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

Final Report

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Executive Summary

Catch and release fishing commonly occurs in recreational fisheries, including the striped bass *Morone saxatilis* and American shad *Alosa sapidissima* fisheries of the Atlantic Coast. The contribution of catch and release practices to overall fishing mortality is often not estimated. This study was conducted in two parts of two springs in the Hudson River.

We estimated the catch and release mortality for the Hudson River spawning stock of striped bass in 2001. Methods utilized volunteer anglers assigned both J-hooks or circle hooks combined with live or chunk bait (herring). Anglers caught striped bass within a portion of their spawning area near Kingston NY during the period April 30 to May 16, 2001. Fish were transferred to transport boats with a live well then to tanks onshore within 20 minutes of being caught. Control fish were collected by electro-fishing. All striped bass were marked, placed in the holding tanks and held for five days.

Total mortality was calculated as hooking mortality (angled fish) plus handling mortality (angled and control fish). Catch and release mortality for striped bass averaged 14 % over the entire time period. However, the mortality rate increased when water temperatures reached 16°C. This mortality rate is significant and should be considered when accounting for removals from the spawning population of Hudson River striped bass.

We estimated the catch and release mortality for the Hudson River spawning stock of American shad in 2002. Methods utilized volunteer anglers using shad darts with relatively light tackle. Anglers caught shad near Green Island-Troy NY during the period April 29 to May 9, 2002. Angled shad were transferred to transport boats with a live well then to tanks onshore within 30 minutes of being caught. Control fish were collected by electro-fishing. All shad (controls were marked by a fin clip) were placed in the holding tanks and held for five days.

Total mortality was calculated as the number of shad that died within the 5 d observation period. Controls fish exhibited a higher mortality than angled fish invalidating any correction for handling mortality. The catch and release mortality was 1.6 %. All mortality occurred for fish caught on or after May 6 when water temperature increased to greater than 12°C.

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Action Plan Project

Hudson River Estuary

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Chapter I: Striped Bass

Introduction

Catch and release fishing commonly occurs in recreational fisheries, including the striped bass *Morone saxatilis* fishery of the Atlantic Coast. The contribution of catch and release practices to overall fishing mortality is often not estimated. Recent national recreational fishing survey reports indicate that striped bass anglers released over 90% of their catch in 1997 and 1998 (personal communication from the National Marine Fisheries Service (NMFS), Fisheries Statistics and Economics Division). Consequently, hooking mortality may contribute substantially to fishing mortality in the Atlantic coast striped bass fishery. Estimates from the NMFS recreational fishery survey indicated that an average of over 14.5 million striped bass were caught and released each year between 1996 and 2000 (personal communication from the National Marine Fisheries Service (NMFS), Fisheries Statistics and Economics Division). The ASMFC fishery management board for striped bass currently assumes a 8% hooking mortality rate. This rate infers a 5-year average annual mortality of over 1.3 million released fish along the Atlantic coast between 1996 and 2000. These estimates of hooking mortality exceed the estimates of directed commercial harvests in 1998, 1999, 2000, and 2001 (ASMFC 1999, 2000, 2001, 2002).

The overall hooking mortality of 8% currently accepted by ASMFC managers was a preliminary estimate from a study performed in a saltwater coastal system (Diodati and Richards 1996), and higher rates of hooking mortality in striped bass may be expected in freshwater river systems (Wilde et al. 2000). The restoration of the striped bass fishery on the east coast has increased opportunities for the recreational and commercial fishing communities. Fishery managers must routinely monitor sources of mortality and implement responsive prudent management actions in order to maintain this fishery. For this reason, we believe an evaluation of hooking mortality for striped bass in the primarily freshwater environment of the Hudson River is necessary.

The 8% 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 a 58-day observation period in a saltwater system, whereas Nelson (1998) observed fish held in freshwater tanks for 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). Biologists working in brackish waters (approx. 5 -10 ppt) in Chesapeake Bay in 1999 found that hooking mortality of striped bass during a 3-day observation period was greater in deep-hooked fish (i.e., fish hooked posterior to the gills) and in shallow-hooked fish captured during periods of high air temperature (> 95EF). This study also showed a marked difference in hooking mortality between fish caught with traditional bait hooks and those caught with non-offset circle hooks, with the latter expressing decreased mortality (R. Lukacovic, Maryland Dept. of Natural Resources, Annapolis, MD, personal communication).

Striped Bass in the Hudson River

The spawning migration of striped bass usually begins in the Hudson River Estuary around the third week in April (McLaren et al. 1981). Peak spawning usually occurs in mid May when water temperatures are above 14 C. Spawning activity ranges from Croton Point (km 56) to Coxsackie, but appears to be concentrated near Kingston and just upriver of West Point. Following spawning, most adults leave the estuary (McLaren et al. 1981).

Larvae and early juvenile striped bass disperse to shallow-water nursery areas in the early summer. Juveniles move downriver through summer, and by fall are concentrated in the Hudson's Harvestraw Bay and Tappan Zee area. Recent data (McKown and Brischler 2001) suggest that this nursery area has expanded to near shore areas of western Long Island. Most age zero juveniles emigrate to marine waters by late fall.

After spawning, adult bass move north along the Atlantic coast to summer in the waters off Massachusetts to the Gulf of Maine. In the fall, fish move south along the

coast to wintering areas in lower Delaware Bay to near-shore waters off North Carolina (A. Kahnle and K. Hattala, NYSDEC unpublished striped bass tag data). An over-wintering population of striped bass also moves into the river in mid to late fall. This population includes immature fish and possibly some pre-spawning adults (McLaren et al. 1981). It is suspected that these fish are of mixed stock origin and not only Hudson stock.

Given the importance of striped bass in New York, as well as the Atlantic coast, much scrutiny has been placed on east coast spawning stocks. New York's Hudson River striped bass fishery is one of the few recreational fisheries that is directed on a spawning stock for the duration of the spawning season. In late March to early April, the recreational fishery begins in the down river areas of Haverstraw Bay and the Tappan Zee, as bass begin to enter the river. The fishery follows the migration north as fish move into the spawning areas during May and winds down in early June as spawners begin to leave.

A preliminary catch and release study was conducted jointly by the USFWS and NYSDEC in spring 1999 (Millard et al. 2000). In our 1999 study, angled and electrofished (control) striped bass were held together in large net pens submerged in the Hudson River. Fish were held for 5 days, after which the pens were emptied and mortalities were counted. Results indicated that mortality for striped bass approached 30%. These results were consistent with the overall 29% mortality found for striped bass in the freshwater studies analyzed by Wilde et al. (2000). A major difficulty identified in the preliminary study included distortion and partial collapse of the submerged net pens due to accumulation of detritus and flotsam and the effect of tidal currents. Another problem was a relatively small sample size of angled fish (N=47). The current study used shore-based tanks to circumvent the problem of inadequate containment conditions, plus many more recreational anglers were recruited to assist with collection of fish, thereby increasing our sample size. We believe these modifications allow us to refine the estimates reported in Millard et al. (2000). The objectives were to estimate the mortality associated with catch and release practices that commonly occur in the spring recreational striped bass fishery in the Hudson River, and assess the influence of selected variables on hooking mortality rates (water temperature, hook type, playing and handling time, hook

location, and fish length). This study provides information necessary to determine the contribution of hook and release mortality to the overall fishing mortality rate in the Hudson River striped bass fishery. The results are useful in developing guidelines for reducing mortalities of released fish and formulating regulations designed to reduce the non-consumptive mortality rates associated with recreational fishing. This information is particularly important given that the fishery targets one of the largest concentrations of spawning striped bass in the Hudson River.

Methods

Striped bass field collection

Striped bass were collected from the Hudson River immediately upriver from the Kingston-Rhinecliff bridge, north of Kingston, NY, in a popular angling area known as the Kingston Flats (Figure 1.1). Volunteer recreational anglers were recruited to provide the angled fish between April 30 and May 16, 2001. Participating anglers reported to an anchored project boat upon arrival at the fishing site each day and received bait (primarily alewife *Alosa psuedoharengus*) and a supply of hooks. Each angler boat was randomly supplied with either traditional straight-shanked "J" hooks or non-offset circle hooks and were requested to use the assigned hook-type throughout the day. Hooks provided were 3/0, 4/0, and 5/0 nickel-plated Mustad #3406 "O'Shaughnessy", and 5/0, 6/0, 7/0, and 8/0 black-finish Mustad #39950BL "Demon Circle" (Figure 1.2). Some anglers chose to use their own "J" hooks or circle hooks, and a small number of the latter were known to have offset points.

The anglers were free to use live or chunk bait and to fish the bait in any manner they chose as long as they stayed within the approximately 2km reach of the project boundary. All anglers used spinning or bait-casting gear. Three or four transport boats with aerated, flow-through live wells were distributed among the anglers each day and remained in contact with anglers either via radio or manual signal flags. Immediately after hook-up with a fish, an angler notified a transport boat, the transport boat noted the time of hook-up, and began approaching the angler's boat. Once the fish was brought to net, the project boat closed with the angler boat and retrieved the fish either directly out of the net or from the angler. Data initially recorded for each angled fish included playing

time, transport time, hook type, bait type, line weight/test, hook location, and presence of bleeding.

Angled fish were placed in the transport boat live well, received a uniquely-numbered T-bar anchor tag (Floy Tag and Mfg. Inc., Seattle, WA) near the anterior base of the dorsal fin, and were immediately transported to a shore-based holding tank. An array of nine holding tanks (4.6m diameter, 15,000 liter capacity) were provided with flow-through river water at a turnover rate of 50% total volume per hour. Tanks were lined with black polypropylene and were covered with screening which provided 70% light blockage.

Control fish were captured from the same river reach by electrofishing with pulsed DC current via bow-mounted dropper cable electrode arrays. Control fish were tagged and transported similar to angled fish. All fish captured on a given day were placed in the same holding tank and a vacant tank was used each day; that is, fish from different days were not mixed within a tank. Fish were held in captivity for five days (six days in one case), with visible mortalities removed and recorded daily from each tank. After the holding time had elapsed, all remaining fish in a tank were removed, measured, and recorded as being (1) angled/control and (2) male/female and (3) alive/dead. All survivors were released back into the river. A subset of dead angled fish were necropsied to assess the presence/absence of gross physical trauma in the esophagus and surrounding tissues. Any trauma or hemorrhaging was assumed to be related to hooking or hook removal.

Water temperature was continuously recorded in the river and in one holding tank throughout the duration of the project.

Data analysis

Analysis of mortality data followed that of Millard et al. (2000). For comparative purposes, mortality rates associated with hook and release of striped bass were estimated using two methods: conditional mortality rates, and additive finite mortality rates. The two methods differed in their assumptions about the relationship between the two possible sources of mortality: hook and release and experimental handling.

Conditional mortality rates

This method assumed the two mortality components associated with hook and release and experimental handling acted simultaneous with each other, and, in effect, competed with each other during the 5-day holding period. As such, this method assumed that 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:

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

No natural mortality was assumed 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:

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

This method 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). The estimate of the conditional mortality rate associated with hook and

release, $m_{c\text{-}hook}$, that would occur in the absence of handling mortality, was computed as:

$$m_{c\text{-}hook} = (A \times m_{hook}) / m_t \qquad [5]$$

Equation [5] follows the traditional fisheries expression $u = A\ell F' Z$, which can be rewritten as:

$$u = A - [AM / -\ln(1-A)] \qquad [6].$$

Confidence limits for *u,* as defined in equation [6], were generated using a variance term derived with the delta method (Oehlert 1992):

where:

$$V\hat{a}r(\hat{u}) = \left(\partial\hat{u} / \partial A\right)^2 \times \hat{\text{var}}(M) + \left(\partial\hat{u} / \partial M\right)^2 \times \hat{\text{var}}(A)$$

with:

$$\left(\partial\hat{\mu} / \partial A\right) = 1 - \left\{\left(AM / [\ln(1-A)]^2 \times (1-A)\right) + \left(M / \ln(1-A)\right)\right\}$$

and

$$\left(\partial\hat{u} / \partial M\right) = A / -\ln(1-A).$$

This approach was employed with the assumption that capture by electrofishing did not cause mortality in the control fish.

