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June 30, 2025

To: The Honorable Jimmy Dixon, Representative
Co-chair, Environmental Review Commission
The Honorable Norm Sanderson, Senator
Co-chair, Environmental Review Commission

From: Jeffrey Warren, PhD, Executive Director, North Carolina Collaboratory

Re: Collaboratory Study of the Coastal and Marine Fisheries of the State

SENT VIA ELECTRONIC MAIL

For your consideration, following this letter, is the report summarizing the legislative recommendations of the North Carolina Collaboratory's Study of Coastal and Marine Fisheries of the State, pursuant to Session Law 2021-180 section 8.11(a), as amended by Session Law 2022-6 Section 2.10., which requires submission of a report to the Environmental Review Commission by June 30, 2025. This information is publicly available on our website.

Of note, recent legislative actions – specifically, those related to shrimp trawling language in the current version of House Bill (H) 442 – have brought into question the contents of this report. Because this specific issue was out of the scope of this study, this report neither advocates for nor opposes a ban on shrimp trawling.

Multiple comments by legislators in both chambers of the North Carolina General Assembly (NCGA), as well as statements circulating in the media, suggested the Senate was aware of the contents of this report and this advance knowledge drove actions to amend the legislation to include a shrimp trawling ban prior to the report's release. These statements remain untrue and undermine the credibility of this multi-year research study carried out by nine researchers across four UNC System campuses.

The recommendations presented do not address, or respond to, the shrimp trawling language contained in the current version of H442 (or, for that matter, the related H441), nor were they ever designed to. Further, no legislative influence or pressure impacted the legislative recommendations or the scope of work, which has remained consistent over the three-year arc of the broader study.

Instead, in advance of the 25th anniversary of the State's Fisheries Reform Act of 1997 and the 50th anniversary of the Coastal Area Management Act (1974), the NCGA directed the

Collaboratory to analyze the status of North Carolina's fisheries and develop policy recommendations to better manage the overall health of fisheries and fisheries' habitats. The NCGA's language mandated that thirteen species be studied, including the health and extent of the habitat required to sustain them.

The research team was led by Dr. Joel Fodrie, Director of the UNC-Chapel Hill Institute of Marine Sciences, and included a team of researchers from East Carolina University, NC State University, UNC-Chapel Hill and UNC-Wilmington. Over the last three years, the study team has comprehensively evaluated a myriad of factors contributing to fishery health while assessing management approaches.

Today's submission includes a summary of legislative recommendations as well as supporting information including data and methodology highlights that have been generated by the research team to inform the decision-making of policymakers.

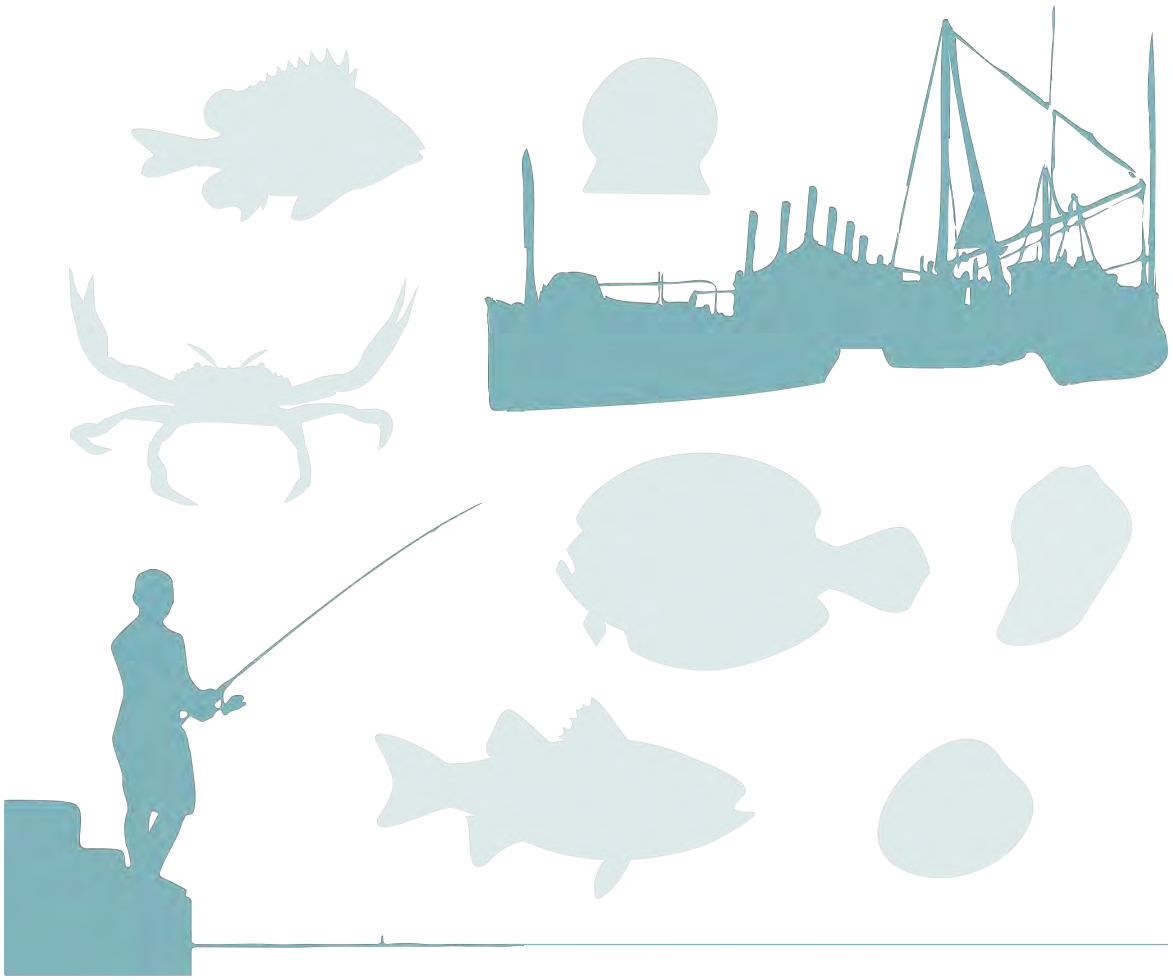
Because of the breadth and scope of this project, which began in earnest in 2022, an additional set of supporting documentation will put these recommendations into context. This supplemental Policy Implementation Report is expected to comprise over 400 pages of supporting information including fishery and other data analyses, policy evaluation, literature reviews, surveys, and stakeholder engagement analyses. This is a typical approach to closing out an extensive, multi-year research study.

The Policy Implementation Report will be available later this year once the principal investigators refine and enhance data visualization, formatting, and structural organization to ensure a broad variety of users can access the data and information. To be clear, this clarifying work will not substantively change the recommendations provided herein.

If you have any questions or would like more information about the report, please do not hesitate to contact me (jeff.warren@unc.edu) or Dr. Joel Fodrie (jfodrie@unc.edu).

Jeffrey Warren, PhD
Executive Director

The Status of North Carolina's Marine Fisheries and Coastal Habitats – with Recommendations to Enhance Marine Public Trust Resources and Management Outcomes



Summary Report Submitted

June 30th, 2025

Submitted to the North Carolina General Assembly by the North Carolina Collaboratory

Research and Syntheses Contributed by:

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NC STATE UNIVERSITY

UNIVERSITY of NORTH CAROLINA WILMINGTON

Summary Report Contents Page

Study Mandates and Approaches

The North Carolina (NC) General Assembly's 2021 Appropriations Act included a request for a synthetic "study on the overall status of the coastal and marine fisheries [and their habitats] regulated by the State". This mandate was in response to "the twenty-fifth anniversary of NC's Fisheries Reform Act (FRA) of 1997 and the fiftieth anniversary of NC's Coastal Area Management Act", as these time markers represent valuable horizons to critically appraise the efficacy (e.g., functional implementation) of these acts in serving critical missions within the NC Department of Environmental Quality (DEQ). The appropriation listed 13 focal species that are managed by the NC Division of Marine Fisheries (NC DMF) and Marine Fisheries Commission (NC MFC), although the scope of the study allowed for considerations of all harvested species in NC – including those with interjurisdictional management involving the Atlantic States Marine Fisheries Commission and South/Mid Atlantic and Gulf Fishery Management Councils.

In response to this mandate, the NC Collaboratory engaged researchers at the University of North Carolina at Chapel Hill (PIs Joel Fodrie, Nathan Hall, Elizabeth Havice, and Janet Nye), East Carolina University (PIs Rachel Gittman, James Morley, and Eric Wade), North Carolina State University (PI Jeff Buckel), and the University of North Carolina, Wilmington (PI Fred Scharf) to conduct a synthesis project evaluating the status of NC's marine public trust resources and their management. This research team – working with postdocs, graduate students, and undergraduate students – represents expertise in fish biology/ecology, estuarine ecology, fisheries management, and environmental governance.

To evaluate the status of NC marine fisheries, coastal habitats, and management operations, the research team has efforted a broad (per mandate) multi-pronged approach which included: (1) a quantitative comparison of NC fisheries stocks with those in other nearby jurisdictions (at state, multi-state, and federal levels) [led by Buckel and Scharf]; (2) a qualitative analysis of fisheries management plans for NC state-managed fisheries [led by Havice and Wade] ; (3) a quantitative analysis of the level of management intensity across stocks within NC, as well as a comparative analysis gauging management in NC with management in a set of comparable states of the Mid-Atlantic, Southeast Atlantic, and Gulf coasts of the United States [led by Scharf and Buckel]; (4) a holistic, ecosystem-based analysis of fisheries and environmental patterns in NC across several decades to identify key trends and explore potential drivers of change at state-level scales [led by Nye, Morley, Gittman, and Hall]; (5) an analyses of patterns in the NC

management process related to the mode and tempo by which stock assessments and fishery management plans in NC are developed and implemented (multiple prisms of exploration) [led by Fodrie]; (6) an assessment of spatiotemporal patterns in NC coastal habitat quality and quantity, as well as an exploration of strengths and weaknesses of the NC Coastal Habitat Protection Plan (CHPP) and NC's network of designated nursery areas [led by Gittman, Fodrie, and Hall]; and (7) an exploration of stakeholder engagement in NC marine fisheries and coastal habitat management process [led by Wade and Havice].

To explore these diverse-yet-connected facets of NC's coastal human-natural system, the research team sought to leverage all relevant fisheries data (e.g., species-specific life-history data, fishery dependent data, fishery independent data), environmental data (e.g., human population trends, water quality, storminess, etc.), and management practices to guide study findings. This approach leveraged existing data/information, with the exception of the exploration of stakeholder engagement in NC management which involved developing a new survey instrument that was distributed to commercial and recreational fishermen. The research team focused key findings and subsequent management recommendations on topics/issues for which available data could be used to inform understanding of the status or drivers of patterns in NC's coastal and marine ecosystems or within the relevant management processes. This approach led to two notable caveats for the summary report: (a) absence of data or absence of data clarity precluded the ability of the research team to make recommendations on all issues of potential importance for coastal and marine fisheries in NC; and (b) some recommendations are qualified in their specificity due to absence of data to generate consensus or guide galvanizing deliberations on specific paths forward.

This summary report fulfills NC General Assembly's mandate to evaluate the status of NC's coastal and marine fisheries and habitats and provide opportunities for improved management of NC's marine public trust resources. A long-form report with a complete description of all data acquisition, analyses, and details for policy implementation will be submitted at the end of 2025.

Key Findings – the Status of North Carolina's Marine Fisheries, Coastal Habitats, and Management Efficacy a Quarter Century After the Fisheries Reform Act

FINDING 1 – North Carolina's fisheries are intensely managed based on the presence of three core factors: peer-reviewed stock assessments, an organized regulatory structure with public participation, and management adaptability; as well as four supplementary factors: access/entry controls, accounting of discards/bycatch, limits on fishing pressure, and habitat protection. A quantitative index of management intensity (IMI) based on these factors was created and applied to fisheries in NC and other states in the region. The index revealed that management intensity in NC has increased over time and equals or exceeds the levels of management intensity observed in other states throughout the Southeast/Mid-Atlantic and Gulf of Mexico.

The IMI is a scoring framework that was used to quantify the level of fishery management intensity based on the cumulative amount of management applied to a given fishery stock. The core and supplemental factors outlined above were selected to ensure that the IMI reflected the flexibility, thoroughness, and effectiveness of management systems in responding to the needs of a fishery. Lower scores indicated that a management system for a given fishery lacked several of the core/supplemental factors. For core factors, IMI scores ranging from 0 - 20 = a "Low" IMI; 21 - 40 = a "Moderate" IMI; and 41 - 49 = a "High" IMI. Core and supplementary factor scores were combined to generate a total IMI score, for which scores of 0 - 50% = "Low" IMI; 51% - 74% = "Moderate" IMI; and 75% - 100% = "High" IMI.

For the Core IMI score, seven of the fourteen (fourteen to account for two separately managed striped bass stocks) NC stocks assessed received a Moderate score, and seven received a High score (Figure 1). For the Total IMI Score, seven stocks received a High score, six received a Moderate score, and only one received a Low score (Figure 2). The one stock that received a Low Total MI score was Sheepshead, which is the only coastal fishery managed by NC without a Fishery Management Plan (FMP). Overall, NC's IMI scores have increased over time from the 1990s (with the largest increases in the early 2000s), when most of the stocks assessed had Low or Moderate IMI scores.

Across the Southeast/Mid-Atlantic and Gulf regions, NC, Louisiana, and the Chesapeake Bay were characterized by the highest core and total IMI scores among the states/regions evaluated for the 13 stocks included in the study (Figures 3 and 4). Indeed, NC had higher IMIs than all other states evaluated for eight out of thirteen stocks using either Core or Total IMI scores.

