INTERSTATE FISHERIES MANAGEMENT PROGRAM IMPLEMENTATION FOR NORTH CAROLINA

By

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DOCUMENTATION AND REDUCTION OF BYCATCH IN NORTH CAROLINA FISHERIES

Evaluation of the Estuarine Hook and Line Recreational Fishery in the Neuse River, North Carolina

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Abstract

Short term (72 hour) release mortality was determined for 176 striped bass (*Morone saxatilis*), 103 spotted seatrout (*Cynoscion nebulosus*), 226 red drum (*Sciaenops ocellatus*), and 89 southern flounder (*Paralichthys lethostigma*) caught with both natural and artificial baits from low salinity (< 5 ppt) and high salinity (≥ 5 ppt) sites in the Neuse River, North Carolina throughout 2006. Fish were captured independently during all seasons of the year and held in pens near the fishing sites. Jaw/lip hooked fish were used as controls. Mean observed mortalities for the low salinity sites were 39.2% for striped bass, 58.6% for spotted seatrout, 19.4% for red drum, and 51.5% for southern flounder. Mean observed mortalities for the high salinity sites were 4.3% for striped bass, 12.2% for spotted seatrout, 5.4% for red drum, and 8.9% for southern flounder. Data from each site were pooled together to perform logistic regression analyses for each species. Level of bleeding (p=0.0325), mean water temperature (P=0.0244), handling time (P=0.0101), and hook type (P=0.0033) were identified as good predictors of striped bass release mortality. Mean DO (P=0.0002) was found to be a good predictor of spotted seatrout release mortality. Mean DO (P=0.0042) and handling time (P=0.0001) were identified as good predicators of red drum release mortality. Mean water temperature (P=0.0481), mean DO (P=0.0002), and hook removal (P=0.0666) were found to be good predictors of southern flounder release mortality. Recommended management measures include promoting better fishing practices such as proper gear selection and fish handling techniques to reduce release mortality.

Table of Contents

List of Tables

List of Figures

Background

Common management strategies for recreational fisheries include creel limits, size limits, harvest quotas, and time/area closures. These management approaches often promote catch and release fishing, which results in high levels of discards. The hook and release mortality of discards varies among species with some being more tolerant than others. A review of the literature reveals that many factors influence release mortality rates, including water temperature, air temperature, dissolved oxygen, salinity, depth, handling time, fight time, angler experience, terminal tackle, hooking location, and fish size.

Recreational anglers conducted an estimated 1,685,122 coastal inland fishing trips in North Carolina during 2005 (NOAA 2007). Striped bass (*Morone saxatilis*), spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), and southern flounder (*Paralichthys lethostigma*) are among the top species most often targeted by these anglers (NCDMF 2006). Each of these species is managed through either federal or state Fishery Management Plans (FMPs) or both. Spotted seatrout are currently managed under an Atlantic States Marine Fisheries Commission FMP (ASMFC 1984), and North Carolina is scheduled to begin development of a state FMP in 2007. The spotted seatrout stock is currently considered viable in North Carolina (NCDMF 2006). Striped bass are managed under both a North Carolina state FMP (NCDMF 2004) and an ASMFC interstate FMP (ASMFC 2003) and are considered overfished in the Central/Southern Management Area (CSMA). Red drum are also managed under both a North Carolina state FMP (NCDMF 2001) and an ASMFC interstate FMP (ASMFC 2002) and are listed as recovering in North Carolina (NCDMF 2006). Southern flounder are managed under a North Carolina state FMP (NCDMF 2005) and are considered overfished. All of these species are regulated by size and creel limits in North Carolina. These regulations promote a catch and release fishery and, considering the amount of directed recreational fishing effort on these species, hook and line discard mortality might constitute a significant source of mortality.

Many studies have been conducted to determine the short-term release mortality of these species. The results of these studies are highly variable due to differences in environmental conditions, methods, and experimental design. The release mortality of red drum reported in previous studies varied from 2.4% (Duff 1999), for red drum caught on single hooks in Alabama, to 6.7% (Aguilar and Rand 2002), for adult red drum in the lower Neuse River, North Carolina, to 10.9% (Gearhart 2002a), for red drum caught in low salinity sites in Core, Roanoke, and Pamlico sounds, North Carolina, to 16.1% (Jordan 1991), for red drum caught during the summer in Georgia, to 44.7% (Childress 1989), for red drum caught during the summer in a freshwater reservoir.

Similar studies have been conducted to determine the release mortality of striped bass. Diodati (1991) reported a 7.9% mortality rate while Nelson (1994) reported a 19.0% adjusted mortality rate for striped bass on the Roanoke River, North Carolina. Gearhart (2002b) reported a 7.8% mortality rate for striped bass caught in the Albemarle Sound, North Carolina whereas Hysmith et al. (1992) reported a 38% mortality rate of striped bass caught in Lake Texoma, Texas-Oklahoma.

Previous research conducted on spotted seatrout indicates that the release mortality rates for this species are generally higher than that of red drum and striped bass. Release mortality estimates reported in previous studies varied from 4.6% (Murphy et al. 1995), for spotted seatrout in Florida, to 7.3% (Matlock et al. 1993), to 37.0% (Hegen and Green 1983) for spotted seatrout in Texas, to 55.6% (Matlock and Dailey 1981).

Very little literature is available on the release mortality of southern flounder. Gearhart (2002a) reported a 9.5% mortality rate in high salinity water and 19.4% mortality rate in low salinity waters in Core, Roanoke, and Pamlico sounds, North Carolina. A few studies have been conducted on summer flounder (*Paralichthys dentatus*). Gearhart (2002a) reported a 5.3% mortality rate for summer flounder caught in North Carolina and an 8.8% mortality rate for summer flounder caught in Virginia, whereas Malchoff et al. (2002) reported a 14.6% mortality rate of summer flounder caught in New York.

Objectives

The FMPs for each of these species are based on predictive stock assessments, which require an estimate of all sources of mortality, including discards. Failure to account for all sources of mortality could result in inaccurate stock size estimates, which could lead to the implementation of inappropriate management measures. Currently, the number of recreational discards for each of these species is estimated through the Marine Recreational Fisheries Statistics Survey (MRFSS), but the discard mortality of each is rarely known and is generally overlooked or crudely estimated. The objectives of this project were to:

- Provide delayed mortality estimates in the North Carolina estuarine hook and line recreational fishery
- Compare striped bass, red drum, southern flounder, and speckled trout CPUE and delayed mortality between circle hooks, treble hooks, and standard J-hooks
- Identify factors that influence delayed mortality of striped bass, red drum, southern flounder, and speckled trout using two recreational gear types
- Compare these results to previous delayed hook and line mortality research
- Provide management alternatives for reducing delayed hook and line mortality in the estuarine recreational fishery in the Neuse River, North Carolina.

