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[Article]

Catch-and-Release Mortality of Spotted Seatrout in Texas: Effects of Tournaments, Seasonality, and Anatomical Hooking Location

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Abstract.—The purpose of this study was to assess initial and delayed mortality of spotted seatrout *Cynoscion nebulosus* captured during live-release tournaments. Additionally, we examined spotted seatrout mortality as a function of season and anatomical hooking location. We assessed tournament-related mortality at 10 live-release fishing tournaments held in four Texas bays—Galveston, Matagorda, Aransas, and Upper Laguna Madre—from February 2004 to April 2006. Combined overall mean mortality was 22.9%, mean initial mortality (percent of dead fish brought to weigh-in) was 10.4%, mean delayed mortality (percent of fish that died in tournament holding tanks) was 14.1%, and delayed short-term mortality (percent of fish that died during a 14-d observation period in laboratory tanks) was 1.9%. To assess seasonal mortality, we examined a total of 364 spotted seatrout captured by hook and line from July 2004 to June 2005 using replicated 3.5-m^3 field enclosures for 72 h. Overall mortality for the seasonal study was 6%. Mortality rates were higher during spring (9%) and summer (10%) than during fall or winter (both 0%). Tournament organizers should avoid scheduling events during late spring and summer, when seasonal mortalities are the highest. To assess mortality as a function of anatomical hooking location, we examined a total of 479 spotted seatrout held in field enclosures after capture. We assigned hooking locations to four body regions: mouth, gills, esophagus, and external. Overall mortality for the anatomical hooking location study was 19%. Mortalities were higher for fish hooked in the esophagus (95%) and gills (75%) than for fish hooked in the mouth (10%) and externally (8%). Our results suggest that spotted seatrout mortality during live-release tournaments exceeds that observed under normal catch-and-release fishing practices and that posttournament delayed mortality is low. Anatomical hooking location is a major factor influencing mortality, but under normal fishing practices only about 12% of fish are hooked in locations that consistently cause mortality.

Competitive sportfishing tournaments have continued to increase in popularity over the last 30 years (Shupp 1979; Duttweiler 1985; Schramm et al. 1991b). In 1989, a survey conducted by the American Fisheries Society's Competitive Fishing Committee listed an annual total of 978 competitive saltwater fishing tournaments in North America, 33 of which were hosted in Texas (Schramm et al. 1991b). By 2003, the number of saltwater fishing tournaments held in Texas increased to 183 events (i.e., a 555% increase within 15 years; Oh et al. 2006). One of the most sought-after tournament sport fish in Texas is the spotted seatrout *Cynoscion nebulosus*, which was targeted in 36% of the Texas tournaments listed by Schramm et al. (1991b). Although numerous studies have examined tournament-related mortality of freshwater fish, research is lacking for marine fish (Muoneke and Childress 1994).

Negative impacts of competitive fishing tournaments on fishery resources have long concerned fishery managers, tournament organizers, and the general public (Barnhart 1989; Schramm et al. 1991a, 1991b; Radonski 2002). Concerns regarding intensified harvest and sustainability of fish stocks have led many tournament organizers to adopt live-release formats that encourage anglers to keep their fish alive throughout the tournament (Nielsen 1985; Barnhart 1989; Fielder and Johnson 1994; Muoneke and Childress 1994; Radonski 2002). Clearly, mortality is reduced in live-release tournaments; however, postrelease survival is of great concern (Plumb et al. 1988; Schramm et al. 1991a; Muoneke and Childress 1994). Unlike catch and release by recreational anglers, tournament anglers subject their fish to considerably more stress. Stressors include (1) the holding of fish in on-board live wells for extended periods of time, (2) the weigh-in process, (3) use of fish for photographic opportunities, and (4) release procedures. The additional stress applied to tournament fish may increase the potential for postrelease mortality.

