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ARTICLE

Red Drum and Spotted Seatrout Live-Release Tournament Mortality and Dispersal

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Abstract
Although catch-and-release fishing tournaments undoubtedly reduce mortality of target species, postrelease mortality and fish stockpiling at release sites remain common concerns related to these tournaments. The impacts of live-release tournaments on freshwater species have been widely studied. However, research on estuarine sport fishes is lacking even though catch-and-release tournaments targeting these species are prevalent and popular recreational fisheries exist. Therefore, we estimated the post-weigh-in mortality and dispersal of Red Drum *Sciaenops ocellatus* and Spotted Seatrout *Cynoscion nebulosus* released from the 2016–2018 Alabama Deep Sea Fishing Rodeo live-weigh-in categories using acoustic telemetry. To concurrently estimate overall post-weigh-in mortality and dispersal, we used a Bayesian multistate model. Overall Red Drum post-weigh-in mortality (median = 6.12%; posterior credible interval [CrI] = 5.67–9.24%) was lower than overall Spotted Seatrout mortality (median = 30.63%; CrI = 26.74–40.00%). These estimates were within reported catch-and-release mortality ranges; however, they were higher than recent estimates for Spotted Seatrout. Within 1 week postrelease, Spotted Seatrout dispersal estimates (median = 87.03%; CrI = 72.96–95.72%) were higher than Red Drum (median = 55.62%; CrI = 42.75–68.10%) or *Micropterus* spp. in coastal and inland ecosystems. Long-term stockpiling at the release site was also not present; at the end of our 8-week observation period, median dispersal estimates were 94.41% (CrI = 87.15–98.19%) and 98.54% (CrI = 93.68–99.82%) for Red Drum and Spotted Seatrout, respectively. Red Drum fisheries may benefit most from live-release tournaments given that maximum mortality was <10%, but Spotted Seatrout fisheries may also benefit, especially if considerations are made to further reduce tournament mortality. Although we do not know the ratio of tournament mortality to recreational harvest for these species, live-release tournaments may be able to relieve some harvest pressure on heavily exploited inshore marine fisheries and research validating their usefulness should continue.

Fishing tournaments are prevalent throughout the United States in both freshwater and marine water and can impact fisheries that are targeted by commercial and recreational anglers in addition to competitive ones (Schramm et al. 1991a, 1991b). Tournaments use catch and release to alleviate impacts on targeted species, given that

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mortality is undoubtedly reduced in live-release categories (Schramm and Gilliland 2015). Although initial mortality is reduced, postrelease mortality (Allen et al. 2004; James et al. 2007; Sylvia and Weber 2019), fish stockpiling at release sites, and displacement of fishes from their capture areas (Richardson-Heft et al. 2000; Schramm and Hunt 2007; Brown et al. 2015) are all concerns associated with catch-and-release tournaments. Given that live-release tournaments can elevate effort on highly exploited sport fish stocks (Schramm et al. 1991b), these concerns need to be investigated on a species-specific and stock-specific basis.

The format of black bass *Micropterus* spp. catch-and-release tournaments resembles those of inshore marine species tournaments, and comparisons between these tournament types are more applicable than those hosted on large marine fishes (Graves and Horodysky 2015). Furthermore, research on black bass catch-and-release tournaments is prevalent, because black bass are highly sought-after sport fish and live-release tournaments are common (Siepker et al. 2007; Driscoll et al. 2012). Black bass live-release tournament mortality is highly variable; low (<7%; Kwak and Henry 1995; Edwards et al. 2004; Kerns et al. 2016), mid-range (14–33%; Welborn and Barkley 1974; Schramm et al. 1987; Sylvia and Weber 2019), and high mortality estimates (>40%; Neal and Lopez-Clayton 2001; Wilde et al. 2002; Siepker et al. 2007) have been reported. This mortality variability may result from variable water temperatures and the experience of anglers and tournament directors (Schramm and Gilliland 2015; Kerns et al. 2016; Sylvia and Weber 2019).

After release, black bass can disperse more than 500 m in less than 20 d (Richardson-Heft et al. 2000; Kaintz and Bettoli 2010; Brown et al. 2015), while others may never leave release locations (Wilde 2003; Wilde and Paulson 2003). Dispersal times are typically faster, and distances also tend to be larger in tidal freshwater portions of estuaries than in reservoirs (Richardson-Heft et al. 2000; Norris et al. 2005; Brown et al. 2015). Variable dispersal rates may be a result of species-specific differences or release site habitat (Siepker et al. 2007; Brown et al. 2015; Slagle et al. 2020). Although the impacts of live-release tournaments have been studied in freshwater, limited information exists on live-release estuarine sport fish tournaments and their impacts (but see James et al. 2007).

Red Drum *Sciaenops ocellatus* and Spotted Seatrout *Cynoscion nebulosus* are heavily targeted estuarine-dependent sport fish in the southeastern United States, and competitive fishing tournaments exist for both species (Schramm et al. 1991b; James et al. 2007). Gulf of Mexico Red Drum populations were drastically depleted by commercial harvest in the 1980s (GMFMC 1988; Powers and Burns 2010; Powers et al. 2012), and Spotted Seatrout have experienced recent population declines and increased recreational pressure (Leaf et al. 2018). From Texas to Apalachicola, Florida Spotted Seatrout are a single population (Seyoum et al. 2018), while Red Drum have two distinct populations which likely overlap in Alabama (Hollenbeck et al. 2019). Within these populations, isolation by distance is present supporting current state-specific stock management (Seyoum et al. 2018; Hollenbeck et al. 2019). To ensure sustainable harvest and persistence of these popular fisheries, Red Drum and Spotted Seatrout are currently managed with daily bag and slot limits in Alabama (ADCNR 2020). Although limited harvest is allowed, many anglers practice catch-and-release fishing after their daily bag limits are reached (R. Rutland, charter fishing captain, personal communication). Recreational catch-and-release mortality of Red Drum and Spotted Seatrout is variable (Muoneke and Childress 1994), but mortality is generally lower for Red Drum (4–16%; Jordan and Woodward 1992; Matlock et al. 1993; Vecchio and Wenner 2007) than for Spotted Seatrout (7–56%; Matlock and Dailey 1981; Matlock et al. 1993; Stunz and McKee 2006).

