

Perceived impacts of climate change, coastal development and policy on oyster harvesting in the Southeastern United States



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ABSTRACT

Oyster harvest has long been an important industry of the eastern coast of the United States. However, coastal development, overfishing and climate change are threatening this industry and way of life. This study examines the perspectives of oyster harvesters and merchants in Brunswick County, North Carolina, USA to explore their capacity to adapt to these changing conditions. Using in-person, semi-structured interviews researchers collected information from seventeen interviewees, generating qualitative data that were analyzed using MAXQDA software. From the data collected several themes emerged revealing mixed sentiments on the impacts of climate change but a widespread sense that development and regulations threaten livelihoods and cultural heritage. This social–ecological system (SES), created through centuries of regulation, is experiencing rapid population growth with concurrent coastal development; it also includes oyster industry workers who have limited voice in decision-making but are affected by the political ecology of the region. Deliberately including oyster harvesters and merchants when formulating and implementing policy can help to strengthen the adaptive capacity of this SES while sustaining Brunswick County's coastal heritage.

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1. Introduction

The Eastern oyster (*Crassostrea virginica*), also referred to as the American or Virginia oyster, is found along the Gulf and the Atlantic coasts of North America from Mexico to Canada. A once-ubiquitous source of food, it has been harvested and traded for millennia [1]. Between 2000 and 2004, the Eastern oyster was ranked eighth in dollar value among estuarine species in the United States [2]. Given its importance, it is no surprise that the oyster industry has employed thousands and become a substantial source of seasonal income in many towns along the US Atlantic coast. Over 15,000 jobs were attributed to the 2009 oyster industry in the South Atlantic Region alone [3]. However, oyster landings are decreasing along the US eastern seaboard [4].

Climate change [5], coastal development [6], and overharvest [7] are cited as likely underlying causes for this decrease. Although declines in oyster habitat are well documented [8], the socio-ecological consequences of habitat declines are less explored. For example, zu Ermgassen, Spalding, Grizzle, and Brumbaugh [9] recently linked declines in oyster reef density to losses in

ecosystem services (i.e., filtration) on the US Atlantic and Gulf of Mexico coasts. Yet, impacts to the sociological system have largely been confined to losses in coastal heritage from trade and environmental regulations to the shrimp [10] and crab [11] industries. It is uncertain how oyster harvesters and merchants along the eastern seaboard are being affected by declining oyster habitats and populations. Therefore, documenting the changes experienced and resultant concerns perceived by individuals involved in the oyster trade will enable a more complete understanding of the changing social–ecological conditions in the southeastern United States. The purpose of this study was to investigate how climate change, coastal development, and government programs and policy-making affect the local oyster industry community in Brunswick County, North Carolina.

In annual interviews of oyster fishermen conducted by the North Carolina Division of Marine Fisheries, most recent respondents said that, historically, commercial fishing was “vital” for their community [12]. From 2000 to 2012 oysters landings were valued at \$27.8 million dollars in North Carolina [13], and had a total economic impact in 2009 that exceeded \$100 million [3]. Brunswick County was selected as the study location due to its affiliation with the North Carolina Oyster Festival and “Brunswick Catch”, a local seafood marketing effort developed by the area's fishermen, seafood merchants and restaurateurs. Using qualitative research methodology, this study documents these individuals'

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perceptions of the fate of the oyster industry in Brunswick County and explores this community's capacity to adapt to the challenges identified.

2. Climate change and coastal development

Climate change and development are two of the most important issues facing coastal resilience at this time. Saltwater intrusion, erosion and flooding are of primary concern in North Carolina [14]. Rogers and McCarty [15] link changes in salinity to increased disease outbreaks. Yet, rising sea surface temperatures (SST) may also impact estuarine and marine fish and shellfish, including oysters [16]. Increasing SST could affect oysters by creating conditions for rapid spread of disease. For example, Dermo, a disease of the Eastern oyster caused by the parasite *Perkinsus marinus*, has been directly linked to El Niño Southern Oscillation (ENSO); the prevalence and intensity of Dermo in the Gulf of Mexico lowers when ENSO produces wetter and cooler conditions and increases when La Niña produces drier and warmer conditions [17]. Studies also showed an increase of *P. marinus* in the Northeastern US when an increase in winter SST occurs [18,19]. *Hapslosporidium nelsoni*, a pathogen causing MSX (Multinucleated Spore Unknown) in oysters, also thrives and spreads under warmer SST [20]. Other SST related impacts include declines in spatfall [21] and increased frequency of harmful algal blooms [22], both of which impede efforts to reestablish oysters in stressed environments.