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Several studies have examined catch-and-release mortality of spotted seatrout during various seasons (mainly in summer), and the reported mortality rates have been wide ranging. In each study, spotted seatrout were captured on hook-and-line gear using single and treble hooks with natural and artificial baits. Matlock and Dailey (1981) observed hooking mortalities of 56% in August and 0% in September. Hegen et al. (1984) reported mortalities ranging from 37% in summer to 16% in winter. Matlock et al. (1993) observed a 7.3% mortality rate for spotted seatrout caught in July and August. Stunz and McKee (2006) reported an overall mortality rate of 11% for spotted seatrout caught during the summer. Murphy et al. (1995) examined Florida spotted seatrout catch-and-release mortality in multiple seasons and years (October 1991 to February 1993); they reported a mortality rate of 4.6%. Although these studies provide useful information on spotted seatrout mortality, none examined seasonal mortality for 12 consecutive months or during the winter or early spring, the common period for many live-release spotted seatrout tournaments. Moreover, only Murphy et al. (1995) examined mortality associated with anatomical hooking location; they reported that mortality was higher for fish hooked in the gut than for those hooked in the jaw or mouth. Although the observations by Murphy et al. (1995) are important in understanding mortality associated with anatomical hooking location, several additional common hooking locations should be evaluated for their effects on spotted seatrout mortality.

The purpose of this study was to assess spotted seatrout mortality from live-release tournaments and posttournament delayed mortality. Additionally, we examined spotted seatrout mortality as a function of season and anatomical hooking location.

Methods

Ten separate live-release tournaments held in four Texas bays—Galveston, Matagorda, Aransas, and Upper Laguna Madre—were visited from February 2004 to April 2006 to assess mortality. Tournaments were 2-d events held between February and June. Initial mortality rates were calculated as the number of dead fish brought to weigh-in divided by the overall number of fish weighed in. Delayed mortality rates were calculated as the number of fish that died in tournament holding tanks divided by the number of live fish placed in the tanks. Overall tournament mortality was calculated as the number of all dead fish (initial and delayed mortalities) divided by the overall number of fish brought to weigh-in. To assess delayed short-term mortality, we transported 105 tournament-caught fish to a laboratory holding facility at the Marine Development Center (MDC; Texas Parks and Wildlife Department and Coastal Conservation Association), Flour Bluff, Texas, where they were placed in large, circular holding tanks (12,160 L). A maximum of 30 fish/tank were monitored for 14 d. Fish were fed live penaeid shrimp or finfish every 3–4 d. Water temperature (°C), dissolved oxygen (mg/L), and salinity (‰) were recorded daily. The MDC routinely holds spotted seatrout as broodstock at their facility, and such fish served as controls.

To assess seasonal mortality, we collected spotted seatrout during July 2004–June 2005 in Aransas and Corpus Christi bays, located along the middle Texas coast. Experimental fish were captured by hook and line using soft plastic swimming baits (12.7 cm or 5 in) with 1.8-g (0.0625-oz) jig heads. All fish were landed by hand gripping the fish dorsally, and hooks were removed either by hand or with pliers. Fish were placed immediately in floating mesh baskets (45-cm diameter, 65-cm length) for 30–60 min (maximum density = 5 fish/basket). After the holding period, fish were removed from the baskets and placed in oxygenated, insulated temporary holding boxes for transport to field enclosures. We frequently monitored water quality of the holding boxes to approximate ambient water conditions (temperature, dissolved oxygen, and salinity).

