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ARTICLE

Spatial and temporal variation in exploitation rates of the Louisiana blue crab spawning stock

Helen D. Olmi-Graham | **M. Zachary Darnell**

Division of Coastal Sciences, School of Ocean Science and Engineering, The University of Southern Mississippi, Ocean Springs, Mississippi, USA

Correspondence
Helen D. Olmi-Graham
Email: helen.olmi@usm.edu

Abstract

Objective: Blue crabs *Callinectes sapidus* support one of our nation's most valuable fisheries, and Louisiana has led national landings from 2012 to 2021. Fishery-independent estimates of abundance have declined in recent years; in 2015, the Louisiana spawning stock biomass reached the lowest point ever recorded. Management efforts for the blue crab spawning stock have been hindered by incomplete knowledge of the dynamics of natural and fishing mortality. The purpose of this study was to examine spatiotemporal variation in exploitation rates of the Louisiana blue crab spawning stock.

Methods: From 2016 to 2017, we conducted a mark–recapture study in three Louisiana estuaries. During this period, we tagged 6133 mature female blue crabs, of which 964 were recaptured. Exploitation rate estimates were calculated using recapture data. In 2018, Louisiana implemented a 2-month female harvest prohibition; to examine impacts of this harvest prohibition on exploitation rates of female blue crabs, we tagged additional females before, during, and after the harvest prohibition.

Result: Overall exploitation rate estimates for 2016–2017 ranged from 0.27 to 0.30 (i.e., 27–30%), but significant spatial and temporal variation was observed. During 2018, estimated exploitation rate without the harvest prohibition was 0.16–0.18, but with the prohibition, exploitation rate decreased to 0.08–0.09, indicating that this management action was effective in reducing mortality of mature females.

Conclusion: Nearly one-third of mature female blue crabs in southeastern Louisiana are captured in the fishery at some point during their life. The 2018 female harvest prohibition reduced exploitation rate of mature females by ~50%. These spatiotemporal estimates of exploitation rate will be directly applicable to future Louisiana blue crab management plans and stock assessments.

KEYWORDS

blue crab, exploitation rate, fishing mortality, Louisiana, spawning stock

INTRODUCTION

The blue crab *Callinectes sapidus* is one of the most commercially and ecologically significant species in the United States (Hines et al. 1990; National Marine Fisheries Service 2022). Coastwide U.S. commercial landings in 2021 totaled over 53,070 metric tons for a dockside value of US$240 million (National Marine Fisheries Service 2022). Blue crabs also play a major role in structuring faunal communities (Hines et al. 1990; Wolcott and Hines 1990; Lipcius and Stockhausen 2002; Bromilow and Lipcius 2017). Blue crab landings and estimates of abundance fluctuate dramatically year to year, and many regions have seen decreases in landings and abundance in recent years (National Marine Fisheries Service 2022). Management efforts for the fishery have been hindered by an incomplete understanding of blue crab life history and the dynamics of natural and fishing mortality, in particular spatial and temporal variation in fishing effort and exploitation rates in the commercial and recreational fishery (Cagle and Isaacs 2022).

Blue crabs have a migratory life cycle and inhabit both estuarine and offshore habitats. The life cycle begins offshore as zoeae larvae develop in the plankton (Epifanio et al. 1984; Milliken and Williams 1984; Johnson and Perry 1999). After seven zoeal stages (~30–50 days), blue crab zoeae metamorphose into megalopae (Costlow and Bookhout 1959), which are transported into estuaries by surface currents (Perry et al. 1995; Rabalais et al. 1995; Ogburn et al. 2009, 2012), where they settle and metamorphose into the first juvenile stage in structured habitats, including seagrass beds and marsh edges (Heck and Thoman 1984; Orth and Van Montfrans 1987). This estuarine ingress occurs throughout the warm months, with peaks in recruitment generally occurring from midsummer through fall in the Gulf of Mexico (Rabalais et al. 1995). Juvenile blue crabs remain in these habitats until later juvenile stages when they begin to disperse throughout the estuary (Blackmon and Eggleston 2001; Reyns and Eggleston 2004) and move into unstructured habitats once they reach a size that provides a refuge from predation (Pile et al. 1996). Blue crabs reach maturity in 10–20 months after hatching, after undergoing 18–20 postlarval molts (Milliken and Williams 1984). After the female crab's terminal, pubertal molt, mating takes place primarily in shallow, marsh-lined tidal creeks (Wolcott and Hines 1990). Mating occurs nearly year-round in the Gulf of Mexico, and after mating females forage for several weeks before beginning their seaward spawning migration (Turner et al. 2003; Aguilar et al. 2005; Darnell et al. 2010b). Inseminated females migrate to the lower estuaries and coastal ocean, where they spawn multiple clutches of 2–5 million zoeae larvae (Prager et al. 1990; Hines et al. 2003; Darnell et al. 2009; Graham et al. 2012). Once females complete their spawning migration to high-salinity waters, they remain in the high-salinity waters of the lower estuary and coastal ocean (Van Engel 1958; Forward et al. 2005; Darnell et al. 2012; Kemberling and Darnell 2020). The spawning season in the northern Gulf of Mexico is protracted, with an extended peak in spawning throughout the warm months (April–November) and low-level spawning occurring year-round.

