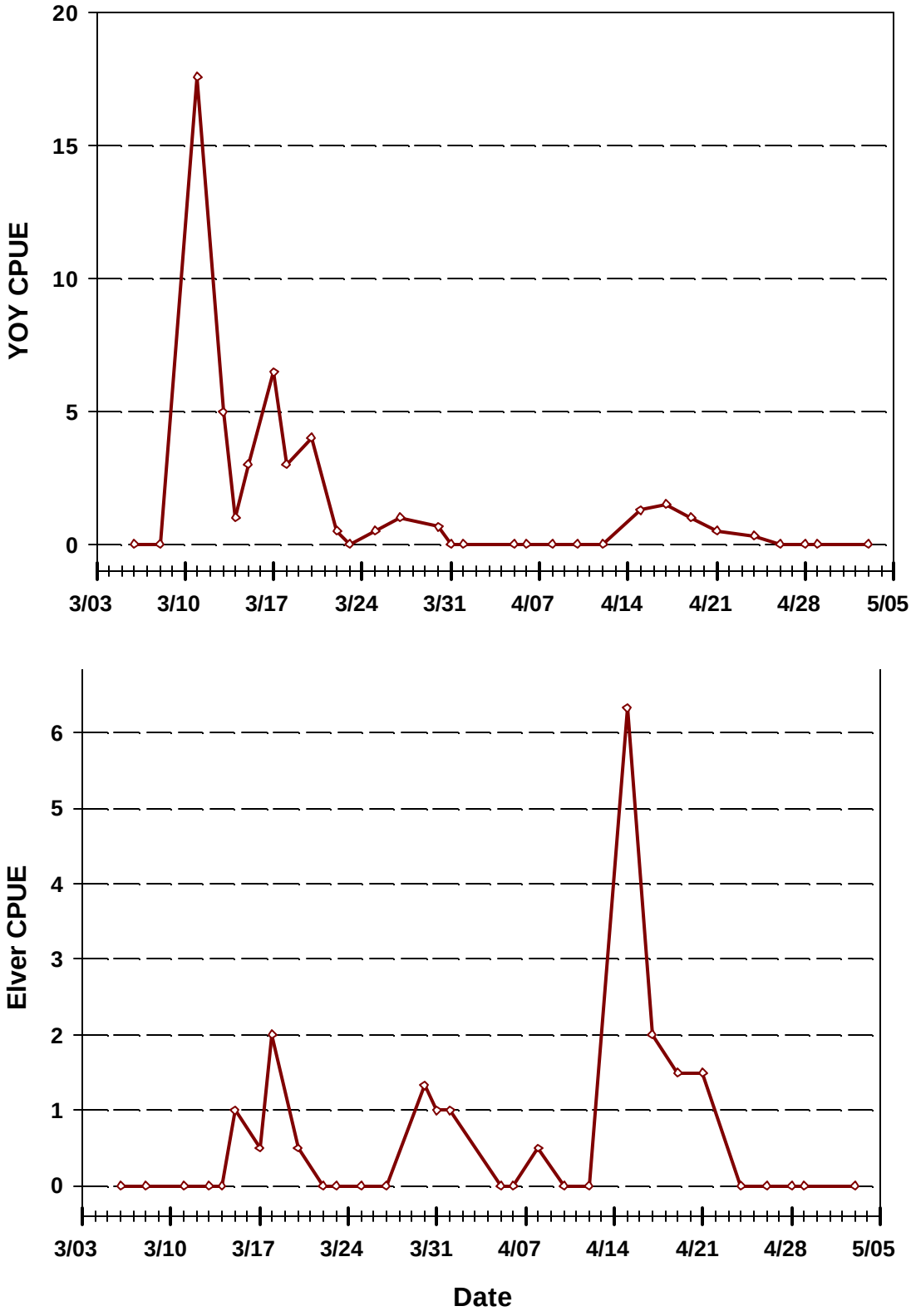
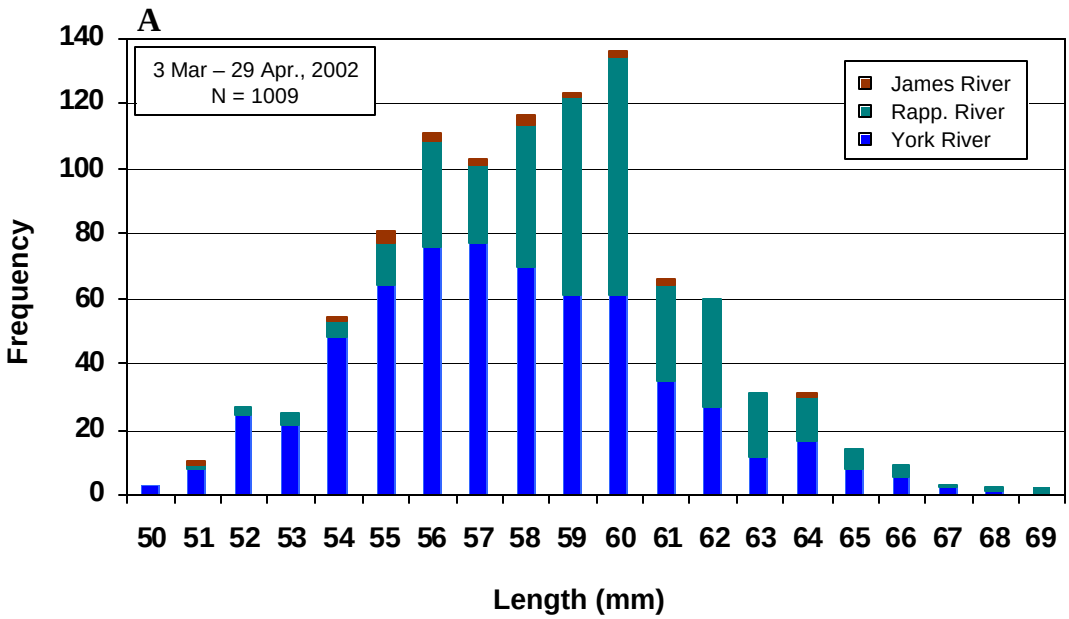


