Evaluating Recruitment of American Eel, *Anguilla rostrata*, to the Potomac River (Spring 2008)

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By

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Introduction

American eel (*Anguilla rostrata*) is a valuable commercial species along the Atlantic coast of North America from New Brunswick to Florida. In recent years, harvest along the U.S. Atlantic Coast has declined, with similar patterns occurring in the Canadian Maritime Provinces (Meister and Flagg 1997). Landings from Chesapeake Bay typically represent 63% of the annual United States commercial harvest (ASMFC 2000). In 2005, Virginia commercial landings were one-third of the average annual landings since mandatory reporting began in 1993 (VMRC 2006).

A decline in abundance of American eel has been observed in recent years with conflicting evidence regarding spatial synchrony throughout their range (Richkus and Whalen 1999; Sullivan et al. 2006). Limited knowledge about fundamental biological characteristics of juvenile American eel has complicated interpretation of juvenile abundance trends (Sullivan et al. 2006). Hypotheses for the decline in abundance include locational shifts in the Gulf Stream, pollution, overfishing, parasites, and barriers to fish passage (Castonguay et al. 1994; Haro et al. 2000). Additionally, factors such as unfavorable wind-driven currents may affect glass eel recruitment on the continental shelf and may have a greater impact than fishing mortality or continental climate change (Knights 2003).

The Atlantic States Marine Fisheries Commission (ASMFC) adopted the Interstate Fishery Management Plan (FMP) for the American eel in November 1999. The FMP focuses on increasing coastal states' efforts to collect American eel data through both fishery-dependent and fishery-independent studies. Consequently, member jurisdictions agreed to implement an annual survey for young of the year (YOY) American eels. The survey is intended to "…characterize trends in annual recruitment of the YOY eels over time [to produce a] qualitative appraisal of the annual recruitment of American eel to the U.S. Atlantic Coast" (ASMFC, 2000). The development of these surveys began in 2000 with full implementation by 2001. Survey results should provide necessary data on coastal recruitment success and further understanding of American eel population dynamics. A recent American eel stock assessment report (ASMFC,

2006) emphasized the importance of the coast-wide survey as an index of sustained recruitment over the historical coastal range and an early warning of potential range contraction of the species. The Virginia Institute of Marine Science continued its spring sampling to estimate relative abundance of YOY American eels in the Potomac River. Funding was provided by the Potomac River Fisheries Commission, which ensured compliance with the 1999 ASMFC Interstate Fishery Management Plan for American Eels.

Life History

The American eel is a catadromous species that occurs along the Atlantic and Gulf coasts of North America and inland in the St. Lawrence Seaway and Great Lakes (Murdy et al. 1997). The species is panmictic and supported throughout its range by a single spawning population (Haro et al. 2000; Meister and Flagg 1997). Spawning takes place during winter to early spring in the Sargasso Sea. Eggs hatch into leaf-shaped transparent ribbon-like larvae called leptocephali, which are transported by ocean currents (over 9-12 months) in a generally northwesterly direction and can grow to 85 mm TL (Jenkins and Burkhead 1993). Within a year, metamorphosis into the next life stage (glass eel) occurs in the Western Atlantic near the east coast of North America. A reduction in length to about 50 mm TL occurs prior to reaching the continental shelf (Jenkins and Burkhead 1993). Coastal currents and active migration transport the glass eels (= YOY) into Maryland and Virginia rivers and estuaries from February to June (Able and Fahay 1998). As growth continues, the glass eel becomes pigmented (elver stage) and within 12 to14 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. Metamorphosis into the silver eel stage occurs during the seaward migration that occurs from late summer through autumn. 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). American eel 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).

It has been suggested that glass eel migration consists of waves of invasion (Boetius and Boetius 1989) and perhaps a fortnightly periodicity related to tidal currents at stratification of the water column (Ciccotti et al. 1995). Additionally, alterations in freshwater flow (timing and magnitude) to bays and estuaries may affect the magnitude, timing, and spatial patterns of upstream migration of glass eels and elvers (Facey and Van Den Avyle 1987). Eel YOY may use freshwater "signals" to enhance recruitment to local estuaries, thereby influencing year-class strength (Sullivan et al. 2006).

Objectives

1. To monitor the young of the year (glass eel) migration into the Potomac River watershed to determine spatial and temporal components of American eel recruitment.

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

3. Collect basic biological information on recruiting glass eels, including length, weight, and pigment stage.

Methods

Minimum criteria for YOY American eel sampling have been established in the ASMFC American Eel FMP, with the 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 during 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 and a minimum of 60 glass eels (if present per system) must be examined for length, weight, and pigmentation stage weekly.

Due to the importance of the eel fishery in Virginia and the Potomac River, the methods used must ensure proper temporal and spatial sampling coverage, and provide reliable recruitment estimates. To provide the necessary spatial coverage and to assess suitable locations, numerous sites in both Virginia and Maryland were evaluated previously (Geer, 2001). Final site selection was based on known areas of glass eel concentrations, accessibility, and specific physical criteria (e.g. proper habitat) suitable for glass eel recruitment to the sampling gear. The Maryland sampling of the Potomac River (northern shore site) was discontinued in 2001, due in part to the low catch rates in 2000 (Geer, 2001). At the request of PRFC, the Virginia Institute of Marine Science (VIMS) began sampling two sites on the southern shore of the Potomac River (Gardy's Millpond and Clark's Millpond; Figure 1) in 2000.