Of these two species, tournament mortality has been studied for Spotted Seatrout (mean = 22.9%; James et al. 2007). Live-release tournament mortality may be higher than recreational catch-and-release mortality, given that tournament entries are subject to added stress from live well confinement, transport, and release procedures (Siepker et al. 2007). Furthermore, estimates of black bass tournament mortality are higher than recreational catch and release (Kerns et al. 2016). Both Red Drum and Spotted Seatrout are euryhaline and can be encountered throughout the estuary from marine water to freshwater (Helser et al. 1993; Bacheler et al. 2009c; Livernois et al. 2020). Therefore, these fishes may be transported long distances to tournament live-release sites, and the abiotic conditions in release waters could be vastly different from collection waters. These additional stressors could exacerbate typical live-release tournament stress (Siepker et al. 2007), potentially increasing postrelease mortality.

Established in 1929, the Alabama Deep Sea Fishing Rodeo (ADSFR) currently holds the Guinness Book of World Records title for the world's largest fishing tournament and maintains collaborations with local fisheries scientists. Currently this tournament is held during late July each year across the span of 3 d out of Dauphin Island, Alabama. A Spotted Seatrout live-weigh-in category was added in 2015 amid concerns about the northern Gulf of Mexico Spotted Seatrout fishery (Leaf et al. 2018). Given the popularity of this category and its perceived success, Red Drum were added to the live-release category in 2016 and both classes have remained in each subsequent ADSFR. Separate cash prizes from the open categories entice anglers to enter live fish, because a single fish could win both open and live-weigh-in categories. To determine species-specific impacts of Red Drum and Spotted Seatrout live-weigh-in categories, we estimated post-weigh-in mortality and dispersal of these fishes from the 2016 to 2018 ADSFRs (Red Drum 2016–2018, Spotted Seatrout 2017–2018). We used acoustic telemetry to determine the fates of released fishes and multistate mark–recapture models to estimate mortality and dispersal.

METHODS

Live weigh-in and tagging.— Anglers transported live Red Drum and Spotted Seatrout from Louisiana, Mississippi, and Alabama to the weigh station on Dauphin Island, Alabama for tournament entry. We accepted potential entries from anglers, measured each fish to ensure that it met tournament size regulations (Red Drum: 406–660 mm TL, Spotted Seatrout ≥406 mm TL), and placed fishes in an aerated holding tank (Rubbermaid 378.5-L stock tank). We filled this tank daily with ambient water, performed 50% water changes as needed, and cooled the tank with bagged ice. During this time, we also attempted to obtain exact collection location from anglers; however, this information was not always reliable or forthcoming. We verbally asked anglers where their fish was caught and would get answers ranging from approximate locations, large bodies of water, or only the collection state.

To encourage angler participation in the live-weigh-in category, any movement from the fish while in the holding tank qualified it for entry, as per instruction from tournament directors. This inclusion criteria included some fishes that were moribund and therefore did not receive an acoustic tag. We only tagged fishes that exhibited the following positive reflex action mortality predictors: opercle movement and attempt to right themselves when turned upside down (Davis and Ottmar 2006; Davis 2007). We considered any fish that did not pass these inclusion criteria an initial mortality and included them in our overall post-weigh-in mortality estimates. In fishes that met inclusion criteria, we surgically implanted a Vemco V13 transmitter (30–90-s ping, 362-d battery life) and an externally visible FLOY tag (FT-1-94, printed with reporting information). Surgical procedures for both species followed the surgery methods of Nelson and Powers (2020). To encourage angler return and fate validation of tagged fishes, each FLOY tag had the word "reward" printed on the tag, and anglers would receive a low reward of either a hat or t-shirt after tag reporting.

After tagging, we held fishes in a large observation tank (20,388 L) filled with ambient water to monitor for mortality and allow public viewing. We monitored water temperature and dissolved oxygen (DO) with a multiparameter water quality sonde (YSI EXO1) and used a large aquarium chiller to cool and maintain temperatures near 24°C. We continuously aerated the tank with ambient air and used oxygen as needed to maintain adequate DO levels. We deployed a Vemco VR100 acoustic receiver within this tank and detected each implanted tag, ensuring that all deployed tags were working. After the tournament weigh station closed each day, we released all live tagged fishes into the bay adjacent to the ADSFR site (Figure 1). We considered any fishes that died in the tank observed mortalities and included them in our overall post-weigh-in mortality estimates.