Five replicate field enclosures were constructed to maintain four experimental groups and one control group of spotted seatrout. The field enclosures were 2.4 m long, 1.2 m wide, and 1.2 m high and were constructed with 1.9-cm polyvinylchloride pipe surrounded by 1.9-cm extruded plastic mesh attached with plastic cable ties. Field enclosures were secured beneath a dock to allow shade. Water depth was approximately 1.5 m; depending on tide level, field enclosures were completely covered by water during most experimental trials. For each treatment, five fish were maintained in replicate field enclosures. In certain instances, fish died during transport, resulting in use of fewer than five fish for some replicates. We selected a 72-h observation period based on reports that mortality typically occurs within that time period (Klein 1965; Mason and Hunt 1967; Hunsaker et al. 1970; Marnell and Hunsaker 1970; Warner and Johnson 1978; Stunz and McKee 2006). Temperature, dissolved oxygen, and salinity were determined twice daily to assess environmental conditions. After 72 h, we assessed mortality by removing fish from the field enclosures. Fish used in the anatomical hooking location study were captured and maintained in the same manner as fish used in the seasonal mortality study but with the following modifications: anatomical hooking location was classified into four body regions (mouth, gills, esophagus,

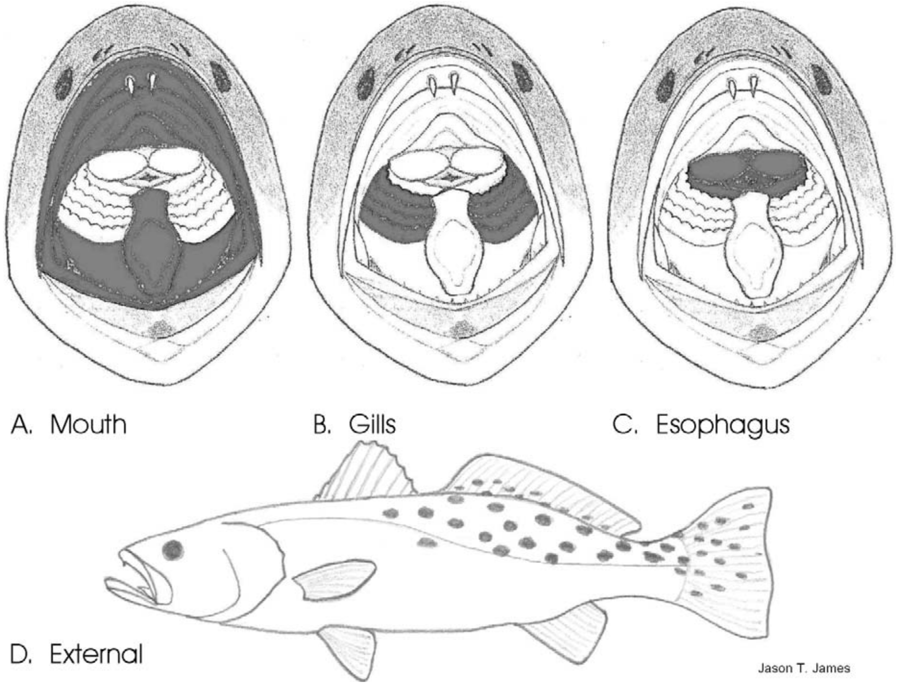

FIGURE 1.—Four designated anatomical hooking locations (shaded areas) in spotted seatrout caught on hook and line along the Texas coast: **(A)** mouth, **(B)** gills, **(C)** esophagus, and **(D)** external (outside the oral cavity).

and external) as modified from Nelson (1998; Figure 1); floating mesh baskets were predesignated according to anatomical hooking location; and fish with different hooking locations were maintained in different field enclosures.

To assess the effect of caging on mortality, we examined a control group of spotted seatrout captured on hook and line with soft plastic swimming baits (6.4 cm or 2.5 in) at night under illuminated lights adjacent to the field enclosures. Each control fish was landed with minimal handling and was immediately placed in a designated field enclosure. The control group consisted of five fish maintained in one field enclosure. During a previous study assessing catch-and-release mortality of spotted seatrout, control fish were successfully captured by this method with 100% survivorship, suggesting no caging effect (Stunz and McKee 2006).

