

Full length article

Understanding a changing crustacean fishery through industry perspectives and ecological insights

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ABSTRACT

Fishers' local knowledge can complement scientific information to improve understanding of fishery systems and enhance resource management. Shrimps in the genus *Penaeus* are ecologically important species in coastal areas globally, and populations of penaeid shrimp support economically valuable fisheries. In the coastal zone of the states of Georgia and South Carolina in the southeastern United States, referred to here as the 'Lowcountry', the fishery for these species is facing a series of challenges that have impacted landings. Concurrently, the stocks that support this fishery are facing increasing environmental variability. Here, we integrate the perspectives of commercial shrimpers as well as researchers studying shrimp populations and their associated fisheries from diverse lenses, ranging from anthropology to fisheries science to population ecology, focusing on the period since ~ 1980. We quantify trends in landings for white (*P. setiferus*) and brown (*P. aztecus*) shrimp and then outline challenges faced by this fishery, many of which are shared by other fishery systems. We also summarize recent natural science findings regarding shrimp population ecology. We find general overlap between the perspectives of commercial shrimpers with natural science data describing shrimp populations and their environment, particularly as it relates to warming temperatures and changes to shrimp size. Our effort to bring together diverse perspectives about a changing fishery can serve as a framework for other shrimp stocks, as well as other fisheries undergoing comparable changes and facing similar challenges.

1. Introduction

Fishing is, by nature, an ever-changing profession that is subject to a wide range of pressures on both the natural resource and the humans that conduct the fishery. These biological and socioeconomic factors can influence the viability of any given fishery, and many are pressures that fisheries (and the humans that work in them) have experienced for centuries or millennia. However, new pressures such as globalization and climate warming are adding additional stress on fisheries worldwide (Perry et al., 2011), including those focused on shrimps (Foster and Vincent, 2010; Gillett, 2008). Understanding how internal perceptions from within a fishery relate to empirical natural science findings can be a

valuable means for expanding knowledge used in the fishery management process (del Valle et al., 2024; Heck et al., 2025). Comparing these two sources of information also helps to enhance the framework for building local ecological knowledge into natural resource management discussions, potentially enhancing sustainability or minimizing conflicts between industry and managers to the degree possible (Foster and Vincent, 2010; Thornton and Scheer, 2012).

White shrimp (*Penaeus setiferus*) and brown shrimp (*Penaeus aztecus*) are economically and ecologically important penaeid shrimp species found in coastal and estuarine waters along the southeastern US Atlantic and Gulf of Mexico coastlines. These species support major fisheries and together make up the vast majority of the commercial shrimp landings in

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our focal study region (the coasts of South Carolina and Georgia, USA), where penaeid food shrimp were valued at \$12.6 million annually in 2024 (ACCSP 2024). White and brown shrimp have similar life history strategies (albeit with different timing), with adults spawning in the coastal ocean and producing eggs and larvae that disperse as plankton before metamorphosing and ingressing into estuarine habitats as post-larvae (Weymouth et al., 1933). These species rely on estuaries as nursery habitats during critical juvenile and sub-adult stages before migrating offshore to mature and spawn (Fig. 1). Penaeid shrimp life history occurs on an annual scale and, in general, shrimp populations exhibit high interannual variability that is likely driven by their sensitivity to factors such as habitat availability and access, as well as environmental conditions including water temperature and salinity (DeLancey et al., 2008; Dunn et al., 2025; Fowler et al., 2018; Lindner and Anderson, 1956).

The fishery for penaeid shrimp along the southeastern US Atlantic coast occurs in nearshore state-managed waters (less than 3 miles off the coastline) and offshore federally-managed waters (3–200 miles off the coastline), and shrimp are most commonly collected by pulling trawl nets over muddy and sandy bottom. These species are managed in state waters by state natural resource management agencies (e.g., Department of Natural Resources, DNR) and in federal waters by the South Atlantic Fishery Management Council (SAFMC) and the US National Oceanic and Atmospheric Administration. Historically in Georgia and South Carolina, white shrimp have been targeted during two seasons (spring and fall) while brown shrimp were the focus of a secondary fishery caught largely during summer months, in between the white shrimp seasons. These fisheries in Georgia and South Carolina are managed seasonally by opening and closing state waters to trawling, the timing of which is intended to provide for protection of overwintering white shrimp that compose the spawning stock during the spring. Thus, winter water temperature is a key factor in determining the timing to close the fishery in the winter and then open the fishery in the spring. During extreme cold weather events, state and federal agencies may co-

manage the fishery with concurrent closures to protect overwintering white shrimp that have survived. In South Carolina, the DNR regularly interacts with industry to gather information on the composition of the commercial catch as well as reproductive status in the shrimp population. Likewise, the Georgia DNR seeks similar input from a shrimp advisory panel made up of local fishery end-users. Additionally, the regional management council (SAFMC) gathers input from shrimping industry members through an Advisory Panel which is a venue to discuss the industry on the regional scale and give feedback to management agencies directly.

Rarely are data, research methods, and perspectives from biologists, social scientists, resource managers, and commercial fishing industry members brought together in a research context to examine a fishery system (but see Heck et al., 2025), and such an effort has not coalesced for the commercial shrimp industry in the Lowcountry of South Carolina and Georgia on the southeastern US Atlantic coast for decades (Henry et al., 2001; Jones et al., 1979; Lindner and Anderson, 1956; Theiling, 1977). Therefore, we sought to assess current shrimp fisher (hereafter: shrimper) perceptions of the commercial shrimping industry in this region to provide socioeconomic context to natural resource data collection and analyses. Specifically, we used semi-structured, in-person interviews to understand perceptions of commercial shrimp harvest and effort within the context of changing environmental conditions, focusing on the period since ~ 1980. To achieve this socio-ecological synthesis, we first provide background on the fishery for penaeid shrimp along the southeastern US Atlantic coast (Section 1; this section), followed by a presentation of trends in shrimp landings in South Carolina and Georgia over the last five decades (Section 2). We then outline the historic and current challenges facing the shrimp fishery in the region (Section 3) before describing results from a detailed examination of the perspectives of the commercial shrimp industry members interviewed (Section 4). Finally, we place these industry perspectives within the context of recent natural science insights on decadal-scale changes observed in environmental conditions and fisheries-independent surveys (Section 5). Our



Fig. 1. Life cycle for white and brown shrimp along the southeastern US Atlantic coast depicting major life stages. Adults spawn offshore producing eggs that develop into larvae that metamorphose and ingress through inlets into estuarine habitats. Once inshore, postlarvae settle to the benthos, grow to juveniles and sub-adults, then migrate back offshore as adults to spawn.

qualitative analysis of shrimper's perceptions of the fishery was designed to determine changes to the shrimp fishery related to harvests, effort, and operations, along with changes in shrimp population distribution, biology, and disease prevalence. This effort allowed us to gather detailed information from members of the shrimping industry that could then be compared to the current understanding of shrimp ecology in this region as well as commercial harvest records from South Carolina and Georgia. Examination of historical regional shrimper demographics and commercial shrimp landings data, along with findings from shrimper interviews, allowed us to assess if challenges currently experienced by shrimpers were related to perceived or observed changes in shrimp populations. Ultimately, our goal was to examine the intersection of social, cultural, and biological factors to develop a more comprehensive understanding of the commercial shrimp fishery in the Lowcountry of the southeastern US.