The spawning migration from low- to high-salinity waters is essential to ensure that larvae are released in salinities favorable for survival (>20‰; Costlow and Bookhout 1959). During the spawning migration, female blue crabs are exposed to heavy fishing pressure and are frequently caught in commercial crab pots (Rudershausen and Turano 2006). Although harvest of ovigerous females is prohibited in most states (Gulf States Marine Fisheries Commission 2015), harvest of nonovigerous mature females is generally permitted (though often with minimum size limits). Since blue crabs produce multiple clutches of eggs, many of these females are between clutches, and their harvest represents an underrecognized source of spawning stock mortality. Additionally, ovigerous females are frequently caught in pots by the commercial fishing sector, and though they may be released, the stress of trap confinement and handling can decrease survival rate and reproductive output (Ballance and Ballance 2004; Rudershausen and Turano 2006; Darnell et al. 2010a).

Impact Statement

Blue crabs support valuable commercial fisheries throughout much of their range. This study estimated that nearly one-third of the Louisiana blue crab spawning stock (i.e., mature females) are harvested by the fishery at some point during their life.

Blue crabs support Louisiana's fourth largest commercial fishery, and Louisiana regularly leads the nation in blue crab landings (National Marine Fisheries Service 2022). Louisiana landings average 20,003 metric tons and $55.7 million per year (averages from 2010 to 2020) (National Marine Fisheries Service 2022). Louisiana maintains the only sustainable blue crab fishery certified by the Marine Stewardship Council, although fishery-independent estimates of abundance have declined in recent years and are trending below long-term averages as well as target reference points (West et al. 2022). Furthermore, the spawning stock biomass in 2015 was the lowest in history, and the fishery was overfished during 1995, 2013, and 2015 (West et al. 2022). Exploitable biomass in 2021 was the highest exploitable biomass since 2006, although it is unclear if this trend will continue (West et al. 2022). Management efforts for the fishery have been hindered by an incomplete understanding of blue crab life history and the dynamics of natural and fishing mortality. The data gaps have been highlighted by the Louisiana Department of Wildlife and Fisheries as critical to ensure continued sustainability of the fishery (West et al. 2022).

Although the Louisiana blue crab fishery spans the coast, over 80% of total blue crab landings in the state come from the Terrebonne, Barataria, and Pontchartrain basins, which together supply an average of ~14,500 metric tons per year (Cagle and Isaacs 2022). Terrebonne basin averaged ~5170 metric tons annually from 2000 to 2018, Barataria basin averaged ~3500 metric tons, and Pontchartrain basin averaged ~5783 metric tons with the highest dockside price per pound in the state (Cagle and Isaacs 2022). Louisiana also has a large recreational fishery, with over 6000 recreational crab trap licenses issued in 2018. Although there is a lack of long-term landings data for the recreational sector, it has been estimated at ~4.1% of the commercial harvest (Guillory 1998). The current management plan for the Louisiana blue crab stock is based on precautionary management benchmarks, including both target and limit reference points for spawning stock biomass and estimated fishing mortality (West et al. 2019). A 2016 stock assessment of the blue crab fishery in Louisiana found that after consecutive annual increases in fishing mortality, the stock was overfished in both 2013 and 2015 (West et al. 2016). Additionally, 9 of the last 10 estimates of juvenile abundance have been the lowest on record, with the exception of 1976 (West et al. 2022). The first statewide fishery closure was proposed in 2016 (West et al. 2016) and enacted in 2017, with a 30-day closure of the entire crab fishery from February 20 to March 22. In 2018, the Louisiana Wildlife and Fisheries Commission implemented a commercial harvest prohibition on female blue crabs from February 1 to March 31. Although recent management efforts have focused heavily on protection of the spawning stock, little quantitative data exists on exploitation rates of mature female blue crabs in the Louisiana commercial fishery.