Irish eel ramps were used to collect eels at all sites. The ramp configuration successfully attracts and captures small eels in tidal waters of Chesapeake Bay. Ramp operation requires a continuous flow of water over the climbing substrate and the collection device, which was accomplished through a gravity feed. Hoses were attached to the ramp and collection buckets with adapters to allow for quick removal for sampling. Enkamat™ erosion control material on the ramp floor provided a textured climbing surface and extended into the water below the trap. The ramps were placed on an incline (15-45^{o}), often on land, with the ramp entrance and textured mat extending into the water. The ramp entrance was placed in shallow water (< 25 cm) to prevent submersion. The inclined ramp and an additional 4^{o} incline of the substrate inside the ramp provided sufficient slope to create attractant flow. A hinged lid provided access for cleaning and flow adjustments.

Sampling on the Potomac River (Clark's Millpond and Gardy's Millpond) was conducted from 20 March to 20 June 2008. Clark's Millpond (Coan River – Northumberland County) spillway is situated approximately one meter above the creek with a steady stream flow that requires a modified ramp extension to allow eels access to the spillway. Gardy's Millpond (Yeocomico River – Northumberland County) contains a spillway that drains through four box culverts, across a riffle constructed of riprap and into a lotic area of the Yeocomico River.

Only eels in the ramp's collection bucket (not on the climbing surface) were recorded. Trap performance was rated on a scale of 0 to 3 (0 = new set; 1 = gear fishing; 2 = gear fishing, but not efficiently; 3 = gear not fishing). Water temperature, pH, air temperature, wind direction and speed, and precipitation were recorded during most site visits. All eels were counted and placed above the impediment, with any subsample information recorded, if applicable. Specimens less than or equal to ~ 85 mm total length (TL) were classified as YOY, while those greater than 85 mm TL were considered elvers. These lengths correspond to the two distinct length frequency modes observed in the 2000 survey, which likely reflects differing year classes (Geer 2001). Individual length, weight, and pigmentation stage (see Haro and Krueger 1988) from 60 eels were collected weekly. Daily catch (raw number of eels caught per day) and annual geometric mean catch per unit effort (CPUE) were calculated for each site. Annual CPUE at each site was standardized to a 24 hour soak time and geometric means were calculated from samples captured in the time period during which 95% of the cumulative total catch occurred (i.e., dates in which 0%-2.5% and 97.5%-100% of the cumulative total catch were collected were excluded). We used this modification to reduce variability in catch rates associated with the interannual variability in the period of maximum recruitment.

Results and discussion

Timing of maximum glass eel recruitment generally occurred in mid April for each site. Glass eels were first captured at Clark’s Millpond on 14 April with a peak in the number of eels captured a few days later on 17 April (Figure 2). At Gardy’s Millpond, glass eels were observed earlier (20 March), but the peak in captures occurred about the same time as that observed in Clark’s Millpond (between 10 and 14 April; Figure 3). Catches of elvers occurred consistently throughout the sampling season at Clark’s Millpond (average catch = 10.6; Figure 4), whereas there appeared to be a decreasing trend in catch of elvers at

Gardy's Millpond (Figure 5). Timing of glass eel and elver recruitment to rivers in Chesapeake Bay follows a pattern related to the proximity of the sampling locations to the Atlantic Ocean. Stations nearer to the mouth of Chesapeake Bay show recruitment peaks earlier in the year compared with those further away from the mouth of the bay. Initial arrival and migration of juvenile eels may be correlated with increases in water temperature, however elver migration may be delayed at freshwater interfaces until certain behavioral and physiological changes have occurred (Sorensen and Bianchini, 1986).

The number of glass eels captured at Clark's Millpond was very low with only 22 eels collected out of 63 trap days; this represents the second lowest CPUE in the nine-year time series (Table 1, Figure 6). Elver catches at Clark's Millpond were relatively high compared with recent years and were more than three times the number caught in 2007 (Table 2, Figure 7). At Gardy's Millpond, the number of glass eels was comparable with the previous six years, while the catch of elvers increased to levels similar to those observed from 2002 to 2006. Elver recruitment at the two sites follow similar patterns and according to our nine-year sampling history, more elvers are consistently collected at Gardy's Millpond (Figure 7).

Glass eels with pigmentation stages 2 through 7 were collected with more developed stages occurring later in the survey (Figure 8). Pigmentation stages for Potomac River sites were, in general, more advanced than those collected from James and York River sites (VIMS American Eel Survey, unpublished data) possibly a result of the greater distance and longer migration period necessary to reach the middle Chesapeake Bay. Similar to previous years, glass eel weight increased with glass eel length (Figure 9). In general, glass eel size increases with increasing distance from the breeding grounds (Boetius, 1976). Glass eels from Nova Scotia were on average 6 mm longer than those from Florida (Vladykov, 1966 as reported by Boetius, 1976).