Additive finite mortality rates

This method assumed the two mortality components associated with hook and release and experimental handling were independent. In this case, an additive relationship was assumed between the two rates observed at the end of the five day holding period and hooking mortality was computed as the difference between the total mortality rate observed in the treatment fish and the handling mortality rate observed in the control fish. This is equivalent to the "adjusted mortality rate" reported by Nelson (1998). Confidence limits for *d*, the simple difference between 2 proportions, were generated using the variance and associated standard error formulas found in Fleiss (1981).

Factors influencing mortality

The effect of angling-related variables on mortality of hooked fish was evaluated with logistic regression analysis (Menard 1995). We assessed how the probability of mortality was affected by the following explanatory variables: hook type, bait type, hook location, presence of external bleeding, playing time, sex, and fork length. The standard logistic regression model $p_i = e^{\beta} / 1 + e^{\beta}$ was fit, where p_i = probability of mortality and e^{β} = a linear function of the explanatory variables mentioned above. Maximum likelihood estimates of the coefficients and their associated odds ratios, plus logistic regression diagnostics were generated with SAS software (SAS Institute, Inc. 1989). Variables were included in the final model when the likelihood-ratio test of their coefficient was significant ($P < 0.1$). Odds ratios are helpful in interpreting logit model coefficients because of the nonlinear relationship between the probability and the explanatory variables. This property precludes the straightforward interpretation of coefficients that one normally encounters with linear regression. A common helpful approach to interpreting odds ratios is to subtract 1 from the odds ratio and multiply by 100; the result provides the *percent change* in the odds (of mortality, in this case) for each 1 unit increase in the explanatory variable. A probability-based interpretation of the logit model, as opposed to odds ratio-based, was also provided via the equation (Allison 1999):

$$\partial p_i / \partial x_i = \beta p_i (1 - p_i) \qquad [7]$$

This allows for the interpretation of the average change in probability of mortality given a 1-unit increase in the explanatory variable X having parameter estimate β

Results

Overall catch and mortality

Participating anglers contributed 159 striped bass during the 13 angling days between April 30 and May 16, and 143 control fish were captured via electrofishing. Mortality of the control fish was low; only 4 (2.8%) died within the 5-day observation window, whereas 26 (16.3%) of the angled fish died (Table 1.1). Angled and control fish had similar characteristics. The mean fork length of female angled and control fish was

831mm and 882mm, respectively. Mean fork length of male angled and control fish was 697mm and 723mm respectively, although the length distribution of male control fish appeared to be bimodal, with peaks at 660mm and 820mm (Figure 1.3). Of the 287 fish whose sex was identified, 88% of the control fish were male, and 71% of the angled fish were male.

The overall handling time for angled fish consisted of angler play time plus transport handling time. Mean angler play time was 5 minutes and mean transport time was 8 minutes. Of the 26 total mortalities suffered by angled fish, 14 (54%) occurred in fish which had been played 5 minutes or less and 13 (50%) occurred in fish with a transport time of 8 minutes or less (Figure 1.4). The mean overall play time for angled fish was 5.6 minutes; there was no significant difference between playing time for male and female fish (t-test, $P > 0.35$) (Figure 1.4). Total handling time (angler play time plus transport time) averaged 14 minutes. Twelve (46%) of the 26 total mortalities among angled fish occurred in fish experiencing less than the average handling time of 14 minutes (Figure 1.5). These results suggest that angler playing time and transport handling time had little influence on observed mortality.

Although hook-specific effort was not recorded, attempts to exert approximately equal effort with circle hooks and J-hooks were generally unsuccessful, primarily due to the unwillingness of anglers to employ circle hooks. Consequently, only 37 of the 159 angler-caught fish were captured on circle hooks, and 3 (8.1%) of these died within the observation period. Of the 122 fish caught with J-hooks, 23 (18.9%) died within 5 days (Table 1.2).

Hooking mortality estimates

Adjusting the observed mortality of angled fish to account for the effects of transport, handling, and holding resulted in slightly reduced estimates of hooking mortality. The overall estimate of hooking mortality, for both hook types combined, was 14% (Table 1.2). The mortality rate for circle hooks was 5%, whereas that for J-hooks was 16%. The independent estimates provided by additive rates and the conditional rate estimator were similar (Table 1.2).

Factors influencing mortality

Hook location and the occurrence of bleeding were the most influential variables in determining the probability of death of a hooked and released fish (P <0.05, Table 1-3). The odds ratio for the bleeding variable was 15.77; thus the odds of death for a fish that bled around the hooking site was about 15 times greater than for a fish with no observable bleeding (Table 1.3). In a probabilistic framework, the probability of death, on average, was 0.38 higher for fish that exhibited bleeding compared with those that didn't show bleeding.

Hook location was a significant variable, but is somewhat more difficult to quantitatively interpret because the response had four possible outcomes: lip, mouth, gill, or swallowed. Recoding the data so that each of the four possible outcomes becomes a separate, binary variable allows us to compare three of the responses against the remaining fourth response. When the hook location classifications of mouth, gill, and swallowed are compared against the "lip" classification, only the "swallowed" variable was significant ($P < 0.05$) with an odds ratio estimate of 5.8, indicating that the odds of death for a fish that swallowed the hook are 5.8 times the odds of death for fish that are lip-hooked. Of the 47 fish that were lip-hooked, only 2 (4.5%) exhibited bleeding, and neither fish died within the 5-day observation period. Of the 74 fish that swallowed the hook, 7 (9.5%) exhibited bleeding and all 7 of these fish died.

Interestingly, hook type was not significantly related to the mortality of a hooked and released fish ($P > 0.3$, Table 3). Since hooking location and bleeding were important determinants of the ultimate fate of the fish, it is particularly inviting to attempt to predict hooking location or bleeding as a function of hook type and/or bait type. Traditional J-hooks were swallowed with greater frequency than were circle hooks, although the differential was not statistically significant. Descriptive statistics for catch and mortality by hook type × bait type combinations are provided in Table 1.4.

Fork length category was nearly significant ($P = 0.058$, Table 1.3) in predicting mortality. The negative parameter estimate suggests that the odds of mortality decreased as fork length increased. Fish equal to or smaller than the 10th-percentile in fork length (615mm) suffered 19.2% of the total mortality observed in the study, whereas fish longer

than the 90th-percentile in fork length (865mm) exhibited no mortality (Figure 1.6). In general, larger fish were less likely to die.

The average daily water temperature steadily increased from 12EC on April 30 to 17EC on May 12, and then varied between 16EC and 17.5EC through the end of the study period (Figure 1.7). Water temperature in the tanks generally deviated 2EC or less from that of the river. Although no strong correlation between temperature and mortality is seen when daily mortality of angled fish is compared with the tank thermograph, our data suggest a possible threshold temperature of 16EC, at or above which mortality was elevated. Twenty of the 26 (77%) total mortalities of angled fish were recorded when mean daily water temperature on the final holding day was at or above 16EC (Figure 1.8).

Inspection of 14 of the 26 deceased angler-caught fish suggested that physical damage to the esophagus and surrounding organs during hooking or hook removal was the probable cause of death. This appeared to be true regardless of hook type. Everted and lacerated esophageal tissue, internal hemorrhaging, lacerated liver tissue, and/or damage to the heart and pericardial tissue was observed in 13 of the 14 inspected mortalities (Figure 1.9).

Discussion

In-river losses to the recreational fishery far out-weigh the bycatch loss in the commercial shad net fishery by an order of magnitude in recent years (~250,000 lbs v 25,000). However, all in-river losses to the Hudson striped bass stock are minor compared to the losses in ocean waters. In NY waters alone, the ocean recreational fishery by far outstrips all other losses combined (commercial harvest and bycatch and in-river recreational harvest and bycatch) (Figure 1.10).

Our results suggest that the mortality associated with the hook and release of striped bass in fresh water can approach 15%, although the impact can be mitigated somewhat by the use of circle hooks. Our results are consistent with other reported mortality rates in freshwater systems (Hysmith et al. 1993; Nelson 1998; Wilde et al. 2000). Most studies found hooking mortality season or temperature-dependent, with

higher mortality occurring at higher temperatures (Harrell 1987; Nelson 1998; Wilde et al. 2000). Water temperatures during our observation period were less than 20 °C; the temperature at which Nelson (1998) observed a distinct increase in hooking-related mortality was 22 °C. The 5-day observation period for our study was longer than the 72-h period used by Nelson (1998).

While not statistically significant, the use of circle hooks appeared to decrease the incidence of gut-hooked fish. Similar to Nelson (1998) and Diodati and Richards (1996), the location of hooking had a significant effect in the probability of death, with the odds of death for gut-hooked fish being almost six times the odds of death for fish hooked in the lip. The occurrence of bleeding associated with gut-hooked fish was also associated with high mortality. This trend is also consistent with Nelson (1998). While external bleeding was not always observed in those fish which were hooked in the esophagus, this hooking location appeared to increase greatly the opportunity for internal damage to organs and blood vessels located near the esophagus, e.g. the heart, liver and ventral aorta. Many factors can affect the likelihood of hooking mortality due to physical damage to organs and tissue, such as the use of barbed hooks or J-hooks instead of circle hooks (Taylor & White 1992; Orsi et al 1993).

The use of live bait, as opposed to artifical lures, has been shown to result in increased hooking mortality rates (Hysmith et al. 1993; Wilde et al. 2000), although this trend has not always been detected (Bettoli and Osborne 1998). Our results compared the use of live bait versus cut, natural bait, with no significant difference detected between the two. Our results were hampered by the fact that few participating fishermen used whole, live bait once they found that cut bait worked well. We hypothesize that any bait configuration that facilitates swallowing of the terminal gear will exacerbate mortality due to physical trauma associated with hooking and hook removal. We observed that many anglers, upon encountering a swallowed hook, simply cut the line at some point inside the buccal cavity; the effect of this practice is unknown but we assume that is does little to prevent mortality due to hook-induced trauma. We hypothesize that the physical trauma from swallowed hooks occurs during the initial hook penetration and subsequent playing of the fish; any mitigative actions taken after that point are likely ineffective.

We found that mortality due to hooking was inversely related to the length of the fish, although the association was weak. Nelson (1998) and Bettoli and Osborne (1998) did not observe any relation between length and mortality, and Wilde et al. (2000) discounted a weak association between mortality and an interaction term involving bait type and length as being spurious. Contrary to these results, Hysmith et al. (1993) found a relationship between mortality and fish length, although the nature of the relationship differed between seasons. Our results were similar to their cool season data, where smaller fish exhibited higher mortality.

Our estimation techniques assume that mortality due to method of capture in the control group was negligible; i.e. electrofishing for control fish did not impart any mortality in that group. Harrell and Moline (1992) investigated the stress physiology of striped bass captured by electrofishing, and noted that the mature fish recovered from the stress of capture within 48 hours. The use of control fish to adjust overall observed mortality for the effects of handling and confinement has been employed (Nelson 1998), but we believe this is the first use of conditional rates for the correction. The small mortality rate exhibited by the control fish resulted in similar estimates for hooking mortality for both the conditional rate technique and the additive finite rate technique. However, in studies where control fish exhibit more significant mortality due to handling and confinement, we recommend the conditional rate estimator as a more appropriate technique. The technique adjusts for the likelihood that the two sources of mortality, hook and release trauma and stress, and stress due to handling and confinement, occur simultaneously over the observation period.

