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FEATURE ARTICLE

Assessing Northeast Florida Offshore Blue Crab Fishing Effort within Florida's State Waters

Samantha L. Ehnert-Russo,* Claire E. Crowley, and Katharine L. Becker
Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, Florida 33701, USA

Abstract
During the winter months, commercial fishery effort targeting blue crabs *Callinectes sapidus* increases in the offshore Atlantic waters of northeast Florida as crabbers follow the seasonal migration of female blue crabs. The present study sought to describe offshore commercial fisher behavior through a mail survey (2020) and to characterize fishing effort using landings data (from 2009–2010 to 2019–2020) and an aerial survey from January to March (2021). Offshore fisher effort (i.e., number of participants and landings) varied each winter, and the effort was greatest in the winters of 2011–2012 and 2018–2019. The number of participants that reported offshore landings ranged from 6 to 11. Offshore landings accounted for 2.6% of the total landings in northeast Florida and were correlated with a decrease in inshore landings. The mail and aerial surveys determined that crab traps were concentrated off two sections of the coast within 1.61 km (1 mi) of shore: (1) from Vilano Beach to south of Ponte Vedra Beach and (2) between Neptune Beach and Atlantic Beach. Participants in the mail survey reported fishing a median of 150 traps (range = 50–400 traps), while aerial counts estimated an average ± SD of 59.5 ± 5.4 traps/crabber. Average trap counts from the aerial survey during the winter of 2020–2021 suggested that 9.33 km (5.8 mi) of vertical line were used within the survey area. This study successfully characterized the northeast Florida offshore blue crab fishery as a small but valuable fishery for a few crabbers, with effort driven by seasonal demand and crab availability.

The commercial fishery for blue crab *Callinectes sapidus* is the second highest grossing fishery in northeast Florida, surpassed only by the shrimp fishery (Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute [FWRI], unpublished data). This regional blue crab fishery accounts for 25% of landings (kg), 27% of revenue (US$), and 26% of trips taken by blue crab fishers statewide (Table 1). Landings in this northeast Florida fishery fluctuate greatly from year to year, with a 10-year average (from 2009–2010 to 2019–2020) of 816,000 kg, equating to a fishery worth more than $3 million annually (Table 1).

The year-round commercial blue crab fishery in northeast Florida is characterized by small, local operations, usually with one to three people onboard a fishing vessel (Gandy 2012). Both full-time and part-time crabbers work in this fishery, and a majority of the crabbers have been fishing for more than 20 years (Gandy 2012). The fishery is almost exclusively a trap fishery, in which a buoy, line, and weight are attached to a wire-mesh crab trap (Cooper et al. 2011). Traps for each crabber can be identified by the crab trap buoy color and the engraved Saltwater Products License endorsement number (V number) on the crab trap buoy and trap tag (attached to the wire mesh; Florida Department of State 2009). Anecdotal accounts from industry participants suggest that the type of buoy, the length and type of line, and the amount of weight attached

*Corresponding author: samantha.russo@myfwc.com
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TABLE 1. Comparison of trip ticket data for the northeast Florida blue crab fishery and the statewide blue crab fishery. Landings (kg), revenue (US$), and number of trips taken for the blue crab fishery from 2009 to 2020 are presented.

	Landings		Revenue		Number of trips	
Year	Statewide	NE Florida	Statewide	NE Florida	Statewide	NE Florida
2009	2,301,022	514,595	6,669,756	1,692,648	28,273	7,417
2010	3,868,723	655,399	10,395,750	1,964,913	36,243	7,769
2011	4,803,066	1,322,881	12,526,145	3,677,620	37,608	10,113
2012	3,724,700	1,435,260	10,643,440	4,190,527	36,013	11,231
2013	3,226,247	866,781	10,827,752	3,217,028	35,869	9,456
2014	2,777,882	648,604	10,806,819	2,929,878	31,517	8,674
2015	3,021,664	661,534	12,150,140	2,895,904	33,692	8,749
2016	2,618,408	698,869	10,387,436	2,941,296	32,914	9,021
2017	3,135,202	873,840	11,875,339	3,437,461	31,587	8,574
2018	3,303,365	632,611	12,837,773	2,891,915	31,490	7,497
2019	3,776,290	815,503	14,411,062	3,408,154	33,270	7,806
2020	2,938,596	892,017	12,774,173	3,966,759	30,474	8,141

to the bottom of each trap vary by water column current and bottom depth.

The factors that drive this fishery include crab availability, crab demand, sale price, weather (e.g., nor'easters, hurricanes, and droughts), and the cost of operations (e.g., fuel, gear, bait, and licensing; Cooper et al. 2011; Gandy 2012). Many crabbers in this region also operate as wholesalers, which increases their operational costs over crabbers in other regions where seafood markets operate as wholesalers. Although the northeast Florida crabbers will travel to areas where crabs are more abundant, they typically fish in their own region within 80.5 km (50 mi) of their home bases (Gandy 2012). Florida's longest river, the St. Johns River, flows north through this region, and it is a major body of water in which blue crabs are caught. A small, undetermined proportion of these landings are made up of crabs from northeast Florida's offshore Atlantic waters.

The supply and demand for blue crab fluctuate seasonally with changes in retail price. During the summer, in-state and out-of-state imports to this region increase market competition and this competitive market often reduces the price ($/lb) of local crabs (Gandy 2012). Conversely, based on submitted trip tickets, there are roughly 13% fewer commercial crabbers in the winter and early spring, which may decrease market competition and could lead to increased retail prices. Additionally, the blue crab fishery is closed during January 16–25 in even years in the northeast region so that the Derelict Trap and Trap Debris Removal Program (Florida Fish and Wildlife Conservation Commission) can remove abandoned traps from the St. Johns River, its tributaries, and associated lakes (Florida Department of State 2007, 2009). This closure of inshore waters may decrease crab availability, leading to increased retail prices, and may encourage crabbers to set traps in offshore waters.

Seasonal changes in inshore and offshore blue crab abundance reflect ontogenetic crab movement along salinity gradients (Tagatz 1968). Blue crab mating can occur year-round in Florida, but most mating typically occurs from March to July and from October to December in lower-salinity waters (<20‰; Tagatz 1968; Hart et al. 2021). After mating, mature females migrate to higher-salinity waters (>20‰) to spawn, and the largest observed migration occurs from November to April (Tagatz 1968). These females then stay offshore until water temperatures warm (>18°C), which initiates spawning (Tagatz 1968; Hart et al. 2021). The use of blue crab traps in federal waters off Florida was prohibited in 1998; therefore, the fishery targeting migrating blue crabs only operates in Florida state waters (Florida shoreline to 4.83 km [3 mi] offshore; Florida Department of State 2009).

Florida state waters not only serve as blue crab fishing grounds during the winter, but also provide critical habitat for the North Atlantic right whale *Eubalaena glacialis* (NARW; Gowan and Ortega-Ortiz 2014). The International Union for Conservation of Nature lists the NARW as critically endangered, with the last published population estimate at 410 individuals, and it is steadily declining (Christiansen et al. 2020; Cooke 2020; Pettis et al. 2021). The calving season begins in the southeastern United States in December, peaks in late January through late February, and ceases when females and calves depart the region (Brunswick, Georgia, to Sebastian, Florida) in March (Gowan and Ortega-Ortiz 2014). Concern is increasing about the risk of NARWs becoming entangled in gear in these areas, so it is important to determine the potential areas of co-occurrence of commercial fixed-gear fisheries with NARW wintering and calving grounds.

The commercial blue crab fishery is required to report fishery landings and effort through the use of trip tickets. The information reported on trip tickets includes items such as date, landings (lb), exvessel value (US$), number of days soaked, number of traps fished, area fished, and depth. However, this information lacks the precise locations at which traps are set, resulting in significant gaps in our understanding of the fishing effort and behavior of participants in the northeast Florida offshore blue crab fishery.

