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MANAGEMENT BRIEF

Bycatch in a Coastal Black Drum Trotline Fishery

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Abstract
Bycatch remains a challenging issue for many fisheries across the globe. Due to the cost and effort of (bycatch) observer programs, many fisheries—particularly those not in U.S. federal waters—operate with little information about bycatch. The Black Drum *Pogonias cromis* and Sheepshead *Archosargus probatocephalus* fishery in Louisiana comprises one of the largest fisheries by volume and in recent years has exceeded US$5 million in annual value. The vast majority of Black Drum and Sheepshead are harvested by the baited trotline fishery that operates in state waters. Very little is known about the bycatch from this fishery; however, because of the magnitude of the fishery quantifying bycatch is needed for the management of this resource. We observed 59 baited trotline sets on 13 different dates spanning 2 years of sampling (2020–2021). The total bycatch ($n = 1{,}392$) was similar in number to the harvest of the target species ($n = 1{,}265$). However, most bycatch species were nongame fishes and were released alive. Of all the bycatch caught, only 4% was dead and the majority of that 4% (47 out of 57 fish) consisted of Gafftopsail Catfish *Bagre marinus* and Hardhead Catfish *Ariopsis felis*, both species for which there is little fishery and no known issues with the populations. We also found that catch rates for bycatch did not vary by season or between the two areas fished. The catch rate of bycatch did not increase as the catch rate of target species increased; although, as expected, bycatch mortality did significantly increase as water temperature increased. Overall, the baited trotline fishery for Black Drum and Sheepshead catches about one individual of bycatch for one target individual; however, the overall extremely low bycatch mortality (of common species) suggests that this fishery operates with few adverse effects on nontarget species.

Most fisheries are managed through attempts to control fishing mortality, which is often documented as commercial and recreational harvest. However, the effects of bycatch on fishes—including everything ranging from temporary physiological stress all the way to mortality (Wilson et al. 2014)—can be an added pressure on a fishery through reducing the quantity and quality of the fished population. Most fishing methods have some amount of bycatch, although the attributes of bycatch can vary greatly depending on gear characteristics and how and when the gear is fished. Bottom trawls have long been the example of bycatch problems in fisheries writ large (e.g., Andrew and Pepperell 1992); however, bycatch effects are highly variable and many fishing gears have relatively little bycatch—most or all of which may survive. One limitation to fully assessing a fishery and developing effective regulations often comes from the fact that bycatch is not well understood or quantified, meaning that the effects of bycatch are not accounted for during assessment or management. Although there is an increasing number of bycatch studies in the literature (reviewed in Soykan et al. 2008), the number and diversity of active fisheries far outpaces the accumulation of bycatch information.

Black Drum *Pogonias cromis* and Sheepshead *Archosargus probatocephalus* comprise one of the top commercial finfish fisheries in Louisiana and the western Gulf of Mexico (hereafter we will simply refer to it as the "Black Drum fishery" due to the relative importance of Black Drum as a target species). Although the species are similar in many ways, Black Drum tend to dominate the landings. From 2015 to 2020, approximately 3.5 million pounds of Black Drum were annually landed in Louisiana, compared with about 1.5 million pounds of Sheepshead. Black Drum is valued around US$1 per pound and Sheepshead is valued at about half of that. Combined, these two species have a current value of 4–5 million dollars per year

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(https://www.fisheries.noaa.gov/national/sustainable-fisheries/commercial-fisheries-landings). Despite the consistently high landings, commercially licensed Black Drum fishers have declined during the past two decades; over 900 licenses were sold in 2000, whereas only 306 were sold in 2017 (Adriance et al. 2019). Both species are fished year-round, with some seasonal increases and decreases; for example, there is a clear price increase in the summer when Black Drum typically exceeds $1 per pound. Both species also have a minimum size (406 mm total length for Black Drum and 254 mm fork length for Sheepshead), but Black Drum effectively have a slot with an upper size limit of 686 mm (and a quota of 300,000 individuals >686 mm, which means that some large fish are targeted and harvested).

