Mortality Associated with Catch and Release of American Shad and Striped Bass in the Hudson River

---

Final Report: 1999 Project Year

submitted by

Michael J. Millard[1], Stuart Welsh[2], Jorgen Skjeveland[2],
John Fletcher[1], Jerre Mohler[1], and Michael Hendrix[1]

U.S. Fish and Wildlife Service
[1]Northeast Fishery Center
Lamar, PA 16848

[2]Maryland Fisheries Resources Office
Annapolis, MD 21401

and

Andrew Kahnle and Kathryn Hattala

NY State Department of Environmental Conservation
Hudson River Fisheries Unit
New Paltz, NY 12561

to

NY State Department of Environmental Conservation
New Paltz, NY 12561

January 2000

COOPERATORS

This project was developed and conducted jointly by the Maryland Fisheries Resource Office and the Northeast Fishery Center, US Fish and Wildlife Service (USFWS), and the Hudson River Fisheries Unit, New York State Department of Environmental Conservation (NYSDEC).

INTRODUCTION

Catch and release sport fishing commonly occurs in many fisheries, such as the striped bass Morone saxatilis (Marine Recreational Fisheries Statistics Survey (MRFSS) 1996) and American shad Alosa sapidissima (Lukacovic 1998) fisheries of the Atlantic Coast. The contribution of catch and release practices to overall fishing mortality is often not estimated. Recent MRFSS (1996) striped bass reports indicate that anglers release over 90% of their catch. Consequently, hooking mortality may contribute substantially to fishing mortality in the Atlantic striped bass fishery. Estimates from the MRFSS recreational fishery survey indicated that over 16 million and over 15 million striped bass were released in 1997 and 1998, respectively (Atlantic States Marine Fisheries Commission (ASMFC) 1998, 1999; unpublished reports). Assuming an 8% hooking mortality rate for striped bass (Diodati and Richards 1996), this translates to over 1.2 million mortalities each year. These estimates exceed the 1997 and 1998 commercial harvest. The 8.0% hooking mortality rate of Diodati and Richards (1996) was determined in a saltwater coastal system, and higher rates of hooking mortality are expected in freshwater river systems. We found one study of hooking mortality of American shad (Lukacovic 1998) which inferred low hooking mortality (3 of 309 died in two days) in the catch and release fishery of the Conowingo Dam tailwaters, Susquehanna River, Maryland. In a similar study, Lukacovic and Pieper (1996) reported no mortality of hickory shad within two days after capture (n=150). Anecdotal evidence, however, suggests that American shad are intolerant to handling (A. Kahnle, personal communication). Results from studies conducted in one river system or coastal area, or in different environmental conditions, may not be directly transferable to other geographic areas or environmental regimes; therefore, rates of hooking mortality of Hudson River striped bass and American shad may differ from those reported in other areas.

Many factors can increase hooking mortality, such as the use of barbed hooks (Taylor and White 1992), the use of “J” hooks rather than circle hooks (Orsi et al. 1993, MDDNR 1998), the use of single hooks instead of treble hooks (Nuhfer and Alexander 1992), the use of live bait instead of artificial lures (Clapp and Clark 1989, Hysmith et al. 1992, Taylor and White 1992), lower salinity, higher water temperature (Hysmith et al. 1992, Muoneke 1992), larger fish size (Hysmith et al. 1992), deep instead of shallow hooked (Bendock and Alexandersdottir 1993, Gjernes et al. 1993, DuBois et al. 1994, Persons and Hirsch 1994, Schisler and Bergersen 1996), longer playing and handling times (Schisler and Bergersen 1996), and angler inexperience. Hooking mortality will also likely be higher in fish released into areas of less than three mg/l dissolved oxygen (Lee and Bergersen 1996).

The 8.0 % hooking mortality rate for striped bass of Diodati and Richards (1996) is similar to the 7.3% (artificial lures) and 5.3% (live bait) estimates of Nelson (1998). Diodati and Richards (1996) employed a58-day observation period, whereas Nelson (1998) observed fish for only 3 days after capture. Employing a 2-week observation period, Harrell (1987) reported a hooking mortality rate for striped bass of 4% (artificial) and 6% (bait) in October, and 2% (artificial) and 0% (bait) in February; however, hooking mortality increased in June (21% for artificial, and 17.6% for bait) and August (36% for artificial, and 40% for bait). Lukacovic and Uphoff (1997) found that hooking mortality of striped bass after five days was greater in larger fish, warmer seasons, and deeply hooked fish (i.e., fish hooked posterior to the gills). Three of 309 American shad died within two days in the hooking mortality study of Lukacovic (1998); two of these fish bled profusely after capture, and the third one was handled roughly.

OBJECTIVES

The objectives of this study were as follows:

(1) estimate the mortality of striped bass and American shad associated with catch and release practices commonly occurring in the spring recreational fisheries in the Hudson River, and

(2) assess the influence of selected variables, e.g. water temperature, playing and handling time, hook location, degree of bleeding, and length, on hooking mortality rates.

These results provide fishery managers with information necessary to determine the contribution of hook and release mortality to the overall fishing mortality rate in the Hudson River striped bass and American shad fisheries. The results may be useful in developing guidelines for reducing mortalities of released fish and the possible development of regulations designed to control mortality rates associated with recreational fishing.

METHODS

American shad

Hooking mortality of American shad was assessed for two periods: late April and late May. In each trial, American shad were angled from the Hudson River immediately downstream of the U.S. Army Corps of Engineers navigation lock and dam at Troy, New York (river km 245) (Figure 1). The area represents the up-river limit to the spawning reach and is a popular shad angling location. Tackle consisted of light action spinning rods and reels with 6 or 8 lb.-test monofilament line and 1/8 or 1/4 oz. shad darts. All fishing occurred from anchored boats, and landing nets were used to remove fish from the water for processing. All fish were landed in three minutes or less. Immediately upon hook removal, fish were either tagged in the dorsal musculature with a uniquely numbered T-bar anchor tag (April 28-29 captures) or clipped on the

right pectoral fin (May 24-25 captures) and placed in an aerated live well aboard the transport boat. Playing time, hook location (inside mouth and anterior to gills, or posterior to gills), and degree of bleeding (bleeding profusely, slight bleeding, no bleeding) were recorded for each fish.

Concurrent with the angling effort, control fish were captured below the Troy dam via electroshocking. Once on board the boat, control fish were handled and tagged identically to angled fish. During the May trial, electroshocked fish received a left pectoral fin clip. We assumed that electroshocking imparted negligible mortality to the control fish.