Some tournaments allowed wadefishing (hereafter, "wadefishing tournaments"), whereas others did not (hereafter, "non-wadefishing tournaments"). Student's *t*-tests ($\alpha = 0.05$) were used to compare initial, delayed, and overall mortality rates between wadefishing and non-wadefishing tournaments. Single-factor analysis of variance (ANOVA; $\alpha = 0.05$) was used to analyze seasonal and monthly mean percent mortality calculated from each replicate holding pen. Replicate percent mortality was arcsine transformed to calculate mean percent mortality. Significant differences in ANOVA were further examined by using Fisher's least-significant-difference method to test for differences among treatment means ($\alpha = 0.01$). Simple linear regressions ($\alpha = 0.05$) were used to examine relationships between environmental conditions and mortality.

Results

Tournament-related mortality at 10 live-release fishing tournaments held from February 2004 to April 2006 was 22.9%; 1,442 fish were brought to weigh-in, and 1,091 were released alive (Figure 2). Combined mean initial and delayed mortality rates were 10.4% and 14.1%, respectively. Wadefishing tournaments ($n = 6$) yielded a combined overall mean percent mortality of 26.2%; initial mean percent mortality was 12.3%, and delayed mean percent mortality was 15.8%. Non-wadefishing tournaments ($n = 4$) yielded a combined overall mean percent mortality of 17.9%; mean initial mortality was 7.4%, and mean delayed mortality was 11.6%. However, mean initial, delayed, and overall mortality rates were not significantly different between wadefishing and non-wadefishing tournaments; therefore, data from the two tournament types were

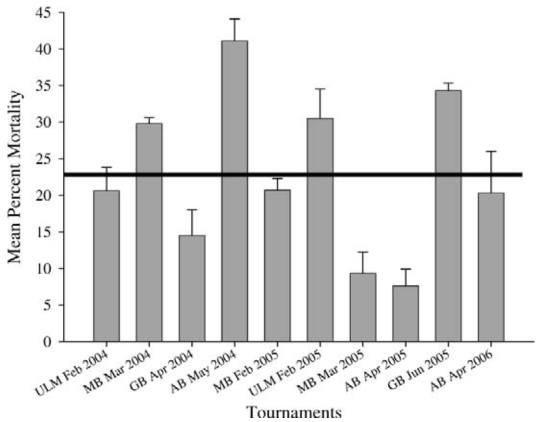

FIGURE 2.—Overall mean percent mortality (±SE) of spotted seatrout at 10 live-release fishing tournaments held in Texas between February 2004 and April 2006 (solid horizontal line indicates combined mean across tournaments). Tournaments are designated by the bay system (AB = Aransas, GB = Galveston, MB = Matagorda, and ULM = Upper Laguna Madre), month (February–June) and year (2004–2006) in which each event was held.

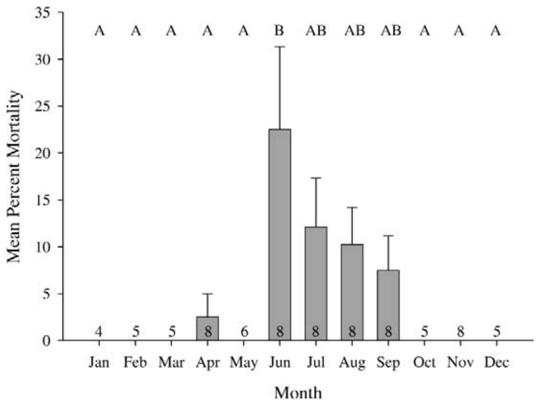

FIGURE 3.—Monthly mean percent mortality (±SE) of spotted seatrout caught by hook and line along the Texas coast (number of replicates per month is shown at the bottom of each bar). Letters denote significant differences (Fisher's protected least-significant-difference test: $P < 0.01$) among months.

combined. We assessed the delayed short-term mortality of tournament-caught spotted seatrout during a 14-d study. Mean percent mortality was 1.9% (2 of 105 fish). Control fish survival was 100% over the 14-d observation period.