Estuaries are also facing greater development-related threats due to the rise in coastal tourism [23] and in-migration of retirees [24]. Coastal development has the concomitant negative effect of deteriorating water quality within nearby estuarine systems [6,25,26]. According to Mallin, Williams, Esham and Low [6], the most important factor in enteric bacteria over-abundance was the percentage of impervious surfaces that accompany coastal development. In suburban areas, impervious surfaces and lawns are significant sources of fecal coliform bacteria from animal feces in stormwater runoff [27]. However, faulty septic systems are another source of increased fecal matter¹ [28]. Coastal development is also increasing chemical contamination, particularly from pesticides [29]. With the health of tidal creek ecosystems deteriorating, increased closures are likely in rapidly developing coastal watersheds to ensure safe human consumption of oysters.

3. Government regulations and programs in North Carolina

Currently, ten North Carolina coastal counties have Eastern oyster harvesting areas [30] and landings have varied by location over time [7]. The majority of oysters were historically harvested from the Pamlico Sound, but more recent trends show greater landings in the southern portions of the state, including Brunswick County [31]. Although current trends show an increase in oyster landings since the 1990s, the NC Division of Marine Fisheries (NCDMF) lists the Eastern oyster stock status as “concern” (Table 1). According to the NCDMF, “Stocks designated as concern are those stocks that exhibit increased effort, declining landings, truncated age distribution, or are negatively impacted by biotic and/or abiotic factors that cannot be controlled” [32].

North Carolina began regulating the harvest of oysters in 1822 when laws were passed permitting harvest by tongs in waters less than eight feet deep [33]. In the late 1800s a dredging law was amended to simplify oyster harvesting, which resulted in the two

largest landing years in the early twentieth century [7]. This dredging practice, combined with a lack of size limit enforcement, likely “had a pronounced effect on oyster habitat” in the first half of the twentieth century [7].

In the mid 1920s, with the outbreak of typhoid in Chicago and the consequential nationwide decrease in oyster demand, principles of shellfish sanitation were developed which later became the National Shellfish Sanitation Program (NSSP) [34]. This voluntary, cooperative program continues to regulate the interstate commerce of shellfish and protect the health of consumers [35]. The NSSP established a series of classifications (approved, conditionally approved, restricted or prohibited) for oyster harvest based on annual pollution and bacteriological data coupled with bi-monthly water testing. Areas with conditional approval must meet regular test standards and are usually closed after heavy rainfall due to runoff [36]. Restrictions and prohibitions, particularly temporary closures after heavy rainfall, are common in areas with high coastal development [26]. To communicate restrictions, the NCDMF provides maps of permanent and temporary oyster harvesting area closures on its website under “Polluted Area Proclamations”.²

Other regulations encompass the legal size of oyster to harvest, nighttime and daily harvest restrictions, mechanical harvest, and under dock oyster culture. Most recently, laws prohibit harvest in sanctuaries [7]. In parallel, the NCDMF has initiated efforts to increase the abundance of oysters. From 2003 to 2010, the NCDMF “planted” over 43,000 bushels of oyster cultch in Brunswick County to encourage growth of oyster reefs and improve habitat for other reef-dwelling sea life [37]. As the NCDMF has stated, these types of programs are funding-dependent and recovery of oyster stocks suffers when program funding is not appropriated [7].

While relatively few people feel the effects of temporary closures, over time permanent closures can have a large social impact on oyster harvesters [38]. Climate change impacts are expected to include an increase in heavy downpours in the Southeastern US [39]. Higher amounts of rainfall on increasing amounts of impervious surfaces, due to continued coastal development, will influence the future of this industry [26,16] and, thereby, local oyster trade communities. Moreover, unfunded recovery programs could further exasperate impacts to the oyster industry and local trade communities.

4. Materials and methods

4.1. Study location

Brunswick County is located in southeastern North Carolina and has a total area of 1050 square miles (2719.5 km²), with 18.8% of landcover being classified as water [40]. The US Census Bureau [41] calculated the total population in 2010 at 107,431 residents, which is a 333% increase since 1980. As the fifth fastest growing county in the state [42] and the 89th fastest growing county in the nation [43], Brunswick County is experiencing increased development in the forms of golf course and retirement communities, Wilmington commuter bedroom communities, and others. Seasonal beach tourism and second home occupation increases the population by more than 2.5 times the census estimates [44]. The value of shellfish landings in Brunswick County overtook finfish in the mid-1980s, with the total value of oyster landings (1994–2001) at nearly \$2.2 million [45].

