Atlantic States Marine Fisheries Commission

Summer Flounder, Scup, and Black Sea Bass Management Board

August 7, 2019
1:00 p.m. - 3:45 p.m.
Arlington, Virginia

Draft Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1. Welcome/Call to Order *(R. Ballou)* 1:00 p.m.
2. Board Consent 1:00 p.m.
    - Approval of Agenda
    - Approval of Proceedings from May 2019
3. Public Comment 1:05 p.m.
4. Review Potential Black Sea Bass Commercial Management Strategies and Consider Initiating Management Action to Address Commercial Allocation *(C. Starks)* **Possible Action** 1:15 p.m.
5. Update on the Summer Flounder Management Strategy Evaluation: A Recreational Fishery Project *(J. McNamee)* 2:05 p.m.
6. Report from the Atlantic Coastal Fish Habitat Partnership/Mid-Atlantic Fishery Management Council Project: Characterizing Black Sea Bass Habitat in the Mid-Atlantic Bight *(B. Stevens)* 2:35 p.m.
7. Discussion on Discard Mortality *(C. Starks)* 3:05 p.m.
8. Progress Update on the Recreational Management Reform Working Group *(C. Starks)* 3:35 p.m.
9. Other Business/Adjourn 3:45 p.m.

The meeting will be held at the Westin Crystal City, 1800 S. Eads Street, Arlington, Virginia; 703.486.1111

MEETING OVERVIEW

Summer Flounder, Scup, and Black Sea Bass Management Board
August 7, 2019
1:00 p.m. - 3:45 p.m.
Arlington, Virginia

Chair: Bob Ballou (RI) Assumed Chairmanship: 10/17	Technical Committee Chair: Greg Wojcik (CT)	Law Enforcement Committee Representative: Snellbaker (NJ)
Vice Chair: Adam Nowalsky (NJ)	Advisory Panel Chair: Vacant	Previous Board Meeting: May 1, 2019
Voting Members: MA, RI, CT, NY, NJ, DE, MD, PRFC, VA, NC, NMFS, USFWS (12 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from May 2019

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time must sign-in at the beginning of the meeting. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance the Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Review Potential Black Sea Bass Commercial Management Strategies and Consider Initiating Management Action to Address Commercial Allocation (1:15-2:05 p.m.) Possible Action
Background • In May, the Board reviewed a report from the Black Sea Bass Plan Development Team (PDT) including analysis of several potential management options to address changes in stock distribution and abundance. The approaches supported by the Board for further development included 1) a dynamic allocation approach (referred to as TMGC) that gradually shifts allocations over time based on a combination of historical landings information and current biomass distribution information, 2) a trigger-based allocation approach, and 3) hybrid approaches. **(Briefing Materials)** • Additional options were submitted for consideration by Connecticut. One option addresses Connecticut's disproportionately small commercial black sea bass allocation by reallocating a small amount from states that either do not have fisheries or that have relatively large allocations. The second option combines a trigger approach with the TMGC approach. **(Briefing Materials)**
Presentations • Review of Potential Management Strategies for Commercial Black Sea Bass by C. Starks

Board Actions for Consideration

- Consider draft goal statement
- Initiate a management document to address commercial black sea bass management

5. Update on the Management Strategy Evaluation Project for the Summer Flounder Recreational Fishery (2:05-2:35 p.m.)

Background

- This project uses a Management Strategy Evaluation framework to conduct a set of model forecast simulations of alternative management options for the recreational summer flounder fishery to compare the expected performance of policy alternatives.
- The objective is to provide decision support tools to assist in the specification setting process for summer flounder.

Presentation

- Update on the Management Strategy Evaluation Project for the Summer Flounder Recreational Fishery by J. McNamee

6. Report from the ACFHP/MAFMC Project: Characterizing Black Sea Bass Habitat in the Mid-Atlantic Bight (2:35-3:05 p.m.)

Background

- Dr. Brad Stevens and his lab at the University of Maryland Eastern Shore recently completed a three-year study on black sea bass habitat utilization in the Mid-Atlantic Bight. **(Briefing Materials)**
- This project was funded by the Mid-Atlantic Fishery Management Council through the Atlantic Coastal Fish Habitat Partnership.
- Key findings on habitat structure and fish preference, seascape connectivity and fish abundance, and feeding ecology of black sea bass at natural and artificial reefs will be presented.

Presentation

- Characterizing Black Sea Bass Habitat in the Mid-Atlantic Bight by B. Stevens

7. Discussion on Discard Mortality (3:05-3:35 p.m.)

Background

- Recently several Board members have expressed an interest in reviewing available information on discard mortality in the summer flounder, scup and black sea bass fisheries.
- In particular, there has been some concern that the black sea bass recreational discard mortality rate assumed in the assessment may not be reflective of the true mortality rate. A recent study funded by the Collaborative Research Program of the Mid-Atlantic Fishery Management Council (MAFMC) estimated mean discard mortality rates of 21% for vented and 52% for unvented black sea bass following capture and release in 45 m depth, as opposed to the 15% discard mortality rate assumed in stock assessments and management plans. **(Briefing Materials)**

Presentation

- Review of Discard Mortality in the Summer Flounder, Scup and Black Sea Bass Fisheries by C. Starks

Board Discussion

- The Board may wish to define specific areas (i.e. species or sectors) and ways (e.g. regulatory, education) in which discard mortality should be addressed. **(Supplemental Materials)**

8. Progress Update on the Recreational Management Reform Working Group (3:35-3:45 p.m.)

Background

- At the March 2019 joint meeting with the MAFMC, the two bodies agreed to form a joint working group to address the topic of recreational management reform. Specifically, the group's objective is to propose strategies reform recreational management to increase management flexibility and stability for summer flounder, scup, and black sea bass while reducing the year-to-year workload required to evaluate and establish measures.
- The working group includes representation from ASMFC, MAFMC, and NOAA Fisheries.
- The group has convened twice since its formation to gather information related to management requirements and discuss potential pathways to achieving the objective.

Presentation

- Progress Update on the Recreational Management Reform Working Group by C. Starks

9. Other Business/Adjourn

Summer Flounder, Scup, & Black Sea Bass 2019 TC Tasks

Activity level: High

Committee Overlap Score: High (Multi-species committees for this Board)

Committee Task List

- September 2019: In person meeting to review operational assessments and develop recommendations on 2020-2021 specifications (coastwide quota and RHLs) for scup and black sea bass, and review 2020 specifications for summer flounder
- November 2019: In person meeting on 2020 recreational measures

TC Members: Greg Wojcik (CT, TC Chair), Alex Aspinwall (VA), Julia Beaty (MAFMC), Peter Clarke (NJ), Dustin Colson Leaning (ASMFC), Karson Coutre (MAFMC), Kiley Dancy (MAFMC), Steve Doctor (MD), Emily Gilbert (NOAA), Jeff Kipp (ASMFC), John Maniscalco (NY), Jason McNamee (RI), Gary Shepherd (NOAA), Caitlin Starks (ASMFC), Mark Terceiro (NOAA), Todd VanMiddlesworth (NC), Richard Wong (DE)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SUMMER FLOUNDER, SCUP AND BLACK SEA BASS MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
May 1, 2019

These minutes are draft and subject to approval by the Summer Flounder, Scup and Black Sea Bass Management Board.
The Board will review the minutes during its next meeting.

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INDEX OF MOTIONS

1. **Approval of agenda** by consent (Page 1).

2. **Move to approve Paul Caruso from MA to the Advisory Panel** (Page 26). Motion by Nichola Meserve; second by Emerson Hasbrouck. Motion carried (Page 26).

3. **Move to adjourn** by consent (Page 26).

ATTENDANCE

Board Members

David Pierce, MA (AA)
Raymond Kane, MA (GA)
Sarah Ferrara, MA, proxy for Rep. Peake (LA)
Bob Ballou, RI (Chair), proxy for J. McNamee (AA)
David Borden, RI (GA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
Sen. Craig Miner, CT (LA)
Maureen Davidson, NY, proxy for J. Gilmore (AA)
Emerson Hasbrouck, NY (GA)
Joe Cimino, NJ (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Sen. Andrzejczak (LA)
John Clark, DE, proxy for D. Saveikis (AA)
Roy Miller, DE (GA)
Craig Pugh, DE, proxy for Rep. Carson (LA)
Mike Luisi, MD, proxy for D. Blazer (AA)
Russell Dize, MD (GA)
Phil Langley, MD, proxy for Del. Stein (LA)
Rob O'Reilly, VA, proxy for S. Bowman (AA)
Sen. Monty Mason, VA (LA)
Chris Batsavage, NC, proxy for S. Murphey (AA)
Jerry Mannen (GA)
Marty Gary, PRFC
Emily Gilbert, NMFS
Mike Millard, USFWS

(AA = Administrative Appointee; GA = Governor Appointee; LA = Legislative Appointee)

Ex-Officio Members

Staff

Robert Beal
Toni Kerns
Kirby Rootes-Murdy
Caitlin Starks
Jessica Kuesel

Guests

Julia Beaty, MAFMC
Casey Brennan, NMFS
Mike Celestino, NJ DFW
Heather Corbett, NJ DFW
Kiley Dancy, MAFMC
Lynn Fegley, MD DNR
Matthew Gates, CT DEEP
Pat Geer, VMRC
Doug Grout, NH (AA)
Jon Hare, NOAA
Pat Keliher, ME (AA)
Adena Leibman, Ofc. Sen. Whitehouse, DC
Arnold Leo, E. Hampton, NY
Loren Lustig, PA (GA)
Conor McManus, RI DEM
Jay McNamee, RI (AA)
Nichola Meserve, MA DMF
Stew Michels, DE DFW
Alan Risenhoover, NMFS
Steve Train, ME (GA)
Jack Travelstead, CCA
Megan Ware, ME DMR
Chris Wright, NMFS

The Summer Flounder, Scup, and Black Sea Bass Management Board of the Atlantic States Marine Fisheries Commission convened in the Jefferson Ballroom of the Westin Crystal City Hotel, Arlington, Virginia; Wednesday, May 1, 2019, and was called to order at 10:45 o'clock a.m. by Chairman Robert Ballou.

CALL TO ORDER

CHAIRMAN ROBERT BALLOU: Good morning and welcome. I'm going to call this meeting of the Summer Flounder, Scup, and Black Sea Bass Management Board to order. My name is Bob Ballou. I have the honor of serving as Board Chair. I would like to start out by welcoming two new members to the Board, Phil Langley from the state of Maryland, welcome, and Jerry Mannen from the state of North Carolina, welcome.

APPROVAL OF AGENDA

CHAIRMAN BALLOU: Having dispensed with Item 1 on the agenda, we're on to Item 2, which is the agenda itself. Before I ask whether any members of the Board have any requested changes, I do have one and that is a brief report out on the outcomes of the three Board votes, done via polling on the two conservation equivalency proposals for recreational fluke, submitted by Rhode Island and New Jersey, and the Virginia proposal for accounting for recreational black sea bass harvest during their February fishery.

Is there any objection to adding that brief update? Seeing none, we'll add that between Items 3 and 4. Then also under other business I would like to briefly address agenda items for our next Board meeting in August, in particular, a suggestion for a focused discussion on discard mortality in the recreational black sea bass fishery. Are there any other recommended changes or modifications to the agenda? Tom Fote.

MR. THOMAS P. FOTE: It's not a change or a modification, but I wanted to say just a few words. I put Jersey Coast Newsletters back there, because I wrote an article on summer flounder. I basically commented to what a great job NMFS actually did with handling the MRIP numbers. They don't get credit for what they do.

But they did the job right by expanding the numbers out, and basically reevaluating what the stock was, instead of just saying we were overfished and overfishing is taking place. I really wanted to make sure I thanked them for doing that. But the bad part of it was that if you accepted those numbers, which I thought the commercial fishery should have got the 49 percent increase, and you're telling me you're accepting those numbers to increase by 49 percent.

We've been under for the last five years, up to the last three years 15 percent. They could have given us the 3.5 percent. I know the shut down came and stopped a lot of the paperwork, but that is not sitting well with the recreational community. They understand why the 49 percent was put there, but if you are trusting them to give a 49 percent increase and can't do a 3.5 percent increase on us, based on the 15 percent that we've been under for the last three years, it doesn't sound good.

CHAIRMAN BALLOU: Are there any other recommended changes to the agenda? Seeing none is there any objection to approving the agenda as modified?

PUBLIC COMMENT

CHAIRMAN BALLOU: Seeing none, the agenda as modified stands approved by consent, and we're on to Item 3, which is public comment. No one has signed up.

But is there anyone here from the public who would like to address the Board on any issue that is not on today's agenda?

REPORT ON CONSERVATION EQUIVALENCY PROPOSALS

CHAIRMAN BALLOU: Seeing no hands, we are on to the next item, and that is the item that I asked to be added, and that is just a brief report out on the votes taken by the Board on the three issues. I believe Kirby has a quick update on that, Kirby.

MR. KIRBY ROOTES-MURDY: As Bob noted, there was an e-mail vote regarding a conservation equivalency on summer flounder for Rhode Island, for New Jersey, and then for Virginia regarding black sea bass. Rhode Island had proposed to have a shore site for summer flounder allowing anglers to harvest fish at 17-inch minimum size and a 2-fish bag limit.

That is in addition to their current 19-inch size limit, and the state has a 6-fish bag limit. In total, anglers can harvest up to six fish from those sites; four of them may be at 19 inches, two have to be at 17 inches. For New Jersey they proposed to adjust their season by one day on either end of the start and end, so their new season for 2019 is a start date of May 24, and an end date of September 21.

Regarding Virginia, the change in their black sea bass measures is specific to their season, accounting for the February fishery that took place this year. They had a February fishery that lasted from February 1 to February 28. They now have an opening in May for two weeks, starting May 15 through May 31, and then opening again from June 22 through December 31. With that I'll take any questions but, as noted earlier, these proposals were approved without objection.

REVIEW PLAN DEVELOPMENT TEAM ANALYSIS OF BLACK SEA BASS COMMERCIAL MANAGEMENT STRATEGIES TO ADDRESS FISHERY SHIFTS

CHAIRMAN BALLOU: Any questions for Kirby? Seeing none, we're on to Item 4, which is a Review of the Plan Development Team a/k/a PDT analysis of the Black Sea Bass Commercial Management Strategies to Address Fishery Shifts. Our meeting materials include two reports, one from the PDT the other from the Joint Advisory Panel meeting held to review that PDT report.

Our plan today, this is really the heart of the agenda. We'll be spending the majority of today's meeting on this agenda item. Our plan is to first have Caitlin provide a presentation on both reports, and that will be followed by Board review and discussion. With that Caitlin the floor is all yours.

MS. CAITLIN STARKS: Actually, before I get into the PDT report, the Board Chair had asked me to quickly go over the items that this Board has on its plate and has recently dispensed with. I'm going to do that really quickly, just to make sure everyone is on the same page with where we are today. Some of the recent actions this Board has taken included the Board and Council jointly recommending approval of the Summer Flounder Amendment at the joint meeting in March, and the Board and Council approving Addendum XXXI in December, and the Board approving Addendum XXXII in December as well.

Then as for ongoing activities and actions, this Board is looking at again the Summer Flounder Amendment will be considered for final approval by the Business Section today, so I just wanted to note that. Then black sea bass commercial management has been ongoing through the PDTs work, so we will review today the PDTs report, and have a possible action on that item.

Black Sea Bass Recreational Reform is also continuing work through a working group, jointly with the Council as well, and meetings on that likely will occur over this summer. Then lastly, for the Black Sea Bass and Scup Operational Assessments, we're scheduled to have those available for Board review in October, 2019. I just wanted to quickly lay out the field for us before getting into the PDT report, and if there are any questions on that I can take them.

CHAIRMAN BALLOU: Are there any questions for Caitlin on that review? Seeing none, why don't we move on to the next agenda item, thank you?

PLAN DEVELOPMENT TEAM REPORT

MS. STARKS: Again I'll be going over the Plan Development Team's report, and going over the work that they've done in the last couple of months on additional analyses of potential approaches for black sea bass commercial management. I'll start out with some background information, and then review the problem statement that the Black Sea Bass Commercial Working Group presented at the last meeting in February.

Then go over the analysis that the PDT has put together on these potential management strategies that are related to commercial state-by-state allocations, and those include, the TMGC approach, a trigger approach, a quota option approach and some hybrid approaches. Then I'll present some of the general decision points that the PDT identified for these approaches, and wrap up with next steps for the Board and take questions.

In August 2018, the Board established a Commercial Working Group, in response to a Board motion last May to identify actions that would address changes in black sea bass abundance and distribution. The purpose of the Working Group was specifically to identify issues in commercial black sea bass fishery related to these changes, and brainstorm some ideas for management that could address those issues.

The Working Group presented their report in February, and after that point the Board established the Plan Development Team, to continue fleshing out and analyzing the proposed management strategies that the Working Group identified, as well as a few others put forward by Board members. After that PDT was formed in February, the Board met jointly with the Mid-Atlantic Council in March to discuss this work on commercial issues that had been done at the Board.

At that meeting the Council initiated an amendment to address commercial issues, namely allocation and other related issues. The action taken by the Council at that meeting was mostly procedural at this point, as it will allow them to direct some of their staff resources towards supporting and contributing to the Board's ongoing work, and allow the Council and Board to coordinate on the development of options that would require Council involvement. As a result, the Council staff has participated on the PDT, and will continue to do so as their work continues, and we also held a joint Advisory Panel meeting at the beginning of April, to get feedback from the advisors of both bodies on the approaches that have been discussed by the PDT.

That leads us to today, where the Board will consider the PDT's report as well as the AP's feedback, and determine the best path forward for commercial management issues. Before getting into the PDT's work, I just want to quickly review the commercial issues that the Working Group identified and the Board supported in February.

The first of those issues was that the commercial state allocations, which were set back in 2003 under Amendment 13, are not reflective of the current distribution of the resource. These allocations were loosely based on landings for the period from 1980 to 2001, and they resulted in 33 percent of the quota being distributed between the states of Maine to New York, and 67 percent between New Jersey and North Carolina.

The Working Group noted that these allocations have remained unchanged, though there have been some substantial changes observed in the distribution of the stock over the past 15 years. Those changes are shown by this figure, which is derived from the last stock assessment, and it shows the spawning stock biomass estimates for north and south of Hudson Canyon.

SSB in the southern region is shown by the blue line, and the orange line shows SSB in the northern region, and around 2007 you can see that orange line increases rapidly, while the blue line also increases but to a lesser extent. As of 2015, the majority of the spawning stock biomass is occurring north of Hudson Canyon.

The open circles at the end of the time series there, represent the retro adjusted regional values that were peer reviewed in late 2016, early 2017, and that have been used for management and projections since then. The second issue that the Working Group identified was related to the coastwide quota management by NOAA Fisheries, which can create the possibility for the fishery to be closed as soon as the coastwide quota is exceeded.

That could potentially leave states who have not harvested their full quota without the ability to do that. At the joint meeting in March with the Council, the Board and Council did discuss this issue, and noted that it could be addressed in collaboration with the Council and NOAA Fisheries, so the PDT did not focus on this issue.

Instead, the PDT focused on that first issue of commercial state-by-state allocations, and they specifically focused on the management strategies that were proposed in the Working Group Report, and those that were offered up in February by Board members. Those options are listed on this slide.

First is status quo, which is of course an option the Board can consider. The next three approaches that have been proposed are a change from the current state allocation system. The first of those is the dynamic approach referred to as TMGC, which gradually shifts allocations over time, based on a combination of historical landings information and current biomass distribution information. Second is a trigger-based allocation approach, similar to that which was recently adopted for summer flounder. Third is a quota auction approach or ASQ, and fourth is the option of combining approaches to create a hybrid approach.

In addition to those, the Board could also consider establishing a timeline or a trigger, for reevaluating allocations on a regular basis. But this was not something that the PDT discussed. What is circled in red here is what the PDT focused on, and what I'll be going over in the next slides.

First is the TMGC approach, and again this approach was put forward by the Working Group, as a potential strategy for phasing in a new dynamic approach to allocation setting for the black sea bass fishery. It was modeled after the TMGC approach, which was originally used to adjust allocations for shared Georges Bank resources between the United States and Canada.

Essentially, the strategy uses a formula to gradually adjust state-by-state allocations, by transitioning from allocations that are based mostly on resource utilization or historic landings, and then over time shifting those allocations to be based more on regional resource distribution, or biomass information.

In the first years of implementation of this strategy, the historic landings or the current allocations would be the most important part in the formula, and then gradually over time that would shift, so that the distribution of the stock is more important in determining allocations for the states.

The equation that establishes the gradual transition is pretty flexible in how it can be set up, and also because the current biomass distribution is what eventually becomes the most important factor in determining allocations. This equation can result in allocations that fluctuate in either direction, so it does allow for quota to move back and forth between areas, rather than from one area to another.

The last thing I'll say about this before showing some examples is that the strategy also has the option to establish a control rule, so that in any year the total allocation given to a region could not change by more than an established amount, and that can add some stability to this process as well. To give you an idea of the flexibility in this approach, these are the dials that can be adjusted within that formula, to determine how allocations would change over time.

For one, you can change the way the resource utilization and distribution information are weighted in that equation. For example, you could start out setting it at 90 percent utilization, 10 percent distribution at the beginning, and then at the end have that transition to 10 percent utilization versus 90 percent distribution at the end.

That can be modified so you can use different percentages if you would like. You can also increase or decrease the transition speed, so how frequently adjustments are made to allocations. They could either be set at annual or biannual adjustments. The total time that it takes for that transition to occur can also be altered, so that you either have a longer or shorter timeframe over which that transition occurs. The state allocations that you start out with for the resource utilization information can also be altered. They could either be set at status quo, or they could be changed to accommodate different objectives, for example maybe adjusting the states quotas that are deemed inequitable or disproportionate to their current resource availability.

For example, the Working Group did note in their report that Connecticut and New York have disproportionately low quotas, compared to what their resource availability is now. Then lastly there is that Control Rule again that can be adjusted to restrict the maximum amount that the allocations can change each time they're adjusted.

This is a visual aid to show how the different types of information in the allocation formula are applied over time. As I mentioned, you start out with the historic resource utilization or the current allocations being the larger contributor to the resulting allocations, and the weighted importance of that historic information is shown here in blue.

Then in red you have the importance of the resource distribution information, or the regional biomass information. What you see happening over time in this example is that each year, or however frequently you are setting those adjustments to occur, the percent contribution of the historic information decreases, as the percent contribution of the resource distribution information increases.

Eventually you get to a point where the allocations that are being produced by the equation are mostly being influenced by the resource distribution, rather than the historic information. In this example the ending weights are set at 90 percent resource distribution and 10 percent historic landings, but again those proportions could be modified to something like 70/30.

This is an example of how the actual allocations would shift over time, if you were to apply the weights that I showed on the last slide to those two types of information that go into the equation. In this example, the formula uses the current allocations as the starting point, or the resource utilization information, and the regional spawning stock biomass estimates from the last stock assessment as the resource distribution information.

It also has a Control Rule set, which caps the regional allocation change at a maximum of 3 percent per year, and the lines on the graph represent the state allocations that come out of the equation. To highlight the difference in the regional effects, the states between Massachusetts and New York are shown in shades of blue, and New Jersey to North Carolina are shown in shades of red or pink.

For this example, the TMGC equation was applied retrospectively to allocations in recent years. Starting in 2007, you have the current allocations, and then in 2008 that formula starts to transition the weights, so that the historic information contributes 90 percent to the allocation and the resource distribution contributes 10 percent.

Then in each year after that the weights continue to shift by 10 percent, so by 2015 it reaches a level where historic information contributes 10 percent, and resources distribution contributes 90. What you see in the allocations over time is that because the equation is gradually applying more weight to the resource distribution, and during this time period that proportion of spawning stock biomass in the northern region is increasing, you see the allocations of Massachusetts through New York generally increasing proportionally as well, while the southern region is proportionally decreasing.

But what I also want to point out is that from 2014 to 2015 you see the direction of those changes flips, so that the southern states are increasing and the north is decreasing, and that's because there was a change in the biomass distribution from the assessment during that year. I just wanted to point that out so you can see how this approach can result in multidirectional change in allocations to each region.

I also wanted to note that the PDT report does provide several retrospective examples of how this approach could be used with different configurations, and it shows how those allocations would have changed in each of those scenarios, but for time I obviously couldn't go through all of those here. But just know that they are there to compare.

The next management strategy that the PDT discussed is the trigger-based allocation approach, and this approach would establish a quota trigger, or a base level of quota that is always allocated using the current state allocations, and then it would evenly allocate any quota above that trigger value to the states of Massachusetts through North Carolina.

As proposed, Maine and New Hampshire would receive a smaller allocation percentage, based on their historically low participation in the fishery. With this option there were two different trigger levels that were proposed, and those were 3 million and 4 million pounds. The first is approximately based on the average coastwide commercial quota between 2003 and 2018, but excluding the years where we were using the constant catch approach.

The second trigger is approximately based on the highest quota in our time series, which was 4.12 million pounds. This graph is just to show you how those two trigger values compare to the coastwide quotas from 1998 to 2018, and looking at the 3 million pound quota trigger, which is represented by the orange line, you have 10 coastwide quotas since 1998 that exceeded that trigger, and with the 4 million pound trigger shown by the green line, you have only the 2017 quota exceeding that trigger.

This table shows the percent allocations that would be distributed to each state for the quota up to and including the trigger, and those are the current allocations. Then the proportions that each state would get of the quota above the trigger, so you can see in that last column that each state from Massachusetts to North Carolina gets 10.89 percent of the quota above the trigger, while Maine and New Hampshire get 1 percent of that additional quota.

This second table is to show how the final state allocations would look, if this trigger approach were applied to the 2017 quota of 4.12 million pounds using a 3 million pound trigger. You can see the final state allocations in the third column, and then in the last column you see the percent change from that state's current allocation. I just want to note here that you see allocation increases in the states whose original allocations were lower than the percent of additional quota, so 10.89 percent that they receive of the quota above the trigger value, and that would be true regardless of what trigger value is used. Those states are Maine, New Hampshire, Connecticut, New York and Delaware. As the PDT discussed this approach they also considered how it could be modified to address changes in black sea bass distribution. The idea that was put forward was to still allocate the quota up to and including the trigger with the current allocations.

But instead of distributing the quota above the trigger evenly to the states of Massachusetts through North Carolina, they suggested instead allocating the quota above the trigger based on regional biomass. In the examples that the PDT put together for this modification, they used the Rho-adjusted regional SSB in 2015, which is the terminal year of the stock assessment, and those values result in regional biomass proportions of 86 percent for the northern region and 14 percent for the southern region.

Using this approach, additional quota above the trigger would first be allocated to each region based on those proportions. Then for allocating that additional quota within each region, the PDT proposed two different options. One would be to allocate equally to the states within each region, and the other is to allocate to the states within each region based in proportion to their historic allocations. There are examples of both methods in the PDT report.

This slide here is just to visualize the trigger approach as it was originally proposed. You have the quota up to the trigger in blue, distributed based on the current allocations. Then here the quota above the trigger shown in green is being distributed to the states equally, except for Maine and New Hampshire, which get 1 percent each.

Then you can compare that to the modification developed by the PDT, and you can see in this case the quota above the trigger is being split up regionally, based on those biomass distribution proportions from the stock assessment, and then split equally or proportionally to the states within each region. The percent allocation that each state would end up with would be dependent on which of those two methods are chosen.

I want to point out here that this modified trigger approach does maintain the smaller proportion for Maine and New Hampshire, but here they are getting that 1 percent each, but it's coming directly from the northern region's proportion rather than from the coastwide quota above the trigger. For the trigger approach, the PDT also highlighted a few considerations that might require some more thought if this option were to move forward.

First they noted that though 3 and 4 million pounds were proposed as two options for a trigger value, there may also be other appropriate options to consider, depending on what the desired outcome is. Second, they noted that again there is multiple ways to choose how to allocate quota above the trigger, whether that's evenly or in proportion to historic allocations, or in some other proportions. That would be another decision point for this approach.

Then lastly, the group also brought up the idea of using a soft trigger instead of a hard trigger, and a soft trigger would be allocating a certain percentage of the quota above a trigger based on the current allocations, and the rest of it based on a different set of allocations. The PDT thought that this might also be something the Board would want to consider. The last of the quota allocation strategies that the PDT discussed is the idea of an auctioned seasonal quota or ASQ System. To be clear in this case, the season refers to the full fishing year, so this option would occur on an annual basis. The idea that was put forward is to annually set aside a small portion of the quota, probably 10 to 20 percent to start looking at this option. That would be available for option to harvesters in the black sea bass management unit with all the required permits.

The auctionable quota would then be divided into smaller auction blocks by whichever agency is administrating the auction, and there could be certain rules established to limit the amount of quota that any one permittee can get in any year, in order to reduce quota consolidation. All interested participants would be able to bid on those quota blocks, and then the highest bidders would be awarded with that quota, and any funds gained from the auction would be funneled back into administration and enforcement of the auction.

This is the idea as it was generally laid out in the proposal. But there are obviously a lot of additional details that would need to be hammered out if this is of interest. Quickly I'll just provide a summary of the pros and cons that the PDT discussed with this approach. There is more detail on this in the PDT report as well.

But on the positive side, the auction could potentially increase fishery efficiency, by directing quota to harvesters with the greatest capacity to take advantage of that quota, and it could also be a relatively flexible way of allocating quota independently from state allocations. However, the PDT did highlight a number of concerns and challenges involved with running and administering this type of program, and because of the nature of this program it would need to be administered by either NOAA Fisheries or by ASMFC.

Both of those organizations have a number of concerns about running this type of program. For NOAA, this includes the fact that if they were running it they would only be able to auction quota to vessels with federal moratorium permits under the FMP regulations, and that would exclude state-only-permitted vessels.

They also noted that they would not be able to monitor landings at the vessel-specific level, so that would make enforcement difficult. There is also a concern that a quota auction could lead to consolidation of quota in the hands of operations with the most capital, and there is also uncertainty about how this program would interact with the ITQ systems that are already established in some of the Mid-Atlantic States.

Lastly, because we don't have the appropriate socioeconomic data at this point, it would be really difficult for us to analyze and predict the impacts of this type of program. The PDT emphasized that if this program is of interest it would require a high level of effort to develop. They felt that if it moves forward it would need to be the sole focus of the PDT.

In addition to those three strategies, the PDT also talked about the possibility of combining options to create a hybrid approach. For example, it could take 50 percent of the quota and allocate it using status quo allocations, and allocate the other 50 percent using something like TMGC or the trigger approach. But the PDT noted that if this is of interest, it would be important to weigh any potential flexibility that is gained from using a hybrid approach against any potential increases in complexity, and possible confusion among the public, since combining approaches might make it more difficult to parse out what the impacts of each component of the hybrid approach are. At the end of the PDT report, after considering all of these different approaches. They laid out some broader decision points, to help the Board think through the potential management strategies that have been proposed related to black sea bass commercial state allocations.

First, the PDT noted that it might be beneficial to set a clear understanding of the Board's intentions or objectives with looking at commercial allocation changes, in order to provide some direction to the PDT if a management action moves forward. The PDT also noted that for the options where there is a regional component, the Board should consider the best way of allocating to states within each region, as was mentioned during the discussion of the trigger approach.

Additionally, the PDT emphasized that the regional biomass information that we have, and that we used in the examples, that may change depending on the outcome of the Operational Assessment. It is still uncertain whether that assessment will be able to produce regional biomass estimates, and if it doesn't then the Board may need to consider using something else like federal survey data, or a combination of federal and state survey data to get regional information.

Another decision point is how to define the regional configurations in these approaches. Most of the examples that the PDT put together used Massachusetts through New York as the northern region, and New Jersey through North Carolina as the southern region. But the Board could consider some different configurations if it was deemed more appropriate.

For example, the discussion about Maine and New Hampshire was something the PDT brought up, and how to treat those two states, as well as potentially treating New Jersey as a separate region like it was done in recreational black sea bass. Lastly, the PDT discussed the idea of stability in the fishery.

Maintaining stability has been a concern for a number of states as we've had these discussions, and it's not clearly defined what stability means, so it might be useful for the Board to define stability, in terms of either a maximum percent change in allocations, or a minimum allocation or quota level that states would be comfortable with.

To wrap up my presentation, I have some next steps here for the Board. Today the Board may consider initiating a management action to address black sea bass commercial allocation issues, and as the PDT noted, it might be helpful to determine what the objectives of that management action would be, in order to guide the Board in choosing which strategies should be considered.

I'll also note here that the type of management document needed would probably depend on the options the Board wants to consider. The Board might also want to think about a potential timeline for developing a management action. For reference, this is an example timeline of what it could look like if an addendum were initiated today.

A draft document could be developed this summer with the options the Board is interested in considering. Then those options could be reviewed in August, but they likely wouldn't be fully fleshed out. The Board will not be able to review the operational assessment until October, so it might be appropriate to wait until October to consider approving a draft addendum for public comment, until we have that updated stock size and distribution information. If the Board were to approve a document for public comment in October, then public hearings could be held from November to December, and the Board could consider the document for final approval in February, 2020 at the earliest.

If it was approved in February 2020 that would make it difficult to implement for the 2020 fishing year, so it might be necessary to consider an implementation date of 2021. That is what I have for this presentation. Thank you for bearing with me, and I think we could take a second for any quick questions.

CHAIRMAN BALLOU: We have the AP Report, and I was thinking that it might be good to run through that sort of next in sequence, and then get to questions and then get to discussion. If it's okay with the Board, I would like to just encourage Caitlin to move through the AP presentation next. Then we'll circle back to questions and discussions, so why don't we do that Caitlin.

MS. STARKS: Alright, sounds good. The Advisory Panel did have a meeting jointly with the Council Advisory Panel on April 2, to go over these potential management options for commercial black sea bass. At that meeting we had 12 Commission advisors in attendance and 16 Council advisors in attendance. Fourteen of those were representatives of the commercial sector, ten of the recreational sector, and three that overlapped with both.

Six additional comments were sent to us via e-mail after the meeting, and those were included in the summary as well. In the next few slides I'll just go over the APs comments related to each of the proposed approaches that we just discussed. Regarding status quo, 10 advisors were in support of status quo commercial allocations.

The reasons that they gave included that the southern states are still catching their full quotas, and that there is too much uncertainty regarding both what the resource distribution looks like now, a few years after the stock assessment, as well as the impacts of the proposed approaches for reallocation. Two advisors opposed status quo, referencing that resource availability in the northern states is high, but the current quotas do not allow them to have the ability to take advantage of that availability.

For TMGC, 6 advisors opposed that approach, most of whom were from New Jersey to North Carolina. The reasons that they gave for the opposition were that they felt the results of the approach are too uncertain, and that it's unfair to the southern states, and that the allocations would not actually respond in real time to changes in biomass distribution, and lastly that there are still concerns about using the Northeast Fisheries Science Center Trawl Survey data to inform regional allocations.

There were also two advisors from Massachusetts and New York that supported the TMGC approach, and then one general comment that was given on this approach was that a minimum allocation level should be set in the approach, so that state allocations can't drop too low.

Looking at the trigger approach, there were 3 advisors that commented in support, and their comments included that this option would protect investments in the fishery, that areas where black sea bass has expanded should be able to get some of that excess quota, and that it is a start towards more flexibility for the northern region.

Six advisors said that they supported continued evaluation of this approach, though they didn't necessarily support it at the time. They noted that it needs further development before they could support it, and the focus should first be on getting updated stock information before looking into an approach like this.

As for the ASQ approach, 8 advisors opposed it, and only 1 supported it, and those opposing comments included that it would cause the same issues as the research set aside program, but under a different name, that it would produce more Carlos Rafaels, and that those with more capital shouldn't necessary get more quota.

The supporter of the ASQ comment said that maybe a Letter of Authorization program could be used to improve enforcement of a program like this. The advisors also gave a few more general comments on black sea bass commercial management, and one theme that they addressed was that changes to allocation shouldn't be made until after the Operational Assessment is complete.

Another comment that was given by multiple advisors was that the black sea bass stock is not shifting to the north, but rather expanding. One advisor also commented that it makes more sense to include New Jersey in the northern region than it does in the southern region. Another commented on the need to reduce bycatch mortality, and suggested that quotas could be subdivided by gear type.

Finally there was a comment that abundance should also be considered in the regional approaches, in addition to biomass. That is what I have for the AP report, and I just figured I would just put this slide back up to bring us back to the Board's discussion for today. With that I can take any questions.

CHAIRMAN BALLOU: Thanks so much, Caitlin and I really do want to just pause briefly and just thank the members of the PDT for what I think has been yeoman's work on this initial analysis. I think the report was extremely well written, and I think Caitlin's presentation was excellent.

I also want to thank the members of the AP, the joint AP, both from the Council and Commission for their input, which again was I thought very meaningful and helpful, and well detailed in the report. With that we're going to first take questions on the presentation that Caitlin just provided. We'll then be spending the rest of the meeting pretty much on a discussion regarding these issues. We'll move to that discussion after we take questions. First will be questions. Adam Nowalsky.

MR. ADAM NOWALSKY: The presentation on timelines showed a timeline for an addendum. Should we be considering this as an amendment process as well, or if we go through this process it would be by addendum only?

MS. STARKS: You could choose to do this through an addendum, if it was just an action that was to alter the state-by-state allocations. But something like the ASQ approach would require an addendum. It really just depends on the options that are wanting to be considered.

CHAIRMAN BALLOU: I think she meant would require an amendment for the latter; Adam, a follow up.

MR. NOWALSKY: ASQ would require an amendment, TMGC or trigger could be done through addendum, but could either of those first two. Could we choose to do it through an amendment process if we so desired?

CHAIRMAN BALLOU: Yes, I think that's the Board's prerogative. Either option is available. Additional questions, David Borden.

MR. DAVID V. BORDEN: I'm looking at one comment by Mr. Ruhle on Page 3, and I was just wondering if anybody could explain what the basis for the comment. I'll just read it, it's short. He's talking about the performance of the NOAA trawl project. He is quoted as saying "49 percent of the tows are invalid by their own admission." Is there any basis for that? Is there a factual basis for that statement?

CHAIRMAN BALLOU: I see Mike Luisi's hand up.

MR. MICHAEL LUISI: To the question. I can't say whether or not that value is accurate, I would assume that Mr. Ruhle in his work with the Northeast Trawl Advisory Panel that I sit on as a member of the Mid-Atlantic Council. The Council has been working with the Northeast Fisheries Science Center in evaluating the trawl survey.

Over the last year there has been the identification by the Science Center for a high number of their trawls. This is getting outside of the specifics of what I understand about how trawls work. But the geometry of the trawl has been outside of what has been defined as an optimal trawl setting.

Therefore, it's been agreed that a high number of these trawls that have been conducted over the years have been outside of that, which means that they're not fishing at that optimum geometry to capture the fish being targeted. I saw Dr. Hare here earlier. I don't want to necessarily want to put him on the spot. He might be better to explain and answer your question. I just thought I would give you what I know. Jon.

CHAIRMAN BALLOU: Dr. Hare, are you better able to explain and respond, and if you are please do so.

DR. JONATHAN A. HARE: I'll try, and you can determine if I'm better able. How's that? Jon Hare, Northeast Fisheries Science Center, Director, you know we very much appreciate working with Captain Ruhle on NEAMAP and working with the Trawl Advisory Panel. I don't know if 49 percent is the right number or not. But there are some large number of Northeast Fishery Science Center trawls which are outside of the specific bounds that are placed, in terms of the sort of how the trawl has worked on NEAMAP. It's an issue which the Northeast Trawl Advisory Panel and the Northeast Fisheries Science Center is looking at. The way we've been approaching it is several fold. One is doing field work, both on the Bigelow and on commercial vessels to understand the magnitude.

Captain Ruhle uses the word invalid. I wouldn't use the word invalid. But there is the catchability of a trawl when it's not the optimal shape is a question, and we're trying to sort of quantify what that catchability is in these different trawl performance areas, sort of deepwater mid-shelf and shallow water.

The other approach that we are taking is we are going to do some flume tank work to look at the trawl under different sort of spreads. That work was scheduled for January, because of the shutdown we were unable to do it, and we're in the process of rescheduling that work. That will also be open to the Trawl Advisory Panel as a group.

Then the third approach that we are taking is looking at, as we do an assessment, looking at the potential impact of catchability in the trawl, in the range of tows and how that would sort of impact the index that's coming out of the Bigelow, and then how that would impact an assessment. We've done it so far with yellowtail flounder.

Yellowtail flounder step distribution is in sort of a mid-range, which is where the trawl is performing well, so there is minimal impact. It was also looked at in the summer flounder assessment. The Bigelow time series was adjusted for catchability as the NTAP group thought that the catchability might be impacted.

That was included in the assessment. We are going to continue to work on this. I think the term invalid, I wouldn't use that term, but there are a large percentage of trawls which were outside of the narrow bounds, which the

NEAMAP survey is conducted under. But we are going to continue to work on this.

CHAIRMAN BALLOU: David. Did you have a follow, David?

MR. BORDEN: Please. Thank you, Dr. Hare. Just so I'm clear in my own mind. Is this a problem with the NOAA trawl project or the NEAMAP project or both?

DR. HARE: No, it's a Northeast Fisheries Science Center Trawl Survey issue. The NEAMAP Survey has very tight protocols, and Captain Ruhle fishes very efficiently, uses the protocols and then they throw out any trawl which is outside of the bounds. Just to be clear, it's not an issue of the NEAMAP Survey, it's an issue of the Northeast Fisheries Science Center Trawl Survey.

MR. BORDEN: Thank you very much.

CHAIRMAN BALLOU: Additional questions, Nicola Meserve.

MS. NICOLA MESERVE: With regards to the trigger approach. The PDT offered up two trigger levels, a 3 and 4 million pound trigger. Looking at the 4 million pound trigger there is only one year in the time series where he would have been above that. I guess I'm looking for a little more context as to the PDTs discussion as to how that would have provided for meaningful reallocation, and possibly whether it was based on assumption that we might have higher quotas in the future, similar to what happened with fluke recently in the new assessment.

CHAIRMAN BALLOU: Caitlin.

MS. STARKS: The PDT didn't put those two options forward. That was put forward with the original proposal by Rob O'Reilly. He might have something to say about those two options, but the PDT did suggest that there might be other levels that could be considered.

CHAIRMAN BALLOU: Rob, do you want to weigh in?

MR. ROB O'REILLY: Thank you, Caitlin for your report. Yes that is exactly it. We came through a very nice assessment result in 2016. We keep hearing about the tremendous biomass and abundance of black sea bass throughout the range. I think there should be an expectation that quotas will indeed remain somewhat on the higher end than they have since 2003 overall.

If that's the case, then it makes sense to bracket this trigger point evaluation with a high value. That is the only reason to do that. The 3 million pound trigger point is a little different in that is the average over time, with the exception of the years where constant catch was what the fishery was bound by.

Really, I think it's just a matter of one comment that we just looked at was from the AP, was let's see essentially what the next assessment looks like as well. Then there is a choice there. There is a choice; you have a 3 million pound trigger which you saw has quite a few entries of quotas above that and then the 4 million only one now.

It's sort of planning for the future. That is what we hope the future looks like. The other part, if I may Mr. Chair, to talk about that option for just a second more is that certainly putting in the option and having the PDT come out with the variation is fine, on the soft trigger. It's just that I'm wondering if it was looked at as a way to have an intersection with the TMGC approach, where I realize it's early.

Nothing was really done on the soft trigger. There was sort of a recommendation there that if it was 50 percent and a couple of examples are given in the document, but clearly that is sort of bridging the two approaches a little bit, because the TMGC would also at some point, some number of years, end up with that situation as a soft trigger would as well. I'm wondering did the PDT have a discussion about that? Was that the rationale for the soft trigger?

CHAIRMAN BALLOU: I'm not sure, but Caitlin you want to take a stab at that?

MS. STARKS: Sure. I don't know if it was exactly the rationale for looking at a soft trigger. But it was just another idea that was brought up by the PDT of something that could be done. It does kind of intersect with the hybrid approaches part of the PDT report. You could choose to use kind of a soft trigger to set 50 percent that's going to be allocated based on the current allocations. Then something above that could be allocated using TMGC, but it could also be allocated using the trigger approach, and it could also be allocated in a different way. It was just a suggestion that they also put forward for consideration.

CHAIRMAN BALLOU: Any other questions, yes, Joe Cimino?

MR. JOE CIMINO: Thank you, Caitlin. That was a great presentation. I think you may have a slide that we didn't have. Could you bring up the TMGC example? Well actually, it might help if I speak to this a little bit. What we saw in the document was some very smooth lines that looked like they had long time periods. With examples, it talks about regional distribution assumptions being based on spawning stock biomass by region from the assessment time period 2004 to 2012.

I don't know if I'm putting you or Jay on the spot. In those long time periods in the projections that we have in the document is that a single value for the biomass, and then just using all the other levers if you will to slowly adjust it over time? Is this doing something different? I guess it must be, because it's changing throughout.

CHAIRMAN BALLOU: Caitlin is going to take a stab at that.

MS. STARKS: I'll try, and if Jay is around maybe he can correct me if I'm wrong. But I believe the examples that were provided in the report are also retrospective, which did allow them to use the changing biomass information from the stock assessment. It shouldn't be a constant value that was used for those projections.

CHAIRMAN BALLOU: I see Jay in the back nodding his head in the affirmative. He is concurring with Caitlin's response.

MR. CIMINO: Then there was the potential for each year. It could have been a jagged line. It's shifting towards the northern states, but a year or two later for whatever reason; the Trawl Survey would bring it back to the southern states. That's happening in the projections. Okay that is something that was not clear.

CHAIRMAN BALLOU: Adam.

MR. NOWALSKY: Let me build on that question then. In the examples that we saw, the quotas that were shown in a given year, how far did the assessment lag, in terms of the information used for that decision? Were we essentially seeing a quota in a given year was based on distribution from four or more years prior in those examples?

I understand the TMGC approach talked about, and the PDT review talked about, the concerns about the lag between an assessment and actually using it, which would be on this four-year timeline approximately, versus possible using state surveys or something else. But for the examples that we're looking at, are we looking at essentially a four-year lag between when we're going to have a quota for fishermen to utilize, and the distribution that that would have been based on?

CHAIRMAN BALLOU: I think the answer is yes that the projections were based on the assessments that were done, and the projections associated with those assessments. Yes to your comment. There was a lag, there is a lag, there always is, with regard to looking back on the most recent assessment. I believe that's how these projections were developed.

Right, and each time there is an update that would get folded in. That is the concept and that was the attempt made here, with regard to these examples, to show how it would have played out had this process been in place, and based on the information we had in hand. It looks like that answered the question. Mike Luisi.

MR. LUISI: Based on Adam's question. Could we assume that the same lag would be part of the formula that would go into the regional biomass example for the trigger alternative, rather than an equal distribution of the extra fish above the trigger? I mean I would assume that there would be some basis to assign those differences within the region, which would also be lagged. Can we assume that?

MS. STARKS: Yes, I believe that's the case.

CHAIRMAN BALLOU: Any further questions? Nicola.

MS. MESERVE: To this point, Mr. Chairman. The assessments are on a two-year schedule, right, moving forward. The next one is in 2021. That would include data through 2020. But in 2021 we get the assessment, there is only a one-year lag between incorporating data on regional biomass from 2020 into the approach for the next year.

If you were doing it on an every two year basis that is all of the assessment. I'm not seeing as much concern about a multiyear lag in incorporating stock information into that approach. Right now we're not doing it at all. It is certainly an improvement beyond that.

CHAIRMAN BALLOU: With that let's see if we can pivot now to discussion. I'm just going to kind of reset that discussion briefly. The Working Group Report, which preceded the PDT Report, identified two main issues. The first being, state commercial allocations implemented in 2003 do not reflect the current distribution of the resource, which has expanded significantly north of Hudson Canyon.

Two, federal coastwide quota management can limit harvest opportunities for some states, if another state's harvest overage results in a coastwide fishery closure. That second issue, identified by the Working Group is slated to be addressed in collaboration with the Mid-Atlantic Council and NOAA Fisheries, and will likely be brought back for consideration at our next joint meeting in October, or as early as that.

The first issue is what we want to focus on today. The PDT undertook an initial analysis of management options and alternatives suggested by members of the Board. As noted in the report, and by Caitlin in her presentation, some of the options relate well to the problem statement, others less so. Thus it would behoove the Board to offer a clearer sense of direction to the PDT regarding the Board's intent on the issue of reallocation. In other words, what is the primary purpose for revisiting allocations for commercial black sea bass, and what is the primary goal for the options and alternatives to be further developed and considered? One version offered solely for the purposes of seeding today's discussion, might be something like this.

Given the shift in resource distribution and abundance, the Board should consider changes in commercial allocation to provide fair and equitable access to the resource, by better aligning allocations with updated scientific information on resource distribution and abundance, while affording due consideration to the socioeconomic needs and interest of coastal communities.

That straw man language draws from the initial problem statement developed by the Working Group, and comports with key relevant provisions in the Commission's Strategic Plan. I reviewed that plan and I have them in front of me. But I can circle back to them if anybody wishes. I'm game to put that straw man goal statement that I just offered up on the screen, for purposes of seeding today's discussion upon request, but won't do so unless so requested.

I just wanted to kind of set the stage, and now open the floor to discussion on a proposed goal statement, and any other set of objectives related thereto, that's one. Two, some clarification and guidance as to which management strategies the PDT should continue developing, and three, what our potential timeline should be as we move forward with this initiative.

Those are the sort of three. I want to frame this discussion with regard to those three issues. I think it was bracketed the same way in Caitlin's slide, so just kind of resetting this next phase of our meeting today. With that I will now open the floor to discussion, comments, and suggestions. I don't anticipate the need for motions.

We're not adopting anything today. We're really just in a mode of trying to provide guidance on these issues. But it's an important step in the process, because it will inform what happens over the next several months. With that the floor is open for anyone who wishes to weigh in on any of those questions, or any of the issues that have been raised. Who would like to go first? Tom Fote.

MR. FOTE: I asked a while ago about when we're doing biomass, and we basically put it in numbers of fish, and compare the numbers of fish over the period of time, because as we know black sea bass like summer flounder, if you put higher size limits you reallocate by doing that because the bigger fish move north.

I'm looking at what were the figures by numbers of fish that basically has that change over the period of time. I can understand why they get bigger fish, because basically like summer flounder, black sea bass they do the old go out to the Canyon and come back further north, as they get larger.

We've been providing a nursery for the south for the big fish to go north. When we started raising the size limit, we did over the years from the smaller size limit on black sea bass and summer flounder, we started doing the reallocation ourselves of where the biomass, because the bigger fish are up north. I've asked for that a couple of times. I wonder if we could get that and we can probably start really looking at this.

CHAIRMAN BALLOU: Before I go to the next hand, I just want to note that I misspoke when I said no motion would be needed. A motion would clearly be needed if we were to initiate a management action today. I just want to clarify that point. On these issues, who is ready to weigh in and provide guidance on some of these areas? David Borden.

MR. BORDEN: I don't have a problem with the statement that you put up there. I do have some issues with some of the options that are in the document; specifically the Auction Option. I think should be taken out, unless somebody can convince me that they've fixed the problems that manifested themselves with the RSA project. If you want to just focus on this, I'm happy with this statement.

CHAIRMAN BALLOU: Just to keep the meeting moving along well. How does the Board feel about this straw man proposal for a goal statement? I say this. I'm pointing to the language that's up on the board. Again, this was just offered based on what I drew from, based on drawing from the sort of record if you will, the problem statement developed by the Working Group, principles that I drew upon from the Commission's Guiding Documents.

Does this speak to the purpose upon which this Board is looking to move forward with this issue of revisiting commercial allocation? If there is no objection, again we are not formally adopting anything today. We're just making sure that we're clear on what it is that we're looking to achieve. Is there any objection or any recommended changes to this language? John Clark.

MR. JOHN CLARK: It would just be a clarification, Bob. I'm just wondering by having a goal like this. Are we saying as we get further into these discussions, which if summer flounder was any indication are going to be long and excruciating, that we would have to base any allocation on, you know we said in our goal we were going to allocate based on the new distribution of the species.

It almost seems that this goal would say the status quo is not an option. I know from just from what we saw from the AP report for example, status quo is favored by a lot of the fishermen in our region. I just want to make it clear that if that goal is in there, there could be a situation where status quo is something that would not be seen as an option.

CHAIRMAN BALLOU: My response would be status quo is always an option, and the key word here is the first word, consider. This is just indicating the purpose by which this initiative would move forward. It doesn't mean that anything has to be adopted, but it would guide the development of the options and alternatives. John.

MR. CLARK: I understand Dave said to remove the Auction Option. I had come up with that. I just didn't put much effort into that because I didn't figure it would go anywhere. But one of the real advantages that was not really brought up in the PDT report, was that it would take us out of this allocation effort here, because we would have a situation where the allocation would be allocated based on whoever would be best able to take advantage of it.

I think what I've heard from some of the joint meetings is there is already a de facto reallocation going on, and that some of the quota from permit holders in some of the southern states has been bought by commercial boats in other states. In any event, as I said, I certainly understand the difficulties with going to that. But it would be one thing to think about for the future, to try to avoid these long-drawn-out-allocation arguments.

CHAIRMAN BALLOU: Understood, thanks. Mike.

MR. LUISI: I'm comfortable with what's on the board and what we're discussing here, and I'm happy that the first sentence doesn't reference shifts or expansion, and that we've kind of steered clear of that and we're talking more about distribution and abundance. I think there is a debate still over whether or not the stock is shifting, or if it's just been redistributed and expanding in certain areas. I think that I would be happy to leave that alone.

Last, just for the record, I'm assuming that reading the last part of the sentence, "the socioeconomic needs and interest of coastal communities," is in reference to what's been developed over the time that the allocations have allowed for those states to capitalize and put forth in their communities the harvest of that resource at the level that they're harvesting now. I think in my mind this does address the issue, but it also secures to some degree that historical nature of the fishery as an important element as we move forward.

CHAIRMAN BALLOU: I think you put it well. That is certainly my take. Eric Reid.

MR. ERIC REID: I just have a question about our current utilization of the resource. Is there any state that is underperforming on their current quota?

CHAIRMAN BALLOU: Well, I'm going to let Caitlin answer that. She just whispered in my ear, if you want to I can put that on the record.

MS. STARKS: I have taken a look at the recent years, and there isn't any state that is significantly and consistently underperforming. It does alter from year to year, and there has only been a couple states in the last few years that have been under their quota, but it's only been by a few percent.

CHAIRMAN BALLOU: Why don't we by consensus, agree that the goal statement that's on the Board is worth adopting. But I use that word loosely with a small "a" for the purposes of guiding future development. I was next going to turn to the management strategies and options, but Adam you have your hand up, go ahead.

MR. NOWALSKY: My one concern with this approach is that it tells us, in my opinion relatively prescriptively, that fair and equitable access is based on resource distribution and abundance. I don't disagree with the statement that resource distribution and abundance should be one of the considerations.

But I have a level of discomfort with this statement as written, whereby fair and equitable access to the resource by better aligning allocations. I would be more comfortable with replacing "by better" with something along the lines of "including consideration of," whereby we're clearly identifying this as something we want to consider. But I appreciate the effort you put here, in terms of trying to guide us. I'm just uncomfortable with the focus on that as the means for equitable access.

CHAIRMAN BALLOU: I appreciate that. I would just kind of revisit Mike Luisi's comment and that is that the last part is aimed at identifying a second key factor, socioeconomic needs and interest of coastal communities. You could say balanced by or in due consideration to that. I sort of read this as addressing two key factors, the one that you just spoke to is one, but it's not limited to that.

It's also sort of balanced by or also complemented by that last part. But to your point, if the language were changed to just say, including consideration of, it leaves it more open ended. It means that other factors could be introduced, and I guess the point that I would want to focus on today is what would those other factors be? If so, let's try and identify them now. If this is missing pieces, let's try to get those missing pieces in. Adam.

MR. NOWALSKY: I think historical allocation is the first one that was highlighted by the Working Group here. I don't disagree that while affording due consideration touches on that. I don't think it's as clear that saying historical allocation or whatever it might be. I don't think we have to list them all.

I think having gone through the summer flounder process; we've touched on a lot of the issues. I'm just looking to whatever they may be, whether they're here today. I don't view this as a guiding principle for the next three weeks, three months, or three years, Mr. Chairman. I think this is something this Board could hold true for a longer period of time potentially.

I think it's important that we don't box ourselves into a corner by saying fair and equitable access is defined by aligning allocations with updated scientific information, without stating that that is just one of the items we want to. If you specifically need another, I would offer historical allocation as an item to have here as another example if you needed one.

CHAIRMAN BALLOU: Responses to Adam's suggestion. Toni, sounds like you've got an idea.

MS. TONI KERNS: I just have a question, Adam. Maybe it's by interpretation, which will be subject to question or something, I don't know. But by saying that we're trying to better align allocations with updated scientific information on resource distribution in abundance, I would say that underlying that is the historical allocation, so that's what you're starting with is historical allocation.

Then this is saying that you want to consider changes to take those historical allocations and somewhere realign. How much you realign is a big question with this updated information on distribution and abundance. I'm trying to think like how to fit that in, because this sort of goal statement or whatever we're going to call it, is telling you what you're considering the options to shift to. If you already have historical allocation as the underlying current allocation, then how do you blend that in here? Do you know what I'm saying?

CHAIRMAN BALLOU: Adam.

MR. NOWALSKY: This is the crux of the issue is that is resource distribution and abundance the right way to reallocate? That is the question that is put before us. My point is that's one consideration. I'm not comfortable leaving this room with that being the phrase that we're using as the means for fair and equitable access.

I think the AP was very clear in highlighting that. I think we would be doing the AP process a huge disservice by essentially disregarding that. Again, I was fine with leaving it. My specific suggestion, which is replacing "by better" with "including consideration of," I thought that left this as a focus, but didn't explicitly say this was our means for fair and equitable access.

I think it comes down to if you are in favor of abundance distribution as the means for reallocation, then you could say okay, this includes historical allocation. This includes all the other things, because you like this. If you have concerns that that way forward is not necessarily the best way forward, I think it's clear where I land on the issue here.

I think you're going to have some more considerations, and you're going to look for a little bit more consideration of the other side of the coin. I don't know what more I could say than that. I mean this is a decision the Board ultimately has to make in how we moveforward, and that's my proposed way forward is by changing "by better" to "including consideration of."

CHAIRMAN BALLOU: I'll take Tom, and then we do want to kind of come to terms on this, move to the other issues, and we're about 15 minutes away from I think needing to wrap up. We do have to move through this as quickly as we can. Tom Fote.

MR. FOTE: As I read this it says that we haven't been fair and equitable in the way we've been managing black sea bass. That is what you just said here; consider changes in commercial allocation to provide fair and equitable. Are we not doing that now, as by doing it historically? Now we're talking differently. I mean I agree with Adam. This wording is not the right wording.

CHAIRMAN BALLOU: Eric.

MR. REID: Other than I'm trying to avoid a nervous breakdown at this moment. I do agree with Adam, because my definition of better is going to be substantially different than maybe Rob O'Reilly's for example. I agree with Adam that we should change that a little bit.

CHAIRMAN BALLOU: Okay. What I'm thinking is that we don't necessarily have to arrive at a finite decision today on the exact wording. We can certainly take the Board's input, and work on continuing to craft this goal statement. We're trying to move the ball forward. It doesn't mean we have to score a touchdown today. But we do need to get through a couple of other issues, so I'll take two or three additional comments; Joe, Matt, and Rob, and then we'll need to move on to the next issue. Joe Cimino.

MR. CIMINO: I think to me socioeconomic means more than just the historical allocation. The fact that we're going to set something in motion that is constantly shifting, I think. We've seen the concerns with summer flounder industry saying, even in Rhode Island where they're saying we might benefit at town dock, but this does not seem safe to us.

A concept of telling sea bass fishermen, you know you're going to lose this quota for ten years, but don't worry you may get it back. In that amount of time if they had to sell their sea bass pots to survive, getting it back in ten years isn't exactly helpful to them. I think moving forward, socioeconomic needs puts a lot of onus on us to do something we don't always do, and have good information on the gear types, on the capacity of the fisheries, on the capacity of the docks and stuff like that.

CHAIRMAN BALLOU: Matt Gates.

MR. MATTHEW GATES: I think the allocations originally set in 2003 were probably what people thought at the time is fair, and probably were fair at the time, because the change in resource distribution has created a situation where it's a lot I think less fair for certain states, Connecticut being one of them, with a 1 percent share of the allocation. I think I like keeping the term better aligning with allocation with updated scientific information. I wouldn't want to make it worse than it is now. I think keeping better in there is a good descriptor of that.

CHAIRMAN BALLOU: Got you. Let me go to Rob and Maureen, and then we're going to move on. Rob.

MR. O'REILLY: Joe has covered my thoughts there, so thank you.

CHAIRMAN BALLOU: Maureen.

MS. MAUREEN DAVIDSON: Right now the Board is considering changes in the commercial allocation to black sea bass. Obviously, we can foresee which states might want change, and which states don't want to change. Are we considering changing our commercial allocations to black sea bass?

If we're not, for historical reasons, for socioeconomic reasons, fine. But I think that if we're going to change the allocations for black sea bass, we have to have some justification for why we're changing it, and the direction we're going to go in the change, and what we're going to use as the basis for making these decisions.

I know this is hard. I got to watch parts of the summer flounder discussion. I don't want to go back to the basics, but I really want to ask, do we want to change it? I mean I'm from New York, I want to change it. But there are other states that are comfortable where they are now. Before we start arguing, are we willing to consider real change to our black sea bass commercial allocation?

CHAIRMAN BALLOU: I'm going to take this position. We have not reached consensus on a goal statement. We have some language that I think is something that we can circle back to, incorporating input received today by the Board, and then bring it back before the Board at our next meeting. I don't think we're going to achieve any sort of sense of finality on this today. What I would like to do next is just see if, and this is a little awkward, because the next issue has to relate to this first issue.

But are there any alternatives or options that are currently being analyzed by the PDT that should be struck, or are there any new options or alternatives that should be added? This would be for the purpose of giving guidance and direction to the PDT, and their continuing efforts to work on this issue. I would like to get some input on those questions, they are related. Anything new to be added, anything that is in there now to be struck? Emily Gilbert.

MS. EMILY GILBERT: GARFOs input on the ASQ Approach, the Auction Seasonal Quota Approach, was already discussed a bit during the presentation. It's discussed more in the PDT Document itself. But I just wanted to reiterate that given the difficulty in effectively enforcing, monitoring and managing such a program, in addition to the limitations of staff and resources to administer an auction. These are thoughts similarly shared by the Commission staff. We would have strong reservations over our ability to ultimately be able to successfully implement that program. That's my comment.

CHAIRMAN BALLOU: That echoes sentiments that David Borden mentioned earlier. Are there any other thoughts on this, and I would put it in the form of is there any objection to removing the, we're calling it the Auction, I'm sorry I forget the name, the ASQ Option. Is there any objection to removing that from the document for now?

Sorry John, appreciate, it was teed up well and I thought it actually received a good amount of analysis. I don't sense that you're objecting to removing it for now. It can certainly be placed on a back burner and be brought forward again, but for now in terms of focusing our resources, is there any objection to pulling that third option?

I see no objection, so we'll take that as a consensus opinion on the part of the Board. Then the last issue is the timeline, and this does relate to the sort of core final issue, and that is whether or not there is any interest in formally initiating an addendum or any sort of management action. I guess it could be an amendment today. That doesn't need to happen. It could, but certainly it relates to the timeline, and Caitlin if you could put that timeline, the one that you had offered up back on the board to help that would be wonderful. Rob O'Reilly.

MR. O'REILLY: I didn't know you were closing the door on the option, so I do have a comment on that if I may.

CHAIRMAN BALLOU: Oh sure, I'm sorry, thank you.

MR. O'REILLY: In February meeting, winter meeting at the very end. The Chair allowed other options to be brought forward, and at the time just speaking about my thought process, having one option available at that time, the TMGC, with four key decision points, which I could see would be a big hurdle to overcome to figure out when, where, and who is going to make those decisions with that approach. I did supply both you and Caitlin with the trigger point approach, and I think the PDT certainly is welcome to flesh out other options. But by putting in the soft trigger, it sort of mutes the effect of what I had intended when I supplied that. Now granted, I borrowed that from elsewhere, you know from the flounder document, the Summer Flounder Commercial Amendment Document, and made some modifications for the constant catch to not include that.

But to see in the document that there's going to be taking that particular option, putting a 50 percent would be the approach, which would rest with historical allocation. The other 50 percent would be with some other type of allocation. To me that's a pretty big departure. I don't mind that departure, as long as the documentation is separated.

That is not really something that was introduced for that purpose; it was introduced so that there could be a stepping stone to reallocation that would be a little more moderate. My supposition early on, based on Nicola's question was that yes, 3 million pounds is something that would prove to be a pretty good trigger point.

If we come back after the next assessment and the assessment after that, and this resource is showing that 5 million, 6 million pound quotas are available, well then yes the Board can come back, the Board and the Council can get together and say, well you know what? We really do have something that we can rely on here.

But in the meantime, to put in the soft trigger does mute the effect of putting in that option, and so I would request that as this goes further that that be set aside, and not included as part of the trigger point option. It may be included however the PDT wishes to characterize it. But clearly it's confounding, and I just want to make that statement for the record.

CHAIRMAN BALLOU: Caitlin, do you want to respond to that?

MS. STARKS: Sure, I just want to say understood, and if the Board didn't want that option in there at all that is also your prerogative. I think right now I'm looking for some direction, on which of the things the PDT put forward as additional ideas you guys are interested in moving forward, versus not interested in moving forward. That's helpful feedback, Rob, and I think if that stays in based on the rest of the Board's will, we can definitely separate it out as a different kind of option than the trigger option.

CHAIRMAN BALLOU: Adam.

MR. NOWALSKY: Just continuing in that vein. The quotas that we see coming out of the next assessment, as a result of the revised MRIP numbers, I'm not sure we're comparing apples to apples anymore, in quotas that we have for 2022 and beyond, relative to where we were in 2012, 2015, because they're going to be based on very different information.

I would request, I support moving forward with further development of a trigger based option. But I would ask the PDT to specifically look at what this means, and we now have the example of summer flounder to look at, where our quota for 2019 now means something very different. Even though the quota went up, it's not to say that the quota went up because suddenly the resource doubled in size. That is not what happened. The resource didn't change in size, our understanding of it did. What the quota means today is very different relative to where we are. I would ask for that consideration. In terms of a timeline moving forward, I'm of the opinion that allocation should not be done through an addendum process.

I think if you're trying to hold this meeting to a timeline today, a motion to initiate a management document today is probably going to take you significantly over the time that's been allocated. That would be your discretion where we go from there. But I would be a proponent, if we're going to go through an allocation it should be done through an amendment timeline process.

CHAIRMAN BALLOU: I'm going to take two more comments and then try to bring this to a conclusion. I think, was it David? Did you have your hand up? Yes, go ahead.

MR. BORDEN: I'll just follow up on Adam's point. I look at the whole MRIP recalibration as an opportunity for us to fix problems. In other words, given the experience that we've all had on summer flounder, where the quota went up by 72 percent. Had we had the benefit of actually taking a step back and taking some portion of that quota, and I'm just using this as an example, not to argue summer flounder at a black sea bass meeting, but had we taken advantage of that 72 percent increase, and tried to fix some of the problems that some of the states around the table have been having, particular New York and Connecticut. It was a way forward, and a painless way forward.

In other words, the states wouldn't have had to give up their basic allocations. We could have fixed the problems, and then figured out a way to move forward. We're going to have, at least my own understanding of where we're going to be is we're going to be in almost that exact same position on black sea bass, if things transpire the same way.

I'm more inclined to pick up the pace of this, and try to pick up the pace of it so that we can take advantage of that opportunity to try to solve, particularly the situation with Connecticut and New York on black sea bass is feeling intolerable. Connecticut gets 1 percent of the allocation, it's just unheard of.

They've got 1,400 square miles of area in Long Island Sound that's packed with black sea bass that didn't exist back in the initial timeline. But we've got the opportunity to fix that if the quota goes up. I'm more inclined to accelerate this rather than slow it down.

CHAIRMAN BALLOU: Nicola Meserve, and then we're going to have to try to bring this to a conclusion. Nicola.

MS. MESERVE: With regards to the trigger option. I think it's really important to note that the PDT said that in its original design, it does not respond to the problem statement. Moving forward, I would oppose to continuing with a trigger approach that has equal shares of the quota above the trigger level. What that does is distribute the extra quota to states, indifferent of their geographic location along the coast. It doesn't respond to the statement of the problem. I am much more interested in a modification to the trigger approach, as provided by the PDT, that would include the regional resource availability, and how the quota above the trigger level is distributed.

CHAIRMAN BALLOU: Duly noted. I think that would be good guidance that we'll be able to draw upon. At this point what I want to do is try to bring this portion of the meeting, this agenda item to a conclusion. One way to do that is to entertain a motion to initiate a management action. If anyone feels a burning desire to do that I'll entertain it.

Another way forward is to just pause. You know hit that pause button as we sometimes do. Our next meeting is in August. We could take the guidance provided today on all the issues that we discussed, work to further massage and develop the document, bring it back in August, see where we are, maybe drill down a little bit more to some of these issues we discussed today.

That is a second option. Is there any preference on the part of any Board member to move forward with one versus the other, and I'll take that in the form of is there anyone who wishes to make a motion pertaining to initiating a management action today? Seeing no hands, I'll assume there is consensus on the second approach that I just mentioned. I think with that do we need anything else today? Caitlin, what else do you need today?

MS. STARKS: I think if you're going this route of continuing PDT work on developing management options that could be considered in August, then the PDT would definitely need some more direction from you all on which of those options to include. I obviously heard that you would prefer to scratch the ASQ Option, so they won't look at that anymore.

But with the TMGC and Trigger Approach they've put forward several examples, so it would be very helpful to know which of those you're interested in. Are there other examples that you would like to see of how those two options could be configured? I heard Nicola say to keep looking at a modification that would take into account regional biomass information. But are there other things that the PDT could do from now until August, to bring back to the Board?

CHAIRMAN BALLOU: That's a good question. It's a question asked three minutes following what was supposed to be the end of this meeting. I wish we had more time to delve into that. I'm not sure that we do. But if anyone has any immediate thoughts, I really want to honor Caitlin's request.

On the other hand I'm not sure we have enough time to really get into. Well, e-mailing is fine. The problem with e-mailing is it doesn't necessarily represent the consensus view of the Board, it represents individual interest. That said there is no harm done given where we are in the process, to open the door to individual suggestions from individual Board members, provided to Caitlin via e-mail. Any such input will be vetted at our August meeting.

We're not going to move forward in any new direction or any particular direction based on any individual Board member's wishes. But it is invited. It will be conveyed to the PDT, if anyone wishes to weigh in. I don't know how else I can handle this at this point, given where we are with regard to timing. But if any Board member has a different take on how best to proceed, I'm open. Otherwise I want to try to move on to our last agenda item. Matt, it looks like you had a thought. Did you want to offer something?

MR. GATES: I just had one suggestion for Caitlin, but I can handle it in an e-mail if you like.

CHAIRMAN BALLOU: Yes, why don't we do that? Why don't we live up to that suggestion? E-mail input is open; the door is open to that. Rob.

MR. O'REILLY: I'll be very brief. The trigger point option we saw what the AP thought, so three AP members thought go forward, six thought it can go forward, give it some idea. I think what I am objecting to is the open-endedness that I saw in the document. If the PDT wants to refine that and take into consideration the resource, then that's fine, but there has to be some decisions on how that goes in time.

For example, the current trigger option that came out the Summer Flounder Commercial Amendment, it is cut and dried. You reach a certain point, allocation changes. The PDT can change the allocations, not make them evenhanded to the states. That is fine. That is a different option and that's fine. Then there has to be a decision on how much, so there has to be some information on how much of the range, not just throw out 50 percent and say well, here is some examples of 50 percent.

It has to be worked up with data. Unfortunately, when we went through the Summer Flounder Commercial Amendment, I don't think a lot of the states at the time had everything worked out as to how that actually changed allocation, and what amount of poundage was transferred through the trigger point option, for example. That is my recommendation; I'll put it in e-mail as well.

CHAIRMAN BALLOU: Toni.

MS. KERNS: I guess Rob just gave one piece of a question for the PDT. In that though, you know the PDT isn't making these management decisions. You all are making those management decisions, and then they are working up those examples for you. The PDT really needs advice on what more do you want from them, outside of what they have here?

Based on the discussion today, I'm not really sure they are going to provide you anything different than what you have here today, unless you say I want a TMGC Approach with no more than 1 percent movement per year, and a trigger here. That's what they need from you all, in order to bring you a document, or you can say we want a range of these pieces.

But they can't make those management decisions. That's what this body is here to do. They've built the program for you, and I think they did an excellent job with this document, to provide you all with some really good background and backbone to then turn into a document. But they need that advice back. I'm just not sure they're going to give you anything new from what they already have, so I just hope that there is not this big expectation that you're going to get much of a different document.

CHAIRMAN BALLOU: I think that is a fair comment. I think that seems to be where we are. I'll just leave it at that. Again, I'm trying to wrap up, but I see Adam's hand up. I realize I didn't go to the audience, so Arnold I will allow you to offer a comment. But go ahead, Adam.

MR. NOWALSKY: Taking those comments to heart, I would propose we leave here with a date, May 15 maybe, of anyone who wants to provide specific things they want to see, or comments on the variation to get back to staff. This is what we would like the PDT to do for us. You could give that to them. You could distribute it if you felt so inclined to the entirety of the Board, so they knew what everybody was doing. That might be a way forward where we are, given the timeframe today, and hopefully get something back then for our next meeting.