2. Fishery-dependent trends in shrimp landings

Commercial fishery-dependent landings data across multiple fisheries are generally tracked in the United States by resource management agencies through mandatory fishing reports, as required by the Magnuson-Stevens Fishery Conservation and Management Act of 1976. Although concerns and limitations with these self-reported data have been documented (Sampson, 2011), they remain a cost-effective source of the best available commercial catch data for use by researchers and fisheries managers. In the present study, monthly commercial penaeid shrimp landings data were sourced from the Georgia DNR and South Carolina DNR from 1979 to 2025 and summarized seasonally and annually. Because not all commercial shrimp landings are reported at the species level, estimates of species composition of commercial shrimp landings for these states are calculated based on dockside observations or fishery-independent sampling conducted by the SC DNR and GA DNR, respectively. Commercial penaeid shrimp landings in the Lowcountry are dominated by white shrimp and brown shrimp (Fig. 2), although pink shrimp (*Penaeus duorarum*) and seabobs (*Xiphopenaeus kroyeri*) are also commercially reported in limited amounts (Atlantic Coastal Cooperative Statistics Program, 2024). Some landings characterized as 'mixed penaeid shrimp' are also reported but are typically a small proportion of the total catch and are not included in these analyses.

Brown shrimp are typically harvested in the summer, while white shrimp landings occur primarily in the fall and spring. Our examination of commercial shrimp landings in the region revealed that landings fluctuated over the decades for brown and white shrimp differently (Figs. 2 and 3). Landings of white shrimp and brown shrimp appear to have peaked in the 1990s, but since that time both fall white shrimp landings and year-round brown shrimp landings decreased (Fig. 2). Conversely, spring white shrimp landings have trended upward since ~2010 (Fig. 2).

These trends are highlighted by substantial changes in the relative importance of different shrimping seasons over the past four decades. On average, the fall white shrimp season has historically been the season with the highest commercial penaeid shrimp landings, but its importance has significantly decreased over time (Fig. 2; $\tau = -0.24$, $p = 0.019$; models fitted using the EnvStats package in R; Millard, 2013; R Development Core Team, 2025). Similarly, brown shrimp have seen significant declines in their contribution to total shrimp landings (Fig. 2; $\tau = -0.49$, $p < 0.001$). During that same time, the spring white shrimp season, typically made up of large mature white shrimp, has seen significant increases in its contribution to total shrimp landings (Fig. 2; $\tau = 0.51$, $p < 0.001$). In the subsequent sections, we sought to put these changes into context based on known challenges facing this industry as well as observed trends in environmental conditions and shrimp populations based on natural science data.

3. Challenges facing the shrimping industry

The commercial shrimping industry of the Lowcountry has faced numerous challenges over the last half century, with each new issue compounding the others (Tookes et al., 2026). The age and size of the fleet have impacted, and been impacted by, decreasing shoreside infrastructure such as fishing docks, fish houses, and marine parts stores, along with a declining workforce (Fig. 3). Profit margins are being directly affected by the high cost of diesel fuel and competition with lower-priced shrimp imported from other countries. These struggles are set against changing environmental conditions, which affect the health of the species on which the industry relies, and the industry's ability to harvest the resource. Here, we detail five key challenges facing the industry in the southeastern US Atlantic coastal regions of South Carolina

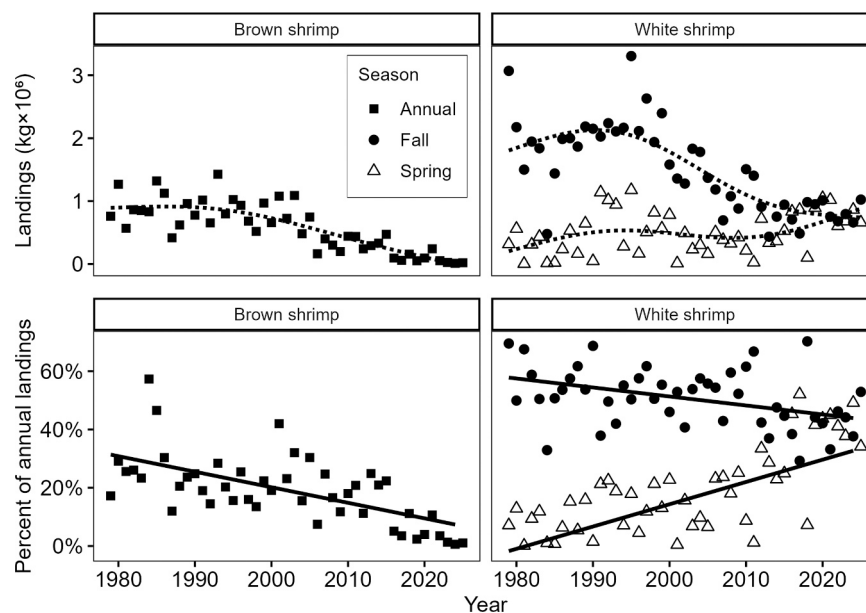


Fig. 2. Top row: Trends in brown shrimp and white shrimp commercial landings from South Carolina and Georgia combined for each year over the period 1979-2025 with lines representing fitted GAMs ($k = 4$). Bottom row: Trends in the percentage of total landings from white shrimp and brown shrimp, including spring (Mar-Jun) and fall (Aug-Dec) for white shrimp and total annual landings for brown shrimp; solid black lines represent significant ($p < 0.05$) Kendall trend tests.