Captured fish were placed in a flow-through live well and were transported approximately 500m and placed in floating holding pens anchored in-river. Residence time in the live well for angled fish averaged 40 minutes for the April 28-29 trial (Figure 2). For the May 24-25 trial, transport to the holding tanks began 30 minutes after the first fish had been placed in the live well. As a result, no fish was held in the live well longer than 45 minutes during the second trial.

Holding pens were vertical cylinders, 2.5m diameter and 2.3m deep, constructed of a PVC pipe frame covered with 25mm square plastic mesh. Styrofoam was attached to the top and the bottom was weighted with rebar to hold the cylinders open in the water column. Circles of plastic netting (2.5m diameter) served as lids and bottoms of the cylinders. Each holding pen contained no more than 16 treatment (angled) fish and 16 control (electroshocked) fish. Fish were allocated among holding pens such that roughly equal numbers of treatment and control fish were in each unit. Fish were held in the pens for 5 days, after which time all fish were removed, measured, and recorded as being (1) treatment or control and (2) alive or dead. All survivors were released back into the river. Water temperature was monitored daily at the holding pen site.

Striped Bass

Striped bass were caught with live bait (blueback herring) on spinning gear, primarily via casting or drifting over historically productive areas near the mouth of Catskill Creek and the Rip Van Winkle Bridge, at Catskill, New York (river km 180-182). This site is located within the upper third of the striped bass spawning reach and typically receives concentrated recreational fishing activity. Volunteer recreational fisherman were recruited on the river between May 11 - 14, 1999 to provide angled fish and ensure that tackle and angling techniques were consistent with normal practice for the recreational fishery for striped bass. After a striped bass was angled from the river, a uniquely numbered Floy T-bar anchor tag was inserted below the anterior portion of the dorsal fin, and fish were transported in on-board aerated live wells to floating net pens anchored in the river. Bait type, degree of bleeding (bleeding profusely, slight bleeding, no bleeding), and location of hook (anterior to or posterior to gills) was recorded for each fish. Control fish were captured by electroshocking and were transported and placed in the holding pens similarly to treatment fish. Each holding pen contained an equal number angled fish and control fish, with generally no more than 10 total fish placed in each pen. Fish were held in the pens for 5 days, after which time all fish were removed, measured, and recorded as being (1)

treatment/control and (2) male/female and (3) alive/dead. All survivors were released back into the river.

The floating net pens had 50mm square plastic meshing and were otherwise similar to those described above for American shad. Ten pens were cabled together (two abreast and five pairs long) and anchored approximately 100m offshore, out of the main river current between two anchoring poles embedded in the river bottom. The string of pens was anchored parallel with the current to minimize drag and collection of debris.

DATA ANALYSIS

For comparative purposes, mortality rates associated with hook and release of American shad and striped bass were estimated using two methods: conditional instantaneous mortality rates, and additive finite mortality rates. The two methods differed in their assumptions about the relationship between the two mortality components associated with (1) hook and release and (2) experimental handling.

Conditional instantaneous mortality rates.— This method assumed the two mortality components associated with (1) hook and release and (2) experimental handling acted simultaneous with each other, and , in effect, competed with each other during the five day holding period. As such, we assumed the two mortality components, hooking and handling, acted on the treatment fish over the course of the 5-day observation period and that handling mortality alone acted on the control fish. The additive relationship for instantaneous rates is described as :

$$\text{total observed mortality} = \text{hooking mortality} + \text{handling mortality} \qquad [1].$$

We also assumed no natural mortality occurred during the 5-day observation period. An instantaneous handling mortality rate was estimated from the control group as:

$$m_h = -\ln(S_h) \qquad [2]$$

where: m_h = handling mortality
$S_h = 1 - A_h$
$= 1 -$ [fraction that die in control group].

An instantaneous total mortality rate in each treatment group was estimated as:

$$m_t = -\ln(S_t) \qquad [3]$$

where: m_t = total mortality in treatment group
$S_t = 1 - A_t$
$= 1 -$ [fraction that die in treatment group].

From equation [1], the instantaneous hooking mortality rate was calculated for each treatment as:

$$m_{hook} = m_t - m_h \qquad [4]$$

We assumed that both handling and hooking mortality acted on the treatment fish concurrently during the observation period, representing a situation similar to a Type II fishery, where natural and fishing mortality act concurrently on a stock (Ricker 1975). We treated the computations similar, then, and computed $m_{c\text{-}hook}$, the conditional instantaneous mortality rate associated with hook and release that would occur if handling mortality did not exist, as

$$m_{c\text{-}hook} = 1 - \exp(- m_{hook}) \qquad [5]$$

and the associated finite hook and release mortality, $m_{f\text{-}hook}$, as:

$$m_{f\text{-}hook} = (A^* m_{hook}) / m_t \qquad [6]$$

Additive finite mortality rates.— This method assumed the two mortality components associated with (1) hook and release and (2) experimental handling were independent. In particular, this approach treats the two mortality sources as being essentially instantaneous over the course of the five day holding period, rather than simultaneously acting on the treatment (angled) fish. In this case, we assumed an additive relationship between the two rates observed at the end of the five day holding period. Hooking mortality was computed as the difference between the finite total mortality rate observed in the treatment fish and the finite handling mortality rate observed in the control fish. This equates to simply substituting the five-day finite rates into equation [1] and solving for hooking mortality.

Factors affecting mortality.— Logistic regression analysis (Menard 1995) was used to determine the relation between the estimates of mortality and playing and handling time, hook location, degree of bleeding, plus bait type and total length for the striped bass study. Computations were performed with SAS software (SAS Institute, Inc. 1990).

RESULTS

American shad

Estimated hook and release mortality.—Over both trials, a total of 255 American shad were captured with hook and line and placed in holding pens, while 284 shad were captured via electroshocking for use as controls. For the first trial in late April, angled fish exhibited 76% total mortality, whereas control fish exhibited 56% mortality (Figure 3). The observed mortalities for angled and control fish during the late May trial were 59% and 38%, respectively. When pooled over trials, 69% of the angled American shad were dead after five days, whereas 48% of the control fish suffered mortality (Figure 3). Importantly, while overall mortality decreased during the second trial, the differential mortality between treatment and control groups remained constant (~20%) for both trials. Using conditional instantaneous rates to correct for handling-induced mortality, the estimated hooking mortalities for American shad during trial 1, trial 2, and pooled together were 33.1%, 26.7%, and 30.7%, respectively (Table 1). When assuming additive finite rates, the estimated mortalities associated with hook and release for trials 1 and 2, and pooled data, were 20.5%, 20.3%, and 21.5% respectively (Table 1).