Methods

This study was conducted in the Neuse River, North Carolina between 1 January 2006 and 31 December 2006. Sampling was stratified throughout the year by high and low salinity sites. Sampling sites were determined based on knowledge of fish presence by season. Sample sites were divided into upper and lower Neuse River (Figure 1). The upper and lower estuarine sites were determined based on five year average surface salinities found in this region. There were four primary sites within each the high and low salinity regions. In addition, alternate sites were used for sampling when data was unavailable at the primary sites. Sampling trials were conducted monthly at low salinity (upper) and high salinity (lower) Neuse River sites. Sampling alternated between low salinity and high salinity sites each week. Seasons were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September), and fall (October, November, December).

Striped bass, red drum, southern flounder, and spotted trout were captured by hook and line using different hook types throughout the year. Control captures for this experiment consist of fish captured by the standard J-hook most commonly used in this fishery. The mortality rates of these captures were compared to those captured by other hook types.

Fish were collected by means of a fishery-independent survey using common fishing practices. Anglers used medium action rods equipped with either spinning or bait casting reels, spooled with 15-20 lb test line. Both trolling and casting methods were employed using jigs, plugs, and live and cut bait.

Fish were landed as quickly as possible to minimize variability between angling methods. Landed fish were tagged with numbered T-bar tags (FF-94 T-bar anchor tag, Floy Tag and Manufacturing Co., Seattle, Washington) and placed in an onboard 450 L live well. Hooks were removed by hand when possible, unless the fish were deep hooked. If fish were deep hooked, the line was cut and hooks were left in place. Total length (mm), tag number, handling time, bait type, hook location, hook removal, and degree of bleeding were recorded for each fish landed.

Fish were transferred to a 0.71 m^3 cylindrical holding pens constructed of stainless steel connected by ¾ inch stretched mesh knotless webbing. Pens were held in place by danforth anchors. Mortality and water quality were monitored at 24-hour intervals for three days. Dead fish were removed from the pens and identified by tag number. Jaw/lip hooked fish were used as controls to determine pen and handling mortality.

A logistic regression model was fit to the data using stepwise techniques to determine whether each variable significantly affected mortality (SAS 1989). The model describes the probability of mortality for individual fish as:

$$P_{mortality} = e^u/(1+e^u),$$

where e is the base of the natural logarithm and u is a linear function of the independent variables. Independent variables considered in the analysis of release mortality included: level of bleeding, mean water temperature (°C), handling time (seconds), hook type, mean DO (mg/L), fish length, bait type, mean salinity (ppt), hook removal, and hook location. However, the models for southern flounder and spotted seatrout did not include level of bleeding or hook location because their inclusion in the model created a possible quasicomplete separation of data points, resulting in a suspect model. The stepwise linear logistic regression has an acceptance level of 0.10 for incorporating a variable into the model and an acceptance level of 0.05 for retaining a variable. A Hosmer and Lemeshow goodness-of-fit test was used to assess the goodness of fit of the model.

Factors associated with release mortality were identified and estimates of release mortality were provided.

Project Limitations

Trials were conducted throughout the year, but availability of fish precluded trials for all species during all seasons. This resulted in unmatched seasonal trials for each species in each location. In addition, increased control fish mortality was observed during spring and summer, indicating that hooking was not the only source of mortality. Finally, both artificial and natural baits were used to varying degrees throughout the study to catch all species, which resulted in an unbalanced sampling design with respect to bait type.

Results

Striped Bass

Collectively, 176 striped bass were captured and held in pens for 72-hour periods throughout the study. A total of 153 striped bass were captured at the low salinity sites and 23 striped bass were caught at the high salinity sites. Observed mortality at the low salinity trials averaged 39.2% and ranged from 0.0 to 65.5%, while mortality at the high salinity sites averaged 4.3% and ranged from 0.0 to 20.0%. Control mortality (pen/handling mortality) at the low salinity sites averaged 33.6% and ranged from 0.0 to 60%, while there was no observed control mortality at the high salinity sites. Average adjusted mortality (observed mortality minus control mortality) at the low salinity sites was 5.6% and ranged from 0.0 to 15.4%, while average adjusted mortality at the high salinity sites was 4.3% and ranged from 0.0 to 20.0% (Table 1).

For all striped bass trials combined, 57% of the mortality occurred within 24 hours, 71% within 48 hours, and 100% within 72 hours (Figure 2). Water temperatures for the low salinity sites ranged from 10.4°C during the winter to 27.3°C in the summer. Water temperatures for the high salinity sites ranged from 13.0°C in the winter to 22.5°C in the spring. The average water temperature for the low salinity sites was 23.2°C and was 16.8°C at the high salinity sites. Dissolved oxygen at low salinity sites ranged from 3.9 mg/L during the summer to 7.7 mg/L in the winter. Dissolved oxygen at the high salinity sites ranged from 6.6 mg/L in the spring to 8.8 mg/L in the winter. Salinities at the low salinity sites ranged from 2.9 ppt to 4.8 ppt, while salinities at the high salinity sites ranged from 6.0 ppt to 8.1 ppt (Table 1).