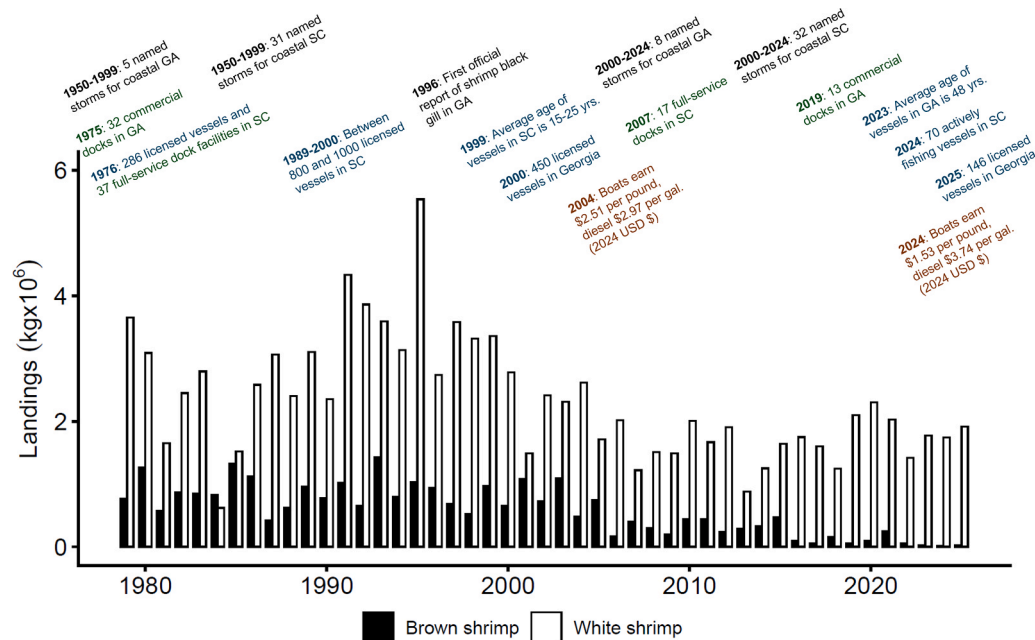


Fig. 3. Significant milestones in the Lowcountry shrimp fishery are overlaid on aggregated annual commercial landings for brown and white shrimp in South Carolina and Georgia, USA for the period 1979–2025. Significant environmental events are shown in black text, vessel data are denoted in blue, infrastructure is in green, and economic figures are in brown.

and Georgia, many of which are relevant to other fishery systems around the world.

3.1. Aging and shrinking fleet

The “graying of the fleet” is a known issue within fishing industries throughout the US, with both vessels and the workforce growing older, and insufficient younger labor and newer vessels entering the fleets (Cramer et al., 2018; Donkersloot and Carothers, 2016; Johnson and Mazur, 2018). Much like other commercial fishing industries, the commercial shrimping fleet in Georgia and South Carolina has both aged and decreased in number over the past three decades. The number of licensed double-rig shrimp trawlers in South Carolina was just below 300 boats in the mid-1970s (271 in 1974, Jones et al., 1979; 286 in 1976, Theiling, 1977). The number of vessels of all sizes had risen to and remained between 800 and 1000 vessels from 1989 to 2000, before decreasing to around 350 licensed vessels in 2024, by which time, the number of actively fishing double-rigged vessels had decreased to 70 (J. F.B., pers. obs.). There was a similar decline in the number of shrimp vessels in Georgia in the late 20th century, with an estimate of approximately 450 licensed boats remaining in 2000 (Blount, 2007) and only 146 licensed vessels at the beginning of the 2025 state season (pers. comm., J. Califf, Georgia DNR, 3 August 2026).

Likewise, shrimp harvests in recent years in South Carolina and Georgia have come from a small number of vessels, relative to historic numbers. In South Carolina in 2024, 89 vessels reported some level of shrimp harvest, although in many cases the harvest was very limited (J. F.B., pers. obs.). Although a recent and detailed analysis of the commercial shrimping fleet in South Carolina is not available, a 1999 survey of licensed South Carolina shrimpers found that the average age of shrimp vessels was 15–25 years (Henry et al., 2001). Nonetheless, a recent survey of the commercial operations of shrimpers in Georgia likely reflects the current circumstances of those in South Carolina because shrimpers in both states experience similar environmental and socioeconomic conditions. In Georgia, a 2023 study of commercial vessels with shrimp licenses in the state found that 53 were actively fishing for food shrimp (as opposed to bait shrimp) at that time (Fluech and Tookes, 2024). This group was systematically sampled by county of

residence to gather data about vessel conditions, maintenance, needed repairs, and challenges that owners faced in keeping the vessel actively shrimping in the commercial sector (Fluech and Tookes, 2024). Of the 25 vessels examined in depth from Georgia, they exhibited a mean vessel age of 47.8 years and ranged from 28 to 72 years of age (Fluech and Tookes, 2024). Vessel owners explained that maintaining their place in the commercial fleet grew more challenging each year, particularly in terms of the types of repairs and maintenance required of aging vessels that are predominately wood and fiberglass construction. Critically, the speed and quality of repair and replacement of vessel components are impacted by the financial resources of the vessel owner, which is ultimately linked to fishing success.

Related to repairs, Georgia shrimpers also expressed that the accessibility, affordability, and quality of parts for use on vessels have declined dramatically in recent decades (Fluech and Tookes, 2024). Products were difficult to obtain because many stores that carried these parts have closed. The costs of needed parts have increased dramatically, while the quality of the parts has decreased substantially. In many cases, people were choosing to refurbish or rebuild parts that were years or even decades old because the quality of the repaired piece would be higher than a newly purchased part. There was little financial assistance available to replace parts, even in cases of disaster, as most vessels were not insured. Of the 25 vessels examined in Georgia, only nine (36%) had insurance coverage, primarily due to barriers in the affordability of coverage and the refusal of most companies to cover wooden hull vessels (Fluech and Tookes, 2024).

3.2. Aging infrastructure

Shoreside infrastructure associated with fishing industries is facing similar challenges to those described for vessels. A dock census conducted in 1975 identified 32 commercial docks in Georgia (Nix et al., 1975). This number declined over the intervening decades, and a comprehensive study of shoreside infrastructure for commercial fishing in Georgia in 2019 identified only 13 docks in operation (Tookes et al., 2020). Since then, several others have quietly dwindled their operations, and ongoing research indicates only eight docks in Georgia currently have shrimp crossing through their business (Fluech and Tookes, 2024).

In South Carolina in 1976, there were 62 licensed dockside facilities of which 37 were considered full-time packers providing docking, unloading, heading, packing, and shipping for commercial shrimpers (Theiling, 1977). By 2007, there were only 17 of these facilities remaining in South Carolina (Rhodes et al., 2008). While we do not have a current estimate of shoreside infrastructure in South Carolina, this number has likely continued to decline.

