Communications Memo

To: Public Files
From: Kenneth Hogan
Date: July 23, 2013
Dockets: P-1889-081 and P-2485-063
Project: Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project

Subject: Communications between Commission staff and the U.S. Geological Survey's Conte Anadromous Fish Research Center (Conte Lab)

On January 27, 2014 Ken Hogan of the Commission's staff spoke (via telephone) with Theodore Castro-Santos with the U.S. Geological Survey (USGS), S.O. Conte Anadromous Fish Research Center (Conte). The purpose of the call was for Commission staff to better understand the disposition of study data and subsequent reports for studies conducted by Conte at the Turners Falls Project and specifically associated with Adult shad radio-telemetry studies in the project's fishways and power canal.

In response to Commission staff's inquiry, Mr. Castro-Santos provided via email three reports: (1) *Gatehouse Fishway Telemetry Studies: Progress Report, 2008-2010*; (2) *Results of Turners Falls Fishway Studies: 2011*; and (3) *Results of Turners Falls Fishway Studies: 2012*.

The reports are attached to this memo and have been provided to the Commission with the caveat that they contain preliminary data that is subject to revision and that the reports have not been subject to independent peer review.

Gatehouse Fishway Telemetry Studies:

Progress Report, 2008-2010

By

Theodore Castro-Santos

And

Alex Haro

USGS-BRD
S.O. Conte Anadromous Fish Research Center
Turners Falls, MA 01376
tcastrosantos@usgs.gov

PRELIMINARY DATA SUBJECT TO REVISION

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Telemetry studies of American shad passage through the Turners Falls fishway complex continued in 2010. This year's studies built on those of previous years (Castro-Santos and Haro 2005; Castro-Santos and Haro 2008; Castro-Santos et al. 2009; Sullivan et al. 2001), and in particular continued the work done since 2008 to evaluate modifications to the fishway entrances at Gatehouse.

These studies have been designed around a framework that segregates components of passage into Guidance, Attraction, and Passage zones. Each zone has a characteristic suite of rates that determine proportion of fish entering the next zone; these rates consist of both rates of movement to the next zone and of retention within a given zone. Importantly, shad are only able to transition to a subsequent zone if they are retained within the previous zone. Using this framework it is possible to isolate components of passage and identify favorable and unfavorable effects of modifications. This method also allows for identification of conflicting results, whereby effectiveness of one rate might be increased but its complementary rate decreased, resulting in no change or benefit in percent passage. In this way, both positive and negative effects are quantified leading to a more complete understanding of the mechanics of passage, and the ultimate causes for poor passage at this site. It is our hope that this approach will ultimately improve our ability to resolve the passage problems at Gatehouse and elsewhere.

In 2007 a New Entrance was installed on the right bank of the canal (Figures 1 and 2). The intent of this entrance was to improve passage by increasing rates of guidance (or more accurately, to place the fishway where the fish were already being effectively guided). Previous studies have shown that guidance to this location did improve over the previously existing conditions at the Old Entrance (Castro-Santos and Haro 2008; Castro-Santos et al. 2009). Entry rates (Attraction), however, were poor at the New Entrance in both 2008 and 2009 (Table 1, Figure 3).

Modifications were made to the New Entrance in 2010 to address this problem, including a) extending the guide screen on the canal side of the New Entrance; and b) adding an extension grating to the floor of the New Entrance. A primary objective of this study was to quantify the effectiveness of these modifications.

An alteration was also made to the Old Entrance in 2010. Since installing the New Entrance, guidance to the Old Entrance attraction zone has markedly improved. This appears to be an unintended consequence of a) reducing the size of the Old Entrance by half and/or b) increasing the head differential between the Gatehouse Gallery and the Canal from 30 cm to 45-75 cm. A boulder ramp installed below the Old Entrance before the 2009 season may also have influenced guidance and/or retention. Although guidance to and retention within the Old Entrance Attraction zone appear to have improved, overall passage has not. This prompted a structural change at the Old Entrance: a weir was installed within the Gallery, just upstream of the Old Entrance to reduce the total discharge and flow velocity there, with the idea that this should help to improve both attraction and passage.

One consequence of this last alteration is that by reducing discharge through the Old Entrance, more flow was available for the New Entrance (Figure 4). Earlier work had indicated that discharge and velocity through the New Entrance were insufficient to stimulate entry, suggesting that this factor was limiting success of the structure. Thus this new modification held the potential to affect overall entry into both the New and the Old Entrances.

A new component was added to these studies in 2009 and 2010. Data had been accumulating that indicated that shad might be experiencing an energetic and/or hormonal limit to their migration, perhaps induced by challenging passage through Cabot Ladder. To control for the combined effects of migrating upstream from Holyoke and through Cabot Ladder, we matched releases of PIT- and radio-tagged shad a) that ascended Cabot Ladder, and b) that were transported by truck from the Holyoke Fishlift. A single pilot release done in 2009 suggested that shad transported from Holyoke had superior passage performance, and that this effect had bearing on passage through Gatehouse because a planned replacement of the Cabot Ladder with a fishlift could help remove any negative consequences accrued during passage through the ladder. Because of this, the study was continued in 2010, with matched releases from Holyoke and Cabot Trap.

A total of 219 shad were tagged (Table 2), split approximately evenly between Holyoke and Cabot collections. Shad from each location were tagged and released in four releases spread over the migratory season, with shad from each site being released within approximately 2 h of each other. While all shad received PIT tags, only slightly less than half of these also received radio tags.

Equipment failure was a significant problem for the 2010 studies. Four antennas failed at least once, and data were lost from both PIT and radio receivers on more than one occasion (primarily caused by a regional power outage beginning May 26). The total amount of lost telemetry data was small, owing to rapid response to developing problems: broken antennas were repaired within 24 h, and total downtime for the receivers amounted to 33 h, or 2.5% of the period from May 7 – July 1. An important result of this is that passage estimates may be low—at least one fish is known to have passed during one of these outages, and others may have as well. Because the amount of receiver downtime was minimized the magnitude of this error is probably small. Also the effect of these problems would be on total passage estimates; estimates of guidance, attraction, and retention rates should be unaffected.

The timing of the 2010 shad run was earlier than most years (Figure 5), probably as a result of warmer river temperatures, particularly early in the season (Figure 6).

Overall passage improved during 2010, with passage through Gatehouse accounting for about 50% of the shad that ascended Cabot Ladder (Table 1, Figure 3). Evaluation of the two entrances indicated that this improvement was almost entirely due to improved entry rates into the New Entrance (Figures 7-14). The total amount of effort spent trying to pass (indicated by retention time within the Guidance Zone (Figure 8) and number of canal ascents (Figure 9)) was not appreciably different in 2010. Rates of guidance to the two entry zones (Figures 10-11) and retention within each entry zone (Figures 12-13) were not notably better than previous years, and in some cases were actually worse. Likewise numbers of approaches to the two entrances were similar (Figures 14 & 15). Only entry rate in the New Entrance changed, and this improved markedly (Figure 13b). This leads to the conclusion that improved attraction to the New Entrance accounts for the improved overall passage. Thus far, however, we have not been able to discern whether and to what extent this improved attraction is the result of the structural modifications to the New Entrance, and to what extent it can be attributed to the increased head differential that was present throughout the 2010 season, owing to the new weir installed just upstream of the Old Entrance (Figure 4).

Guidance to the Old Entrance remained strong in 2010 compared with pre-modification conditions (2003-2005), as did retention near the entrance (Figures 10 & 12a). Entry rates into the Old Entrance, however, were very poor (Figure 12b), suggesting that the modifications there have failed to provide the intended benefit to attraction.

The paired release experiment confirmed the previous year's results, showing improved overall passage and component rates for shad transported from Holyoke. These included: a) More rapid post-release ascent of the canal (Figure7; (Proportional Hazard Regression (PHReg): P = 0.017); b) greater number of approaches to the canal head-end (Figure 16a & 16b; P>F = 0.020); c) greater retention time in the Canal head-end on each approach (Likelihood Ratio test: P=0.011—the effect was only present for the upper quartile of residence time) ; with b) and c) resulting in d) greater total time spent at the canal head-end trying to pass (P>F=0.022). There was also some suggestion that Holyoke shad were more aggressive in seeking passage routes, with improved guidance rates to the New Entrance (Wilcoxon P= 0.054, LogRank P=0.36—this discrepancy occurs when the effect is present only for the left-hand end of the distribution, i.e. for faster-guided shad). Retention near the New Entrance was not affected by origin (PHReg P= 0.555). There was no suggestion of any difference between Holyoke and Cabot shad with respect to retention near (PHReg P=0.775) or entry into the Old Entrance (PHReg P=0.598). Assessment of the distribution functions for each of these components verifies that differences in Attraction Zone behaviors are nonexistent or minor, and so must not be important drivers of passage performance. Instead, the improved passage of the Holyoke-transported shad appears to stem from greater migratory motivation and stamina, as manifested by more rapid ascent and greater time spent in the Guidance Zone.

One issue that raises concerns over the validity of these studies is the effect of tagging and handling on the shad. Shad are well-known to be very susceptible to handling stress, with high rates of 'handling loss' being the norm for tagging studies. Just what this loss means is not clear, however. In each year of study, we have documented extensive post-tagging movements for a large majority (typically in the vicinity of 90% or more) of our radio-tagged fish. However a much smaller proportion ascend the canal and attempt to pass the Gatehouse fishway (Table 2). Importantly, the proportion of tagged shad passing Gatehouse is consistently lower than actual passage proportion, based on countbased estimates (Table 1, Figure 3). Previously we have assumed that this reflected the immediate effects of handling, and that behaviors of shad that ascended the canal were representative of untagged individuals. Evaluation of the proportions of shad ascending the canal and subsequently passing Gatehouse, however, shows that even controlling for shad that do not ascend the canal we still see a consistent underestimate of passage performance. This indicates that the effects of tagging and handling shad probably contains a latent component, with reduced performance even among those shad that exhibit continued upstream migratory behavior. This has several unsettling implications, including the possibility that estimates of passage performance elsewhere and from previous studies may also be low. Note, however, differences between shad that received radio and PIT tags and those receiving only PIT tags was not significant, suggesting that the increased handling associated with radio tags was not a major factor in this effect. More work is needed to address this concern, however available data from repeat spawners and shad tagged in the lower river support existing passage and entry estimates through Cabot Ladder (Castro-Santos and Haro 2005). Furthermore, although the reduced passage performance of tagged shad is undeniable, it is likely the result of reduced effort (i.e. number of attempts), rather than changes to the underlying functions of guidance, attraction, and passage. This last statement is broadly consistent with behavior theory, but it must remain speculative until further analysis can be performed, and specific studies developed to address these questions.

These studies have been performed in the context of the New Entrance being installed at a location upstream of where we felt optimal passage could be achieved. One objective has been to evaluate whether the existing location of the New Entrance could be configured in such a way as to make extending the entrance unnecessary. This year’s study included re-deployment of a 2-dimensional antenna array, similar to those deployed in 2003-2005, but using a MITAS signal processing system (All other antennas were monitored using Lotek SRX-400 receivers). The MITAS array makes it possible to re-assess the potential benefits of extending the fishway entrance, by allowing for calculation of rates of guidance to and retention near potential fishway entrance locations, as well as number of approaches to each location. The MTAS system was configured differently from the systems used and described throughout the 2008-2010 studies, and more work is needed to verify data and perhaps remove spurious detections. Our assessment of the data to date suggests, however, that although the detection range of each antenna within the 2-D array was smaller than the LOTEK antennas, the sensitivity was greater, with more detections logged per location by the MITAS system. This accounts, for example, for the greater number of presences shown in Figure 15 relative to Figure 14. Data from the MITAS array have been included in Figures 11b, 13a, and 15 to provide comparisons of the New Entrance Location with where the mock entrance was located in 2004-2005 (Figures 11b, 13a), as well as a potential location further downstream (Antenna 1-1, Figure 15). We have also included for reference guidance (Figure 11b), retention (Figure 13a) and entry rates (Figure 13b) to the Mock Entrance using 2005 data.

Data from the MITAS system indicate that, while guidance to the Mock Entrance location was similar in 2010 to previous years, retention at that location has improved.

Two likely causes for this are 1) shad entered the Mock Entrance at a relatively high rate and so were not retained as long in the Attraction Zone; and 2) the presence of the New Entrance has modified hydraulics in the canal such that the former Mock Entrance Attraction Zone is now a more desirable location for shad to spend time. With only a single year of data we must recognize the possibility that the increased retention may be an artifact. Nevertheless, the improved guidance to the former Mock Entrance Attraction Zone (Figure 11a and 11b), coupled with improved retention there (Figure 13a) suggests that some benefit may be realized by extending the fishway entrance. Likewise, although entry rates were improved at the New Entrance this year, those rates are still well-below what was achieved with the Mock Entrance (Figure 13b).

It is unclear why this difference in performance exists. Likely explanations include a) insufficient flow through the New Entrance; b) complex hydraulics, high velocity and turbulence at the upstream location make the New Entrance less attractive; and c) shad are swimming lower in the water column at the upstream location, perhaps being attracted by the primary canal flow coming from the headgates. The Mock Entrance studies of 2004-2005 indicated that shad are very sensitive to turbulence and noise near the entrance, and that they prefer a strong signal coming from the entrance with little competing flow surrounding the entrance. Those conditions may be difficult to create at the existing location, but if they could be created they hold some potential for creating effective passage. The data from the three MITAS antennas near the right bank of the canal (Figure 15) offer hope that this could be achieved: there was no apparent difference in number of approaches to each location, so at the very least the opportunity for passage exists. To improve passage, further improvements will be needed in guidance, retention, and attraction to the New Entrance zone. Likewise the data from 2008-2010 point to potential benefits from improving the Old Entrance—shad are now approaching that entrance much more frequently than before modifications were put in place, and if attraction into the Old Entrance can be improved that also holds the potential for significantly enhancing passage performance at Gatehouse.

A final component that has not received much attention to date is passage through the fishway itself. Only about half the shad that enter Gatehouse pass on a given attempt. This problem can be overcome, either by improving passage within the ladder, or by improving entrance conditions such that individuals have multiple opportunities to pass. Data from this year's study are consistent with observations from 2005, where shad were able to overcome challenges posed by the fishway by staging multiple attempts. This suggests that continued focus getting shad to enter and re-enter the fishway may be the best way to improve passage, although improving within-fishway passage rates would also be beneficial.

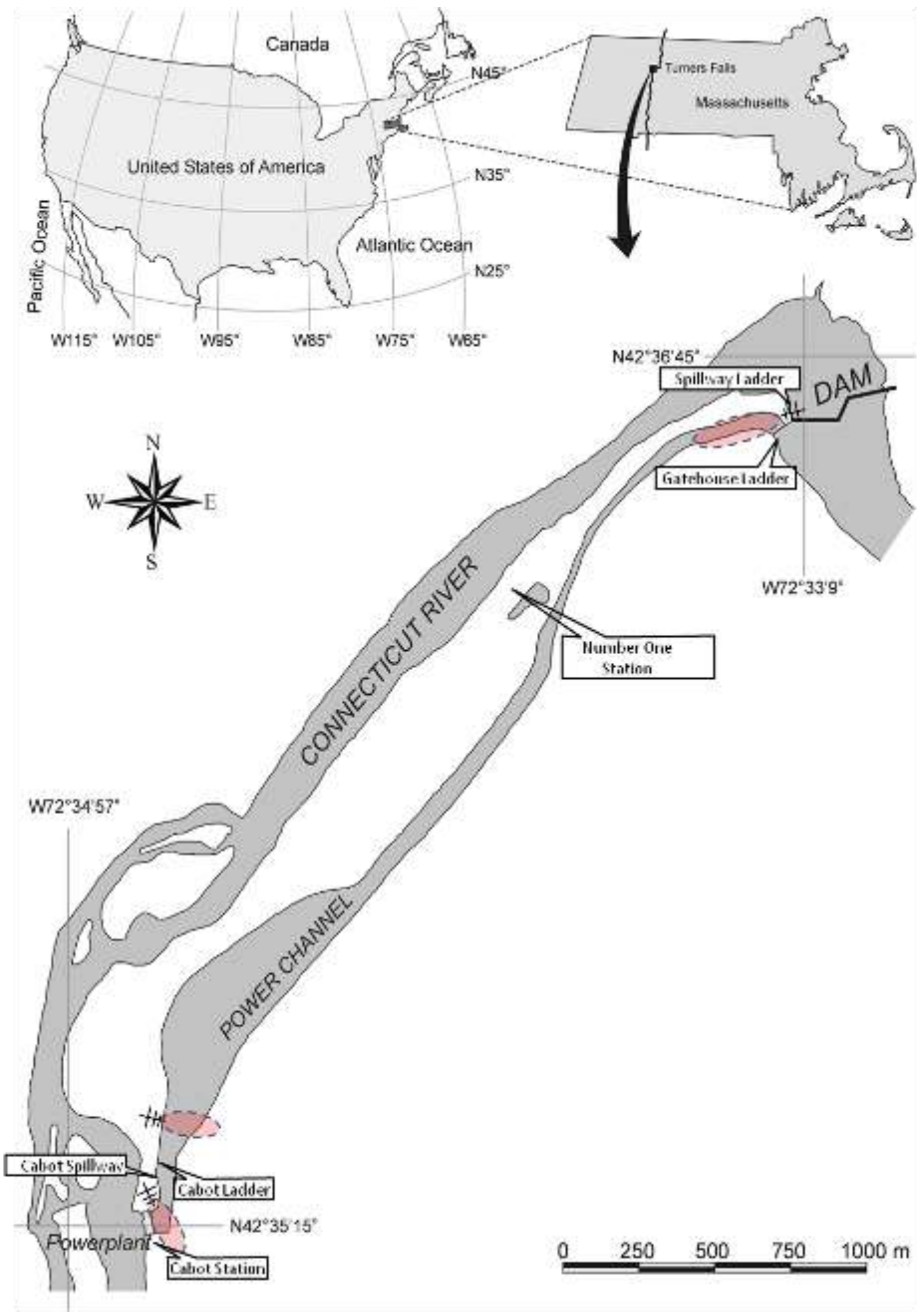

Figure 1. Location of Turners Falls Power Canal. Note locations of Yagi antennas—ellipses indicate approximate coverage. Drawing provided by Sergio Makrakis.