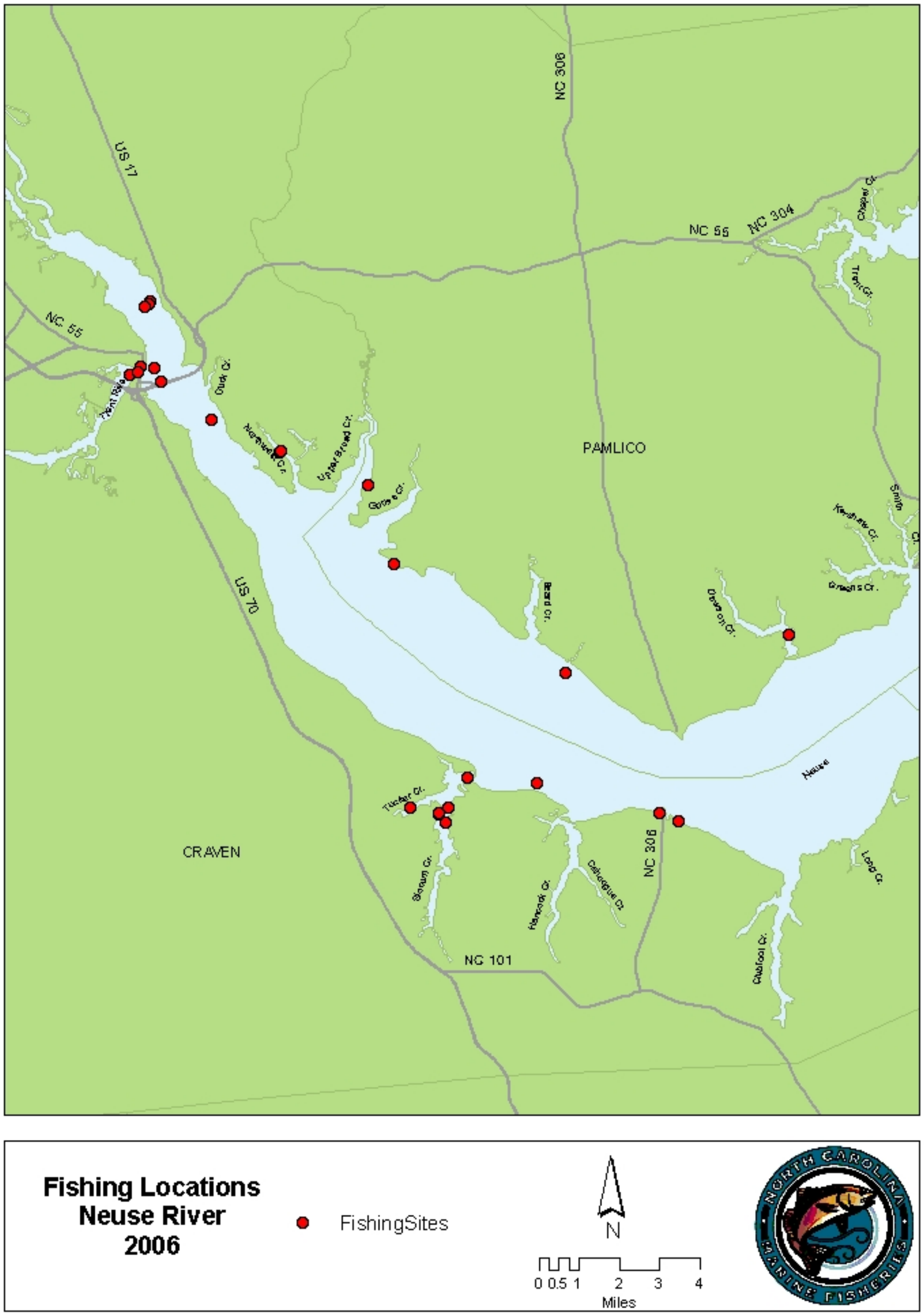

Figure 1. Map of fishing sites in the Neuse River, North Carolina throughout 2006.

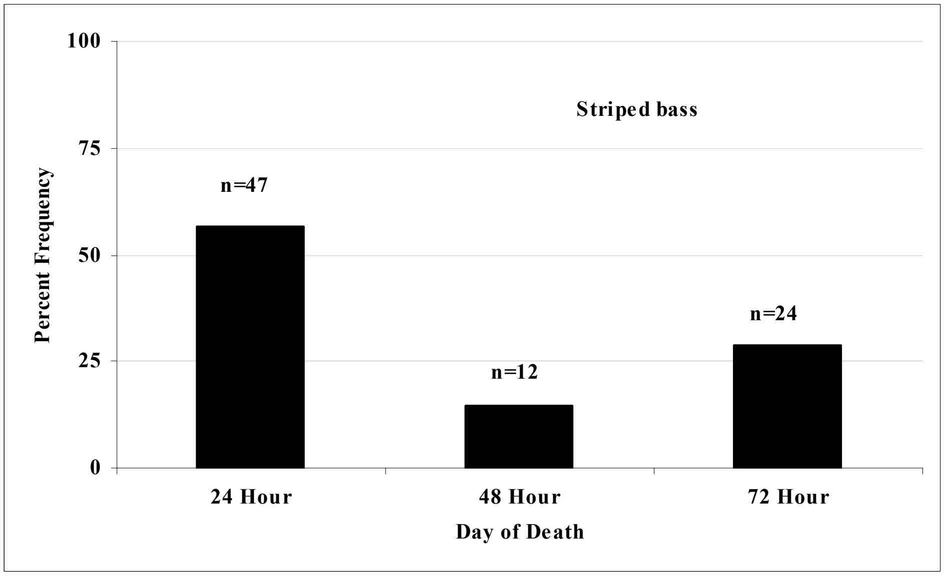

Figure 2. Day of death for all striped bass mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Table 1. Number of individuals (n), observed mortality, control mortality, adjusted mortality (observed – control), mean water temperature (°C), dissolved oxygen (mg/l), and salinity (ppt) by site for striped bass release mortality trials conducted in the Neuse River, North Carolina throughout 2006.

Site	Season	n	Observed Mortality	Control Mortality	Adjusted Mortality	Mean Water Temp (ºC)	Mean DO (mg/L)	Mean Salinity (ppt)
New Bern: Low Salinity	Winter	13	15.4%	0.0%	15.4%	10.4	7.7	3.6
	Spring	67	29.9%	25.5%	4.4%	22.7	5.2	2.9
	Summer	58	65.5%	60.0%	5.5%	27.3	3.9	4.8
	Fall	15	0.0%	0.0%	0.0%	18.8	6.3	3.8
		Mean	39.2%	33.6%	5.6%	23.2	5.0	3.9
Slocum: High Salinity	Winter	17	0.0%	0.0%	0.0%	13.0	8.8	6.0
	Spring	5	20.0%	0.0%	20.0%	22.5	6.6	7.5
	Fall	1	0.0%	0.0%	0.0%	16.1	7.6	8.1
		Mean	4.3%	0.0%	4.3%	16.8	7.9	6.7

To perform the logistic regression analysis, data from each site were pooled together to determine the influence of several variables on mortality. A backward logistic regression analysis indicated that mortality was dependent on level of bleeding (P=0.0325), mean water temperature (P=0.0244), handling time (P=0.0101), and hook type (P=0.0033) (Tables 2 and 4). Dependent variables that were eliminated by the backward stepwise procedure included: mean DO, fish length, bait type, mean salinity, hook removal, and hook location. A Hosmer and Lemeshow goodness-of-fit test indicated that the model provided a good fit for the data (χ^2=2.5459, df=7, P=0.9236). The max-rescaled r-square was 0.3033, indicating that the model explains 30.33% of the variability in the data. The predicted concordance or proportion of survivals and deaths correctly predicted by the model was 75.9%.