3.3. Fuel cost vs. landings price

One of many challenges facing the industry is that over the past two decades there has been a steady increase in the cost of fuel, and a concurrent decrease in the price of shrimp at the boat and dock. In 2004, the retail price for a gallon of diesel fuel was \$2.97 (in 2024 US dollars adjusted for inflation), and in 2024, that same gallon of diesel retailed for \$3.74 (United States Energy Information Administration, 2025). The same increase has not occurred in the prices for shrimp paid to the shrimp boats or at the docks. In 2004, a pound of shrimp earned \$2.51 (in 2024 US dollars adjusted for inflation) to the boat, while in 2024, that price was \$1.53. Thus, there is a narrowing gap between the expenses associated with running a commercial shrimping vessel and the revenue that can be made in current economic conditions. We note that this declining profit margin is a compound effect of multiple factors, including fuel prices and market competition from imported shrimp, and we do not attribute economic challenges facing shrimpers solely to this discrepancy between trends in fuel prices and trends in the value of shrimp landed. However, this is a stark discrepancy that shrimpers observe on a near-daily basis.

3.4. Shrimp imports

The low price for US wild caught domestic shrimp is due in large part to less expensive imported shrimp (Asche et al., 2022). In interviews with Georgia shrimpers across multiple studies between 2013 and 2026, many shrimpers described financial competition with shrimp produced in other countries with less stringent environmental and employment guidelines (Tookes et al., 2018, 2020; Fluech and Tookes, 2024). To illustrate, in 2025 The Southern Shrimp Alliance pointed to record low landings of US shrimp, explaining “American importers continue to claim that cheap, contaminated, unfairly-traded foreign shrimp is not the root cause of the devastation experienced by the US shrimp industry over the last two years...low prices in the marketplace forced shrimp boats throughout the Gulf of America [Mexico] and South Atlantic coastline to tie up and not work” (National Fishermen Staff Writer, 2025). The competition from the less expensive imported product is further intensified by the relatively common mislabeling of product origin, whether intentional or inadvertent (Buck, 2007; Korzik et al., 2020; Ogden, 2008). Nevertheless, there is recent progress to address this foreign competition, with legislative bodies in both states passing bills requiring labelling of imported shrimp served in Georgia and South Carolina restaurants (i.e., Georgia House Bill 117: Shrimp Transparency Act and South Carolina State House Bill 4248: The Truth in Shrimp Labeling Act).

3.5. Climate impacts

While each of the previous factors can be traced back to the globalized economy and food systems, they are all taking place against a backdrop of a changing natural environment. Ocean levels have risen 25 cm in coastal Georgia since 1935 (NOAA, 2025), and high tide flooding days in South Carolina have increased from an average of 0–2 days per year prior to 2000 to 5–10 days per year by 2020 (Sweet et al., 2022). While there were only five named storms and hurricanes that impacted coastal Georgia in the second half of the 20th century (1950–1999), the first quarter of the 21st century (2000–2024) has already seen eight (NOAA/National Hurricane Center: Tropical Cyclone

Naming History, 2026; National Weather Service, 2026). Named storms impacting South Carolina have been far more common, but the 31 named storms between 1950 and 1999 have been quickly outpaced by the 32 that have already impacted South Carolina in the first 25 years of this century (NOAA National Hurricane Center; National Weather Service). Additionally, there have been several regional droughts in the early 21st century that are associated with decreased landings of shrimp (GA DNR, 2026). While commercial shrimpers in Georgia and South Carolina shared mixed responses to weather and climate related queries (see below, Section 4), collectively, these ecosystem impacts will likely influence both the ecology of these fishery stocks as well as the operational decisions of commercial shrimpers themselves.

4. Perspectives of commercial shrimping industry members

4.1. Interview methods

Fisheries extension agents in Georgia and South Carolina designed research instruments and conducted informal, semi-structured interviews with commercial shrimpers (N = 12) whose home ports were located in South Carolina and Georgia between 2022 and 2023 (see Supplemental Material: Shrimper Semi-Structured Survey Questions). The study utilized purposive convenience sampling, with interview participants selected based on their home ports and shrimping experience, previous engagement with Sea Grant extension staff, or by being recommended by others in the industry. However, there was no minimum number of years in the industry required to participate in the interviews, participation was voluntary, and interviewees were offered a \$100 stipend for participation. Interview participants filled out a consent form prior to the interview, and all interviews were conducted in person and recorded using portable recorders. Interview recordings were machine-transcribed using Otter.ai and reviewed by the interviewers for accuracy. To identify overarching themes, we used a Microsoft Excel database to organize shrimper responses to main questions from the survey instrument (Supplemental Material), and, when possible, we calculated percentages to describe analogous responses to survey questions.

The purpose of the interviews was to gather shrimper observations and perceptions of shrimp harvest and effort trends within the context of changing environmental conditions in the southeastern US Atlantic region. Participants were asked to discuss any changes in the environment and weather conditions they have observed since they started shrimping, as well as changes they have observed in the distribution, abundance, size, and condition of the shrimp they caught. In addition, participants were asked how, if at all, they have had to change the way they shrimped in light of these observations and factors. Finally, participants were asked to list their top three concerns as a shrimper today compared to ten years ago. We note that saturation was not reached with only 12 participants, and that this was never our goal. Our effort here was intended to provide a snapshot of industry perspectives for comparison with other data sources.

4.2. Interview demographics and broad themes

Commercial shrimpers interviewed were all white, male, and served as the captain or owner (or both) of their vessel and had an average of 38 years of experience in the shrimping industry (Table 1). Home ports for the interviewed shrimpers ranged from St. Marys, Georgia to McClellanville, South Carolina and included docks in Brunswick, Darien, Townsend, Valona, and Savannah in Georgia and St. Helena in South Carolina; collectively, shrimping locations extended from Cape Canaveral, Florida to the Outer Banks of North Carolina (Fig. 4). Shrimping activities in North Carolina typically took place in mid to late summer for brown shrimp or fall for white shrimp, or both. Shrimping activities in Florida typically occurred in late fall through early spring for white shrimp. Those who primarily shrimped in the state and federal waters of

Table 1

Demographic information on the commercial shrimpers interviewed (n = 12), including the number of years they have been in the commercial shrimping industry, home port, role on the shrimping vessel, and the geographic range of their shrimping activities. All interviewees were white males.

Years in Industry	Home Port	Role on Vessel	Shrimping Range
40	St. Marys, GA	Owner, Captain	State and federal waters between Jekyll Island, GA and Amelia Island, FL
Over 50	Brunswick, GA	Owner, Captain	State and federal waters in GA between St. Simons Island and Jekyll Island
44	Savannah, GA	Captain	State and federal waters between Frying Pan Shoals, NC and Cape Canaveral, FL
15	Townsend, GA	Captain	State and federal waters between Outer Banks, NC and Cape Canaveral, FL
10	Valona, GA	Owner, Co-Captain	State and federal waters between Outer Banks, NC and Cape Canaveral, FL
30	Darien, GA	Owner, Captain	Mostly state waters off Sapelo Island, GA
40	Townsend, GA	Captain	Between Ossabaw Island, GA and New Smyrna, FL
37	St. Helena, SC	Owner	Mostly southern state waters of SC
50	McClellanville, SC	Owner, Captain	Mostly state waters between Bulls Island & Bay, SC and Rockville, SC
40	McClellanville, SC	Owner, Captain	Georgetown, SC to Edisto, SC in both state and federal waters
50	St. Helena, SC	Owner, Captain	State and federal waters between Pamlico Sound, NC and FL-GA border
55	McClellanville, SC	Captain	State and federal waters of NC, SC, and FL; sometimes GA

their home state indicated they liked being ‘closer to home’ due to family, their age, the age of the vessel, fuel costs, consumer demand, or convenience and personal preferences. Respondents willing to travel beyond their home port states indicated a desire to catch the biggest and most shrimp per market demands.