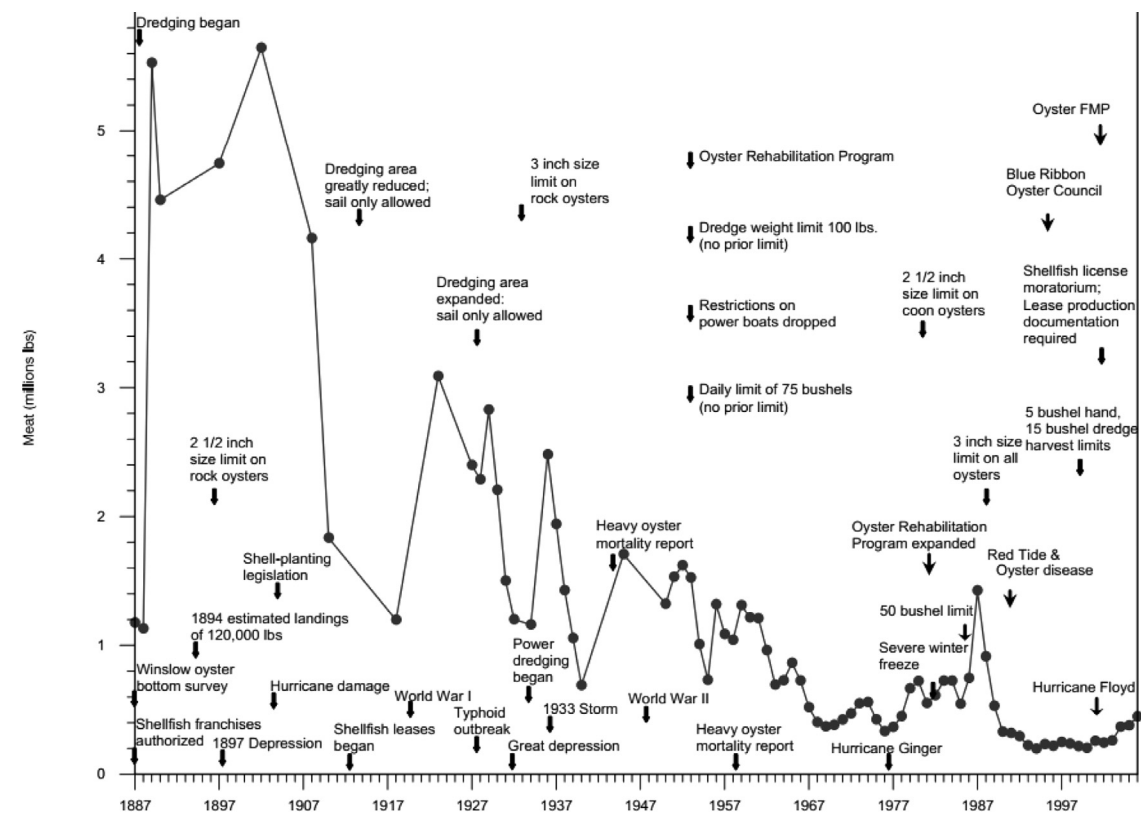
The primary areas of shellfish harvesting in Brunswick County are at the confluences of the Intracoastal Waterway and the Lockwood Folly and Shallotte Rivers, with limited open areas

¹ A 2006 study conducted in Brunswick County, NC documented faulty septic systems as the primary factor in affecting temporary oyster closures.

² See portal.ncdenr.org/web/mf/proclamations-polluted-areas for examples.

Table 1

Factors affecting the NC oyster fishery, 1887–2006 Used with permission from NC DENR, Division of Marine Fisheries (NCDMF, 2001: 66).



between the barrier islands and mainland along the Intracoastal Waterway (e.g., Tubbs Inlet between Ocean Isle and Sunset Beach, Fig. 1). Between the towns of Calabash and Southport, there are a few oyster shucking businesses and many small merchants selling local seafood and shellfish. Some of the small businesses only sell oysters directly out of their homes, advertising oyster availability with hand painted signs. Brunswick County fishermen and merchants—with the assistance of the Brunswick County Economic Development Commission, Brunswick County Commissioners, and North Carolina Sea Grant—formed a local seafood marketing initiative (Brunswick Catch) in 2009 to sustain the livelihood and heritage of the Brunswick County seafood industry. During oyster season (October 15–March 31³), oyster roasts are common community events (e.g., the 60th Annual Oyster Roast at Dixon Chapel United Methodist Church in Varnamtown, NC was celebrated in 2013) and the season kicks off with the annual North Carolina Oyster Festival in Ocean Isle Beach (the 33rd event was held in 2013).

4.2. Data generation

Qualitative data were generated during two sampling periods of the 2012–2013 oyster season. Two researchers co-conducted in-person, semi-structured interviews with oyster harvesters and oyster merchants. A list of seafood merchants was compiled for areas A-1, A-2, A-3, and B-1 (Fig. 1) from Internet searches of seafood business. Individuals selling oysters from their homes

³ Brunswick County is different than the rest of the state in that they typically close the season prior to March 31, which is the longest the public bottoms can stay open.

were identified by driving along routes between listed merchants and through chain-referral sampling with area residents and individuals previously interviewed. Oyster harvesters were identified by intercepting individuals selling oysters to local merchants at times specified by the merchants. Interviews were either conducted at the time of first contact or were scheduled for a set time that was more convenient for the individual.