Each of the variables were contrasted to estimate the difference between groups. Striped bass were 3.4 times more likely to survive when there was no bleeding compared to individuals experiencing minimal bleeding (P=0.0415). Striped bass were 3.8 times more likely to survive when handling time was less than 30 seconds compared to individuals handled between 30 and 60 seconds (P=0.0032), and they were 3.8 times more likely to survive when handling time was less than 30 seconds compared to individuals handled greater than 60 seconds (P=0.0227). Striped bass were 7.4 times more likely to survive when caught on a treble hook compared to those caught on a circle hook (0.0009) and were 7.8 times more likely to survive when caught on treble hooks compared to individuals caught on J hooks (P=0.0048) (Table 3).

Table 2. Summary of stepwise logistic regression analyses of independent variables on the release mortality rates of striped bass captured by hook and line in the Neuse River, North Carolina throughout 2006.

Independent Variable	df	Wald χ^2	P
Level of bleeding	2	6.8511	0.0325
Mean water temperature	1	5.0635	0.0244
Handling time	2	9.1851	0.0101
Hook type	2	11.4301	0.0033

Table 3. Contrast estimation and testing results of independent variables on the release mortality rates of striped bass captured by hook and line in the Neuse River, North Carolina throughout 2006.

Contrast	Odds Ratio	Standard Error	Confidence limits		Wald χ^2	P
No bleeding vs. minimal bleeding	3.3601	1.9974	1.0480	10.7732	4.1569	0.0415
Minimal bleeding vs. moderate to excessive bleeding	2.1480	2.6847	0.1854	24.8849	0.3741	0.5408
No bleeding vs. moderate to excessive bleeding	7.2173	8.1656	0.7859	66.2842	3.0519	0.0806
Handling time less than 30 sec vs. handling time 30-60 sec	3.8452	1.7572	1.5702	9.4167	8.6864	0.0032
Handling time 30-60 sec vs. handling time greater than 60 sec	0.9758	0.4775	0.3739	2.5464	0.0025	0.9601
Handling time less than 30 sec vs. handling time greater than 60 sec	3.7522	2.1780	1.2028	11.7049	5.1898	0.0227
Circle hooks vs. J hooks	0.9414	0.4839	0.3438	2.5782	0.0138	0.9065
Circle hooks vs. treble hooks	0.1359	0.0816	0.0418	0.4411	11.0378	0.0009
J hooks vs. treble hooks	0.1279	0.0933	0.0306	0.5342	7.9508	0.0048

Table 4. Analysis of maximum likelihood estimates on the release mortality rates of striped bass captured by hook and line in the Neuse River, North Carolina throughout 2006.

Parameter	df	Estimate	Standard error	Wald χ^2	P
No bleeding	1	1.9765	1.1314	3.0519	0.0806
Minimal bleeding	1	0.7645	1.2499	0.3741	0.5408
Mean water temperature	1	-0.1625	0.0722	5.0635	0.0244
Handling time less than 30	1	1.3223	0.5805	5.1898	0.0227
Handling time 30-60 sec	1	-0.0245	0.4894	0.0025	0.9601
Circle hooks	1	-2.0565	0.7293	7.9508	0.0048
J hooks	1	-1.9961	0.6008	11.0378	0.0009

The release mortality of striped bass was lower for fish experiencing no bleeding (30.7%) than for those experiencing minimal (47.4%) or moderate to excessive bleeding (85.7%) (Figure 3). However the contrast test results indicated no significant difference in fish with no bleeding and moderate to excessive bleeding (P=0.0806) (Table 3). The release mortality of striped bass was lower relative to handling time, with a 23.9% observed mortality rate when handling time was less than 30 seconds, 40.7% observed mortality rate when handling time was between 30 and 60 seconds, and a 33.3% observed mortality rate when handling time exceeded 60 seconds (Figure 4). The contrast test results showed no significant difference in mortality between circle hook (40.9%) and J hooks (43.8%). However, both of these hook types had significantly higher observed mortality than treble hooks (12.2%) (Figure 5). Mean water temperature also had a significant relationship with mortality, as temperature increased so did mortality.

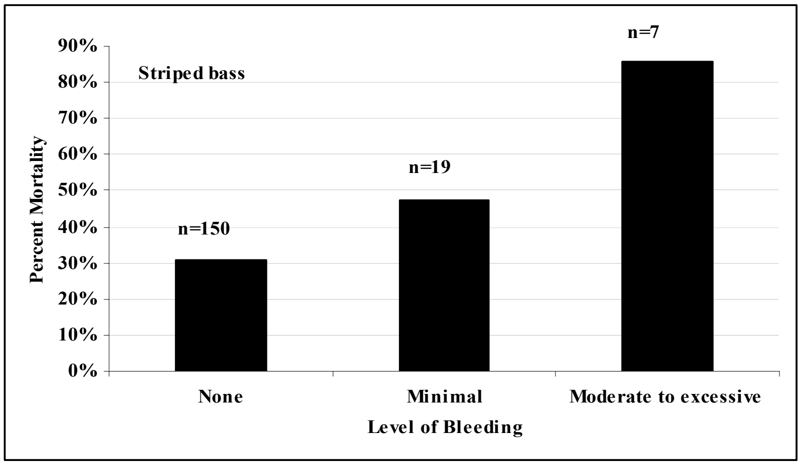

Figure 3. Mortality by level of bleeding for all striped bass mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

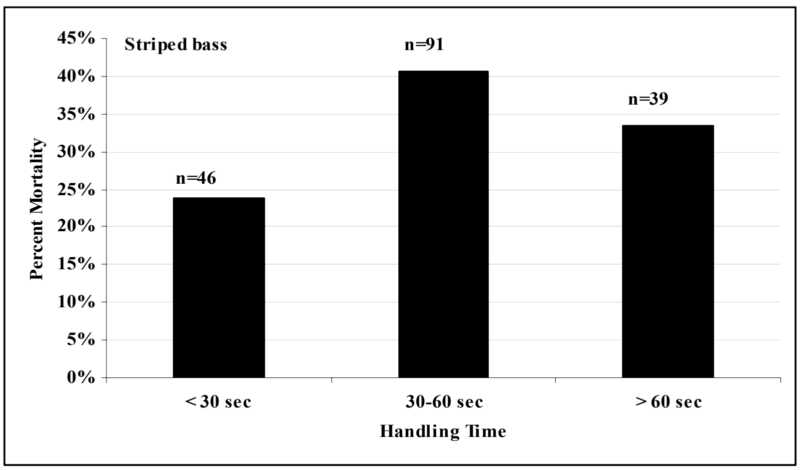

Figure 4. Mortality by handling time for all striped bass mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