CHAIRMAN BALLOU: Here is how we're going to resolve it. I'm going to take Adam up on his suggestion, but it's with a caveat, and that is by May 15 we will, with staff. I will review any and all input provided. If I think that input veers off from what I would consider to be a direction that the Board as a whole would support, I'm going to really hit the pause button and wait until we reconvene in August.

Because I do not want to see the PDT engaging in analysis on options and alternatives that may be of interest to a particular Board member, but might not be shared by the Board as a whole. I'll make that judgment call as to whether the input provided by May 15, based on this meeting and any additional input provided by May 15, warrants continued work by the PDT.

I'll consult with staff obviously, and with my Vice-Chair, and we'll try and make that determination. I will be very vigilant on behalf of the Board to make sure that we don't put too much time and effort into any new ideas or options that haven't been sort of cleared by the Board. With that we may end up not making a whole lot more progress until August.

But, I will challenge you to be ready in August to kind of get a little bit more concrete in our direction forward. But I think this is a process of the ball moving forward, I think we have moved the ball forward today, and I appreciate that. I'm ready to wind it up, but Arnold I will give you this opportunity to comment, and while he's coming up Tina, if you're not already ready. I'm going to be calling on Tina next for the AP membership issue. Go ahead, Arnold.

MR. ARNOLD LEO: Thanks, a recommendation to include in the possible addendum. It has occurred to me that when it comes to these questions of allocation among the states or the user groups, they're always stalled, because obviously the states or user groups who are going to lose will oppose change, and those who might gain will be in favor of change.

We're constantly stalled at making any progress. I wonder if it's not time to consider the appointment of a wholly independent body, say consisting of three marine scientists from like Iceland, England, and Portugal who don't have a dog in this fight, to consider the allocation questions, and make the decision that obviously is a torturous process for the Commission to make the way it's presently set up. That would be my suggestion for an item to be included. Thanks.

REVIEW AND POPULATE ADVISORY PANEL MEMBERSHIP

CHAIRMAN BALLOU: Thank you. Any other input from the public on this matter? Seeing none; we'll move on to our next agenda item, which is to review and populate AP membership, Tina, welcome, thank you.

MS. TINA BERGER: I offer for your consideration and approval the nomination of Paul Caruso, a recreational angler from Massachusetts as an addition to the Summer Flounder, Scup, and Black Sea Bass AP.

CHAIRMAN BALLOU: **Thank you is there a motion to approve the appointment of Paul Caruso, made by Nicola Meserve, seconded by Emerson Hasbrouck. Is there any objection to the motion? Seeing no objection, Paul is appointed.** Thank you and we welcome Paul to the AP.

OTHER BUSINESS

AGENDA ITEMS FOR AUGUST BOARD MEETING

CHAIRMAN BALLOU: Under other business, I just want to briefly speak to an issue that I had referred to earlier.

For our next Board meeting in August, I am anticipating that there will be a report out on the status of the ongoing preliminary work being done by the Recreational Working Group regarding management reform. That effort being undertaking initially by a relatively small group, involving myself and Adam Nowalsky, as well as Caitlin and Toni.

Mike Luisi and Rob O'Reilly on behalf of the Mid-Atlantic Council, along with staff from the Mid-Atlantic Council, as well as staff from GARFO, is seeking to frame a set of priority issues associated with recreational management, particularly the desire to achieve more inter-annual stability that is obviating or at least lessening the need to engage in our annual process of chasing the RHL.

As part of that effort, or as a corollary to that effort, I would like to engage in a long overdue discussion on reducing discard mortality in our recreational fisheries, particularly black sea bass, but perhaps summer flounder as well. My good friend and colleague, Ray Kane, who I thought was here but may have left, from the Commonwealth of Massachusetts, has been pushing for consideration of this issue, backed by the results of a couple of recent studies.

We've been so inundated with issues over the past year, and as a result this issue of discard mortality has unfortunately gotten pushed back in line time and again. But I think the time is a good one now to bring this to the fore at our next meeting in August. I am therefore proposing we do that. If there are no objections to the idea, I will work with staff to ensure that we get that teed up, and invite all

Board members to contact us if you have any specific ideas related to the project.

Again, this is picking up on an issue that has been recommended to me by one Board member repeatedly, and I just want to honor that request by acknowledging that it will be folded into our August meeting.

ADJOURNMENT

With that is there any other business to be brought before the Board? Seeing no hands is there any objection to adjourning? Seeing no objection, we are adjourned. Thank you very much.

(Whereupon the meeting adjourned at 12:30 o'clock p.m. on May 1, 2019)

Caitlin Starks

From:	Comments
Sent:	Monday, July 15, 2019 11:01 AM
To:	Caitlin Starks
Subject:	FW: BSB potential commercial measures

Public comment

-----Original Message-----
From: Fishthewizard [mailto:fishthewizard@aol.com]
Sent: Sunday, July 14, 2019 5:43 PM
To: Comments <comments@asmfc.org>
Subject: BSB potential commercial measures

To Whom It May Concern:

There should be no change in state allocations of BSB, unless NJ is getting a larger percentage. We already gave up 18%, and if anything, should have a larger share. The fish are abundant, and we have no problem catching our quota. Any cut in the allocation will lead to economic hardship and discards. The coastwise quota should be increased to reflect the population of fish available.

Joan Berko
Commercial fisherman

Plan Development Team Report: Black Sea Bass Commercial Management

Prepared by:

Black Sea Bass Plan Development Team
Caitlin Starks, Chair, ASMFC Staff
Alex Aspinwall, VMRC
Jeff Brust, NJ DEP
John Maniscalco, NYS DEC
Jason McNamee, RI DEM
Julia Beaty, MAFMC
Emily Gilbert, NOAA Fisheries

April 22, 2019

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I. Introduction

The Commission's Summer Flounder, Scup and Black Sea Bass Management Board formed a Commercial Black Sea Bass Working Group in August 2018 to identify management issues related to changes in stock distribution and abundance, and propose potential management strategies for Board consideration. In February 2018, the Board reviewed the Working Group report, which identified two main issues: (1) state commercial allocations implemented in 2003 do not reflect the current distribution of the resource, which has expanded significantly north of Hudson Canyon, and (2) federal coastwide quota management can limit harvest opportunities for some states if another state's harvest overage results in a coastwide fishery closure (Appendix A). In February, the Board requested the Plan Development Team (PDT) perform additional analyses and further develop proposed management options related to the issue of state-by-state commercial allocations. The second issue identified by the working group will be addressed in collaboration with the Mid-Atlantic Council (Council) and NOAA Fisheries.

This document presents the analyses and findings of the PDT. For each of the proposed management strategies, the PDT discussed potential variations of the strategy that could be implemented to achieve different management objectives or outcomes. The PDT also highlighted additional considerations the Board should take into account when evaluating these approaches.

II. Potential Management Strategies for Adjusting Commercial Allocations

A. Status Quo

One potential management option is to maintain the current state allocation percentages. The current allocations were originally implemented by the Commission in 2003 as part of Amendment 13, loosely based on historical commercial landings by state from 1980-2001 (Table 1). In a complementary action, the Council adopted an annual coastwide quota system to facilitate the state-by-state quota system adopted by the Commission. Each state sets measures to achieve, but not exceed, their annual state-specific quotas. The annual coastwide quota is implemented and administered by NOAA Fisheries. The fishery is closed when the coastwide quota is projected to be taken, regardless of whether individual states still have unutilized quota.

Table 1. Current black sea bass commercial state-by-state allocations.

State	% Allocation
ME	0.5
NH	0.5
MA	13.0
RI	11.0
CT	1.0
NY	7.0
NJ	20.0
DE	5.0
MD	11.0
VA	20.0
NC	11.0

B. TMGC Approach

The first approach to adjusting the state-by-state allocations discussed by the Black Sea Bass Commercial Working Group, and then the PDT, is a dynamic approach for gradually adjusting state-specific allocations using a combination of resource utilization (historical allocations) and current levels of resource distribution. The alternative is modeled after the Transboundary Management Guidance Committee (TMGC) approach, which was developed and used for the management of Georges Bank resources shared by the United States and Canada. Though the approach proposed here for black sea bass differs from the TMGC approach used for Georges Bank, in this document the black sea bass allocation approach will also be referred to as TMGC.

This new strategy sets forth a formulaic approach that balances stability within the fishery, based on historical allocations, with gradual allocation adjustments, based on regional shifts in resource distribution derived from updated stock assessments or surveys. The former recognizes traditional involvement and investment in the development of the fishery since the beginning of black sea bass management, and the latter addresses the changing distribution of the black sea bass resource and the resulting effects within the fishery. Through incremental adjustments over time, the state allocations become less dependent on the historical allocations and more dependent on regional resource distribution.

This option proposes use of the existing state-by-state allocations to reflect initial values for historical participation (resource utilization) and proposes use of the 2016 benchmark stock assessment results (NEFSC 2017) to determine the values for resource distribution; the two values are then integrated in the form of regional allocation shares. An alternative to using the stock assessment would be to use synoptic trawl survey information. Two regions are proposed, as defined in the assessment: (1) ME - NY, (2) NJ - NC. They emanate from the spatial stratification of the stock into subunits that generally align with those used for the assessment, which used Hudson Canyon as the dividing line based on several pieces of evidence that stock dynamics had an important break in this area. The regional allocation shares are then subdivided into state-specific allocations. Appendix B includes a complete description and examples of the TMGC approach retrospectively applied to recent years.

1. TMGC Variations

The TMGC approach affords considerable flexibility, both with regard to initial configuration and application of the allocation formula over time. A key feature involves the use of control rules to guard against abrupt shifts in allocations. The overall approach can be modified by the Board and Council in various ways. For example, sub-alternatives can be developed for:

- the regional configuration (e.g., alternative regions to those proposed here);
- the values for historical participation/resource utilization (e.g., current, status quo allocations, or some variant thereof);
- the starting and ending weighting values for resource utilization and resource distribution (e.g. 90:10 to 10:90, or some variant thereof);
- the increment of change in the weighting values per year (10%/year, or some variant thereof;)
- the periodicity of adjustments (e.g., annually vs. biannually);
- the overall time horizon for the transition between starting and ending weights for resource utilization and resource distribution (e.g., 8 years vs. 16 years).
- control rule (e.g., maximum regional allocation change of 3% per year, or some variant thereof)

Of the numerous potential configurations that could be created by adjusting these parameters, the PDT focused on four examples to evaluate potential effects on state-by-state allocations. In these examples, the resource distribution information is derived from the unadjusted regional spawning stock biomass proportions from the 2016 benchmark stock assessment. The other parameters of the formula vary in each example, as follows:

1. The first example represents a configuration resulting in a more liberal change in state allocations. The parameters are set as follows: 2 regions (ME - NY; NJ - NC); resource utilization = status quo allocations; transition from 90:10 to 10:90; 10% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 90% weight on the resource distribution is 9 years; 10% control rule; regional distribution assumption is based on the spawning stock biomass by region from the assessment for the time period of 2004 - 2012; distribution of adjustments to states within a region based on historic allocations.
    a. Any TMGC configuration could also be modified to distribute the allocation adjustments equally to the states within each region, instead of distributing those adjustments proportionally to the historic state allocations. An example of this modification applied to the above configuration is shown in Figure 2 below.

2. This example represents a more conservative configuration, with more limited changes to state allocations. The parameters are set as follows: 2 regions (ME - NY; NJ - NC); resource utilization = status quo allocations; transition from 90:10 to 30:70; 5% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 70% weight on the resource distribution is 12 years; 3% control rule; regional distribution assumption is based on the spawning stock biomass by region from the assessment for the time period of 2004 - 2015; distribution of adjustments to states within a region based on historic allocations.

3. The last example is intended to showcase a number of additional modifications that could be made to the approach to achieve certain objectives. In discussions amongst the PDT (and previously the Board regarding recreational black sea bass) it has been noted that it may be appropriate to treat New Jersey as an individual region due to its geographic position straddling the division of the Northern and Southern regions adjacent to Hudson Canyon. Additionally, some Board members have suggested modifying the "resource utilization" part of the equation to increase the allocations for Connecticut and New York due to their disproportionate allocations compared to their current resource availability. Lastly, the PDT discussed the option of holding Maine and New Hampshire's current allocations static throughout the transition.

    To demonstrate these modifications, the parameters are set as follows: 4 regions (ME and NH remaining as a non-dynamic region with static allocations; MA - NY; NJ as a stand-alone region; and DE - NC); resource utilization = CT and NY base allocations increased by 1% in each of the first three years; transition from 90:10 to 10:90; 10% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 90% weight on the resource distribution is 9 years; 10% control rule; regional distribution assumption is based on spawning stock biomass by region from the assessment for the time period of 2004 - 2012, and assumes NJ is consistently 60% of the southern region distribution; distribution of adjustments to states within a region based on historic allocations.

The changes to the state allocations resulting in each of these examples are shown in Figures 1-4. A more detailed description of the methods applied in each example is included in Appendix B. It is important to note that the TMGC approach continually adjusts the state-by-state allocations beyond the time period over which the transition of the weights of resource utilization and resource distribution occurs. These adjustments would be made according to updated regional resource distribution information from either the stock assessment or synoptic trawl survey information as it becomes available, depending on which data source is selected.

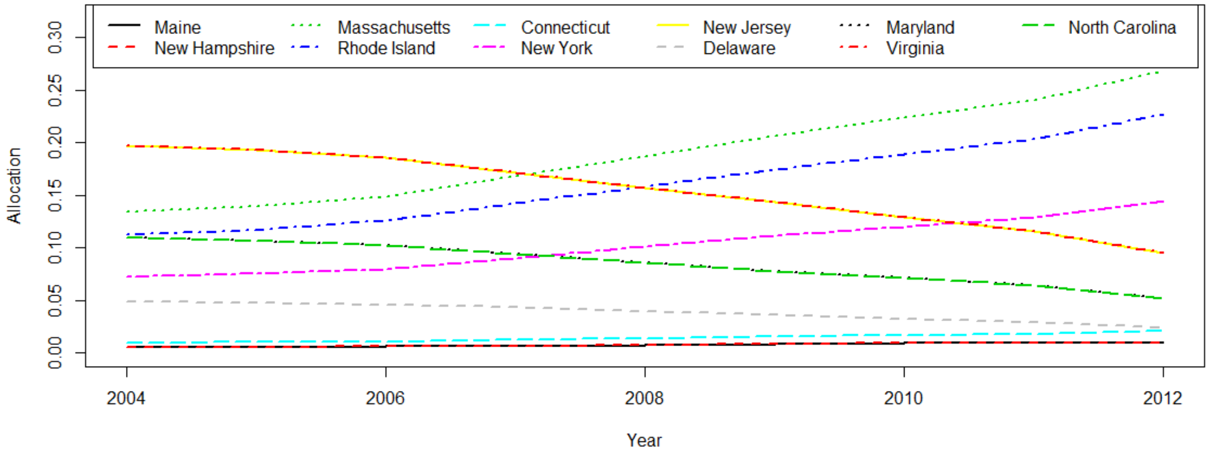

Figure 1. Allocation trajectory for all states under the parameters outlined in example 1 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

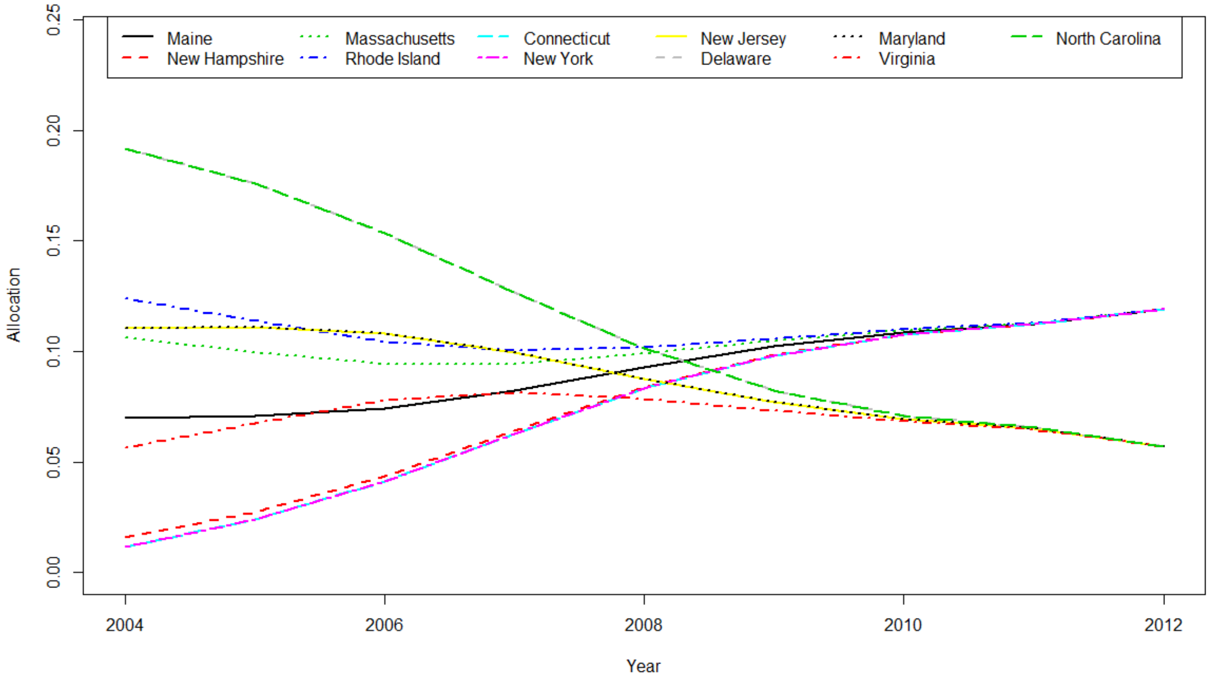

Figure 2. Allocation trajectory for all states under the parameters outlined in example 1a above (equal distribution to the states of regional allocation adjustments). The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

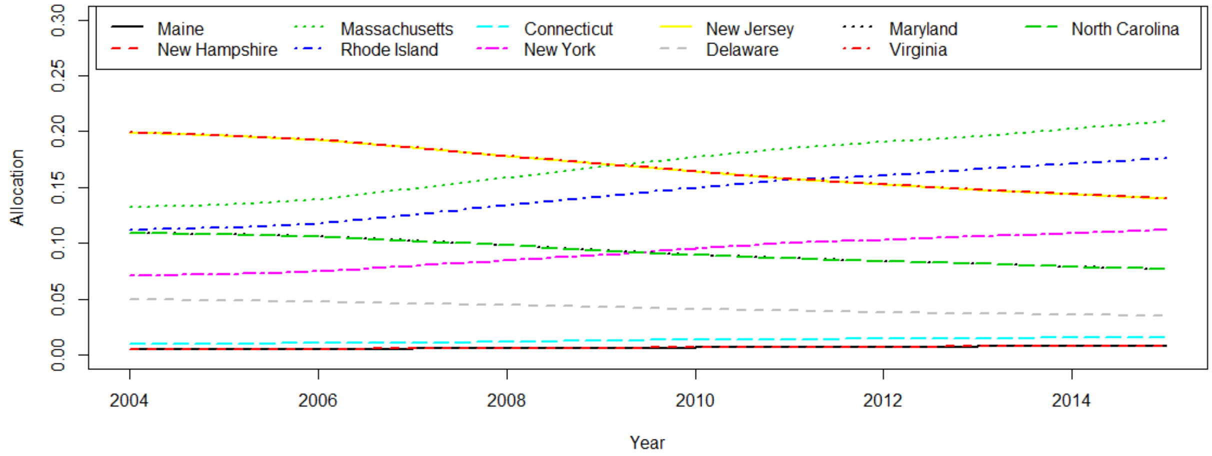

Figure 3. Allocation trajectory for all states under the parameters outlined in example 2 above. The control rule is triggered in each year from 2012 through 2015 in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

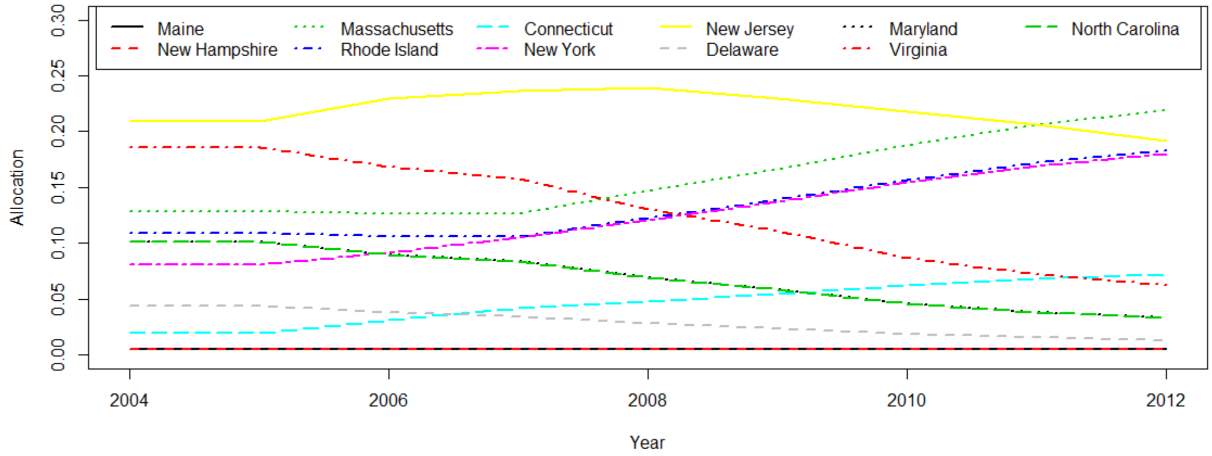

Figure 4. Allocation trajectory for all states under the parameters outlined in example 3 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

2. TMGC Considerations

There are two options for calculating the resource distribution. The first option is to use the spatial stock assessment to determine the amount of resource in each region (north = NY, CT, RI, MA, NH, ME; south = NJ, DE, MD, VA, NC). The spatial stock assessment calculates north and south spawning stock biomass values, which can then be turned in to a proportion. The benefit of this approach is the regional biomass values are calculated through a synthesis of many biological parameters and represent the best available science for the population. The drawback is that the assessment is updated periodically (not every year); thus updated resource distribution could not be produced annually but would depend on the assessment cycle[1]. Additionally, if the spatial stock assessment were to fail at some point in the future, this could impact the ability to implement the dynamic allocation calculations.

As an alternative to using the stock assessment information, values for resource distribution could be obtained and calculated using scientific surveys, with results apportioned into regions. Since surveys are undertaken annually, the values for regional resource distribution could be recalculated and updated annually, biannually, or upon whatever timeframe is deemed most appropriate, affording an opportunity to regularly adjust allocations in sync with shifts in resource distribution. Such shifts may, or may not, follow consistent trends. Accordingly, the technique affords a dynamic approach, consistent with actual changes in resource distribution as defined by the survey information. There are more options with regard to the regional configurations that could be established with this approach, whereas a two-region configuration is the only option with the assessment. The overall benefit of this approach is that it could be performed annually with the most contemporary data. The drawback is that survey data are prone to variability. Smoothing techniques and the proposed control rule are designed to account for some of this variability and prevent it from causing unreasonable changes in a single year.

C. Trigger Approach

The second approach the PDT discussed is a quota trigger approach. In this approach, a minimum coastwide quota would be established as a trigger for a change in allocations to the states. If the coastwide quota established by NOAA Fisheries in a given year were higher than the established quota trigger, then the quota would be distributed to the states in two steps: 1) the amount of coastwide quota up to and including the trigger is distributed to the states according to the current state-by-state allocations, as set forth in Amendment 13 in 2003; and 2) the amount of quota exceeding the established trigger is distributed equally to the states of Massachusetts through North Carolina, with Maine and New Hampshire receiving a smaller percentage based on their historically low participation in the fishery. Should the annual coastwide quota be less than or equal to the established quota trigger, allocation percentages would default to the current state-by-state allocations. This method limits fishery disruption by guaranteeing states some minimum level of quota based upon the 2003 allocations.

Two potential quota trigger options have been proposed: 3 million pounds, or 4 million pounds. The 3 million pound trigger represents approximately the average coastwide commercial quota from 2003 through 2018. Years in which specifications were set using a constant catch approach were excluded from the average (i.e., 2010-2015). Commercial quotas remained essentially the same from 2010 until 2013 when there was a slight change in the coast-wide quota established by the SSC in 2013 however, that was merely an extension of the constant catch that extended until 2016. The average commercial quota from 2003 through 2018 is 3.12 million pounds.

The 4 million pound trigger represents approximately the highest commercial quota from 2003 through 2017. The highest commercial quota was 4.12 million pounds in 2017. A 3 million pound trigger is lower than 10 out of the last 13 years (2008-2019) of coastwide commercial quotas established by the

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[1] The Northeast Region Coordinating Council approved an assessment prioritization process and management assessment track schedule in November 2018 that would provide management assessments for black sea bass every two years. Following the upcoming operational assessment, the next assessment would be available in 2021, with information available for management in 2022-2023.

National Marine Fisheries Service. A 4 million pound trigger is higher than all but one year of coastwide commercial quotas in the last 13 years (Figure 5). Table 2 shows an example of the quota trigger approach using a 3 million pound trigger and the 2017 coastwide quota of 4.12 million pounds. Additional quota trigger examples are provided in Appendix C.

Figure 5. Commercial BSB Quota over Time Compared to 3M Pound and 4M Pound Triggers

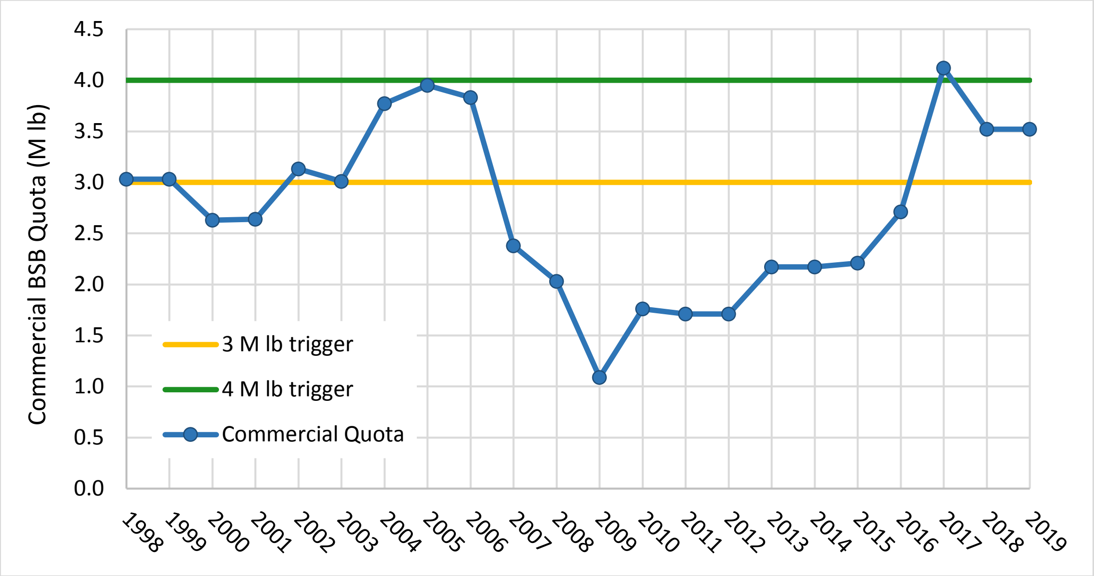


Table 2. Reallocation of black sea bass commercial quota above a 3 million pound trigger, based on the 2017 coastwide quota of 4.12 million pounds.

3 Million Pound Trigger					
State	**Current allocation (%) of quotas up to and including 3 million lbs**	**Status Quo distribution of first 3 million lbs of quota**	**Allocation (%) of additional quota beyond 3 million lb**	**Example state allocations (lbs) under a 4.12 million lb quota**	**Example state allocations (%) under a 4.12 million lb quota**
ME	0.5%	15,000	1.00%	26,200	0.64%
NH	0.5%	15,000	1.00%	26,200	0.64%
MA	13.0%	390,000	10.89%	511,956	12.43%
RI	11.0%	330,000	10.89%	451,956	10.97%
CT	1.0%	30,000	10.89%	151,956	3.69%
NY	7.0%	210,000	10.89%	331,956	8.06%
NJ	20.0%	600,000	10.89%	721,956	17.52%
DE	5.0%	150,000	10.89%	271,956	6.60%
MD	11.0%	330,000	10.89%	451,956	10.97%
VA	20.0%	600,000	10.89%	721,956	17.52%
NC	11.0%	330,000	10.89%	451,956	10.97%
Total	**100.0%**	**3,000,000**	**100%**	**4,120,000**	**100.00%**

1. Trigger Approach Variations

The PDT noted that the initial trigger approach proposals do not directly address the first problem identified in the Working Group's Report: the distribution of biomass has changed significantly since the state allocations were established in 2003, and the allocations do not reflect these changes. Changes in biomass distribution are supported by the 2016 stock assessment and peer reviewed literature.

To better address these changes within a trigger approach, the PDT discussed a modification that would distribute quota above the trigger based upon the proportion of coastwide biomass in each region, as informed either by the assessment models or fishery independent survey data. Fishery independent survey data may be required if the benchmark assessment regional model framework cannot produce valid regional results after inclusion of the updated MRIP estimates. The terminal year of the assessment can be used if retrospective bias adjustments to the assessment outputs of SSB are required, or the last three years of the assessment can be averaged if no adjustment is necessary. Tables 3-4 in Appendix C show examples of allocation above the trigger based on regional biomass, using the Rho adjusted regional model outputs from the terminal year of the 2016 benchmark assessment (2015). It should be noted that if this approach were selected, the Board would need to specify which regional biomass values to use. In the event that regional assessment outputs cannot or should not be used, a method to use fishery independent survey data must be developed – preferably one that utilizes a multi-year average or a smoothing approach (for instance, the approach described in the TMGC methods in Appendix B). The regional proportions used to distribute quota above the trigger should be updated every time appropriate new data is available.

Within the regions, quota above the trigger can also be distributed to individual states in different ways. One approach is to distribute quota above the trigger in equal shares to all states within the region (ME and NH receive a flat 1% of this additional quota from the northern region pool; this could be modified if they express increased interest in participating in the fishery) (Table 3, Appendix C). A second method would be to distribute quota above the trigger to all states within the region in proportion to their 2003 allocations (Table 4, Appendix C).

2. Trigger Approach Considerations

If a trigger-based approach is of interest, the Board would need to consider the most appropriate configuration based on the objective of reallocating black sea bass commercial quota. First, a quota trigger should be selected based on the amount of quota the Board feels should be distributed under the current allocations, versus the amount of quota that should be made available to the states using an alternative allocation scheme. The Board should also choose an allocation method for quota above the trigger that best addresses the issues facing the fishery (i.e. equal distribution of additional quota or distribution based on regional resource availability).

While the trigger approach as proposed establishes a hard quota of three or four million pounds, the PDT discussed the possibility of using a soft trigger, which would allocate a percentage of the quota using historical allocation, rather than a set number of pounds. Fluctuations in annual quota values would result in similar fluctuations in the poundage being allocated using historical values. For example, if a trigger is set at 50% of the quota, the historical allocations would apply to two million pounds of a 4 million pound quota, and 3 million pounds of a 6 million pound quota. Using a hard trigger, if the annual coastwide quota is below the trigger, then the full quota is allocated using the historic allocations. With a soft trigger, lower quotas would still allow some portion of the quota to be allocated using a distribution other than the historic allocations.

The PDT has explored several options for potential quota triggers, and allocation schemes for additional quota above the trigger. However, the Board may wish to consider alternative trigger levels or allocation schemes that are deemed more appropriate. Additionally, the size of the population and subsequent quota amounts may change due to the 2019 operational assessment for black sea bass. This should also be considered before selecting a trigger value if this method is eventually adopted.

D. Auctioned Seasonal Quota

The Auctioned Seasonal Quota (ASQ) approach was proposed by a Board member in February 2019. The proposed management strategy is to annually auction off part of the total commercial allocation under an ASQ. While all of the allocation could be auctioned, that would be disruptive to the current fishery, so it was proposed that this strategy could be applied only to 10-20% of the coastwide quota. The portion of the quota to be auctioned would be divided into auction blocks (e.g. 2,000 pounds, 5,000 pounds) by the agency charged with holding the auction. The proposal suggests the auction should be open to all fishers in the black sea bass management unit with the required federal and/or state permits. Rules could be set to limit the number of blocks that any one permittee can acquire. High bidders would be awarded the auction blocks. The proposal also indicated that auction funds received by the administrating agency should be used to administer and enforce the auction.

The rationale presented by the Board member who proposed the ASQ strategy is that it responds to several problems with the current quota allocation method:

- Quota allocated among states loosely based on landings from 1980-2001, so more recent shifts in black sea bass distribution are not reflected in state allocations.
- Quota allocation among states is a ‘zero-sum game’ – one state can only increase its allocation if another state(s) decreases its allocation.
- States have treated their allocations as permanent property and each state has stakeholders that depend on getting their share of the allocation, making it difficult for a state to agree to a reallocation plan that does not provide its stakeholders the same benefit.
- In three states, quota is allocated to individual permittees through Individual Transferable Quotas (ITQ). Participants in the fishery at the time the state allocations were established were grandfathered into the fishery and received ITQ. The distribution of ITQ makes it difficult for new participant to enter the fishery.

1. ASQ Considerations

a) Administration

The PDT discussed a number of considerations regarding administration of an ASQ program. For one, the group noted that because the auction would be open to harvesters from all states in the management unit, such a program could not be administered at the state level. Thus, either NOAA Fisheries or the Commission would need to manage the program.

Administering an ASQ program would pose numerous challenges for both bodies. From GARFO’s perspective, initial concerns include the following:

- The limited access privilege program (LAPP) provisions of Magnuson-Stevens Fishery Conservation and Management Act (MSA) allow for auctions to establish allocations. GARFO has significant concerns about the resource and staffing needs it would take to host and monitor such an auction.
- The MSA allows funds from these auctions to be deposited into a Limited Access System Administration fund and would require a cost recovery fee (up to 3% of ex-vessel value of fish harvested) that would be applied to the costs of management, data collection, analysis, and enforcement activities related to this program. However, NOAA Fisheries would not be able to transfer this money to state agencies or state law enforcement to assist with monitoring and enforcing the program.
- GARFO is only able to establish this type of program for Federal moratorium permit holders, which would place state-only permitted vessels at a disadvantage. GARFO is unable to monitor vessel-specific landings for state-only permitted vessels. If the entire quota were eventually moved to an ASQ system, this would prevent state-only vessels from fishing for black sea bass. Even if a transfer program were to be developed that allowed state-only permitted vessels to lease in quota, GARFO would not be able to monitor that quota.
- Any ASQ or Individual Fishing Quota (IFQ) program requires very robust monitoring and reporting, and GARFO believes the current system in place for black sea bass is inadequate to support an ASQ system. Other similar IFQ/ITQ fisheries in the region and country require systems such as vessel monitoring systems and pre-landing reporting for effective monitoring.
- Having part of the quota be allocated coastwide and part of it available for auction is also problematic:
    - Without a more robust system to track individual allocations at a vessel level, it would be difficult to track which landings should be counted against the coastwide quota and which should count against the ASQ.
    - It has not yet been specified how vessels could use this additional quota. For example, would they use the purchased quota only if the coastwide quota was harvested and Federal waters were closed? If so, what if the coastwide fishery does not close? Or would the additional quota allow for increased possession limits for certain individuals? This would be very difficult to monitor and enforce.
    - Past experiences with the research set-aside quota auction system demonstrated that it can be very difficult to effectively monitor and enforce additional allocated landings beyond a coastwide/state-managed quota.
- Though the term ASQ implies that there are seasonal quotas, GARFO assumes the intent is to hold one auction per year. If the intent were to have multiple seasonal auctions, this increases the complexity and concerns mentioned above.

There is also uncertainty regarding the Commission’s ability to administer an ASQ program. The Commission has concerns about the resource and staffing needs required to host and monitor such an auction. Currently, the Commission does not have a staff member that would be able to take on this role. In addition, the Commission does not have experience in administering ASQ or IFQ/ITQ systems; therefore a significant amount of staff time would be needed to determine the details of administering an auction. Based on past experiences, a quota auction system would likely be very difficult to monitor and enforce, therefore the Commission would need to determine if it would be possible to administer such a program with its current resources and authority.

b) Data Concerns

It has been suggested that commercial fishery efficiency may increase under the ASQ approach because the fishermen/vessels with the lowest operating costs relative to potential revenues may be most willing to purchase additional quota. The PDT noted that potential changes in fishery efficiency will be difficult to analyze based on available economic data and given that a variety of factors will likely influence fishermen's decisions regarding purchasing additional quota.

The PDT noted that some states may be better positioned to take advantage of additional black sea bass quota than others, depending on the scale of the increase in quota. For example, states with higher numbers of Federal black sea bass moratorium permits may be better able to utilize additional quota than states with lower numbers of moratorium permits. However, given the high demand for black sea bass and the high ex-vessel price compared to many other species (averaging $3.05 per pound in 2017), even states with lower numbers of permits may fully harvest additional quota. The PDT reviewed preliminary data on the number of federal moratorium permits issued each year from 1997 through 2017, as shown in Figure 6 below. The PDT cautioned that this analysis does not account for state-only permitted vessels, and some states may have robust fisheries in state waters.

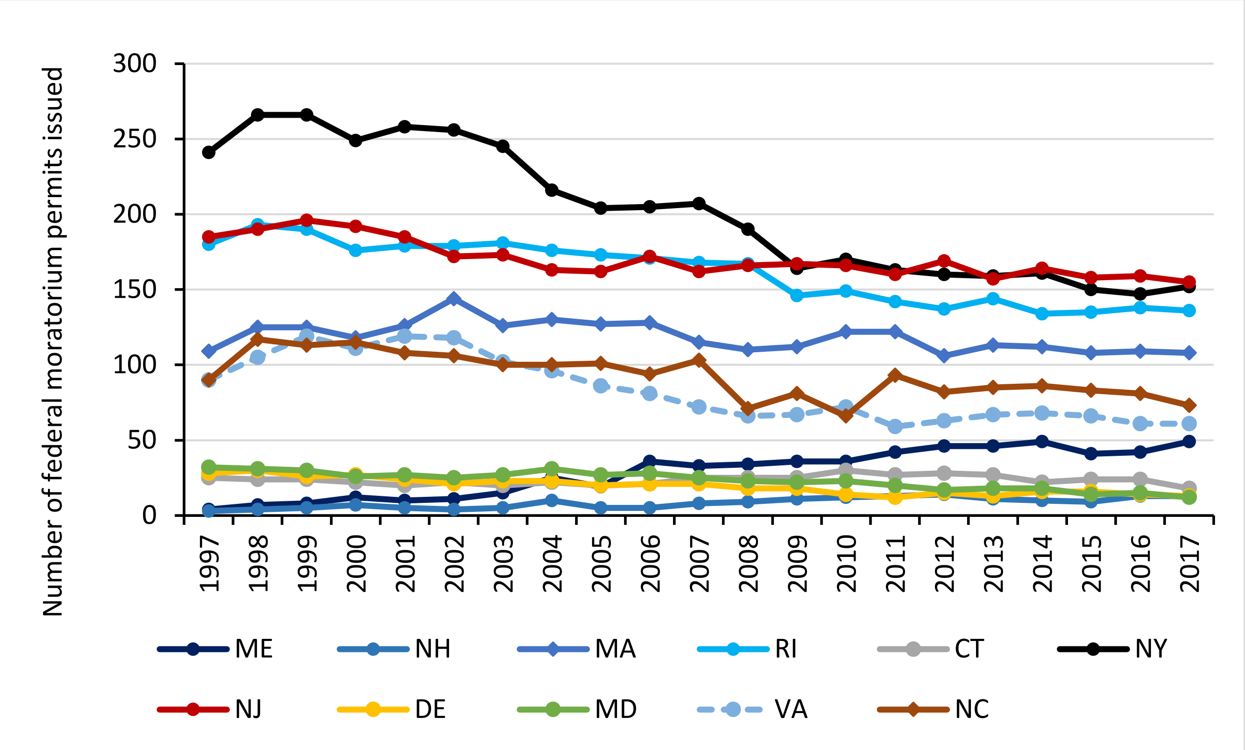


Figure 6. Number of vessels issued Federal moratorium black sea bass permits issued by state and year, 1997-2017. State is defined as the home port of the permitted vessel. Values should be considered approximate as they do not account for mid-year permit transfers and, as a result, may indicate higher numbers of moratorium permits than actually exist in a given year. Vessels in confirmation of permit history (i.e., eligible for a permit, but not issued a permit in a given year) are not accounted for.

c) Impacts of an ASQ Approach

As mentioned above, impacts of the ASQ approach to the black sea bass commercial fishery are inherently difficult to predict. The resulting quota distribution would be dependent on a number of factors, which could be related to economic forces as well as changes in the stock and the fishery. If the auction were to occur annually, there could be significant differences in the resulting ASQ allocations from year to year. Without reliable economic information on individual operations, it is difficult to estimate potential outcomes of this approach.

Some theoretical positive impacts that have been suggested are that an ASQ program could increase efficiency in the fishery, as top bidders would likely be those best able to catch the quota, and that it could provide more flexibility in allocation. Some possible negative impacts are: 1) it could allow for concentration of quota among those with more financial resources and/or larger operations which could disrupt the economies of many fishing communities; 2) states may want to consider an ITQ 'buy back' to compensate current ITQ holders, as ITQ has been a dependable source of income for these participants; 3) it would disadvantage state-only permitted vessels who would not be able to participate in an auction managed at the Federal level; and 4) increased complications of monitoring and enforcing such a program could result in compliance issues and exceeding the commercial quota without a clear way to pinpoint responsibility for the overage.

Considering the uncertainty and administrative concerns surrounding the ASQ approach, the PDT recommends careful consideration of this strategy. If the Board were interested in further developing the ASQ approach, the PDT feels it would have to focus *solely* on this approach, as adequately developing it will require an all-encompassing effort, and could not be done in parallel with multiple other options. It should also be noted that implementation of an ASQ program would require a joint amendment with the Council.

E. Hybrid Approaches

In addition to the individual methods presented above, the PDT discussed hybrid approaches where the coastwide quota is allocated among the states using two or more methods. This could essentially be an extension of the trigger approach (a portion of the quota, either a fixed amount or a percentage, up to the trigger value is distributed using historic allocation, and any remaining quota is distributed using equal allocation or biomass distribution), but could incorporate other options as the Board wishes. Use of a hybrid approach may offer flexibility and compromise for different perspectives, but at the cost of increased complexity. For example, a hybrid approach that incorporates a trigger, equal allocation, and regional allocation could be developed that assigns a portion of the coastwide quota using historic allocation to account for existing markets and fishing communities, a portion distributed equally to each state, and a portion to each region based on biomass distribution. Considerations and decision points for any hybrid approach would include all the considerations and decision points of each of the individual methods being combined. Additionally, depending on how a hybrid approach is developed, the drivers behind allocation adjustments could become unclear and difficult to track. Consideration of transparency is needed if selecting a hybrid approach, and additional work by the PDT may be required to clearly identify the impacts of each element of the approach.

III. Discussion

Throughout their discussions of each management strategy described above, the PDT highlighted a number of decision points the Board may need to consider in selecting the appropriate management programs for continued development. To come to a decision on some of these issues, it may be helpful to first define the Board's intention in considering changes to the black sea bass state-by-state allocations. Agreeing on a clear intention may guide the Board in focusing on the management strategies that best align with the objectives the Board seeks to meet.

Thus, the first general decision point would be to determine what the Board's goals are with regard to considering reallocation of the state-by-state commercial quotas. The key issue identified by the Commercial Working Group is that state commercial allocations implemented in 2003 do not reflect the current distribution of the resource. If the Board's goal is to address this issue by adjusting state-by-state commercial allocations to be more reflective of the current distribution of the resource, then the Board may want to focus on those strategies that incorporate regional information on resource distribution. If the Board's primary goal is to maintain historic access to the fishery, then it could consider options that place more weight on historic landings.

When considering approaches that address changes in resource distribution, another decision point arises in both the TMGC approach and the modified trigger approach: how to distribute quota to states within regions. Two general methods were discussed: equal distribution of regional quota, or distribution based on historic allocation. Though the PDT did not explore additional methods, it may be appropriate to consider distributing quota to states within the regions in a different way, depending on the purpose of reallocation. For example, if the Board aims to create more equality within the regions with regard to state quotas, then equal allocations of additional quota to the states in each region may be more appropriate (see TMGC Example 1a, and trigger Table 3, Appendix C). Alternatively, if the Board aims to maintain state access based on historic landings, it may be preferable to distribute quota to the states within each region based on their current allocations (see TMGC Examples 1 and 2, and trigger Table 4, Appendix C). Some compromises between these two goals could be addressed through a hybrid approach.

As mentioned in the considerations for the TMGC and modified trigger approaches, the ability to use regional biomass information from the stock assessment may change. It is uncertain whether incorporation of the new MRIP data will still produce biomass estimates for the northern and southern stock subareas. If not, it may be necessary to use survey information to do any resource distribution based approach. The Board should consider the implications of using either source of information to adjust allocations according to regional biomass. If regional biomass information from the stock assessment is available, the Board may need technical guidance on the most appropriate method for calculating regional proportions.

Another decision point the PDT discussed is regional configuration. In particular the group focused on how to incorporate Maine and New Hampshire, considering their historically low participation in the fishery, and how to incorporate New Jersey, as its geographic location adjacent to Hudson Canyon makes it difficult to place it in either the northern or southern spatial subarea of the stock. The PDT analyzed options that maintain static or proportionally lower allocations for Maine and New Hampshire, but these could be modified if the states were to express an interest in increased participation. The PDT also discussed potential methods for treating New Jersey as a stand-alone region, if deemed more appropriate than including it in the Southern Region. If a regional approach is taken, the Board should determine the most appropriate regional configuration.

The PDT also discussed the issue of stability in state commercial allocations. In prior discussions at the Working Group and Board level, some states expressed concerns about abrupt allocation changes that could disrupt the fishery. To better understand what constitutes abrupt change in order to avoid such disruptions, it may be helpful to define minimum quotas, or the maximum percent change per year with which the states would be comfortable. For comparison, Table 3 shows the coastwide quotas, and magnitude of change in quotas from year to year since 2003. On average, the coastwide quotas (and therefore the state quotas) have changed by 22% per year, excluding years where the constant catch approach was applied. It is important to bear in mind that state-by-state and coastwide quotas will continue to vary depending on the status of the stock, regardless of whether state-by-state allocations are modified.

Lastly, the PDT noted it could be important to establish a better understanding of where the fishery is occurring, and whether that has changed over time. Due to time limitations, the PDT was only able to analyze estimated commercial landings by state, year, and statistical area provided by the ACCSP. Preliminary results of this analysis are provided in Appendix D. If desired, the Board may request additional analysis of spatial data on black sea bass landings and or trips.

Table 3. Magnitude of annual change in black sea bass commercial quotas.

Year	Coastwide Quota (pounds)	% Change from Previous Year (absolute value)
2003	3,024,545	-
2004	3,768,575	25%
2005	3,966,345	5%
2006	3,832,312	3%
2007	2,385,390	38%
2008	2,025,763	15%
2009	1,093,190	46%
2010	1,758,610	61%
2011	1,711,080	3%
2012	1,710,000	0%
2013	2,174,312	27%
2014	2,174,312	0%
2015	2,212,923	2%
2016	2,702,867	22%
2017	4,120,000	52%
2018	3,520,000	15%
2019	3,520,000	0%
Average (excl. constant catch years)**		**22%**
Average (2016-2019)		**22%**

* Final adjusted quota after RSA

**Constant catch approach was used from 2010 to 2015

Appendix A. Black Sea Bass Commercial Working Group Report, February 2019

Working Group Members: David Borden (Chair, RI), Nichola Meserve (MA), Matthew Gates (CT), Joe Cimino (NJ), Rob O'Reilly (VA)

ASMFC Staff: Caitlin Starks, Toni Kerns

Additional Attendees: Julia Beaty (MAFMC), Greg Wojcik (CT), Jason McNamee (RI), Tiffany Vidal (MA)

Statement of the Problem

The working group has identified two problems associated with the current FMP. First, the commercial black sea bass allocations to the states were originally implemented in 2003 as part of Amendment 13, loosely based on historical landings from 1980-2001. The state shares in Amendment 13 allocated 67% of the coast-wide commercial quota among the states of New Jersey through North Carolina (North of Cape Hatteras) and 33% among the states of New York through Maine. These state commercial allocations have been unchanged for 15 years. Meanwhile, the resource has experienced shifts in distribution and abundance, and changes in fishing effort and fishing behaviors have occurred.

There is scientific information to support these shifts. For example, according to the last black sea bass stock assessment, which modeled fish north and south of Hudson Canyon separately, the majority of the stock occurred in the south prior to the mid-2000s. Since then the biomass in the north has grown considerably and currently accounts for the majority of spawning stock biomass (Figure 1). While the region specific models created for the assessment were never intended to be stand-alone, this shift in black sea biomass distribution has been supported by peer reviewed journal articles (e.g., Bell et al., 2015).

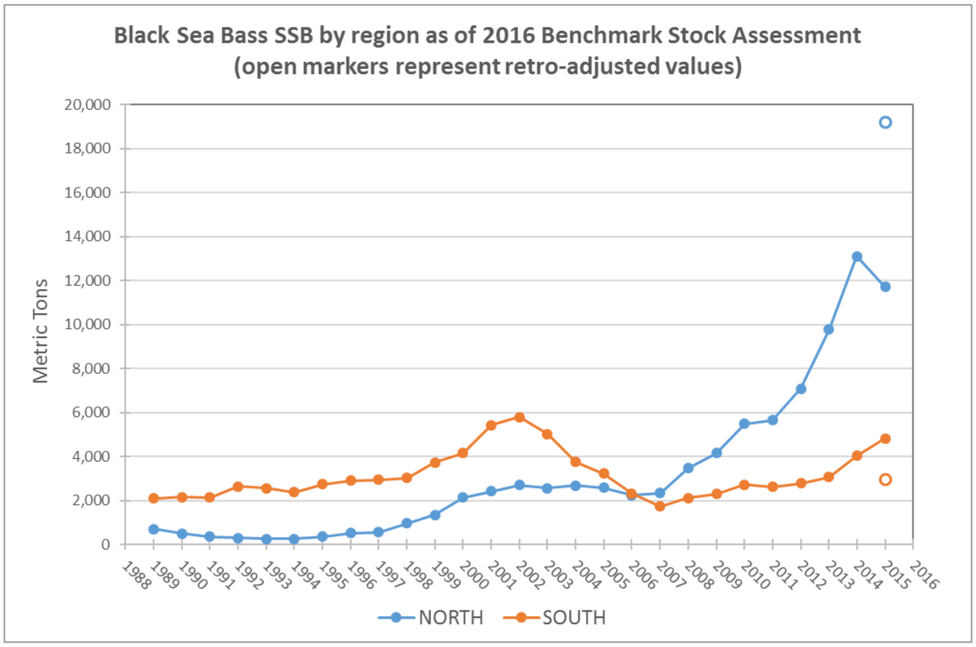


Figure 1: Black Sea Bass SSB by Region, 1989-2016. Source: 2016 Black Sea Bass Stock Assessment.

In some cases, expansion of the black sea bass stock into areas with historically minimal fishing effort has created significant disparities between state allocations and current abundance and resource availability. The most noteworthy example is Connecticut, which has experienced significant increases in black sea bass abundance and fishery availability in Long Island Sound in recent years but was only allocated 1% of the coastwide commercial quota based on landings from 1980-2001.

Any consideration of management changes by the Commission should be responsive to shifts in in black sea bass distribution, abundance, behavior, fishing effort and harvest by gear type. However, there are many additional factors requiring rigorous discussion and evaluation should reallocation be considered. Changes in allocations should take into account the following considerations and issues:

1. Allocations should be reviewed and revised on a regular basis to ensure equity of access and improve fishery efficiency (human safety, fuel use, and discards), using the latest and most appropriate data sources.
2. Changes in allocations should be linked to stock assessments to the extent practicable, or use other peer reviewed data sources. If such sources are unavailable, other scientific information such as state and federal survey indices could be used.
3. The relatively recent shift in spawning stock biomass does not mean that future abundance dynamics will proceed in the same manner, especially since a strong or weak year-class can provide an increase or decrease in abundance throughout the range or a portion of the range.
4. For states where resource availability has shifted significantly in recent years, the current allocations may provide either a disproportionate advantage or disadvantage if used as the basis for allocation adjustments (e.g. Connecticut's 1% allocation). Small changes to the original allocations may not reflect resource abundance, thus, adjustments may need to be made using a formula other than a simple percent change.
5. Participants in different areas have invested in the commercial fishery based on historic landing patterns as well as state management programs. For example, some mid-Atlantic states have adopted management through Individual Transferrable Quotas (ITQs), and the industry has invested in these fishing rights and infrastructure. To avoid unnecessary economic hardships and enhance the ability of the industry to respond and make long term business decisions, slow or gradual implementation of allocation changes should be considered.
6. Due to the high abundance relative to current allocations in the northern area, some states have lengthy closures that promote discards. Any reallocation formula should consider these factors and attempt to reduce closures and discards.
7. Review and reevaluation of commercial quota allocations should not occur in a vacuum and should take into account changes in recreational information. In particular, new recreational harvest estimates should be incorporated into the stock assessment before commercial changes are adopted.

A second problem relates to the provision in the FMP that prescribes a coastwide black sea bass quota managed by NOAA Fisheries. Under the current regulations, all states in the management unit are subject to fishery closures if a coastwide quota overage occurs, despite state-by-state quota management by the ASMFC. These closures can leave states with remaining commercial quota, especially ITQ, unable to utilize their full allocation of the resource. Management should aim to reduce impacts of state-specific commercial quota overages to other states. The working group recommends that the Mid-Atlantic Council consider actions to address this issue. For example, the working group suggested the Council consider allowing conservation equivalency for the commercial fishery, similar to what is allowed for recreational black sea bass and summer flounder.

Objectives and Goals to Address the Problem

The WG identified the following as management objectives for commercial black sea bass:

- Ensure fishing mortality and spawning stock biomass are maintained within established thresholds and targets, and the stock is not overfished nor experiencing overfishing
- Improve equity in access to the fishery among the states
- Improve fishery efficiency (e.g. use of time, fuel and other resources; reducing discards)

The WG discussed the need to determine what metric(s) would be used to evaluate equity in access to the fishery. Some ideas discussed were socioeconomic benefits or opportunities, as well as resource availability related to the distribution of exploitable biomass and abundance. The WG noted discard reductions and increased efficiency would likely result from allocations based on more current information on the resource's distribution along the coast. However it was noted that fishery efficiency may also be impacted by factors other than resource allocation (e.g., allowances to possess multiple states' limits in the same trip).

The WG proposed the following information, particularly for recent years, should guide further development of management objectives and strategies.

- Descriptions of each state's fishery including but not limited to: management program, participation, effort, landings by gear, distribution of landings and trips, commercial size distribution, and socioeconomic information
- A comprehensive review of survey data for black sea bass to inform understanding of stock biomass/abundance distribution and availability to state commercial fisheries
- Current scientific information on the geographic shifts in black sea bass biomass

Potential Management Strategies

The WG agreed a wide range of options should be considered, and that some management strategies may require coordination with the Mid-Atlantic Fishery Management Council. Some of the ideas the WG supported exploring further included:

1. Adjustments to the state-by-state allocations. Potential options include:
    a. Status quo
    b. Dynamic approach modeled after the Transboundary Management Guidance Committee (TMGC) approach (Appendix I)
2. Defined timeline or trigger for reevaluation of allocations
    a. Future consideration of a strategy similar to the scup model to increase equitability in access for federal vessels (i.e. winter coastwide quota management and summer state-by-state quota management) (Appendix II)

As indicated in the problem statement, consideration should be given to how management approaches may impact fishery stakeholders in each region, and efforts made to balance negative economic impacts with enhanced equity and efficiency of the fishery along the coast.

Appendix B. TMGC Approach

Proposed New Allocation Alternative For Black Sea Bass: Dynamic Transboundary Approach

Black Sea Bass PDT

22 April 2019

Introduction

This proposal offers a new alternative for modifying the allocation of the commercial black sea bass quota. It involves a dynamic approach for gradually adjusting state-specific allocations using a combination of resource utilization (historical allocations) and current levels of resource distribution. The alternative is modeled after the Transboundary Management Guidance Committee (TMGC) approach, which was developed and used for the management of shared Georges Bank resources between the United States and Canada.

As noted by Gulland (1980), the designation of units for management entails a compromise between the biological realities of stock structure and the practical convenience of analysis and policy making. For black sea bass, the Atlantic Coast states from North Carolina to Maine - acting through and by the MAFMC, ASMFC, and GARFO – use a single management unit encompassing the entire region occupied by the stock, from the southern border of North Carolina northward to the U.S.- Canadian border. While there is a general scientific consensus that the black sea bass population has shifted its center of biomass to the northen portion of its range (Bell et al. 2014 and NEFSC 2017), the current management structure, as reflected by current state-by-state allocations, does not recognize this new population dynamic.

This new alternative sets forth an approach that balances stability within the fishery, based on historical allocations, with gradual adjustments to the fishery, based on regional shifts in resource distribution emanating from updated stock assessments or surveys. The approach affords considerable flexibility, both with regard to initial configurization and application over time. A key feature involves the use of control rules to guard against abrupt shifts in allocations.

This new alternative draws upon established principles of resource sharing, which include consideration of access to resources occurring or produced in close spatial proximity to the states in the management unit and historical participation in the exploitation of the resources (Gavaris and Murawski 2004). The former has emerged from the changing distribution of the black sea bass resource and the effects this creates within the fishery. The latter recognizes traditional involvement and investment in the development of the fishery since the the beginning of black sea bass joint management in 1996. Both principles were incorporated in the TMGC approach; historical participation was initially afforded primary emphasis, then gradually down-weighted so that, after a nine-year phase-in period, the annual allocation was based primarily on resource distribution (Murawski and Gavaris 2004). The approach proposed here for black sea bass is similar; the proposal envisions a gradual transition, giving more weight to historical participation at first, then slowly phasing in the distributional aspects over time, and then implements changes to state specific allocations through a two-step process.

Details for the calculations used for the TMGC approach were described by Murawski and Gavaris (2004). Modifications to that approach are necessary, given key differences between the shared Georges Bank resources and the shared black sea bass resource. Those differences include the state-by-state allocation system currently in place for black sea bass, the need to translate from regional to state-specific allocations, and the need to accomodate multiple jurisdictional differences in the fishery.

This new alternative proposes use of existing state-by-state allocations to reflect initial values for historical participation (aka resource utilization) and proposes use of the 2016 benchmark stock assessment results(NEFSC 2017) to determine the values for resource distribution; the two values are then integrated in the form of regional shares. An alternative to using the stock assessment would be to use synoptic trawl survey information. This potential alternative is described in more detail below. The two regions as defined in the assessment are proposed: (1) ME - NY, (2) NJ - NC. They emanate from the spatial stratification of the stock in to units that generally align with those used for the assessment, which used the Hudson Canyon as the dividing line based on several pieces of evidence that stock dynamics had an important break in this area. These regional shares are then sub-divided into state-specific allocations.

The overall approach can be modified by the Board and Council in various ways. For example, sub-alternatives can be developed for:

- the regional configuration (e.g., other regions beyond those proposed here);
- the values for historical participation/resource utilization (e.g., current, status quo allocations, or some variant thereof);
- the percentage weighting values for Resource Utilization and Resource Distribution (90:10, or some variant thereof);
- the increment of change in these values from one year to the next (10%/year, or some variant thereof;
- the periodicity of adjustments (e.g., annually vs. biannually); and
- the overall time horizon for the transition (e.g., 9 years vs. 18 years).

The control rule can also be evaluated via two or more sub-alternatives (e.g., a cap that's higher or lower than 10%).

Data and Methods

Formula

Adapted from the TMGC application (TMGC 2002), the approach for calculating the respective regional shares, which takes historical utilization in to account and adapts to shifts in resource distribution, is as follows:

$$\%RegionalShare = (\alpha_y * \sum_r StateSpecAlloc) + (\beta_y * \%ResDistr_{r,y}) \quad (1)$$

Where α_y = percentage weighting for utilization by year; β_y = percentage weighting for resource distribution by year; $\alpha_y + \beta_y = 100\%$; $StateSpecAlloc$ = state specific allocation; $ResDistr$ = resource distribution; r = region; y = year

Proposed regions:
Two regions are proposed: (1) ME - NY, (2) NJ - NC.

Proposed values for historical participation/resource utilization:
See Resource Utilization section below.

Proposed values for resource distribution:
The current proposal is to use the distribution in the two regions based on the stock assessment biomass calculations. This could be altered to use synotpic trawl survey information, therefore resource distribution would be based on most recent trawl survey information in that case.

Proposed percentage weighting values for resource utilization and resource distribution:
The initial sharing formula is proposed to be based on the weighting of resource utilization (from historical allocations) by 90% and the weighting of resource distribution by 10%. Additional alternatives are prtesented below.

Proposed increments of change in the weighting values from one adjustment period to the next: Initially proposed at 10% per period. Thus, 90:10 to begin, then: 80:20, 70:30, 60:40, 50:50; 40:60; 30:70; 20:80, concluding at 10:90. Other alternatives are tested below.

Proposed periodicity of the adjustments:
Bi-annually based on stock assessment updates. If the survey alternative were used, this could be increased to annually.

Overall time horizon for the transition:
The initial proposal would conclude in 9 years. If commenced in 2020, it would conclude in 2028

With these - or alternative - parameters assigned, the region-specific shares then need to be prorated into the existing state-specific allocation structure. This can be accomplished by:

$$NewStateAllocation = \frac{Allocation_s}{\sum_r StateSpecAlloc} * \%RegionalShare \quad (2)$$

Where $Allocation_s$ = the specific state being calculated

Resource Utilization

Historical state-specific commercial allocations for black sea bass are codified in Amendment 13 to the Fishery Management Plan for Black Sea Bass (FMP) (MAFMC 2003) (Table 2). These allocations can serve as the basis for the resource utilization values in the allocation formula. These values, as used in the formula, would remain consistent throughout the reallocation process, even as the final state allocations change over time, based on equations 1 and 2. This is philosophically consistent with the FMP, as this portion of the allocation formula is meant to represent the historical fishing aspects of the black sea bass fishery.

However, alternative strategies (set forth in the form of sub-alternatives) could be used to set the initial allocation design. That is, the initial resource utilization portion of the allocation design could be adjusted, via revised state allocations, before transitioning into the formulaic approach to be used as the process moves forward.

One way to implement this type of approach would be the following, working from equation 2 above:

$$NewStateAllocation = \frac{Allocation_s + \lambda_s}{\sum_r StateSpecAlloc} * \%RegionalShare \quad (3)$$

Where λ = a state specific allocation additive or reduction factor and s = the state being calculated.

This formula allows for a shift in initial (status quo) allocations to account for potential discrepencies believed to be represented in the existing allocations.

Resource Distribution

This proposal offers two options for calculating the resource distribution. The first option would be to use the spatial stock assessment to determine the amount of resource in each region (north = NY, CT, RI, MA, NH, ME; south = NJ, DE, MD, VA, NC). The spatial stock assessment calculates a north and south biomass value, which can then be turned in to a proportion. The benefit of this approach is this number is calculated through a synthesis of many biological parameters and represents the best available science for the population. The drawback is that the assessment is updated periodically (not every year), therefore the information will not be evaluated every year, but would depend on the assessment cycle. Additionally, if the spatial stock assessment were to fail at some point in the future, this would impact the ability to do the dynamic allocation calculations. The current estimated allocation from the benchmark assessment would be 6,800 MT (January 1 biomass) in the south, 17,000 MT (January 1 biomass) in the north, equating to 29% of the biomass in the south and 71% of the biomass in the north (NEFSC 2017). It is important to note that these are the unadjusted biomass amounts from the assessment. Since data are readily available for this option, an example calculation and projection has been developed below. The process set forth below addresses total biomass, but it could be modified (and presented as a sub-alternative) to address exploitable biomass.

As an alternative, values for resource distribution can be obtained and calculated using scientific surveys, with results apportioned into regions. Since surveys are undertaken annually, the values for resource distribution, by region, can be recalculated and updated annually, biannually, or upon whatever timeframe is deemed most appropriate, affording an opportunity to regularly adjust allocations in sync with shifts in resource distribution. Such shifts may, or may not, follow consistent trends. Accordingly, the technique affords a dynamic approach, consistent with actual changes in resource distribution. Drawing upon the TMGC approach, a swept area biomass, considered a relative index of abundance, can be computed in each stratum, then summed to derive the biomass index for each region. The biomass index estimate derived from each survey would represent a synoptic snapshot of resource distribution at a specific time during a year. Combining the results of multiple surveys requires an understanding of seasonal movement patterns and how much of the biological year each survey represents. For this reason, it is proposed to use the National Marine Fisheries Service (NMFS) Trawl Survey in combination with the North East Area Monitoring and Assessment Program (NEAMAP) Survey. These are both well-established surveys, currently used in the stock assessment, and are synoptic, covering both offshore and inshore strata. As proposed in this alternative, the existing survey strata could be used to partition the survey information into two stock regions: (1) ME - NY, and (2) NJ - NC. The strata do not align perfectly with these two spatial configurations, but they are relatively close (Figures 1 and 2). Table 1 provides an example of how the strata could be applied for each region.

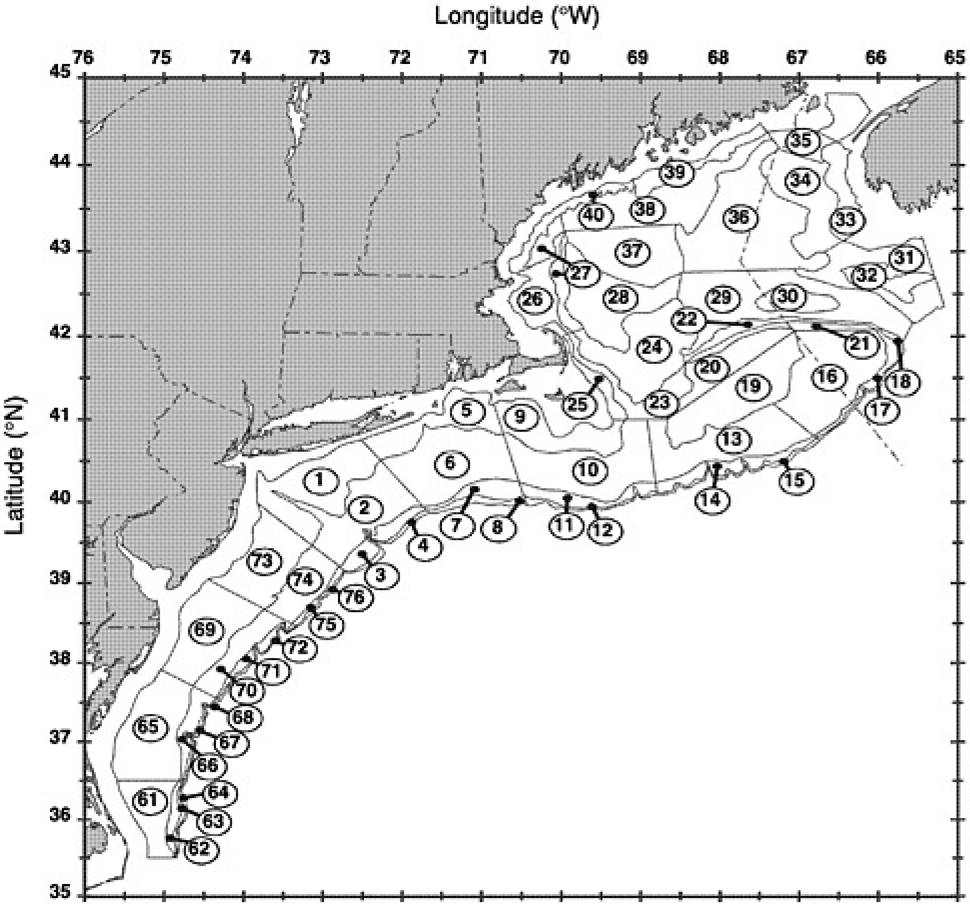
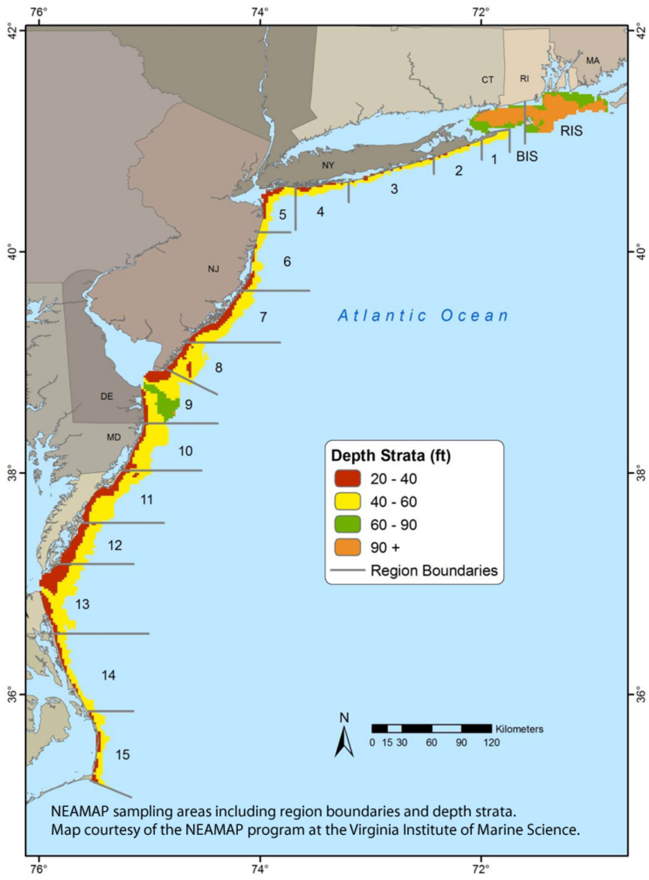


Figure 1: Map of National Marine Fisheries Service trawl survey strata.



NEAMAP sampling areas including region boundaries and depth strata.
Map courtesy of the NEAMAP program at the Virginia Institute of Marine Science.

Figure 2: Map of North East Area Monitoring and Assessment Program trawl survey strata.

Table 1 - Strata or Region assigned to each region for resource distribution calculations.

Regions	NMFS Strata	NEAMAP Regions
Region 1: ME - NY	1 - 40	1 - 5, BIS, RIS
Region 2: NJ - NC	3, 61 - 76	6 - 15

*Note: This is a first cut, these should be finalized through discussions between the TC and survey staff.

This approach could be refined over time by developing area polygons that better align with the boards desired regional configuration. Then, using the spatial information from the surveys, the survey information could be partitioned into the polygons.

Additionally, there may be ways to use state survey information within the analysis – either directly by averaging those surveys into the swept area biomass calculations, or indirectly such as using them to verify or corroborate the information from the surveys used in the calculations. Such use of state survey information could be developed and integrated into the process over time via analysis and recommendations from the monitoring and technical committees.

A robust, locally weighted regression algorithm (Cleveland 1979), referred to as LOESS, could then be used to mitigate excessive variations in sampling results. Per the TMGC approach, a 30% smoothing parameter could be used. That level of smoothing was chosen because it reflected current trends, was responsive to changes, and provided the most appropriate results for contemporary resource sharing. The recommended default of two robustness iterations also was adopted (Cleveland 1979) in the TMGC approach and could also be adopted here. Resource distributions could then be updated annually by incorporating data from the latest survey year available and dropping data from the earliest survey used in the previous year so that a consistent window of data is maintained. After the surveys are combined, the LOESS smoother would be applied to the survey data. The fixed resource utilization (90% weighting in year 1) and the most recent resource distributions as calculated by the surveys (10% weighting in year 1) can then be applied to the sharing formula to determine regional allocation shares for the upcoming fishing year.

The benefit of this approach is that it could be performed annually with the most contemporary data. The drawback is that survey data are prone to variability. The LOESS smoothing and the control rule set forth below are designed to account for some of this variability to keep it from causing unreasonable changes in a single year.

As a final nuance to the survey alternative, a sophisticated modeling approach could be developed to achieve the same information as above. Techniques like the use of the VAST model (Thorson 2015) have been shown to be appropriate for this type of an analysis and could be adopted, in lieu of the swept area biomass technique, as a method for calculating resource distribution by region.

For this proposal, the assessment technique will be used as there is actual data that can be used to examine an example. With additional work, a retrospective analysis using trawl survey information could be developed.

Control Rule

In addition to the formula for calculating the regional allocations and then translating into the state specific allocations, additional measures could be added by way of a control rule. Such measures would enable various checks and balances to be incorporated into the process to guard against unintended consequences.

One such control rule, proposed here, is to guard against any abrupt change occurring to any regional allocation in any given year (or other time frame), and thus minimize short-term impacts, by capping the amount of any annual or bi-annual change to the regional shares at 10%. This can be shown as:

$$\%RegionalShare = \begin{cases} 10\%, & \text{if } \Delta AnnualChange > 10\% \\ \%RegionalShare, & \text{if } \Delta AnnualChange \leq 10\% \end{cases} \tag{1}$$

The effect would be to ensure that any changes to allocations occur incrementally, even in a case of large shifts in resource distribution in any given year or period. This control rule serves as an additional layer of protection against large changes, in addition to the other factors outlined above that are also built in to contend with uncertainty and variability.