Individuals who voluntarily agreed to participate in the study were asked open-ended questions related to their background in the oyster industry, the role of oysters in local coastal heritage and tourism, their perceptions of the threats to and opportunities for the oyster industry, and their outlook for the future of the oyster industry. Probing was used to elicit specific information contained within participants' responses to interview questions [46], including threats related to changes in water temperature and urban development. Participants were provided with a small gift at the end of the interview. Interview length ranged from 9 to 45 min, with an average of 17 min. All interviews were digitally audio-recorded and transcribed verbatim for analysis. The two researchers collaboratively compiled observational notes after the completion of each interview. Each researcher independently made memos [47] of the key themes emerging from the interviews at the end of each sampling period.

4.3. Data analysis

Transcribed interviews, observational notes, and memos were uploaded into the qualitative data organization software program, MAXQDA. Both researchers first co-constructed an initial list of themes and then independently coded several interview transcripts using open and axial coding techniques [48]. Using insider peer debriefing techniques [49], the researchers collectively reviewed

Shellfish Harvesting Areas in Southeastern North Carolina

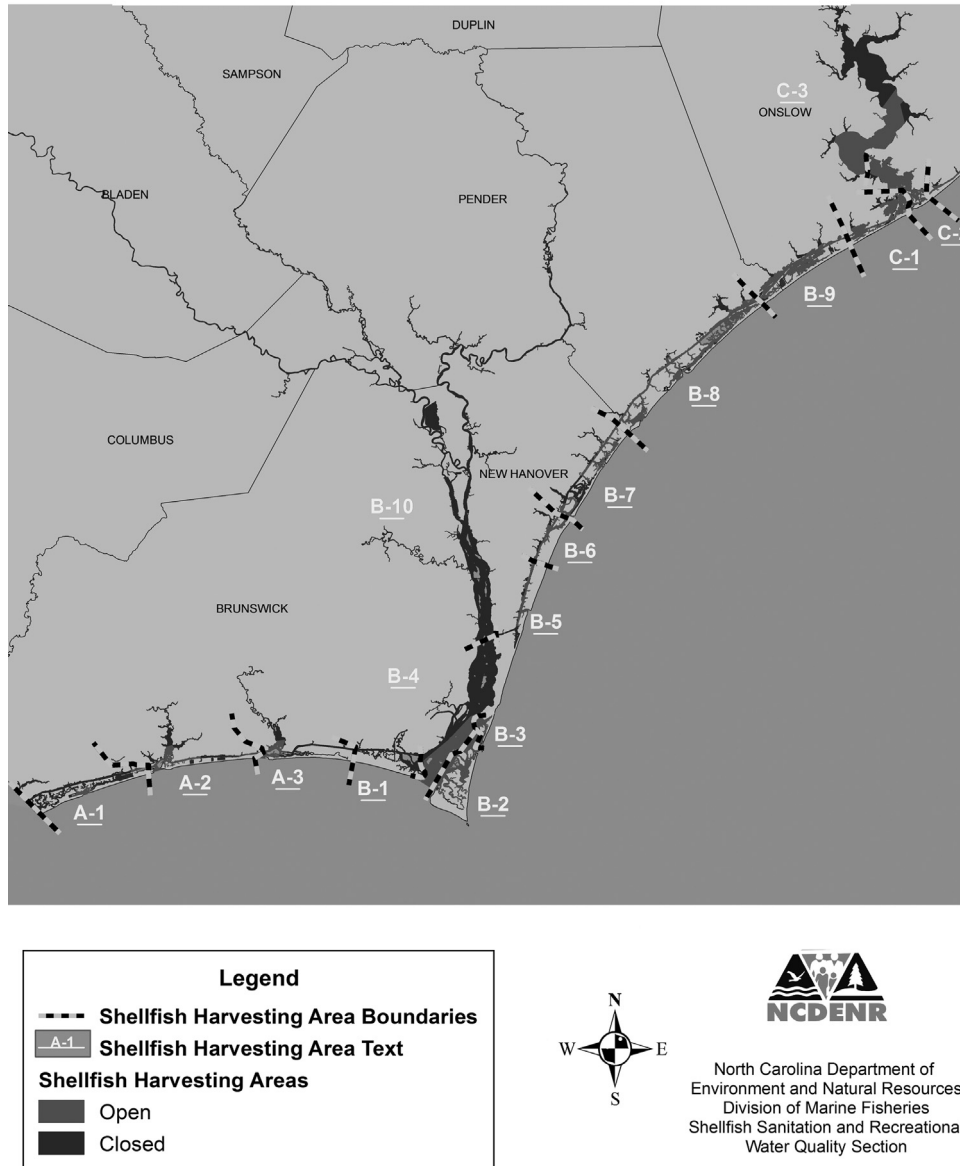


Fig. 1. Open and closed shellfish harvesting areas in Brunswick County, North Carolina. (Modified from <http://portal.ncdenr.org/web/mf/shellfish-closure-maps>).

each other's codes and coding patterns, discussing differences until agreement was reached and a codebook developed. The remaining interviews and supporting materials (observational notes and memos) were then coded collaboratively. Additional axial coding for this paper was conducted by one of the researchers. A third researcher was asked to review the coded material to enhance data quality by ensuring consistency in the interpretive pattern [50].