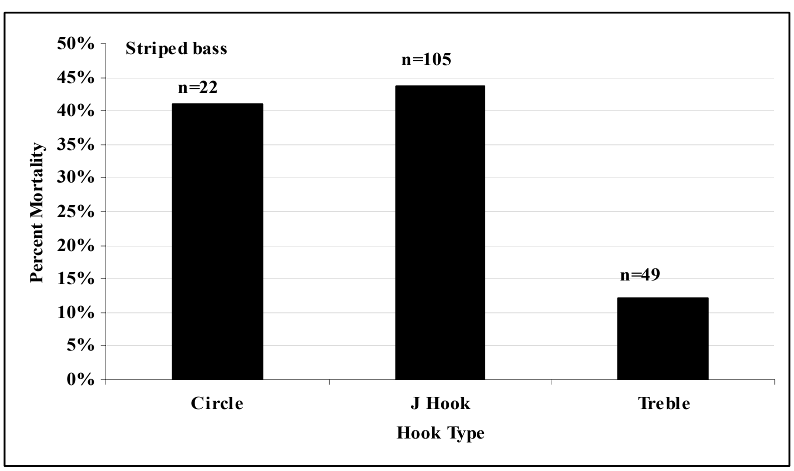

Figure 5. Mortality by hook type for all striped bass mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Southern Flounder

Collectively, 89 southern flounder were captured and held in pens for 72-hour periods throughout the study. A total of 33 flounder were captured at the low salinity sites, while 56 flounder were captured at the high salinity sites. Observed mortality at the low salinity sites averaged 51.5% and ranged from 33.3 to 66.7%, while observed mortality at the high salinity sites averaged 8.9% and ranged from 0.0 to 11.6%. Control mortality at the low salinity sites averaged 42.3% and ranged from 16.7 to 53.3%, while control mortality at the high salinity sites averaged 7.7% and ranged from 0.0 to 10.0%. Average adjusted mortality (observed mortality minus control mortality) at the low salinity sites was 9.2% and ranged from 0.0 to 26.7%, while the average adjusted mortality at the high salinity sites was 1.2% and ranged from 0.0 to 1.6% (Table 5).

For all southern flounder trials combined, 81% of the mortality occurred within 24 hours and 100% occurred within 48 hours (Figure 6). Water temperatures for the low salinity sites ranged from 23.9°C in the fall to 26.7°C in the summer, while the water temperatures for the high salinity sites ranged from 15.4°C in the winter to 24.9°C in the summer. The average water temperature was 25.6°C at the low salinity sites and was 21.4°C at the high salinity sites. Dissolved oxygen at the low salinity sites ranged from 4.9 mg/L in the summer to 7.1 mg/L in the fall, while dissolved oxygen at the high salinity sites ranged from 6.6 mg/L in the spring and 8.4 mg/L in the winter. Salinities ranged from 3.2 ppt to 6.5 ppt at the low salinity sites and from 5.8 ppt to 7.1 ppt at the high salinity sites (Table 5).

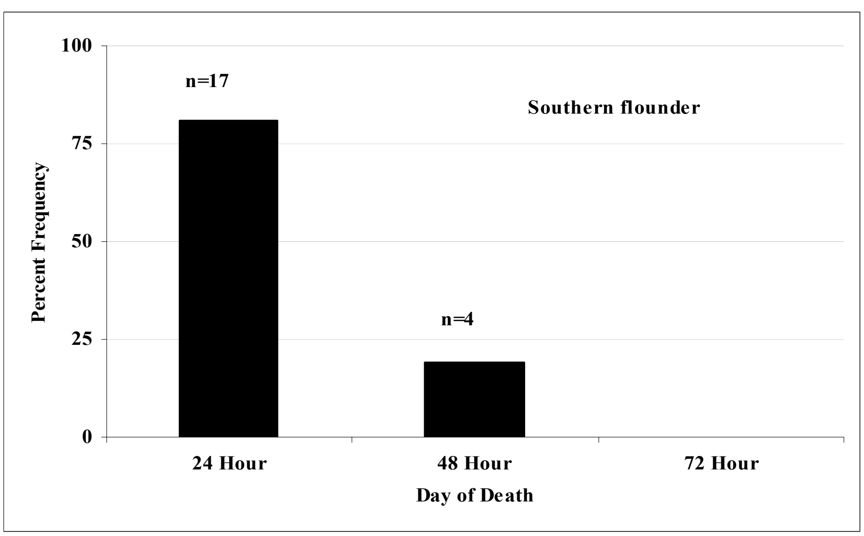

Figure 6. Day of death for all southern flounder mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Table 5. Number of individuals (n), observed mortality, control mortality, adjusted mortality (observed – control), mean water temperature (°C), dissolved oxygen (mg/L), and salinity (ppt) by site for southern flounder release mortality trials conducted in the Neuse River, North Carolina throughout 2006.

Site	Season	n	Observed Mortality	Control Mortality	Adjusted Mortality	Mean Water Temp (ºC)	Mean DO (mg/L)	Mean Salinity (ppt)
New Bern: Low Salinity	Spring	9	66.7%	40.0%	26.7%	24.9	5.0	3.2
	Summer	15	53.3%	53.3%	0.0%	26.7	4.9	6.5
	Fall	9	33.3%	16.7%	16.7%	23.9	7.1	6.2
		Mean	51.5%	42.3%	9.2%	25.6	5.3	5.4
Slocum: High Salinity	Winter	5	0.0%	0.0%	0.0%	15.4	8.4	5.8
	Spring	43	11.6%	10.0%	1.6%	23.0	6.6	7.1
	Summer	7	0.0%	0.0%	0.0%	24.9	7.2	6.6
	Fall	1	0.0%	0.0%	0.0%	16.4	6.7	7.1
		Mean	8.9%	7.7%	1.2%	21.4	7.0	6.8

To perform the logistic regression analysis, data from each site were pooled together to determine the influence of several variables on mortality. The forward logistic regression analysis indicated that mortality was dependent on mean water temperature (P=0.0481) and mean DO (P=0.0002) (Table 6, 8). Hook removal (P=0.0666) was not found significant at the 0.05 significance level but was contrasted to estimate the difference between groups. Dependent variables that were included in the model, but were eliminated through forward regression included: level of bleeding, handling time, hook type, fish length, bait type, and mean salinity. A Hosmer and Lemeshow goodness-of-fit test indicated that the model provided a good fit for the data (χ^2=1.1133, df=5, P=0.9529). The max-rescaled r-square was 0.3956, indicating that the model explains 39.56% of the variability in the data. The predicted concordance or proportion of survivals and deaths correctly predicted by the model was 78.8%.

Table 6. Summary of stepwise linear logistic regression analyses of independent variables on the release mortality rates of southern flounder captured by hook and line in the Neuse River, North Carolina throughout 2006.