The goal of this study was to quantify exploitation rates of the Louisiana blue crab spawning stock, focusing on the commercial fishery in the Terrebonne, Barataria, and Pontchartrain basins. Additionally, this study assessed the effectiveness of the 2-month female harvest prohibition in 2018. A better understanding of spatial and temporal variation in exploitation, as well as a quantitative analysis of the effect of fishery closure on exploitation rates, can improve understanding of the decline of the Louisiana blue crab spawning stock and better inform future management actions.

METHODS

Mark–recapture methods

A fishery-dependent mark–recapture study was conducted from 2016 to 2018, focusing on the Terrebonne, Barataria, and Pontchartrain basins and Breton Sound. Breton Sound is a subset of the Pontchartrain basin but is geographically separated by the Mississippi River Gulf Outlet canal and is evaluated as its own basin.

Mature female blue crabs were collected in collaboration with local commercial crabbers and marked with printed plastic tags (Figure 1). Each tag had a unique ID number, request for recapture data, offer of a reward when recapture data was reported ($5 or $50), and contact information. Tags were attached externally by 0.26–0.35-mm-diameter annealed 316 stainless steel wire wrapped around the lateral spines (Figure 1). This is a tagging method commonly used for blue crabs that does not impact survival and has a low rate of tag loss (Aguilar et al. 2005; Medici et al. 2006; Darnell and Kemberling 2018). Tag loss probability has been estimated to be 0.00067/day (Corrick 2018, based on Hines et al. unpublished data).

Blue crabs were released within ~30 min of collection tagging, typically within 2 km of the collection site. Blue crabs in poor health or missing both chelipeds, one or more

FIGURE 1 Tagged ovigerous blue crab.

swimming legs, or more than three total limbs were not selected for tagging. Tagging took place during four seasons each year in 2016–2017: spring (March 8–May 23), summer (July 1–September 23), fall (October 18–December 2), and winter (January 1–February 16). Recaptures were reported through both a toll-free telephone number and a Web-based form, with follow-up calls to obtain additional information and verify submitted information.

Estimation of exploitation rates

Tags used in the mark–recapture study consisted of both standard-value ($5 per recapture, ~95.4% of all tags) and high-value ($50 per recapture, ~4.6%) tags, allowing for calculation of reporting rates following Pollock et al. (2001). Reporting rate is the proportion of recaptured tags that are actually reported as some standard-value tags are caught and not reported. Following the tagging report estimation models (Pollock et al. 2001), we assumed that standard- and high-value tags were recaptured at the same rate and that all high-value tags recaptured were reported (i.e., reporting rate = 1), which allows for an unbiased estimate of the reporting rate for standard-value tags, using the following formula:

$$\lambda = \frac{R_s \cdot N_h}{N_s \cdot R_h},$$

where λ is the reporting rate (ranging from 0 to 1), R_s is the number of standard tags reported, N_s is the number of standard tags released, R_h is the number of high-value tags reported, and N_h is the number of high-value tags released. All reported recaptures were included in λ calculations, regardless of the reproductive state of the blue crab at the time of recapture. Reporting rates were calculated independently for each analysis described below, allowing us to adjust for underreporting and generate unbiased estimates of exploitation rate. Exploitation rate (μ), defined here as the proportion of females caught at any point during their mature lifetime, was calculated as follows:

$$\mu = \frac{\frac{R_{sn}}{\lambda} + R_{hn}}{N_s + N_h},$$

where R_{sn} is the number of nonovigerous standard-value tags reported and R_{hn} is the number of nonovigerous high-value tags reported. Recaptures of ovigerous females, while included in reporting rate calculations, were excluded from exploitation rate calculations as these females would have been released upon capture.