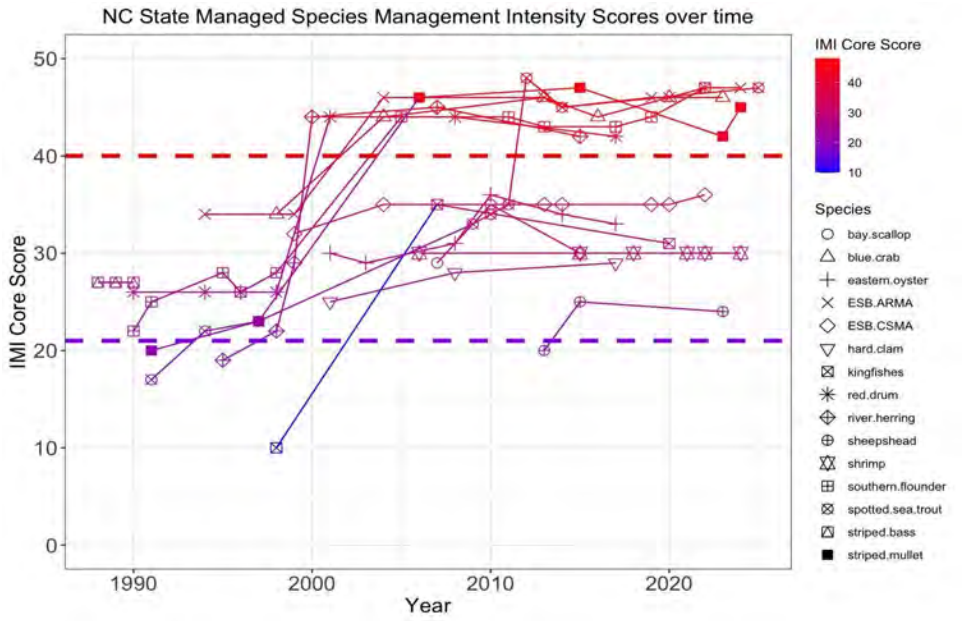


Figure 1. Core IMI scores for state-managed marine and coastal fisheries in NC. Data extend from the late 1980s, prior to the Fisheries Reform Act, to the present. The purple dashed line references the transition between Low and Moderate IMI scores (21) the red dashed line references the transition between Moderate and High IMI scores (40). Symbols below the purple line = Low IMI scores and symbols above the red line = High IMI scores.

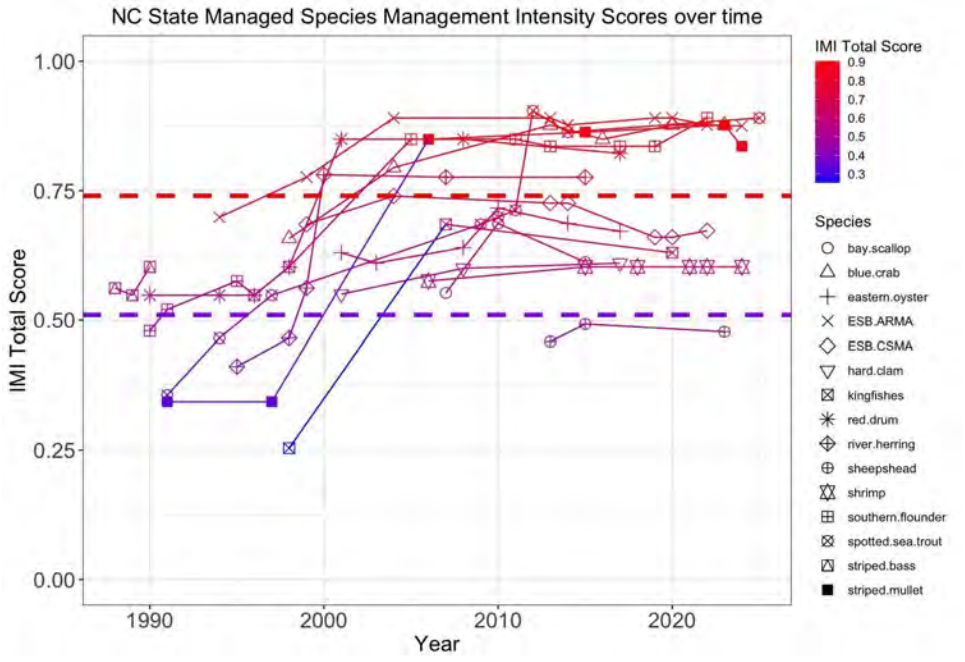


Figure 2. Total IMI scores for state-managed marine and coastal fisheries in NC. Data extend from the late 1980s, prior to the Fisheries Reform Act, to the present. The purple dashed line references the transition between Low and Moderate total IMI scores (51%) the red dashed line references the transition between Moderate and High total IMI scores (74%). Symbols below the purple line = Low total IMI scores and symbols above the red line = High IMI scores.

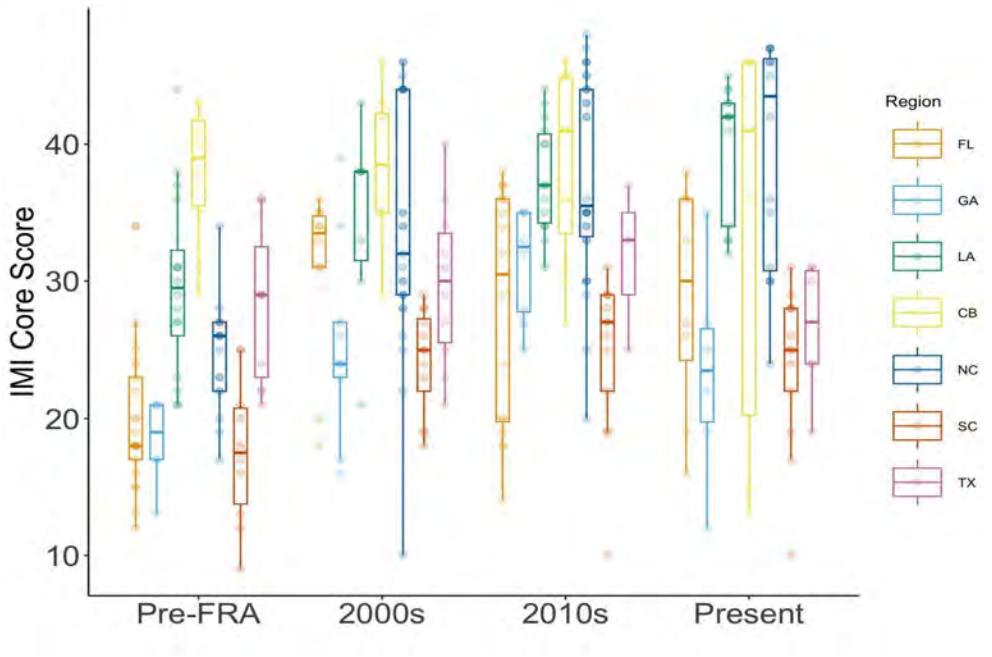


Figure 3. Boxplots representing the distribution (demonstrating mean and range) of Core IMI scores across stocks combined in each region or state during four time periods: Pre-FRA (pre-1997), 2000s (1998 to 2008), 2010s (2009 - 2019), and Present (2020 and later).

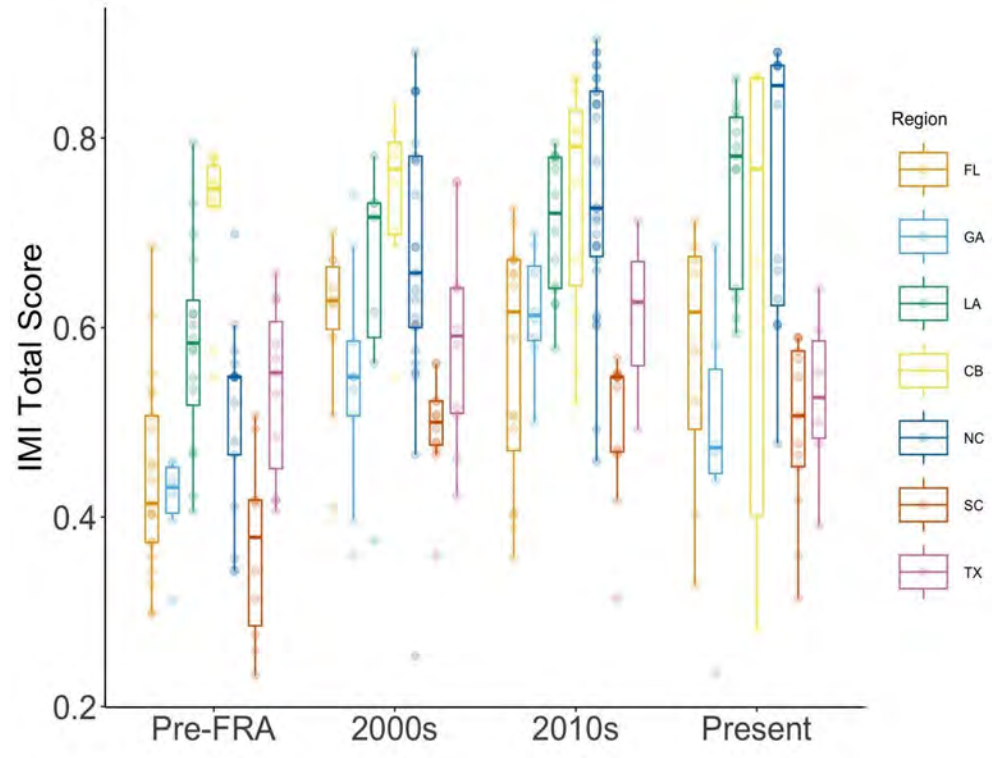


Figure 4. Boxplots representing the distribution (demonstrating mean and range) of total IMI scores across all stocks combined in each region or state during four time periods: Pre-FRA (pre-1997), 2000s (1998 to 2008), 2010s (2009 - 2019), and Present (2020 and later).

FINDING 2 – Despite the presence of a rigorous management structure, NC continues to exhibit challenges in achieving the core goals of the FRA: "to protect and enhance … coastal fisheries in NC" (S.L. 1997-400; HOUSE BILL 1097).

Quantitative stock assessments produce estimates of stock biomass and the harvest rate, which define overfished/overfishing status for the population, and are the benchmark for informed fishery management. Seven fisheries managed by NC (blue crab, red drum, sheepshead, southern flounder, spotted seatrout, striped bass, and striped mullet) include quantitative stock assessments with an average terminal year of ~2019. The most recent stock assessments estimate that five of these stocks (blue crab, southern flounder, spotted seatrout, striped bass, and striped mullet) are experiencing overfishing (harvest rate is too high), four of the stocks (blue crab, southern flounder, striped bass, and striped mullet; Figure 5) are overfished (stock biomass is too low), and two (sheepshead and red drum) are neither overfished or experiencing overfishing. Supplementary analyses assessed the long-term trends in stock biomass, fishing mortality rates, and fishery-independent survey (e.g. recruitment, adult abundance, juvenile abundance) trends. In NC, post-1997 fishery-independent estimates of biomass have trended downward for blue crab, red drum, southern flounder, striped bass, and striped mullet, while sheepshead and spotted seatrout biomass has trended upward. Since 1997, the fishing mortality rate has decreased significantly over time for blue crab, sheepshead, and spotted seatrout in NC while fishing mortality has increased for southern flounder and striped bass.

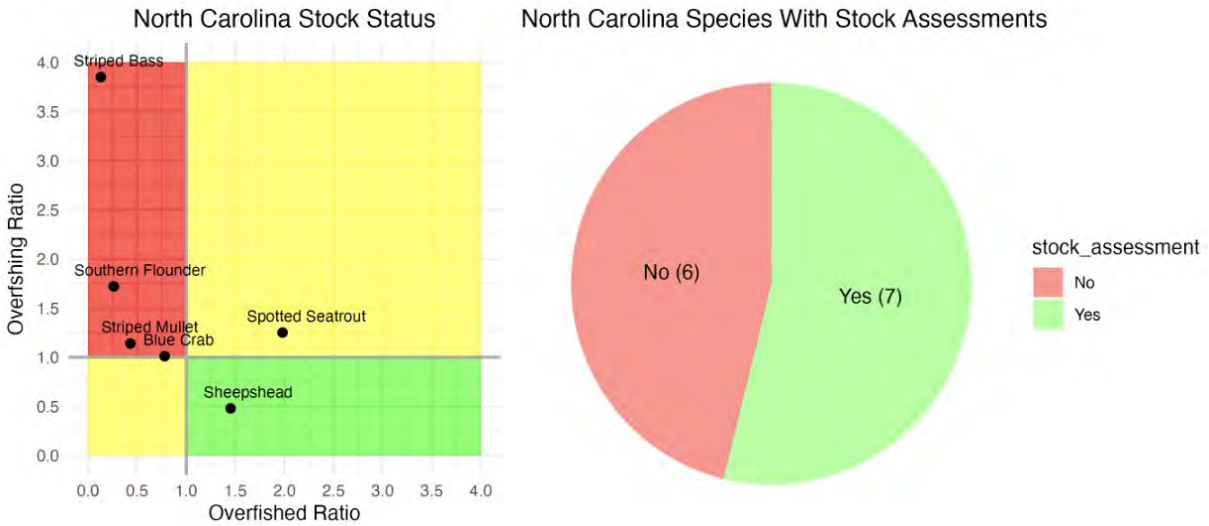


Figure 5. Left Panel: Kobe Plot showing the status of NC fishery stocks. The upper-left quadrant (red) includes stocks that are both overfished and experiencing overfishing. The lower-right quadrant (green) includes stocks that are not overfished or experiencing overfishing. Stocks in the yellow quadrants are either overfished or experiencing overfishing, but not both. Right Panel: Pie Chart of NC stocks with or without peer-reviewed stock assessments.

Relative to other states in the Southeast Atlantic, Mid-Atlantic, and Gulf regions (seven jurisdictions included in analyses, with Florida east and west coasts fisheries considered separately) NC has the greatest number of stock assessments (seven) and species with a designated stock status (also seven) among the 13 fishery species evaluated in this study. NC has the fourth highest (i.e., most recent) average terminal year (2018.9) for its stock assessments. Texas does not report any formal stock assessments or stock status designations, while Virginia, South Carolina, and Georgia have few of their stocks assessed and with at least one of those existing assessments performed by the NC DMF (e.g. southern flounder). Louisiana has the second most species with a stock assessment and stock status designation (six) with the third highest average terminal year (2019.3) for its stock assessments. Using available/existing stock assessments, NC is tied with South Carolina and Georgia exhibiting the second highest percentage of stocks with an overfished designation (67%; behind only Florida – Atlantic Coast at 80%) and the highest percentage of stocks with an overfishing designation (65%) (Table 1).