Our results suggest that mortality of fish released in the recreational fishery in the Hudson River is a significant component of total mortality of striped bass and, as such, should be considered in accounting for removals from the spawning population. Consideration of loss of spawners due to hook and release mortality in stock assessments dictate that data exist on the magnitude of the recreational fishery and, in particular, the rate of catch and release in the recreational fishery. Periodic estimates of angling effort and associated catch and release rates are needed to incorporate this source of mortality into stock assessments and subsequent management decisions.

Table 1.1 Daily catch and ultimate fate of angled and electrofished striped bass from the Hudson River.

Date		Angler Caught		Controls	
Captured	Released	Survived	Mortality	Survived	Mortality
30-Apr	5-May	5	0	28	0
1-May	6-May	15	3	10	0
2-May	7-May	18	3	9	0
3-May	8-May	12	0	11	0
4-May	9-May	5	0	2	1
7-May	13-May	16	0	14	2
8-May	13-May	7	4	12	0
9-May	14-May	18	2	17	0
10-May	15-May	5	1	17	0
11-May	16-May	5	0	16	1
14-May	19-May	14	6	3	0
15-May	20-May	5	4	0	0
16-May	21-May	8	3	0	0
	Totals	133	26	139	4

Table 1.2 Estimates of mortality for striped bass in the Hudson River associated with hook and release and corrected for handling mortality using additive and conditional rate estimators.

				Hook & line mortality estimates			
Gear	Total caught	# mortalities	% mortalities	Additive rates	Conditional rates	Conditional rate Confidence Intervals	
J-hooks	122	23	18.9	16.1%	16.3%	9.7%	22.5%
Circle hooks	37	3	8.1	5.3%	5.4%	0.0%	14.1%
Angling total	159	26	16.3	13.6%	13.8%	8.1%	19.4%
Electrofishing	143	4	2.8				

Table 1.3 Logistic regression results assessing the factors influencing the mortality of striped bass caught with hook and line. Categorical data coding scheme for each variable shown below the variable in parentheses.

Variable	Likelihood Ratio P^2	P	Odds ratio	Parameter estimate	Avg change in P(mortality) w/ 1-unit increase in X^1
Hook type (Circle = 0; J-hook = 1)	0.94	0.333	1.97	0.679	0.09
Bait type (Cut = 0; Live = 1)	0.01	0.910	1.15	0.138	0.02
Hook location (Lip = 0; Mouth = 1; Gill = 2; Gut = 3)	12.29	<0.001	2.10	0.739	0.10
Presence of bleeding (No = 0; Yes = 1)	11.27	<0.001	15.77	2.758	0.38
Sex (Unknown = 0; Female= 1; Male = 2)	2.02	0.155	2.44	0.891	0.12
Fork Length Category (<500 = 0; 500-600 = 1; 600-700 = 2; 700-800=3; 800-900 = 4; >900 = 5)	3.60	0.058	0.54	-0.622	-0.09
Playing time (< 5 min = 0; >5min = 1)	1.96	0.162	2.17	0.773	0.11

Table 1.4 Descriptive statistics for catch and mortality of striped bass by hook type × bait type (top) and their combinations (bottom). Bait type was unreported for one fish, resulting in one fewer fish in the overall sample size for the bait type data.

	Hook type	
	Circle	J-hook
Total number caught	37	122
Mortalities	8.1%	18.9%
Bleeding observed	5.4%	7.4%
Lip-hooked	54.1%	22.1%
Gut-hooked or swallowed hook	29.7%	51.6%
	Bait type	
	Cut	Live
Total number caught	147	11
Mortalities	17.0%	9.0%
Bleeding observed	7.5%	0.0%
Lip-hooked	26.5%	63.6%
Gut-hooked or swallowed hook	48.3%	27.3%

		Hook type			
		circle hook		**J-hook**	
Bait type	**cut bait**	Total number caught	31	Total number caught	116
		Mortalities	6.4%	Mortalities	19.8%
		Bleeding observed	6.5%	Bleeding observed	7.8%
		Lip-hooked	48.4%	Lip-hooked	20.7%
		Gut-hooked or swallowed hook	32.3%	Gut-hooked or swallowed hook	52.6%
	live bait	Total number caught	5	Total number caught	6
		Mortalities	20.0%	Mortalities	0.0%
		Bleeding observed	0.0%	Bleeding observed	0.0%
		Lip-hooked	80.0%	Lip-hooked	50.0%
		Gut-hooked or swallowed hook	20.0%	Gut-hooked or swallowed hook	33.3%

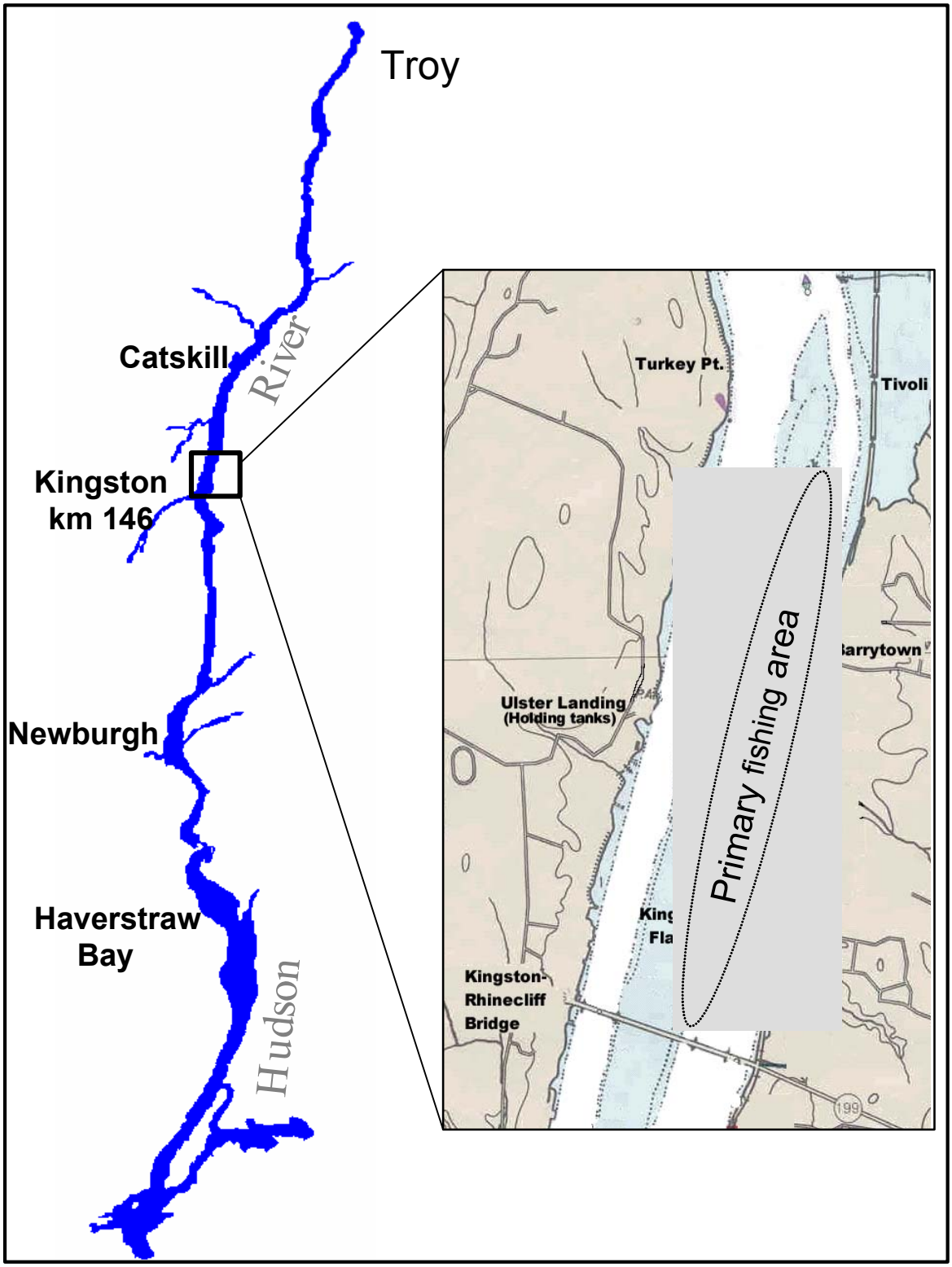


Figure 1.1 Study site for striped bass hooking mortality study.

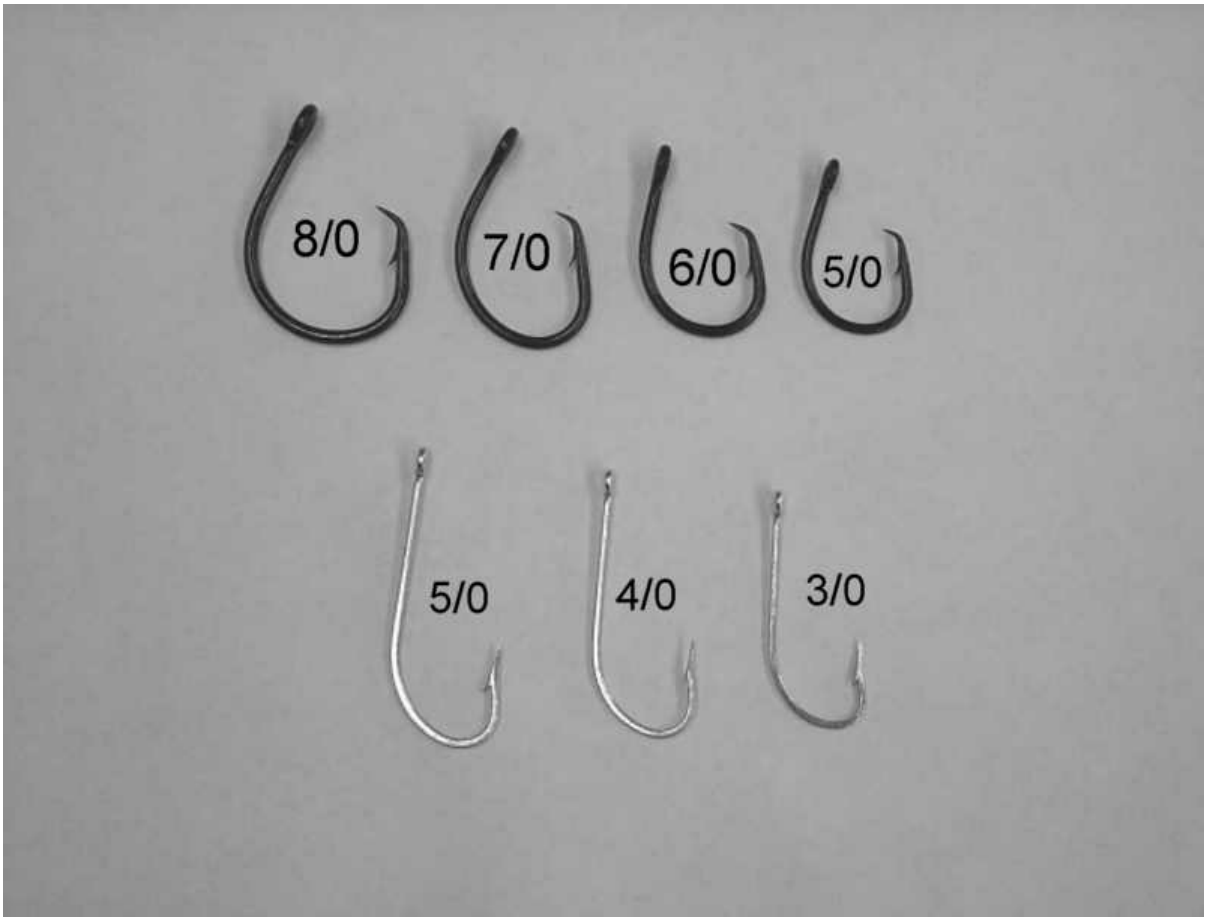


Figure 1.2 Circle hooks (top) and J-hooks (bottom) used in hook and release mortality study of striped bass.

