Mortality associated with catch and release of striped bass in the Hudson River

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Abstract Catch-and-release fishing has increased in many fisheries, but its contribution to fishing mortality is rarely estimated. This study estimated catch and release mortality rates of striped bass, Morone saxatilis (Walbaum), for the spring recreational fishery in the Hudson River. Treatment fish (caught with live bait on spinning gear) and control fish (captured by electric fishing) were placed in in situ holding pens for 5 days. Mortality rates were estimated using conditional instantaneous mortality rates and additive finite mortality rates. Influences of variables (playing and handling time, hook location, degree of bleeding and fish length) on hooking mortality rates were examined by logistic regression. Conditional instantaneous mortality rates and additive finite mortality rates were 31 and 28%, respectively. Hook location significantly affected the survival of striped bass. Angling catch, effort, and release rates must be integrated with associated hooking mortality rates before this component of overall population mortality can be incorporated into management decisions.

Keywords: catch and release fishing, hooking mortality, striped bass management.

Introduction

Catch-and-release fishing is commonly practised in recreational fisheries, including the striped bass, Morone saxatilis (Walbaum), fishery of the Atlantic Coast. The contribution of catch-and-release practices to overall fishing mortality is, however, rarely estimated. This is of concern since recent reports indicated that striped bass anglers release over 90% of their catch; over 16, 15 and 12.5 million striped bass were released in 1997, 1998 and 1999, respectively in 1997 and 1998 (Fisheries Statistics and Economics Divisions, National Marine Fisheries Service, personal communication). The Atlantic States Marine Fisheries Commission (ASMFC) fishery management board for striped bass currently assumes a 9% hooking mortality rate (Diodati & Richards 1996). This rate translates to over 1.1 million mortalities each year. These estimates of hooking mortality exceed the estimates of commercial harvest in 1997, 1998 and 1999 (ASMFC unpublished data). The 9% hooking mortality currently accepted by ASMFC managers was determined in a saltwater, coastal system (Diodati & Richards 1996), and higher rates of hooking mortality in striped bass may be expected in freshwater river systems (Wilde, Muoneke, Bettoli, Nelson & Hysmith 2000). Consequently, an
evaluation of hooking mortality for striped bass in the freshwater environment of the Hudson River is needed.

The objectives of this study were to: (1) estimate the mortality associated with catch and release practices that commonly occur in the spring recreational striped bass fishery in the Hudson River; and (2) assess the influence of selected variables on hooking mortality rates (playing and handling time, hook location, degree of bleeding, and fish length). The results of this study may be useful in developing guidelines for reducing mortality of released fish and developing regulations designed to control mortality rates associated with recreational fishing.

**Materials and methods**

Striped bass were caught with live bait [blueback herring, *Alosa aestivalis* (Mitchill)] on spinning gear, primarily via casting or drifting near the mouth of Catskill Creek and the Rip Van Winkle Bridge, at Catskill, New York (river km 180–182) (Fig. 1). This site is located within the upper third of the striped bass spawning reach and typically experiences intensive recreational fishing activity. Volunteer recreational anglers were recruited on the river between 11 and 14 May 1999 to provide angled fish and ensure that tackle and angling techniques were consistent with normal practice for the striped bass recreational fishery. After each striped bass was netted by the angler, the fish was transferred to a biologist’s boat, where a uniquely numbered Floy T-bar anchor tag was inserted below the anterior portion of the dorsal fin, and fish were transported in 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) were recorded for each fish. Average playing time for angled striped bass was just over 5 min, with only four of the 47 treatment fish requiring more than 10 min to land.

Control fish were captured by pulsed DC electric fishing. Control fish were transported and placed in the holding pens similarly to treatment fish. Each holding pen contained an equal number of angled fish and control fish, with generally no more than 10 fish placed in each pen. Fish were held in pens for 5 days, after which time all fish were removed, measured, and recorded as being treatment or control, and alive or dead. All survivors were released to the river. Water temperatures throughout the 5-day holding period ranged from 16.7 to 19.4 °C.

Holding pens were vertical cylinders, 2.5-m diameter and 2.3-m deep, constructed of a PVC pipe frame covered with 50-mm square plastic mesh. Styrofoam was attached to the top, and the bottom was weighted with a steel bar to hold the cylinders open in the water column. Circles of plastic netting (2.5-m diameter) served as lids and bottoms of the cylinders. Ten pens were cabled together (two abreast and five pairs long) and anchored approximately 100 m 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 minimise drag and collection of debris.