Conclusions and Recommendations

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

2. Sampling in the Potomac River tributaries should start in March and continue until peak recruitment has occurred. In 2008 this occurred in April, while in 2007, peak recruitment occurred in June. The early arrival of glass eels was also apparent in the level of pigmentation as glass eels collected during 2007 were mostly stages 5 to 7, while those captured during 2008 were mostly stages 2 to 5.

3. Catch per unit effort for glass eels remained at levels observed since 2002 at Gardy's Millpond. Similar low catch rates of glass eels were observed at Clark's Millpond throughout the time series (2000 – 2008). Glass eel catch rates were almost an order of magnitude higher prior to 2002 at Gardy's Millpond, and these levels have not been recorded since.

4. Elver CPUE increased at both sites during 2008 relative to 2007, which was a low year in the time series. Elver catch rates at the two sites exhibited consistent patterns indicating that the performance of the gear was similar for this life history stage (assuming equal elver recruitment to the two sites).

5. The ultimate goal of this survey is to provide estimates of recruitment for glass eel and elver stage American eels. 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 variables should be evaluated in an attempt to provide a relative value for each site. This value could then be used to weight the catch rates at each site to provide a more reliable abundance estimate.

References

Atlantic States Marine Fisheries Commission (ASMFC). 2000. Interstate Fishery Management Plan for American Eel. Fishery Managament report No. 36. Washington, D.C. 79p.

ASMFC 2006. Terms of Reference and Advisory Report to the American Eel Stock Assessment Peer Review. Stock Assessment Report No. 06-01. 23p.

Castonguay, M., P.V. Hodson, C.M. Couillard, M.J. Eckersley, J.D. Dutil and G. Verreault. 1994. Why is recruitment of American Eel, *Anguilla rostrata*, declining in the St. Lawrence River and Gulf? Can. J. Fish. Aquat. Sci. 51:479-488.

Ciccotti, E, T. Ricci, M. Scardi, E. Fresi and S. Cataudella. 1995. Intraseasonal characterization of glass eel migration in the River Tiber: space and time dynamics. J. Fish Biol. 47:248-255.

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

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.

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

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, Symposium 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.

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. Summary of glass eel collections on the Potomac River at Clark’s Millpond, Gardy’s Millpond, and the combined datasets (2000 – 2008). CPUE is the standardized 95% geometric mean catch.

Source	Year	Start Date	End Date	Total Catch	Number Used	Trap Days	CPUE	Standard Error
Clark's Millpond	2000	28-Apr	15-May	15	12	18	0.650	0.088
	2001	9-Apr	22-Apr	4	3	14	0.186	0.069
	2002	1-Apr	27-Apr	115	109	27	3.387	0.115
	2003	25-Apr	15-May	24	22	21	0.902	0.090
	2004	21-Apr	27-May	447	430	37	6.006	0.179
	2005	13-Apr	26-May	223	213	44	3.311	0.128
	2006	6-Apr	22-May	80	77	47	1.311	0.079
	2007	26-Apr	1-Jul	435	379	67	3.934	0.122
	2008	14-Apr	19-Jun	22	20	63	0.208	0.041
Gardy's Millpond	2000	16-Apr	27-Apr	291	262	12	18.266	0.183
	2001	8-Apr	24-Apr	729	707	17	10.956	0.471
	2002	29-Mar	25-Apr	129	122	28	2.281	0.190
	2003	7-Apr	13-May	71	68	37	1.407	0.103
	2004	2-Apr	18-May	39	38	47	0.612	0.071
	2005	28-Mar	5-May	94	89	39	1.462	0.126
	2006	17-Mar	11-May	46	39	56	0.419	0.066
	2007	23-Apr	27-Jun	248	237	66	1.590	0.120
	2008	20-Mar	11-Jun	187	180	80	1.516	0.078
Combined	2000	16-Apr	12-May	306	295	27	4.510	0.280
	2001	8-Apr	24-Apr	733	711	17	11.223	0.467
	2002	29-Mar	27-Apr	244	233	30	5.649	0.138
	2003	9-Apr	13-May	95	87	35	1.886	0.114
	2004	13-Apr	27-May	486	461	45	5.712	0.164
	2005	30-Mar	26-May	317	305	58	4.000	0.095
	2006	20-Mar	21-May	126	119	63	1.373	0.083
	2007	23-Apr	1-Jul	683	619	70	5.877	0.123
	2008	20-Mar	11-Jun	209	199	84	1.604	0.077

Table 2. Summary of elver collections on the Potomac River at Clark's Millpond, Gardy's Millpond, and the combined datasets (2000 – 2008). CPUE is the standardized 95% geometric mean catch.