Interview participants shared their top three concerns as shrimpers today as compared to ten years ago. Of the 34 total responses provided, only six responses (18%) were related to biological or environmental concerns. The overwhelming majority of responses (82%) had ties to socioeconomic concerns, with competition with imported shrimp mentioned most often (6). In addition, in response to open-ended questions about changes in the environment, shrimp stocks, and their shrimping practices, two main themes emerged: (1) socioeconomic concerns linked to operational challenges, and (2) environmental and biological changes. We explore both themes in detail below.

4.3. Interview findings: socioeconomic concerns linked to operational challenges

Socioeconomic issues were a key concern for interviewed shrimpers. Interviewees generally agreed that local markets were increasingly favoring larger shrimp than in the past. Several commented that prior to the past four or five years they had no problem selling smaller brown or white shrimp, but that it had become a significant challenge getting suitable prices for them more recently.

“Right now the way it's getting in this industry, if you don't have a shrimp that, with the head off, [is] a 31–35 or better, it's kind of not even worth messing with.” - Georgia shrimper

“It's more of a peddler's market, more of direct sales, so I always steer towards catching bigger shrimp because that's what my customers want.” - Georgia shrimper

Many interviewees commented that they have “given up on brownies

[brown shrimp]” because of the smaller sizes and lower quantities they encounter, and the lower prices brown shrimp typically bring, particularly after Hurricane Katrina destroyed several of the peeling and deveining processing facilities in Louisiana where they previously sent these smaller brown shrimp. Some noted that smaller brown shrimp were often discarded when mixed with the larger, more valuable roe white shrimp. Further, some noted that they sometimes stopped fishing and relocated their efforts if they began catching too many of the smaller brown shrimp in their trawls. However, several shrimpers who sell directly to consumers commented that they were still able to easily sell the brown shrimp they caught and that they had some customers who actually preferred the smaller shrimp.

In addition, interviewees from both states referenced the growing economic importance of the spring roe white shrimp season. While the fall white shrimp season was once a primary source of income for many shrimpers (and brown shrimp were considered a summertime staple), several interviewees mentioned that the spring roe white shrimp season now holds the most economic importance to them, as they can get more money for their larger white shrimp. Crews prioritized maintaining the quality of roe white shrimp, and one captain even referenced adding extra crew to handle high volumes of roe white shrimp in warmer conditions.

“[I] can remember back when [I was] a young man...roe [white] shrimp in the spring, if you caught any at all, it was a bonus, you didn't count on them at all. Now, people rely on maybe 40% of their income from roe [white] shrimp.” - South Carolina shrimper

“[I] could have kept fishing past February, but [was] at [the] dock for maintenance reasons... had to make time to stop... didn't want [to] risk missing roe [white shrimp] season this year – that's the money maker.” - Georgia shrimper

As local markets continued favoring larger shrimp, however, the harvest of late fall and early winter large white shrimp still remained important to shrimpers' operations, with one Georgia shrimper mentioning that ‘white shrimp is a blessing.’

Shrimpers also emphasized the need for adaptability, with most reporting changes in how they operated: fishing year-round, traveling farther or out of state, switching to direct marketing, or altering crew payment structures to stay viable in response to recent conditions. Many also described becoming more strategic about when and where they shrimped, particularly due to rising fuel costs and fluctuating market prices, carefully weighing risks and benefits before leaving the dock. Examples included upgrading engines to boost productivity despite higher fuel use, or choosing not to shrimp at all unless they were confident that marketable shrimp were present to ensure the trip remained profitable.

“If you are going to be a successful fisherman you have to adapt just like anything else, just try to find a way to deal with it” - Georgia shrimper

“You have to risk it for the biscuit. It's fishing! A lot of reward to risk ratio... need to still remain financially ahead.” - Georgia shrimper

4.4. Interview findings: environmental and biological concerns

Interview participants in both states reported observing at least one notable change in environmental or weather conditions during their careers, with ten of 12 specifically noting increasingly mild winters. For example, a South Carolina captain remembered the Thanksgiving holiday (late November, in the United States) traditionally being colder in the past. A shrimper in Georgia also mentioned ice being fairly common on boat decks (and his beard) in winter months during the 1970s. Perspectives were mixed about whether the warmer winters appeared to be an ongoing trend or a temporary cycle. However, six shrimpers did note how unusual they found the growing presence of commercial quantities of shrimp in the Chesapeake Bay region, which historically had been