Fish detections and analysis.— After release, we inferred tagged fish fates with passive acoustic detections from the Coastal Alabama Acoustic Monitoring Program (CAAMP) receiver array and any receivers maintained by neighboring states. The array consisted of 55 Vemco VR2W acoustic receivers and included a receiver near the ADSFR release site (Figure 1). We assumed that the detection range of this receiver was 300 m and based this assumption on previous range tests we performed with other V13 tags in similar conditions (Nelson and Powers 2020). Although there were some places within the release site that this receiver may not have fully covered, all deployed tags were detected on this receiver after release. We used daily acoustic tag detections to build our observation histories and known states (S) of individuals (i) at a daily time interval (t). We inferred release site mortalities from tags with continuous detections at the release site receiver; however, continuous detections elsewhere were unobserved (Supplemental Tables S.1, S.2 available separately online). We inferred that tags at the release site that did not meet this mortality criteria were live fish. Finally, we inferred live fish had dispersed from the release site when a tag was detected on receivers other than the one at the release location. If live fish were detected back at the release site after initial dispersal, we continued to assign a dispersed observation. This approach ensured that the same individual was not included in dispersal estimates multiple times. These criteria resulted in a total of four possible observations including undetected/unobserved, three states, and six possible state transitions (Table 1).

To concurrently estimate post-weigh-in mortality and dispersal from the release site, we analyzed our telemetry observations with Bayesian multistate capture–recapture models (Kéry and Schaub 2012; Ellis et al. 2017; Hightower and Harris 2017). These models estimated the probability that tagged individuals would remain in or transition out of a possible state at $t+1$ and the probability that states were observed correctly. We only released individuals that did not die in the observation tank. Therefore, each individual (i) was alive at release and all subsequently estimated true states ($z_{i,t}$) were conditional on $S_{i,\ t-1}$. Given state transition criteria, we defined two different state transition probability matrices for the ith individual—one for the first state transition period and one for all remaining periods. The only difference is that for the first period, transitions for $S_t = 3$ could not occur, because fish could not have already dispersed from the release site. We defined these matrices as follows:

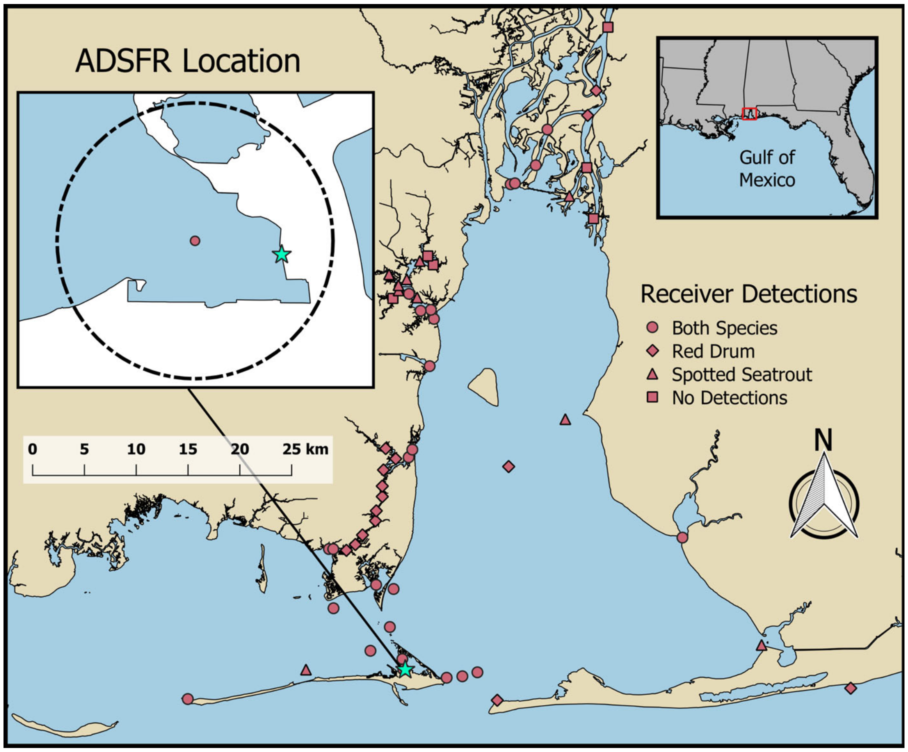

FIGURE 1. Receiver locations of the Coastal Alabama Acoustic Monitoring Program and receiver species-specific detections. The left panel is the Alabama Deep Sea Fishing Rodeo (ADSFR) release site (star) and receiver. The dashed line in this panel represents the 300-m receiver detection range. In the upper right Gulf of Mexico inset, the study area is denoted with a red square.

$$P_{z_{i,t+1}} = \begin{Bmatrix} S_{t+1}=1 & S_{t+1}=2 & S_{t+1}=3 & \\ R\Phi_t & F_t(1-R\Phi_t)/ZR_t & RE_t(1-R\Phi_t)/ZR_t & \text{when } S_t=1 \\ 0 & 1 & 0 & \text{when } S_t=2 \\ 0 & 1-e^{-F_t} & E\Phi_t & \text{when } S_t=3 \end{Bmatrix}$$

$$R\Phi_t = e^{-ZR_t}; ZR_t = F_t + RE_t$$

$$E\Phi_t = e^{-F_t};$$

where $R\Phi_t$ was the t-specific probability of surviving and remaining at the release site. This value was a function of daily instantaneous rates of mortality (F) and dispersal (RE) from the release site. The $E\Phi_t$ parameter was the t-specific probability of surviving after initial dispersal and was a function of the daily instantaneous mortality rates (F). Observed states of each individual at time t ($y_{i,t}$) were conditional on true states ($z_{i,t}$). Similar to transition matrices, we defined the probability of states being observed correctly with two probability matrices—one for the first observation period where observations for $S_t = 3$ could not occur, and one for all remaining periods. We defined these matrices as follows:

$$P_{y_{i,t}} = \begin{Bmatrix} y_t=1 & y_t=2 & y_t=3 & y_t=4 & \\ p_t & 0 & 0 & 1-p_t & \text{when } S_t=1 \\ 0 & p_t & 0 & 1-p_t & \text{when } S_t=2 \\ 0 & 0 & p_t & 1-p_t & \text{when } S_t=3 \end{Bmatrix},$$

where p_t was the t-specific detection probability. It is possible that undetected fish on any given day could have been alive or dead, and we accounted for this uncertainty in the above observation probability matrix (Supplemental Code available separately online).