Source	Year	Start Date	End Date	Total Catch	Number Used	Trap Days	CPUE	Standard Error
Clark's Millpond	2000	5-Apr	15-May	5	3	41	0.078	0.022
	2001	19-Mar	10-May	205	196	53	2.711	0.099
	2002	13-Mar	21-Apr	90	83	40	1.810	0.071
	2003	17-Mar	8-May	225	213	53	2.165	0.140
	2004	2-Apr	23-May	314	299	52	3.029	0.153
	2005	28-Mar	24-May	62	59	58	0.773	0.068
	2006	15-Mar	24-May	153	146	71	1.351	0.081
	2007	15-Mar	27-Jun	90	85	105	0.646	0.045
	2008	24-Mar	15-Jun	276	258	80	2.209	0.068
Gardy's Millpond	2000	16-Apr	15-May	15	14	30	0.232	0.065
	2001	16-Mar	1-May	624	605	47	7.887	0.135
	2002	15-Mar	27-Apr	273	261	44	3.682	0.154
	2003	19-Mar	6-May	300	280	49	4.248	0.109
	2004	10-Mar	11-May	483	470	63	4.663	0.109
	2005	23-Mar	17-May	313	304	56	4.540	0.072
	2006	10-Mar	14-May	692	672	66	5.300	0.129
	2007	15-Mar	27-Jun	198	190	105	1.320	0.059
	2008	20-Mar	11-Jun	393	380	80	3.714	0.076
Combined	2000	5-Apr	15-May	20	17	41	0.318	0.062
	2001	16-Mar	8-May	829	801	54	9.942	0.114
	2002	15-Mar	27-Apr	363	346	44	5.614	0.127
	2003	17-Mar	8-May	525	503	53	6.868	0.114
	2004	10-Mar	20-May	797	740	72	6.558	0.107
	2005	23-Mar	19-May	375	365	58	5.266	0.073
	2006	10-Mar	21-May	845	821	73	6.367	0.118
	2007	15-Mar	27-Jun	288	275	105	2.030	0.059
	2008	20-Mar	15-Jun	669	651	88	5.564	0.080

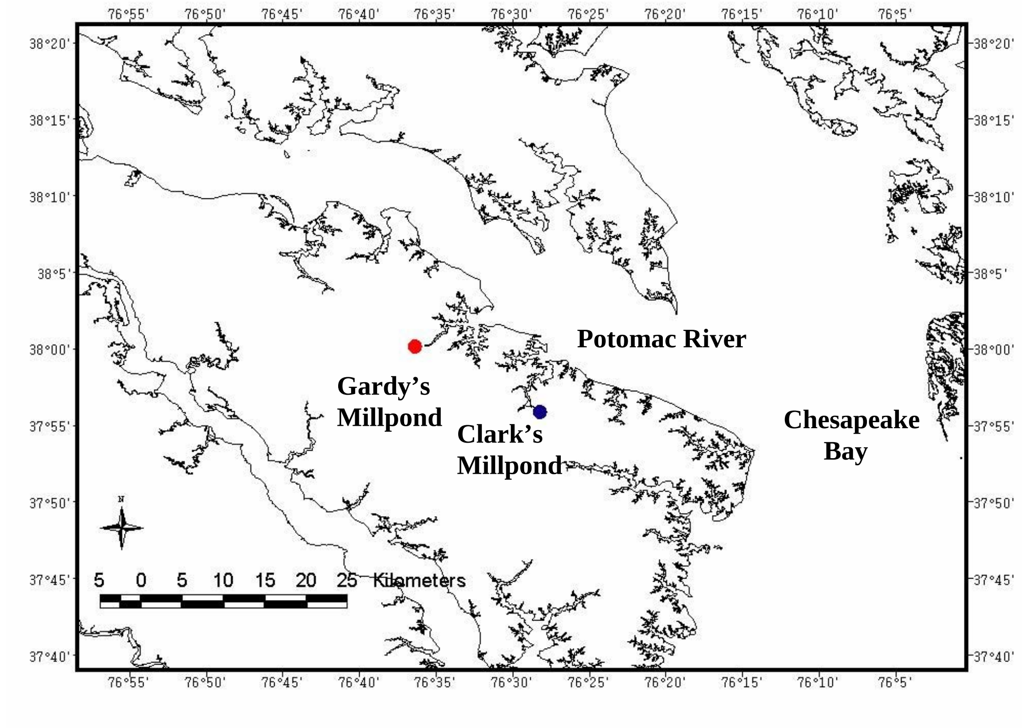

Figure 1. Sampling sites in the Potomac River.