Water temperatures ranged between 10.5^{O} and 15° C throughout the holding period.

Factors affecting mortality.— Of the 151 shad that were captured via hook and line during the first trial, 143 fish had the appropriate data available for this analysis. Angled fish were primarily hooked in the lip and less than five fish bled from hook damage to gills or the esophagus; therefore, hook location and degree of bleeding were not included as variables in the logistic regression analysis. The few fish that did exhibit hooking-related bleeding did not survive long enough to be placed in the holding pens. Transport time was the only variable that significantly affected the survival of American shad (Table 2). Fish that were in the live well of the transport boat for over 45 minutes had a higher likelihood of dying than those that were in the live well under 45 minutes ($P < 0.05$). No variables significantly affected mortality when fish that experienced transport times greater than 45 minute were removed from the analysis.

Mortality data for American shad, by net pen, are provided in Appendix 1, 2, and 3.

Striped bass

Estimated hook and release mortality.— Between May 10 and 14, a total of 47 striped bass were captured with hook and line, and 35 individuals were captured via electroshocking for use as control subjects. Angled fish exhibited 43% total mortality, whereas control fish exhibited 14% mortality after the five day holding period (Figure 4). Using conditional instantaneous rates to correct for mortality associated with handling and confinement, the estimated hooking mortalities for striped bass was 30.7% (Table 1). When making the adjustment assuming additive finite rates, the estimated mortalities associated with hook and release was 28.3% (Table 1).

Water temperatures throughout the 5-day holding period ranged from ? to ?.

Factors affecting mortality.— Hook location was the only variable that significantly affected the survival of striped bass (Table 3). Specifically, individuals hooked in the gut had a higher likelihood of dying than those hooked in the lip ($P < 0.05$).

Mortality data for striped bass, by net pen, are provided in Appendix 4 and 5.

DISCUSSION

American shad

Our data suggest that a significant amount of mortality is associated with the hook and release of American shad. Two estimation techniques assigned hook and release mortalities of 31% and 22% after five days. While these estimates were corrected for handling mortality via the use of control fish, the confinement of fish in artificial holding pens may have biased the results. American shad, in particular, are intolerant of handling and transport (Backman and Ross 1990). We observed clear indications of pen effects in mortality trends of American shad, in that fish in the terminal pens appeared to suffer higher mortality than those in the pens situated in the middle of the array (see Appendix 2). This effect could have been due to current-induced distortion of the pens and subsequent impairment of the swimming ability of the fish. Experience with shad hatchery techniques has shown that American shad require the ability to continually swim forward in order to survive in captive environments (R. St. Pierre, USFWS, personal communication).

Our estimates of mortality associated with catch and release of American shad differ greatly from those of Lukakovic (1998). Lukakovic observed less than 1% mortality in American shad that were caught and held for 48 hours in land-based holding tanks. The three observed mortalities in the Lukakovic study died within 24 hours, and were reportedly either deep-hooked or handled roughly. Water temperatures in the Lukakovic (1998) study ranged between 12°C and 18°C, similar to the temperatures experienced during the first trial of this study. Water temperatures during our second trial (late May) were much higher, ranging mostly between 18° and 26° C. Our study also differed in that we used in-river holding pens and, perhaps most importantly, we recorded mortality after five days. The increased holding period in our study may have added additional stress to the shad which resulted in the increased mortality, or it may have allowed us to record the additional latent mortality attributable to stress from catch and release practices. We believe our estimates were likely influenced by both of these factors.

Our estimates for American shad were based on the use of artificial lures (¼-oz. and c-oz. "shad darts"), which were the predominate lure being used by the recreational fisherman observed during the study. Other gear, primarily fly rods, may impart different mortality rates to American shad due to differing effects of fatigue and physical damage by hooks. Our analysis of fishing-related factors affecting mortality suggest the elapsed time between capture and placement into holding tanks, or release into the river by recreational fishers, should be minimized in order to increase survival. The use of landing nets by recreational anglers may also affect mortality associated with hook and release.

Nevertheless, given the wide range of angling and handling techniques exhibited by recreational shad fishermen, we believe our estimates do approximate the magnitude of mortality associated with catch and release of recreational-caught American shad in the Hudson River. A hook and release fishery which imparts mortalities approaching 30% demands attention in the management regime for the species. We suggest that this mortality be considered for inclusion in

future stock assessment efforts on American shad, provided there exists some associated data on the magnitude of the recreational fishery and, in particular, the rate of hook and release by the recreational fishers.

Striped bass

Our estimates of mortality associated with hook and release of striped bass are consistent with other reported rates (Nelson 1998, Hysmith et al, 1992). Most studies found hooking mortality to be season or temperature-dependent, with higher mortality occurring with higher temperatures (Nelson 1998, Hysmith et al. 1992, Harrell 1987). As pointed out by Diodati and Richards (1996), our study had the potential for bias incurred by holding large fish in a relatively small, confined space. The effect of this confinement on stress and mortality is unknown. The "pen effect" which we observed in the American shad study was not observed in the striped bass study (see Appendix 4). The striped bass nets were arrayed differently with respect to the river current, and striped bass may be less inclined to require the continual forward swimming behavior exhibited by American shad.

Similar to Nelson (1998) and Diodati and Richards (1996), our data suggested that hooking location (lip vs. gut) exerted a significant influence on subsequent survival rates. These results suggest that future experimentation with circle-hooks may provide useful information on reducing the incidence of deep-hooking and thereby reducing mortality associated with hook and release fisheries.

As with American shad, our results suggest that hook and release mortality should be accounted for in the management of the Hudson River striped bass fishery. Angling effort and associated hook and release rates should be assessed before this component of population mortality can be appropriately incorporated into management decisions.

ACKNOWLEDGMENTS

This project greatly benefitted from the cooperation and volunteer effort provided by many people: Mike Clancy, Scott Davis, Dan Fera, Pat Festa, Steve Hammond, Walt Keller, Bjorn van der Leeuw, Bruce McMillan, and John Powell receive a special thanks for their assistance. The authors also wish to thank the following people and organizations for their contributions: Mike Agular, Mike Callan, Michael F. Carlow, Michael F. Carlow, Jr., Sheila Eyler, Pat Farrell, John Galvez, Patrick Hanchik, Wade Jodun, Mike Johnson, Mayor McNulty, Matthew Merchant, New York Department of Transportation, Richard Popp, Dick St. Pierre, Gary Swihart, Hugh Templeton, Sean E. Ward, and Steve Watson.