We assessed seasonal mortality in 364 captured spotted seatrout ranging from 220 to 539 mm total length. The number of replicates and fish varied by season because of weather conditions and successful capture of fish. Twenty-two (6%) experimental fish died during the 72-h observation period. Mortality rates in spring (9%) and summer (10%) were significantly higher than those in fall (0%) and winter (0%; $P = 0.002$). Month of capture was also significantly ($P = 0.003$) associated with mortality (Figure 3). We recorded the highest monthly mean mortality in June (22%); thereafter, mortality decreased gradually each month (July: 12%; August: 10%; September: 7%). Mean mortality was 0% in virtually all months from October to May (except 2% mortality in April). For all trials, control fish survival was 100% over the 72-h observation period.

We used simple linear regression to assess the relationships between environmental conditions (water temperature, dissolved oxygen, and salinity) and mortality. Throughout the study, temperature ranged from 16.2°C to 32.9°C, dissolved oxygen ranged from 4.6 to 7.5 mg/L, and salinity ranged from 25‰ to 34‰. All three variables were significantly related to mortality for spotted seatrout hooked in the mouth (Figure 4).

We captured 479 spotted seatrout for the assessment of mortality associated with anatomical hooking location. Approximately 86% of these fish were hooked in the mouth, 9% were hooked in the esophagus, 2.5% were hooked in the gills, and 2.5% were hooked externally. Ninety-two (19%) experimental fish died during the 72-h observation period. Mortality rates were higher for fish hooked in the esophagus (95.3%) and gills (75.0%) than for fish hooked in the mouth (10.0%) and externally (7.7%; Table 1). Replicate treatments for fish hooked in the esophagus or gills were not possible because of high mortality associated with these hooking locations (i.e., the fish died before stocking in holding pens). Given that high mortality for these anatomical locations resulted in our inability to replicate treatments, anatomical hooking location data are reported as total number captured and percent mortality. In addition, replicate treatments for fish hooked externally were not possible because of a low capture rate. For all trials, control fish survival was 100% over the 72-h observation period.

Discussion

Overall, these results suggest that tournament-related initial and delayed (posttournament) mortality rates are low considering the amount of handling that occurs. This is encouraging for the continued support of live-release fishing tournaments versus tournaments that do not promote live release. However, seasonal data