A similar analysis of the number of stock assessments and stock status designations was also performed at the federal level, evaluating the Mid-Atlantic Fishery Management Council (MAFMC), South Atlantic Fishery Management Council (SAFMC), and Gulf of Mexico Fishery Management Council (GMFMC). This analysis provided context to interpret the performance of individual state fishery management efforts (stock status) relative to federal management jurisdictions. For stocks managed by the federal fishery management councils, management performance has been better than state-managed fisheries based on stock status indicators. Across all three federal management jurisdictions, only 9-35% of stocks are currently overfished and 18-28% are experiencing overfishing, based on the most recent stock assessments (Table 2). Among the three federal councils analyzed, the SAFMC exhibited the highest percentage of stocks with an overfished designation (35%) and the highest percentage of stocks with an overfishing designation (28%), while their stock assessments had the oldest average terminal year (2018.6). These data suggest that the SAFMC could be experiencing challenges in their ability to obtain the necessary data and/or complete timely stock assessments compared to the MAFMC and GMFMC. Our interpretation is that increased frequency of stock assessments increases the probability of successful management outcomes.

Table 1. Summary table of state-level stock assessment and stock-status analyses for the 13 species included in this study: bay scallop, blue crab, eastern oyster, hard clam, kingfishes, red drum, river herring, sheepshead, shrimp, southern flounder, spotted seatrout, striped bass, and striped mullet.

	Average Terminal Year	Stock Status	Overfished Ratio	Overfishing Ratio	Overfished Designation	Overfishing Designation	Percent (%) Overfished	Percent (%) Overfishing
Maryland	2022.5	2	1	1	0	0	0%	0%
Virginia	2020.8	4	3	3	0	1	0%	33%
North Carolina	2018.9	7	6	6	4	4	67%	65%
South Carolina	2019.0	3	3	2	2	1	67%	50%
Georgia	2019.0	3	3	2	2	1	67%	50%
Florida - Atlantic	2018.5	5	5	5	4	2	80%	50%
Florida - Gulf	2018.0	5	4	4	1	1	25%	25%
Louisiana	2019.3	6	6	6	2	2	33%	33%
Texas								

Table 2. Summary table of assessed fishery stocks and current stock status designations for federal management jurisdictions (MAFMC, SAFMC, and GMFMC).

	Average Terminal Year	Stocks Assessed	Stocks w/Status	Overfished Ratio	Overfishing Ratio	Overfished	Overfishing	Percent (%) Overfished	Percent (%) Overfishing
MAFMC	2021.9	13	12	11	11	1	2	9%	18%
SAFMC	2018.6	18	18	17	18	6	5	35%	28%
GFMC	2019.1	20	17	15	17	3	3	20%	18%

Across states of comparable size or environmental context (i.e., South Carolina, Florida (separated by Atlantic and Gulf coasts), Louisiana, and Texas), NC's commercial landings (pounds per acre) and recreational harvest (fish per acre) indexed by the spatial extent of estuarine area are comparable with its regional neighbors, with the exception of commercial harvests in Louisiana and recreational harvests in Florida – those states far outpace other states in those respective sectors (Figure 6).

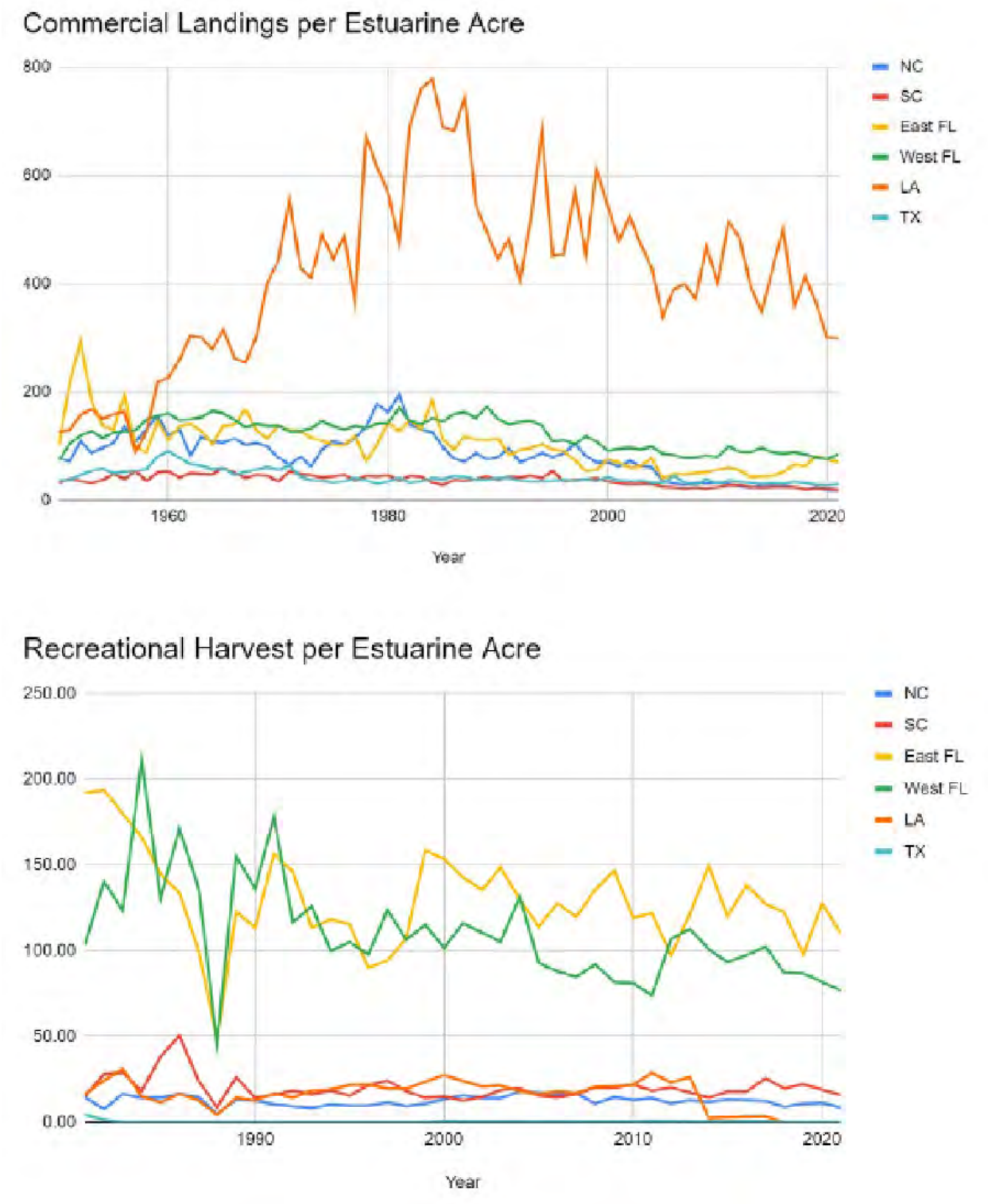


Figure 6. Commercial (upper panel: pounds per acre) and recreational (lower panel; fish per acre) harvests over time (1950-2022) in comparable Southeast Atlantic and Gulf states, with catches standardized by estuarine habitat area in each state.

FINDING 3 – There are opportunities for improving stakeholder engagement, enhancing trust, and expanding transparency in the fisheries management process.

A statewide survey was developed to examine stakeholder engagement in state-level fisheries management and participation in decision-making among commercial fishers and recreational anglers in NC. Surveys were distributed to fishing license holders and state residents in the summer of 2023. Surveys were completed by 272 commercial fishers (13% response rate) and 264 recreational anglers (13% response rate).

Participation in fisheries management activities was low among both commercial fishers and anglers (Table 3). On average, members of each sector participated in fisheries management activities less than once every few years. Commercial fishers were more likely to participate in all individual management activities than anglers ($p<0.001$). Among commercial fishers, participation was highest in mail or web surveys and in-person meetings, with a majority participating in these activities at least once every few years (Table 3).

Interest in participating in fisheries management activities was low among both commercial fishers and anglers, though commercial fishers demonstrated about 70% greater interest overall than anglers (Table 4). Both commercial and recreational fishers demonstrated a similar, moderate amount of interest in participating in mail or web surveys and outreach events/seafood festivals. Commercial fishers demonstrated about twice the interest in participating in NC DMF, NC MFC, and Advisory Committee meetings than recreational anglers ($p<0.001$).

Among commercial fishers, the greatest barrier to participation was frustration with the management process, followed by “meetings are scheduled when I am working” (Table 5). Among anglers, the greatest barrier to participation was a lack of knowledge of fisheries issues. Across both groups, similar numbers of respondents felt that they are not informed about opportunities to participate in decision-making and that it is difficult to participate in-person. Very few respondents (<1%) experienced difficulty participating because of a language barrier.

Commercial fishers were more knowledgeable about the aspects of the fisheries management process included in the survey than anglers (Table 6; $p<0.001$). Overall, however, respondents in both sectors were unclear about the role of the NC DMF and the NC MFC in determining and enforcing fisheries policies, with less than half of commercial fishers and only one-eighth of

anglers correctly answering questions related to NC's fisheries management process. About half (53%) of commercial fishers and a quarter of anglers (26%) knew that any member of the public can serve on an advisory committee. A similar number of respondents in each sector knew that all NC MFC meetings are open to the public (44% of commercial fishers and 37% of anglers, $p=0.084$).

Commercial fishers were more strongly dissatisfied with all elements of management than anglers, who had more neutral views ($p<0.001$; Table 7). Both groups were most dissatisfied with the management of fish stocks, the speed of decision-making processes, and the management of conflict between user groups compared to other aspects of management. Both groups were twice as dissatisfied with the NC MFC than with the NC DMF, though the difference was greater in magnitude among commercial fishers. The most satisfactory aspect of fisheries management for both commercial fishers and anglers was licensing and permitting processes.

Concerns for fisheries management differed between commercial fishers and anglers, though both groups selected fish stock status as a top concern (Table 8). Commercial fishers indicated strong concern over fairness (64%), loss of culture and heritage (56%), and political conflict (51%), while anglers were more concerned about wildlife conservation (63%) and ecosystem health (56%) than issues relating to the fisheries management process. Among both groups, the issues of least concern included climate change, enforcement, and aquaculture.

Anglers had neutral attitudes toward fisheries managers on average, while commercial fishers held more negative views ($p<0.001$; Table 9). Commercial fishers disagreed that managers make the right decisions for commercial fisheries, make decisions based on the best available science, and make the right decisions for sustainable marine ecosystems. In contrast, anglers held more neutral attitudes toward managers in all contexts (Table 9).

Commercial fishers were more distrusting of management entities than anglers ($p<0.001$; Table 10). Both groups held moderate levels of trust in their respective fishing groups and distrusted the other, though commercial fishers were more distrustful of recreational fishing groups than anglers were of commercial fishing groups. Both commercial fishers and anglers were the most distrustful of state officials. Commercial fishers more strongly distrusted the NC MFC and

federal/regional management bodies than the NC DMF and scientists. Anglers slightly trusted scientists and held near-neutral levels of trust in all other entities.

Participation in catch-reporting programs was lower among recreational anglers than commercial fishers. The majority of commercial fishers (78%) had participated in the mandatory Trip Ticket Program or voluntary reporting programs, including dockside, mail, or telephone surveys. Among commercial fishers who had fished in the past 12 months, a quarter (25%) had participated in mail surveys and ~14% had participated in other voluntary reporting activities. In contrast, only 13% of anglers had participated in mail surveys, just 5% in dockside surveys, and 2% in the Marine Recreational Information Program (MRIP).

Table 3. Commercial fishers and recreational angler participation in fisheries management decision-making activities.

	Commercial Fisher		Recreational Angler		
	Mean	SD	Mean	SD	*p* value
Participation in Decision-Making[1]	.63	.70	.10	.28	<.001
In-Person Meetings	.97	1.07	.14	.51	<.001
Online Meetings	.54	.93	.12	.46	<.001
NCDMF Meetings	.87	.98	.06	.34	<.001
NCMFC Meetings	.63	.94	.03	.19	<.001
Advisory Committee Meetings	.38	.80	.03	.20	<.001
Management Workshops	.30	.69	.04	.28	<.001
Public Comment	.92	1.08	.33	.77	<.001
Mail or Web Surveys	1.14	1.02	.64	.89	<.001
Outreach Events / Seafood Festivals	.94	1.06	.67	.95	.002

[1]Participation was measured on a scale of 0-3, where 0=never participate, 1=participate once every few years, 2=participate once per year, and 3=participate more than once per year.

Table 4. Interest in participating in fisheries management decision-making activities among commercial fishers and recreational anglers.

	Commercial Fisher		Recreational Angler		
	Mean	SD	Mean	SD	*p* value
Interest in Participation[1]	.95	.61	.56	.52	<.001
In-Person Meetings	.84	.73	.40	.58	<.001
Online Meetings	.64	.68	.48	.65s	.012
NCDMF Meetings	.95	.72	.41	.57	<.001
NCMFC Meetings	.90	.74	.36	.56	<.001
Advisory Committee Meetings	.82	.73	.35	.57	<.001
Management Workshops	.70	.72	.40	.60	<.001
Public Comment	.91	.77	.57	.69	<.001
Mail or Web Surveys	.94	.74	.90	.69	.484
Outreach Events / Seafood Festivals	.88	.76	.90	.76	.831

[1]Interest in participation was measured on a scale of 0 to 2, where 0=not interested, 1=somewhat interested, and 2=very interested.

Table 5. Barriers to participating in fisheries management decision-making among commercial fishers and recreational anglers.

	Commercial Fisher		Recreational Angler		
	Mean	SD	Mean	SD	*p* value
Barriers to Participation[1]					
I am not knowledgeable about fisheries issues	.05	.21	.32	.47	<.001
My interests are already well-represented by others	.12	.33	.13	.33	.875
I am not informed about opportunities to participate	.29	.46	.29	.45	.921
I am frustrated with the management process	.60	.49	.12	.33	<.001
Meetings are scheduled when I am working	.32	.47	.16	.37	<.001
I am satisfied with current regulations and therefore have no reason to participate	.05	.21	.10	.30	.026
A language barrier makes it difficult for me to participate	.01	.12	.00	.07	.284
Management does not affect my well-being or livelihood	.05	.23	.08	.27	.253
I am not interested in participating	.05	.23	.19	.40	<.001
The management process is too slow	.20	.40	.07	.26	<.001
It is hard for me to participate online	.14	.35	.08	.27	.026
It is hard for me to participate in-person	.29	.45	.23	.42	.133
Other	.17	.38	.09	.28	.003

[1]Barriers to participation were measured on a binary scale, with a value of 1 indicating agreement with the statement and a value of 0 indicating disagreement.

Table 6. Fisher knowledge of decision-making processes.