Flexibility

A key attribute of this proposed new approach for modifying the allocation system is its flexibility. All of the decision points set forth in this proposal, once agreed to, can be adjusted as the process moves forward. Such adjustments, emanating from routine reviews by the Board and Council, can address any of the range of parameters initially set by the Board and Council. The Board and Council could define how changes to the system would be considered and enacted moving forward - e.g., via Addenda and Frameworks, the specifications process, or some other mechanism. The ranges of parameters/issues that readily lend themselves to such adjustment include:

- The α and β parameters can be adjusted to change the way the utilization and distribution are weighted in the equation;
- The increment of change in the α and β parameters can be adjusted to increase or decrease the transition speed;
- The time horizon for the transition can be changed;
- The initial state allocations can be set at status quo, or shifted to accommodate various objectives; and
- The control rule can be adjusted to be more or less protective of incremental changes.

Given such flexibility, the Board and Council could decide to implement a transition program that begins in 2020, with either current, status quo allocations, or some variant thereof, and based on assessment information through 2018 (same information used for the proposed 2019 operational stock assessment update), establish resource distribution values for each of the two regions. Using those parameters, and a weighting of allocations by 90% and resource distribution by 10%, enact new, slightly revised state-specific allocations for 2020. If the Board and Council opted for a transitional program involving 10% annual increments, until the weightings reached 10% utilization from historical allocations and 90% resource distribution, this sharing formula would transition from a 90:10 resource utilization-to-resource distribution weighting in 2020 to a 10:90 weighting by 2028. During every transitional period, the trawl survey information would be updated and factored into the resource distribution values. As such, each regional and associated state-specific adjustment would not necessarily be the same, whether in magnitude or direction.

Alternatively, the Board and Council could opt for a transitional program involving 10% increments every two years, or 5% annual increments, or 5% increments every two years, etc. Those alternatives would significantly slow the transition. Some of these variants are illustrated below as examples.

Example

The following are examples of how the new approach can be applied; it incorporates various proposed or strawman parameters, all of which can be modified upon review and consideration by the Board and Council:

- The assessment information is used to calculate the Resource Distribution values.
- Step 1: Apply the state-specific allocations and resource distribution information to equation 1.
    - Summed state allocations for Region 1 (sum of ME-NY)

```
sum.reg1
```

```
## [1] 0.33
```

- Summed state allocation for Region 2 (NJ - NC)

```
sum.reg2
```

```
## [1] 0.67
```

- Step 2: Apply the Resource Distribution information to equation 1.
    - Strawman values:

```
dist.reg1 = 0.71
dist.reg2 = 0.29
```

- Step 3: Select α and β parameters for equation 1 for year 1:
    - The initial sharing formula is proposed to be based on the weighting of resource utilization (from historical allocations) by 90% and the weighting of resource distribution by 10%. Thus:

```
alpha = 0.9
beta = 0.1
```

- Step 4: Calculate the results, in the form of proportional regional shares, from equation 1:

```
# Region 1 equation and result
Reg1.Share = (alpha*sum.reg1) + (beta*dist.reg1)
Reg1.Share
```

```
## [1] 0.368
```

```
# Region 2 equation and result
Reg2.Share = (alpha*sum.reg2) + (beta*dist.reg2)
Reg2.Share
```

```
## [1] 0.632
```

  - This does not account for any change to the original allocations, see step 6 below.

- Step 5: Determine need to apply the control rule

```
# Control Rule
if (abs(Reg1.Share-sum.reg1) > 0.1 | abs(Reg2.Share-sum.reg2) > 0.1 ) {
  if (Reg1.Share-sum.reg1 > 0) {
    Reg1.Share = (sum.reg1*(0.1))+sum.reg1
    Reg2.Share = (sum.reg2*(-0.1))+sum.reg2

  }
  if (Reg2.Share-sum.reg2 > 0) {
    Reg1.Share = (sum.reg1*(-.1))+sum.reg1
  Reg2.Share = (sum.reg2*(0.1))+sum.reg2

  }

}
```

  - As proposed, the rule would cap any change at 10%. Since none of the resulting shares change by more than 10%, the control rule would not apply in this case.

- Step 6: Establish the state-specific allocation structure to be pro-rated by the regional shares. This example **does not** apply a λ value to alter the allocations per equation 3.
  - The state-specific allocations could be the current, status quo allocations; or they could be variants, established via equation 3.

Table 2 - Current state by state allocations.

State	Current Allocation
Maine	0.005
New Hampshire	0.005
Massachusetts	0.130
Rhode Island	0.110
Connecticut	0.010
New York	0.070
New Jersey	0.200
Delaware	0.050
Maryland	0.110
Virginia	0.200
North Carolina	0.110

Four hypothetical examples of state-specific allocations under the new program were performed and are presented below (Tables 3, 4, 5, and 6; Figures 3, 4, 5, and 6).

Example 1: The first example represents a configuration resulting in more liberal change in state allocations. The parameters are set as follows: 2 regions (ME - NY; NJ - NC); resource utilization = status quo allocations ; transition from 90:10 to 10:90; 10% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 90% weight on the resource distribution is 9 years; 10% control rule;

distribution assumption is based on the biomass by region from the assessment for the time period of 2004 - 2012; distribution of adjustments to states within a region are based on historic allocations.

Example 2: Any TMGC configuration could also be modified to distribute the allocation adjustments equally to the states within each region, instead of distributing those adjustments proportionally to the historic state allocations. This example represents a configuration resulting in more liberal change in state allocations as noted in example 1. The parameters are set as follows: 2 regions (ME - NY; NJ - NC); resource utilization = equal allocations to each state within the region; transition from 90:10 to 10:90; 10% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 90% weight on the resource distribution is 9 years; 10% control rule; distribution assumption is based on the biomass by region from the assessment for the time period of 2004 - 2012; distribution of adjustments to states within a region are based equal distribution.

Example 3: The third example represents a more conservative configuration, with more limited changes to state allocations. The parameters are set as follows: 2 regions (ME - NY; NJ - NC); resource utilization = status quo allocations; transition from 90:10 to 30:70; 5% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 70% weight on the resource distribution is 12 years; 3% control rule; distribution assumption is based on the biomass by region from the assessment for the time period of 2004 - 2015; distribution of adjustments to states within a region are based on historic allocations.

Example 4: The final example is intended to showcase a number of additional modifications that could be made to the approach to achieve certain objectives. In discussions amongst the PDT (and previously the Board regarding recreational black sea bass) it has been noted that it may be appropriate to treat New Jersey as an individual region due to its geographic position straddling the division of the Northern and Southern regions adjacent to Hudson Canyon. Additionally, some Board members have suggested modifying the "resource utilization" part of the equation to increase the allocations for Connecticut and New York due to their allocations being disproportionate to their current resource availability. Lastly, the PDT discussed the option of holding Maine and New Hampshire's current allocations static throughout the transaction. To demonstrate these modifications, the parameters are set as follows: 4 regions (ME and NH remaining as a non-dynamic region with static allocations; MA - NY; NJ as a stand-alone region; and DE - NC); resource utilization = CT and NY base allocations increased by 1% in each of the first three years; transition from 90:10 to 10:90; 10% per year change in the transition from utilization to distribution; annual adjustments; the transition time to 90% weight on the resource distribution is 9 years; 10% control rule; distribution assumption is based on the biomass by region from the assessment for the time period of 2004 - 2012, and assumes NJ is consistently 60% of the southern region distribution; distribution of adjustments to states within a region are based on historic allocations plus the incremental change as noted above.

The allocations presented in these tables would be different if any of the parameters were changed. Additionally, note that these examples are based on a scenario where the approach was implemented in 2004. The example shows how the system would work and the effects to the states over the initial period of adjustment from Resource Utilization having the highest weight in the equation to Resource Distribution having the highest weight during a period of time where the biomass was rapidly changing.

Table 3 - Allocation trajectory for all states under the parameters outlined in example 1 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

State	2004	2005	2006	2007	2008	2009	2010	2011	2012
Maine	0.005	0.005	0.006	0.006	0.007	0.008	0.009	0.009	0.010
New Hampshire	0.005	0.005	0.006	0.006	0.007	0.008	0.009	0.009	0.010
Massachusetts	0.134	0.139	0.149	0.168	0.187	0.206	0.224	0.240	0.268
Rhode Island	0.113	0.117	0.126	0.142	0.158	0.174	0.189	0.203	0.227
Connecticut	0.010	0.011	0.011	0.013	0.014	0.016	0.017	0.018	0.021
New York	0.072	0.075	0.080	0.090	0.101	0.111	0.120	0.129	0.144
New Jersey	0.197	0.193	0.186	0.171	0.157	0.143	0.129	0.116	0.095
Delaware	0.049	0.048	0.046	0.043	0.039	0.036	0.032	0.029	0.024
Maryland	0.109	0.106	0.102	0.094	0.086	0.078	0.071	0.064	0.052
Virginia	0.197	0.193	0.186	0.171	0.157	0.143	0.129	0.116	0.095
North Carolina	0.109	0.106	0.102	0.094	0.086	0.078	0.071	0.064	0.052

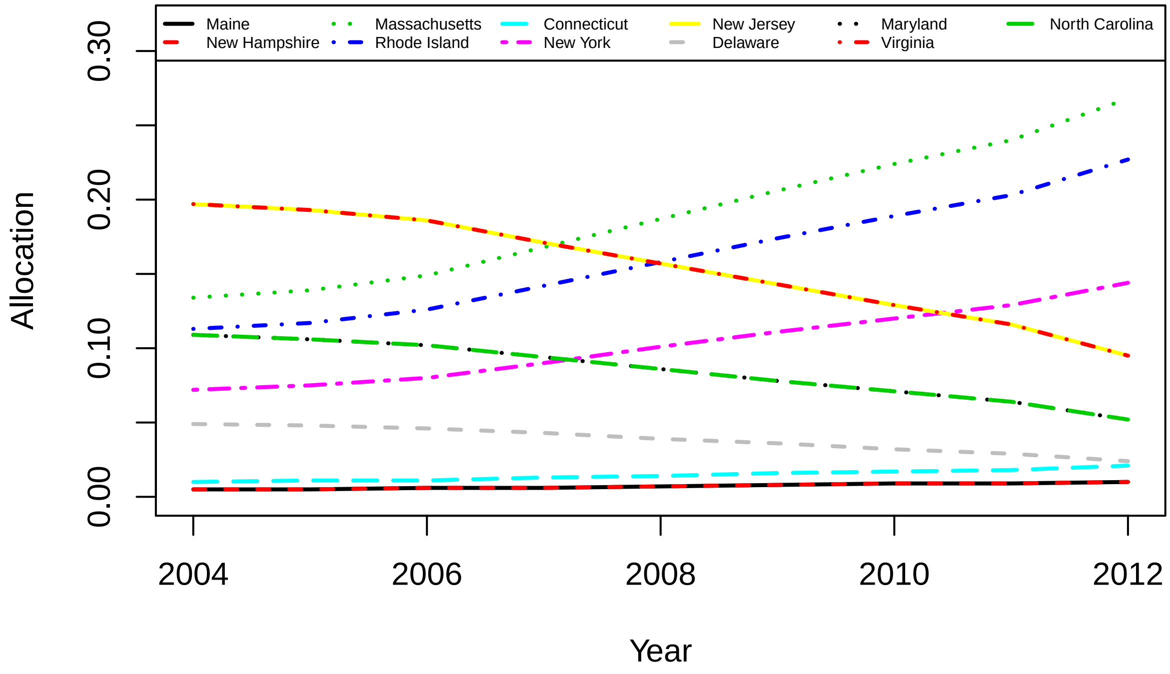


Figure 3: Allocation trajectory for all states under the parameters outlined in example 1 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

Table 4 - Allocation trajectory for all states under the parameters outlined in example 2 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

State	2004	2005	2006	2007	2008	2009	2010	2011	2012
Maine	0.070	0.071	0.074	0.082	0.093	0.102	0.109	0.112	0.119
New Hampshire	0.016	0.027	0.044	0.064	0.084	0.099	0.108	0.112	0.119
Massachusetts	0.106	0.099	0.094	0.094	0.099	0.105	0.110	0.113	0.119
Rhode Island	0.124	0.114	0.104	0.101	0.102	0.106	0.110	0.113	0.119
Connecticut	0.012	0.024	0.041	0.063	0.083	0.098	0.108	0.112	0.119
New York	0.012	0.024	0.041	0.063	0.083	0.098	0.108	0.112	0.119
New Jersey	0.111	0.111	0.108	0.099	0.088	0.077	0.069	0.065	0.057
Delaware	0.192	0.176	0.154	0.127	0.101	0.083	0.071	0.065	0.057
Maryland	0.111	0.111	0.108	0.099	0.088	0.077	0.069	0.065	0.057
Virginia	0.057	0.068	0.078	0.081	0.079	0.073	0.068	0.065	0.057
North Carolina	0.192	0.176	0.154	0.127	0.101	0.083	0.071	0.065	0.057

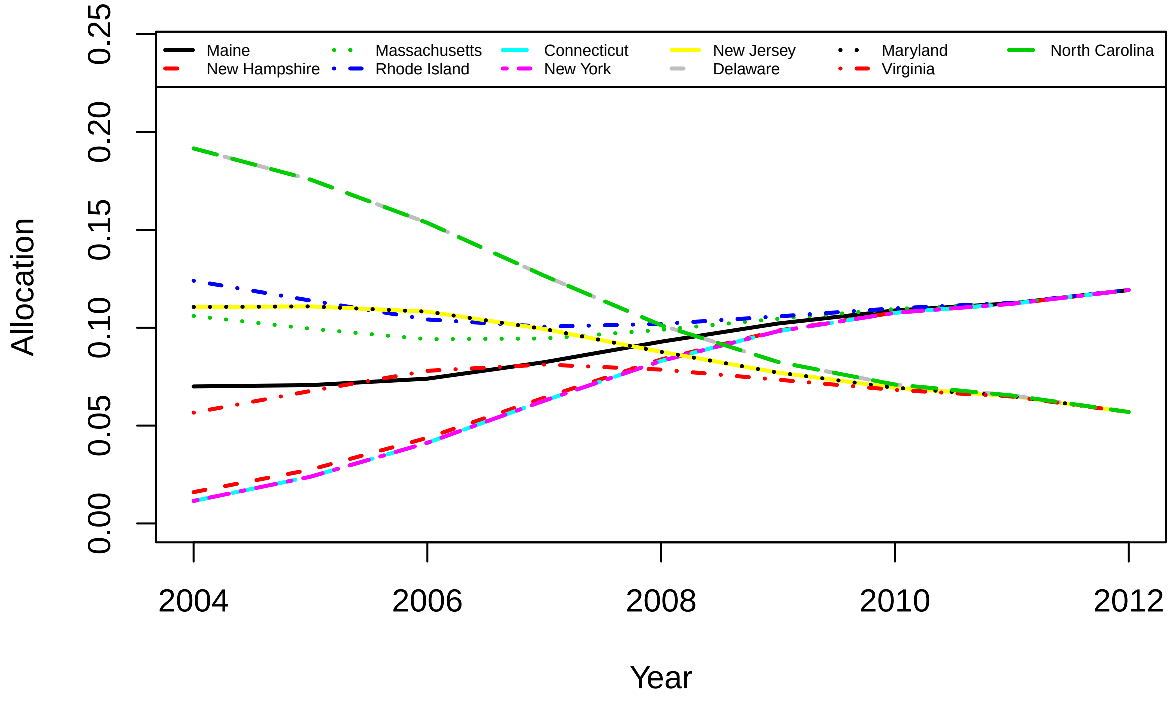


Figure 4: Allocation trajectory for all states under the parameters outlined in example 2 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

Table 5 - Allocation trajectory for all states under the parameters outlined in example 3 above. The control rule is triggered in each year from 2012 through 2015 in this example. This is a retrospective analysis as if this method were in place beginning in 2004. The control rule is triggered in 2012 - 2015 in this example.

State	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Maine	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008
New Hampshire	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008
Massachusetts	0.132	0.134	0.139	0.149	0.159	0.168	0.177	0.185	0.191	0.196	0.202	0.209
Rhode Island	0.112	0.114	0.118	0.126	0.134	0.142	0.150	0.157	0.161	0.166	0.171	0.176
Connecticut	0.010	0.010	0.011	0.011	0.012	0.013	0.014	0.014	0.015	0.015	0.016	0.016
New York	0.071	0.072	0.075	0.080	0.085	0.090	0.095	0.100	0.103	0.106	0.109	0.112
New Jersey	0.199	0.197	0.193	0.186	0.178	0.171	0.164	0.158	0.153	0.148	0.144	0.140
Delaware	0.050	0.049	0.048	0.046	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.035
Maryland	0.109	0.108	0.106	0.102	0.098	0.094	0.090	0.087	0.084	0.082	0.079	0.077
Virginia	0.199	0.197	0.193	0.186	0.178	0.171	0.164	0.158	0.153	0.148	0.144	0.140
North Carolina	0.109	0.108	0.106	0.102	0.098	0.094	0.090	0.087	0.084	0.082	0.079	0.077

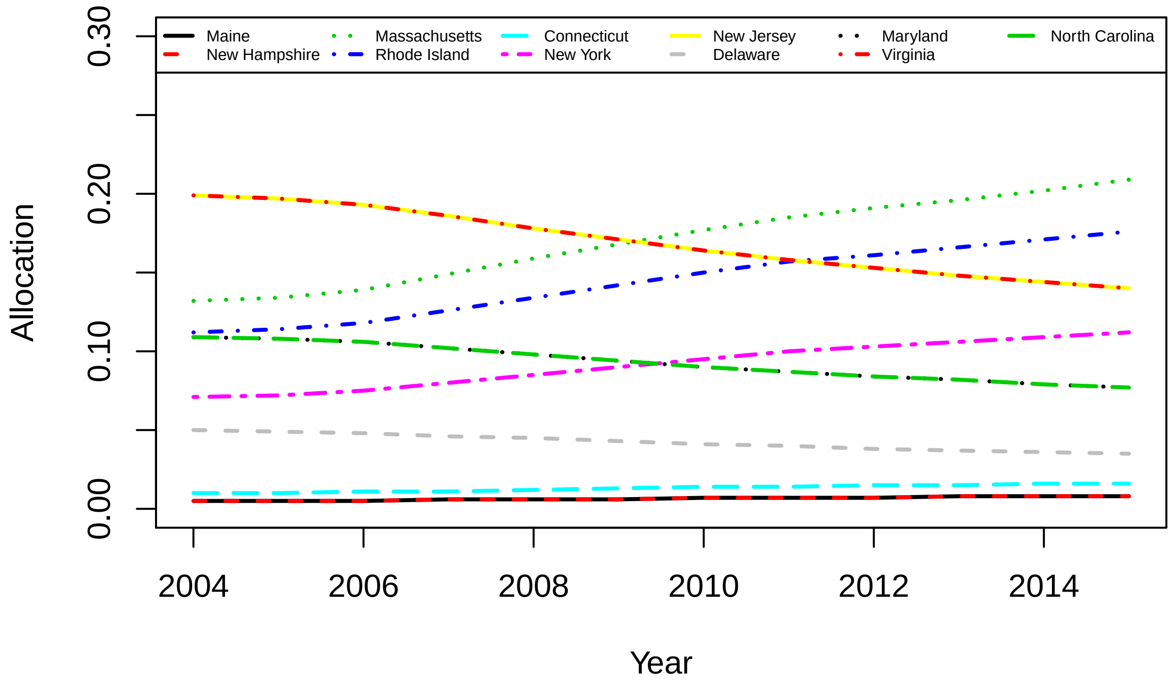


Figure 5: Allocation trajectory for all states under the parameters outlined in example 3 above. The control rule is triggered in each year from 2012 through 2015 in this example. This is a retrospective analysis as if this method were in place beginning in 2004. The control rule is triggered in 2012 - 2015 in this example.

Table 6 - Allocation trajectory for all states under the parameters outlined in example 4 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

State	2004	2005	2006	2007	2008	2009	2010	2011	2012	NA
Maine	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
New Hampshire	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Massachusetts	0.129	0.129	0.127	0.127	0.147	0.166	0.188	0.206	0.219	0.236
Rhode Island	0.109	0.109	0.106	0.106	0.123	0.139	0.157	0.172	0.183	0.197
Connecticut	0.020	0.020	0.031	0.042	0.048	0.055	0.062	0.068	0.072	0.078
New York	0.081	0.081	0.092	0.105	0.121	0.137	0.155	0.169	0.180	0.195
New Jersey	0.209	0.209	0.230	0.236	0.239	0.230	0.218	0.206	0.192	0.170
Delaware	0.044	0.044	0.038	0.034	0.028	0.024	0.019	0.016	0.013	0.011
Maryland	0.101	0.101	0.090	0.084	0.069	0.059	0.046	0.038	0.033	0.026
Virginia	0.186	0.186	0.168	0.158	0.130	0.111	0.087	0.072	0.062	0.049
North Carolina	0.101	0.101	0.090	0.084	0.069	0.059	0.046	0.038	0.033	0.026

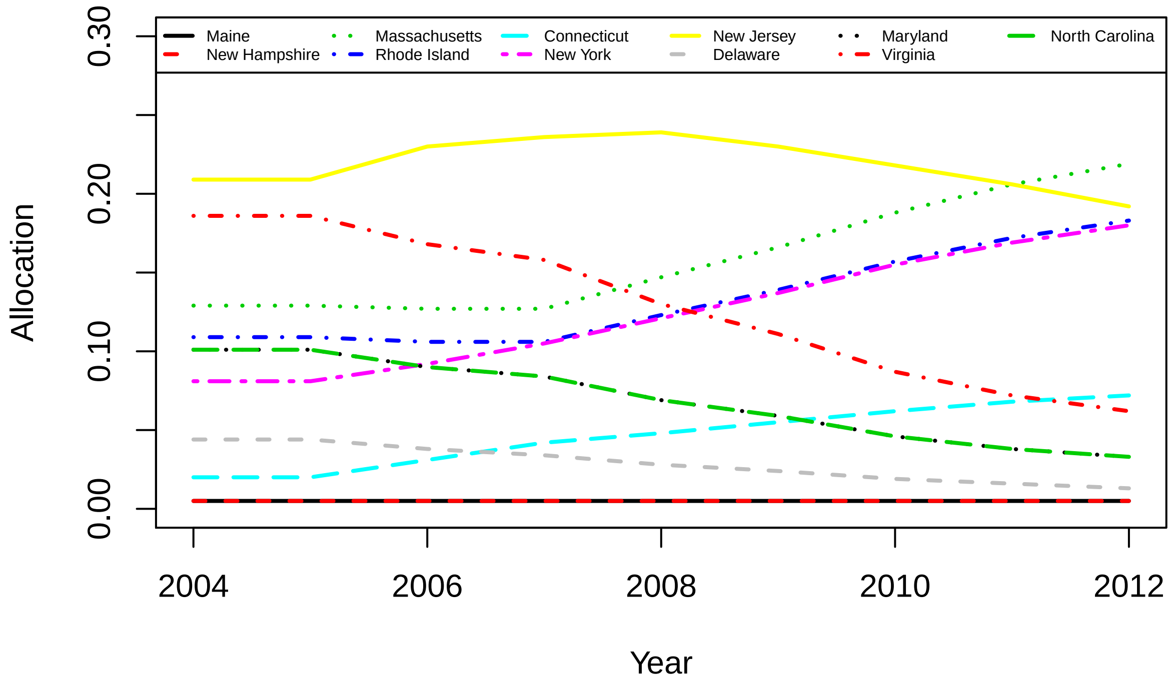


Figure 6: Allocation trajectory for all states under the parameters outlined in example 4 above. The control rule is not triggered in any year in this example. This is a retrospective analysis as if this method were in place beginning in 2004.

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Appendix C. Trigger Approach

Table 1. Reallocation of black sea bass commercial quota above a 3 million pound trigger, based on the 2017 coastwide quota of 4.12 million pounds. Quota up to and including 3 million pounds is distributed according to the status quo state allocations. Quota above the trigger is distributed equally to the states of Massachusetts through North Carolina, while Maine and New Hampshire are each allocated 1% of the quota above the trigger.

3 Million Pound Trigger					
State	**Current Allocation (%) of quotas up to and including 3 million lbs**	**Status Quo distribution of first 3 million lbs of quota**	**Allocation (%) of additional quota above 3 million lb**	**Example state allocations (lbs) under a 4.12 million lb quota**	**Example state allocations (%) under a 4.12 million lb quota**
ME	0.5%	15,000	1.00%	26,200	0.64%
NH	0.5%	15,000	1.00%	26,200	0.64%
MA	13.0%	390,000	10.89%	511,956	12.43%
RI	11.0%	330,000	10.89%	451,956	10.97%
CT	1.0%	30,000	10.89%	151,956	3.69%
NY	7.0%	210,000	10.89%	331,956	8.06%
NJ	20.0%	600,000	10.89%	721,956	17.52%
DE	5.0%	150,000	10.89%	271,956	6.60%
MD	11.0%	330,000	10.89%	451,956	10.97%
VA	20.0%	600,000	10.89%	721,956	17.52%
NC	11.0%	330,000	10.89%	451,956	10.97%
Total	100.0%	3,000,000	100%	4,120,000	100.00%

Note: Should an annual coastwide quota be equal to or less than 3 million pounds, allocation percentage defaults to current allocation percentage.

Table 2. Reallocation of black sea bass commercial quota above a 4 million pound trigger, based on the 2017 coastwide quota of 4.12 million pounds. Quota up to and including 3 million pounds is distributed according to the status quo state allocations. Quota above the trigger is distributed equally to the states of Massachusetts through North Carolina, while Maine and New Hampshire are each allocated 1% of the quota above the trigger.

4 Million Pound Trigger					
State	**Current Allocation (%) of quotas up to and including 4 million lbs**	**Status Quo distribution of first 4 million lbs of quota**	**Allocation (%) of additional quota above 4 million lb**	**Example state allocations (lbs) under a 4.12 million lb quota**	**Example state allocations (%) under a 4.12 million lb quota**
ME	0.5%	20,000	1.00%	21,200	0.51%
NH	0.5%	20,000	1.00%	21,200	0.51%
MA	13.0%	520,000	10.89%	533,067	12.94%
RI	11.0%	440,000	10.89%	453,067	11.00%
CT	1.0%	40,000	10.89%	53,067	1.29%
NY	7.0%	280,000	10.89%	293,067	7.11%
NJ	20.0%	800,000	10.89%	813,067	19.73%
DE	5.0%	200,000	10.89%	213,067	5.17%
MD	11.0%	440,000	10.89%	453,067	11.00%
VA	20.0%	800,000	10.89%	813,067	19.73%
NC	11.0%	440,000	10.89%	453,067	11.00%
Total	100.0%	4,000,000	100%	4,120,000	100.00%

Note: Should an annual coastwide quota be equal to or less than 4 million pounds, allocation percentage defaults to current allocation percentage.

Table 3. Reallocation of black sea bass commercial quota above a 3 million pound trigger according to the Rho adjusted regional biomass proportions produced by the 2015 stock assessment, applied to the 2017 coastwide quota of 4.12 million pounds. Quota up to and including 3 million pounds is distributed according to the status quo state allocations**. Quota above the trigger is distributed to the northern and southern regions according to their respective biomass proportions, and then equally to the states within each region, except Maine and New Hampshire which are each allocated 1% of the quota allocated to the northern region.**

3 Million Pound Trigger – Allocations of Additional Quota Based on Regional Biomass Proportions						
State	**Current Allocation (%) of quotas up to and including 3 million lbs**	**Status Quo distribution of first 3 million lbs of quota**	**2015 Assessment Rho Adjusted Regional Biomass Proportion**	**Allocation (%) of additional quota above 3 million lb**	**Example state allocations (lbs) under a 4.12 million lb quota**	**Example state allocations (%) under a 4.12 million lb quota**
ME	0.5%	15,000	0.86	1.0%	26,200	0.64%
NH	0.5%	15,000		1.0%	26,200	0.64%
MA	13.0%	390,000		21.0%	625,200	15.17%
RI	11.0%	330,000		21.0%	565,200	13.72%
CT	1.0%	30,000		21.0%	265,200	6.44%
NY	7.0%	210,000		21.0%	445,200	10.81%
NJ	20.0%	600,000	0.14	2.8%	631,360	15.32%
DE	5.0%	150,000		2.8%	181,360	4.40%
MD	11.0%	330,000		2.8%	361,360	8.77%
VA	20.0%	600,000		2.8%	631,360	15.32%
NC	11.0%	330,000		2.8%	361,360	8.77%
Total	100.0%	3,000,000	100.0%	100.0%	4,120,000	100.0%

Note: Should an annual coastwide quota be equal to or less than 3 million pounds, allocation percentage defaults to current allocation percentage.

Table 4. Reallocation of black sea bass commercial quota above a 3 million pound trigger according to the Rho adjusted regional biomass proportions produced by the 2015 stock assessment, applied to the 2017 coastwide quota of 4.12 million pounds. Quota up to and including 3 million pounds is distributed according to the status quo state allocations. **Quota above the trigger is distributed to the northern and southern regions according to their respective biomass proportions, and then distributed to the states within each region based on their current allocation proportions.** The highlighted state allocations for quota above the trigger are the product of multiplying each state's share of the regional biomass proportion by the regional biomass proportion.

3 Million Pound Trigger – Allocations of Additional Quota Based on Regional Biomass Proportions							
State	**Current Allocation (%) of quotas up to and including 3 million lbs**	**Status Quo distribution of first 3 million lbs of quota**	**2015 Assessment Rho Adjusted Regional Biomass Proportion**	**State Share of Regional Biomass Proportion Based on current allocations**	**Allocation (%) of additional quota above 3 million lb**	**Example state allocations (lbs) under a 4.12 million lb quota**	**Example state allocations (%) under a 4.12 million lb quota**
ME	0.5%	15,000	0.86	1.52%	1.30%	29,594	0.72%
NH	0.5%	15,000		1.52%	1.30%	29,594	0.72%
MA	13.0%	390,000		39.39%	33.88%	769,442	18.68%
RI	11.0%	330,000		33.33%	28.67%	651,067	15.80%
CT	1.0%	30,000		3.03%	2.61%	59,188	1.44%
NY	7.0%	210,000		21.21%	18.24%	414,315	10.06%
NJ	20.0%	600,000	0.14	29.85%	4.18%	646,806	15.70%
DE	5.0%	150,000		7.46%	1.04%	161,701	3.92%
MD	11.0%	330,000		16.42%	2.30%	355,743	8.63%
VA	20.0%	600,000		29.85%	4.18%	646,806	15.70%
NC	11.0%	330,000		16.42%	2.30%	355,743	8.63%
Total	100.0%	3,000,000	100.0%	100.0%	100.0%	4,120,000	100%

Note: Should an annual coastwide quota be equal to or less than 3 million pounds, allocation percentage defaults to current allocation percentage.

Appendix D. Spatial Distribution of Black Sea Bass Harvest, 2010-2017

The PDT examined data on the location of commercial black sea bass harvest during 2010-2017. Commercial landings by state, year, and statistical area were provided by the ACCSP. Landings by area were estimated based on a combination of state and federal VTR and dealer data.

Black Sea Bass landings in pounds prepared by year, state, and gear were validated with the states, with the exception of CT. Reported quantity of landings from the federal VTR data and state fishermen reports was queried and proportions by gear type and statistical area by year and state were calculated. These proportions were applied to the validated landings for all states with the exception of NY and NC, as these two states provided validated landings by gear and area. The PDT was provided with the original landings, the VTR and fishermen data, the calculated proportions, final landings with proportions applied, and a comparison of pounds by year and state.

In the most recent benchmark stock assessment, the NEFSC commercial statistical areas were partitioned into northern and southern spatial subunits, as defined in Table 1. The data suggest the proportion of total coastwide (i.e., ME-NC) commercial black sea bass landings caught in northern region statistical areas increased by about 11% between 2010-2013 and 2014-2017 (Figures 1-3, Table 2). This proportional increase was greater when considering just landings in the southern region (i.e., 19.56% if the southern region is defined as NJ-NC and 13.22% if the southern region is defined as DE-NC; Tables 5-6). Although the proportion of southern region landings caught in northern region statistical areas increased from 2010-2013 to 2014-2017, the pounds of southern region landings from southern region statistical areas increased over that time period.

New Jersey commercial harvest was close to evenly distributed between northern and southern region statistical areas during 2010-2017. A greater proportion of New Jersey harvest occurred in southern region statistical areas compared to northern region statistical areas during 2010-2013. Northern region statistical areas accounted for a greater proportion of New Jersey harvest, compared to southern region statistical areas, during 2014-2017 (Table 3).

Figures

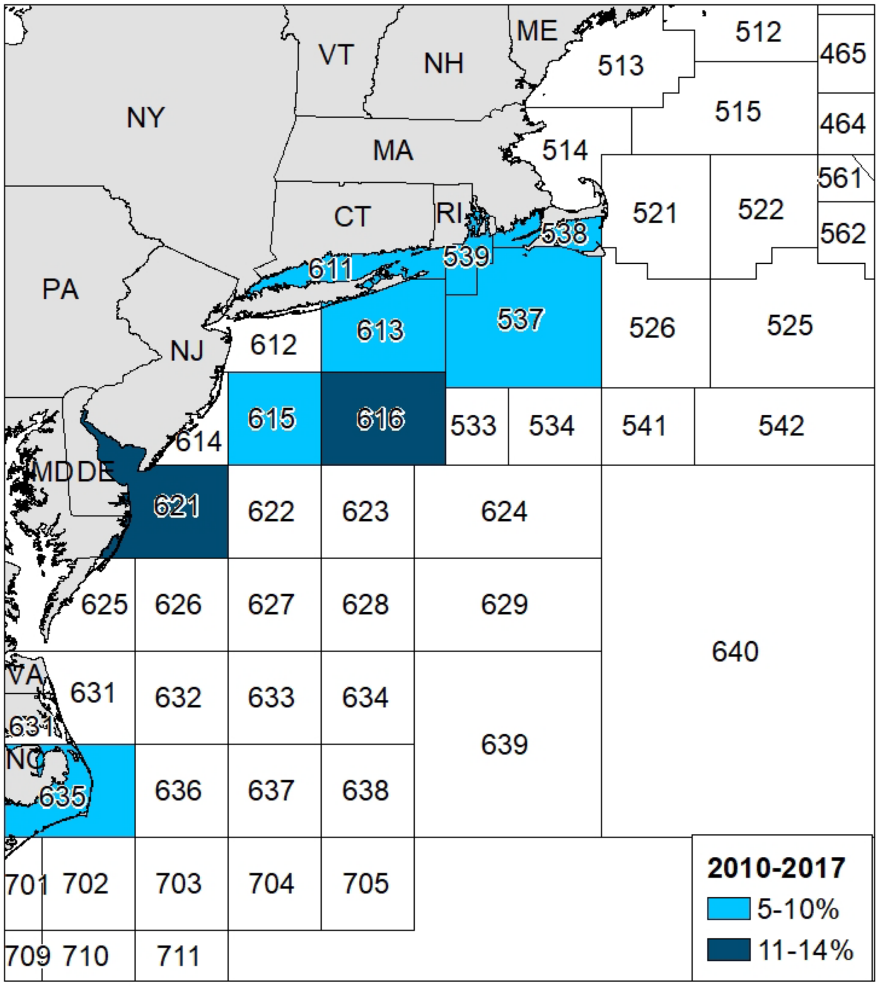

Figure 2. Proportion of commercial black sea bass landings, MA-NC, by statistical area, 2010-2017. Statistical areas accounting for less than 5% of total landings are not shown and collectively accounted for 22.79% of total landings. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

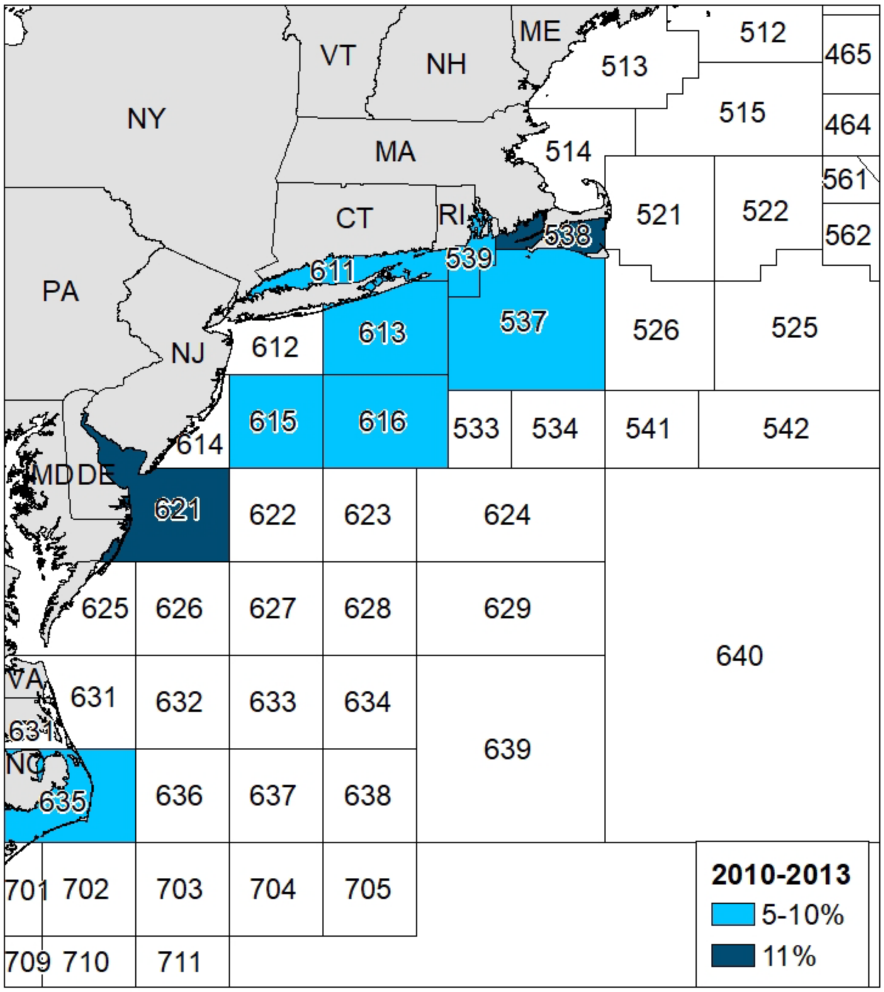

Figure 3. Proportion of commercial black sea bass landings, MA-NC, by statistical area, 2010-2013. Statistical areas accounting for less than 5% of total landings are not shown and collectively accounted for 17.20% of total landings. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

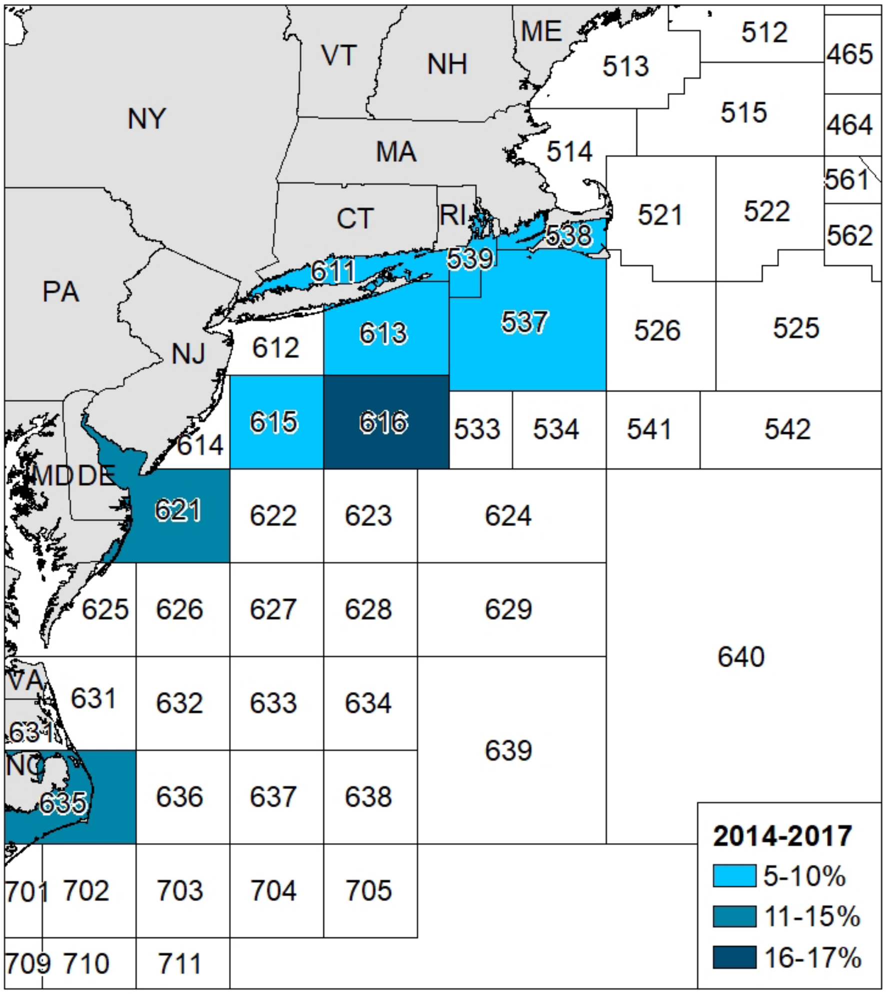

Figure 4. Proportion of commercial black sea bass landings, MA-NC, by statistical area, 2014-2017. Statistical areas accounting for less than 5% of total landings are not shown and collectively accounted for 12.87% of total landings. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

Tables

Table 1. Regional partitioning of statistical areas for the black sea bass spatial stock assessment.

Statistical Areas in Northern Region	511, 513, 514, 515, 521, 522, 525, 526, 533, 534, 537, 538, 539, 541, 542, 543, 561, 562, 611, 612, 613, 616
Statistical Areas in Southern Region	614, 615, 621, 622, 623, 624, 625, 626, 627, 628, 631, 632, 633, 634, 635, 636

Table 2. Proportion of black sea bass commercial harvest, MA-NC, from northern and southern region statistical areas. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

MA-NC Landings by Statistical Area						
	2010-2017		2010-2013		2014-2017	
	Proportion	Pounds	Proportion	Pounds	Proportion	Pounds
Total N areas	57.82%	9,805,213	51.54%	3,554,769	62.13%	6,250,444
Total S areas	42.18%	7,152,885	48.46%	3,342,576	37.87%	3,810,309
Total	100%	16,958,098	100%	6,897,345	100%	10,060,753

Table 3. Proportion of New Jersey black sea bass commercial harvest from northern and southern region statistical areas. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

NJ Landings by Statistical Area			
	2010-2017	2010-2013	2014-2017
Total N areas	52.04%	34.40%	61.87%
Total S areas	47.96%	65.59%	38.13%
Total	100%	100%	100%

Table 4. Proportion of black sea bass commercial harvest, MA-NY, from northern and southern region statistical areas. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

MA-NY Landings by Statistical Area						
	2010-2017		2010-2013		2014-2017	
	Proportion	Pounds	Proportion	Pounds	Proportion	Pounds
Total N areas	98.94%	6,270,079	98.66%	2,650,281	99.15%	3,619,799
Total S areas	1.06%	67,062	1.34%	35,970	0.85%	31,093
Total	100%	6,337,142	100%	2,686,251	100%	3,650,891

Table 5. Proportion of black sea bass commercial harvest, NJ-NC, from northern and southern region statistical areas. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

NJ-NC Landings by Statistical Area						
	2010-2017		2010-2013		2014-2017	
	Proportion	Pounds	Proportion	Pounds	Proportion	Pounds
Total N areas	33.28%	3,535,133	21.48%	904,488	41.04%	2,630,645
Total S areas	66.72%	7,085,823	78.52%	3,306,606	58.96%	3,779,217
Total	100%	10,620,956	100%	4,211,094	100%	6,409,862

Table 6. Proportion of black sea bass commercial harvest, DE-NC, from northern and southern region statistical areas. Only landings associated with valid northeast region statistical areas were included in the calculations. Data were provided by the ACCSP. Landings by area were estimated by applying VTR proportions of landings by area to dealer data.

DE-NC Landings by Statistical Area						
	2010-2017		**2010-2013**		**2014-2017**	
	Proportion	**Pounds**	**Proportion**	**Pounds**	**Proportion**	**Pounds**
Total N areas	23.24%	1,606,816	15.53%	448,024	28.75%	1,158,791
Total S areas	76.76%	5,308,566	84.47%	2,436,253	71.25%	2,872,314
Total	100%	6,915,382	100%	2,884,277	100%	4,031,105

Caitlin Starks

From:	Gates, Matthew <Matthew.Gates@ct.gov>
Sent:	Wednesday, May 15, 2019 2:36 PM
To:	Robert Ballou
Cc:	Caitlin Starks; Justin Davis; WILLIAM HYATT; Sen. Craig A. Miner
Subject:	Black Sea Bass Commercial Options
Attachments:	Black Sea Bass Commercial Options_CT_5-13-19_MG.DOCX; BSB Commercial Proposal_GW.xlsx
Follow Up Flag:	Follow up
Flag Status:	Flagged

Hi Bob,
Attached are two potential options for the PDT to consider.

The first option addresses CT's disproportionately small commercial black sea bass allocation by reallocating a little from states that either do not have fisheries or that have relatively large allocations. This was an issue identified by the Commercial Working group.

The second option combines a trigger approach with the TMGC approach and has an example illustrated in the attached spreadsheet.

I view the first option as one that should be implemented prior to and in addition to, any of the options that dynamically reallocate the resource, to put CT on a more even playing field with the other states.

If you have any questions or concerns with these options, please give either me (860.235.9048) or Justin (860.447.4322) a call.

Thanks,

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Options for consideration by Black Sea Bass Commercial PDT

CT DEEP
5/13/2019

Option 1: Address Connecticut's disproportionately small allocation of the coastal quota

Connecticut has experienced a substantial increase in abundance of black sea bass in state waters over the last seven years (see Fig. 1 below). This increased resource availability has rendered Connecticut particularly disadvantaged by its current low allocation of the coastal quota (1%). This option addresses the disparity between abundance of black sea bass in Connecticut waters and Connecticut's quota allocation by increasing Connecticut's allocation to 5%, using the following approach:

1) Hold NY and DE allocations constant
    a. NY has experienced a similar substantial increase in black sea bass abundance in state waters; therefore, it would not be appropriate to reduce their allocation.
    b. DE current allocation is 5 %. As a "control rule", this option does not seek to make CT percent allocation larger than any other state.
2) Move 1/2 of ME and NH quotas to CT.
3) Move MA, RI, NJ, MD, VA, and NC allocation to CT. The amount moved from each state is proportional to that state's current percent allocation.

Figure 1. CT Long Island Sound Trawl Survey Spring Black Sea Bass Index.

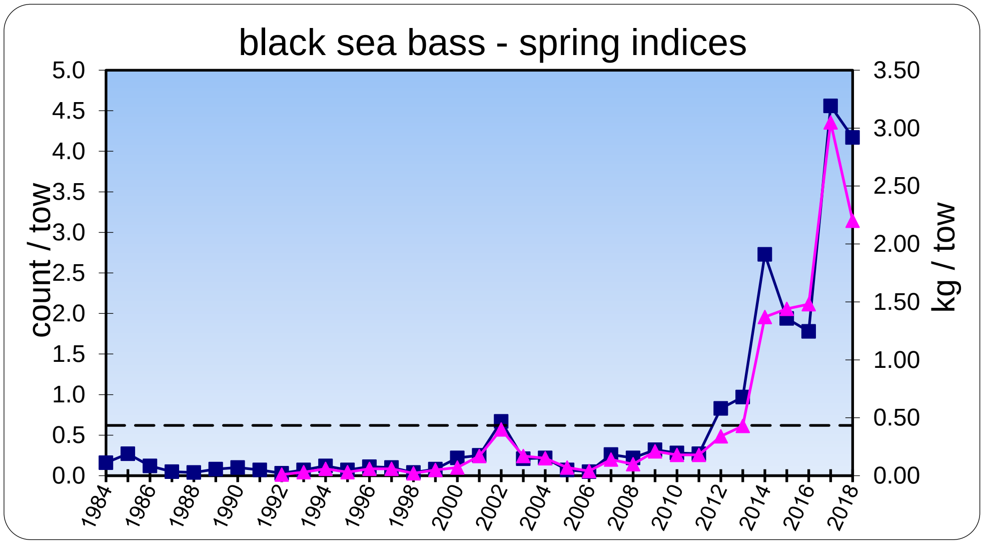

Table 1. Proposed changes in base allocations

State	Current % Allocation	Change in % Allocation	New % Allocation
ME	0.5%	-0.2500%	0.2500%
NH	0.5%	-0.2500%	0.2500%
MA	13.0%	-0.5260%	12.4740%
RI	11.0%	-0.4451%	10.5549%
CT	1.0%	4.0000%	5.0000%
NY	7.0%	0.0000%	7.0000%
NJ	20.0%	-0.8092%	19.1908%
DE	5.0%	0.0000%	5.0000%
MD	11.0%	-0.4451%	10.5549%
VA	20.0%	-0.8092%	19.1908%
NC	11.0%	-0.4451%	10.5549%

<u>Option 2</u>: Trigger option with adjustment of "base" allocations on an annual basis

This option uses a 3 million pound "trigger" while also incorporating the spirit of the TMGC approach (dynamic adjustment of allocations over time with consideration of resource availability and previous allocation regime). This option uses the following decision tree to allocate quota within a given year:

1) If the coastal quota is <u>less than or equal to 3 million pounds</u>:
    a. Allocate quota using the previous year's state allocation percentages.
2) If the coastal quota is <u>greater than 3 million pounds</u>:
    a. Allocate 3 million pounds of quota or "base" quota using the previous year's state allocation percentages.
    b. Allocate the remaining quota or "surplus" (amount above 3 million pounds) as follows:
        i. Split surplus quota to north vs. south region according to proportion of available biomass in each region (ME-NY = north region; NJ-NC = south region).
        ii. Further sub-divide surplus quota within each region according to existing intra-regional proportional allocation.

<u>This option provides the following benefits</u>:

1) By employing a 3 million pound trigger approach, ensures that there will not be substantial decrease to southern region state-by-state allocations in immediate future.
2) This option directly incorporates data on distribution of the resource. The proportions of available biomass in each region could be obtained from a periodic stock assessment, or could be determined annually using fishery-independent survey data.
3) This option allows state-by-state allocations to evolve over time as resource availability shifts (either north to south, or south to north). The rate of allocation shift is accelerated during periods of high resource availability (high quotas), and effectively "pauses" during periods of low resource availability (quotas below 3 million pounds).
4) Overall, year-year changes in state allocations will be moderate – only the "surplus" quota above 3 million pounds will be "shifted" in any one year. The allocation of the "base" quota of 3 million pounds will be the same as the previous year.

The attached Excel spreadsheet can be used to model outcomes during 2021-25 under various scenarios of regional resource distribution, coastal quota, and trigger points. The spreadsheet assumes 2021 implementation of the new regime; the 2020 quota is allocated according the existing state-by-state allocations.

- Use cells I3 through I7 to adjust annual north vs south biomass distribution.
- Use cells K3 through K7 to adjust annual coastwide commercial quota.
- Use cells L3 through L7 to adjust the trigger.

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **Summer Flounder, Scup and Black Sea Bass Management Board**

FROM: **Robert Ballou, Board Chair**

DATE: **July 19, 2019**

SUBJECT: **Commercial Black Sea Bass Allocation – Review and Recommendations**

At the upcoming Board meeting on August 7, one of the first agenda items will be to review proposed black sea bass commercial management strategies and consider initiating a management action to address commercial allocation. To facilitate the Board's review of this issue, I am taking this opportunity to offer some recommendations in advance on how the Board may want to proceed with addressing the issue at our upcoming August meeting, and at our joint meeting with the Mid-Atlantic Council in October.

Our meeting on August 7 on this agenda item will begin with a brief staff presentation, highlighting the following:

- In August 2018, the Board formed a Working Group (WG) and tasked it with identifying management issues related to changes in stock distribution and abundance and proposing potential management strategies for Board consideration.
- In February 2019, the WG provided a report to the Board which identified two main issues:
  - State commercial allocations implemented in 2003 do not reflect the current distribution of the resource which has expanded significantly north of Hudson Canyon; and
  - Federal coastwide quota management can limit harvest opportunities for some states if another state(s) overage(s) result in a coastwide quota overage resulting in a coastwide fishery closure.
- In response to the WG Report, the Board formed a PDT and tasked the PDT to perform additional analyses and further development of proposed management options related to the issue of state commercial allocations.
- In March 2019, at the Board's joint meeting with the Mid-Atlantic Council, the Council initiated an Amendment to address commercial black sea bass issues. The key reasons for this action were to enable the Council to commit staff resources to the PDT, and to formalize the Council's interest in remaining engaged with the Board regarding commercial allocation and other related issues.
- In May 2019, the PDT provided a report to the Board, setting forth an initial analysis of proposed management strategies for modifying commercial allocations. The report also highlighted some key decision points for the Board to consider in selecting the most appropriate options/alternatives for further development. The first such decision point is to define the Board's goal(s) regarding the consideration of new allocation approaches, to enable the Board and PDT to focus on further development of those strategies that best align with the Board's goal(s).

M19-57

- Also in May 2019, the Board agreed to move forward with the continued development of the proposed management strategies set forth in the report (with the exception of the auctioned seasonal quota approach) and to allow for additional suggestions from Board members within the two-week period following the Board meeting.

Staff will then present on the two new proposals submitted by Board members.

As the next order of business, I would like to take up the matter of reaching consensus on a goal statement for the pending action pertaining to commercial allocation. I would like to seed the discussion with the same draft language presented to the Board at our last meeting in May. That draft language is provided below. Please come to the meeting prepared to either lend support to this wording or offer suggested changes. Once consensus is reached, Board discussion will shift to further consideration of the existing suite of options/alternatives, including the new proposals offered since our last meeting.

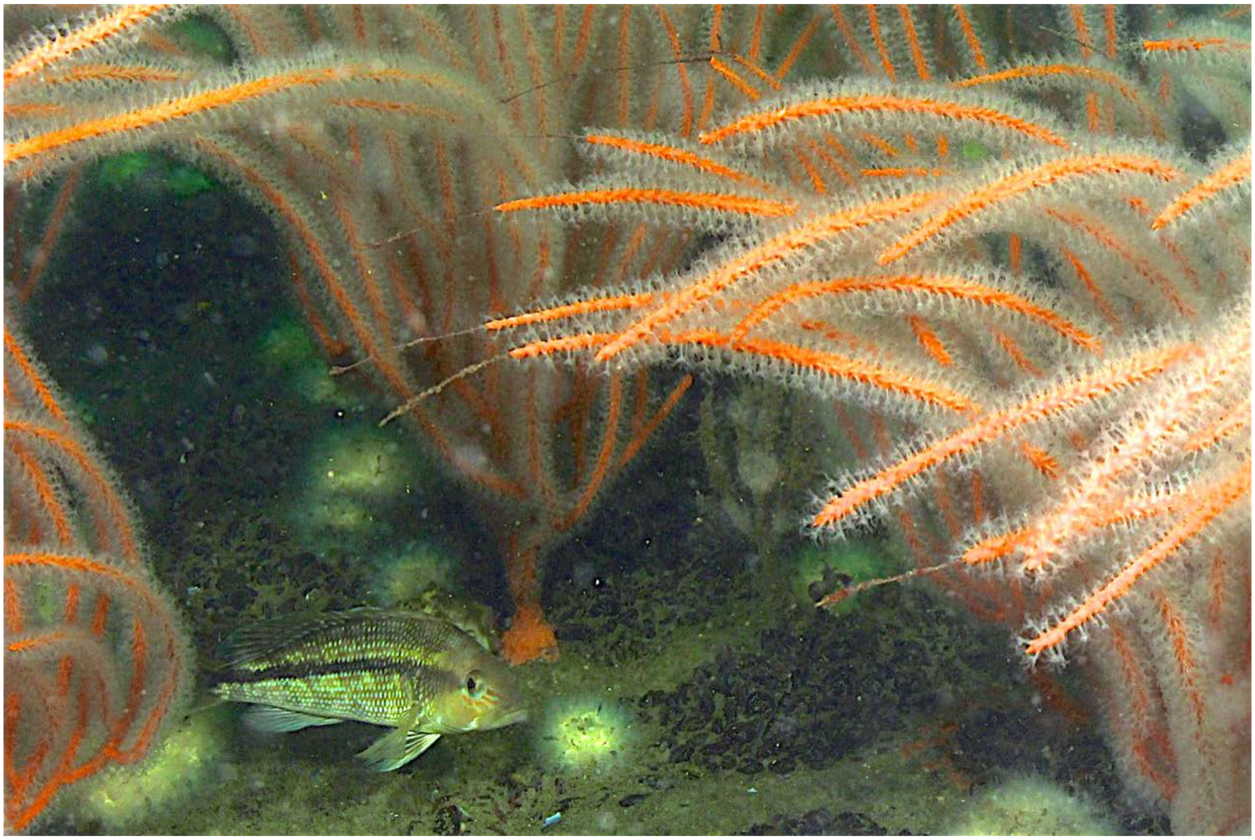
The final order of business on this agenda item will be to consider the initiation of a management document. While the Board has the prerogative to initiate such an action on August 7, my preference is to consider taking action at our joint meeting with the Mid-Atlantic Council in October. That would afford the opportunity to refine the PDT report, by adding a goal statement and making any further adjustments to the options and alternatives, and to present that report to the Council and obtain their feedback and input – still allowing for stand-alone action by the Board, but on the basis of a well-developed report that has been vetted with the Council. This process would be consistent with the discussion and recommended direction offered at the joint meeting in March 2019.

Thank you for your willingness to consider this recommended way forward. I look forward to your thoughts and comments when we convene on August 7.

Proposed Goal Statement:

Consider changes in commercial black sea bass allocation to provide fair and equitable access to the resource by better aligning allocations with updated scientific information on resource distribution and abundance while affording due consideration to the socio-economic needs and interests of coastal communities.

Hab in the MAB:
Characterizing Black Sea Bass Habitat in the Mid-Atlantic Bight



Final Report to the Atlantic Coastal Fish Habitat Partnership (ACFHP)

May 2019

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Acknowledgements

This study was conducted by faculty and students at the University of Maryland Eastern Shore. We would not have been able to conduct this work without the assistance of many people. We would especially like to thank Captain J. Kogon of the *OCDiveBoat*, and fellow divers B. McMahon, A. Sterling, E. Gecys, and C. Coon for assistance with diving. Scuba diving and dive training was conducted under AAUS guidelines and the supervision of L. Burke and J. Dykman, Dive Safety Officers for the University System of Maryland. Angling support was provided by Capt. C. Mizurak of the *Angler*, and fellow fisher-students I. Fenwick, N. Coit, I. Oliver, O. Scott Price, J. Rice, and N. Olsen. I. Fenwick assisted greatly with fish capture, dissection, and stomach content analysis during summer of 2017 as an intern with the National Science Foundation Research Experiences for Undergraduates program at UMES. Funding for this project was provided by the Mid-Atlantic Fisheries Management Council, via a competitive award from the Atlantic Coast Fish Habitat Partnership. Funding for graduate student support was provided by the National Oceanic and Atmospheric Administration, Office of Education Educational Partnership Program award numbers NA11SEC4810002 and NA16SEC4810007. Chapters 1 and 2 of this work were submitted in partial completion of the PhD Dissertion for Cara S. Schweitzer at UMES. Chapter 3 of this work was submitted in partial completion of the MS Degree for Andre L. Price at UMES.

Introduction and Summary of Results

The mid-Atlantic Bight (MAB) stretches from North Carolina to Massachusetts but is poorly studied, especially the nearshore regions of the Delaware, Maryland, and Virginia (Delmarva) peninsula. The nearshore continental shelf is composed primarily of unconsolidated sediments consisting of sand, silt, shells, and small gravels. Bedforms consist mainly of sand waves, small hills, and gullies created by ancient riverbeds, with rare outcroppings of rock, consolidated mud, and clay. There is very little hard bottom in the area. The distribution of habitats in the Delmarva MAB is poorly known, although some recent surveys have produced information on the bottom characteristics within the Maryland WEA. Seafloor sediments in the Delmarva region are characterized by large expanses of sand and shell, with widely scattered hard-bottom outcrops. These outcrops form small biological oases among a sandy seafloor desert, and are populated by sedentary invertebrate organisms that create structured habitat. Sedentary organisms are also present on anthropogenic debris (mostly shipwrecks). Numerous artificial reefs have been built in the region to enhance fishing and diving opportunities.

The nearshore continental shelf in this area is inhabited by several economically valuable species, including Tautog *Tautoga onitis*, Croaker *Micropogonias undulatus*, American Lobster *Homarus americanus*, summer flounder *Paralichthys dentatus*, and Black Sea Bass *Centropristis striata*. The most valuable inshore fishery is for black sea bass (BSB), which are considered a data poor species, due to a paucity of biological information regarding reproduction, age, growth, habitat preference, and mortality. Black sea bass are targeted by both recreational and commercial fisheries in equal measure, and the majority of commercial black sea bass landings are captured via fish traps. Commercial fish traps are often deployed on or near benthic structured habitat where economically valuable species aggregate. Recreational fishing is also mostly targeted on the many wrecks, artificial reefs, and natural bottom areas that are widely scattered throughout the region.

The MAB has become a proposed focal area for wind-power development, and wind energy areas (WEAs) have been designated offshore most of the coastal states including Maryland. Future development of wind power will affect bottom habitat in ways that are unknown, but the WEAs have been designed to avoid the most important habitats and fishing areas in the region. However, there is little information on habitat preferences of black sea bass, and how fishing or wind power development will affect the fish and their habitats. To understand the impacts of fishing or wind power development on black sea bass, we need a better understanding of the distribution and composition of benthic habitats in the MAB, and their importance to fish abundance, which is currently unknown.

Black sea bass *Centropristis striata* (BSB) are a carnivorous, primarily benthic fish that range from the Gulf of Maine to the Gulf of Mexico. Atlantic populations are separated into northern and southern stocks at Cape Hatteras, NC, and are considered a separate sub-species (*Centropristis striata striata)* from their Gulf of Mexico counterparts (*Centropristis striata melana*). Northern stock BSB perform seasonal migrations, residing in coastal waters in spring and summer months, then move to deeper waters near the continental shelf in the late fall through winter. BSB are protogynous hermaphrodites, with some individuals changing sex from female to male between 1 and 8 years of age. Common prey items for BSB include amphipods, decapods, bivalves, and small fish. Black sea bass tend to reside at sites with high rugosity at depths <28 m, that are largely associated with hard structure such as corals, mussel beds, and hard-bottom habitats or "reefs". During the summer, fish show some site fidelity to these habitats. Currently, there are few studies that describe the habitat characteristics of BSB, or their feeding dynamics, and how these two aspects of their biology are related.

This research project, designated “Hab in the MAB”, was designed to answer some of these questions. The original objectives were to:

1) Determine the preference of BSB for particular habitats by assessing their abundance, size structure, and feeding ecology within natural and artificial reefs;
2) Improve the understanding of benthic habitat structure by quantitatively assessing biodiversity, rugosity, and other habitat characteristics of natural and artificial reefs;
3) Determine if reduced fragmentation and increased connectivity of habitats increases fish recruitment, by experimentally manipulating corridors between isolated habitat patches.

During the course of the research, these goals were restructured into three specific sub-projects, and several minor ones as follows:

1. Determine the composition of biogenic structure on benthic habitat patches and the relationship to fish abundance, by
    a. Estimating relative cover of fouling organisms and fish abundance at different types of reefs, and
    b. Exploring the relationship between benthic diversity and fish abundance.
2. Investigate how seascape connectivity affects fish abundance, by
    a. Establishing a small stepping-stone corridor connecting two existing reefs, and
    b. Monitoring changes in abundance of fish on the experimental and control reefs before and after deployment;
3. Determine the dietary habits of black sea bass and their trophic relationships, by
    a. Estimating trophic position using stable isotope analysis, and
    b. Comparing food habits between fish caught at artificial and natural reefs, and during NOAA surveys.

Summary of Results

Chapter 1: Habitat structure and fish preference

From 2016 through 2018, we investigated the interactions between black sea bass and their habitats at over a dozen artificial and natural reefs in the Delmarva MAB using a variety of techniques. At each of these reefs, we estimated fouling community composition using quadrat sampling with a digital camera and ¼ m^2 frame along linear transects. We also estimated fish abundance using digital video cameras set on tripods, and by strip-transect censusing. Quadrat and video sampling were conducted both within the structured habitats and on nearby open-sand bottoms for comparison. Surveys of benthic habitats showed that the predominant marine biogenic structures in the Delmarva MAB are comprised of multiple species including northern stone coral *Astrangia poculata*, sponge *Cliona celata*, blue mussels *Mytilus edulis*, various hydroids (i.e. *Tubularia* sp., *Obelia* sp., *Campanularia* sp.), and gorgonian corals, putatively identified as sea whips *Leptogorgia virgulata*. Sea whips are one of the most prominent structure-forming invertebrates, and are responsible for most of the vertical structure above habitat baselines. Fish abundance at the studied sites was compared to the relative abundance of all other habitat-forming organisms present. Fish abundance was significantly correlated only with the relative abundance of sea whip corals, but not with abundance of any other species, or to total coverage of biogenic structure. Sea whips are ‘autogenic engineers’ (i.e. they create biogenic structure) that add complexity to benthic habitats by altering the environment with their own physical structures. Previous studies (Schweitzer et al, 2018) have shown that 50% of commercial fish traps come into contact with emergent epifauna during deployment or recovery, including sea whip corals, often resulting in damage or breaking of corals. Assessment of sea whip condition (as a damage index) at our study sites showed that sea whip corals on artificial reefs off the Delmarva coast exhibited minor levels of degradation that did not differ significantly among study sites.

Chapter 2. Seascape Connectivity and Fish Abundance

To determine if increasing seascape connectivity increases fish abundance on isolated habitat patches, we used a **Before-After-Control-Impact** (BACI) experimental design. In 2016, we constructed a stepping-stone corridor (the '**Impact'**) connecting two established sections of an artificial reef (the **Impact** site). A similar, nearby, two-section reef was designated as the **Control** site. Both the Control and Impact site consisted of two structured components (parts of shipwrecks) separated by 20 or 120 m, respectively, of unstructured, open sand bottom. Fish abundance was estimated by conducting stationary video surveys during three sampling seasons for one year **Before Impact** and one year **After Impact** at both the **Control** and **Impact** sites, and on both the structured and unstructured components. Prior to Impact, fish were more abundant at the Impact than at the Control site, both sites showed seasonal variation in abundance, and fish were completely absent from unstructured bottom at both sites. After Impact, fish abundance increased significantly only at the (previously) unstructured portion of the Impact site (where the reef was built), but did not change at any of the structured portions of either site, or at the unstructured portion of the Control site. Furthermore, fish were observed on the corridor structure during all three sampling periods. Results suggest that corridor construction increased habitat availability for fish at the Impact site, without drawing fish away from nearby sites. This small-scale study demonstrated that increasing connectivity via corridor construction may be an effective method to enhance available habitat in marine ecosystems.

Chapter 3. Feeding Ecology of Black Sea Bass at Natural and Artificial Reefs

We sampled BSB at selected natural and artificial reefs near Ocean City, MD in 2016 and 2018, using hook-and-line angling to determine if reef type influenced length frequency, sex ratios, diets, and stable isotope ratios of $\partial^{12}C/\partial^{13}C$ and $\partial^{14}N/\partial^{15}N$ in liver, muscle, and mucus. BSB caught by angling were compared to a NOAA dataset of trawl-caught BSB spanning 2000-2016. There were no significant differences in size, age, or sex composition between fish at natural and artificial habitats. The primary prey items of BSB by proportion and frequency of occurrence were crustaceans (primarily *Cancer* crabs) at both artificial and natural sites and among the NOAA samples. Values of $\partial^{15}N$ and $\partial^{13}C$ differed between habitat types in liver and muscle, but not in mucus. This study showed that natural and artificial reefs are ecologically similar for Black Sea Bass caught near Ocean City, MD, but subtle differences in diet between reef types suggest that their physical form may affect access of fish to different prey items.

Conclusions and Recommendations

Previous studies suggesting that BSB are associated with "course-grained" material are but a crude approximation of habitat. The results of this project confirm that black sea bass are tightly structure-oriented, and primarily occur within <1 m of hard bottom substrata with substantial vertical and biological structure that includes the presence of gorgonian corals, aka sea whips.

While BSB did occur near newly placed structures with little overgrowth, abundance at most sites was significantly correlated with density of sea whips, but not of any other species. Increasing the presence of structured habitat, by placement of artificial structures, resulted in an increase in abundance of BSB, without detracting from nearby structures. Diets of BSB appear to derive mostly from areas surrounding reefs, rather than among them, and differ little based on the type of reef or other source. However, the structure and extent of reefs may have a minor impact on diet due to availability of different food sources. Nonetheless, this indicates that habitat selection is probably not associated with proximity to food sources, but is more likely to be associated with actual physical structure that provides other biological benefits, such as protection from predation, optimization of reproductive opportunities, or stress reduction.

With regard to future alteration of marine habitats in the MAB, we suggest that artificial reefs should be constructed out of solid structures with appropriately scaled interstitial space, rather than concrete blocks, pipe, or steel structures that are subject to degradation, subsidence, or disintegration. We also predict that construction or installation of wind power turbines will likely provide abundant hard structure supporting invertebrate fouling communities that black sea bass and other fish prefer as habitat. Increasing the availability of such artificial habitats in the MAB, and including some in protected areas, will likely have positive benefits for the regional population of black sea bass.

Chapter 1. The Relationship Between Fish Abundance and Community Structure on Artificial Reefs in the Mid-Atlantic Bight, and the Importance of Gorgonian Sea Whip Corals (*Leptogorgia* sp.)

Adapted from: Schweitzer, C. C., and B. G. Stevens. in review. The importance of soft coral sea whips (*Leptogorgia* sp.) to fish abundance on artificial reefs in the Mid-Atlantic Bight. PeerJ.

Abstract

Autogenic engineers (i.e. biogenic structure) add to habitat complexity by altering the environment by their own physical structures. The presence of autogenic engineers is correlated with increases in species abundance and biodiversity. Biogenic structural communities off the coast of Delaware, Maryland, and Virginia (Delmarva) are comprised of multiple species including sea whips (putatively identified as *Leptogorgia virgulata),* northern stone coral *Astrangia poculata*, sponge *Cliona celata*, blue mussels *Mytilus edulis*, and various hydroids (i.e. *Tubularia* sp., *Obelia* sp., *Campanularia* sp.). Sea whips are soft corals that provide the majority of vertical height to benthic structure off the coast of the Delmarva peninsula. The mid-Atlantic bight is inhabited by several economically valuable fishes; however, data regarding habitat composition, habitat quality, and fish abundance are scarce. We collected quadrat and sea whip images from 12 artificial reef sites (i.e. shipwrecks) to determine proportional coverage of biogenic structures and to assess habitat health, respectively. Underwater video surveys were used to estimate fish abundances on the 12 study sites and determine if fish abundance was related to biogenic coverage and habitat health. Our results showed that higher fish abundance was significantly correlated with higher proportional sea whip coral coverage, but was not related to other species or total coverage of biogenic structure. Assessment of sea whip condition (as a damage index) showed that sea whip corals on artificial reefs off the Delmarva coast exhibited minor signs of degradation that did not differ significantly among study sites.

Introduction

Structurally complex habitats, such as cobble and rock reefs, and natural or artificial reefs, are profoundly important for fish and crustaceans by providing spatial refuge and feeding sites (Robertson and Sheldon 1979; Hixon and Beets 1993; Forrester and Steele 2004; Scharf *et al.* 2006; Johnson 2007; Cheminee *et al.* 2016; Gregor and Anderson 2016). Structural habitat can be essential for the settlement and proliferation of autogenic engineers (e.g. corals, sponges, bivalves, sea grasses). The presence of biogenic structure can increase the quality of habitats and can affect habitat selection, abundance of economically valuable species, and survival and settlement of fishes (Gibson 1994; Garpe and Öhman 2003; Diaz *et al.* 2004; Miller *et al.* 2012; Komyakova *et al.* 2018; Seemann *et al.* 2018; Soler-Hurtado *et al.* 2018). This is most evident when biogenic structures are damaged or undergo mortality events, which often results in regional loss of fish biomass, biodiversity, and abundance (Jones *et al.* 2004; Lotze *et al.* 2006; Thrush *et al.* 2008; Dudgeon *et al.* 2010; McCauley *et al.* 2015). The extent to which autogenic engineers influence fish abundance has been well studied in tropical marine ecosystems (Richmond 1996; Downs *et al.* 2005; Hughes *et al.* 2010; Newman *et al.* 2015), but is poorly understood within temperate rock reef systems of the mid-Atlantic.

Within the mid-Atlantic Bight, biogenic structure primarily consist of sponge *Cliona celata*, blue mussels *Mytilus edulis*, and various hydroids (i.e. *Tubularia* sp., *Obelia* sp., *Campanularia* sp.), northern stone coral *Astrangia poculata* (Steimle and Zetlin 2000), and sea whips (putatively identified), *Leptogorgia virgulata* (Gotelli 1991). Among this community, sea whip corals are the primary contributors of additional height to artificial and natural rock reefs. Previous studies conducted within coral reef ecosystems have demonstrated that rugosity and coral height are the strongest predictors of fish biomass (Harborne *et al.* 2012). The mid-Atlantic Bight is a poorly studied region and the composition of benthic biogenic structures is unknown.