4.4. Informant profile

Seventeen interviews (16 male, 1 female) were conducted with oyster merchants and oyster harvesters; one oyster harvester declined to participate in the study. Participants' ages varied, and included young adults (29% < 30 years of age), middle-aged adults (35% 30–60 years of age), and older adults (35% > 60 years of age). Four participants were first-generation in the oyster trade. Participants also were associated with a wide range of stages in the oyster trade, including: incipient (29% < 3 years), establishing

(12% 3–9 years), established (12% 10–24 years), and mature (47% > 25 years). Most participants harvest oysters. Oyster harvesting experiences were classified as: no experience (25%), dabbler (38% occasionally for personal consumption), novice (13% for few years or not in many years), and lifer (25% since childhood).

Four participants currently harvest oysters commercially for sale at their home or to local merchants; the other 13 participants indicated that their primary role in the oyster trade was sales. Nine participants were business owners. Merchant categories included family seafood market and restaurants, family seafood markets, seafood stands, and at-home sales. No interviews were conducted with owners of oyster shucking business, as initial contact revealed that these businesses only use imported oysters due to local stock declines and harvesting restrictions. Three participants defined their primary occupation as commercial fishing and an additional three participants were retired commercial fishermen. Four participants claimed the oyster trade as their only fishing activity and four participants claimed that their work in the oyster trade supplements their primary income.

5. Results

5.1. Climate change

Interviewers did not use the term “climate change” during follow-up probing questions about the threats facing the local community unless specifically mentioned by a participant. Instead, the interviewers used phrases like, “seasons getting longer,” “changes in water temperature over the years,” and “trends over time with water staying warmer.” Roughly the same number of participants believed that climate change will have or already is having an impact on the oyster industry as those who believed that the weather is cyclical and there are no long-term changes.

Those participants who indicated that climate change will have an impact stated things like, “[it] seems like it takes longer for [the water] to get colder every year,” “now you never see a frozen mud puddle, ...it seems like to me, the winters are warmer,” and “global warming is taking place...so it's gonna affect us.” Participants who did not believe that climate change is impacting the oyster industry responded with, “we have good years and bad years,” “it's up and down...it's unpredictable,” and “I don't think this is the first time it's gotten hot, ...I think it's happened before, we just weren't there to record it.” Two participants displayed indifference when questioned about changes in the weather patterns: “There's not a whole lot I can do about it,” and “oysters are a very resilient animal and they will grow no matter what.” Interestingly, five participants did not discuss changes in climate or weather when asked about threats to the oyster industry, which could be attributed to climate change not being a salient issue for these individuals.

One recurring theme when talking about weather and water temperature was that respondents noticed the water was staying warmer longer, thus delaying harvest. This delay affected their ability to find harvestable oysters at the beginning of the season and is negatively impacting their profits. More than one respondent noted this delay and one offered this suggestion as a solution to this issue:

“The other thing you could do, like you're allowed to oyster the 15th of October. Well it's hot and the oysters are not growing, so if they would wait, say the middle of November, when the water cools off, there would be a lot more oysters to start on and then like they close it the last February or 15th of March, just run it a little bit longer at the end when the water's still cold. And I think they'd get a lot more production, just by making that little change right there.”

5.2. Coastal development

Most participants identified development as a threat to the oyster industry, blaming development for pollution of the rivers and harvest area closures, without additional probing. When specifically asked if development was changing the local oyster industry one respondent replied:

“It's definitely changing things. ...One of the problems that commercial fishermen have had is a lot of development on the rivers and it causes a lot of run off, which is one of the main causes of pollution in our rivers that close shellfish areas. And that's always been a big problem.”

Another recollected the history of the closure due to development: “Well it started in here in the 80s, that's when development started up. The mid 80s, and ever since then, the river's been closed. They've had one closure, two, three, four, five; they've moved [the closure boundary] down the river six different times. ... They finally got us about 200 acres. ... So we've only got about a third of the river working. And the demand is greater than what we can catch, most of the time.” One participant lamented that, “...of course where oysters used to grow, now we grow condominiums.”

Four participants specifically mentioned golf courses as one of the sources of shellfish beds being closed to harvest. According to these individuals, the fertilizers from the golf courses run directly into the waters causing them to be closed by the Division of Marine Fisheries, usually after a heavy rainfall. When asked about the impact of golf courses, responses included, “the golf courses are killin' us,” and “the runoff on these golf courses...goes right into the river and pollutes [it].” One participant said:

“And so we've got all these golf courses round here and I do know that golf courses have got something to do with the pollution because all the fertilizer they use on the greens, 'cause I've helped a friend of mine spray pines and stuff in golf courses around, so I know a little about that too. And a lot of times they're pretty close to rivers and every time we get a heavy rain, all that stuff goes washing right into the river.”