	Commercial Fisher	Recreational Angler	P
	% Correct	% Correct	
Marine fisheries policies are determined by the Division of Marine Fisheries (NCDMF). **Correct answer=false**	49.6	12.5	<.001
Marine fisheries policies are enforced by the Marine Fisheries Commission (NCMFC). **Correct answer=false**	34.2	12.4	<.001
Any member of the public can apply to serve on a Marine Fisheries Commission (NCMFC) Advisory Committee. **Correct answer=true**	53.2	25.8	<.001
All Marine Fisheries Commission (NCMFC) meetings are open to the public. **Correct answer=true**	44.4	36.8	.084

[1]Knowledge was measured using a T/F question series.

Table 7. Satisfaction with elements of fisheries management among commercial fishers and recreational anglers.

	Commercial Fisher		Recreational Angler		
	Mean	SD	Mean	SD	*p* value
Satisfaction with Elements of Management[1]	-.68	.78	.00	.76	<.001
Marine Fisheries Commission (NCMFC)	-.92	1.02	-.06	.87	<.001
Division of Marine Fisheries (NCDMF)	-.45	1.24	-.03	.88	<.001
Advisory Committees	-.79	1.02	-.08	.79	<.001
The speed of decision-making processes	-1.01	.97	-.15	.83	<.001
Enforcement of regulations	-.25	1.29	.08	.96	.001
Management of conflict between user groups	-.99	.99	-.14	.90	<.001
Management of fish stocks	-1.23	.97	-.24	1.07	.005
Reporting requirements and programs	-.59	1.16	-.05	.89	<.001
Licensing and permitting processes	.14	1.43	.47	1.04	.003

[1]Satisfaction was measured on a scale between -2 and 2; where -2=very dissatisfied, -1=somewhat dissatisfied, 0=neutral, 1=somewhat satisfied, and 2=very satisfied.

Table 8. Concerns for fisheries management in North Carolina among commercial fishers and recreational anglers.

	Commercial Fisher	Recreational Angler
	%	%
Concerns for Fisheries Management[1]		
Fish Stock Status	54.8	69.8
Climate Change	15.9	24.6
Ecosystem Health	39.4	56.2
Enforcement	21.0	24.5
Transparency	36.2	27.8
Political Conflict	51.6	20.6
Fairness	64.0	45.6
Access	23.3	31.7
Market Prices	34.4	14.7
Wildlife Conservation	18.5	62.8
Coastal Development	47.1	38.7
Food Source Availability	28.9	34.2
Aquaculture Development	16.7	13.1
Loss of Culture/Heritage	55.5	20.5
Other	10.3	3.5

[1]Respondents were asked to select their top 5 concerns for fisheries management in North Carolina.

Table 9. Attitudes toward fisheries managers among commercial fishers and recreational anglers.

	Commercial Fisher		Recreational Angler		
	Mean	SD	Mean	SD	*p* value
Attitudes toward Fisheries Managers[1]	-.46	.50	-.06	.49	<.001
Fisheries Managers…					
listen to public input throughout decision-making processes	-.41	.72	-.08	.58	<.001
provide fair opportunities for public participation in management	-.20	.73	.03	.58	<.001
are transparent about decision-making processes	-.48	.63	-.07	.55	<.001
make decisions based on the best available science	-.51	.65	-.01	.62	<.001
make the right decisions for sustainable marine ecosystems	-.52	.64	-.03	.61	<.001
make the right decisions for commercial fisheries	-.62	.62	-.06	.61	<.001
make the right decisions for recreational fisheries	-.43	.68	-.16	.67	<.001
make the right decisions for coastal communities	-.49	.62	-.05	.57	<.001

[1]Attitudes toward fisheries managers were measured on a scale of -1 to 1, where -1=disagree, 0=neutral, and 1=agree.

Table 10. Trust in fisheries managers among commercial fishers and recreational anglers.

	Commercial Fisher		Recreational Angler		
	Mean	SD	Mean	SD	*p* value
Trust in Management Entities[1]	-.80	.79	.00	.82	<.001
Marine Fisheries Commission (NCMFC)	-.99	1.04	.00	.96	<.001
Division of Marine Fisheries (NCDMF)	-.62	1.17	.06	.96	<.001
Advisory Committees	-.67	1.04	-.01	.89	<.001
State Officials	-1.15	.90	-.36	1.04	<.001
Scientists	-.59	1.18	.29	.99	<.001
Federal/Regional Management Bodies (ASMFC, MAFMC, SAFMC)	-.84	1.02	-.03	.92	<.001
Commercial Fishing Groups	.29	1.20	-.18	1.06	<.001
Recreational Fishing Groups	-.95	1.06	.42	.91	<.001

[1]Trust was measured on a scale of -2 to 2, where -2=completely distrust, -1=somewhat distrust, 0=neutral, 1=somewhat trust, and 2=completely trust.

FINDING 4 – The management of fishery stocks via the Fishery Management Plan (FMP) process is relatively slow, which potentially limits the efficacy of science- and process-based public trust resource management (hallmark goals of the FRA). Furthermore, the fishery management process in NC has been characterized by an apparent decrease in consensus actions over time, likely further delaying implementation of effective management actions.

In dynamic coastal zones (See Finding 5), adaptive management that is responsive to changing socio-ecological conditions is crucial for the effective implementation of measures to ensure the sustainability and productivity of NC's fishery resources. Analyses of publicly available data regarding the mode and tempo of management actions related to the FMP process, NC MFC votes, NC DMF proclamation activity, and even NCGA engagement in fisheries-related legislation highlight a number of patterns which suggest NC's management structures and operations possess potential for further optimization.

Across the 12 stocks managed by NC for which an initial FMP exists (i.e., excluding sheepshead), the average time between the initial FMP and FMP Amendments, across stocks, is 7.0 years (not accounting for time between the terminal FMP and present, Figure 7). Even after accounting for Supplements to Amendments, the average time between FMP actions across species is 5.2 years (Figure 7).

In the context of these timelines, there is little evidence that adaptive management is being achieved by increased activity within the NCGA, by the breadth of motions adopted by the NC MFC, or via proclamation authority vested with the NC DMF (Figure 8). Indeed, the frequency of motions considered/passed by the NC MFC and proclamations issued by the NC DMF (excluding shellfish sanitation water quality closures) appear to have waned over time.

Potentially related to these patterns, measures of "consensus" (whether via shared values/objectives or through the effectiveness of galvanizing debate) appear to have decreased through time, as proxied by either: (1) the frequency of unanimous or near-unanimous votes among the NC MFC over time; or (2) the patterns of concurrence between NC DMF recommendations in the FMP process and the adoption of FMP actions by the NC MFC over time (Figure 9).

	Average Number of Years Between FMPs and Amendments	Average Number of Years Between All FMP Items
Bay Scallop	3.7	3.7
Blue Crab	7.1	4.3
Eastern Oyster	3.9	3.1
Estuarine Striped Bass	9.3	3.7
Hard Clam	7.8	7.8
Kingfishes		6.4
Red Drum	7.7	8.2
River Herring	7.5	7.5
Shrimp	8.0	4.0
Southern Flounder	5.8	3.5
Spotted Seatrout		2.1
Striped Mullet	9.6	8.3
Overall Average	7.0	5.2

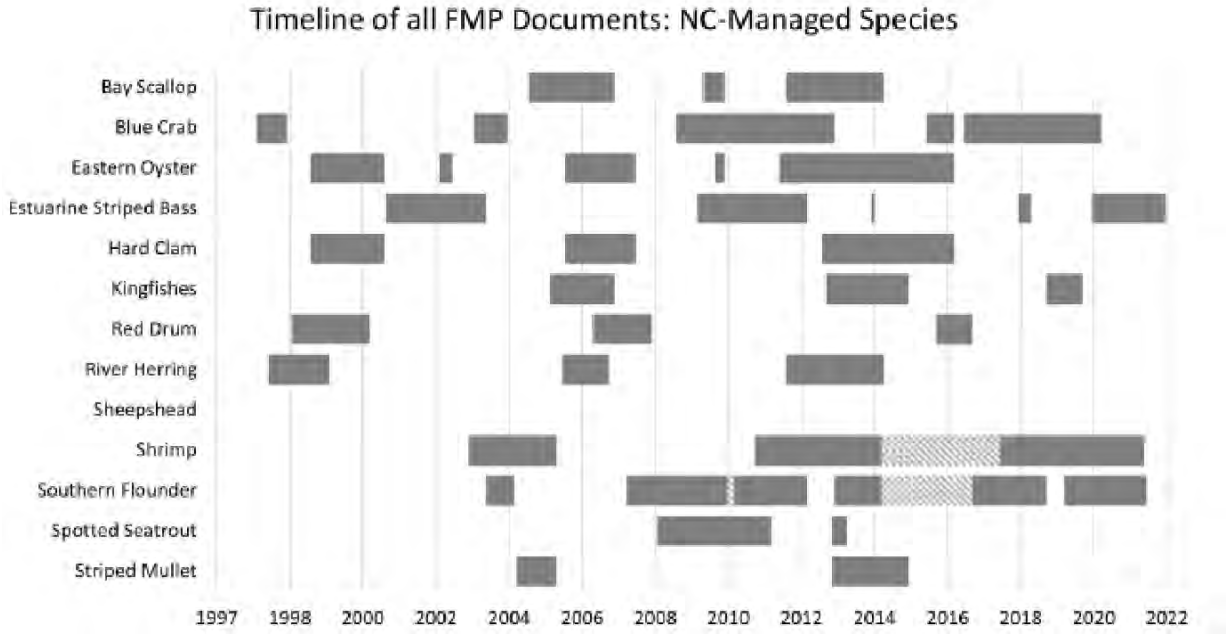


Figure 7. Upper Panel: Time between adoption of FMP and subsequent Amendments (left) or Amendments + Supplements (right) actions. Lower Panel: Timeline of FMP actions, highlighting the duration of each FMP, Amendment, or Supplement action for each of 13 stocks managed by NC.

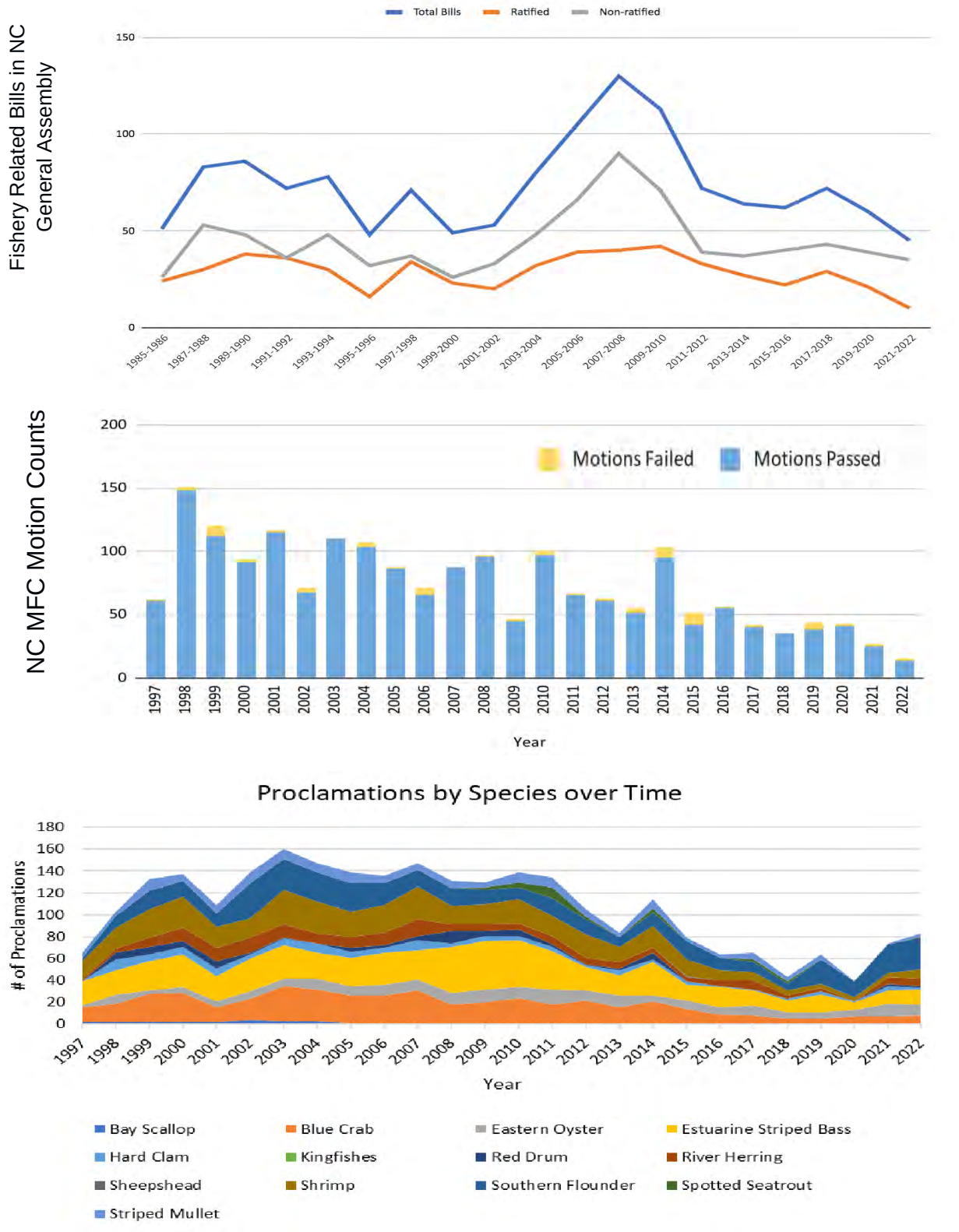
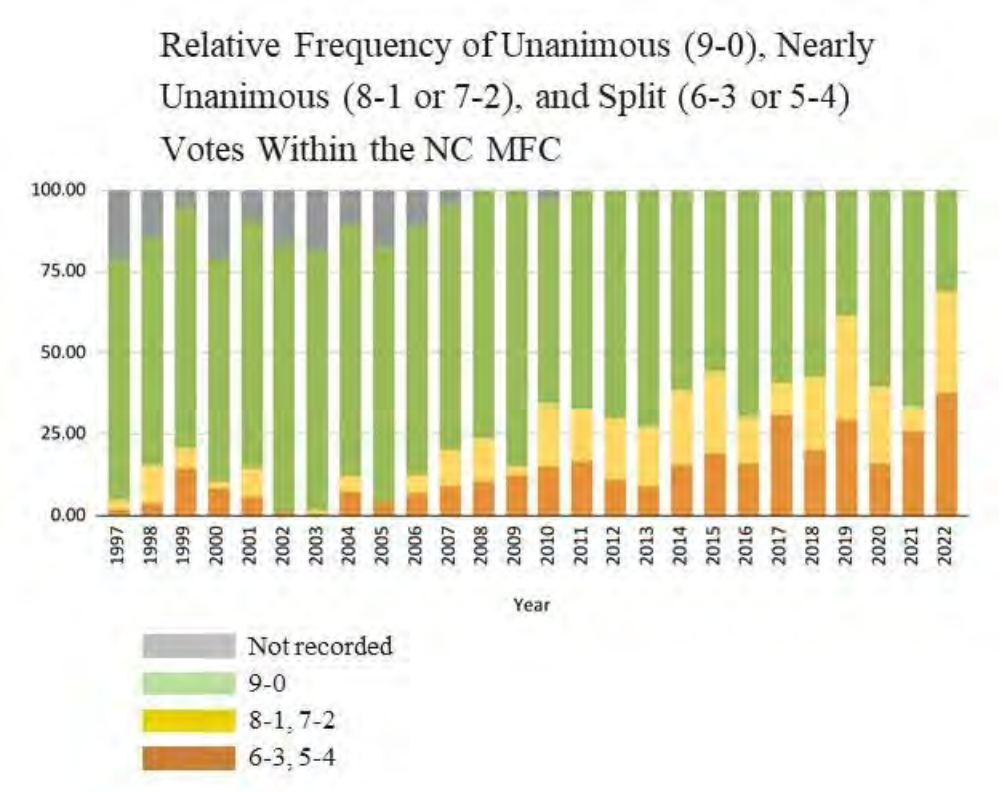


Figure 8. Upper Panel: Fisheries-related legislative activity within the NCGA. Middle Panel: Number of motions voted on and adopted by the NC MFC. Lower Panel: Proclamation activity as vested within the NC DMF.