Marine benthic structure within the Delaware, Maryland, Virginia peninsula (Delmarva) portion of the mid-Atlantic Bight consists of both natural rock reefs and artificial reefs. Natural reefs are composed of rock, mud, and clay outcrops, and artificial reefs, both unintentional (e.g. shipwrecks) and intentional (e.g. concrete blocks and pipes, subway cars, ships). Natural reefs are sparse, sporadically distributed and highly fragmented. Artificial reefs provide the dominant source of benthic structure either through accidental shipwrecks or constructed through artificial reef programs. Artificial reef construction has become a popular way to increase regional habitat production, biodiversity, fish abundance, and to restore biogenic structure (Bohnsack 1989; Grossman *et al.* 1997; Sherman *et al.* 2002; Granneman and Steele 2015; Scott *et al.* 2015; Smith *et al.* 2017). Artificial reef sites are constructed regularly off the coast of the Delmarva peninsula, with the goal of increasing the abundance of structure-oriented fish of economic value. Some of these species, such as black sea bass *Centropristis striata,* and tautog *Tautoga onitis,* reside directly within the structures; whereas others, such as Atlantic croaker *Micropogonias undulatus,* and summer flounder *Paralichthys dentatus,* are commonly found on sandy bottoms near benthic structures as adults (Feigenbaum *et al.* 1989; Hostetter and Munroe 1993; Scharf *et al.* 2006; Fabrizio *et al.* 2013).

Habitat quality and its relationship to species abundance has been largely been neglected in the mid-Atlantic Bight. Previous research investigating habitat association for economically important species (e.g. black sea bass) within the mid-Atlantic Bight focused on benthic hardness and did not consider biogenic composition (Fabrizio *et al.* 2013). Diaz *et al.* (2003) performed a small-scale study investigating fish abundance in relation to biogenic structure (infaunal tube densities) at Fenwick Shoals off the coast of Delaware. They found that patch size and presence of biogenic structure was significantly related to juvenile fish abundance for that site. However, there are still insufficient data to suggest that these results are representative of habitat patches throughout the mid-Atlantic Bight. To date, there is a paucity of data regarding the composition and degree of coverage of biogenic structure on reefs, and its relationship to fish abundance within the mid-Atlantic Bight

We undertook a study to determine the structure of marine biogenic communities and their relationship to fish abundance in the Delmarva portion of the mid-Atlantic Bight. Our study had four specific objectives which were: 1) to determine the species composition and coverage of biogenic structure at various artificial reefs; 2) to estimate relative fish abundance at those sites; 3) to estimate habitat quality using a damage index (DI) for sea whips, and 4) to determine the relationships between fish abundance and the quantity and quality of biogenic habitat.

Methods

Description of study sites

Twelve artificial reef study sites were selected based on site age and SCUBA accessibility (Table 1.1). Sites were located off the coast of the Delaware, Maryland, and Virginia (Delmarva) Peninsula between the latitudes of 37° N and 38.5° N ranging from 9 to 32 km off the coast (Fig. 1.1) at depths from ~10 to ~24 m. The maximum distance between sites (Site 1 and 6) was ~60.1

km and the minimum distance (between Sites 2 and 3) was ~0.52 km. The majority of the sites (n = 8) were intentionally sunk in association with the Maryland Artificial Reef Program, and the remaining four were natural wrecks. Both sites PH and RG became separated into two sections with approximately 122 m and 27 m between each section, respectively.

There have been few studies on habitats in the mid-Atlantic Bight by SCUBA or other in-situ methods due to unpredictable weather and turbid conditions. For these reasons, diving and data collection were restricted to the months of June through November during 2017 and 2018 and only conducted on days with a wave height ≤ 1 m. Fish abundance surveys were conducted June through August. If quadrat sampling could not be completed during the same sampling day, the site was resampled at a later time. During these months bottom water temperatures ranged from 9.31°C to 22.57°C and surface temperatures ranged from 13.48 to 27.23° C (CTD data). Bottom visibility in the mid-Atlantic is highly unpredictable and ranged from ~0.5 to ~18 m. Neither quadrat nor video data could be collected on days with bottom visibility < 1.5 m.

Table 1.1. Sites surveyed during this study, including name, abbreviation, approximate age, depth, month in which fish abundance surveys were completed, and category, indicating whether sites were constructed deliberately or sank unintentionally. Site names are the common name of wreck for the region, however some site names are not universal.

Site	Site Name	Abbr.	Approx. Age (y)	Approx. Depth (m)	Month Surveyed	Category
1	Fenwick Shoals	FW	120	10	July	Unintentional
2	Elizabeth Palmer	EP	104	23.5	July	Unintentional
3	EP-2	E2	100	24	July	Unintentional
4	Pharoby	PH	37	20	June	Deliberate
5	Blenny	BL	30	23.5	July	Deliberate
6	Kathleen Riggins	RG	28	16.5	June	Unintentional
7	Memorial Barge	MM	26	18	—	Deliberate
8	Sussex	SX	24	24	July	Deliberate
9	Navy Barge	NV	19	20	July	Deliberate
10	Barge	BA	2	19	August	Deliberate
11	New Hope	NH	0.5	18	August	Deliberate
12	Boiler Wreck	BW	NA	24	July	Deliberate

Data Collection

Quadrat sampling was used to estimate the proportional coverage of the dominant biogenic organisms: sea whip corals, putatively identified as *Leptogorgia virgulata*, northern stone coral, *Astrangia poculata*, blue mussels, *Mytilus edulis*, sponge, *Cliona celata*, and various hydroid species (e.g. *Tubularia sp., Obelia sp., Campanularia sp.*). Quadrat images (*n* = 11 to 60) were taken by SCUBA divers with a Canon DSLR camera in a housing attached to a 0.25 m^2 PVC frame[1]. Images were taken at 1 m intervals along the long axis of the artificial reef for 30 m, or to end of the wreck. Quadrat sampling was conducted once at each of the sites. To assess sea whip damage, a haphazardly selected subset of sea whips was photographed with GoPro® *Hero* 4 action camera[1] if abundant (e.g. > 1 m^{-2}), otherwise all sea whips present were photographed.

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[1] Reference to trade names does not imply endorsement by either the University of Maryland Eastern Shore or funding sources.

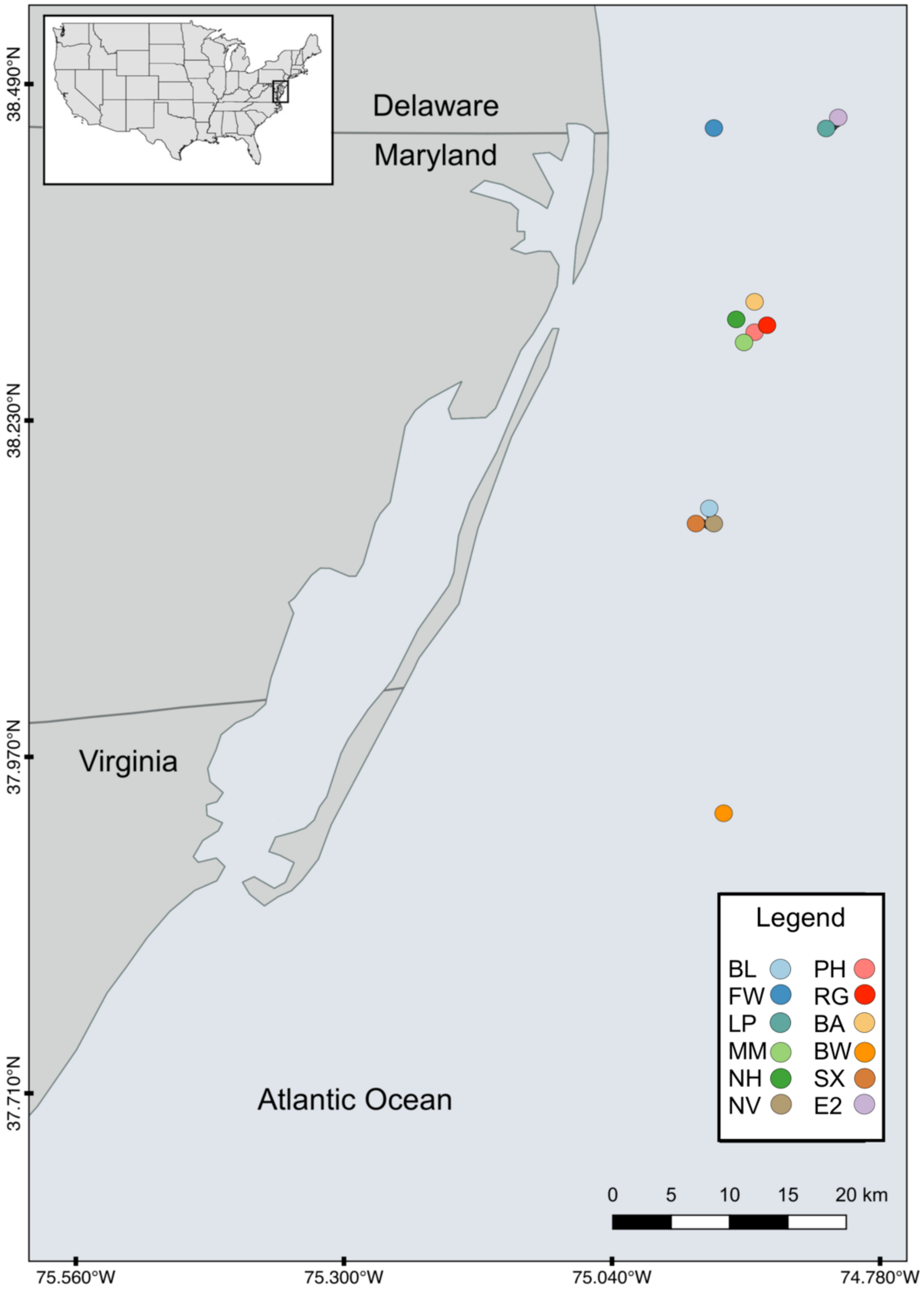

Figure 1.1. Map of study sites showing the locations of the 12 artificial reefs off the coast of the Delmarva (Delaware, Maryland, Virginia) peninsula.

Fish abundance on artificial reefs was estimated using two different types of underwater video survey: 1) line transect method, and 2) stationary cameras. Line transects were conducted at eight sites while stationary camera surveys were conducted at four of the sites. The latter method was used primarily to estimate fish abundance for an artificial reef construction project (Chapter 2 of this document) and incorporated into this analysis. Line transects were conducted for 30 m along the long axis of the site, or until the end of the wreck. Divers swam along the transect ca. 1 m above the wreck with the camera facing at a slight angle toward the wreck surface. The mean duration of line transect videos was 306 ± 102 s (mean ± SD). Stationary surveys were conducted using non-baited aluminum tripods each of which bore two GoPro® cameras placed at 90º angles. Two tripods were placed facing the wreck at a distance of approximately 1 m from where fish were observed. At Sites PH and KR, tripods were also placed in the open bottom area between each section to determine the abundance and behavior of fish at those sites. Cameras were left on tripods to record for 45 min, and then retrieved. Stationary tripod observations were repeated at least twice at each location, but line transect counts were not repeated due to hazardous weather that restricted diving frequency.

Data Analysis

Images were analyzed with image analysis software ImageJ (version 2.0.0-rc-69/1.52J, NIH) and statistical analysis was completed with R statistical software (v 3.5.2; R Core Team, 2018). Proportional cover for each of the biogenic species was estimated by outlining regions of interest (ROI) in each quadrat image. For sea whip corals, ROI were drawn over the projection of the sea whip on the surface (See Appendix Photos E-H). Analysis of similarities (ANOSIM) based on Euclidean distance was used to test for differences between biogenic structure assemblages at sampling sites. Logit transformation was applied to all proportional data before linear model (LM) analysis. Non-metric multidimensional scaling (NMDS) was used to visualize similarities and differences in biogenic composition across the research sites. Five biogenic fouling species including two corals and three non-coral organisms were included in the NMDS analysis, which represent the dominant biogenic structure organisms that inhabit the mid-Atlantic.

Due to the frequency of low bottom visibility during video survey, identification of species was substantially impaired, such that only fish relatively close to the camera could be identified. Therefore, fish abundance was estimated for all fish present and not separated by species. However, the predominant species was black sea bass, with a small amount of tautog. To estimate fish abundance on artificial reefs, we used a modified method of the MeanCount method, which is defined as the mean number of individuals observed in a series of frames throughout a viewing interval (Bacheler and Shertzer 2014). To maintain independence between frames, twelve frames were randomly selected from the line transect surveys and the number of fish within each frame was counted. The MeanCount was calculated as the mean of those twelve frame counts. For the stationary camera video surveys, fish were counted at 30 s intervals for the duration of the 30 min video, for a total of 60 counts per video. Due to the frequency of low visibility conditions, short clips of ~1.6 s length were viewed that included of 0.8 s before and after the frame selected for analysis. Frame counts were averaged over the three videos collected that year. In addition to MeanCount, the highest number of fish observed in a single frame during the video (MaxNo) was also reported, because fish were often observed aggregated near biogenic structure, specifically sea whip corals, rather than dispersed throughout the wreck. Relationships between abundance of biogenic structure and fish abundance (MeanCount or MaxNo) at each site were analyzed with a linear model. Because of the different methods used, analyses were conducted separately for line transect counts and stationary video counts.

To estimate sea whip damage, we calculated the relative area of sea whips in each image using ROIs via a line segment tool that was set at the same width as the sea whip branches. We then calculated the damaged area or region of overgrowth as a proportion of total line length.

Proportional damage of individual sea whip corals was averaged at each site, and the mean value was used to assign a damage index (DI) from 1 to 5 (Table 2) as described in Schweitzer *et al.* (2018) (See Appendix Photos O, P). The proportional data was analyzed with a linear model to determine if sea whip DI differed between sites and if DI had an effect on fish abundance.

Table 1.2. Criteria used to classify individual sea whip damage index (DI) and overall habitat DI for images captured. For individual sea whips, damage is defined as any visible tissue damage, exposed skeletal structure, or overgrowth by hydroids or bryozoans.

DI	Damage	Description
1	Minimal	< 0.05 damage or overgrowth
2	Minor	0.06-0.25 damage or overgrowth
3	Moderate	0.26-0.50 damage or overgrowth
4	Severe	0.51-0.75 damage or overgrowth
5	Critical	> 0.75 damage or overgrowth

Results

Composition of artificial reefs

Data derived from quadrat images showed a significant difference between study sites, but with some overlap in biogenic assemblages (ANOSIM $R = 0.32$; $p = 0.001$; Fig. 1.2). The mean proportional coverage of biogenic structure on artificial reefs off the Delmarva coast was 0.47 ± 0.14. Proportional coverage was lowest at Site SX (0.27), and greatest at Site NV (0.81; Fig. 1.3). Sea whip corals (*Leptogorgia* sp.) and northern stone coral (*A. poculata*) were present on 10 of the 12 sites. One of the two sites void of sea whip corals was constructed 6 mo prior to the quadrat survey and only exhibited colonization by hydroid species (Site NH; Table 1.3). Blue mussels (*M. edulis*) were found on 5 of the 12 sites. Boring sponge (*C. celata*) was observed at 8 of the 12 sites. Site BW was the only location that contained all five structure-forming species. Results from the NMDS supported the results from the ANOSIM in that some sites exhibited distinctive biogenic structure communities, while others showed considerable overlap (Fig 2).

Table 1.3. Proportional cover of biogenic structures by site. *n* is the number of quadrat images analyzed at each site; $\bar{x}$ is the mean proportional coverage for each variable: SW = sea whip coral, SC = northern stone coral, SP = boring sponge, MS = blue mussel, HY = hydroids.

Site	*n*	$\bar{x}$ SW	$\bar{x}$ SC	$\bar{x}$ SP	$\bar{x}$ MS	$\bar{x}$ HY
FW	27	0.00	0.10	0.31	0.00	0.11
LP	36	0.06	0.17	0.05	0.00	0.15
E2	11	0.11	0.18	0.04	0.00	0.15
PH	60	0.14	0.11	0.10	0.00	0.07
BL	51	0.01	0.01	<0.01	0.23	0.24
RG	41	0.08	0.26	<0.01	0.00	0.00
MM	33	0.08	0.10	0.00	0.29	0.05
SX	31	0.17	0.07	<0.01	0.00	0.03
NV	37	0.11	<0.01	0.00	0.65	0.07
BA	27	<0.01	0.00	0.00	0.54	0.01
NH	31	0.00	0.00	0.00	0.00	0.35
BW	27	0.11	0.05	0.02	0.24	0.1

Northern stone coral and blue mussels were negatively correlated. Sites NV and NH were associated with blue mussel coverage, while sites EP, E2, PH, and RG were associated with northern stone coral (Fig. 1.2). Sea whip corals and hydroids were negatively correlated, suggesting a chronological succession of the fouling community. Sites PH, RG, MM, SX, NV, and BW were associated with sea whips, whereas sites BL and BA were associated with hydroids. Sites FW and PH were associated with boring sponge (Fig. 1.2).

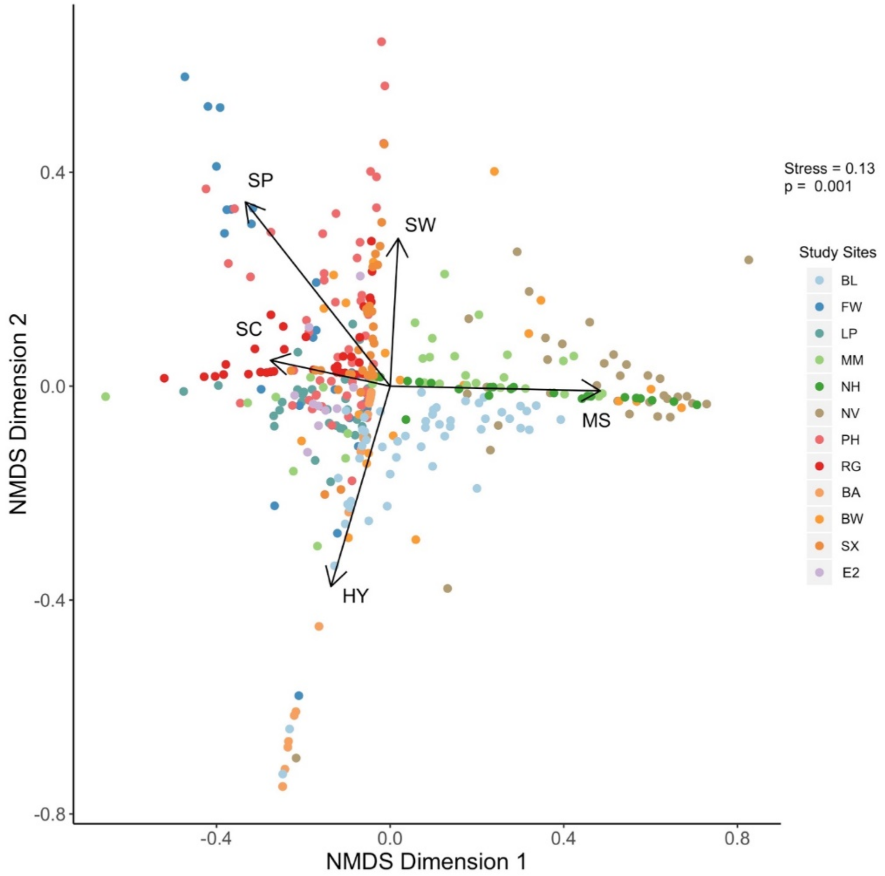

Figure 1.2. Nonmetric multidimensional scaling analysis of biogenic structure assemblages at the 12 artificial reef sites off the Delmarva coast. P value is from the ANOSIM analysis. Variables: SW = sea whip corals; SC = northern stone coral; SP = boring sponge; MS = blue mussel; HY = hydroids.

MeanCounts of fish were obtained from 11 of the 12 sites. Visibility was too poor for a video survey to be conducted at Site MM, and hazardous weather prevented additional outings. MeanCounts of fish were highest at Sites E2 and PH, and lowest at Sites FW and NH, whereas MaxNo was highest at Sites E2 and SX (Fig. 1.3, Table 1.4). No fish were observed swimming on open sandy bottom. MeanCounts and MaxNo were highly correlated ($r^2 = 0.94$). A linear model using fish MeanCounts as the response variable and total proportional coverage as the predictor variable was not significant (ANOVA, $F = 0.14$; $p = 0.72$; $r^2 = 0.02$), indicating that abundance of fish was not related to total proportional coverage of biogenic structure. MeanCounts were significantly related to proportional coverage of sea whip corals at sites with stationary tripods ($p = 0.036$; $r^2 = 0.48$; Table 1.5; Fig. 1.5) as well as at sites where line transect video surveys were conducted ($p = 0.014$; $r^2 = 0.69$).

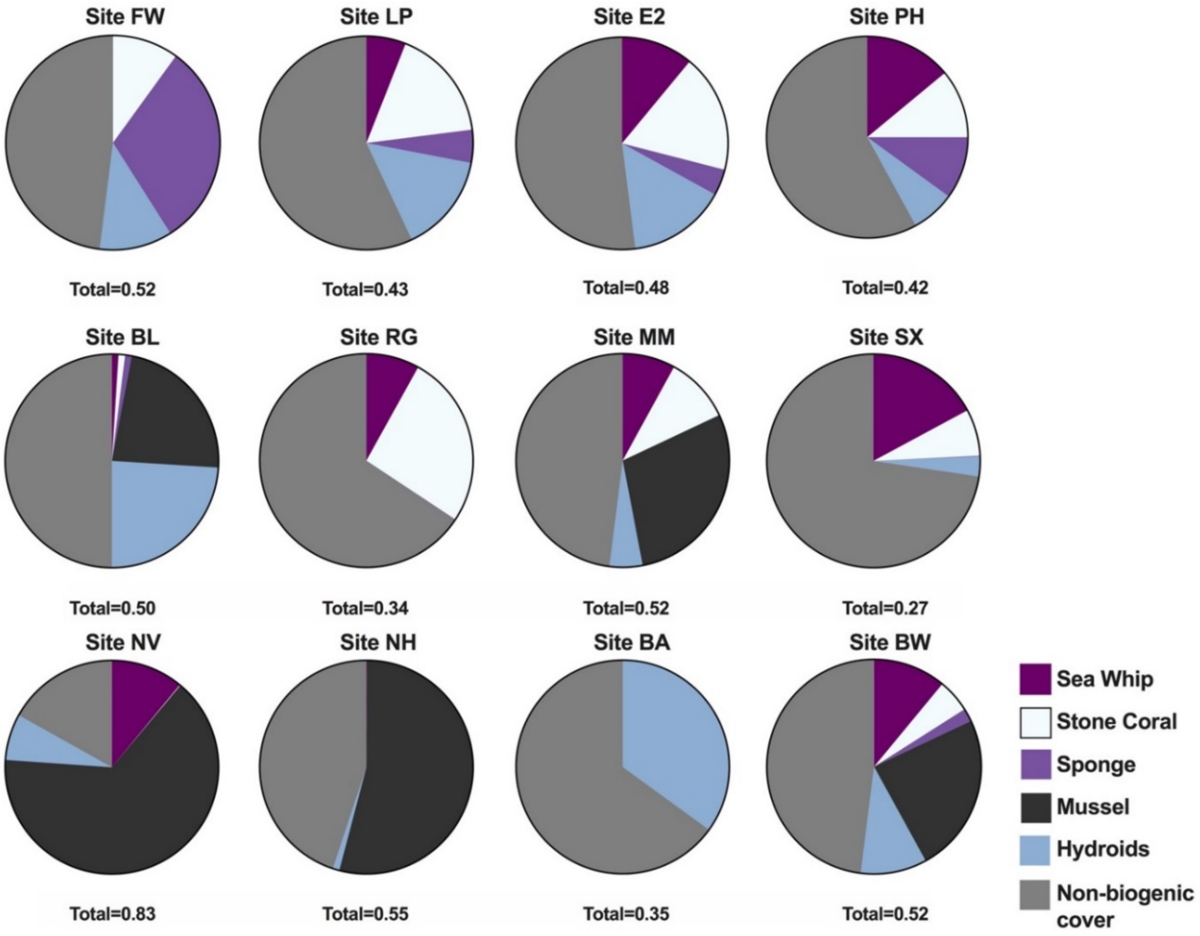

Figure 1.3. Proportional cover of five structure-forming species at 12 study sites. Total = Cumulative total coverage of all five biogenic species groups from quadrat images.

Table 1.4. Summary of fish MeanCount and MaxNo for underwater video census surveys.

Site	MeanCount	SD	MaxNO
FW	0.50	0.76	2
LP	5.25	2.18	14
E2	14.4	5.67	35
PH	7.49	3.07	24
BL	3.93	5.44	18
RG	5.05	2.66	18
MM	—	—	—
SX	6.64	7.56	27
NV	4.36	4.86	15
NH	0.64	2.41	3
BA	1.57	0.84	7
BW	7.07	4.92	19

Table 1.5. ANOVA results from the linear model analysis for 11 of the 12 sites. Fish MeanCount is the response variable and biogenic structural species are the predictor variables.

Variable	**Sum Sq**	**F value**	**df**	***P* value**
Sea whips	73.87	9.31	10	0.028
Stone Coral	20.01	2.52	10	0.173
Sponge	0.13	0.17	10	0.904
Blue mussel	7.87	0.99	10	0.365
Hydroids	11.21	1.41	10	0.288

Evidence of habitat disturbance due to fishing (e.g. lures, fishing line, abandoned traps) was observed at 10 of the 12 sites (all but Sites E2 and BA). Observations of tangled fishing line were common at edges of shipwrecks. Fishing gear was observed in direct contact with sea whip corals at 9 of the 10 sites where sea whips occurred (Fig. 1.6). To determine if cumulative sea whip damage was related to reduced habitat quality and fish abundance we analyzed a total of 193 sea whip images from 10 of the 12 study sites, excluding Sites FW and NH, where sea whip corals were absent. Sea whips at most sites exhibited various levels of degradation (Fig. 1.7). However, despite evidence of fishing disturbance at all sites, with the exception of Site E2, the mean damage index (DI) was 0.15 ± 0.19 SD for all sites, which is indicative of minor levels of degradation (Table 1.6). Site LP showed the highest DI with a mean of 0.26 ± 0.19 indicating a moderate level of degradation, however this was not significantly different from the other sites (*p* = 0.061).

Table 1.6. Summary of the mean proportional damage for sea whips and the habitat DI by site. *n* is the number of sea whips analyzed at each site. $\bar{x}$ is the mean proportional damage for the measured sea whips. SD is the standard deviation. Max is the highest proportional damage observed. Min is the lowest proportional damage observed. D.I. is the damage index assigned to the site.

Site	***n***	$\bar{x}$	**SD**	**Max**	**Min**	**D.I.**	**Degradation Category**
1	0	–	–	–	–	–	–
2	31	0.26	0.19	0.77	0.05	3	Moderate
3	11	0.02	0.02	0.02	0.00	1	Minimal
4	19	0.15	0.24	1.00	0.00	2	Minor
5	17	0.15	0.24	1.00	0.00	2	Minor
6	19	0.07	0.05	0.18	0.02	2	Minor
7	24	0.15	0.15	0.47	0.00	2	Minor
8	21	0.12	0.11	0.40	0.00	2	Minor
9	26	0.11	0.15	0.66	0.00	2	Minor
10	7	0.15	0.30	0.82	0.00	2	Minor
11	0	–	–	–	–	–	–
12	28	0.15	0.21	0.78	0.00	2	Minor

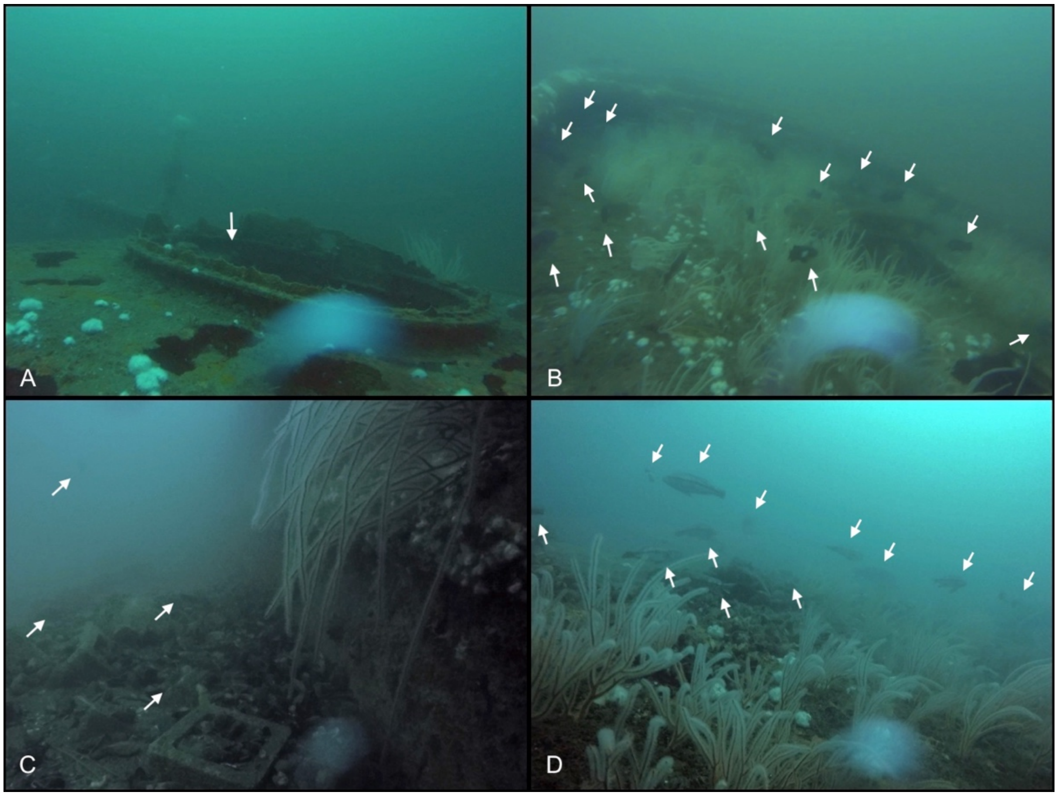

Figure 1.4. Photos illustrating fish and sea whip density at two locations (Sites SX and NV). A) Region of Site SX with minimal biostructure. White arrow highlights the single fish located within this frame. B) Region of Site SX with higher sea whip coverage, on same dive as 4A. White arrows show the location of the 14 fish observed. C) An area of Site NV that is mostly composed of rock, broken shells and concrete blocks with a single sea whip coral and some colonies of northern stone coral on the wall of the wreck. White arrows show the locations of four fish. D) Region of Site NV with increased sea whip coverage during same dive as 4C. White arrows show the location of 12 fish.

Discussion

The presence of autogenic engineers often increases habitat quality resulting in increases in species abundance and biodiversity across terrestrial, freshwater, and marine ecosystems (Jones *et al.* 1994; Hastings *et al*. 2007). However, not all types of structures are equivalent, or have positive correlations with species biodiversity and abundance (Jones *et al.* 1997). Therefore, it is important to understand the relationships between composition of biogenic structure and its effect on community structure. The mid-Atlantic Bight is a poorly studied region inhabited by multiple economically important species (Hostetter and Munroe 1993; Shepherd *et al.* 2002) that are exploited both recreationally and commercially. Many of these species (e.g. black sea bass and tautog) are considered structure oriented, but it remains unclear if biogenic structure affects their habitat selection. Insights into the relationships between biogenic structure and fish abundance will be useful for developing ecosystem-based fisheries management (EBFM).

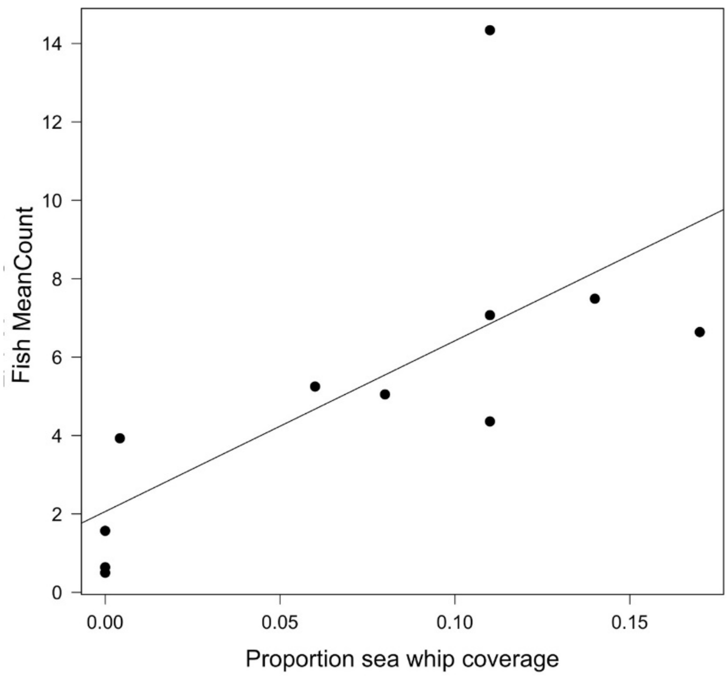

Figure 1.5. Relationship of MeanCount and proportional sea whip coverage for 11 of the 12 study sites. There is a significant positive correlation ($p = 0.018$; $r^2 = 0.48$).

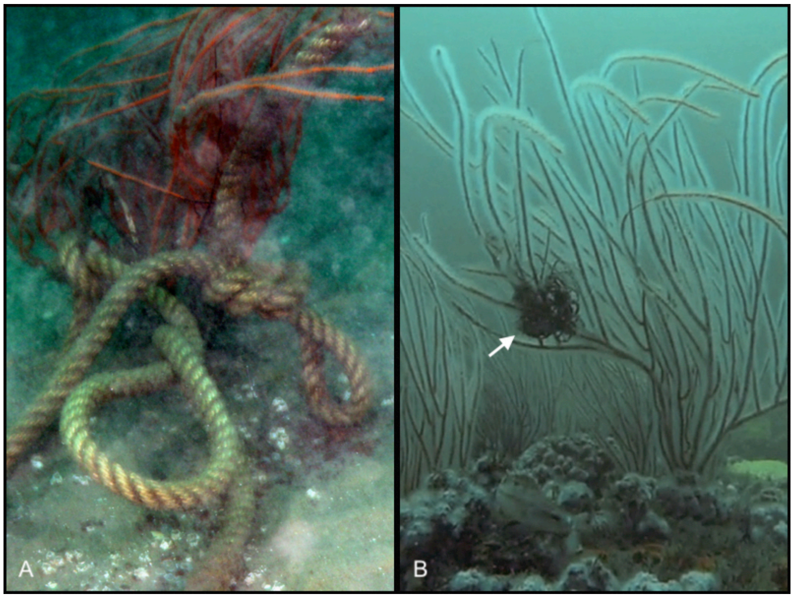

Figure 1.6. Two photographs showing representative examples of anthropogenic disturbance observed at the research sites. A) Sea whip coral from Site PH entangled in rope. B) Sea whip from Site NV with fish line entangled around a portion of branches.

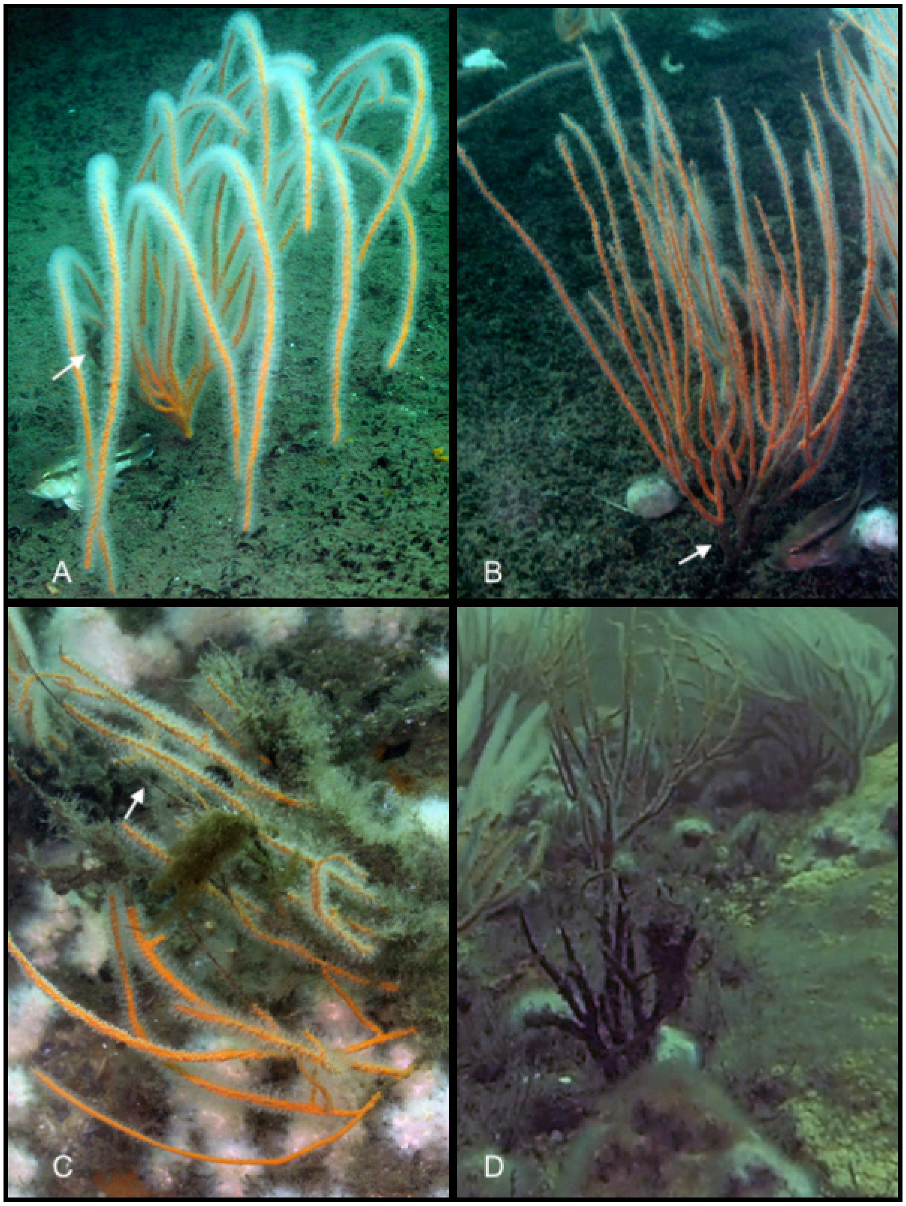

Figure 1.7. Photographs showing sea whip corals with four different degrees of damage. A) Sea whip coral exhibiting a minimal proportional damage index of 0.02. White arrow highlights the region of damage. B) Sea whip coral exhibiting minor proportional damage index of 0.13, localized at the base of the coral. C) Sea whip coral exhibiting a severe proportional damage index of 0.51. The white arrow is showing a region where the tissue has completely decayed, exposing the skeletal structure. This coral also exhibits colonization by hydroids. D) Sea whip coral exhibiting critical proportional damage index of 1.00 with no live tissue remaining.

In this study we measured habitat composition and relative abundance of fish on 12 artificial reef sites to determine if relationships existed between biogenic structure and habitat use by fish. We concluded that abundance of fish was significantly correlated with abundance of sea whip coral and that fish were often aggregated near sea whips. In fact, sites without sea whips, or having a proportional abundance <0.01, exhibited low values for both fish MeanCounts and MaxNo. Within the mid-Atlantic Bight, sea whip corals are the primary autogenic engineer that increases the relative height of benthic structure, increasing the structural complexity of such habitats. In previous studies, coral height has been found to be a significant predictor of fish abundance and biodiversity within coral reef systems (Hoyle and Harborne 2005). Due to their height, sea whip corals can be susceptible to disturbance (e.g. fishing) that may result in damage and degradation (Schweitzer *et al.*, 2018), which could lead to reduced fish abundance.

Habitat degradation is commonly correlated with a reduction in biodiversity and abundance of associated species (Wilson *et al*. 2006). We observed sea whips entangled in fishing line and rope, along with various levels of damage to colonies throughout the study sites. However, our study sites did not differ significantly from each other; therefore, we could not determine the effect of sea whip damage on fish abundance. This result is not surprising because, despite receiving recreational fishing pressure, these 12 sites are seldom fished by commercial fishers. Previous studies have shown that commercial traps drag along the ocean bottom upon retrieval, running over and breaking sea whips (Schweitzer *et al.* 2018), which may accelerate degradation. In order to test the hypothesis that sea whip coral health affects fish abundance on patch reefs, data are needed on sites with wider distribution of impact levels, ranging from moderate to severe degradation, to compare with less-impacted sites.

In this study we did not investigate natural reef sites due to their inaccessibility to SCUBA. Natural reefs off the coast of the Delmarva Peninsula are highly fragmented and sparse, occurring at depths ≥ 27 m. Attempts to locate these by SCUBA diving along commercial trap lines demonstrated that greater amounts of time were needed to locate and sample patch reefs than could be accommodated by no-decompression diving on air or EAN32 gas mix. Natural reefs are commonly targeted by both recreational and commercial fishers; therefore, it is important for future studies to incorporate surveys of natural reefs. Schweitzer et al. (2018) surveyed three naturally occurring patch reefs with a remotely operated vehicle in an area targeted by commercial fishers. The stratified DI for those sites was 0.37, substantially greater than 0.15 for the study sites in this survey. However, biogenic structure composition and relative fish abundance for those sites or other natural reef sites is unknown. Schweitzer et al. (2018) also determined that 50% of commercial fish traps encountered biological organisms including sea whips during recovery, often resulting in running over, damaging, or breakage of structures. However, further research is needed to determine whether the higher damage index observed at those sites is due to fishing impacts or natural disturbance.

Our research showed a significant difference in the composition of biogenic structure between sites. Blue mussels were the dominant epifauna at five sites (i.e. ≥ 22% cover), however they were not observed at the other seven sites. Northern stone coral was observed at ten sites and was dominant (≥17%) at three. Only two sites were not inhabited by sea whips, one of which was an artificial reef constructed ~6 mo prior to quadrat sampling. Site NH, constructed 2 y prior to being surveyed exhibited <0.01 proportional sea whip coverage, indicating that it takes a minimum of 2 y for sea whips to begin to grow on concrete and metal substrata. However, settlement and growth rates for sea whips (*L, virgulata*) are currently unknown. In contrast, sites BA and NH, both of which were constructed <3 y before surveying, were occupied exclusively by hydroids and mussels, respectively, indicating that those species settle quickly, and are probably replaced over time by longer-lived species such as sea whips and stone corals. We conducted quadrat surveys only once at each site. Repeated quadrat surveys, especially after severe weather events, would give insight on rates of succession and sea whip colonization rates on newer artificial reefs.

Fish abundance was estimated via two underwater video survey methods: line transects and non-baited stationary cameras, conducted over the course of two years, which is a limitation to this study. Ideally, abundance censuses would be conducted in a synoptic fashion; however, weather and water conditions in the mid-Atlantic Bight are unpredictable, and were often deemed too hazardous for SCUBA surveys, making it difficult to collect data within specific time blocks. The video surveys acquired from the stationary cameras at four sites (Sites LP, E2, PH, & RG) could result in an upward bias of the MeanCount; nevertheless, fish MeanCount still showed a significant correlation with sea whip abundance at the remaining seven sites. Additional surveys are needed to understand how fish abundance at sites can vary throughout and over years since many of the prominent fish species (e.g. black sea bass and tautog) are seasonal migrators.

Our study is the first to quantify the composition of biogenic structure on artificial reefs off the coast of Delmarva Peninsula and to show that fish abundance is significantly correlated with the presence and abundance of sea whip corals. Construction of artificial reefs off the coast of Delmarva occurs on an annual basis to increase the local abundance of economically valuable species. Creating artificial reefs near regions with established sea whip coral populations may help facilitate sea whip settlement and colonization of new structures. Future studies to determine variations in fish abundance over time, and to determine the succession of biogenic structure would be useful. In addition, future surveys of naturally occurring patch reefs should be conducted, in order to gain a more detailed assessment of habitat quality in the mesophotic regions of the Mid-Atlantic Bight.

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Chapter 2. Effects of Habitat Enhancement on Local Fish Abundance: A Before-After/Control-Impact (BACI) Design Study on Artificial reefs in the Mid-Atlantic Bight

Cara C. Schweitzer and Bradley G. Stevens

Adapted from: Schweitzer, C.C. and B. G. Stevens (MS in preparation). Response of fish abundance to increased seascape connectivity using a mosaic corridor connecting artificial reefs in the Mid-Atlantic Bight.

Abstract

Seascape connectivity, the arrangement and proximity of nearby habitats, which can facilitate or impede animal movements, has been a well-studied research topic in terrestrial systems and is becoming a topic of interest in marine systems. Despite this, there are few studies that actively increase seascape connectivity to existing reefs. To determine if increasing seascape connectivity increases fish abundance on habitat patches, we constructed a stepping-stone corridor connecting two established sections of an artificial reef based on a Before-After-Control-Impact (BACI) experimental design. Fish abundance was estimated by conducting stationary video surveys during three sampling seasons for one year before corridor placement (the impact) and one year after impact at the study site and control site. We observed a significant increase in fish abundance at the corridor (impact) site and no significant change at the control site. Furthermore, fish were observed on the corridor during all three sampling series. This study tests the terrestrial concept of corridor functional connectivity of patches to facilitate animal movement and abundance. This small-scale study demonstrates that increasing corridor connectivity may be an effective method for enhancing habitats in marine as well as terrestrial ecosystems.

Introduction

Landscape connectivity of terrestrial systems and the effect of increasing and decreasing connectivity have been well studied over the decades (Fahrig and Merriam 1985; Fahrig 2001; Fahrig 2002; Kindlmann and Burel 2008; Ayram *et al.* 2016). Within terrestrial ecosystems enhancing landscape connectivity has been shown to increase species abundance, biodiversity, and viability (Schooley and Branch 2011; Ayram *et al.* 2016). A popular mechanism for increasing habitat patch connectivity is the implementation of corridors (Beier and Noss 1998; Bennett 2003; Hilty 2012). Although there has been some debate on the success rate of corridors, some studies show that corridors help facilitate the movement of birds, insects, reptiles, and mammals, and have also been shown to increase plant richness (Beier and Noss 1998; Schooley and Branch 2011). In marine ecosystems, seascape connectivity has only more recently been studied. However, there have been few experimental studies that have investigated the effects of connectivity through manipulation of artificial reefs or corridor construction.

Within marine ecosystems, increasing seascape connectivity results in positive effects on marine reserve performance, accelerated recovery of community composition after disturbance, and increased facilitation of fish movement (Mumby and Hastings 2008; McCook *et al.* 2009; Olds *et al.* 2012; Engelhard *et al.* 2017). These studies, however, did not manipulate connectivity through artificial reef construction. There are few studies of the effects of patch connectivity on fish aggregation and abundance on those sites.

Within the mid-Atlantic Bight, benthic structure is predominantly provided by artificial reefs, which are frequently constructed, often in isolation. Isolated reefs exhibit slower settlement rates of spores and larvae (Svane and Petersen 2001; Connell and Slatyer 1977) and reduced fish settlement (Overholtzer-McLeod 2006; Turgeon *et al.* 2010) compared to artificial reefs constructed in closer proximity to other reef systems. As shown in Chapter 1, abundance of fish on Delmarva reefs was significantly associated with relative abundance of sea whip corals, and recently constructed artificial reefs exhibited lower relative coral and fish abundance compared to established artificial reefs (Chapter 1, Schweitzer and Stevens in review).

In this study we explore the terrestrial corridor model by increasing seascape connectivity between two sections of established artificial reefs. We use a Before-After-Control-Impact (BACI; Smith 2014) experimental design to statistically assess whether a mosaic stepping-stone style corridor connecting two established sections of an artificial reef increases fish abundance at that site compared to a control site.

Methods

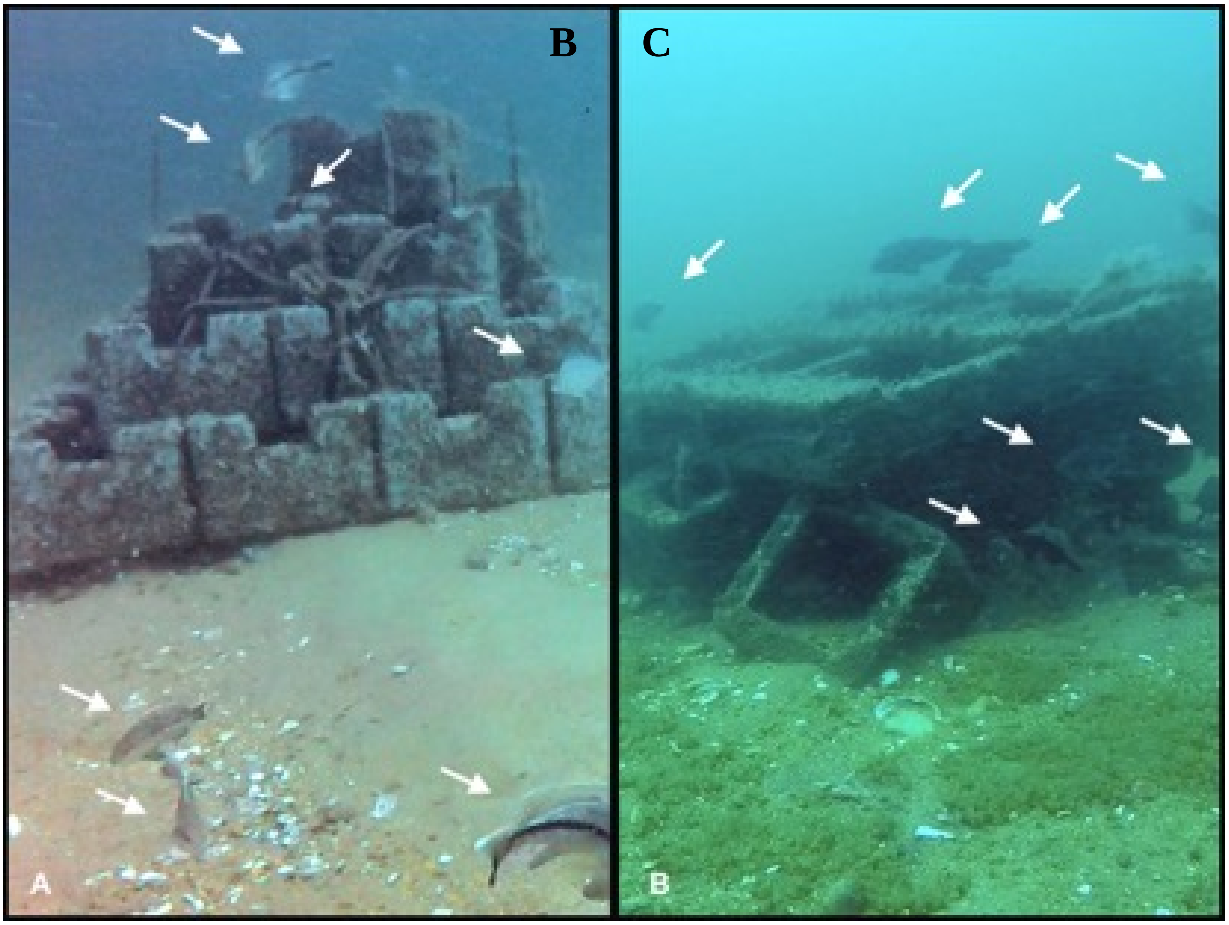
We used a simple two year before-after-control-impact (BACI) design to measure the change in fish abundance after increasing connectivity between an established artificial reef. Two artificial sites (PH and RG in Table 1.1) located ~ 14.5 km off the coast of Maryland, USA were selected based on SCUBA accessibility and spatial pattern. Both sites had broken into two distinct sections of established structure, separated by open sandy bottom. The control site (RG in Table 1.1) is designated as Site C, or CS for the two structured portions. It is a natural shipwreck that sank accidentally in 1991 and is still largely intact; its two sections are separated by ~24 m and lie at a depth of 16.7 m. The impact site (Site PH in Table 1.1), designated as site I (or IS for the structured portions) was a wooden vessel sunk intentionally in 1980; its two sections are separated by ~120 m at a depth of 19.8 m. The open bottom areas between the structured sections at sites C and I were designated CO and IO, respectively. Sites C and I are separated by a distance of 1.3 km, and both sites are subject to recreational fishing pressure. Site C is primarily colonized with sea whip *Leptogorgia virgulata* and northern stone corals *Astrangia poculata*. In addition to sea whip and northern stone corals, Site I is colonized by the boring sponge *Cliona celata*, and various hydroid species (i.e. *Tubularia* sp., *Obelia* sp., *Campanularia* sp; see Chapter 1 for detailed descriptions of the sites and biogenic structure).

At the impact site, a mosaic stepping-stone style corridor was constructed on the open bottom between the two structured sections. The corridor was constructed with concrete oyster castles stacked to form pyramid-like structures of various heights (See Appendix Photos K, L). Three size categories of pyramids were placed: large = 4 tiers; medium = 3 tiers; small = 2 tiers (Table 2.1). A total of 29 pyramids were deployed via a utility vessel December 21, 2016 (Fig. 2.1), spaced at intervals of ca. 6 m. Construction occurred during winter because most fish had undergone a seasonal migration to deeper offshore waters at that time. Site C did not receive any pyramids or other modifications.

Table 2.1. Specifications of the pyramids that comprise the stepping stone corridor. Tier refers to the layers of oyster castle blocks in each pyramid. *n* Blocks are the number of blocks used to build each pyramid size. *n* pyramids are the number of pyramids of each tier size.

Tier	n Blocks	n Pyramids
2	5	15
3	14	14
4	30	4

Figure 2.1. Pyramids made of oyster-castle blocks that were used to create the corridor. A) Image of 3-tier and 4-tier pyramids. B) A 4-tier pyramid with white arrows highlighting fish. C) A 3-tier pyramid that landed upside down.



To estimate fish abundance at the research sites, two GoPro® cameras were fastened on non-baited aluminum tripods and set facing outward at 90º angles (See Appendix Photos A, B, I). Cameras were set to record at a rate of 60 frames s^{-1} and at a resolution of 1080 x 720 pixels, with an approximate field of view of 90º. Tripods were placed by divers approximately 1 m from each structure (CS or IS) in areas where fish were observed. Tripods were also placed in the stretch of open bottom between the separated sections of both the study sites (CO and IO), at a distance of ~10.5 m and ~18 m away from the structure for Sites C and I, respectively. Cameras were left to record for 45 to 50 min in order to obtain at least 30 min of video that was void of diver interruptions. Tripods were then retrieved and placed on the second structured section of the wreck. Both sections of a site were recorded within a single sampling day. Video surveys were conducted approximately six months before (B) augmentation (2016), and 6–8 months after (A) augmentation (2017). Video surveys were conducted during three time periods in each year: early summer, mid-summer, and fall. Weather in the mid-Atlantic Bight is highly variable, unpredictable, and causes frequent turbid conditions, which can impede scuba accessibility and video surveys due to poor visibility. Bottom visibility < 1.5 m was deemed too poor for video surveys. Due to weather restrictions, our sampling series occurred during 2-week windows with a minimum of 4 weeks between each survey (Table 2.2).

Table 2.2. Dates of video surveys at the research sites before and after corridor implementation.

	Before			**After**		
Site	Series 1	Series 2	Series 3	Series 1	Series 2	Series 3
Control	06/15/16	9/09/16	10/30/16	7/19/17	9/16/17	11/12/17
Impact	06/16/16	9/18/16	10/19/16	7/11/17	9/04/17	11/12/17

Video and data analysis were conducted using Final Cut Pro X$^{©}$ 10.4 (Apple Inc., Cupertino, California USA) and GraphPad Prism Software 7.0c (GraphPad Software Inc., La Jolla California USA). Videos were trimmed to 31 min and edited with color corrections to enhance the clarity of the video. Fish abundance was estimated using a modification of the MeanCount method described in Bacheler and Shertzer (2014). Fish were counted at 30 s intervals for the duration of the 30 min video, for a total of 60 counts per video. Due to the frequency of low visibility conditions, counting fish in still frames was unreliable, therefore short clips of ~1.6 s length were viewed that included of 0.8 s before and after the frame selected for analysis. Fish movement within that interval permitted a more precise count. The total number of fish observed during the clip was recorded for the count. Furthermore, low visibility conditions substantially impaired species identification, such that only fish relatively close to the camera could be identified. Therefore, fish abundance was counted in aggregate, and not separated by species. Values of fish abundance are expressed as mean fish-per-frame (fpf) ± standard error (SE)

We used a BACI design to analyze the video count data, in which surveys were designated as belonging to Before (2016) or After (2017) groups at each of the sections of the control and impact site. Linear mixed effects modeling (LME) was used to determine the effects of various factors. Multiple models were tested that included different factors: Time (i.e. Before vs. After), Site (C vs I), Sub-sites (CS, CO, IS, IO), and the interaction between Time and Site. Since multiple cameras were used to determine fish counts, videos analyzed during a sampling series were treated as pseudo-replicates. In all models, the two cameras on each tripod were treated as random effects. A null model containing only the intercept was also tested. The Akaike Information Criterion (AIC) was used to select the best fit model. The Δ_i values were used to rank the different models (m_i) against the null model. Additionally, a multiple-comparisons 2-way ANOVA was conducted to look at annual changes of fish abundance between sites. We corrected for multiple comparisons with the Bonferroni correction and report the adjusted p values. The BACI interaction effect estimate (differential change) was calculated using the equation: $\widehat{BACI} = \mu_{CA} - \mu_{CB} - (\mu_{IA} - \mu_{IB})$.

Results

Despite our best efforts, some of the pyramids landed upside down, and others fell apart during winter storms. To estimate fish abundance on the research sites, six recordings were attempted with a goal of 360 frame counts for each site per sampling series: four recordings of the artificial reef sections and two recordings of the open bottom separating the sections. However, due to poor weather conditions, poor visibility, and strong currents knocking over tripods, the goal of 360 frame counts was met only once (Table 2.3). Fish were observed on pyramids at Site I during all three series, and schools of fish were observed swimming between pyramids (Fig. 2.1).

Table 2.3. Mean of fish counts during three sampling series in two years for the Control and Impact sites. Control (CS) = established structure at the control site; Control (CO) = open sand between the two structures at the control site; Impact (IS) = established structure at the impact site; Impact (IO) = open sand between the structure (Before) and site of corridor construction (After). All values displayed as mean fish-per-frame (fpf) from all survey videos, plus/minus standard error ($\bar{x}$ ± SE).

Time	Site	Section	Code	Series 1	Series 2	Series 3	Annual
Before	Control	Structured	CS	7.17 ± 0.24	1.23 ± 0.10	7.06 ± 0.29	5.15 ± 0.19
		Open	CO	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	Impact	Structured	IS	8.53 ± 0.27	11.75 ± 0.39	3.55 ± 0.30	8.23 ± 0.24
		Open	IO	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
After	Control	Structured	CS	7.68 ± 0.29	1.07 ± 0.13	5.82 ± 0.56	5.61 ± 0.27
		Open	CO	0.02 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01
	Impact	Structured	IS	6.23 ± 0.28	13.93 ± 0.71	5.24 ± 0.25	8.14 ± 0.30
		Open	IO	6.55 ± 0.28	4.78 ± 0.16	8.50 ± 0.27	6.35 ± 0.34

Fish abundance at site C was higher on the structured portions (mean >5.0 fpf) than on the open bottom (CO; mean 0.0 fpf), but differed little between years (t test; $p = 0.82$; Fig. 2.2). Only one fish was observed on the open sand in 2017. Abundance varied seasonally, with abundance during survey series 2 being lower than either series 1 or 3, and this pattern was similar in both years (F = 6.4; $p = 0.12$).

Fish abundance at site I in 2016 was also higher on the structured portions (mean ~ 8.2 fpf) than on the open bottom (mean 0.0 fpf, Fig. 2.3). However, in 2017, after corridor construction, mean abundance on the structured portions was similar to 2016, but the mean on open bottom increased significantly to ~6.4 fpf (t test, $p = 0.001$). Abundance at site I also varied seasonally, but in the opposite direction from site C, with abundance during survey series 2 being significantly greater ($p < 0.001$), than either series 1 or 3, which did not differ ($p = 0.29$), and this pattern was similar in both years (F = 6.4; $p = 0.12$).

When averaged across all series, fish abundance increased only at the impacted, open bottom portion of site I, and there were no changes at the structured portions of either site, or at the non-impacted open-bottom portion of site C (Fig. 2.4). The BACI interaction effect estimate was: $\widehat{BACI} = 2.98 \pm 0.27$ (Fig. 2.4). The best mixed effects model was model m_5, which included Time, Series, Subsites, and Time x Site interactions (Table 2.4). Therefore we concluded that the increase in observed fish abundance was due to the corridor implementation.

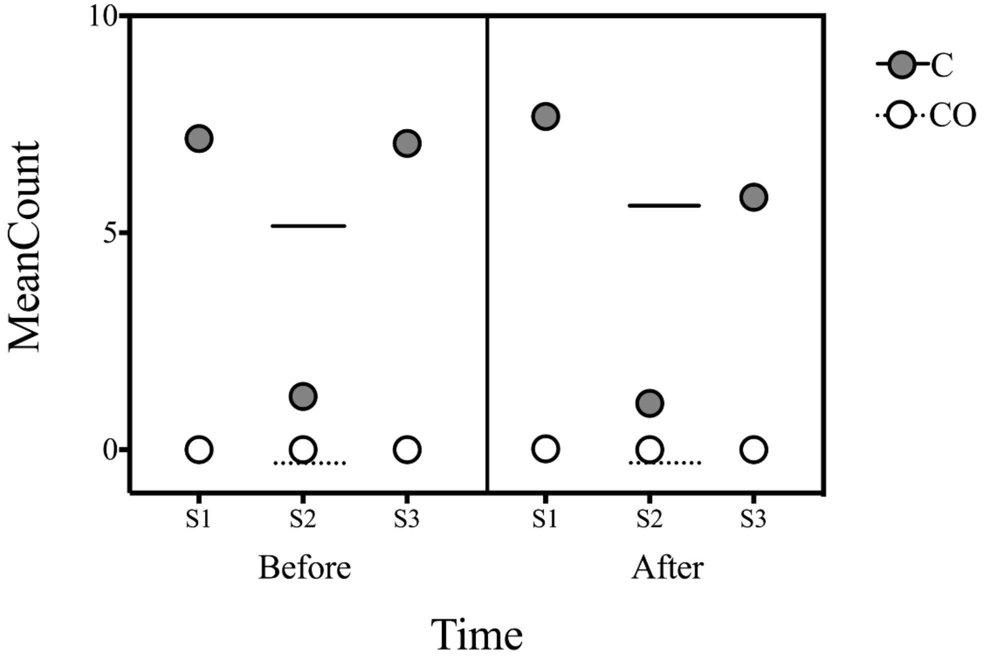


Figure 2.2. Fish abundance at the Control site. C = established structure; CO = open sand between the control sections. Horizontal bars are the annual means of fish counts before and after the corridor construction (Table 2.3).

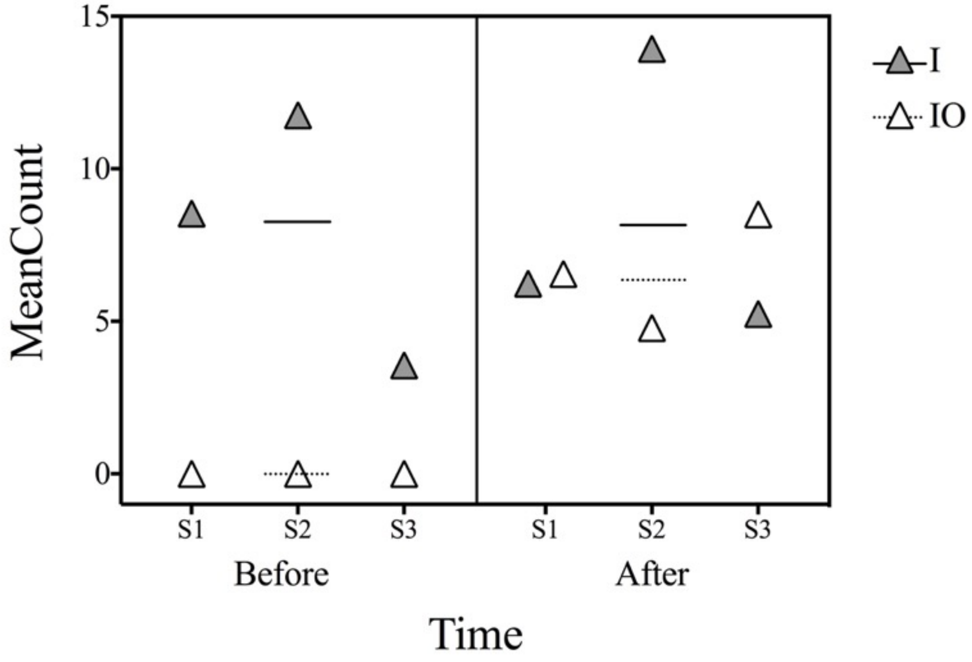


Figure 2.3. Fish abundance at the Impact site. I = established structure; IO = open sand before impact; corridor after placement. Horizontal bars are the annual means of fish counts before and after the corridor construction (Table 2.3).

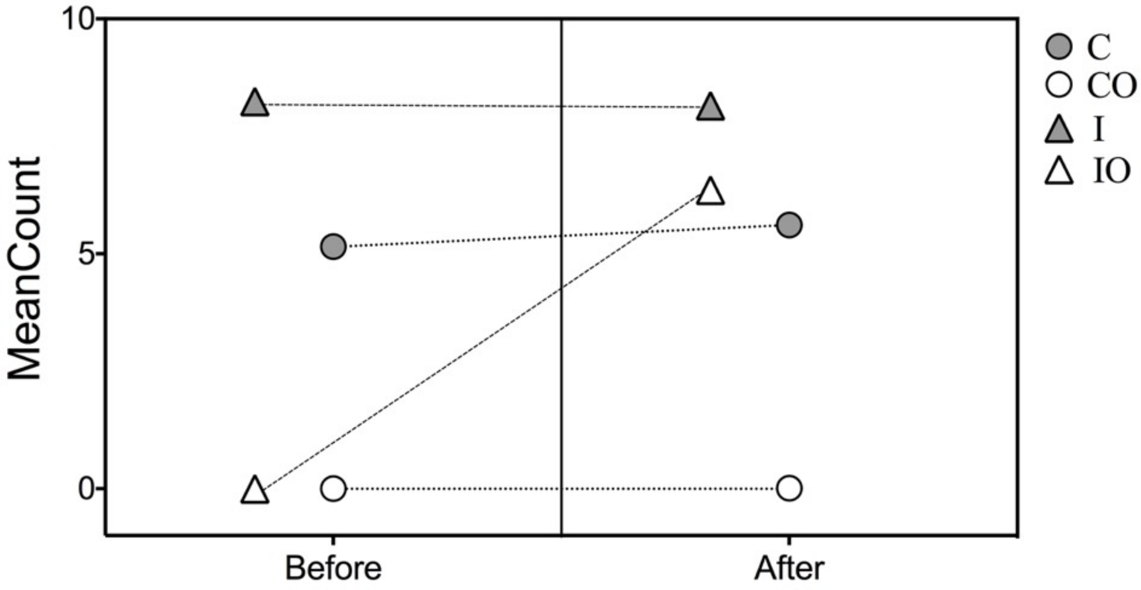


Figure 2.4. Annual mean fish abundance observed at structured and open portions of each site. C = established structure at the Control site; CO = open sand between the structure sections; I = established structure at the Impact site; IO = the modified section of the Impact site.

Table 2.4. Comparisons of mixed effects models m_0 – m_5, where m_0 is the null model; all models included cameras as a random effect. Time = before (2016) vs after (2017) corridor construction; Series = three sampling series of early summer, mid-summer, and fall; Site = control vs impact sites as two categories (including structured/unstructured subsites); TxS = interaction of Site (control/impact) and Time (before/after); Subsites = control and impact site separated into established structure and open space; TxSS = interaction of Time and Subsites; df = degrees of freedom; Loglik = log likelihood; AIC = Akaike information criterion value; Δ_i = increase in AIC value from the selected model (bolded); w_i = model probability. Model m_5 was selected as the best fit model.

Model	Variables	df	Loglik	AIC	Δ_i	w_i
m_5	**Time, TxS, Series, Subsites**	**12**	**-6966.43**	**13957.0**	**—**	**0.992**
m_4	Time, TxS, Subsites	10	-6973.24	13966.6	9.58	0.008
m_3	Time, Site, Series, TxS	8	-7156.83	14329.7	372.72	0.000
m_2	Time, Site, TxSS	6	-7193.89	14399.8	442.83	0.000
m_1	Time	4	-7258.38	14524.8	567.79	0.000
m_0	Intercept only	3	-7287.24	14580.5	623.50	0.000

Discussion

This study tested a common terrestrial method to increase seascape connectivity in an attempt to increase fish abundance on an artificial reef off the coast of Ocean City, Maryland. Connectivity was increased by constructing a stepping stone style corridor connecting two established patches of an artificial reef. This experimental design was based on the Before-After-Control-Impact (BACI) designs (Smith 2014).

Our results showed that fish abundance increased significantly on the corridor within a few months of construction, but did not change at the unmodified portions of either site. After corridor implementation, the impact site showed a significant increase in fish abundance not only from the previous year, but also when compared to the control site. Fish abundance recorded on the established sections did not change significantly between years at either site indicating that the observed increase in fish abundance was a result of the corridor implementation. We also observed a significant change in abundance between sampling series at both sites, which occurred both before and after the corridor. Interestingly, the seasonal variation at each site was identical between years, but exhibited opposite patterns between sites, and persisted after corridor construction. During both 2016 and 2017, the control site showed a reduced abundance during Series 2 before increasing to numbers similar to what was observed during Series 1. At the impact site during both 2016 and 2017, fish abundance increased in Series 2 and then decreased in Series 3. However, after corridor implementation the reduction in fish abundance during Series 3 was not as pronounced.

These results demonstrate that corridor connectivity can be an effective method to increase fish abundance on isolated habitat patches. Our observations support previous research that investigated relationships in seascape connectivity. Turgeon *et al.* (2010) showed evidence that open sand acted as a barrier for structure-oriented fish, significantly reducing attempts to cross large gaps of open sand. Our observations before the corridor implementation support those findings. No fish were observed swimming on open sand during the video surveys in 2016 (before), and only a single fish was observed on open sand at the control site in 2017 (after). When the distance of open sand was reduced at the impact site, fish were seen not only on the pyramids, but swimming between them.

This study was a simple, small-scale, one-year before/after study with one control and one impact site, and therefore has limitations. Since this study was focused on testing corridors in a marine environment, study site specifications were highly specific: easily accessible to scuba, separated into two sections, and established (i.e. >10% of the structure colonized by biogenic structure). This limited the number of sites available, resulting in a single impact and single control. A second control site would have given more insight into the seasonal fluctuations at the study sites and annual abundance. Another limitation is monitoring for only 1 year after modification, which was not the original plan. In addition to frequent poor visibility in 2018, which severely impeded consistent data collection, hurricanes and bomb cyclones destroyed much of the pyramid corridor. In addition, dive time was limited by the need to complete other study requirements for estimating fish abundance and fouling community structure at other sites.

Our first year observations, however, indicate that increasing connectivity via stepping stone corridor may increase fish abundance more effectively than building artificial reefs in isolation. Fish abundance was 1.57 ± 0.84 fpf at an artificial reef constructed 6 mo prior to the video survey (Table 1.4, site NH), whereas fish were observed on all the surveyed pyramids during all three series despite being void of biogenic structure. Additional surveys at the impact site and the incorporation of additional sites are needed.

Our experience with corridor construction lead us to recommended that corridors be constructed using more durable materials, and a structure designed to withstand severe weather events. Stacked concrete oyster castles did not stay in place during storms, and became scattered and partially buried. We have also observed that concrete pipes (Site MM in Table 1) also became buried over time, leaving little of the structure exposed. Structures should include a wide enough base to prevent rapid burial, and should include a variety of spaces that are scaled appropriately for body sizes of both juvenile and adult fish.

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Chapter 3. Trophic Ecology of Black Sea Bass Elucidated Using Gut Contents and Stable Isotopes: Comparisons between Natural and Artificial Reefs, and Offshore Surveys in the Mid-Atlantic Bight

Andre Price and Bradley G. Stevens

Abstract

Diets of Black Sea Bass (BSB, *Centropristis striata*) have been studied in the Mid-Atlantic Bight, but no studies have compared differences in dietary composition of BSB between natural and artificial reefs. We sampled 407 BSB at selected natural and artificial reefs near Ocean City, MD in 2016 and 2018, using hook-and-line angling to determine if reef type influenced length and age relationships, sex ratios, diets, and stable isotope ratios of $\partial^{12}C/\partial^{13}C$ and $\partial^{14}N/\partial^{15}N$ from three tissue types: liver, muscle, and mucus. BSB caught in 2016 and 2018 were compared to a NOAA dataset (n=1304) of trawl-caught BSB spanning 2000-2016 in proximity to the reef sites where angling occurred. There were no significant differences in age composition between fish at natural and artificial habitats, indicating that the sorting of age by location type did not occur. Stomach content analyses indicate that crustaceans (primarily *Cancer* crabs) dominated diets of BSB at artificial and natural sites by proportion and by frequency of occurrence; crabs were also the dominant dietary item in the NOAA samples. However, this may be overestimated due to the long gut residence time of crustacean tissues. ANOVA determined that location type had a significant effect on stable isotope values in all tissues except for $\partial^{15}N$ in mucus. This study showed that natural and artificial reefs are ecologically similar for Black Sea Bass caught near Ocean City, MD, however, subtle differences in diet between reef types suggest that their physical form may affect access of fish to different prey items.

Introduction

An important requirement of Ecosystem Based Fisheries Management is to determine the trophic relationships between fish, their prey, and their predators. Consequently, studies of fish diets are of primary importance in understanding their ecological relationships. Many such studies catch fish over wide temporal or spatial ranges and attempt to make large-scale conclusions, but diets may vary over temporal and spatial scales that are much smaller than the scales at which most sampling occurs.