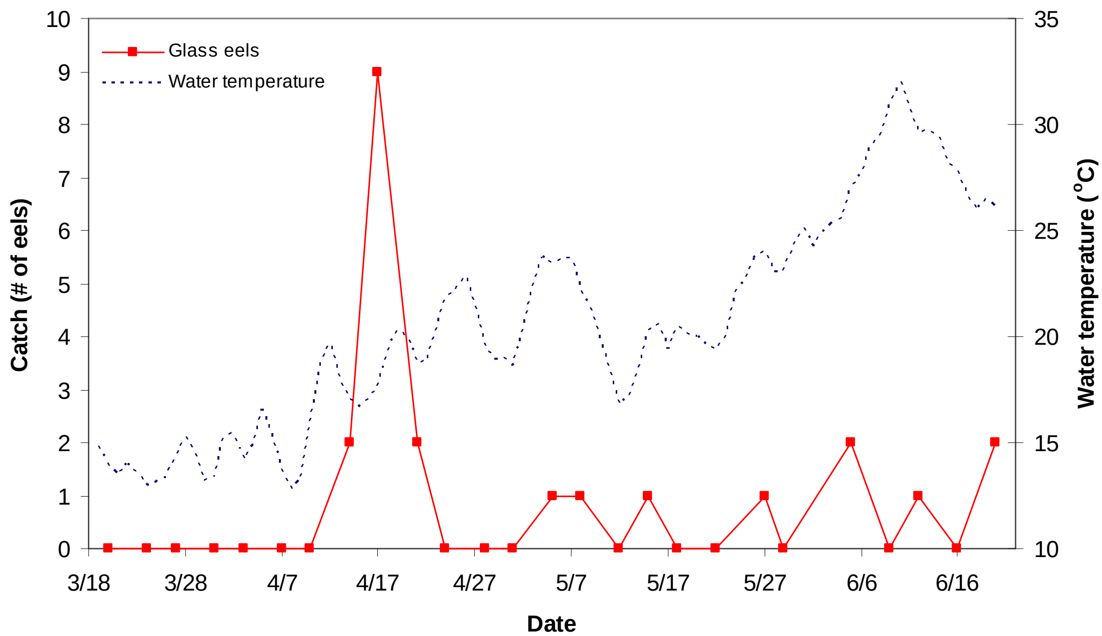

Figure 2. The total number of glass eels captured each sampling event and water temperature at Clark's Millpond, 2008.

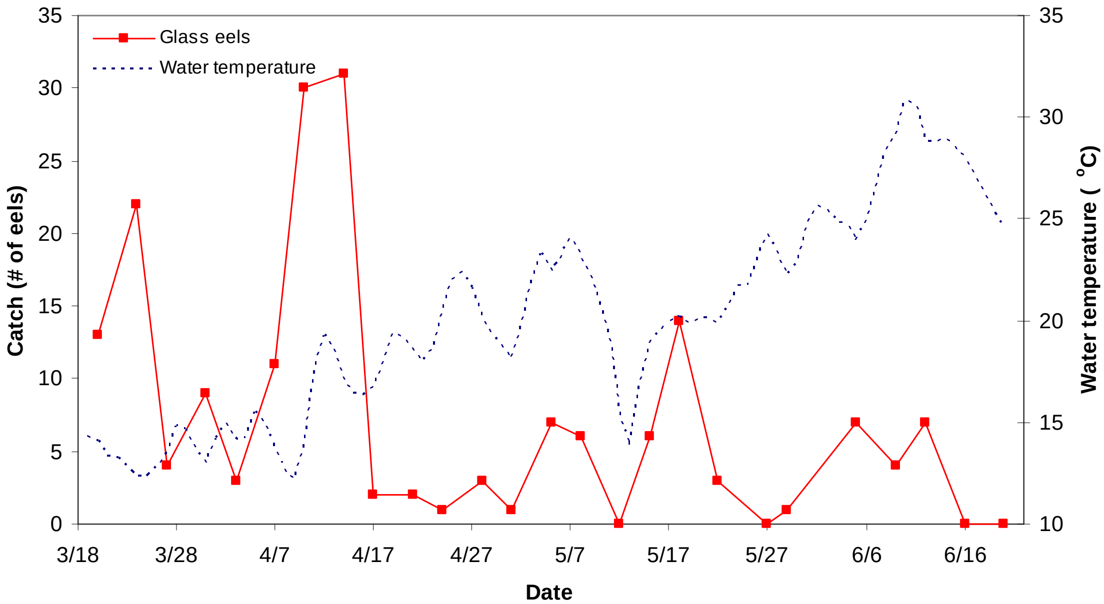

Figure 3. The total number of glass eels captured each sampling event and water temperature at Gardy's Millpond, 2008.