Models had 62 observation periods including release, day 1–60 after release, and a final fate column. If angler harvest occurred prior to 60 d, we censored fish after harvest and assigned a dispersed observation (3) on the harvest day if it did not occur at the release site. Two Red Drum were harvested at the release site; one received a dispersed observation (3) on that day, given that it had previously dispersed and returned. The other received a live undispersed observation (1) at harvest because it had never been detected away from the release site; however, detections indicated that the fish was alive. Final fate was the first observation ≥61 d postrelease when a fish was

TABLE 1. Potential observations from Red Drum and Spotted Seatrout detection data following release at the Alabama Deep Sea Fishing Rodeo, including possible states (S) of a given individual with each observation, the classification criteria of observations and states, and possible state transitions at day $t+1$. State transitions when $S=3$ could only occur at times $\geq t=2$.

Observations	Possible states (S)	Classification criteria	Possible state transitions at $t+1$
1	1	Live fish at the release site (prior to first dispersal detection)	$1 \rightarrow 1$ $1 \rightarrow 2$ $1 \rightarrow 3$
2	2	Mortality (stationary tag)	$2 \rightarrow 2$
3	3	Live fish after first dispersal from the release site	$3 \rightarrow 2$ $3 \rightarrow 3$
4	1, 2, or 3	Undetected/unobserved fish without a detected dispersal	
4	2 or 3	Undetected/unobserved fish with a previously detected dispersal	

detected (e.g., 1 or 3) or 4 if a fish remained undetected. We assigned stationary tags a final fate of 2. We also assigned a final fate of 3 to any uncensored known angler-captured fish that remained undetected after the 60-d observation period.

We obtained initial moribund fish mortality (DOA) by dividing the number of fish that did not meet inclusion criteria (based on reflex action mortality predictors) by the total number of fish weighed and converted this value to an instantaneous rate (DOA_Z). To obtain known observation tank mortality (Ob_A), we divided the number of fish that died in the observation tank by the number of tagged fish and converted this value to an instantaneous rate (Ob_Z; Supplemental Code). To calculate our 3-d overall post-weigh-in mortality estimate (W), we converted the sum (pwm) of the instantaneous mortality rates (F) of days 1–3, instantaneous initial fish mortality (DOA_Z), and instantaneous observation tank mortality (Ob_Z) to a discrete proportion. We generated discrete cumulative weekly dispersal probabilities (D_w) for 8 weeks by converting the sum of instantaneous daily dispersal rates (RE), for each day within each time period. To obtain species-specific estimates, we ran a model for each species. We implemented multistate models with JAGS (Plummer 2003), running through R version 3.6.2 (R Core Team 2019), and used uninformative priors (Supplemental Code). To estimate the posterior probability distributions for each parameter, we used three Markov chains with 100,000 iterations (2,000 iterations used for burn-in). We visually inspected trace plots obtained with the R function "diag_plots" (Staton 2020) and used the Brooks–Gelman–Rubin statistic to assess convergence.

Our model had assumptions similar to other multistate capture–recapture studies outlined by Hightower et al. (2001) and Hightower and Harris (2017). We assumed that all tagged fishes in specified states had equal mortality rates and detection probabilities and that fates of tagged individuals were independent. However, as individuals left the release site, detections decreased, resulting in <65% detection probability for both species after 3 d. We assumed tag expulsion and failure to be negligible for both species. This assumption has been confirmed in previous studies (Bacheler et al. 2009a; Ellis et al. 2017), and we detected 15 tags for >300 d. We assumed that tagging mortality did not occur and that tagging did not affect dispersal. For our observed and overall mortality estimates, it is impossible to disentangle post-weigh-in and tagging mortality, and we highlight consequences of this violation in the Discussion. Finally, we assumed that observations were classified without error and that these occurred instantaneously at the start of the detection period.

RESULTS

Across all years of the study (2016–2018), 71 Red Drum were entered into the live-weigh-in category (Tables 2, S.3). Of these, four individuals died (5.63%), two were initial mortalities (2.82%), and two died in the observation tank (2.82%). Anglers provided capture information on the majority of Red Drum ($n=68$), and individuals were caught in Alabama ($n=49$), Mississippi ($n=8$), and Louisiana ($n=11$); however, only fish caught in Alabama died. Two of these individuals were caught ~50 km from the release site, but the other two were caught <8 km away, indicating no collection distance mortality trend. We released a total of 67 acoustically tagged individuals and detected no mortalities. Fifty-nine Red Drum (88.01% of released fish) were detected on receivers other than the one at the release site, confirming successful dispersal of these individuals (Table 2; Figure 1). Acoustic arrays in Florida detected two of our released individuals,

TABLE 2. The number of fish moribund on arrival at the weigh station (DOA), observed tank mortality, mortality inferred from stationary tag detections (release mortality), and total mortalities are reported across years and overall for Red Drum and Spotted Seatrout following release at the Alabama Deep Sea Fishing Rodeo. The number of fish detected at the release site, elsewhere, and the number of individuals recaptured by anglers from a given year of tagging are also reported.