The purpose of this study was to better understand the northeast Florida offshore blue crab fishery and to provide stakeholders and managers with the information they need to understand the dynamics of this system. We accomplished this by evaluating fisher behavior, seasonal effort, and spatial effort in the fishery. A mail survey was used to improve our understanding of the behavior of licensed commercial crabbers in northeast Florida. Blue crab trip ticket landings data were used to characterize seasonal and annual trends in blue crab fishing effort. Finally, aerial surveys were used to determine the locations of individual blue crab traps in offshore waters.

METHODS

Mail survey.— A mail survey was developed in 2019 to collect data on the fishing behavior and preferences of offshore blue crab fishers in northeast Florida, and it asked the participants to recollect the winters during which they had fished offshore from 2009–2010 to 2019–2020. The survey gathered information from commercial fishers who had current, valid blue crab endorsements associated with their Saltwater Products License (V number; Florida Department of State 2009) and who cited their business address as being within or near northeast Florida counties (Brevard, Clay, Duval, Flagler, Nassau, Orange, Putnam, Saint Johns, Seminole, or Volusia). These commercial crabbers were sent a cover letter, a 20-question survey (Supplement I available in the online version of this article), maps of the northeast Florida coastline (Supplement II), and a stamped return envelope. The survey was intended to characterize spatial and temporal fishing behavior, trap configuration, and gear preferences. The survey package was mailed during the week of December 16, 2019, to 148 commercial crabbers, who were requested to return the survey by January 31, 2020. All survey responses were kept anonymous.

Multiple answers to the multiple-choice questions were allowed; therefore, the total number of responses could be higher than the total number of participants that returned the survey. The percentages for multiple-choice questions were then reported as the percent of responses that indicated a certain answer. Open-ended questions that asked for a numerical response (e.g., questions 7, 8, 15, and 16; Supplement I) could be answered as a single number or as a range (low to high). If only one number was given, it was considered the low and high of a range. Low, high, and median values across all participants were used in downstream analyses of fishing effort. Imperial units reported by participants were converted to metric units. Lastly, the mail survey asked participants to circle the areas they fished on the maps provided (Supplement II). The marked locations were used to create a layer of known fishing areas in ArcGIS Pro version 2.7.3 (Esri, Inc., Redlands, California).

Commercial blue crab landings data.— The landings data were compiled from trip tickets submitted to the Marine Fisheries Trip Ticket Program (FWRI Marine Resources Information System) for the offshore Atlantic waters of northeast Florida between November and April of each winter from 2009–2010 to 2019–2020. The FWRI created the Marine Fisheries Trip Ticket Fishing Area Codes (FACs) for the fishers to report the area in which crabs are caught (Table 2).

We totaled the monthly and seasonal weight of blue crabs landed (kg), the number of trips taken, the number of crabbers, and the value of landings ($) for northeast Florida. The number of blue crab traps fished on each trip was not used for analyses due to known over- and underestimations of these values (FWRI, unpublished data). Additionally, monthly averages with SDs were calculated for the crabs landed (kg) and value ($) for the winter inshore and offshore blue crab fisheries of northeast Florida. Pearson's correlation was used to determine any relationships between the average value per month for the offshore and inshore fisheries. Analyses were performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria). On each trip ticket, fishers must report the FAC where crabs were collected and the county in which the crabs were landed. There can be reporting inaccuracies due to the similarities in the FACs with and without a decimal of zero (e.g., 722.0 and 722). Anecdotally, we know that fishing only occurs offshore in winter months; therefore, only the winter months were used to calculate the offshore landings.

Aerial surveys.— Aerial surveys were conducted every 3 weeks from January 26 through March 31, 2021. Surveys were conducted from a Cessna 172 at an altitude of 152.4–304.8 m (500–1,000 ft). The mail survey and returned maps indicated that the most heavily fished areas were off St. Augustine and Jacksonville, within 3.22 km (2 mi) from shore (Figure 1). Therefore, two transects were flown from south to north, starting at Pellicer Creek and ending at Nassau Sound. Due to the age of the plane's technology and the nonlinear shape of the shoreline, the predelineated transects at 0.80 km (0.5 mi) and 2.41 km (1.5 mi) were not easily followed by the pilot; therefore, transect ranges were established with a 0.80-km (0.5-mi) buffer. The first range was 0.00–1.61 km (0–1 mi) from shore; the second range was 1.61–3.22 km (1–2 mi) from

TABLE 2. Florida Fish and Wildlife Research Institute's Marine Fisheries Trip Ticket Fishing Area Codes (FACs) used in northeast Florida. The FACs are shown in parentheses.

	Region		
Description	Jacksonville (722)	St. Augustine (728)	Cape Canaveral (732)
Area (FAC)	Offshore waters (722.0)	Offshore waters (728.0)	Offshore waters (732.0)
	Other inland waters (722.1)	Other inland waters (728.1)	Other inland waters (732.1)
	Federal waters (722.9)	Federal waters (728.9)	Federal waters (732.9)
	St. Johns River (722.5)	St. Johns River from Lake George to Green Cove Springs (728.5)	St. Johns River below Lake George (732.5)
	St. Marys River (722.2)	Lake George (728.8)	
	Nassau River (722.4)		

shore. Throughout the survey, the Beaufort Sea State (WMO 1970) and the glare (presence or absence) were recorded. As the plane traveled on the transect, the number of crab traps in view were called out by an FWRI observer as a second FWRI observer selected the number of traps on an ArcGIS QuickCapture Application using an iPhone X_R (Apple, Inc., Cupertino, California). The application saved the specific GPS location for every buoy count entered, which was loaded as a layer into ArcGIS Pro version 2.7.3 for analysis. The total number of crab traps per 1-km^2 cell on a grid was determined. The average number of crab traps per square kilometer was then

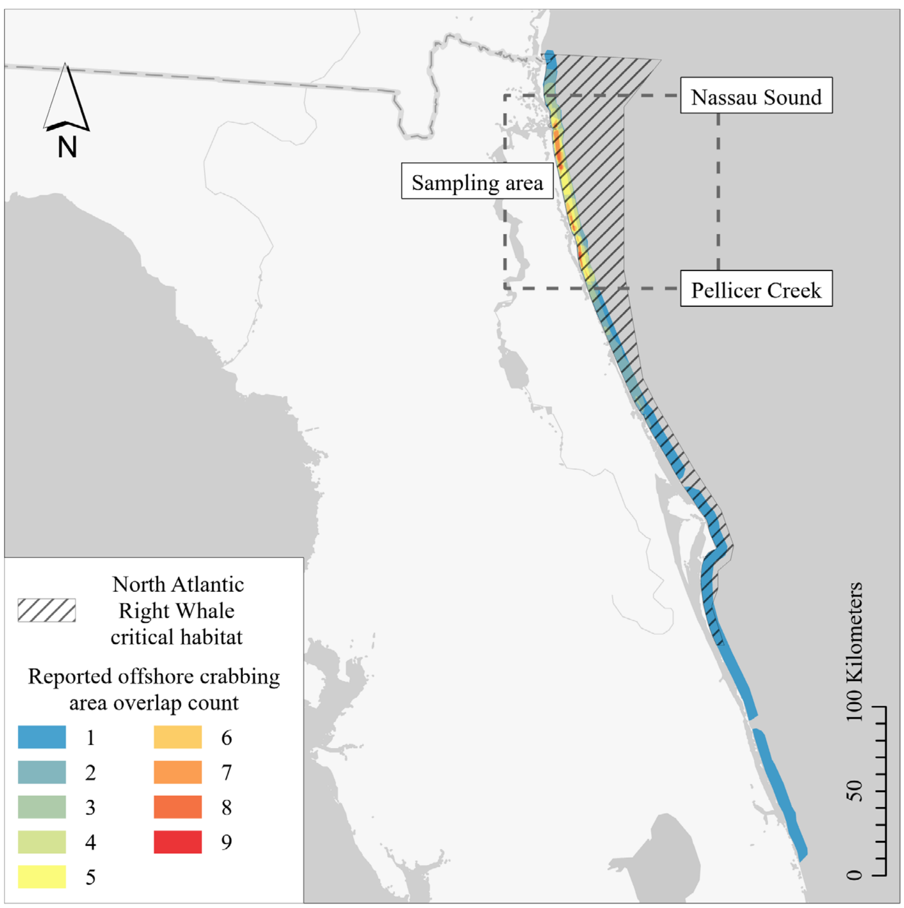

FIGURE 1. Map of northeast Florida offshore blue crab fishing grounds, depicting the locations reported as crabbing areas in relation to the North Atlantic right whale critical habitat area. The sampling area selected for aerial surveys is indicated.