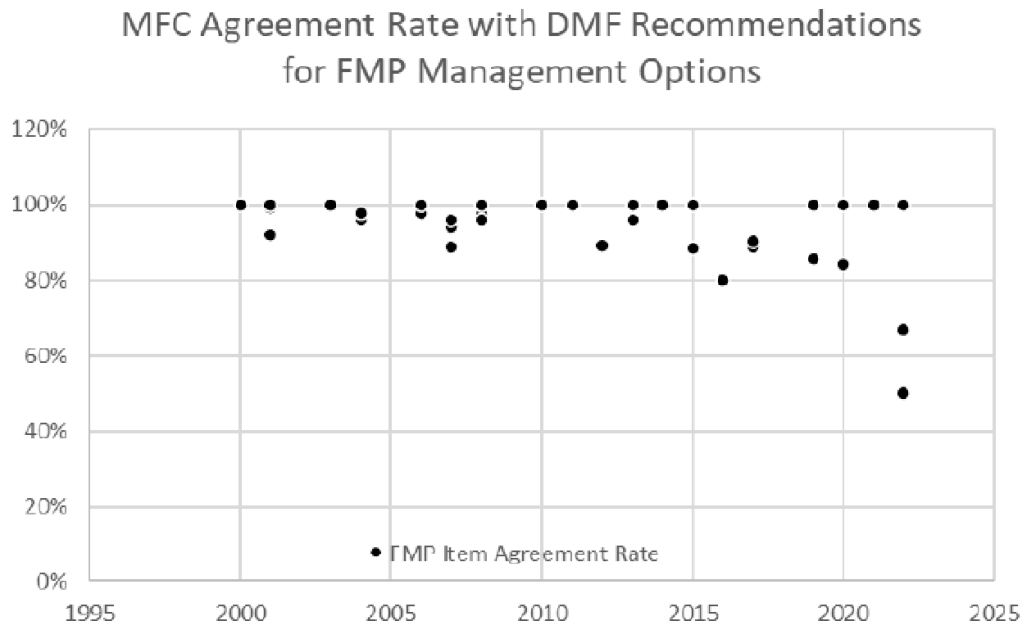


Figure 9. Measures of "consensus" in the NC fishery management process, proxied either by: (1) the frequency of unanimous or near-unanimous votes among the NC MFC through time; or (2) the patterns of concurrence between NC DMF recommendations in the FMP process and the adoption of FMP actions by the NC DMF through time.

FINDING 5 – NC marine fisheries and coastal habitats exist in a dynamic system defined by consistently changing conditions and multiple drivers of change. This exacerbates issues related to a slow(ing) and more contentious management process (See Finding 4).

The diverse and expansive fishery resources and supporting habitats of NC are under pressure from fishing, coastal and inland development, climate variability, and other human activities. To understand how species, habitats, and ecosystems have shifted over time, we collated long-term data on a wide array of ecosystem indicators. An ecosystem indicator is a measurement to characterize how one specific aspect of a system is changing over time. This report analyzes the trends and relationships of 186 ecosystem indicators and are grouped into three categories:

1. Coastal **drivers and pressures**–measurements of change in the physical environment, coastal population densities, and development trends, that may affect coastal resources;
2. Biological **states**–status of select marine species or communities and coastal habitats, which might be responding to coastal drivers and pressures, and also interacting with fisheries impacts;
3. Fisheries **impacts/characteristics**–changes in attributes of the commercial and recreational fisheries in NC.

Viewed holistically, the data reveal a significant shift in the entire socio-ecological system of NC over the last ~30 years and since the passing of the FRA in 1997. Of 132 indices eligible for formal statistical analyses based on data structure and longevity, 51% of these indices manifest statistically significant changes over decadal scales, including most notably: increases in human population density and development along the NC coast; decreases in Phosphorus loading and increases in Nitrogen loading (after normalizing for flow); increases in total (not just economically prized) finfish and penaeid shrimp abundance, but decreases in abundance of nekton in shallow estuarine habitat; increases in coastal river and air temperatures; and a rate of sea-level rise higher than the global average.

Coincident with these shifts, the commercial fishing sector had exhibited declines in number of licenses, registered vessels, participants, trips, and landings since the passing of the FRA, while increasing trends were observed for recreational fishing participation as indicated by the increase in number of licenses and trips over this same period. Both commercial and recreational sectors have been characterized by significant shifts in target species throughout the last 45 years (Figures 10-11).

To identify patterns of change in coastal NC ecosystems, we also conducted two multivariate analyses on the suite of ecosystem indicators developed in this report, the first of which characterizes the change in harvested species (NMDS) and the second of which evaluates both the relationship among indicators and the association of each year in the time series with indicator trends (PCA). These methods require complete (or near-complete) data; therefore, indicators with too many data gaps (i.e., missing years) and indicators with short time series were excluded from these analyses.

Leveraging 144 indicators from 2000-2019 (Figure 12), 32.5% of variation in the data could be explained by the following key indicators (i.e., the biggest contributors to differences among years): increased coastal population size, increased riverine nitrogen loads, shifts in the demographics of fishers, declines in overall commercial catch, and declines in the estimated abundance of many economically prized species. Interannual fluctuations in physical conditions of the ecosystem (e.g., temperature, rainfall) were also notable contributors to differences among years, accounting for 17.3% of the variation among the combined indicators. This ecosystem indicator analysis of Drivers and Pressures, States, and Impacts and Responses together confirms that coastal NC is experiencing a profound shift in its ecological state that is reflected in changes to, and consequences for, both its natural resources and stakeholders.

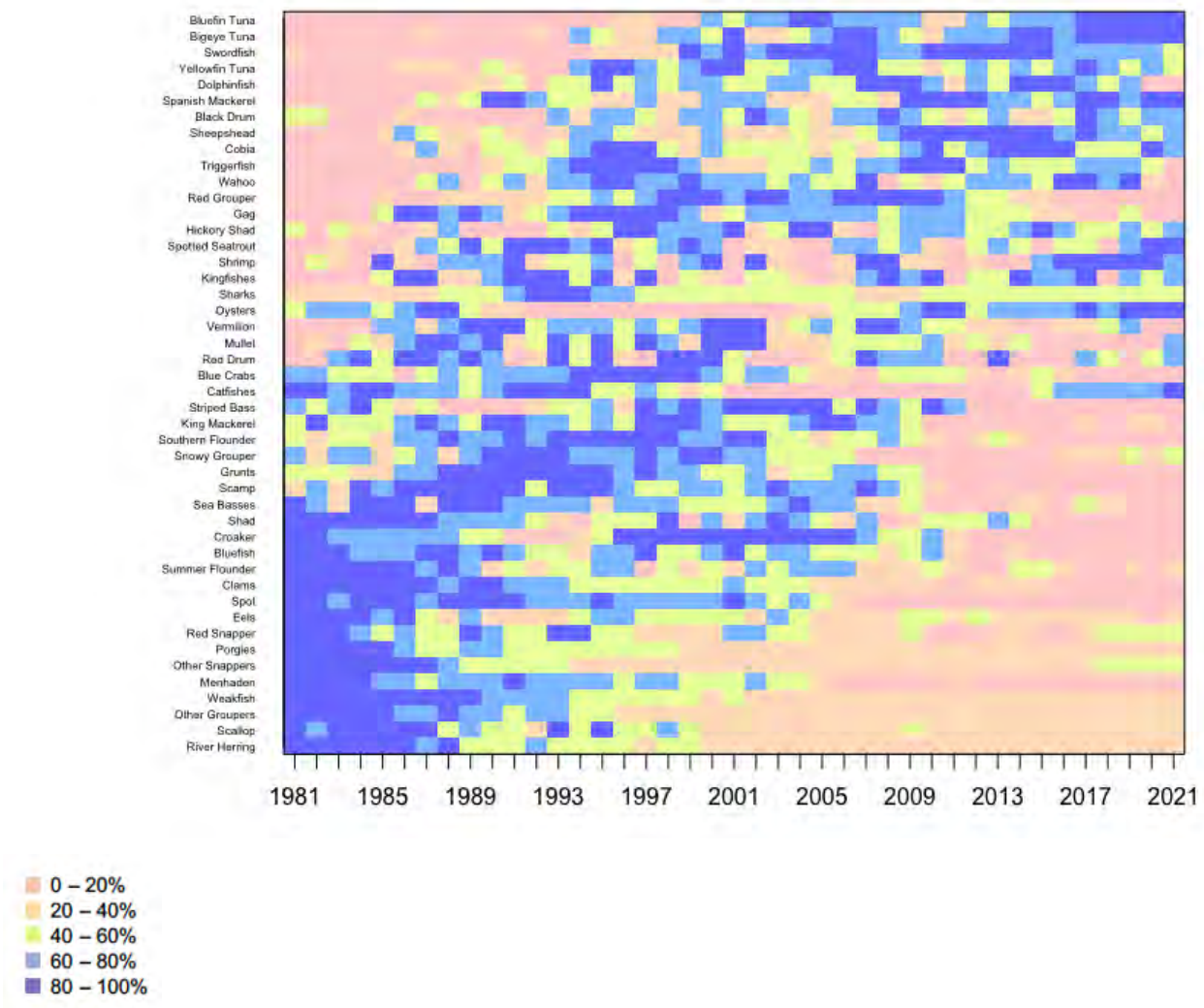


Figure 10. Plot of commercial landings from 1981 to 2021. Colors represent percentile of landings normalized for the landings of each species (darker blue colors indicate higher harvest for that species in a given year – relative to all other years for that same species). Species are shown on the y-axis such that species that have similar patterns of landings over the time series are closer together. There has been a shift over time where some species had relatively large landings during the more historic period (species near the bottom) and some species have increased landings in more recent years (species near the top).

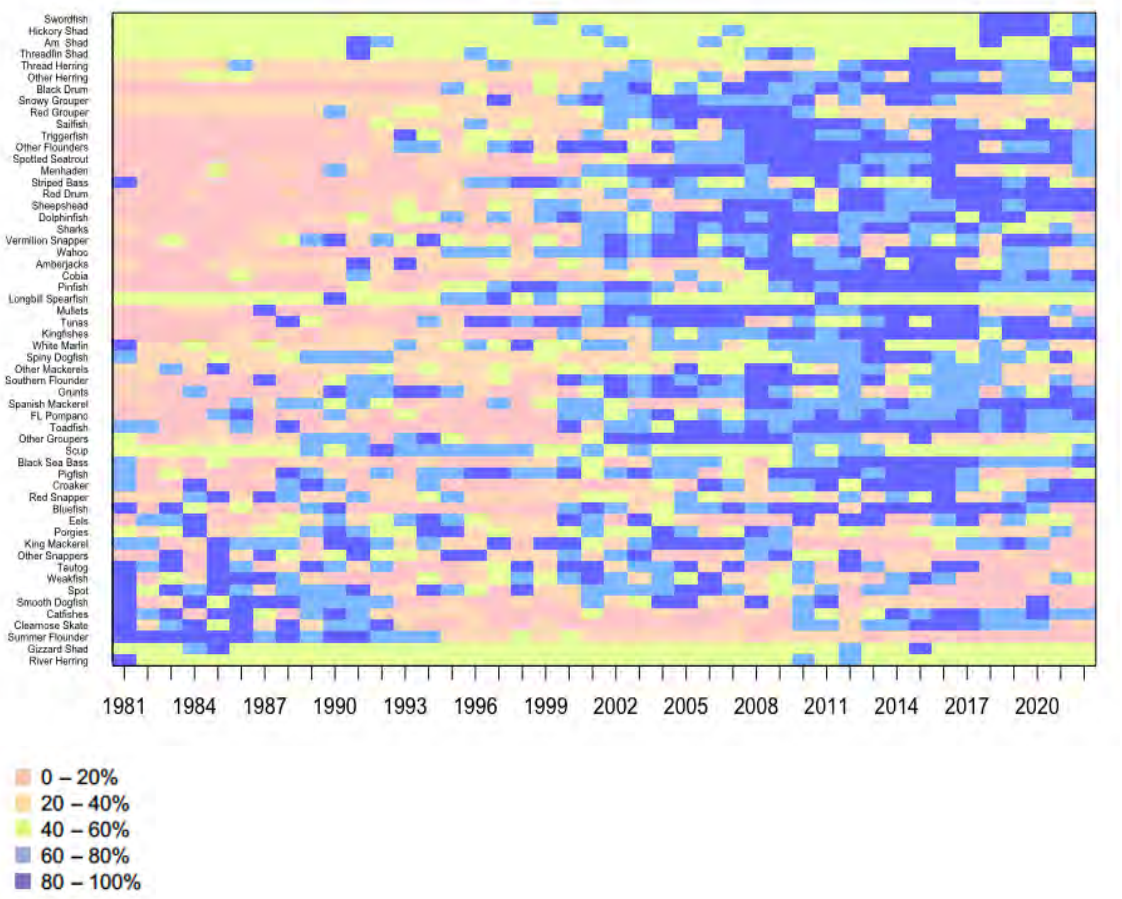


Figure 11. Plot of recreational catches (harvested plus released) from 1981 to 2022. Colors represent percentiles of landings normalized for the landings of each species (darker blue colors indicate higher harvest for that species in a given year relative to all other years for that same species). Species are shown on the y-axis such that species that have similar patterns of landings over the time series are closer together. The majority of species have experienced increases in catch over time.