The Black Drum fishery in Louisiana grew substantially in the late 1980s when increased regulations on Red Drum *Sciaenops ocellatus* reallocated effort to Black Drum, which are of similar market quality. In 1997 Louisiana prohibited trammel nets, gill nets, and seines, at which point the use of baited trotlines increased dramatically and has since become the dominant fishing gear for Black Drum in state waters (Adriance et al. 2019). Baited trotlines are used to harvest both Black Drum and Sheepshead but are the dominate gear for Black Drum. Baited trotlines have yielded landings of 2.5 to 3 million pounds of Black Drum annually over the last decade, which greatly exceeds the combined Black Drum landings from handlines, fish trawls, shrimp trawls, and skimmer nets. Given the size of the Black Drum fishery and the dominance of baited trotlines, recent knowledge gaps have been identified about bycatch in this fishery. A recent comprehensive Fishery Management Plan (Adriance et al. 2019) identified the evaluation of bycatch and discards as a research need for informed management decisions.

Studies of bycatch in the northern and western Gulf of Mexico's state waters are relatively rare, although over the past decades some work has been done to better understand bycatch that is associated with baited trotlines. McEachron et al. (1985) compared two hook types that are used on trotlines in Texas and found that circle hooks caught over three times more fish of all species than did straight-shanked hooks. McEacheron et al. (1987) also reported that fishing trotlines on the bottom instead of the water column (where water column hooks were set ≥0.6 m from the surface) greatly reduced the catch of all non-Black Drum species. However, since the 1980s little work has been done to quantify Black Drum bycatch or further understand trotline gears. Baited trotlines are anecdotally reported to have relatively low bycatch, and other studies have reported on low bycatch mortality related to hooking duration (Steffensen et al. 2013). Yet, to date, no scientific study has documented bycatch rates and fates for the Black Drum trotline fishery.

The objectives of this study were part descriptive and part analytical. Without knowing what species would be observed as bycatch, the first part of the study was intended to provide descriptive results about the species, catch rate, and timing of bycatch that are associated with commercial trotline fishing. The analytical part of the study was intended to explore catch rates over space and time for Black Drum and Sheepshead and then use the bycatch data to quantify how bycatch related to catch rates of the target species. Finally, we wanted to examine the available environmental factors that might account for the probability of dead discards.

METHODS

Field observations.— The trotline fishery for Black Drum and Sheepshead operates year-round in coastal Louisiana (although landings are not equal across coastal basins). Through the Louisiana Fisheries Forward program (a joint venture between Louisiana Sea Grant and Louisiana Department of Wildlife and Fisheries), we arranged for observers on commercial trotline fishing trips throughout 2020. Due to a number of issues, including the onset of the COVID-19 pandemic, fishery observations had to be unexpectedly continued into 2021 (see Results). For each trip, one observer would be aboard a fishing vessel and record the characteristics (without engaging in fishing activities) of the trotline set and resulting catch. The observers recorded the *date*, *coordinates*, *number of hooks*, and *species* caught for each set. A *set* is the line or lines set out at one time that used between 100 and 1,600 circle hooks (size 8/0) fished on the bottom at a unique coordinate location. We used *set* as the observational unit because sets are spatially unique and take place across seasons. (Note, although state regulations required a maximum of 402 meters and 660 hooks per line set, our definition of *set* includes all lines with a shared coordinate, which is why some of our sets exceed 660 hooks.) Water depth was not a variable of interest because it was consistent across sites; nearly all sites were between 2 and 3 m in depth with little variation. Additionally, blue crab *Callinectes sapidus* claws were used as bait in the vast majority of sets (96%) and due to its ubiquity, we did not analyze bait. The trotline soak times were typically around 12 h, with deployment the night before retrieval (although observers were not part of deployment, so exact soak times are not known).