NOAA conducts annual spring and fall bottom trawl surveys on the Northeast Atlantic Shelf. A small number of black sea bass (BSB) are caught during these surveys, and gut contents of those BSB have been analyzed over the scale of the surveys (Bowman et al. 2000). Byron and Link (2010) showed that BSB sustained ontogenetic shifts in diet from mostly polychaetes and arthropods to fish, particularly between sizes of 9 and 14 cm total length. Other studies have analyzed differences in diet between fish caught at widely varying locations, from New York to North Carolina (La Rosa, 2018). However, few studies have exclusively focused on determining differences in food choices between specific locations or habitats in the Mid-Atlantic Bight.

Traditional studies of fish diets have used stomach content analysis, which offers only a “snapshot” of what the animal has consumed in the past few hours to days (Hurst and Conover 2001; Araújo et al. 2007), but is insufficient to make long term inferences about dietary activity (Hurst and Conover 2001; Araújo et al. 2007). In contrast, stable isotopes can be used as “time capsules,” to infer what the animal has eaten over time, with the ability to reflect changes in ecological and dietary patterns in different tissues over varying temporal scales (West et al. 2006; Buchheister and Latour 2011). However, stable isotope analyses should be paired with stomach analysis, and multi-tissue sampling for validation purposes and to avoid misrepresentation of stable isotope readings (Post 2002). Furthermore, the time required for isotopic turnover in different tissues is associated with growth, tissue type, and other metabolic processes (Herzka 2005; Carleton et al. 2008; Buchheister and Latour 2011).

Stable isotope analyses of ∂^{13}C and ∂^{15}N have been utilized in a variety of organisms with different tissue fractions in order to infer trophic position and how ∂ values are affected by diet (Becker et al. 2007; Bauchinger and McWilliams 2009). Within fish species, stable isotopes have traditionally been examined from muscle and liver tissues, which have turnover rates of months or weeks, respectively. Church et al. (2009) indicated the utility of using external mucus to determine short-term (30-36 days) turnover in $\partial\ ^{13}$C and $\partial\ ^{15}$N in juvenile Steelhead Trout *Oncorhynchus mykiss*, and Maruyama et al. (2017) indicated a much longer turnover (200 days) in the mucus of 5-year old Amur catfish (*Silurus asotus*). Winter et al. (2019) suggested that epidermal mucus collected from live Common Carp (*Cyprinus carpio*) can replace the use of dorsal muscle for isotope readings, but cautioned that differences in tissue turnover rates are dependent on diet. Sampling of epidermal mucus can be used as a non-lethal method to obtain stable isotope samples, but few studies have verified its reliability in wild fish, and none have tested this method in BSB.

Stable Isotopes: ^{13}C, ^{15}N, and delta (∂) notation

Isotopes are variants of a particular element that differ by the number of neutrons in that element's nucleus; stable isotopes are the non-radioactive isotopes of an element (Fry 2006). Isotopes can be defined as "light", or "heavy", based on the sum of the protons and neutrons in the isotope's nucleus. For example, ^{13}C is heavier than ^{12}C. For most elements, the lighter isotope is naturally more abundant than the heavier isotope (Fry 2006; West et al. 2006). The difference in the ratio of heavy to light isotopes is commonly expressed in ∂ notation, which can be expressed in the following equation (cited in Hayes 2004), originally introduced by McKinney et al. (1950), where ∂ is the abundance of isotope A of element X in a sample relative to the abundance of that same isotope in a standard (Hayes 2004):

$$\partial^{A}X_{STD}=({}^{A}R_{Sample}/{}^{A}R_{STD})-1$$

Carbon and nitrogen are among the most abundant elements in living organisms, and are used in many ecological studies to infer environmental and trophic data, respectively (West et al. 2006). Differences in isotopic abundance are important because the accumulation of ∂^{15}N is strongly related to trophic level. Additionally, ∂^{13}C signatures can provide additional information about whether dietary items originate from benthic or pelagic sources (Post 2002; Carabel et al. 2006; Fry 2006; Glibert et al. 2018). Generally, higher ∂ values in ^{13}C/^{12}C and ^{15}N/^{14}N ratios represent higher tropic levels. The accumulation and excretion of these isotopes due to feeding, growth, and metabolic processes can provide us with "ecological timelines" that allow inference of dietary activity that surpasses the capability of inferences solely made by stomach content analysis (MacNeil et al. 2006; Heady and Moore 2013).

The goal of this study was to obtain a greater understanding of the trophic relationships between BSB and their prey items, and differences in feeding behavior between fish occupying natural and artificial reefs in the Mid-Atlantic Bight. This was done by the examination of gut contents, and isotope signatures in BSB tissues. Specific objectives were to:

1. Determine the primary prey items for BSB near Ocean City, MD.
2. Determine if differences in length, age distribution, or diet exist between BSB caught at artificial and natural reef sites; and
3. Estimate ontogenetic shifts in feeding dynamics of BSB near Ocean City, MD using gut contents and stable isotope analyses of $\delta\ ^{13}C$ and $\delta\ ^{15}N$ in liver and muscle tissue

Methods and Materials

<u>Sample Collection of BSB and Prey</u>

Black sea bass were collected using hook and line angling from natural and artificial reef sites from spring through fall of 2016, and from spring through summer of 2018. (We also sampled >400 fish in 2017, but those were all lost when electric power loss at our laboratory caused a freezer to thaw). All angling occurred during daylight hours, and squid was used as bait. Sampling sites consisted of a mix of natural bottoms (mostly cobble and shell with a few gorgonian corals) and artificial reefs (mostly shipwrecks and metal structures, Table 3.1). Some of these sites overlapped with those sampled for fish and invertebrate community structure in Chapters 1 and 2. In 2016 we sampled at sites 1 through 6, but due to low catches, in 2018, we sampled different sites that produced a higher CPUE and were more clearly defined by unique substrates (sites 7-12). All sites were classified as either natural or artificial based on the substrate type. Additional data on stomach analysis of BSB for comparison to fish caught in this study were obtained from the NOAA NEFSC seasonal bottom trawl surveys. Comparisons to the angling dataset were made with a subset of NOAA's data that only included BSB obtained in the Spring and Summer months, from 2000 through 2016, and were caught between 36 and 40 ^{o}N degrees latitude. On 10 August 2018, beam trawl tows were conducted near sites 8 and 10 to obtain samples of prey items for isotopic baselines. The trawl used consisted of a net with 2.0 cm (0.75-inch) mesh hung on a 1.0 m wide frame. The net was towed at an average speed between 2.5 and 3.0 knots.

<u>Fish and Stomach Analysis</u>

Stomach contents and stable isotope analyses were conducted on each fish caught by angling. Upon retrieval, fish were immediately placed in individual plastic freezer bags to prevent mucus contamination, and dispatched by placement in super-cooled ice, which slowed digestive processes. Preservation by freezing was chosen because it has a minimal effect on isotope values in contrast to other methods (Bosley and Wainright 1999; Kaehler and Pakhomov 2001). Carcasses remained in plastic bags and were frozen at -80 ^{o}C for mucus removal later. In the laboratory, total length (TL) of fish was measured to the nearest cm, and fish were weighed to the nearest 1.0 g, macroscopically sexed, and dissected to remove stomachs, muscle, and liver samples (See Appendix Photos M, N). Fish that were not clearly identifiable as male (M) or female (F) after dissection were considered to be in transitional, but some were classified as unknown (U). All stomachs were initially placed in 10% formaldehyde for a minimum of 2 weeks and transferred to 70% ethanol for preservation until further sorting of prey items. Liver and muscle samples were prepared for stable isotope analysis of $\partial^{13}C$ and $\partial^{15}N$. Livers were removed and white muscle tissue was excised from an area directly above the pectoral fin and immediately frozen at -80 °F. In 2018 a subsample of fish were selected to test mucus for stable isotope analysis of $\partial\ ^{13}C$ and $\partial\ ^{15}N$.

Table 3.1. Sites where Black Sea Bass were captured for this study, and number captured in 2016 (Fish16) and 2018 (Fish18). ND= no data. Site type is defined as artificial (A) or natural (N).

Site	Location	Lat	Long	Type	Fish16	Fish18	Description
1	Pharoby North	38.556666	-74.903611	A	25	ND	Scalloper boat, sunk 1980, section 1 of 2
2	Pharoby South	38.543888	-74.902222	A	45	ND	Scalloper boat, sunk 1980, section 2 of 2
3	Kathleen Riggins Main	38.543888	-74.985833	A	30	ND	Clammer boat; sank in 1991
4	Kathleen Riggins Debris	38.383055	-74892777	A	3	ND	Rubble field from shipwreck
5	Elizabeth Palmer	38.636944	-74.876388	A	1	ND	Wooden schooner wrecked in 1915
6	Unknown Wreck #2 (Palmer East)	38.599722	-75.154444	N	3	ND	Highly deteriorated wooden wreck of unknown origin
7	Natural Bottom Site 1	38.410833	-75.080277	N	ND	102	Mostly shell & cobble covering mud and sand bottom
8	Natural Bottom Site 2	38.447777	-74.969444	N	ND	108	Mostly shell & cobble atop mud and sand bottom
9	Jimmy Jackson	38.331111	-75.033888	A	ND	2	Concrete and metal structures; constructed circa 2011
10	Blenny	38.153333	-79.91666	A	ND	24	Submarine; scuttled 1989. Mussel and gorgonian coral growth on site
11	Cable cars	38.540555	-74.991944	A	ND	51	Staggered subway cars; mussel growth on substrate
12	Navy Barges	38.168333	-75.154444	A	ND	13	Sunken cargo barges

Prey items were removed, weighed to the nearest 0.01 g, and identified to the lowest possible taxonomic level. Stomach content data were analyzed using percent number (%N), percent weight (%W), percent frequency of occurrence (%FO), and prey specific index of relative importance (PSIRI), as expressed in Varela et al. (2017) and Brown et al. (2012) as:

$\%PSIRI = [\%FO * (\%PN + \%PW)] / 2$ where

$\%N_i$=number of prey item i*100/ total number of prey items

$\%W_i$ = weight of prey item i *100 / total weight of all prey items

$\%FO_i$ = number of stomachs with prey item i *100/ total number of non-empty stomachs

Preparation for stable isotope analysis

All samples for stable isotope analysis were prepared in accordance to UC Davis' ^{13}C and ^{15}N Analysis of Solids by EA-IRMS protocol[2]. Samples of muscle and liver tissue were dried for 48 h in an oven at 65 °C, homogenized with a mortar and pestle, enclosed in tin capsules, and stored in a desiccator until shipment. Mucus samples were treated in accordance to methods adapted from Church et al. (2009). Fish were removed from the freezer in their respective bags and thawed for 5 minutes, or until mucus appeared on the dermis of the fish. Mucus was gently scraped from the dorsal side of the fish and placed into a glass scintillation vial. The mucus received three consecutive 5 ml rinses of reverse osmosis (RO) water, shaken between each addition, after which the mucus-water filtrate was passed through a 5 µm polycarbonate filter. One final 5 ml rinse of RO water was passed through the filter, and the filtrate was decanted into a 50 ml plastic test tube. Subsequently, the filtrate was frozen for at least 24 h in a freezer at 0^oC, then cryodesiccated for 48 h in a lyophilizer, mixed by spatula, weighed, and enclosed in tin capsules. All samples were shipped to UC Davis' Stable Isotope Facility in Davis, CA, where they were analyzed with an elemental analyzer interfaced to a continuous flow isotope ratio mass spectrometer (IRMS).

Data analysis

Diet composition was expressed as a proportion of total contents, by frequency of occurrence (FO), and gravimetric weight. Weight, number and FO were used for the calculation of PSIRI. Chi-square tests of independence were used to determine if significant differences in fish diets existed between site types (artificial vs natural), size groups, or sex. PSIRI was used to compare prey composition between fish collected by this project and those collected by NOAA. The base code for plotting PSIRI was created by Simon Brown.

Diet data were also analyzed using non-metric multidimensional scaling (NMDS). This method uses rank order of prey weights to calculate positions of each prey item and groups of data within a multi-dimensional space. Weights of seven prey groups were included: Annelids, Worms (non-annelids), Arthropods, Molluscs, Fish, Animal Remains (AR), and Miscellaneous. Data were analyzed for differences between sexes (Male, Female, Transitional), and by capture locations. Cluster analysis was also used to analyze the data by location, using Euclidean distances calculated on a matrix that was centered (i.e. as residuals from the mean) and scaled (in standard deviation units).

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[2] https://stableisotopefacility.ucdavis.edu/13cand15nsamplepreparation.html

Stable isotope data were compared using two-way analyses of variance (ANOVA) to determine whether significant differences existed by site type, fish size, or the interaction of site and size. The linear model tested by the ANOVA was:

$$D_T \sim L_i * S_i + \varepsilon$$

Where D is either ∂^{15}N or ∂^{13}C, T is tissue type, L is location type, S is size, and ε is experimental error. Because multiple similar tests were conducted, a Bonferroni correction was applied to prevent error-rate inflation, and results were compared to a critical value of p=0.01. Scatterplots with ellipses were used to display overlap of ∂^{15}N and ∂^{13}C data, where ellipses represent the 95% confidence interval. Ellipses were created using the R function "stat_ellipse" with ggplot2 (R Core Development Team, 2011). Fish were categorized as "small", "medium", or "large", with ranges of 0-25 cm, 25-50 cm, and >50 cm TL, respectively. Differences in mean size between sexes were tested using a student's t-test, whereas differences in size distribution between site types were tested with at Komogorov-Smirnov non-parametric ANOVA (K-S test).

Results

A total of 407 fish were caught by angling for this study; 197 at artificial sites and 210 at natural sites (Table 3.1). In 2018, sampling locations were changed due to low CPUE with our sampling gear at many of the 2016 locations. There was considerable variation in sample size for most locations sampled, particularly in 2016 (Table 3.1). Sampling did occur in 2017, but the 400 fish sampled from that year were destroyed during an electrical outage and were excluded from this study.

Female BSB were caught more often than males in the samples obtained by angling as well as in the NOAA data (Fig. 3.1). Sex ratios were 235:165:6:1 (F:M:T:U) in our samples and 874:323:2:105 in the NOAA samples. Female fish were the most abundant sex across habitat types by proportion (Fig. 3.2), but males grew to a larger total length (Fig. 3.1). Mean size of male BSB caught in this study (27.2 cm TL) was greater than mean size of females (23.921 cm TL, t=6.83 ,p=4.82e-11). There were no significant differences in mean size of fish between artificial and natural sites (K-S test, p=0.49, D=0.82). Mean size of males in the NOAA data (26.7 cm TL) was also greater than mean size of females (23.7 cm TL) (t=5.8947, p=6.88e-09).

Stomach Content Analysis

Arthropods comprised the highest proportion of organic stomach contents at nearly 60% of total consumed biomass (Figure 3.3). The majority of arthropods in our data and in the NOAA data were composed of decapod crabs and hermit crabs. The majority of identifiable decapod crabs were rock crabs, *Cancer irroratus*. Over 50% of the 205 fish caught at natural sites had empty stomachs, while only 13% of 193 fish stomachs from artificial sites were empty. The top four prey items at both natural and artificial sites were arthropods, annelids, fish, and worms (Figure 3.4). A chi square test of independence showed no significant differences in prey consumption between artificial and natural sites for prey count by fish size (p=0.29), or sex (p=0.18) between site types. PSIRI values for top prey items consumed by BSB caught with our gear at artificial and natural sites, and between our data and NOAA, are shown in Table 3.2. Graphic analysis of diet PSIRI for Black sea bass collected in this study show that arthropods dominated the diets of BSB at artificial sites in percent number, weight, and FO (Fig. 3.5).

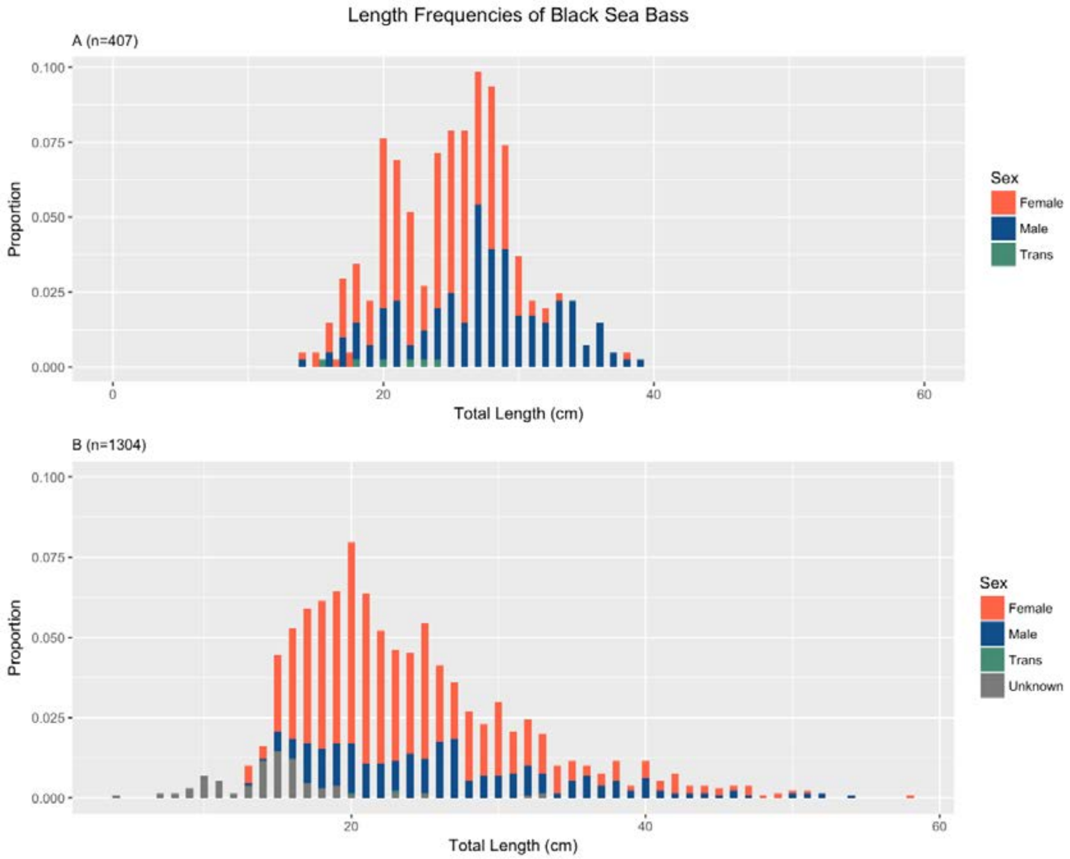


Figure 3.1. Length frequencies of Black sea bass. A, Fish sampled by hook and line in 2016 and 2018; B, Data from NOAA seasonal trawl surveys. Females were more abundant in both data sets, while mean size of males was greater than that of females.

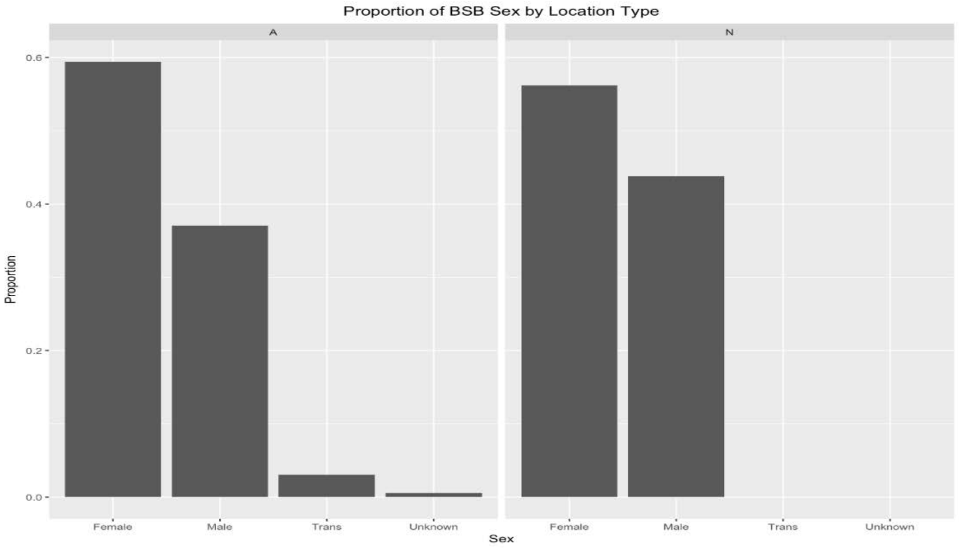


Figure 3.2. Proportions of Black sea bass of different sex caught by angling at artificial (left) and natural (right) sites in 2016 and 2018.

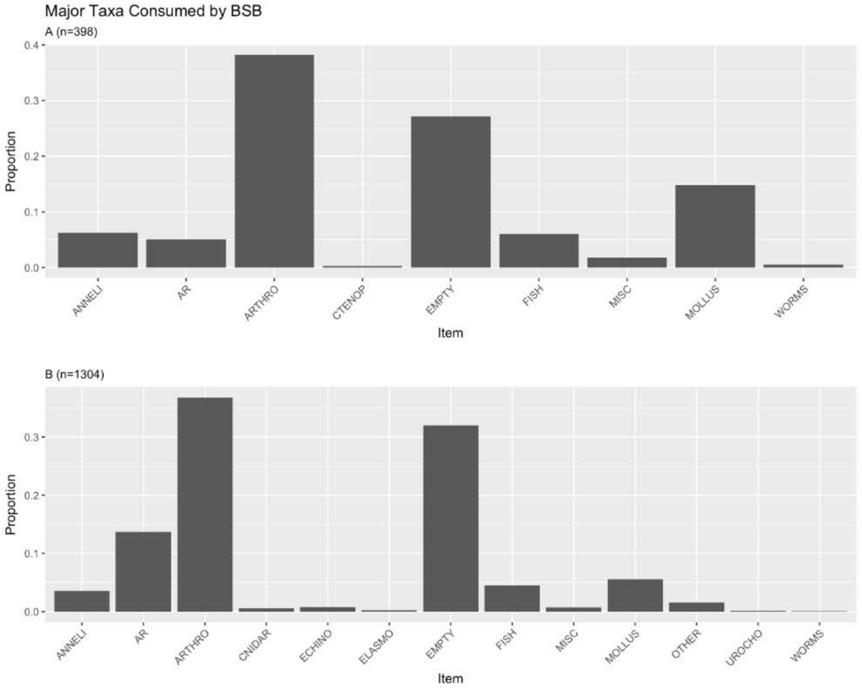


Figure 3.3. Proportion of major prey taxa consumed by Black sea bass. A) Fish caught by hook and line in 2016 and 2018; B) Fish captured during NOAA trawl surveys from 2000-2016.

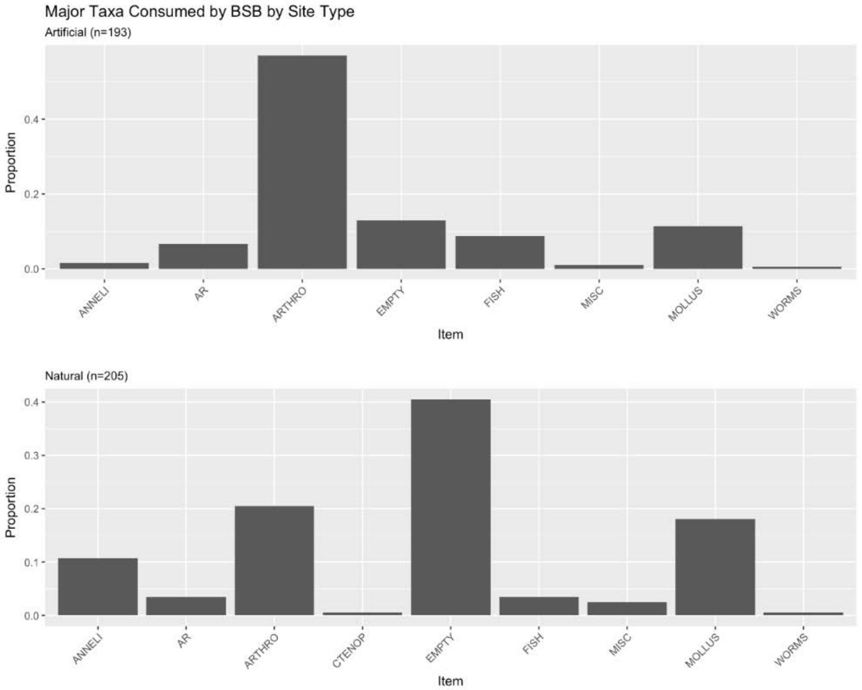


Figure 3.4. Proportion of major prey taxa consumed by Black sea bass caught by hook and line at artificial and natural sites in 2016 and 2018. The top four prey items (arthropods, fish, molluscs, annelids) were the same at natural and artificial sites, and empty stomachs occurred more frequently among fish at natural bottom sites.

Table 3.2. %PSIRI values for the top four prey items by habitat type (artificial or Natural) and source, i.e. caught with hook and line by UMES researchers (2016 and 2018), or from NOAA trawl surveys (1980-2016).

	Habitat type		Source	
Prey Item	Artificial	Natural	UMES	NOAA
Annelids	0.100	10.61	0.72	1.44
Arthropods	28.87	17.36	32.08	48.5
Fish	1.067	0.53	1.00	10.70
Molluscs	2.317	11.09	6.01	1.705

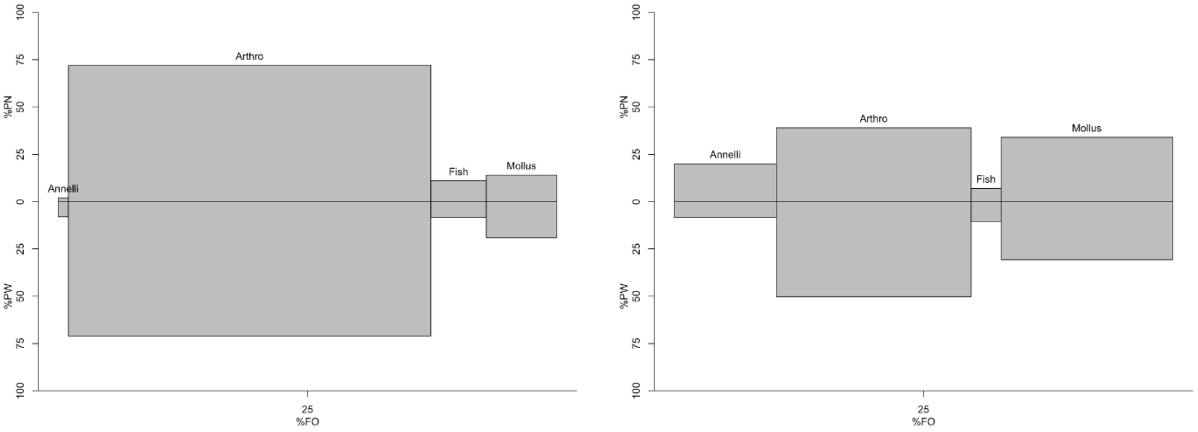


Figure 3.5. PSIRI for the main food items in diets of Black sea bass caught in 2016 and 2018 by angling at A) artificial sites and B) natural sites.

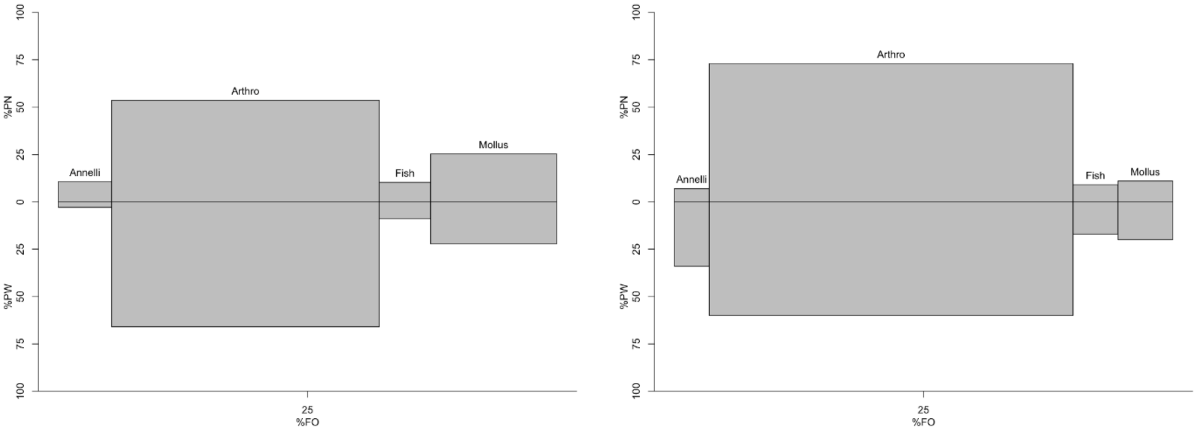


Figure 3.6: PSIRI for the main food items in diet of Black sea bass caught by: A) angling in 2016 and 2018 (our study), and B) during NOAA trawl surveys from 2000-2016.

At natural sites, arthropods were still the dominant prey item, but annelids had a higher FO and greater PSIRI compared to artificial sites. Graphic analysis of PSIRI for BSB collected in our study and by NOAA (Fig. 3.6) showed similar results. In the NOAA data, annelids composed a higher percent weight, but a lower FO than in BSB caught by angling.

Stable Isotope Analysis

There was considerable overlap in values for ∂^{13}C and ∂^{15}N of all tissue types between site types (artificial vs natural) and fish size (large vs small) (liver, muscle, and mucus are shown in Figures 3.7, 3.8, and 3.9, respectively). Although ellipses show a high degree of overlap and very little defined independence, ANOVA tests showed statistical differences ($p<0.05$) due to both site type and size (Table 3.3).

Table 3.3. Summary of comparisons between stable isotope ratios by tissue, site, and size group. Significant p-values for ANOVA tests are designated as: **=0.05; **=0.01; ***=0.001.

Test	**∂^{15}N**	**∂^{15}N**	**∂^{15}N**	**∂^{13}C**	**∂^{13}C**	**∂^{13}C**
Source	Liver	Muscle	Mucus	Liver	Muscle	Mucus
Site	4.38e-07***	7.249e-09***	0.0678 ns	<2e-16***	<2.2e-16***	0.6887e-6***
Size	0.0105*	0.9892 ns	0.0316 *	0.7445 ns	0.0004***	6.209e-05***
Interaction	0.8837 ns	0.7877 ns	0.8059 ns	0.9222 ns	0.0007***	0.5387ns

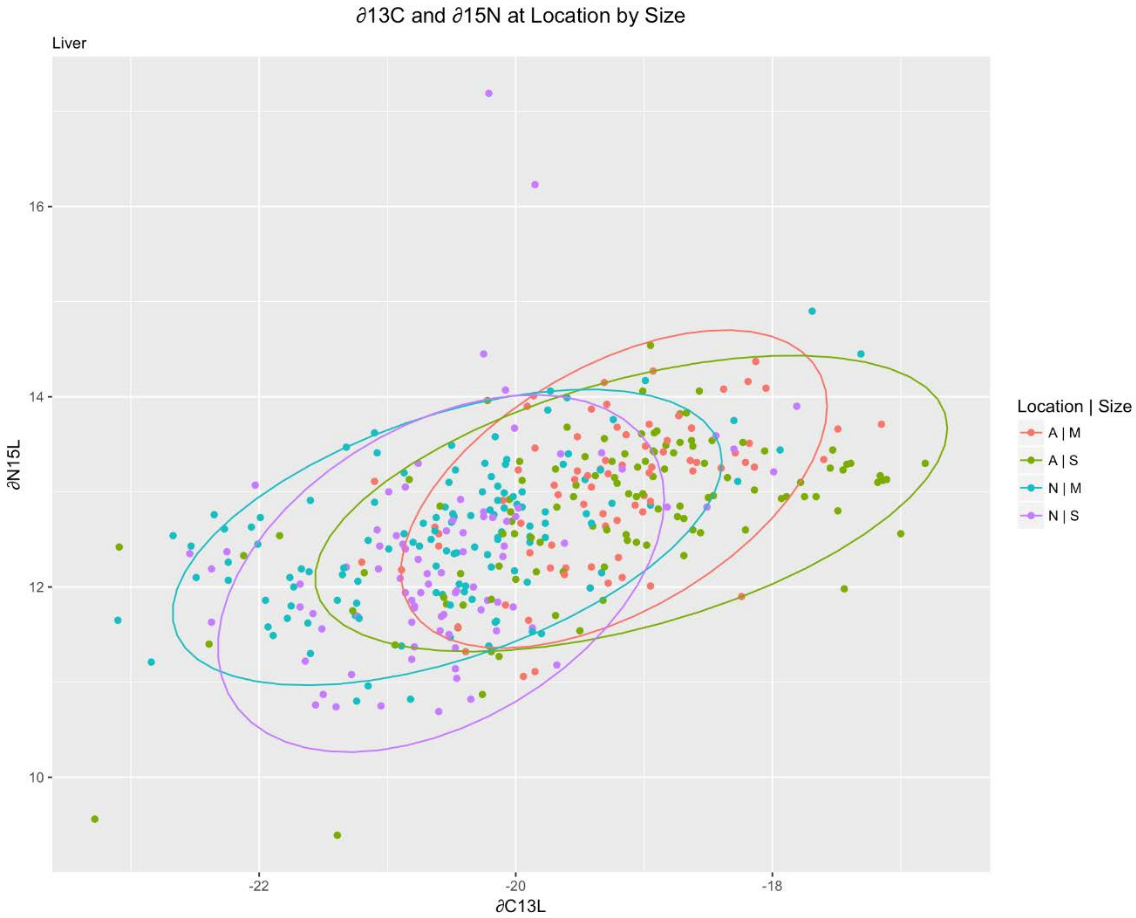


Figure 3.7. Stable isotope ratios for ∂^{13}C and ∂^{15}N in liver of Black sea bass, categorized by size (M=medium, S=small) and location (A=Artificial, N=Natural). Significant differences occurred in both isotopes between artificial and natural sites.

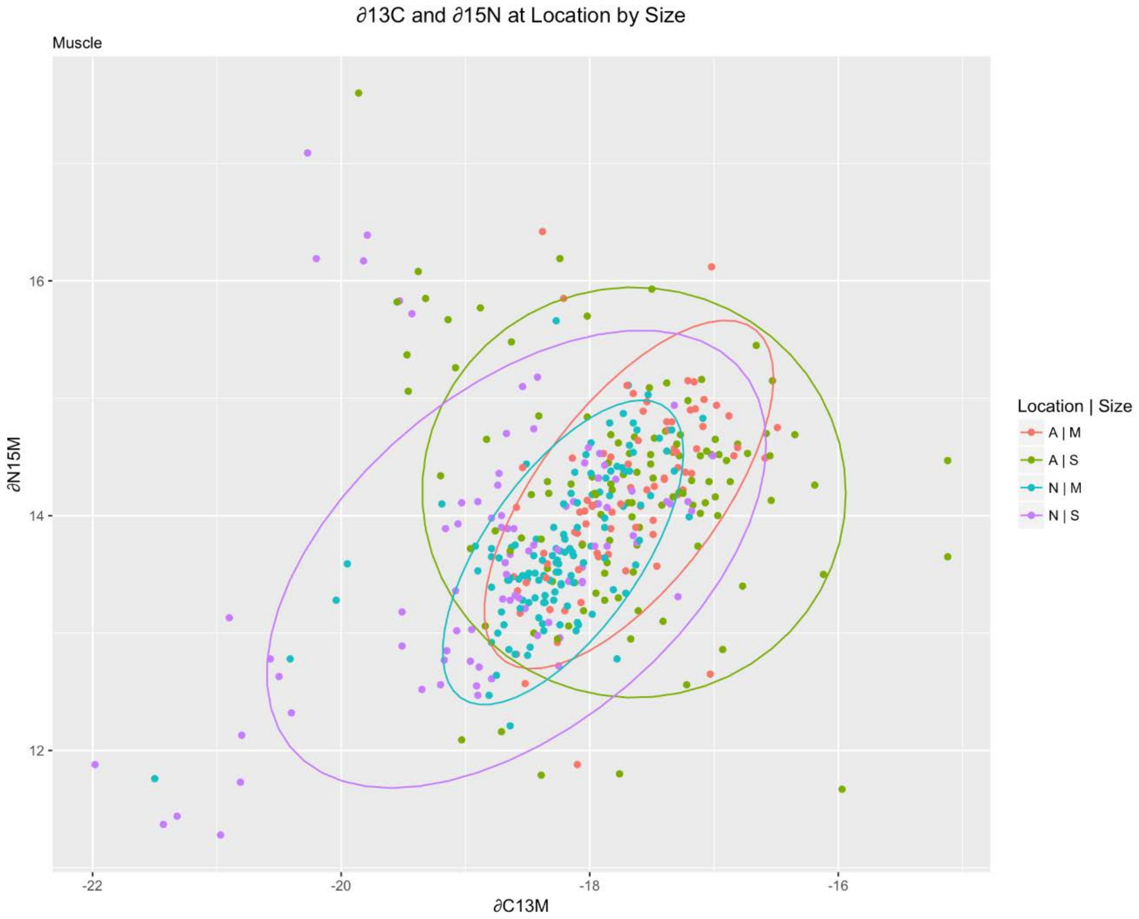


Figure 3.8. Stable isotope ratios for ∂^{13}C and ∂^{15}N in muscle of Black sea bass, categorized by size (M=medium, S=small) and location (A=Artificial, N=Natural). Significant differences occurred between size, location, and their interaction in ∂^{13}C, but only between location types in ∂^{15}N.

Significant differences in ∂^{13}C and ∂^{15}N were more commonly due to site, and less often to size (Table 3.3). Significant differences were found between location types for all tissues, and both isotopes, with the exception of ∂^{15}N in mucus (p=0.67). Mean values of ∂^{15}N were higher at artificial sites than at natural sites in both liver (12.86 vs 12.43, respectively) and muscle (14.20 vs 13.70), indicating that fish on artificial reefs were feeding at slightly higher trophic levels. Similarly, ∂^{13}C values were higher at artificial sites than at natural sites in liver (-19.24 vs -20.54, respectively) and muscle (-17.71 vs -18.48), indicating that fish on artificial reefs were consuming slightly more prey from littoral sources, vs benthic sources. These results demonstrate that our sample sizes were large enough to detect differences as small as 0.4 units of ∂^{15}N, or about 10% of a trophic level, though such small differences may not have great biological significance. Significant differences were found between size groups for ∂^{15}N in liver and mucus, and for ∂^{13}C in muscle (p=0.0004) and mucus (p=0.03). The interaction between site and size was significant only for ∂13C in muscle (p=0.0007).

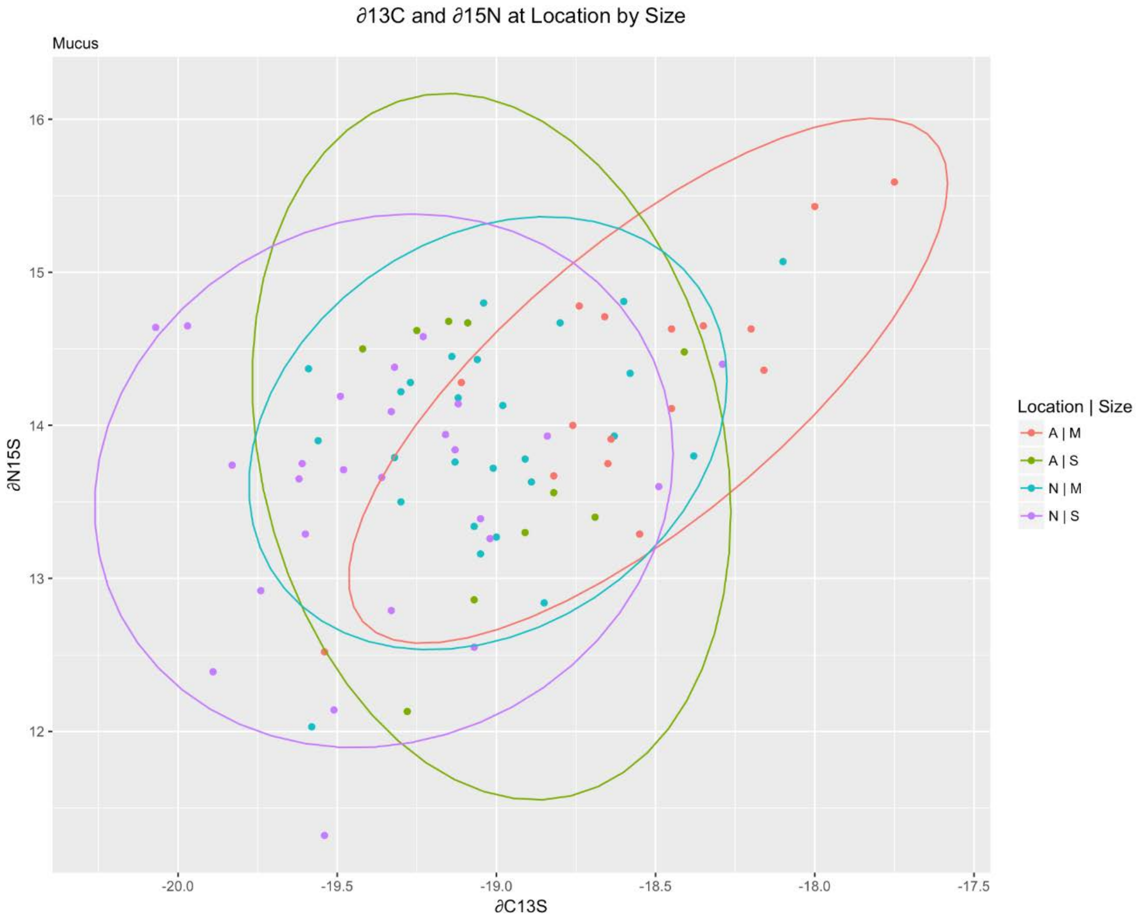
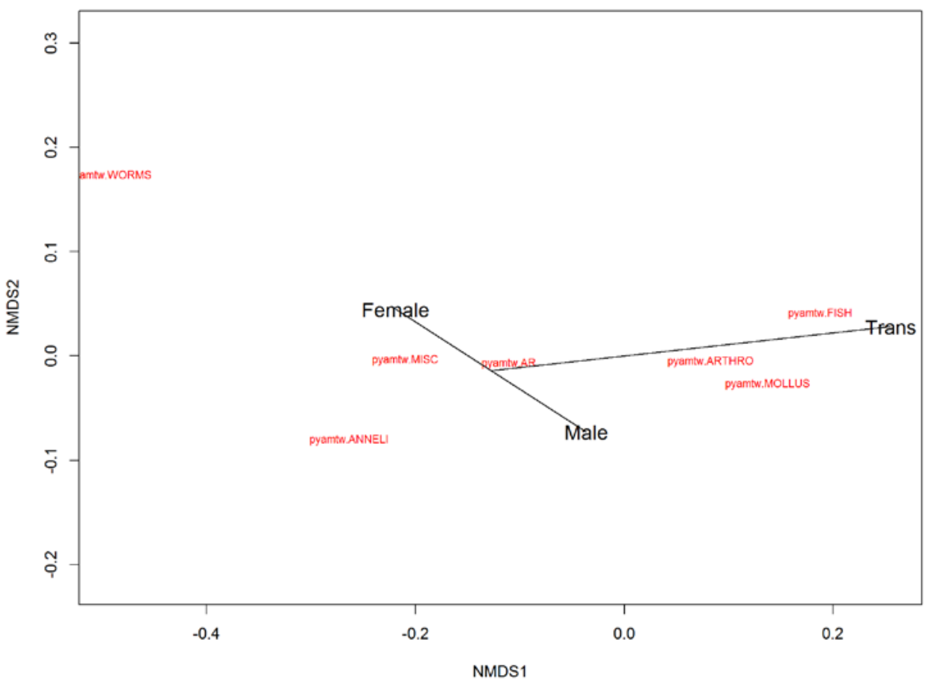


Figure 3.9. Stable isotope ratios for ∂^{13}C and ∂^{15}N in mucus, by size (M=medium, S=small) and location (A=Artificial, N=Natural). Significant differences occurred by location type and by size in ∂^{13}C only.

<u>Multivariate Analysis</u>

NMDS analysis by sex shows that males and females are slightly separated along a diagonal axis and that transitional fish have a very restricted diet, but this may be an artifact of small sample size (Fig. 3.10). Analysis of diet by location shows that fish diets at the natural sites (NB_ONE and NB_TWO) were similar, as were sites PS & PN (the South and North sections of the Pharoby shipwreck), but the two sections of site KR (KR and KRM) were widely separated (Fig. 3.10). The dendrogram produced by cluster analysis of the locations showed that site CARS forms a unique group, sites KRM and NB_TWO form a second group, and the remaining sites form a third group (Fig. 3.11). It also shows sites AV and JJ as being closest together, which doesn't occur in the NMDS plot. Both analyses show that PN and PS are highly similar; that JJ and BLEN are similar but far to the right end of the scale, that KRM is at the opposite end of the scale, and that KR and KRM are much more different than would be expected. However, it is surprising that the cluster analysis showed large distances between sites NB_ONE and NB_TWO. The differences between these two methods are due to the fact that NMDS uses ranks, so is "non-metric" as well as multi-dimensional, whereas cluster analysis uses Euclidean distances along one dimension between each pair of samples. Both are different ways of looking at a complex data set in a reduced set of dimensions, and both provide useful information.



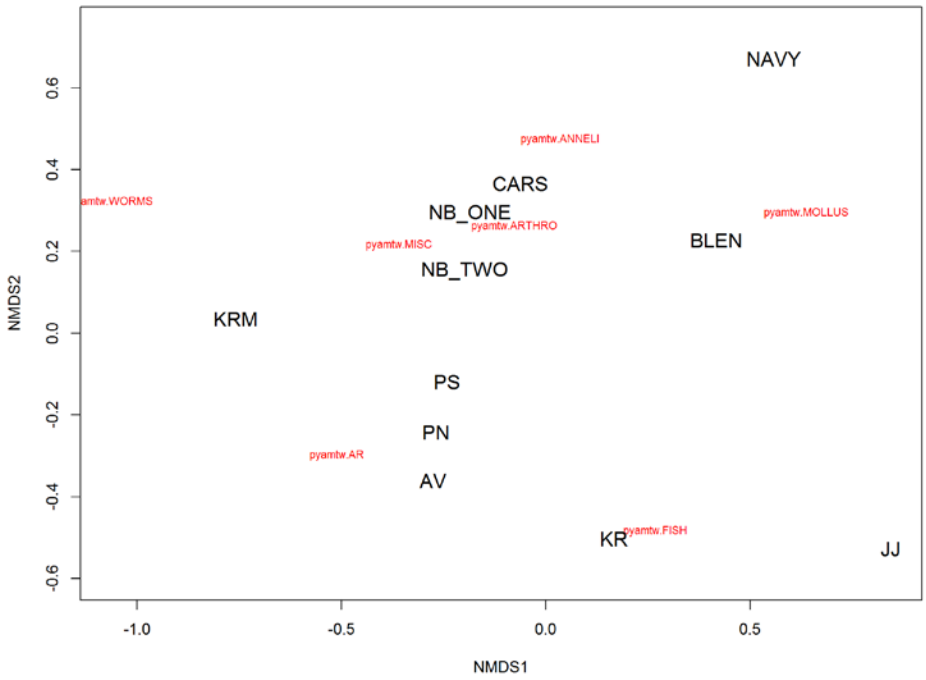


Figure 3.10. Non-metric multidimensional scaling plot of fish diets, using weights of seven prey groups: Annelids, Worms (non-annelids), Arthropods, Molluscs, Fish, Animal Remains (AR), and Miscellaneous. Top: Data overlaid by Sex groupings; Bottom: Data overlaid by Location groupings.

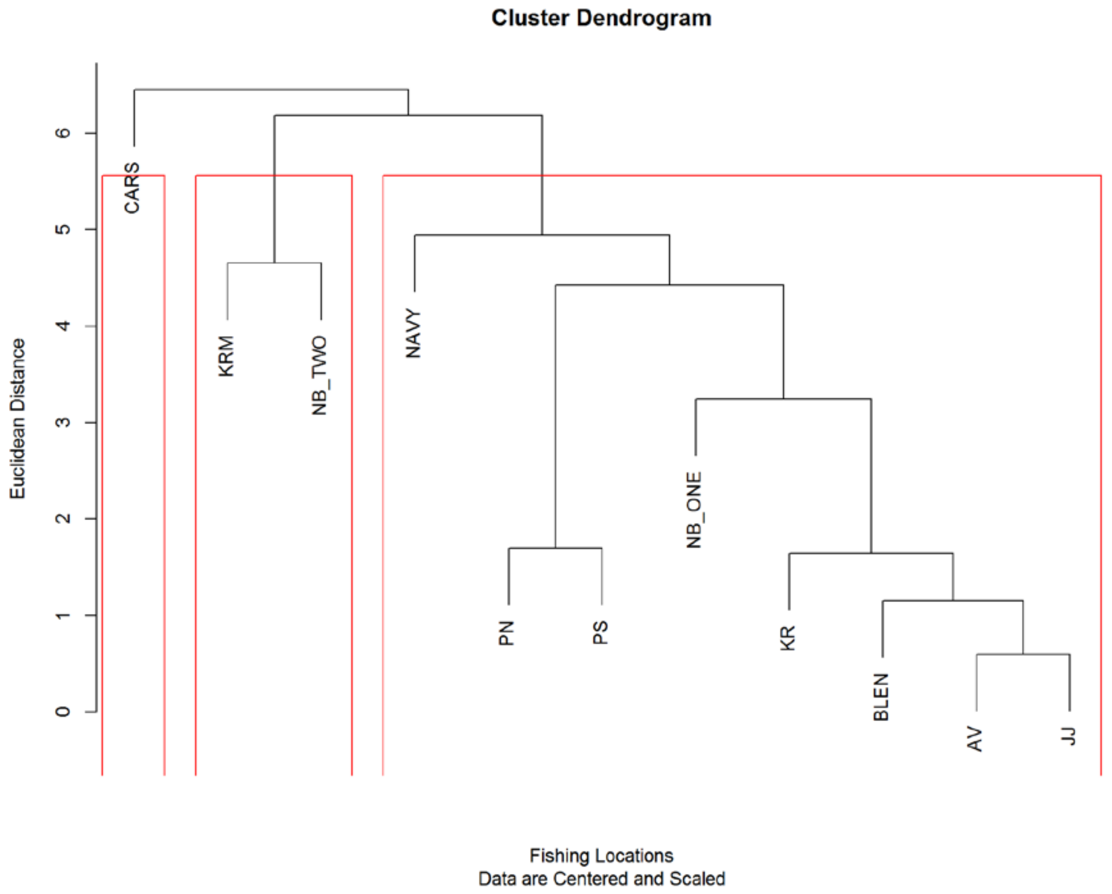


Figure 3.11. Cluster analysis dendrogram of prey weights by sampling location. Three groups of sites are separated at a distance of 5.5.

Discussion

Our results show that the ecological functionality of artificial reefs is similar to that of natural reef habitats for Black sea bass in the Mid-Atlantic Bight, based on several traits examined including size, sex, gut contents, and trophic position. Diet composition did not differ significantly between fish captured at natural or artificial sites, despite the fact that benthic organisms caught by beam trawl sampling differed between the two site types (Fig. 3.12). However, trawls only sampled the sandy seafloor near the reefs and wrecks, and not the actual structured habitat, so only indicate what prey items were present in the nearby area. We used trawl sampling only to collect specimens for comparative isotope ratios, and did not try to assess abundance. However, recent studies using small mesh trawls in the nearby Maryland wind energy area showed that the most common epifaunal organisms were sand dollars *Echinarachnius parma*, hermit crabs *Pagurus* sp., auger snails *Terebra dislocata*, and sand lance *Ammodytes americanus* (Cruz-Marrero et al. 2019). Of these four species, probably only sand lance were consumed by black sea bass. Astarte clams *Astarte castanea* and rock crabs *Cancer irroratus* were #6 and #8 in order of abundance, but were prominent among BSB stomach contents. Compared to BSB muscle, the isotopic signatures of ∂^{13}C and ∂^{15}N in epifaunal organisms were distinct and lower in mussels, scallops, clams, rock crabs, snails, shrimp, and sand dollars, although there was some overlap with flounder (probably gulfstream flounder *Citharichtys arctifrons*) (Fig. 3.13). These results suggest that BSB probably forage in the sandy seafloor adjacent to structured habitats, rather than among the reefs and wrecks, as crabs, worms, and clams are not common on the wrecks. The higher proportion of empty stomachs at natural sites may indicate less frequent feeding at those sites, or that fish may have regurgitated stomach contents during retrieval, as those sites were relatively deeper than the artificial sites. Alternatively, feeding may have been impacted by recreational fishing effort, since several of the artificial sites that we sampled are popular fishing destinations.

Figure 3.12. Organisms caught in beam trawls near natural (top) and artificial (bottom) sites for this study. Catch at the natural site consisted mostly of large shells and cobble, with some sea robin and squid egg mops. Catches at the artificial sites mostly consisted of Crangonid shrimp and smaller shells.

Analysis of stomach contents did not show evidence of a shift in diet with ontogeny for fish caught in our study. Few black sea bass >50 cm TL were caught at the sites that we sampled; this was likely due to commercial and recreational fishing pressure at those sites, as well as a much smaller sample area and sample size obtained in this study compared to the NOAA data and Byron and Link (2010). Despite the lack of major differences, subtle differences may provide insight about the habitat types.

Stable isotope ratios varied most significantly by location type. Significant differences between locations for a given tissue type or size category cannot be definitively correlated to prey type consumption. Significant differences in both ∂^{15}N and ∂^{13}C occurred between artificial and natural sites, but not between size groups of fish, indicating that fish at the different site types may be feeding at slightly different trophic levels. Even differences that were significant may not have great biological significance. Differences in ∂^{13}C in liver between location types may indicate that fish at particular sites frequently prey on items with a higher ∂^{13}C values. Prey items with higher ∂^{13}C values would be characteristic of items from more littoral sources, yet this was not reflected in diet analyses. Isotopic values in mucus were not drastically different for $\partial\ ^{15}$N or $\partial\ ^{13}$C, so it may be possible to use mucus as a non-lethal sampling method for Black sea bass in future studies.

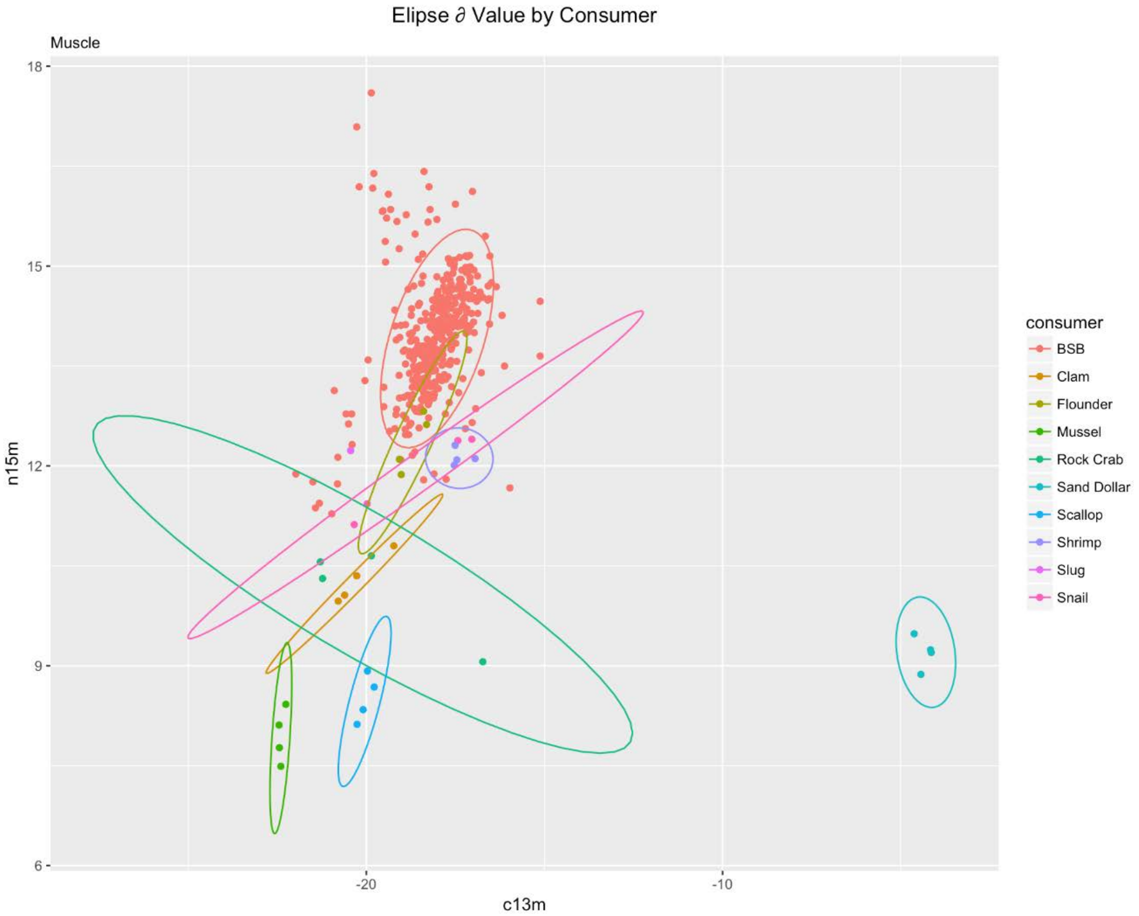


Figure 3.13. Stable isotope ratios for ∂^{13}C and ∂^{15}N in muscle of black sea bass (red dots and ellipse), compared to items caught in trawl on August 10, 2018.

If the small differences in either prey or isotope levels between site types were to be considered ecologically significant, it could be argued that they are due to structural differences between reef types. Most of the artificial reefs consisted of relatively intact masses of vertical structure, with heights ranging from 1 to 5 m above bottom. Fish on those sites would have to move meters away from the center of the site to access sandy seafloor on which to feed, but would have easy access to the water column above the wreck. In contrast, natural sites are broken into many irregular small patches and fish would not have to move far to find natural seafloor. Previous studies (Cullen and Stevens, 2017) have shown that fish hide among cracks and crevices, and beneath the canopy of sea whips, where they have close access to sandy seafloor, but would have to move multiple meters up into the water column to feed there. Thus it is possible that artificial reefs restrict access to lower trophic level seafloor resources but improve access to higher trophic level pelagic resources by some small amount.

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Chapter 4. Conclusions and Recommendations

This study has provided a preliminary look at the relationships between black sea bass (BSB) and their habitats. These interactions are mediated both by diet and behavior. Previous studies suggesting that BSB are associated with “course-grained” material (Fabrizio et al, 2013) gave only a crude approximation of their habitat. The results of this project confirm that black sea bass are tightly structure-oriented, and primarily occur within a few meters of hard bottom substrata with substantial vertical and biological structure that includes the presence of gorgonian corals, aka sea whips *Leptogorgia virgulata*. Sea whips are responsible for most of the vertical structure above habitat baselines, and are the primary biological indicator for abundance of BSB. Visual observations indicate that sea whips provide structure that BSB like to occupy. We have documented a continuum of proportional damage to sea whip colonies across a spectrum of fishing intensity, ranging from very low (0.02) at small, rarely fished sites, to minor (0.15) at sites fished primarily by recreational fishers, to moderate (0.37) at those targeted by commercial fishers. However, this relationship is circumstantial, since we do not have a quantitative measure of fishing intensity. In this study we observed many sea whips that had evidence of damage by recreational fishing line. Previous studies (Schweitzer et al. 2018) have shown that 50% of commercial fish traps come into contact with emergent epifauna during deployment or recovery, including sea whip corals, often resulting in damage or breaking of corals. Additional studies conducted at some of these same sites (as part of a separate study) found that sea whips ranged in size from 15 to <100 cm, and in age from 2 to 15 years, with 50% of corals in the age range of 6-8 years (Wenker 2019). These results indicate that recruitment of sea whips is episodic, possibly occurring only at decadal intervals. Episodic recruitment may be facilitated by the action of major storms or hurricanes that remove other competing epifauna (e.g. mussels) from hard-bottom seafloor habitats, releasing habitat for recruits to settle and attach. Thus sea whips damaged by natural or artificial causes, including fishing activity (whether recreational or commercial), may require decades to recover.

We found only minor differences in diets of black sea bass between natural and artificial reefs. Likewise, stable isotope ratios of $\partial^{12}C/\partial^{13}C$ and $\partial^{14}N/\partial^{15}N$ from liver, muscle, and mucus showed minor differences between reef types. Crustaceans (primarily *Cancer* crabs) were the major prey item in both our study and comparative data from NOAA, but may be overestimated due to the low digestibility crustacean shells. Diet studies indicate that black sea bass probably derive the majority of their prey by foraging over the sandy seafloor away from structured reef sites. However, we did not observe such foraging activity during daytime video surveys, suggesting that it is a nighttime or crepuscular activity. This study showed that natural and artificial reefs are ecologically similar for black sea bass caught near Ocean City, MD, although subtle differences in diet between reef types suggest that their physical form may affect access of fish to different prey items. Nonetheless, this indicates that habitat selection is probably not associated with proximity to food sources, but is more likely to be associated with actual physical structure that provides other biological benefits, such as protection from predation, optimization of reproductive opportunities, or stress reduction.

Construction of a stepping-stone corridor connecting established sections of an artificial reef resulted in an increase in fish abundance at the corridor site, compared to nearby sites that showed no change in abundance. This demonstrates that corridor construction increased habitat availability for fish at the Impact site, without drawing fish away from nearby sites. Our results suggest that increasing connectivity between patch reefs may be an effective method to enhance available habitat in marine ecosystems. The structures that we built, however, did not turn out to be the best choice. Stacks of concrete "oyster castles" did provide a variety of interstitial space that was attractive to fish. However, the stacks did not remain intact, but were scattered and partially buried by storms. We also observed that concrete pipes placed near one site were also mostly buried in the sand. Future construction of artificial reefs should utilize structural designs that will not easily come apart, or be buried, and will provide a variety of interstitial spaces that are scaled to the size of both juvenile and adult fish.

There is currently much public discussion about development of wind power infrastructure in the MAB in the near future, particularly off of the Maryland coastline. Evidence from other wind power sites suggests that the hard substrata introduced by construction or installation of turbines, whether composed of rock or steel, will support invertebrate fouling communities that black sea bass and other fish prefer as habitat (Andersson and Ohman 2010). Video surveys of the Maryland wind energy development area have shown that this portion of the coastal zone has little in the way of hard-bottom habitats (Cruz-Marrero et al., 2019). Likewise, searches of thousands of seafloor images collected during the NOAA Habcam surveys in the Maryland WEA produced only a few images containing sea whips or black sea bass (Wenker 2019). Consequently, it seems highly likely that construction of such artificial habitats in the MAB will increase the availability of preferred habitats for black sea bass, and possibly lead to increased local population abundance.

While there is circumstantial evidence that sea whips are damaged by both recreational and commercial fishing activities, there is not yet enough evidence to indicate that such activity has caused declines in sea whip populations, and natural disturbances (e.g. by storms or pathogens) may have a greater impact on populations over small time scales. At the same time, global climate change, including ocean warming and acidification, is known to have detrimental impacts on corals worldwide, and may also be a source of stress or disease among sea whips. Gorgonians in the Caribbean, including *Leptogorgia* sp., have shown increased incidence of infection by *Aspergillus sydowii*, a soil-borne fungus that causes tissue erosion and death of some coral colonies, possibly associated with disturbance of the normal microbiome community (Smith et al. 1996, Rosenberg et al. 2007). These outbreaks are associated with terrestrial runoff and dust storms that may be a consequence of climate change (Harvell et al. 1999, Hallegraef et al. 2014, Soler-Hurtado et al. 2016). Whether the observed condition of sea whip communities in the MAB is the result of repeated acute disturbance from fishing, or of persistent stress from long-term climate change is currently unknown. However, both acute and repetitive stressors probably have an impact on coral populations, and consequently fish abundance.

Regardless of future development, protection and/or conservation of habitats dominated by sea whips would probably have positive benefits for black sea bass. Prior studies have shown that protecting portions of the habitat of a fished stock within a marine protected area (MPA) leads to an increase in density, biomass, and size of individuals, which subsequently leads to increased reproduction and recruitment (Botsford 2005, Pitchford et al. 2007). However, it would be inappropriate to institute conservation measures that restrict commercial or recreational fishing at existing reef sites. However, as new reefs are built, or wind power turbines constructed, it would be worthwhile to consider setting some areas aside as marine protected areas where black sea bass fishing would be prohibited. Since most of these new sites will be developed in areas where there is currently little available habitat or fish, such measures should not create conflict with existing fishing practices.

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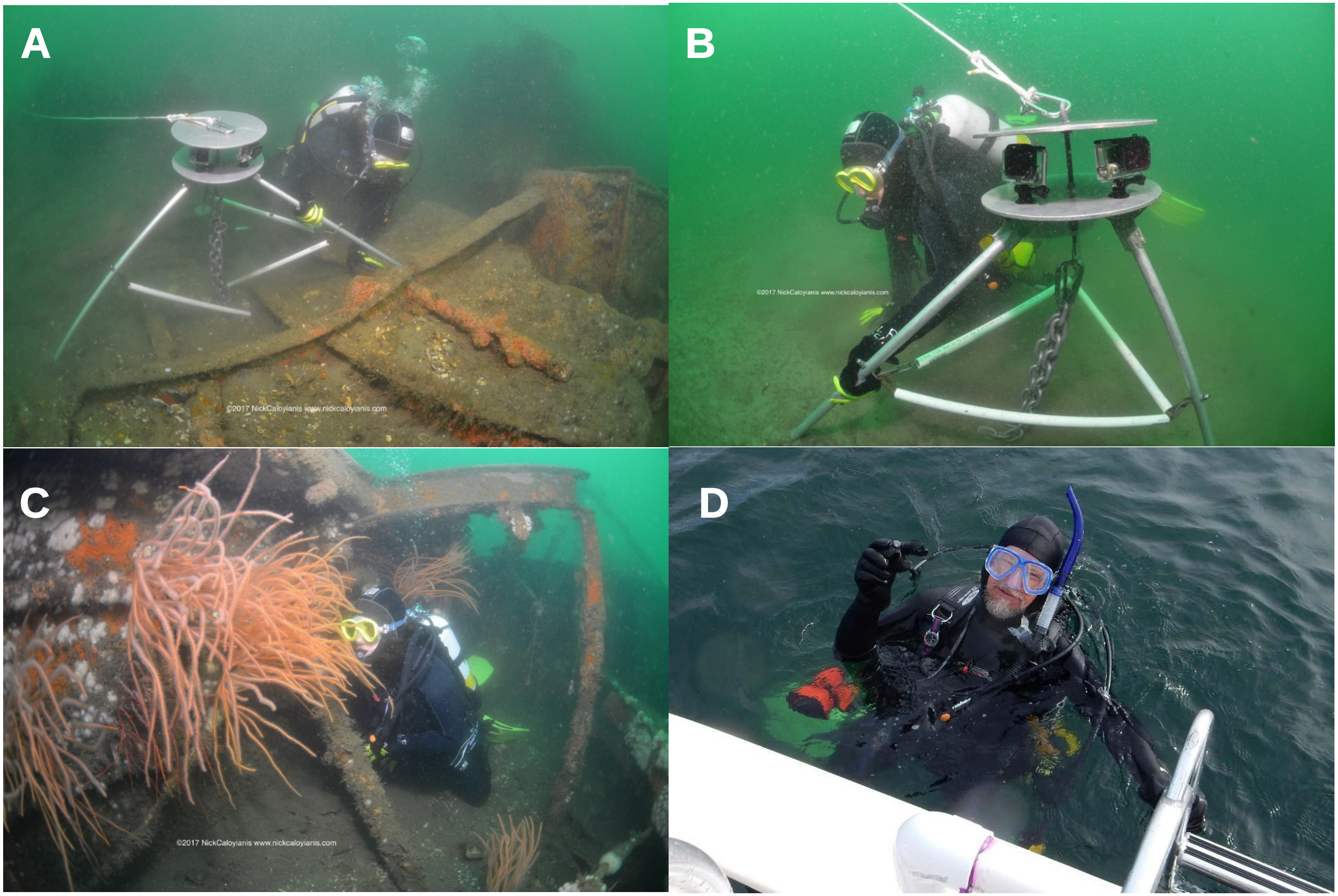
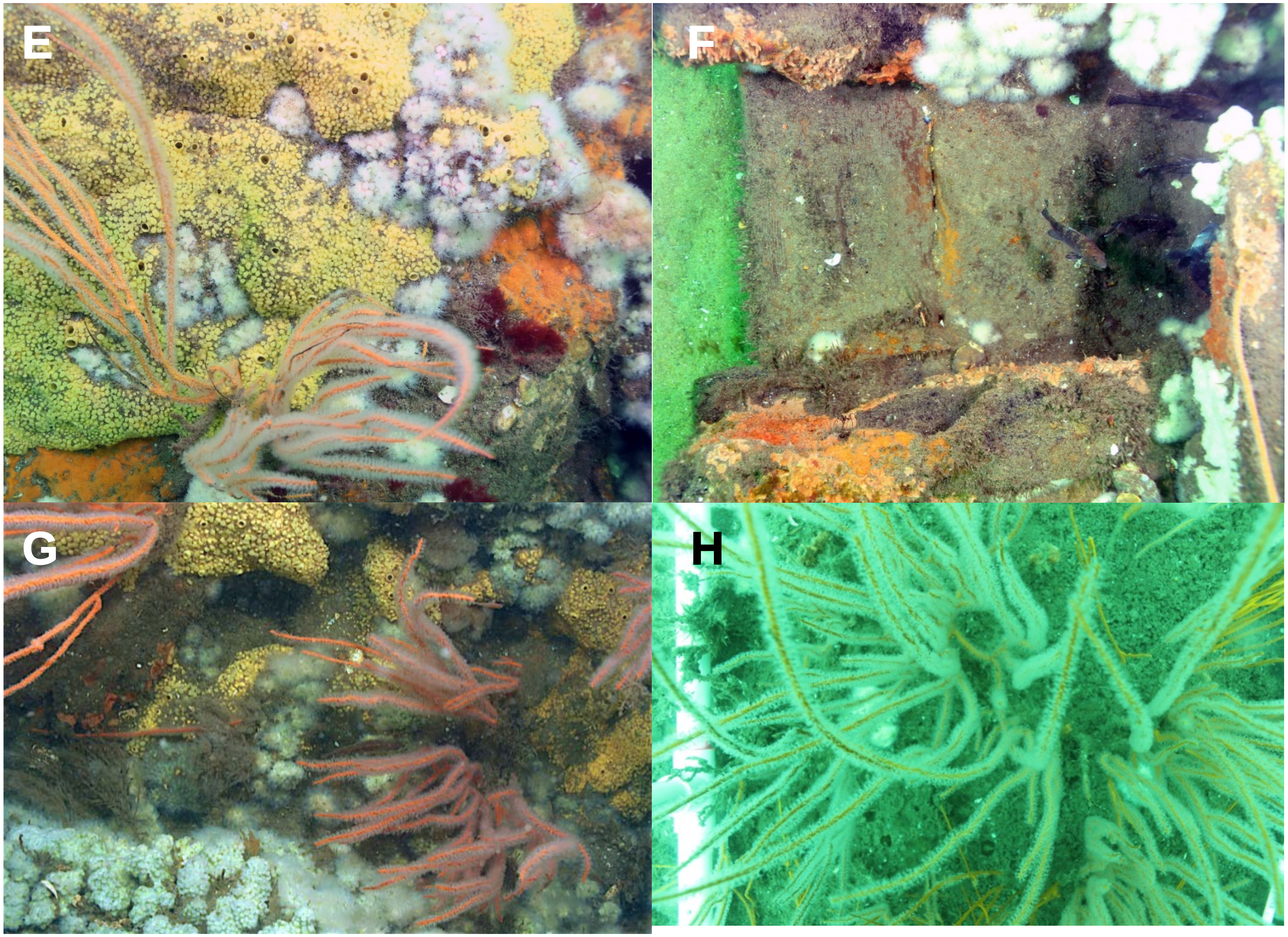
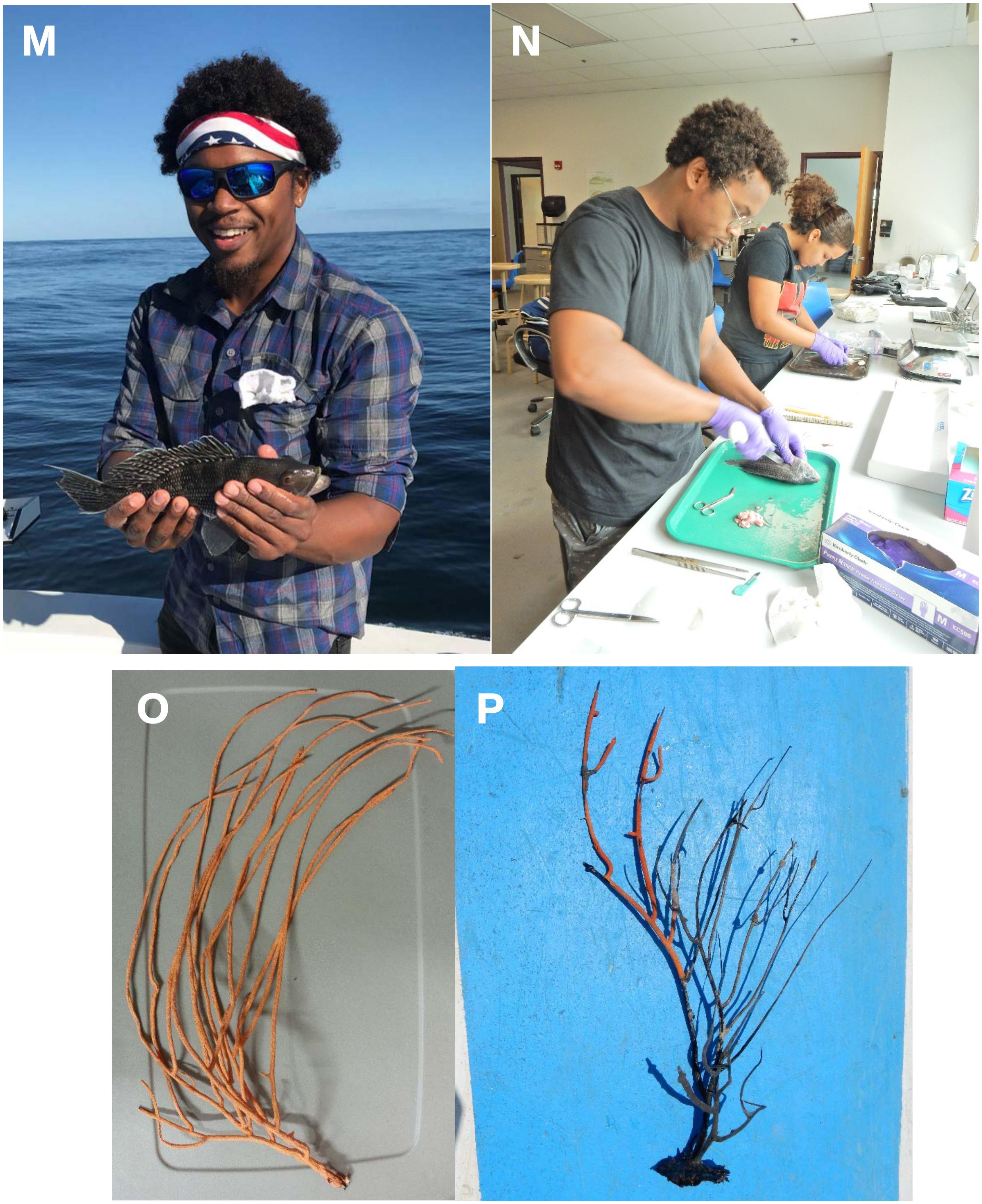


Appendix Photographs. Diving activities during the project: A-C, Cara Schweitzer setting up video tripods (Nick Caloyianis); D, Brad Stevens preparing to dive (Jeremiah Kogon).