calculated from flights with a Beaufort Sea State of 0–2 (0 = sea is like a mirror; 1 = sea is rippled; 2 = small wavelets are being formed). Trap counts associated with a Beaufort Sea State above 2 were excluded from the calculated average of crab traps because we could not assume that all crab traps were counted. Hot spots (i.e., areas with the highest concentrations of crab traps) were calculated in ArcGIS Pro version 2.7.3 using Esri's Getis-Ord Gi* statistic (parameter = number of crab traps; radius = 15 m).

RESULTS

Mail Survey

Participation.— In total, 148 surveys were mailed to commercial fishers with a valid blue crab endorsement and 34 completed surveys were returned (23%). The number of commercial crabbers and the number of returned surveys from each county varied, and the largest number of returned surveys were from Duval County ($N = 11$; 32% of survey participants; Table 3). Of the survey participants, 15 (44.1%) indicated that they had fished for blue crabs in Florida's offshore Atlantic waters during one or more years from 2009–2010 to 2019–2020. Additionally, within this period at least six participants (18% of the total participants; 40% of the participants that fished offshore) said that they had fished in offshore waters during each winter (November–April). The years in which the participants reported fishing offshore varied; however, the greatest number of offshore participants ($N = 11$; 73.3%) indicated that they had fished during the 2018–2019 winter (Figure 2A). When participants were asked to indicate the month during which they fished in offshore waters, the greatest number of responses were for January and February (January: $N = 14$, 25.5%; February: $N = 15$, 27.3%; Figure 2B).

Areas fished.— Participants indicated that the most heavily used inlets were Mayport ($N = 8$; 23.5%) and St. Augustine ($N = 8$; 23.5%), followed by Matanzas ($N = 6$; 17.6%), Nassau ($N = 4$; 11.8%), Ponce ($N = 4$; 11.8%), Fort George ($N = 2$; 5.9%), and Canaveral ($N = 1$, 2.9%; Figure 3A). When asked to mark fishing areas on a map, the most frequented inlets marked were also Mayport, St. Augustine, and Matanzas (Figure 1). One participant indicated having fished an inlet that was not listed on the survey, and no participants fished out of Sebastian Inlet.

TABLE 3. Number of blue crab commercial license endorsement holders and the number of survey respondents by county in northeast Florida.

County	Endorsement holders	Survey respondents
Brevard	28	6
Clay	8	1
Duval	29	11
Flagler	4	0
Nassau	2	0
Orange	2	0
Putnam	13	3
St. Johns	32	7
Seminole	4	0

Most participants indicated that once exiting an inlet, they fished both north and south of the inlet ($N = 12$, 80%; Figure 3B). Three participants fished only north ($N = 1$; 6.7%) or only south ($N = 2$; 13.3%), and one participant (6.7%) fished directly outside of the inlet. Participants set their traps primarily parallel to the shore ($N = 11$; 73.3%), in a random orientation ($N = 3$; 20.0%), or in some "other" orientation ($N = 1$; 6.7%), but traps were never set perpendicular to the shore ($N = 0$, 0.0%; Figure 3C). Additionally, participants either set their traps in a series of rows ($N = 10$; 58.7%) or one long, continuous row ($N = 7$; 41.2%). When asked how far from shore they set their traps, participants generally selected several answers, which were presented in the mail survey in 1.61-km (1-mi) increments. Most of the responses indicated that fishing occurred within 1.61 km (1 mi) of shore ($N = 11$; 39.3%) and that the number of participants decreased farther from shore (Figure 4A). Trap fishing in federal waters (i.e., >4.83 km [>3 mi] offshore) is not permitted (Florida Department of State 2009), but two participants (four responses) indicated that they fished more than 4.83 km from shore. To better understand the distribution of fishing offshore, participants were asked to provide the depth at which they fished their traps. Six participants (15.8%) fished in waters less than 6 m (20 ft) deep (Figure 4B), but most participants generally fished in water depths of 6–8 m (20–29 ft; $N = 11$, 28.9%), and the number of participants decreased with increasing depth.

Trap distribution and gear type.— The number of traps used by an offshore crabber in the winter and the trap soak time were each reported as a single number or as a range. The number of traps fished offshore ranged from 50 to 400 traps (median = 150 traps; Figure 5A). Soak time was less variable and ranged from 1 to 4 d (median = 2 d; Figure 5B).

The blue crab fishery is conducted with a trap, line, and buoy. The style of trap line and the buoy type are variable and based on fishing location and fisher preference. When asked to report the type of line used, five participants answered. Four participants indicated that they used "number 8" line (i.e., sinking braided-nylon rope with a diameter of 0.635 cm [0.25 in] and a breaking strength of 633 kg [1,395 lb]), and one participant just indicated that nylon rope was used. The length of rope used could be reported as a single number or as a

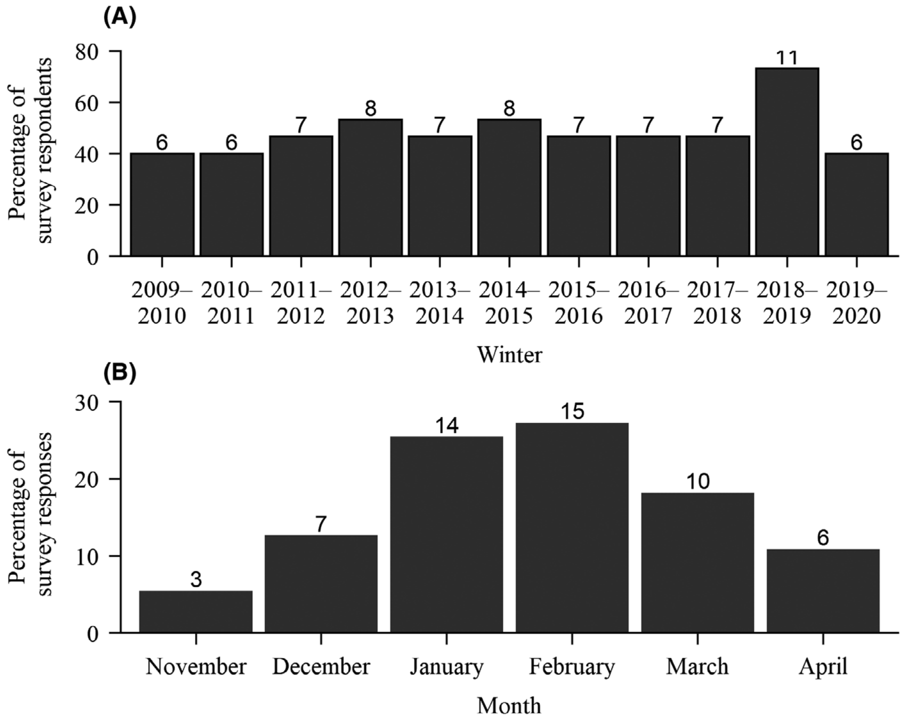

FIGURE 2. Years and months during which the blue crab fishery participants fished offshore in northeast Florida: **(A)** percentage of survey participants that fished offshore each winter from 2009–2010 to 2019–2020; and **(B)** percentage of responses for each month of the winter. The number of participants (*N*) is indicated above each response.