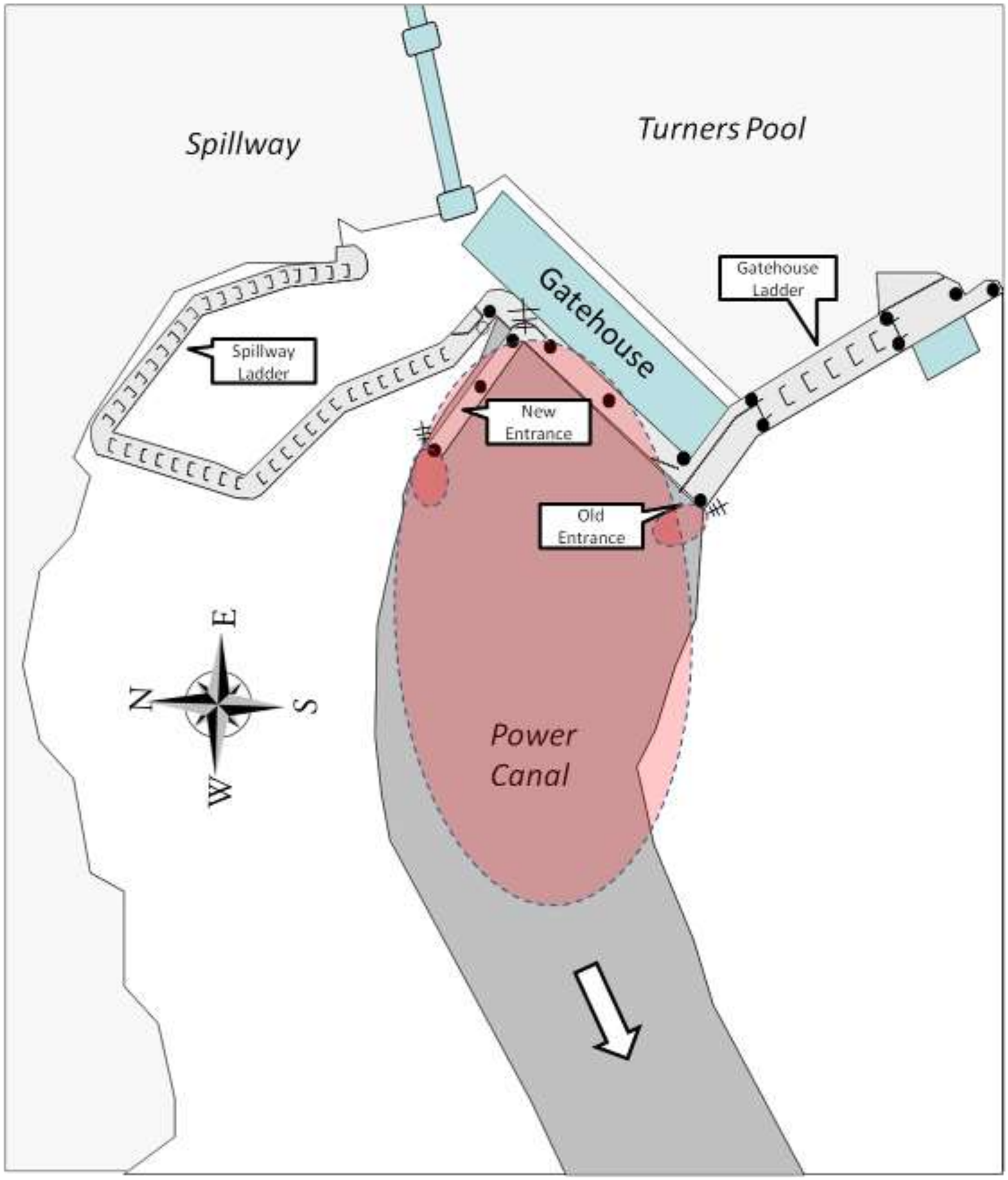

Figure 2. Shematic of the head-end of the Turners Falls Power Canal, showing locations of fishways, fishway entrances, and antennas. Coverage for yagi antennas are indicated by dashed ellipses. The large yagi monitors the Guidance Zone, the smaller yagis (actually coaxial antennas) monitor Attraction Zones. Entry and passage is documented by PIT antennas (indicated by black dots).

Table 1. Passage Counts by year at each of the Turners Falls Fishways. Period of study highlighted in bold. Estimated % of Cabot values refer to Gatehouse passers and are calculated assuming 60% passage success of shad ascending Spillway fishway (Jay McMenemy, pers. comm.). In 2002 this produced a negative estimate, which indicates some error in the estimate. Small values may not be significantly different from zero.

Year	Cabot	Spillway	Gatehouse	Estimated % of Cabot
1980	687	5	298	42.9%
1981	224		200	89.3%
1982			11	
1983	26697	263	12705	47.0%
1984	1831	4563	4333	87.1%
1985	31000	843	3855	10.8%
1986	22144	5857	17858	64.8%
1987	33114	3679	18959	50.6%
1988	28546	3354	15787	48.3%
1989	14403	1494	9511	59.8%
1990	31056	5898	27908	78.5%
1991	87168	6282	54656	58.4%
1992	94046	11760	60089	56.4%
1993	21045	898	10221	46.0%
1994		1507	3729	
1995	33938	543	18369	53.2%
1996		2293	16192	
1997	22518	3473	9216	31.7%
1998	14947	4721	10527	51.5%
1999	11501	4215	6751	36.7%
2000	12289	2240	2590	10.1%
2001	20933	2344	1540	0.6%
2002	7922	5372	2870	-4.5%
2003				
2004	5933	1980	2192	16.9%
2005	5404	1626	1581	11.2%
2006	11991	2577	1810	2.2%
2007	11130	1793	2248	10.5%
2008	**15809**	**627**	**4000**	**22.9%**
2009	**13391**	**918**	**3813**	**24.4%**
2010	**30232**	**2735**	**16768**	**50.0%**

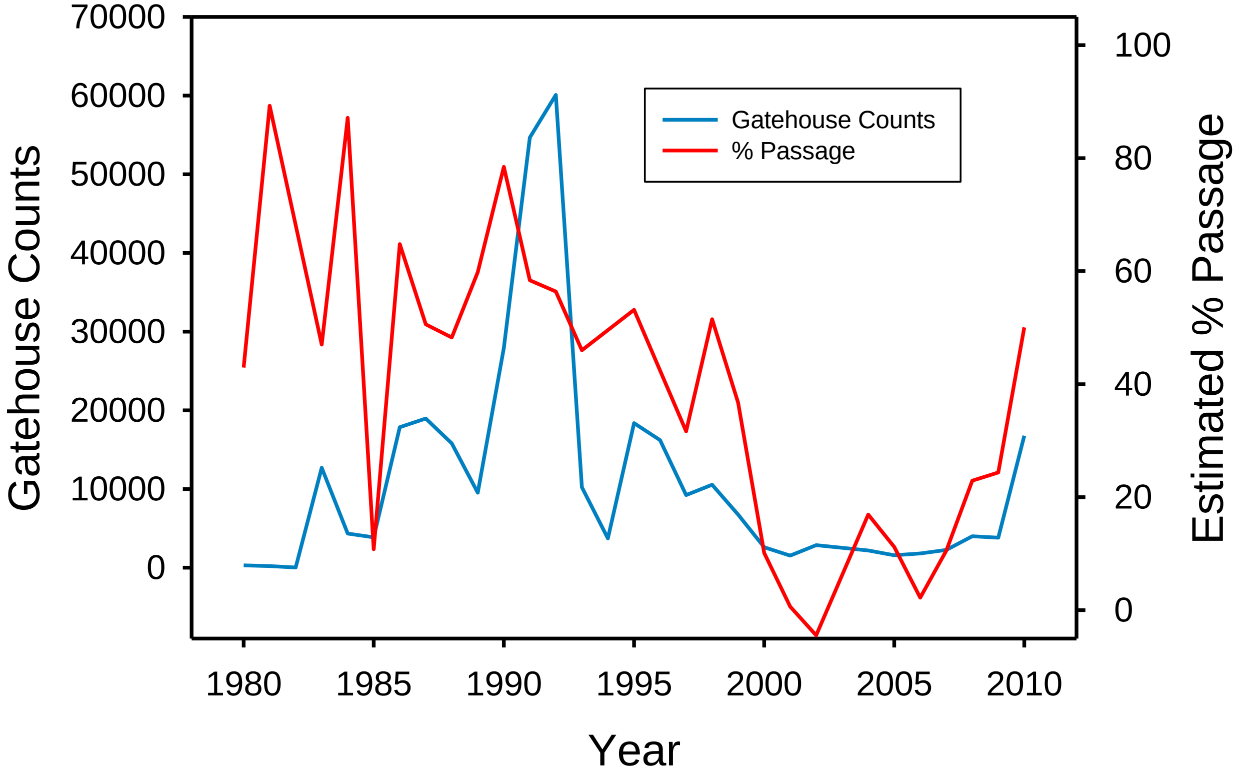

Figure 3. Data from Table 1 presented in graphical format.

Table 2. Summary of telemetry results of American shad in the Turners Falls Canal, 2008-2010. Data are separated by year, origin, and tagging method. Range of tagging dates are indicated next to origin. Note that in 2009 there was only a single release from Holyoke-origin shad. Entry route are presented separately, and numbers indicate discrete entry events—in each year some individuals entered more than once, but no individual passed more than once. Thus % passage for each entry route indicates passage success per attempt. Overall data are presented in the right two columns, showing what percent of radio-tagged individuals arrived at the Gatehouse and attempted to enter (% Arrival); % Passage indicates percent of tagged shad passing gatehouse through either route.

		New Entrance			Old Entrance			%	%
	Tagged	Entered	Passed	%	Entered	Passed	%	Arrival	Passage
2008									
Cabot	May 16 - June 05								
PIT Only	109	26	7	27%	4	3	75%		9%
PIT & RT	71	12	4	33%	7	5	71%	52%	13%
Combined	180	38	11	29%	11	8	73%		11%
2009									
Cabot	May 12 - June 04								
PIT Only	161	13	10	77%	18	13	72%		14%
IP	(74)	(04)	(04)		(11)	(08)			
Gastric	(54)	(08)	(05)		(05)	(03)			
IM	(33)	(01)	(01)		(02)	(02)			
PIT & RT	64	2	1	50%	4	2	50%	66%	5%
Combined	225	15	11	73%	22	15	68%		12%
Holyoke	Jun 05								
PIT Only	32	2	1	50%	3	2	67%		9%
PIT & RT	16	2	1	50%	3	2	67%	88%	19%
Combined	48	4	2	50%	6	4	67%		13%
2010									
Cabot	May 07 - June 07								
PIT Only	58	26	14	54%	3	1	33%		26%
PIT & RT	48	17	9	53%	1	0	0%	79%	19%
Combined	106	43	23	53%	4	1	25%		23%
Holyoke	May 07 - June 07								
PIT Only	63	47	20	43%	9	5	56%		40%
PIT & RT	50	42	9	21%	3	3	100%	92%	24%
Combined	113	89	29	33%	12	8	67%		33%

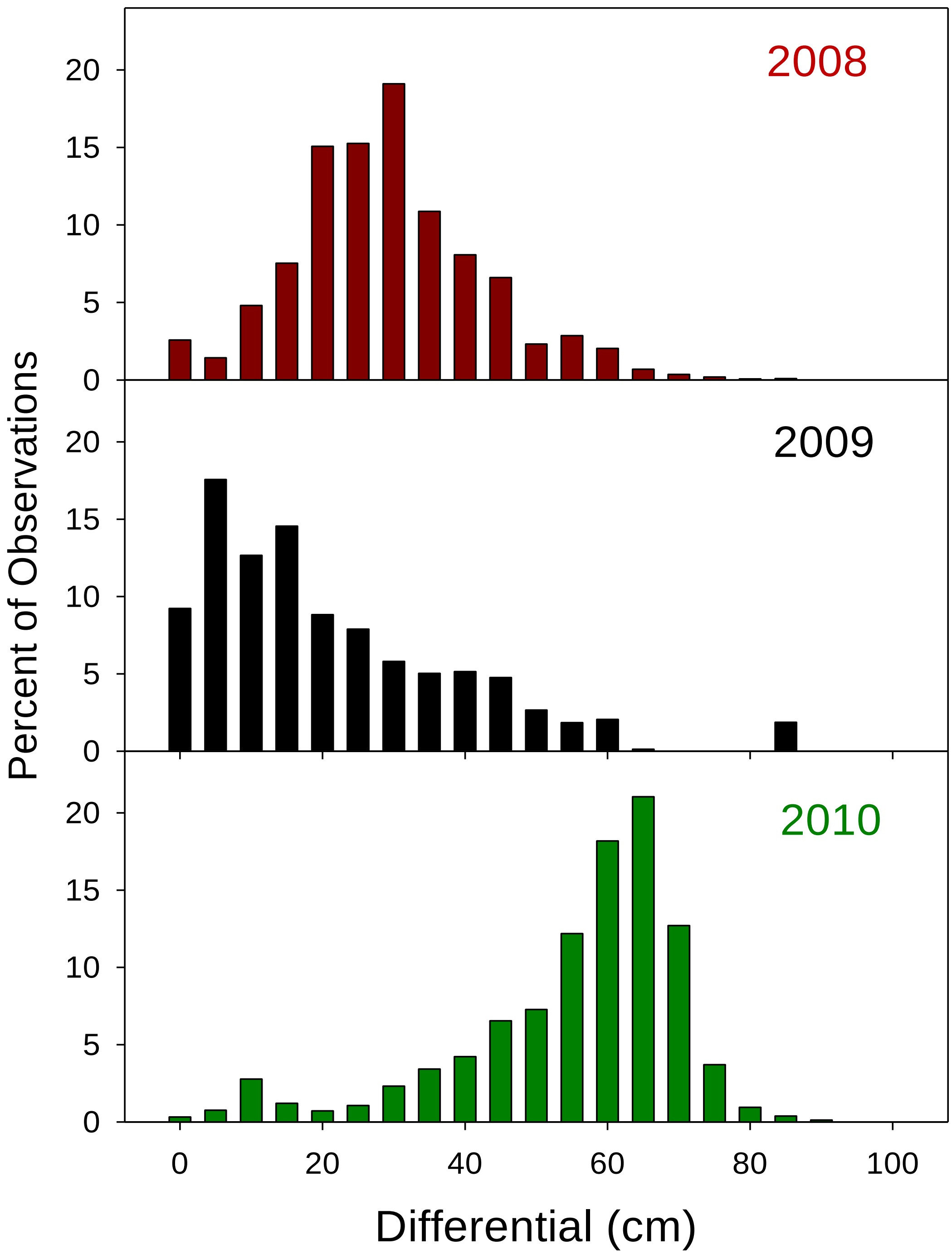

Figure 4. Distribution of head differential between the Gatehouse Gallery and Canal level at the New Entrance, 2008-2010. Greater differential corresponds closely with increased flow velocity and discharge, although discharge is also a function of canal depth, which correlates with total canal discharge. Note that 2010 had the greatest differential of all years of study.

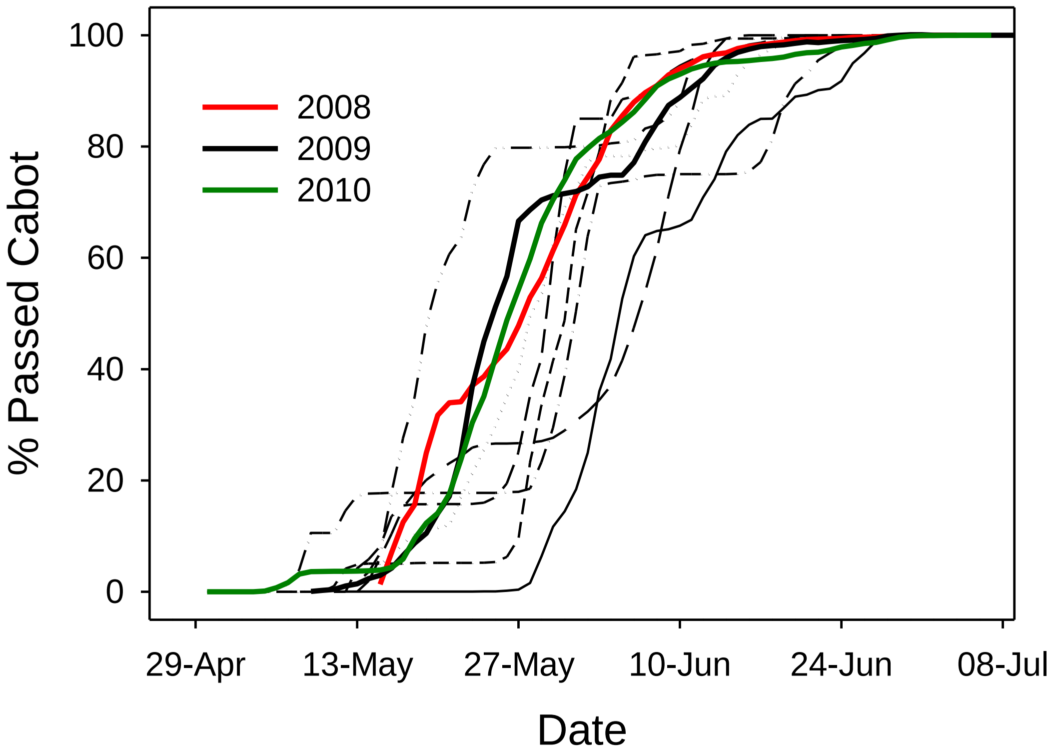

Fig 5: Cumulative passage curves from Cabot Counts. Counts from 2000-2007 are indicated by thin curves; 2008-2010 indicated in bold. Note the earlier onset of the migration during 2010.

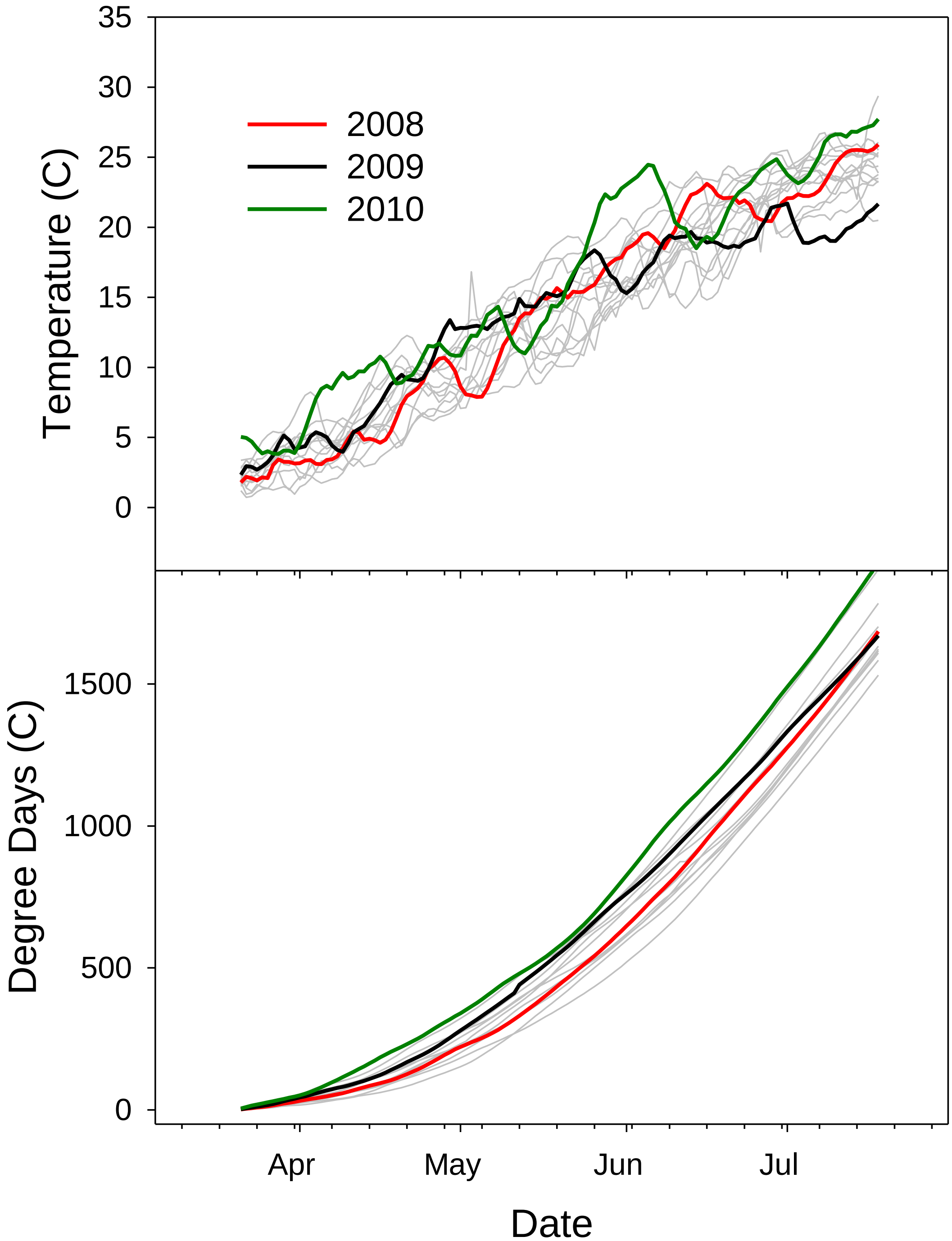

Fig. 6: Temperatures and Degree Days; 1996-2007 indicated in light gray, bold curves represent period of study (2008-2010).