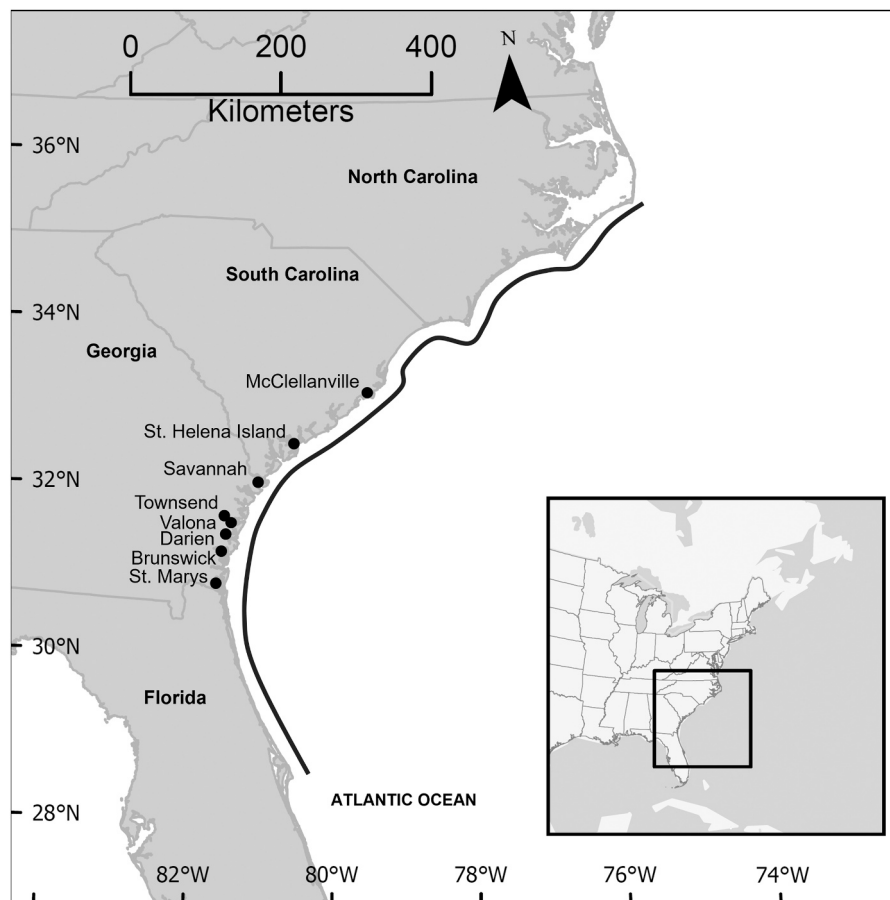


Fig. 4. Home port locations of interviewed commercial shrimpers in South Carolina and Georgia along the southeastern US Atlantic coast. Shrimping grounds utilized by these shrimpers extended from the Outer Banks of North Carolina to Cape Canaveral, Florida, as denoted by the black line along the coast.

beyond the range of these species due to thermal limitations.

“It seems like that ‘melt your face off days’ are [occurring] more often” - Georgia shrimper

Seven shrimpers referenced connections between winter temperatures and the productivity of the spring roe white shrimp season; prolonged colder winter temperatures can negatively impact roe white shrimp while milder temperatures can positively impact productivity. However, no shrimper made any connections between winter conditions and fall white shrimp productivity. April was a commonly identified month for the arrival of roe white shrimp, specifically in Georgia and northeast Florida, but their presence in March was also observed as the region experienced milder winters. Some captains also observed more overlap between brown shrimp and roe white shrimp seasons with more ‘mixed up’ catch than they remembered historically.

In addition, shifts in the timing of the fall white shrimp season were mentioned by four of the shrimpers. A South Carolina shrimper acknowledged that while “each year is different,” October has now become the main month where he starts targeting white shrimp instead of August and September. Another shrimper commented, “now, quite often, September is a sorry month.” Seven interviewees reported decreased quantities of brown shrimp and a shorter window of their seasonal presence, though timing generally still ran from late May through July.

Shrimpers from both states also observed at least one change in the amount and size of the shrimp they caught since they began in the industry, with some shrimpers mentioning that the fall white shrimp catch was not as ‘uniform’ in size as they remembered in the past. Four shrimpers also felt that the overall quantity of the fall white shrimp crop

had decreased, compared to what they historically remembered. Eleven of the 12 shrimpers mentioned that the size of the summer brown shrimp they caught seemed smaller than in the past. Shrimp “counts” are based on the average number of shrimp needed to comprise a pound; thus 16–20 count shrimp are quite large and often the feature of a seafood entree or appetizer (e.g., shrimp scampi, shrimp cocktail), but 71–90 count shrimp are very small and primarily used in salads or dips. While one Georgia shrimper commented that he used to regularly catch 31–35 count brown shrimp in the 1980s, the biggest brown shrimp currently observed by these shrimpers varied substantially, with some reporting 40–50 as their biggest and others reporting 26–30 count sizes.

“Our brown shrimp used to be pretty much a staple in the summertime, now they show up very small and are only around for two or three weeks and they never grow. It used to be up into August catching brown shrimp but for the last 3–4 years, August, you pretty much stay tied up because [there’s] no shrimp and plenty of sharks” - South Carolina shrimper

The most common non-shrimp species noted by shrimpers was sharks, with eight of the 12 shrimpers mentioning an increase in shark interactions. Our interviews were not focused on this particular stressor, but we acknowledge that shark depredation is a growing concern. Similarly, black gill was discussed, and shrimper descriptions generally matched scientific understanding (see below, [Section 5.4](#)). Shrimpers noted that black gill syndrome becomes most apparent in warm months and declines as waters cool. Many remembered first noticing black gill between the mid-1990s and early 2000s and agreed that the first seasonal sightings typically occur between May and July each year. Seven shrimpers felt black gill severity had decreased in the past two years, and many observed high infection rates, sometimes exceeding 90%, in small

white shrimp exiting sounds and creeks in late summer, which they attributed to the high numbers of shrimp in those areas at that time. Shrimpers also reported black gill presence in brown shrimp, which was a change from early years, and occasional low-level observations in roe white shrimp.

"I think its because there are so many shrimp in the sounds, in the rivers and stuff, it's chalkblock [sic] full and they ain't got nowhere to feed off of." - Georgia shrimper

"September used to be the best month, but in the last decade or so with black gill disease, the first crop of September is almost non-existent; it isn't until October-January now when they get a good spring spawned crop." - South Carolina shrimper

5. Natural science insights: abiotic conditions and fisheries independent surveys

5.1. Warming winters and variable salinities

Coastal and estuarine ecosystems along the southeastern US Atlantic coast are experiencing changing environmental and physical conditions, many related to the impacts of climate warming, including rising seas, increased frequency and intensity of extreme weather events, and changes in water temperatures and salinities (Baker et al., 2020; Ohenhen et al., 2024; Paerl et al., 2019). These changes can lead to dramatic alterations to these coastal and estuarine ecosystems. Considering the North Inlet estuary in South Carolina as one example, examination of multiple decadal-scale time series revealed that considerable environmental change has occurred in this system: subtidal creeks have warmed during the winter and summer periods, while salinities during summer and fall have been reduced (Kimball et al., 2020); chlorophyll-*a* concentration in surface waters increased beginning in the mid-2010s (Dunn et al., 2023); and tidally-driven submergence time has increased, modifying nutrient dynamics on the intertidal marsh platform (Krask et al., 2022). Each of these changes may independently or synergistically impact coastal and estuarine flora and fauna, such as penaeid shrimp.

Expanding to other estuaries in this region, long-term records (~20 years) document rising water temperatures in the ACE Basin estuary (South Carolina) and Sapelo Island estuary (Georgia), mainly driven by increases during winter months (December to February; Mallick and Dunn, 2024). In addition, a 42-year water temperature time series from South Carolina's Charleston Harbor and the sounds of Georgia highlights these increasing winter water temperatures (Wagner et al., 2025). Likely associated with this long-term annual increase in water temperature was a widespread decrease in dissolved oxygen concentrations (DO), which also occurred mainly during the cold weather period, though DO levels had not yet become widely hypoxic or anoxic (Mallick and Dunn, 2024). Temporal trends in estuarine salinity along the southeastern US Atlantic coast were highly variable, with different estuaries exhibiting increasing, decreasing, or variable salinities, depending on their degree of riverine influence and geomorphology (Mallick and Dunn, 2024). Overall, these decadal-scale changes in abiotic conditions have wide-ranging implications for coastal and estuarine ecosystems and the organisms that depend on them, such as penaeid shrimp. Warming winters, changing salinities, and alterations to primary production and nutrient cycling can lead to altered habitat use by biotic communities (e.g., phenological changes), shifting species composition, and modified food webs, ultimately impacting the critical ecosystem functions and services provided by estuaries (Barbier et al., 2011).