Interestingly, more than one participant also mentioned the connection between higher-value riverfront property, golf courses and closure areas. One stated that “there's nothing you can do – it's a money thing,” while another said that “a lot of big politicians love to play golf and they're not really worried about ... a little place like this.” Others insinuated that more affluent newcomers with riverfront property do not like to see oyster harvesters in their backyard, “some people buy a million dollar house right there don't want somebody right down there in front of his bulkhead knockin' oysters off.”

While development was typically viewed as negatively impacting the oyster industry in Brunswick County, several participants held a positive outlook on development. Specifically, these individuals commented that retirees and tourism increases sales. The interviewers observed this type of business when an older couple, purchasing four bushels of oysters, explained to the merchant they were going to serve the oysters on the half shell to their friends in their retirement development at their annual Christmas party. One participant explained that retirees “play golf and eat oysters. The two reasons why they're here. ...But I'm glad they play golf, because if they didn't play golf, they'd be out there in the way, getting some oysters. They wouldn't be buying from us local people.” Another participant explained that “without tourists we wouldn't have anyone to buy and the oyster business would be, we would be shipping everything that we sell.” Other participants explained that, “The tourists are the backbone of the sellin',” and “We have more tourists now than we had 30 years ago, so we have more of those people who come down on the weekends and want oysters.”

5.3. Government policies

Participants identified government policies as both threats to and opportunities for the North Carolina oyster industry. The conversations focused on three main issues: restrictions on harvest size and quantity; beach nourishment and dredging; and limited beds due to closure.

5.3.1. Restrictions on harvest

Most participants had a positive association with the government programs that involve limits on harvest, explaining how limits were necessary for keeping the oyster populations healthy and viable.

Two participants noted the difference in regulations and oyster quality between the Carolinas. One explained: “It's good to have restrictions. South Carolina, anything they pick up is an oyster. They pick up a clump of oysters this big and they can put it in their sack and that's oysters, don't matter, it's oysters. There should be size limits.” The other stated, “I think it's good. I think it's good because in South Carolina, they don't have all of that and in some places, you can go down there and you go buy a bushel of oysters and you get 'em home and you ain't got nothing but a basket full of shells. You buy a

bushel of oysters in North Carolina, you get a bushel.” Participants also commented on how regulations enhance the quality of Brunswick County oysters. For example, one merchant stated that those regulations are “good for a business like us because it keeps us in a good quality product.” Another participant talked about supply and demand and stated that if the restrictions are tighter then, “everybody gets less and the price goes up.”

Not all participants agreed with the harvest limits. When asked about restrictions on harvesting one participant blamed the five-bushel per day limit on the poor production of certain oyster beds. He explained that when he was younger, “there was no limit on how many oysters you could get in a day” and now that there are limits to harvest, “the oyster becomin’ so thick on some of those rocks, that it just won’t grow.” The same respondent went on to say:

“I really think that they should probably go back to letting us catch, you know, whatever we can get and probably cut back the length of shells. ...the oysters are really gonna regulate themselves ‘cause if you catch them too small, the public not gonna buy ‘em, and that’s just the way it is. So really, I don’t see a reason that we even need a law ... other than watching, making sure people are catchin’ ‘em clean and not catchin’ too many to a bunch, not putting a lot of dead fills, other than that, I don’t see why we even need it.”

A merchant who purchased directly from local harvester commented on the constraints to harvesters’ incomes from the daily harvest limits. He explained that, “[It’s] hard for a man to make a living [with those restrictions]. He’s got his license, he’s got his fuel, he’s got some of the places he’s gotta pay \$10 to put his boat in the water there, it you know, cuts into it.”

5.3.2. Beach nourishment and dredging

All participants who mentioned beach nourishment perceived the practice as negatively impacting the oyster beds. One participant explained the combined effects of sedimentation from beach nourishment and upstream development by stating:

“They keep [nourishing] the beach over here. All the sand that comes off of that beach comes up this river and also, all the places up there that are being developed, all the run-off goes up that river on this end of the river. It comes down the river and meets up, so the river is being clogged up.”

Other participants stated that beach nourishment is “one of the worst things they’ve ever done to the river or anywhere else” and that due to the type of machinery used in the nourishment process, the sand is “just washin’ in” and it’s now in areas “where it never would be at before,” which is causing the oysters in that area to not “grow anymore because [they’re] not getting enough water flow through there.”

On the other hand, some participants explained that dredging could open up channels for water to flow and help the oysters to grow. One participant said that he is “hoping that sometime or another things will come around and [we’ll] get this river dredged again...for our oysters.” Another shared a similar perspective, stating that “You would think something might help if they would dredge some of those creeks in the main part of both sides of the channel, on both sides of the houses, if they would dredge that out that would help the water flow come through there and that would help [the oysters].”