Quadrat photos taken at sites PH-S and PH-N. E) Quadrat with high abundance of boring sponge *Cliona celata* (yellow dots); F) Photo of wood wreck with black sea bass near center; G) Quadrat with moderate abundance of boring sponge and northern stone coral *Astrangia poculata* (white patches); H) Quadrat with high abundance of sea whips *Leptogorgia virgulata*.

Tools of the Trade. I) Cara Schweitzer with video tripod; J) Digital camera on quadrat frame; K) Brad Stevens with “oyster castle” pyramids of 4-tiers each; L) A 2-tier pyramid with Cobia *Rachycentron canadum* in foreground.



Species studied: M) Andre Price with black sea bass *Centropristis striata;* N) Andre Price and Ileana Fenwick dissect stomachs from black sea bass. O) Healthy sea whip *Leptogorgia virgulata* with Damage Index DI=1; P) Sea whip with extensive damage and tissue loss (DI =5). All photos by B. Stevens.

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Dr. Stevens is a tenured Professor of Marine Science in the Department of Natural Sciences at the University of Maryland Eastern Shore, and Distinguished Research Scientist with the NOAA Living Marine Resources Cooperative Science Center. He received his PhD from the University of Washington in 1982. He previously worked for the National Marine Fisheries Service of NOAA for 22 years in Kodiak, Alaska, where he was Task Leader for Bering Sea Crab Stock Assessment, managed the Seawater Laboratory at the Kodiak Fisheries Research Center, and was Acting Director of the NMFS Kodiak Laboratory in 2006. He has authored or co-authored over 65 peer-reviewed publications and conference proceedings, and is the Editor and principal author of “King Crabs of the World”, CRC Press, 2014. Dr. Stevens’ research program focuses on ecology and reproductive biology of invertebrates (primarily crabs), and impacts of fishing on fish and invertebrate populations and their habitats. In 2003, he discovered the wreck of the Russian barque Kad’yak, the oldest known shipwreck site in Alaska, and the first shipwreck from the Russian Colonial Period ever found, and recently published an account of that discovery: “The Ship, the Saint, and the Sailor: The Long Search for the Legendary Kad'yak” (Ingram Press, 2018). In 2015, he initiated the AAUS Diving program at UMES, and currently serves on the University System of Maryland Diving Control Board.

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Dr. Cara Schweitzer received her PhD in Marine, Estuarine and Environmental Science from the University of Maryland Eastern Shore in May, 2019. The title of her PhD Dissertation was “The Effects of Commercial Trap Fishing on Benthic Structural Habitat and Fish Abundance in the Mid-Atlantic: Case Study of Black Sea Bass *Centropristis striata*”. She is currently weighing offers for postdoctoral employment.

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Mr. Andre Price received his MS Degree in Marine, Estuarine and Environmental Science from the University of Maryland Eastern Shore in May, 2019. The title of his Thesis was “Comparing Localized Feeding Ecology of Black Sea Bass (*Centropristis striata*) at Natural and Artificial Reefs Using Gut Content and Stable Isotope Analyses”. He currently works for the National Marine Fisheries Service, Northeast Fishery Science Center, in Woods Hole, MA.

The relationship between fish abundance and benthic community structure on artificial reefs in the Mid-Atlantic Bight, and the importance of sea whip corals *Leptogorgia virgulata*

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ABSTRACT

Autogenic engineers (i.e., biogenic structure) add to habitat complexity by altering the environment by their own physical structures. The presence of autogenic engineers is correlated with increases in species abundance and biodiversity. Biogenic structural communities off the coast of Delaware, Maryland, and Virginia (Delmarva) are comprised of multiple species including boring sponge *Cliona celata*, various hydroids (i.e., *Tubularia* sp., *Obelia* sp., *Campanular* sp.), northern stone coral *Astrangia poculata*, sea whips *Leptogorgia virgulata*, and blue mussels *Mytilus edulis.* Sea whips are soft corals that provide the majority of vertical height to benthic structure off the coast of the Delmarva peninsula. The mid-Atlantic bight is inhabited by several economically valuable fishes; however, data regarding habitat composition, habitat quality, and fish abundance are scarce. We collected quadrat and sea whip images from 12 artificial reef sites (i.e., shipwrecks) ranging from 10 to 24 m depth to determine proportional coverage of biogenic structures and to assess habitat health, respectively. Underwater video surveys were used to estimate fish abundances on the 12 study sites and determine if fish abundance was related to biogenic coverage and habitat health. Our results showed that higher fish abundance was significantly correlated with higher proportional sea whip coral coverage, but showed no significant relationship to other biogenic structure. Assessment of sea whip condition (as a damage index) showed that sea whip corals on artificial reefs off the Delmarva coast exhibited minor signs of degradation that did not differ significantly among study sites.

Subjects Fisheries and Fish Science, Ecology, Marine Biology

Keywords Sea whip, Black sea bass, Biogenic structure, Mid-atlantic bight, Coral, Fish abundance, Temperate reef, Artificial reef

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INTRODUCTION

Structurally complex habitats, such as cobble and rock reefs, and natural or artificial reefs, are profoundly important for fish and crustaceans by providing spatial refuge and feeding sites (*Robertson & Sheldon, 1979*; *Hixon & Beets, 1993*; *Forrester & Steele, 2004*; *Scharf, Manderson & Fabrizio, 2006*; *Johnson, 2007*; *Cheminee et al., 2016*; *Gregor & Anderson, 2016*). Structural habitat can be essential for the settlement and proliferation of autogenic

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engineers (e.g., corals, sponges, bivalves, sea grasses). The presence of biogenic structure can increase the quality of habitats and can affect habitat selection, abundance of economically valuable species, and survival and settlement of fishes (*Gibson, 1994*; *Garpe & Öhman, 2003*; *Diaz, Solan & Valente, 2004*; *Miller et al., 2012*; *Komyakova, Jones & Munday, 2018*; *Seemann et al., 2018*; *Soler-Hurtado, Megina & López-González, 2018*). This is most evident when biogenic structures are damaged or undergo mortality events, which often results in regional loss of fish biomass, biodiversity, and abundance (*Jones et al., 2004*; *Lotze et al., 2006*; *Thrush et al., 2008*; *Dudgeon et al., 2010*; *McCauley et al., 2015*). The extent to which autogenic engineers influence fish abundance has been well studied in tropical marine ecosystems (*Richmond, 1996*; *Downs et al., 2005*; *Hughes et al., 2010*; *Newman et al., 2006*), but is poorly understood within temperate rock reef systems of the Mid-Atlantic.

Within the Mid-Atlantic Bight, biogenic structure primarily consists of boring sponge *Cliona celata*, various hydroids (i.e., *Tubularia* sp., *Obelia* sp., *Campanular* sp.), northern stone coral *Astrangia poculata,* sea whip corals *Leptogorgia virgulata* (*Gotelli, 1991*; *Guida et al., 2017*), and blue mussels *Mytilus edulis* (*Steimle & Zetlin, 2000*; *Cullen & Stevens, 2017*). Among this community, sea whip corals are the primary contributors of additional height to artificial and natural rock reefs. Previous studies conducted within coral reef ecosystems have demonstrated that rugosity and coral height are the strongest predictors of fish biomass (*Harborne, Mumby & Ferrari, 2012*). Benthic rock reefs and artificial reefs within the Mid-Atlantic Bight are poorly studied and the composition of benthic biogenic structures is unknown.

Marine benthic structure within the Delaware, Maryland, Virginia peninsula (Delmarva) portion of the Mid-Atlantic Bight consists of both natural rock reefs and artificial reefs. Natural rock reefs are composed of rock, mud, and clay outcrops, and artificial reefs, both unintentional (e.g., shipwrecks) and intentional (e.g., concrete blocks and pipes, subway cars, ships). Natural rock reefs are sparse, sporadically distributed and highly fragmented. Artificial reefs provide the dominant source of benthic structure either through accidental shipwrecks or constructed through artificial reef programs. Artificial reef construction has become a popular way to increase regional habitat production, biodiversity, fish abundance, and to restore biogenic structure (*Bohnsack, 1989*; *Grossman, Jones & Seaman, 1997*; *Sherman, Gilliam & Spieler, 2002*; *Granneman & Steele, 2015*; *Scott et al., 2015*; *Smith et al., 2017*). Artificial reef sites are constructed regularly off the coast of the Delmarva peninsula, with the goal of increasing the abundance of structure-oriented fish of economic value. Some of these species, such as black sea bass *Centropristis striata*, and tautog *Tautoga onitis,* reside directly within the structures; whereas others, such as Atlantic croaker *Micropogonias undulatus*, and summer flounder *Paralichthys dentatus*, are commonly found on sandy bottoms near benthic structures as adults (*Feigenbaum et al., 1989*; *Hostetter & Munroe, 1993*; *Scharf, Manderson & Fabrizio, 2006*; *Fabrizio, Manderson & Pessutti, 2013*).

Habitat quality on benthic rock reefs and its relationship to species abundance has been largely neglected in the Mid-Atlantic Bight. Previous research investigating habitat association for economically important species (e.g., black sea bass) within the Mid-Atlantic Bight focused on benthic hardness and did not consider biogenic composition (*Fabrizio,* Manderson & Pessutti, 2013). Diaz, Solan & Valente (2004) performed a small-scale study investigating fish abundance in relation to biogenic structure in relation to density of patches of infaunal tubes at Fenwick Shoals off the coast of Delaware. They found that patch size and presence of biogenic structure was significantly related to juvenile fish abundance for that site. However, there are still insufficient data to suggest that these results are representative of habitat patches throughout the Mid-Atlantic Bight. To date, there is a paucity of data regarding the composition variability and degree of coverage of biogenic structure on natural or artificial reefs, and its relationship to fish abundance within the Mid-Atlantic Bight.

It is important to understand how sensitive, stable, or resilient complex habitats are in order to preserve the sustainability of economically valuable species. An improved understanding in the relationship between benthic habitat quality and fish abundance in the Mid-Atlantic Bight can lead to improvements in management policies. Assessments in habitat quality is commonly achieved by monitoring indicator species that are selected based on their sensitivity to habitat disturbances, and can be effective in the evaluation of an ecosystems response to stressors (Andersen, 1986; Simberloff, 1998; Siddig et al., 2016). Since sea whip corals primarily contribute to additional vertical relief, they may be more susceptible to fishing disturbances, and external damage and over-colonization can be easily quantified, we hypothesize that sea whip corals may be an indicator species for benthic habitats in the Mid-Atlantic Bight.

We undertook a study to determine the structure of marine biogenic communities and their relationship to fish abundance in the Delmarva portion of the Mid-Atlantic Bight. Our study had four specific objectives which were: (1) to determine the species composition and proportional coverage of biogenic structure at various artificial reefs; (2) to estimate relative fish abundance at those sites; (3) to estimate habitat quality using a damage index (DI) for sea whips; and (4) to determine the relationships between fish abundance and the quantity and quality of biogenic habitat.

METHODS

Description of study sites

Twelve artificial reef study sites were selected based on site age and SCUBA accessibility (Table 1). Sites were located off the cost of the Delaware, Maryland, and Virginia (Delmarva) peninsula between the latitudes of 37°N and 38.5°N ranging from 9 to 32 km off the coast (Fig. 1) at depths from ~10 to ~24 m. The maximum distance between sites (Site FW and RG) was ~60.1 km and the minimum separation distance (between Sites EP and E2) was ~0.52 km. The majority of the sites ($n = 8$) were intentionally sunk in association with the Maryland Artificial Reef Program, and the remaining four were natural wrecks. Both sites PH and RG became separated into two sections with approximately 122 m and 27 m between each section, respectively.

There have been few studies on habitats in the Mid-Atlantic Bight by SCUBA or other in-situ methods due to unpredictable weather and turbid conditions. For these reasons, diving and data collection were restricted to the months of June through November during

Table 1 **Table showing approximate age, name abbreviations, and depth of the study sites.** Month surveyed is the month fish abundance surveys were completed. Survey method states whether the fish abundance survey was conducted via line transect method (Line) or via stationary camera method (Stationary). Category states whether sites were constructed or naturally sank. Site names are common names of the wreck or region; however; some site names are not universal.

Site	Site name	Abbr.	Approx. age (y)	Approx. depth (m)	Month surveyed	Survey method	Category
1	Fenwick Shoals	FW	120	10	July	Line	Unintentional
2	Elizabeth Palmer	EP	104	23.5	July	Stationary	Unintentional
3	EP2	E2	100	24	July	Stationary	Unintentional
4	Pharoby	PH	37	20	June	Stationary	Deliberate
5	Blenny	BL	30	23.5	July	Line	Deliberate
6	Kathleen Riggins	RG	28	16.5	June	Stationary	Unintentional
7	Memorial Barge	MM	26	18	—	—	Deliberate
8	Sussex	SX	24	24	July	Line	Deliberate
9	Navy Barge	NV	19	20	July	Line	Deliberate
10	New Hope	NH	2	19	August	Line	Deliberate
11	Barge	BA	0.5	18	August	Line	Deliberate
12	Boiler Wreck	BW	NA	24	July	Line	Deliberate

2017 and 2018 and only conducted on days with a wave height ≤ one m. Fish abundance surveys were conducted June through August. If quadrat sampling could not be completed during the same sampling day, the site was resampled at a later time. Bottom temperatures were collected via a Castaway® CTD (Sontek Inc., San Diego, CA, USA) once daily. During these months bottom water temperatures ranged from 9.31 °C to 22.57 °C and surface temperatures ranged from 13.48 °C to 27.23 °C. Bottom visibility ranged from ~0.5 to ~18 m. Neither quadrat nor video data could be collected on days with bottom visibility <1.5 m.

Data collection

Quadrat sampling was used to estimate the proportional coverage of the dominant biogenic organisms: boring sponge, *C. celata,* various hydroid species (e.g., *Tubularia sp., Obelia sp., Campanularia sp.*), northern stone coral *A. poculata,* sea whip corals *L. virgulata,* and blue mussels *M. edulis*. Quadrat images ($n = 11$ to 60) were taken by SCUBA divers with a Canon DSLR camera in a housing attached to a 0.25 m^2 PVC frame.[1] Images were taken at one m intervals along the long axis of the artificial reef for 30 m, or to end of the wreck. Quadrat sampling was conducted once at each of the sites.

To assess sea whip damage, images of sea whips were taken with GoPro® *Hero* 4 action camera.[1] If sea whips were abundant (e.g., $>1\ m^{-2}$), a subset of sea whips was haphazardly selected and photographed. However, if sea whip abundance was low, then all sea whips present were photographed.

To estimate fish abundance on artificial reefs, an underwater video survey was conducted via two methods: (1) line transect method, and (2) stationary cameras (Table 1). Line transects were conducted at eight sites while stationary camera surveys were conducted at four of sites. The latter method was used primarily to estimate fish abundance for an artificial reef building project and incorporated into this analysis. Line transects were

[1] Reference to trade names does not imply endorsement by either the University of Maryland Eastern Shore or funding sources.

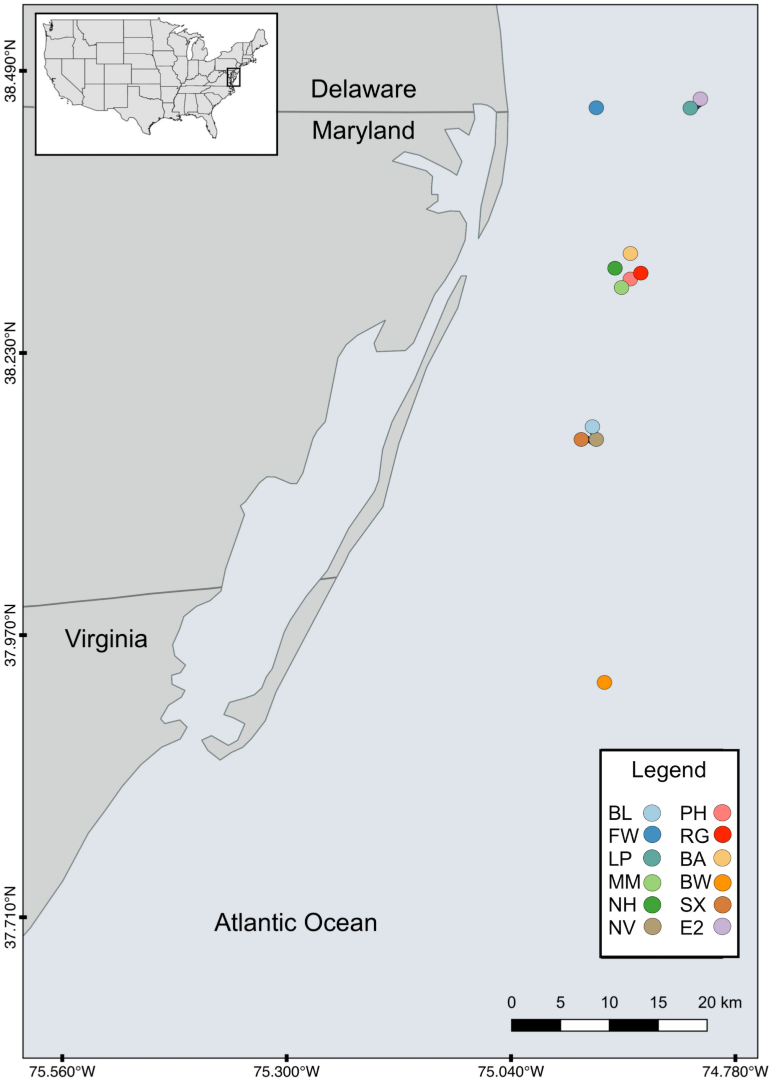

Figure 1 **Map of study sites.** Map of the study area showing the locations of the 12 artificial reefs off the coast of the Delmarva (Delaware, Maryland, Virginia) peninsula.

Full-size DOI: 10.7717/peerj.7277/fig-1

conducted for 30 m along the long axis of the site, or until the end of the wreck. Divers swam along the transect approximately one m above the wreck with the camera facing at a slight angle toward the wreck surface. The mean duration of line transect videos was 306 s ± 102 s SD. Stationary surveys were conducted by placing non-baited aluminum tripods, each of which bore two GoPro® camera placed at 90° angles. Two tripods were placed facing the wreck at a distance of approximately one m from where fish were observed. At Sites 3 and 4, tripods were also placed in the open bottom area between each section to determine the abundance and behavior of fish at those sites. Cameras were left on tripods to record for 45 min, and then retrieved. Stationary camera observations were repeated at least twice at each location, but line transect counts were not repeated due to hazardous weather that restricted diving frequency.

Data analysis

Images were analyzed with image analysis software ImageJ (version 2.0.0-rc-69/1.52J, NIH) and statistical analysis was completed with R statistical software (v 3.5.2; *R Core Team, 2018*). Proportional cover for each of the biogenic species was estimated by outlining regions of interest (ROI) in each quadrat image. For sea whip corals, ROI were drawn over the projection of the sea whip on the surface. Analysis of similarities (ANOSIM) based on the Euclidean distance metric was used to test for differences between biogenic structure assemblages at sampling sites. A non-metric multidimensional scaling (NMDS) was used to visualize similarities and differences in biogenic composition throughout the research sites. Five biogenic species composed of two corals and three non-coral organisms were included in the NMDS analysis, which represent the dominant structural organisms that inhabit the Mid-Atlantic.

Due to the frequency of low bottom visibility during video surveys, identification of species was substantially impaired, such that only fish relatively close to the camera could be identified. Therefore, fish abundance was estimated for all fish present and not separated by species. To estimate fish abundance on artificial reefs, we used a modified method of the fish MeanCount method, which is defined as the mean number of individuals observed in a series of frames throughout a viewing interval (*Bacheler & Shertzer, 2014*). To maintain independence between frames and statistical independence, 12 frames were randomly selected from the line transect surveys and the number of fish within each frame were counted. The MeanCount was calculated as the mean of those 12 frame counts. Since the stationary camera surveys produced two videos, the 12 randomly selected frame counts for each video were averaged per site. In addition to MeanCount, the highest number of fish observed in a single frame during the video (MaxNo) was also reported. Relationships between fish abundance (MeanCount) and coverage of biogenic structure and at each site were analyzed with a linear model (LM) with fish abundance (i.e., MeanCount) as the response variable and biogenic structure species as the predictors. A logit transformation was applied to all proportional data before LM analysis.

To estimate sea whip damage, we initially calculated the relative area of sea whips in using each image using ROIs via a line segment tool that was set at the same width as the sea whip branches. We then calculated the damaged area or region of overgrowth as a proportion of total line length. Proportional damage of individual sea whip corals was averaged at each site, and the mean value was used to assign a damage index (DI) from 1 to 5 (Table 2) as described in *Schweitzer, Lipcius & Stevens (2018)*. The proportional data was analyzed with a LM to determine if there was a was a difference in sea whip DI between sites and if DI had an effect on fish abundance.

RESULTS

Composition of artificial reefs

Data derived from quadrat images showed a significant difference, but with some overlap in biogenic assemblages between study sites (ANOSIM $R = 0.32$; $p = 0.001$; Fig. 2). The mean proportional coverage of biogenic structure on artificial reefs off the Delmarva coast

Table 2 Damage index classifications. Criteria used to classify individual sea whip damage index (DI) and overall habitat DI for images captured. For individual sea whips, damage is defined as any visible tissue damage, exposed skeletal structure, or overgrowth by hydroids or bryozoans.

DI	Damage	Description
1	Minimal	<0.05 damage or overgrowth
2	Minor	0.06–0.25 damage or overgrowth
3	Moderate	0.26–0.50 damage or overgrowth
4	Severe	0.51–0.75 damage or overgrowth
5	Critical	>0.75 damage or overgrowth

was 0.47 ± 0.14 (mean ± SD). Proportional coverage was lowest at Site SX (0.27), and greatest at Site NV (0.83; Fig. 3). Sea whip corals *L. virgulata* and northern stone coral *A. poculata* were present on 10 of the 12 sites. One of the two sites void of sea whip corals was constructed 6 mo prior to the quadrat survey and only exhibited colonization by hydroid species (Site BA; Table 3). Blue mussel *M. edulis* beds were found on 5 of the 12 sites. Boring sponge *C. celata* was observed at eight of the 12 sites. Site BW was the only location that contained all five structure-forming species.

Results from the NMDS supported the results from the ANOSIM such that some sites showed distinction in biogenic structure communities, while some sites showed considerable overlap (Fig. 2). Northern stone coral and blue mussels were negatively correlated. Sites NV and NH were associated with blue mussel coverage, while sites EP, E2, PH, and RG were associated with northern stone coral (Fig. 2). Sea whip corals and hydroids were negatively correlated. Sites PH, RG, MM, SX, NV, and BW were associated with sea whips. Sites BL and BA were associated with hydroids. Sites FW, and PH were associated with the boring sponge (Fig. 2).

Fish MeanCounts were obtained from 11 of the 12 sites. Visibility was too poor for a video survey to be conducted at Site MM, and hazardous weather prevented additional outings. The highest fish count observed (MaxNo; Table 4) in the video survey was also reported because fish were often observed aggregated near biogenic structure, specifically sea whip corals, rather than dispersed throughout the wreck (Fig. 4). The two highest MeanCounts were at Sites E2 and PH, while the lowest were at Sites FW and NH, whereas the Sites E2 and SX had the highest MaxNo (Table 4). No fish were observed swimming on open sandy bottom. Since MeanCounts and MaxNo were highly correlated ($r^2 = 0.94$) results are reported in MeanCounts. A LM analysis of all 12 sites showed that total proportional coverage of biogenic structure was not significant predictor to fish abundance (ANOVA, $F = 0.14$; $p = 0.72$; $r^2 = 0.02$). Proportional sea whip coverage, however, was the only significant predictor to fish MeanCounts ($p = 0.028$; $r^2 = 0.48$; Table 5; Fig. 5). An additional analysis was conducted for sites where video surveys were conducted via line transect method to determine if stationary cameras created an upward bias. Similarly, line transects showed a significant relationship between MeanCount and proportional sea whip coral coverage ($p = 0.014$; $r^2 = 0.69$).

Evidence of habitat disturbance due to fishing (e.g., lures, fishing line, abandoned traps) was observed at 10 of the 12 sites (all but Sites E2 and BA). Observations of tangled fishing

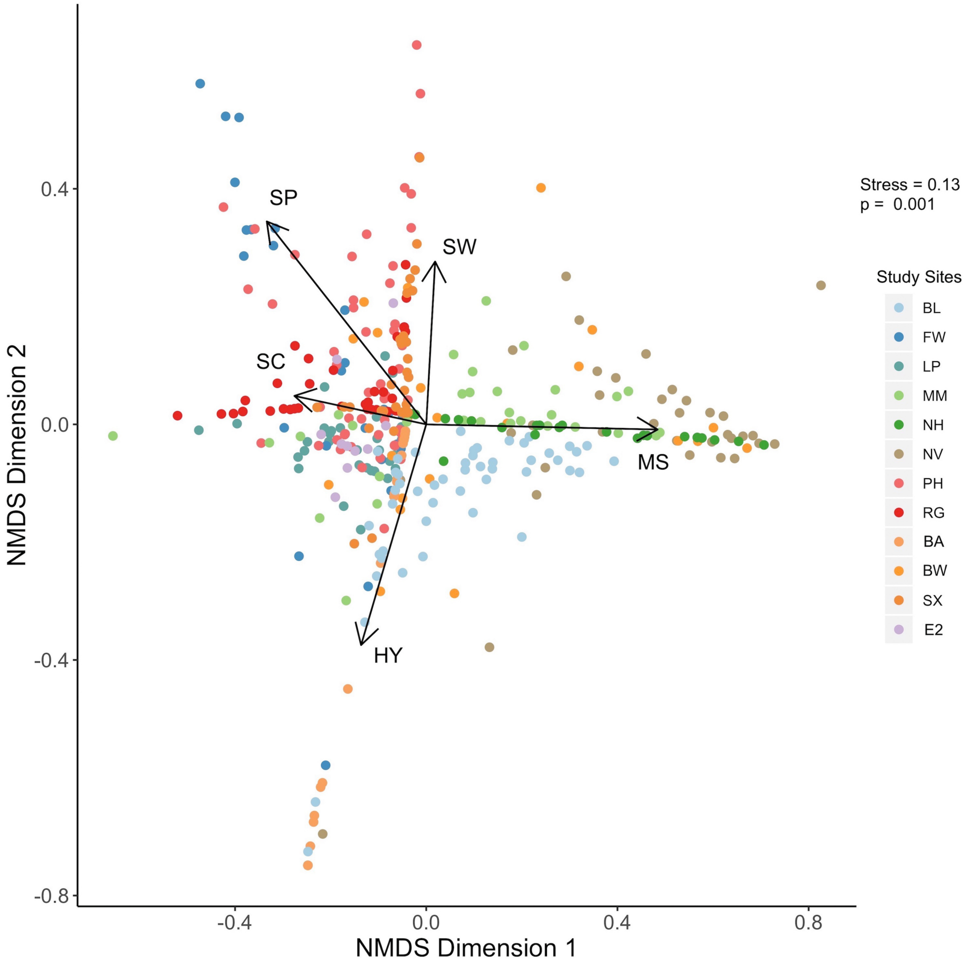

Figure 2 **NMDS plot.** Results of the nonmetric multidimensional scaling analysis depicting biogenic structure assemblages on the 12 artificial reef sites off the Delmarva coast. *P* value is from the ANOSIM analysis. Variables: SW, sea whip corals; SC, northern stone coral; SP, boring sponge; MS, blue mussel; HY, hydroids.

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line were common at edges of shipwrecks. Fishing gear was observed in direct contact with sea whips corals at nine of the 10 sites where sea whips occurred (Fig. 6). To determine if cumulative sea whip damage was related to reduced fish abundance we analyzed a total of 193 sea whip images from 10 of the 12 study sites, excluding Sites FW and BA, where sea whip corals were absent. Sea whips at most sites exhibited various levels of degradation (Fig. 7). However, despite evidence of fishing disturbance at all sites, with the exception of Site E2, the mean damage index (DI) was 0.15 ± 0.19 SD for all sites, which is indicative of minor levels of degradation (Table 6). Site LP showed the highest DI with a mean of 0.26 ± 0.19 indicating a moderate level of degradation, however this was not significantly different from the other sites (ANOVA; $p = 0.061$) therefore no further analysis was conducted. Consequently, we could not determine if sea whip corals could serve as an indicator species for habitat quality.

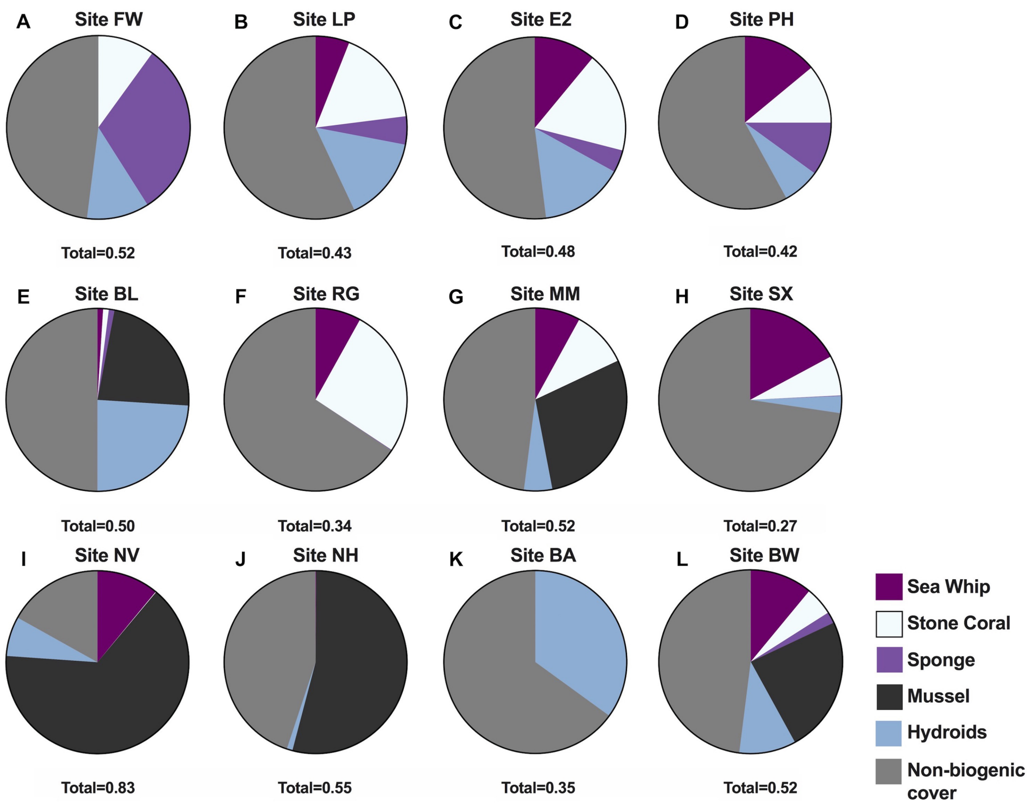

Figure 3 Proportional cover of five structure-forming species groups at the 12 study sites. Pie charts showing the proportions of the five biogenic structures at the 12 study sites (A) Site FW, (B) Site LP, (C) Site E2, (D) Site PH, (E) Site BL, (F) Site RG, (G) Site MM, (H) Site SX, (I) Site NV, (J) Site NH, (K) Site BA, (L) Site BW. Total, Cumulative total coverage of all five biogenic species groups from quadrat images.

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Table 3 Summary table of quadrats. Summary table of proportional cover of biogenic structures by site. *n* quadrats are the number of images taken and analyzed at each site. $\bar{x}$ is the mean proportional coverage for each variable: SW, sea whip coral; SC, northern stone coral; SP, boring sponge; MS, blue mussel; HY, hydroids.

Site	*n* quadrats	$\bar{x}$ SW	$\bar{x}$SC	$\bar{x}$ SP	$\bar{x}$MS	$\bar{x}$ HY
FW	27	0.00	0.10	0.31	0.00	0.11
LP	36	0.06	0.17	0.05	0.00	0.15
E2	11	0.11	0.18	0.04	0.00	0.15
PH	60	0.14	0.11	0.10	0.00	0.07
BL	51	0.01	0.01	<0.01	0.23	0.24
RG	41	0.08	0.26	<0.01	0.00	0.00
MM	33	0.08	0.10	0.00	0.29	0.05
SX	31	0.17	0.07	<0.01	0.00	0.03
NV	37	0.11	<0.01	0.00	0.65	0.07
NH	27	<0.01	0.00	0.00	0.54	0.01
BA	31	0.00	0.00	0.00	0.00	0.35
BW	27	0.11	0.05	0.02	0.24	0.1

Table 4 **Table showing fish MeanCount and MaxNo.** Summary of fish MeanCount and MaxNo for underwater video census surveys.

Site	MeanCount	SD	MaxNO
FW	0.50	0.76	2
EP	5.25	2.18	14
E2	14.4	5.67	35
PH	7.49	3.07	24
BL	3.93	5.44	18
RG	5.05	2.66	18
MM	–	–	–
SX	6.64	7.56	27
NV	4.36	4.86	15
NH	0.64	2.41	3
BA	1.57	0.84	7
BW	7.07	4.92	19

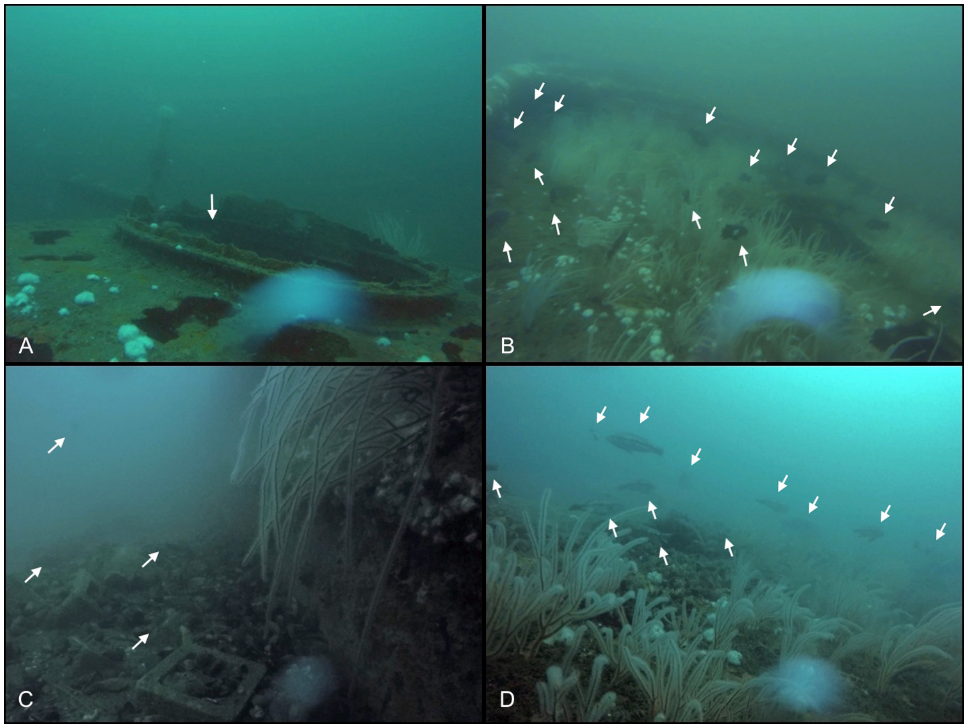

Figure 4 **Comparisons of fish aggregations on sites.** Photos taken at two locations at Sites SX and NV. (A) Region of Site SX with minimal biostructure. White arrow highlights the single fish located within this frame. (B) Photo taken during the same dive survey as 4A. Region of Site SX with increased sea whip coverage. White arrows show the location of the 14 fish seen within this frame. (C) An area of Site NV that is mostly composed of rock, broken shells and concrete blocks with a single sea whip coral and some colonies of northern stone coral on the wall of the wreck. White arrows show the locations of the 4 fish in the frame. (D) Photo taken during the same dive survey as 4C showing an area with increased sea whip colonies. White arrows show the location of the 12 fish within the frame. Photo credit: Cara C. Schweitzer.

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Table 5 Results from linear model of fish MeanCount vs proportional cover. ANOVA results from the linear model analysis for 11 of the 12 sites. Fish MeanCount is the response variable and biogenic structural species are the predictor variables.

Variable	Sum Sq	*F* value	*df*	*P* value
Sea whips	73.87	9.31	10	0.028
Stone Coral	20.01	2.52	10	0.173
Sponge	0.13	0.17	10	0.904
Blue mussel	7.87	0.99	10	0.365
Hydroids	11.21	1.41	10	0.288

DISCUSSION

The presence of autogenic engineers often increases habitat quality resulting in increases in species abundance and biodiversity across terrestrial, freshwater, and marine ecosystems (*Jones, Lawton & Shachak, 1994*; *Hastings et al., 2007*), however, not all can be considered equivalent having positive correlations with species biodiversity and abundance (*Jones, Lawton & Shachak, 1997*; *Daleo et al., 2004*). Therefore, it is important to understand the relationships between composition of biogenic structure and fish abundance. Benthic rock reefs and artificial reefs within the Mid-Atlantic Bight are poorly studied and inhabited by multiple economically important species (*Hostetter & Munroe, 1993*; *Shepherd, Moore & Seagraves, 2002*) that are exploited both recreationally and commercially. Many of these species (e.g., black sea bass and tautog) are considered structure oriented, but it remains unclear if biogenic structure affects their habitat selection. Insights into the relationships between biogenic structure and fish abundance will be useful for developing ecosystem-based fisheries management (EBFM).

In this study we measured habitat composition and relative fish abundance on 12 artificial reef sites to determine if relationships existed between biogenic structure and habitat use by fish. We concluded that fish abundance was significantly correlated with sea whip coral as a proportion of total cover and that fish were often aggregated near sea whips. In fact, sites without sea whips, or having a proportional abundance of <0.01, had low values for both fish MeanCounts and MaxNo. Within the Mid-Atlantic Bight, sea whip corals are the primary autogenic engineer that contributes to height of benthic structure, increasing the structural complexity of such habitats. In previous studies, coral height has been found to be a significant predictor of fish abundance and biodiversity within coral reef systems (*Hoyle & Harborne, 2005*). Due to their height, sea whip corals can be susceptible to disturbance (e.g., fishing) that may result in damage and degradation (*Schweitzer, Lipcius & Stevens, 2018*), which could lead to reduced fish abundance.

Habitat degradation is commonly correlated with a reduction in biodiversity and abundance of associated species (*Wilson et al., 2006*). We observed sea whips entangled in fishing line and rope, along with various levels of damage to colonies throughout the study sites. However, our study sites did not differ significantly from each other; therefore, we could not determine the effect of sea whip damage on fish abundance. This result is not surprising because, these sites are exposed to seasonal recreational fishing pressure, and are seldom fished by commercial fishers. Seasonal fishing pressure (i.e., June through

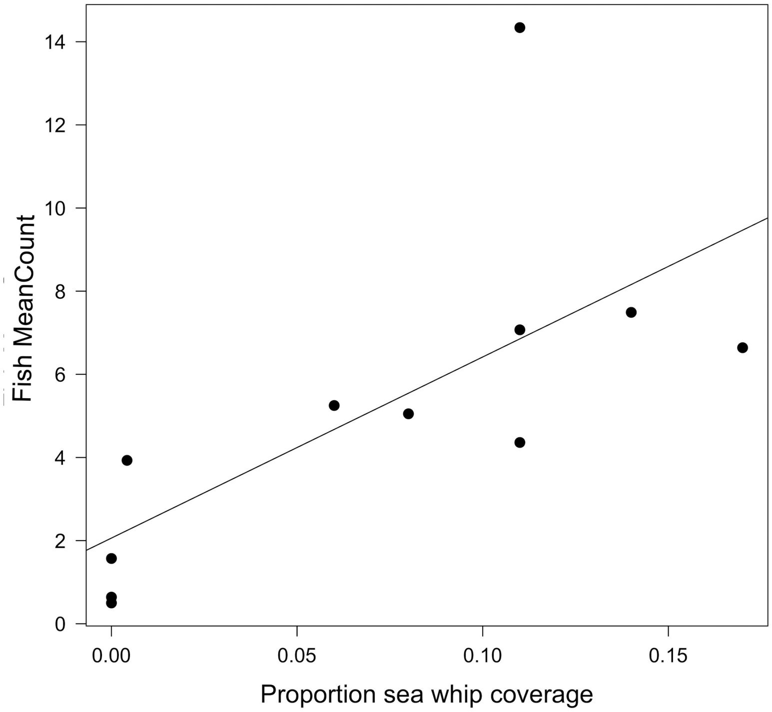

Figure 5 **Relationship between fish MeanCount and proportional sea whip coverage.** Linear model showing the relationship between fish MeanCount and proportional sea whip coral coverage for 11 of the 12 study sites. There is a significant positive correlation ($p = 0.018$; $r^2 = 0.48$).

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September) may allow for some recovery from disturbance, however sea whip recovery rate from tissue damage is poorly understood. Previous studies have shown that commercial traps drag along the ocean bottom upon retrieval, running over and breaking sea whips (*Schweitzer, Lipcius & Stevens, 2018*), which may accelerate degradation. In order to test the hypothesis that sea whip coral health affects fish abundance on patch reefs, data are needed on sites with wider distribution of impact levels, ranging from moderate to severe degradation, to compare with less-impacted sites.

In this study we did not investigate natural reef sites due to their inaccessibility to SCUBA. Natural reefs off the coast of the Delmarva peninsula are highly fragmented and sparse, occurring at depths $\geq$ 27 m. Attempts to locate these by SCUBA diving along commercial trap lines demonstrated that greater amounts of time were needed to locate and sample patch reefs than could be accommodated by no-decompression diving on air or EAN32 gas mix. Natural reefs are commonly targeted by both recreational and commercial fishers; therefore, it is important for future studies to incorporate surveys of natural reefs. *Schweitzer, Lipcius & Stevens (2018)* surveyed three naturally occurring patch reefs with a remotely operated vehicle in an area targeted by commercial fishers. The mean DI for those sites was 0.37, substantially greater than 0.15 for the study sites in this survey. However, biogenic structure composition and relative fish abundance for those sites or other natural reef sites is unknown.

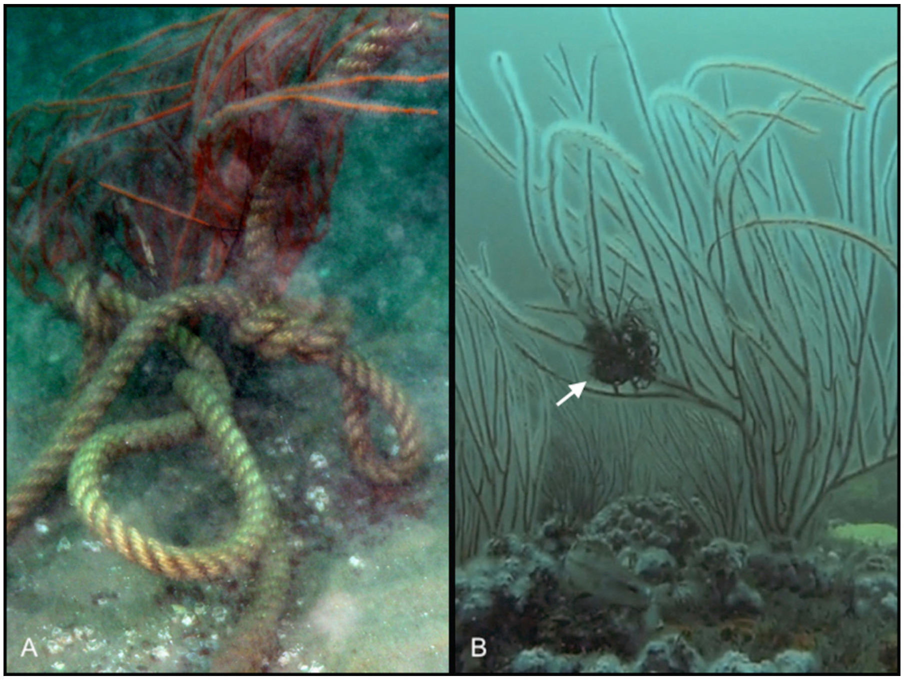

Figure 6 Anthropogenic disturbance effecting sea whip corals. Two photographs showing representative examples of anthropogenic disturbance observed at the research sites. (A) Sea whip coral from Site PH entangled in rope. (B) Sea whip from Site NV with fish line entangled around a portion of branches. Photo credit: Cara C. Schweitzer.

Full-size DOI: 10.7717/peerj.7277/fig-6

Our research showed a significant difference in the composition of biogenic structure between sites. Blue mussels were the dominant epifauna at five sites (i.e., ≥22% cover), however they were not observed at the other seven sites. Northern stone coral was observed at ten sites and was dominant (≥17%) at three. Only two sites were not inhabited by sea whips, one of which was an artificial reef constructed ~6 mo prior to quadrat sampling. Site NH, constructed 2 y prior to being surveyed exhibited <0.01 proportional sea whip coverage, indicating that it takes a minimum of 2 y for sea whips to begin to grow on concrete and metal substrata. However, settlement and growth rates for sea whips (*L, virgulata*) are currently unknown. In contrast, sites BA and NH, both of which were constructed <3 y before surveying, were occupied exclusively by hydroids and mussels, respectively, indicating that those species settle quickly, and are probably replaced over time by longer-lived species such as sea whips and stone corals. We conducted quadrat surveys only once at each site. Repeated quadrat surveys, especially after severe weather events, would give insight on rates of succession, changes in sea whip DI, and sea whip colonization rates on newer artificial reefs.

One limitation of our study is that fish abundance was estimated via two different underwater video survey methods: line transects and non-baited stationary cameras, that were conducted over the course of two years. Ideally, abundance censuses would be conducted in a synoptic fashion; however, weather and water conditions in the Mid-Atlantic Bight were often deemed too hazardous for SCUBA surveys, making it difficult

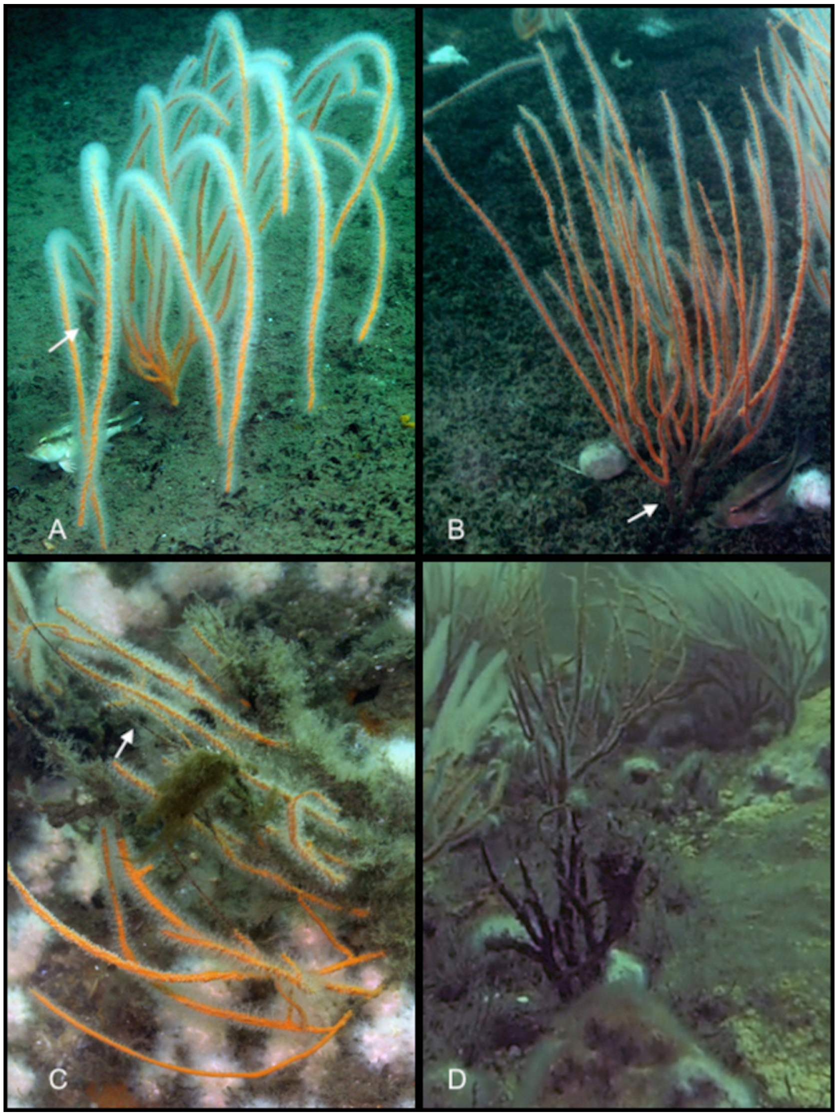

Figure 7 Sea whip corals at various levels of damage. Photographs showing sea whip corals with four different degrees of damage. (A) Sea whip coral exhibiting a minimal proportional damage index of 0.02. White arrow highlights the region of damage. (B) Sea whip coral exhibiting minor proportional damage index of 0.13, localized at the base of the coral. (C) Sea whip coral exhibiting a severe proportional damage index of 0.51. The white arrow is showing a region where the tissue has completely decayed, exposing the skeletal structure. This coral also exhibits colonization of hydroids. (D) Sea whip coral exhibiting critical proportional damage index of 1.00 with no live tissue remaining. Photo credit: Cara C. Schweitzer.

Full-size DOI: 10.7717/peerj.7277/fig-7

to collect data within specific time blocks. The video surveys acquired from the stationary cameras at four sites (Sites LP, E2, PH, & RG) could result in an upward bias of the MeanCount; nevertheless, fish MeanCount still showed a significant correlation with sea whip abundance at the remaining seven sites. Additional surveys are needed to understand how fish abundance at sites varies seasonally and annually since many of the prominent fish species (e.g., black sea bass and tautog) are seasonal migrators.

Table 6 Damage indices for the research sites. Summary of the mean proportional damage for sea whips and the habitat DI by site. *n* is the number of sea whips analyzed at each site. $\overline{x}$ is the mean proportional damage for the measured sea whips. SD is the standard deviation. Max is the highest proportional damage observed. Min is the lowest proportional damage observed. D.I. is the damage index assigned to the site.

Site	*n*	$\overline{x}$	SD	Max	Min	D.I.	Degradation Category
FW	0	–	–	–	–	–	–
EP	31	0.26	0.19	0.77	0.05	3	Moderate
E2	11	0.02	0.02	0.02	0.00	1	Minimal
PH	19	0.15	0.24	1.00	0.00	2	Minor
BL	17	0.15	0.24	1.00	0.00	2	Minor
RG	19	0.07	0.05	0.18	0.02	2	Minor
MM	24	0.15	0.15	0.47	0.00	2	Minor
SX	21	0.12	0.11	0.40	0.00	2	Minor
NV	26	0.11	0.15	0.66	0.00	2	Minor
NH	7	0.15	0.30	0.82	0.00	2	Minor
BA	0	–	–	–	–	–	–
SW	28	0.15	0.21	0.78	0.00	2	Minor

Our study is the first to quantify the composition of biogenic structure on artificial reefs off the coast of Delmarva peninsula and to show that fish abundance is significantly correlated with the presence and abundance of sea whip corals. Construction of artificial reefs off the coast of Delmarva occurs on an annual basis to increase the local abundance of economically valuable species. Creating artificial reefs near regions with established sea whip coral populations may help facilitate sea whip settlement and colonization of new structures. Future studies to determine variations in fish abundance over time, and to determine the succession of biogenic structure would be useful. In addition, future surveys of naturally occurring patch reefs should be conducted, in order to gain a more detailed assessment of habitat quality in the mesophotic regions of the Mid-Atlantic Bight.

CONCLUSION

These results show that there is significant variation in biogenic structure assemblages between artificial reef sites off the coast of the Delmarva peninsula. Fish aggregations and abundance on these artificial reefs are significantly correlated to the abundance of the sea whip coral *L. virgulata*. Sites voided or containing low abundance of *L. virgulata* exhibited the lowest fish abundance. Currently, these artificial reef sites show only minor signs of degradation with no significant difference between sites. It would be important to further these surveys to natural rock reefs and sites that undergo both commercial and recreational fishing pressure to determine if such sites exhibit different levels of sea whip damage, and if higher levels of sea whip degradation effect fish abundance and aggregations. This study could be used as a baseline for current conditions of artificial reef sites off the Delmarva peninsula. Similar surveys should be conducted in the future to monitor succession rates of biogenic structure assemblages. Furthermore, continuing surveys that monitor sea whip settlement rate on new constructed artificial reefs, changes sea whip abundance, and the progression or recovery of damaged sea whips could be valuable to understanding habitat selection and fidelity for economically valuable species in the Mid-Atlantic Bight.

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ADDITIONAL INFORMATION AND DECLARATIONS

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Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Cara C. Schweitzer conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, prepared figures and/or tables, authored or reviewed drafts of the paper, approved the final draft.
- Bradley G. Stevens conceived and designed the experiments, authored or reviewed drafts of the paper, approved the final draft.

Data Availability

The following information was supplied regarding data availability:

Schweitzer, Cara (2019): SW data_FS.xlsx. figshare. Dataset. https://doi.org/10.6084/m9.figshare.7772951.v1.

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1. Title Page

Project Title: Estimating and mitigating the discard mortality rate of black sea bass in offshore recreational rod-and-reel fisheries

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2. Executive Summary

In late fall and winter, black sea bass migrate offshore towards the edge of the continental shelf and overwinter at deep shipwrecks and reefs (45-80+ m). The recreational fishery catches black sea bass offshore during the winter both as the target species and as bycatch while targeting other species (e.g., scup, pollock, hakes, cod, tilefish). Black sea bass are often discarded by recreational anglers during these offshore winter fisheries due to factors such as size restrictions, daily possession limits, "high-grading", or closed seasons. The discard mortality rate of black sea bass has been previously investigated for inshore fisheries conducted in relatively shallow water and warmer seasons (i.e., spring through fall), but the discard mortality rate of black sea bass in the winter offshore recreational fishery has not been previously investigated. As a result, this project focused on providing a robust discard mortality rate estimate for the offshore black sea bass recreational fishery in the Mid-Atlantic to inform stock assessments and fishery management, and provide best-practice recommendations for anglers to reduce discard mortality.

We conducted an extensive tagging study involving collaboration among recreational fishing industry stakeholders, volunteer anglers, commercial fishermen, and scientists. Fieldwork was conducted from November 2016 through March 2017, and included eight research tagging charters aboard recreational headboats. Our primary study site was the Ice Cream Cone shipwreck, which is situated in 45 m depth and ~85 km southeast of Sea Isle City, NJ. A total of five research tagging charters were completed to the Ice Cream Cone shipwreck from early December 2016 through early February 2017. Two additional tagging trips were completed to the Baltimore Rocks (67 m depth) in February 2017 and one trip to the Indian Arrow shipwreck (58 m depth) in late March 2017. On all tagging trips, volunteer anglers were provided with standardized terminal tackle rigs, whose configuration was established based on a survey of 282 recreational black sea bass anglers. The use of this standardized terminal tackle ensured that black sea bass were captured under authentic scenarios that are representative of the Mid-Atlantic offshore recreational fishery. For each captured black sea bass, a series of technical (e.g., capture depth, angler experience level, fight time, unhooking time, handling time, hooking location, hook removal method), biological (e.g., total length [TL], release behavior, injury, barotrauma symptoms), and environmental (air temperature, sea surface and bottom water temperature) variables were recorded to investigate which factors significantly influenced discard mortality.

Since black sea bass captured in deep water often experience barotrauma, we also examined the effect of swim bladder venting (when done properly) on fish submergence (i.e., the ability to swim back down to the bottom after release) and discard mortality. To accomplish this, fish were released at the sea surface either with no intervening measures (i.e., unvented) or following swim bladder venting with a hollow needle by a trained scientist. At the Ice Cream Cone shipwreck, we tagged a subsample of fish with pressure sensing Vemco acoustic transmitters and monitored their movements post-release using an array of 30 acoustic receivers maintained in collaboration with commercial fishermen. Almost all other sampled fish were tagged with conventional t-bar anchor tags and released to investigate migration patterns and confirm survival if recaptured.

A total of 1,823 black sea bass (136 - 612 mm TL) were sampled throughout the three study sites. Of all sampled fish, 1,713 were released (i.e., some were retained for ageing), including 957 that were vented and 756 unvented. A total of 1,467 fish were tagged with conventional t-bar anchor tags. At our main study site, the Ice Cream Cone shipwreck, 566 fish were sampled, and a subset of 96 fish (278 - 546 mm TL) tagged with acoustic transmitters, 48 of which were vented (278 - 546 mm TL) and 48 were not vented (279 - 485 mm TL). Fight times for captured fish ranged from 12 - 251 (Mean ± SD: 78 ± 32) seconds for the full sample. Capture of larger fish at deeper depths by low speed reels, or capture as part of a double header increased fight time. The majority of fish were hooked in the mouth. Released black sea bass exhibited four release behaviors including erratic swimming, sinking, floating, and swimming down, with the vast majority exhibiting the latter two behaviors. Results of a logistic regression indicated that fish total length, capture depth, venting, and the presence of exopthalmia influenced release behavior, with larger fish, that were not vented, caught at deeper depths, and experienced exopthalmia had a lower probability of swimming down.

A total of 304 (17%) black sea bass incurred injuries (i.e., wounds > 2 cm), mostly as a result of hooking trauma and/or the hook removal process. Twelve individuals (0.4%) were dead upon landing, with most having been bitten in half by predators or experienced ripped gills from hooking. The majority (82%) of captured individuals exhibited no injury. The vast majority (95%) of captured black sea bass exhibited symptoms of barotrauma. Stomach eversion was the predominant barotrauma symptom, with stomach eversion score 2 (i.e., stomach protruding from the mouth cavity) being present in 68% of all captured fish. Exopthalmia was present in ~10% of all captured fish. Barotrauma symptoms were generally more prevalent at deeper depths, particularly exopthalmia, which was most prevalent at the deepest capture depth of 67 m.

Acoustic detection data were obtained for 94 of the 96 black sea bass tagged with acoustic transmitters. The two undetected fish exhibited floating behavior and both possibly experienced avian predation. Survivorship of individual black sea bass tagged with acoustic transmitters was objectively determined by a multi-step process that compared their vertical and horizontal movements to those of 'known alive' (positive controls, n=7) and 'known dead' (negative controls, n=2) fish. Of the 94 black sea bass that were detected within the receiver array, 61 survived the capture and handling process and were considered to be alive and 33 died after release. Of the 33 mortalities, nine were attributed to predation following re-submergence. All predation events occurred within 1.8 - 18.4 (7.2 ± 4.5) hours of release. All of the remaining 24 mortalities were assumed to have occurred due to the fishing event, and occurred from 5.0 - 128.0 (17.1 ± 26.7) hours post-release. Of these, 19 (79.2%) mortalities occurred within 24 hours of release, four from 24 - 72 hours post-release (16.7%), and one (4.2%) >72 hours post-release (95.8% of mortality occurred within 72 hours).

Final black sea bass survivorship data were analyzed with the non-parametric Kaplan-Meier estimator and the semi-parametric Cox proportional hazards model to evaluate the suitability of capture-related variables (i.e., covariates) for predicting survival and to identify a parsimonious subset of covariates that best predict survival. Once the subset of influential covariates was identified, a parametric survival analysis modeling approach was used to assess potential models that can describe survivorship over time and estimate overall discard mortality. The results of our survival analyses suggested that swim bladder venting was the most significant predictor of mortality in released black sea bass. Based on the model results, the mean total fishing-related (i.e., discard) mortality rate at the Ice Cream Cone shipwreck in 45 m depth was 0.21 (95% CI: 0.12, 0.37) for vented black sea bass and 0.52 (95% CI: 0.38, 0.67) for unvented black sea bass. When looking only at unvented fish, fight time was the most significant predictor of mortality, with increased fight time (>54 seconds) resulting in a markedly higher discard mortality rate. Based on these findings, discard mortality for both vented and unvented fish may have been elevated at the deeper locations due to the higher mean fight times of 80 seconds at the Indian Arrow shipwreck (58 m) and 94 seconds at the Baltimore Rocks (67 m).

Given that swim bladder venting (when done correctly) was the most influential factor on discard mortality and increased submergence success over all depths, we recommend that anglers vent all black sea bass that are captured during the offshore winter fishery before they are released, particularly those that experience barotrauma symptoms. However, full realization of the benefits of venting will require continued education and outreach on proper venting techniques and recommended venting tools. Based on this study, swim bladder venting would be the best practice for reducing discard mortality, but given that longer fight times significantly increased discard mortality of unvented fish, we recommend the following practices as additional options for reducing fight time and therefore also discard mortality: target black sea bass in as shallow of water as possible, reel in fish at a moderate to fast pace, use appropriate strength tackle that can easily land black sea bass in deep water, and consider using single hook rigs given that double header catches had longer fight times. In addition, the impacts of dead discards could be reduced by avoiding the targeting of other species in fishing locations and seasons when black sea bass retention is prohibited, or avoiding locations and seasons when undersized black sea bass that have to be released are the primary catch.

In conclusion, our study estimated mean discard mortality rates of 21% for vented and 52% for unvented black sea bass following capture and release in 45 m depth. Given that venting is not commonly practiced in the fishery, the 52% estimate for unvented fish is most representative of the current discard mortality rate when the fishery operates at (or near) this depth. However, due to increased fight times, the discard mortality rate is expected to be higher at greater depths. Current black sea bass stock assessments and fishery management plans assume a 15% discard mortality rate for the coastwide, year-round black sea bass recreational fishery. Based on our results, we recommend further evaluation of the appropriateness of this assumption in terms of being able to provide the best possible estimate of total fishery removals and for developing management plans. Because swim bladder venting was the single greatest factor that reduced the discard mortality rate and increased submergence success, fishery managers might consider encouraging, or even mandating, the venting of black sea bass released in offshore and deep water winter recreational fisheries. Yet, as previously stated, this would require extensive education of fishery participants on proper venting technique and tools. Additionally, given that predation events by other fishes primarily occurred early in our field season and that deeper depths had to be fished to catch black sea bass later in the winter, it may be most advantageous to open the fishery in our study areas off southern New Jersey from the period of mid- or late-December through January, which is when fish are more likely to be accessible at 'shallower' depths (i.e., <~55 m) and predation risk is lower. The results of our study are also applicable to other deep water regional fisheries in which black sea bass experience barotrauma, and therefore should assist with the development of regulations that would reduce the number of discards and discard mortality of black sea bass.

3. Introduction

Recreational rod-and-reel fishing is a popular activity that produces significant socioeconomic benefits to coastal communities (Lovell et al., 2013). Each year, a substantial portion of the total recreational catch is discarded due to management measures (e.g., minimum landing sizes, possession limits, closed seasons) or personal conservation ethics (Tufts et al., 2015). However, reliable discard mortality rate estimates are often difficult to obtain, despite being vital for estimating total fishing mortality in stock assessments and for developing fishery management plans. Previous studies on recreational fisheries have indicated that discard mortality rates are species-specific and often influenced by various capture-related variables, including tackle type, fish handling method, air/water temperature, capture depth, and degree of physical injury (e.g., Diodati and Richards, 1996; Hochhalter and Reed, 2011; Curtis et al., 2015). Increased research related to discard mortality in recreational fisheries and associated outreach efforts to educate anglers have also recently been identified as key strategies for addressing challenges in managing recreational fisheries (FishSmart, 2014; NOAA, 2014).

Black sea bass (*Centropristis striata*) are commonly captured along the east coast of the United States by recreational anglers (Shepherd and Nieland, 2010). Throughout their range, the species is caught as part of numerous seasonal recreational fisheries that utilize multiple different gear and tackle types, and occur over a range of water depths, water temperatures, and air temperatures. Accordingly, published black sea bass discard mortality rates vary considerably by region (e.g., 4.7% to 39%), with an increase in mortality rate evident in deeper capture depths (Bugley and Shepherd, 1991; Collins et al., 1999; Rudershausen et al., 2014). Currently, black sea bass stock assessments and fishery management plans assume a 15% discard mortality rate for the coast-wide recreational fishery (NEFSC, 2017), but the wide range of published estimates indicate that this rate may not be representative of all regional fisheries.

In late fall and winter, black sea bass migrate offshore towards the edge of the continental shelf (Moser and Shepherd, 2009) and overwinter on deep shipwrecks and reefs (45-80+ m). Within this time and area, large numbers of fish can be discarded by recreational anglers during directed and non-directed (e.g., scup, cod, tilefish) trips due to size restrictions, daily possession limits, "high-grading", or closed seasons. The discard mortality rate of black sea bass in this offshore fishery is uncertain. Collins et al. (1999) reported black sea bass discard mortality rates up to 39% following rod-and-reel capture in a similar depth range (43-54 m) off South Carolina, but it is unclear the extent to which this estimate is applicable to the Mid-Atlantic offshore recreational fishery that occurs in colder water and air temperatures, sometimes at deeper depths, and in different ecosystem conditions (i.e., predator species and abundance). In addition, the estimates derived by Collins et al. (1999) for the 43-54 m depth range were based on low sample sizes (n=25) and by monitoring fish in cages for 24 h post-release, which is a technique that can bias mortality estimates and potentially serve as under- (i.e., shielding from predation) or over-estimates (i.e., impacts on feeding) of discard mortality (Davis, 2002). Consequently, further research was needed to provide a more robust discard mortality rate estimate for the offshore black sea bass recreational fishery in the Mid-Atlantic to inform stock assessments and fishery management.

This project addressed the Mid-Atlantic Fishery Management Council 2016–2017 Collaborative Fisheries Research Program Priority #4 by determining the discard mortality rate of black sea bass captured by recreational anglers using rod-and-reel fishing gear in the fall/winter Mid-Atlantic offshore fishery. In addition, this project established best practices guidelines to reduce the discard mortality rate of black sea bass in both the offshore and inshore fisheries. These goals were achieved by meeting the following originally proposed research objectives:

(1) Estimate the discard mortality rate of black sea bass following capture with rod-and-reel fishing gear at a deepwater offshore shipwreck in the Mid-Atlantic using passive acoustic telemetry and a longitudinal survival analysis.

(2) Identify the capture-related factors that influence black sea bass discard mortality.

(3) Utilize the results from (2) to establish "best practice" guidelines for reducing the mortality of discarded black sea bass.

(4) Conduct a broad outreach effort to disseminate project results from (1) and (3) to invested stakeholder groups (e.g., fishery managers and scientists, recreational fishing community).

(5) Describe the residency, behavior, and habitat use of black sea bass at an offshore shipwreck in the Mid-Atlantic.

4. Methods

Study Timeline: Fieldwork was conducted from November 2016 through March 2017, which covers the winter period of highest offshore recreational fishing effort for black sea bass in the Mid-Atlantic.

Study Sites:

Ice Cream Cone Wreck (main study site): This study utilized input from a range of industry collaborators to ensure selection of a suitable study site that provided an accurate representation of the winter offshore recreational black sea bass fishery in the Mid-Atlantic, and was in a location conducive for maintaining an acoustic telemetry receiver array. Following extensive conversation with industry collaborators, including those who are part of the Starfish Fleet in Sea Isle City, NJ (e.g., Captain Bob Rush, Capt. Mike Weigel), captains from the United Boatmen of New Jersey, and industry stakeholders from the Partnership for Mid-Atlantic Fisheries Science, it was decided to have the main study site be the "Ice Cream Cone Wreck", which is located ~85 km southeast of Sea Isle City, NJ in 45 m depth (Figure 1). This location is an area with consistently high black sea bass catch rates and a depth range that is representative of common offshore fishing grounds for black sea bass.

Baltimore Rocks and Indian Arrow Wreck: Black sea bass catch rates at the Ice Cream Cone Wreck slowed considerably beginning in the middle of January 2017. In fact, only 14 fish were captured during the last tagging trip to the site on February 3, 2017. In an effort to achieve our target number of observations (i.e., ~1,200 fish) and to investigate how our observations and discard mortality might vary by depth, the decision was made to conduct future trips at alternative, deeper fishing locations that were further from port and are locations where black sea bass have historically been captured later in the winter fishing season. Three additional trips were made, including two trips to the Baltimore Rocks (67 m in depth) and one trip to the Indian Arrow wreck (58 m), during February and March, respectively (Table 1; Figure 1A). Not only did the execution of these trips allow us to reach our target sample size, but they also permitted the observation of fish captured at deeper depths, and the investigation of potential effects of capture depth on barotrauma and fish survival (see Findings section below).

Tagging Methods:

Our team collaborated with the Vemco staff (Halifax, Canada) in order to select the most appropriate pressuring-sensing acoustic transmitters (model V9P-2H; Vemco AMIRIX Systems, Inc., Nova Scotia) and optimal transmitter programming configurations (e.g., tag power, battery life, depth sensor resolution, and transmission schedule; Table 2) to match the study site depth and study objectives. Similarly, our team worked with the Floy tag manufacturing company (Seattle, WA) to design and purchase the conventional t-bar anchor tags most appropriate for black sea bass tagging, including Pedersen discs used to attach the acoustic transmitters (see below).

Transmitter attachment and retention study: Prior to any tagging trips, a holding tank study was conducted in order to test multiple transmitter attachment methods, and evaluate the minimum acceptable fish tagging size, transmitter retention rate, and tagging-induced mortality rate for each method. In collaboration with Bill Hoffman from the Massachusetts (MA) Division of Marine Fisheries, 35 live black sea bass (Total lengths: 27 – 42 cm) were collected while fishing with rod-and-reel aboard the *R/V Mya* in Buzzards Bay, MA on 9/12/2016. Following capture, fish were kept in onboard holding tanks during transport to the Seawater Laboratory at the University of Massachusetts Dartmouth School for Marine Science and Technology in New Bedford, MA. All methods related to the holding tank experiment were performed under approval by the Institutional Animal Care and Use Committees (IACUC) at both Rutgers University and the University of Massachusetts Dartmouth (Appendix 1).

Two methods for externally attaching acoustic transmitters were tested beginning on 9/20/2016. Method 1 involved the use of Floy spaghetti tag material, which was passed through the dorsal musculature of the fish with a hollow needle and tied around the transmitter end cap to secure it in place (n=10 fish; Figure 2A). Method 2 involved the use of 22.7 kg test monofilament line, 0.25 – 0.75” Pedersen discs, and copper crimps (n=5 fish; Figure 2B). For this method, a 20 cm length of monofilament line was first tied to the transmitter end cap. Next, a small baffle and Pedersen disc were threaded onto the line and pushed flush against the transmitter. Using a hollow needle, the monofilament line was threaded through the dorsal musculature of the fish, and a Pedersen disc and baffle were threaded onto the tag end of the line. Finally, Pedersen discs were snugged in place on either side of the fish’s body and a small, single sleeve, copper crimp was threaded onto the tag end, positioned flush against the baffle/disc assembly, and secured in place by a crimping tool. The monofilament line tag end was then cut.

After 62 days of observation following tagging with each method, there was zero tag shedding or mortality at the termination of the study on 11/21/2016. Given this, (1) any mortality observed in the field could be assumed to be due to the capture, handling, and release processes, rather than the tagging process, and (2) tag shedding is unlikely to occur during this time window. Although both attachment methods were successful, Method 1 resulted in a high prevalence of skin lesions and tissue irritation. Thus, Method 2 was chosen as the preferred attachment method, because it did not cause as much harm to the fish (i.e., fewer and less severe tag-induced lesions were observed) and was generally thought to provide a more solid attachment of acoustic transmitters to black sea bass. The minimum acceptable fish size for tagging was also established at 27 cm, which is consistent with the size of the smallest fish monitored in this holding study and permitted the tagging of black sea bass that are under the current federal minimum size limit (12.5" or 31.75 cm).