5.2. Increasing abundance of postlarval brown and white shrimp

Examination of a 37-year biological and environmental time series

indicated long-term increases in both white and brown shrimp postlarvae from 1981 to 2017 in the North Inlet estuary in South Carolina along the southeastern US Atlantic coast (Dunn et al., 2025). Interannual variation in brown and white shrimp postlarval abundance was negatively correlated with salinity, and white shrimp abundances and timing of ingress to estuaries were also sensitive to winter water temperatures, with delayed ingress and lower abundances associated with cold winters. The only other studies that have sampled penaeid postlarvae in estuaries for a decade or more were also conducted in the southeastern US, in North and South Carolina. A 17-year (1975–1992) sampling program for postlarval penaeid shrimp ingress near Charleston, South Carolina suggested an increase in white shrimp postlarvae over that time period (DeLancey et al., 1994), which generally overlaps with the early years of the sampling effort in the North Inlet estuary (Dunn et al., 2025). Interestingly, pink shrimp (*Penaeus duorarum*) postlarvae were the most abundant species collected throughout the 37-year sampling effort in the North Inlet estuary, yet juvenile and sub-adult stages of pink shrimp are exceedingly rare in estuaries of the southeastern US Atlantic coast without seagrass beds (e.g., South Carolina and Georgia). Likewise, adult pink shrimp are not a key fishery stock in this region, likely due to lack of seagrass habitat to serve as a nursery for earlier life stages. Seagrass cover is strongly positively correlated with survival in this species (Pérez-Castañeda and Defeo, 2005). As a result, changing environmental conditions will likely have minimal impact on adult pink shrimp populations in the region.

With changes in environmental conditions associated with climate warming, the quantity, timing, and mechanics of postlarval shrimp ingress to estuaries should be expected to continue to change in coming decades. A recent qualitative expert assessment of potential impacts of climate change on populations of penaeid shrimp in the southeastern US projected differences in the vulnerability of white and brown shrimp (Craig et al., 2025). The distribution of white shrimp was rated with a high possibility to change due to expected changes in water temperature, salinity, and sea level rise; however, the possibility for brown shrimp distributions to shift was projected to be moderate (Burton et al., 2023). Climate change effects on overall population size were projected to be neutral for white shrimp and negative for brown shrimp (Burton et al., 2023), in contrast with the increasing trends for postlarval abundances of both white and brown shrimp observed in the North Inlet estuary (Dunn et al., 2025).

5.3. Changes to phenology and potential community impacts of these shifts

Changes in the phenology of white and brown shrimp estuarine nursery habitat use over the past four decades, linked to key environmental conditions, have been observed for southeastern US Atlantic coast populations (Batchelder et al., 2024). The phenological metrics of timing (when in a year an event occurs), synchrony (the distribution of an event's occurrence throughout a year), and duration (the period of time over which a majority of individuals undergo the focal event) were calculated for both brown and white shrimp in the North Inlet estuary in South Carolina based on 38 years of bi-weekly sample collections (1984–2022). The timing of white shrimp nursery habitat use and ingress into intertidal creek habitats did not change over that period, but white shrimp nursery habitat use became less synchronized and occurred over a longer interval, with no single environmental variable strongly predicting any phenological metric. Brown shrimp did not show a directional change in timing, synchrony, or duration over the 38-year period, however, salinity and winter water temperature were strong predictors of variability in all three phenological metrics. The different responses between white shrimp and brown shrimp nursery habitat phenology are most likely due to differences in the life history and environmental preferences of each species (Doerr et al., 2016; Dunn et al., 2024; Glover et al., 2023). Regardless, because white and brown shrimp phenology is strongly influenced by environmental conditions

that are themselves changing, these phenological changes will likely continue to evolve with potentially profound effects for the ecology of these species along the southeastern US Atlantic coast (e.g., [Wagner et al., 2025](#)).

These changes in phenology were also associated with apparent shifts in migration patterns of white shrimp, modifying size distributions of white shrimp in estuaries but not changing sizes of adults in the offshore (fished) population ([Wagner et al., 2025](#)). Salinity was an important factor in determining shrimp size within particular habitats, and is known to have important influence on shrimp migratory behavior ([Bauer, 2018](#); [Lindner and Anderson, 1956](#); [Pullen and Trent, 1969](#)). But, the effect of salinity was diminished at warmer water temperatures, highlighting one way that warming temperatures are interacting with biology to alter shrimp populations. These shifting white shrimp size distributions were most apparent during the fall when sub-adult white shrimp begin moving offshore to overwinter, which is also when commercial landings were historically the greatest.

5.4. Black gill

Shrimp black gill syndrome ('black gill') is the melanization of gill tissues that occurs as a part of the innate immune response in many crustaceans ([Frischer et al., 2022](#)) and impairs the ability of shrimp to take up oxygen ([Burnett and Kendrick, 2024](#)). The late 1990s saw an increase in the prevalence of black gill in penaeid shrimp throughout the southeastern US. Black gill in this region is generally most prevalent in the late summer and fall ([Frischer et al., 2017](#); [Kendrick et al., 2021](#)) and is associated with infection by parasites ([Landers et al., 2020](#); [Zuidema et al., 2023](#)). Black gill outbreaks are sensitive to large-scale climate patterns, and the magnitude and timing of outbreaks have been linked to warming winter water temperatures and fluctuations in salinities ([Fowler et al., 2018](#); [Kendrick et al., 2021](#); [Swinford and Anderson, 2021](#)). Both scientists and commercial shrimpers have hypothesized that black gill is contributing to reductions in shrimp populations and declines in commercial shrimp landings in the region ([DeLancey et al., 2008](#); [Gooding et al., 2020](#); [Kendrick et al., 2021](#); this study). While there is some support that black gill may be related to commercial shrimp landings ([Frischer et al., 2017](#)), fall shrimp abundances from fishery-independent surveys do not appear to be related to black gill prevalence and infection patterns do not appear to be related to shrimp abundance ([Fowler et al., 2018](#); [Kendrick et al., 2021](#); [Tomamichel et al., 2026](#)). More work is needed to understand black gill as a symptom of infection, as well as the underlying infection itself (which may be symptomatic or asymptomatic).