State	2016	2017	2018	Total
Red Drum				
Total weighed	28	23	20	71
DOA	1	1	0	2
Observed mortality	1	1	0	2
Release mortality	0	0	0	0
Total mortality	2	2	0	4
Detected release	26	21	20	67
Detected elsewhere	21	21	17	59
Recaptured	9	7	4	20
Spotted Seatrout				
Total weighed		32	22	54
DOA		4	4	8
Observed mortality		3	3	6
Release mortality		1	1	2
Total mortality		8	8	16
Detected release		25	15	40
Detected elsewhere		24	9	33
Recaptured		4	0	4

and two different arrays in Mississippi detected another; however, this individual was caught in Alabama. Maximum individual Red Drum detection times ranged from 1 to 368 d (mean = 100.40 d; SE = 12.62) postrelease, and maximum distance detected from the release site ranged from 0 to 94.00 km (mean = 16.71 km; SE = 2.60; Figure 2). Two individuals had detections that ceased prior to our 3-d post-weigh-in mortality estimate. Therefore, we were uncertain of the final fate of these individuals. Since tagging, anglers have reported 20 recaptured Red Drum (29.85% of released fish) 13–485 d postrelease and 0–60 km away from the release site.

During the two years (2017, 2018) we tagged Spotted Seatrout, 54 were entered into the live-weigh-in category (Tables 2, S.4). Of these, 16 individuals died (29.62%); 8 were initial mortalities (14.81%), 6 died in the observation tank (11.11%), and we inferred two mortalities from stationary tag detections (3.70%). All Spotted Seatrout with known capture locations ($n = 46$) were caught in Alabama, except for one that was collected in Mississippi, and this individual was not a detected mortality. Furthermore, all deceased individuals with known capture locations ($n = 12$) were caught within 25 km of the release site. We released 38 tagged Spotted Seatrout that did not die, and 33 (86.84%) were detected on receivers not at the release site (Table 2; Figure 1). Unlike Red Drum, no arrays in neighboring states detected any of our tagged individuals. We detected Spotted Seatrout individuals for a maximum of 0–348 d (mean = 121.40 d; SE = 23.26) postrelease and 0–49.60 km (mean = 9.40 km; SE = 2.25) from the release site (Figure 2). Eight fish had detections that ceased before our 3-d mortality estimates, so we were unsure of their final fate. Only four Spotted Seatrout (10.53% of released live fish) have been reported by anglers with recapture times from 15 to 35 d and distances from 7 to 20 km.

Overall Red Drum post-weigh-in mortality (median = 6.12%; posterior credible interval [CrI] = 5.67–9.24%) was significantly lower than total Spotted Seatrout post-weigh-in mortality (median = 30.63%; CrI = 26.74–40.00%; Figure 3A). Within 1 week postrelease, dispersal estimates for Spotted Seatrout (median = 87.03%; CrI = 72.96–95.72%) were higher than estimates for Red Drum (median = 55.62%; CrI = 42.75–68.10%; Figure 3C). This difference was driven by a higher dispersal rate of Spotted Seatrout during the first day postrelease (Figure 3D). After the first week, credible intervals of cumulative weekly dispersal probabilities overlapped between species; however, Spotted Seatrout median estimates remained higher. After week two, Spotted Seatrout median dispersal estimates were >90% and by week five, median Red Drum dispersal had reached the same percentage (Figure 3C). Our final estimates of dispersal after 8 weeks postrelease were 94.41% (CrI = 87.15–98.19%) and 98.54% (CrI = 93.68–99.82%) for Red Drum and Spotted Seatrout, respectively. Trace plots indicated convergence of all monitored parameters, and all Brooks–Gelman–Rubin statistics were <1.05.

DISCUSSION

Although Red Drum and Spotted Seatrout were caught throughout various estuaries, transported to the weigh-in, and handled multiple times before release, our mortality estimates fell within the range of recreational catch-and-release mortality (Muoneke and Childress 1994) and black bass tournaments (Siepker et al. 2007). Red Drum mortality was similar to the low end of black bass tournaments (Kwak and Henry 1995; Edwards et al. 2004; Kerns et al. 2016), while Spotted Seatrout approached the upper end (Schramm et al. 1987; Siepker et al. 2007). Similar to trends in recreational fisheries (Matlock et al. 1993; Muoneke and Childress 1994), Red Drum mortality was lower than Spotted Seatrout in initial, observed, and overall post-weigh-in estimates. Although Spotted Seatrout mortality was within the range of some studies (Muoneke and Childress 1994), it was higher than recent estimates from recreational catch and release (11%; Stunz and McKee 2006), and mean estimates from live-release