References

ASMFC (Atlantic States Marine Fisheries Commission). 1998. 1998 status of the Atlantic striped bass. Unpublished report submitted by the Striped Bass Technical Committee, August 1998.

ASMFC (Atlantic States Marine Fisheries Commission). 1999. 1999 status of the Atlantic striped bass. Unpublished report submitted by the Striped Bass Technical Committee, August 1999.

Backman, T.W. H., and R.M. Ross. 1990. Comparison of three techniques for the capture and transport of impounded subyearling American shad. The Progressive Fish-Culturist 52:246-252.

Bendock, T. and M. Alexandersdottir. 1993. Hooking mortality of chinook salmon released in the Kenai River, Alaska. North American Journal of Fisheries Management 13:540-549.

Clapp, D.F. and R.D. Clark, Jr. 1989. Hooking mortality of smallmouth bass caught on live minnows and artificial spinners. North American Journal of Fisheries Management 9:81-85.

Dedual, M. 1996. Observed mortality of rainbow trout caught by different angling techniques in Lake Taupo, New Zealand. North American Journal of Fisheries Management 16:357-363.

Diodati and Richards. 1996. Mortality of striped bass hooked and released in salt water. Transactions of the American Fisheries Society 125:300-307.

Dubois, R.B., T.L. Margenau, R.S. Stewart, P.K. Cunningham, ad P.W. Rasmussen. 1994. Hooking mortality of northern pike angled through ice. North American Journal of Fisheries Management 14:769-775.

Gjernes, T., A.R. Kronlund, and T.J. Mulligan. 1993. Mortality of chinook and coho salmon in their first year of ocean life following catch and release by anglers. North American Journal of Fisheries Management 13:524-539.

Harrell, R.M. 1987. Catch and release mortality of striped bass caught with artificial lures and baits. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 41:70-75.

Hysmith, B.T., J.H. Moczygemba, and G.R. Wilde. 1992. Hooking mortality of striped bass in Lake Texoma, Texas-Oklahoma. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 46:413-420.

Lee, W.C. and E.P. Bergersen. 1996. Influence of thermal and oxygen stratification on lake trout hooking mortality. North American Journal of Fisheries Management 16:175-181.

Lukacovic, R. 1998. Mortality of American shad Alosa sapidissima caught and released by anglers below Conowingo Dam. Maryland Department of Natural Resources Fisheries Service. Fisheries Technical Report Series, Number 21.

Lukacovic, R. and L. Pieper. 1996. Short term mortality rate of hickory shad, Alosa mediocris, caught and released by fishermen in Deer Creek, Maryland. Maryland Department of Natural Resources Fisheries Service. Fisheries Technical Report Series, Number 19.

Lukacovic, R. and J.H. Uphoff. 1997. Hook location, fish size, and season as factors influencing catch-and-release mortality of striped bass caught with bait in Chesapeake Bay. Unpublished Report, Maryland Department of Natural Resources, Annapolis, Maryland.

MDDNR (Maryland Department of Natural Resources). 1998. Study 3 - Mortality rate of striped bass associated with spring season chumming. Pages V32-V55 in Stock assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay, U.S. Department of the Interior Fish and Wildlife Service Federal Aid Annual Report, F-54-R, MDDNR, Fisheries Service, Annapolis, Maryland.

Matlock, G.C., L.M. McEachron, J.A. Dailey, P.A. Unger, and P. Chai. 1993. Short-term hooking mortalities of red drum and spotted seatrout caught on single-barbed and treble hooks. North American Journal of Fisheries Management 13:186-189.

Menard, S. 1995. Applied logistic regression analysis. Sage University Paper Series on Quantitative Applications in the Social Sciences, Series no. 07-106, Thousand Oaks, CA.

MRFSS (Marine Recreational Fisheries Survey). 1996. MRFSS striped bass report for 1996. Retrieved 1 August 1998 from the World Wide Web: http://www.st.nmfs.gov/recreational/species_rpt.html

Muoneke, M.I. 1992. Seasonal hooking mortality of bluegills caught on natural baits. North American Journal of Fisheries Management 12:645-649.

Nelson, K.L. 1998. Catch-and release mortality of striped bass in the Roanoke River, North Carolina. North American Journal of Fisheries Management 18:25-30.

Nuhfer, A.J. and G.R. Alexander. 1992. Hooking mortality of trophy-sized wild brook trout

caught on artificial lures. North American Journal of Fisheries Management 12:634-644.

Orsi, J.A., A.C. Wertheimer, and H.W. Jaenicke. 1993. Influence of selected hook and lure types on catch, size, and mortality of commercially troll-caught chinook salmon. North American Journal of Fisheries Management 13:709-722.

Persons, S. E. and S.A. Hirsch. 1994. Hooking mortality of lake trout angled through ice by jigging and set-lining. North American Journal of Fisheries Management 14:664-668.

Schisler, G.J. and E.P. Bergersen. 1996. Postrelease hooking mortality of rainbow trout caught on scented artificial baits. North American Journal of Fisheries Management 16:570-578.

Taylor M.J. and K.R. White. 1992. A meta-analysis of hooking mortality of nonanadromous trout. North American Journal of Fisheries Management 12:760-767.

Table 1.- Two estimates of mortality associated with hook and release of American shad and striped bass in the Hudson River after a five day observation period.

		Hook and release mortality	
Species	**Trial**	**w/ instantaneous rates**	**w/ additive finite rates**
American shad	April 28 - May 4	33.1%	20.5%
	May 24 - May 30	26.7%	20.3%
	Pooled total	31.0%	21.5%
Striped bass	May 10-14	30.7%	28.3%

Table 2. Fates of American shad caught with hook and line (categorized by transport time).

Transport Time (minutes)	0-15	15-30	30-45	> 45	Total
Dead	4	29	21	53	107
percent	3.7	27.1	19.6	49.5	
Survive	4	11	15	6	36
percent	11.1	30.6	41.7	16.7	
Total	8	40	36	59	143

Table 3a. Logistic regression results indicating the Contribution of independent variables (playing and transport time, total length, hook location, and degree of bleeding)to mortality of striped bass caught with hook and line.

Variable	÷²	*P*	Odds Ratio
PLAYING TIME	0.0698	0.7916	0.794
TRANSPORT TIME	0.2597	0.6103	1.600
TOTAL LENGTH	0.2571	0.6121	1.511
HOOK LOCATION	6.3457	0.0118	12.409
BLEEDING	1.4651	0.2261	0.478

Table 3b. Fates of striped bass caught with hook and line (categorized by hook location).