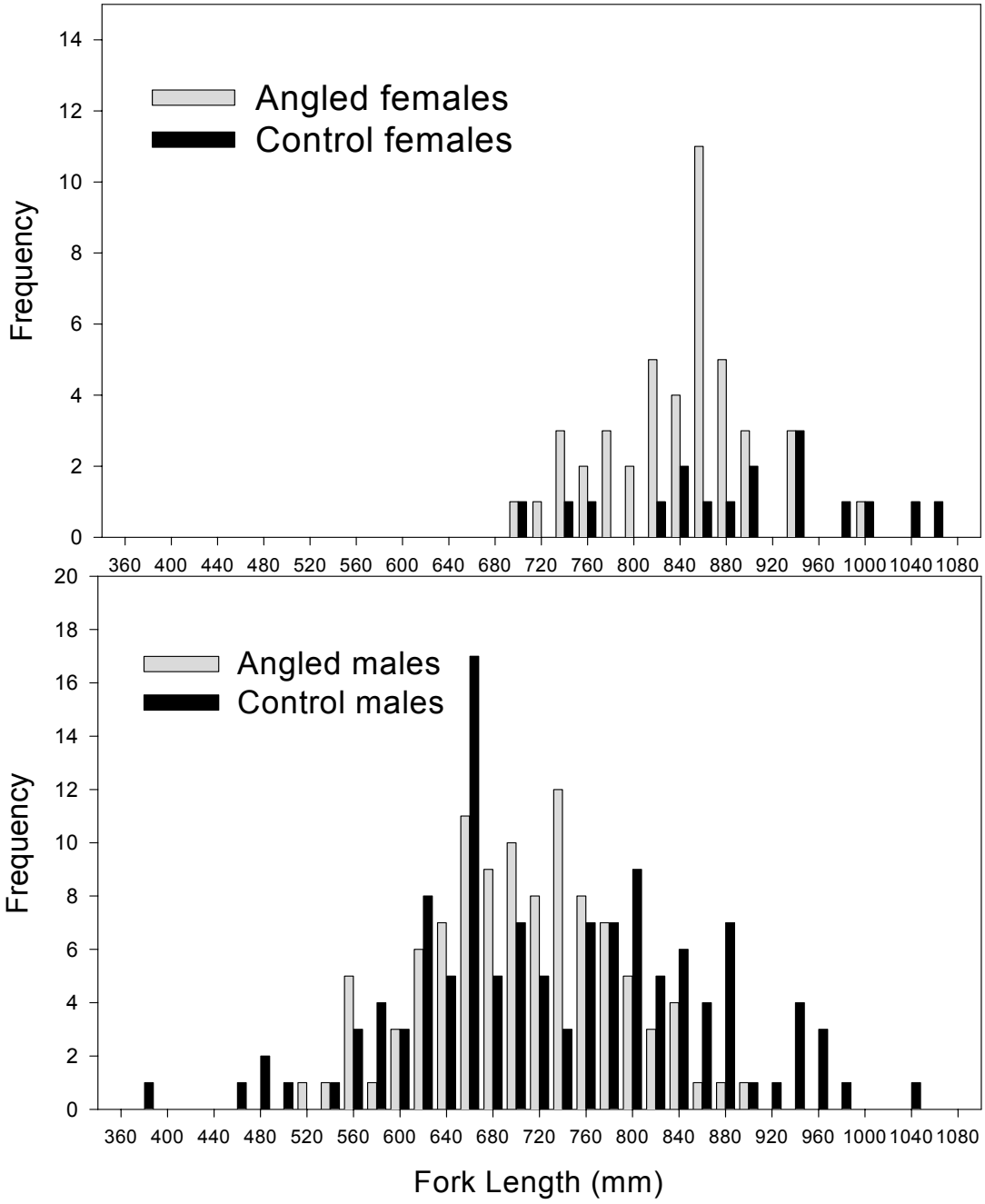


Figure 1.3 Length frequency of angled and electrofished female (top) and male (bottom) striped bass.

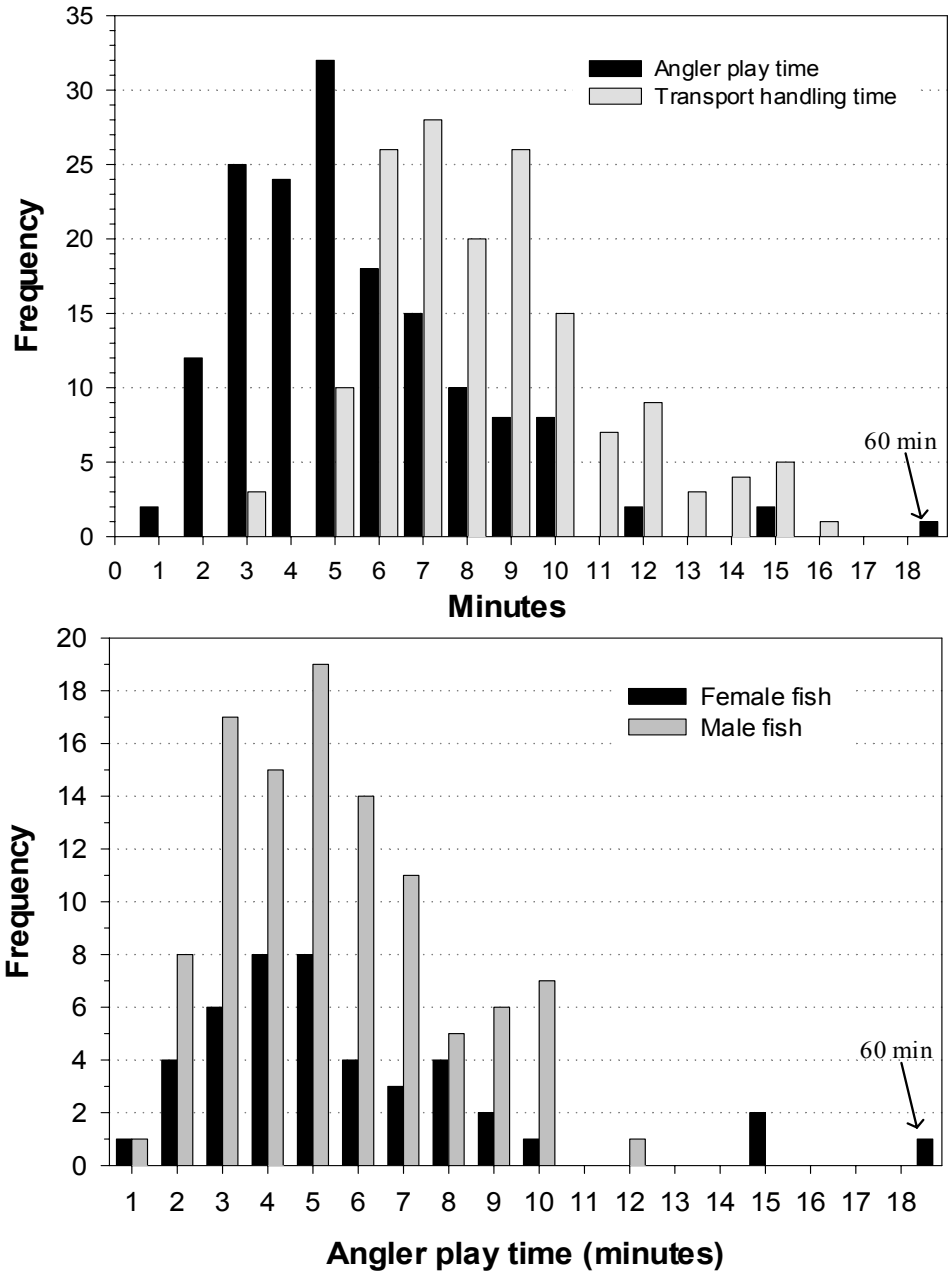


Figure 1.4 Distribution of angler playing time and transport time for all fish (top) and angler play time for male and female (bottom) striped bass.

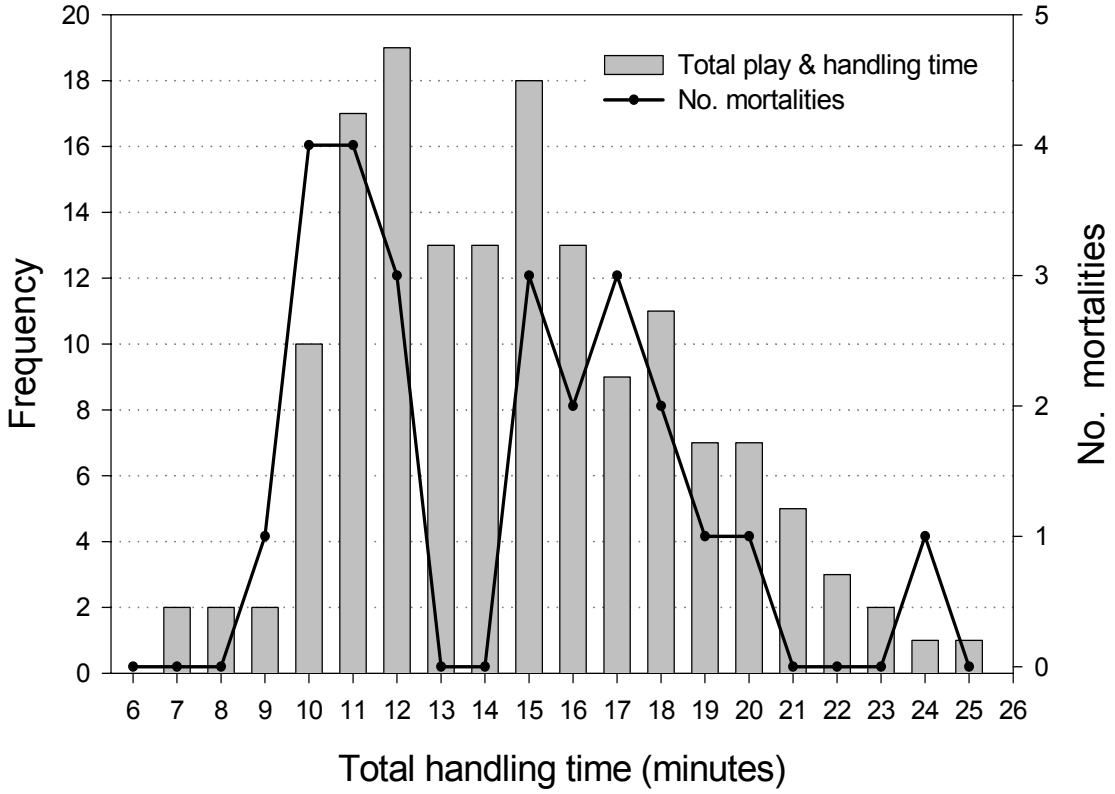


Figure 1.5 Distribution of total handling time (angler play time + transport time) and frequency of mortalities for angled striped bass.