Field protocol, tagging strategy, and data collection:

Determining standardized terminal tackle: Prior to any sampling, we conducted an extensive survey of recreational black sea bass anglers and captains to determine the reel type (e.g., conventional, spinning, or electric), tackle (e.g., line type and strength, hook type and size, etc.), and rigging techniques (e.g., use of monofilament topshot, topshot length, etc.) that are most commonly used in the Mid-Atlantic recreational offshore black sea bass fishery. This survey was hosted on SurveyMonkey during October and November 2016, and was distributed primarily via online message boards for recreational anglers (e.g., www.thebassbarn.com, www.noreast.com, and www.njfishing.com). A total of 282 anglers responded to the survey. This survey was originally intended to designate standardized rod-and-reel setups and terminal tackle rigging for use by all volunteer anglers during all research tagging charters. However, it was ultimately only used to select standardized terminal tackle rigging, because the volunteer anglers wanted to use their personal rods and reels while fishing. Our research team permitted this, because rod choice is not expected to impact discard mortality and it gave us the opportunity to investigate how other factors such as reel speed/retrieve ratio might impact discard mortality while still keeping the terminal tackle rigging standardized. Based on the results of the online tackle survey (Table 3), our standardized terminal tackle rigging was a High-Low rig made with 50 lb. (22.7 kg) monofilament leader material and two 5/0 Octopus J-hooks (Mustad Ref. # 92553-BN) (Figure 3). All terminal tackle rigs were tied by co-PI D. Zemeckis. Anglers were provided the appropriately sized lead sinkers for the current sea conditions that day to keep the baits on the bottom to catch black sea bass (i.e., 10 - 20 ounces, 284 - 567 grams).

Tagging trips: Eight for-hire charter trips were conducted from December 2016 – March 2017 (Table 1). Research tagging charters to deploy acoustic transmitters at the Ice Cream Cone wreck were conducted aboard the *F/V Susan Hudson* from Sea Isle City, NJ, from December 2016 – February 2017 (n=4 trips), and one charter aboard the *F/V Porgy IV* sailing from Cape May, NJ, in January 2017. The final three tagging trips were all completed aboard the *F/V Susan Hudson*, with two trips fishing the Baltimore Rocks and the final trip fishing the Indian Arrow shipwreck. Each tagging trip had 6 - 14 volunteer anglers of varying experience levels (as quantified by questionnaire) and up to four scientific personnel. Prior to the commencement of fishing activity on each trip, each volunteer angler was required to complete an angler questionnaire that quantified their experience level (Appendix 2). For all fishing activities, volunteer anglers were given the option to fish with their own fishing rod-and-reel setup as long as their terminal tackle rig was the standardized design as described above. If the angler did not have their own rod and reel setup they were provided one that was rigged accordingly by scientific staff. All anglers were provided the same bait (chopped sea clam or squid, provided by the chartered vessel) and allowed to determine how best to fish, handle, and unhook their catch to promote authentic scenarios. Each volunteer angler was provided a stopwatch in order to record the following times for each fish: fight time, unhooking time, and handling time.

For each captured black sea bass, a series of technical variables that describe the capture event were recorded, including: capture depth, angler experience level, fight time, unhooking time, handling time, hook location (Figure 4), and hook removal method. Biological variables including total length (TL), air and water temperature, and release behavior were also recorded. Each fish was also assigned a physical injury score (i.e., present or absent), as well as exopthalmia and stomach eversion scores, which assessed the impacts of the capture process and barotrauma, respectively. See Table 4 for a description of all recorded variables. To monitor post-release fate, a subset of 96 black sea bass were tagged with Vemco acoustic transmitters. Captured fish not tagged with acoustic transmitters were tagged with conventional t-bar anchor tags (Floy FD-94; n=1,467) to confirm survival or identify movement patterns if recaptured, or otherwise retained for biological sampling (i.e., ageing: n = 74). The remaining 282 captured fish were not tagged due to logistical issues (e.g., too many fish that needed processing during a very short period of time) or after our conventional t-bar tag supply was exhausted.

Previous research on black sea bass indicated that swim bladder venting may decrease discard mortality (Collins et al., 1999), and anecdotal reports from the industry suggest that the inability to submerge (due to barotrauma) is a major contributor to discard mortality (Gary Shepherd, pers. comm.). To examine the true extent to which swim bladder venting impacts submergence success and discard mortality rate, a subset of captured black sea bass were vented using a Ventafish VF-1 Fish Venting Tool following techniques outlined at www.catchandrelease.org. This tool included a 16 gauge replaceable needle with a 45 degree front end. To minimize risk of internal injury to the fish from improper technique, all fish were vented by a single trained scientist (co-PI D. Zemeckis) by placing the fish flat on the measuring board and inserting the needle into the swim bladder behind the pectoral fin while using the spring-loaded button on the tool to insert the needle and let the gas release out of the vent holes on the needle. Having one trained scientist perform all of the venting of the fish ensured that we were able to test the influence of proper venting technique on black sea bass discard mortality. An equal number of vented and non-vented fish were tagged with acoustic transmitters (n=48 fish per treatment), and efforts were made to vent fish over all observed lengths and in an equal ratio for all other capture observations.

Tag recaptures and lottery: A toll free phone number was maintained through Rutgers University to retrieve fishery-dependent recapture information. That number was printed on all conventional t-bar anchor tags and Pedersen discs used for attaching acoustic transmitters so that whenever a tagged fish was recaptured it would hopefully be reported to our research team. A database of all reported recaptures was maintained and a lottery reward system was used to randomly award three anglers (who reported tag recaptures) a $500 reward on three separate occasions during the project (i.e., June, September, and December of 2017).

<u>Acoustic receiver array design, deployment, and monitoring</u>: To monitor the fate of fish tagged with acoustic transmitters, an array of 30 acoustic receivers (Vemco model VR2W) was strategically deployed based upon extensive communication among the project team and fishing industry collaborators in order to maximize the coverage of the Ice Cream Cone shipwreck and surrounding areas and to minimize the risk of losing equipment (Figure 1). All receivers were deployed using an established mooring system based on that depicted in Figure 5A. Twenty five receivers (Stations: SB1 - SB25) were deployed on November 28, 2016 in cooperation with Captain Eric Burcaw aboard the *F/V Rachel Marie* from Sea Isle City, NJ and an additional five receivers (Stations: SB26 - SB30) were deployed on January 17, 2017 in cooperation with the *F/V Porgy IV* (Figure 5B). These five additional receivers were deployed based on preliminary data that showed a high degree of movement towards the southern portion of the acoustic array and our desire to increase our ability to monitor movements in this direction. HOBO Pendant temperature

loggers (Onset Computer Company, Onset, MA) were placed at the surface and bottom of receiver mooring lines at stations SB1, SB8, SB21, and SB23 and were programmed to record water temperature every 5 minutes (Figure 1B). Three trips (12/20/2016; 1/21/2017; 2/21/2017) were conducted aboard the *F/V Rachel Marie* to download, clean, and maintain acoustic receivers, with most receivers being permanently hauled and downloaded on 3/27/2017. Three acoustic receivers were lost over the period of November 28 to March 27 (SB3, SB10, SB24). All downloaded acoustic telemetry detection data were backed-up on external drives and quality controlled for data analysis.

Three acoustic receivers (SB12, 13, and 15: Figure 5B) positioned in close proximity to the shipwreck were left in place after 3/27/2017 to continue monitoring the study site in case tagged black sea bass visited this location during their inshore spring migration. Unfortunately, all three acoustic receivers and mooring systems were lost when they were attempted to be retrieved by Captain Burcaw during one of his commercial fishing trips on 6/4/2017. Efforts were made to grapple at the location at which each receiver was set, but Captain Burcaw was unable to recover any of the gear. Although these receivers were positioned around the shipwreck and were not previously disturbed or lost, it's possible that there was a negative interaction with another trap or scallop dredge fisherman in the spring, or perhaps a passing cargo ship or tugboat. Despite these losses, the loss of only six total receivers was viewed as being relatively minor given the distance of the receiver array from shore, the rough winter weather, and the regular presence of passing cargo ships in the study site, as well as the presence of commercial sea scallop fishing vessels near and inside the array in March 2017. Further, the loss of only three receivers during the main study period, including no losses around the wreck, permitted excellent data recovery to meet study objectives.

Given the importance of 'known alive' (i.e., positive control, see below) fish to the analysis, a last attempt to monitor for any acoustically-tagged black sea bass that may have remained at or returned to the Ice Cream Cone wreck was made in December 2017. To accomplish this, we provided the *F/V Susan Hudson* with a single acoustic receiver to deploy during one of their charter fishing trips to the wreck. This receiver was deployed as planned, however, no acoustic detections were obtained.

Statistical analysis: All statistical analyses were performed with the statistical computing software R (R Foundation for Statistical Computing, 2018). Significance was accepted at a level of $p < 0.05$. To investigate the relationship between fight time and fish TL, capture depth, capture as part of a 'double header' (i.e., two fish captured simultaneously, one on each hook), and reel ratio (i.e., high or low speed reels) a generalized additive mixed effect model with an inverse link function was performed using the 'mgcv' package (Wood, 2011) in R. To account for variation resulting from angler behavior, 'Angler' was included as a random effect. All model variants were compared using the Akaike Information Criterion (AIC; Akaike, 1973) to examine the effect of each factor on fight time, with the model variant with the lowest AIC score being chosen as the best fitting model.

A fixed-effects logistic regression was also employed to evaluate the relationship between release behavior and several capture-related variables, including depth, fish TL, physical injury, presence of exopthalmia, presence of stomach eversion, and venting. A parsimonious set of these variables were selected with a stepwise forward model selection process using AIC following Benoit et al. (2010). In brief, variables were added incrementally to an intercept-only model and retained only if the AIC score was reduced by at least three units. If final models had an equal number yet different composition of variables and an AIC score ≤ 3 units, both were kept and considered equally plausible.

Survivorship assessment: Survivorship of individual black sea bass tagged with acoustic transmitters was objectively determined by comparing vertical and horizontal movement against black sea bass with known statuses (see below). Following procedures detailed by Capizzano et al. (2016), prior to analysis all transmitter data were initially vetted for false detections using the FDA Analyzer tool in VEMCO's User Environment (version 2.2.2) and irrational detection data that coincided with transmitter failures.

Dead controls (known dead fish): Accurate identification of the post-release fate of black sea bass is predicated upon a thorough understanding of the horizontal and vertical movements that are exhibited by a dead fish. For example, surface currents can move dead fish as it sinks to the bottom and bottom currents can cause a carcass to drift along the bottom, providing the perception of directed movement (i.e., a living fish). To identify behaviors that were indicative of a dead fish, five dead fish were tagged with acoustic transmitters and released at the study site. Preliminary data from dead controls released early in the study suggested that carcasses tended to drift out of the array, thus, to obtain a representation of a stationary fish (i.e., a dead fish that was resting in one place), an additional transmitter was deployed on a stationary mooring line within the acoustic array (Figure 1B). Resulting dead control data were used as standards by which to determine the fate of all other acoustically-tagged fish. Reliable data were obtained from two of the fish dead control fish released within the receiver array; data from the three other dead controls were determined to be insufficient due to the extreme brevity of their monitoring period (i.e., hours).

Positive controls (known alive fish): Throughout the study period, seven acoustically-tagged black sea bass were confirmed to be alive either by acoustic detection (n=4), or fishery-dependent recapture (n=3). Acoustic detections were obtained for these fish in collaboration with the Atlantic Cooperative Telemetry (ACT) Network (Table 5). Since the fate of these fish was known (i.e., 'alive'), they were treated as positive controls and used as standards by which to determine the fate of all other acoustically-tagged fish.

Given the impact of misclassifying mortality events on subsequent longitudinal survival results (see below), we employed a three-step approach to determine individual fish fate. Step (1) of our approach involved the use of a discriminant function analysis, which creates a function capable of classifying individuals of unknown origin into groups based on metrics from individuals of known origin (White and Ruttenberg, 2007) using solely acoustic detection data. A discriminant function was created using gross movement metrics from positive and negative controls, specifically maximum depth variance, minimum depth, and the proportion of total depth observations that were shallower than an individual's mean overall observed depth minus the mean depth variance of dead control fish, using the R package "MASS" (version 7.3-45; Venables and Ripley, 2002). Discriminant function results included a fate assignment (alive or dead) for each fish.

Step (2) included the application of a depth variance test applied to depth observations recorded at defined intervals throughout the detection history of each acoustically-tagged fish. Because transmitters were programmed to emit transmissions on a phased schedule, acoustic detection data were binned into specific time intervals post-release to maintain a consistent number of expected detections per interval (Capizzano et al., 2016). Only bins with at least 10 observations were included in the analysis. To account for the effect of tide height on individual depth observations, the study site's tidal cycle was estimated and subsequently removed from each transmitter's depth record using the R package "oce" (version 09-21; Kelley and Richards, 2017). The variance of tide corrected depth observations in each time bin were compared to that of the negative controls for each fish using a one-tailed t-test of the absolute difference from the median (modified Browne–Forsythe–Levene test for homogeneity of population variance; Lyman Ott and Longnecker, 2010); from now on referred to as the depth-variance survival test. Tide-adjusted depth data of negative controls were assumed to be representative of dead black sea bass in the study area since they interacted with the area's bathymetric features over time. Due to the infrequency of off-bottom movement exhibited by black sea bass, when a tagged black sea bass's depth-variance was significantly different ($p < 0.05$) from the negative controls during one or more time intervals, the fish was classified as being alive.

Following Steps 1 and 2, all fish that were detected for >2 days whose fate was predicted to be the same by both the discriminant analysis and depth variance test (n=50 fish) were assigned the appropriate fate (e.g., Discriminant analysis result = ALIVE, Depth variance test result = ALIVE, Final fate = ALIVE). For the remaining 44 detected fish, due to the brevity of their monitoring period (i.e., the lack of critical movement data) and the discrepancy between the discriminant analysis and depth variance results, each fish was subsequently subjected to a semi-quantitative analysis that used multiple metrics to objectively infer their final fate. This analysis included: (1) a semi-qualitative assessment of the horizontal and vertical movement patterns of each fish that placed particular emphasis on the comparison of their movements to those evident in both positive and negative controls; and (2) the analysis of the trajectory of horizontal movements in relation to surface and bottom currents predicted at the study site by the Regional Ocean Modeling System (ROMS) (data available at https://www.myroms.org/).

For (1), individual horizontal and vertical movement plots (see Appendix 3 for example plots) were first examined to determine if the general pattern of movement was consistent with either positive (characterized by bottom-oriented behavior with some vertical movements up to ~20 m and more extensive horizontal movements, including non-linear emigration from the receiver array) or negative control fish (characterized by small vertical movements on the order of the depth range evident in the study site and no or limited horizontal movement restricted to straight line emigration from the array). In nine instances, vertical movements, represented by repeated, extensive movements from the bottom to 15 - 20 m that commenced at the onset of darkness (night), that were not observed in either positive or negative control fish were evident (Fish #'s: 3358, 3359, 3365, 3367, 3370, 3372, 3374, 3376, 3379; Appendix 3). Based on the observation of numerous predation events (e.g., the capture of fish that were bitten while being brought to the surface) that occurred during each of the research trips on which these nine fish were tagged, each fish was considered to have been predated upon following release. Based on conversations with vessel captains and crews, there is strong evidence that predation events such as these commonly occur during the early part of the offshore black sea bass fishing season (e.g., November and December when dogfish and bluefish abundance are highest at these locations), thus, all predation events were included in the survival analysis as 'dead' fish (see below).

For (2), the trajectory of horizontal movements exhibited by each fish during periods when they were floating at the surface (i.e., depth = 0 m) or moving along the bottom in a manner that resulted in their emigration from the receiver array was compared with ROMS current predictions at the study site (at the time of detection) to determine if movements were indicative of active swimming or drifting behavior. In brief, examination of directional movement data from both positive and negative controls indicated that while positive controls (i.e., known alive fish) often moved in opposition or tangential to the direction of the prevailing current (i.e., into the current), dead control fish (i.e., known dead fish) almost always drifted in the direction of the prevailing current (i.e., with the current). Furthermore, positive control fish also generally exhibited straight line movement out of the array over a much shorter period (<10,000 seconds) than dead controls (>10,000 seconds), thereby providing evidence of active movement. Given these observations, the fate of all remaining fish (n=35) was determined by comparing the duration and trajectory of their movement in relation to the bottom current direction, with fish that slowly moved along the bottom (i.e., with only small differences in depth evident) in the direction of the current being classified as ‘dead’ and those that moved more rapidly against or tangential to the direction of the bottom current being classified as ‘alive’.

Analysis of survival data: Final black sea bass survivorship data were analyzed to address the following objectives: (1) to evaluate the suitability of capture-related variables (i.e., covariates) for predicting survival and to identify a parsimonious subset of these that best predict survival; and (2) to use this subset of covariates to assess potential models that can describe survival over time and estimate overall discard survival. Event times for both dead (i.e., time of death) and surviving (i.e., time of last observation) black sea bass, along with the values for a suite of capture-related variables that may affect survival (i.e., covariates) were compiled following methods described by Benoît et al. (2015) and Capizzano et al. (2016). Such event times were categorized as one of three types of data censoring: (1) fish that were inferred to have died within the acoustic receiver array (i.e., uncensored), (2) fish that died during capture and handling or release (i.e., left-censored), and (3) fish released alive whose death was not inferred/observed during the experiment (i.e., right-censored).

A combination of non-parametric and semi-parametric longitudinal survival analyses were used to address objective (1) following procedures outlined by Knotek at al. (2018). First, the empirical Kaplan-Meier (KM) estimator was used to visually assess the influence of biological, technical, and environmental covariates on the survival function (cumulative probability of survivorship over time; Cox and Oakes 1984). Because the KM estimator is non-parametric, it follows the proportion of individuals alive as a function of time in the absence of censored observations. Log-rank tests, specifically the Peto & Peto modification of the Gehan-Wilcoxon test, were performed to accept or reject the null hypothesis that there was no statistical difference between survival functions for categorical covariates. The median for covariates with continuous data were used to establish broad categories for the KM estimator and log-rank tests.

A mixed-effects Cox proportional hazards model (CPHM) was then used following Knotek et al. (2018) to objectively evaluate the suitability of covariates as predictors of survival given the model’s ability to simultaneously evaluate the additive effect of multiple covariates (Cox 1972; Therneau and Grambsch, 2000). The model is expressed as:

$$h(t) = h0(t)\exp(X'+Z'b) \qquad \textbf{(Eq. 1)}$$

where h(t)is the instantaneous probability of mortality at time *t* conditional on having survived to time *t* (i.e., the estimated hazard function), which is a function of a non-parametric baseline hazard function h0(t), a vector of covariates X’ and a Gaussian random effect *Z’*. Because this class of survival analysis is semi-parametric, it makes no assumption about the shape of h0(t) but assumes that the ratio of hazards for two individuals is constant over time and is a function of both the covariates and random effects (Cox, 1972). To identify a parsimonious subset of covariates, the stepwise forward selection process using Akaike's Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson 2002) was used as per Benoit et al. (2010). The random effect ('sampling trip') was considered to incorporate any within-trip correlations (e.g., Benoît et al. 2010) as outlined by Knotek et al. (2018). Seven sensible covariates were identified *a priori* and with KM estimators as potentially influencing discard mortality in black sea bass and were included in the model selection procedure: fight time, handling time, TL, physical injury, air temperature, sea surface temperature, season (fall and winter), and venting. The release behavior covariate was dropped due to insufficient sample size of fish that floated after release (*n*=10). Covariates that produced the best fit model were used in the subsequent modeling as the predictors for survival.

Despite their ability to fit the data, non-parametric and semi-parametric models cannot be used to parse out different mortality sources (e.g., capture-handling, post-release) or provide mechanistic interpretations of survivorship patterns over time (Benoit et al. 2015). Therefore, the parametric survival modeling approach developed by Benoît et al. (2015) was used due to its ability to explicitly account for these types of mortality and provide estimates for each. Specifically, this model assumes that there are two general groups of fish (i.e., fish that have been adversely affected by the fishing event and will die vs. fish unaffected by the fishing event and will not die). The KM estimator of the survival function suggested the presence of two types of mortality over time when viewing survival across all observations: capture and handling mortality that occurred prior to release, and capture-related post-release mortality which occurred within days of release (Figure 6; Benoît et al. 2012, 2015). The survival function for this model (S(*t*); probability of surviving to time *t*) is expressed as:

$$S(t) =(\exp[-(t)]+(1-)) \qquad \textbf{(Eq. 2)}$$

where τ is the probability of surviving capture and handling, π controls the probability that an individual was adversely affected by the fishing event, and α and γ are respectively the scale and shape parameters of an underlying Weibull distribution that determines the mortality patterns over time for the adversely affected individuals. From Equation (2), it is clear that at $t = 0$, $S(t) = \tau$. Therefore, as $t\to\infty$, the term $exp[-(t)]\to 0$ (i.e., all affected fish die) and S(t) (1-)(i.e., only unaffected individuals remain alive). Thus, is the conditional post-release mortality rate (i.e., the mortality rate for individuals that were alive when released but subsequently died as a direct result of discard mortality), and 1-+ is the total discard mortality probability.

After determining the basic model and appropriate terms to include, model variants of Equation (2) were developed and fit with the parsimonious subset of covariates. The influence of capture-related variables that may affect survival can be included in the model via the α, γ, τ, and π terms but the effects are most often and strongly observed on the two latter terms (e.g., Benoît et al. 2012, 2015; Capizzano et al. 2016). Three model variants of Equation (2) were considered for model selection procedures (Table 6). Model variants were fit with selected covariates from the CPHM using maximum likelihood and constructed with the same forward selection procedure using AICc.

Because venting may be difficult to implement, the non-parametric KM estimator and semi-parametric CPHM survival analyses were performed on unvented fish to examine the suitability of covariates for predicting survival. Eight sensible covariates determined *a priori* and with KM estimators were included in CPHM model selection with the forward selection procedure using AICc: fight time, handling time, TL, physical injury, sea surface temperature, temperature differential between bottom water and air, season (fall and winter), and release behavior. Since no parametric survival analysis was applied to these data, only general trends are provided.

5. **Problems Encountered**

Some unanticipated problems were encountered during the project, but these problems did not prevent us from addressing our core objectives. With regard to fieldwork (tagging trips and receiver deployment and maintenance), we experienced some difficulty completing offshore tagging trips due to the rough weather conditions, particularly during January 2017. There were also some mechanical and logistical issues that arose with the primary tagging vessel, the *F/V Susan Hudson*, which was unavailable for approximately three weeks in January 2017, because of repairs that needed to be performed following an inspection by the United States Coast Guard. However, the recruitment of a backup vessel (*F/V Porgy IV*, Cape May, NJ) allowed us to quickly capitalize on a nice weather window and not only deploy all of our acoustic transmitters on schedule, but also exceed our target number of black sea bass capture observations by almost 50%. We were also able to spread the acoustic transmitter releases over a variety of weather conditions, and collect observations at multiple locations.

As communicated above, the acoustic receiver array was expanded on January 17, 2017 to provide increased monitoring at the southern extent of the array. This helped to counter the problems observed in data from the first acoustic telemetry receiver download on 12/20/2017, which indicated that the majority of the fish that emigrated from the array did so in a south/southwest direction. In addition to the six acoustic receiver mooring systems that were completely lost during this study (see above), there were three mooring systems that had their surface buoys destroyed by ship strikes. This became evident after they were recovered off the seafloor using a grappling system that couldn't have been employed without the expertise of the collaborating commercial fishermen. Recovery of this equipment not only salvaged the expensive research gear, but also permitted downloading of the valuable data stored on the acoustic receivers. Therefore, strategically rigging our mooring systems and collaborating with commercial fishermen helped to minimize the amount of lost equipment and data.

Due to the complex and diverse nature of the black sea bass movements and behavior in the study site, the need to allow the maximum amount of time for tag recaptures and detections (i.e., the establishment of positive controls), and the complexity of the final survival analysis, the final estimation of discard mortality rate and the identification of the capture-related factors that were predictors of mortality were slightly delayed until later in the project timeline than expected. However, this thoroughness resulted in the most robust results as possible for inclusion in this final report, but it did delay our ability to conduct broad outreach efforts to disseminate out results and educated anglers on recommended best practices for reducing discard mortality (i.e., Objective 3). But, due to the overwhelming importance of the positive control fish to both the accurate identification of individual fish fate and the estimation of the discard mortality rate, it was necessary to obtain as many positive control fish as possible in an effort to maximize the validity of our results. As outlined below, we did begin to disseminate our results to the scientific community and recreational fishing community, and have outlined a detailed plan for completing those efforts with the finalization of our results for this final project report.

6. Findings

Summary of capture events: During the eight research tagging charters conducted from December 2016 to March 2017, a total of 1,823 black sea bass ranging in size from 136 - 612 mm TL were captured over three depths (45, 58, and 67 meters; Figure 7). Due to the sometimes high volume nature of the fishery (i.e., many fish being captured over a short time), a complete set of data for all quantified variables was not available for all captured fish, hence the discrepancies in sample size presented throughout this report. All fishing activities were performed with the standardized High-Low, two-hook terminal tackle setup that was chosen as the most representative gear configuration used in the offshore black sea bass fishery. A total of 50 volunteer anglers of all experience levels participated in tagging trips, however, there were markedly more experienced (scores 5 - 9; n=43 anglers, n=1,663 capture events) than inexperienced (scores 0 - 4; n=7 anglers, n=155 capture events) anglers. However, we feel as though this relationship is representative of true conditions, given that more experienced (i.e., 'die hard') fishermen tend to participate in this fishery given its offshore nature and occurrence during characteristically cold and rough winter months.

Anglers used a fairly wide range of conventional fishing reels, with retrieve gear ratios from 2.5:1 to 7.1:1. For analysis, these reel retrieve ratios were broadly classified as 'low' (reel retrieve ratio <5.0:1; n=891 capture events) and 'high' (reel retrieve ratio >5.0:1; n=927 capture events) speed. All captured black sea bass were lifted onboard while still attached to the hook, no fish were netted or gaffed. A total of 321 capture events were classified as 'double headers', with two fish captured simultaneously (one on each hook). Of the 1,823 captured fish, 1,713 were released including 957 that were vented and 756 that were not vented (Table 7). A total of 1,467 fish were tagged with conventional Floy tags, 766 of which were double tagged (to estimate tag shedding rate). A subset of 96 fish (278 - 546 mm TL) were tagged with Vemco acoustic transmitters, 48 of which were vented (278 - 546 mm TL) and 48 of which were not vented (279 - 485 mm TL).

Technical variables: Fight times ranged from 12 - 251 (Mean SD: 78 ± 32) seconds for the overall sample, with transmitter-tagged fish being fought for 17 - 225 (56 ± 24) seconds (Table 8). Results of a generalized additive mixed effect model indicated that fight time was influenced by fish TL, capture depth, capture as part of a double header, and reel ratio (Table 9). Comparison of delta AIC scores suggested that depth was the most influential factor impacting fight time, with fish captured at the deepest depth (67 m) experiencing the longest fight times (Figure 8). There was a positive relationship between fight time and TL, with larger fish being fought for longer periods (Figure 9). At each depth, interpolation of mean fight time suggested that fish >491 mm TL were fought for longer than average durations. Capture as part of a double header and by low gear (speed) reels also increased fight time (Figures 10 and 11).

Unhooking times and handling times for all observations and transmitter-tagged fish are presented in Table 8. The majority of fish were unhooked by the capturing angler (Figure 12), however, there was no apparent difference in unhooking time between anglers and fishing vessel mates/deckhands or between experienced and inexperienced anglers (Table 8). The majority of fish were hooked in the mouth (shallow or medium mouth), but fish were hooked in various locations of the body throughout the study (Table 10).

Biological variables: Released black sea bass exhibited four behaviors including erratic swimming, sinking, floating, and swimming down, with the vast majority of fish exhibiting the latter two behaviors (Table 11; Figure 13). Results of a logistic regression indicated that fish TL, capture depth, venting, and the presence of exopthalmia influenced release behavior, with larger fish, that were not vented, caught at deeper depths, and experienced exopthalmia had a lower probability of swimming down (Tables 12&13; Figure 14). Air, sea surface water, bottom water, and deltaT (the difference between surface and bottom temperature) temperatures experienced by fish are presented in Table 8. Bottom and surface water temperature at the Ice Cream Cone study site ranged from 6.1 - 14.5 C from the first to last day of monitoring (Figure 15).

Injury score: A total of 304 (17%) black sea bass incurred injuries (i.e., wounds > 2 cm), mostly as a result of hooking trauma and/or the hook removal process. Twelve individuals (0.4%) were dead upon landing, with most having been bitten in half (n=8) or experienced ripped gills (n=2). The majority (82%) of captured individuals exhibited no injury.

Barotrauma: The vast majority (95%) of captured black sea bass exhibited symptoms of barotrauma. Stomach eversion was the predominant barotrauma symptom, with stomach eversion score 2 (i.e., stomach protruding from the mouth cavity) being present in 68% of all captured fish (Figure 16). All four stomach eversion scores were observed in fish tagged with acoustic transmitters, with the relative distribution of scores being comparable to the broader sample (Table 14). Exopthalmia was present in ~10% (n=172) of all captured fish, and in ~6% of fish tagged with acoustic transmitters (Table 14). Barotrauma symptoms were generally more prevalent at deeper depths, particularly exopthalmia, which was most prevalent at the deepest capture depth (67m; Figures 16 & 17).

<u>Survivorship assessment (Objectives 1 & 2)</u>: Acoustic detection data were obtained for 94 of the 96 black sea bass that were tagged with acoustic transmitters. The two fish that were not detected after release (Transmitters 3360 and 3375), were both captured during December (5 & 13th) sampling trips, exhibited ‘floating’ release behavior, and were among the smallest individuals that were acoustically-tagged (286 - 287 mm TL). Given that several other acoustically-tagged fish were detected for extended periods (i.e., minutes to hours) while they floated at the surface (e.g., Fish 3418, 3419; Appendix 3) and these weren’t, it is highly possible that these two undetected fish experienced avian predation shortly after release. Avian predators, primarily herring and black-backed seagulls, were present in abundance during each of these sampling trips, and were observed to actively predate upon other released fish at distances of 15 m or more from the anchored vessel. Regardless, due to the lack of acoustic detection, these individuals were not included in the survival analysis, because avian predation events could not have been visually confirmed for these fish despite our research team observing acoustically-tagged fish floating at the sea surface for as long as possible.

Of the 94 black sea bass that were detected within the receiver array, 61 survived the capture and handling process and were considered to be alive and 33 died after release. Of the black sea bass determined to be alive, 60 emigrated from the receiver array during the monitoring period. The single fish that was detected within the acoustic array on the last day of monitoring (3/27/2017) was later detected by a receiver array off Maryland, thereby confirming its survival. Of the 33 mortalities, nine were attributed to predation following re-submergence (i.e., as the animal swam or sank towards the bottom or after it reached the bottom). All predation events occurred within 1.8 - 18.4 (7.2 ± 4.5) hours of release. The remaining 24 mortalities were assumed to have occurred due to the capture and handling process or natural mortality, and occurred from

5.0 - 128.0 (17.1 ± 26.7) hours post-release. Of these, 19 (79.2%) mortalities occurred within 24 hours of release, four from 24 - 72 hours post-release (16.7%), and one (4.2%) >72 hours post-release (95.8% of mortality occurred within 72 hours).

Analysis of survival data (Objectives 1 & 2):

A fixed-effects CPHM was selected because the inclusion of a random effect did not reduce the AICc by more than three units (-0.651). The best-fit CPHM for black sea bass survival data retained only the effect of venting (Table 15). Results of individual KM estimator survival functions by covariate are reported in Appendix 4. Of note, KM plots suggested that release behavior was a significant predictor of mortality with floating fish exhibiting higher discard mortality than those that swam down (Figure A3; Appendix 4). However, because release behavior was highly correlated with venting and the low sample size for fish that floated, only venting was included in the CPHM model selection.

An effect of venting on only the probability that a fish was adversely affected by discard mortality (π) reduced the AICc by 5.21 units and produced the best model fit (Table 16; model variant 2). The inclusion of venting in model variants 1 (effect on both the capture and handling mortality [τ] and the probability that a fish was adversely affected by discard mortality post-release [π]) and 3 (effect only on the probability that a fish was adversely affected by discard mortality post-release [π]) did not lower the AICc by three units. Consequently, these variants were not considered further. The selected model produced estimates that matched well with those from the empirical KM estimator (Figure 18). Most of the black sea bass mortality is estimated to have occurred post-release (Table 17; Figure 18). Mean post-release mortality rates for non-vented fish were nearly two and a half times greater than vented fish. The mean total fishing-related (i.e., discard) mortality rate was 0.21 (95% CI: 0.12, 0.37) for vented black sea bass and 0.52 (95% CI: 0.38, 0.67) for non-vented black sea bass.

With respect to the unvented black sea bass in the acoustic subsample, a fixed-effects model was selected because the random effect failed to reduce the AICc by more than three units (-3.11). Only fight time was found to predict survival for unvented fish using the CPHM (Table 18; Figure 19). The hazard ratio from the CPHM model summary results suggest that fight time is positively associated with the event probability (i.e., increased fight times increase the chance of mortality; Table 19). Results of individual KM survival function tests by parameter are reported in Appendix 4.

Best-practice capture and handling guidelines (Objective 3): The successful identification of factors that influenced mortality, and therefore the discard mortality rate, of black sea bass in the winter offshore Mid-Atlantic recreational fishery (Objective 2) permitted the formulation of best-practice capture and handling guidelines for reducing discard mortality. Based on the findings that swim bladder venting (when done correctly) was the most influential factor impacting discard mortality and increased submergence success over all depths (i.e., reduced the incidence of floating), we recommend that anglers vent all black fish that are captured during the offshore winter fishery before they are released, particularly those that experience barotrauma symptoms (e.g., exopthalmia or stomach eversion). Given previous documentation of the negative impacts from improper venting technique (e.g., increased injury and mortality: Wilde, 2009), full realization of the benefit of venting will require a broad education and outreach campaign to educate anglers on proper venting techniques and recommended venting tools (see Project Outreach section below).

In light of the extent of the Mid-Atlantic deepwater black sea bass fishery and the large number of anglers who participate in it, educating the majority of participants on proper venting technique may be difficult. As an alternative, particularly if a mandatory venting policy is considered for this fishery, one option would be to focus on educating for-hire (e.g., charter and headboat) vessel captains and crews (e.g., mates/deckhands) about proper venting technique and recommend that anglers who are unfamiliar or uncomfortable with venting protocols to have their catch unhooked and vented by these personnel. This approach would be advantageous since it would focus on properly educating a smaller population, and likely work to reduce the occurrence of improper venting by maximizing the number of ventings that are performed by trained individuals. In addition, these trained individuals will be able to educate other anglers, which, in combination with our team's education and outreach efforts, will help to create a larger population of anglers who are educated on how to properly vent black sea bass. This will be important given the frequently high catch rates in this fishery and the fact that crew members are unlikely to be able to vent all black sea bass that are to be released.

Based on the finding that longer fight time (i.e., >54 seconds) increased mortality in the acoustic subsample, another logical best-practice guideline is to explore methods to minimize the time black sea bass spend on the line while being reeled to the surface. Examination of the GAMM model results indicated that depth of capture had the greatest influence on fight time, thus, we recommend that anglers target black sea bass in as shallow of water as possible (see Management recommendations below). Regarding reel retrieve ratio, although lower speed reels yielded longer fight times (on average), the effect of individual angler had a seemingly large impact on the apparent relationship. In other words, angler behavior (i.e., whether they may have turned the reel handle faster or slower than average) seemed to influence the impact that reel gear had on fight time more than the reel gear ratio itself. Given this, it seems more logical (and practical) to recommend that anglers reel their catch to the surface at a moderate to fast pace, rather than implement restrictions on reel speeds/retrieve ratios. It should be noted, however, that we do not recommend that anglers reel fish to the surface as quickly as possible, because it is possible that this could lead to greater injury to the fish and possible more severe barotrauma-related injury such as swim bladder or stomach rupture.

Capture as part of a double header also resulted in increased fight time. Given this, discard mortality may be reduced if anglers fish with only one hook (as this will eliminate the chance of catching a double header). However, given the deepwater nature of the fishery and the clear indication that the vast majority of anglers use a two-hook high-low rig (as determined by our tackle survey), it is likely that a one-hook recommendation or restriction would be met with strong opposition. Instead, we recommend that anglers use fishing gear (i.e., rod and reel, line) of appropriate strength for the area in which they are fishing (i.e., water depth, size of fish being caught, potential for double headers, etc.) to avoid unnecessary increases in fight time.

Lastly, due to the aforementioned logistical issues with swim bladder venting, reducing fight time may be a more practical recommendation to provide anglers. However, it should be noted that the restriction of fight time will likely not result in the same reduction in mortality that is evident with swim bladder venting.

Anglers can reduce the overall number of black sea bass that are discarded when targeting other species (e.g., cod, pollock, scup, tilefish) by avoiding fishing locations and seasons when black sea bass retention is prohibited, or by avoiding locations and seasons when primarily undersized fish are caught. Also, it is recommended that anglers avoid the practice of "high-grading" (i.e., discarding keeper-sized fish in search of larger fish) to reduce the number of black sea bass that are discarded.

Movements, habitat use, and residency (Objective 5): Movement patterns, habitat use, and residency times at the shipwreck were examined for the 61 fish that were considered to be alive. Detection periods for these fish ranged from 0.07 - 52.07 (12.39 ± 11.70) days. The majority of fish remained at or in close proximity to the shipwreck during their residency within the receiver array, being detected at or directly adjacent to the wreck for continuous periods of 0.00 - 52.06 (12.33 ± 11.73) days (Appendix 3). Excluding fish that emigrated from the wreck within one day of tagging (n=6), 23 fish (41.8%) remained resident at the wreck for periods of 1-7 days, 13 (23.6%) for 7-14 days, 6 (10.9%) for 14-21 days, and 13 (23.6%) for >21 days. By month of tagging, residency times at the wreck were as follows: December: 0.00 - 44.26 (12.12 ± 11.74) days; January: 3.41 - 6.4 (5.87 ± 0.89); and February: 1.83 - 52.07 (13.74 ± 21.48) days. This pattern suggests that cohorts of fish may have been migrating through the study site during their offshore migration, with some individuals remaining at the wreck for longer periods and others spending only brief periods (i.e., <3 days) at the wreck before continuing offshore. The majority of fish emigrated from the array to the southeast (n=35) or south (n=17), with the remaining moving out to the southwest (n=5), east (n=2), and west (n=1). Some additional preliminary habitat use results are presented in Appendix 5 (Winton et al., *In review*), and expanded investigation into black sea bass spatial ecology is planned once those advanced methods are published.

A total of 37 fisheries-dependent recaptures were recorded as of the composition of this report. In general, these recaptures primarily occurred in the Mid-Atlantic region, however, a single fish was recaptured south of Cape Cod, MA (Figure 20). Minimum linear displacements for recaptures ranged from 0 - 464 (89 ± 75) km, and times at liberty from 56 - 365 (160 ± 70) days. Of the recaptured fish, 24 were vented (13 not vented), and 28 swam down at release while 7 floated. A single fish was recaptured at the Ice Cream Cone wreck exactly one year after tagging (12/21/2016 - 12/21/2017).

Project Outreach (Objective 4): An oral presentation was given at the monthly meeting of the Sunrise Rod and Gun Club in Red Bank, NJ on June 2, 2017, entitled "Estimating and mitigating discard mortality in recreational fisheries". Approximately 40 recreational anglers were in attendance and the presentation communicated preliminary results from our project and recommended best practices for reducing discard mortality based on the findings of other published studies. On February 4, 2017, a booth was manned at the Raritan Bay Anglers Club fishing tackle flea market in New Brunswick, NJ. The booth included project materials and plots of preliminary acoustic telemetry results to communicate to anglers the importance of adopting recommended best practices in catch-and-release to reduce discard mortality. Most anglers who visited the booth were very interested in the research and excited to see this type of work being completed to improve the sustainability of the recreational black sea bass fishery. Furthermore, each offshore tagging trip conducted for this project included up to 14 volunteer anglers. Communications with these anglers, which included emails, online message board posts, and phone conversations, also contributed to the outreach component of this project and helped to spread the word about the research objectives and early findings. In addition, when recovered tags were reported it was an excellent opportunity to convey information on the project objectives, as well as preliminary findings and best-practice recommendations. Co-PI D. Zemeckis also recently appeared on a one hour session of Mike Shepherd's fishing talk radio show, "Shep of Fishing" on

News Talk 1400 AM WOND on January 20, 2018. Black sea bass discard mortality was discussed during this radio show and results from the study were shared with listeners.

Given that the project has been completed and recommended best-practices have been developed for reducing black sea bass discard mortality in recreational fisheries, we will continue our outreach efforts to educate recreational anglers and fishery managers on these recommended best practices. Although these efforts have been delayed while completing the data collection and analysis for the project, our project team is actually now better prepared to perform outreach given that co-PI D. Zemeckis recently became an Extension Professor of Fisheries and Aquaculture at Rutgers University. Therefore, in addition to the outreach outlets of other project partners (e.g., the New England Aquarium and MA Division of Marine Fisheries), we will now be able to capitalize on the wide reach of Rutgers Cooperative Extension. In fact, co-PI D. Zemeckis already has the following presentations scheduled in order to educate recreational anglers on project results and recommended best practices for reducing discard mortality:

- Saltwater Anglers of Bergen County (SWABC), monthly meeting, February 20, 2018, Rochelle Park, NJ
- Saltwater Fishing Expo, March 16-18, 2018, Edison, NJ (http://www.sportshows.com/saltwater/)
- Sunrise Rod and Gun Club, monthly meeting, April 4, 2018, Red Bank, NJ
- New Jersey Federation of Sportsmen's Clubs, annual banquet, April 21, 2018, Ocean City, NJ

In addition to these already scheduled presentations, our project team will seek more opportunities to speak at meetings involving recreational anglers. We will also prepare appropriate educational materials (e.g., flyers, infographics) for dissemination on recreational fishing message boards, websites of our collaborating institutions (e.g., Rutgers University, New England Aquarium, MA Division of Marine Fisheries) and other regional partners (e.g., NJ Department of Environmental Protection, Cape Cod Charterboat Association), at booths at saltwater and outdoorsmen shows, and other opportunities that arise for connecting with the recreational fishing industry. Therefore, these ongoing efforts, during which Mid-Atlantic Fishery Management Council funding will be acknowledged, will allow for widespread dissemination of our results and recommended best-practices for reducing the discard mortality of black sea bass.

Dissemination of preliminary project results to the scientific community and fishery managers was accomplished at the 2017 annual meeting of the American Fisheries Society in Tampa, FL when co-PI D. Zemeckis delivered a presentation entitled "Estimating and mitigating discard mortality in recreational fisheries: Case Studies from the northeast U.S." in a symposium focused on bycatch reduction in fisheries. Co-PI D. Zemeckis also delivered a presentation including preliminary results on this project at the 2017 annual meeting of the Mid-Atlantic Chapter of the American Fisheries Society in October 2017 in Dover, DE, entitled "Utilizing collaborative scientist-industry partnerships to estimate and reduce discard mortality in recreational fisheries". Preliminary results were also shared by co-PI D. Zemeckis in a seminar presentation delivered at the NOAA NEFSC James J. Howard Laboratory in Sandy Hook, NJ in December 2017, as part of a talk entitled "Applying previous experiences in marine sciences to expand Rutgers' marine extension program". Co-PIs D. Zemeckis and J. Kneebone are also co-Organizers of a relevant symposium at the 2018 annual meeting of the American Fisheries Society and this project will be the focus of a presentation at that meeting.

After submission of this final report, copies will be disseminated to members of the scientific community who have interest in topics such as black sea bass, discard mortality, fisheries management, electronic tagging, and recreational fisheries. This final report will also be reformatted for publication in a peer-reviewed scientific journal, such as *Fisheries Research* or *Transactions of the American Fisheries Society*, which will allow for expanded and wide dissemination of our results to the scientific community and fishery managers. In addition, a scientific manuscript that seeks to publish new analytical approaches of acoustic telemetry data, with inclusion of data from this black sea bass discard mortality study, is presently in review with the journal of *Methods in Ecology and Evolution* (see submitted draft in Appendix 5). This paper includes co-authorship by co-PIs J. Kneebone and D. Zemeckis:

M.V. Winton, J. Kneebone, D.R. Zemeckis, and G. Fay. *In Review*. A spatial point process model to estimate individual centers of activity from passive acoustic telemetry data. *Methods in Ecology and Evolution* (draft was submitted for publication on December 31, 2017).

7. Discussion

This project represented a collaborative research effort involving recreational fishing industry stakeholders, volunteer anglers, commercial fishermen, and scientists to address an important data gap in our understanding of black sea bass discard mortality in the winter, deepwater, offshore Mid-Atlantic recreational rod-and-reel fishery. Meaningfully involving industry stakeholders in this project helped to ensure that our methods provided an accurate representation of actual fishery conditions, thereby maximizing the applicability of our results for consideration in stock assessments and fishery management plans. Additionally, findings from this project have improved our general understanding of black sea bass biology, discard mortality in recreational fisheries, methods to reduce discard mortality, and the impacts of bycatch in recreational and commercial fisheries.

Our study estimated mean total fishing-related discard mortality rates of 21% for vented and 52% for unvented black sea bass following capture and release in 45 m depth. Acknowledging that venting is not commonly practiced in the fishery, the 52% estimate (for unvented fish) is therefore representative of the current discard mortality rate that is evident when the fishery operates at (or near) this depth. This discard mortality rate is higher than previous estimates generated for a similar depth range (43-54 m) by Collins et al. (1999), who reported discard mortality rates of up to 39% after monitoring fish in cages for 24 hrs. However, this difference could be due in part to the methods in which fish were monitored after release in both studies. For example, while Collins et al. (1999) briefly monitored post-release fate in cages where animals were shielded from predation, while our electronic tagging approach was able to account for predation and monitor mortality over a longer monitoring period. In contrast, Rudershausen et al. (2014) estimated a 19% mean discard mortality rate for non-vented black sea bass following capture at depths of 20-35 m, which is less than half of our estimate for 45 m depth. This discrepancy may be due differences in fight times that were evident between the two capture depths (i.e., 20-35 m vs. 45 m), given our finding that longer fight times (which were evident at deeper depths) resulted in reduced submergence success and higher mortality.

Current black sea bass stock assessments and fishery management plans assume a 15% discard mortality rate for the coastwide, year-round black sea bass recreational fishery (NEFSC, 2017). Our results, as well as those reported in Collins et al. (1999), suggest that this rate is not representative of the discard mortality rate that is evident in the offshore, deepwater, winter recreational fishery. Given this, it is recommended that stock assessment scientists and fishery managers re-evaluate the validity of the currently assumed 15% estimate and consider whether a single mean discard mortality rate is still appropriate for accurately estimating total recreational fishery removals for the diverse, coastwide recreational fishery. This could be particularly important moving forward, because according to accounts from multiple stakeholder groups, the winter offshore fishery may not be well monitored and there have been many options presented in recent years with respect to opening certain months to black sea bass fishing during the winter period.

Venting the swim bladder of black sea bass significantly reduced discard mortality, with vented fish being more than two times as likely to survive than unvented fish. This finding is at odds with a previous review by Wilde (2009) who concluded that venting fish should not only be discouraged by fishery management agencies, but be prohibited rather than required by regulation given the possibility that venting may adversely affect survival of fish captured from deep water. However, a more recent meta-analysis by Eberts and Somers (2017) found that swim bladder venting, along with the use of descending devices, had positive effects on reducing discard mortality. As a result, Eberts and Somers (2017) recommended that fishery managers consider barotrauma relief options carefully on a case-by-case basis. This study provides robust results indicating that swim bladder venting can reduce the discard mortality rate of black sea bass in the offshore recreational fishery in the Mid-Atlantic. However, as communicated in other papers (e.g., Scyphers et al., 2013; Brownscombe et al., 2016), it is imperative that anglers are educated on proper venting technique to maximize the benefits of this practice and minimize the risk of potentially increasing discard mortality from improper technique. Therefore, as outlined above, our project team will continue our outreach and education efforts in order to share our project findings, including recommended best practices for reducing discard mortality and proper swim bladder venting techniques for black sea bass.

Avian predation is another potential source of mortality in the Mid-Atlantic offshore black sea bass fishery that was not well accounted for by our study. Due to the high catch rates on many of the tagging trips it was difficult or impossible to monitor the disposition of floating fish for more than a few minutes post-release as they drifted away from the anchored vessel. Despite this, there is strong evidence that two acoustically-tagged fish that were floating were consumed by avian predators due to the lack of any acoustic detections for these fish (see Findings). Regardless, although the frequency of avian predation could not be estimated by our study, swim bladder venting will reduce its occurrence given that vented fish will experience higher submergence success and therefore be able to escape avian predators.

Tackle recommendations, such as the use of different hook types (e.g., circle hooks), are often offered as methods to reduce injury and discard mortality in both recreational and commercial fisheries. However, in the Mid-Atlantic offshore black sea bass fishery, hooking location and injury were not found to be significant predictors of mortality, and there was a low incidence of ‘deep’ or ‘internal’ hooking (i.e., in the gills or internal organs). This low incidence of deep mouth hooking may be due in large part to the fact that the most common terminal tackle setup is a High-Low rig with short leaders from the main line to each hook (i.e., dropper loops of 3-5”, or 7.6 - 12.7 cm). As suggested by Capizzano et al. (2016), this configuration does not leave much opportunity for the fish to swallow the hook, and therefore results in a high incidence of mouth hooking. Given this, circle hooks, which have been demonstrated to increase the incidence of mouth hooking in other fisheries, may not offer an added conservation benefit for black sea bass in the offshore Mid-Atlantic fishery.

Future work

Although our results convincingly demonstrate that swim bladder venting (when done properly) can reduce discard mortality rate, future research should investigate the relative benefit of descending devices as an additional option for reducing the discard mortality rate of black sea bass in deep water fisheries. Previous research has shown that the descending devices can increase the submergence success of black sea bass (Musick et al., 2015), but no studies have been conducted to quantify the relative benefits of descending devices for reducing black sea bass discard mortality. In this study, our project team opted to test swim bladder venting as a method to mitigate barotrauma-related mortality because it is a relatively quick process that is already adopted by some recreational anglers, and therefore was considered more likely to be adopted by anglers in a fishery with high catch rates (such as the offshore black sea bass fishery). However, it would be valuable to evaluate the relative benefits of swim bladder venting and descending devices for reducing discard mortality, and, depending on the differences, educate anglers on the best practices that would provide maximum benefit for reducing discard mortality.

The movement patterns and population structure of black sea bass in offshore Mid-Atlantic waters is another issue that requires additional research. Many of our volunteer anglers and fishing industry partners hypothesized that the large black sea bass that are caught at some of these offshore locations in the Mid-Atlantic would migrate seasonally from southern New England (e.g., Rhode Island and Massachusetts), which is supported by some previous tagging research (Moser and Shepherd, 2009). However, we only had one tag recapture from a fish migrating to the area off Cape Cod (Figure 20) despite tagging hundreds of large fish. Nonetheless, the stock structure of black sea bass remains a largely unresolved issue (NEFSC, 2017). Based on the previous research and our limited observations of movement patterns, we recommend that additional research on black sea bass stock structure be conducted in the future. Our findings of relatively low discard mortality in vented black sea bass at these offshore depths presents the opportunity to expand future tagging efforts to these offshore locations.

Management implications

The results of our study have direct and significant implications for the management of the offshore recreational black sea bass fishery in the Mid-Atlantic, and likely beyond. Given our findings that swim bladder venting was the single greatest factor that reduced the discard mortality rate and increased submergence success, there is strong evidence that total mortality would be greatly reduced if anglers were encouraged, or possibly even required, to vent all black sea bass that are released in the Mid-Atlantic offshore fishery. Furthermore, our results provide strong support that venting will increase the post-release survival of black sea bass that experience barotrauma in any other fishery that occurs along the coast. However, as previously mentioned, such reductions in mortality are predicated upon the widespread education of recreational anglers about and adoption of proper venting technique. Therefore, substantial and continued outreach would be necessary to maximize the benefits of venting.

Observations of the timing of post-release predation events, the negative impact of extended fight times on survival, and the relationship between fight time and capture depth also hold strong management implications for the fishery. Based on our survivorship assessment, predation (at-depth both during capture and post-release) by other fishes was evident in the acoustically-tagged subsample only during early December, primarily on the first research trip on December 5, 2016. Based on previous experiences of our research team and discussions with the captain and crew of the *F/V Susan Hudson*, predation events such as those observed are common in the early part of the offshore fishing season before predators such as bluefish and spiny dogfish migrate further offshore or south as waters cool with the onset of winter. Interestingly, subsequent sampling trips to the Ice Cream Cone wreck on December 21st and January 17th experienced one or no predation events by other fishes, respectively, and there were no predation events by other fishes observed during the trips to deeper fishing spots in mid-February through late-March.

Although predation by other fishes was absent during the latter tagging trips to the Indian Arrow wreck (58 m depth) and Baltimore Rocks (67 m depth), discard mortality may have actually been elevated at these locations due to the increased fight times that were evident. Results of our survival analysis on unvented fish suggest that longer fight times (>54 seconds) resulted in markedly higher mortality. Thus, since mean fight times for the 58 and 67 m capture depths were 80 and 94 seconds, respectively, it is likely that the discard mortality rate of both vented and unvented fish captured at these deeper depths was higher than those estimated for 45 m depth at the Ice Cream Cone wreck. In addition, based on the data collected during this study, the overall mortality resulting from discarding of fish would be expected to be higher at the Baltimore Rocks (i.e., the deepest fishing location) due to the fact that nearly half of the black sea bass captured at this location were less than the 12.5” (318 mm) federal and New Jersey minimum size limit, and would have been mandated to be released (Figure 7). Taken together, the occurrence of predation events by other fishes primarily at the beginning of the season and the need to fish at deeper depths during the latter part of the season (due to the continued offshore migration of black sea bass during the winter), our results suggest that in order to reduce the impacts of discards it may be most advantageous to open the fishery from the period of mid- or late-December through January, which is when fish are more likely to still be accessible at ‘shallower’ depths (i.e., <~55 m) and predation risk is lower. However, these observations are based on the 2016-2017 fishery off southern New Jersey and there could be variation inter-annually and along the coast. Therefore, it is recommended that fishery managers consider and apply these findings for each local and regional fishery.

8. Acknowledgements

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10. Tables

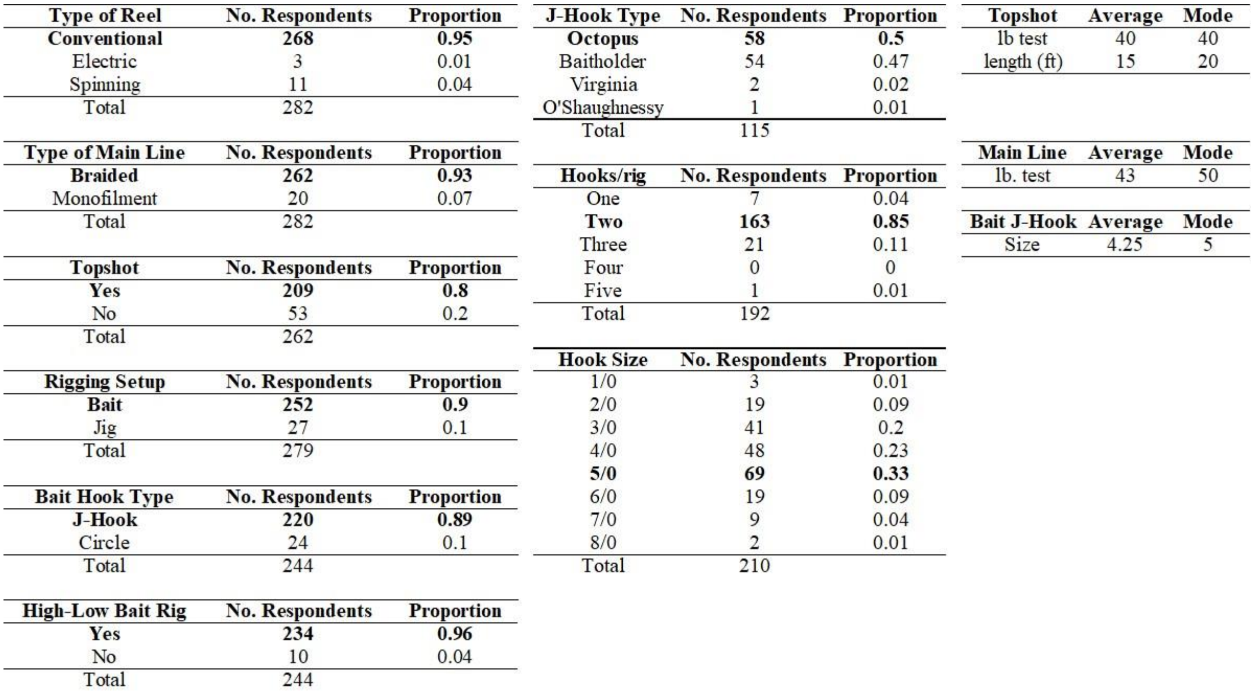
Table 1 – Summary of tagging trips by location and tagging vessel. The depth fished during each trip as well as the number of volunteer anglers, number of acoustic transmitters deployed, number of convention t-bar tags deployed, and total capture observations are reported.

Date	Vessel	Fishing Location	Depth (m)	Number of anglers	Transmitters	t-bar tags	Total observations
Dec 5, 2016	F/V Susan Hudson	Ice Cream Cone	45	7	20	172	197
Dec 13, 2016	F/V Susan Hudson	Ice Cream Cone	45	7	24	168	202
Dec 21, 2016	F/V Susan Hudson	Ice Cream Cone	45	7	24	73	98
Jan 17, 2017	F/V Porgy IV	Ice Cream Cone	45	10	18	37	55
Feb 3, 2017	F/V Susan Hudson	Ice Cream Cone	45	7	10	4	14
Feb 18, 2017	F/V Susan Hudson	Baltimore Rocks	67	14	0	316	362
Feb 24, 2017	F/V Susan Hudson	Baltimore Rocks	67	14	0	427	440
Mar 21, 2017	F/V Susan Hudson	Indian Arrow	58	13	0	270	455
			Total	**50**	**96**	**1467**	**1823**

Table 2 – Programming specification for the Vemco acoustic transmitters used in this study.

		Step 1			Step 2			Step 3		
Tag Model	**Est tag life (days)**	**End Time (dy hr:min:sec)**	**Min Delay (sec)**	**Max Delay (sec)**	**End Time (dy hr:min:sec)**	**Min Delay (sec)**	**Max Delay (sec)**	**End Time (dy hr:min:sec)**	**Min Delay (sec)**	**Max Delay (sec)**
V13-2H	673	15 00:00:00	60	180	15 00:00:00	220	340	660 00:00:00	360	480

Table 3 – Results from online tackle survey (n=282 respondents) to select standardized terminal tackle rigging.



Type of Reel	No. Respondents	Proportion
Conventional	**268**	**0.95**
Electric	3	0.01
Spinning	11	0.04
Total	282	

Type of Main Line	No. Respondents	Proportion
Braided	**262**	**0.93**
Monofilment	20	0.07
Total	282	

Topshot	No. Respondents	Proportion
Yes	**209**	**0.8**
No	53	0.2
Total	262	

Rigging Setup	No. Respondents	Proportion
Bait	**252**	**0.9**
Jig	27	0.1
Total	279	

Bait Hook Type	No. Respondents	Proportion
J-Hook	**220**	**0.89**
Circle	24	0.1
Total	244	

High-Low Bait Rig	No. Respondents	Proportion
Yes	**234**	**0.96**
No	10	0.04
Total	244	

J-Hook Type	No. Respondents	Proportion
Octopus	**58**	**0.5**
Baitholder	54	0.47
Virginia	2	0.02
O'Shaughnessy	1	0.01
Total	115	

Hooks/rig	No. Respondents	Proportion
One	7	0.04
Two	**163**	**0.85**
Three	21	0.11
Four	0	0
Five	1	0.01
Total	192	

Hook Size	No. Respondents	Proportion
1/0	3	0.01
2/0	19	0.09
3/0	41	0.2
4/0	48	0.23
5/0	**69**	**0.33**
6/0	19	0.09
7/0	9	0.04
8/0	2	0.01
Total	210	

Topshot	Average	Mode
lb test	40	40
length (ft)	15	20

Main Line	Average	Mode
lb. test	43	50

Bait J-Hook	Average	Mode
Size	4.25	5

Table 4 – Description of all of the technical and biological capture-related variables and the injury and barotrauma scores that were recorded for each captured black sea bass.

Variable	Description
Technical	
Capture depth	Water depth at the location of capture
Angler experience	Angler experience score as quantified by questionnaire
Fight time	Elapsed time from when a fish was hooked to when it reached the surface
Unhooking time	Elapsed time from surfacing until the fish was unhooked
Handling time	Elapsed time from surfacing until fish was released (time out of water)
Hook location	Location where the fish was hooked on the body
Hook removal method	Manner in which the fish was unhooked
Angler hand	Fish was unhooked by hand by the capturing angler
Mate hand	Fish was unhooked by hand by a fishing vessel mate/deckhand
Biological	
Total length	Length from the tip of the snout to the tip of the center of the tail
Air temperature	On deck temperature at the time of capture
Surface temperature	Water temperature at the surface
Bottom temperature	Water temperature at the bottom/wreck
Delta temperature	Difference between surface and bottom water temperatures
Release behavior	Observed behavior exhibited by a fish immediately upon release
Floating	Fish floated on surface
Swam down	Fish swam down towards bottom
Erratic swimming	Fish swam erratically and appeared disoriented
Sinking	Fish sank without swimming
Injury score	
Present (1)	Hook or other wound present >2 cm in length
Absent (0)	Injury limited to hook entry/exit
Barotrauma score	
Exopthalmia	
Present (1)	Eyes bulging from orbitals, bubbles may be present in eyes
Absent (0)	Eyes not bulging from orbitals
Stomach eversion	
0	Stomach not everted
1	Stomach everted but remains within mouth cavity
2	Stomach everted but is protruding from the mouth
3	Stomach everted and ruptured

Table 5 – Summary of acoustic detections received for four transmitters in collaboration with the Atlantic Cooperative Telemetry Network. Note: these four fish were used as positive controls.

Transmitter	**Date released**	**Date detected**	**Latitude**	**Longitude**	**Detections**	**Detecting institution**
3356	12/21/2016	9/9/2017	38.37	-74.54	1	University of Maryland
3357	12/21/2016	6/8/2017	40.38	-73.59	2	Stony Brook University
3385	12/13/2016	6/20 – 6/26/2017	38.73	-74.61	42	University of Delaware
3441	2/3/2017	9/22/2017	38.37	-74.54	4	University of Maryland

Table 6 - Assumptions for the capture and handling (CH; τ) and the probability of being adversely affected by the fishing event post-release (π) parameters of Equation (2) used to define the three competing model variants for analyzing black sea bass survival data.

Variant	Parameters	Description
1	$\tau = [1 + \exp(-X'\beta_1)]^{-1}$ $\pi = [1 + \exp(-X'B_2)]^{-1}$	Covariate effects on the CH mortality and the probability of being adversely affected by the fishing event post-release
2	$\pi = [1 + \exp(-X'B_3)]^{-1}$	Covariate effect on the probability of being adversely affected by the fishing event post-release only
3	$\tau = [1 + \exp(-X'\beta_4)]^{-1}$	Covariate effect on the CH mortality only

Footnote: X is the design matrix for the covariate(s) and β is the vector of parameters for the effect of the covariates.

Table 7 – Summary of capture variables for all vented and non-vented black sea bass ('All observations'), including the 96 fish that were tagged with acoustic transmitters ('Transmitters'). Values in parentheses represent the mean ± standard deviation.

Category	Number of fish	Length range (mm)	Range of time (seconds)		
			Fight	Unhooking	Handling
All observations					
Vented	957	136-612 (349±66)	12-251 (80±32)	2-215 (17±18)	16-420 (141±77)
Non-vented	756	194-548 (323±69)	18-240 (75±69)	3-189 (18±19)	13-575 (142±81)
Total	**1713**	**136-612 (339±70)**	**12-251 (78±32)**	**2-215 (17±19)**	**13-575 (142±81)**
Transmitters					
Vented	48	278-546 (351±61)	17-225 (57±31)	2-42 (12±10)	80-326 (158±50)
Non-vented	48	279-485 (357±52)	29-90 (55±13)	3-52 (17±12)	91-310 (171±51)
Total	**96**	**278-546 (354±57)**	**17-225 (56±24)**	**0-52 (15±11)**	**80-326 (164±51)**

Table 8 – Summary of capture variables recorded for all captured black sea bass (‘All observations’) and the subset of 96 fish that were tagged with acoustic transmitters (‘Transmitters’). Values in parentheses represent the mean ± standard deviation.

Variable	**Transmitters**	**All observations**
Capture depth (m)	45	45, 58, 67
Total length (mm)	278 – 546 (354 ± 57)	136 – 612 (339 ± 70)
Fight time (s)	17 – 225 (56 ± 24)	12 – 251 (78 ± 32)
45 m	17 – 225 (56 ± 24)	12 – 225 (55 ± 22)
58 m	-	32 – 240 (80 ± 27)
67 m	-	35 – 251 (94 ± 30)
Unhooking time (s)	2 – 52 (15 ± 11)	10 – 215 (17 ± 19)
Angler hand	2 – 49 (15 ± 11)	1 – 215 (18 ± 20)
Mate hand	3 – 52 (15 ± 12)	2 – 173 (17 ± 17)
Experienced anglers	2 – 52 (14 ± 11)	1 – 189 (17 ± 19)
Inexperienced anglers	13 – 36 (29 ± 9)	2 – 215 (19 ± 21)
Handling time (s)	80 – 326 (164 ± 51)	13 – 575 (142 ± 81)
Air temperature (°C)	5.9 – 15.1 (10.7 ± 2.3)	4.7 – 17.4 (13.9 ± 2.4)
Sea surface temperature (°C)	7.4 – 13.8 (11.4 ± 2.1)	7.2 – 13.9 (12.4 ± 1.7)*
Bottom temperature (°C)	7.4 – 13.8 (11.3 ± 2.0)	7.5 – 13.4 (12.2 ± 1.4)*
Delta temperature (°C)	-0.6 – 0.4 (0.1 ± 0.3)	-0.3 – 0.5 (0.3 ± 0.3)*

* Data only available for trips to the Ice Cream Cone wreck

Table 9 – Model selection results for the generalized additive mixed effect model examining the relationship of each variable on fight time. The model with the lowest Akaike Information Criterion (AIC) value is in bold. TL=total length; DH=double header

Model	Estimated degrees of freedom	Deviance explained	AIC	ΔAIC
Fight time ~ s(TL) + Depth + DH+Reel_gear	**51.52**	**64.3%**	**15088**	**0**
Fight time ~ s(TL) + Depth + DH	50.64	64.0%	15102	14
Fight time ~s(TL) + DH + Reel_gear	50.22	55.5%	15480	392
Fight time ~ s(TL) + Depth+ Reel_gear	50.37	63.4%	15132	43
Fight time ~s(TL) + DH	49.29	55.5%	15479	391
Fight time ~ s(TL) + Depth	49.46	63.1%	15147	58
Fight time ~s(TL) + Reel_gear	49.23	54.2%	15530	441
Fight time ~s(TL)	48.29	54.2%	15528	440
Fight time ~ 1	47.32	49.9%	15685	597

Table 10 – Summary of hooking locations for all captured black sea bass (‘All observations’) and the 96 fish that were tagged with acoustic transmitters (‘Transmitters’). Percentages represent the percent of total observations in each group.

	Transmitters		**All Observations**	
Hook Location	**Observations**	**%**	**Observations**	**%**
Shallow mouth	47	49.5%	955	54.0%
Medium mouth	38	40.0%	675	38.2%
Deep mouth			9	0.5%
Eye	1	1.1%	5	0.3%
Gills			6	0.3%
Head	1	1.1%	8	0.5%
Isthmus	7	7.4%	96	5.4%
Operculum			5	0.3%
Dorsal surface			5	0.3%
Ventral surface	1	1.1%	4	0.2%
Total	95		1768	

Table 11 – Summary of the number of black sea bass that exhibited each release behavior in the full set of observations (‘All observations’) and the subset of 96 fish that were tagged with acoustic transmitters (‘Transmitters’). ES=Erratic swimming; F=Floating; S=Sinking; SD=Swam down

Category	**Release behavior**			
	ES	**F**	**S**	**SD**
All observations				
Vented	3	190	6	724
Non-vented	4	234	4	465
Total	**7**	**427**	**10**	**1190**
Transmitters				
Vented		1		47
Non-vented		11		37
Total		**12**		**84**

Table 12 - Forward selection process for the logistic regression model that evaluated release behavior against a set of sensible covariates for all released black sea bass (*n*=1594). Covariates that produced a conservative corrected Akaike Information Criterion (AICc) reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model.

Run	Covariates	AICc	ΔAICc
1	~1	1832.163	
2	~depth	1783.034	49.129
3	~depth + venting	1747.244	35.79
4	~depth + venting + total length	1740.044	7.2
5*	~depth + venting + total length + exopthalmia	1736.882	3.162
6	~depth + venting + total length + exopthalmia + injury	1738.367	-1.485

Table 13 - Regression output coefficient table of the logistic regression model used to analyze the impact of covariates on release behavior for all black sea bass (*n*=1594). Parameter estimates for covariates are listed and include estimates for the regression coefficient, standard error of the regression coefficient (Std. error), the exponentiated coefficient called the odds ratio, the Wald statistics value (*z*-value), and overall statistical significance (*p*-value).

Coefficients:	*Estimate*	*Std. error*	*Odds ratio*	*z-value*	*p-value*
(Intercept)	2.190271	0.308884	8.937631	7.091	1.33E-12
Exopthalmia					
Presence	-0.42472	0.184109	0.653956	-2.307	0.02106
Depth					
57.912 m	-0.252	0.185813	0.777247	-1.356	0.17504
67.056 m	-0.92272	0.149485	0.397439	-6.173	6.72E-10
Venting technique					
Vented	0.800121	0.122604	2.225811	6.526	6.75E-11
Total length	-0.02957	0.009175	0.970866	-3.223	0.00127

Table 14 – Summary of the number of black sea bass that exhibited exopthalmia and each stomach eversion score in the full set of observations (‘All observations’) and the subset of 96 fish that were tagged with acoustic transmitters (‘Transmitters’).

Category	**Exopthalmia**		**Stomach Eversion Score**			
	Present	**Absent**	**0**	**1**	**2**	**3**
All observations						
Vented	92	863	30	193	714	18
Non-vented	80	670	65	207	442	36
Total	172	1533	95	400	1156	54
Transmitters						
Vented	1	47	2	8	35	3
Non-vented	5	43	4	13	29	2
Total	6	90	6	21	64	5

Table 15 - Forward selection process for the Cox Proportional Hazards Model that evaluated the survival function for black sea bass in the acoustic transmitter subsample over a set of sensible covariates determined from Figures A1 – A3 and Table A1 (Appendix 4). Covariates that produced a conservative AICc reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model and parsimonious set of covariates to be considered in the parametric survival analysis. Note: model variants 2 and 3 were indistinguishable by AICc, thus, the most parsimonious model (run 2) was selected as the final model.

Run	Covariates	AICc	ΔAICc
1	~1	285.175	
2*	~ venting	278.2613	6.913218
3	~ venting + total length	277.8582	0.403035

Table 16 - Summary of model variant and covariate selection results using maximum likelihood and a forward selection procedure for black sea bass in the acoustic transmitter subsample. An asterisk denotes the strongest evidence was for variant 2 of the model with the effect of venting covariate on the mixture model component only.

Run	Covariates	Variant	AICc	ΔAICc
1	~1		134.9005	
2*	~venting	2	129.4044	5.4961
2	~venting	1	132.5241	2.3764
2	~venting	3	146.05	-11.1495

Table 17 - Sample sizes and estimates of key parameters for the analysis of survival data for vented black sea bass. The number of fish that died upon release (dead), that died during capture and handling or immediately after release (left-censored), and that were last seen alive (right-censored) are presented. Estimates (95% confidence intervals) of the capture and handling mortality rate ($1-\tau$), the conditional post-release mortality rate ($\tau \cdot \pi$) and the total mortality rate associated with the fishing event (i.e., discard mortality; $1-\tau+\tau \cdot \pi$) are presented by treatment group.

	Numbers				Fishing mortality rates		
Season	Total	Dead	Left	Right	Capture-Handling	Post-Release	Total
Vented	48	9	1	38	0.017 (0.001, 0.158)	0.203 (0.107, 0.351)	0.219 (0.131, 0.406)
Not vented	46	18	5	23	0.017 (0.001, 0.158)	0.487 (0.319, 0.633)	0.504 (0.362, 0.662)

Table 18 - Forward selection process for the Cox proportional hazards regression model that evaluated the survival function for only unvented black sea bass in the acoustic subsample over a set of sensible covariates determined from Figures A4 – A6 and Table A2 (Appendix 4). Covariates that produced a conservative AICc reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model

Run	Covariates	AICc	ΔAICc
1	~1	162.0427	
2*	~ fight time	154.6790	7.3637
3	~ fight time + handling time	155.7066	-1.0276

Table 19 **-** Regression output coefficient table of the Cox proportional hazards regression model used to analyze the impact of fight time on the overall survival of unvented black sea bass in the acoustic subsample (*n*=46). Parameter estimates for fight time are listed and include estimates for the regression coefficient, standard error of the regression coefficient (Std. error), the exponentiated coefficient called the hazard ratio, 95% confidence intervals (CI) for the hazard ratio, the Wald statistics value (*z*-value), and overall statistical significance (*p*-value).