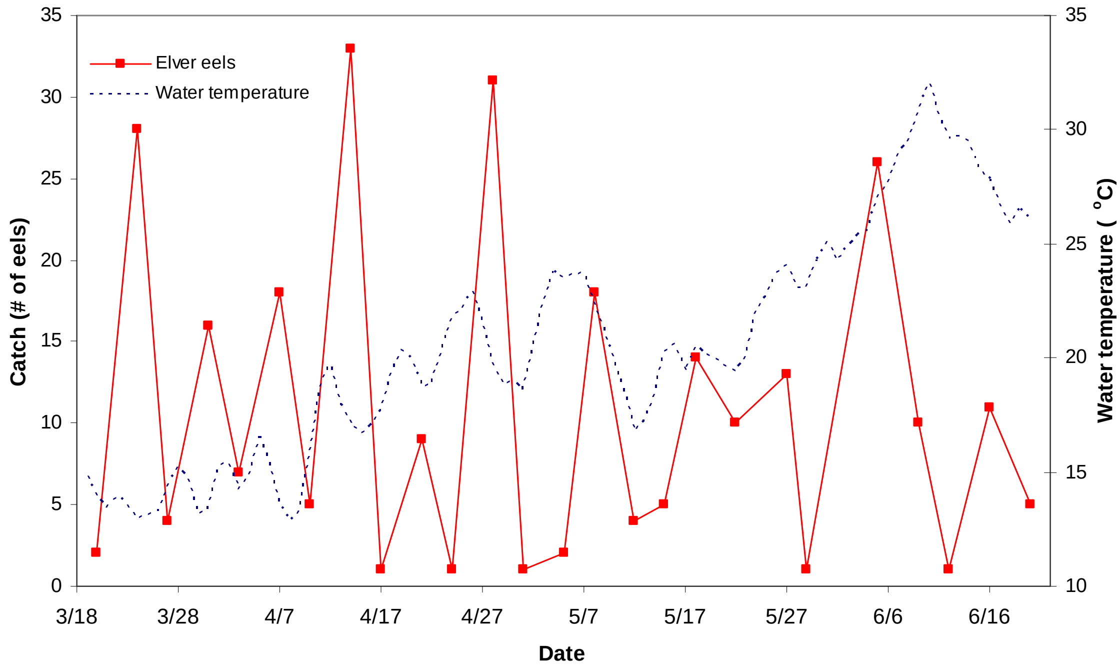

Figure 4. The total number of elver eels captured each sampling event and water temperature at Clark's Millpond, 2008.

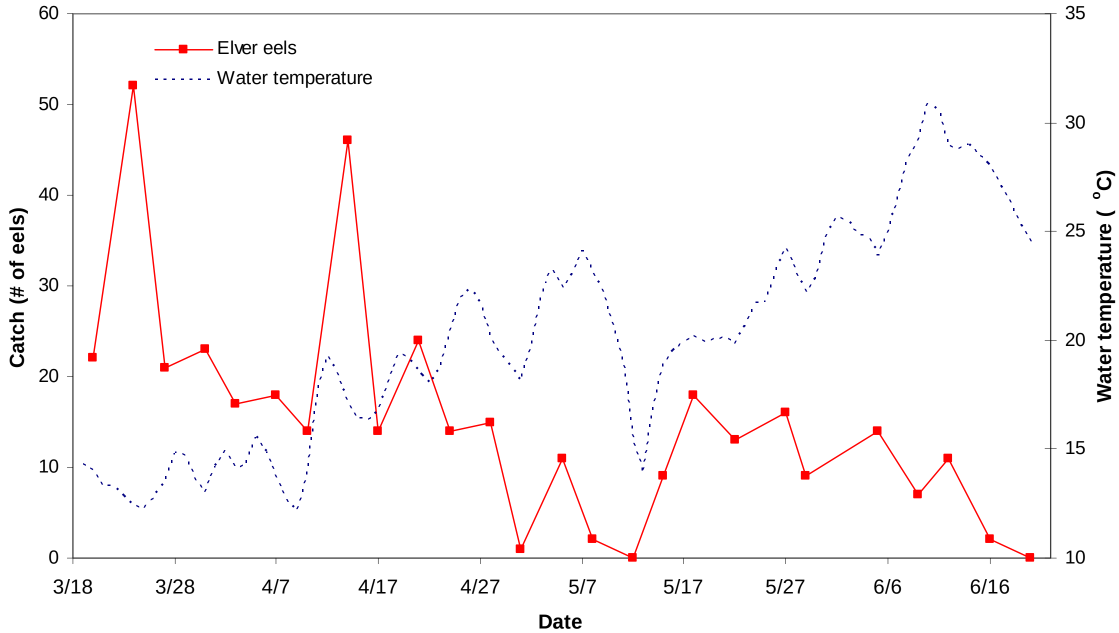

Figure 5. The total number of elver eels captured each sampling event and water temperature at Gardy's Millpond, 2008.