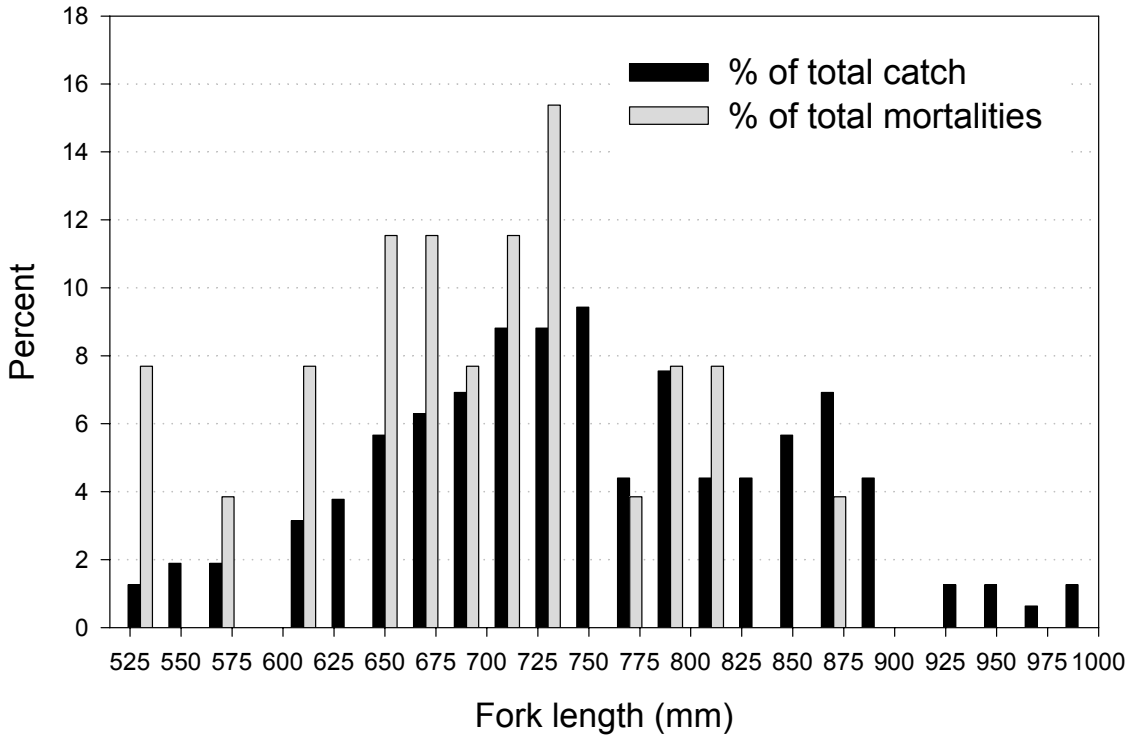


Figure 1.6. Relative distribution of size and mortalities of angler-caught striped bass.

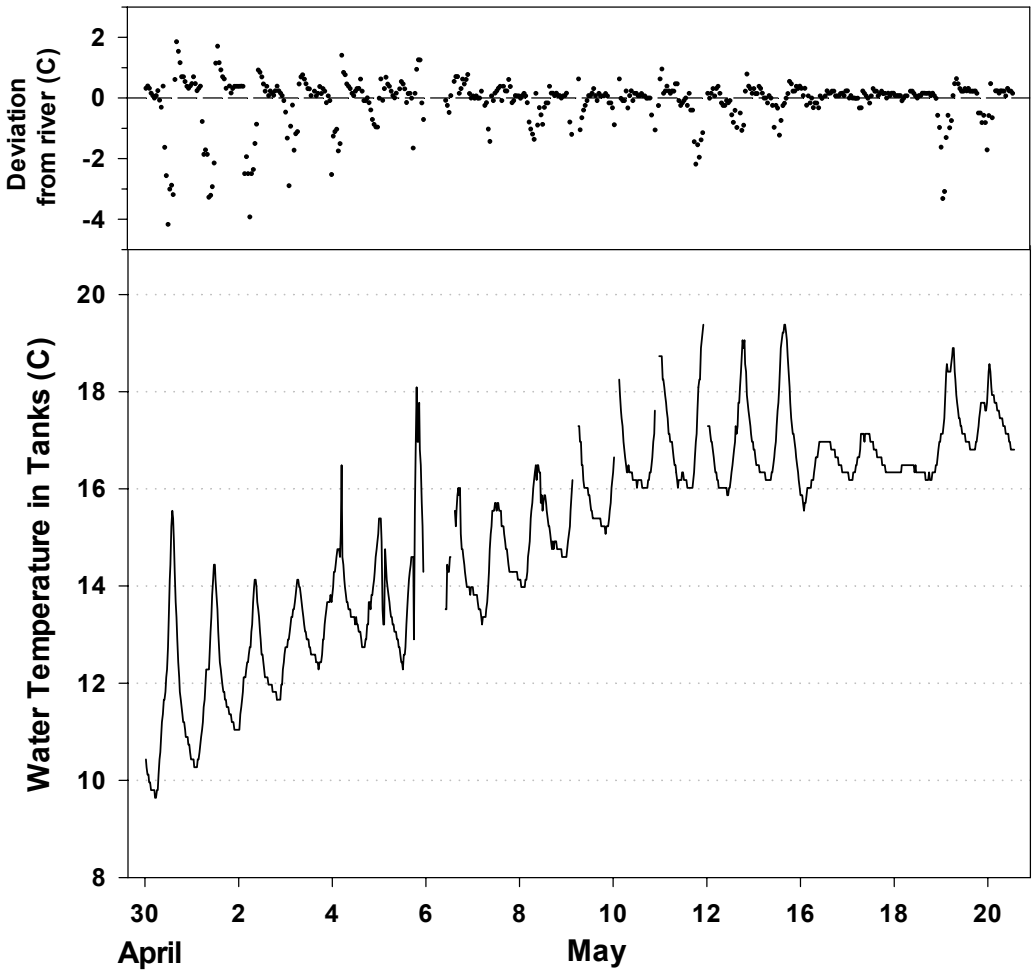


Figure 1.7 Holding tank water temperature (bottom) and the hourly deviation of tank temperature from that of river surface waters (top).

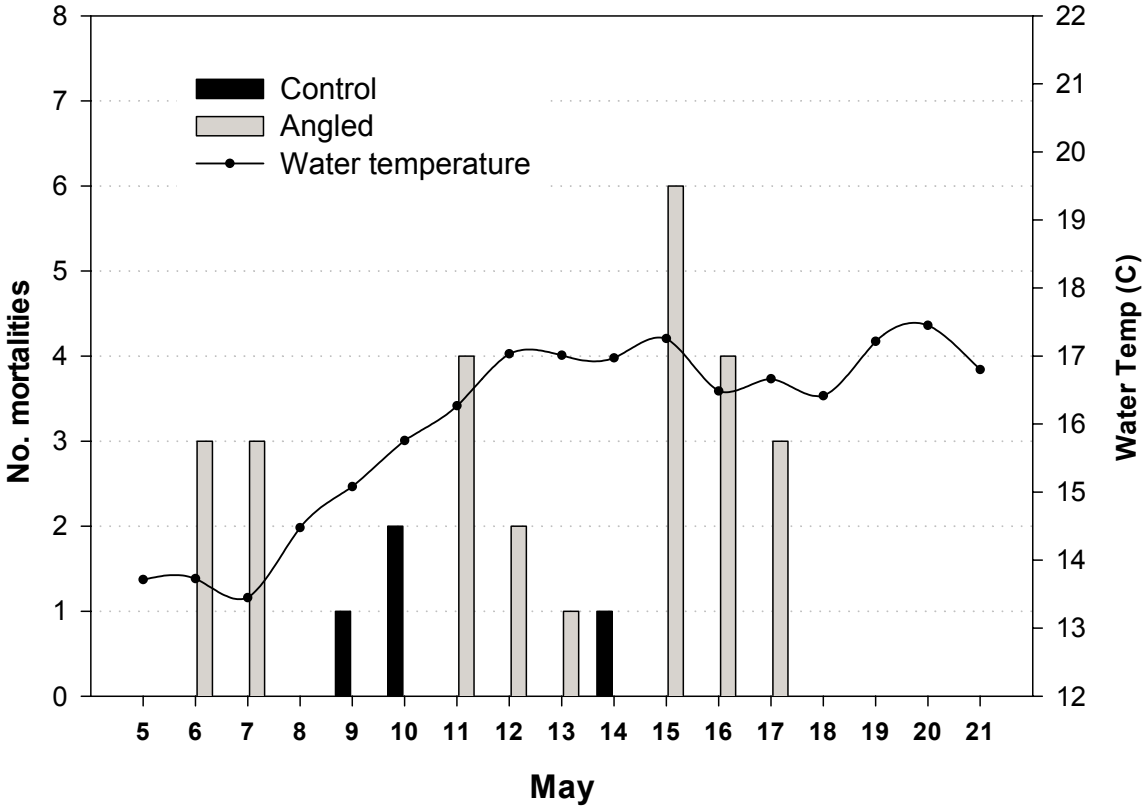


Figure 1.8 Daily mortality of angled striped bass (bars) and coincident tank thermograph (line).