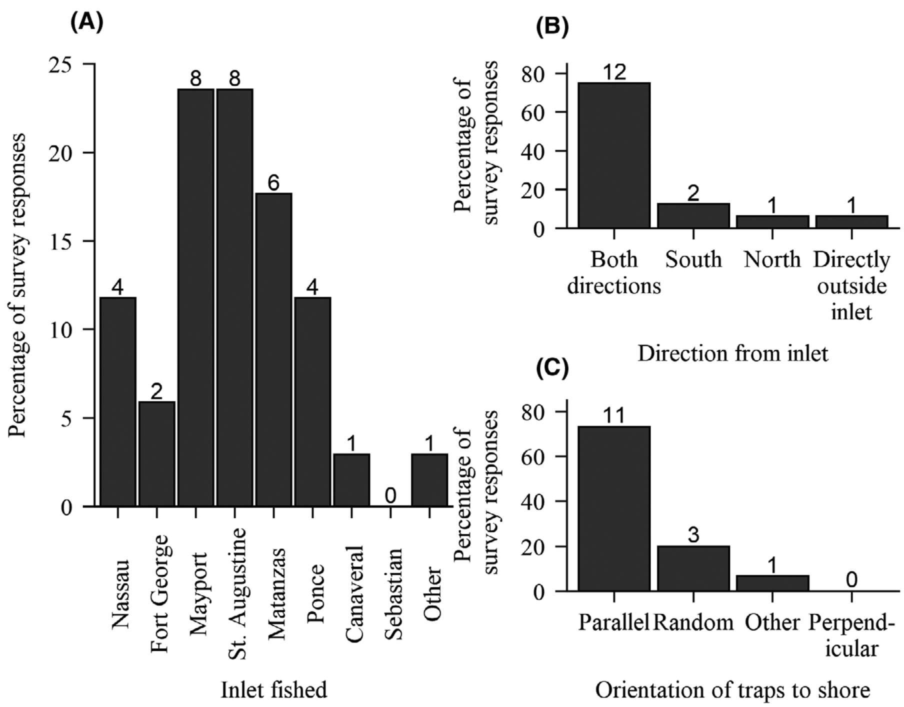

FIGURE 3. Direction, orientation, and inlets fished in the northeast Florida offshore blue crab fishery: **(A)** percentage of survey responses indicating the use of each inlet (ranging from north to south), **(B)** the direction in which the respondents fished once leaving the inlet, and **(C)** the specific orientation in which the traps were set relative to the shore. The number of participants (*N*) is indicated above each response.

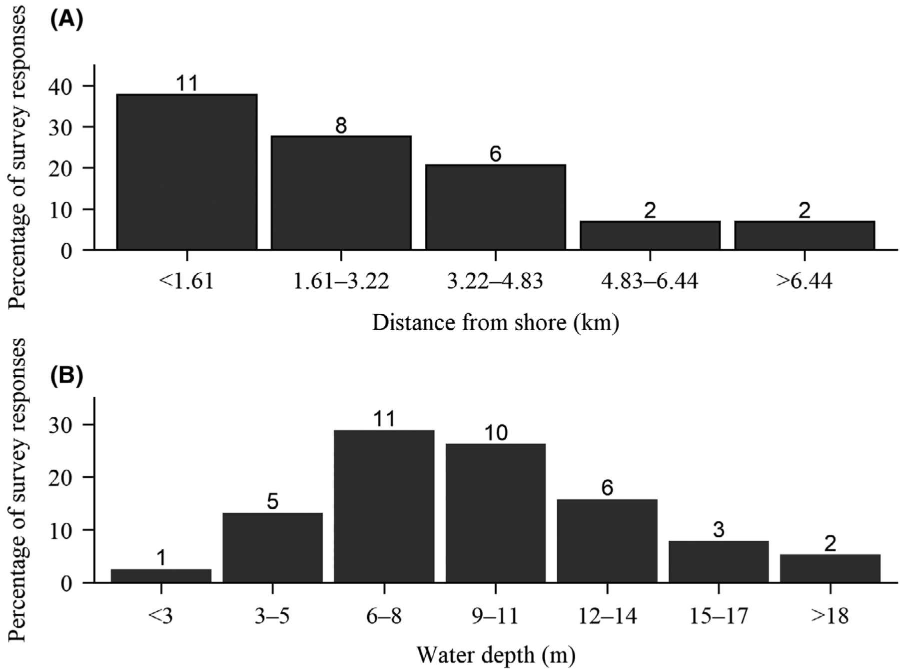

FIGURE 4. Quantification of areas fished in the northeast Florida offshore blue crab fishery: **(A)** percentage of survey responses for each distance from shore (km) and **(B)** the depth (m) at which the participants fished. The number of participants (*N*) is indicated above each response.

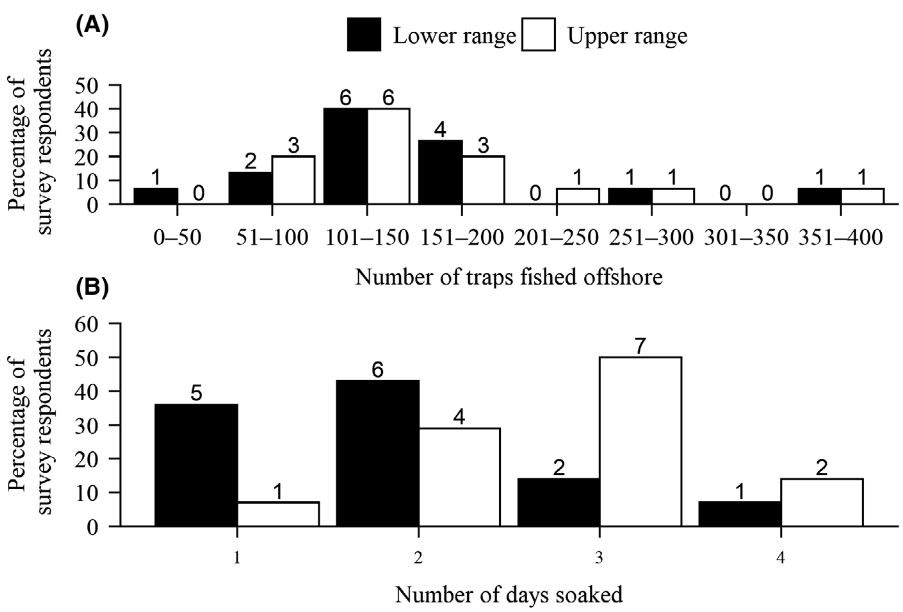

FIGURE 5. Percentage of blue crab fishery participants within each bin of **(A)** the number of traps fished and **(B)** the number of days for which the traps were soaked. The number of participants (*N*) is indicated above each response.

range (Supplement I). The length of rope used per trap ranged from 9.14 to 45.72 m (median = 24.38 m [30–150 ft; median = 80 ft]; Figure 6A). The most common buoy shape used was the bullet ($N = 12$; 60%), followed by the 15.24-cm (6-in) round ($N = 5$; 25%) and the 20.32-cm (8-in) round ($N = 3$; 15%). The amount of weight added to the bottom of the traps ranged from 0.00 to 13.61 kg (median = 6.35 kg [0–30 lb; median = 14 lb]; Figure 6B). Participants reported losing 0–100 traps/season (median = 20 traps/season; Figure 7A). The most common reasons for trap loss were weather ($N=13$; 65%), boat cutoff ($N=3$; 15%), theft ($N=3$; 15%), and other (e.g., shrimp boats running over traps; $N=1$, 5%; Figure 7B).