	Hook location		
Fate	Shallow	Deep	Total
Dead	7	11	18
percent	38.9	61.1	
Survive	19	5	24
percent	79.2	20.8	
Total	26	16	42

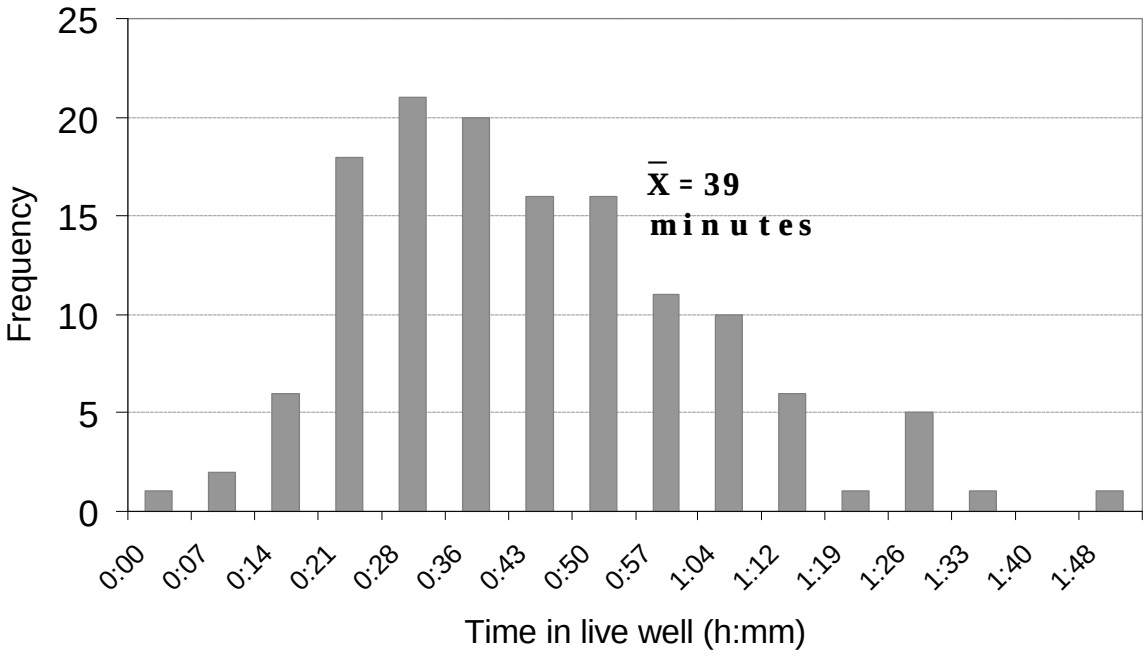


Figure 2. Frequency histogram of residence times in live well for American shad angled from the Hudson River, April 28-29, 1999.

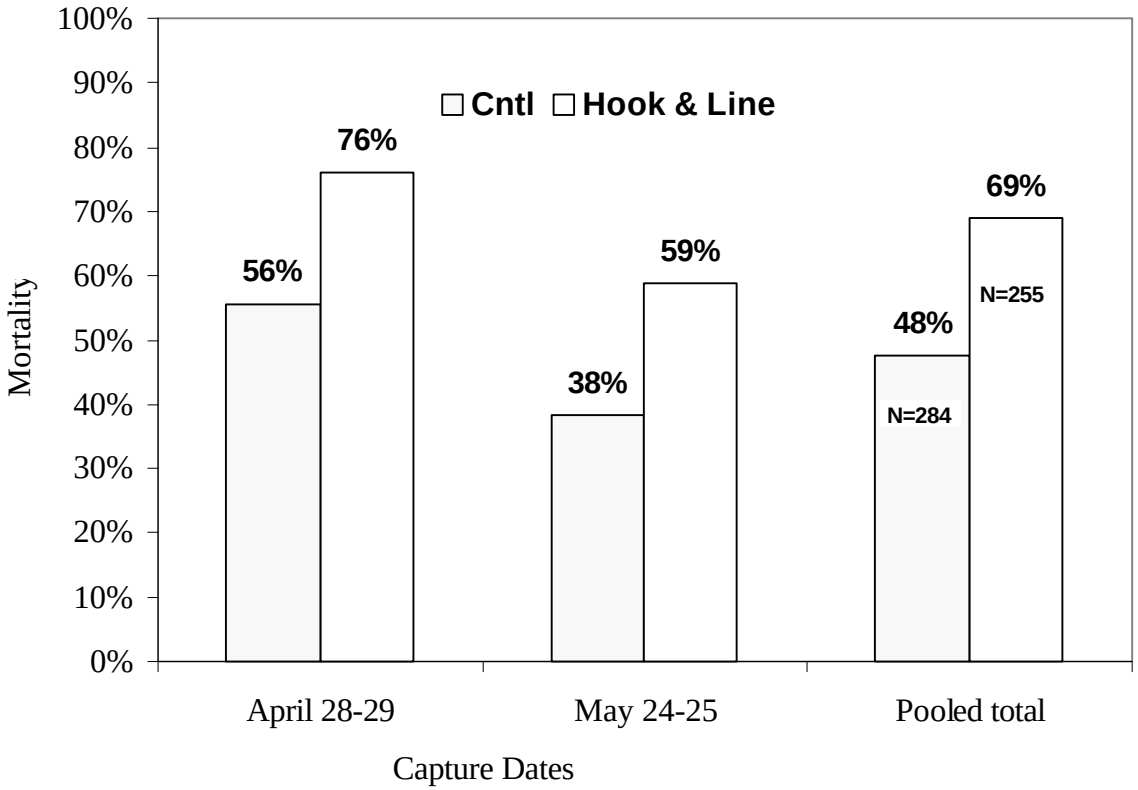


Figure 3. Mortality after five days of American shad angled from Hudson River and held in net pens. Control fish were simultaneously electroshocked and held in same pens. Data are pooled over ten net pens.