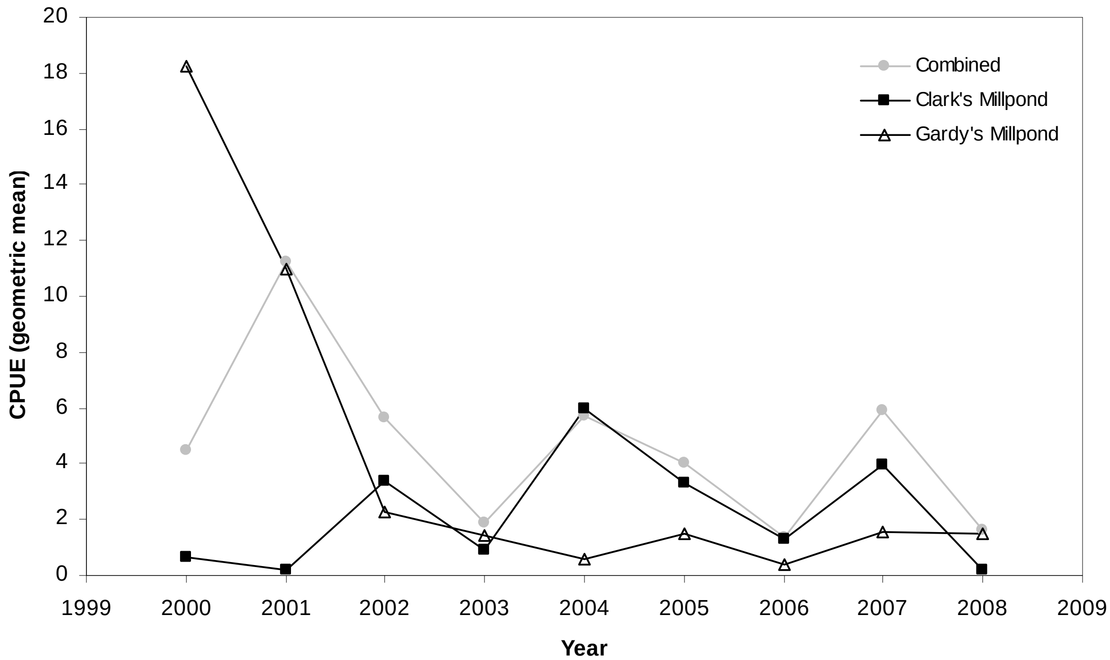

Figure 6. Glass eel CPUE from 2000 to 2008.

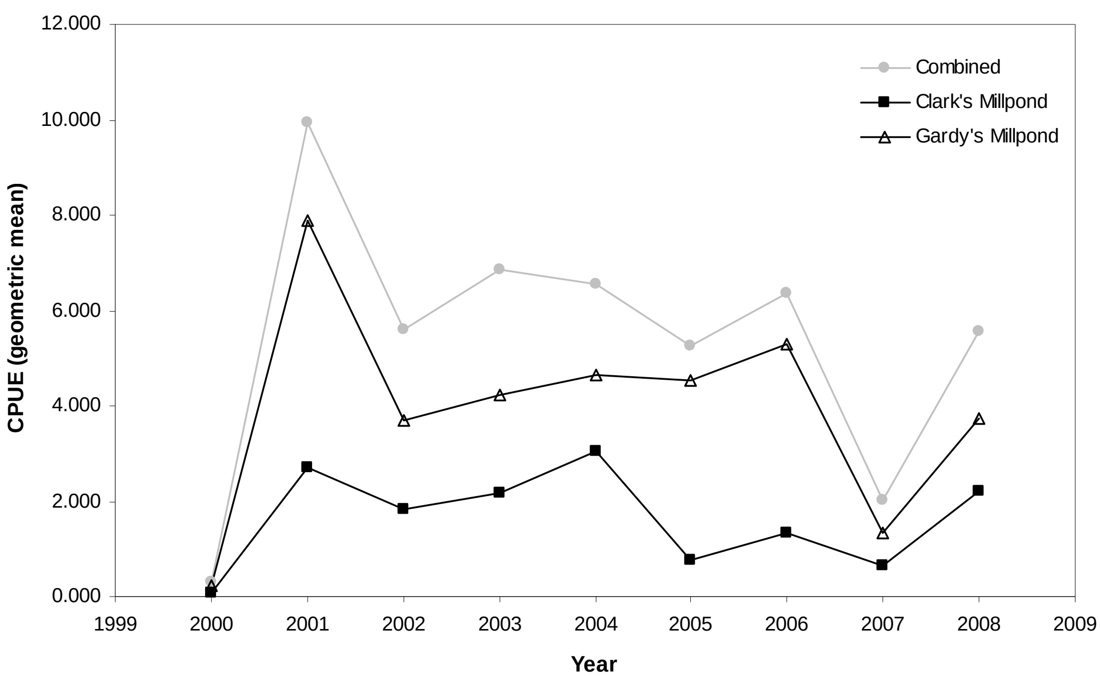

Figure 7. Elver eel CPUE from 2000 to 2008.