All of the fish were visually estimated for size, but those estimates were often compared with reference measurements on the boat (with size-bins based on Louisiana Department of Wildlife and Fisheries size regulations). The fate of each fish caught was also categorized into *caught* (for fish that were harvested) or *released* (for those returned to fishing grounds). Released fish were further categorized into *alive* or *dead*. The observers would look for any physical signs of death (missing flesh or body parts, a stiff body, and sunken or cloudy eyes), decomposition, or lack of movement. For signs of movement (alive), the observers looked for movement of the gills and whether the fish moved under its own power as the hook was removed. Additionally, upon release, swimming away indicated a live fish and floating indicated death. In general, we attempted to follow the reflex action mortality predictor (Davis 2010) guidelines but were limited to gross physical observations. In addition to the observed data, salinity and water temperature for each set were obtained from historical data from the National Oceanic and Atmospheric Administration (NOAA 2021) and United States Geological Survey (USGS 2021). Finally, we calculated *catch rate* as the number of individuals that was caught, standardized to the number of hooks on a set.

Data analysis.— First we sought to descriptively report bycatch (e.g., species, catch over time) because we were unsure what species would be observed along with their distribution across time and place. Second, we used statistical models to quantify how both target catch and bycatch were affected by the variables *season* and *region*. Specifically, we used a two-way ANOVA with independent variables of (meteorological) *season* and *region* to test for differences in *target catch rate* (or CPUE, calculated as the count of fish caught divided by the number of hooks) and (in a separate ANOVA) *bycatch catch rate*:

$$y_i = \alpha + \beta_j x_{1i} + \delta_k x_{2i} + \varepsilon_i,$$

where y_i is the *catch rate* of either target species or bycatch (both modeled but in separate models), α is the overall intercept, β_j is the effect of *season* (with $j = 4$ levels: winter, spring, summer, fall), x_{1i} is the indicator variable for *season*, δ_k is the effect of *region* (with $k = 2$ levels: Lake Calcasieu and Vermilion Bay), x_{2i} is the indicator variable for *region*, and ε_i is the residual error, assumed to be normally distributed with a mean of 0 and variance of σ^2. The subscript *i* is used to index the observation level and applied to observed variables in the model.

We used a simple linear regression to test for a relationship between *target catch rate* and *bycatch catch rate*, which would tell us whether bycatch increased, decreased, or was unaffected by target catch rate.

$$y_i = \alpha + \beta x_{1i} + \varepsilon_i,$$

where y_i is the *bycatch catch rate* from set *i*, α is the intercept, β is the effect of *target species catch rate*, x_{1i} is the *target species catch rate*, and ε_i is the residual error, assumed to be normally distributed with a mean of 0 and variance of σ^2.

To evaluate the environmental variables that influence dead discards, we took all events of any bycatch discards (of which dead discards, if any, are a component) and created a binomial response whereby 1 indicated dead discards present in the bycatch and 0 indicated no dead discards present in the bycatch. A binomial generalized linear model was used:

$$y_i = \alpha + \beta x_{1i} + \delta x_{2i} + \varepsilon_i,$$

where y_i indicates the presence (1) or absence (0) of *dead discards* in the bycatch, α is the overall intercept, β is the effect of *water temperature*, x_{1i} is the *water temperature* in Celsius, δ is the effect of *salinity*, x_{2i} is the *salinity* in parts per thousand, and ε_i is the residual error, assumed to be normally distributed with a mean of 0 and variance of σ^2. The subscript *i* is used to index the observation level and applied to variables in the model.

Although some sets occurred on the same day and therefore date could be considered the observational unit, (1) different sets on the same date were fished in different locations and (2) an ANOVA testing the effect of *date* on CPUE was nonsignificant and an intraclass correlation coefficient (Nakagawa et al. 2017) added to the linear regression for target versus bycatch cate rates was only 0.3, indicating weak evidence for an effect of *date*. All models were run in R version 4.2.0 (R Core Team 2022).