Independent Variable	df	Wald χ^2	P
Mean water temperature	1	3.9068	0.0481
Mean DO	1	13.7419	0.0002
Hook Removal	1	3.3641	0.0666

The contrast test results indicated that southern flounder were 10.4 times more likely to survive when the hook was removed compared to individuals that hook was not removed (P=0.0477) (Tables 7 and 8). The release mortality of southern flounder was 22.4% when the hook was removed and was 75.0% when the hook was not removed (Figure 7).

Table 7. Contrast estimation and testing results of independent variables on the release mortality of southern flounder captured by hook and line in the Neuse River, North Carolina throughout 2006.

Contrast	Odds Ratio	Standard Error	Confidence limits		Wald χ^2	P
Hook removed vs. hook not removed	0.0960	0.1136	0.0094	0.9764	3.9208	0.0477

Table 8. Analysis of maximum likelihood estimates on the release mortality rates of southern flounder captured by hook and line in the Neuse River, North Carolina throughout 2006.

Parameter	df	Estimate	Standard error	Wald χ^2	P
Hook removal	1	-2.3438	1.1837	3.9208	0.0477

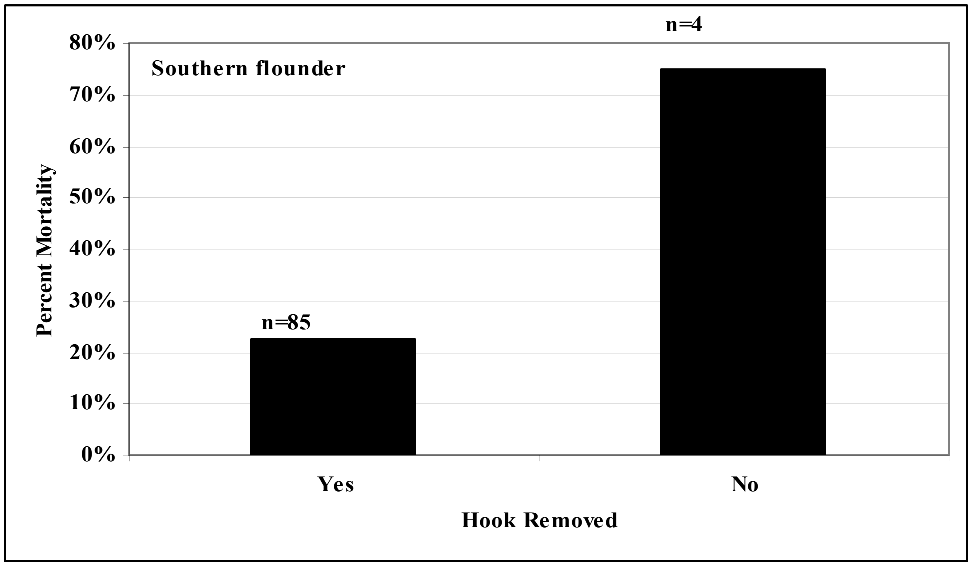

Figure 7. Mortality by hook removal for all southern flounder mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Spotted Seatrout

Collectively, 103 spotted seatrout were captured and held in pens for 72-hour periods throughout the study. A total of 29 spotted seatrout were captured at the low salinity sites, while 74 spotted seatrout were captured at the high salinity sites. Observed mortality ranged from 40.0% to 100.0% at the low salinity sites and from 0.0% to 50.0% at the high salinity sites. Control mortality ranged from 0.0% to 64.7% at the low salinity sites and from 0.0% to 50.0% at the high salinity sites. Average adjusted mortality (observed mortality minus control mortality) was 3.1% at the low salinity sites and 3.3% at the high salinity sites (Table 9).

For all spotted seatrout trials combined, 72% of the mortality occurred within 24 hrs and 89% within 48 hours (Figure 8). Water temperatures ranged from 16.3°C to 28.4°C at the low salinity sites and from 14.8°C to 25.3°C at the high salinity sites. The average water temperature was 21.0°C at the low salinity sites and 20.0°C at the high salinity sites. Dissolved oxygen ranged form 4.4 mg/L to 5.7 mg/L at the low salinity sites and from 6.6 mg/L to 9.1 mg/L at the high salinity sites. Salinities ranged from 2.6 ppt to 7.5 ppt at the low salinity sites and from 6.5 ppt to 8.1 ppt at the high salinity sites (Table 9).

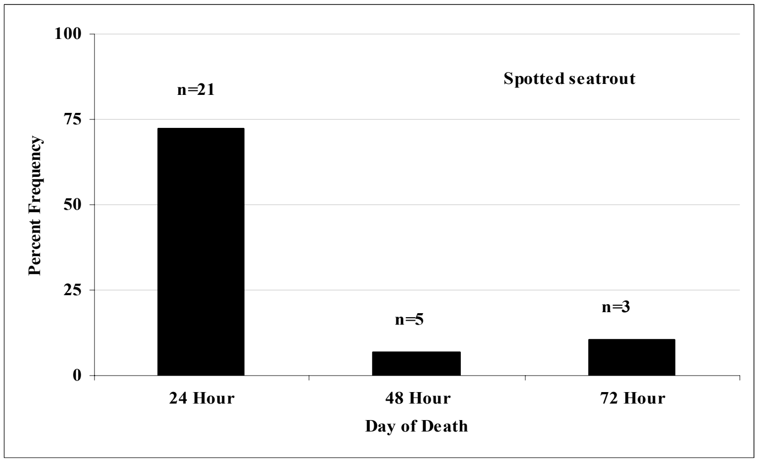

Figure 8. Day of death for all spotted seatrout mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Table 9. Number of individuals (n), observed mortality, control mortality, adjusted mortality (observed – control), mean water temperature (°C), dissolved oxygen (mg/L), and salinity (ppt) by site for spotted seatrout release mortality trials conducted in the Neuse River, North Carolina throughout 2006.

Site	Season	n	Observed Mortality	Control Mortality	Adjusted Mortality	Mean Water Temp (°C)	Mean DO (mg/L)	Mean Salinity (ppt)
New Bern: Low Salinity	Spring	10	40.0%	40.0%	0.0%	23.4	5.7	3.2
	Summer	2	100.0%	0.0%	100.0%	28.4	4.4	7.5
	Fall	17	64.7%	64.7%	0.0%	16.3	5.7	2.6
		Mean	58.6%	55.6%	3.1%	21.0	5.5	3.6
Slocum: High Salinity	Winter	9	0.0%	0.0%	0.0%	14.8	9.1	7.5
	Spring	62	12.9%	10.3%	2.6%	21.5	6.6	7.9
	Summer	2	50.0%	0.0%	50.0%	25.3	6.6	6.5
	Fall	1	0.0%	0.0%	0.0%	16.1	7.6	8.1
		Mean	12.2%	8.8%	3.3%	20.0	7.3	7.6

To perform the logistic regression analysis, data from each site were pooled together to determine the influence of several variables on mortality. The forward logistic regression analysis indicated that mortality was dependent on mean DO (P=0.0002) (Tables 10 and 11). Dependent variables that were included in the model, but were eliminated through forward regression included: mean water temperature, handling time, hook type, fish length, bait type, mean salinity, and hook removal. A Hosmer and Lemeshow goodness-of-fit test indicated that the model provided a good fit for the data (χ^2=0.2885, df=3, P=0.9622). The max-rescaled r-square was 0.2013, indicating that the model explained 20.13% of the variability in the data. The predicted concordance or proportion of survivals and deaths correctly predicted by the model was 61.4%. Mean DO was the only variable tested that had a significant relationship with mortality. As expected, this was an inverse relationship meaning that as mean DO increased mortality decreased.