5.3.3. Limited beds and oyster planting

Many sellers and harvesters discussed the lack of available oyster beds to harvest and various old timers compared the amount of open beds to what it was like when they were younger. One spoke of having “less than half of the area” they used to have when he was young. Pointing out to an area in front of the interview location, one participant explained, “Used to be you could get them right out there, now all this is closed.” Other

responses included, “There’s a big area we don’t even work anymore,” “we’ve only got about a third of the river working,” and “There’s so much area closed now, the areas that are open is really small.” One estimated that in the next ten years the “whole Shallotte River will be closed down” to oyster harvest and lamented that “a bunch of us” are already leaving Brunswick County to harvest. Another harvester offered a common sentiment, “The oysters here, all the good areas are closed and are never gonna open again, the line in the river here in Shallotte River, it moves down stream every year and it’s never gonna move back up stream in the good areas again.” Other harvesters explained that they are already driving to areas north of Brunswick County due to the limited number of open beds in Brunswick County and the ability to fill the daily take in a fraction of the time it takes in the Lockwood Folly and Shallotte River beds. A few merchants explained that they no longer only sell Brunswick County oysters for similar reasons.

Several respondents discussed the former oyster planting program, or “seeding” as referred to by study participants, in a positive light and lamented that they didn’t exist anymore.⁴ Not only were they employed and earning extra money by seeding oyster beds for the State, but they also saw the benefits of seeding for increasing the sustainability of the oyster industry and increasing water quality for the estuaries. When discussing seeding oysters, one harvester commented, “They’ll cleanse the whole river if you put ‘em in there.” Another harvester, however, expressed discontent with the way the State handled the seeding program. He felt that the authorities did not value local knowledge about where oysters grew best, even though he had been harvesting and selling oysters for over fifty years. When asked about planting oysters he responded that, “there’s better places to put ‘em than what the state picks out,” and he later added that, “if they come up this year and say ‘volunteer planting oysters’ I’m not going to plant any ‘cause when they planted last year, I can’t tell no difference.”

6. Discussion and conclusions

Social-ecological systems (SES) are comprised of easily recognizable constituent parts; yet, these constituent parts are inextricably linked, with both systems affecting and being affected by the other [51]. Coastal SESs, like the oyster estuaries and trade community in Brunswick County, exemplify this link. Social systems (e.g., politics, development, tourism, residential and harvester behaviors) directly impact coastal ecosystems (e.g., reefs, estuaries, beaches); and changes in ecological resources (e.g., warming waters, pollution) also directly impact the social systems that depend on those resources for their livelihood (e.g., economy, cultural heritage). There is growing evidence that resource users are a valuable piece of this resource management puzzle [52,53]. This study extends the evidence from the general fishing industry [54–56] to oyster harvesters and merchants in the southeast US.

Integrating traditional knowledge into SES management has been demonstrated to enhance the adaptive capacity of coupled systems to withstand, learn from, and even utilize disturbance to increase resilience [57–59]. Decentralized government that is able to make timely and locally-based decisions in the face of disturbance characterizes a SES with high adaptive capacity [60]. Furthermore, “sustainability requires both change and persistence” [61]. Historically, management of coastal zones and resources has not taken into account social-ecological linkages [62] nor have Marine Management Areas included sociological

⁴ Cultch planting still occurs creating new reefs for juvenile spat to inhabit, but seed planting of live oysters from polluted areas to new locations no longer occurs.

data in decision-making processes [63]. Some argue that ignoring these linkages has placed coastal community culture at risk [64].

Including sociological data or traditional ecological knowledge in management planning is not necessarily straightforward, however, and this study finds a complex scenario that is likely not unique to Brunswick County. While study participants repeatedly spoke of their lack of voice in decision-making that directly affects them, contacts with NC DMF told a different story. For example, in response to harvesters' discussion of the open and closing dates of oyster harvest, a DMF official stated that the closure date varies from year to year and is a result of fishery policy in addition to input from fishermen and dealers (personal communication, April 7, 2013). Moreover, our DMF contacts explained that flexibility is embedded in the oyster management plan with some changes taking less than six months to implement. Communication with DMF officials has revealed that while they try to incorporate fishermen input into marine management decisions (e.g., through annual meetings to discuss cultch planting sites) and offer assistance where requested, they have very low attendance at meetings to gather input and no applications for fishery resource grants have been submitted from the Brunswick County area. Although our DMF contacts explained that they would like increased involvement from oyster fishermen, they expressed uncertainty about the how to best promote their open meetings and grant opportunities.