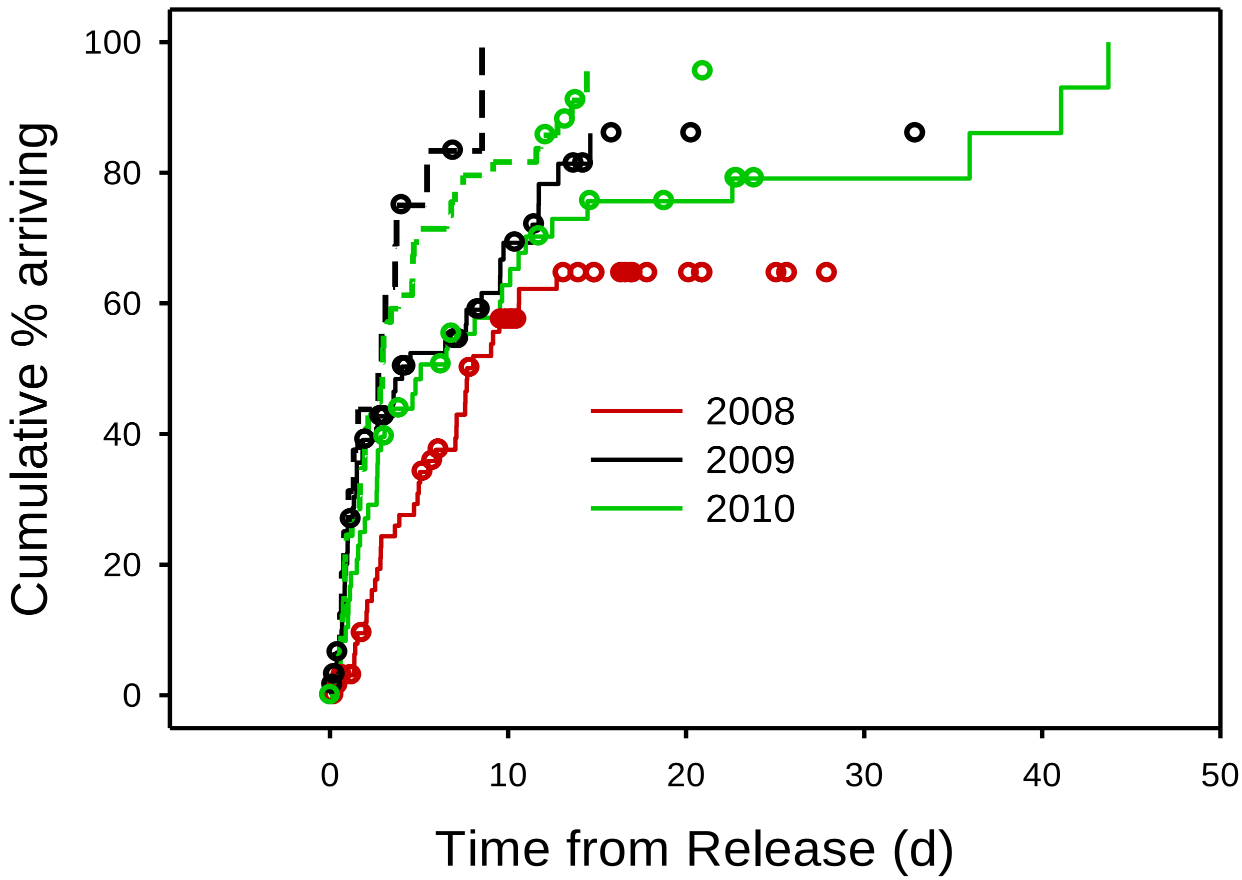

Figure 7. Time elapsed between release and first detection at Gatehouse. Solid lines indicate shad from Cabot Trap, dashed lines are from Holyoke Lift. Circles indicate censored observations, i.e. last radio detection of shad that did not arrive at Gatehouse. Note the slow arrival times during 2008. Also note the rapid arrival times of Holyoke transported shad, particularly of the 3rd -4th quartiles. Of those shad that arrived at the Guidance Zone, most returned at least once (i.e. >=2 presences—Figure 13).

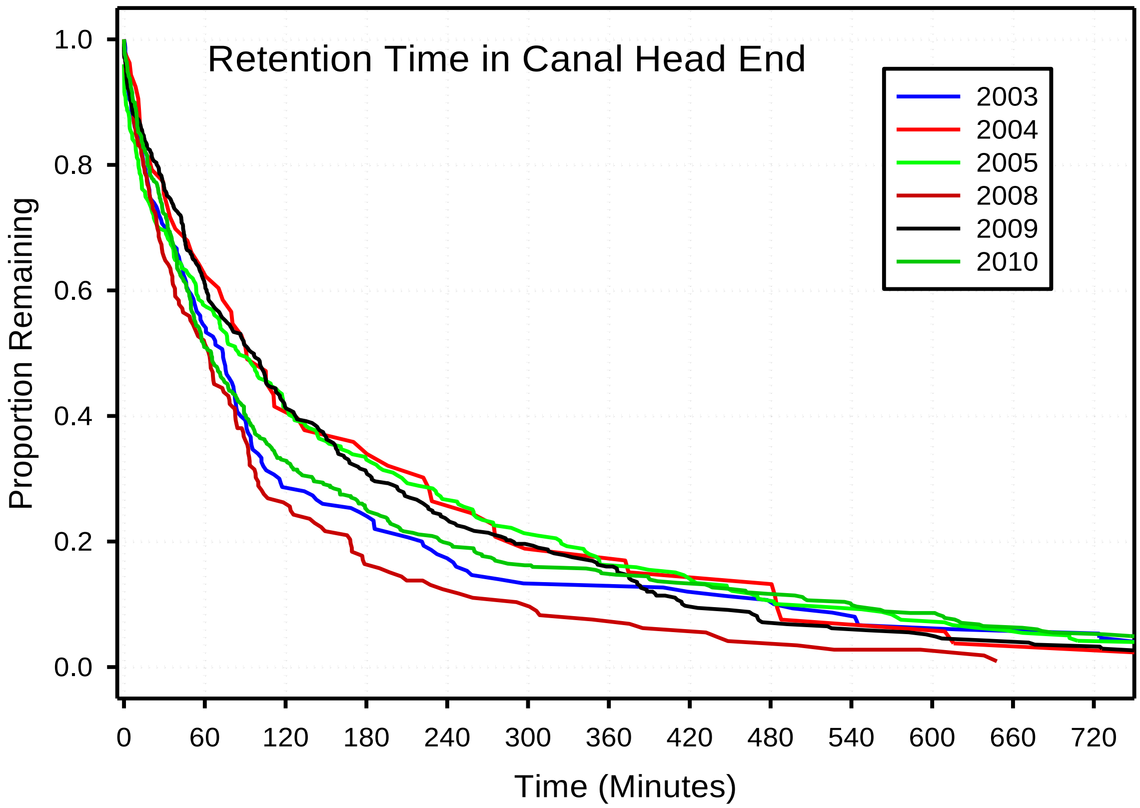

Figure 8. Guidance Zone Retention: Study years 2003-2010. Data are not cumulative, i.e. they represent exposure time for a single Guidance Zone Presence. Note that 2010, the year with best passage, had relatively low retention in the Guidance Zone.

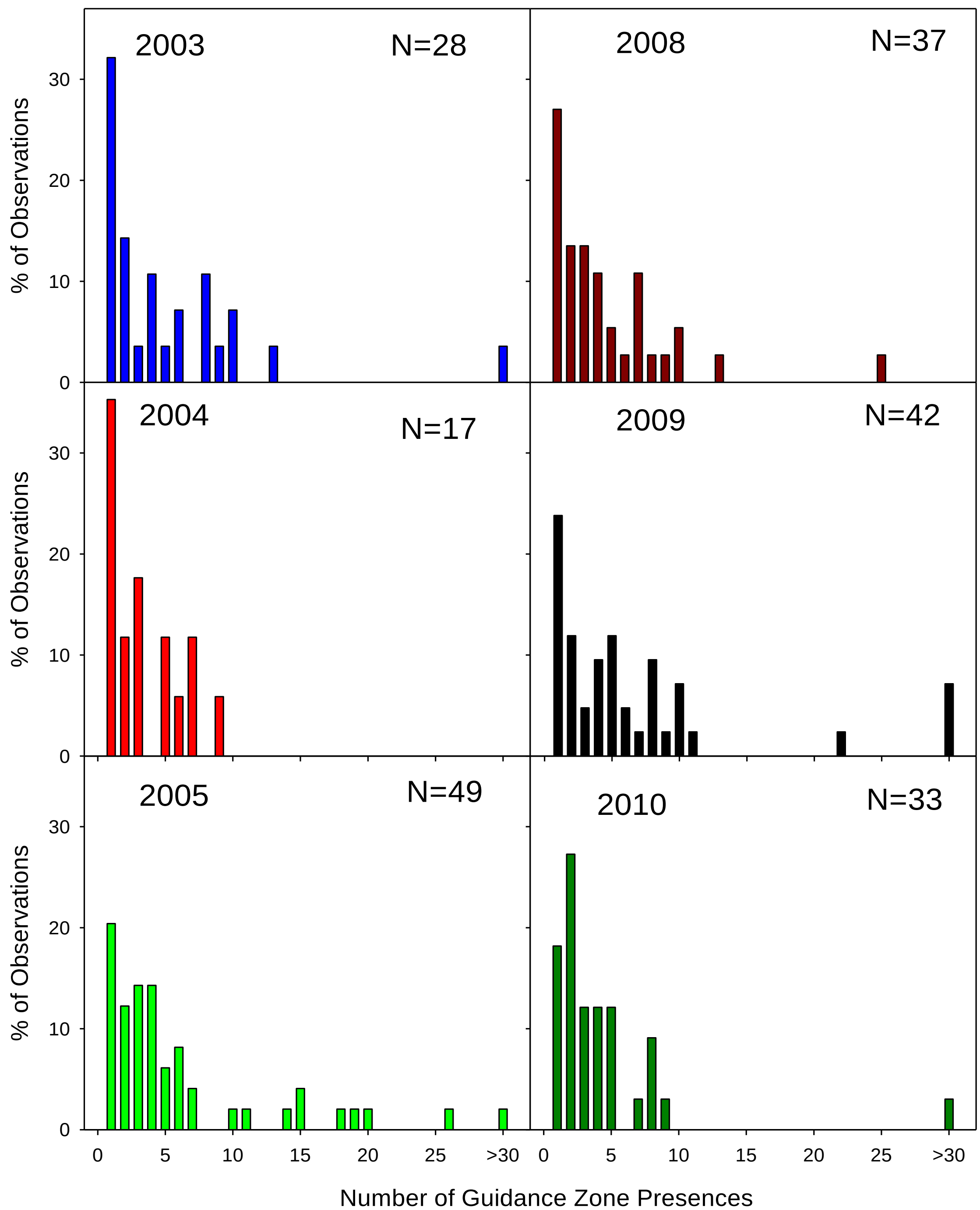

Figure 9. Number of Guidance Zone presences of Cabot Trap-caught shad, 2003-2005 and 2008-2010. Note that 2010 is unique in having a mode at 2 presences: in each previous year the mode was at 1. Only shad that entered the Guidance zone are included in this figure.

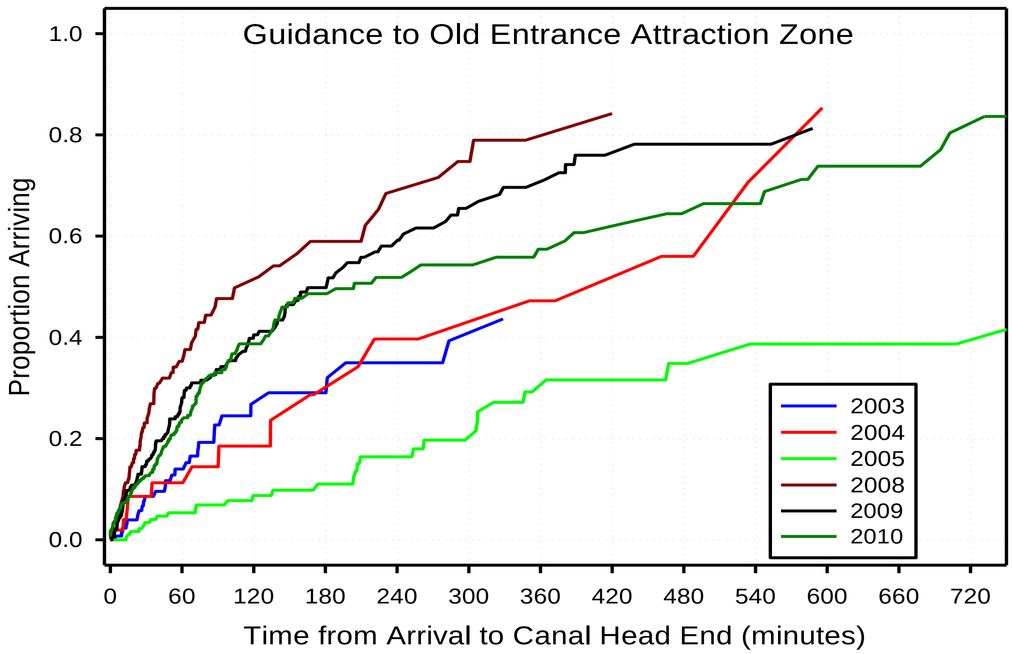

Figure 10. Guidance to Old Entrance Attraction Zone. Note improved guidance in 2008-2010. Proportion guided is the product of the probability density function (pdf) of this distribution and the survivorship function of Retention (Figure 6). Note that multiple guidance events can occur within a single Guidance Zone presence (Figures 13 & 14).

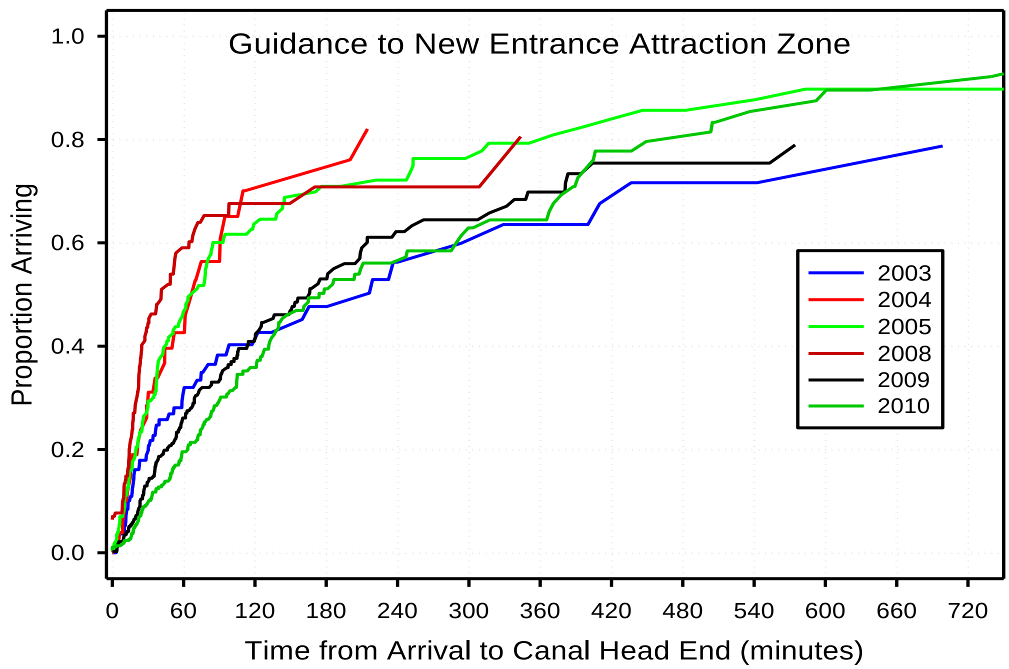

Figure 11a. Guidance to New Entrance Attraction Zone. . Proportion guided is the product of the pdf of this distribution and survivorship funcition of Retention (Figure 6), which often results in multiple entry zone presences (Figures 13 &14).

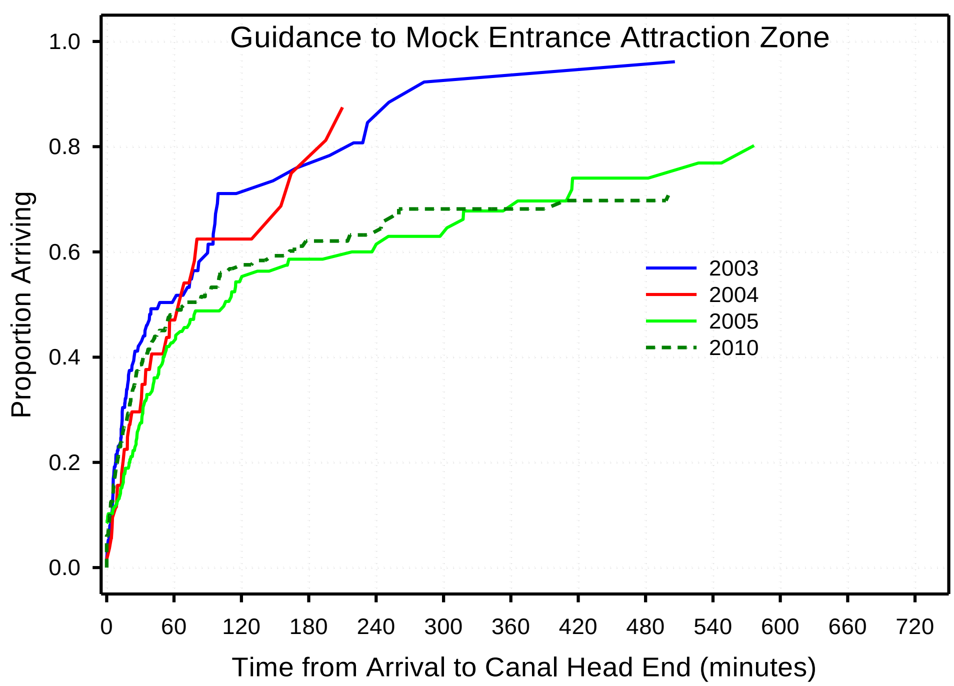

Figure 11b. Guidance time to Mock Entrance Attraction zone. 2010 data shown in green.