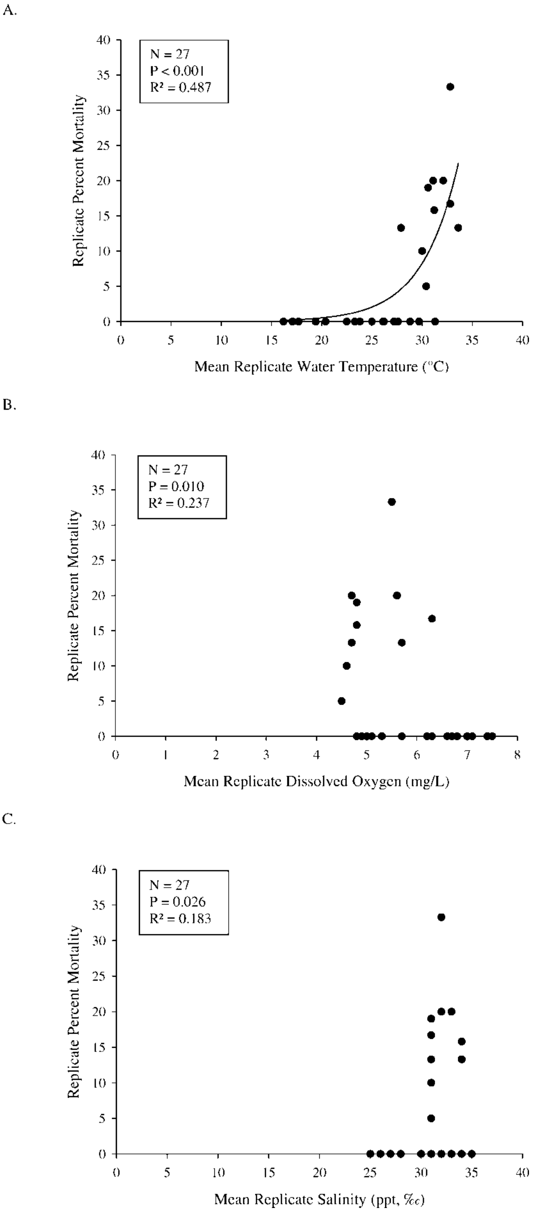

FIGURE 4.—Relationship between replicate means of three environmental variables and replicate mean percent mortality of mouth-hooked spotted seatrout caught by hook and line along the Texas coast: **(A)** water temperature (°C) (mortality = $0.002e^{0.28 \cdot \text{temperature}}$); **(B)** dissolved oxygen (DO; mg/L) (mortality = $-4.09 \cdot \text{DO} + 29.86$); and **(C)** salinity (‰) (mortality = $1.20 \cdot \text{salinity} - 30.26$). Variables were recorded twice daily, and mortality was calculated from replicate field enclosures during a 72-h observation period.

TABLE 1.—Overall percent catch and mortality of spotted seatrout hooked at four anatomical locations by use of hook and line along the Texas coast. Number of fish caught (total $N = 479$) and released (total $N = 387$) after a 72-h observation period is shown.

Anatomical hooking location	Number caught	Percent of catch	Number released	Mortality (%)
Mouth	411	85.8	370	10.0
Gills	12	2.5	3	75.0
Esophagus	43	9.0	2	95.3
External	13	2.7	12	7.7

suggest that tournaments should be held during the fall, winter, and early spring months to reduce mortality. Our results also suggest that anatomical hooking location is a major factor influencing mortality. However, under normal fishing practices, the number of fish hooked in the locations that routinely caused mortality is low.

Mortality rates of spotted seatrout caught during live-release fishing tournaments fell within the range of values reported in other studies examining catch and release of spotted seatrout in Texas (Matlock and Dailey 1981; Hegen et al. 1984; Matlock et al. 1993; Stunz and McKee, 2006). In general, tournament anglers handle their fish more than recreational anglers. In tournaments, fish are landed, placed in live wells, removed from live wells for weigh-in, handled during the weigh-in process, held for photographs, and maintained in holding tanks before release. The fish may be injured in the live wells during transport from the capture site to the weigh-in site, especially when fishing and boating conditions are unfavorable. Fish may also be confined for long durations in live wells without properly regulated water conditions.

The survival rate for tournament-caught spotted seatrout, even with the excessive handling, may be attributed to bonus incentives in tournament formats and carefully planned weigh-in procedures. Tournament organizers know that not all fish will survive the tournament; thus, they take steps to minimize mortalities. All tournaments surveyed in this study had a 227-g (8-oz) bonus weight incentive for fish that were brought live to weigh-in. This bonus encouraged anglers to take additional care with their fish, such as using better handling techniques and live-well oxygen systems. Weigh-in procedures were organized to minimize the fish's time out of water. Anglers were required to keep their fish in live wells until the weigh-in station was ready to receive the fish. One tournament series had multiple holding tanks connected to oxygen tanks leading from the dock to the weigh-in station. These tournament procedures were meant to maximize the number of surviving spotted seatrout and lessen the detrimental effects on the population.

Delayed short-term mortality of spotted seatrout caught during live-release fishing tournaments was also low. Initial and delayed tournament mortalities caused by acute stresses and severe physical damage are easily observed. True postrelease mortality caused by sublethal stresses (e.g., protective slime coat damage, osmoregulatory dysfunction, and their additive effect) is generally not known (Schramm et al. 1987; Neal and Lopez-Clayton 2001). We are aware of no other studies that assess short-term tournament mortality of spotted seatrout; our findings show high postrelease survival, indicating that sublethal stresses are minimal (only two mortalities were observed). The two fish that died were subjected to additional stresses not experienced by the other tournament-caught fish: increased handling, overcrowding in the transport trailer, and transport from the tournament site to the laboratory holding facility. Our data should be encouraging to fishery managers and others concerned about potential adverse effects created by tournament angling on the fishery resource.