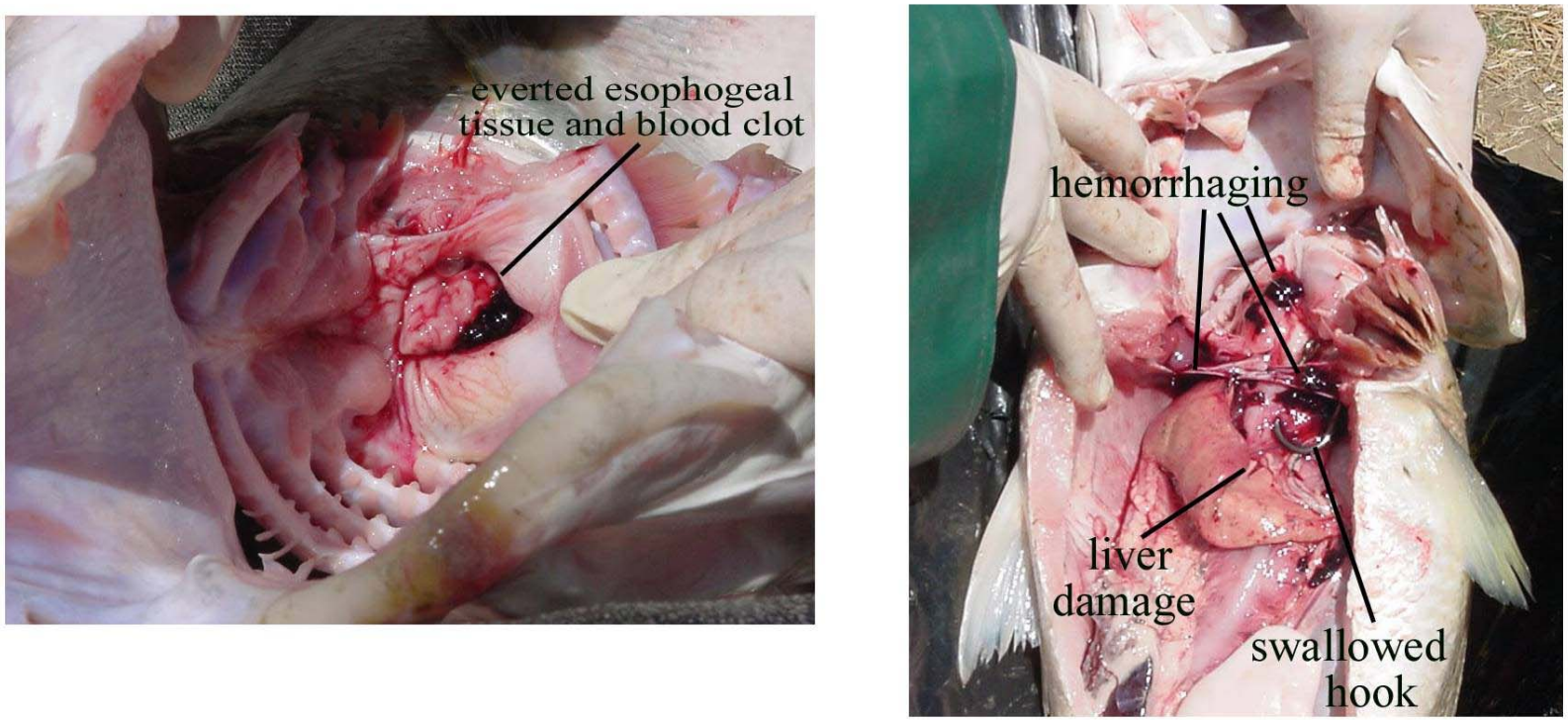
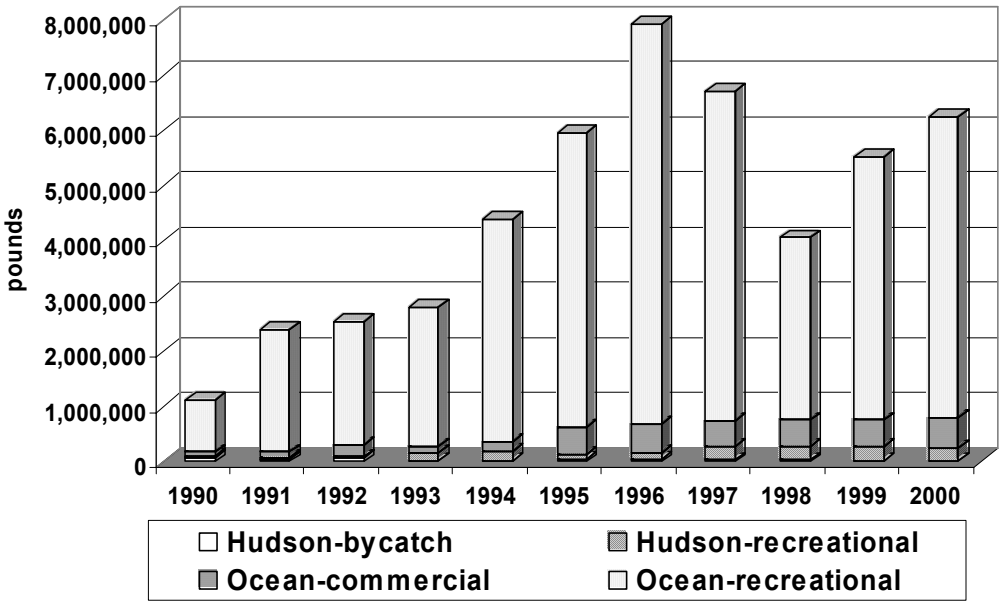


Figure 1.9 Examples of tissue and organ damage exhibited by hooked and released striped bass which suffered mortality.



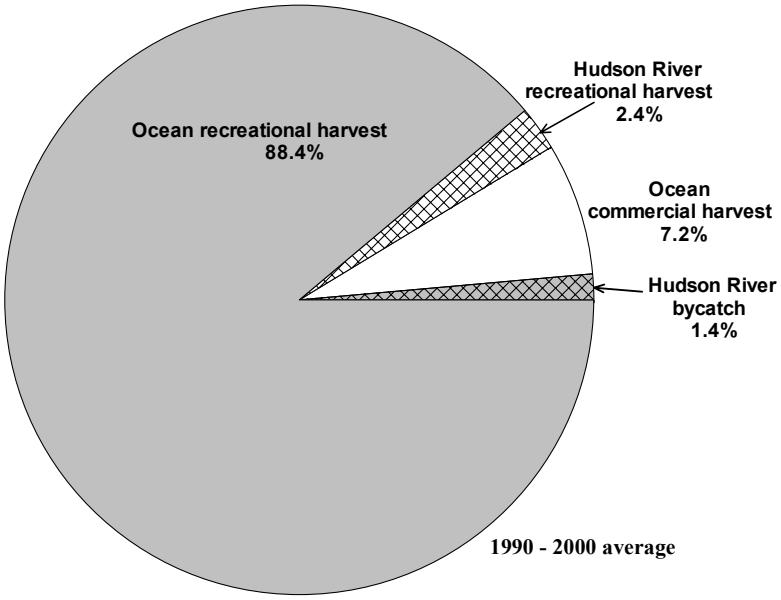


Figure 1.10 Annual harvest of striped bass from New York waters by various sources from 1990 to 2000 (top) and average relative harvest for the 11-year period (bottom). (Source: New York Dept. of Environmental Conservation, Hudson River Fisheries Unit, New Paltz, NY.)

Chapter II: American Shad

Introduction

Total mortality estimates for American shad *Alosa sapidissima* in the Hudson River increased dramatically in the mid 1990s. This decline was attributed to an increase in fishing mortality on the stock primarily in ocean waters (Hattala and Kahnle 1998). Recreational fisheries for alosines are common in several rivers throughout the Atlantic coast (ASMFC 1999), including the Hudson River, yet the mortality resulting from the practice of catch and release is often unestimated. Lukacovic and Pieper (1996) reported no short-term mortality of hickory shad *Alosa mediocris* (n=150). In addition to our pilot study carried out in the Hudson River (Millard et al. 2000), we found one study of hooking mortality of American shad (Lukacovic 1998). The results of the American shad studies vary widely. Lukakovic (1998) observed angled fish held in captivity in shore-based tanks for 48 hours and reported approximately 1% hooking mortality. The Lukakovic study used fish that were captured in the catch and release fishery of the Conowingo Dam tailwaters, Susquehanna River, Maryland.

Millard et al. (2000) provided hooking mortality estimates of 21% and 31%, depending on the estimation technique employed. These fish were caught below the Troy Dam in the Hudson River and held in in-river pens for 5 days. Observation of the pen configurations in the USFWS pilot study, river condition effects on the pens, plus the behavior of the fish in the pens, suggested that conditions were not conducive to fish survival (A. Kahnle, NY Dept. Environmental Conservation, personal communication). While the effect of handling and captivity was controlled for in the estimation technique, the results of the USFWS pilot study were possibly biased by the study design. In order to allow fishery managers to further account for all extractions, and to refine our estimate of hooking mortality for the Hudson River recreational fishery, we re-designed the study with respect to holding angled fish for observation and repeated the study in spring of 2002.

Methods

American shad field collection

American shad were collected from the Hudson River immediately downriver from the U. S. Corps of Engineer Troy Lock and Dam at Troy, NY (Figure 2.1). The tailwaters of this dam are a popular angling area for shad due to the barrier effect of the dam. Angling occurred between April 29 and May 9, 2002. All anglers used light to medium-light spinning gear with monofilament line ranging from 6-lb to 10-lb test. Terminal tackle was either shad darts between ⅛ and ½ oz., or small flutter spoons configured either singly or in tandem. Barbed hooks were used in almost all cases. All project boats were equipped with an aerated live-well. Angled fish were generally netted at boat-side, had the hook removed, and immediately placed in the live well. Captured fish were promptly transported to one of five shore-based holding tanks, such that no fish remained in a live well longer than 30 minutes. The holding tanks (4.6m diameter, 15,000 liter capacity) received flow-through river water at a turnover rate of 50% total volume per hour. Tanks were lined with black polypropylene and were covered with screening which provided 70% light blockage.

Control fish were captured from the same river reach by electrofishing with pulsed DC current via bow-mounted dropper cable electrode arrays. Control fish had their left pelvic fin clipped, but were otherwise transported similar to angled fish. All fish captured on a given day were placed in the same holding tank and a vacant tank was used each day; that is, fish from different days were not mixed within a tank. Fish were held in captivity for five days in 9 trials and four days in 2 trials, with visible mortalities removed and recorded daily from each tank. After the holding period had elapsed, all remaining fish in a tank were removed, measured, and recorded as being (1) angled/control and (2) male/female and (3) alive/dead. All survivors were released back into the river.

Water temperature was continuously recorded in the river and in one holding tank throughout the duration of the project. Temperatures ranged from 8°C May 2 to 15°C on April 11. The rate of water turnover in the holding tanks was such that water

temperatures in the tanks closely reflected those in the river (Figure 2.2).

Data analysis

Analysis of mortality data for American shad consisted of simply calculating the percentage of angled fish that died within the 5-day observation period. Control fish exhibited a greater mortality rate than did angled fish, thereby invalidating a quantitative correction for handling mortality. Confidence limits around the percentage estimate employed the normal approximation technique (Cochran 1977).

Results

Overall catch and mortality

Anglers caught 485 American shad during the 10 angling days between April 29 and May 9, and 233 control fish were captured via electrofishing between April 29 and May 15. Mortality of both the angled and the control fish was low; only 8 (1.6%) angled American shad died within the 5-day observation window, and 9 (3.9%) of the control fish died (Table 2.1). The data suggest that control fish suffered mortality at a greater rate than did angled fish (χ^2 =5.3, p = 0.021).Within a treatment group, mortality rates between males and females did not appear to differ (angled fish: χ^2 =0.19, p = 0.658; control fish: χ^2 =0.06, p = 0.805; Table 2.2). Males dominated the catch (Figure 2.3). Of the 712 fish whose sex was identified, 59% of the angled fish were male and 63% of the control fish were male.

Length frequencies of angled and control fish were similar, with both treatment groups exhibiting a bimodal trend (Figure 2.4). Examination of length frequencies by sex suggested that males were primarily responsible for the bimodal trend, with modes at 410mm TL and 490mm TL, whereas females exhibited a single mode around 550mm TL (Figure 2.5).

Hooking mortality estimates

No adjustment to the observed mortality of angled fish to account for the effects of transport, handling, and holding was performed for American shad. Although mortality

in both groups was low, the mortality rate in control fish (3.9%) was over twice that observed in angled fish (1.6%). We could not assume that this low mortality rate observed in control fish was not significantly influenced by injury related to electrofishing, therefore their use as a control was deemed inappropriate.

The estimate of hooking mortality for American shad was 1.6% (95% confidence interval: 0.40% - 2.88% ; Table 2.2).

Factors influencing mortality

The common angling technique used for American shad in this study resulted in almost all fish being hooked in the distal margins of the mouth. While the hooking location occasionally involved gill elements, true swallowing of the hook was never observed. Thus, trauma to internal organs due to hooking or hook removal was not believed to be a source of mortality. The few fish that had gill structures damaged in the catch and release process bled profusely. While these fish were not individually followed through the 5-day observation period, we believe that even minor gill damage results in high mortality among American shad.

All the observed mortality occurred in the latter half of the study, i.e. in fish caught on or after May 6. This also coincided with the period in which water temperatures rose significantly and when water temperatures exceeded 12°C during the 5-day period of captive observation (Figure 2.6).

Discussion

Our data suggest that the mortality associated with the hook and release of American shad is low, i.e. less than 3%, provided the fish are unhooked and released in a reasonably careful and efficient manner. The fact that the mortality rate observed in angled fish was included in the interval estimate for mortality in our control fish provides for the possibility that much or all of the mortality of the treatment fish may have been due to handling. In this case, mortality due to our catch and release practice would actually have been smaller than the estimated 1.6%. Our estimates of mortality associated with catch and release of American shad are consistent with those of Lukacovic (1998).

Lukacovic 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 Lukacovic study died within 24 hours, and were reportedly either deep-hooked or handled roughly. Water temperatures in the Lukacovic (1998) study ranged between 12°C and 18°C, somewhat higher than temperatures experienced during this study. Our study differed in that we observed fish for five days. The increased holding period in our study did not appear to result in increased mortality.