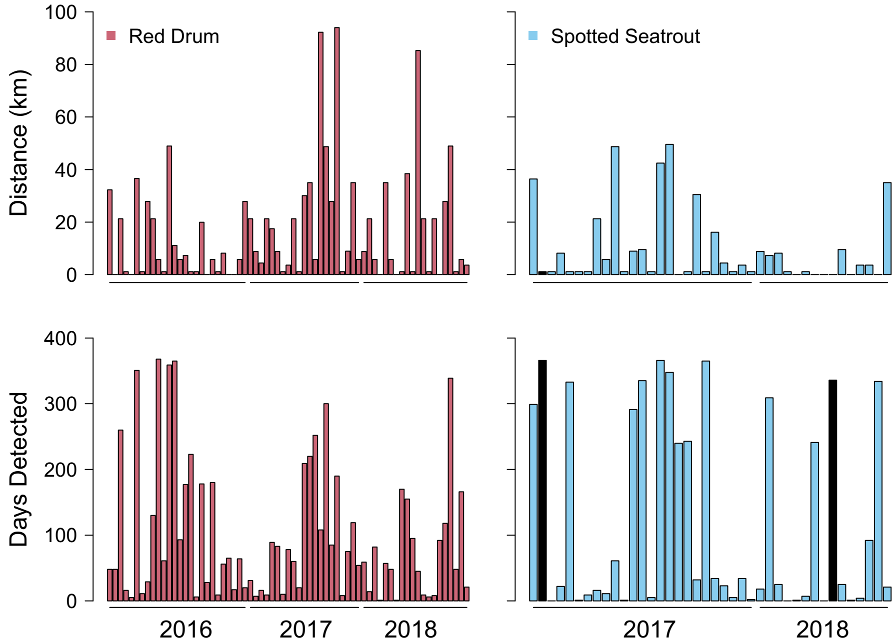

FIGURE 2. The maximum distance from the release site (km) and days after release (days detected) that individual Red Drum and Spotted Seatrout were detected on acoustic receivers following release at the Alabama Deep Sea Fishing Rodeo. Black bars indicate the two inferred Spotted Seatrout mortalities.

tournaments (22.9%; James et al. 2007). Therefore, Spotted Seatrout tournament mortality may be higher than recreational catch-and-release mortality, as has been reported for black bass (Kerns et al. 2016). Elevated Spotted Seatrout mortality may have been driven by high water temperatures during the summer tournament we studied, given that James et al. (2007) found elevated summer tournament mortality for this species. Furthermore, elevated water temperatures decrease tournament release survival of black bass, Walleye *Sander vitreus*, and Sauger *Sander canadensis* (Schramm et al. 2010; Kerns et al. 2016; Sylvia and Weber 2019). Increasing angler education on proper live-well practices could decrease this summer mortality in the future, a trend that has been observed in black bass tournaments (Schramm and Gilliland 2015).

We did not observe long-term stockpiling at the release site because over time, most individuals dispersed. Within 1 week postrelease, Spotted Seatrout dispersal estimates (87%) were higher than Red Drum (56%) or black bass in coastal (57–64%; Richardson-Heft et al. 2000; Brown et al. 2015) and inland (47%; Slagle et al. 2020) ecosystems. Within 2 weeks, Spotted Seatrout dispersal estimates were >90%, but Red Drum took until 5 weeks to reach the same cumulative dispersal probabilities. This faster dispersal rate of Spotted Seatrout may have been driven by the habitat characteristics surrounding the release site. Although these species can occupy the same habitats (Livernois et al. 2020), Spotted Seatrout associate with deeper open waters (Moulton et al. 2016) and the release site was a shallow enclosed bay. Therefore, Spotted Seatrout may have quickly moved to more favorable conditions, while some Red Drum remained in the shallow habitat near the release location. Assessing environmental drivers of dispersal rates was beyond the scope of this study, but it is an interesting research direction for the future.

Although we only estimated one source of mortality in our study, these multistate models provide the ability to simultaneously estimate various component mortality rates and other loss rates (Kéry and Schaub 2012; Hightower and Harris 2017). In our study, we were able to estimate daily dispersal rates and discrete weekly dispersal percentages while concurrently estimating daily mortality rates and 3-d post-weigh-in mortality. This framework also allowed us to easily include initial and observed mortalities in our overall post-weigh-in mortality estimates. Finally, our model accounted for unobserved individuals by increasing posterior credible intervals around estimates of mortality and dispersal. Instead of lumping various mortality states for binomial classification (Bohaboy et al. 2019) or censoring dead fishes for dispersal studies (Slagle et al. 2020), future release mortality and dispersal studies could take advantage of this approach. The sum of instantaneous component mortality rates could then be taken to obtain the total mortality rate (Z) and transformed to provide discrete survival (e^{-Z}) and mortality ($1-e^{-Z}$) estimates across time intervals of interest.