RESULTS

A total of 59 trotline sets were observed on 13 different sampling dates ranging from January 24, 2020, to December 15, 2021. The effects of the COVID-19 pandemic (lockdowns, travel restrictions, and temporary reduced markets for fish) both decreased the total number of sampling dates from our original design and extended the work in 2021. Additional sampling events were lost due to engine trouble, weather, and other routine challenges to commercial fishing. Between 2 and 8 sets were recorded on a given sampling date, and in total 24,100 hooks were fished (ranging between 100 and 1,600 hooks per set with a median of 300; full metadata on the sets is available in the Supplement available in the online version of this article). The sets were roughly balanced across seasons (13 winter sets, 14 spring sets, 15 summer sets, and 17 fall sets) and region (27 Vermilion Bay sets and 32 Calcasieu Lake sets). The vast majority of sets (56/59, or 95%) caught the target species of Black Drum or Sheepshead. Seven species including Black Drum (the primary target species) were represented among the 1,265 individual fish that were caught and harvested. Of these seven species, Black Drum comprised 81% of the harvest (Figure 1; the other species included Alligator Gar *Atractosteus spatula*,

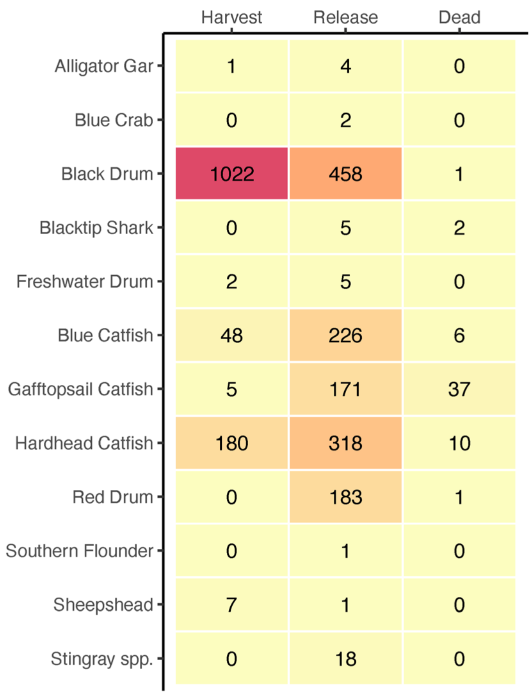

FIGURE 1. Counts of *harvested* ($n = 1{,}265$), *released* bycatch ($n = 1{,}392$), and *dead* bycatch ($n = 57$) species recorded from 59 trotlines from 13 trips spanning January 2020 to December 2021. The counts are presented as numbers in the cells, and the cell colors correspond to the numbers.