Our results differ greatly from our pilot study performed in 1999 (Millard *et al.* 2000). While our 1999 results demonstrated much higher mortality estimates (between 20% and 30%), we now discount those results due to problems with our experimental holding design. The in-river pens used for holding fish in 1999 were inadequate, and we believe the high mortality rates were a direct result of holding pen effects.

Our estimates for American shad were based on the use of artificial lures, which are the predominate lure being used by the recreational fisherman in the study area (A. Kahnle, NY Dept. Environmental Conservation, personal communication). Other gear, primarily fly rods, may impart different mortality rates to American shad due to differing effects of fatigue and physical damage by hooks. The use of landing nets by recreational anglers may also affect mortality associated with hook and release.

While mortalities were low over the five day observation period, we did observe many fish with varying levels of fungus on fins and dermal areas which appeared to have been abraded. The cumulative impacts of physiological stress due to capture, handling, and confinement may affect the long term survival of American shad. The primary author has documented deterioration in the blood chemistry parameters in American shad which were subjected to handling and confinement (M. Millard, U.S. Fish and Wildlife Service, Lamar, PA, unpublished data). Plasma glucose levels decreased in shad which were transported in tanks, and then increased dramatically after arrival at a holding facility. Hyperglycemia in fishes can result from increased physical activity in response to a disturbance (Nakano and Tomlinson 1967) or as a secondary response to some stressor, such as hypoxia or handling (Mazeaud et al. 1977). Plasma chloride levels also decreased after handling and confinement. We hypothesized that the cumulative impacts of capture, handling, transport, and long-term confinement on American shad resulted in a fatal

progression of stress-related effects, e.g. impaired osmoregulatory function, depressed immunological functions, fungal attacks and, ultimately death. Females appeared to be more susceptible to stress-induced mortality, possibly due to elevated initial physiological stress levels associated with gonad maturation and migration demands. It remains unclear whether immediate return to the natural river environment, as would occur with normal catch and release practices, may mitigate or eliminate altogether any negative physiological effects associated with the stress of hooking, handling, and release.

In summary, we observed very little mortality associated with the catch and release of American shad in the freshwater environment of the middle Hudson River. The mortality in the angled fish was essentially indistinguishable from that seen in control fish, whose deaths could be attributed to the effects of handling and confinement associated with the study design. A hook and release fishery which imparts mortalities less than 3% may be a low priority when considering management options for the protection and conservation of the population.

Table 2.1 Daily catch and ultimate fate of angled and electrofished American shad from the Hudson River.

Date		Angler Caught		Controls	
Captured	Released	Survived	Mortality	Survived	Mortality
29-Apr	4-May	17	0	2	0
30-Apr	5-May	13	0	-	-
1-May	6-May	27	0	-	-
2-May	7-May	2	0	-	-
3-May	7-May	7	0	-	-
5-May	9-May	31	0	-	-
6-May	11-May	97	1	1	2
7-May	12-May	157	6	63	2
8-May	13-May	60	0	65	0
9-May	14-May	66	1	55	5
15-May	20-May	-	-	38	0
	Totals	477	8	224	9

Table 2.2 Estimates of mortality for American shad in the Hudson River associated with hook and release.

	Total caught	# mortalities	% mortalities	95% Confidence interval	
ANGLING					
Males	283	3	1.06%		
Females	198	3	1.52%		
Unknown	4	2	50.00%		
Angling total	**485**	**8**	**1.65%**	**0.40%**	**2.88%**
CONTROL					
Males	145	6	4.14%		
Females	86	3	3.49%		
Unknown	2	0	0.00%		
Control total	**233**	**9**	**3.86%**	**1.17%**	**6.56%**

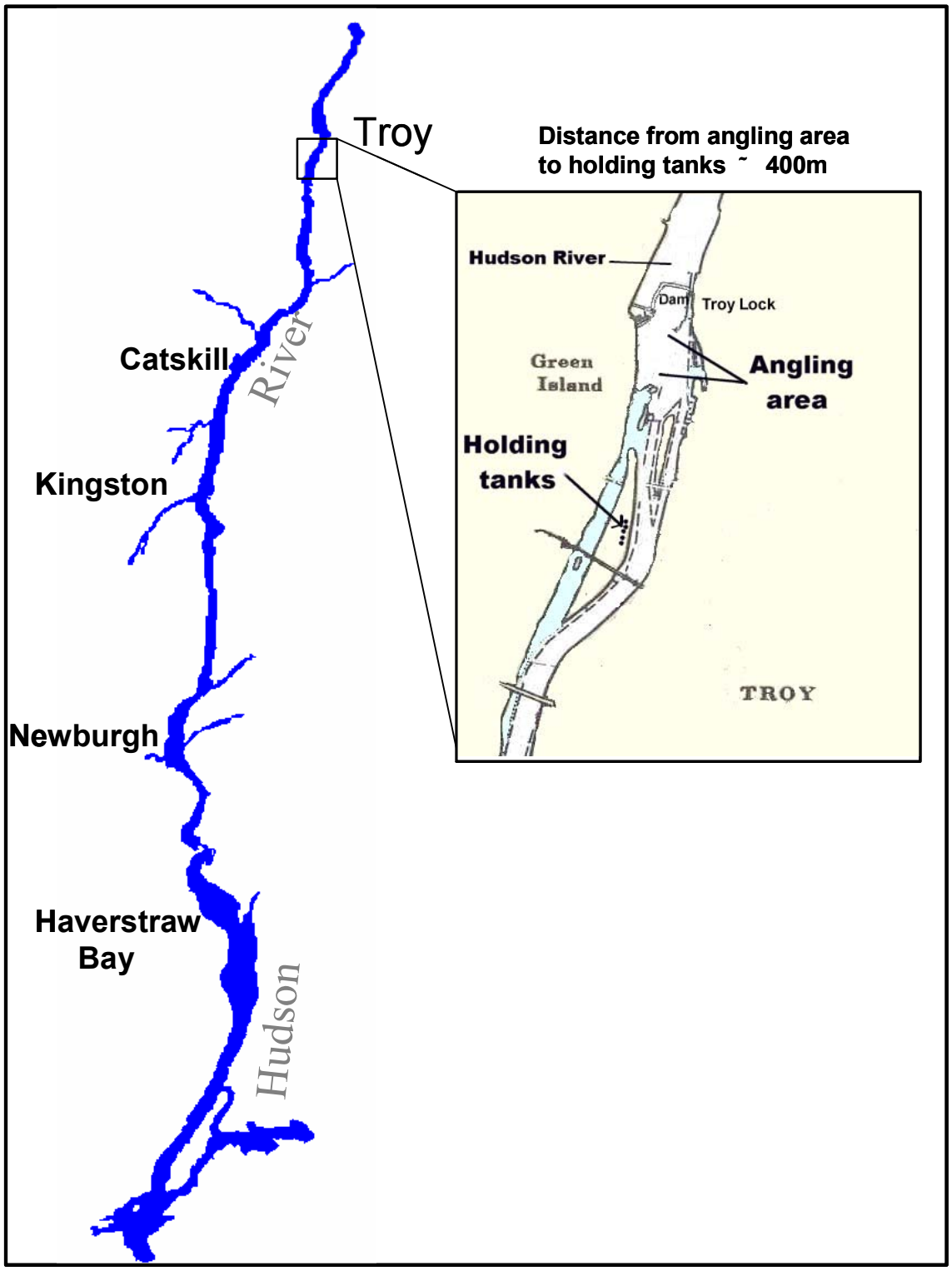


Figure 2.1. Study site for Hudson River American shad hooking mortality study, 2002.

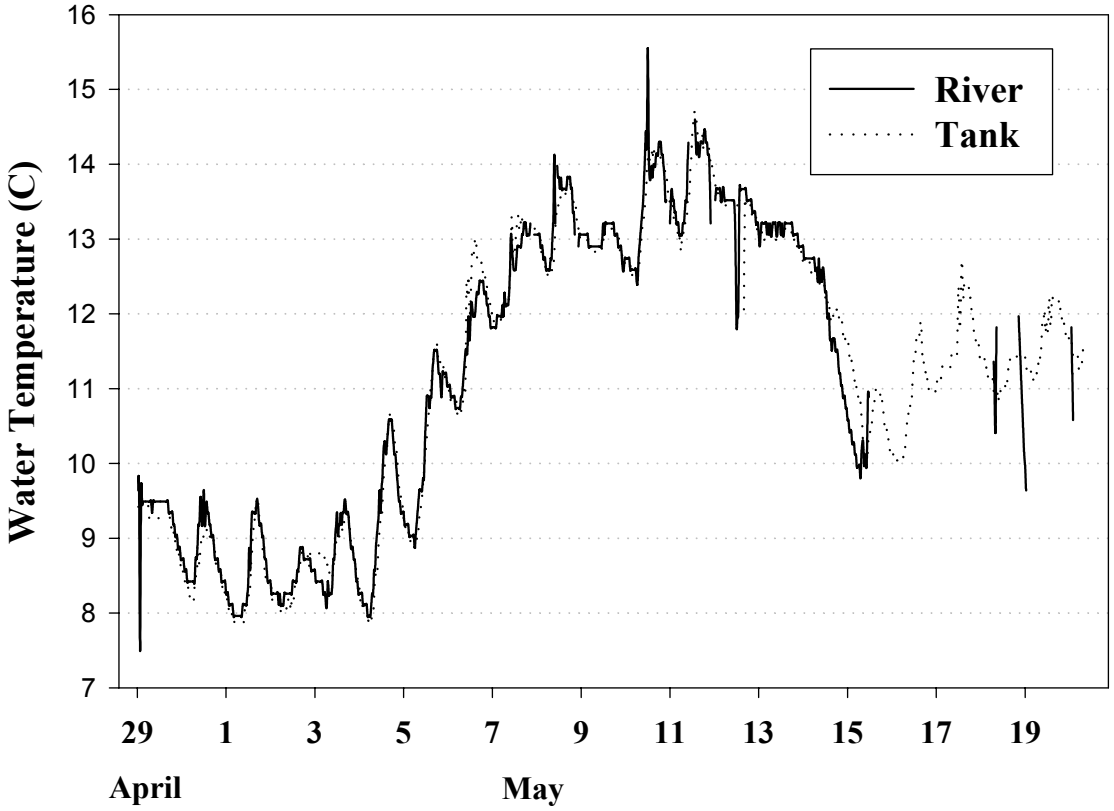


Figure 2.2. Water temperature of Hudson River below Troy Dam and in holding tanks, 2002.