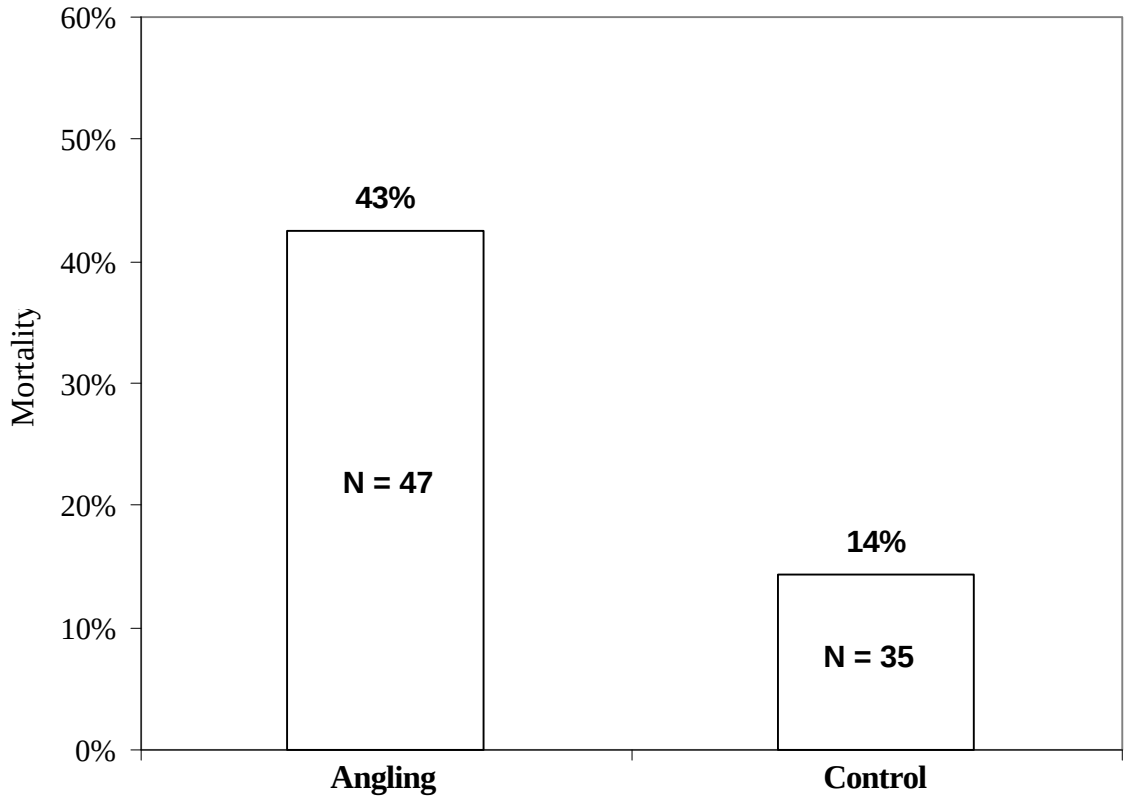


Figure 4. Mortality after five days of striped bass angled from Hudson River and held in net pens. Control fish were simultaneously electroshocked and held in same pens.

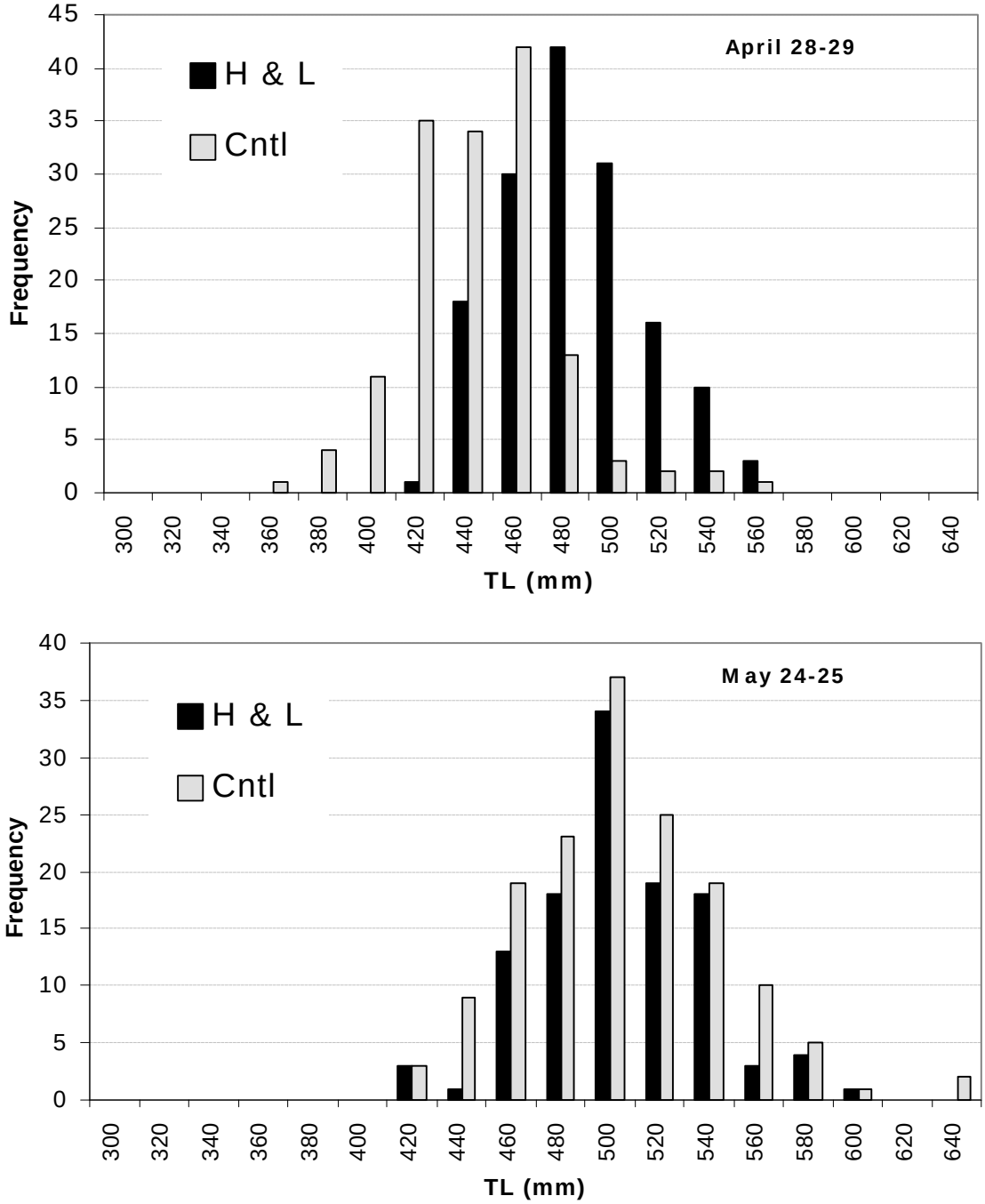


Figure 5. Length frequency distribution of American shad captured by angling (H&L) and electroshocking (Cntl) during two time periods in the Hudson River.