Figure 12. James River (Lake Maury) CPUE.

Figure 13. A. Glass eel length frequency.
B. Linear regression of length and weight for YOY eel collected at the VMRC sites in 2002 (all sites combined).



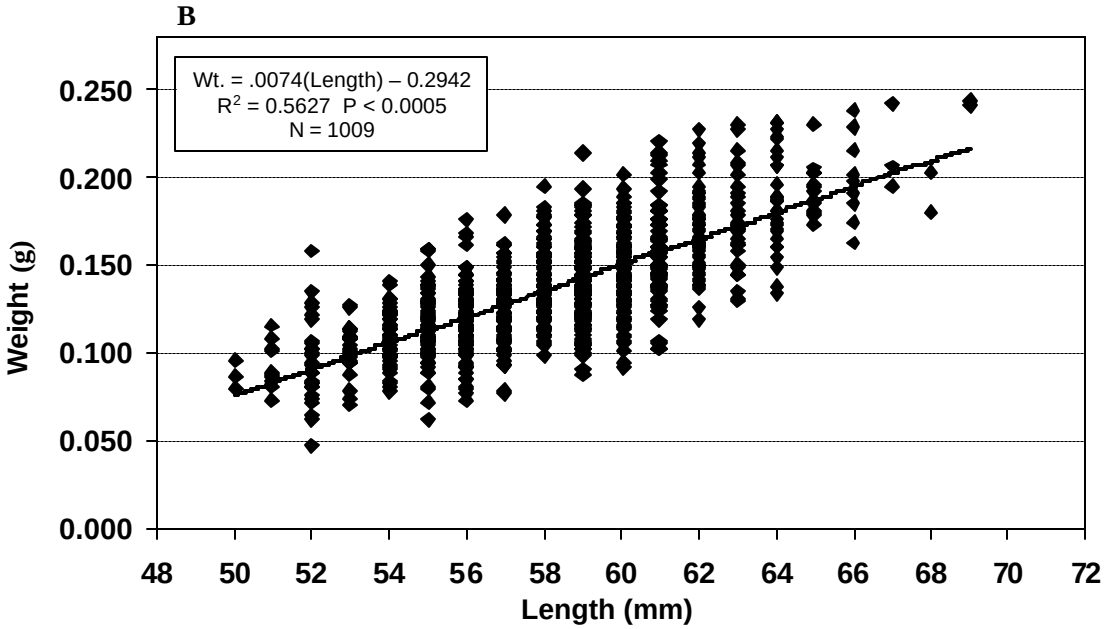


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Figure 14. Pigmentation Stages of York River Glass Eels