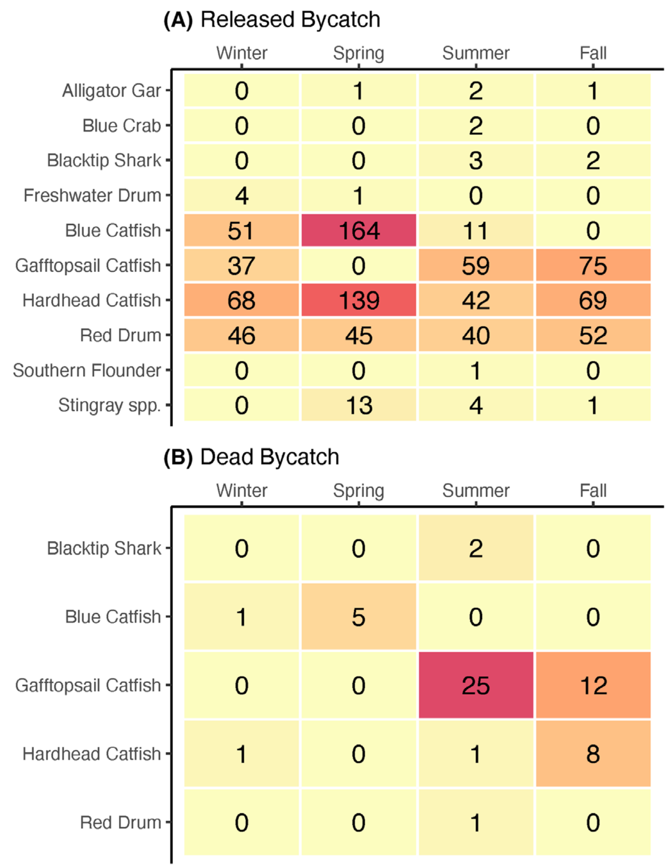

FIGURE 2. **(A)** Released bycatch and **(B)** dead bycatch species by season, recorded from 59 trotlines from 13 trips spanning January 2020 to December 2021. The counts are presented as numbers in the cells, and the cell colors correspond to the numbers (with color ranges endemic to each panel). Note that 458 Black Drum were released (174 in winter, 59 in spring, 129 in summer, and 96 in fall) because they were outside the slot limit (most were over the slot limit).

Freshwater Drum *Aplodinotus grunniens*, Blue Catfish *Ictalurus furcatus*, Gafftopsail Catfish *Bagre marinus*, Hardhead Catfish *Ariopsis felis*, and Sheepshead). Twelve species made up 1,392 individual fish that were caught and released alive. In addition to the harvest species, blue crab, Blacktip Shark *Carcharhinus limbatus*, Red Drum, Southern Flounder *Paralichthys lethostigma*, and stingray (family Dasyatidae) were also taken. It is worth noting that Black Drum was the most common species that was released ($n = 458$) because they were outside the size limits. However, a limited number of oversized fish are allowed to be kept, so we did not consider them bycatch and excluded them from our analyses of bycatch. Only 57 individual fish (representing 4% of the total bycatch represented by six species; Figure 1) were recorded as dead when released. The seasonal breakdown of released bycatch included 10 species, of which only five were represented in the dead bycatch (Figure 2). When considering all of the bycatch species that were released, Blue Catfish, Gafftopsail Catfish, Hardhead Catfish, and Red Drum were the four most commonly caught bycatch, with species counts variable across seasons. Blue Catfish and Hardhead Catfish peaked in abundance in the spring months, whereas not a single Gafftopsail Catfish was recorded in the spring. Red Drum were captured and released nearly uniformly across seasons. Dead bycatch was rare (4% of all bycatch) when considering the total amount of bycatch, and Gafftopsail Catfish in summer and fall accounted for the majority (65%) of dead discards.

The two-way ANOVA (with type II sums of squares) that we used to examine for effects of *season* and *region* on *target catch rates* reported no significant effect of *season* ($F = 1.543$, $P = 0.214$; Figure 3A) but a significant effect of *region* ($F = 5.339$, $P = 0.0247$; Figure 3B). The catch rates for Black Drum in Vermilion Bay were significantly higher than were those in Calcasieu Lake. The two-way ANOVA (with type II sums of squares) that we used to examine for effects of *season* and *region* on *bycatch catch rates* reported no significant effect of *season* ($F = 1.423$, $P = 0.246$; Figure 3C) and no significant effect of *region* ($F = 0.268$, $P = 0.607$; Figure 3D).

The simple linear regression examining *target catch rates* on *bycatch catch rates* was nonsignificant (β