Fishers' motivation to fish offshore.— Participants were asked to explain what motivated them to fish offshore. Most of the responses were related to crab movement to offshore waters or the lack of crabs in the inshore waters ($N=12$, 80%; Figure 8A). Other reasons included increased profits, trapping closures in the St. Johns River to remove derelict traps, and weather. Similarly, the reason for moving traps out of offshore waters was primarily due to crab movement ($N=10$, 55.6%; Figure 8B). Additional reasons included weather, the presence of egg-bearing crabs, trap loss, better profitability elsewhere, and crab mortality.

Commercial Blue Crab Landings Data

Annual offshore blue crab fishery landings in winter from 2009–2010 to 2019–2020 ranged from 3,207 to 101,512 kg (mean ± SD = 17,578.519 ± 28,826 kg). Those landings had a yearly value of \$11,555 to \$249,973 (\$54,687 ± 69,650). The number of crabbers fishing offshore in each winter month (November–April) ranged from 1 to 16 fishers (mean ± SD = 5 ± 3 fishers). The number of fishers that fished inshore ranged from 47 to 102 (73 ± 12 fishers), although some of those crabbers might also have been fishing offshore. Seasonal peaks in offshore landings occurred in January and February; inshore landings were lowest during those months (Figure 9A). The average value per month of the inshore fishery had a strong negative correlation with the average value per month of the offshore fishery (i.e., inshore profit decreased with increased offshore profit; Pearson's product-moment correlation coefficient $r=-0.95$, $P<0.05$, $N=6$; Figure 9B). The offshore landings varied substantially between years, and they were greatest in the winters of 2011–2012 and 2018–2019 (Table 4). The inshore landings also varied substantially between years, and the inshore landings decreased during the offshore peak in the 2018–2019 season (Table 4). The offshore fishery accounted for 0.9–17.3% (median = 2.6%) of the total blue crab landings for northeast Florida and 0.1–2.6% (median = 0.3%) of the blue crab landings statewide.

Aerial Surveys

Crab traps were present during the first aerial survey (January 26), and the crab traps had likely been in the water since mid-December based on communication with fishers (Figure 10). No crab traps were present during the last survey on March 31. Sea conditions were not favorable for accurate counts on the February 17 flight (Beaufort Sea State > 2). Therefore, the average number of crab traps per 1-km^2 cell for the season was calculated from the January 26 and March 12 flights. An average of 387 crab traps were counted on each flight in the survey area during the 2021 offshore season. The minimum and maximum numbers of crab trap buoys counted within a square kilometer were 0 and 24, respectively (Figure 11A). Aerial

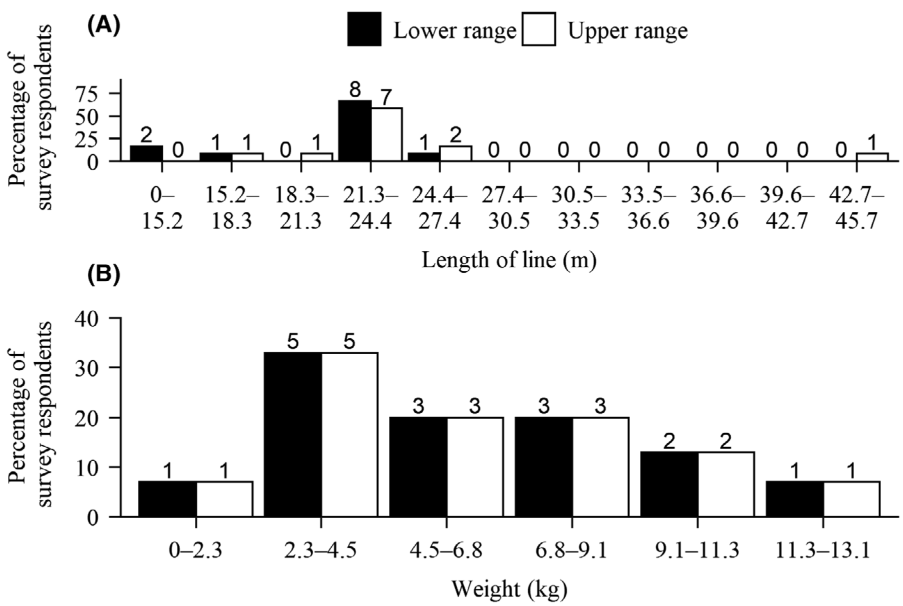

FIGURE 6. Blue crab trap variables, indicating the percentage of blue crab fishery participants within each bin for **(A)** the length (m) of line used and **(B)** the amount of weight (kg) attached to traps fished by the participants in offshore Atlantic waters. The number of participants (N) is indicated above each response.

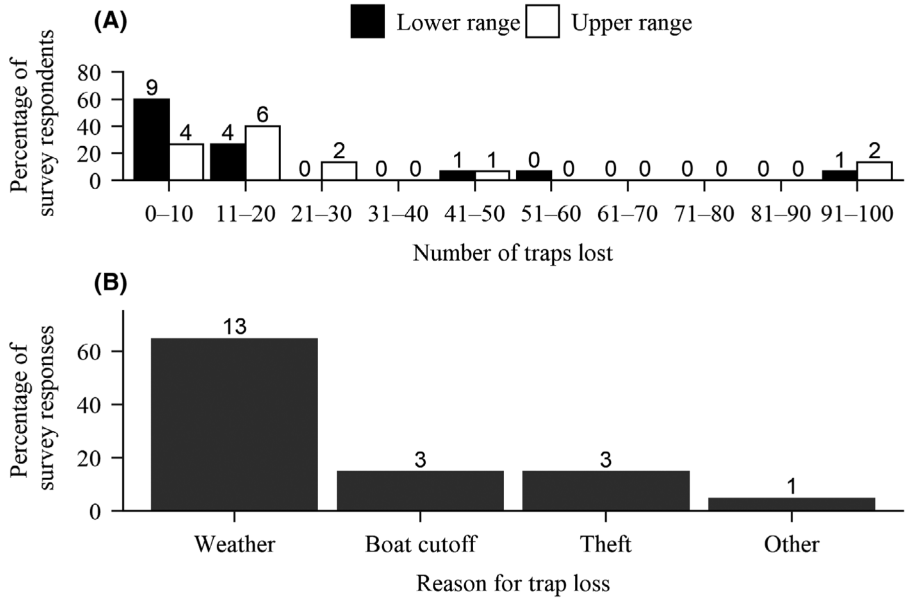

FIGURE 7. Characterization of blue crab trap loss: **(A)** percentage of participants within each bin of the number of traps lost per season and **(B)** percentage of survey responses indicating each reason for trap loss in offshore Atlantic waters. The number of participants (*N*) is indicated above each response.