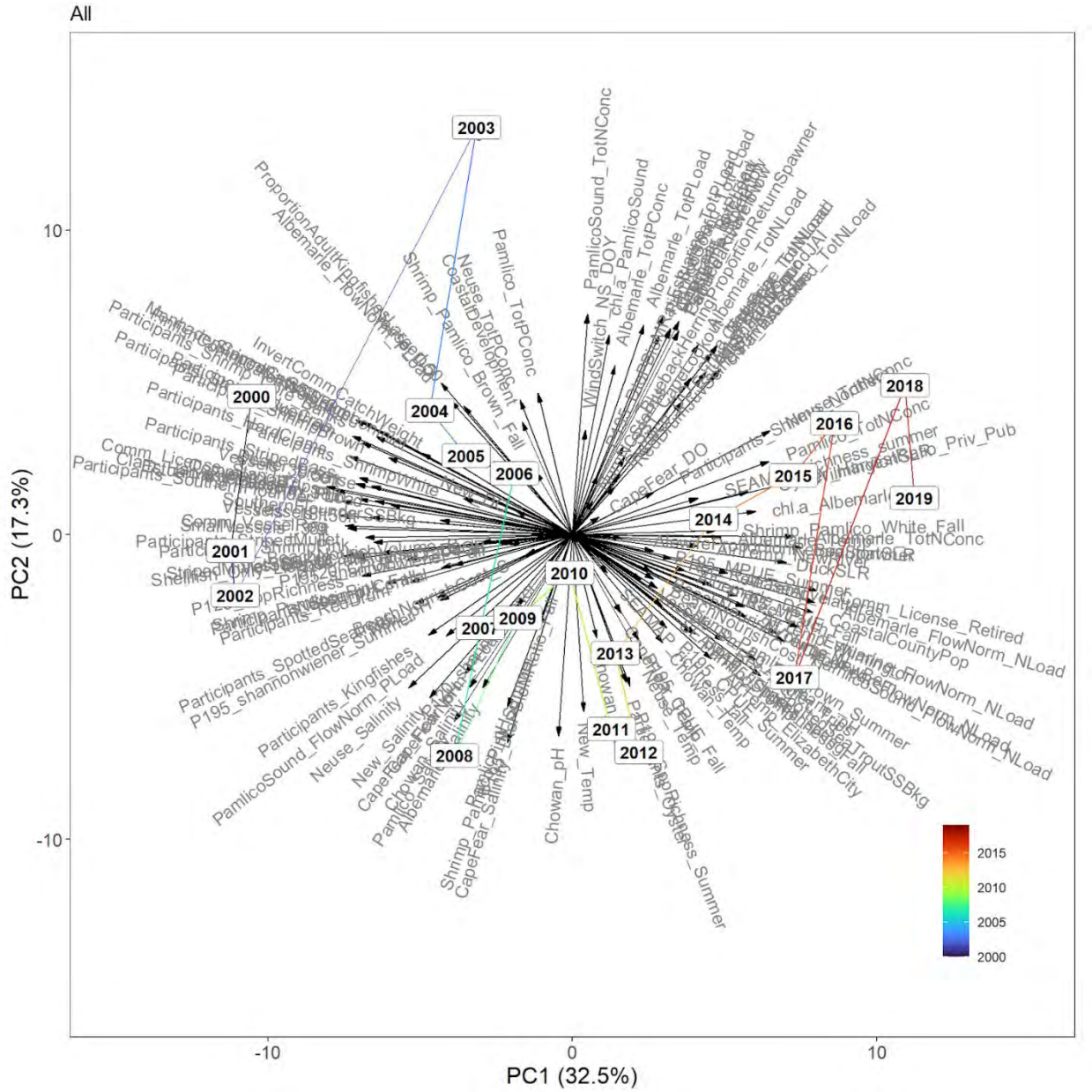


Figure 12. Multivariate analysis (PCA) of all eligible indicators (Drivers and Pressures, States, Impacts and Responses) for coastal NC from 2000-2019. Line color follows the time series from early to late years. Years that are close together have more similar conditions. Gray arrows and text show the direction of individual indicators. Longer arrows indicate stronger influence, arrows in the same direction are positively correlated, arrows in the opposite direction are negatively correlated, and arrows at 90-degree angles show no correlation.

FINDING 6 – NC's benthic, structured habitats are severely degraded (marsh and oyster historical; SAV ongoing), and water quality is also impacted. While absolute quantitative links to fishery production remain elusive, fishery management processes have not fully integrated these changes in coastal habitat quality and quantity.

Coastal and estuarine habitats, particularly structured habitats, such as submerged aquatic vegetation (SAV, including seagrasses and other macrophytes), tidal wetlands, and oyster reefs, can support high densities of commercially and recreationally valuable juvenile fishes and crustaceans as compared to other marine habitats. As such, these habitats are thought to contribute disproportionately to fisheries production and thus often designated as essential fish habitat. We reviewed available data on the current and historic extent of SAV, tidal wetlands, and oyster reefs in NC to evaluate how these habitats have changed over time. However, long-term, continuous data for tidal wetland, SAV, and oyster reef extent were not available, and thus were not included in the key indicator analyses described under Finding 5. Here, we evaluate habitat changes in coastal NC based on available, yet discontinuous data.

Incremental mapping of high-salinity SAV (seagrass) suggests losses of 6.5% of total seagrass area from 2006 to 2013, with the largest losses (-17.9 km^2) in northern NC and the largest percent declines (-10.5%) observed in southern NC. Further, seagrass has also shifted from continuous to patchy meadows in many areas, meaning actual losses likely exceed current estimates. Historic and current statewide estimates of low-salinity SAV extent were not available, but an estimated 33% decline in low-salinity SAV extent has been reported in the Neuse, Pamlico, and Albemarle river sub-estuaries.

Although there were net gains in estuarine marsh area (16.5 km^2) and freshwater marsh area (478 km^2) in coastal NC from 1996 to 2016, estuarine marsh declined in 9 of the 20 NC coastal counties, with the largest decline observed in Dare county, and freshwater marsh area declined in 5 of the 20 NC coastal counties, with the largest declines observed in Carteret, Craven, and Pamlico counties.

State-wide data on the historic and current extent of oyster reefs are limited; however published estimates for contemporary and historic oyster extent in some NC water bodies suggest 29% declines in oyster extent over a 125-year period.

While many coastal river-estuarine (e.g., Cape Fear River Estuary, Neuse River Estuary) systems are systematically monitored across NC, large portions of major water bodies such as Pamlico, Currituck, Bogue and Core sounds lack regular, standardized water quality monitoring. Furthermore, the past two decades have been defined by a ~50% decline in water quality monitoring effort (Figure 13), presumably due to reduced funding levels at the NC DEQ Division of Water Resources (DWR). Thus, the magnitude and impacts of shifts in water quality are poorly constrained.

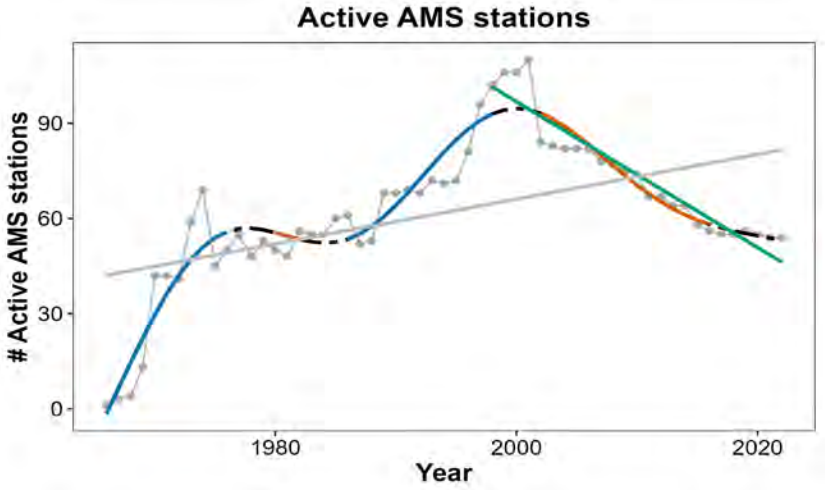


Figure 13. Time series of active NC DEQ DWR Ambient Monitoring System stations within NC estuarine waters.

Mapping and monitoring of coastal wetlands, oyster reefs, and SAV is currently being conducted by separate entities (e.g., National Oceanic and Atmospheric Administration [NOAA], NC DMF, NC DCM, Albemarle-Pamlico National Estuary Partnership [APNEP]) and federal and state funding for mapping and monitoring has been limited and irregular. Additionally, processing and validation of habitat data is labor intensive, often resulting in significant delays (5+ years) in the release of updated habitat maps and habitat change estimates. Lack of access to up-to-date habitat maps and change estimates can limit the ability of managers to make informed decisions about where and how habitat protections and resources should be allocated.

The NC Coastal Habitat Protection Plan (NC CHPP) led by NC DMF has recommendations related to management, conservation, restoration, and mapping/monitoring of coastal habitats. However, as of 2025, none of the primary recommendations related to mapping and monitoring have been completed (Figure 14). Further, many of the recommendations in the CHPP are qualitative (e.g., “Continue high salinity mapping and sampling with existing staff [DMF, APNEP,

volunteers] and funds") and lack quantifiable targets to assess progress. For the recommendations that do have clear targets (e.g., "By 2022, DEQ will commit to protecting and restoring SAV to reach an interim goal of 191,000 acres.") there are no clear penalties or regulatory triggers that would require the State to take action when recommendations are not met. Despite these limitations, the CHPP is a valuable tool that is actively and successfully being used to coordinate management; identify management, regulatory, conservation, and restoration priorities; and assess monitoring, mapping, education, outreach, and research needs that should be strengthened with greater statutory and financial support.

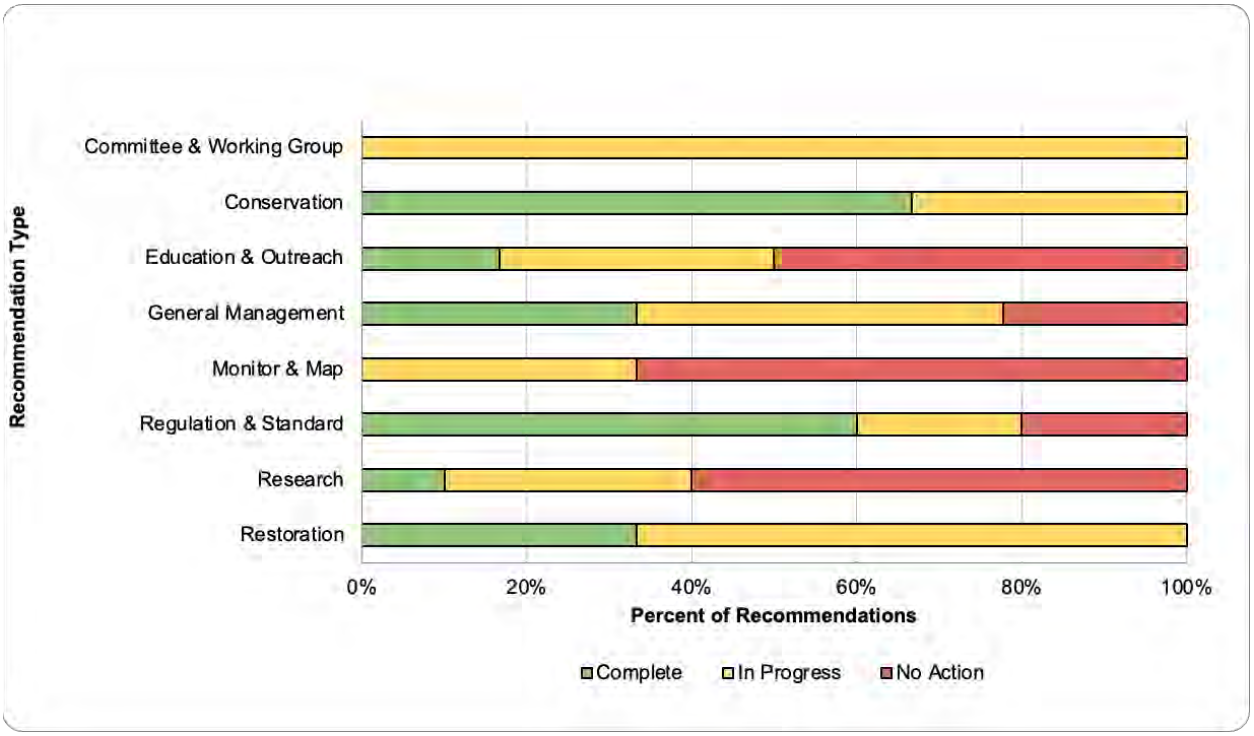


Figure 14. Primary recommendations outlined in the NC Coastal Habitat Protection Plan (CHPP) by category (number of recommendations have been standardized across categories) and by current status: complete (green), in progress (yellow), and no action (red) as reported in 2025 by the CHPP Steering Committee.

FINDING 7 – While the scope and timing of NC's efforts to identify and protect Primary Nursery Areas (PNAs) appear exceptional in comparison with other states, NC's PNAs have not been managed adaptively over decadal scales, and they do not appear to be functioning as intended.