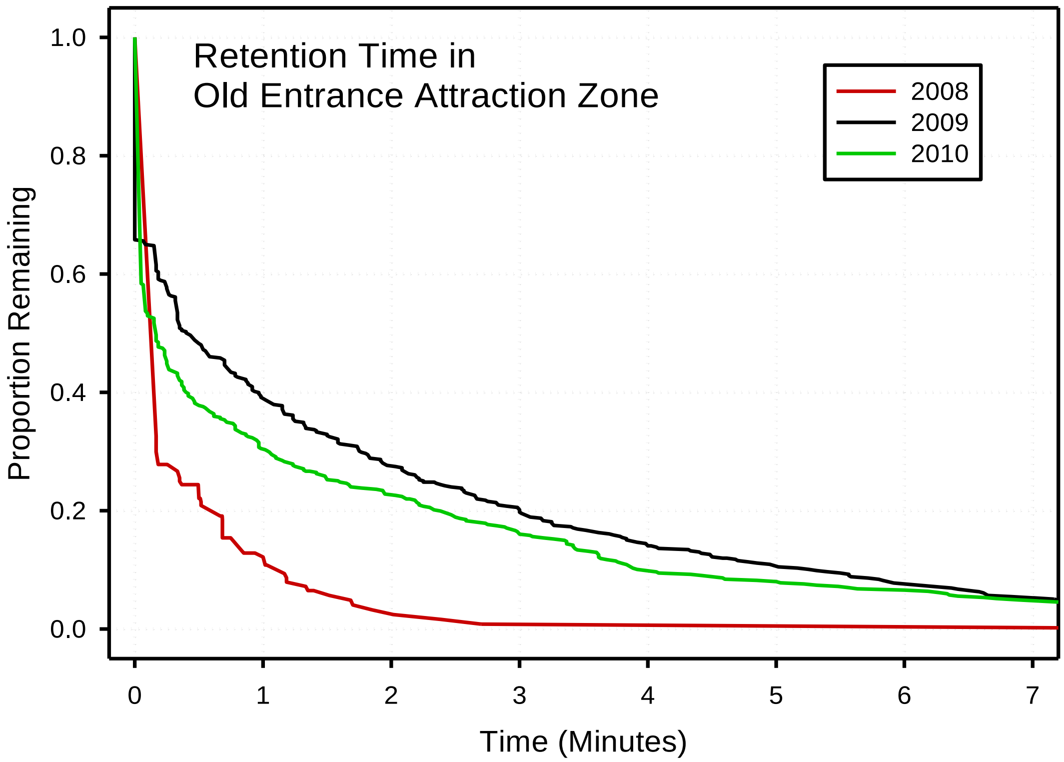

Figure 12a. Retention time in Old Entrance Attraction Zone.

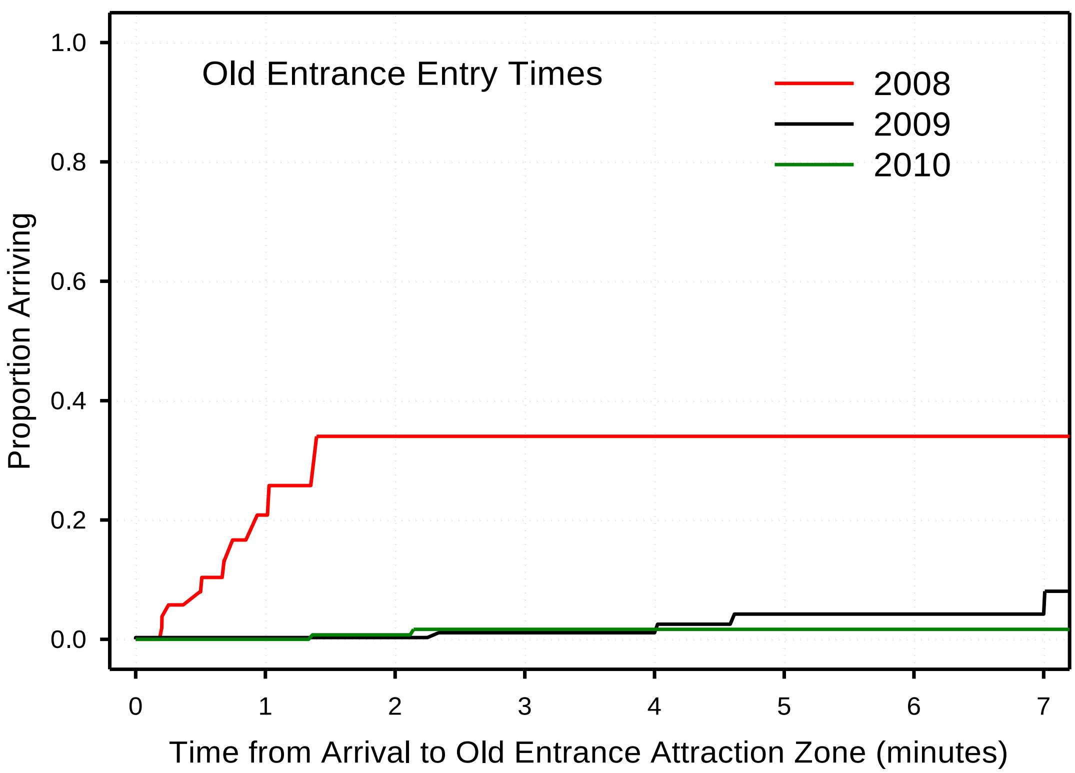

Figure 12b. Attraction time into Old Entrance.

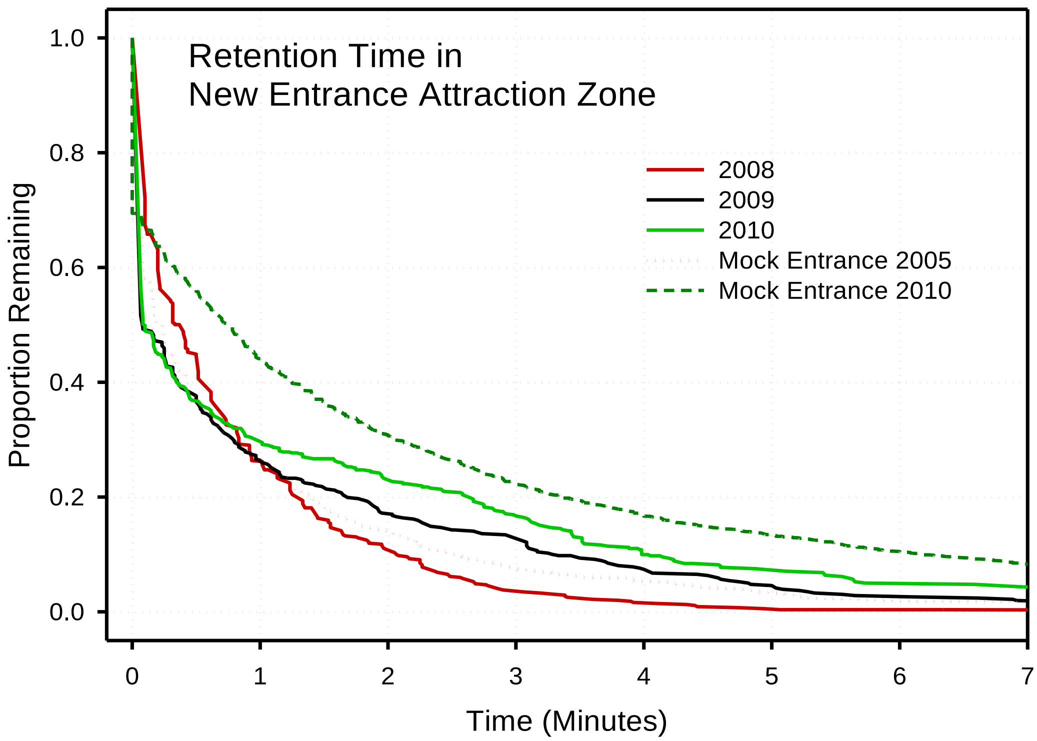

Figure 13a. Retention time in New Entrance Attraction Zone ($S(t_{RE})$). 2005 Mock Entrance data included for reference; 2010 MITAS data from Mock Entrance Attraction Zone added for comparison.

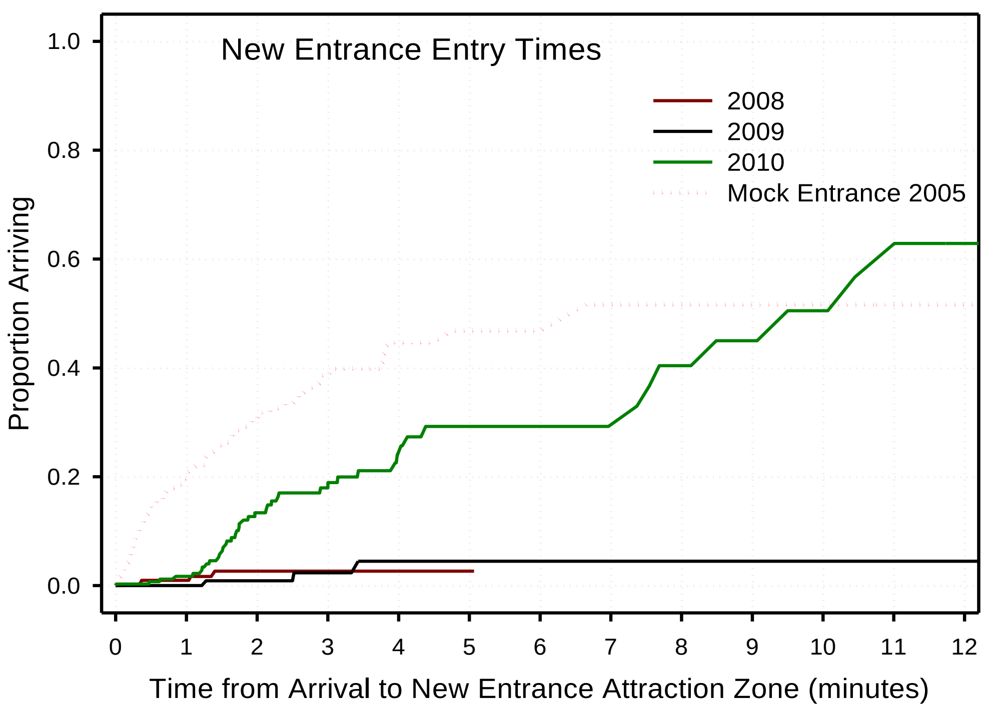

Figure 13b. Attraction time into New Entrance. Note that the scale has been expanded to accommodate the data. A single outlier has been removed from the 2008 curve. Mock Entrance data included for reference.

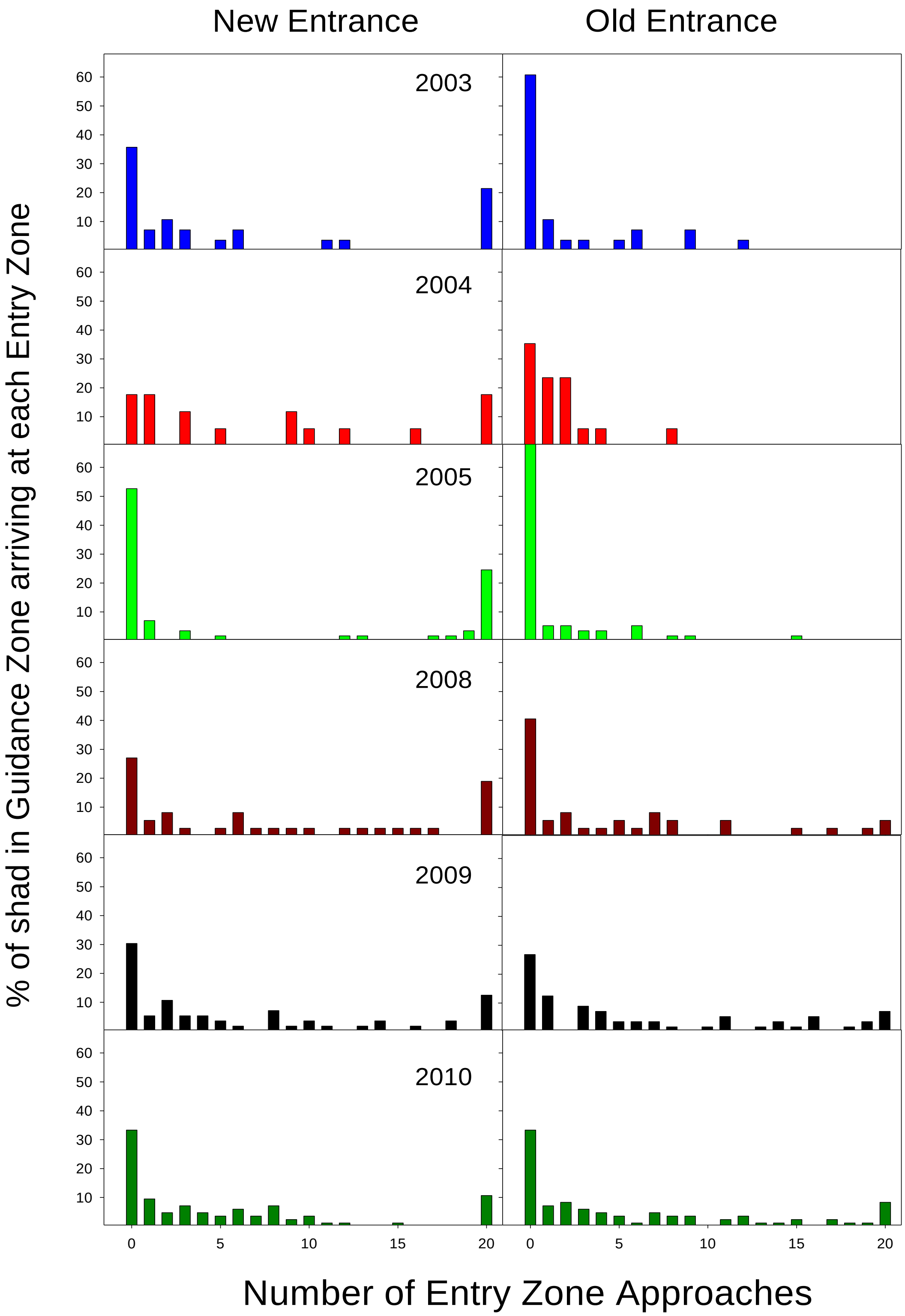

Figure 14. Percentages of shad present in guidance zone approaching each entry zone by year. Note the superior guidance to the New Entrance location before installation (2003-2005). This advantage disappears after installation of the New Entrance (see Figure 8), not because of reduced guidance, but because guidance to the Old Entrance improved.

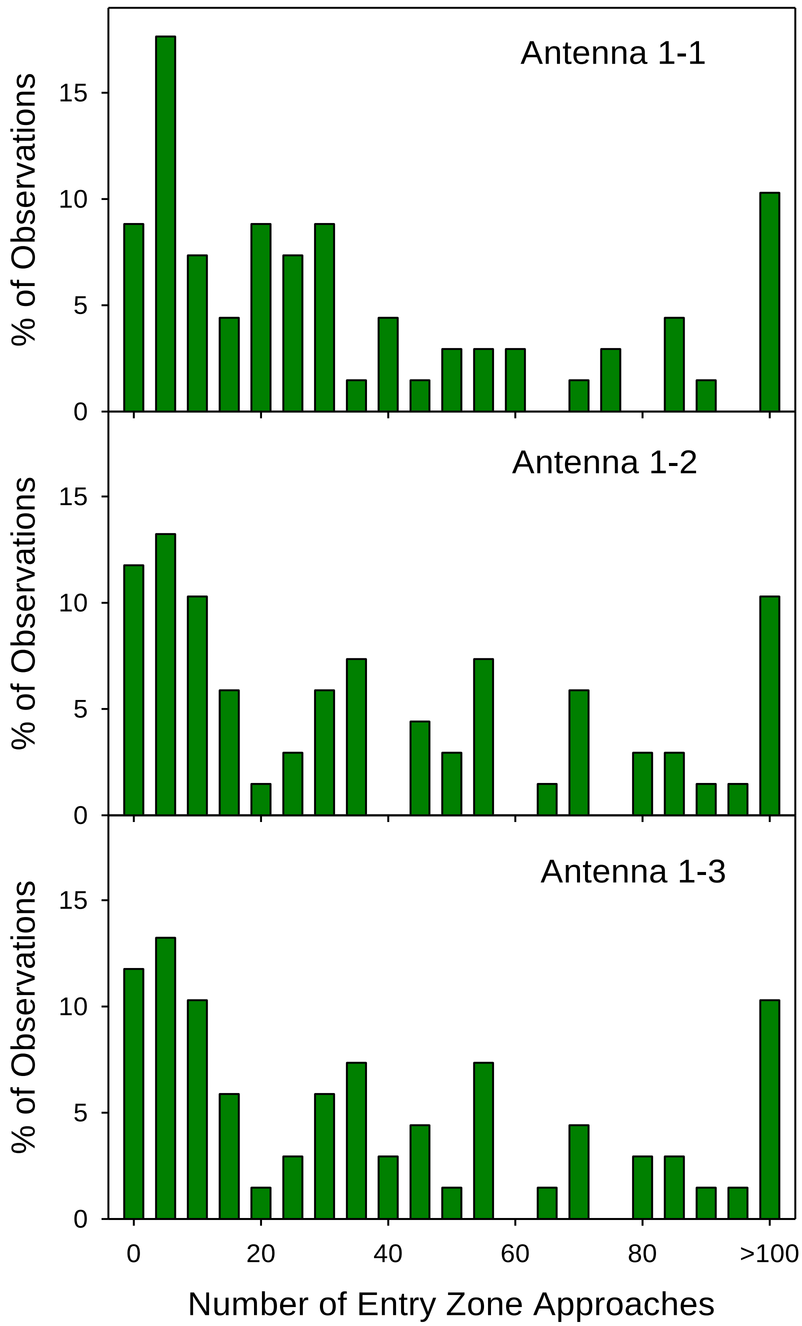

Figure 15. Number of approaches to potential entrance locations, corresponding to MITAS antennas 1-1, 1-2, and 1-3. Location 1-3 is the existing New Entrance Location; 1-2 is the former Mock Entrance location, and 1-1 is downstream, near the chainlink fence. Note that the total number of approaches from the MITAS antennas is greater owing to reduced detection area of each antenna. These data are provided to assist in evaluating the potential benefits of extending the New Entrance. See Appendix A for antenna configuration.