To attempt to develop a more accurate estimate of exploitation rate, these data were adjusted to consider natural mortality as well as tag loss, following a modification of the methods used by Corrick (2018). Reported values for natural mortality (M) for blue crabs varies quite substantially (Miller et al. 2005; Hewitt et al. 2007; Corrick 2018; West et al. 2019). We thus used two natural mortality rates: $M = 0$ (no mortality) and $M = 1$, with $M = 1$ representing the average natural mortality assumed in the most recent Louisiana blue crab stock assessment (West et al. 2022). We assumed a tag loss probability of 0.00067/day following Corrick (2018). Adjusted exploitation rates, corrected for natural mortality and tag loss, were calculated after scaling for the average time at large (T; the time between tagging and recapture) using the following equation:

$$\mu_M = \frac{\frac{R_{sn}}{\lambda} + R_{hn}}{\left(N_s + N_h\right)(1 - 0.00067)^T e^{-M\left(\frac{T}{365}\right)}}.$$

Baseline seasonal and spatial variation in exploitation rates

Baseline exploitation rates (μ and μ_M) were estimated using mark–recapture data from 2016 to 2017 as these represent "normal" years prior to the introduction of fishery closures and sex-specific harvest prohibitions. An overall estimate of exploitation rate was first developed using all data from 2016 to 2017. Basin-specific and season-specific estimates of exploitation rates were then developed using the same data set. Basin-specific exploitation rates represent the proportion of females originating in a particular basin that were caught at any point during their mature lifetime, while season-specific exploitation rates represent the proportion of females tagged in a particular season that were caught at any point during their mature lifetime.

Assessing the effectiveness of the 2018 female harvest prohibition

The effectiveness of the 2018 commercial female harvest prohibition was evaluated using mark–recapture data for blue crabs tagged in Pontchartrain and Barataria basins between February 9 and April 30, 2018, to assess exploitation rates associated with the female harvest prohibition that extended from March 1, 2018, to April 30, 2018. Exploitation rates were first calculated assuming that all nonovigerous female blue crabs that were recaptured (regardless of whether they were recaptured during the female harvest prohibition) were harvested. These estimates, following exactly the methods described above for 2016–2017, are denoted as "without closure" and represent estimated exploitation rates had the harvest prohibition not occurred. Exploitation rates were then calculated assuming that all females recaptured by commercial crabbers during the harvest prohibition were released (as harvest of these crabs was illegal). These estimates are denoted as "with closure" and represent estimated exploitation rates under the harvest restrictions implemented in 2018. Both scenarios used reporting rates calculated using the full 2018 data set.

RESULTS

Overall estimate of exploitation rate

During 2016–2017, a total of 6133 mature female blue crabs were tagged, with 964 (15.7%) reported as recaptured by March 2021 (Figure 2). Recaptures were reported by commercial crabbers ($n = 889$ recaptures), commercial shrimpers ($n = 23$), commercial fishermen (unknown target species, $n = 3$), and recreational crabbers/shrimpers/fishers ($n = 34$), and fishery sector was not reported for 15 recaptures. Most blue crabs that were recaptured (909 of the total 964 recaptured, or 94%) were recaptured in the same basin as where they were tagged. Overall reporting rate (λ) was calculated as 0.55 (i.e., we estimate that 55% of recaptures were reported; Table 1). Overall base estimate of exploitation rate (μ; without correcting for tag loss and natural mortality) was 0.27. After correcting for tag loss and natural mortality, adjusted exploitation rate (μ_M) was 0.27 for the $M = 0$ scenario and 0.30 for the $M = 1$ scenario (Table 1).

Basin-specific estimates of reporting rates

Basin-specific reporting rates (λ) ranged from 0.55 in Barataria and Pontchartrain basins to 0.75 in Terrebonne basin (Table 1). Base calculation of exploitation rate (μ) was lowest in Breton Sound (0.18) and