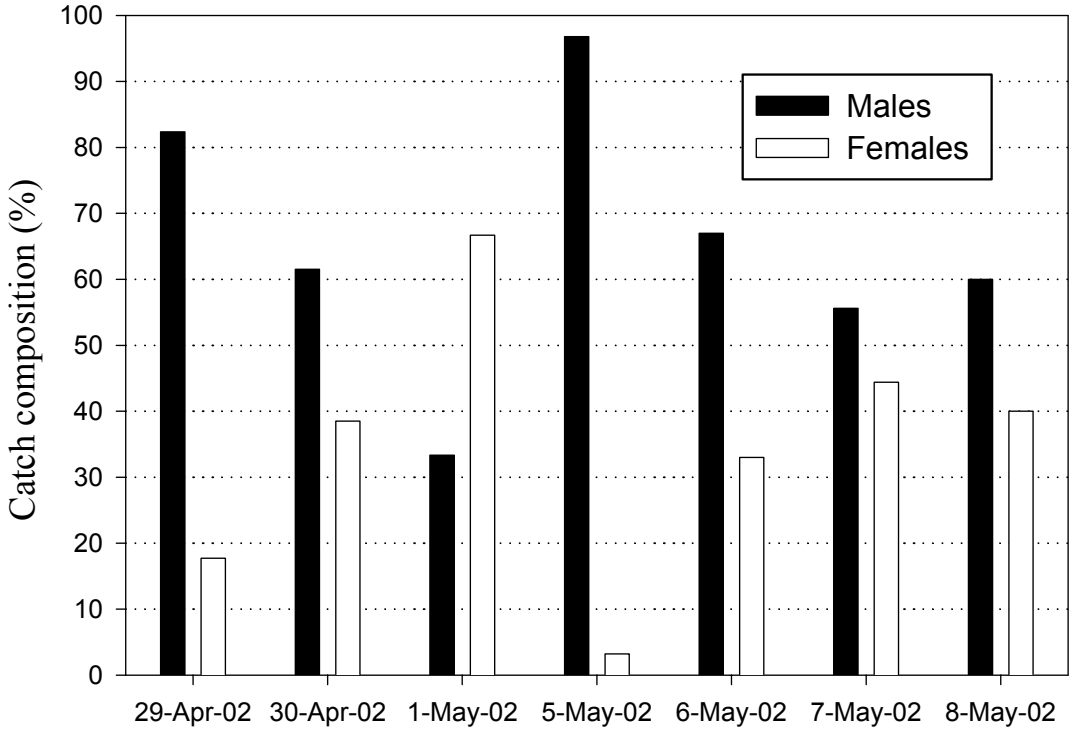


Figure 2.3. Composition, by sex, of American shad caught by hook and line below Troy Dam, Hudson River, 2002.

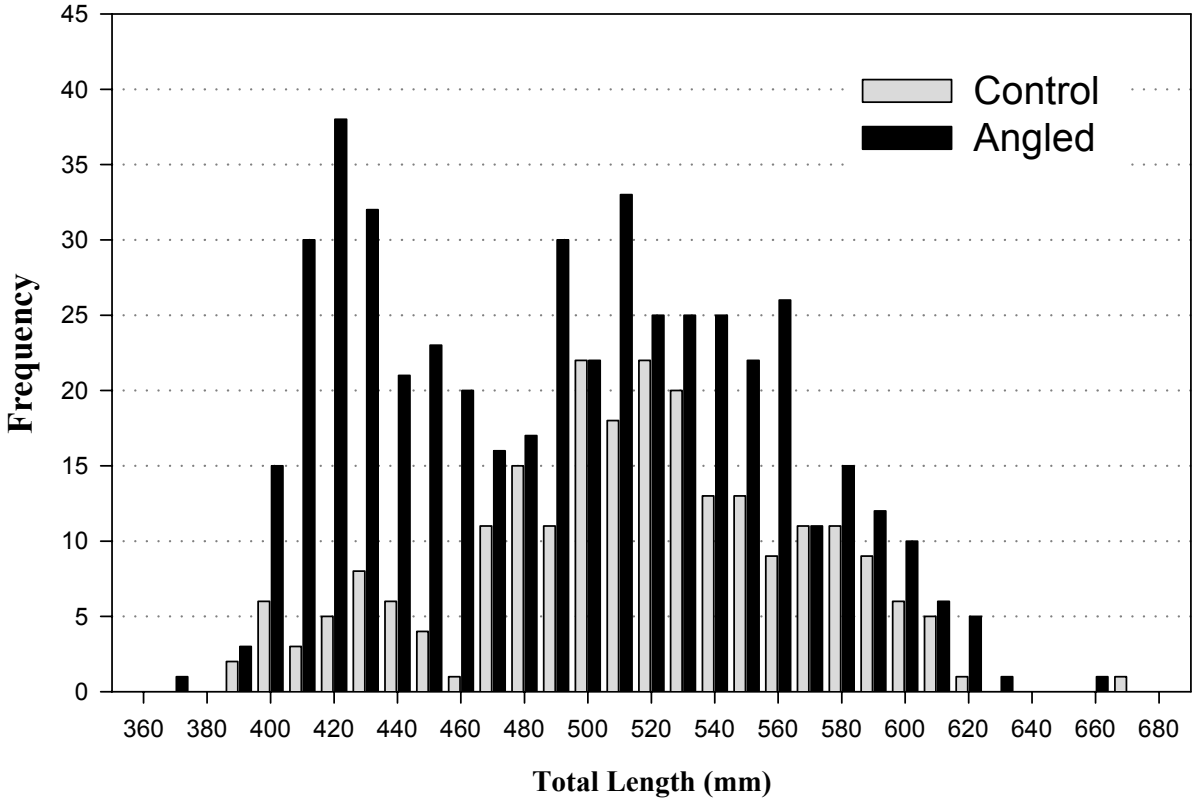


Figure 2.4. Length frequency of all American shad caught below Troy Dam, Hudson River, 2002.

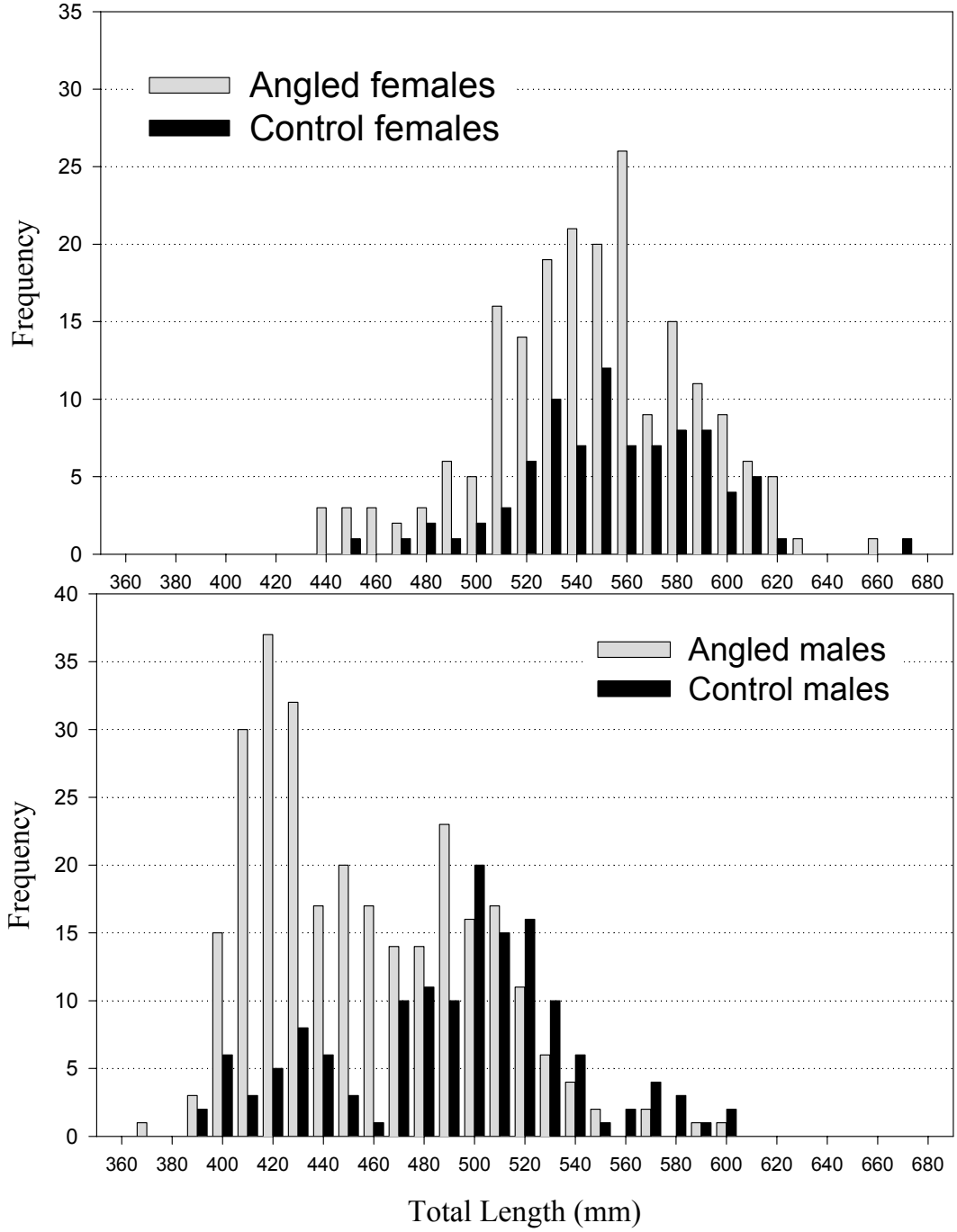


Figure 2.5. — Length frequency of female (top) and male (bottom) American shad caught below Troy Dam, Hudson River, 2002

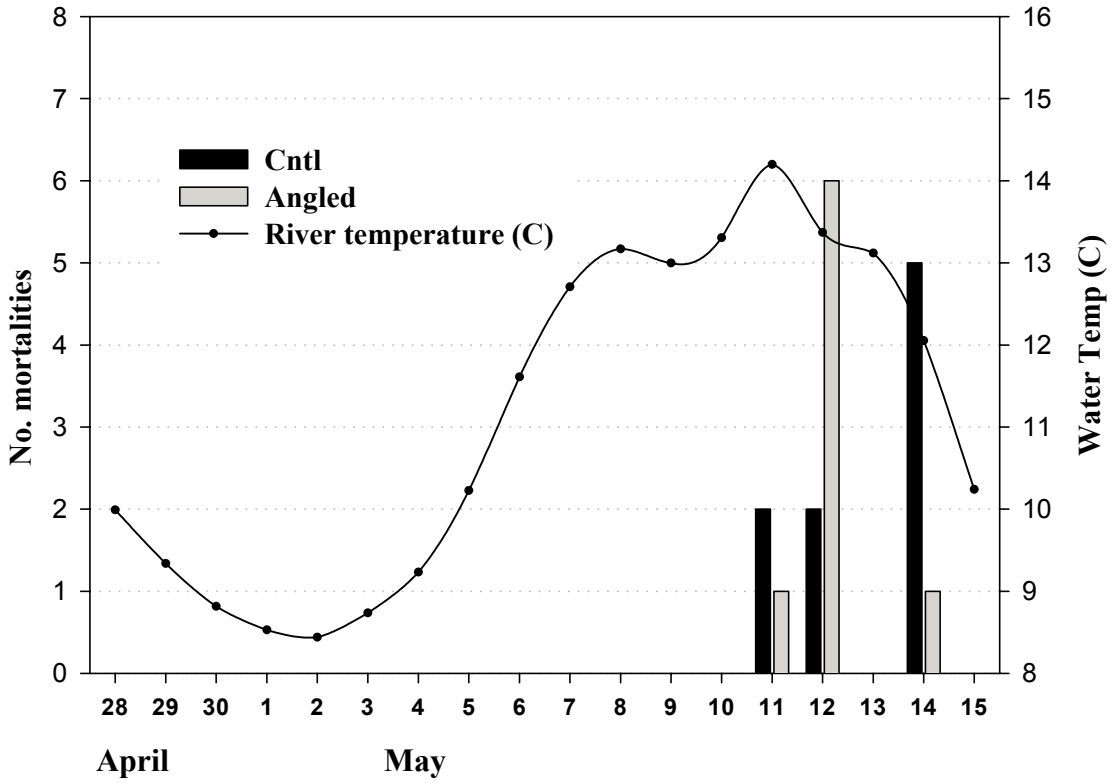


Figure 2.6. — Mortality of captive American shad and associated water temperatures of Hudson River below Troy Dam.

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