North Carolina initiated juvenile fish surveys in the 1970s to identify areas with elevated densities of juvenile and subadult managed fishes and then used those inventories to designate estuarine waters afforded with additional protections, with the intent to limit destruction and degradation of important nursery habitats. Under these protections, more than 80,000 acres of shallow estuarine areas in NC are designated as Primary Nursery Areas (PNAs), because these areas are hypothesized to be where initial post-larval development occurs based on biophysical characteristics (e.g., temperature, salinity, bottom type) and sampling of juvenile fishes by NC DMF. PNAs have restrictions related to commercial fishing activity (e.g., gears) and nearby development. We evaluated data from five of the most abundant and management-relevant taxa that were key in the original siting of PNAs: Atlantic croaker, brown shrimp, blue crab, southern flounder, and spot, to assess the impacts of protected PNAs on productivity within these waters relative to similar sites that lack specific protections (e.g., non-designated [ND] areas). Statewide survey methods of nursery habitat (P120 Estuarine Trawl Survey) for juvenile finfish and crustaceans have remained largely consistent since 1989, thus we compared juvenile catch per unit effort (CPUE) in May and June for Atlantic croaker, brown shrimp, blue crab, southern flounder, and spot between PNA trawl stations and ND trawl stations during that period, excluding 1992-1993 because of reduced sampling effort during those years.

Atlantic croaker CPUE was lower in PNAs compared to similar non-designated (ND) areas in May and June surveys (Figure 15). Blue crab CPUE was higher in PNAs than in ND areas in May, but there was no observable difference in blue crab CPUE between PNA and ND areas in June surveys (Figure 16). Brown shrimp CPUE was consistently higher in PNAs compared to similar ND areas in May and June surveys over time (Figure 17). Compared to other species, southern flounder CPUE was low in both PNAs and ND areas but was higher in PNAs relative to ND areas in May and June surveys (Figure 18). Spot CPUE did not differ between PNAs and ND areas in May but was higher in PNAs relative to NDs in June (Figure 19). Although we observed some statistically detectable differences in CPUE between PNAs and NDs areas, the effect sizes were generally small, furthermore for blue crab, southern flounder, and spot, long-term trends suggest decreasing CPUE in PNA (and ND areas) over decadal scales. Thus, with

the exception of brown shrimp, there is no clear evidence that PNAs enhance the abundance of juvenile nekton as anticipated when the nursery program began.

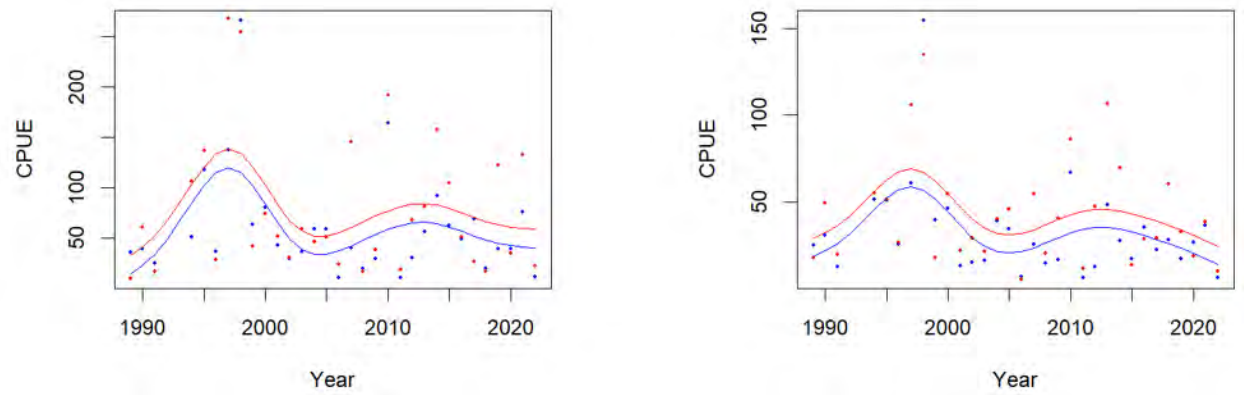


Figure 15. Generalized additive models (GAMs) for Atlantic croaker catch per unit effort (averaged over all years sampled from 1989-2022 at each station, except 1992-1993) as part of the P120 survey. Data from May (left) and June (right) are best modeled by a model independently incorporating nursery designation and trends through time. The red trendline represents average catch in non-designated stations, while the blue trendline represents average catch in PNAs, and the presence of two lines indicates significant variation between catches at PNAs and non-designated sites.

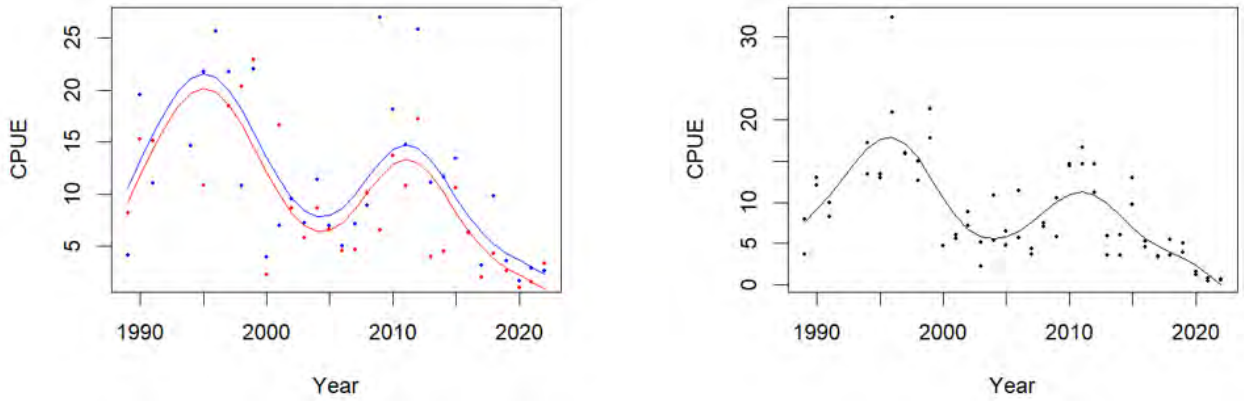


Figure 16. GAMs for blue crab catch per unit effort (averaged over all years sampled from 1989-2022 at each station, except 1992-1993) as part of the P120 survey. Data from May (left) is best modeled by a model incorporating both nursery designation and trends through time, and the interaction between these two variables. The red trendline represents average catch in non-designated stations, while the blue trendline represents average catch in PNAs, and the presence of two lines indicates significant difference between catches at PNAs and non-designated sites, although effect sizes are small. Data from June (right) is best modeled by a model solely incorporating trends through time. The presence of a single line indicates no significant variation between catches at PNAs and non-designated sites.

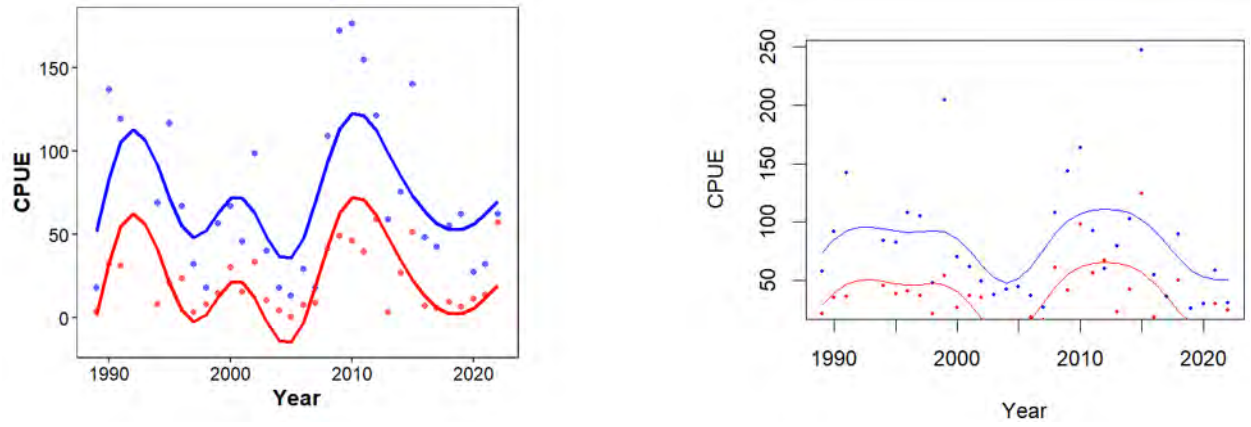


Figure 17. GAMs for brown shrimp catch per unit effort (averaged over all years sampled from 1989-2022 at each station, except 1992-1993) as part of the P120 survey. Data from May (left) is best modeled by a model incorporating both nursery designation and trends through time, and the interaction between these two variables. Data from June (right) is best modeled by a model independently incorporating nursery designation and trends through time. The red trendline represents average catch in non-designated stations, while the blue trendline represents average catch in PNAs, and the presence of two lines indicates significant difference between catches at PNAs and non-designated sites.

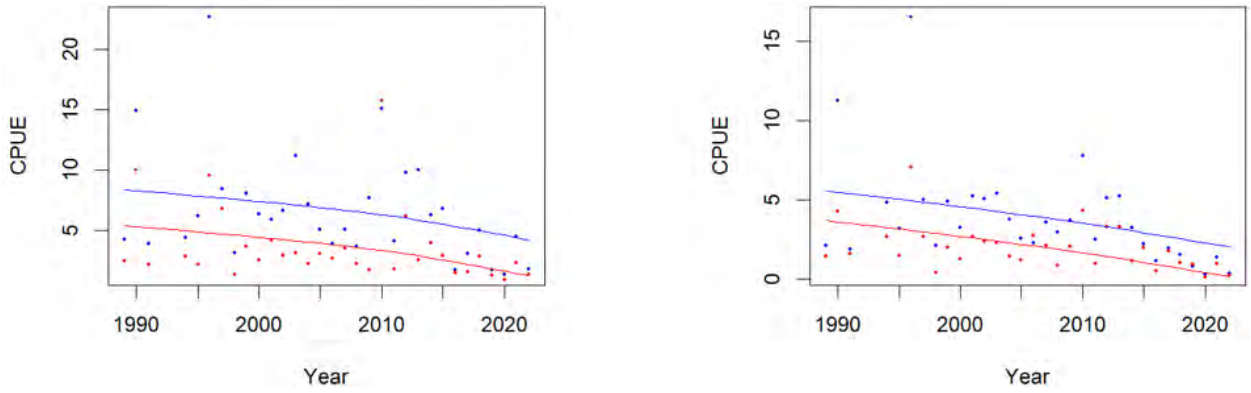


Figure 18. GAMs for southern flounder catch per unit effort (averaged over all years sampled from 1989-2022 at each station, except 1992-1993) as part of the P120 survey. Data from May (left) is best modeled by a model independently incorporating nursery designation and trends through time. Data from June (right) is best modeled by a model incorporating both nursery designation and trends through time, and the interaction between these two variables. The red trendline represents average catch in non-designated stations, while the blue trendline represents average catch in PNAs, and the presence of two lines indicates significant difference between catches at PNAs and non-designated sites.

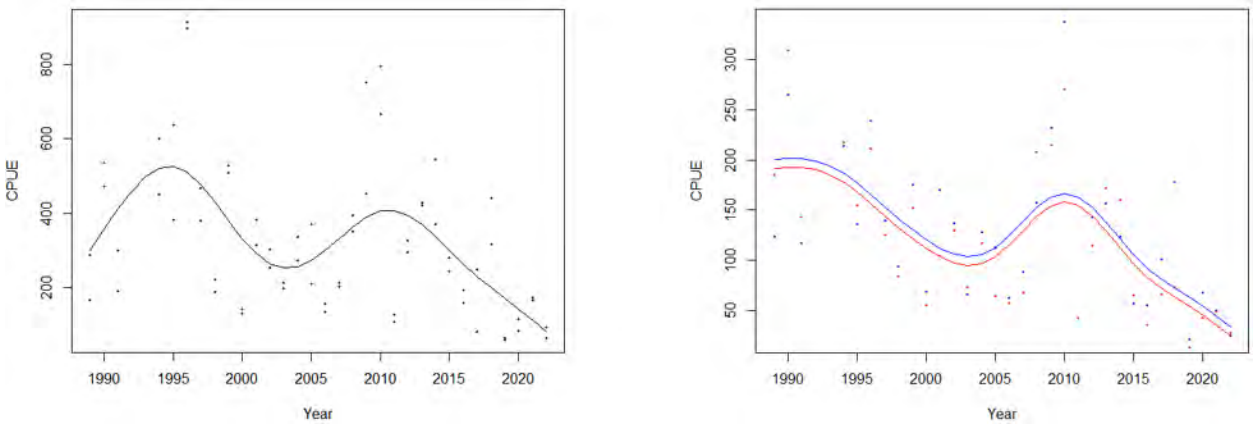


Figure 19. GAMs for spot catch per unit effort (averaged over all years sampled from 1989-2022 at each station, except 1992-1993) as part of the P120 survey. Data from May (left) is best modeled by a model solely incorporating trends through time. The presence of a single line indicates no significant variation between catches at PNAs and non-designated sites. Data from June (right) is best modeled by a model incorporating both nursery designation and trends through time, and the interaction between these two variables. The red trendline represents average catch in non-designated stations, while the blue trendline represents average catch in PNAs, and the presence of two lines indicates significant difference between catches at PNAs and non-designated sites, although effect sizes are small.

Core Recommendations to Achieve the Vision of the Fisheries Reform Act

RECOMMENDATION 1: Integrate an independent Science and Statistical Committee to improve fishery management outcomes in NC

The adoption of the FRA in NC was heavily influenced by the reauthorization of the Magnuson Stevens Act (MSA) in 1996. While the MSA has continued to be reauthorized and updated throughout the 2000s, management in NC has not adjusted with those reauthorizations, likely missing opportunities to optimize management outcomes (but here we acknowledge a solid foundation on which NC may build).

In particular, we note the following factors as key challenges or patterns that need redress:
(a) absence of peer-reviewed stock assessments for several marine fisheries taxa in NC;
(b) the average age of the terminal stock assessment for NC-managed stocks that do have an assessment;
(c) extended periods between Amendments, and even Supplements, that would update FMPs across NC-managed stocks;
(d) generally better outcomes for stocks managed at the Federal Council level that include independent science and statistical committees (i.e., MAFMC, SAFMC, GMFMC) compared with those stocks managed by states across the Mid-Atlantic, Southeast Atlantic, and Gulf of Mexico;
(e) evidence of decreasing consensus within the NC MFC and between the NC MFC and NC DMF;
(f) relatively high attrition of stock-assessment scientists within NC DMF, as well as frequency/ duration of unfilled stock-assessment positions in the NC DMF; and
(g) declining influence of the NC DMF's Advisory Committees in contributing to management directions.