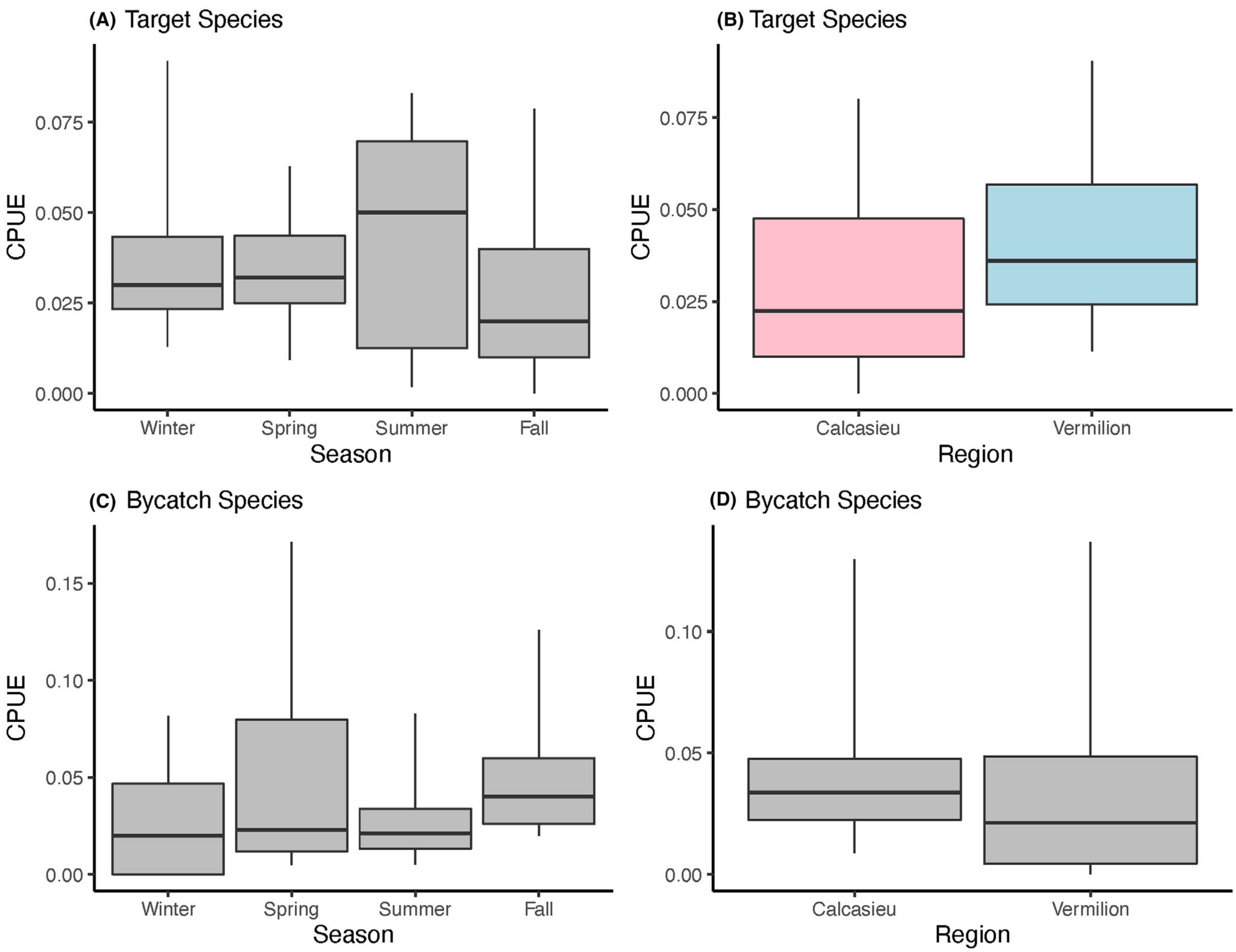

FIGURE 3. Box plots of **(A)** target species CPUE by season, **(B)** target species CPUE by region, **(C)** bycatch species CPUE by season, and **(D)** bycatch species CPUE by region. Panel B illustrates the only comparison that revealed a statistically significant difference between groups, which is indicated by the different colors (whereas the gray boxes in other panels indicate no significant differences between or among groups). For all of the box plots, the box represents the interquartile range, with the median shown by the thick black line within the box. The whiskers extend to the 95% quantiles.