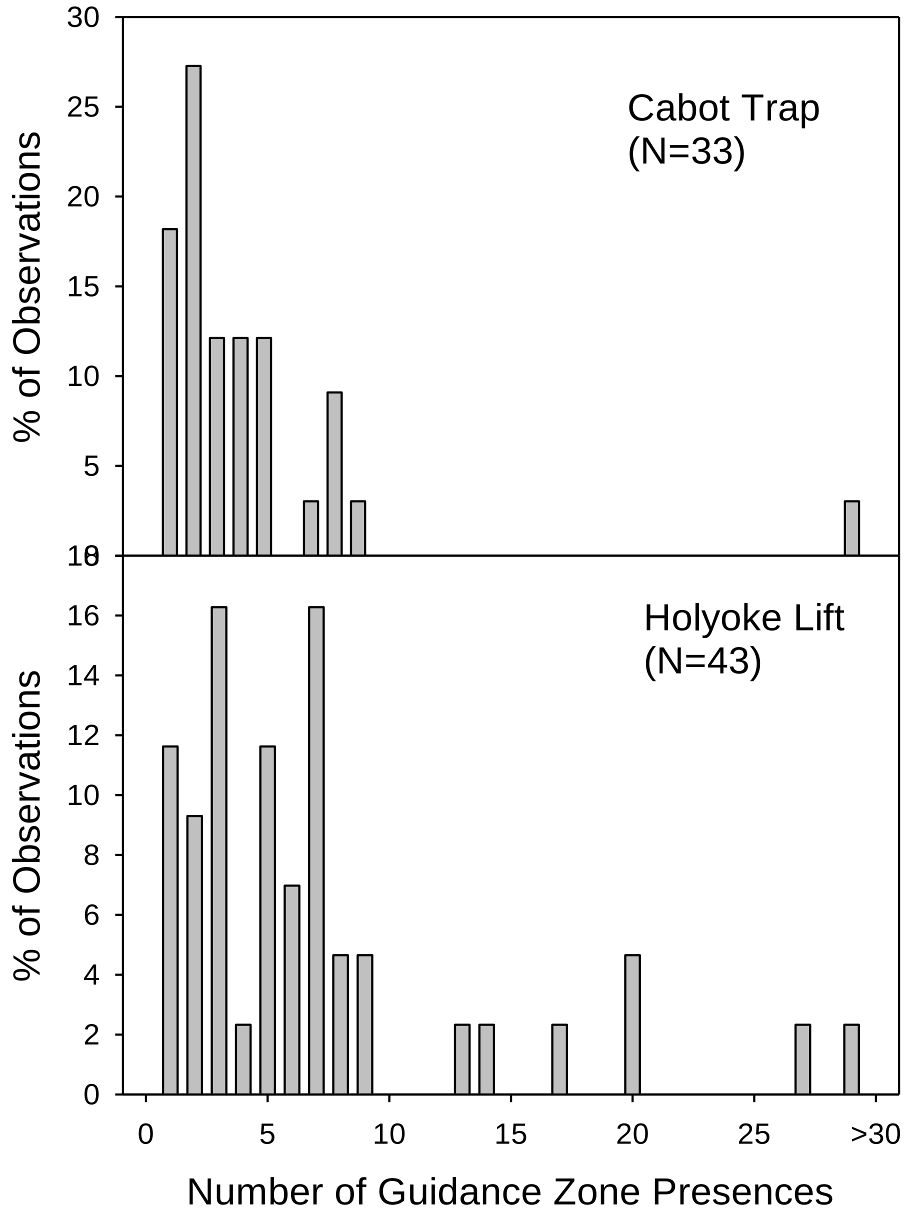

Figure 16a. Comparison of guidance zone presences during the 2010 study for shad obtained from the Cabot Trap and those from Holyoke. The two distributions are significantly different (K-W test P=0.0143).

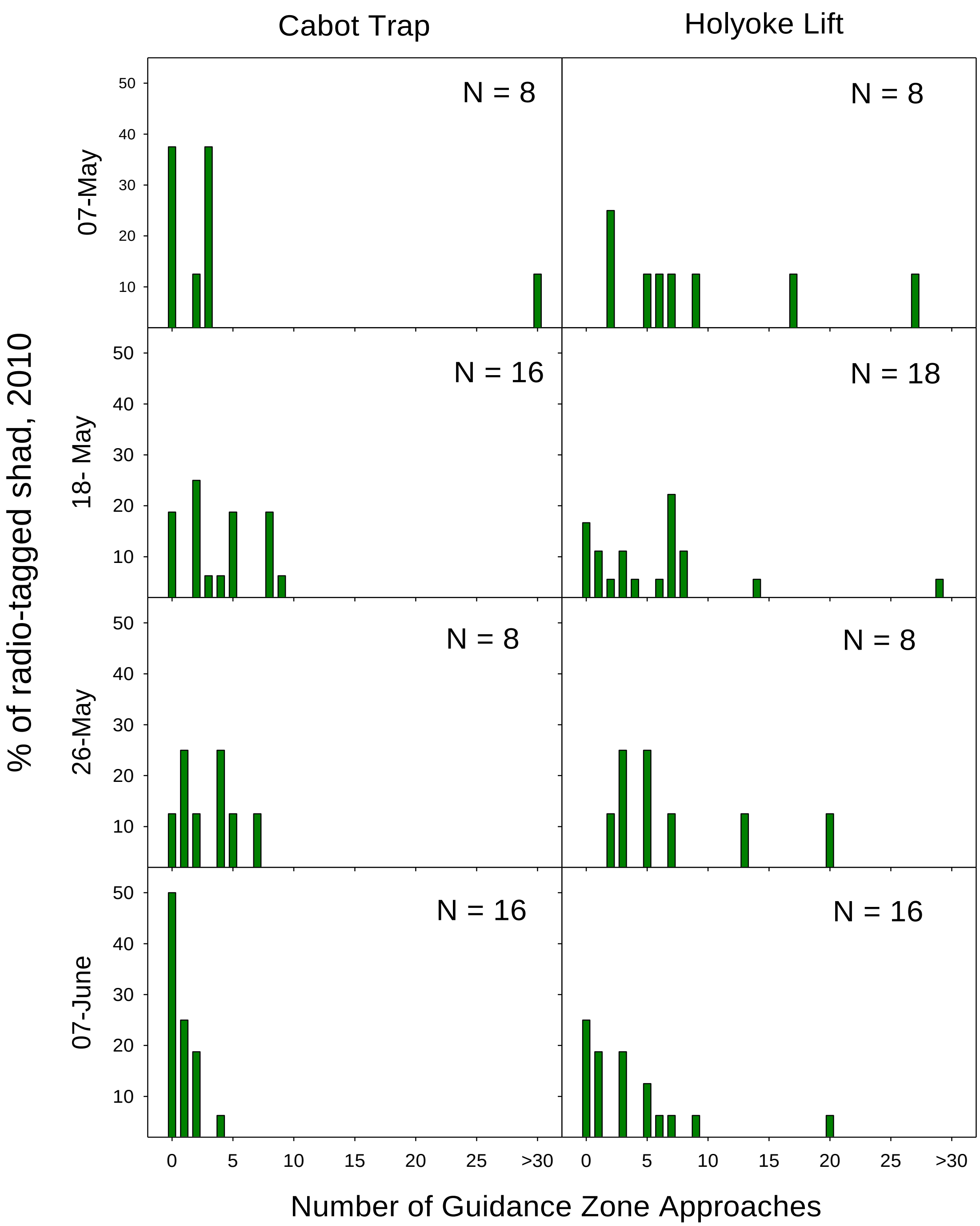

Figure 16b. Distribution of guidance zone approach number by release date and origin during 2010. Note that shad from the Holyoke Lift consistently have greater numbers of approaches.

Literature Cited

Castro-Santos, T. and Haro, A. 2005. Turners Falls fish passage studies 2005: results from PIT and radio telemetry studies. CAFRC Internal Report #2005-04.

Castro-Santos, T. and Haro, A. 2008. Preliminary Report of 2008 Gatehouse Telemetry Studies. S.O. Conte Anadromous Fish Research Center Internal Report.

Castro-Santos, T., Haro, A., and ` 2009. Turners Falls Gatehouse Telemetry Studies 2009: Interim Report.

Sullivan, T. J., Haro, A., and Castro-Santos, T. 2001. Passage of American Shad at Turrners Falls Fishways: PIT Tag Evaluation 2001. S.O. Conte Anadromous Fish Research Center CAFRC Internal Report No. 2002-01. Turners Falls, MA

Appendix A. Schematic layout of MITAS antenna array. Data from this array was used in this study to compare 2010 observations with similar array data from 2003-2005. Antenna locations are labeled for comparison with Figure 15.

Results of Turners Falls Fishway Studies: 2011

By

Theodore Castro-Santos
And
Alex Haro

S.O. Conte Anadromous Fish Research Center
USGS-Ecosystems, Leetown Science Center
One Migratory Way, P.O. Box 796
Turners Falls, MA 01376

PRELIMINARY DATA SUBJECT TO REVISION

This report is being provided as a courtesy of the USGS and is for information purposes only. The report has not been subject to independent peer review and USGS makes no warranty as to reliability of results or their interpretation.

This report summarizes results of studies conducted during the 2011 migration of adult American shad on the Connecticut River as they passed through the Turners Falls fishway complex. This is part of a larger effort that has been ongoing since 1999 and of a focused effort to improve passage at the Gatehouse Fishway that has been underway since 2003.

During 2011, adult shad were tagged and released into the Turners Falls power canal from two sources: the fishway trap at the top of Cabot Ladder, adjacent to the power canal, and from the Holyoke fishlift in Holyoke, MA. Capture, handling, transport, and tagging were all performed using the same protocols described previously (Castro-Santos and Haro 2010).

During 2011 expanded work was performed upstream and downstream of Turners Falls. Some of this has already been reported elsewhere (Castro-Santos 2011). A consequence of this increased effort is that tags released for studies at Vernon Dam were also monitored at Gatehouse, providing ancillary benefits to the analysis. Likewise, shad being tagged in the lower river and at Holyoke also contributed to the data available in 2011 (Table 1).

In addition to these totals, 11 repeat spawners from the 2010 study returned to Holyoke in 2011. This is an unusual occurrence and may represent the first time we have seen significant numbers of repeat spawners from above Turners Falls. They were split nearly 50:50 between Holyoke Lift and Cabot Trap origin shad.

Because we expected shad to be arriving from Holyoke and the Lower River, we deployed PIT and radio antennas at the entrances of both Cabot and Spillway ladders in addition to those deployed at Gatehouse. Although 15 shad entered the Spillway ladder, none of these passed successfully. In contrast, 6 of 7 salmon that entered the Spillway ladder did pass successfully. The shad passage numbers were unusually low at Spillway, suggesting that a problem existed with that fishway during the 2011 season.

Table 1. Numbers of Connecticut River American shad tagged during 2011

Source	Release Loc	Pit only	Pit & Radio	Combined N
Lower River	LR	10	82	92
Holyoke Lift	HL	3	70	73
Cabot Trap	Cabot	94	54	148
Trucked from Holyoke	Cabot	117	63	180
Total		224	269	493

Passage performance through Cabot was better than usual however (Table 2). Twenty four Shad tagged downstream of Turners Falls during 2011 entered Cabot Fishway; of these 6 (25%) passed successfully. The percentage passing from Holyoke was slightly lower (20%)—this value is important because we have comparable data on passage from Holyoke shad from previous years (Castro-Santos and Haro 2005) which suggest that 20% passage is as good or better than we have documented in several years of monitoring this fishway. Passage of repeat spawners was even greater (5 of 8 entering, or 63%), but the small sample size of this group means that the confidence intervals around this measure are broad (35-91%). Nevertheless, they do point to passage performance being better than we have expected in recent years. This suggests that the passage performance observed at Gatehouse might also have been better than we might expect in future years, and the apparent progress (see below) may be at least in part an artifact of an unusually good passage year for shad.

Table 2. Passage through Cabot Ladder

Origin	Fishway	N Entered	N Passed	% Passage
HL	Cabot	10	2	20%
LR	Cabot	14	4	29%
RS	Cabot	8	5	63%

The above caveats notwithstanding, passage performance at Gatehouse Fishway was similar to what we saw in 2010, and much improved over the previous decade: Counts data indicate that 57.7% of Cabot-passed shad successfully passed Gatehouse. Turbid conditions affected counts on some days, so the error in this estimate may be greater than usual. Also there were serious problems with the camera system at the top of Spillway, meaning that counts data for Spillway ladder were unavailable for large parts of the run. Because we had good PIT coverage of that fishway, however, and given that we observed 100% failure within Spillway ladder in 2011, it is unlikely that large numbers of shad passed Spillway, meaning that the counts data at Gatehouse comprised almost entirely shad that ascended Cabot fishway. Given that the total number counted was nearly identical to last year, it seems likely that the % Passage value based on counts data is reasonably accurate.

Telemetry data support this interpretation. Of 117 radio-tagged shad released into the canal, 109 provided data. Of those, 80 arrived at the Gatehouse tailrace, or 73% of the available shad (Figure 1). This is somewhat lower than we observed in 2010 (85% arrival). One possible explanation for this is the warm conditions under which shad were being tagged. The migration began with an early strong pulse in 2011, and by the time of the first release on 24-May, 25% of the run had already passed Cabot. More shad migrated downstream out of the system shortly after release than in previous years, particularly among Cabot-trapped shad (Figure 1).

Table 3. Percent passage through Gatehouse of available shad. Shad were either caught in the Cabot Fishway trap and released at its upper end (Cabot Trap Shad) or were caught at the Holyoke Lift and trucked to Turners Falls, where they were released into the power canal (Holyoke Shad). Contribution of lower river shad and those tagged and released at Holyoke, as well as repeat spawners are also included.

	2011	2010	2009
Counts	58%	50%	24%
CabotTrap Shad			
PIT Only	23%	28%	18%
PIT&Radio	22%	19%	5%
Combined	23%	24%	12%
Holyoke Shad			
PIT Only	43%	40%	
PIT&Radio	48%	24%	
Combined	45%	33%	
Lower River			
(incl. Holyoke)	67%		
RepeatSpawners	60%	(N=5)	

Both the radio and PIT data indicate that tagged shad pass at lower numbers than untagged shad. This probably represents a handling effect, which we have experienced in all previous years, and is a well-known feature of shad telemetry. Handling is the same between years, however, and percent passage of tagged shad was comparable to 2010 observations (Table 3).

Passage behavior at Gatehouse was generally similar to previous years, with some notable exceptions (Figures 2-5). Behaviors are best understood when separated into events of approach, entry, and passage. Within each zone, shad have the ability to advance into the subsequent zone (e.g. Approach zone to Entry zone) or retreat to the previous zone. Opportunity to advance is determined by the amount of time spent in each zone (retention time). Figures 2-4 are arranged to show retention time in the approach zone and each of the two entry zones, as well as rates of advancement to the next zone.

Table 4. Summary of approach data for shad arriving at the Gatehouse Approach zone as well as the Entry Zones of the New Entrance and Old Entrance. Range and median refer to number of approach events by individual shad.

Zone	N Events	N Shad	Range	Median
Gatehouse Approach Zone	344	80	1 - 12	3
Entry Zone				
New Entrance	159	66	1 - 9	2
Old Entrance	90	51	1 – 6	1

Retention time at the canal head-end was within the range of what we have observed in previous years, but was generally lower than average. This means that on a given exposure shad had relatively less time in which to locate and enter either of the fishway entrances (Figure 2, top panel). This was offset for the New Entrance by the fact that shad approached more rapidly than usual (center panel). Approaches to the Old Entrance were about average, but lower than we have seen in recent years (lower panel). Combined, these data suggest that conditions were conducive to improved guidance to the New Entrance compared with 2010.

Once fish arrived at either entrance they were once again confronted with opposing rates of retention and entry. For the New Entrance (Figure 3), retention rates near the entrance (upper panel) were the highest we have seen at this location to date. Entry rates (lower panel) were also among the highest, but notably lower than were observed in 2010.

A similar pattern was observed at the Old Entrance (Figure 4). Here retention (upper panel) was remarkably higher than previous years; entry was also the highest seen since 2008. Importantly, 2008 had very poor retention: the improved entry coupled with improved retention appears to suggest significant improvement to the Old Entrance in 2011. This appearance may be misleading, however. Gain tolerances on the receiver were changed in 2011 owing to new evidence provided by the MITAS system (Figure 5). It may be that the extended retention we observed is a result of increased sensitivity of the receiver at this location. Further analysis will be needed to assess the magnitude of this effect.

Despite these apparent improvements, proportion entering each of the two routes was comparable to 2010, with 81% of all entry events occurring through the New Entrance (Table 4).

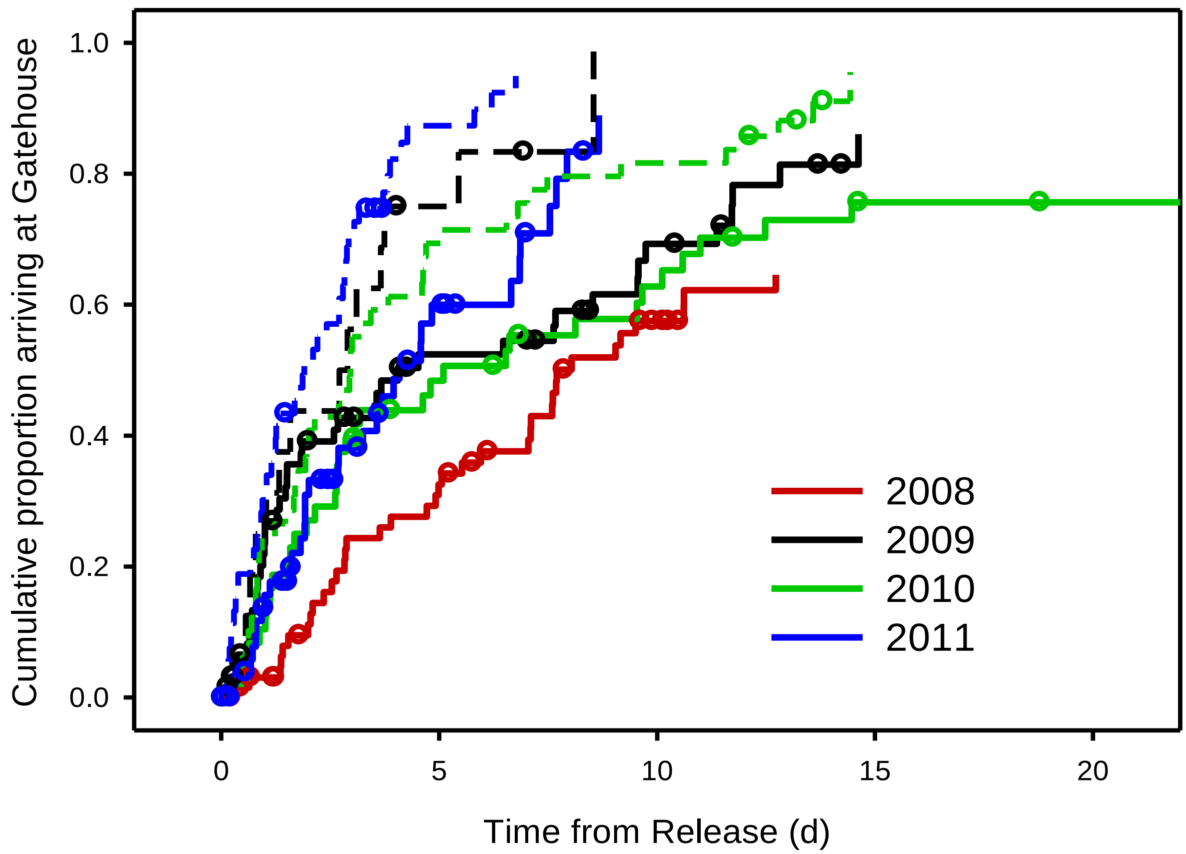

Figure 1. Elapsed time between release and arrival at the Gatehouse Approach Zone. Solid lines represent shad collected at Cabot Trap, Dashed lines represent shad collected and trucked from Holyoke. Circles indicate last-known observation in the canal or known time of downstream passage at the Cabot bypass—these observations are censored at their last extant time.