Table 10. Summary of stepwise linear logistic regression analyses of independent variables on the release mortality rates of spotted seatrout captured by hook and line in the Neuse River, North Carolina throughout 2006.

Independent Variable	df	Wald X^2	P
Mean DO	1	13.838	0.0002

Table 11. Analysis of maximum likelihood estimates on the release mortality rates of spotted seatrout captured by hook and line in the Neuse River, North Carolina throughout 2006

Parameter	df	Estimate	Standard error	Wald χ^2	P
Mean DO	1	0.4852	0.1304	13.838	0.0002

Red Drum

Collectively, 226 red drum were captured and held in pens for 72-hour periods throughout the study. A total of 134 red drum were captured at the low salinity sites and 92 red drum were captured at the high salinity sites. Observed mortality ranged from 0.0% to 45.3% at the low salinity sites and from 0.0% to 5.7% at the high salinity sites. Control mortality ranged from 0.0% to 37.2% at the low salinity sites and from 0.0% to 6.3% at the high salinity sites. Average adjusted mortality was 4.7% at the low salinity sites and was 1.6% at the high salinity site (Table 12).

For all red drum trials combined, 95% of the mortality occurred within 24 hours and 100% within 72 hours (Figure 9). Water temperatures ranged from 18.8°C to 27.3°C at the low salinity sites and from 12.1°C to 24.9°C at the high salinity sites. The average water temperature was 23.3°C at the low salinity sites and 21.9°C at the high salinity sites. Dissolved oxygen ranged from 5.2 mg/L to 6.3 mg/L at the low salinity sites and from 6.6 mg/L to 9.6 mg/L at the high salinity sites. Salinities ranged from 2.9 ppt to 7.4 ppt at the low salinity sites and from 6.6 ppt to 8.0 ppt at the high salinity sites (Table 12).

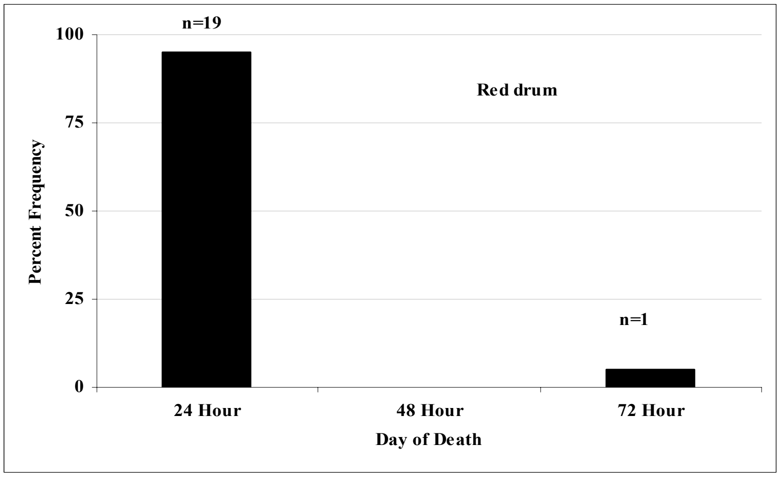

Figure 9. Day of death for all red drum mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Table 12. Number of individuals (n), observed mortality, control mortality, adjusted mortality (observed – control), mean water temperature (°C), dissolved oxygen (mg/L), and salinity (ppt) by site for red drum release mortality trials conducted in the Neuse River, North Carolina throughout 2006.

Site	Season	n	Observed Mortality	Control Mortality	Adjusted Mortality	Mean Water Temp (ºC)	Mean DO (mg/L)	Mean Salinity (ppt)
New Bern: Low Salinity	Spring	20	0.0%	0.0%	0.0%	22.2	5.9	2.9
	Summer	53	45.3%	37.2%	8.1%	27.3	5.2	7.4
	Fall	61	3.3%	1.7%	1.6%	18.8	6.3	3.8
		Mean	19.4%	14.7%	4.7%	23.3	5.7	5.0
Slocum: High Salinity	Winter	1	0.0%	0.0%	0.0%	12.1	9.6	6.8
	Spring	18	5.6%	6.3%	- 0.7% *	22.7	6.6	8.0
	Summer	70	5.7%	3.3%	2.4%	24.9	7.2	6.6
	Fall	3	0.0%	0.0%	0.0%	16.4	6.7	7.1
		Mean	5.4%	3.8%	1.6%	21.9	6.9	7.6

*Adjusted mortality is negative because the only mortality and it was a control mortality (n=1).

To perform the logistic regression analysis, data from each site were pooled together to determine the influence of several variables on mortality. The forward logistic regression analysis indicated that mortality was dependent on mean DO (P=0.0042) and handling time (P=0.0001) (Tables 13 and 15). Dependent variables that were included in the model, but eliminated by forward regression included: level of bleeding, mean water temperature, hook type, fish length, bait type, mean salinity, hook removal, and hook location. A Hosmer and Lemeshow goodness-of-fit test indicated that the model provided a good fit for the data (χ^2=2.9923, df=5, P=0.7012). The max-rescaled r-square was 0.2571, indicating that the model explained 25.71% of the variability in the data. The predicted concordance or proportion of survivals and deaths correctly predicted by the model was 73.6%.

Each of the variables was contrasted to estimate the difference between groups. Red drum were 5.5 times more likely to survive when handling time was less than 30 seconds compared to individuals with a handling time of between 30 and 60 seconds (P=0.0015). Red drum were 2.9 times more likely to survive when handling time was between 30 and 60 seconds compared to individuals where handling time greater than 60 seconds (P=0.0611). Red drum were 15.8 times more likely to survive when handling time was less than 30 seconds compared to individuals where handling time was greater than 60 seconds ((P=<0.0001) (Table 14).

Table 13. Summary of stepwise linear logistic regression analyses of independent variables on the release mortality rates of red drum captured by hook and line in the Neuse River, North Carolina throughout 2006.