Therefore, we recommend:

(1) The State should provide increased support for stock-assessment scientists within the NC DMF. These positions should all be competitively salaried to ensure the institutional memory/capacity represented by these state-supported lines will not be lost to recruitment efforts by other management agencies (an issue that has plagued NC DMF historically). The NC DMF should be provided support to staff a stock assessment unit

capable of conducting updated stock assessments (SA) for all NC-managed stocks (N = 13) on a regular (3-5 year) basis. Critically, these regularly scheduled stock assessments should include formal processes for developing and implementing a methodology for meaningful stakeholder engagement throughout each step of the process, such as - but not limited to - workshops that include key stakeholders (i.e., recreational and commercial sectors, NC DMF Advisory Committees) in the assessment process during model development and prior to external peer-review. Such participation should improve understanding of and confidence in these assessments, such as the rationale and implementation of selected biological reference points (See links to Recommendation 2 vis-à-vis transparency, clarity, communications, and engagement).

(2) Following examples at the federal level, NC should provide statutory and financial support for an independent Science and Statistical Committee (SSC). Relatedly, the State should consider the merits of a Chief Scientist to lead this SSC group. The independent SSC, composed of scientists external to the NC DMF and NC MFC, would be responsible for using SAs to develop stock-specific harvest control rules, primarily a Total Allowable Catch (TAC). The SSC would be responsible for determining TACs on a frequent (annual) basis. This would move NC away from primarily gear-, season-, and daily-bag-limit-based approaches to management. Improved technologies and data collection programs (i.e., new mandatory catch reporting requirements now being implemented for select species in NC) make TAC-based management viable going forward, whereas this framework was not possible in 1997 when the FRA was enacted. Indeed, southern flounder are currently being managed under a TAC, highlighting the feasibility of employing this approach.

(3) While the SSC would determine the TAC, the NC DMF would continue to develop and make recommendations via the FMP process regarding implementation of the TAC, such as - but not limited to - season start dates, gear and spatial requirements/restrictions, and allocation among recreational/commercial sectors.

(4) Within the structure of the FMP process, the NC MFC would retain responsibility to select preferred management implementation options, but with the following structural and functional changes recommended for the NC MFC:

We recommend the NC MFC be comprised of 8 members: four representing the commercial sector and four representing the recreational sector. A super majority of votes (i.e., 6 or more out of 8 votes) would be required for this eight-member NC MFC to select their preferred management measures in response to NC DMF recommendations. In the absence of super-majority votes by the eight-member NC MFC, FMPs would proceed using the actions recommended by the NC DMF, thus preventing perpetual status quo.

These proposed changes to the NC MFC are intended to: (a) remove the political appointments of two at-large seats; (b) mandate that the commercial and recreational sectors work collaboratively to strengthen public-trust resource management; and (c) replace the commission seat reserved for a scientist with a stronger science advisory role via an SSC.

(5) Existing FMPs each detail specific data gaps and research needs that would enhance SA performance and/or certainty as well as overall understanding of fishery and ecosystem health. The proposed SSC and NC DMF should be allocated appropriate resources to collaboratively develop research and monitoring programs to address identified and emerging data and research needs. Furthermore, the NC DMF (with increased stock assessment capacity) and the SSC should work collaboratively to build and expand on the existing practice of publishing annual updates for FMPs. These updates should be enhanced versions of the annual reports the NC DMF already generates. For instance, these updates should include more up-to-date data, even though these data would likely not be incorporated into formal SA models on an annual basis. Additionally, these updates could include expert (scientist, stakeholders) analyses and contextualization of current patterns and dynamics. Furthermore, these annual updates should help support and explain NC DMF adaptive management actions such as fishery closures in response to environmental perturbations (e.g., ‘cold kill’ events) that are critically valuable management tools.

RECOMMENDATION 2: Enhance stakeholder participation, trust, and management transparency

The NCGA should provide enhanced research and personnel for the NC DMF via new communications and social sciences positions that are focused on building trust in the fisheries management process. As above, these positions should all be competitively salaried to ensure the institutional memory/capacity represented by these state-supported lines will not be lost to recruitment efforts by other management agencies. Activities of these new positions should center on enhancing stakeholder participation, enhancing trust among and between stakeholders, and increasing transparency about decision making. Associated changes in fisheries management practices should be developed and implemented via a co-design process.

First, managers should strengthen public representation and participation in fisheries management and decision-making processes across all stakeholder groups. To facilitate stakeholder engagement, participation opportunities, and the communication of these opportunities to stakeholders must be framed within the values and priorities of specific groups. General education and outreach about participation that is not framed within the specific values and needs of each group will not be as effective. Managers can use proven methodologies such as stakeholder analysis to identify and deliver targeted communications to stakeholders relevant to specific proceedings, such as FMP amendments, and make information about regulations and relevant data available and easily accessible to the public.

Second, managers should take action to improve and repair stakeholder trust in the NC MFC, the NC DMF, Advisory Committees, and other aspects of the decision-making process. Resources should be allocated to conduct a robust study that builds from the findings of the stakeholder engagement work for this project and further examines the drivers of trust and legitimacy by stakeholder groups and explores processes for building trust within the management ecosystem. This should guide engagement with professionals or advisors trained in stakeholder engagement to identify approaches to (1) explore the root causes of conflict between stakeholder groups and (2) to design strategies that may support opportunities for dialogue between stakeholders to create productive meeting spaces and foster open communications among conflicting stakeholder groups and managers.

Third, managers should increase transparency about all dimensions of fisheries management from decision making through to regulatory enforcement and reform. In particular, managers should clearly document how stakeholder input, such as public comment, has been and will be considered in fisheries management. At present, it is not clear how public input is used in decision-making, creating a black box between participation and management outcomes that has contributed to fisher distrust in the management process. A first step in this process is to increase the availability and accessibility of scoping and decision documents and to enhance the format of these materials. The NC DMF should develop consistent practices for sharing substantive information on how participation is considered, analyzed, and incorporated into rule making and management actions. It should clarify what information from participation is not used and explain the reason. These steps will offer a more substantive template for tracing stakeholder input through management.

Related, NC DMF should make all fishery dependent, fishery independent, and related environmental monitoring data easily searchable and downloadable from the NC DMF website.

To inform these steps, NC fisheries managers should initiate the development of a systematic co-design process. Co-design is a process in which managers and stakeholders work together to define management objectives and develop priority management actions; it is an approach that has improved decision-making in small- to industrial-scale fisheries globally, as well as to other natural resource management systems in the United States. NC's co-design processes should identify and prioritize actions that will support and enhance the economic and ecological sustainability of state-managed fisheries, including through developing near-term and longer-term (e.g. 10-year) strategic plans for state-managed fisheries. The co-design process should involve defining specific financial, personnel, and time resources to prioritize and manage tradeoffs associated with key management needs and subsequently develop a plan of action for budgeting and implementation. This process should inform budget requests for additional resources from the NCGA. Additionally, co-design will help facilitate a system that is structurally able to manage and mediate conflict among stakeholder groups. The co-design process could potentially build from a revived and re-envisioned Joint Committee on Seafood and Aquaculture (JCSA) to provide a forum for increased communication among managers, the commercial and recreational sectors, and the NCGA.

RECOMMENDATION 3: Adopt an ecosystem-based management approach to quantitatively assess the health of the NC fisheries as a whole and the drivers that affect them

The Fisheries Reform Act of 1997 was the first step towards using ecosystem-based fisheries management (EBFM) approaches in NC when it integrated fisheries management with habitat protection via the CHPP. The FRA recognized that factors other than fishing affect the population status of NC fish populations and our report shows that the natural resources of NC are subject to a variety of pressures ranging from global to highly localized. As such, a wide variety of factors or "indicators" that track the status of these pressures and the state of natural resources should be routinely evaluated to effectively manage the state's habitats and fisheries. The purpose of an ecosystem indicator evaluation and report is to give a holistic view of the change in NC estuarine and coastal and the effectiveness of management and policy actions. Assembling an indicator report can also allow managers to identify data gaps and monitoring needs that can prevent the state of NC from taking effective management actions (See Recommendation 4).

We recommend that the State implement a quantitative indicators-based evaluation of the state of NC estuarine and coastal ecosystems. This evaluation would be conducted by a workgroup comprised of stakeholders, resource managers, natural scientists, and social scientists. This indicator evaluation would be complementary to the APNEP's Comprehensive Conservation and Management Plan and be compared to Regional Ecosystem Status Reports being conducted by NOAA to monitor the interplay between fisheries, human, and environmental dynamics. At the onset of the working group, a subset of the time series that we have compiled for this analysis and summary report should be selected by stakeholders, managers and scientists based on several criteria. An effective indicator is one that provides the working group with information about the state of the ecosystem and the processes that potentially affect the ecosystem. It should be consistently measured, either sensitive to changes in the system and/or to management actions. Although each indicator is useful individually, the combined analysis of indicators is often more useful to stakeholders and managers to understand how the ecosystem is functioning more broadly.

Indicators that are deemed to be management-relevant and representative of important ecosystem processes should be updated every 2 years by the working group to monitor the

progress of ecosystem approaches to fisheries management that are implemented in NC. A key value of this approach is the ability to identify areas of vulnerability in the ecosystem, such as overharvest of species, impacts of storms on habitats, notable short- and long-term shifts in water quality, and climate trends. Finally, an ecosystem report effectively brings together different scientific fields, which can motivate interdisciplinary research that may lead to effective management action.

Recommendation 4: Halt or reverse patterns of habitat loss and degradation, requiring improved monitoring of habitat extent and water quality

Despite federal and NC management efforts and designated protections, coastal, structured fish habitats, including marshes, SAV, and oyster reefs are being degraded and lost, largely due to human activities. However, efforts to reduce habitat degradation and loss are stymied by the lack of continuous, standardized, long-term mapping and monitoring of habitat extent and condition. Mapping and monitoring of changes in coastal habitats can be labor-intensive and costly, and has historically been conducted by multiple, often disparate entities (e.g., NOAA, NC DMF, NC DCM, APNEP) and federal and state funding for such efforts has been piecemeal and inconsistent. Thus, we recommend that the State invest in a designated "coastal habitat unit" within the NC DEQ, to implement a tiered, long-term plan to monitor estuarine habitats in NC at regular intervals (e.g., 3 to 5 years).

When developing the tiered habitat mapping and monitoring program, the new unit should work with researchers and practitioners to ensure that new technologies and methodologies (e.g., drones, artificial intelligence [AI] are incorporated to increase efficiency without compromising comparability to historical data. The tiered mapping and monitoring system should include a collection of "coarse metric data" such as total area/extent at the state-level and more fine-scale habitat condition data (e.g., shoot/stem densities, live oyster counts) at established sentinel sites and sites selected using a stratified random design throughout the coast to better identify and understand drivers of observed changes in estuarine habitats and fish use of estuarine habitats. Further, changes in the extent or condition of existing habitats resulting from state-permitted actions (e.g., NC DCM permits for shoreline hardening, marina or boat ramp installation, and habitat restoration) should be incorporated into habitat assessments at a regular interval (e.g. 3-5 yr) via a linked, geospatially referenced permitting system. All habitat data should be stored in a publicly accessible, actively maintained repository or clearing house, such as NC One Map.

This new "coastal habitat" office should coordinate with current multi-organizational NC habitat-focused steering committees (e.g., the CHPP Steering Committee, the Salt Marsh Action Plan Steering Committee, the APNEP SAV and Water Quality Workgroups) to ensure that habitat data are readily available and accessible when conservation, management, and restoration goals and targets are being set. We recommend that the State take action to strengthen the NC CHPP and to increase its usefulness as a tool to protect, manage, conserve, and restore

coastal fish habitats. The CHPP Steering Committee should be given the authority to take action when recommendations are not met. This authority should be analogous to the statutory requirements within the FRA to protect fishery stocks from overexploitation (e.g., mandated regulatory management triggers and conservation/restoration triggers that are codified as either statutes or rules). For example, if coastal wetlands decrease by 10% in a coastal county, the State would be required to develop, implement, and fund a mitigation plan or restrict future development actions that could cause further wetland loss. NC has the individual components necessary to make real strides in conserving and restoring coastal fish habitats, but needs to restructure and modernize these components, enabling managers to take meaningful action.

Recommendation 5: Re-evaluate the nursery designation system (i.e., PNA siting) and create an adaptive framework for protecting critical nursery areas

Despite scientific advances towards understanding how fishes and crustaceans use habitats across life history stages, the raw or per-unit-area-standardized contribution of juvenile habitats to fisheries production is unknown for most fish and crustacean species. Further, analyses of P120 trawl program CPUE data from PNA and ND areas suggest that NC PNAs are not protecting and supporting juvenile fish and crustacean populations as originally intended. The data from the NC P120 monitoring program are invaluable to conduct meaningful stock assessments and implement fishery management plans but are seemingly having little impact on identifying critical habitats to maximize fishery production across NC. This is in part because managers are ultimately designating nursery areas based on one or more assumptions about the value of designated nursery areas to fisheries production. As such, the State should expand juvenile fish monitoring programs (e.g., P120) to include estuarine areas with SAV and other structured bottom habitats not currently surveyed. This will likely require expansion of sampling methods and a tiered sampling approach and thus will require additional funding and staff support. The recommended ecosystem-based management assessments and habitat monitoring programs (Recommendations 3 and 4) should be used to regularly (every 2-5 years) evaluate the effectiveness of current protections and adaptively manage primary and secondary nursery area designations and monitoring.

To provide managers with the information they need to make more informed decisions about where and how to designate nursery areas and subsequently design habitat protections, they need:

- Consistently collected, long-term data on how juvenile fishes and crustaceans use habitats and the associated environmental conditions within those habitats.
- Rigorous testing of methods to quantify the relationship between habitat-specific juvenile abundances/densities and production contribution to adult populations for individual species.
- Evaluation of how existing designated nursery areas affect adult populations of managed species.

In line with the ecosystem indicator recommendation, further study is needed to explore which environmental factors have led to the degraded functioning of existing PNAs to understand what

measures could be taken to improve their nursery function. For example, potential drivers of declining nursery function may range from lack of spawning stock biomass to over-sedimentation in tidal creeks and estuaries. A mechanistic understanding of decadal-scale drivers of juvenile fish catch rates within PNAs (and non-PNA reference sites) remains elusive but could be clarified by a more comprehensive assessment of habitat change in conjunction with continued assessments of juvenile abundances.