6. Conclusions

Our approach has attempted to investigate the biology and ecology of shrimp, perceptions from the commercial shrimping industry, and the abiotic conditions these populations are experiencing. In some cases, those perceptions were consistent with the findings of previous natural science research in the region, as has been observed for other fishery systems ([Dlamini et al., 2022](#)). For example, the perception that winter water temperature is increasing is supported in the literature. On the other hand, shrimpers commented that the summer brown shrimp and fall white shrimp 'crops' have decreased, despite the finding of increasing abundance of white and brown shrimp postlarvae in South Carolina ([Dunn et al., 2025](#)). Observed changes in the phenology of postlarval ingress may explain this apparent disconnect for white shrimp, at least in part, but no changes in brown shrimp phenology were observed ([Batchelder et al., 2024](#)). Bottlenecks between life stages could also contribute to variation between postlarval and adult life stages, but additional work is required to better understand how population abundances at one life stage relate to abundance patterns at subsequent life stages. The impact of black gill on the abundance of commercially available shrimp also remains unclear, as impacts of black gill on fall

abundances of white shrimp have not been observed ([Fowler et al., 2018](#); [Kendrick et al., 2021](#)). Nevertheless, some shrimpers suggest that black gill is negatively impacting the abundance of shrimp in legal fishing areas, and some research does indicate negative consequences of black gill ([Burnett and Kendrick, 2024](#); [Gooding et al., 2020](#)). Finally, shark depredation associated with the commercial shrimping industry along the southeastern US Atlantic and Gulf coasts has long been reported by shrimpers and researchers (e.g., [Fertl and Leatherwood, 1997](#) and therein). While shark interactions were not the focus of this project, it is clear that future research efforts are warranted to fully understand the impact of shark depredation on the shrimping industry in the Low-country and for fisheries operating in other regions, as relatively little is known about shark depredation on commercial fisheries worldwide ([Tixier et al., 2021](#)). This includes, for example, quantifying the frequency and costs associated with shark interactions, as well as a better understanding of which species are typically involved.

Previous efforts to integrate fishers' local ecological knowledge with other data types have come to varying conclusions regarding the agreement between these sometimes disparate sources of information ([Ainsworth and Pitcher, 2005](#); [Azzurro et al., 2019](#); [Dlamini et al., 2022](#)). A recent effort demonstrated that shrimpers' knowledge and empirical models can come to similar inferences about long-term trends in shrimp abundance, and that the length of time spent in the fishery was related to the ability to identify changes that are long-term (e.g., water temperature) or episodic (e.g., frequency of storms) ([Heck et al., 2025](#)). The results of our study and others suggest that more work needs to be done to better understand any apparent disconnects between observations from fishery-independent research and perceptions within the shrimping industry. We note that shrimpers interviewed here (white, male, experienced captains or vessel owners) may not fully capture the demographic range of the shrimping industry as a whole and could lead to generational or cultural biases. Nevertheless, because we were interested in perceptions of long-term changes and cyclical environmental factors, the insights from shrimpers with at least 10 years of experience were particularly valuable. We recommend future efforts that utilize a systematic qualitative research approach to effectively capture insights from the industry writ large.

There is an overarching need for additional efforts to explore the capacity for natural science data, anthropological approaches, management agency perspectives, and fishers' local ecological knowledge to complement each other and contribute to sustainable fishery management ([Heck et al., 2015](#); [Hind, 2015](#)). Efforts to address the numerous challenges facing the shrimping industry would benefit from an expanded, holistic view of population dynamics that includes numerous ecosystem components. In addition to their role as predators and as a fishery resource, shrimp also serve as a vital prey base for numerous economically important predatory fishes (e.g., red drum, *Sciaenops ocellatus*; spotted seatrout, *Cynoscion nebulosus*; flounders, *Paralichthys* spp.), exemplifying the benefits of an ecosystem-based approach to management, wherein the relationships between the various components of ecosystems, including human components, are considered ([Link, 2010](#)).

The intersection between interview findings and natural science insights demonstrates strong support for an ecosystem-based management approach to this ecologically and economically valuable fishery. Incorporating commercial shrimpers' knowledge provides a complementary, real-time indicator of potential ecological shifts, and can also help to identify potential management strategies most likely to be effectively implemented ([Foster and Vincent, 2010](#); [Lozada et al., 2024](#); [Thornton and Scheer, 2012](#)). In this way, industry perspectives can serve as an early warning system to help managers identify and respond to changing population dynamics. At the same time, the subtle differences in biological and industry trends suggest that consideration of socioeconomic and market data could aid in the effective support and management of the fishery. In addition to the benefits of incorporating their insights into management, shrimpers also expressed a clear desire for increased

cooperative research with academic and natural resource management agency scientists. We see this as a critical framework for future research.

Our findings highlight knowledge gaps that, if filled, could help the shrimping industry in this region. For example, Georgia recently conducted a systematic survey of commercial shrimp industry vessel and infrastructure needs (Fluech and Tookes, 2024). Expanding similar surveys to other states (e.g., Lozada et al., 2024), including South Carolina, and repeating these efforts on an approximately decadal scale, would build a better understanding of trends in the socioeconomic conditions within the fishery. Our work also serves to highlight the benefits of collaborative efforts between researchers, resource managers, extension agents, and industry end-users, all of whom bring different perspectives. Ultimately, stressors similar to those described here for shrimp in the Lowcountry are impacting many other fisheries, and our effort to integrate perspectives from industry members, resource managers, extension agents, and natural and social scientists could serve as a template for other fishery systems in the southeastern US and beyond.

CRedit authorship contribution statement

Robert P. Dunn: Conceptualization, Supervision, Writing – original draft, Writing – review & editing, Funding acquisition, Project administration, Investigation, Visualization. **Jeff F. Brunson:** Writing – review & editing, Investigation. **Bryan Fluech:** Writing – review & editing, Investigation, Data curation. **Jocelyn Juliano:** Writing – review & editing, Data curation. **Michael R. Kendrick:** Writing – review & editing, Visualization, Formal analysis, Data curation. **Matthew E. Kimball:** Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Conceptualization. **Jennifer Sweeney Tookes:** Writing – review & editing, Writing – original draft, Investigation, Data curation.

Contributions

RPD, MEK, JFB, MRK, JJ and BF contributed to the study conception and design. Interviews were conducted by JJ and BF; analyses of fisheries landings data were conducted by MRK. The first draft of the manuscript was written by RPD, and all authors contributed to subsequent versions of the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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“Not Human Research.” This article represents contribution number 917 to the SCDNR Marine Resources Research Institute.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.fishres.2026.107869](https://doi.org/10.1016/j.fishres.2026.107869).

Data availability

All data associated with the Lowcountry Shrimp Collaborative are available via the ‘Data’ tab at the following URL: <https://nerrsciencecollaborative.org/project/Dunn21>.

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