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 mortality components associated with: (1) hook and release; and (2) 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:

\begin{equation}
\text{total observed mortality} = \text{hooking mortality} + \text{handling mortality}
\end{equation}

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

\begin{equation}
m_h = -\ln(S_h)
\end{equation}

where \(m_h\) is the handling mortality, \(S_h = 1 - A_h = 1 - \text{[fraction that die in control group]}.\) An instantaneous total mortality rate in each treatment group was estimated as:

\begin{equation}
m_t = -\ln(S_t)
\end{equation}

where \(m_t\) is the total mortality in treatment group and \(S_t = 1 - A_t = 1 - \text{[fraction that die in treatment group]}.\)

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

\begin{equation}
m_{\text{hook}} = m_t - m_h
\end{equation}

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

\begin{equation}
m_{\text{c-hook}} = (A \times m_{\text{hook}}) / m_t
\end{equation}

Equation (5) follows the traditional fisheries expression \(u = (A-F)/Z\), which can be rewritten as:

\begin{equation}
u = A - [AM/\ln(1 - A)]
\end{equation}

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

\begin{equation}
\mathbf{v}{\text{ar}}(\hat{u}) = (\partial \hat{u} / \partial A)^2 \times \mathbf{v}{\text{ar}}(\hat{M}) + (\partial \hat{u} / \partial M)^2 \times \mathbf{v}{\text{ar}}(A)
\end{equation}

with

\begin{equation}
\partial \hat{u} / \partial A = 1 - \left\{ \left[ (AM/\ln(1 - A))^2 \times (1 - A) + M/\ln(1 - A) \right] \right\}
\end{equation}

and

\begin{equation}
(\partial \hat{u} / \partial M) = A/(-\ln(1 - A))
\end{equation}

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 particular, this approach treats the two mortality sources as being essentially instantaneous over the course of the holding period, rather than simultaneously acting on the treatment (angled) fish. In this case, an additive relationship was assumed between the two rates observed at the end of the 5-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 5-day finite rates into equation (1) and solving for hooking mortality, and is equivalent to the ‘adjusted mortality rate’ reported by Nelson (1998).

Confidence limits for \(d\), the simple difference between two proportions, were generated using the variance and associated standard error formulae given by Fleiss (1981).

**Factors affecting mortality**

Information was collected on several different angling-related variables to evaluate their effect of mortality of hooked fish. Logistic regression analysis (Menard 1995) was used to assess the relation between mortality among angled fish and the following independent variables: playing time, transport time, total length, hook location, and degree of bleeding. The standard logistic regression model was fit as:

\begin{equation}
p_i = e^{X_i} / (1 + e^{X_i}),
\end{equation}

where \(p_i\) is the probability of mortality and equal to a linear function of the explanatory variables mentioned above, i.e. \(= 0 + \sum_{i=1}^{5} a_i X_{i},\) where \(a_i\) are the coefficients of the variables. Maximum likelihood estimates of the coefficients, associated odds ratios and logistic regression
diagnostics were generated with SAS software (SAS Institute, Inc. 1989).

**Results**

**Estimated hooking mortality**

Between 10 and 14 May, 47 striped bass were captured with hook and line, and 35 individuals were captured via electric fishing for use as controls. The mean total lengths for angled and control fish were 839 mm (SE ± 12.5 mm) and 826 mm (SE ± 29.9 mm), respectively, although control fish contained a larger range of fish sizes (Fig. 2). Mortality data for striped bass, by net pen, are provided in Table 1. Angled fish exhibited 43% total mortality, whereas control fish exhibited 14% mortality after the 5-day holding period. Using conditional instantaneous rates to correct for mortality associated with handling and confinement, the hooking mortality was 31% (95% confidence interval 17–44%). When making the adjustment assuming additive finite rates, the estimated mortality associated with hook and release was 28% (95% confidence interval 10–47%).

**Factors affecting mortality**

Hook location significantly ($\chi^2 = 6.35, P = 0.012$) affected the survival of angled striped bass (Table 2). Specifically, individuals hooked in the oesophagus or gut had a higher likelihood of dying than those hooked in the lip. The odds ratio for the dichotomous hooking location variable (either anterior or posterior to gills) was 12.4, suggesting that the odds of mortality for deep hooked fish were over 12 times the odds for lip-hooked fish (Table 2). Further inspection of the mortality patterns with respect to hooking location showed that 11 of 16 (69%) deep-hooked fish did not survive, whereas seven of the 26 (27%) shallow-hooked fish died (Table 3).