= −0.185, SE = 0.238, $P = 0.439$; Figure 4A); increasing catch rates of the target species did not increase catch rates of the bycatch species. Finally, the binomial generalized linear model examining *water temperature* and *salinity* on the probability of *dead discards* in the bycatch found a significant effect of water temperature ($\beta = 0.130$, SE = 0.036, $P < 0.001$) and a nonsignificant effect of salinity ($\delta = -0.058$, SE = 0.046, $P = 0.205$). The effect of water temperature suggested that the probability of dead discards increased as water temperature increased but remained relatively low at only 25% probability of one or more dead discards in a set at the warmest (summer) water temperatures (Figure 4B).

DISCUSSION

Although bycatch remains a serious issue in many fisheries across the globe, it is not a universal problem in all fisheries. Furthermore, when fisheries operate with minimal or no bycatch they should be recognized because they provide examples of efficient and targeted harvest of fish. Interpreting bycatch in our study is relative. We do not know of any comparable studies of Black Drum trotline bycatch for comparison, and even the units of bycatch (e.g., counts of fish vs. biomass) can create different interpretations. The baited trotline fishery for Black Drum in Louisiana does encounter a seemingly high amount of bycatch when examining the raw counts of fish: 1,265

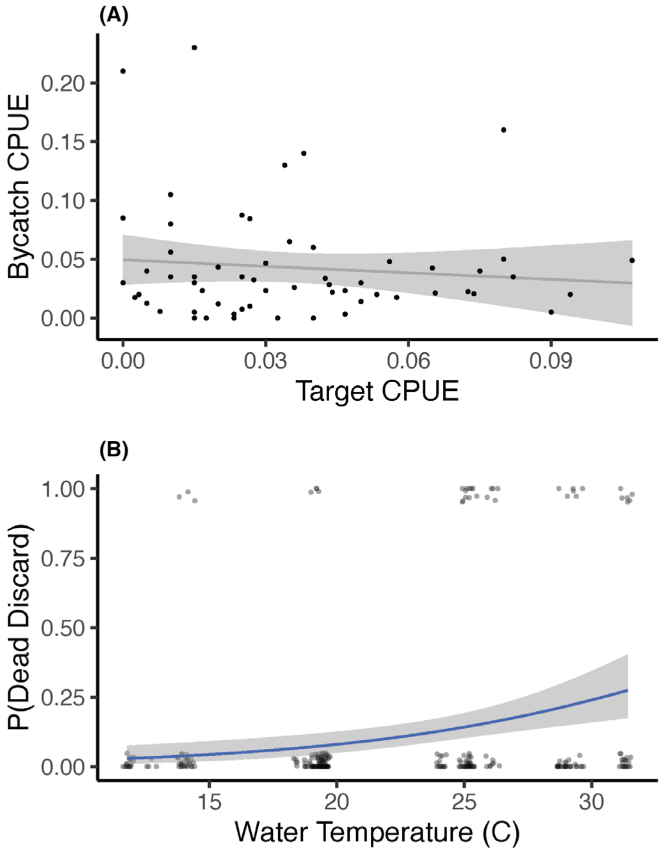

FIGURE 4. Panel **(A)** shows the relationship between target species CPUE and bycatch species CPUE, with observed CPUE values shown with black dots and the linear relationship represented with the gray line and gray uncertainty region. The linear relationship is nonsignificant and shows that as target species CPUE increases, bycatch CPUE does not increase. Panel **(B)** shows the relationship between water temperature and bycatch condition. The observed data (occurrences of bycatch capture) are shown as jittered points either alive (represented at 0) or dead (represented at 1). The blue line and gray uncertainty region represent the binomial model fit and show a significant effect of increasing water temperature increasing the probability of dead bycatch.

target fish compared with 1,392 bycatch fish over 59 trotline sets. However, a closer look at the bycatch should reduce some of the concern. First, the total bycatch was comprised of 33% Black Drum (the majority of which were oversized and outside the slot limit quota), 51% catfishes that have no known population issues, and 13% Red Drum. Second, only 4% of all bycatch was observed as dead—93% of which were catfish species. So, although the bycatch numbers may seem relatively high, the bycatch species are commonly encountered (none were threatened or endangered) and we did not observe marine mammals, sea turtles, or other species of concern. We acknowledge that the bycatch that we recorded as alive was based on behavior, which is imperfect data and results in a conservative mortality estimate. No discard survival or mortality was able to be estimated once the fish were released back in the water, and we had to make assumptions about health and survival based on established characteristics and behaviors.