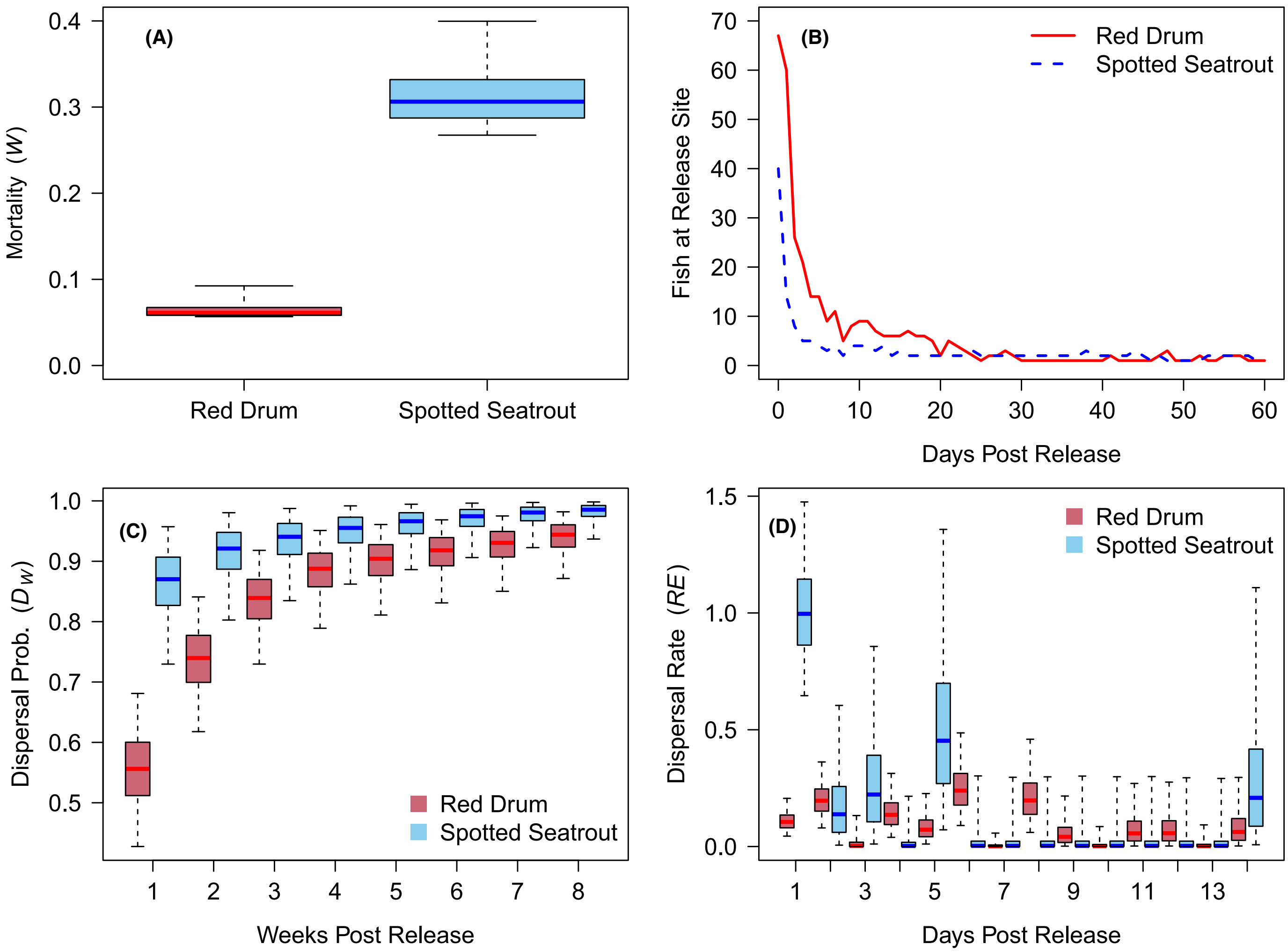

FIGURE 3. **(A)** Overall post-weigh-in mortality estimates (≤3 d of Red Drum and Spotted Seatrout following release at the Alabama Deep Sea Fishing Rodeo, **(B)** the number of live fish detected at the release site each day that were not previously detected elsewhere, **(C)** the species-specific cumulative weekly dispersal probability, and **(D)** the species-specific daily dispersal rate. In each box plot, the posterior median estimate is the bar, the box limits are the 25% and 75% quartile estimates, and the whiskers are the 95% posterior CrI (2.5% and 97.5% quartiles).

Study Considerations and Future Recommendations

We were able to quantify mortality after fish arrived at the weigh station; however, we did not have information on tournament mortality prior to this point. Given that tournaments may increase fishing pressure (Schramm et al. 1991b) and anglers likely only retained fish that could place in the live-weigh-in, it is likely that more fish were caught and released, and potentially harvested, then what we observed (Allen et al. 2004). Furthermore, catch-and-release mortality associated with tournaments has been shown to be higher than recreational catch-and-release mortality (Kerns et al. 2016). Therefore, additional catch-and-release mortality could have increased overall tournament mortality beyond our estimates, but we could not account for this in our study design. To generate a more complete picture of live-release tournament mortality, future work could strive to obtain this information with directed creel surveys, similar to Allen et al. (2004).

An additional caveat of our mortality estimates is that surgery mortality and post-weigh-in mortality could not be disentangled. This mortality entanglement occurred because we could not use censorship intervals to account for tagging mortality as in other studies (e.g., Bacheler et al. 2009a; Ellis et al. 2017; Nelson and Powers 2020). Given that 2.82% of Red Drum and 11.11% of Spotted Seatrout died in the observation tank, tagging mortality may have elevated our post-weigh-in mortality estimates. However, similar-sized Spotted Seatrout and Red Drum implanted with acoustic transmitters had no observed surgery mortality in laboratory studies (Bacheler et al. 2009a; Ellis et al. 2017). Furthermore, 97% survival of Spotted

Seatrout after tag implantation has been observed in laboratory studies elsewhere (Callihan et al. 2013). Low rates of inferred surgery mortality have also been observed in the field for both species (Ellis et al. 2017; Nelson and Powers 2020). Although surgery mortality may have biased our mortality estimates high, censoring all observed tank deaths would have resulted in an overly negative bias in our estimates. Furthermore, potential surgery mortality individuals may have survived surgical procedures if it were not for other tournament induced stressors (Siepker et al. 2007). Therefore, we retained these observed mortalities to provide an encompassing estimate of post-weigh-in mortality. External attachment of acoustic transmitters can overcome surgery effects in postrelease mortality studies (Curtis et al. 2015; Dance et al. 2016; Runde and Buckel 2018; Bohaboy et al. 2019; Runde et al. 2020) and should be considered for future studies of live-release tournaments.

The censorship period after acoustic telemetry surgeries also accounts for the assumption that surgery does not affect fish behavior and movement (Cooke et al. 2011; Hondorp et al. 2015). In the laboratory, Spotted Seatrout implanted with acoustic tags exhibited no differences in schooling behavior when compared to untagged individuals and returned to feeding within 24 h (Callihan et al. 2013). Additionally, no behavioral differences were observed in Red Drum after transmitter implantation; fish resumed feeding within 0–2 d (Bacheler et al. 2009b). In sturgeon *Acipenser* spp., swimming performance was also not affected by transmitter implantation in laboratory (Miller et al. 2014) and field studies (Hondorp et al. 2015). However, when tag burdens were large, the swimming performance of juvenile salmonids was affected (Collins et al. 2013). Given that the weight of V13 tags was ≤1.57% of fish weight for all individuals in our study, it is likely that tag burden was not an issue and transmitters did not affect swimming ability. Although we could not use a censorship interval and are uncertain how tag implantation may affect fish dispersal, the above evidence indicates that dispersal tagging effects were likely minimal.