Seasonality plays an important role in the catch-and-release mortality of spotted seatrout. The seasonal effect on mortality was significant; mortalities occurred in late spring, continued through summer, and were absent during the fall and winter. Hegen et al. (1984) similarly reported higher summer mortality rates and lower winter mortality rates for spotted seatrout; however, they determined that season was not significant, and spring and fall mortality rates were not fully examined. Seasonal mortality trends for spotted seatrout are distinct when examined as monthly means. Mean mortality rate was highest in June and gradually decreased during the subsequent summer months; no mortalities were recorded during the fall, winter, and early spring periods.

These seasonal and monthly trends in mortality are most likely attributable to the changing environmental conditions. Increases in mortality were observed as water temperature and salinity levels increased and as dissolved oxygen levels decreased through spring and into summer. Most mortality occurred when the water temperature exceeded 29°C, dissolved oxygen levels were below 5 mg/L, and salinity levels exceeded 30‰. Fish must regulate their internal osmotic levels to ensure proper cellular function. Any deviation from this process can alter internal ionic concentrations and lead to osmotic stress (Helfman et al. 1997). The stressful conditions of high water temperature and low dissolved oxygen levels during summer months, coupled with high salinity levels, may affect spotted seatrout osmoregulation and ion balance and thus amplify physiological stress, especially in fish that are already stressed from excessive handling.

Anatomical hooking location is a major factor in catch-and-release mortality of spotted seatrout. Mortality rates of spotted seatrout caught by hook and line increased with the depth of hooking location within the oral cavity. A large difference in mortality rates was evident between fish hooked in the gills and esophagus and those hooked externally and in the mouth. Fish hooked in the gills and esophagus experienced mortality rates over sevenfold greater than those of fish hooked externally and in the mouth. Managers should therefore consider strategies encouraging the use of hook types that minimize deep hooking (e.g., circle or kahle-type hooks). Our observations are similar to those of other anatomical hooking location studies. In striped bass *Morone saxatilis* (Diodati and Richards 1996; Lukacovic and Uphoff 2002; Millard et al. 2003), mortality rates were higher for fish hooked posterior to the gills than for those hooked in areas anterior to the gills. In red drum *Sciaenops ocellatus* (Jordan and Woodward 1994), New Zealand blue cod *Parapercis colias* (Carbines 1999), and white seabass *Atractoscion nobilis* (Aalbers et al. 2004), mortality increased with the depth of ingested hooks. Murphy et al. (1995) also recorded higher mortality rates for gut-hooked spotted seatrout than for those hooked in the jaw and inside the mouth.

Mortalities associated with anatomical hooking location can be attributed to the extent of hooking injury, excessive bleeding, and damage to vital organs. In our study, the one externally hooked spotted seatrout that died was hooked in the abdomen, which is a rare occurrence. In several mouth-hooked fish, a large wound was present in the roof of the mouth where the hook penetrated and tore the tissue. Some of these fish displayed excessive bleeding, indicating that a major blood vessel had ruptured. The majority of mortalities associated with anatomical hooking location in this study can be attributed to the damage of vital organs. Such fish were hooked in either the gills or the esophagus. Esophagus-hooked fish may have had other vital organs penetrated, as Aalbers et al. (2004) reported for deeply hooked white seabass; however, no necropsies were performed to determine cause of mortality.

Our results suggest that spotted seatrout mortality associated with tournament handling is relatively low. The live-release tournament format is a viable management option that encourages release of a valuable fishery resource, and the majority of released fish survive these events. Based on our seasonality data, tournaments should be held during October–May, when survival is highest. A small percentage of fish are hooked in regions that routinely cause mortality (i.e., esophagus and gills); however, management practices encouraging the use of hook types (e.g., circle and kahle) that maximize the number of mouth-hooked fish should be considered for the spotted seatrout fishery.

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