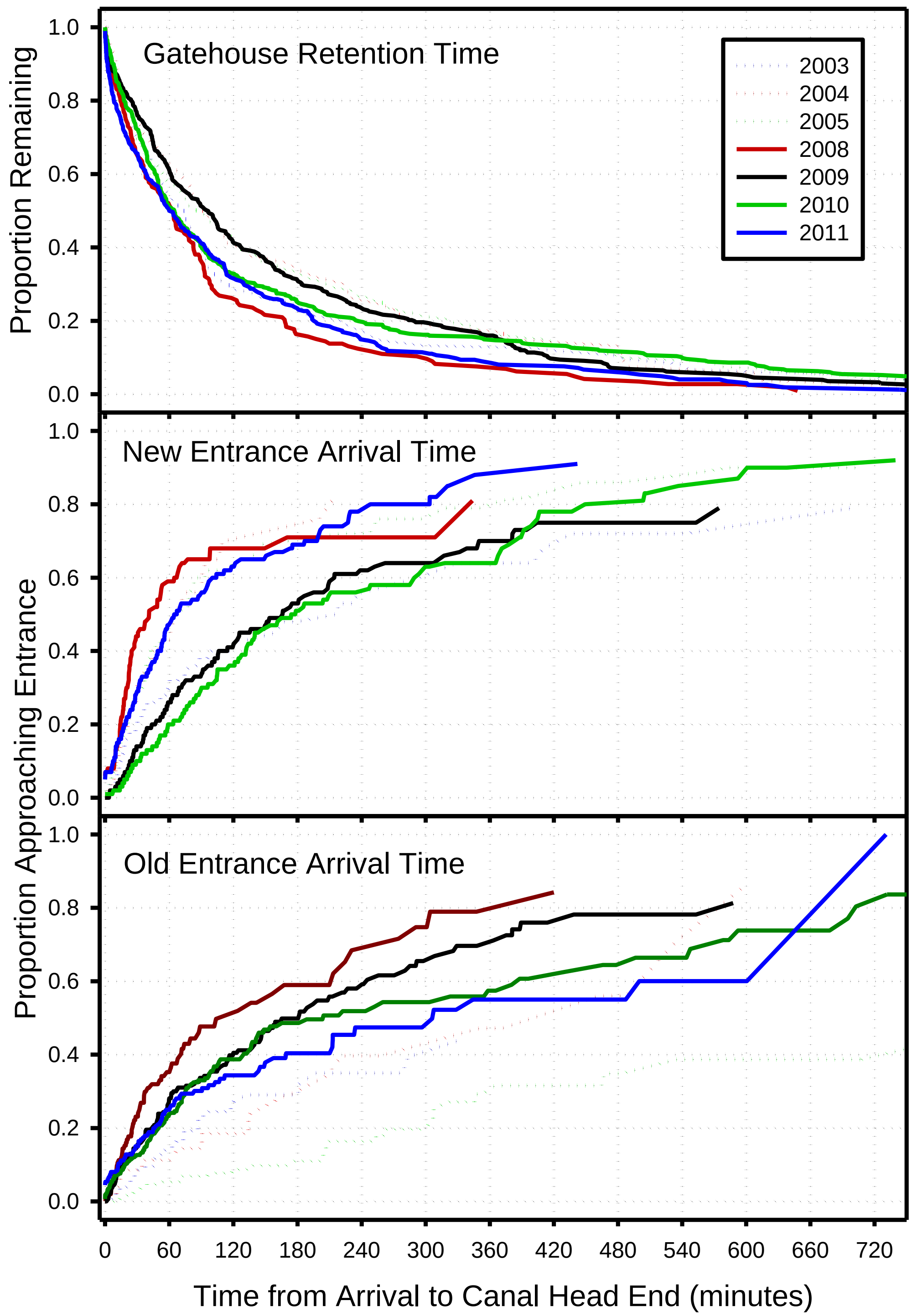

Figure 2. Retention time in the canal head-end and approach times to each of the two entrances. Note that shad approached the New Entrance at a greater rate than in the previous 2 years.

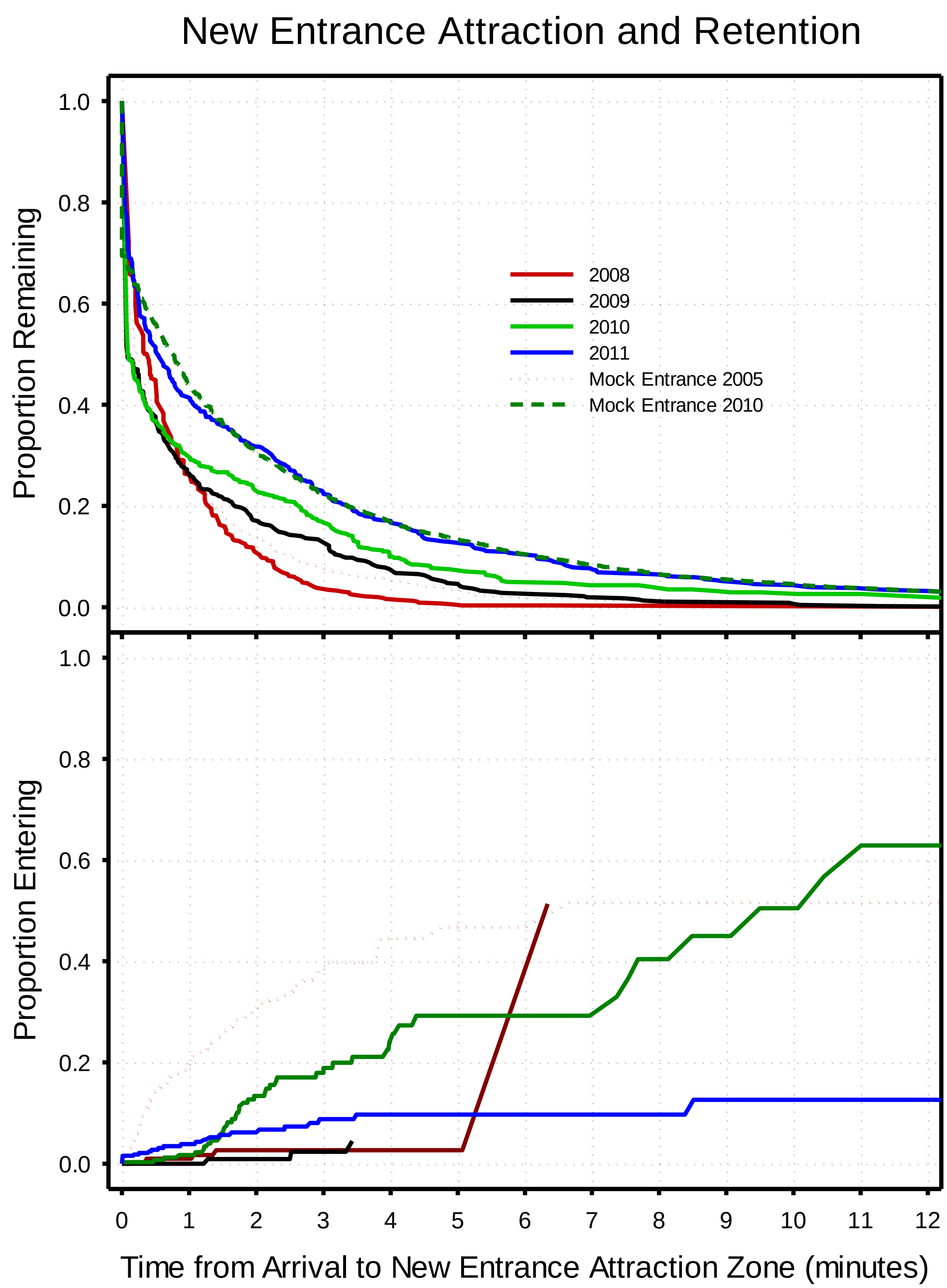

Figure 3. Retention time (upper panel) and entry time (lower panel) for American shad within the Entry Zone of the New Entrance. Dotted curves indicate comparable retention and entry data for the Mock Entrance in 2005. An additional dashed curve shows retention data in the same location as the Mock Entrance during 2010. Note that retention times increased in 2011, which appears to have offset the reduction in entry rate.

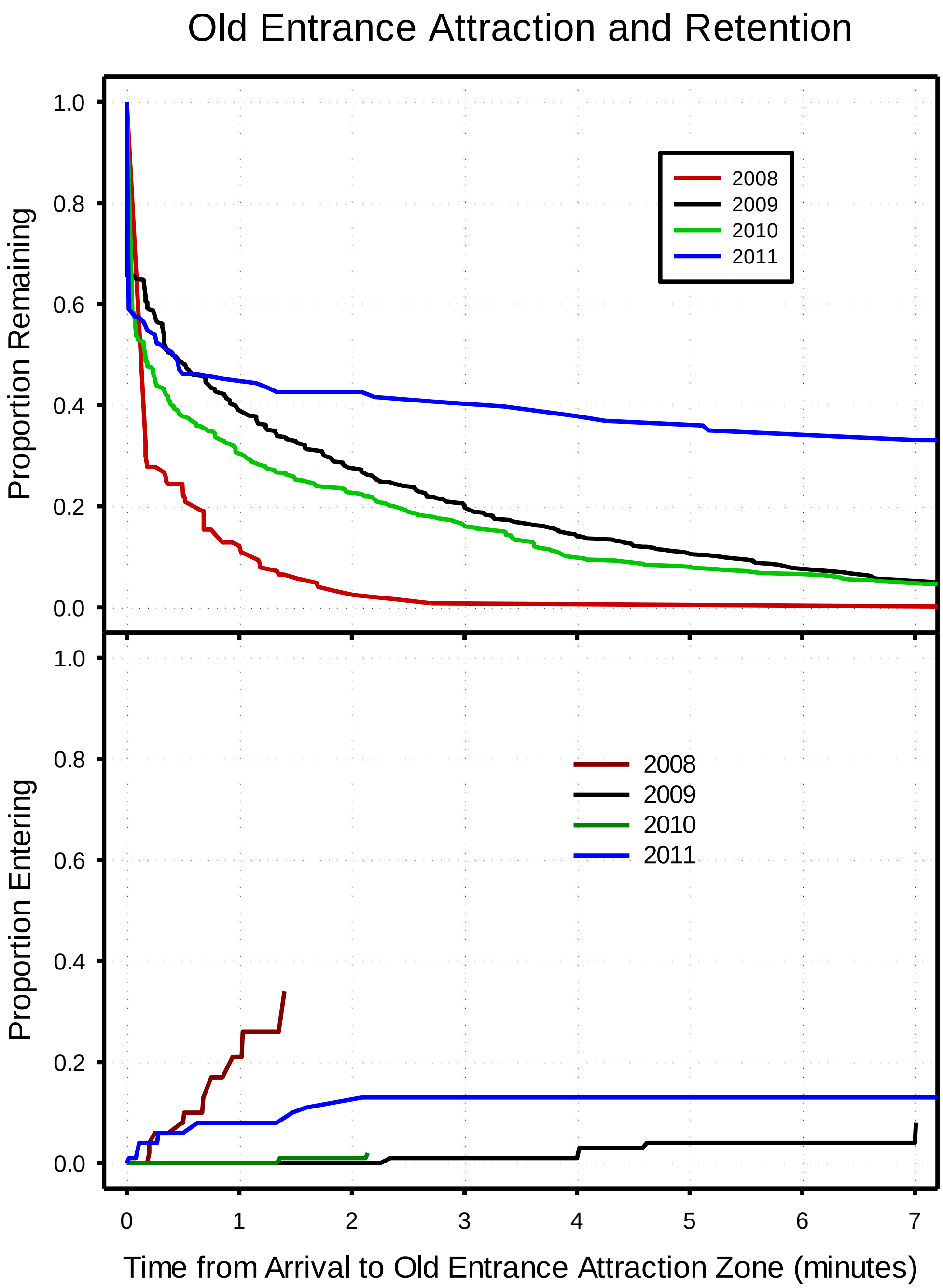

Figure 4. Retention and entry times for American shad in the Entry Zone of the Old Entrance. Data for 2011 have a lower power threshold than in previous years and may overestimate retention time.

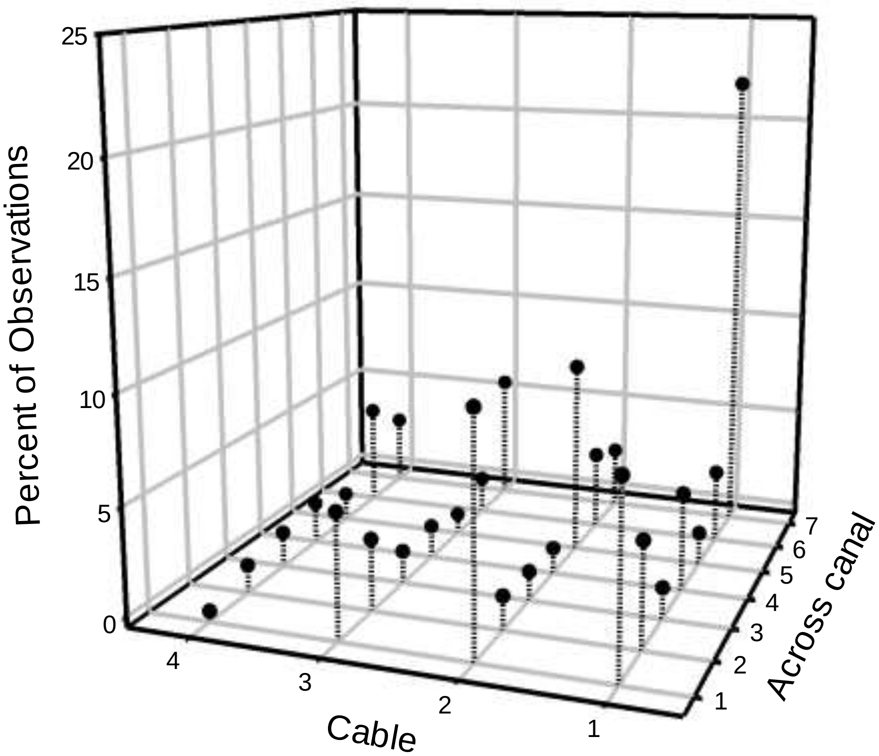

Figure 5. Distribution of shad in the Canal head-end (Approach Zone) as logged by MITAS system. The Cable axis is parallel to flow, with flow moving from left-to-right. The Gatehouse was upstream of Cable 4; the Old Entrance is nearest to position 4,7, and the New Entrance was nearest to 3,1. Data points represent mean values across all individual shad, with each location getting a unique value for each individual that represents the proportion of time spent near that antenna. In this way the distribution of each individual received equal weight, regardless of the amount of total time spent in the Approach Zone.

Table 4. Entry into Gatehouse Fishway: 121 PIT-tagged shad passed Gatehouse, or 81% of entrants (N Entering). Note that this summarizes across all attempts—Max N refers to the maximum number of times an individual shad entered the fishway. This means that Actual passage success per attempt was much lower.

	N Entering	Max N
N Entered Gatehouse	149	7
New Entrance	129	6
Old Entrance	36	2

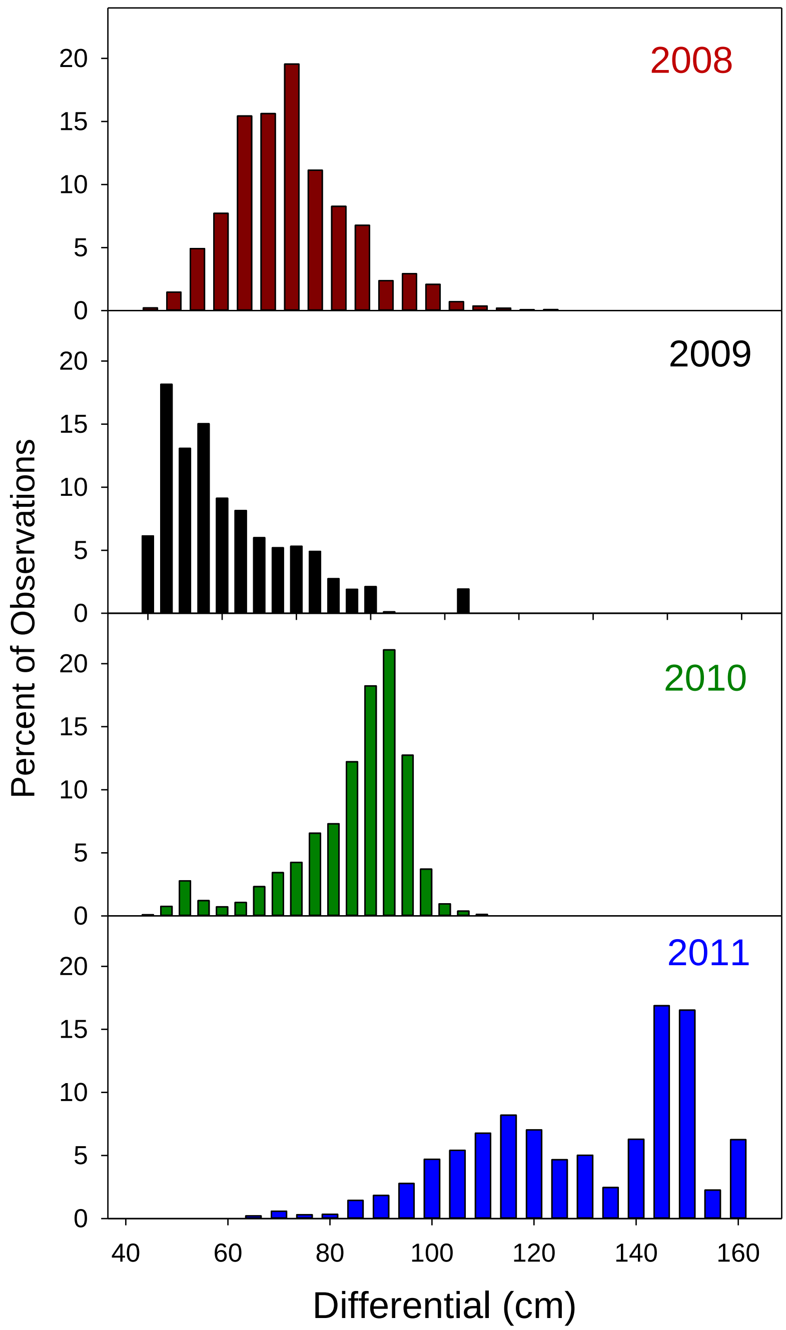

Figure 6. Head differential between the Gatehouse Gallery and the Canal right bank (adjacent to New Entrance). Modifications to the gallery in 2011 affected regulation of levels, producing larger-than-average differentials in 2011. These directly affect flow velocity at both entrances. Future work will assess the effect of differential on entry and retention rates.