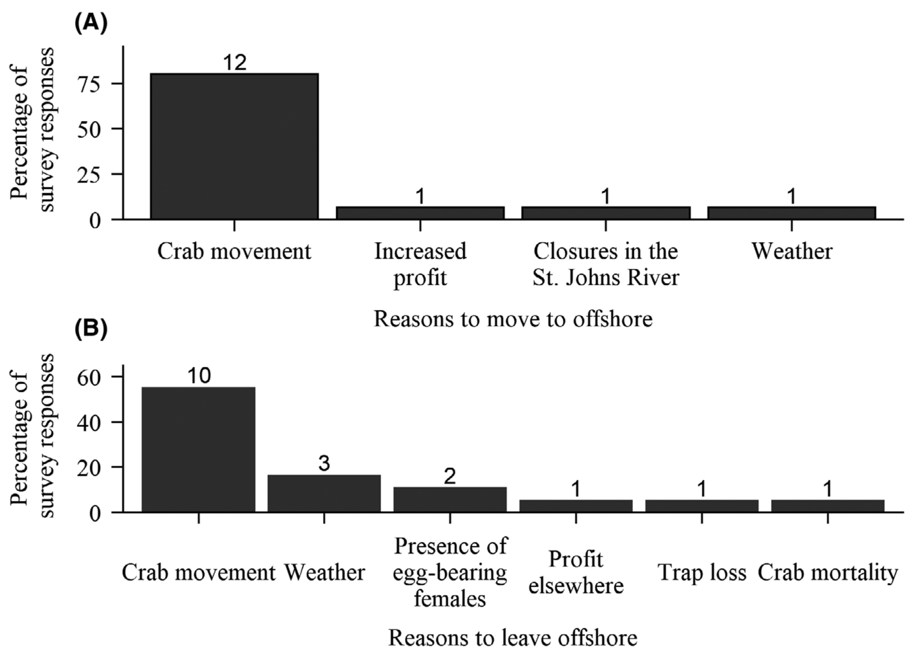

FIGURE 8. Percentage of survey responses indicating blue crab fishers' reasons for **(A)** moving traps to offshore waters and **(B)** moving traps out of offshore waters. The number of participants (*N*) is indicated above each response.

survey constraints (i.e., weather, glare, altitude, plane speed, buoy color similarities, and budget) prevented the specific number of traps used by individual crabbers to be determined. Analyses in ArcGIS Pro revealed two hot spots (high concentrations of buoys): (1) between Vilano Beach and just south of Ponte Vedra Beach and (2)

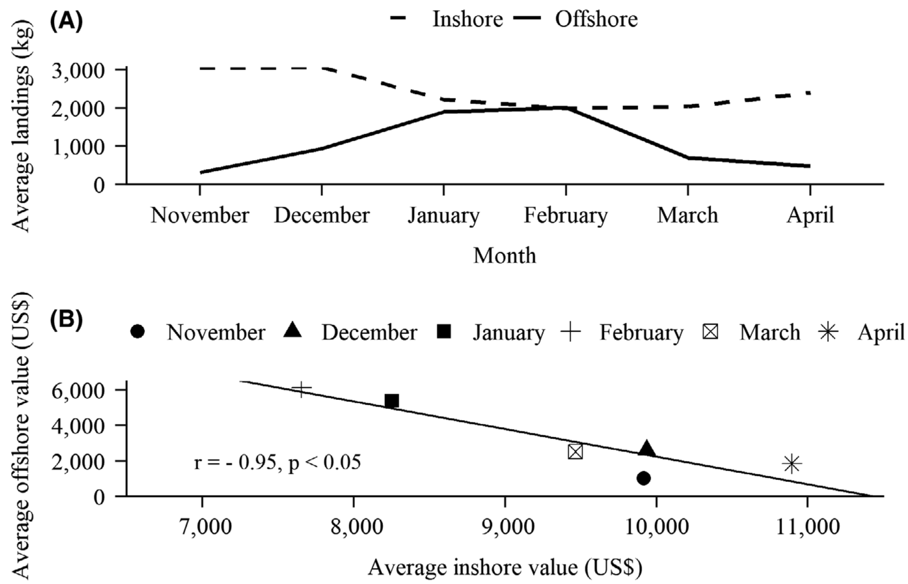

FIGURE 9. Comparison of landings (kg) and value (US$) of the inshore and offshore blue crab fisheries during winter (November–April) from 2009–2010 to 2019–2020: **(A)** average monthly landings (kg) for each fishery and **(B)** correlation between the average monthly values ($) of the inshore and offshore fisheries (Pearson's product-moment correlation coefficient $r = -0.95$, $P < 0.05$, $N = 6$).

TABLE 4. Commercial blue crab trip ticket data (landings, kg; revenue, millions of US$; and number of trips taken) from offshore waters and inshore waters of northeast Florida during the winter (November–April) from 2009–2010 to 2019–2020.

	Landings		Revenue		Number of trips	
Year	Offshore	Inshore	Offshore	Inshore	Offshore	Inshore
2009–2010	7,939	188,711	27,068	619,907	136	2,688
2010–2011	14,854	357,338	48,811	1,175,759	154	3,712
2011–2012	101,512	485,014	249,973	1,545,933	406	4,398
2012–2013	9,919	300,111	31,114	1,056,674	96	3,658
2013–2014	3,948	253,670	15,919	1,072,231	61	3,402
2014–2015	5,711	221,846	31,530	1,036,323	73	3,244
2015–2016	7,432	281,773	38,431	1,203,251	98	3,847
2016–2017	4,498	318,359	22,773	1,320,386	46	3,843
2017–2018	4,963	362,197	19,021	1,522,181	77	3,447
2018–2019	29,386	263,001	105,359	1,144,641	178	2,994
2019–2020	3,207	354,110	11,555	1,499,882	29	3,534

between Neptune Beach and Atlantic Beach (Figure 11B). All of the crab traps observed from the aerial surveys were 0.48–0.80 km (0.3–0.5 mi) from shore at an estimated depth (based on nautical depth contours) of 7.62–10.67 m (25–35 ft).

DISCUSSION

The 2020 mail survey represented blue crab fishers from northeast Florida counties and had a response rate of 23%. This response rate was lower than the response rate of previous statewide surveys of the commercial blue crab fishery in Florida. Gandy (2012) had a 41.7% response rate for northeast Florida crabbers and a 38.9% statewide response rate, while McMillen-Jackson et al. (2003) reported a statewide response rate of 35%. This is to be expected because the blue crab offshore fishery is a specialized fishery that requires extra modifications to fishing gear (Table 5), and we did not expect a high return from fishers who did not go offshore. The number of mailed survey participants who reported fishing offshore ($N = 15$) was very close to the average monthly number of crabbers

FIGURE 10. Heat maps of the number of crab traps sighted during each aerial survey conducted in northeast Florida during the 2021 offshore season. Each square represents a 1-km^2 cell in the grid.

(mean ± SD = 5 ± 3) who submitted commercial landings data during the winters from 2009 to 2020. With at least six of the participants reporting fishing during each offshore season, the survey represented the habits and opinions of the small—but consistent—offshore blue crab fishery in northeast Florida.

The number of participants per year was generally constant and did not reflect the annual fluctuations in landings, but both the landings data and the mail survey responses indicated that seasonal participation was highest during the 2018–2019 offshore season. Conversely, participation in the fishery, as indicated by survey responses, did