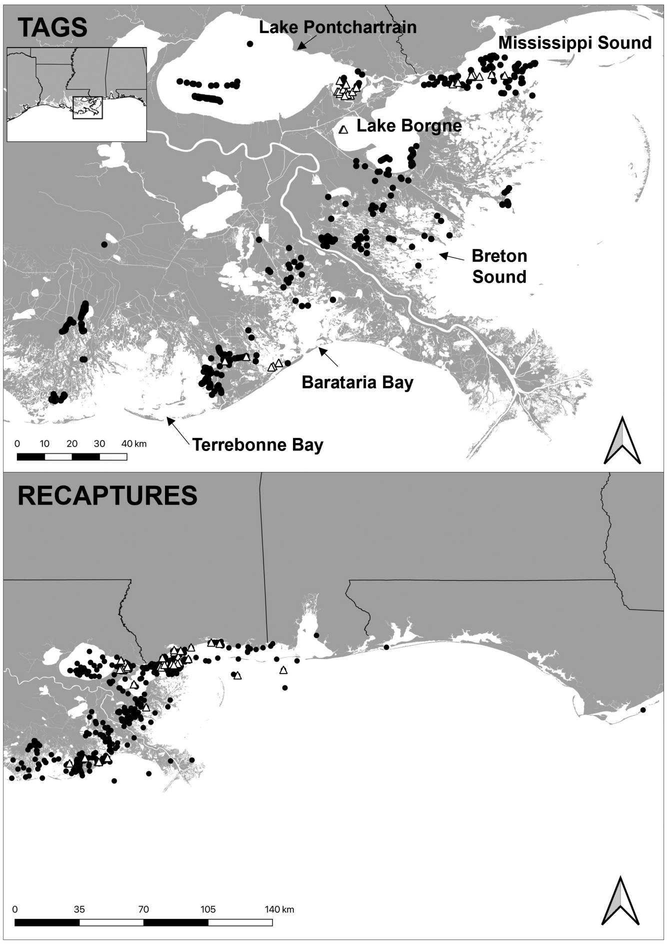

FIGURE 2 Tagging and recapture locations for blue crab in southeastern Louisiana during 2016–2018. Tagging locations are indicated in the top panel and recapture locations in the bottom panel. Each point represents the location where one or more blue crabs was released (top) or recaptured (bottom). Tag and recapture locations for blue crabs tagged in 2016–2017 are represented by circles and those tagged in 2018 are represented by triangles.

TABLE 1 Summary of mark–recapture results and estimates of exploitation rates for 2016–2017. N_h, the number of high-value tags released; N_s, the number of standard-value tags released; R_h, the number of high-value tags returned; R_{hn}, the number of high-value tags returned from nonovigerous females; R_s, the number of standard-value tags returned; R_{sn}, the number of standard-value tags returned from nonovigerous females; T, average time at large; λ, reporting rate; μ, exploitation rate. The term $\mu_M = 0$ is the exploitation rate adjusted for tag loss and a natural mortality rate of 0, and $\mu_M = 1$ is the exploitation rate adjusted for tag loss and a natural mortality of 1.

Data set	N_s	N_h	Total N	R_s	R_{sn}	R_h	R_{hn}	Total R	T	λ	μ	$\mu_M = 0$	$\mu_M = 1$
Full 2016–2017	5890	243	6133	897	867	67	66	964	30.5	0.55	0.27	0.27	0.30
Basin-specific analyses													
Barataria	1042	50	1092	191	187	18	18	209	17.1	0.51	0.35	0.36	0.37
Breton	812	33	845	101	98	6	6	107	13.1	0.68	0.18	0.18	0.18
Pontchartrain	3261	129	3390	436	421	34	34	470	42.9	0.51	0.25	0.26	0.29
Terrebonne	775	31	806	169	161	9	8	178	16.7	0.75	0.28	0.28	0.29
Season-specific analyses													
Fall	1357	71	1428	231	230	27	27	258	53.6	0.45	0.38	0.39	0.45
Spring	1830	63	1893	281	264	13	13	294	30.5	0.74	0.19	0.20	0.22
Summer	2289	95	2384	323	312	22	21	345	16.1	0.61	0.22	0.23	0.24
Winter	414	14	428	62	61	5	5	67	12.6	0.42	0.35	0.35	0.37

highest in Barataria basin (0.35) (Table 1). After adjusting base exploitation rates to include tag loss and natural mortality, exploitation rates (μ_M) ranged from 0.18 in Breton Sound to 0.36–0.37% in Barataria basin (Table 1). Pontchartrain and Terrebonne basins had intermediate exploitation rates (μ_M = 0.26–0.29 and 0.28–0.29, respectively) (Table 1).