Our estimates of mortality and dispersal were also sensitive to detection probability. For a fish state to shift from live at the release site to a successful dispersal, it needed to be detected away from the release location. Detection probability decreased as fish presumably left the release site, which increased the uncertainty surrounding dispersal timing, dispersal estimates, and mortality estimates. Given this decrease in detection probability, we could not assess delayed release mortality and our mortality estimates were limited to 3 d postrelease. However, long-term Spotted Seatrout catch-and-release mortality is low (0–1.9%; Stunz and McKee 2006; James et al. 2007), and all inferred mortalities were observed within 3 d. Furthermore, short-term postrelease mortality has been estimated within this timeframe (Matlock et al. 1993; Malchoff and Heins 1997; James et al. 2007), and survival estimates of tournament-released black bass matched uncaptured individuals 3 d after release (Sylvia and Weber 2019).

Increasing receiver coverage near release locations would likely increase detection probability, improve fate assignment, and decrease uncertainty in future studies. Deploying receiver gates with 100% detection efficiency 500 m away from release locations should detect all successfully dispersed individuals in studies that employ similar dispersal criteria. This distance is a common dispersal definition that has been used in black bass dispersal studies (Richardson-Heft et al. 2000; Brown et al. 2015; Slagle et al. 2020) and could be adopted for inshore marine species. Increasing receiver coverage may also help with mortality identification and allow for longer term post-weigh-in mortality estimates to be generated (e.g., 14–30 d; Runde and Buckel 2018; Kerns et. al 2016). Active relocations may also help with detection probability in future studies, but the efficiency of this approach should be considered. In our study, active relocations within 1.5 km of release may have increased detection probability. However, any active tracking beyond this distance would have been inefficient given the large water bodies surrounding the release site.

We also assumed that tags with continuous detection histories represented fish mortality and that mobile tags detected away from the release site represented live fish. Tag expulsion near a receiver could bias mortality estimates high; however, expulsion is negligible in both study species (Bacheler et al. 2009a; Ellis et al. 2017) and we assumed it did not occur. Released fish predation could bias mortality low if depredated tags were detected on receivers other than the ones at the release site. Two piscivores in the estuary are Atlantic bottlenose dolphins *Tursiops truncates* and juvenile Bull Sharks *Carcharhinus leucas*. However, fish were above the typical size ranges (≤400 mm TL) taken by dolphins (Barros and Wells 1998; Gannon and Waples 2004) and likely too large to be eaten by the juvenile Bull Sharks (mean shark fork length 679 mm) collected in Mobile Bay (Bethea et al. 2015). Predation was likely negligible, but future studies of tournament postrelease mortality could employ predation detection acoustic tags and larger receiver arrays to detect potential predation.

Additional Research and Conclusions

Although our study provided live-release tournament mortality and dispersal rate estimates, there are many factors that may have affected mortality and dispersal of Red Drum and Spotted Seatrout that we did not assess here. Hooking location impacts catch-and-release mortality of these species (Jordan and Woodward 1992; Murphy et al.

1995; James et al. 2007) and should be assessed in future inshore marine tournament studies, as in James et al. (2007). Angler experience is also a major driver of catch-and-release mortality and should be investigated in the context of both fishing and live fish transport experience (Diodati and Richards 1996; Stunz and McKee 2006; Landsman et al. 2011). Similar to previous work with black bass tournaments, additional research could also evaluate how transport distances, live-well treatments, and abiotic release conditions may affect mortality and dispersal (e.g., Schramm et al. 1987; Schramm and Gilliland 2015; Sylvia and Weber 2019). Our study was also not designed to test the ability of released fish to return to their original capture location (homing), but future studies with simulated tournament transport and release (e.g., Richardson-Heft et al. 2000; Norris et al. 2005; Brown et al. 2015) could test this ability. Finally, determining the ratio of tournament to overall mortality (Allen et al. 2004; Kerns et al. 2016) may elucidate how tournaments affect Red Drum and Spotted Seatrout populations.

Most fish of both species survived tournament and tagging procedures and dispersed from the release site. Red Drum fisheries may benefit most from live-release tournaments given that maximum mortality was <10%, but Spotted Seatrout fisheries can also benefit, especially if considerations are made to further reduce tournament mortality. If live-release tournament categories are going to be an effective conservation tool, the mortality from these categories needs to be compensatory instead of additive with other tournament mortality. One way to ensure that this occurs is to move all tournament categories for Red Drum and Spotted Seatrout to live-release. However, in three of the four Alabama live-release tournaments we know of, live and traditional weigh-ins run concurrently. Moving live-release tournaments away from summer when elevated water temperatures could contribute to mortality may also be a wise decision; however, the timing of the tournament studied here is fixed. The other three live-release Alabama tournaments occur in the fall and winter, so Spotted Seatrout mortality may be reduced (e.g., James et al. 2007) and should be investigated in the future. Although we do not know the ratio of tournament mortality to recreational harvest for these species, live-release tournaments may be able to relieve some harvest pressure on heavily exploited inshore marine fisheries and research validating their usefulness should continue.

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SUPPORTING INFORMATION

Additional supplemental material may be found online in the Supporting Information section at the end of the article.