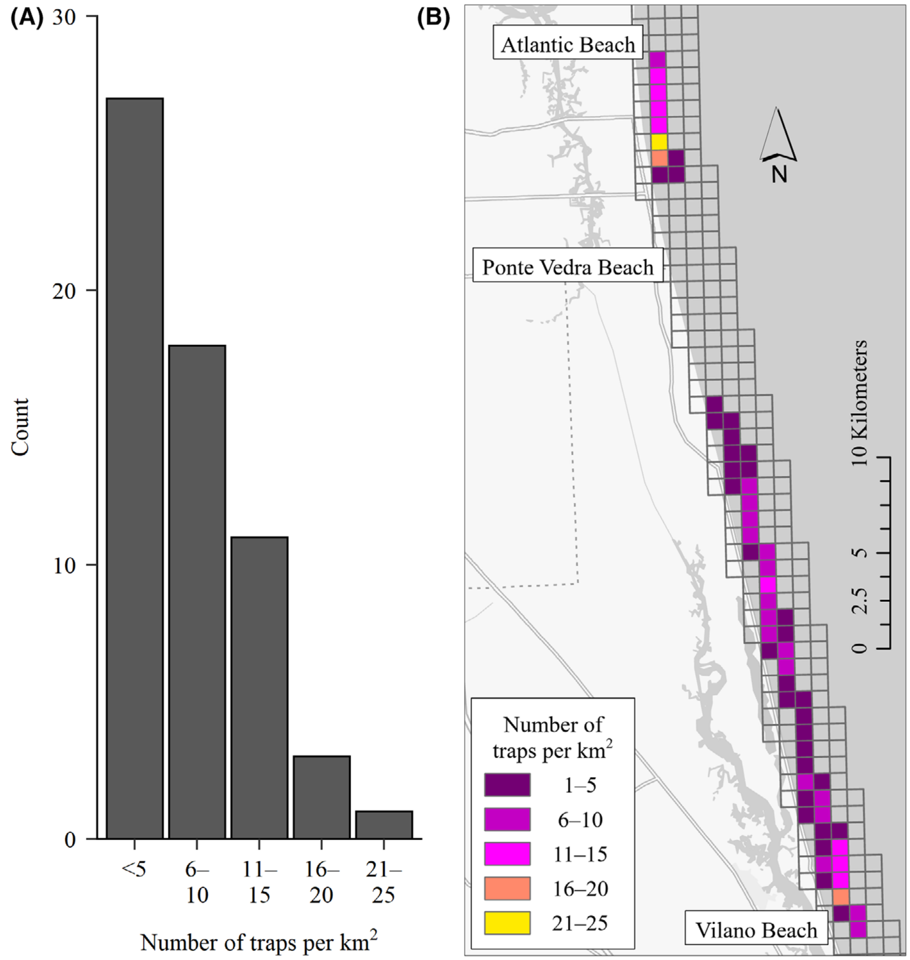

FIGURE 11. **(A)** Average number of crab traps per square kilometer for the 2021 offshore season and **(B)** map of the average number of traps per square kilometer. The average is based on the number of crab traps counted during aerial surveys in northeast Florida on January 26 and March 12.

not reflect the increased landings reported on trip tickets during the 2011–2012 offshore season. This could indicate that some of the fishers participating in the 2011–2012 offshore season did not regularly fish offshore, were from regions of Florida that were not targeted in the mail survey, were no longer in the fishery and did not receive the mail survey, or did not respond to the survey. Regulatory changes in the 2010–2011 license year, as implemented under the Blue Crab Effort Management Plan (Florida Department of State 2009), reduced the number of blue crab endorsements in Florida and may have contributed to the reduction in the number of responses (Cooper et al. 2011).

Participants of the mail survey indicated that during the winter, the most heavily fished months were January and February, which corroborated the landings and aerial survey data. The survey participants indicated that the transition to offshore waters was most often motivated by higher offshore catch rates at this time, especially in years with low inshore catch. This was demonstrated in 2018–2019, when the increase in offshore landings corresponded with a decrease in inshore landings. Likewise, decreases in the offshore fishery were attributed to a lack of crabs offshore, unfavorable weather, or crab availability inshore. The decrease in harvestable crabs offshore at the end of winter can be related to changes in temperature, leading to a higher proportion of egg-bearing females, the harvest of which is prohibited (Tagatz 1968; Florida Department of State 2009; Hart et al. 2021).

Since this fishery follows mature blue crab females as they migrate from the estuaries to saline offshore waters, it is not surprising that the offshore fishing grounds are focused near inlets (Tagatz 1968). Most offshore effort occurs on the coastline adjacent to Jacksonville and St. Augustine, as indicated by the mail survey and the landings data. The aerial surveys further delineated the fishing grounds from Vilano Beach to south Ponte Vedra Beach and from Neptune Beach to Atlantic Beach. The separation

TABLE 5. Blue crab Southeast Restricted Area North (SERA-N) fishery regulations from November 15 to April 15 in Florida state waters. For full details, see NOAA Protected Resources (2020).

SERA-N requirements in Florida state waters from Cumberland Sound to Ponce Inlet, Nov 15–Apr 15 (U.S. Office of the Federal Register 1997)
• Buoy lines must be made of sinking line. • Gear must be marked blue and orange. • Maximum of one trap per vertical line. • Entire buoy line must be the same diameter and free of objects except where it attaches to the buoy and the trap. • Gear must be hauled out of the water at least once every 30 d. • All buoys, flotation devices, and/or weights must be attached to the buoy line with a weak-link breaking strength ≤90.72 kg (200 lb). • Vertical lines must have a breaking strength ≤680.39 kg (1,500 lb).

between the fishing grounds can be due to a distance from the inlet that the crabber deems too far to travel. The distance traveled from the inlet varies with inlet topography, weather, the abundance of crabs, and the fishing vessel.

The inlets used most frequently were Mayport, St. Augustine, and Matanzas, which correspond to the St. Johns, Guana, Tolomato, and Matanzas River basins. This area includes many important habitats (e.g., salt marshes, tidal creeks, mangrove swamps, and submerged aquatic vegetation) that are used by the crabs throughout different life stages (e.g., recruitment, molting, and mating; Orth and van Montfrans 1990; Steele and Bert 1994; Radabaugh et al. 2017). These habitats are ideal because they are near the source of competent recruits from offshore spawning grounds, they are frequently flooded by incoming tides that can aid in megalopal transport, the extensive range in salinity is critical for osmoregulation, and the density of the vegetation may reduce predation (Orth and van Montfrans 1990; Steele and Bert 1994; Criales et al. 2019; Hart et al. 2021).

Once offshore, fishery participants set their traps parallel to and within 1.61 km (1 mi) of shore at a depth of 6.10–11.89 m (20–39 ft). The number of lines of traps (single or multiple) and the buoy type (bullet or round) were consistent between mail and aerial surveys. Setting the traps parallel to shore allows crabbers to set along depth contours—specifically, the contour close to 3.14 m (30 ft). Setting traps close to a steep depth contour provides some protection from trap movement during weather events. Trap fishing is limited to state waters, which, on the east coast of Florida, extends to 4.83 km (3 mi) from shore (Florida Department of State 2009). The proximity to shore at which traps are set may be a function of vessel size and capabilities, which in this fishery generally means vessels less than 7.62 m (25 ft) long.

Gear preference also varied by participant. Mail survey participants indicated that they used 9.14–45.72 m (23.80 ± 4.72 m [30–150 ft; 78.1 ± 15.5 ft]) of line and 0.00–13.61 kg (6.89 ± 2.88 kg [0–30 lb; 15.2 ± 7.2 lb]) of weight. Conversations with northeast Florida commercial blue crab fishers indicated that these line and weight setups reduce trap movement caused by wind, waves, and currents. Based on the number of traps observed in the aerial surveys and the average line length as reported in the mail survey, we estimate that there were 9.33 km (5.8 mi) of vertical line present within the bounds of the aerial survey during the 2020–2021 offshore season.

The number of traps set offshore by each participant varied. The mail survey indicated that the number of traps fished by each participant ranged from 50 to 400, with a median of 150 traps/fisher, which is equivalent to the 100–200 traps/fisher stated by crabbers at a special interest stakeholder meeting in 2019. This stakeholder meeting included seven representatives of the northeast Florida blue crab fishery and Florida Fish and Wildlife Conservation Commission staff, including one of us (C. E. Crowley). During the 2021 season, an average of 387 ± 35 traps were counted during each aerial survey, and the landings data indicated that there were 6.5 ± 0.7 active fishers in this area, resulting in an average of 59.5 ± 5.4 traps/fisher. The discrepancies between the aerial surveys and mail survey may be due to (1) fishers inaccurately reporting landings or (2) crab trap buoys being undetectable (e.g., buoys were fouled) from the plane and flight path. The survey area encompassed the restricted air space of the Mayport Naval Station, so flight elevation was temporarily increased for incoming military planes and helicopters. Additionally, due to poor weather conditions and required plane maintenance, the starting date of the aerial survey was delayed until mid-January and surveys were conducted in 3-week intervals.