More attention is being devoted to the importance of including sociological perspectives (e.g., social networks, actor groups, and social memory) into analysis and planning for adaptive management [65]. Despite uncertainty about how to best integrate this knowledge, as clearly demonstrated above, Koehn et al. state that these data are more frequently being recognized as "indispensable to management" [64]. Regardless of the different perceptions of empowered local voices, this study documents the perspectives of the harvesters and merchants who were interviewed. Through these interviews, this study identifies a SES in Brunswick County that: (a) has been created through centuries of regulation at the state and federal level; (b) is rapidly changing from increased development that corresponds with expanded oyster bed closures; and (c) is comprised of a community that perceives itself as having limited to no voice in decision-making yet is affected by the area's political ecology.

Interestingly, those involved in the oyster trade are mixed about the impacts of climate change on the local industry and sentiments did not correspond with age of study participants. There is common acknowledgment that water temperatures are increasing and that oyster growth is occurring later in the season; however, perceptions of the threat differ between the effects of climate change and normal cyclical changes in ocean temperatures. Regardless, finding ways to include local ecological knowledge in regulatory decision-making—such as, shifting the season (not shortening) to a later start date when water temperatures are more conducive to oyster development—may enhance SES resilience by increasing feedback learning [58] and adapting to ecosystem dynamics [59]. However, such resilience may also be enhanced by a more unified recognition of climate change threats by the oyster community, as "factors such as perception of risk, habit, social status and age operate at individual decision-making levels but also constrain collective action" [66]. Thus, a learning environment—on behalf of scientists, managers and members of the oyster trade community—is necessary for adaptive governance [67].

Population growth is a key factor influencing this coastal SES. Brunswick County is rapidly developing and, as this study documents, many people who work in the oyster industry see that as a threat to their way of life. Even though some enjoy the growing market, most express concern with development-related impacts that population growth brings and a few hold a general feeling of helplessness when it comes to more affluent newcomers' political

power. Incorporating these sentiments into regional and local planning decisions may yield proactive zoning regulations and more widespread adoption of best management practices on golf courses that not only enhance water quality but also protect the attractors drawing newcomers and tourists to Brunswick County. However, changes in zoning rules (such as low impact development) and turf grass management are insufficient. Sustainable watershed management requires building capacity at multiple levels [68], including individual actions (e.g., enhancing homeowner education on proper septic system maintenance), relationships (e.g., fostering trust between political authorities and locals involved in the oyster trade), organizational structures (e.g., promoting fair and meaningful public engagement in local planning), and coordinated policies (e.g., monitoring both water quality and social conditions to promote flexibility and detect small scale disturbances prior to system collapse).

Government policies have and continue to impact the livelihoods of oyster harvesters. Harvest restrictions, beach nourishment, temporary closures and former seeding programs are points of contention among most harvesters and merchants interviewed in this study. Frustrated by their inability to have their voices heard, small-scale fishermen might decide to harvest elsewhere. Some have already left the industry altogether. Both of these outcomes pose a threat to this coastal industry and the area's cultural heritage. Conserving coastal SESs necessitates the sustainability of both natural and cultural heritage [69], as well as integrating local knowledge into water quality and oyster fishery plans [70]. Such integration of local ecological knowledge into fisheries plans—acquired through two-way collaborative processes that foster dialog between scientists, managers and stakeholders—builds trust, promotes innovative management strategies, and fosters more informed and response management [71]. The NC DMF has stated that a process exists in which oyster fishermen can provide input at multiple levels; however they report that engagement is lacking within the Brunswick County oyster community. Intentionally including oyster harvesters when formulating and implementing policy, perhaps by accessing a community gatekeeper to help the DMF build trust in the area [72], could strengthen the adaptive capacity of the oyster-related SES while sustaining Brunswick County's coastal heritage.

In the book *Resilience Thinking*, authors Walker and Salt discuss the concept of adaptive capacity and the complex links between communities and ecosystems [73]. Considering the biophysical threats to oyster populations from climate change, development and policy documented in the literature in tandem with local perspectives of these impacts on the oyster trade, this SES appears to be endangered. Specifically, the declining quality and extent of oyster beds and, thus, the oyster industry in Brunswick County represents a regime change that could ultimately disconnect the community from its long-standing, oyster-related cultural heritage.

As already noted, enhancing resilience fosters adaptive capacity in SESs. This study demonstrates the numerous challenges facing the oyster producing SES of Brunswick County, including communication among fishermen and policy-makers. Further, this study highlights the successful inclusion of local knowledge in planning and management decisions as an ideal starting point for enhancing the resilience of oyster-related resources and heritage. Given the multigenerational tradition of the oyster trade, the important traditional knowledge held by those involved in it, and their ability to provide real-time information about changing conditions in harvesting areas, oyster harvesters are well equipped to foster adaptive capacity. Balancing traditional ecological knowledge and the ability to make quick changes with scientific knowledge and management expertise can alert resource managers and policy-makers to changing conditions and increase the timeliness of appropriate responses, avoiding system collapse [73].

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