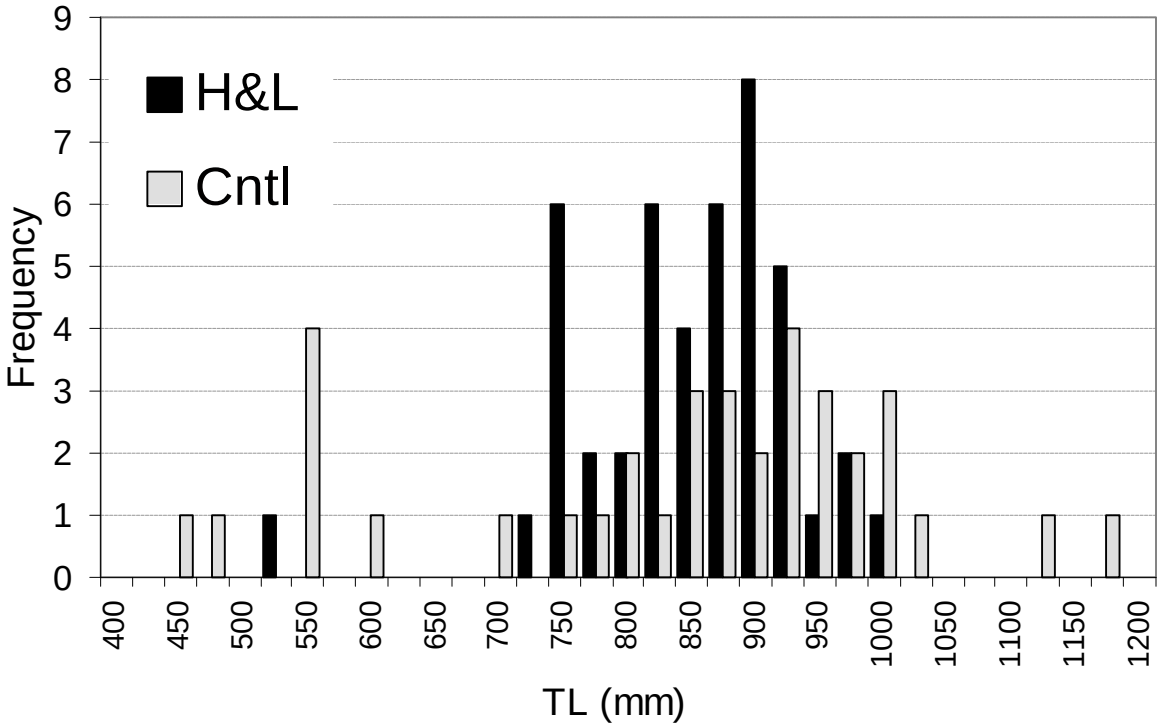


Figure 6. Length frequency distribution of striped bass shad captured by angling (H&L) and electroshocking (Cntl) in the Hudson River.

APPENDIX 1.- Mortality data for American shad angled from Hudson River during two spring periods, 1999. Control fish were electroshocked simultaneously with angling efforts. Mortality was recorded after a five day holding period.

April 28 - May 4 Trial

	Hook & Line				Control				Total			
PEN	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality
1	15	14	1	93%	15	13	2	87%	30	27	3	90%
2	15	15	0	100%	15	11	4	73%	30	26	4	87%
3	16	14	2	88%	15	6	9	40%	31	20	11	65%
4	15	12	3	80%	15	5	10	33%	30	17	13	57%
5	15	8	7	53%	15	5	10	33%	30	13	17	43%
6	15	12	3	80%	15	7	8	47%	30	19	11	63%
7	14	5	9	36%	16	6	10	38%	30	11	19	37%
8	15	15	0	100%	16	9	7	56%	31	24	7	77%
9	15	9	6	60%	15	11	4	73%	30	20	10	67%
10	16	11	5	69%	14	11	3	79%	30	22	8	73%
Total	151	115	36	76%	151	84	67	56%	302	199	103	66%