Seasonal exploitation rates

Reporting rates (λ) ranged from 0.42 during the winter to 0.74 during the spring (Table 1). Base exploitation rate (μ) was lowest in the spring (0.19) and highest in the fall (0.38) (Table 1). After adjusting exploitation rates to include tag loss and natural mortality, exploitation rates (μ_M) were 0.20–0.22 in spring and 0.39–0.45 in fall (Table 1). Summer and winter had intermediate exploitation rates (μ_M = 0.23–0.24 and 0.35–0.37, respectively) (Table 1).

Assessing the effectiveness of the 2018 female harvest prohibition

During 2018, blue crabs were tagged in the Pontchartrain and Barataria basins during periods before, during, and after the 2-month female harvest prohibition. A total of 1094 blue crabs were tagged during the 2018 season, and 123 were recaptured (11.2%) (Table 2). Reporting rate (λ) was 0.50 (Table 2). The base exploitation rate estimate was 0.16 in the "without prohibition" scenario (assuming all captured nonovigerous blue crabs are harvested) and 0.08 in the "with prohibition" scenario (assuming all females captured in the commercial fishery during the harvest prohibition are released and survive). After adjusting base fishery exploitation to include tag loss and natural mortality, exploitation rate estimates (μ_M) were 0.16–0.18% without the female harvest prohibition and 0.08–0.09% with the female harvest prohibition.

DISCUSSION

Spatial and temporal variation in fishery exploitation of the Louisiana blue crab spawning stock and efficacy of the 2018 female harvest prohibition were examined using a large-scale mark–recapture study. Overall exploitation rate (μ_M) during 2016 and 2017 was 0.27–0.30, indicating that nearly one third of the blue crab spawning stock is harvested in the fishery.

This exploitation rate estimate for the Louisiana blue crab spawning stock (0.27–0.30) is nearly three times the average exploitation rate estimate from a recent study of the Chesapeake Bay blue crab spawning stock (0.105) (Corrick 2018). The 0.27–0.30 exploitation rate estimate for this study instead lies between the recent estimate by Corrick (2018) and an estimated 0.47 average fishery exploitation rate for the Chesapeake Bay spawning stock for the years 1990–1998, before major action was taken to reduce fishing pressure and bolster the spawning stock (Sharov et al. 2003). Louisiana's increased regulation of the blue crab fishery includes measures that are similar to those enacted by management in the Chesapeake Bay area and North

TABLE 2 Summary of mark–recapture results and estimates of exploitation rates for 2018 used for assessing the efficacy of the female harvest prohibition. The "without prohibition" scenario assumes that all captured nonovigerous females were harvested and thus represent exploitation rate estimates had the harvest prohibition not occurred. The "with prohibition" scenario assumes that all females in the commercial fishery were released and thus represent exploitation rate estimates with the female harvest prohibition. N_h, the number of high-value tags released; N_s, the number of standard-value tags released; R_h, the number of high-value tags returned; R_{hn}, the number of high-value tags returned from nonovigerous females; R_s, the number of standard-value tags returned; R_{sn}, the number of standard-value tags returned from nonovigerous females; T, average time at large; λ, reporting rate; μ, exploitation rate. The term $\mu_M = 0$ is the exploitation rate adjusted for tag loss and a natural mortality rate of 0, and $\mu_M = 1$ is the exploitation rate adjusted for tag loss and a natural mortality of 1.

Scenario	N_s	N_h	Total N	R_s	R_{sn}	R_h	R_{hn}	Total R	T	λ	μ	$\mu_M = 0$	$\mu_M = 1$
Without prohibition	986	108	1094	101	77	22	18	123	38.7	0.50	0.16	0.16	0.18
With prohibition	986	108	1094	61	39	12	8	73	48.1	0.50	0.08	0.08	0.09

Carolina in recent years. Yet, Louisiana has maintained the highest landings in the nation since 2000, with the exception of 2010 and 2011 following the Deepwater Horizon oil spill (Bourgeois et al. 2014; National Marine Fisheries Service 2022). Nevertheless, the fishery continues to grow, so much so that recent management efforts have included steps to limit entry into the fishery after 2000–2013 commercial crab licenses climbed to ~3300 (Bourgeois et al. 2014).