Independent Variable	df	Wald χ^2	P
Mean DO	1	8.1971	0.0042
Handling time	2	17.9562	0.0001

Table 14. Contrast estimation and testing results of independent variables on the release mortality of red drum captured by hook and line in the Neuse River, North Carolina throughout 2006.

Contrast	Odds Ratio	Standard Error	Confidence limits		Wald χ^2	P
Handling time less than 30 sec vs. handling time 30-60 sec	5.4788	2.9326	1.9190	15.6421	10.0977	0.0015
Handling time 30-60 sec vs. handling time greater than 60 sec	2.8875	1.6347	0.9520	8.7582	3.5083	0.0611
Handling time less than 30 sec vs. handling time greater than 60 sec	15.82	10.6324	4.2376	59.0595	16.8796	<0.0001

Table 15. Analysis of maximum likelihood estimates on the release mortality rates of red drum captured by hook and line in the Neuse River, North Carolina throughout 2006.

Parameter	df	Estimate	Standard error	Wald χ^2	P
Handling time less than 30 sec	1	2.7613	0.6721	16.8796	<0.0001
Handling time 30-60 sec	1	1.0604	0.5661	3.5083	0.0611

The release mortality of red drum was lower relative to handling time, with a 4.2% observed mortality rate when handling time was less than 30 seconds, 19.8%

observed mortality rate when handling time was between 30 and 60 seconds, and 42.9% observed mortality rate when handling time was greater than 60 seconds (Figure 10).

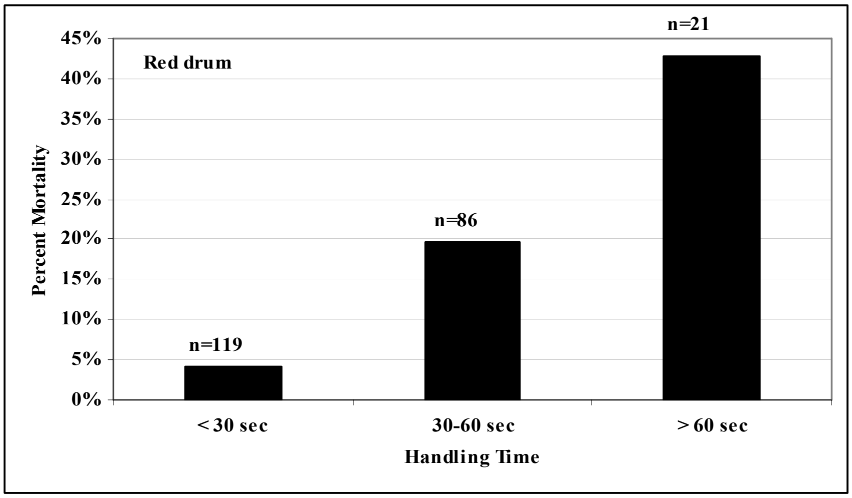

Figure 10. Mortality by handling time for all red drum mortalities observed during trials conducted in the Neuse River, North Carolina throughout 2006.

Discussion and Management Implications

The overall unadjusted mortality rates throughout the study were 34.7% for striped bass, 24.7% for southern flounder, 13.7% for red drum and 25.2% for spotted seatrout. These results are comparable to previous research. Hysmith (1992) reported a 38% mortality rate of striped bass; Gearhart (2002a) reported the release mortality rates of southern flounder at high salinity sites at 9.5% and at low salinity sites at 19.4%. The release mortality rate of red drum was considerably lower than those observed for other species. This trend is supported in other literature and likely reflects the hardiness of the species (Duff 1999). Hegen and Green (1983) reported a 37% release mortality rate for spotted seatrout in Texas.

Most mortality for all species occurred in the first 24 hours, and except for striped bass the mortality rate had an inverse relationship with handling time. This indicates that there was minimal confinement stress associated with the mortality trials. The increase in the 72 hour mortality rate for striped bass compared to the 48 hour mortality rate was likely due to a drop in DO that caused 100% mortality of one trial. Previous research suggests an inverse relationship between salinity and hooking mortality (Gearhart 2002b). This is supported by the higher control morality for all species at the low salinity sites compared to the high salinity sites that were observed during this study. However, the logistic regression analyses did not find salinity as a significant predicator of mortality in any of the species. This result may have been confounded by the unbalanced seasonal design of the study.

Level of bleeding was found to be a good predicator of the release mortality of striped bass release mortality. Gearhart (2002b) also found that level of bleeding was a good predicator of striped bass release mortality. Bleeding is typically a good indicator of a sensitive hook location, which previous research has found as a significant predicator of release mortality (Diodati and Richards 1996, Nelson 1998).

The results of this study indicate a positive relationship between release mortality, of striped bass and southern flounder, and mean water temperature. The observed mortality and control mortality increased sharply when the mean water temperature was near or above 25°C.

There was also a positive relationship between handling time and release mortality of striped bass and red drum. Increased handling time often resulted from factors such as the hook location, generally fish that were hook in the jaw or lip (non sensitive areas) had short handling times as compared to those individuals that were hooked in more sensitive areas.

Hook type was also a significant predicator of release mortality of striped bass. Both circle and J hooks had higher release mortality rates than treble hooks (40.91%, 43.81%, and 12.24% respectively). This is likely due in part to adverse hooking location associated with single hooks in relation to treble hooks and the fact that the treble hooks that were used in this study were part of larger gear (artificial lures) that is difficult for fish to swallow.

The results of this study indicate that mean DO and handling time were significant predicators of release mortality of southern flounder, spotted seatrout and red drum. Gearhart (2002a) also found DO to be a good predicator of red drum release mortality, observing a higher mortality rate (12%) when DO was less than 7 mg/L compared to individuals experiencing a DO more than 7 mg/L (1%).

Hook removal was found to be a good predicator of southern flounder release mortality. The removal of the hook is closely associated with hook location, since the hook was only left in fish that were deep hooked. Gearhart (2000 and 2002a) found hook location to be a good predicator of southern flounder release mortality. However, the logistic regression analysis of southern flounder and spotted seatrout in this study did not include the independent variables of hook location or level of bleeding, because their inclusion in the model created a possible quasicomplete separation of data points, resulting in a suspect model (SAS 1989). This problem is often associated with a small sample size.

Creel limits, size limits, harvest quotas, and time/area closures are viable management practices for these species. Since these restrictive regulations often promote catch and release fishing, it is imperative to collect data on these regulatory discards. Collecting data on the composition of hook types used by recreational anglers is important in the estimate of release mortality of recreational species. It is also important for NCDMF to promote better fishing practices, including selection of proper fishing equipment, terminal tackle, and proper handling techniques to reduce the release mortality of recreational species.

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