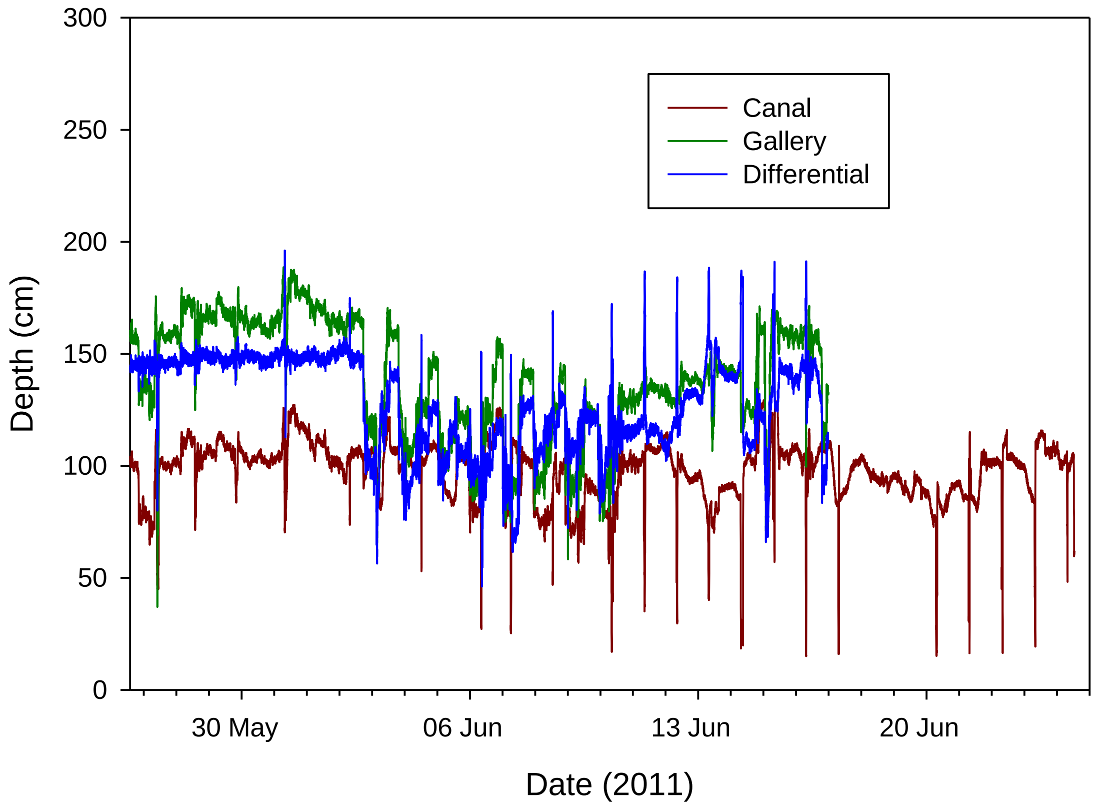

Figure 7. Level logger plots used to calculate differentials in Figure 6. Note the initial high differential from May 26 to June 3. Future analyses should assess the effect of these values on entry rate as well as effects of total canal flow, etc.

Reference List

1. *Castro-Santos, T. 2011. Analysis of American shad passage at Vernon Dam 2011. USGS Conte Lab Internal Report.*

2. *Castro-Santos, T. and Haro, A. 2005. Turners Falls fish passage studies 2005: results from PIT and radio telemetry studies. No. CAFRC Internal Report #2005-04.*

3. *Castro-Santos, T. and Haro, A. 2010. Gatehouse fishway telemetry studies: progress report, 2008-2010. USGS CAFRC Internal Report No. CAFRC201001.*

Results of Turners Falls Fishway Studies: 2012

By

Theodore Castro-Santos
And
Alex Haro

S.O. Conte Anadromous Fish Research Center
USGS-Ecosystems, Leetown Science Center
One Migratory Way, P.O. Box 796
Turners Falls, MA 01376

PRELIMINARY DATA SUBJECT TO REVISION

This report is being provided as a courtesy of the USGS and is for information purposes only. The report has not been subject to independent peer review and USGS makes no warranty as to reliability of results or their interpretation.

Background

This report summarizes results of studies conducted during the 2012 migration of adult American shad on the Connecticut River as they passed through the Turners Falls fishway complex. This is part of a larger effort that has been ongoing since 1999 and of a focused effort to improve passage at the Gatehouse Fishway that has been underway since 2003.

Two important changes occurred in 2012 compared with previous years. The depth gauge in the Gatehouse Gallery was moved and recalibrated, thus fixing a problem that had precluded accurate regulation of gallery water levels (and hence attraction flows) in 2011. In 2012 gallery-canal differential was regulated and switched on a regular schedule between 2.0 and 2.6 ft (60 and 76 cm). In addition, FirstLight changed the gate operations in an effort to develop a flow profile in the canal that might be more conducive to improved passage. In addition to these planned changes, unplanned events occurred that also may have affected passage. Specifically, interior steel panels on the New Entrance broke free of their bolts and bent into the channel, obstructing the flow. This happened twice, and both times the canal water levels had to be lowered so the entrance could be repaired.

Tagging and monitoring

During 2012, adult shad were tagged and released into the Turners Falls power canal from two sources: the fishway trap at the top of Cabot Ladder, adjacent to the power canal, and from the Holyoke fishlift in Holyoke, MA. Capture, handling, transport, and tagging were all performed using the same protocols described previously (Castro-Santos and Haro 2010).

During 2012 expanded work was performed upstream and downstream of Turners Falls. Some of this has already been reported elsewhere (Castro-Santos 2011). A consequence of this increased effort is that tags released for studies at Vernon Dam were also monitored at Gatehouse, providing ancillary benefits to the analysis. Likewise, shad being tagged in the lower river and at Holyoke also contributed to the data available in 2012 (Table 1).

In 2011, 11 repeat-spawning shad that had been tagged in previous years returned to the Holyoke Fishlift. This was an unusual occurrence and was not repeated in 2012. All shad detected during the 2012 season were tagged in 2012.

Because we expected shad to be arriving from Holyoke and the Lower River, we deployed PIT and radio antennas at the entrances of both Cabot and Spillway ladders in addition to those deployed at Gatehouse.

Entry and Passage at Cabot and Spillway fishways

Although 12 shad entered the Spillway ladder, only one of these passed successfully (Table 2). Similarly low passage in 2011 was attributed to problems with the fishway, and with maintaining appropriate water levels in the fishway owing to a failed level meter coupled with efforts to maintain sufficient flow in the New Entrance. The level logger was reconfigured in 2012, and flows were more consistent with what managers recommend for this fishway. The reason for the continued poor passage are unclear, however they are consistent with earlier observations—passage through Spillway fishway of less than 20% is common.

Table 1. Numbers of Connecticut River American shad tagged during 2012

Source	Release Loc	Pit only	Pit & Radio	Combined N
Lower River	LR	56	89	145
Holyoke Lift	HL	53	76	129
Cabot Trap	Cabot	62	58	120
Trucked from Holyoke	Cabot	61	59	120
Total		232	282	514

Passage performance through Cabot was better than usual however (Table 2), and was similar to the relatively strong passage performance (compared with historical numbers) seen in 2011. Twenty seven shad tagged downstream of Turners Falls during 2012 entered Cabot Fishway; of these 5 (18.5%) passed successfully. This value is comparable to the better passage years between 1999 and 2005 (Castro-Santos and Haro 2005).

One recurring concern is that these passage proportions may be lower than occurs for untagged shad. In 2011, 8 repeat spawners entered Cabot fishway and 5 of these passed (63%, CI= 35-91%, more than twice the passage rate of shad tagged in 2011). A similar result has been reported once before (Sullivan et al. 2001), with 36% of repeat spawners passing compared with 17% passage for shad tagged in 2001.

Analysis of the whole-river telemetry data is ongoing. There too, however, results point to an important handling effect. Of 17 radio-tagged shad collected in the Lower River that passed Holyoke, 9 (53%) arrived at Turners Falls. Of 76 shad radio tagged at Holyoke, however, only 16 (21%) arrived at Turners Falls. This is consistent with a handling effect of about 50% that we have documented previously. Interestingly, the Lower River-tagged shad also entered Cabot in greater proportions than those tagged at Holyoke. Further analysis will be needed to understand why this was. The possibility that latent effects continue to impede passage performance even among shad that move upstream has important implications for our understanding of how and why the fishways perform or fail to perform, and more work should be done to improve our understanding of these effects and how these studies can be designed to avoid unintended bias in the analysis. For the time being, readers should be aware that these numbers underestimate passage performance, and the magnitude of this bias is unclear. Past analyses have suggested that these biases fall within the margin of error. Nevertheless, readers should be aware of this issue and read the passage proportions as relative values for the purposes of comparing between years, rather than as accurate estimates of actual passage.

Table 2. Passage through Cabot and Spillway Ladders of shad tagged downstream of Turners Falls. There were no PIT-tagged repeat spawners in 2012.

Origin	Fishway	N Entered	N Passed	% Passage
HL	Cabot	12	2	17%
LR	Cabot	15	3	20%
HL	Spillway	4	1	25%
LR	Spillway	8	0	0%

Overall Passage at Gatehouse Fishway

Passage performance at Gatehouse Fishway appears to have been poorer than was achieved in 2010 and 2011. This assessment is based on counts data: assuming as we have done in the past 60% per-attempt failure among shad that ascended Spillway, overall passage through Gatehouse of shad that ascended Cabot Fishway was about 39% (Table 3—this may be a slight overestimate: passage success in 2012 was 76%). Note, however, that this decrease was not observed among tagged shad, for which passage numbers were comparable to the previous 2 years. One important change in 2012 was that shad were tagged earlier in the run—in 2011 25% of shad had passed Cabot fishway before we performed our first release. In 2012 we performed our first release (25%) on May 8 and 9, at which point only 11% of the run had passed Cabot. By our third release (75%) on May 24, only 50% of the population had passed. One of the results of our work appears to show that shad tagged later in the run have much lower motivation than those tagged early. A detailed analysis of this effect is underway—in each year we attempt to match the run; since 2012 was a particularly strong run, we ended up tagging early (matching expected numbers, since total numbers were unknown). This accounts for the improvement in tagged shad passage at Gatehouse, and further emphasizes the caution that must be exercised when interpreting these data.

Post-tagging Behavior: Initial approach and comparisons between Cabot-Trap and Holyoke-Trucked shad

One group of tagged shad that performed less well in 2012 was the shad that were trucked from Holyoke. The cause of this is uncertain; however it is possible that it was the fault of the handlers: in an effort to reduce trucking, we combined loads of shad with those being brought up for studies in the Conte Flume. This meant that the total number of shad in the truck was greater than in the past. Although total numbers were consistent with common practices (60-80 per load), we observed greater than usual mortality and reduced motivation among released shad. Typically, Holyoke-trucked shad ascend the canal in greater numbers and more rapidly than those released from Cabot Trap. In 2012, however, the two rates were comparable, and both were lower than observed in previous years (Figure 1).

Of 117 radio-tagged shad released into the canal, 114 provided data. Of those, 67 arrived at the Gatehouse tailrace, or 59% of the available shad (Figure 1). This is lower than we observed in 2010 and 2011 (85% and 73% arrival, respectively). This was surprising, given that we released the shad earlier than usual, but it is possible that the reduced performance of Holyoke-trucked shad may account for this difference.

Table 3. Percent passage through Gatehouse of available shad. Shad were either caught in the Cabot Fishway trap and released at its upper end (Cabot Trap Shad) or were caught at the Holyoke Lift and trucked to Turners Falls, where they were released into the power canal (Holyoke Shad). Contribution of lower river shad and those tagged and released at Holyoke are also included, with the exception of the one shad that ascended Spillway fishway, which also passed Gatehouse, but is excluded from these data.

	2012	2011	2010	2009
Counts	39%	58%	50%	24%
CabotTrap Shad				
PIT Only	34%	23%	28%	18%
PIT&Radio	19%	22%	19%	5%
Combined	27%	23%	24%	12%
Holyoke Shad				
PIT Only	43%	43%	40%	
PIT&Radio	29%	48%	24%	
Combined	36%	45%	33%	
Lower River				
(incl. Holyoke)	60%	67%		
RepeatSpawners	NA	60%	(N=5)	

Elements of Passage: Approach, Entry, and Passage

Passage behavior at Gatehouse was generally similar to previous years, with some notable exceptions (Tables 4&5, Figures 2-5). Behaviors are best understood when separated into events of approach, entry, and passage. Within each zone, shad have the ability to advance into the subsequent zone (e.g. Approach zone to Entry zone) or retreat to the previous zone. Opportunity to advance is determined by the amount of time spent in each zone (retention time). Figures 2-4 are arranged to show retention time in the approach zone and each of the two entry zones, as well as rates of advancement to the next zone.

Table 4. Summary of approach data for shad arriving at the Gatehouse Approach zone as well as the Entry Zones of the New Entrance and Old Entrance. Range and median refer to number of approach events by individual shad.

Zone	N Events	N Shad	Range	Median
Gatehouse Approach Zone	304	67	1 - 22	3
Entry Zone				
New Entrance	505	49	1 – 56	5
Old Entrance	116	30	1 – 13	3

Retention time at the canal head-end was within the range of what we have observed in previous years, but was generally lower than average, and nearly identical to what was observed in 2011. This means that on a given exposure shad had relatively less time in which to locate and enter either of the fishway entrances (Figure 2, top panel). This was offset for the New Entrance by the fact that shad approached more rapidly than usual (center panel). Approaches to the Old Entrance were also more rapid than usual (lower panel). Perhaps the most striking change in 2012 was the sharp increase in total number of approaches to both fishway entrances compared with previous years (Table 4, and Castro-Santos and Haro 2012, Table 4). Combined, these data suggest that conditions were conducive to improved guidance to both the New and Old Entrances compared with previous years.

Once fish arrived at either entrance they were once again confronted with opposing rates of retention and entry. For the New Entrance (Figure 3), retention rates near the entrance (upper panel) were the highest we have seen at this location to date, exceeding the previous record set in 2011. This was not matched by increased entry rates, however. Instead, entry rates were slightly lower, but effectively comparable to the 2011 results.

A similar pattern was observed at the Old Entrance (Figure 4). Here retention (upper panel) continued to be strong compared with other years, but entry was notably worse than in 2011. In 2011 we expressed concern that the improved retention might have been an artifact of a new receiver configuration. These data suggest that this trend is real. How this couples with the altered canal hydraulics is unclear, but further analysis of 2-dimensional data gathered using the MITAS system, coupled with ADCP data might shed further light on this pattern.

Despite the reduced entry rates, relative entry into the Old Entrance appears to be improved over previous years, In the past we have seen over 80% entry in the New Entrance, but in 2012 67% of all entry events occurring through the New Entrance (Table 5), with the remainder entering through the Old Entrance. Given the poor entry rate, this must reflect the combined effects of improved retention coupled with a much greater number of approaches, which indicate an elevated return rate (not shown).

Table 5. Entry into Gatehouse Fishway: 79 PIT-tagged shad passed Gatehouse, or 87% of entrants (N Entering). Note that this summarizes across all attempts—Max N refers to the maximum number of times an individual shad entered the fishway. Actual success rate per entry was 76%.

	N Entering	Max N	Median
N Entered Gatehouse	91	3	1
New Entrance	74	2	1
Old Entrance	36	2	1

Factors affecting entry rate

One factor that appears to influence entry rate is the differential between the Gatehouse Gallery and the canal. We used Cox Regression to evaluate this effect, and the results (tragically) are unclear. This is in part because differential is correlated with canal level, which in turn is correlated with discharge. We used and AIC approach, including various permutations of differential and flow (continuous vs. binned into high and low groups). When only data from 2008-2010 are considered, strong effects of both differential and discharge were apparent, with entry rates under high differential (>40 cm) 4.5 times greater than under low differential (<40 cm). Discharge appeared to have a non-linear effect, with best entry rates occurring at the highest discharge levels (this was surprising), but lowest entry rates occurring at an intermediate discharge level (5,000-10,000 cfs). The magnitude of this effect was dramatic, ranging from 10- to 18-fold.

During 2011 the expected relationship between elevation and discharge was not maintained. This, coupled with the extreme observations of differential reported that year (Figure 6) suggests that there was a problem with our level logger in 2011. As such we have rejected those data, and no other data are available to estimate what actual differentials might have been (I suspect that I know what was wrong here, and am working to see if the differential data can be recovered, at least for part of the season). Effect of discharge appeared similar to the previous years.

In 2012 only discharge seemed important, again showing a strong non-linear effect with the worst entry rates associated with canal flows between 5,000 – 10,000 cfs.

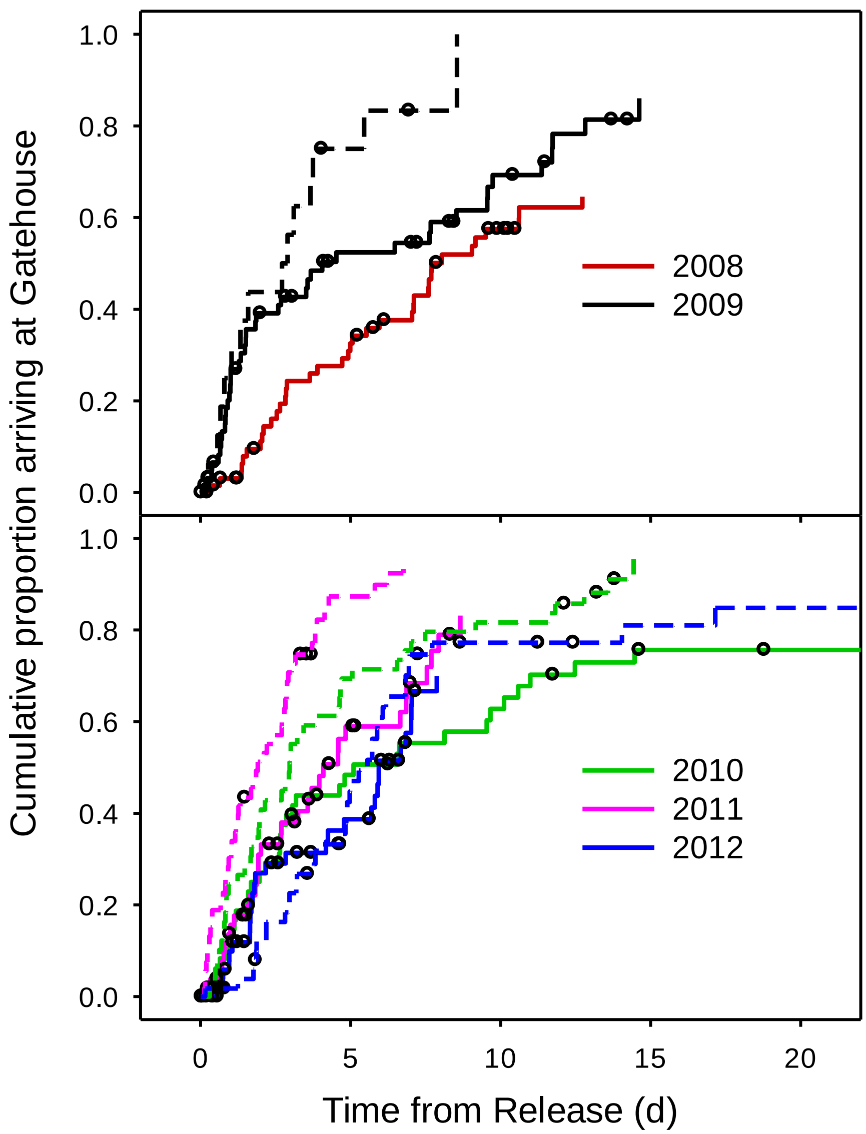

Figure 1. Elapsed time between release and arrival at the Gatehouse Approach Zone. Solid lines represent shad collected at Cabot Trap, Dashed lines represent shad collected and trucked from Holyoke. Circles indicate last-known observation in the canal or known time of downstream passage at the Cabot bypass—these observations are censored at their last extant time. Data for 2008 and 2009 are shown on a separate panel for clarity.