During the 2 years of this study (2016–2017), Breton Sound had the lowest exploitation rate (0.22) and Barataria basin had the highest (0.35–0.37); Pontchartrain and Terrebonne basins were intermediate (0.25–0.29 and 0.28–0.29, respectively). These spatial patterns of exploitation rates likely represent the interacting result of spatial variation in blue crab abundance and fishing effort and blue crab demographics in the heavily fished areas of each basin (e.g., relatively more females in the lower estuary, more males in the upper estuary), as well as the spatial distribution or concentration of effort within each basin. This pattern does not necessarily mirror landings data; in both 2016 and 2017, the Pontchartrain basin led the state in blue crab landings, followed by Terrebonne basin, with Barataria basin supporting the lowest landings of the three basins (Cagle and Isaacs 2022).

Exploitation rates were lowest for blue crabs released during the spring (0.19–0.22), followed by summer and winter, and highest during the fall (0.38–0.45). This seasonal pattern contrasts with the seasonal pattern observed by Corrick (2018) in the Chesapeake Bay, who observed exploitation rates of 0.081 and 0.021 for fall and spring–summer recaptures, respectively, of fall-released blue crabs, and 0.125 for summer-released blue crabs. This is likely related to differences in fishing seasons and blue crab life history due to significantly different temperature regimes in the two regions. In the fall and winter, temperatures are still quite high and blue crabs are actively foraging and migrating in the northern Gulf of Mexico, whereas in the Chesapeake Bay area, it is much colder and blue crabs are not as active during the winter and fall seasons.

By tagging before and during the 2018 female harvest prohibition, we were able to assess the impact of this management action. In our "without closure" scenario, the overall exploitation rate (μ_M) during the 2018 tagging season was 0.16–0.18, slightly lower than our spring season exploitation rate estimate for 2016–2017 (0.19–0.22) (Tables 1, 2), possibly reflecting reduced fishing effort in female-dominated areas during the harvest prohibition. The 2-month female harvest prohibition in 2018 reduced exploitation of the spawning stock from 0.16–0.18 (without prohibition estimate) to 0.08–0.09 (with prohibition estimate). This represents a substantial reduction in exploitation of the female spawning stock, allowing many of these blue crabs to migrate beyond the areas of heavy fishing pressure, although it is certainly possible that this harvest prohibition actually increased fishing pressure on males if crabbers shifted their effort to target areas dominated by males. We suggest that the timing of the female harvest prohibition could be improved upon for maximum effect. The 2018 female harvest prohibition occurred during the season of lowest exploitation rates (spring). To have a greater effect on the population, we would suggest a season that boasts a higher exploitation rate. Fishery exploitation is lowest in the spring and highest in the fall. Perhaps a closure during the fall may have more effect on increasing spawning stock biomass over subsequent years. Seasonal closure in 2018, during the lowest exploitation season, decreased overall fishery exploitation by approximately half, so it could be even more productive if utilized during a season that boasts a higher average fishery exploitation rate. Furthermore, the closure is occurring when per-pound prices are highest and landings are lowest (Cagle and Isaacs 2022), thus resulting in the greatest cost to fishers (in terms of lost revenue) for the lowest potential benefit. In 2019, a 35-day harvest prohibition on female blue crabs was enacted beginning on September 9; unfortunately, similar data are not available to assess the effectiveness of this management action.

The observed spatial and temporal variations in fishery exploitation and the efficacy of the female harvest prohibition can be used to inform future management plans. It is important to note that we considered only exploitation rates of female blue crabs, and further evaluation of the fishery exploitation of male blue crabs is necessary for a more complete understanding of the impacts of the fishery on the population. The information provided in this study can serve to fill gaps in the current knowledge and provide biological evidence for harvest controls that are better suited to provide maximum effect in ensuring the prolonged economic and environmental value of the Louisiana blue crab.

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CONFLICT OF INTEREST STATEMENT

No conflicts of interest are reported.

DATA AVAILABILITY STATEMENT

All data are available upon request.

ETHICS STATEMENT

This was conducted under permit SCP-155, issued by the Louisiana Department of Wildlife and Fisheries.

ORCID

M. Zachary Darnell https://orcid.org/0000-0003-0429-9313

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