Coefficients:	*Estimate*	*Std. error*	*Hazard ratio*	*Lower CI*	*Upper CI*	*z-value*	*p-value*
Fight time	0.05284	0.0169	1.05426	1.02	1.09	3.126	0.00177

11. Figures

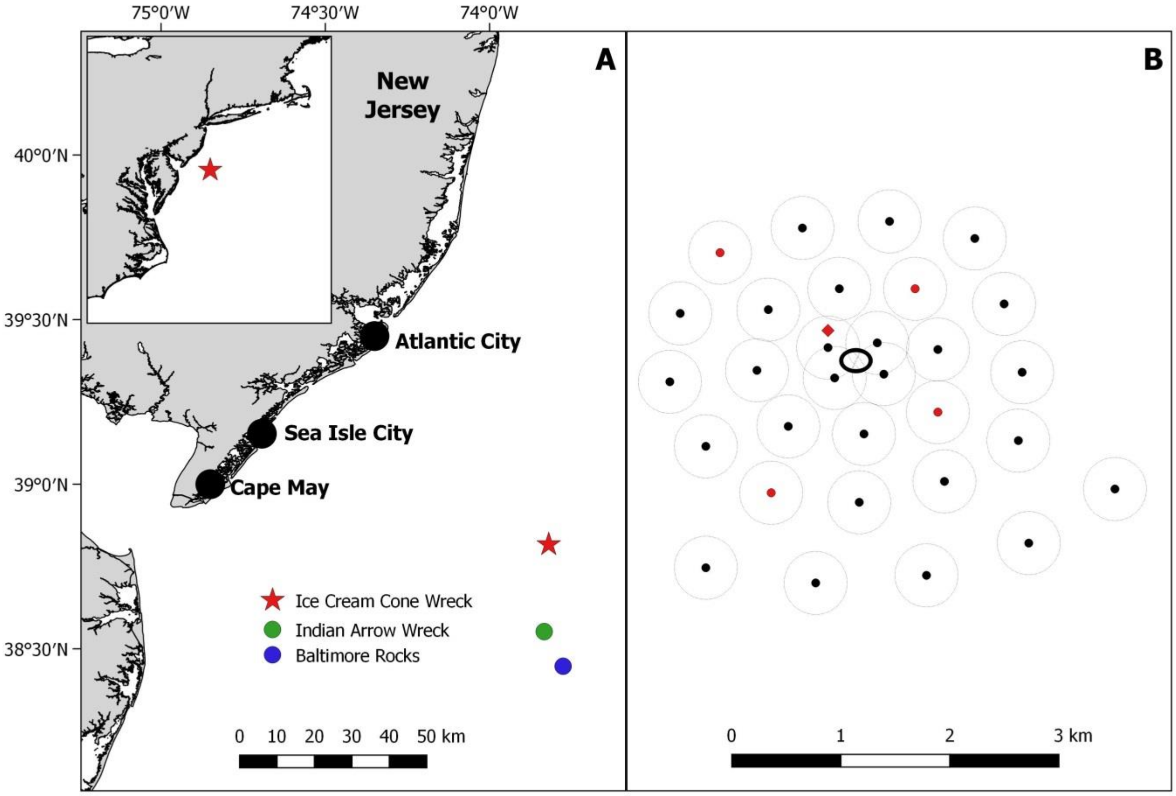


Figure 1 - Map of the approximate location of the “Ice Cream Cone” shipwreck (A: red star and B: black oval), which was the primary study site for this project, as well as the two secondary tagging locations (Baltimore Rocks, Indian Arrow Wreck) (A), and the acoustic receiver array that was deployed to monitor the post-release fate of tagged black sea bass around the wreck (B). Individual acoustic receiver locations (small circles) with (red) and without (black) temperature loggers deployed on their mooring lines are presented. Estimated individual receiver detection range (dotted circles) are presented around each receiver location. The location of the stationary (dead) negative control tag (red diamond, B) is also presented.

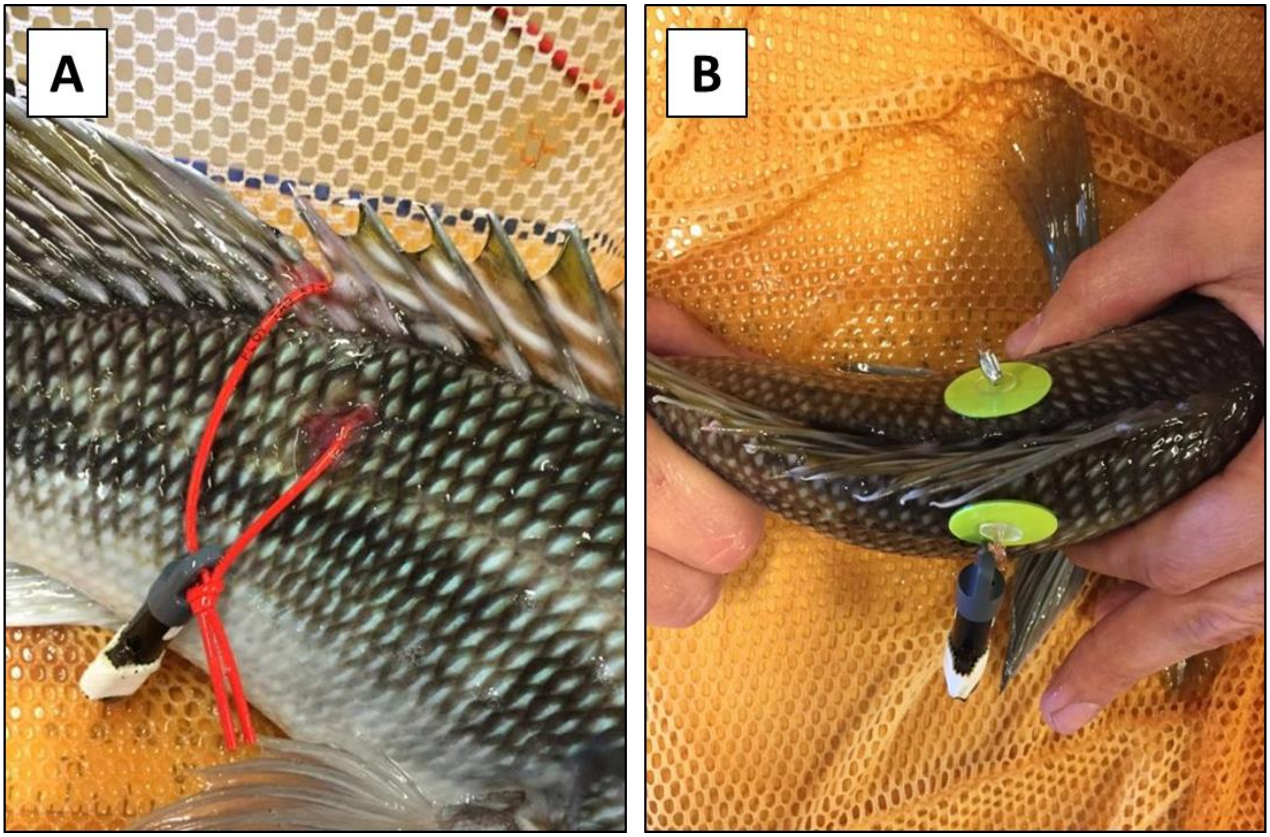


Figure 2 – Example of acoustic transmitter attachment method 1 (A) and method 2 (B) used in the experimental holding tank study. Lesions that were evident with method 1 are visible in A. Note: smaller Pedersen discs were used when tagging black sea bass in the discard mortality component of the study.

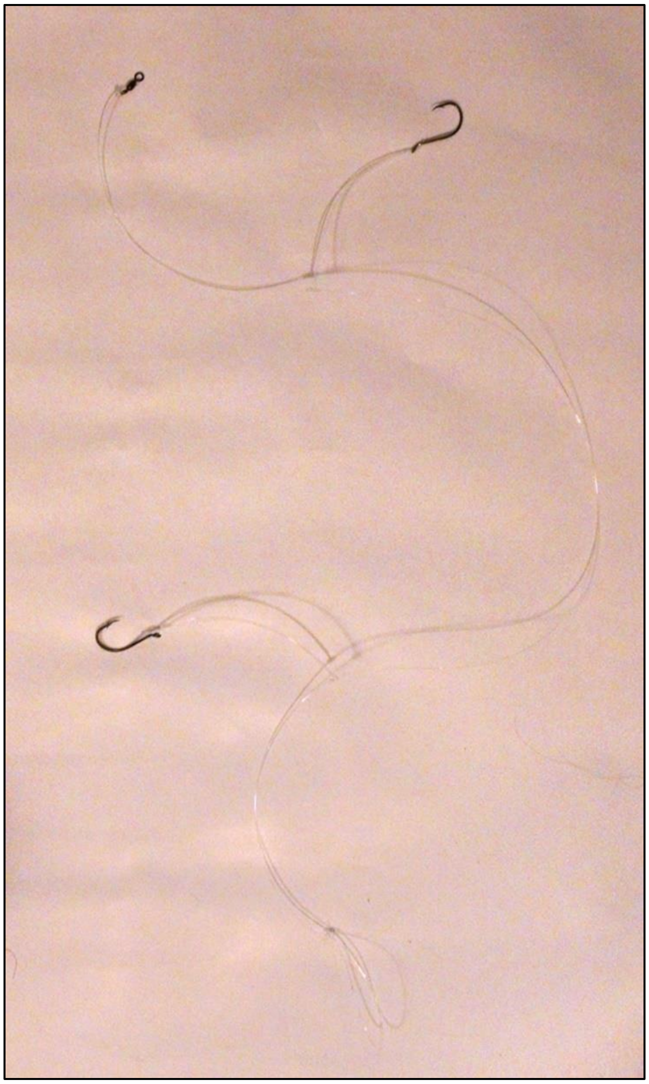


Figure 3 – Example of the standardized ‘high-low’ terminal tackle setup that was used during all sampling trips. This setup was determined to be most representative of the deep water Mid-Atlantic black sea bass fishery based on results of an extensive survey of 282 recreational anglers.

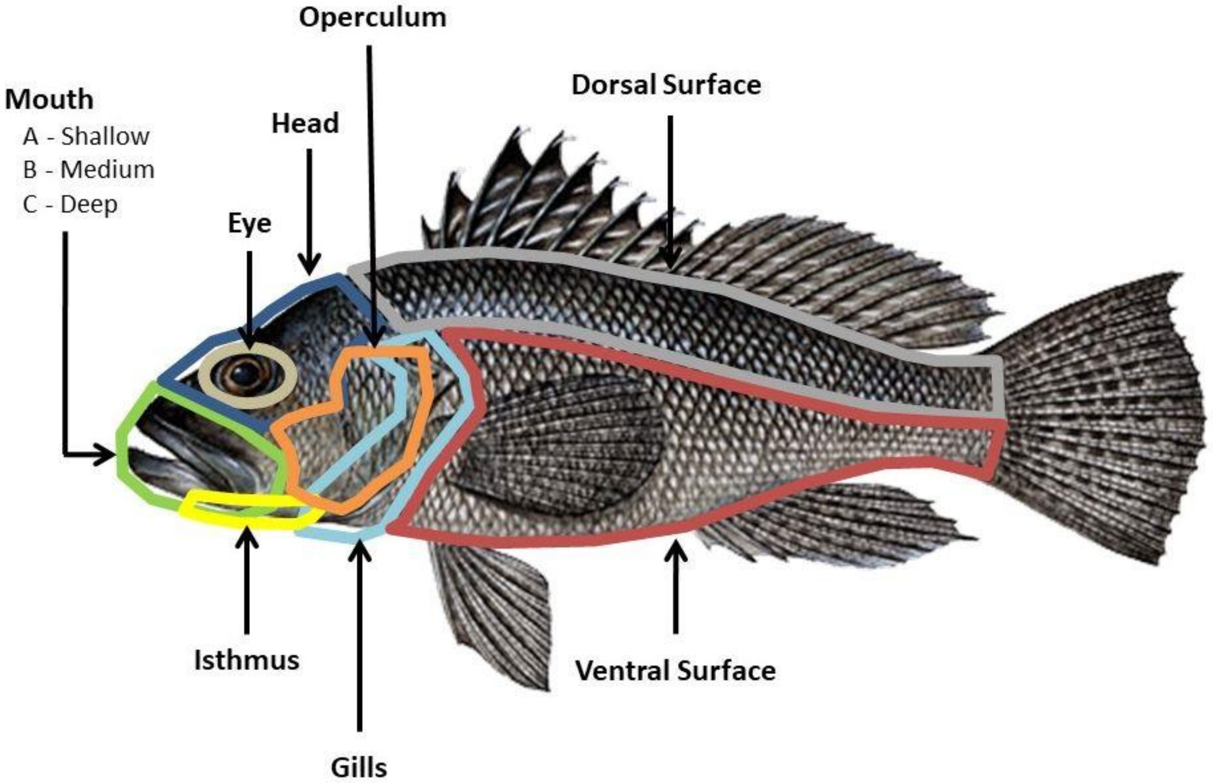


Figure 4 - Designations for hooking locations of black sea bass. Note: 'Gills' denotes the internal hooking location.

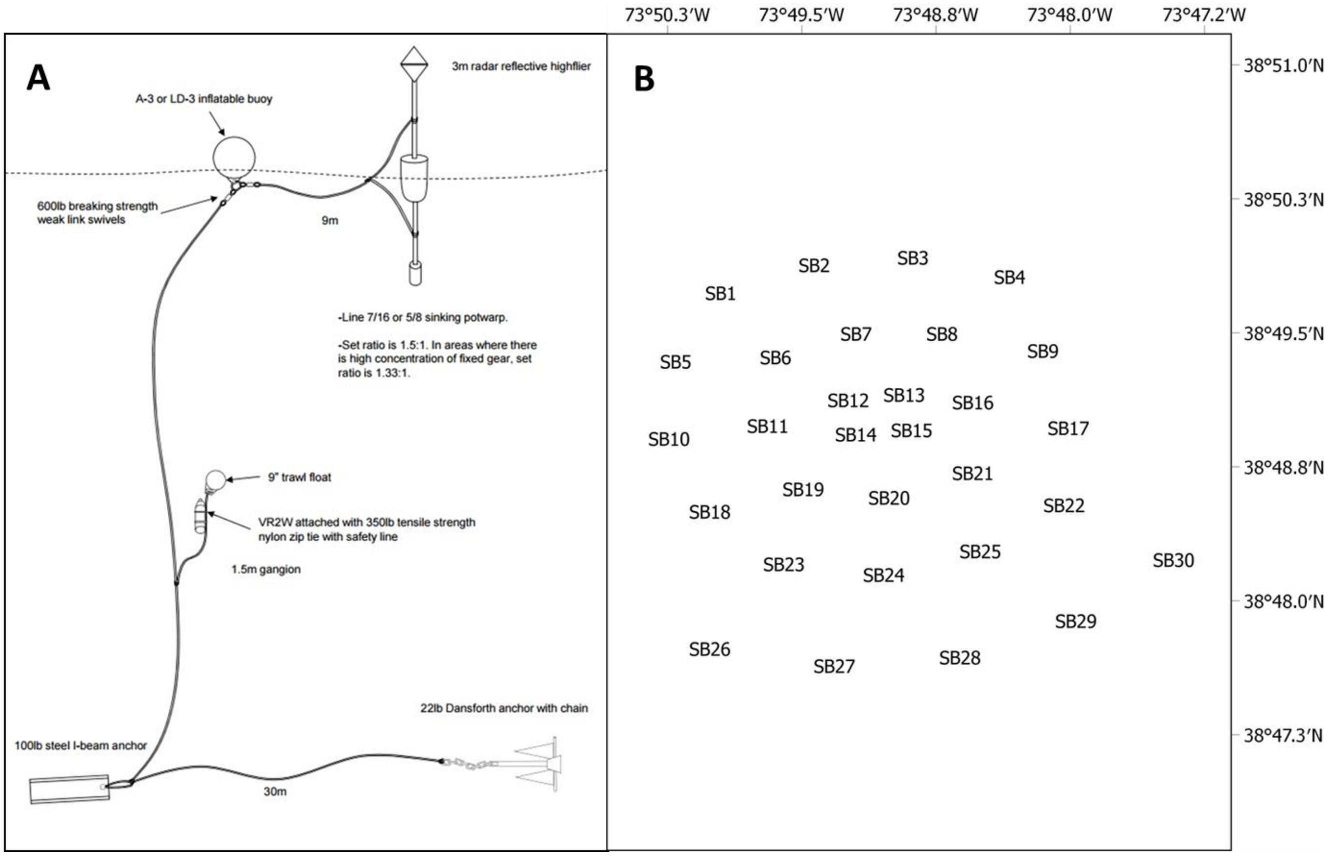


Figure 5 – Schematic of acoustic receiver mooring system (A) and the station identification labels for each receiver that was deployed in the array (B). Note that pot-style buoys with sticks were used as surface floats instead of highfliers with radar reflectors.

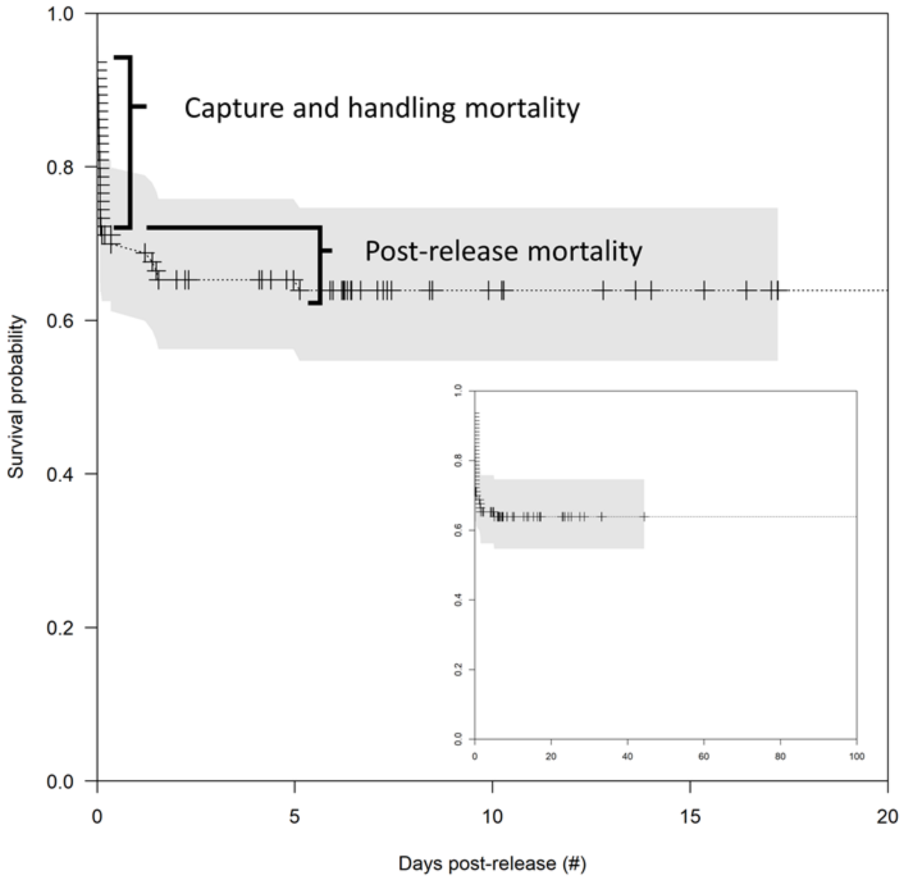


Figure 6 - Plot of the Kaplan-Meier estimator of the overall survival function for all tagged and released black sea bass over the first 20 days, with the 95% confidence interval indicated by shaded areas, and times of right censoring indicated with plus (+) signs. Time zero is the time of release back into the water. The plot is annotated to indicate the presence of two types of mortality over time for black sea bass that were captured and released (no evidence of natural mortality). The inset plot displays the Kaplan-Meier estimator of the overall survival function for these fish over 100 days.

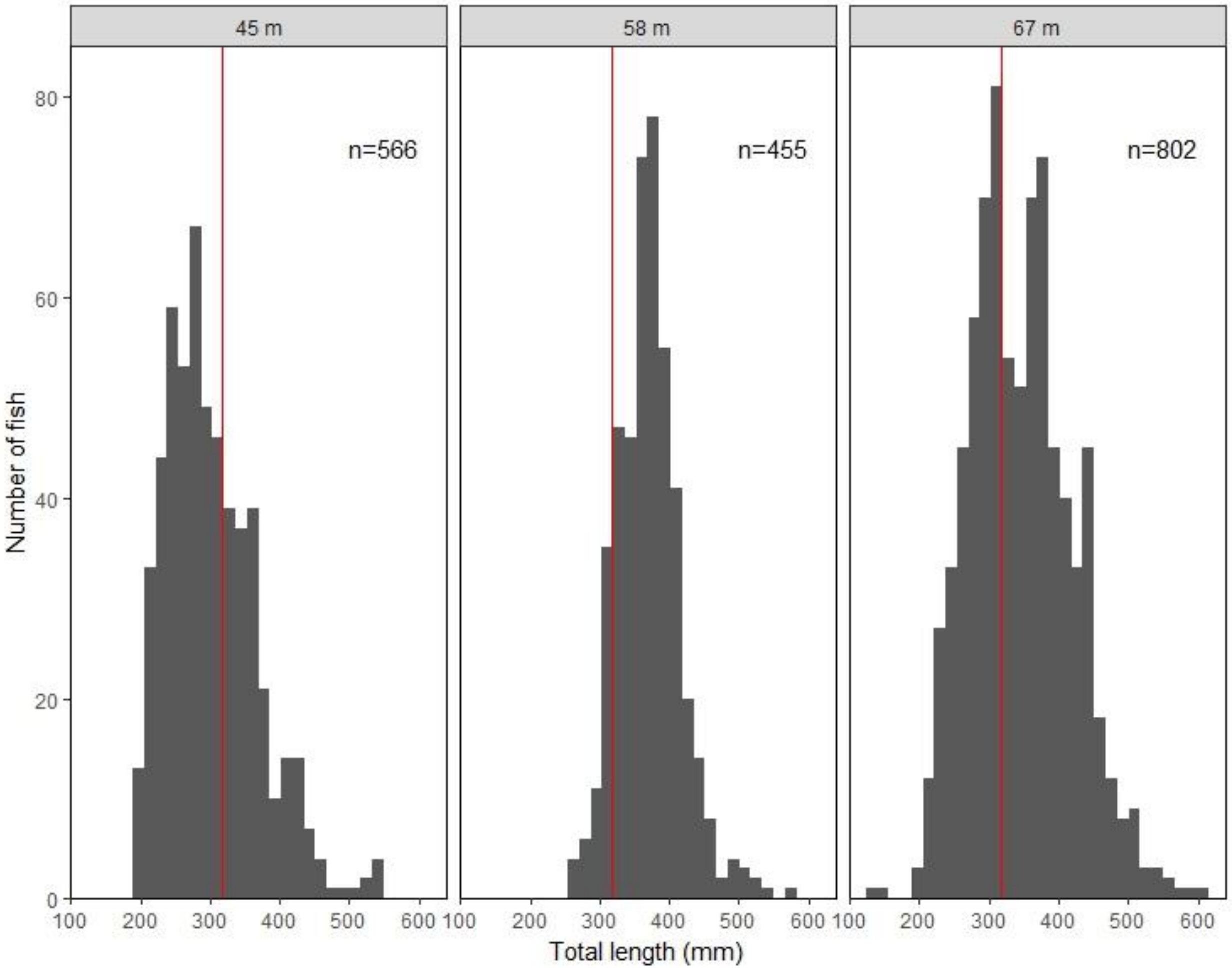


Figure 7 – Length frequency histograms of black sea bass captured at each depth. Sample sizes are presented for each depth. Red lines represent the federal minimum black sea bass size limit (12.5”, 318 mm).

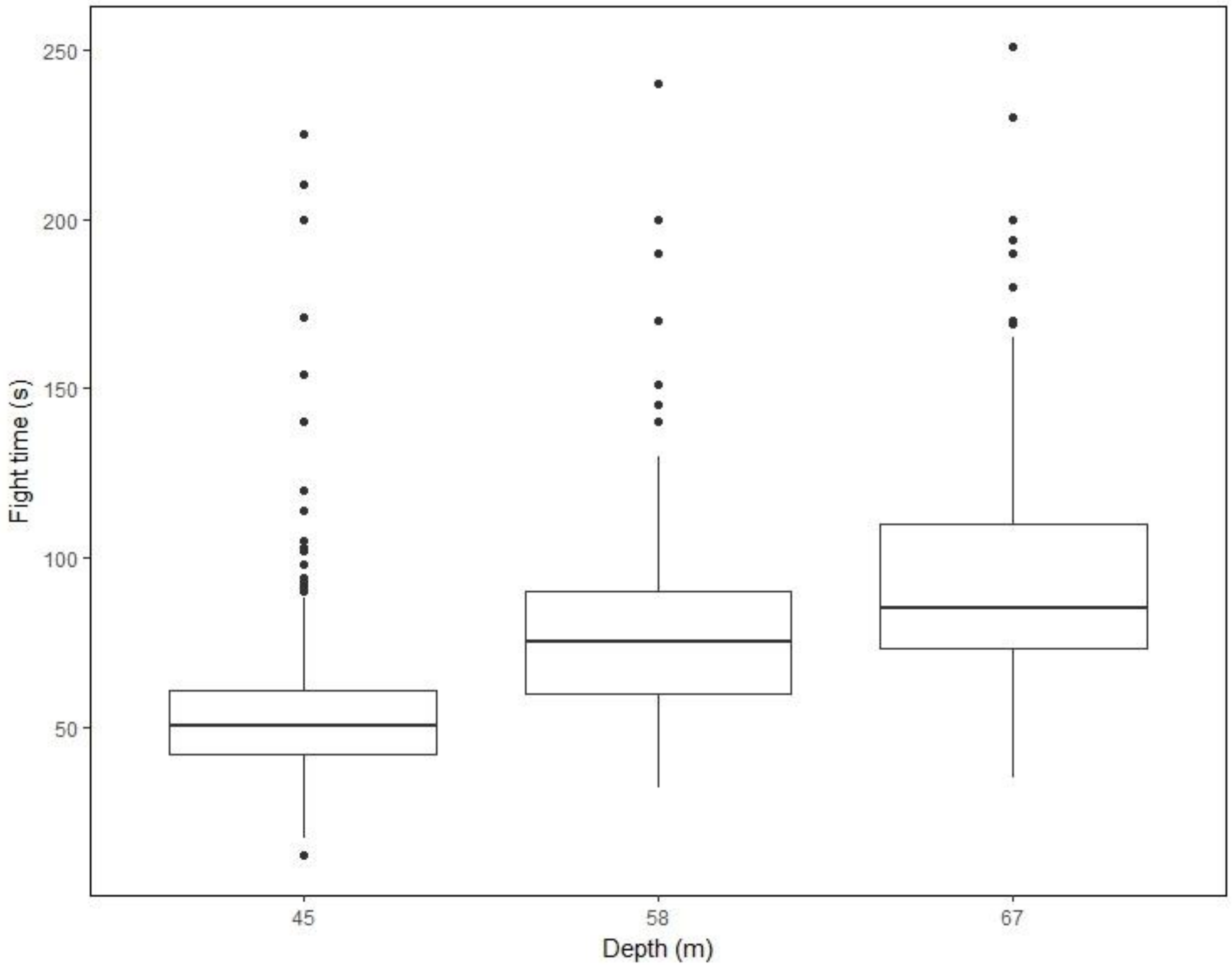


Figure 8 – Boxplot demonstrating the relationship between fight time (seconds) and capture depth (meters). Whiskers represent upper (75%) and lower (25%) quantiles and the black line represents the median value.

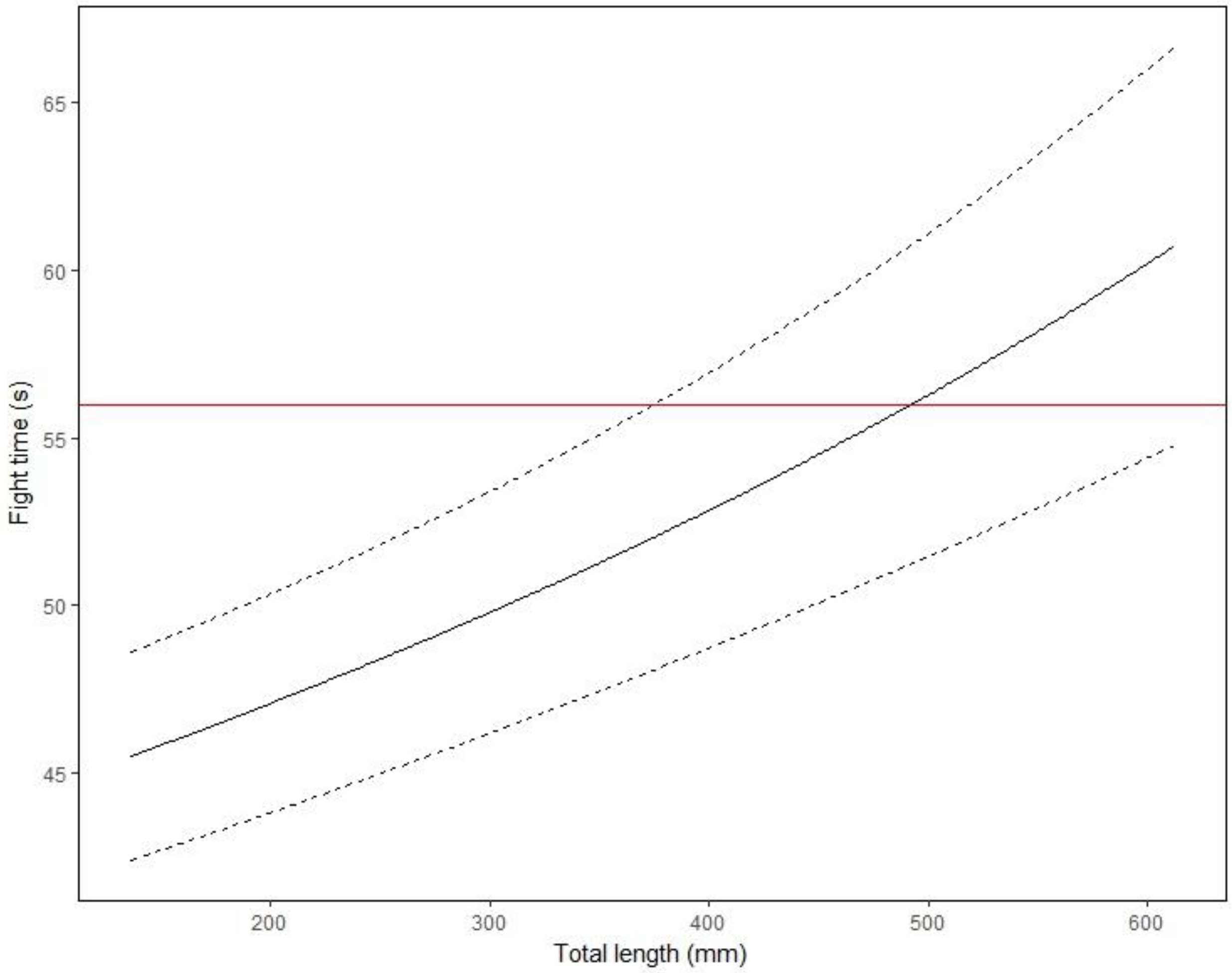


Figure 9 – Relationship between fight time and total length as predicted by the best-fitting generalized additive mixed effect model (solid black line). Upper and lower 95% confidence intervals (dotted lines) are also presented. Red horizontal line demonstrates the mean fight time for the model intercept depth (45 m), and suggests that fish >491 mm total length were generally fought longer than average.

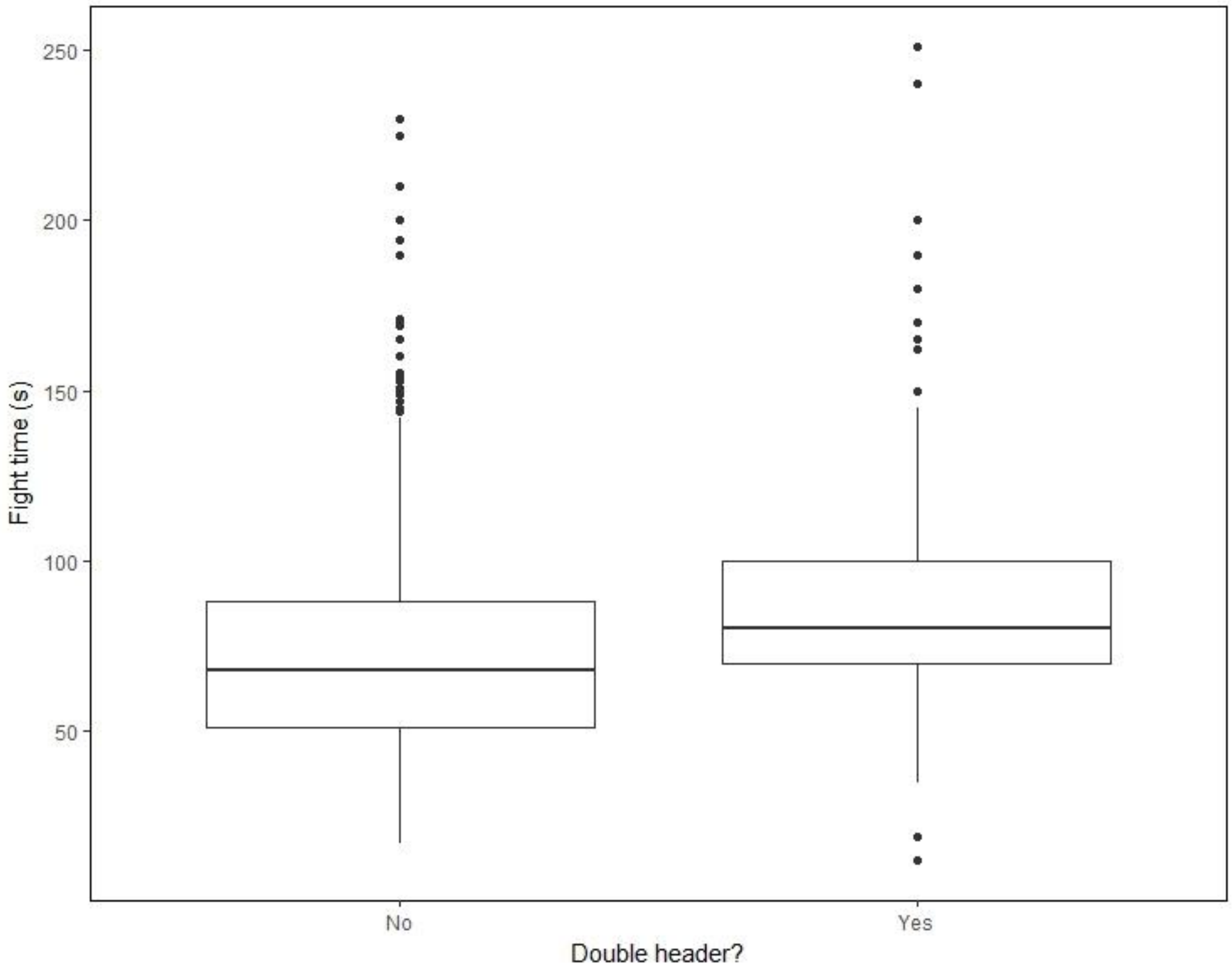


Figure 10 – Boxplot demonstrating the relationship between fight time and capture of fish as part of a double header (i.e., two fish captured simultaneously, one on each hook). Whiskers represent upper (75%) and lower (25%) quantiles and the black line represents the median value.

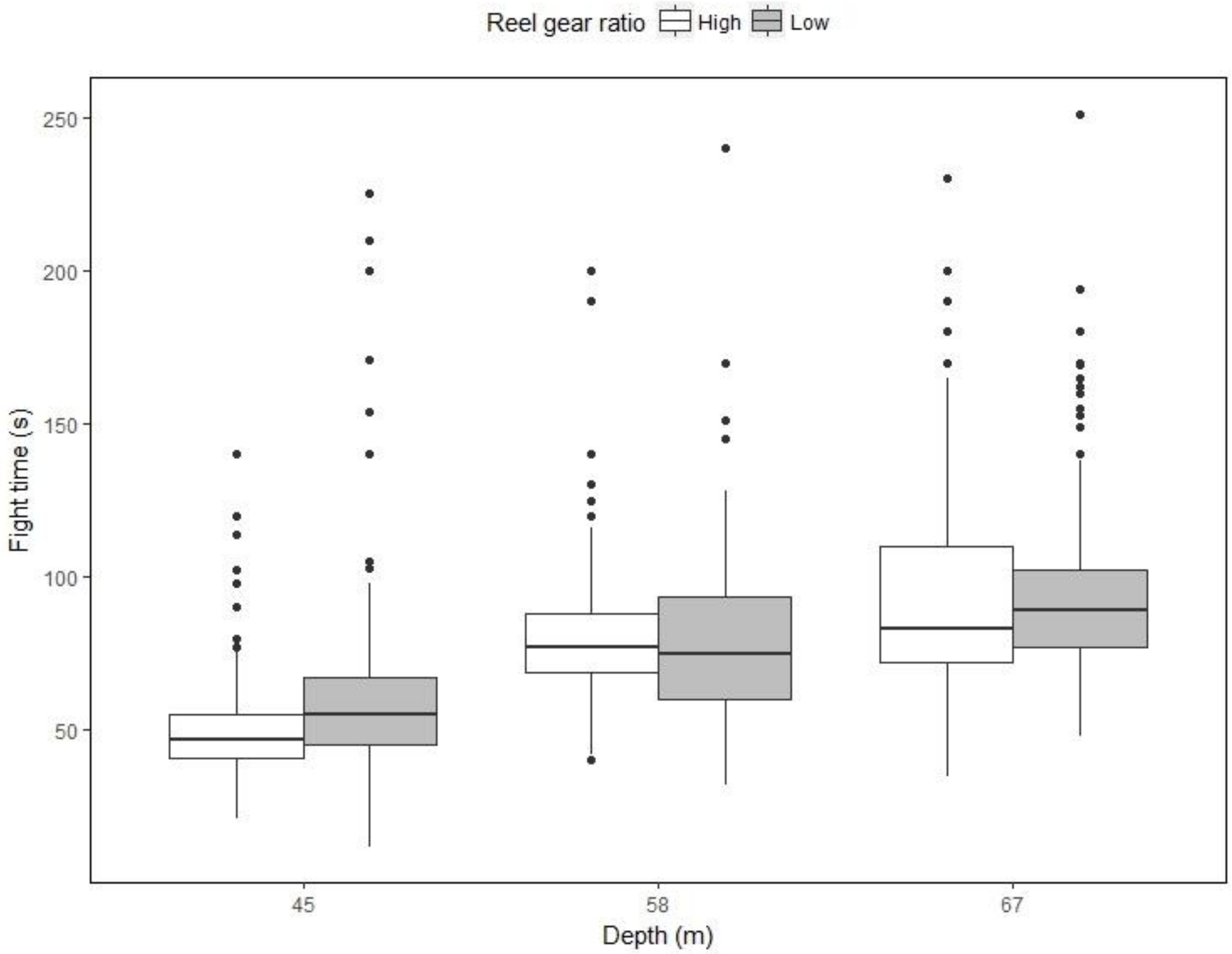


Figure 11 – Boxplot demonstrating the relationship between fight time and capture depth for each reel gear retrieve ratio ('reel gear'). Whiskers represent upper (75%) and lower (25%) quantiles and the black line represents the median value.

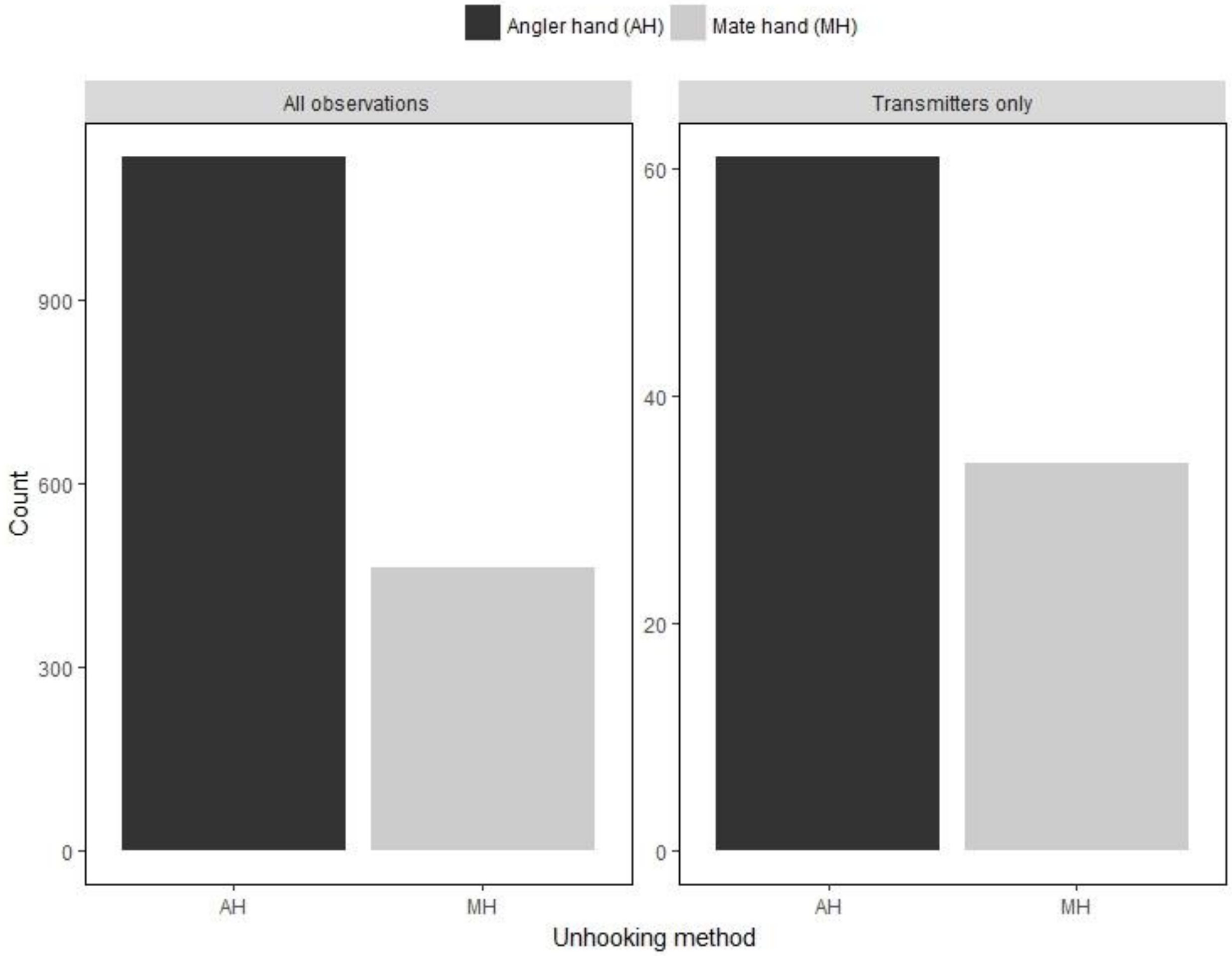


Figure 12 – Histogram of the number of black sea bass that were unhooked by hand by the capturing angler (‘Angler hand’) or by fishing vessel crew/mate (‘Mate hand’) for all capture observations and the 96 fish that were tagged with acoustic transmitters.

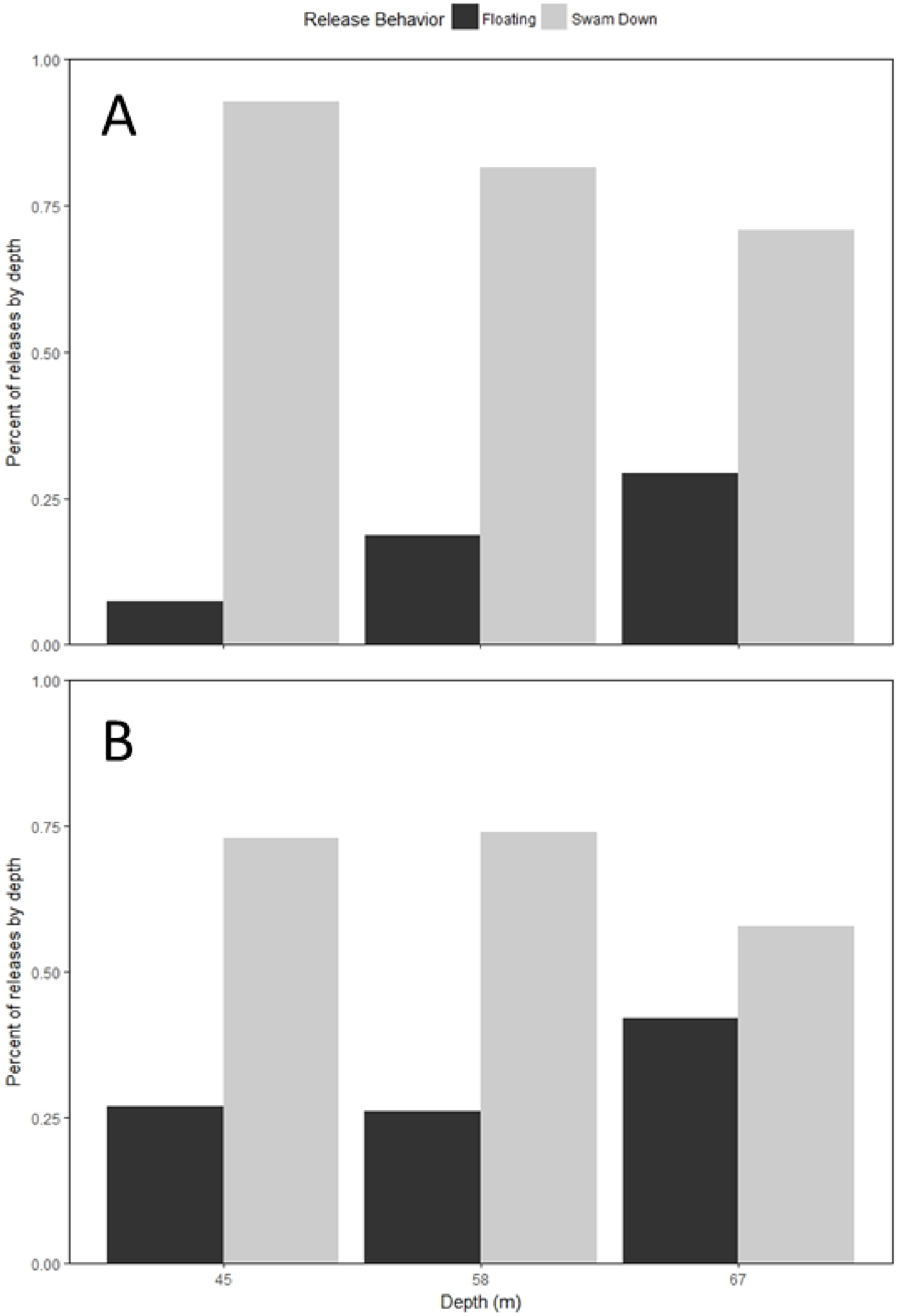


Figure 13 – Histogram of the prevalence of ‘floating’ and ‘swam down’ release behaviors by depth for vented (A) and non-vented (B) fish.

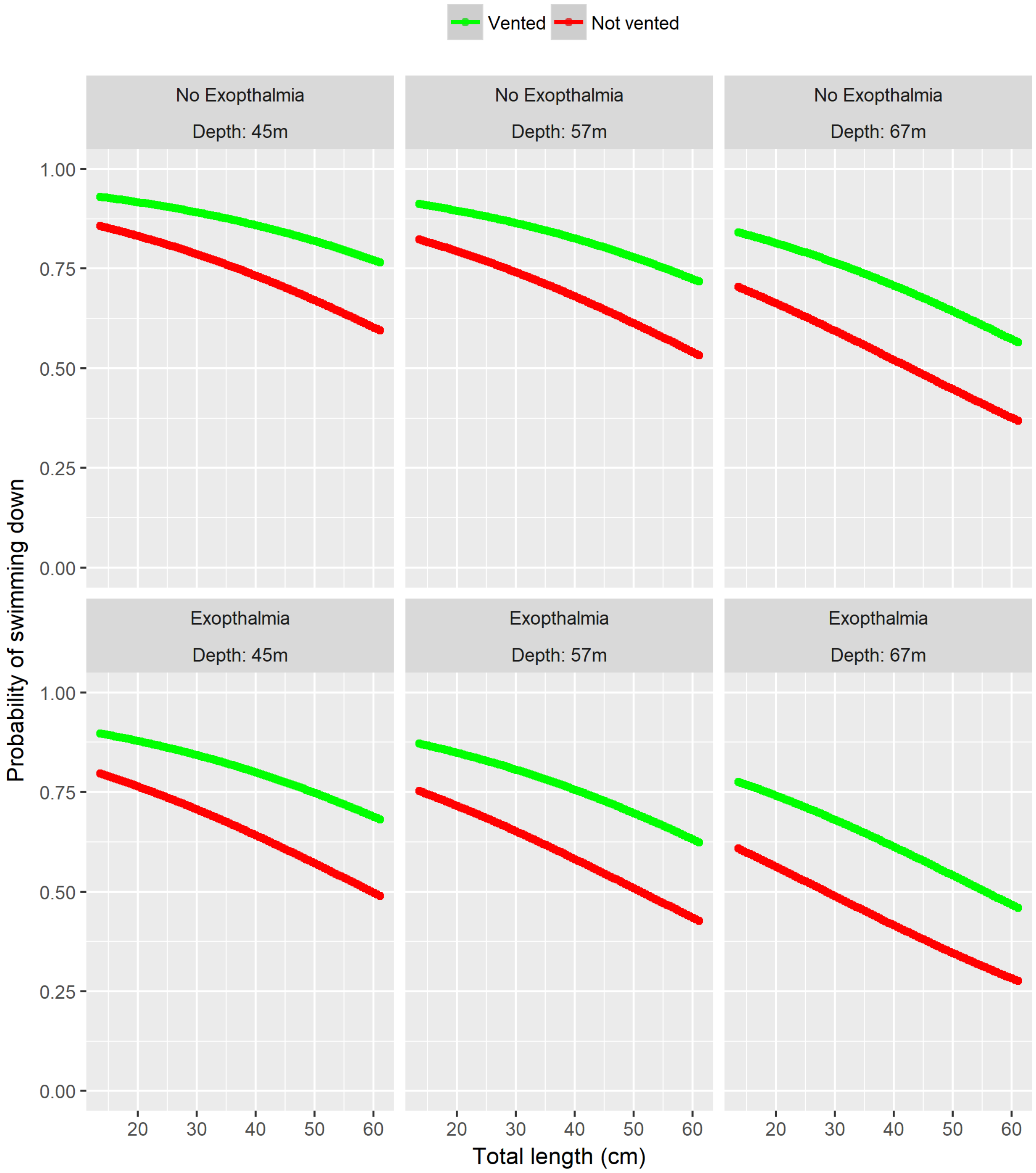


Figure 14 - Probability that a released black sea bass will actively swim down as a function of venting as well as total length, capture depth, and presence of exopthalmia. Larger fish, that were not vented, caught at deeper depths, and experienced exopthalmia had a lower probability of swimming down (i.e., higher probability of floating upon release).

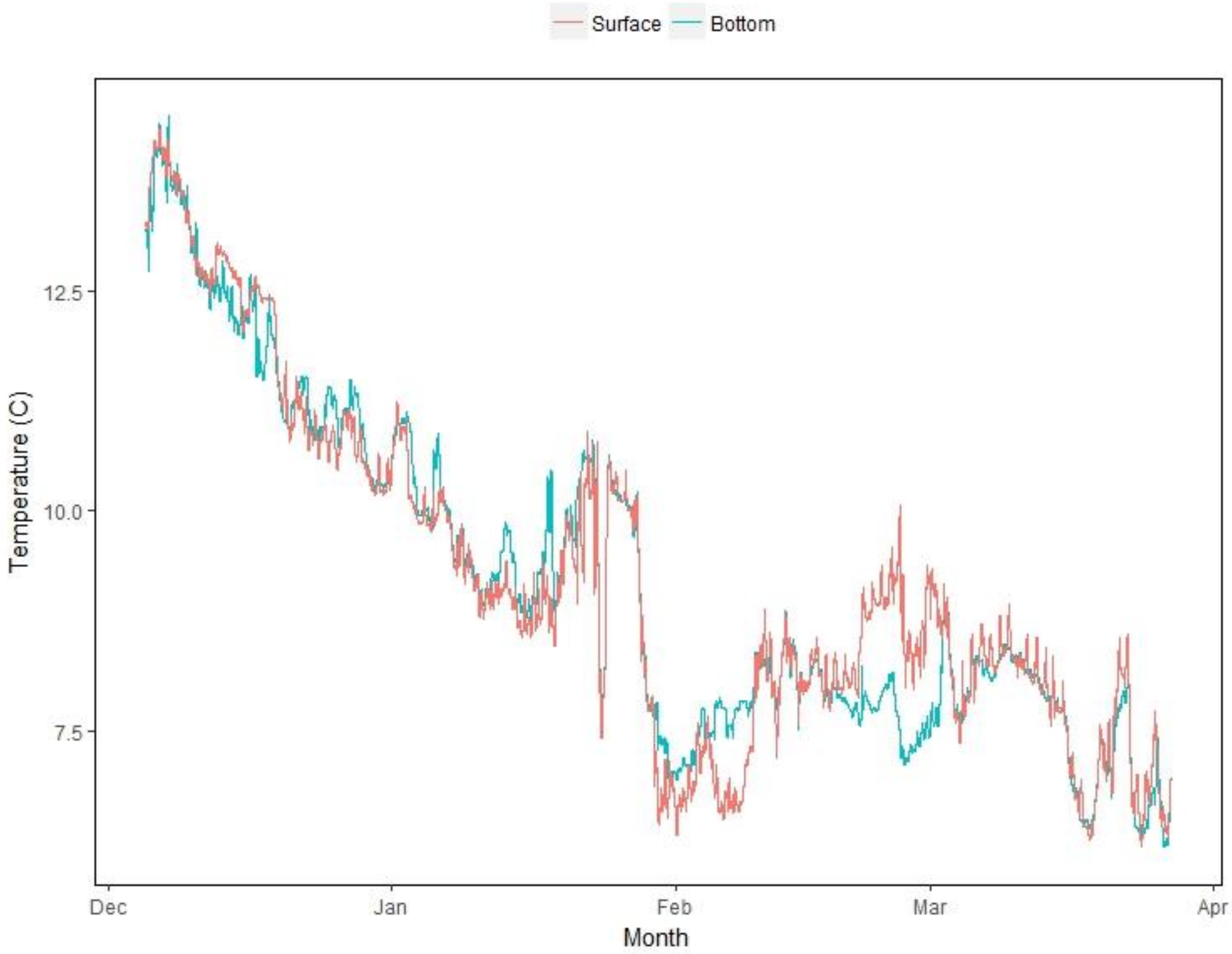


Figure 15 – Surface and bottom water temperatures measured by HOBO Pendant temperature loggers placed on the station SB8 receiver mooring from December 5, 2016 to March 27, 2017. All acoustically tagged black sea bass were monitored between these dates. Note that fishing slowed dramatically at the wreck on February 3, 2017, shortly after a significant drop in surface and bottom temperature.

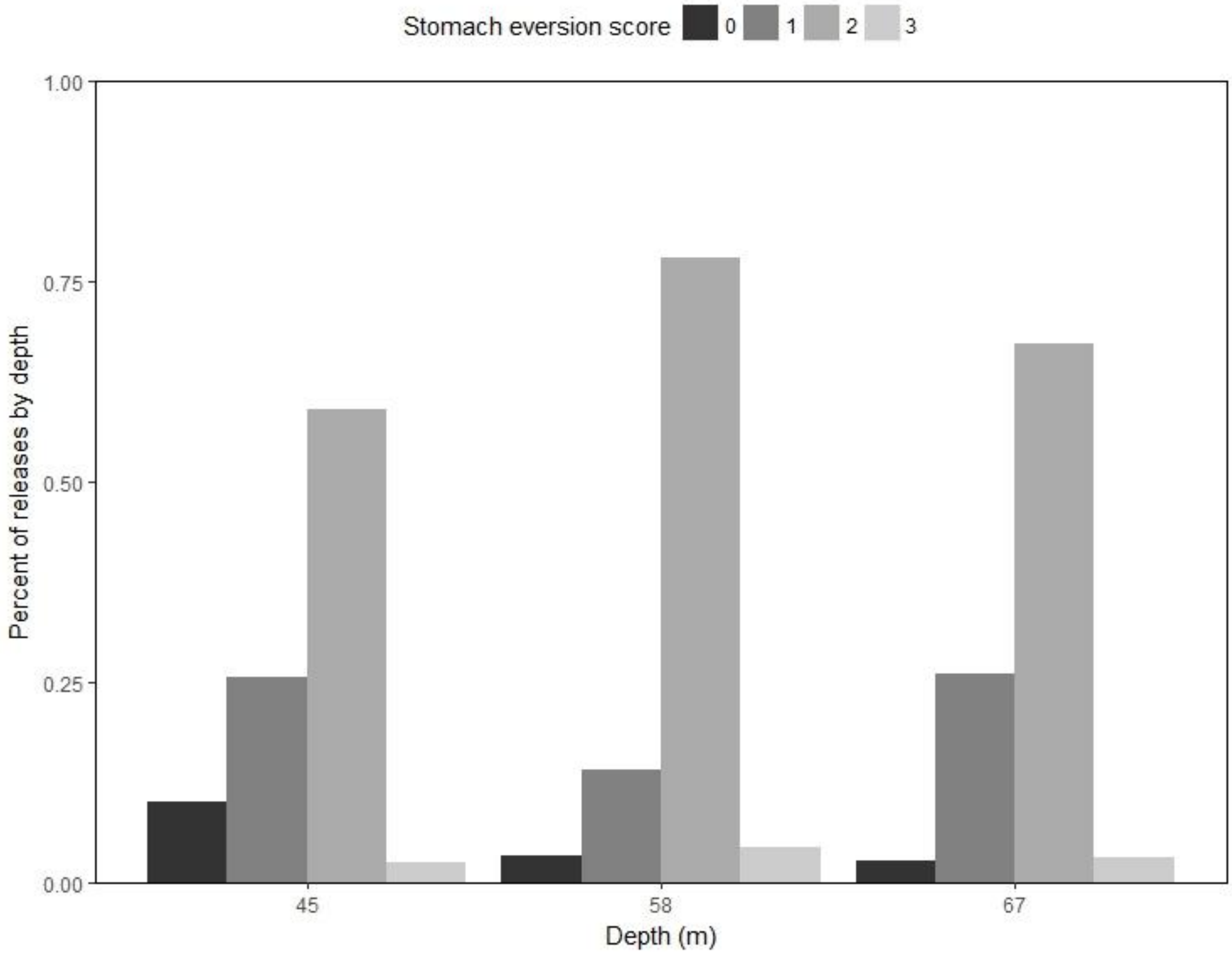


Figure 16 – Histogram of the percent of total fish releases that experienced stomach eversion scores 0, 1, 2, and 3 for each capture depth. Score 0: Stomach not everted; Score 1: Stomach everted but remains within mouth cavity; Score 2: Stomach everted but is protruding from the mouth; Score 3: Stomach everted and ruptured.

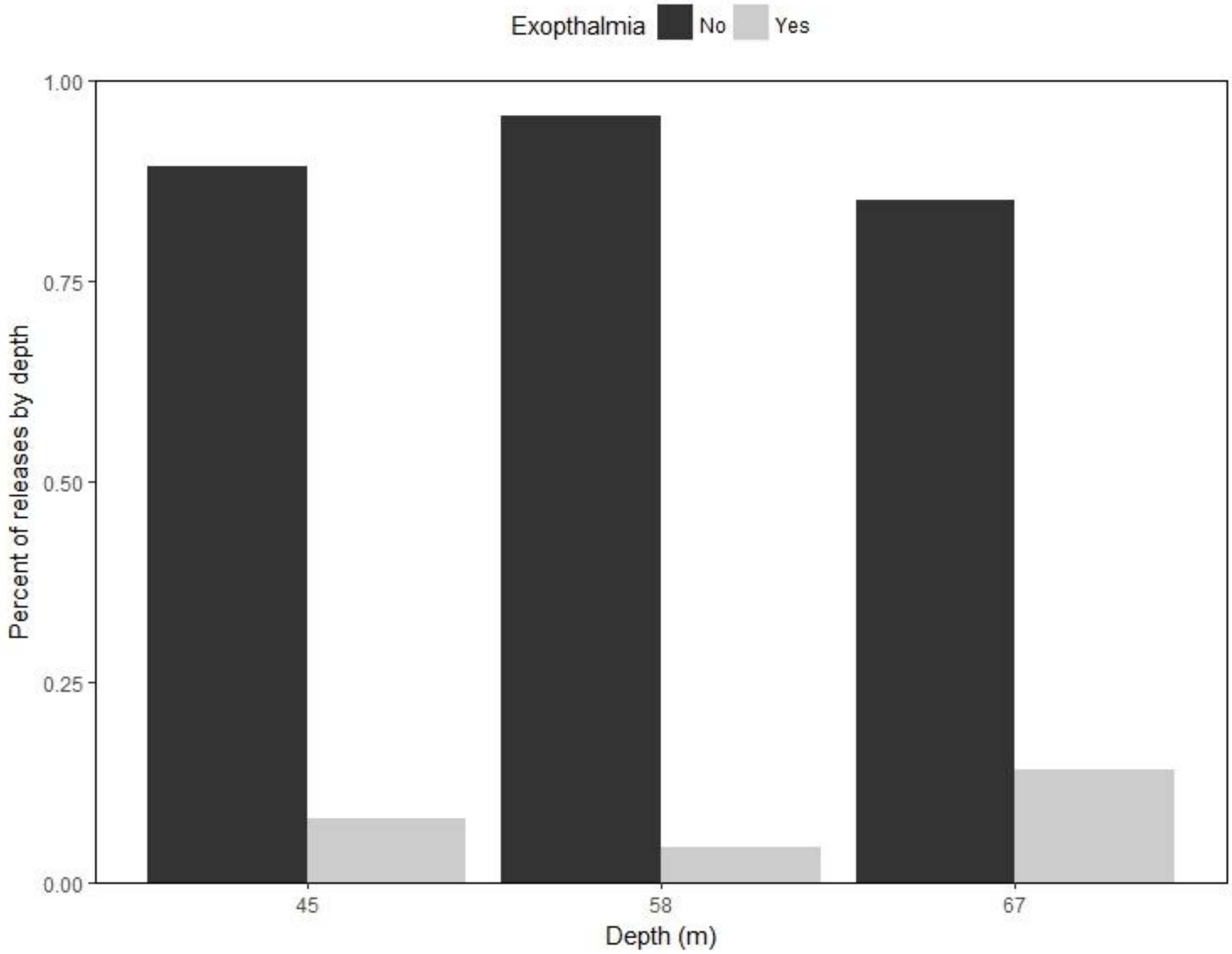


Figure 17 – Histogram of the percent of total fish released by depth that experienced exopthalmia.

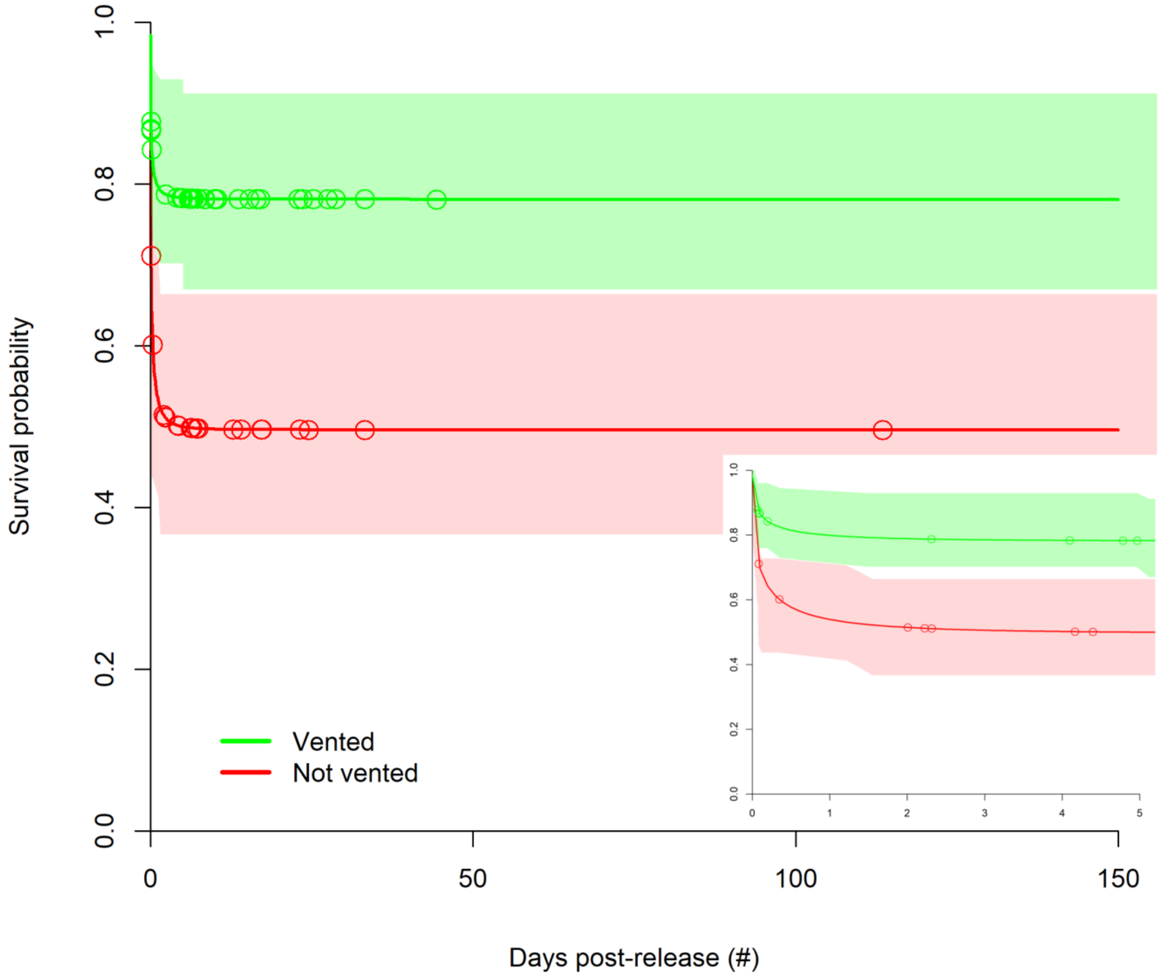


Figure 18 - Nonparametric and model-based estimates of survival functions for black sea bass that were either vented (green) or not vented (red) prior to release, where time zero is the time of release back into the water. Shaded areas indicate the 95% confidence band for the Kaplan-Meier survivor function estimates, the solid lines are estimates from the preferred survival model, and the circle location and size indicate the occurrence and relative number of right-censored observations. The inset plots in each panel show the finer scale survival functions during the first five days after release, when all of the discard-related mortality is estimated to have occurred.

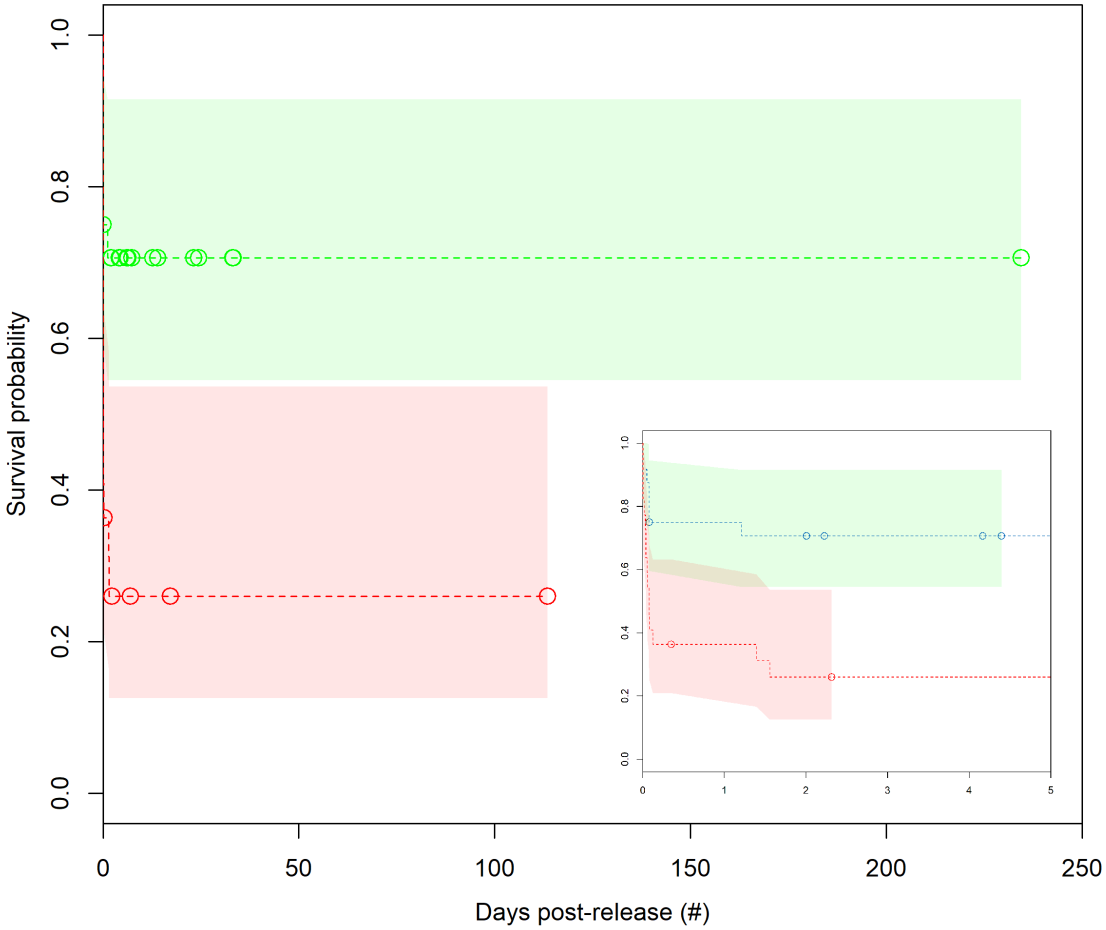


Figure 19 - Plot of the Kaplan-Meier survival function estimate for only unvented black sea bass in the acoustic subsample by low (≤54 s) and high (>54 s) fight times. Shaded areas indicate the 95% confidence interval and circles indicate the time when an individual was last observed alive (i.e., right-censored). Time zero is the time of release back into the water. The inset plot shows the finer scale survival functions during the first five days after release.

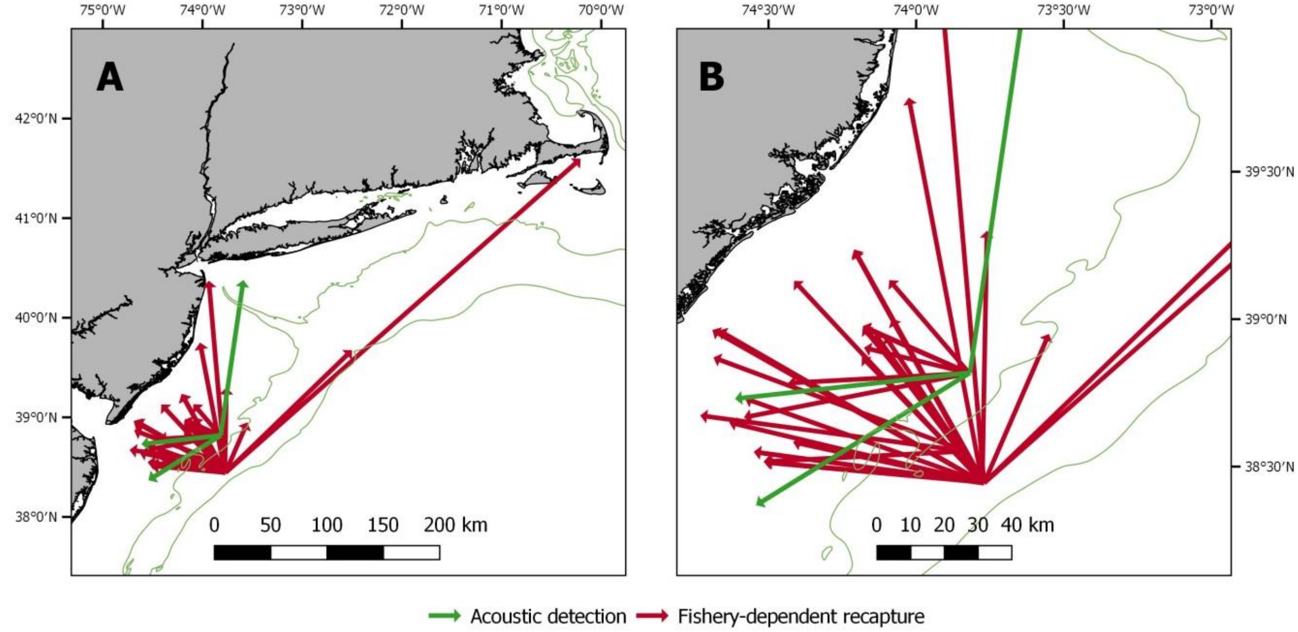


Figure 20 – Plot of fishery-dependent recaptures and acoustic detection events that occurred as of February 1, 2018. Directional arrows depict minimum linear displacement vectors. Note: three acoustic transmitters were reported as fishery-dependent recaptures. Panel A represents the full geographic area over which recaptures or detections occurred and panel B is a zoom of the southern New Jersey region.