Ignoring the Red Drum and oversized Black Drum—both of which had negligible bycatch mortality—catfishes were the only other group that comprised a substantial portion of bycatch. Blue Catfish are typically considered a freshwater catfish, but they can live in estuarine environments (Nepal and Fabrizio 2019) and are commercially and recreationally targeted. Gafftopsail and Hardhead catfishes were recently found to have greater longevity than previously has been assumed (Flinn et al. 2019), yet they still grow fast and reproduce relatively early in life (Pensinger et al. 2021). Although knowledge of catfish populations in Louisiana waters is imperfect, no state assessments have been done because the populations appear to be stable and there is no strong fishery for any particular catfish species, especially the marine catfishes. The near-complete disappearance of marine catfishes in the U.S. southeastern Atlantic (Ballenger 2018) does serve as a cautionary note that without information even abundant species can quickly decline. However, it would be unwise to draw too many parallels to Atlantic basin marine catfishes, as the causes of the decline remain a mystery.

Overall, we found few concerning effects of season, region, or water temperature on target catch or bycatch, which collectively suggest that there are no obvious characteristics of the fishery that contribute disproportionally to bycatch. The target catch rates were consistent across season, and as catch rates increased we found no evidence of any increase (or decrease) in bycatch catch rates. This is a promising result and suggests that during times of high Black Drum catch no additional pressure is placed on the bycatch species. Water temperatures did effect bycatch mortality (as expected), although dead discards remained relatively low even in warmer temperatures and there may be fishing modifications (shorter soak times) that could be used in warmer seasons to reduce dead discards. The slightly higher catch rate of target species in Vermilion Bay compared with Calcasieu was an interesting finding, although we did not have an explicit hypothesis that one location would be more productive than the other. Although the effect of region was significant, this could be due to habitat or simply capturing the temporal fluctuations and productivity that occur in both regions (e.g., Vermilion Bay may currently be in a period of higher productivity then Calcasieu, although productivity trends could reverse in the future).

Although we focused on Black Drum throughout this study, Sheepshead are routinely included as a target species in the trotline fishery. Despite their targeted status, there were relatively few captures of Sheepshead, which have a smaller size limit than Black Drum and no annual harvest limit over a year-round season. We do not know exactly why Sheepshead were caught infrequently (compared with Black Drum), but it is likely that the habitats being fished were more favorable to Black Drum or they are more abundant in regions of the fishery that were not within our study domain. Adult Sheepshead are associated with structure—jetties, piers, etc.—and the longlines that were used in this study were unlikely to be in close proximity to larger structures. Recent stock assessment work has concluded that both Sheepshead (West et al. 2020a) and Black Drum (West et al. 2020b) are not overfished and overfishing is not occurring. The populations of both species appear to be in good condition, and in some years the Black Drum harvest limit is not met. The resulting picture is of a trotline fishery that operates with very low bycatch mortality, and it does not appear to pose a current threat to the target species, specifically Black Drum. We are limited in concluding much about the Sheepshead part of the fishery because we rarely encountered them; however, given their biological and ecological similarity to Black Drum, there are no obvious concerns. Future work would benefit from trotline sets that catch more Sheepshead than the trotlines in our study. Despite the current success of Black Drum and Sheepshead management, future research should consider bycatch across different regions of coastal Louisiana and improving estimates of discard mortality.

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SUPPORTING INFORMATION

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