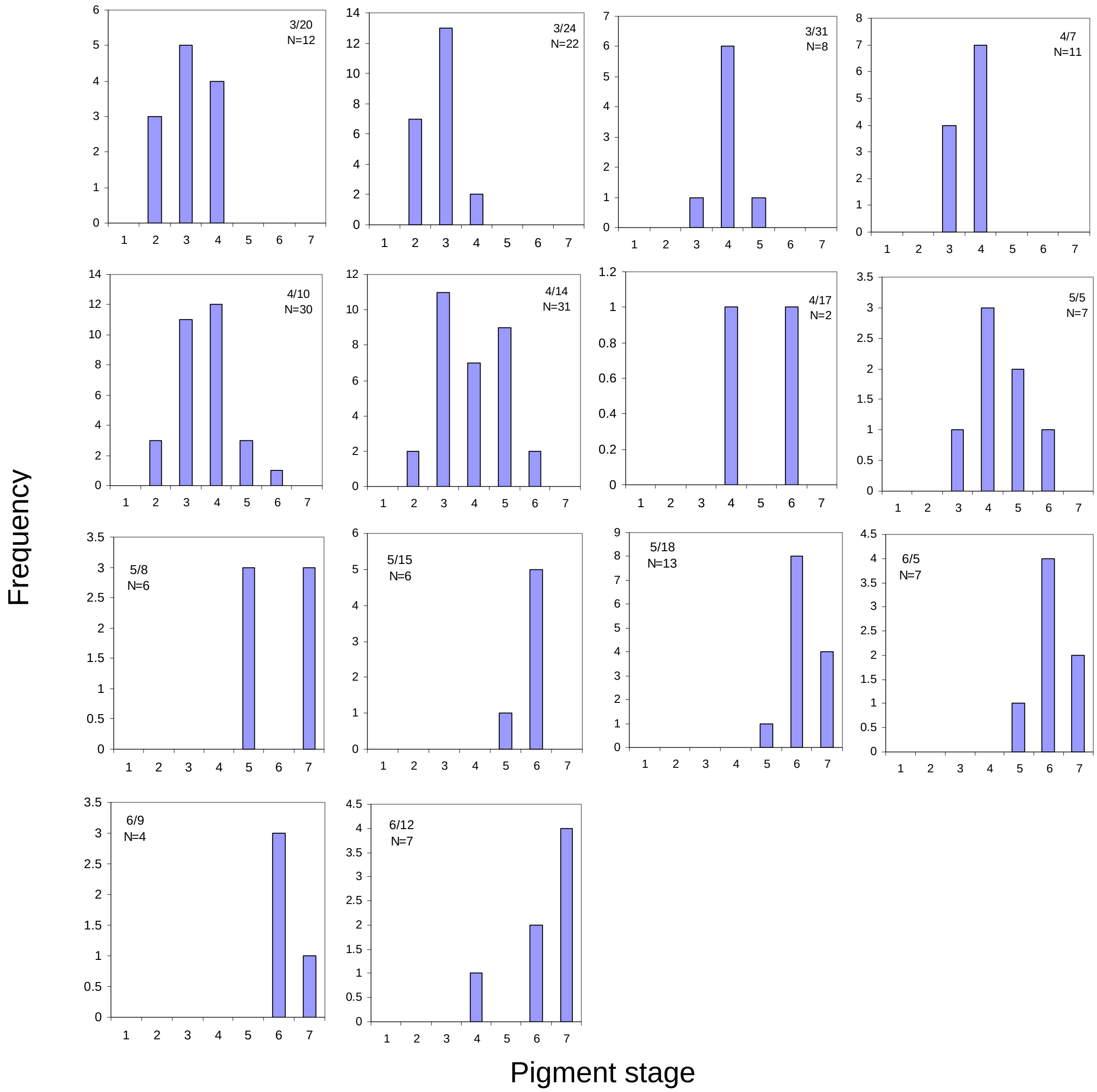

Figure 8. Glass eel pigment stage by date of capture from Gardy's Millpond, 2008.

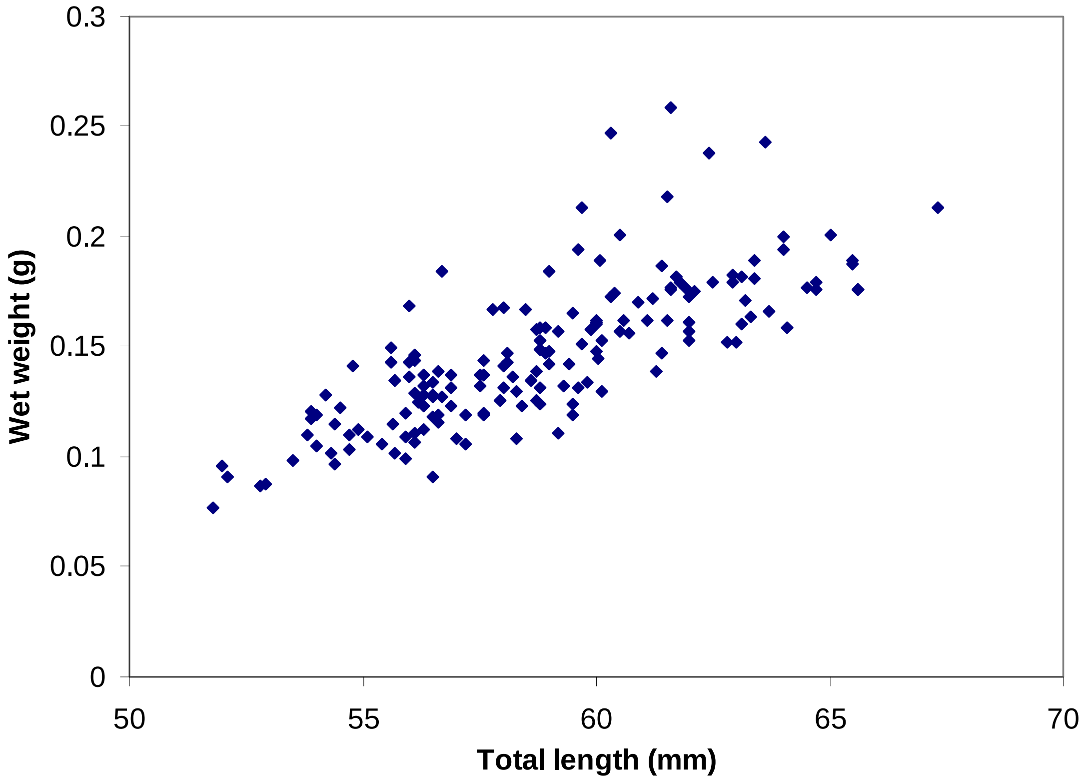

Figure 9. Length and wet weight of glass American eels captured at Gardy's Millpond, 2008. (avg. TL = 58.76 mm, avg. wt. = 0.15 g)