Despite the high density of traps around the inlets during the winter, the offshore landings were much lower than the landings from inshore northeast Florida and statewide. The yearly average of offshore landings makes up approximately 2.6% and 0.3% of the northeast and statewide landings, respectively. We hypothesize that this is a small but valuable fishery to several crabbers, driven by seasonal demand from other states whose blue crab fisheries close in the winter, and that it produces a high-value product when inshore crabs are much scarcer. This fishery also provides a source of crabs when a blue crab trap closure is underway in the St. Johns River for the removal of derelict traps. Variability in the number of crabbers and traps used in offshore waters may result from limitations in the trip tickets. Trip tickets rely on self-reporting by wholesalers, and they do not always report on each trip. This can lead to generalizations by the crabbers on the depth fished, days soaked, and exact number of traps fished for each trip, which increases trip ticket error. Additionally, there is known confusion between the Marine Fisheries Trip Ticket FACs, which may lead to misreported landings.

Other offshore fishing effort in the southeastern United States was noted in a 2010 memorandum to the Atlantic Large Whale Take Reduction Team (ALWTRT) by C. George of the Georgia Department of Natural Resources. In 2009, George conducted a mail survey for trap effort in Georgia ocean waters (George, memorandum). The survey had a 10.7% response rate from blue crab endorsement holders, but responses were collected from 15 of 25 commercial fishers that were believed to fish offshore (George, memorandum). George (memorandum) reported an average of 65 traps/fisher (0–150 traps/fisher) in state ocean waters, with a peak of 90 traps/fisher (50–150 traps/fisher) in January and February, comparable to the average number of traps per fisher observed in our aerial and mail surveys. The length of line used in Georgia waters (George, memorandum) was also similar to our findings and ranged between 12.19 and 27.43 m (40–90 ft; Florida: 9.14–45.72 m [30–150 ft]). However, the type of nylon rope used in Georgia (number 10; George, memorandum) is thicker in diameter than the number 8 nylon rope used in Florida (7.94 mm [0.3125 in] and 6.35 mm [0.25 in], respectively). Additionally, NARW aerial survey observers sighted 4–25 rows of traps in Georgia waters, indicating that the number of fishers could range between 4 and 25 within a season (P. J. Naessig and C. R. Taylor, 2012 memorandum to the Georgia Department of Natural Resources on NARW early warning system aerial surveys, 2011–2012 season).

Entanglement in fishing gear is a threat to the NARW throughout its range. In a study of NARW mortalities between 2003 and 2018, 63% of whale necropsies identified entanglement as the proximate cause of death (Sharp et al. 2019). Entanglement can cause minor to significant injuries in NARWs, lasting from days to years (van der Hoop et al. 2017). Females with prolonged, severe entanglement are significantly less likely to reproduce again or will have prolonged calving intervals because of increased energy requirements (van der Hoop 2017). Less-than-ideal body condition (i.e., body volume as a function of body length), compounded with entanglement, could further hamper the recovery of an animal that is simply entangled in fishing gear (Christiansen et al. 2020).

The ALWTRT, formed in 1997, is composed of fishermen, scientists, conservationists, and state and federal officials from Maine to Florida (U.S. Office of the Federal Register 1997). Under the authority of the National Oceanic and Atmospheric Administration (NOAA), the ALWTRT has implemented offshore requirements for crab fishing gear (i.e., weak links, reduced line-breaking strength) to reduce the risk of serious injury or death as part of the Atlantic Large Whale Take Reduction Plan (Table 5; U.S. Office of the Federal Register 1997). However, marine mammal conservation groups are still concerned with the amount of vertical line, the added weight to each pot, and derelict gear in this region because any trap poses an entanglement risk in these NARW critical habitats and calving grounds (Gowan and Ortega-Ortiz 2014). Generalized additive models by Gowan and Ortega-Ortiz (2014) indicated that the density of NARW sightings per survey effort (km^2) based on the number of flights was greatest close to shore and in the relatively shallow (10–25-m) and cooler (12–16°C) waters west of the Gulf Stream. The Gulf Stream flows closest to shore along Florida's coast. To avoid the warmer sea surface temperatures of the Gulf Stream (>22°C), the NARWs would have to travel closer to shore along the northeast Florida coast (Gowan and Ortega-Ortiz 2014) than they would elsewhere along the U.S. East Coast (i.e., Georgia). Additionally, NOAA's NARW calving report (NOAA 2021a) indicated that there were 19 mother–calf pairs sighted throughout the southeastern USA during the 2021 calving season, with multiple sightings of whales near blue crab trap buoys in northeast Florida. Additionally, in 2019, the FWRI's Marine Mammal Section Aerial Team documented a female and her calf changing direction, diving, and altering speed to maneuver around blue crab trap buoys (T. Pitchford, FWRI, personal communication). We hypothesize that among crabbing grounds in offshore state Atlantic waters, those in northeast Florida may overlap the most with the NARW wintering grounds. However, the extent to which this gear impacts individual whales is still unclear and the present study was not designed to assess this directly. Future focus should also include analyses of NARW behavioral changes in the presence of fixed gear (NOAA 2021b; Pitchford, personal communication).

Several options exist for fishery managers to address the potential interactions between the blue crab fishery and NARWs within critical habitats. The ALWTRT is working with engineers and fishing industry members to develop cost-effective alternatives for reducing the number of vertical lines, such as ropeless gear (i.e., galvanic timed releases, timed line-cutting devices, and acoustic release buoys) or trawls (multiple pots per line; Myers et al. 2019). However, trawls may not be a viable option in the calving areas due to the extra weight potential and additional groundline (Hamilton and Kraus 2019). Hamilton and Kraus (2019) suggested that any groundline fishery poses an increased risk of NARW entanglement because NARWs of all ageclasses will interact with the seafloor throughout their range. In 2021, the Atlantic Large Whale Take Reduction Plan generated additional regulations for fisheries. These regulations included additional requirements for gear markings (in Maine, New Hampshire, Massachusetts, and Rhode Island), seasonal and spatial fishery closures, and the creation of an exempted fishing permit that allows fisheries-related research on ropeless gear during these closures (U.S. Office of the Federal Register 1997). These regulations or some variation thereof may be applicable to southeastern states where NARWs and vertical lines co-occur. Additionally, in Florida a limited-entry, offshore Atlantic Ocean license could be made available to northeast Florida commercial blue crab fishers with qualifying landings. The ability to identify individuals fishing offshore in the NARW critical habitat allows for specific monitoring of the number and locations of crabbers offshore at one time. This would also allow state and federal agencies to maintain a line of communication with participants fishing the offshore waters of northeast Florida during periods of increased whale sightings and potential interactions.

This study has characterized the northeast Florida offshore blue crab fishery, including crabber behavior, seasonal trends, and the geographic areas fished. The primary fishing grounds extend from Vilano Beach to south Ponte Vedra Beach and from Neptune Beach to Atlantic Beach, and the most frequently fished months are January and February. Within these fishing grounds, 50–400 traps can be set each season, parallel to and within 1.61 km of shore, in single or multiple lines, and at a depth of 6.10–11.89 m. Within the bounds of the aerial survey during the 2020–2021 offshore season, it was estimated that 9.33 km of vertical line were used by the crabbers at any one time. This small fishery (2.6% of northeast Florida landings and 0.3% of statewide landings), though valuable to several crabbers, is driven by seasonal demand and produces a high-value product when inshore crabs are less available. Additionally, blue crab fishers of northeast Florida have been receptive to and compliant with the Atlantic Large Whale Take Reduction Plan (Table 5), and they have advanced previous regulations by their involvement on the ALWTRT.

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ORCID

Samantha L. Ehnert-Russo https://orcid.org/0000-0002-7024-8832
Claire E. Crowley https://orcid.org/0000-0002-0793-5234

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SUPPORTING INFORMATION

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