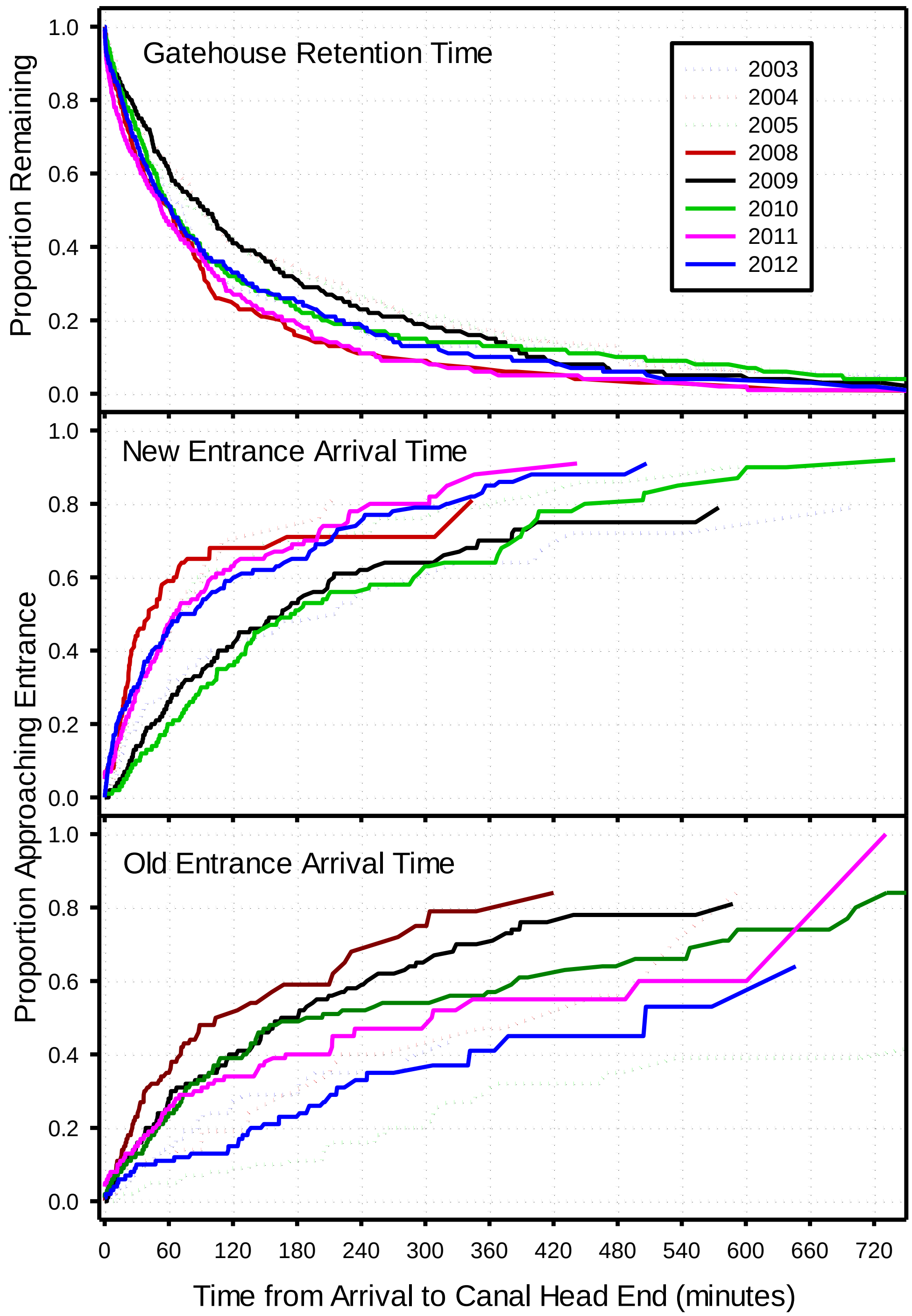

Figure 2. Retention time in the canal head-end and approach times to each of the two entrances. Note that approach to the Old Entrance was worse than we have seen in recent years.

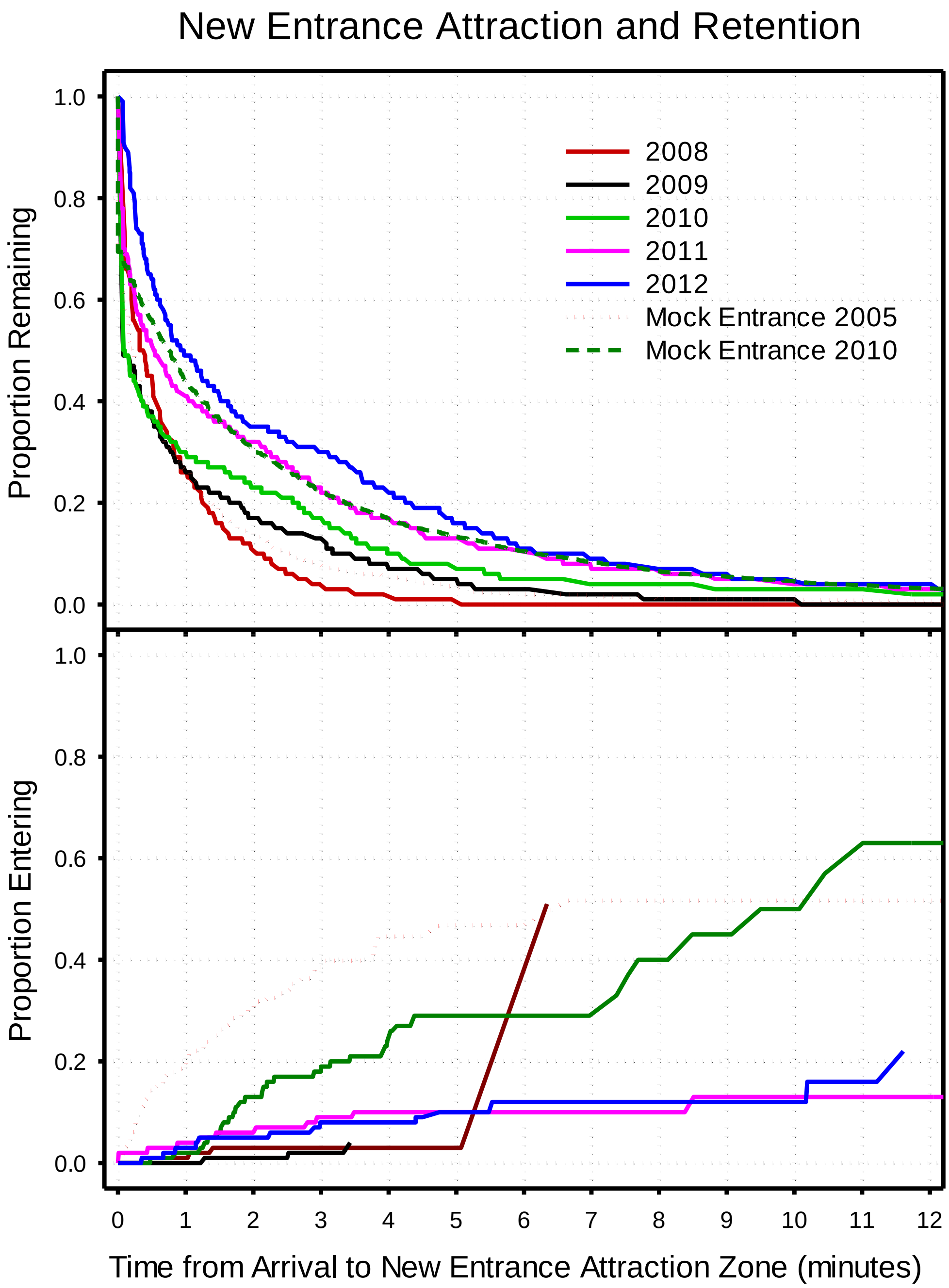

Figure 3. Retention time (upper panel) and entry time (lower panel) for American shad within the Entry Zone of the New Entrance. Dotted curves indicate comparable retention and entry data for the Mock Entrance in 2005. An additional dashed curve shows retention data in the same location as the Mock Entrance during 2010. Note that retention times increased in 2011, which appears to have offset the reduction in entry rate.

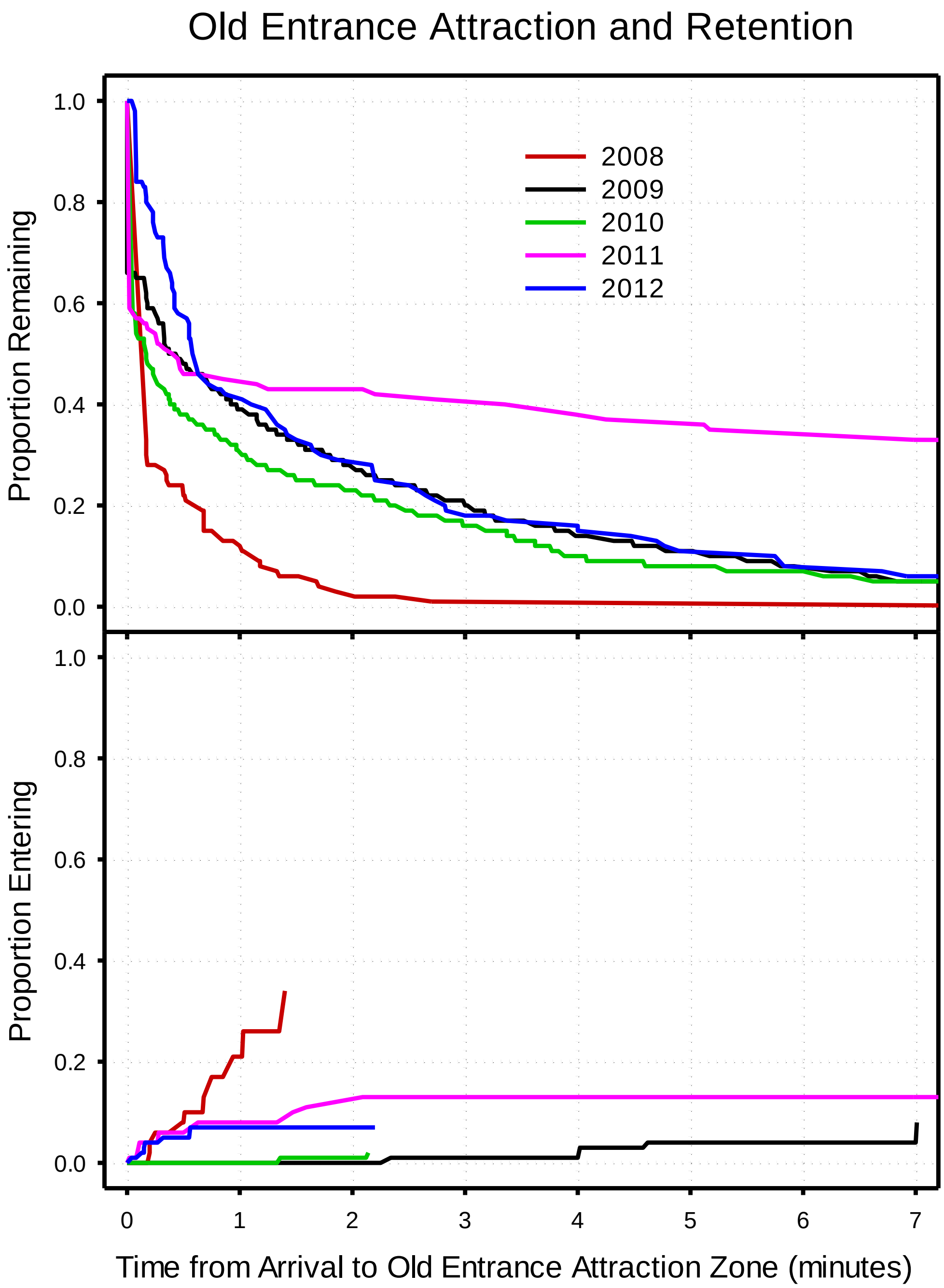

Figure 4. Retention and entry times for American shad in the Entry Zone of the Old Entrance. Data for 2011 have a lower power threshold than in previous years and may overestimate retention time.

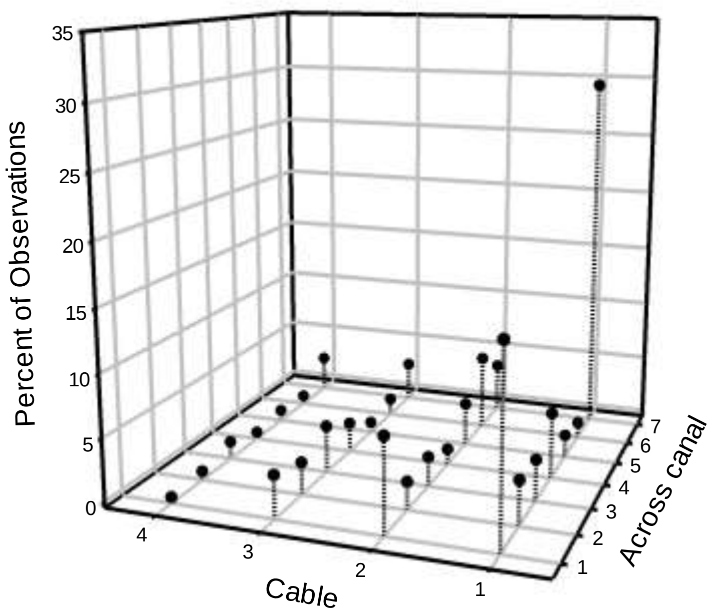

Figure 5. Distribution of shad in the Canal head-end (Approach Zone) as logged by MITAS system during 2012. The Cable axis is parallel to flow, with flow moving from left-to-right. The Gatehouse was upstream of Cable 4; the Old Entrance is nearest to position 4,7, and the New Entrance was nearest to 3,1. Data points represent mean values across all individual shad, with each location getting a unique value for each individual that represents the proportion of time that individual spent near that antenna. In this way the distribution of each individual received equal weight, regardless of the amount of total time spent in the Approach Zone.

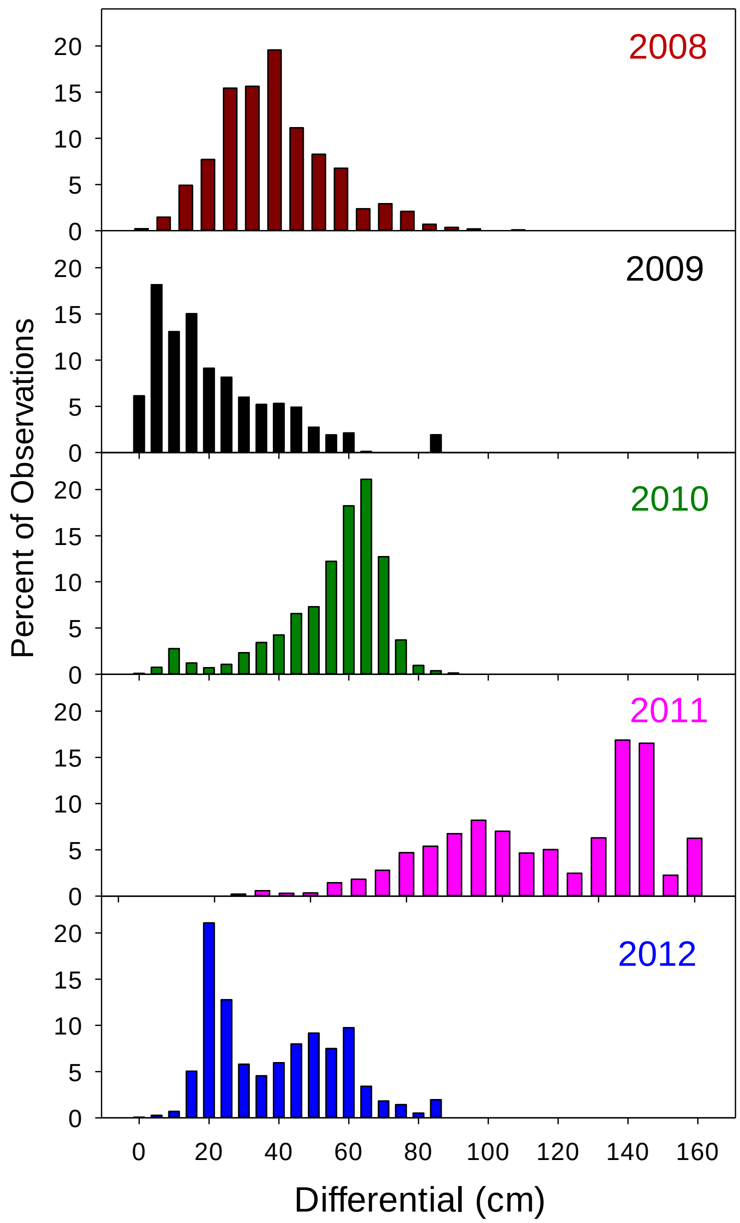

Figure 6. Head differential between the Gatehouse Gallery and the Canal right bank (adjacent to New Entrance). Modifications to the gallery in 2011 affected regulation of levels, producing larger-than-average differentials in 2011. These directly affect flow velocity at both entrances. Future work will assess the effect of differential on entry and retention rates.

Further Observations

- Of 25 radio tagged shad that reached Cabot, 11 entered
  - 16 of the arrivals were from Holyoke, 9 were from the Lower River
  - Of the 11 entrants, 3 were from Holyoke (3/16=19%, CI=10%-60%), 8 (8/9=88%, CI: 67%-99%) were from the Lower River, $P<0.05$.

Literature Cited

Castro-Santos, T. 2011. Analysis of American shad passage at Vernon Dam 2011. USGS Conte Lab Internal Report.

Castro-Santos, T. and Haro, A. 2005. Turners Falls fish passage studies 2005: results from PIT and radio telemetry studies. No. CAFRC Internal Report #2005-04.

Castro-Santos, T. and Haro, A. 2010. Gatehouse fishway telemetry studies: progress report, 2008-2010. USGS CAFRC Internal Report No. CAFRC201001.

Sullivan, T. J., Haro, A., and Castro-Santos, T. 2001. Passage of American Shad at Turners Falls Fishways: PIT Tag Evaluation 2001. S.O. Conte Anadromous Fish Research Center No. CAFRC Internal Report No. 2002-01.

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