**Discussion**

The results indicated that the mortality associated with the hook and release of striped bass in fresh water can be significant. Two techniques estimated hook and release mortality at 31 and 28%, respectively, after 5 days. These estimates of mortality associated with hook and release of striped bass are consistent with other reported rates in freshwater systems (Nelson 1998; Wilde et al. 2000). Most studies found hooking mortality season or temperature-dependent, with higher mortality occurring at higher temperatures (Nelson 1998; Wilde et al. 2000). Hooking mortality will also likely be higher in fish released into areas of

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**Table 1. Mortality of striped bass captured with hook and line and electric fishing (control fish), by net pen**

<table>
<thead>
<tr>
<th>PEN</th>
<th>Hook &amp; line</th>
<th>Control</th>
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<tr>
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<td>Dead</td>
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<td>1</td>
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<td>9</td>
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<tr>
<td>10</td>
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<td>1</td>
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<tr>
<td>Total</td>
<td>47</td>
<td>20</td>
</tr>
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<3 mg L\(^{-1}\) dissolved oxygen (Lee & Bergersen 1996). Water temperatures during the 5-day holding period of the Hudson River study were <20 °C; the temperature at which Nelson (1998) observed a distinct increase in hooking-related mortality was 22 °C. The observation period for the Hudson River study was longer than the 72-h period used by Nelson (1998). The increased holding period in the Hudson River study may add additional stress to the fish, resulting in increased mortality, or it may have allowed observation of additional latent mortality attributable to stress from catch and release practices. The estimates reported herein were likely influenced by both of these factors, but the relative contribution of each is unclear.

The potential for bias incurred by holding large fish in a relatively small, confined space exists with hooking mortality studies which employ captive fish (Diodati & Richards 1996). While the magnitude of this bias is unknown, the present study accounts for the effects of confinement via the adjustments based on mortality of control fish. Similar to Nelson (1998) and Diodati & Richards (1996), hooking location of striped bass (lip v. oesophagus or gut) exerted a significant influence on subsequent survival rates. While external bleeding was not always observed in those fish which were hooked in the oesophagus, this hooking location was considered to increase greatly the opportunity for internal damage to organs and blood vessels located near the oesophagus, e.g., the heart, liver and ventral aorta. Many factors can affect the likelihood of hooking mortality because of physical damage to organs and tissue, such as the use of barbed hooks or J-hooks instead of circle hooks (Taylor & White 1992; Orsi, Wertheimer & Jaenicke 1993), the use of treble hooks instead of single hooks (Nuhfer & Alexander 1992), the use of live bait instead of artificial lures (Clapp & Clark 1989; Taylor & White 1992), larger fish size (Kieffer, Ferguson, Tompa & Tufts 1996), and how deeply the fish is hooked (e.g. Persons & Hirsch 1994; Schisler & Bergersen 1996). Physical stressors, such as longer playing and handling times (Schisler & Bergersen 1996), and angler inexperience, may also exacerbate hooking mortality. 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.

The results suggest that mortality of fish released in the recreational fishery in the Hudson River may be a significant component of total mortality of striped bass and should be considered in any management of the fishery. The spring fishery targets relatively large spawning adults, and these larger fish may have more difficulty recovering from the physiological stresses of capture and handling than would smaller individuals (Ferguson, Kieffer & Tufts 1993, Kieffer et al. 1996). A hook and release fishery that imparts up to 30% mortality on the spawning population demands attention in the management regime for the species. Results suggest that hooking mortality should be considered in future stock assessments of striped bass, provided data exist on the magnitude of the recreational fishery and, in particular, the rate of catch and release in the recreational fishery. Preliminary assessments of effort and associated catch and release rates should be assessed before this component of population mortality can be appropriately incorporated into stock assessments and subsequent management decisions.

Although hooking mortality estimates in the Hudson River appear acceptable, further research is recommended to refine these estimates for specific angling gear and illuminate more specific physiological stress responses. While this study employed the most common angling techniques for striped bass, other methods of angling in terms of tackle and bait combinations could be examined (e.g. J v. circle hooks, lures v. live bait, cut bait v. live bait or eels). Holding and observing post-released fish in a more controlled environment, such as land-based holding tanks, would permit timely removal of dead fish and follow-up necropsies, which in turn could provide valuable information regarding specific causes of death.
Acknowledgments


References