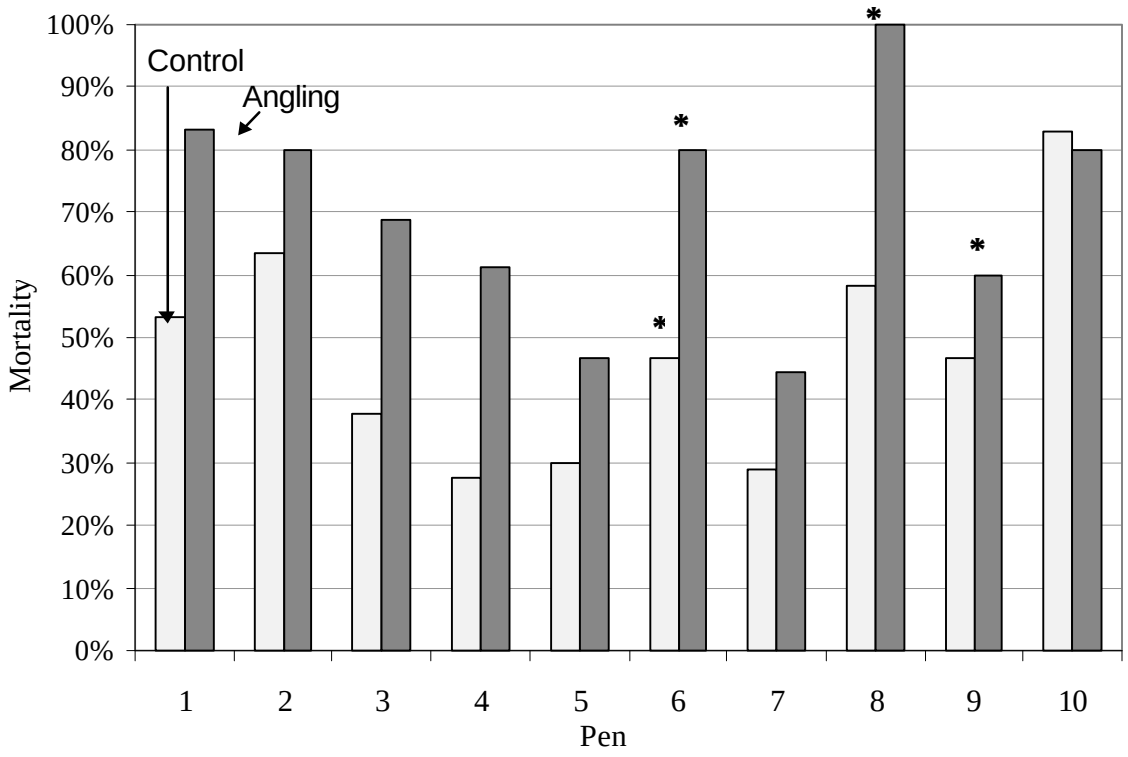
May 24 - May 30 Trial

	Hook & Line				Control				Total			
PEN	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality
1	15	11	4	73%	15	3	12	20%	30	14	16	47%
2	15	9	6	60%	15	8	7	53%	30	17	13	57%
3	16	8	8	50%	14	5	9	36%	30	13	17	43%
4	16	7	9	44%	14	3	11	21%	30	10	20	33%
5	15	6	9	40%	15	4	11	27%	30	10	20	33%
6	0				0				0			
7	13	7	6	54%	15	3	12	20%	28	10	18	36%
8	0				15	9	6	60%	15	9	6	60%
9	0				15	3	12	20%	15	3	12	20%
10	14	13	1	93%	15	13	2	87%	29	26	3	90%
Total	104	61	43	59%	133	51	82	38%	237	112	125	47%

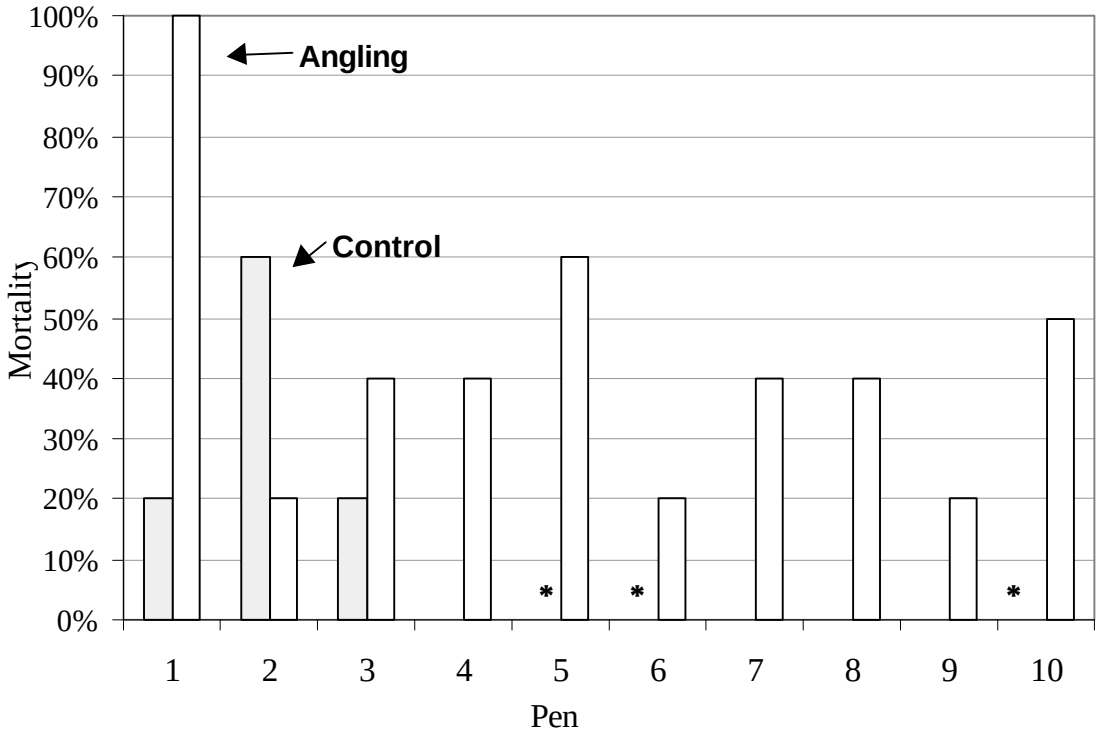
APPENDIX 2.- Mortality data for American shad angled from Hudson River during two spring periods, 1999. Control fish were electroshocked simultaneously with angling efforts. Mortality was recorded after a five day holding period.

	Hook & Line				**Control**				**Total**			
PEN	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality
1	30	25	5	83%	30	16	14	53%	60	41	19	68%
2	30	24	6	80%	30	19	11	63%	60	43	17	72%
3	32	22	10	69%	29	11	18	38%	61	33	28	54%
4	31	19	12	61%	29	8	21	28%	60	27	33	45%
5	30	14	16	47%	30	9	21	30%	60	23	37	38%
6	15	12	3	80%	15	7	8	47%	30	19	11	63%
7	27	12	15	44%	31	9	22	29%	58	21	37	36%
8	15	15	0	100%	31	18	13	58%	46	33	13	72%
9	15	9	6	60%	30	14	16	47%	45	23	22	51%
10	30	24	6	80%	29	24	5	83%	59	48	11	81%
Total	255	176	79	69%	284	135	149	48%	539	311	228	58%

APPENDIX 3. Mortality after five days of American shad, by net pen, angled from Hudson River. Data are pooled over two spring trials. Control fish were simultaneously electroshocked and placed in same pens. Asterisks denote data from 1st trial only (April 28-May 4).



APPENDIX 4.- Mortality data for striped bass shad angled from Hudson River from May 10 - 14, 1999. Control fish were electroshocked simultaneously with angling efforts. Mortality was recorded after a five day holding period.

	Hook & Line				**Control**				**Total**			
PEN	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality	N	Dead	Survive	Mortality
1	5	5	0	100%	5	1	4	20%	10	6	4	60%
2	5	1	4	20%	5	3	2	60%	10	4	6	40%
3	5	2	3	40%	5	1	4	20%	10	3	7	30%
4	5	2	3	40%	5	0	5	0%	10	2	8	20%
5	5	3	2	60%	0				5	3	2	60%
6	5	1	4	20%	0				5	1	4	20%
7	5	2	3	40%	5	0	5	0%	10	2	8	20%
8	5	2	3	40%	5	0	5	0%	10	2	8	20%
9	5	1	4	20%	5	0	5	0%	10	1	9	10%
10	2	1	1	50%	0				2	1	1	50%
Total	47	20	27	43%	35	5	30	14%	82	25	57	30%

APPENDIX 5. Mortality after five days of striped bass, by net pen, angled from Hudson River. Control fish were simultaneously electroshocked and placed in same pens. Asterisks denote pens where no control fish were present.